Stressor identification

March 2019

Cloquet River Watershed Stressor Identification Report

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

MINNESOTA POLLUTION CONTROL AGENCY

CLEAN WATER LAND & LEGACY AMENDMENT

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Key terms and abbreviations

BTSA	Brook Trout Suitability Assessment
CBI	Coldwater Biotic Index
DO	Dissolved Oxygen
IBI	Index of Biological Integrity
IWM	Intensive Watershed Monitoring
MSHA	MPCA Stream Habitat Assessment
MPCA	Minnesota Pollution Control Agency
PSI	Pfankuch Stability Index
SID	Stressor Identification
TIV	Tolerance Indicator Values
TMDL	Total Maximum Daily Load
WRAPS	Watershed Restoration and Protection Strategy

Executive summary

The Cloquet River Watershed is located in northeastern Minnesota between the North Shore of Lake Superior and the Iron Range. A relatively undeveloped watershed, the Cloquet River basin contains many high quality streams, rivers, and lakes that sustain a diverse array of sensitive aquatic life. Despite predominantly healthy watersheds in this region, portions of two streams were classified as “impaired” based on degraded fish and aquatic macroinvertebrate communities.

Intensive water quality and biological data were collected in the Cloquet River Watershed by the Minnesota Pollution Control Agency (MPCA) and partners in 2015 and 2016. This report summarizes the follow-up “Stressor Identification” monitoring completed in these priority watersheds with the goal of informing the Watershed Restoration and Protection Strategy (WRAPS) effort for the Cloquet River Watershed. Major focus areas and findings in this report are listed below:

Beartrap Creek (Impairments: Fish and aquatic macroinvertebrates)

- Fish and aquatic macroinvertebrate communities in Beartrap Creek are limited by poor physical habitat conditions within the impaired reach, although some areas of the watershed continue to support healthy populations of wild, native Brook Trout and other sensitive aquatic life.
- Our monitoring work identified many beaver dams and several impassable road culverts, which result in localized habitat loss, and more importantly inhibit the movement of fish between distinct habitat patches. Restoring connectivity between high quality, year-round coldwater habitats and marginal areas will increase resiliency to drought, flood events, and elevate coldwater fish and macroinvertebrate bio-integrity.
- Water quality parameters (temperature, dissolved oxygen (DO), suspended sediment) were not found to be significant factors in the biological impairments.
- Several recommendations for restoration and protection actions in the Beartrap Creek Watershed are presented in Section 7.0.

Hellwig Creek (Impairments: Fish and Aquatic Macroinvertebrates)

- The impaired reach of Hellwig Creek is limited by poor and frequently “disturbed” physical habitat conditions. The fish and macroinvertebrate community show a high level of variability between sampling events, likely due to frequently changing habitat conditions due to beaver activity and stream channelization. Restoring the impaired reach to a meandering, free-flowing state will result in improved stream habitat complexity and quality, and result in a more diverse fish and macroinvertebrate assemblage.
- Water quality parameters (temperature, dissolved oxygen (DO), suspended sediment) were not found to be significant factors in the biological impairments.
- Several road culverts in the Hellwig Creek Watershed were identified as fish migration barriers, including one crossing immediately upstream of the Hellwig Creek-Cloquet River confluence.
- Several recommendations for restoration and protection actions in the Hellwig Creek Watershed are presented in Section 7.0.

1.0 Report purpose, process and overview

As required by the Clean Water Legacy Act, the MPCA has developed a strategy for monitoring and improving water quality and biological integrity of the state's streams, rivers, wetlands, and lakes in Minnesota's 81 Major Watersheds. This process is known as the WRAPS.

A WRAPS is comprised of several types of assessments. The initial phase of WRAPS is called the Intensive Watershed Monitoring (IWM), through which the MPCA and partners characterize the overall health of streams and lakes, and identify impaired waters that do not meet establish standards. Results of monitoring completed by other state, federal, and local organizations are included in this process. This phase of WRAPS occurred between the years of 2015-2016 in the Cloquet River Watershed, and culminated with the completion of the Monitoring and Assessment Report in the summer 2018. An electronic copy of this report can be found on the Cloquet River Watershed page at MPCA's website, https://www.pca.state.mn.us/.

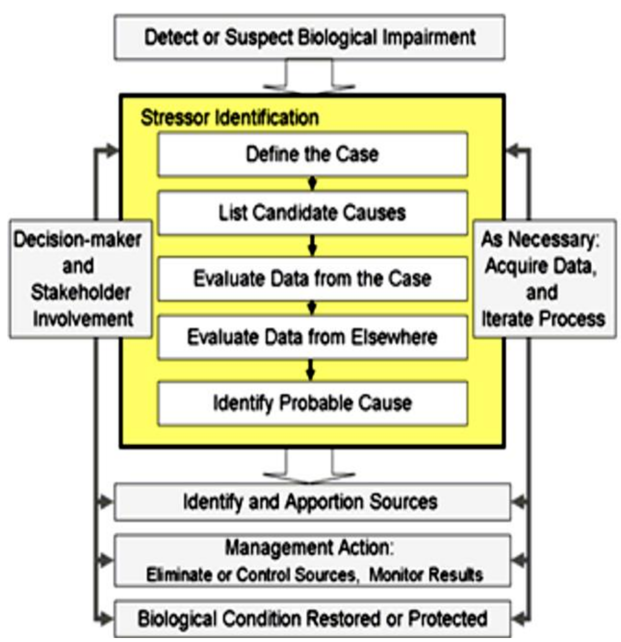
The next phase of WRAPS development is known as the Stressor Identification (SID) Assessment. This process builds on the results of the IWM, but a greater emphasis is placed on the evaluating various physical and chemical factors that either harm or protect aquatic life in a given stream. Whereas IWM is geared to be a non-biased assessment of ecological health, the SID process often targets specific locations in a given watershed to highlight potential restoration or protection priorities. This document is the summary of Stressor Identification results for the Cloquet River HUC8 watershed. The material presented in this report will be used in planning of restoration and protection activities in conjunction with local, state, and federal agencies and various stakeholder groups.

1.1 Organization framework of stressor identification

The SID process used in this report weighs evidence for or against various candidate causes of biological impairment (Cormier et al. 2000). The SID process 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 (Figure 1). Confidence in the results often depends on the quality of data available to the SID process.

Completion of the SID process does not result in completed Total Maximum Daily Load (TMDL) allocations. The product of the SID process is the identification the stressor(s) for which the TMDL load allocation will be developed. For example, the SID process may help investigators identify 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 address and correct the impaired condition.

Figure 1. Conceptual diagram of the SID process for identifying the cause(s) of biological Impairment (Cormier et al 2003).



2.0 Introduction and study areas

2.1 Cloquet River Watershed Assessment Process

The Cloquet River Watershed Monitoring and Assessment Report (MPCA, 2018) identified four impaired stream reaches (Figure 2). Two of the impaired reaches are located on the Cloquet River, and relate to mercury contamination of the water column and fish tissue. The other two impaired streams, Beartrap Creek and Hellwig Creek, are major tributaries to the Cloquet River located near the towns of Independence and Saginaw (Figure 2). These two streams are listed as impaired for failing to meet both the fish and aquatic macroinvertebrate aquatic life criteria. More information on the specific standards used to assess aquatic life can be found by entering "biological monitoring" into the search tool on MPCA's website.

Sections of Beartrap Creek and Hellwig Creek support fish and macroinvertebrate communities that show signs of degradation compared to minimally impacted streams in the region. As a result, a decision was made to list them as impaired for failing to meet established thresholds for biological integrity. The Index of Biological Integrity (IBI) is the tool most commonly used by MPCA to assess biological condition. The specific IBI criteria varies by stream size and type, and are based on a series of "metrics" that pertain to the condition, pollution tolerance, reproductive traits, and trophic (feeding) habitats of fish and aquatic macroinvertebrates. Use of an IBI can help scientists:

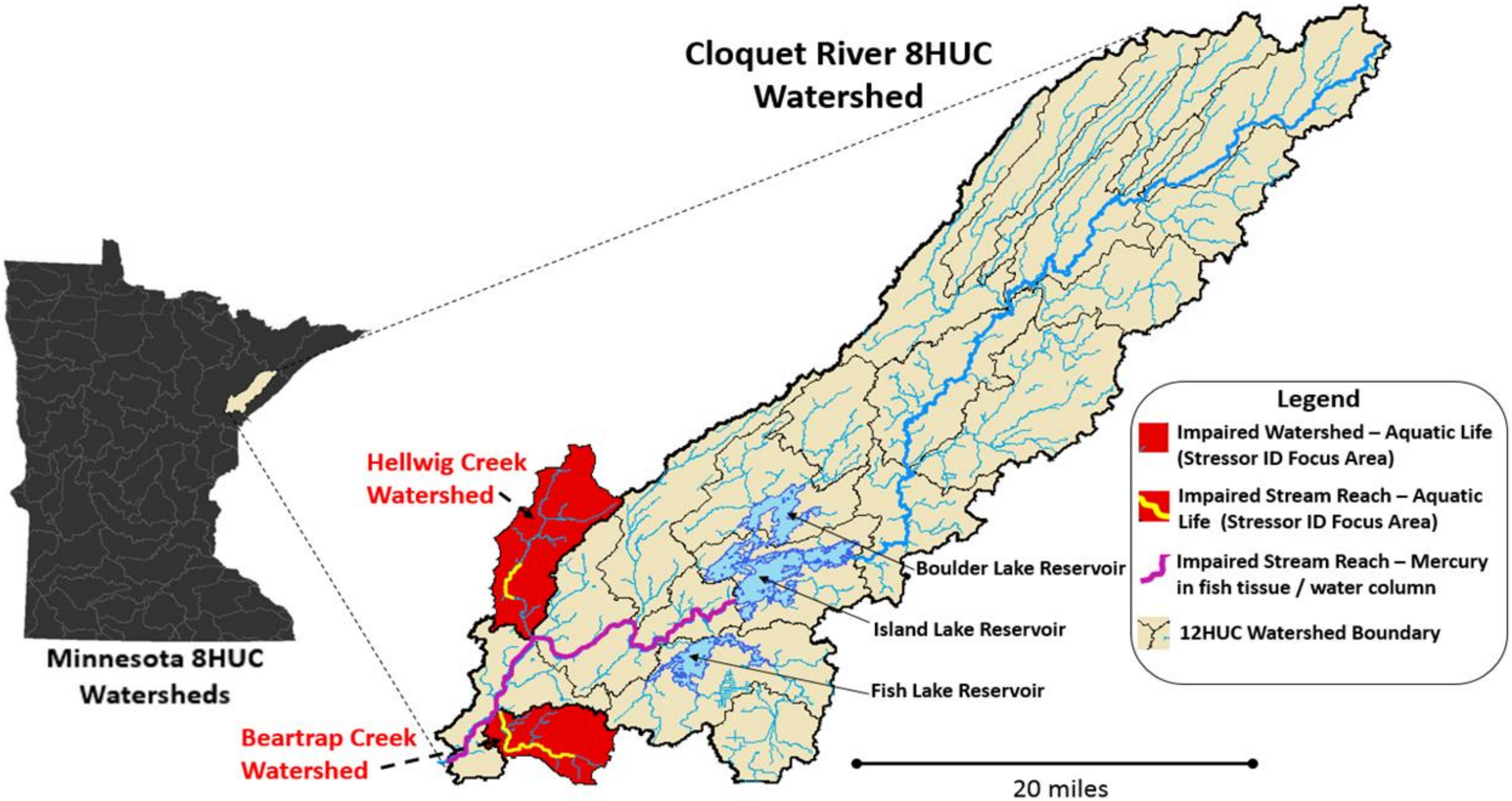
- Measure the health of aquatic life and diagnose the type of stressors damaging a water body
- Define management approaches to protect and restore the water's biological communities
- Evaluate effectiveness of protection and restoration activities

2.2 Stressor Identification monitoring

The MPCA staff and partners completed additional monitoring work in the impaired subwatersheds over the spring, summer, and fall of 2017. The primary objectives of this monitoring effort were to determine the cause(s) of biological impairments as well as identifying the contributing sources and pathways of these stressors. In addition, an equal emphasis was placed on identifying areas that are well suited for restoration projects and high-quality features that are priorities for protection measures.

Several non-impaired areas of the Cloquet River were also targeted for monitoring work in 2017. In 2017, continuous temperature data collectors were deployed at 23 locations downstream of the Island Lake Reservoir in the Cloquet River (n=7) and its tributary streams (n=16). The following year, temperature loggers were installed at 45 locations upstream of Island Lake (Cloquet River n=2, Tributaries n = 43). The objectives of this temperature monitoring effort were to evaluate temperature differences between the main stem and tributary streams, with the specific goal of identifying tributaries that may serve as refuge areas for fish (particularly Brook Trout and Brown Trout) that are known to move between tributaries and the Cloquet River on a seasonal basis. The second phase of this effort will evaluate habitat conditions in these tributaries and their longitudinal connectivity to the Cloquet River main stem. Additional monitoring and assessment work was completed in the Chalberg Creek and Us-Kab-Wan-Ka River watersheds to identify restoration and protection projects. These two coldwater trout streams in the Cloquet River Watershed have been impacted by road and railroad projects. The results of monitoring work completed in non-impaired watersheds will be presented in a separate report to be released in the spring of 2019.

Figure 2. Map of study areas within the Cloquet River 8HUC Watershed.



Waterbody Name	Waterbody ID (WID)	Impaired Reach Length (miles)	Location Description	Impairments
Hellwig Creek	04010202-672	4.75	Unnamed Ck to T52 R17 S15, east line	Aquatic macroinvertebrate bioassessments Fish bioassessments
Beartrap Creek	04010202-521	7.09	T51 R17W S25, south line to Cloquet R	Aquatic macroinvertebrate bioassessments Fish bioassessments
Cloquet River	04010202-504	7.54	Island Lake Reservoir to Beaver R	Mercury in fish tissue
Cloquet River	04010202-501	17.90	Us-kab-wan-ka R to St Louis R	Mercury in fish tissue, Mercury in water column

3.0 Candidate causes of impairments

The SID process uses a weight of evidence to determine the most probable causes of biological impairments. Initially, a broad list of candidate stressors is evaluated in order to improve confidence and transparency in the final stressor diagnosis. A combination of field data from the study watershed, data and observations from other comparable studies, and professional judgement are used to eliminate less probable causes throughout the SID investigation. Ultimately, a smaller set of candidate causes are evaluated more rigorously. This final level of analysis typically requires additional monitoring and data collection specific to the candidate causes.

A broad list of potential causes of impairment was evaluated for Beartrap Creek and Hellwig Creek Watersheds (Tables 1 and 2). Several stressors were eliminated early in the process based on existing data, and current understanding of watershed condition and land-uses. For example, toxicity from heavy metals was eliminated as a candidate cause in both impaired watersheds given that there are no known sources of metals contamination within these predominantly rural landscapes. The eliminated causes are listed in Tables 1 and 2 along with a brief justification for the decisions.

The final candidate causes evaluated for the fish and aquatic macroinvertebrate impairments in Beartrap Creek included; low DO concentrations, poor physical habitat, elevated water temperature, loss of connectivity resulting in barriers to fish movement, predation (predatory warmwater species preying on coldwater fish species), and altered hydrology.

The candidate causes that will be evaluated for the fish and aquatic macroinvertebrate impairments in Hellwig Creek include; low DO concentrations, poor physical habitat, loss of connectivity resulting in barriers to fish movement, and altered hydrology.

Table 1. List of candidate causes evaluated for fish and macroinvertebrate impairments in Beartrap Creek and Hellwig Creek.

Water Chemistry				
Parameter	**Applicable Standards**	**Data Available**	**Stressor Status**	**Justification**
Total Suspended Solids	10 mg/L TSS (coldwater) 25 mg/L (warmwater)		**Beartrap Creek** – Eliminated **Hellwig Creek** - Eliminated	TSS eliminated as a potential stressor in both streams based on snowmelt and rain event sampling results meeting WQ standards at all locations.
Dissolved Oxygen	7 mg/L (coldwater) 5 mg/L (warmwater)	Continuous data Spot Measurements	**Beartrap Creek** – Candidate Cause for Impairment **Hellwig Creek** - Candidate Cause for Impairment	Available data shows variable DO conditions in these streams, with the potential for low DO concentrations in headwaters and/or wetland influenced areas.
Toxicity – Chloride	Chloride (230 mg/L)	None	**Beartrap Creek** – Eliminated **Hellwig Creek** - Eliminated	Possible sources of chloride contamination in these watersheds are minimal, but several major highways are present. Given the lack of urban land-use, chloride toxicity is an unlikely stressor to aquatic life.
Toxicity – Metals	Numerous	None	**Beartrap Creek** – Eliminated **Hellwig Creek** – Eliminated	No land-uses in watershed that correspond with high metals concentrations in streams.

Geomorphology & Physical Habitat Conditions				
Parameter	**Applicable Standards**	**Data Available**	**Stressor Status**	**Justification**
Habitat Degradation	None	Quantitative and Qualitative Habitat and Geomorphic Assessments	**Beartrap Creek** – Candidate Cause for Impairment **Hellwig Creek** - Candidate Cause for Impairment	Physical habitat in these two streams has been negatively impacted by ditching, road development, agricultural, residential, and commercial land-uses
Water Temperature	No material increase	Continuous Data Spot Measurements	**Beartrap Creek** – Candidate Cause for Impairment **Hellwig Creek** – Eliminated	Beartrap Creek is a coldwater stream (2A) with temperature sensitive aquatic life. Elevated water temperatures are a candidate cause for impairment. The impaired reach of Hellwig Creek is classified as warmwater (2B) but temperature will still be evaluated since other reaches of the creek are designated as coldwater (2A)

Table 2. List of candidate causes evaluated for fish and macroinvertebrate impairments in Beartrap Creek and Hellwig Creek (continued).

Biology				
Parameter	**Applicable Standards**	**Data Available**	**Stressor Status**	**Justification**
Predation	None	Fish Community Assessments	**Beartrap Creek** – Candidate Cause for Impairment **Hellwig Creek** - Eliminated	Northern Pike and Smallmouth Bass can enter Beartrap Creek via the Cloquet River. Potential for these species to prey on adult and juvenile Brook Trout and other desirable coldwater species. Eliminated as a stressor in Hellwig Creek, as the impaired reach is a warmwater stream and some predation by northern pike is expected, but not a major cause of fish community structure.
Connectivity				
Parameter	**Applicable Standards**	**Data Available**	**Stressor Status**	**Justification**
Loss of Connectivity/ Barriers to Fish Migration	None	Culvert Assessments Beaver Dam Inventory	**Beartrap Creek** – Candidate Cause for Impairment **Hellwig Creek** - Candidate Cause for Impairment	Numerous road crossings exist in these watersheds that have the ability to reduce or eliminate fish passage and cause habitat fragmentation. Beaver dams are also abundant and can have similar effects.
Hydrology				
Parameter	**Applicable Standards**	**Data Available**	**Stressor Status**	**Justification**
Altered Hydrology	None	Modeled Flows (HSPF)	**Beartrap Creek** – Eliminated **Hellwig Creek** - Eliminated	Both of these watershed are relatively undeveloped and contain a large percentage of forested land and wetlands. Significant hydrological changes resulting from anthropogenic disturbance are not evident based on observations of storm flows, baseflows, or stream channel characteristics (width depth ratio, low flow width depth ratio)

4.0 Field and data analysis methods

4.1 Water temperature

Water temperature plays a large role in the distribution, abundance, and species composition of stream fishes, particularly salmonids. Many of the fish and macroinvertebrate species that serve as indicators of healthy coldwater (trout stream) habitats are highly sensitive to changes in water temperature and possess life history traits (feeding, reproduction, physiological processes) that are dependent on colder thermal regimes. These species are classified as coldwater obligate species. The presence/absence and abundance of these species factor heavily into fish and macroinvertebrate IBI metrics and overall IBI scores. Examples of coldwater obligate fish taxa sampled in the Cloquet River Watershed are listed in Table 3. Also included in this table are several fish taxa that are often sampled from marginal coldwater streams. Several of these species also count favorably in coldwater fish IBI metrics.

Table 3. Fish species included in various coldwater IBI metrics used by MPCA.

Common Name	Thermal Class Metric	Status in Cloquet River 8HUC
Brook Trout	Cold (Coldwater Obligate)	Abundant
Mottled Sculpin	Cold (Coldwater Obligate)	Abundant
Brown Trout	Cold (Coldwater Obligate)	Rare
Finescale Dace	CWSensitive (sensitive species found in coldwater streams)	Common
Longnose Dace	CWSensitive (sensitive species found in coldwater streams)	Common
Pearl Dace	CWSensitive (sensitive species found in coldwater streams)	Common

4.1.1 Thermal tolerance & Temperature values

All aquatic organisms are associated with specific thermal regimes; yet, the vast majority of the research on this topic has focused on salmonid species. The specific criteria used most to evaluate thermal regime suitability in this report are based on Brook Trout, the only stream-dwelling trout native to Minnesota and a sentinel species of stream and watershed health. Temperature requirements for Brook Trout is a complex subject and many factors can determine the suitability of a given stream reach for supporting this species. Examples include the duration/magnitude of exposure to stressful temperatures, habitat patchiness and availability of thermal refuge areas, main stem to tributary connectivity, and local habitat characteristics (esp. pool depths).

MPCA biologists are in the process of testing several models to predict the presence and abundance of coldwater indicator species (e.g. Brook Trout) based on continuous temperature and biological data (Sandberg and Dingman, 2016, personal comm.). The temperature criteria used in these models are based on the classifications of “growth,” “stress,” and “lethal” temperature ranges commonly used by MPCA, Minnesota Department of Natural Resources (DNR), and other agencies (Table 4). Two temperature metrics emerged from the analysis as relatively strong predictors of Brook Trout presence and abundance; % Growth (percent of temperature readings in the growth range) and Summer Average Temperature (mean temperature recorded between June 1 and August 31). These models were based on statewide paired temperature/biological data, and four groupings were defined in the data set (Areas 1-4) to develop generalized predictions of presence/absence and abundance (i.e. Brook Trout almost always present and in good numbers; Brook Trout may be present, generally in low numbers) (Table 4). These models remain in the development phase, but a similar approach was used in this report to summarize the relationships between stream temperature data and biological metrics (see Section 4.1).

Table 4. Thermal criteria used by DNR/MPCA for Brook Trout growth, stress, and lethal temperature ranges.

Classification	Temperature Range (°C)	Description
Growth	7.8 to 20.0 °C	Temperature range favorable for growth
Stress	>20.0 to 25.0 °C	Stress and avoidance behaviors
Lethal	>25.0 °C	Mortality can be expected at prolonged exposure

4.1.2 Thermal classification of Lake Superior Basin coldwater streams

Unlike the spring-fed trout streams of the SE Minnesota driftless Area, the hydrology of many Northeastern Minnesota coldwater streams are heavily influenced by overland runoff, and many streams lack a significant groundwater contribution (more in Section 4.8). Although there are many miles of designated trout streams in this region, a good portion of them offer marginal temperatures for supporting coldwater obligate species (e.g. Brook Trout). This is particularly true in the stream reaches closer to Lake Superior, which often lack cover for fish and are dominated by bedrock substrate which tends to be biologically unproductive and also inhibits groundwater upwelling. Despite these limiting factors, healthy populations of Brook Trout, Sculpin sp., and other sensitive coldwater species are often observed in areas where coldwater and ambient air temperatures persist throughout the year.

Given the unique qualities of NE Minnesota trout streams, a separate analysis of temperature and biological response metrics was completed. The approach used was similar to models developed by MPCA (Sandberg and Dingman, unpublished 2016), but instead of a statewide data set, stations included in the data set were exclusively within the Minnesota portion of the Lake Superior Drainage Basin. The data used were collected between 1998 and 2017. In all, 163 paired stream temperature and biological monitoring data points were scatter-plotted as % Growth vs. Summer Average Temperature to observe the range of coldwater stream conditions among North Shore coldwater streams. Several biological metrics, % Brook Trout (% BKT) and % Coldwater (percent of fish community comprised of "coldwater" individuals) were also incorporated into the analysis to observe relationships between temperature regime and biological response (Figure 3).

Four temperature regime categories were developed based on visual interpretations of the scatterplot results (Figures 11 and 12). Additional work is needed to solidify the categories based on statistical measures, but our objective was to stratify the results sufficiently enough to reveal general trends among North Shore data. The results help provide a broader, regional perspective on whether or not thermal conditions in the impaired reach of Beartrap Creek are limiting for coldwater biota compared to other coldwater streams of the region. Four thermal regime categorizes (Area 1-4) were developed based on stream temperature and biological condition measures described in Table 5.

Brook Trout and other coldwater species were present at some stations in all four thermal categories, which highlights the difficulty in definitively predicting fish communities based on data from a single temperature monitoring point per stream reach. For example, two Brook Trout were sampled at Caribou Creek station 13LS016 (Lake Superior North 8HUC watershed) in 2013, which fell into Area 1 with 42% of temperature readings in the growth range and a summer average temperature of nearly 21° C. Based on the scatterplot in Figure 3, this station should have the lowest potential to support Brook Trout of the 163 data points evaluated. Similar results can be seen in Area 1 and Area 2 of the graph in Figure 3. Localized groundwater inputs, high quality physical habitat, and ability to migrate seasonally to cold tributary streams may explain why several of these stations do not agree with the overall trend.

Despite some variable results, a clear trend is apparent, with stable, cold stream temperatures resulting in a greater probability of supporting Brook Trout and other coldwater species. Slightly over 82% (32 of 39) stations included in "Area 4" (>90% temperature in BKT growth range and summer avgerage.

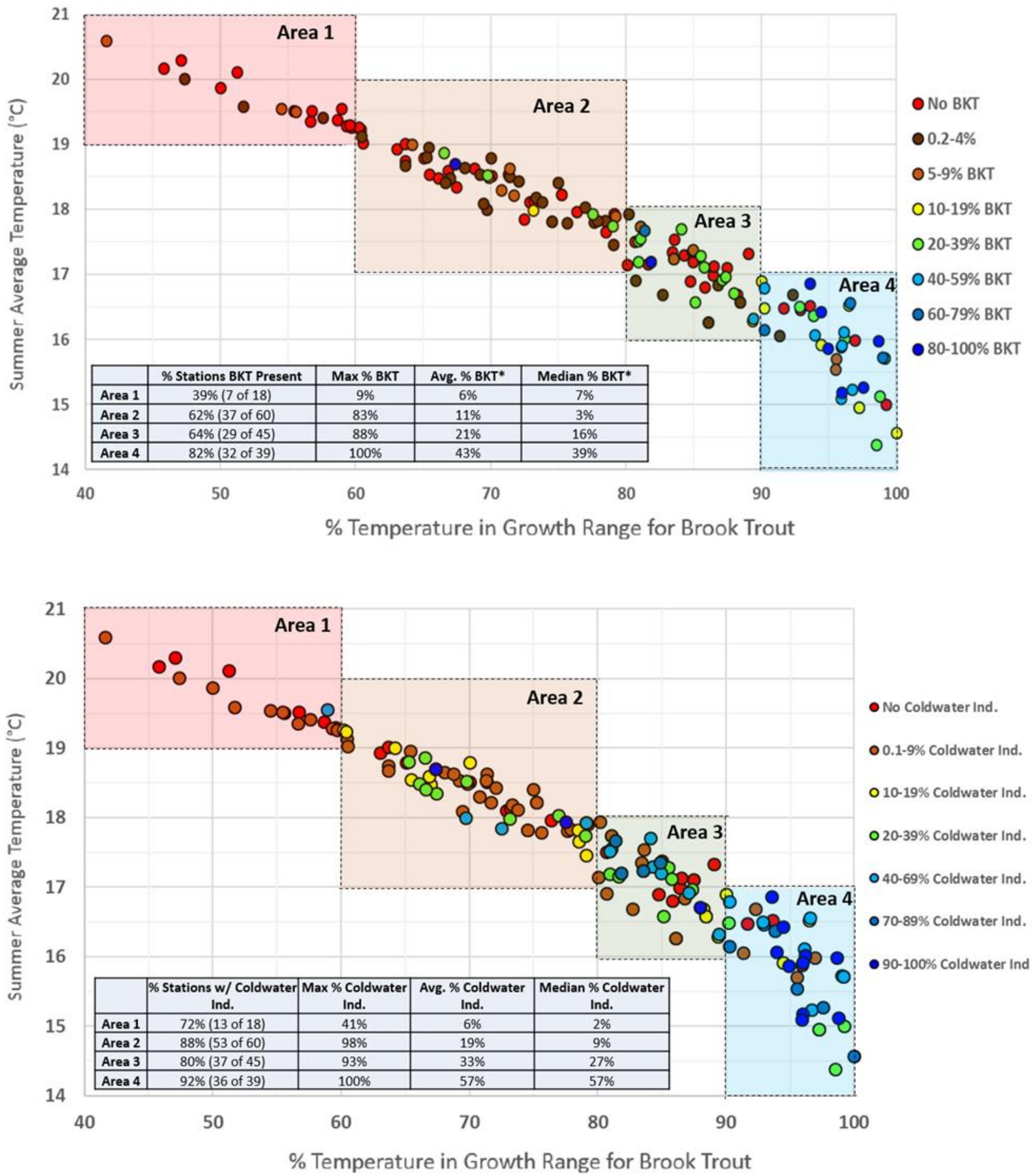
temperature < 17 C) supported BKT and most stations had relatively high populations. The majority (64% or 37/60) of stations within "Area 3" also supported Brook Trout; with slightly lower relative populations compared to most "Area 4", stations (Figure 3). The grouping of stations within "Area 2" shows a similar rate of Brook Trout presence (37 of 60 stations; 62%, but the relative abundance of Brook Trout compared to other species continues to decline. The stations in "Area 1" were more likely than not to be devoid of Brook Trout, and if trout were present, populations were very low (Figure 3). Overall, these classifications provide a broad perspective of the coldwater thermal regimes of Lake Superior Basin streams and are one tool of many available to classify streams and evaluate their suitability to support coldwater species. Refer to Section 5.3.1 for a detailed evaluation of water temperature as a stressor to aquatic life in Beartrap Creek.

Table 5. Four temperature regime categories developed based on visual interpretations of the scatterplot results of North Shore trout streams with temperature/fisheries data.

Grouping	% Temperature Reading in Brook Trout Growth Range	Summer Average Temperature (C)
Area 1	<60%	>19 C
Area 2	60-79%	17 – 20 C
Area 3	80-89%	16 – 18 C
Area 4	90 – 100%	<17 C

Grouping	Description
Area 1	Brook Trout and coldwater species sometimes present, more often a mix of cool/warmwater taxa
Area 2	Can support Brook Trout/other coldwater species, often a mix of cold, cool, and warmwater taxa
Area 3	Frequently supports Brook Trout and other coldwater species, lower relative densities
Area 4	Almost always support high relative densities of Brook Trout and/or other coldwater species, low taxa richness

Figure 3. Scatter-plot of summer average temperature vs % of time temperature within Brook Trout growth range. Marker colors correspond to relative densities of Brook Trout (top) and coldwater individuals (bottom) sampled. Data include all Lake Superior Basin coldwater (Northern Coldwater Fish IBI Class) stations with biological and temperature data from same season.



	% Stations BKT Present	Max % BKT	Avg. % BKT*	Median % BKT*
Area 1	39% (7 of 18)	9%	6%	7%
Area 2	62% (37 of 60)	83%	11%	3%
Area 3	64% (29 of 45)	88%	21%	16%
Area 4	82% (32 of 39)	100%	43%	39%

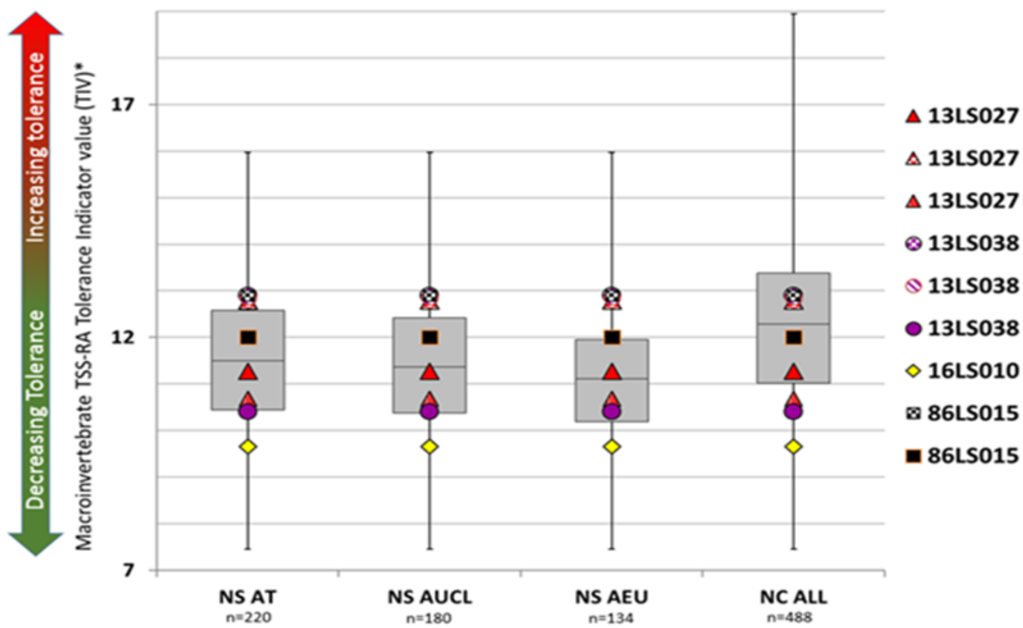
	% Stations w/ Coldwater Ind.	Max % Coldwater Ind.	Avg. % Coldwater Ind.	Median % Coldwater Ind.
Area 1	72% (13 of 18)	41%	6%	2%
Area 2	88% (53 of 60)	98%	19%	9%
Area 3	80% (37 of 45)	93%	33%	27%
Area 4	92% (36 of 39)	100%	57%	57%

4.2 Tolerance indicator values

The MPCA biological monitoring staff has developed a set of Tolerance Indicator Values (TIV) as guidance for how tolerant various fish and macroinvertebrate taxa are to certain stressors. The TIV are calculated using the abundance weighted average of each taxon that is present in conjunction with water quality of physical conditions. For example, Central Mudminnow is a very tolerant fish species that has been observed as the dominant fish species in many streams with low DO conditions in Minnesota. As a result, this species has a TIV value for DO that indicates a very high tolerance to low DO. Each individual species is assigned a TIV value for a given stressor. Community level TIV have also been developed, which is calculated using the abundance weighted average of the tolerance values of each taxon at a station.

The Coldwater Biotic Index (CBI) is an example of a TIV used in this report to evaluate the tolerance of aquatic macroinvertebrate communities to certain water temperatures. The CBI is an abundance-weighted average of the Coldwater TIVs for the macroinvertebrate taxa sampled at a given site.

Figure 4. Example of TIV results as used in later sections of this report. Acronyms are described in Table 5.



Class Abbreviation	Name (long)	Description
NS AT	North Shore - Above Impairment Threshold of General Use Criteria	Collection of results from biological monitoring stations in Lake Superior South and North HUC 8 watersheds with IBI scores (fish or macroinvertebrates) greater than the General Use standard, but below the upper confidence limit. Northern Coldwater IBI class only.
NS AUCL	North Shore – Above Upper Confidence Limit of General Use Criteria	Collection of results from biological monitoring stations in Lake Superior South and North HUC 8 watersheds with IBI scores (fish or macroinvertebrates) greater than the upper confidence limit of the general use standard, but below the exceptional use standard. Northern Coldwater IBI class only.
NS AEU	North Shore – Above Exceptional Use Criteria	Collection of results from biological monitoring stations in Lake Superior South and North HUC 8 watersheds with IBI scores (fish or macroinvertebrates) greater than the exceptional use standard. Northern Coldwater IBI class only.
NC ALL	All Northern Coldwater Class	Collection of results from all of the Northern Coldwater IBI class stations

4.3 Stream channel stability and habitat assessments

4.3.1 Brook Trout Suitability Assessment

The Brook Trout Suitability Assessment (BTSA) is a modification of a methodology developed by Bidelspach (2011) used to assess and rank trout habitat in Colorado. The BTSA is a rapid, semi-quantitative assessment of 25 variables related to habitat conditions for Colorado Cutthroat Trout. A review of scientific literature led to several modifications that are more pertinent to Brook Trout survival and growth. Results from Pfankuch Stability Index forms, continuous temperature loggers, and field observations were factored into the BTSA assessments within impaired watersheds and at numerous “reference” stations throughout the region. BTSA results from stations located on degraded stream reaches were compared to results from high quality “reference” stations to screen for habitat related stressors. A summary of the BTSA parameters, scoring system, and results in included in Appendix A.

4.3.2 Pfankuch Stability Index

The Pfankuch Stability Index (PSI) (Pfankuch, 1975) is a rapid, semi-quantitative assessment of stream channel stability and floodplain connectivity. PSI metrics focus on three major areas, upper streambanks, lower streambanks, and channel bottom (substrate). Metric scores are combined to generate an overall score and stability rating of “unstable”, “moderately unstable”, or “stable”. PSI stability ratings are further stratified by Rosgen stream type (Rosgen, 1996) due to the inherent differences in their resiliency to disturbance. The PSI assessments proved to be useful for evaluating channel stability on a watershed and reach scale during the course of the Stressor ID project. An example PSI data sheet and complete list of PSI results by station are included in Appendix B.

4.3.3 MPCA Stream Habitat Assessment

The MPCA Stream Habitat Assessment (MSHA) was developed to rapidly assess physical habitat conditions and riparian condition of streams and rivers. Habitat characteristics are recorded using a qualitative, observation based method on the Ohio Qualitative Habitat Evaluation Index (QHEI) developed by Midwest Biodiversity Institute (2006). The Ohio QHEI is a physical habitat index designed to provide an empirical evaluation of the lotic macrohabitat characteristics that are important to fish communities other aquatic life. Although similar to the Ohio QHEI, the MSHA has been modified to better assess important characteristics influencing Minnesota streams. The MSHA incorporates measures of watershed land use, riparian quality, bank erosion, substrate type and quality, instream cover, and several characteristics of channel morphology. Additional information on the MSHA methodology can be found on the MPCA website by typing “MSHA” into the search box.

4.4 Stream connectivity, crossings, and aquatic organism passage

4.4.1 Why is stream connectivity important?

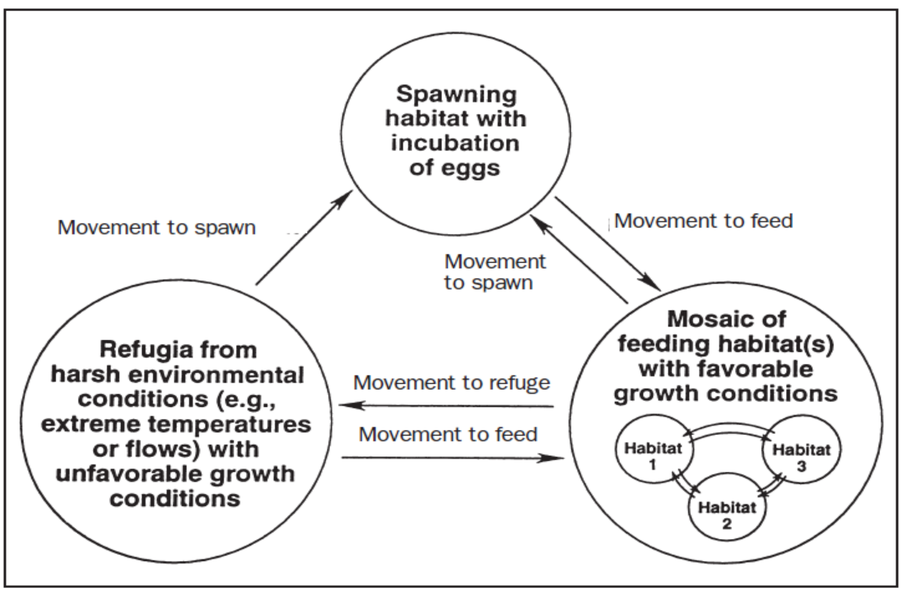
Stream connectivity refers to the maintenance of lateral, longitudinal, and vertical pathways for biological, hydrologic, and physical processes (Annear, 2004). Stream ecosystems are highly complex, as fish movement, habitat heterogeneity, and life-stage dependent habitat requirements interact to influence fish distributions at the watershed scale (Fausch et al., 2002). The ability of fish and other aquatic organisms to move freely within streams plays a key role in assuring that all of the critical habitat components of a species are met, particularly those that are highly sensitive and may require highly specific habitat types to carry out their life cycle (Figure 7).

Until recently, researchers believed that Brook Trout and other stream resident salmonids were rather sedentary by nature (Gerking, 1959; Clapp et al., 1990). Recent studies have demonstrated that long-range movements are relatively common within stream resident Brook Trout populations. Gowan and Fausch (1996) observed that 59% and 66% of marked Brook Trout moved at least 50 meters, and movements between 2000 – 3400 m (1.2 – 2.1 miles) were detected, even though the tracking period lasted only several months. In the upper Cheat River basin in West Virginia, adult Brook Trout commonly undertake large-scale movements between main stem areas and tributaries for the purposes of spawning, feeding, and refuge from elevated water temperatures (Petty et al., 2012).

Culverts, dams, and other barriers to migration negatively affect many non-game native species as well. Log or metal weirs installed in streams along Puget Sound in Washington restricted dispersal, condition, and abundance of native sculpins (Cottus spp.) (Tabor, 2017). Similar impacts to the native sculpin spp. of Minnesota can be expected in streams fragmented by a variety of migration barriers.

A significant portion of Minnesota's remaining native Brook Trout habitat is contained within the Lake Superior Drainage Basin. Although much of the region is sparsely populated and land ownership is predominantly public (e.g. National Forest, State Parks or undeveloped State Land), a substantial network of infrastructure exists to promote tourism, recreation, and economic growth. Maintaining stream connectivity and aquatic organism passage is critical for the short and long-term health of these coldwater streams.

Figure 5. The basic life cycle of stream fish with emphasis on patterns of habitat use and migration (from Schlosser, 1991).



4.4.2 Stream crossing assessment methodology

The DNR Stream Crossing Basic Assessment Form (Appendix C) was used to evaluate road/stream crossings. Among other factors, each crossing was evaluated for proper sizing of structures relative to measured bankfull widths, impacts to channel stability and sediment transport, proper alignment, and aquatic organism passage. Three principal criteria were used to identify culverts as partial or full barriers to aquatic organism passage; outlet perch presence and height, water velocity, and water depth. The width of properly sized culverts should closely match the bankfull riffle width of the river and the alignment of crossings should avoid altering the river's natural pattern.

Three ratings were developed in relation to culvert width: “appropriately sized”, “undersized”, and “oversized”. “Appropriately sized” culverts are those where the total span of the crossing is between 0.8 and 1.5 times the bankfull width of the stream. Appropriately, sized crossings have a reduced chance of negatively impacting fish passage, water quality, ecosystem function, and infrastructure integrity.

A culvert to bankfull width ratio of less than 0.8 was classified as “undersized”. Undersized culverts that tend back up water, sediment, and debris on the upstream side of the crossing, while increasing velocities and bank erosion on the downstream end (Jones et al. 2000). The backwater or impoundment effect of undersized crossings results in increased sediment deposition, which can negatively impact aquatic habitat (Frizzel et. al. 2004). Undersized culverts are generally more likely to be barriers to fish passage, and the greater the degree to which they are undersized, the greater chance they will have of blocking passage.

Culvert to bankfull ratios of 1.5 or greater were classified as “oversized”. Oversized culverts are less common than undersized culverts because the cost of materials and installation is often a limiting factor. Culverts that are too wide for the stream often lead to sediment deposition within the culvert, which decreases the ability to transport sediment even further and leads to more deposition – a process called aggradation. Aggradation within oversized culverts can increase stress on the culvert and generate higher maintenance costs. This aggradation can also create low-flow fish passage barriers if the flow is too shallow or the water flows sub-surface through the aggraded material.

5.0 Beartrap Creek Stressor Identification

5.1 Watershed conditions

5.1.1 Hydrology

The Beartrap Creek Watershed covers 21.7 square miles near the town of Saginaw, MN (approximately 17 miles NW of Duluth, Minnesota). The watershed lies within the southwest portion of the Toimi drumlin field and also along the edge of glacial Lake Upham, resulting in a mix of geological features and soil types. Areas within the former glacial lake consist of flat topography with fine soils (silts, sand, and clay) and tend to be dominated by wetlands and bogs. Portions of the watershed within the Toimi drumlin field are composed of outwash and moraine features, and rocky soil and gravel deposits are common in these areas.

The main stem of Beartrap Creek flows for a distance of 8.2 miles and is a 3rd order stream (Strahler) at its confluence with the Cloquet River. The 1,659-acre Grand Lake is located at the headwaters of the watershed and outlets to Beartrap Creek through a small ditch exiting the southwest side of the lake. Grand Lake is relatively shallow (10 ft.) and supports a warmwater fishery of Bluegill, Walleye, Black Crappie, and Northern Pike.

Two unnamed tributaries provide additional streamflow to Beartrap Creek. The upstream-most tributary (Tributary 3, Figure 7) enters near HWY 33 in T51 R17W S26. This tributary is ditched for most of its length and flows through an extensive peat deposit. Beaver impoundments are prevalent on this tributary, and water clarity is low due to heavy bog-stain (tannins). The second tributary stream is located in the lower 1/3 of the watershed and is comprised of two spring-fed streams (Tributary 1 and 2, Figure 7) that join near Bear Trap Rd in T51 R17W S21. These streams flow through an outwash plain and provide a year-round source of coldwater and seasonal spawning, rearing, and refuge habitat for Brook Trout and other coldwater taxa. A large spring also flows into Beartrap Creek near this tributary from the opposite side of the creek. The importance of these sources of coldwater, and the critical need to protect and restore access to these habitats is discussed in detail in Section 5.3.1.

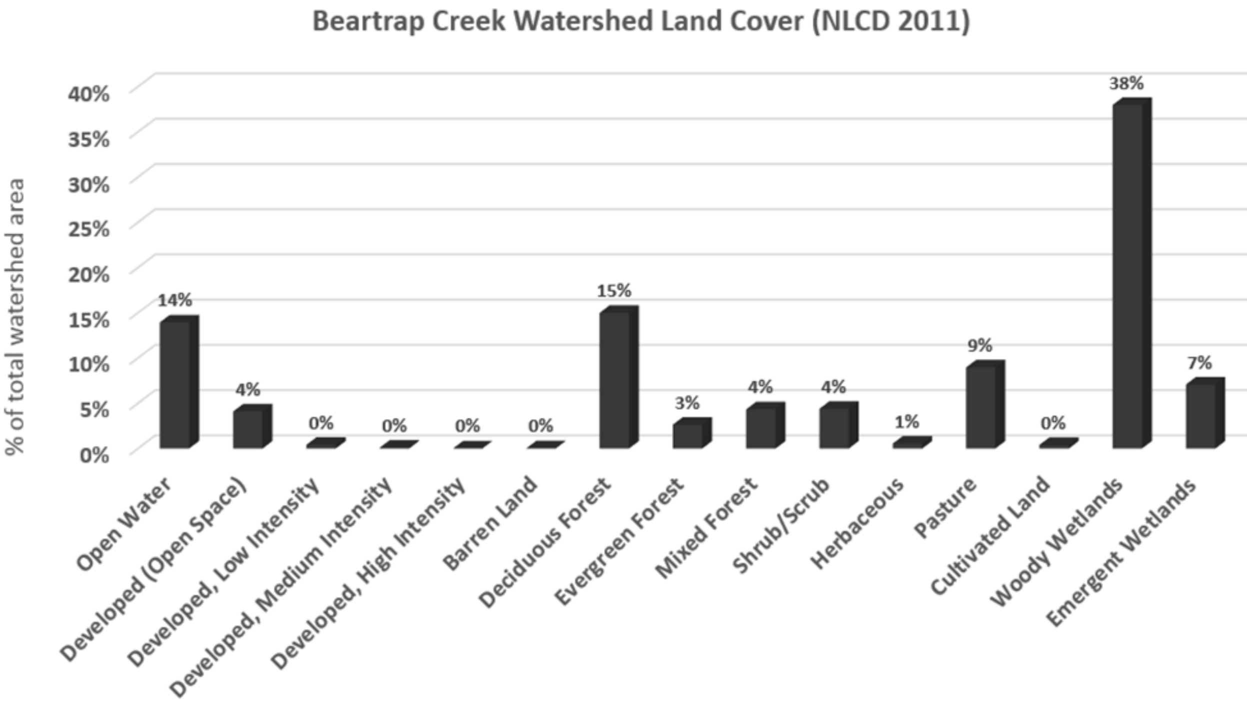
5.1.2 Land-cover and Land-use

The dominant land-cover types in the Beartrap Creek Watershed include wetlands (45% of total land area), forest (22%), and open water (14%, much of which is Grand Lake). Developed areas in the watershed are scarce and are primarily single-family residences, small agricultural operations (pasture/hay), and transportation networks (railroads, gravel roads, and major highways). Although the percentage of developed land is relatively low on a watershed scale, the middle to lower reaches of Beartrap Creek flow through a moderately developed landscape of small farms, gravel mining areas, and road networks. For the most part, a vegetated buffer provides a good level of protection from these land-uses. Land-ownership adjacent to Beartrap Creek is largely privately owned (75%) and the remainder is county tax forfeit (16%) and state-owned land (9%).

Several active gravel-mining operations exist in the lower Beartrap Creek Watershed adjacent to critical coldwater habitats. Gravel and other forms of aggregate mining is an extractive use of resources; mining alters the landscape and its natural hydrologic system (DNR, 2005). Quarries and pits can affect ground-water and surface-water systems in various ways, including; (1) lowering of local ground-water and surface-water levels from mining operations and mine dewatering, (2) changing turbidity levels in groundwater due to blasting and quarry operations, (3) interruption of ground-water conduit flow paths by rock removal, and (4) temperature change (thermal impacts) in springs and surface-water streams. The current and potential impacts of gravel mining in this watershed are discussed in detail in Sections 5.3.1.

Livestock grazing operations are scattered throughout the Beartrap Creek Watershed, but few exist within the riparian corridor. However, two open pasture areas were identified that allow cattle and/or other livestock unrestricted access to Beartrap Creek. These pasture areas are relatively small and run adjacent to 0.25 and 0.1 miles of stream, respectively (main stem of Beartrap Creek is 8.2 miles long). Based on aerial photo analysis, stream channel widths double within the open pasture areas compared to upstream reference reach with a forested riparian corridor. The impacts of unregulated grazing along Beartrap Creek are further evaluated as possible sources of habitat degradation (Section 5.3.5) and water temperature increases (Section 5.3.1).

Figure 6. Land Cover (NLCD 2011) of the Beartrap Creek Watershed.



5.2 Biological assessments

The Beartrap Creek Watershed contains 11.5 river miles of designated trout water, of which 7.1 miles is located on the main stem of Beartrap Creek. The additional designated trout water is located on three small (1st and 2nd order) tributary streams. All designated trout water in the watershed is currently managed to support wild Brook Trout populations. Brook Trout were actively stocked between the years of 1955 and 1981 by DNR.

Short segments of Beartrap Creek and its tributaries are classified as “warmwater” habitat, and are not expected to support coldwater fish and macroinvertebrate species. The warmwater designations are limited to the extreme headwaters of small tributaries and channelized (ditched) sections of the main stem through bog/wetland dominated areas. The impaired reach is located on a coldwater segment, and as a result, very little discussion of the warmwater reaches will be discussed in this report.

5.2.1 Sampling locations and results

The DNR has performed fisheries assessments of Beartrap Creek intermittently since the mid 1960’s. Data are available for nine sampling stations on the main stem of Beartrap Creek. Several of these stations are separated by very short distances and represent similar stream conditions (Figure 7). Differences in sampling objectives and methodology between DNR and MPCA prevent the use of DNR data for calculating coldwater fish IBI scores, yet DNR data remain useful for understanding the history of key species and the condition of the stream over the past 40-50 years.

Brook Trout populations in Beartrap Creek

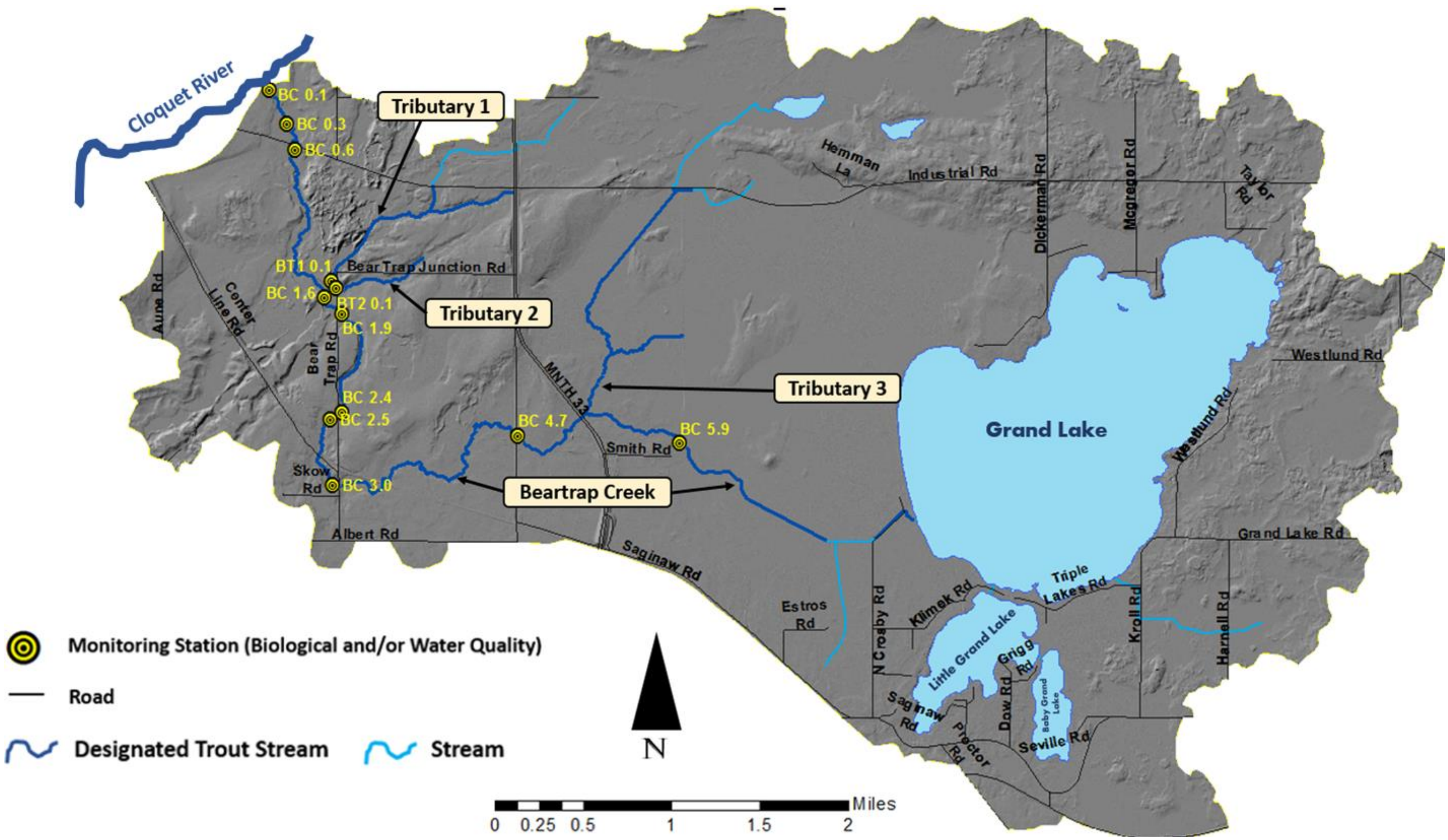
The earliest sampling of Beartrap Creek on record occurred in 1966, when four stations were sampled during the month of August (stations BC 0.1, BC 1.9, BC 2.7, and BC 4.9). No trout were observed at any station during this sampling effort. The absence of trout in this survey is noteworthy considering that Brook Trout were being actively stocked at the time. Several warmwater gamefish species were observed; Northern Pike at station BC 1.6, Bluegill at BC 0.6, Yellow Perch at BC 4.7. Largemouth Bass has also been sampled at station BC 0.6 (2016 sampling). Northern Pike and Largemouth Bass are known to prey upon juvenile and adult trout (Nilsson and Bronmark, 2000), and these species can freely migrate into Beartrap Creek via Grand Lake and the Cloquet River.

The DNR sampled station BC 1.9 again in August of 1982. Both juvenile (age-0) and adult (age-1+) Brook Trout were observed, but in low numbers (n=3, n=5). Considering that stocking efforts ceased in 1979, it can be concluded that the Brook Trout sampled were "wild" (e.g. the product of natural reproduction). Sampling occurred again in 2001 at station BC 0.6 (CR 7/ Industrial Rd). A single adult Brook Trout was collected during this sampling event, which further verifies limited, but successful natural reproduction. The presence of an adult Brook Trout at this station is noteworthy, as no trout were sampled during the 2015 and 2016 sampling events, which factored into the decision to list this reach as an impaired water.

Based on fisheries data collected between the years 1966 – 2001, Brook Trout populations in Beartrap Creek were marginal despite regular stocking attempts. Numerous studies have observed negative relationships between stocking and long term Brook Trout population and growth metrics, as well as a loss of genetic diversity and integrity (Marie et al., 2010; Bohlin et al., 2002; McKenna Jr et al., 2013).

In 2016, the fish community of Beartrap Creek was sampled again at three locations (BC 0.6, BC 1.6, BC 4.7) as part of the Lower Cloquet and Trout Stream Tributaries Brown Trout Stocking Evaluation and Stream Assessment (DNR, 2017). Brook Trout were not observed at stations BC 0.6 and BC 4.7, but a large population of adult and young-of-year (YOY) Brook Trout was sampled at station BC 1.6. Many of these fish were relatively large, with 13 of 103 individuals measuring over 250 mm.

Figure 7. Beartrap Creek Watershed and monitoring stations.



Historic fisheries data for Beartrap Creek suggest that most areas of the watershed provide marginal habitat for Brook Trout, but also reveal localized areas in the watershed where wild Brook Trout abundance and size structure is comparable to the highest quality streams in the region.

Additional coldwater fish taxa

Another coldwater obligate fish species, Mottled Sculpin, has been regularly sampled at several stations in the lower 2.4 river-miles of Beartrap Creek. No records of Mottled Sculpin exist upstream of station BC 2.4, despite sampling visits to several stations in the upper watershed during the summer of 1966, 2006, and 2016. Water temperatures in the upper portion of the watershed tend to be more variable and can reach levels that are lethal or stressful for coldwater species for extended periods.

Aside from Brook Trout and Mottled Sculpin, no other coldwater fish species have been observed in Beartrap Creek.

5.2.2 Fish IBI results

Fish Index of Biological Integrity (FIBI) scores are calculated using methodology developed by MPCA's Biological Monitoring Unit. Only one fish sampling event from Beartrap Creek meets the requirements for a "reportable" sample that can be used to generate an IBI score, a July 2016 visit to station BC 0.6 (MPCA station 01LS006) just upstream of CSAH 7. Station information, FIBI results, and the standards used to assess this reach are included in Table 6.

A FIBI result of 32 (out of a possible 100) was recorded at station BC 0.6 from the single reportable visit. This result is below the impairment threshold score of 35, but within the confidence interval (25 – 45). Fish species that were abundant or common in the sample included Creek Chub (31% of total sample), Mottled Sculpin (17%), White Sucker (15%), and Central Mudminnow (14%). MPCA decided to list Beartrap Creek as an impaired water for failing to meet the FIBI standard. FIBI metrics that factored heavily into the decision to list this reach as impaired included; (1) low numbers of individuals from intolerant coldwater taxa (esp. Brook Trout or Sculpin), (2) a relative high percentage of individuals from taxa that are considered tolerant in coldwater streams (e.g. Central Mudminnow), (3) a relatively high number of "pioneer" taxa (e.g. Creek Chub and Johnny Darter), and (4) the presence of several Perciform taxa (Johnny Darter and Largemouth Bass) in the sample also reduced the overall FIBI score at this station.

Table 6. Beartrap Creek biological monitoring stations used for assessment. This table does not include DNR results due to differences in methodology.

Station	Drainage Area (mi2)	Gradient (%)	Fish IBI Class	Fish IBI Result *(visit year)*	Standard	IBI Lower Confidence Limit	IBI Upper Confidence Limit
BC 0.6 (01LS006)	20.7	0.13%	11	32 *(2015)*	35	25	45

5.2.3 Macroinvertebrate IBI results

Similar to the fish bioassessments, only one reportable macroinvertebrate sample from a single station is available for calculating an IBI result. The macroinvertebrate community was sampled at station BC 0.6 in September of 2016. In addition to the 2016 visit, this station was also visited twice in 2015 (August and September) but was deemed unfit for sampling due to beaver impoundments within and downstream of the reach. The reportable sample resulted in a MIBI score of 27 (out of 100), which is below the impairment threshold (32) but within the confidence limit (20 to 44). Several stenothermic coldwater macroinvertebrate taxa were present in the sample, confirming the potential of this reach to support those taxa. However, several signs of an impaired assemblage were noted, including a large number of Hyallela (freshwater amphipod or “scuds”) and Physella (freshwater snails).

Hyalella can be described as neutral in terms of tolerance to disturbance. Large populations are often found in aquatic vegetation, such as Elodea (waterweeds) and algae. Increases in productivity due to excess nutrients, stagnant flows, or water temperature increases could result in favorable conditions for Hyallela and other freshwater amphipods. Another amphipod taxon, Gammarus, is a more favorable indicator of coldwater habitat, as they are often found near sources of coldwater, such as groundwater seeps or upwelling.

The abundance of Physella snails at this monitoring station is a clear indicator of disturbed coldwater habitat. This taxon is often abundant where in waterbodies with elevated nutrient concentrations, low dissolved oxygen concentrations, and sluggish flow conditions. Oxyethira (Micro-caddisfly) is another taxon observed at this station that is often linked to slow or stagnant flow conditions.

Several intolerant taxa were present at this station, but their numbers were relatively sparse. Some of the intolerant taxa present include Antocha (Crane Fly), Hemerodromia (Dance Fly), Helicopsyche (Snail-case Caddisfly), Ptilostomus (Giant case-maker Caddisfly), Optioservus (Riffle Beetle), Claopteryx (Jewelwing Damselfies) and Somatochlora (Striped Emerald Dragonfly). Several mayfly taxa (Paraleptophlebia, Baetis) were abundant, but neither of these are highly sensitive taxon.

Overall, the macroinvertebrate community can be categorized as a moderately disturbed community with some sensitive coldwater taxa present. The presence of sensitive coldwater taxa at this station suggests that water chemistry stressors are an unlikely cause of impairment. Numerous references to beaver impoundments and related habitat disturbances were made during the initial assessments and discussion of the macroinvertebrate dataset for Beartrap Creek. Localized habitat disturbance due to beaver dams, such as increased deposition of fine particles (sand and silt) within impounded areas, would likely reduce the abundance of intolerant taxa, but not eliminate them. A reach impounded by beaver dams, or recovering from their effects, would offer prime habitat for some of the more tolerant macroinvertebrate taxa that were dominant at this station (such as Oxyethira and Physella).

Table 7. Beartrap Creek biological monitoring stations used for assessment. This table does not include DNR results due to differences in methodology.

Station	Drainage Area (mi2)	Gradient (%)	Invert IBI Class	Invert IBI Result *(visit year)*	Standard	IBI Lower Confidence Limit	IBI Upper Confidence Limit
BC 0.6 (01LS006)	20.7	0.13%	8	27 *(2015)*	32	20	44

Figure 8. (TOP): Biological monitoring station BC 0.6 (MPCA Station ID: 01LS006) in July of 2016 (left) and September of 2015 (right). Fish community data were collected during the July 2016 visit. No biological data were collected in September 2015 due to the presence of several beaver dams within the sampling reach. (Middle): Biological monitoring station BC 1.6. Several gravel/cobble riffles offer high quality spawning habitat within this reach. Banks are stable and deep bend pools are present. (Bottom): Upper reaches of Beartrap Creek at BC 4.7. This area is low-gradient and substrates are composed mostly of fines (silt/sand). Dissolved oxygen levels are often below 5 mg/L due to natural background conditions (wetlands).

5.3 Beartrap Creek Stressor Identification Analysis

5.3.1 Elevated water temperature

Continuous water temperature data are available for several Beartrap Creek monitoring stations dating back to the summer of 2001. The DNR monitored two stations (BC 4.6 and BC 0.6) during the summers of 2001 through 2003, and again at station BC 0.6 in 2015. Following the impairment listing for aquatic life, MPCA installed temperature loggers at six stations on the main stem of Beartrap Creek and two tributary streams in 2017 to evaluate water temperature as a potential limiting factor for Brook Trout and other coldwater species. All monitoring locations are shown in Figure 7 and a complete summary of the results are included in Appendix D.

Water temperatures vary considerably between individual stream reaches of Beartrap Creek and its tributary streams (Figure 9). In general, the upper portion of Beartrap Creek (upstream of station BC 2.5) offers poor to marginal water temperatures for supporting Brook Trout and other coldwater obligate species. The majority of the stations within this reach plotted within the “Area 1” or “Area 2” temperature classes shown in Figure 9, which tend to include sites with few or a complete lack of coldwater taxa. Although marginal water temperatures for coldwater species are commonly observed in upper portion of the watershed, a high degree of year-to-year variability is evident. For example, station BC 4.6 had an average summer temperature of 17.0 C in 2003, which was down from 19.5 C in 2001. The most recent data from this site (2017) shows an average water temperature of 18.2 C.

Water temperatures are more suitable for Brook Trout and other coldwater taxa in the lower reaches of Beartrap Creek, particularly between station BC 1.6 and BC 0.1 (Figure 10). Temperature values were within the optimal range for Brook Trout survival and growth between 80-90% of the summer (June-August), and summer average temperatures fell between 17 - 18 C. Most main stem stations within this reach plotted within Area 3 (Figure 9), which is a grouping of stations that usually support Brook Trout and/or other coldwater fish and macroinvertebrate taxa (see Section 4.1.2) It is important to note that the impaired biological monitoring station (BC 0.6) falls within this colder reach of Beartrap Creek. Water temperatures at this station appear to be suitable for supporting Brook Trout and other sensitive coldwater taxa.

Water temperatures in two spring-fed tributaries to Beartrap Creek were monitored for the first time ever in 2017. Temperatures in both of these tributaries remained in the optimal range for Brook Trout the entire summer and represent some of the coldest temperatures recorded in the Lake Superior Basin (Figure 9). Young-of-year (YOY) and adult Brook Trout were observed using these tributaries for spawning, rearing, and refuge. These tributaries enter Beartrap Creek near station BC 1.6, where Brook Trout abundance is exceptionally high for the Cloquet River Watershed and comparable to many of the highest quality coldwater streams in the Lake Superior Basin. The ecosystem services provided by these tributaries are critical, and measures should be taken to protect them from degradation.

Factors influencing water temperatures in Beartrap Creek

(1) Forest cover and shading

Forested land-cover within a watershed is strong predictor of Brook Trout abundance and habitat suitability (McKenna Jr and Johnson, 2011). Overall, the Beartrap Creek Watershed is not as heavily forested as many Lake Superior Basin streams. However, good forest cover is present in many of the areas of the watershed that offer high quality coldwater habitat and colder water temperatures. Dense canopy cover is provided by mature hardwood/conifer forest between stations BC 2.4 and BC 1.6, and the spring-fed tributaries in this portion of the watershed are heavily shaded by alder. Protection of these forested riparian corridors will continue to safeguard these high-quality habitats from warming due to solar radiation and maintain woody debris inputs (trees, branches) that provide in-stream habitat and organic matter.

(2) Groundwater: springs and tributaries

The lower half of the Beartrap Creek Watershed is dominated by undulating glacial-outwash geology with numerous large gravel deposits. As a result, several springs and spring-fed tributary streams are present in this area. These features create a cooling effect on water temperatures in the main stem of the creek (Figure 10) and provide valuable spawning, rearing, and thermal refugia for Brook Trout and potentially other species of coldwater fish. Many of these features are found immediately adjacent to large gravel deposits, some of which are being removed by active gravel mining operations (Figure 11). Protection measures should include best management practices for gravel mining, and possibly additional focused monitoring efforts to investigate groundwater to surface water connections and potential impacts from gravel extraction.

(3) Ponds on private property

Headwaters streams are some of the most diverse of all running-water habitats, and provide a key role in preserving and enhancing biodiversity and ecosystem services within a watershed (Meyer et al, 2007). Many fish species, especially Brook Trout, are known to use spring-fed headwaters streams for spawning, rearing, and refuge. Many of these streams are so small as to be omitted from USGS topographical maps. Several private ponds have been constructed in the channel of perennial, spring-fed tributaries to Beartrap Creek. These impoundments have the potential to increase water temperatures, alter streamflow, and reduce or eliminate fish passage. Maintaining the quality of spring-fed tributaries and access to them is a critical factor for sustaining coldwater fish and macroinvertebrate communities in the Beartrap Creek Watershed.

(4) Beaver dams

Beaver dams have been shown to cause increased water temperature which can be detrimental in coldwater stream environments (Avery, 2002; Patterson, 1951; Avery, 1992). However, their effects on water temperature can be variable due to natural background conditions and other factors (e.g. local geology, age/height of dam, presence of groundwater inputs). Active and/or abandoned beaver dams were observed in nearly all reaches of Beartrap Creek, but they are especially abundant in the upper and lower portions of the watershed. Analysis of historic aerial photos shows a nearly ten-fold increase in the number of beaver dams in the watershed from 1939 to 2016. The increase in beaver population can be attributed to several factors, including a decrease in demand for beaver pelts and thus less trapping, as well as a shift in forest cover from long-lived coniferous species to rapidly growing, regenerative species such as Aspen, which are highly preferable to beavers. An inventory of beaver dams in the Beartrap Creek Watershed and density comparisons to nearby watersheds is included in Appendix E.

Based on 2017 data, beaver dams had negligible effects on water temperature within the stream reaches that are currently managed by DNR for Brook Trout. Numerous beaver dams were present in between stations BC 1.6 and BC 0.1, yet stream temperatures were colder at BC 0.1. The scale of monitoring effort is likely too large to detect localized changes at the stream reach or micro-habitat scale, but there does not appear to be a major shift in thermal regime due the presence of beaver dams within the impaired reach.

(5) Vegetation removal and livestock grazing

The riparian corridor along Beartrap Creek is largely vegetated and undisturbed, but localized areas of livestock grazing have denuded vegetative cover along relatively short reaches of the creek. Cattle and other livestock within these pasture areas have unregulated access to the stream, and the channel has become wider and shallow in high-traffic areas. Wider, shallower stream channels are generally more susceptible to warming than deep, narrow channels. No temperature data were collected to investigate this potential source of warming in Beartrap Creek, but establishing more perennial vegetation these areas through fencing could help protect the stream from warming.

Biological response to water temperature

Nearly all of Beartrap Creek is classified as a coldwater stream, however DNR monitoring indicates marginal to poor for conditions for coldwater fish upstream of station BC 3.0 due to natural background conditions (unsuitable water temperatures, physical habitat, low DO concentrations). The fish community within this reach reflects these limitations; as the majority of the species sampled in this portion of Beartrap Creek can be classified as “tolerant” and/or “low-gradient wetland” species commonly found in headwaters streams with warm or cool water temperature regimes.

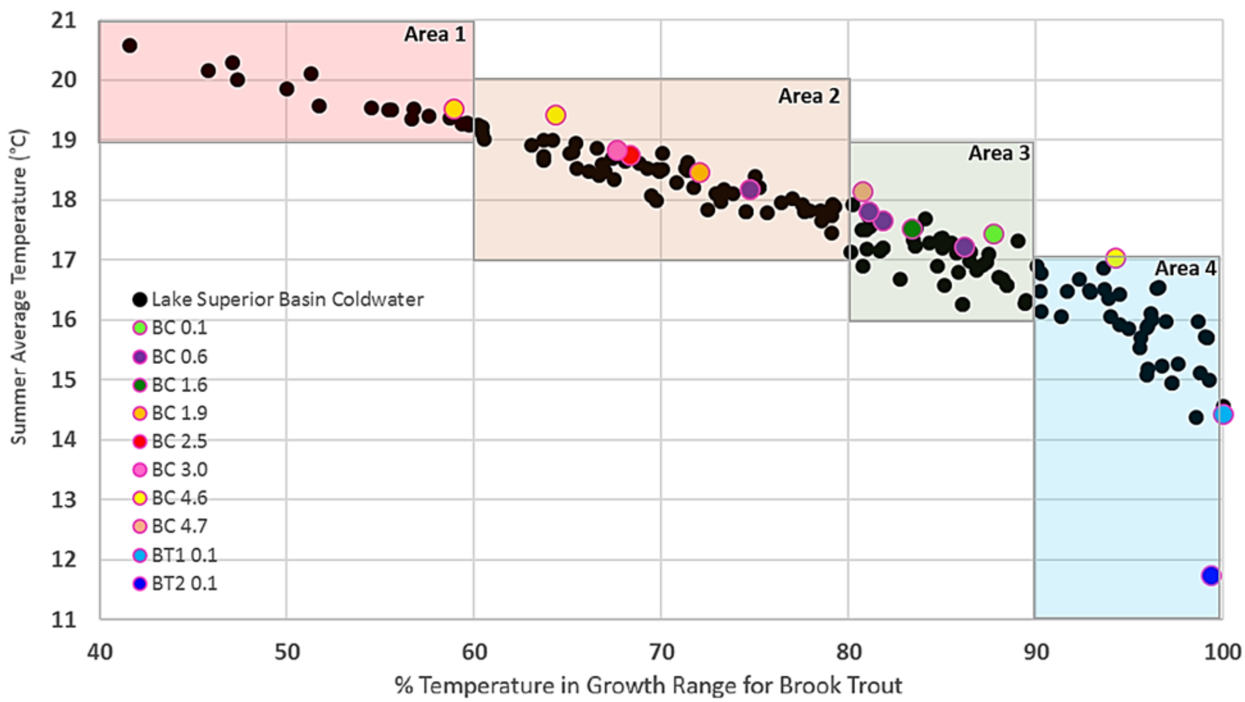
Downstream of station BC 3.0, warmwater species remain dominant, but two coldwater species, Brook Trout and Mottled Sculpin, were sampled during MPCA and DNR monitoring efforts. The range of these species appears limited to the lower 1/3 of the watershed where water temperatures are colder. Mottled Sculpin are widespread within this lower portion of Beartrap Creek and have been observed at every established monitoring station downstream of BC 2.4. Brook Trout populations are more localized (stations BC 0.6, BC 1.6, BC 1.9), and their presence and population sizes have been variable among the sampling visits. In recent years, Brook Trout have been abundant at station BC 1.6 and BC 1.9. This reach of Beartrap Creek supports a healthy population of Brook Trout comparable to some of the highest quality streams in NE Minnesota. On the contrary, Brook Trout have only been intermittently sampled in low numbers roughly one river-mile downstream at the impaired biological monitoring station (BC 0.6) over the past three decades.

Taxa richness and the relative percentage of species that are coldwater obligates (require coldwater temperatures for survival) are two basic metrics that can be used to evaluate the health of coldwater fish communities. Typically, high quality coldwater streams support fewer taxa overall and contain a high percentage of coldwater obligate species relative to non-coldwater taxa. In other words, diversity and high species counts are negative traits in coldwater streams. In general, Beartrap Creek monitoring stations score poorly in these metrics, as results show a relatively high taxa richness values and low relative percentages of coldwater species. Compared to results from a set of non-impaired reference coldwater streams, most results from Beartrap Creek are inferior, with the exception of station BC 1.6. Beartrap Creek is a direct tributary to the Cloquet River. Warmwater species associated with the larger Cloquet River (Bluegill, Walleye, Northern Pike) are frequently observed in the lower reaches of these coldwater streams and therefore negatively influence coldwater metric results.

Macroinvertebrate data are available for only one station on Beartrap Creek (BC 0.6, 01LS006). The MIBI score of 27 (out of 100) at this station is indicative of an impaired coldwater macroinvertebrate community. Several macroinvertebrate taxa associated with coldwater temperatures were present in the sample, but their numbers were fairly sparse. Coldwater Biotic Index (CBI, see Section 4.2) results for station BC 0.6 scored poorer than over 75% of comparable reference streams, which is another indicator that BC 0.6 supports a fair to poor quality coldwater macroinvertebrate community.

Confounding stressors, such as poor habitat quality, can also be expressed through poor coldwater metric scores and CBI values such as those observed at station BC 0.6. Based on several years of temperature data collected at BC 0.6, the thermal regime appears to be capable of supporting a healthy coldwater macroinvertebrate community, but habitat conditions are sub-optimal (see Section 5.3.5). Water temperature and physical habitat quality vary considerably within Beartrap Creek and its tributary streams, and highly mobile organisms such as Brook Trout can migrate to find optimal conditions during critical stages of their life cycle. Macroinvertebrates are far less mobile, and could be exposed to short duration, low magnitude periods of thermal stress without the ability to move into more favorable habitat. Unfortunately, no macroinvertebrate data are available for the reaches of Beartrap Creek with exceptional habitat (BC 1.6) or its extremely cold tributaries for comparison.

Figure 9. Plot of summer average temperature vs % Time in Temperature range supportive of Brook Trout growth. Beartrap Creek monitoring stations are shown in colored markers, while all other coldwater stations in the Lake Superior drainage basin are shown as black markers.



Grouping	% Temperature Reading in Brook Trout Growth Range	Summer Average Temperature (C)
Area 1	<60%	>19 C
Area 2	60-79%	17 – 20 C
Area 3	80-89%	16 – 18 C
Area 4	90 – 100%	<17 C

Grouping	Description
Area 1	Brook Trout and coldwater species sometimes present, more often a mix of cool/warmwater taxa
Area 2	Can support Brook Trout/other coldwater species, often a mix of cold, cool, and warmwater taxa
Area 3	Frequently supports Brook Trout and other coldwater species, lower relative densities
Area 4	Almost always support high relative densities of Brook Trout and/or other coldwater species, low taxa richness

Figure 10. % of summer (June-August) temperatures within the growth range for Brook Trout at Beartrap Creek monitoring stations in 2017.

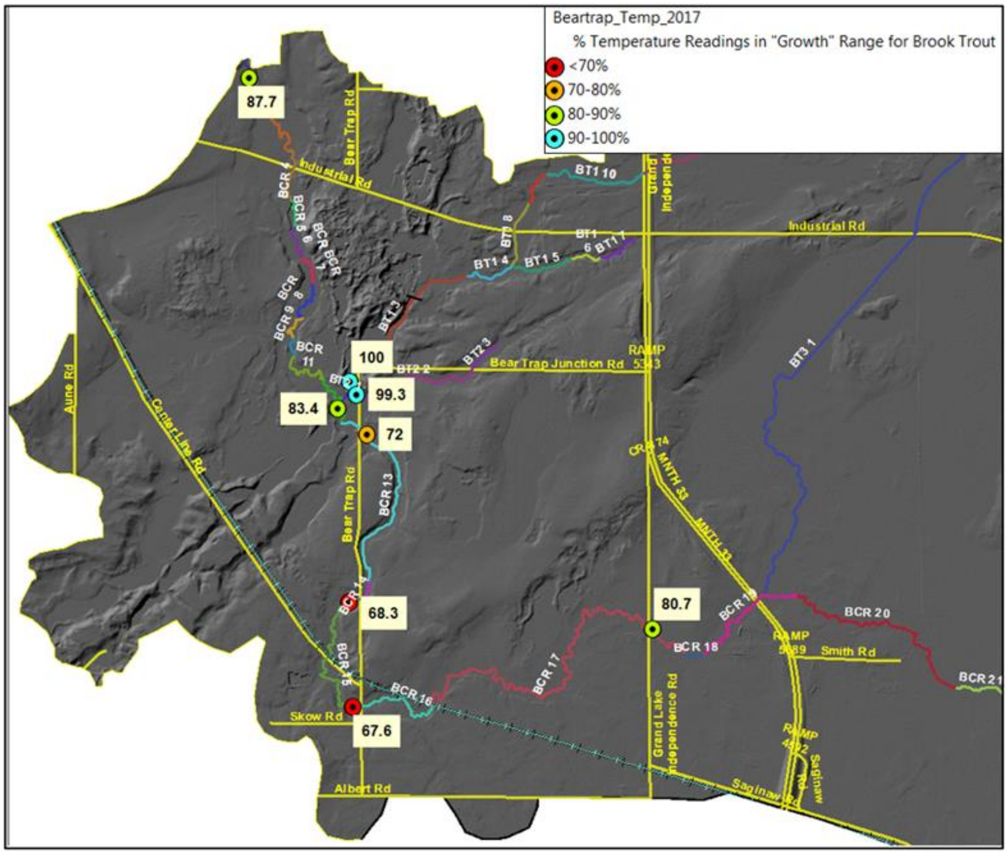
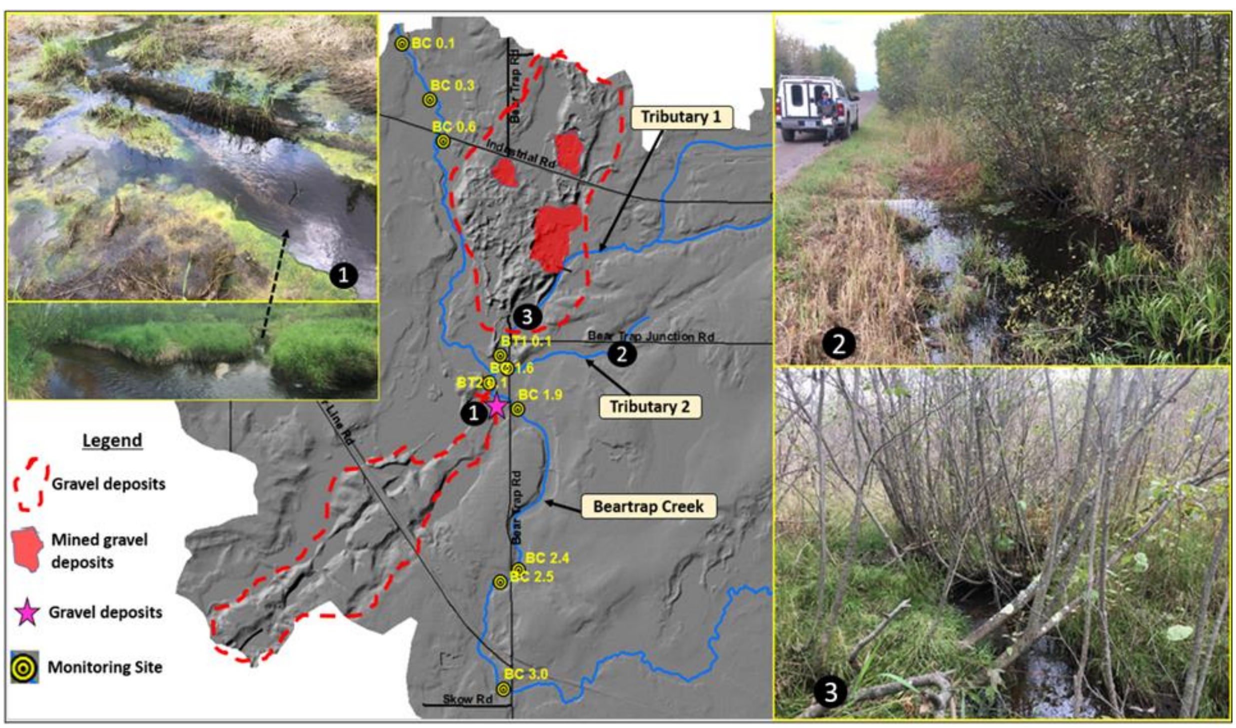


Figure 11. Examples of coldwater inputs to Beartrap Creek. (1) Large off-channel spring near station BC 1.6; (2) Spring-fed tributary stream (Tributary 2); and (3) another spring-fed tributary stream (Tributary 1).



Summary: Water temperature as a stressor in Beartrap Creek

Beartrap Creek and its tributaries offer a wide range of water temperature conditions. Warmer stream temperatures and/or low DO concentrations are limiting for coldwater fish and macroinvertebrates in the upper reaches of Beartrap Creek, from the headwaters down to approximately station BC 3.0. However, elevated water temperatures in this reach are likely the result of natural background conditions and should not be considered a “stressor” or cause of impairment. Low stream gradient, abundant riparian wetlands, fine stream substrates, and numerous beaver dams are all factors that limit coldwater potential in this reach.

From a water temperature standpoint, the potential to support coldwater fish and macroinvertebrate species in Beartrap Creek increases substantially near station BC 1.9 and extends downstream to the Cloquet River. A large spring and two perennial spring-fed tributaries enter the main stem at station BC 1.6 and have a profound cooling effect on the main stem of the creek. Main stem water temperatures are relatively consistent from station BC 1.6 downstream to the Cloquet River. Thus, the large discrepancy in Brook Trout populations between station BC 1.6 and the impaired reach at BC 0.6 cannot be attributed to differences in main stem water temperature, as the thermal regimes of these two stations are relatively similar. In 2017, summer average temperatures were in fact slightly colder at BC 0.6, where no Brook Trout have been sampled since 2001. Maximum temperatures at the two stations were also very comparable, with 11-17% of summer temperature readings exceeding the “stress” threshold for Brook Trout, but no exceedances of the “lethal” threshold. Both of these reaches appear to support water temperatures that are suitable, though not ideal, for supporting coldwater fish and macroinvertebrate taxa.

Stream ecosystems are a complex patchwork of variable physical, chemical, and biological conditions, and unique features in localized areas can be critical for species to carry out their life histories. One critical difference between the productive coldwater reach of Beartrap Creek and the impaired biological monitoring station is access to coldwater refuge areas (springs, tributaries). Although main stem temperatures appear to be similar or even slightly warmer at station BC 1.6, several spring-fed tributaries and off-channel springs are located within this reach. Brook Trout of all age classes can utilize these features as thermal refuge areas when temperatures in the main stem become stressful. In addition, the cold tributaries entering Beartrap Creek at station BC 1.6 provide additional spawning and rearing habitat that is not available near the impaired biological monitoring station at BC 0.6.

Water temperature is a critical variable when evaluating the health and potential of coldwater resources. Beartrap Creek is similar to most streams in the region in that water temperatures vary spatially within the watershed, and localized areas of coldwater input via springs and small tributaries heavily influence the distribution of coldwater fish and macroinvertebrate taxa. The biological data from Beartrap Creek is a prime example of how the patchwork nature of critical habitat features can give rise to distinct differences in stream fish and macroinvertebrate assemblages, even at relatively small scales.

Elevated water temperature is not a conclusive cause of biological impairment in Beartrap Creek. Temperatures within the impaired reach remain suitable for supporting Brook Trout, other coldwater fish species (e.g. Mottled Sculpin), and some coldwater macroinvertebrate taxa. Because coldwater refuge areas are distributed in patches throughout the watershed, the ability of organisms to move throughout the watershed is critical for their long-term survival. Longitudinal connectivity and aquatic organism passage is introduced in Section 4.4 and evaluated as a potential limiting factor in Beartrap Creek in Section 5.3.2.

5.3.2 Longitudinal connectivity and aquatic organism passage

The ability of fish and other aquatic organisms to move freely within river systems plays a key role in assuring that all of the critical habitat components of a species are met (see Figure 5, Section 4.4.1). Critical habitats for spawning, rearing, feeding, and refugia are often limited and arranged in a patchwork pattern within a watershed, thus movement within and between these unique features becomes critical for sustaining wild fish populations. Barriers between main stem rivers and tributaries are especially damaging to brook trout, as habitat fragmentation is widely linked to local extinction of stream salmonid populations (Morita & Yamamoto, 2002; Letcher et al., 2007).

Improperly installed and/or poorly designed road and railroad crossings are negatively affecting aquatic connectivity (e.g. fish passage), water quality, and physical habitat in the Beartrap Creek Watershed. The observed detrimental effects of these crossings include;

- Barriers to fish migration and dispersal, several of which impede access to cold tributaries that provide refugia, rearing, and spawning habitat
- Disruption of downstream transport of sediment, large and fine woody debris, all of which are critical for maintaining habitat diversity/complexity and trophic function
- Altered hydrology, especially during high and low flow periods. Ponding upstream and downstream is evident at several undersized crossings.
- Negative effects on water quality. These include sediment loading resulting from bank erosion near crossings, increased water temperatures and altered DO regime due to ponding.

Specific examples of the negative impacts listed above are discussed in this section. The crossings referenced in this section are all candidates for restoration work in this watershed. A prioritization approach for restoring connectivity in the Beartrap Creek Watershed is presented in Table 8. Loss of longitudinal connectivity is not considered a primary cause of the fish or macroinvertebrate impairment. However, restoration activities directed at restoring these processes are likely to increase the potential for full recovery of biological potential in this watershed.

Fish migration barriers

Stream crossings: Roads, driveways, and railroads

The DNR Stream Crossing Basic Assessment Form (Appendix C) was completed at seventeen stream crossings in the Beartrap Creek Watershed. All assessed crossings are mapped in Figure 12 and complete results can be provided upon request. Each of the seventeen crossings evaluated are culvert structures of some form; no span bridges are present within the watershed. Ten of the crossings consist of a single culvert and the other seven contain two culverts.

Nearly 30% (5 of 17) of the crossings evaluated in the Beartrap Creek Watershed were determined to be full or partial barriers to fish movement. As suggested by several scientific papers on watershed restoration (Roni, 2002; McKay et al., 2016; Petty et al., 2012) we recommend that restoration projects focus initially on reconnecting isolated high-quality fish habitats, such as instream (main stem and tributaries) or off-channel habitats (e.g. groundwater springs) made inaccessible by culverts or other artificial obstructions.

Stream temperature, physical habitat, and biological data indicate that the prime coldwater habitat in the Beartrap Creek Watershed is localized. Perennial inputs of coldwater from springs and several small tributary streams (BT2 and BT1) combined with high quality physical habitat conditions help sustain wild Brook Trout populations in several contiguous reaches of the main stem, namely BCR 12 and BCR 13 (TWP 51/17/21; TWP 51/17/22; TWP 51/17/27) (see map in Figure 20). Fish and other aquatic life are able to move uninhibited within the main stem of Beartrap Creek in this area, as all crossings are bridges or culverts that allow fish passage under all flow conditions.

However, a series of undersized culverts were identified in two primary coldwater tributary drainages in this area of the watershed. Tributaries BT1 and BT2 merge, and shortly downstream join the main stem of Beartrap Creek near station BC 1.6. Adult and young-of-year (YOY or Age 0) Brook Trout have been observed in these tributary streams near their confluence with Beartrap Creek, and Brook Trout YOY have also been observed in tributary BT2 upstream of Beartrap Road in early May (Figure 13). This observation provides evidence that tributary BT1 and BT2 are utilized for spawning and rearing, and proves that adult fish are able to pass through the culverts at some flows. However, access to these tributaries is likely reduced, particularly during periods of low or very high streamflow. In addition, several more impassable culverts exist farther upstream on tributaries BT1 and BT2, further fragmenting this important spawning, rearing, and refuge habitat for coldwater fish.

Replacing undersized and/or perched culverts on tributaries BT1 and BT2 will allow Brook Trout and other species year-round access to approximately 2.30 miles of coldwater habitat. Water temperature in these tributaries remained in the “growth” range for Brook Trout 100% of the summer (May-Sept) in 2017. Based on these coldwater temperatures and observations of adult and YOY Brook Trout occupying these tributaries during summer low flow and spawning and rearing periods, it is clear that these tributaries provide vital habitat for sustaining wild Brook Trout populations in this watershed.

Impacts to physical habitat, hydrology, and water quality

Over 70% (12 of 17) of the crossings evaluated in the Beartrap Creek Watershed are undersized relative to measured bankfull channel widths. Undersized and/or improperly designed crossings are increasing sediment loads to Beartrap Creek, with some causing localized habitat degradation. The impacts are not limited to aquatic life and water quality, as some crossings are also causing damage to property and jeopardizing road infrastructure. Several crossings on tributaries BT1 and BT2 are undersized and improperly aligned with the pattern of the stream, resulting in road and driveway washouts, downstream scour pools and bank erosion, and aggradation (deposition of sediment) upstream of the crossings (see examples in Figure 13).

An undersized railroad culvert at river-mile 4.0 of Beartrap Creek is a priority for restoration work considering that it has an increased chance for blockage (two culverts instead of one) and is the only unnatural fish passage barrier on the main stem of Beartrap Creek. The recommendation for replacing this culvert is to either install a bridge or a box culvert that matches the bankfull width of 14’. Due to the lacustrine valley setting and the relatively wide flood prone area, floodplain culvert installation is also highly recommended.

Undersized or improperly set culverts typically result in stagnant water upstream or downstream of the crossing (ponding). Ponding is not conducive to maintaining coldwater temperatures, suitable dissolved oxygen levels, and optimal habitat conditions for riverine aquatic life. The majority of the hydrological and habitat related impacts from road crossings are located in the upper ½ of the Beartrap Creek Watershed, where low-gradient wetland conditions and abundant beaver impoundments limit coldwater fish and macroinvertebrate potential.

Figure 12. All assessed stream crossings in the Beartrap Creek Watershed with ratings for sizing and fish passage.

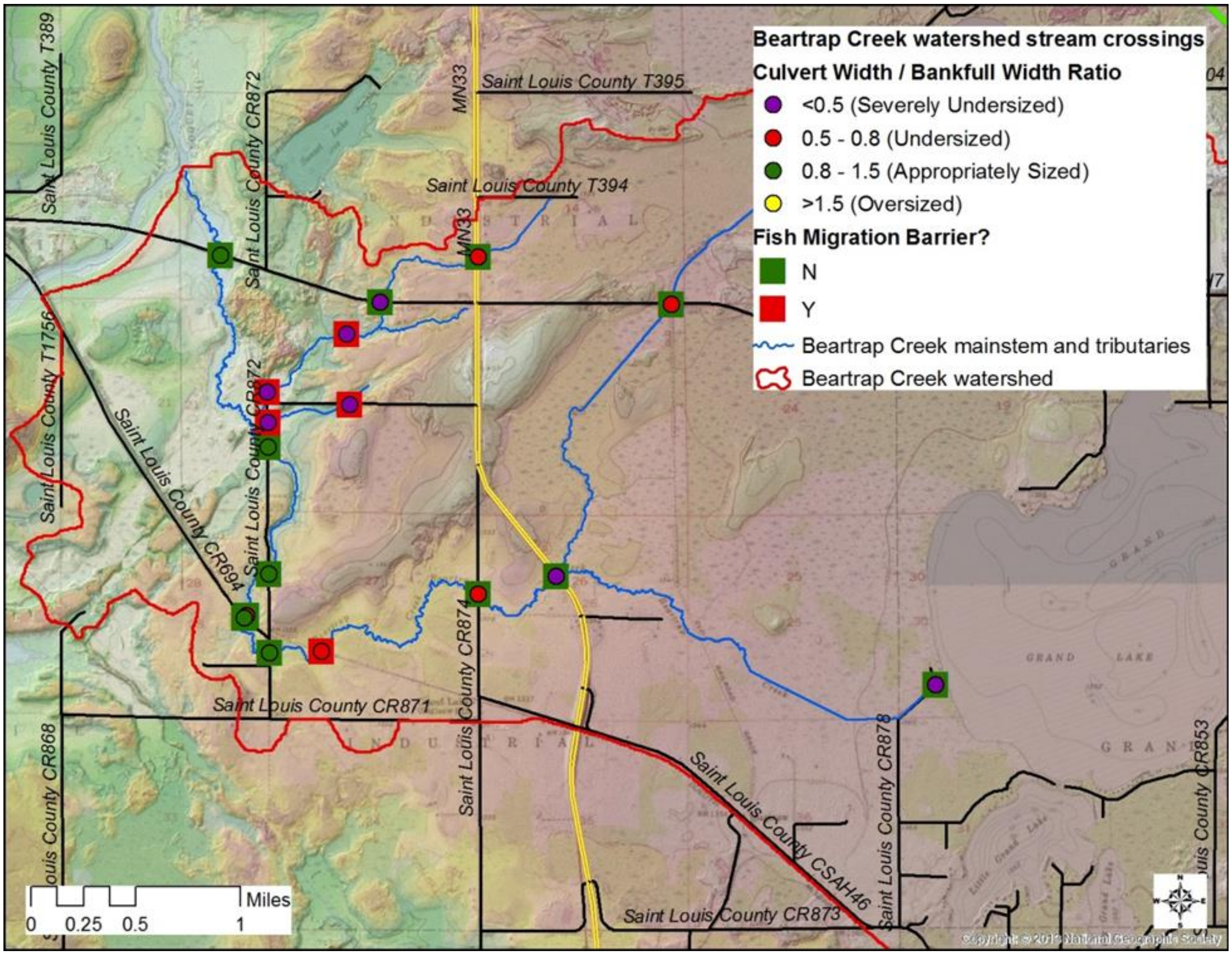


Figure 13. Photographic tour of aquatic connectivity related issues in the Beartrap Creek Watershed. 1) Young-of-year Brook Trout observed in tributary BT2 in late May, 2017. This observation proved that tributary BT2 is used by Brook Trout for spawning and rearing. 2) Tributary BT2; extremely cold, spring-fed tributary 3) Tributary BT1; extremely cold, spring-fed tributary 4) Perched culverts under a farm access road on tributary BT1 5) Driveway washout and ditching of tributary BT1. Undersized and poorly designed culverts at this crossing are a source of sediment loading to the creek, reduce fish passage, and degrade physical habitat 6) Undersized and improperly set culvert causing ponding of spring-fed tributary BT2 7) Undersized and improperly set culvert causing ponding and downstream scour on Beartrap Creek.

Summary and recommendations: Aquatic connectivity

Loss of aquatic connectivity is not considered a direct cause of the fish and macroinvertebrate IBI impairments in this system. However, restoring aquatic connectivity within the Beartrap Creek Watershed would protect existing high quality coldwater habitat, and potentially lead to short-term or permanent dispersal of Brook Trout and other coldwater species into marginal habitats, such as the impaired biological monitoring station BC 0.7. Restoration activities to achieve these goals must focus on replacing road and railroad culverts that act as full or partial barriers to fish movement, as well as adaptive and active management techniques for beaver dam removal and riparian plantings of species that are not preferable to beaver harvest.

Table 8 contains a prioritized list of recommended restoration projects related to aquatic connectivity and fish passage for the Beartrap Creek Watershed. Prioritization rankings are subject to change based on project feasibility, cost, and landowner cooperation. Management of beaver activity in terms of increasing longitudinal connectivity is discussed further in Section 7.0 and Section 5.3.5.

Table 8. Prioritized list of restoration projects related to aquatic connectivity and fish passage in the Beartrap Creek Watershed.

Waterbody	Crossing Name	Location	Primary Impact	Priority
Tributary BT2	Beartrap Rd	46.886571 / -92.491490	1, 2	High
Tributary BT1	Private Drive	46.888599 / -92.491507	1,2	High
Tributary BT1	Private Field Access Rd	46.892546/-92.483518	1	High
Beartrap Creek	Railroad Grade	46.870685/-92.486245	1,3	High
Tributary BT2	Beartrap Rd	46.887744 / -92.483267	1,3	Medium
Tributary BT1	Private Field Access Rd	46.893037/-92.477956	1	Medium

1=Fish Migration Barrier **2**=Localized Habitat Impacts/Sedimentation **3**=Altered Hydrology

5.3.3 Elevated total suspended solids / Turbidity

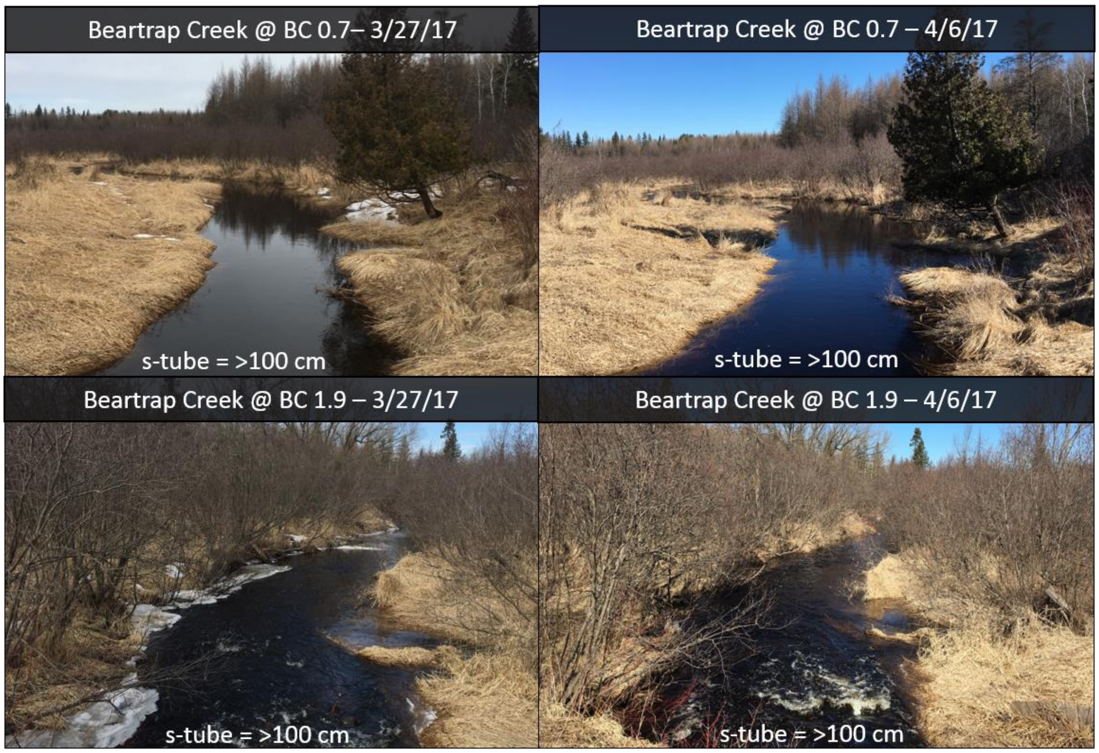
Prior to the SID monitoring effort, elevated TSS concentrations were considered a low probability cause of biological impairment based on historic data and knowledge of watershed conditions. Streams with elevated TSS concentrations are a rarity in the Cloquet River HUC 8 watershed. This statement is supported by the fact that it is one of the few HUC 8 watersheds in NE Minnesota without a turbidity or TSS impairment. The risk of excess erosion and sediment delivery is low throughout the watershed due to the high rate of forest cover (80%) and a relatively low percentage of highly erodible and developed land.

Stream transparency readings were collected throughout the Beartrap Creek Watershed in March and April of 2017 during snowmelt runoff to evaluate suspended sediment concentrations. Discharge during these two sampling events was at or slightly below bankfull stage (Figure 14). Water clarity at all stations was slightly reduced due to tannin (bog) staining from the abundant wetlands in the headwaters of the creek. However, all transparency results were greater than >100 cm. Additional visits were made to several of these stations during mid-summer rain events and transparency readings remained in the range of 90-100 cm or more. TSS concentrations of 4 mg/L were observed during both biological monitoring visits, one of which was during a period of “above normal” streamflow.

Summary: Elevated total suspended solids as a stressor in Beartrap Creek

The transparency standard for coldwater streams is 55 cm, which is equivalent to the 10 mg/L standard for TSS. Transparency and TSS results from Beartrap Creek all met established standards during low, moderate, and high flow conditions. As a result, elevated TSS concentrations can be eliminated as potential cause of biological impairment. Bank erosion and other sources of excess sediment were not observed during habitat surveys throughout the watershed, with the exception of some localized erosion near undersized or improperly set road culverts.

Figure 14. Transparency-tube results and sampling photos during high streamflow events at Beartrap Creek monitoring stations.



5.3.4 Low dissolved oxygen

Continuous DO data were collected at three monitoring stations on Beartrap Creek during the mid-summer months of 2017. Mid-summer low flow periods typically represent the period when DO concentrations are lowest and most limiting for sensitive aquatic life. Monitoring stations were chosen to represent three distinct stream segments in the watershed. The upstream most monitoring station (BC 4.7) was sited to represent conditions in the lower gradient, wetland dominated headwaters of the creek. Historic data from this area, along with comments from the DNR fisheries office, indicate DO concentrations in this reach regularly fall below the 7 mg/L DO standard for coldwater trout streams. Another continuous DO logger was placed at station BC 1.6, a reach that currently supports a healthy population of wild Brook Trout, and represents the most optimal coldwater habitat in the Beartrap Creek Watershed. The third and final DO logger was placed at station BC 0.6, where fish and macroinvertebrate IBI scores failed to meet established standards. Continuous DO levels were recorded at these three stations for a 24-day period between June 22, 2017 and July 17, 2017. Streamflow levels ranged from normal to moderately high during the monitoring period.

As observed in previous monitoring efforts, DO concentrations at BC 4.7 (Independence Rd) were well below the 7 mg/L coldwater DO standard for the entirety of the 24-day monitoring period (Figure 15).

The watershed area draining to station BC 4.7 is predominantly bogs and wetlands, and water entering Beartrap Creek through these features is naturally low in DO content.

DO concentrations improve markedly at station BC 1.6, approximately 3 river-miles downstream of BC 4.7 (Figure 15). DO concentrations were within a range of 7.5 – 9 mg/L and suitable for supporting Brook Trout and other sensitive fish and macroinvertebrate taxa during most of the 24-day monitoring period. A combination of factors is likely contributing to the increase in dissolved oxygen between these two stations. First, the channel type changes from a low-gradient Rosgen E5 channel type (Rosgen, 1995) frequently impounded by beaver dams to a moderately steep gradient Rosgen C4b channel type upstream of BC 1.6. The added gradient and coarse substrate (cobble/gravel/boulder) creates numerous long riffles in this section, which result in increased DO concentrations due to reaeration. Another factor leading to increased DO concentrations is a pronounced decrease in stream temperature near station BC 1.6 due to increased shading from a heavily forested riparian corridor and inputs from numerous springs and spring-fed tributaries.

Station BC 0.6, the impaired biological monitoring station in the watershed, showed a DO profile very similar to that of BC 1.6 with slightly lower concentrations. DO concentrations at BC 0.6 dropped below the 7 mg/L coldwater standard for 17% of the 24-day monitoring period, with a maximum duration of 13.3 hours below the standard. The minimum DO concentrations observed at BC 0.6 was 5.99 mg/L. The relatively short duration, low-magnitude depressions below the 7 mg/L DO standard are unlikely to cause major fish and macroinvertebrate community changes, but may trigger movement of individuals out of this reach into more suitable habitats. The slightly lower DO concentrations in this reach are likely the result of numerous beaver impoundments observed between stations BC 1.6 and BC 0.6.

Two rain events occurred in the watershed during the continuous DO monitoring period, causing an increase in streamflow and a decrease in DO concentrations at all three stations. A 2.14-inch rain event occurred June 28-29 (day 6-7 in Figure 15) resulting in a slight decrease in DO, particularly at station BC 4.7, located in the wetland dominated headwaters reach. An additional 2 inches of rain fell over a three-day period from July 6-8 resulting in a sag in DO concentrations for several days. During this rain event, DO concentrations fell below 3 mg/L at BC 4.7 and dropped below the 7 mg/L coldwater DO standard at BC 1.6 and BC 0.6 for a brief period. These results clearly show the effect of summer rainfall on DO concentrations. Precipitation displaces water with low DO content from the abundant wetlands in the upper half of the watershed into the stream channel, and the effect of lower DO is observed locally and well downstream of these wetland inputs.

Eutrophication and wetland influences

Although a number of nutrients are required for plant growth, phosphorous and nitrogen are the primary drivers of productivity in aquatic systems (Dodds 2006, Dodds & Cole 2007). Total phosphorus (TP) is the primary causal variable used by MPCA to evaluate river eutrophication (Heiskary, 2013). Samples for TP were collected in April, June, and September in attempt to cover a range of temperature and flow conditions. The sampling stations were co-located with continuous DO measurements in the Beartrap Creek Watershed (BC 0.6, BC 1.6. BC 4.7).

TP concentrations were below the 0.050 mg/L standard in all samples collected in the watershed. The highest TP values (0.030 – 0.036 mg/L) were observed in the lower portion of the watershed at station BC 0.6, which is located 0.6 river miles upstream of the Cloquet River. TP concentrations were not significantly lower at the other two stations. Seasonally, TP concentrations were highest at all stations during the July sampling event, but no major seasonal differences were observed.

Biochemical oxygen demand (BOD) and chlorophyll-a (Chl-a) are two “response variables” used in the MPCA’s river eutrophication standard. No Chl-a data are available for Beartrap Creek, however, BOD data are available for several stations from samples collected in July during the continuous DO monitoring period. BOD results ranged from 0.7-0.9 mg/L, well below the eutrophication response variable value of 1.5 mg/L listed in the MPCA's River Nutrient Criteria (Heiskary, 2013).

DO flux (e.g. Daily Maximum – Daily Minimum) is another response variable used by MPCA to evaluate eutrophication levels in streams. An observed DO flux greater than 3.0 mg/L within the "Northern Rivers" nutrient region is considered a response variable indicative of excess nutrients and eutrophication. Average DO flux values in Beartrap Creek ranged from 0.52 mg/L (station BC 4.7) to 1.03 mg/L (BC 0.6). The maximum DO flux observed (1.66 mg/L at station BC 0.6) was still well below the 3.0 mg/L response variable criteria.

Groundwater and wetlands can be very low in DO and enriched in carbon due to microbial processing of organic matter as water passes through the soil (Allan, 1995). The abundance of bogs and wetlands in the upper Beartrap Creek Watershed clearly influence DO concentrations in the headwaters (e.g. station BC 4.7), and to a lesser extent, stations several miles downstream. Dissolved organic carbon (DOC) is a complex mixture comprised largely of decomposed plant material, thus concentrations of DOC are highly correlated with peatlands and wetlands (Dillon and Molot, 1997). DOC concentrations in Beartrap Creek were moderately high compared to other streams in the region (19.7 – 23.2 mg/L), particularly in the headwaters. These elevated DOC concentrations are likely linked to low DO conditions seen in the headwaters and following rain events, which flush organic matter from wetlands and beaver impoundments.

Based on the low TP concentrations and lower productivity measures, river eutrophication can confidently be eliminated as a pathway causing low DO concentrations in Beartrap Creek. The brief periods during which DO concentrations dropped below the 7 mg/L standard occurred during significant precipitation events, which is more indicative of wetland flushing than other anthropogenic causes. The longer duration periods of low DO observed in the headwaters of Beartrap Creek are due to natural background conditions, and not spatially linked with the biological impairment.

Biological response to dissolved oxygen

The impaired reach of Beartrap Creek is a designated trout stream and the applicable dissolved oxygen standard is 7 mg/L. Brook Trout typically require high dissolved oxygen concentrations, with specific requirements varying based on fish age, water temperature, water velocity, and activity level (McKee and Wolf, 1963). Mills (1971) recommended that local or temporal variations in DO concentration should not decrease to less than 5 mg/L, as referenced in the Brook Trout Habitat Suitability Index Model (HSIM) (USFWS, 1982). Numerous coldwater macroinvertebrate taxa also require high concentrations of dissolved oxygen, particularly most members of the orders Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies).

The fish community at the lone "reportable" biological monitoring station (BC 0.6 / 01LS006) included several low DO tolerant fish taxa, but was comprised mostly of species that can be considered neutral in terms DO requirements. The low DO tolerant species Central Mudminnow was common at BC 0.6, accounting for 14% of the total fish population. Brook Stickleback, another low DO tolerant species, were present but in very low numbers. Creek Chub, Mottled Sculpin, and White Sucker were the most abundant taxa (in that order), collectively accounting for over 64% of the total population. Each of these species are observed in a range of DO conditions and are not symptomatic of high or low DO levels.

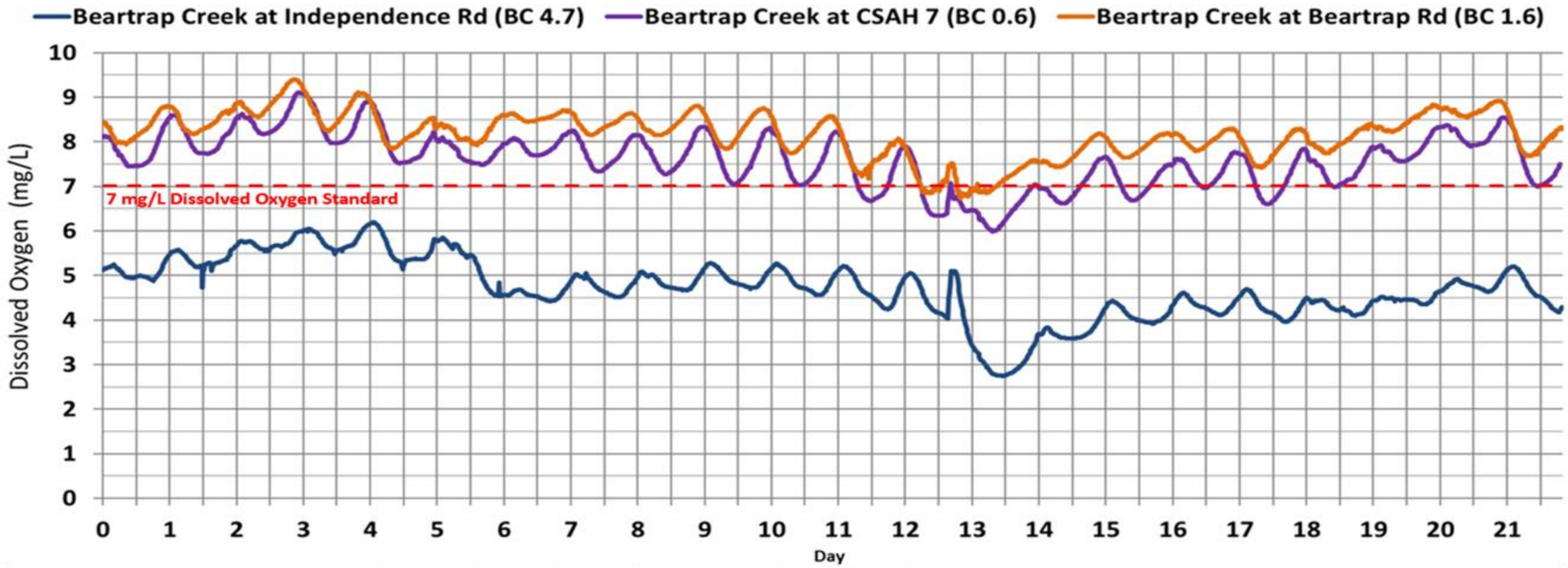
Several of the low DO tolerant or moderately tolerant species observed at BC 0.6 were also observed at the upstream at station BC 1.6, in the same reach that harbors a large population of wild Brook Trout. Overall, the fish community at the impaired station BC 0.6 is fairly similar to that of BC 1.6, with the exception of several species that are likely more symptomatic of poor physical habitat quality than low DO (e.g. Largemouth Bass, Johnny Darter, Yellow Perch).

The macroinvertebrate community at station BC 0.6 (01LS006) contains a mix of highly tolerant and moderately sensitive taxa. As a result, the overall stressor-response relationship that can be attributed to low dissolved oxygen is difficult to decipher. The percentage of tolerant macroinvertebrate taxa at BC 0.6 was very high compared to high quality stations in the Lake Superior Basin (Figure 16). Consequently, the community level DO TIV (see Section 4.2 for TIV information) was also poor compared to these reference sites (Figure 16). These metrics would suggest that low DO is a probable stressor in Beartrap Creek. The abundance of *Physella* (left-handed air breathing snail) could be considered an indicator of low DO, as they tend to dominate in sluggish streams with elevated nutrient concentrations and low DO levels. However, low DO and nutrient-rich conditions are not observed in Beartrap Creek, which provides evidence against that specific stressor pathway.

Many of the tolerant or moderately tolerant taxa present at this station (*Physella, Oxyethira, Hyallela)* are every bit as indicative of physical habitat limitations (excess siltation, stagnant flow) as they are of low DO. In addition, the DO concentrations at this site failed to meet the 7 mg/L by a very slim margin and only for short periods following a rain event. The abundance of low DO tolerant taxa at this station would be much more symptomatic of a DO stressor if measured DO concentrations were found to be in violation of the standard at a higher magnitude and for a longer duration.

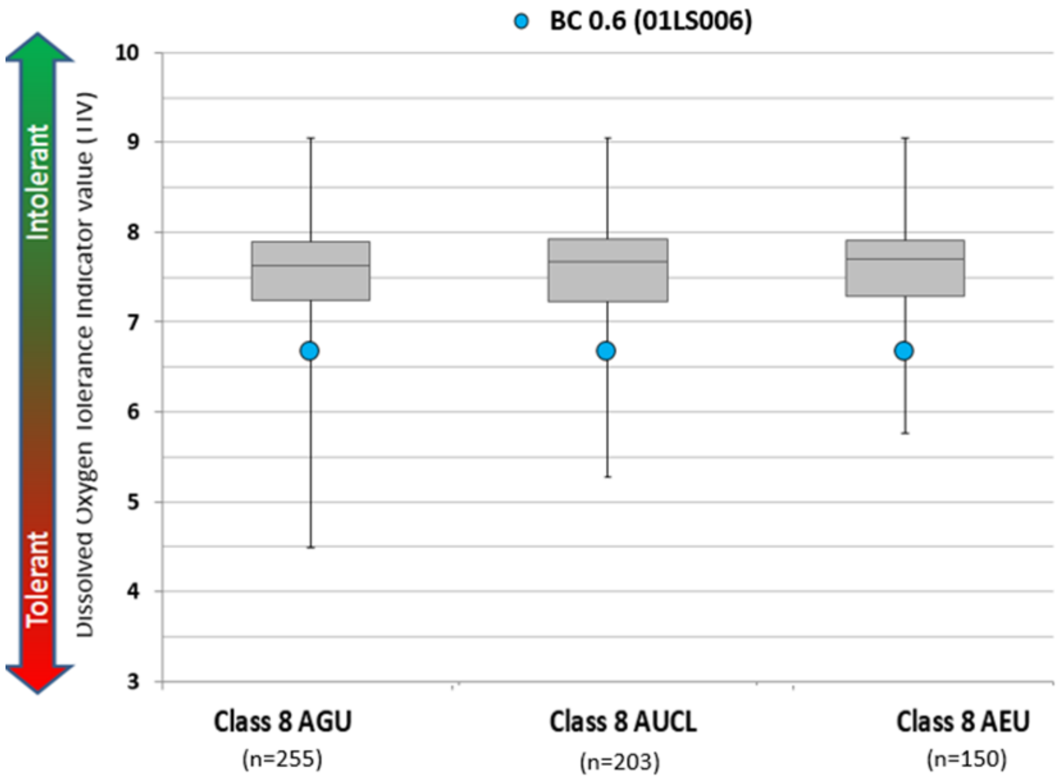
Several taxa sensitive to low DO concentrations were also present in the sample; *Antocha* (crane fly), *Optioservus* (riffle beetle), *Isoperla* (perlodid stoneflies), and *Maccaffertium* (flathead mayfly). These taxa suggest that ample DO concentrations and favorable physical habitat conditions were present in at least some portion of the sampling reach during the time of collection.

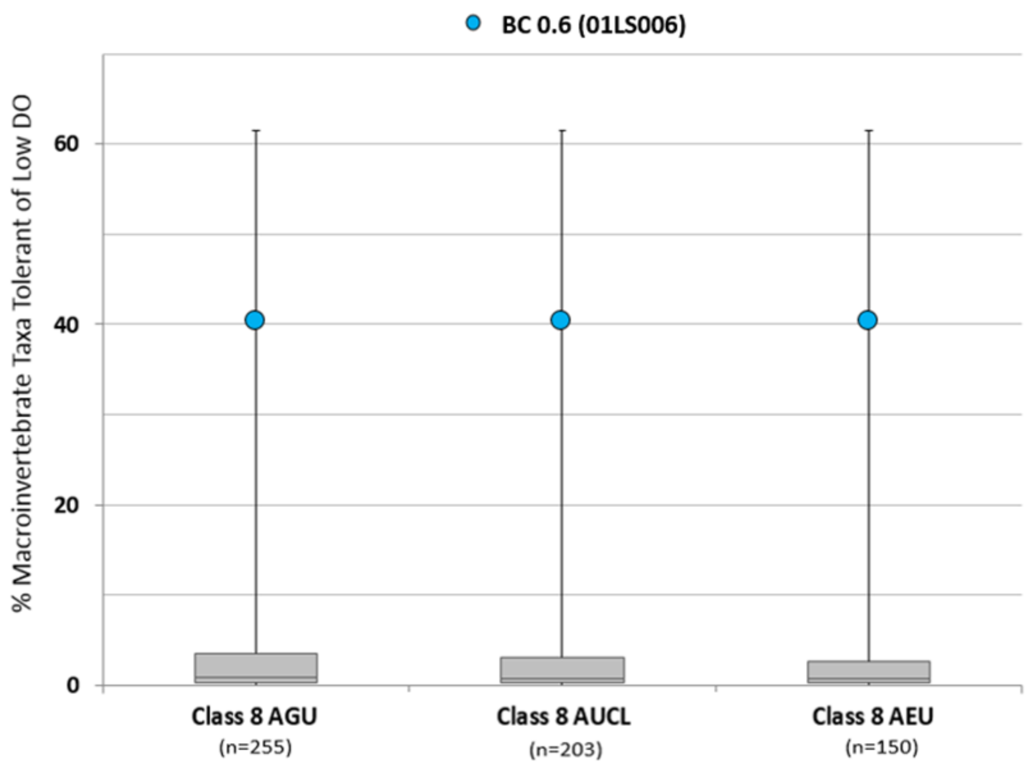
Figure 15. Results of continuous dissolved oxygen measurements at three Beartrap Creek monitoring stations collected June 22 – July 17, 2017.



	# of Readings	Min (mg/L)	Max (mg/L)	24-hr Flux Data Average (mg/L)	Max (mg/L)	Coldwater Dissolved Oxygen Standard - 7 mg/L		
						% Readings below	Avg. Duration below (hours)	Max Duration below (hours)
Beartrap Creek at CSAH 7 (BC 0.6)	2297	5.99	9.11	1.03	1.56	17%	13.3	29.0
Beartrap Creek at Beartrap Rd (BC 1.6)	2297	6.73	9.41	0.74	1.15	4%	6.8	7.3
Beartrap Creek at Independence Rd (BC 4.7)	2297	2.74	6.19	0.52	1.66	100%	Entire period (24 days)	Entire period (24 days)

Figure 16. (Top) Dissolved Oxygen Tolerance Indicator Values for the fish community at Beartrap Creek station 0.6 (01LS006); (Bottom) Percent of the macroinvertebrate community rated at tolerant of low dissolved oxygen concentrations.





Summary: Low dissolved oxygen as a stressor in Beartrap Creek

DO concentrations in Beartrap Creek vary longitudinally from its headwaters to the confluence with the Cloquet River. At station BC 4.7 and upstream, mid-summer DO concentrations appear to fall within the 4-5 mg/L range during low flow, and drop to 2.5 – 4.0 mg/L during precipitation events. Natural factors, such as low stream gradient and wetland influence, are the principal drivers of these lower DO concentrations. Headwaters and wetland minnow species are dominant in this reach of Beartrap Creek, and DNR has never historically managed this portion of Beartrap Creek for Brook Trout or other coldwater fish species.

The middle and lower portions of Beartrap Creek (stations BC 1.6 and BC 0.6) show similar DO concentrations that remain adequate for sensitive coldwater species nearly all of the time. Several spot measurements and short-duration sags in the continuous data from stations BC 1.6 and BC 0.6 indicate that DO concentrations occasionally decrease to 5-7 mg/L for brief periods (coldwater DO standard is 7 mg/L). Large precipitation events were found to be the primary driver of these short-duration decreases in DO concentrations, a product of wetland flushing in the headwaters of the watershed.

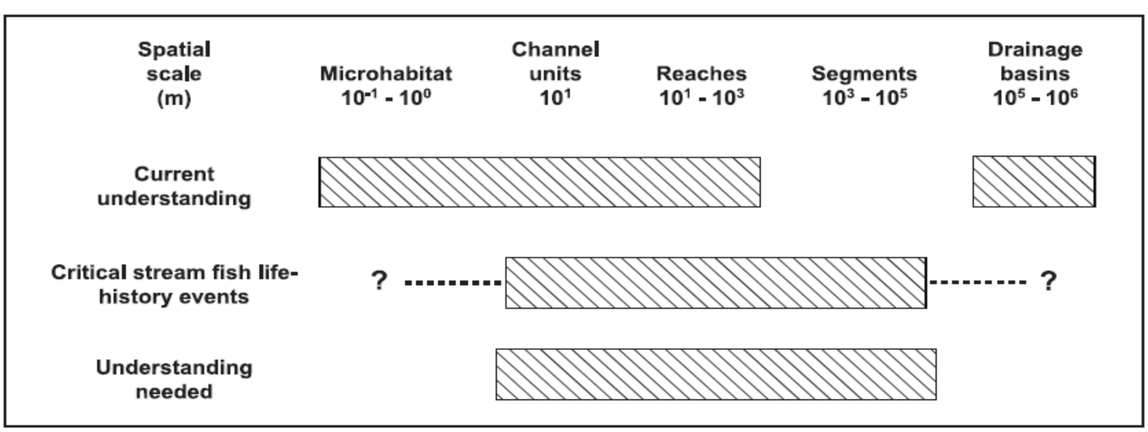
DO concentrations appear to be adequate at normal and low streamflows within the impaired reach. Biological metrics that were symptomatic of low DO (relatively high % DO tolerant taxa, DO TIV results) are more than likely representing confounding stressors, primarily the lack of high quality physical habitat within the impaired reach.

5.3.5 Degraded physical habitat

Sensitive aquatic organisms require physical habitats that are diverse and relatively undisturbed for feeding, refugia, and reproduction. Physical habitat degradation was listed as a potential stressor in the Beartrap Creek Watershed based on initial assessment reports, which mentioned “residual effects from beaver dams, including sedimentation (gravels filling in with finer materials – silts and clays), and potentially due to changing water levels from beaver dams” (MPCA, 2018).

Physical habitat assessments were completed by MPCA stressor identification staff at the “stream segment”, “reach”, and “channel units” scale as described by Fausch (2002). Completing habitat assessments at these various scales helps account for habitat heterogeneity and the patchwork of unique and critical features (e.g. springs, tributaries) that are important for various life stages of aquatic organisms. Evaluating habitat conditions at these various scales also accounts for the fact that organisms, particularly fish, can move relatively long distances to find suitable stream conditions. Reach and segment data were collected during longitudinal assessments completed on foot or by boat.

Figure 17. Spatial scales of our current understanding about lotic fishes vs. the probable range of scales spanned by critical life history events for many species. (Fausch, 2002).



Brook Trout Suitability Assessment

The Brook Trout Habitat Suitability Assessment (BTSA) was used to evaluate physical habitat conditions on a stream segment scale throughout the Beartrap Creek Watershed. The BTSA measures habitat conditions using 26 individual metrics related to water temperature, geomorphology, channel stability, and in-stream habitat conditions. Several critical metrics, such as water temperature, pool depths, and streamflow conditions, are weighted more heavily in the scoring system. Additional information on the BTSA methodology can be found in Section 3.

BTSA results show highly variable coldwater habitat conditions, with distinct patches of high quality and poor habitat separated by relatively short distances. Areas of high quality habitat (excellent BTSA rating) are located predominantly in the middle reaches of Beartrap Creek, at its confluence with a large off-channel spring and several spring-fed tributary streams. This reach of Beartrap Creek provides deep pools, clean gravel substrate, abundant cover, and suitable water temperatures. The tributaries and off-channel spring provide thermal refuge and additional spawning and rearing habitat that is unique to this portion of the watershed. Brook Trout were abundant in this reach during a 2016 assessment, and historically this station has been the most reliable for sustaining a wild population through natural reproduction.

The two downstream-most reaches of Beartrap Creek (BCR 1 and BCR 2) also received a BTSA rating of "excellent" (Figure 18). This segment of the creek is characterized by deep pools, relatively coldwater temperatures, and abundant cover and gravel substrate. Brook Trout have never been sampled at this location, but another coldwater fish species, Mottled Sculpin was observed during the only fish community assessment of this reach back in August of 1966. Warmwater fish from the Cloquet River have year-round access to this reach, and Brook Trout could potentially move between the Cloquet and Beartrap Creek, a life-history trait that has been observed in other coldwater feeder creeks to the Cloquet River system (e.g. Chalberg Creek, Hellwig Creek). Additional sampling of this reach, particularly during mid-summer months, is recommended to determine if coldwater fish are using this reach and moving between the Cloquet and Beartrap Creek.

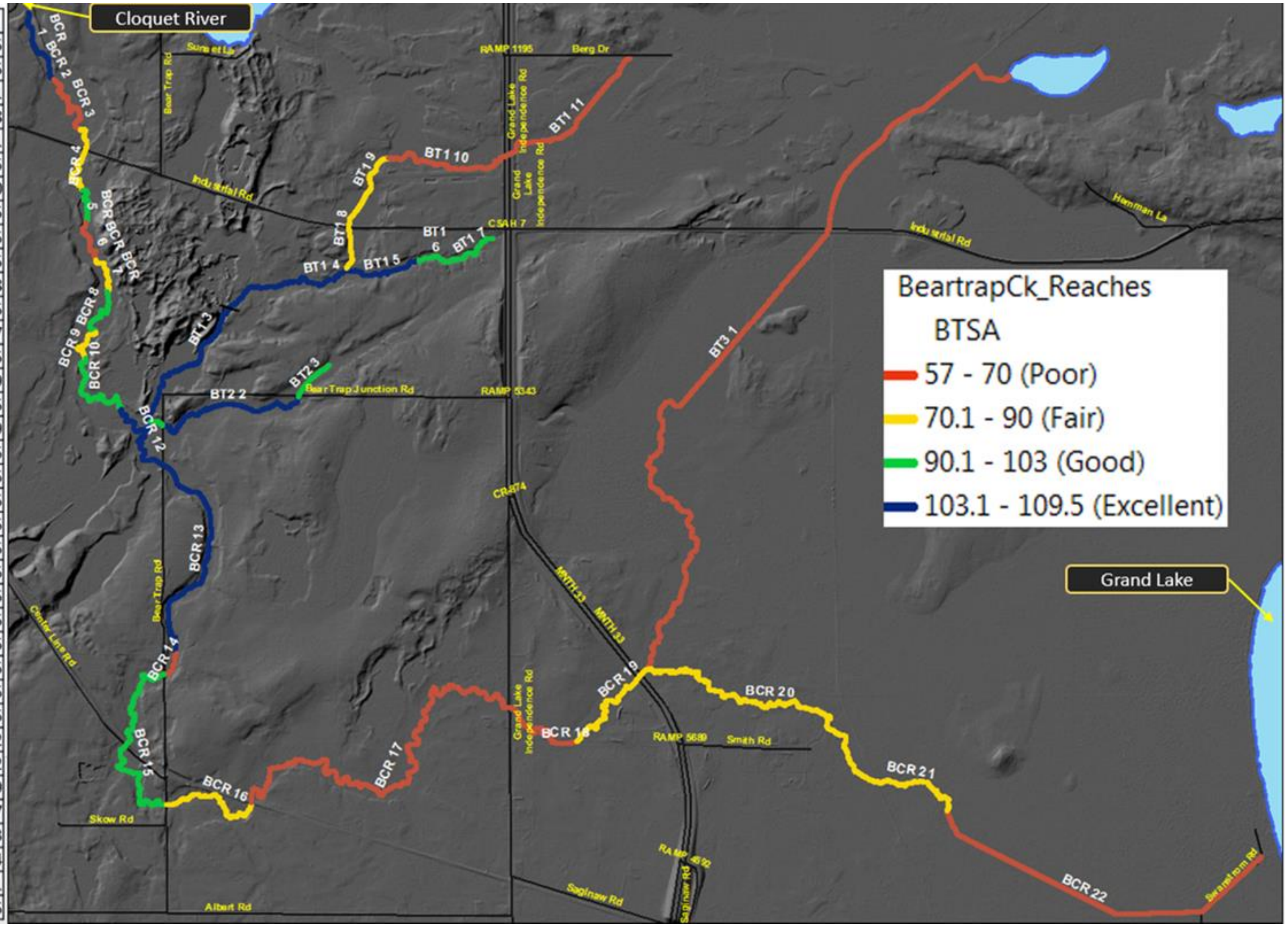
BTSA ratings of poor and fair are dominant throughout the upper half of the Beartrap Creek Watershed. Warmer water temperatures, excessive rate of beaver impoundments, lack of shading, and lack of coarse substrates are the major limiting factors. The potential for increasing the quality of coldwater habitat through restoration activities is extremely low upstream of reach BCR 15. Low dissolved oxygen concentrations, lack of coldwater inputs (springs, tributaries), and fine substrates due to lacustrine geology (old lake bottom) are natural characteristics of these reaches that limit their potential to support intolerant coldwater fish and aquatic macroinvertebrates.

The impaired biological monitoring station (BC 0.6) is located within reach BCR 4, which received a BTSA rating of 88 (Fair). Compared to a high quality reference reach in Beartrap Creek (BCR 12), the impaired station received poorer scores for increased amounts of fine substrates and embeddedness, lack of gravel substrate, higher rates of bank erosion, and altered stream pattern due to the presence of beaver dams. The stream pattern with the sampling reach of BC 0.6 is also impacted by historic channelization of the creek upstream and downstream of CSAH 7 for several hundred feet. The total channel length through this reach has been reduced by several hundred feet due to this ditching effort, which occurred pre-1940.

Reach BCR 14 received a poor BTSA rating due to moderate to heavy cattle grazing activity in the riparian corridor along the creek. Average stream width within the grazed area is two-times greater than forested reaches up and downstream of this location.

Figure 18. Brook Trout Suitability Assessment scores for reaches of Beartrap Creek based on physical habitat, channel stability, and water temperature data. Highest possible score = 141.

Reach	BTSA Score (0-136.5)
BCR 1	103.5
BCR 2	104.5
BCR 3	61
BCR 4	88
BCR 5	101
BCR 6	65.5
BCR 7	90
BCR 8	101.5
BCR 9	78.5
BCR 10	95.5
BCR 11	98
BCR 12	109.5
BCR 13	107
BCR 14	57.5
BCR 15	99
BCR 16	75
BCR 17	69
BCR 18	58.5
BCR 19	89.5
BCR 20	78.5
BCR 21	72.5
BCR 22	59.5
BT1 1	105
BT1 2	108.5
BT1 3	109.5
BT1 4	106.5
BT1 5	106.5
BT1 6	96.5
BT1 7	96.5
BT1 8	72
BT1 9	72
BT1 10	59
BT1 11	57
BT2 1	103
BT2 2	104
BT2 3	101
BT3 1	58.5



Particle size analysis

Pebble count data are valuable for determining the median particle size of a reach (D50), relative composition of substrate types, and major shifts in substrate types within a reach or comparatively between two separate reaches. Wolman (1954) pebble count data were collected at representative riffle transects in most of the delineated reaches between BCR 12 and BCR 1 (Beartrap Creek Road downstream to Cloquet River confluence).

D50 and substrate composition varied widely in the two river-miles of Beartrap Creek assessed (Table 9; Figure 19). D50 classes were predominantly in the sand and gravel classes, with the exceptions being reach BCR 9 and BCR 3, which were both impounded by beaver dams and had substrates composed entirely of silt/clay particles at the representative transects. Gravel substrates were dominant in two reaches, BCR 12 (78%) and BCR 8 (66%), and present in moderate quantities in reach BCR 5 (39%), BCR 2 (36%), and BCR 1 (31%). Sand substrates were dominant with reach BCR 11 (88%), BCR 4 (84%), and BCR 5 (49%). Cobble sized substrates were relatively rare in the lower 2-river miles of Beartrap Creek that were assessed, but BCR 1 just upstream of the Cloquet River had fair amounts of cobble present (29%) relative to other reaches assessed.

Stream reaches with high sand content and moderate to low gravel content may be indicative of areas where habitat loss has occurred due to siltation (e.g. substrate embeddedness). Reach BCR 12 had high gravel content (78%) and low sand content (12%), and Brook Trout have been abundant within this reach during several biological surveys. Several of the reaches downstream of BCR 12 are sand dominated with small amounts of gravel. Reach BCR 4, which contains the impaired biological monitoring station (BC 0.6), is one example of a sand dominated reach (84%) with some gravel present (10%). This scenario is present within many reaches of Beartrap Creek that have been altered by ditching (BCR 4) or located downstream or upstream of areas impounded by beaver dams.

Reach level depth of fines assessment

The smothering of coarse substrates (gravel/cobble) by excessive levels of fine sediment (sand/silt) was a leading candidate cause of biological impairment in Beartrap Creek. To investigate this potential stressor, channel stability and physical habitat assessments were completed from the high quality reference reach (BCR 12 and BCR 13) downstream to the Cloquet River. One of the quantitative habitat variables collected during this effort was the depth of fine substrate, or "depth of fines" (DOF). DOF were measured using a wooden rod marked with centimeter gradations, which was pushed into the substrate until light to moderate resistance was felt. Ten DOF measurements were made at 1-2 transects per reach within a representative riffle cross-section. Additional measurements of substrate condition were collected as part of an in-depth reach level survey using Rosgen Level II methods (Rosgen, 1996) at within two reaches, BCR 12 and BCR 4.

Average DOF results by reach varied from 0.1 cm (cobble bed, reach BCR 10) to 50.7 cm in reach BCR 9. Reach BCR 9 was impounded by a large beaver dam and all measurements collected within in the transect show relatively deep deposits of fine sediments (min=37 cm, max=75 cm) compared to the rest of the reaches surveyed. A clear trend of increasing DOF was observed in reaches with abundant beaver impoundments (BCR 9, BCR 3, BCR 4, BCR 11). Brook Trout were abundant in reaches BCR 12 and BCR 13, which showed lower DOF values (2.5 cm – 5.7 cm) compared to the vast majority of reaches, assessed downstream (Figure 19).

Substrate conditions and depth of fines are expected to vary considerably on watershed scale. In Beartrap Creek, much of this variability is driven by stream gradient and the presence or absence of beaver dams. A beaver dam management proposal is presented in Section 7.1.1 with the goal of increasing quality habitat for Brook Trout and other coldwater fish and macroinvertebrates. In its current state, the highly fragmented physical habitat conditions of lower Beartrap Creek may impede the movement of Brook Trout and other species, not due to physical barriers, but instead to ambient environmental barriers created by long stretches of unsuitable habitat and stagnant flow conditions. In other words, the continuity of the lotic habitat type preferred by sensitive coldwater taxa is broken by beaver dams, allowing taxa associated with fine-substrates and stagnant water to colonize these areas more effectively.

Table 9. Median substrate particle size (D50) measured at representative transects within various reaches of Beartrap Creek.

Reach	D50	D50 Type	Silt/Clay	Sand	Gravel	Cobble
BCR 12	18.5	Coarse Gravel	6%	12%	78%	4%
BCR 11	0.6	Coarse Sand	0%	88%	12%	0%
BCR 9	0.0	Silt/Clay	100%	0%	0%	0%
BCR 8	11.1	Medium Gravel	0%	34%	66%	0%
BCR 5	0.9	Coarse Sand	2%	59%	39%	0%
BCR 4	0.2	Fine Sand	6%	84%	10%	0%
BCR 3	0.0	Silt/Clay	100%	0%	0%	0%
BCR 2	0.8	Coarse Sand	12%	48%	36%	3%
BCR 1	8.8	Medium Gravel	9%	31%	31%	29%

Figure 19. Substrate composition measured at transects within Beartrap Creek sampling reaches.

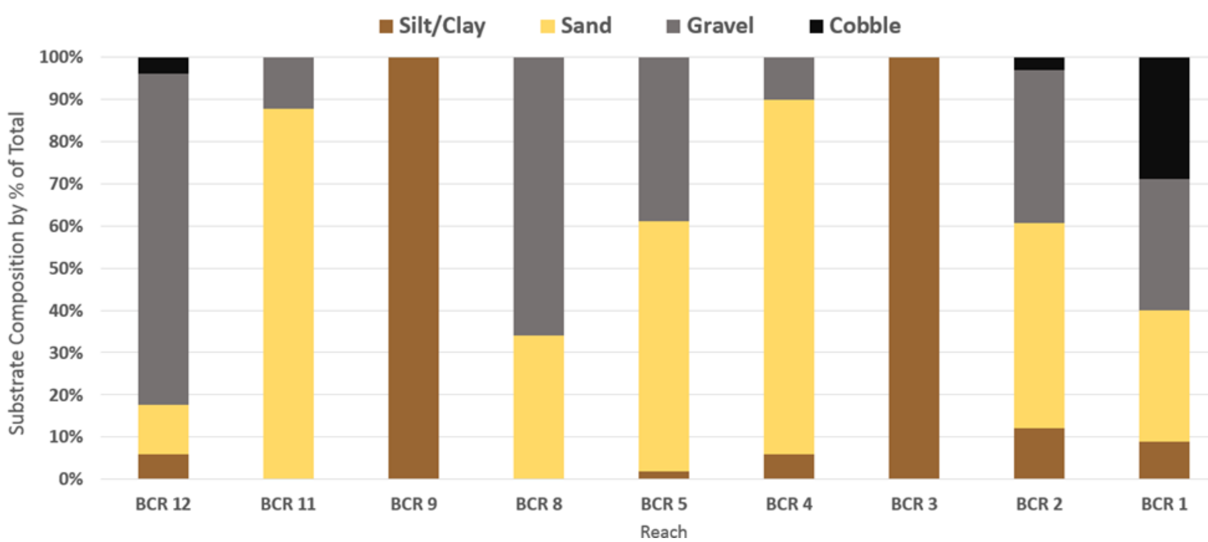
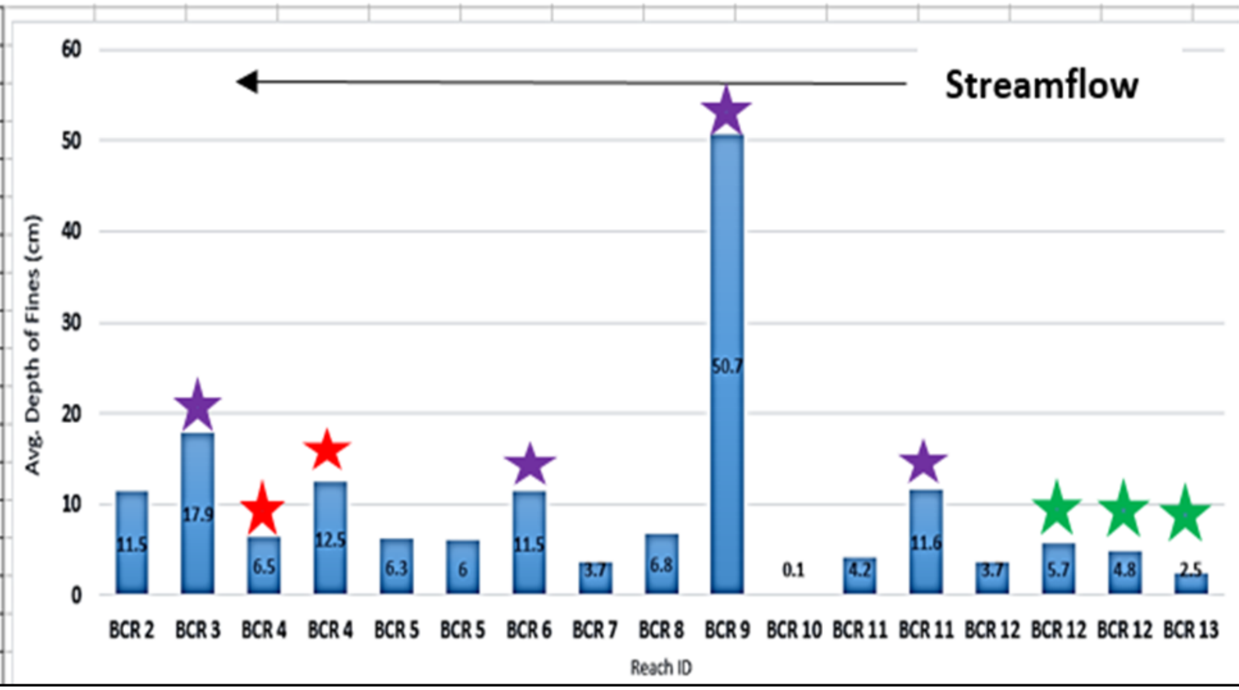


Figure 20. Depth of fine substrates measured within Beartrap Creek sampling reaches. Green Stars = high quality coldwater reaches with abundant wild Brook Trout; Red Stars = Impaired biological monitoring station; Purple Stars = Reaches affected by active beaver impoundments.

Reach ID	Transect	Avg DOF	Max DOF	Min DOF
BCR 2	1	11.5	20	3
BCR 3	1	17.9	35	10
BCR 4	2	6.5	11	4
BCR 4	1	12.5	25	6
BCR 5	2	6.3	21	1
BCR 5	1	6	18	2
BCR 6	1	11.5	20	3
BCR 7	1	3.7	10	1
BCR 8	1	6.8	25	2
BCR 9	1	50.7	75	37
BCR 10	1	0.1	0.1	0.1
BCR 11	2	4.2	18	0
BCR 11	1	11.6	19	5
BCR 12	3	3.7	10	1
BCR 12	2	5.7	17	2
BCR 12	1	4.8	10	1
BCR 13	1	2.5	7	1



Biological response to poor physical habitat conditions

Excess fine sediment deposition and the resulting loss of coarse substrate materials (gravel/cobble) is the most commonly cited habitat related candidate causes of impairment in the Beartrap Creek Watershed. Stream reaches impacted by this stressor should show negative responses to taxa that require coarse substrates for spawning, riffle-dwelling taxa, and a decrease in the abundance and diversity of habitat-sensitive fish and macroinvertebrates. Some of these biological responses can be masked by the ability of organisms, primarily fish, to move to and from upstream and downstream stream reaches that can provide suitable habitat conditions.

The impaired reach of Beartrap Creek (BCR 4) has been sampled numerous times by MPCA and DNR. Dominant fish taxa include Creek Chub, White Sucker, Mottled Sculpin, Central Mudminnow, and Johnny Darter. Most of the species in this list are habitat generalists, although White Sucker are classified as simple lithophilic spawners, and thus require clean gravel habitats for spawning. Mottled Sculpin are also considered a riffle-dwelling taxa, frequently occupying shallow fast-water habitats in and around cobble and gravel deposits. A single Brook Trout was sampled in this reach in 2001, which suggests that there is some suitable habitat for this species within the impaired reach and/or suitable habitat is accessible through movement in the upstream or downstream direction.

Many of these same fish species were reported as "common" or "present" by DNR at station BC 1.6, which also supports a large population of naturally reproducing Brook Trout. DNR sampling methods do not require counting the number of non-game species, making it difficult to compare fish communities at a high level. There is a high degree of similarity between the prevailing physical habitat conditions of the impaired station (BC 0.6) and BC 1.6. Both stations have similar stream slope, channel dimensions, riparian vegetation, and floodplain connectivity. One of the major differences is the abundance of coarse substrates within or nearby the sampling reaches. The impaired biological station lacks the gravel substrates that are found within reach BCR 12 and BCR 13. Brook Trout have easy access to abundant clean gravel for spawning in reaches BCR 12/13 of Beartrap Creek, and natural reproduction and recruitment of wild trout is very high compared to other reaches and nearby coldwater streams.

Fine substrates and high levels of embeddedness can cause profound changes to macroinvertebrate communities. Station BC 0.6 showed poor MIBI metrics scores related to relative percent of collector-gatherer taxa, intolerant taxa, non-insect taxa, and POET taxa (i.e. stoneflies, dragonflies, mayflies, caddisflies). These results can all be indicative of sediment stress, but most of these metrics can also respond in a similar fashion due to other non-habitat related stressors. Most of the other stressors that can cause these symptoms of impairment (e.g. low dissolved oxygen, excess nutrients, elevated water temperature) are not present at the impaired monitoring station, so sedimentation can be considered a leading cause. No macroinvertebrate data are available at the high quality, reference station in reach BCR 12 for comparison. Collecting macroinvertebrate data within that reach would be valuable for refining the analysis of sedimentation as a cause of the impaired macroinvertebrate community.

Summary: Poor physical habitat conditions as a stressor in Beartrap Creek

Physical habitat conditions vary throughout the Beartrap Creek Watershed and the fish and macroinvertebrate communities reflect those differences. Areas of high quality habitat exist in the central portion of the watershed, where gravel deposits, and coldwater inputs (tributaries and springs) are abundant and accessible to fish during various stages of their life cycles. The upper 1/3 of the watershed is habitat-limited due to factors that are predominantly related to natural background conditions (low gradient, silt-peat dominated lacustrine geology), but numerous stream crossings (roads, railroad) and a high rate of beaver activity may be intensifying several of these negative attributes.

Limited physical habitat for sensitive coldwater fish and macroinvertebrate taxa should be considered a cause of biological impairment in Beartrap Creek. However, the spatial extent of this stressor is rather limited, and sources of habitat change are mostly due to factors that could be considered natural (e.g. construction and breaching of beaver dams). Corrective actions should focus on re-meandering the channelized portion of the creek at CSAH 7 as a top priority considering the clear connection of that impact to human disturbance. Encouraging off-channel beaver dam construction would increase longitudinal connectivity and access to spawning gravel and tributaries/springs near station BC 1.6, but careful consideration must be given to the importance of beaver to habitat heterogeneity, biodiversity, and other ecosystem services that may fall outside the realm of coldwater fisheries management.

5.3.6 Predation

Northern pike and other warmwater piscivorous (carnivorous) species can deplete coldwater fish populations through predation and increased competition for habitat. One well-known example of this stressor to coldwater fish comes from Montana's Flathead River, where northern pike predation is responsible for the loss of over 16,000 native cutthroat and bull trout each year (CBB news bulletin, 2008). The primary pathway of this stressor is direct predation of adult or juvenile trout by warmwater species. Yet, indirect effects such as increased competition for food, refugia, and predator avoidance behaviors have also been observed in freshwater systems (Fraser and Cerri, 1992; Fraser and Gilliam, 1992). Vehanen and Hamari (2004) found that the presence of northern pike reduced activity levels in brown trout and caused them to occupy different microhabitats typically not preferred by trout. These behavioral changes can lead to changes in feeding efficiency, and ultimately, reductions in survival or growth rates. Adult trout are also highly predatory and cannibalistic, but these interactions are considered part of a functioning and intact coldwater fish community.

Northern Pike and Largemouth Bass have been periodically sampled in Beartrap Creek. These species likely enter Beartrap Creek via its confluence with the Cloquet River and possibly Grand Lake, which forms part of the headwaters of the watershed. The single Largemouth Bass observed was a young-of-year (YOY) individual measuring 38 mm and would not be capable of preying upon other fish. Northern Pike numbers also appear to be sparse in the creek, although the size range of the individuals sampled is slightly larger. In 2016, three Northern Pike were sampled at station BC 1.6, ranging in size from 150-179 mm (6-7 inches). These represent YOY individuals, but young Northern Pike are quick to begin eating other fishes, especially if other sources of food (e.g. aquatic insects) are in short supply.

Based on pike predation models developed by Nilsson and Bronmark (2000), the YOY Northern Pike sampled in Beartrap Creek could prey upon trout (and other fishes) up to approximately 4.5 inches. Based on these observations, YOY or early Age-1 trout could be susceptible to predation by Northern Pike. Overall, the Northern Pike population in Beartrap Creek is not spatially linked with a decline in Brook Trout abundance. Brook Trout of several age classes greatly outnumbered Northern Pike (103 BKT to 3 NOP) at station BC 1.6 in 2016, and this was the station where pike were most abundant in that sampling year.

Some predation of Brook Trout by Northern Pike and other warmwater species likely occurs in Beartrap Creek. Larger Northern Pike, Smallmouth Bass, Walleye, and other predatory warmwater species are likely more common in the lower reaches of Beartrap Creek near the confluence with the Cloquet River. Predator-prey scenarios like this are common in many watersheds in this region, as most support a variety of native coldwater and warmwater fishes, often with overlapping boundaries in more marginal coldwater streams. The populations of Northern Pike and other warmwater predator species are not problematic in Beartrap Creek based on available data, and are not considered a primary cause of biological impairment.

5.4 Stressor identification results: Beartrap Creek

Six stressors were evaluated to determine the cause(s) of FIBI and MIBI impairment in Beartrap Creek. Ultimately, a lack of quality physical habitat within the impaired reach was the candidate cause supported by the most evidence (Table 10). Loss of connectivity, or the ability of fish to move unimpeded between sections of Beartrap Creek and key tributaries, was also identified as a limiting factor that needs to be addressed by restoration and protection plans.

Restoration and protection project recommendations related to the causes of impairment are included in Section 7 of this report.

Table 10. Final stressor identification results for fish and macroinvertebrate impairments in Beartrap Creek.

Candidate Cause	FIBI Impairment	MIBI Impairment	Report Section
Elevated water temperature	X	X	5.3.1
Low dissolved oxygen	X	X	5.3.4
Lack of quality physical habitat	•	•	5.3.5
Loss of connectivity	•	X	5.3.2
Elevated Total Suspended Solids (TSS)	X	X	5.3.3
Predation by warmwater species (N. pike, Bass)	X	X	5.3.6

Key: **• = confirmed stressor** **○ = potential stressor** **X = eliminated candidate cause**

6.0 Hellwig Creek stressor identification

6.1 Watershed conditions

6.1.1 Hydrology and geologic setting

The Hellwig Creek Watershed covers roughly 36 square miles near the town of Independence, Minnesota (20 miles NW of Duluth, MN). The main stem of Hellwig Creek flows for a distance of 17.2 miles and is a third order stream (Strahler) at its confluence with the Cloquet River. The creek originates from the outflow of Dodo Lake, a 92-acre basin with a max depth of 53 feet, which supports Walleye, Northern Pike, Largemouth Bass, Yellow Perch, and panfish species. The headwaters are also formed by several tributary streams that originate from expansive peat-bog wetland areas. Similar to other watersheds in the area, the origin of the watershed's surface geology is relatively recent, shaped by glacial and post-glacial activity (Minnesota Geological Survey, 1982). Features include glacial outwash and till from the late Wisconsinan stage of glaciation, as well as areas of peat, which have been deposited since the glaciers retreated. The peat deposits are located mostly in the bogs along the northwestern boundary of the watershed (Figure 25).

Hellwig Creek is highly fragmented by beaver dams throughout most of its length, particularly in the upper 16-miles of the creek (i.e. upstream of RM 1.0). From river mile 1.0 to its confluence with the Cloquet River, Hellwig Creek picks up gradient and is distinctly different in character, with abundant cobble-boulder riffles and step-pool features. This portion of the creek is a designated trout stream and supports a resident population of native Brook Trout and non-native Brown Trout, both of which reproduce successfully within this lower reach. Several small, spring-fed tributary streams enter Hellwig

Creek within the lower 1.5 river miles. These streams provide important inputs of coldwater and year-round habitat for Brook Trout and other aquatic life.

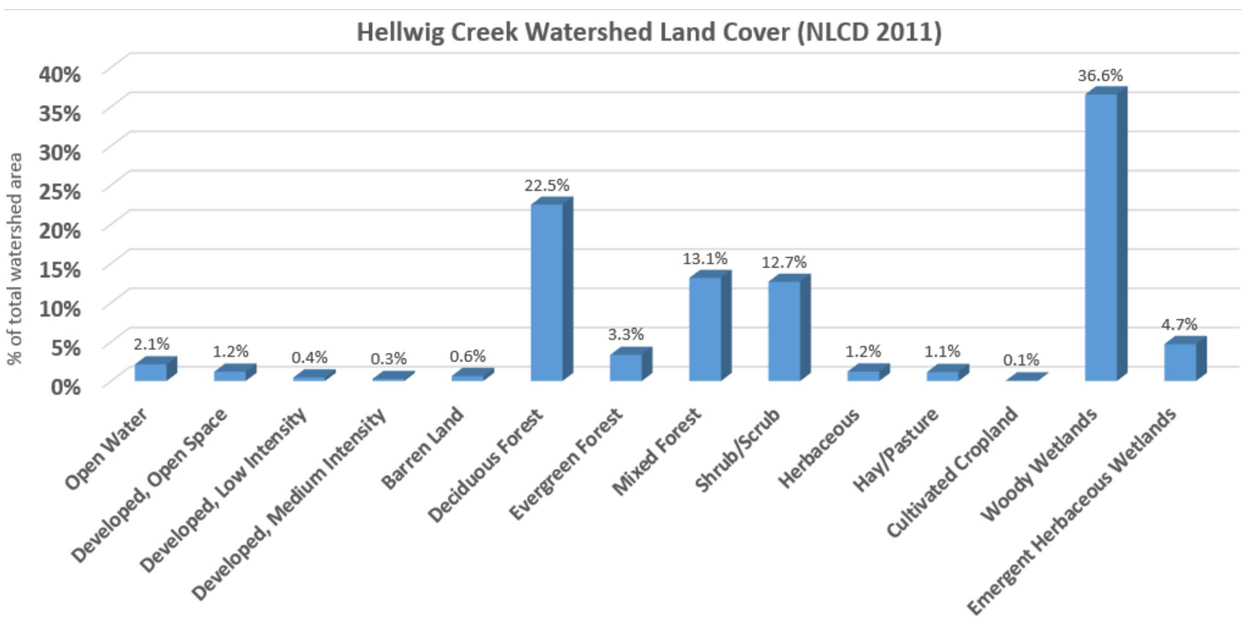
Portions of Hellwig Creek and its tributary streams have been channelized to improve drainage or due to major infrastructure projects. The upper half of the watershed contains many miles of ditches that course through peat bogs and wetlands, a condition that is common in regions of Cloquet and St. Louis River basins where bogs are a dominant feature of the landscape. In the lower half of the Hellwig Creek Watershed, the HWY 53 corridor and several smaller roads have forced the creek into straightened ditches, which have reduced overall stream length, stream habitat complexity, and connectivity to several cold tributary streams.

6.1.2 Land-cover and Land-use

The dominant land-cover types in the Hellwig Creek Watershed include wetlands (41.3% of total land area), and forest (39%) (Figure 21). Developed areas in the watershed are scarce and are primarily single-family residences, small agricultural operations (pasture/hay), and transportation networks (railroads, gravel roads, and major highways). Although the percentage of developed land is relatively low on a watershed scale, the middle to lower reaches of Hellwig Creek flow through a moderately developed landscape including several large gravel mining areas and major highway corridors. For the most part, a vegetated buffer provides a good level of protection from these land-uses. The majority of the land adjacent to Hellwig Creek is privately owned (55%); the remainder is state property (33%), and county tax forfeit land (12%).

Several active gravel-mining operations exist in the lower Hellwig Creek Watershed adjacent to critical coldwater habitats. Gravel and other forms of aggregate mining is an extractive use of resources; mining alters the landscape and its natural hydrologic system (DNR, 2005). Quarries and pits can affect ground-water and surface-water systems in various ways, including; (1) lowering of local ground-water and surface-water levels from mining operations and mine dewatering, (2) changing turbidity levels in groundwater due to blasting and quarry operations, (3) interruption of ground-water conduit flow paths by rock removal, and (4) temperature change (thermal impacts) in springs and surface-water streams.

Figure 21. Land Cover data (2011) for the Hellwig Creek Watershed.



6.2 Biological data

The Hellwig Creek Watershed contains 24 river miles of designated trout water, of which 13 miles is located on the main stem of Hellwig Creek. The additional designated trout water is located on six small (1st and 2nd order) tributary streams. Only a small portion of the designated trout water in the watershed is currently managed to support wild Brook Trout and Brown Trout populations. The prime coldwater habit is located in the lower three-river miles of Hellwig Creek, and several tributaries that enter within that reach. Brook Trout were actively stocked between the years of 1955 and 1965 by DNR, but since 1965, natural reproduction has been relied upon to sustain trout populations.

6.2.1 Sampling locations and results

The DNR has performed fisheries assessments of Hellwig Creek intermittently since the mid 1960's. DNR data are available for eight sampling stations on the main stem of Hellwig Creek, and a few additional stations have been sampled on tributary streams. MPCA has only sampled one location (98LS019 / HC 3.2) with multiple visits (1998, 2015, and 2016). Differences in sampling objectives and methodology between DNR and MPCA prevent the use of DNR data for calculating coldwater fish IBI scores, yet DNR data remain useful for understanding the history of key species and the condition of the stream over several over the past 40-50 years.

Brook Trout / Brown Trout in Hellwig Creek

The earliest sampling of Hellwig Creek on record occurred in 1965, when seven stations were sampled during the month of June (stations HC 0.1, HC 1.7, HC 7.7, HC 10.1, HC 12.2, and HC 15.3). A single Brook Trout was sampled at both stations HC 0.1 and HC 1.7 in the 1965 survey. Several other species commonly found in coldwater streams (Mottled Sculpin and Longnose Dace) were present or common at these sites as well. Several warmwater gamefish species (Walleye, Bluegill, Yellow Perch) were sampled at HC 0.1, highlighting the close proximity of this sampling reach to the Cloquet River just downstream. Brook Trout were not sampled at any other station in 1965, and coldwater species were present at only one other station aside from HC 0.1 and HC 1.7 (Mottled Sculpin at HC 7.7).

The DNR sampled stations HC 0.1 and HC 1.7 again in August of 1990. Both juvenile (age-0) and adult (age-1+) Brook Trout were sampled at HC 0.1 in low numbers (age-0 n=2; age-1+ n=7). Considering that stocking efforts ceased in 1965, it can be concluded that the Brook Trout sampled were "wild" (e.g. the product of natural reproduction). No Brook Trout were sampled at HC 1.7 in 1990. These two stations were sampled again in September of 2002. The results were contradictory to previous sampling events, as two Brook Trout were sampled at HC 1.7 and zero at HC 0.1. Tributary 2 was also sampled in 1990. This tributary showed colder water temperatures than the main stem throughout the summer, and Brook Trout were much more abundant (Age-0 n=18, age-1+ n=121).

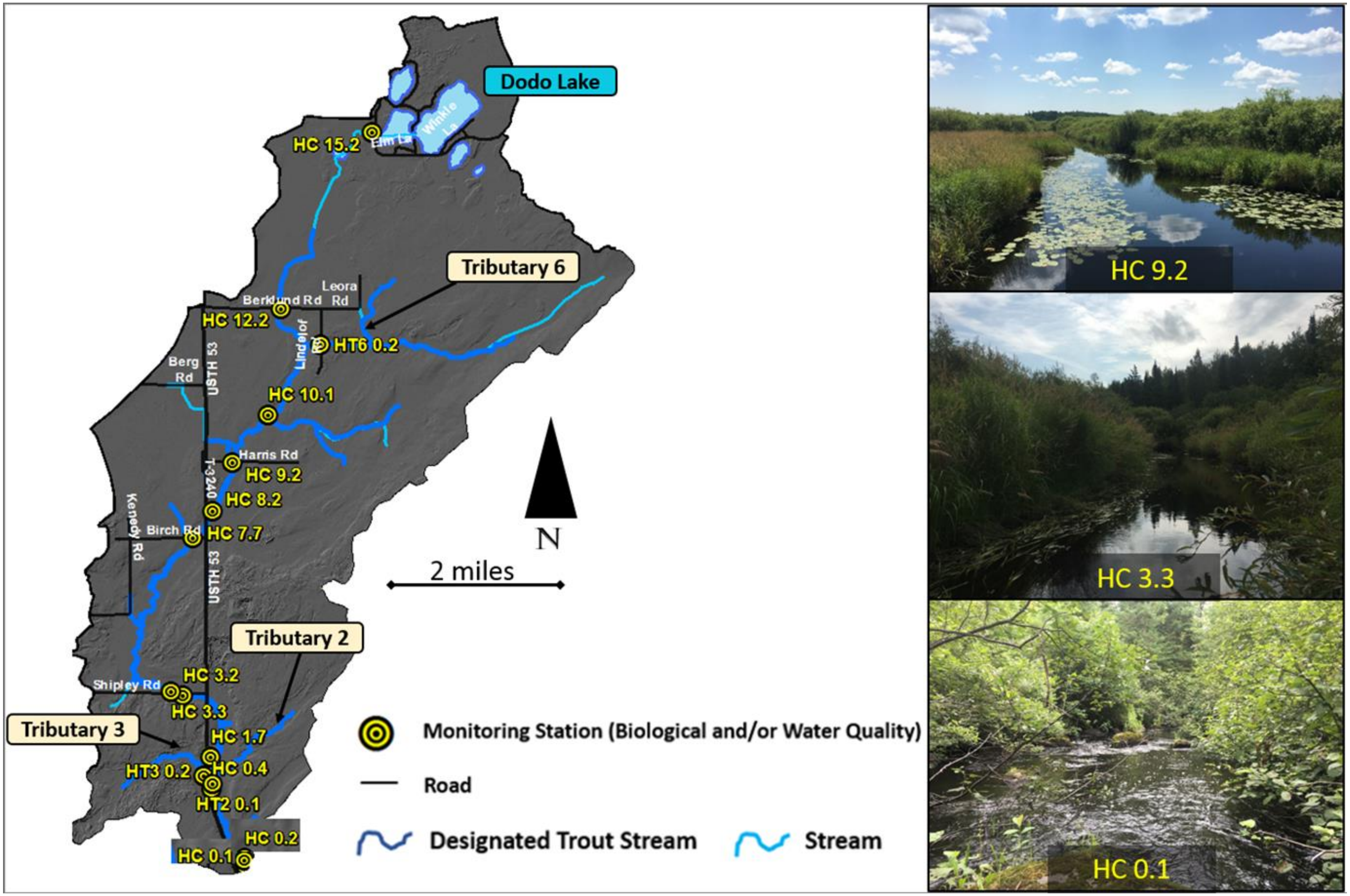
The DNR completed a thorough assessment of Hellwig Creek in 2006, sampling a total of five stations (HC 0.1, HC 1.7, HC 3.6, HC 9.2, and HC 9.9). Brook Trout were sampled at HC 0.1 (n=4, all age-1) and HC 1.7 (n=2, all age-1). One Brown Trout (age-1) was also sampled at station HC 0.1. The Cloquet River was being stocked with Brown Trout at the time of this sampling effort, and it is likely that the individual captured in Hellwig Creek was a product of stocking, as Hellwig Creek does not show a history of natural reproduction of Brown Trout.

Five stations on Hellwig Creek (HC 0.1, HC 1.7, HC 3.4, HC 8.2, HC 12.1) were sampled in 2016 as part of the Lower Cloquet and Trout Stream Tributaries Brown Trout Stocking Evaluation and Stream Assessment (DNR, 2017). Brook Trout were observed at stations HC 0.1 (n=6 and HC 1.7 (n=5), with young of year (age-0) individuals present at HC 0.1.

The extensive sampling history of Hellwig Creek provides evidence of a small population of naturally reproducing, localized Brook Trout population between the Hellwig Creek –Cloquet River confluence upstream to station HC 1.7. Tributary 2 and Tributary 3 provide inputs of coldwater into this reach, and offer year-round habitat for Brook Trout. Tributary 2 supports a relatively high density of trout given the small drainage area (1.66 sq. mi.) and bankfull width of only 10 feet. Two culverts under HWY 53 reduce fish passage from Hellwig Creek into the majority of this tributary stream. Restoration and protection efforts aimed at increasing connectivity between lower Hellwig Creek, Cloquet River, and Tributaries 1 and 2 could increase productivity and survivorship in the Brook Trout population.

Several old DNR reports suggested that Hellwig Creek is more suitable for Brown Trout, but these statements have been refuted by the persistence of wild Brook Trout in this stream as Brown Trout have failed to colonize.

Figure 22. Hellwig Creek Watershed and monitoring stations.



6.2.2 Fish IBI results

Fish Index of Biological Integrity (FIBI) scores are calculated using methodology developed by MPCA's Biological Monitoring Unit. Three fish sampling events on Hellwig Creek meet the requirements for a "reportable" sample that can be used to generate an IBI score. Station information, FIBI results, and the standards used to assess this reach are included in Table 11.

FIBI results from the lone assessable station, (98LS019 (HC 3.3), show a high level of variability between sampling events. Results from two visits (1998 and 2016) score above the FIBI standard and are not indicative of an impaired fish community. However, a significant decrease in FIBI score was observed in the 2015 sample, with a FIBI score of 12, well below the standard of 35 (Table 11). The low FIBI score resulted from the dominance of several tolerant species, Central Mudminnow and White Sucker. The other two species present in this sample are classified as "pioneer" species, which are commonly found in disturbed or rapidly changing environments. The sampling reach is frequently altered by beaver activity, and the major shift in the fish community is likely linked to changes in water levels, current velocity, and substrate conditions that were caused by dam construction.

6.2.3 Macroinvertebrate IBI results

A single station (98LS019/HC 3.3) on Hellwig Creek has reportable macroinvertebrate data for generating MIBI scores, with sampling visits in 1998 and 2015. In a similar pattern to the fish results, a significant drop in MIBI score is evident in the 2015 sampling result. MIBI score fell from 77 (1998) down to 34 (2015), a score that is well below the MIBI criteria of 51 for this stream type (Table 11). The 2015 sample was highly dominated by "mud snails" (Hydrobiidae), which are often found on aquatic vegetation and in large populations. The air-breathing snails Ferrissa and Gyraulus were also relatively abundant compared to other taxa. In general, the macroinvertebrate community at station HC 3.3 had significantly lower taxa richness (1998 n=53; 2015 n=23) and was highly dominated by taxa that prefer slow moving water, aquatic vegetation, and soft-substrates.

Table 11. Summary of Hellwig Creek biological sampling stations, results, and applicable assessment criteria. Map of stations in Figure 22. Bold Black text indicates IBI scores meeting aquatic life standards. Red text indicates IBI score failing to meet aquatic life standards.

Station	Drainage Area (mi2)	Gradient (%)	Fish IBI Class	Fish IBI Result *(visit year)*	Standard	IBI Lower Confidence Limit	IBI Upper Confidence Limit
HC 3.2 (98LS019)	20.7	0.13%	7	44 *(1998)*	35	25	45
HC 3.2 (98LS019)	20.7	0.13%	7	12 *(2015)*	35	25	45
HC 3.2 (98LS019)	20.7	0.13%	7	43 *(2016)*	35	25	45

Station	Drainage Area (mi2)	Gradient (%)	Invert IBI Class	Invert IBI Result *(visit year)*	Standard	IBI Lower Confidence Limit	IBI Upper Confidence Limit
HC 3.2 (98LS019)	20.7	0.13%	4	77 *(1998)*	51	37	65
HC 3.2 (98LS019)	20.7	0.13%	4	34 *(2015)*	51	37	65

6.3 Hellwig Creek stressor identification analysis

6.3.1 Elevated total suspended solids (TSS) concentrations

Prior to the SID monitoring effort, elevated TSS concentrations was considered a low probability cause of biological impairment based on historic data and knowledge of watershed conditions. Streams with elevated TSS concentrations are a rarity in the entire Cloquet River HUC 8 watershed. This statement is supported by the fact that it is one of the few HUC 8 watersheds in NE MN without a turbidity or TSS impairment. In general, the risk of erosion is low throughout the watershed due to low gradient nature of the stream and broad wetland floodplains, high rate of forest cover (80%), relatively low percentage of highly erodible land, and low to moderate rates of development.

Stream transparency readings were collected throughout the Hellwig Creek Watershed in April of 2017 during snowmelt runoff. Discharge during this sampling event was at or slightly below bankfull (Figure 23). Water clarity at all stations was slightly reduced due to tannin (bog) staining from the abundant wetlands in the headwaters of the creek, however, all transparency results were between 95-100 cm and greater. Additional visits were made to several of these stations during mid-summer rain events and transparency readings remained in the range of 90-100 cm or greater. The transparency standard for impaired reach of Hellwig Creek is 40 cm.

Three TSS samples were collected at station HC 3.2 (98LS019) during summer biological sampling visits. Results ranged from 1.8 - 6 mg/L, all well below the TSS standard for warmwater streams of 15 mg/L. These results are also below the TSS standard for coldwater streams (10 mg/L), so elevated TSS concentrations are also not a limiting factor for the coldwater reaches of Hellwig Creek.

Transparency and TSS results from Hellwig Creek are well below established standards during low, moderate, and high flow conditions. As a result, elevated TSS concentrations can be eliminated as potential cause of biological impairment.

Figure 23. Transparency sampling results and photos for several Hellwig Creek monitoring sites during high flow events.

6.3.2 Low dissolved oxygen concentrations

Continuous dissolved oxygen (DO) data were collected at three Hellwig Creek monitoring stations during the mid-summer of 2017, the season during which DO concentrations are typically lowest and most limiting for sensitive aquatic life. Monitoring stations were chosen to represent three distinct stream and riparian types found in the watershed. The upstream-most monitoring station (HC 9.2) was selected to represent conditions in the low gradient, wetland dominated headwaters of the creek. Historic data from this area, along with comments from the DNR fisheries office, indicate DO concentrations in this reach regularly fall below the 5 mg/L DO standard for warmwater streams. Another continuous DO logger was placed at station HC 3.2 within the biological monitoring reach that failed to meet both the fish and macroinvertebrate IBI standards for warmwater streams. The third and final DO logger was placed at station HC 0.1, within the designated trout stream reach of Hellwig Creek. Fisheries data from station HC 0.1 show a naturally reproducing population of Brook Trout within this high quality reach. Continuous measurements of DO were collected at these three stations for a 19-day period between July 28, 2017 and August 15, 2017. Streamflow levels were near or slightly above baseflow during the monitoring period.

DO concentrations at HC 9.2 (Harris Rd) fell below 2 mg/L in late July for several days, and remained below 5 mg/L for almost the entirety of the 19-day monitoring period (Figure 24). The watershed area draining to HC 9.2 is predominantly bogs and wetlands within minimal human disturbance. Water entering Hellwig Creek through these features is naturally low in DO content.

DO concentrations improve markedly by station HC 3.2, located approximately six river-miles downstream of HC 9.2 (Figure 24). Throughout most of the 19-day monitoring period, DO concentrations were within a range of 4.95– 7.5 mg/L, which is suitable for supporting healthy warmwater fish and macroinvertebrate communities. Several factors are likely contributing to the increase in dissolved oxygen at HC 3.2. First, the channel type changes from a low-gradient, channelized Rosgen E6 channel type (Rosgen, 1995) frequently impounded by beaver dams at HC 9.2, to a moderate gradient Rosgen C5 channel type at HC 3.2. The added gradient and sinuosity of the channel around HC 3.2 results in higher water velocities and increased DO concentrations due to turbulence and reaeration. The influence of wetlands is still present at HC 3.2, but less dominant compared to the headwaters station. Evidence of this can be observed by the increase in specific conductance at HC 3.2, which is likely a result of more water entering Hellwig Creek through glacial outwash deposits in this portion of the watershed. Gravel pits are a common feature adjacent to HC 3.2, and a clear indicator of a change in geology toward well-drained outwash and soils.

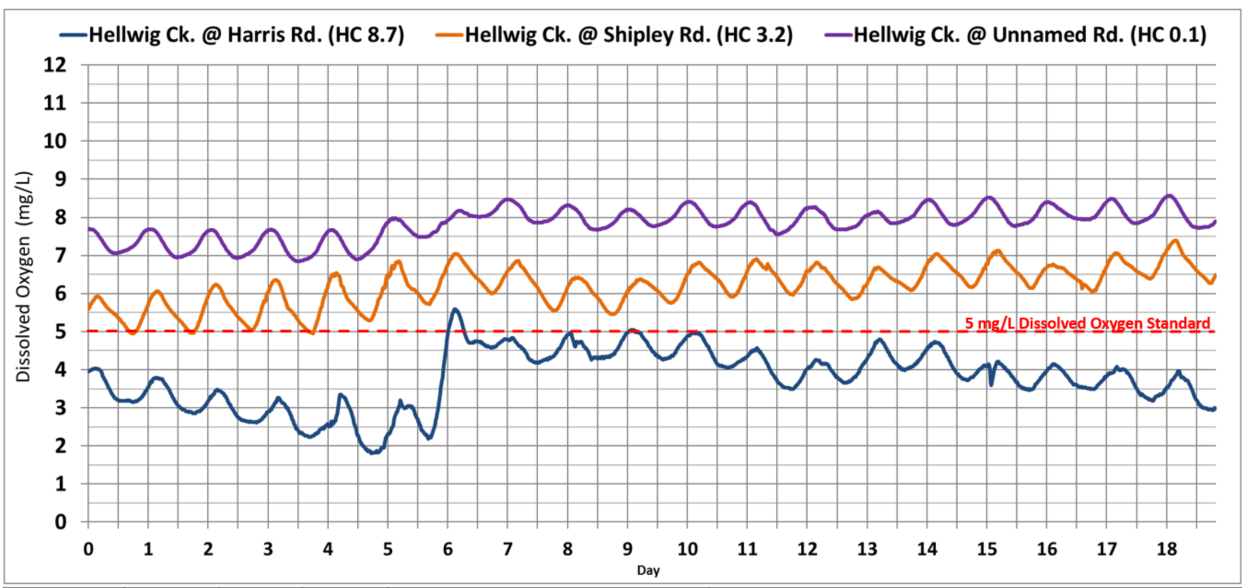
Station HC 0.1 shows a DO profile similar to that of HC 3.2 but with higher DO concentrations. This station is located near the confluence the Cloquet River within the designated trout stream portion of Hellwig Creek. DO concentrations ranged from 6.84 – 8.57 mg/L during the 19-day monitoring period, only narrowly dropping below the 7 mg/L coldwater DO standard for very short durations. The DO regime at this station is adequate for supporting Brook Trout and other sensitive coldwater fish and macroinvertebrate species. DO concentrations increase within this reach due to a change in channel morphology to a steep, coarse-grained B3 channel with numerous step-pools and drops. Stream temperatures were also slightly lower at this station than HC 3.2, which contribute to the more favorable DO concentrations at this station.

One major rain event occurred during the continuous DO monitoring period (1.18 inches on 8/4/17). This rain event caused a sharp decrease in water temperature and corresponding rise in DO concentrations on day 6 (Figure 24). The increase in DO was particularly significant at station HC 9.2 in the headwaters of the watershed. DO concentrations remained higher for nearly one week following the rain event, but by the end of the monitoring period DO concentrations were receding towards pre-rain event levels. The increase in DO concentration at HC 9.2 following the rain event is somewhat surprising given that the surrounding area contains large wetland and bog complexes. One explanation is that the surrounding wetlands were not fully saturated before the storm event, and the 1" rainfall did not cause significant release of water to the creek. Additional DO monitoring during other summer months, other seasons, or other climatic conditions (e.g. drought or wet periods) would be helpful for understanding the DO response to rain events.

Point measurements and effects of beaver dams

In addition to the continuous DO data, three point measurements of DO were collected at HC 3.2 during fish biomonitoring visits. Two of the three measurements were above the 5 mg/L standard and comparable to the data collected during the continuous profiles. However, a concentration of 2.31 mg/L was recorded during the July 26, 2016 sampling event. The site visit notes for this date report high water levels and stagnant flows due to a small beaver dam downstream of the sampling reach. TP concentrations were also much higher during this event compared to other visits to this station. Results from this site visit illustrate the role of beaver as "ecosystem engineers" based on their ability to significantly alter local stream conditions very quickly. Although some of the impacts of beaver at this station may not appear favorable, beaver are well known to provide ecosystem services by increasing habitat heterogeneity and aquatic and terrestrial species richness on a landscape or riverscape scale (Wright et al, 2002; Fausch et al., 2002). The influence of beaver on physical habitat within this reach, and potential management strategies to increase fish and macroinvertebrate IBI scores are discussed further in Section 6.3.3.

Figure 24. Results of continuous dissolved oxygen measurements at three Beartrap Creek monitoring stations collected July 28 – August 15, 2017.



	# of Readings	Min (mg/L)	Max (mg/L)	24-hr Flux Data: Average (mg/L)	24-hr Flux Data: Max (mg/L)	Warmwater Dissolved Oxygen Standard - 5 mg/L: % Readings below	Avg. Duration below (hours)	Max Duration below (hours)
HC 0.1	1807	6.84	8.57	0.68	0.96	0.0%	0	9.25
HC 3.2	1807	4.95	7.39	0.99	1.41	1.33%	190	390
HC 8.7	1807	1.8	5.59	0.69	2.71	97.9%	8840	13920

Date	Time	DO (mg/L)	Station Visit Notes
8/12/1998	9:30	6.70	
7/1/2015	9:30	6.71	Slower flow, lots of veg with decent substrate
7/27/2016	18:10	2.31	Low gradient wetland stream. Marginal site. Small beaver dam just DS of reach which appears to be backing it up. Still within banks, but barely.

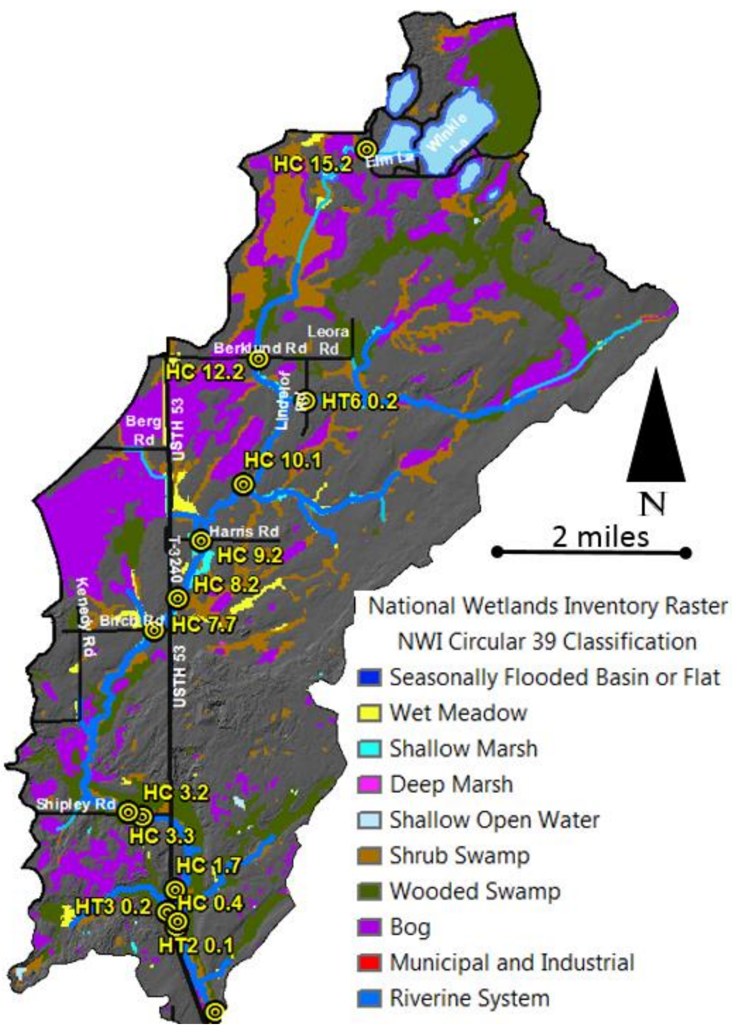


Figure 25. (TOP) Spot measurements of dissolved oxygen collected at station HC 3.2 and corresponding visit notes and photos.

(LEFT) National Wetlands Inventory data for the Hellwig Creek watershed, showing prominent areas of bog/swamp in the headwaters and middle portions of the watershed.

Eutrophication and wetland influences

Although a number of nutrients are required for plant growth, phosphorous and nitrogen are the primary drivers of productivity in aquatic systems (Dodds 2006, Dodds & Cole 2007). Total phosphorus (TP) is the primary causal variable used by MPCA to evaluate river eutrophication (Heiskary, 2013). Samples for TP were collected in April, June, and September in attempt to cover a range of temperature and flow conditions. The sampling stations were co-located with continuous DO measurements in the Hellwig Creek Watershed (HC 0.1, HC 3.2, HC 9.2).

TP concentrations were below the 0.050 mg/L standard in 5 of 6 samples collected in the watershed. The highest TP value of 0.062 mg/L was observed at station HC 3.2 in July of 2016, when the creek was impounded by several beaver dams downstream of the station. In 2017, the highest TP concentrations (0.034 – 0.038 mg/L) were observed in the headwaters of the watershed at station HC 9.2. TP concentrations were slightly lower at the other two stations, but very comparable. Seasonally, TP concentrations were highest at all stations during the September sampling event, but there were no major seasonal differences in TP values overall.

Biochemical oxygen demand (BOD) and chlorophyll-a (Chl-a) are two "response variables" used in the MPCA's river eutrophication standard. There are no Chl-a data available for the Hellwig Creek, but values are likely low due to tannic stained water, low pH values, and general lack of productivity in this creek. BOD data are available for several stations from samples collected in August during the continuous DO monitoring period. Results from two stations, HC 0.1 and HC 3.2, were below the eutrophication response variable criteria of 1.5 mg/L listed in the MPCA's River Nutrient Criteria (Heiskary, 2013). Conversely, BOD concentration observed at station HC 9.2 in the headwaters of Hellwig Creek was 3.1 mg/L, two times greater than the eutrophication response variable criteria. The corresponding TP results from this sampling event were low (0.038 mg/L), so the elevated BOD levels cannot be linked to eutrophication. This reach was impounded by a beaver dam and the elevated BOD concentrations are most likely driven by decaying organics trapped within the impoundment.

DO flux (e.g. Daily Maximum – Daily Minimum) is another response variable used by MPCA to evaluate eutrophication levels in streams. A DO flux greater than 3.0 mg/L within the "Northern Rivers" nutrient region is considered a response variable indicative of excess nutrients and eutrophication. Average DO flux values in Hellwig Creek ranged from 0.68 mg/L (station HC 0.1) to 0.99 mg/L (HC 3.2). The maximum DO flux observed (2.7 mg/L at station HC 9.2) was still below the 3.0 mg/L response variable criteria. Overall, the DO flux values in Hellwig Creek are low and do not indicate excess nutrient loading and eutrophication.

Groundwater and wetlands can be very low in DO and enriched in carbon due to microbial processing of organic matter as water passes through the soil (Allan, 1995). Dissolved organic carbon (DOC) is a complex mixture comprised largely of decomposed plant material, thus concentrations of DOC are highly correlated with peatlands and wetlands (Dillon and Molot, 1997). The abundant of bogs and wetlands in the upper and middle sections of the Hellwig Creek Watershed clearly influence DO concentrations, particularly in the headwaters (station HC 9.2). The elevated DOC concentrations at these stations are clear indicators of the influence of wetlands and bogs on the overall water chemistry at these locations.

Biological response to low dissolved oxygen

The minimum DO concentration required to sustain life varies widely among aquatic organisms. The impaired reach of Hellwig Creek is a classified as a warmwater stream and the applicable dissolved oxygen standard is 5 mg/L. With the exception of tolerant taxa, most warmwater fish and macroinvertebrate species avoid areas with DO concentrations below 3 mg/L, but generally do not begin to suffer fatalities due to oxygen depletion until levels fall below 2 mg/L. The mean DO levels should remain near 5.5 mg/L for optimum growth and survival (US EPA, 1986).

Fish community

Three years of "reportable" fish community data are available for the impaired reach at station HC 3.2 (98LS019). This station was first sampled in 1998, and repeat sampling visits were completed in 2015 and 2016. Several significant changes in the fish community occurred between the 1998 and 2015-16 sampling events. Taxa richness dropped from nine species down to four, and the total number of fish sampled decreased significantly (n=217 in 1998; n=88 in 2015; n=26 in 2016).

Central Mudminnow, which is highly tolerant of low DO and other stressors, was a dominant species in all three sampling events. Other dominant species at this station included Creek Chub, Brook Stickleback, Johnny Darter, and White Sucker. Fish community DO TIV values for station HC 3.2/98LS019 indicate a highly tolerant community compared to high quality stations (Figure 26) (see Section 4.2 for TIV explanation). All three sampling visits resulted in DO TIV scores well below the 25^{th} percentile values of the comparable reference stations, with the 2015 and 2016 visits scoring especially low. These samples were dominated by Central Mudminnow, and many of the intolerant taxa observed in 1998 sampling event were not present. In general, many of the fish species sampled at this station are tolerant of low DO conditions, but also tend to be abundant in frequently disturbed and/or poor quality physical habitats.

The fish community within the impaired reach of Hellwig Creek is symptomatic of a DO-limited stream environment. However, the vast majority of the DO measurements recorded at this station were within a suitable range for supporting a healthy warmwater fish community. When beaver dams are absent from the immediate sampling reach and conditions are free-flowing, DO concentrations appear to be suitable within the impaired reach. Beaver impoundments within the reach periodically reduce DO concentrations locally and alter physical habitat. Fish community changes are bound to occur within the sampling reach as beaver dams are constructed and fail over time. These conditions are not unique to Hellwig Creek and may not represent a true impairment if these data are considered on a longer time-scale that accounts for short-term disturbances caused by beaver activity.

Schlosser (1995) observed major changes in the fish community of a small Minnesota stream based on pulse migrations from adjacent beaver ponds created and destroyed on a decadal time scale. In another study, Schlosser (1995b) found that nearly all the movement of several fish species occurred in a single pulse in a several day period during the course of several summers of monitoring. The scenarios described above may be responsible for the dramatic shifts in fish and macroinvertebrate communities observed within the impaired reach over the three sampling visits.

Macroinvertebrate community

Overall, the macroinvertebrate community at station HC 3.2 (98LS019) can be classified as somewhat tolerant of low DO concentrations. The DO TIV values for all visits were comparable, even though a dramatic shift in MIBI scores, richness, and taxa can be observed between the three visits. TIV results are within the 25^{th} percentile to median range of Class 4 (Northern Forest Streams GP) MIBI stations, indicating a slightly more tolerant community than most stations of the same class (Figure 26). The relative percentage of low DO-intolerant taxa and individuals was relatively low during both visits (0 to 4.5%. Intolerant individuals were more common in the 1998 sample when the reach was not impounded by beaver and more riffle-glide habitat was available.

Spot measurements of DO taken during the 1998 and 2015 were both adequate for supporting sensitive warmwater taxa. Low DO concentrations (2.31 mg/L) were observed during a fish visit in 2016, when a small beaver dam was impounding stream flow within the reach, however, the macroinvertebrate community was not sampled in 2016 under these conditions. Similar to the fish community, the macroinvertebrate assemblage can be expected to shift dramatically depending on the presence of beaver and the amount of dam construction they undertake within the sampling reach.

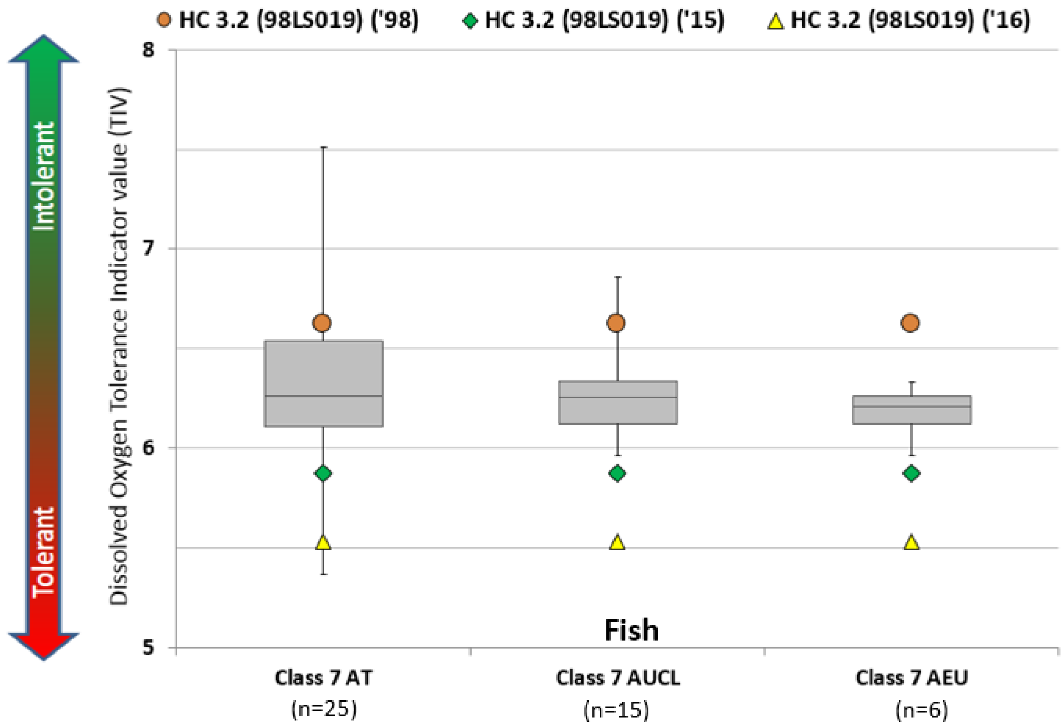
Summary: Low dissolved oxygen concentrations as a stressor in Hellwig Creek

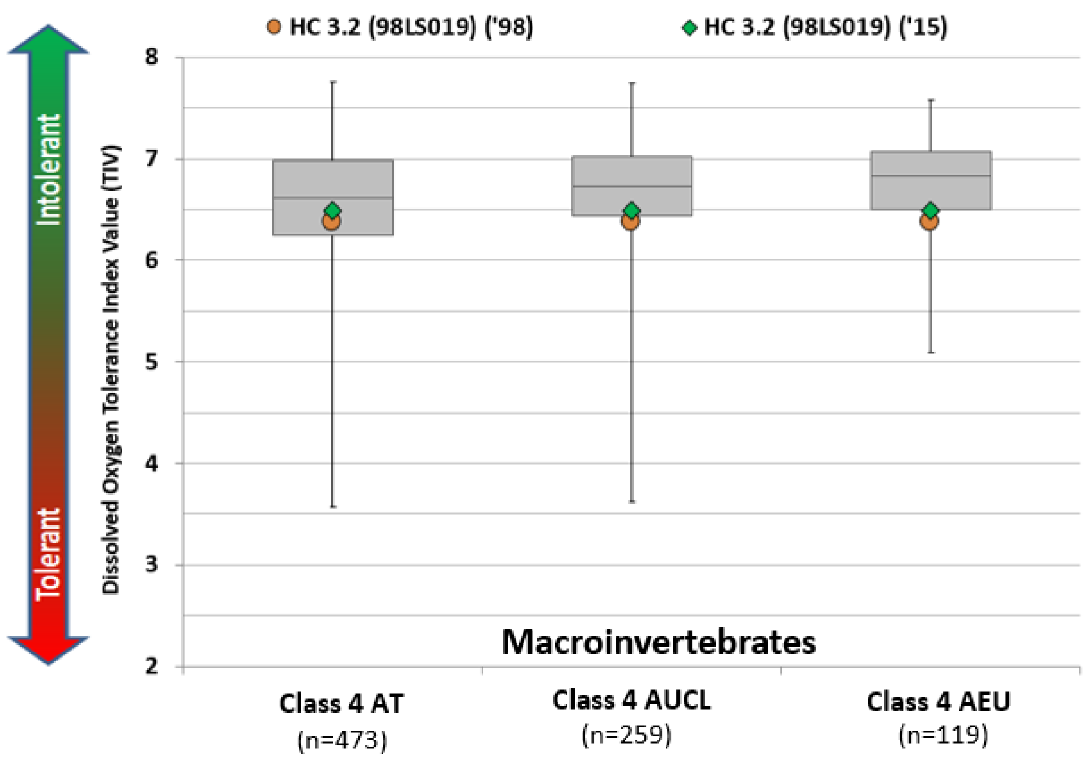
DO concentrations in Hellwig Creek vary longitudinally from headwaters reaches to the middle and lower portions of the main stem. Gradient, channel-type, substrate, and surrounding land-cover (esp. % wetlands) are all factors in this variability. DO concentrations also show variation from year to year within the same reach due to temporary changes in water levels, current velocities, and substrate conditions resulting from beaver impoundments. With the exception of the headwaters, reaches and sections impounded by beaver dams, the DO concentrations observed in Hellwig Creek are suitable under most conditions for supporting a healthy warmwater macroinvertebrate community.

The low total phosphorous concentrations and lack of eutrophication response variable symptoms clearly eliminate eutrophication as a pathway to low dissolved oxygen in Hellwig Creek. Sub-5 mg/L occurred only in low gradient, wetland dominated headwaters reaches and within beaver impoundments. Based on the complete body of evidence, low DO concentrations are unlikely the cause of fish and macroinvertebrate IBI impairments in Hellwig Creek. Low DO concentrations do exist in localized areas due to natural background conditions, but are not the result of excess nutrient loading or other anthropogenic sources.

The DO concentration of 2.31 mg/L recorded within the impaired reach in July of 2016 was the results of a beaver impoundment downstream of the sampling point. This observation indicates that sub-optimal DO concentrations do exist within the impaired reach for short durations, but are not the result of excess nutrient loading (eutrophication) or other anthropogenic sources. Low DO will remain a potential stressor in this watershed, as short duration changes in DO concentrations can cause abrupt shifts in the fish and macroinvertebrate community. However, no TMDL or restoration activity is needed to address this limiting factor.

Figure 26. Box-plot distribution graphs comparing Dissolved Oxygen Tolerance Indicator Values (TIV) data from Hellwig Creek to results from other stations within the same FIBI/MIBI class. * See Section 4.2 for explanation of TIV. AUCL = Stations scoring above upper confidence limit of FIBI threshold; AT = Stations scoring above FIBI Threshold; AEU = Stations scoring above exceptional use criteria.





6.3.3 Poor physical habitat conditions

Poor physical habitat was listed as a potential cause of fish and macroinvertebrate IBI impairments in Hellwig Creek due to clear shifts in fish and macroinvertebrate community composition over several visits to one of the biological monitoring stations (HC 3.2). Changes in water levels, streamflow patterns, and physical habitat condition have been documented over the sampling record. Some of these changes may be related to the ditching of the creek along Shipley Road, and/or the presence of beaver dams within the sampling reach.

Physical habitat and channel stability assessments were completed for six reaches of Hellwig Creek. Data were collected at the "reach" scale as described by Fausch (2002) (see to Figure 17). Due to the length of the stream and similarity of the habitat types available, reach scale data can be extrapolated to other portions of the Hellwig Creek Watershed with similar attributes. The six reaches assessed adequately represent the major habitat types present within the watershed (Table 12).

Physical habitat conditions were evaluated using the MPCA Stream Habitat Assessment (MSHA) protocols (see Section 4.3.3). Results were highly variable, with scores ranging from 32 (rating = "poor") to 84 (rating = "good") out of a possible 100 points. Three out of the six stations assessed (HC 0.1, HC 0.4, and HT6 0.3) recorded an MSHA rating of "good", while station HC 3.2 NC (Natural Channel) rated "fair", and HC 3.2 D (ditched) and HC 8.2 D (ditched) both rated "poor" (Table 12). The highest quality habitat conditions were located in the coldwater reaches of Hellwig Creek, and the poorest habitat scores were associated with ditched headwaters reaches, which have low quality riparian corridors and stream bottoms dominated by fine substrate materials (silt/detritus).

As expected, channel stability scores are closely correlated with MSHA habitat results. Pfankuch Stability Index (PSI) ratings of "unstable" or "moderately unstable" were limited to the two channelized reaches that were assessed, HC 3.2 (ditched portion) and HC 9.2 (see Section 4.3.2 for information on the PSI). All reaches with natural channel pattern, dimension, and profile were rated "stable". The relative lack of channel instability in this watershed suggests that habitat limitations are predominantly associated with natural background factors (e.g. low gradient streams, beaver dams).

Conditions at impaired biological monitoring station

The impaired biological reach (HC 3.2) was split into two reaches for habitat and channel stability assessments, as approximately 1,400 feet (0.25 miles) of the creek is channelized along the south side of Shipley Road. The natural channel portion of the reach (HC 3.2 NC) received an MSHA score of 64 ("fair"). This result is consistent with previous MSHA assessments completed at this station during biological monitoring surveys in 2015 and 2016. Poor to fair scores were given for metrics related to channel condition and morphology, fish cover, substrate, and riparian land-use conditions. The road ditch diverts a significant portion of the flow away from the natural channel downstream of Shipley Rd, reducing the stream power for maintaining sediment transport and a variety of channel features that are critical to fish and aquatic macroinvertebrates (e.g. riffles, glides, deep pools). As a result, substrate conditions are trending towards fine particles (sand/silt) in the natural channel reach. Fish cover is limited in this reach largely due to the lack of large woody debris, the availability of which is naturally limited given the wetland/shrub nature of the riparian corridor. However, other types of fish cover, such as undercut banks and deeper pools, could be increased if channel restoration were completed to return all streamflow to the natural channel.

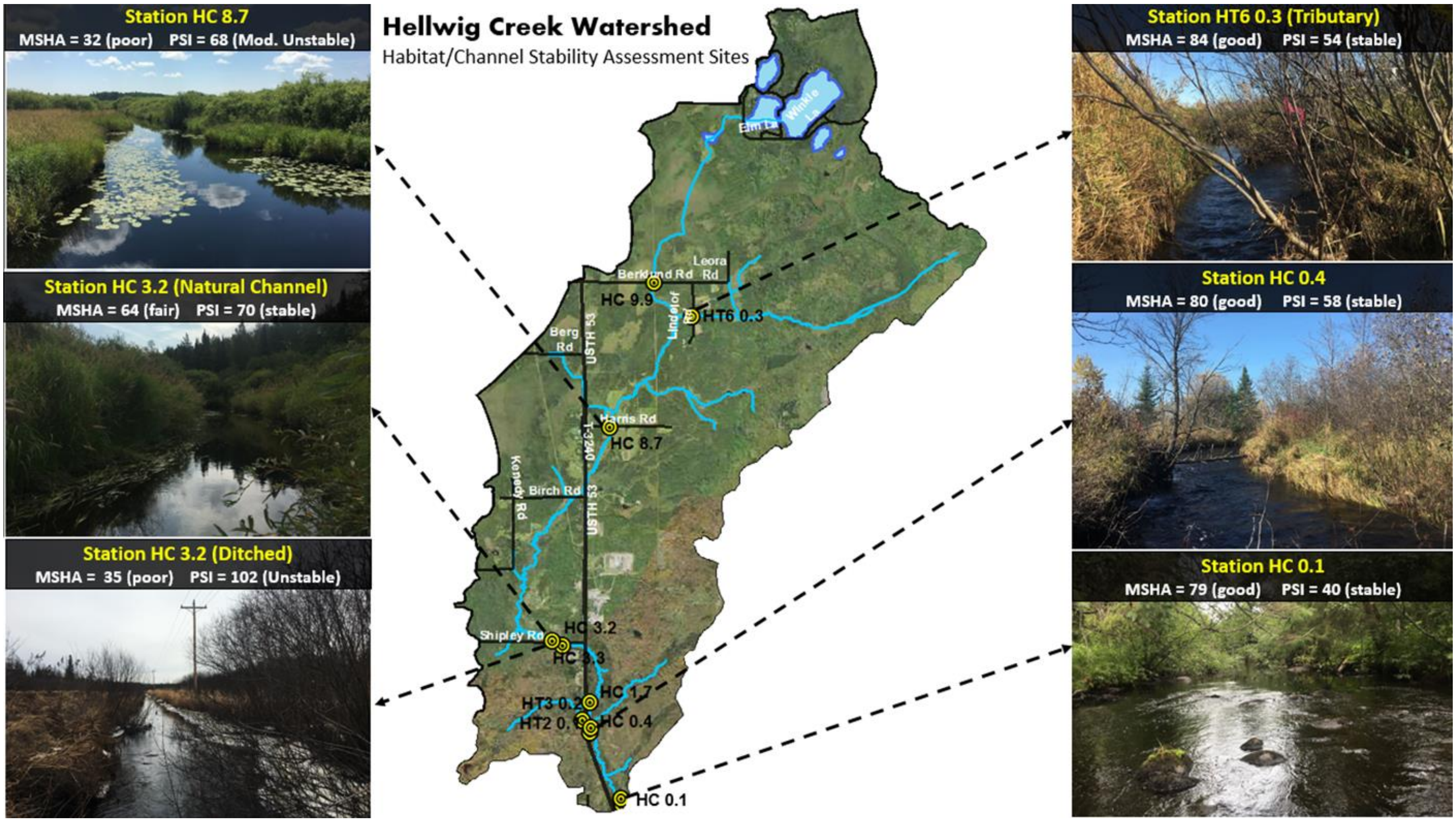
The ditched portion of the biological monitoring reach received an MSHA score of 32, which is a "poor" rating. The ditched channel lacks depth variability and sinuosity, and some areas of instability (erosion, mid-channel depositional bars) are evident near the Shipley Road crossing and along the road ditch.

Table 12. Physical habitat and channel stability scores, ratings, and descriptions for Hellwig Creek monitoring stations.

Stream	Location	Overall MSHA Score	Habitat Types (dominant substrate)	Temp. Class	Pfankuch Stability Index (PSI) Score
Trib. to Hellwig Ck	HT6 0.3	**84 (good)**	riffle-run (gravel/sand)	Cold	**54 (stable)**
Hellwig Ck	HC 9.2 (D)	**32 (poor)**	glide-pool-ditched (silt/detritus)	Warm	**68(mod. unstable)**
Hellwig Ck	HC 3.2 (D)	**35 (poor)**	glide-pool-ditched (silt/detritus)	Warm	**102 (unstable)**
Hellwig Ck	HC 3.2 (NC)	**64 (fair)**	glide-pool (sand/boulder/gravel)	Warm	**70 (stable)**
Hellwig Ck	HC 0.4	**80 (good)**	riffle-run (cobble/gravel/sand)	Cold	**58 (stable)**
Hellwig Ck	HC 0.1	**79 (good)**	riffle-run (boulder/cobble)	Cold	**40 (stable)**

Figure 27. Aerial photo of station HC 3.2 (98LS019) of Hellwig Creek showing the road ditch adjacent to the natural channel. This ditch diverts flow during all flow conditions. Yellow line indicates the reach that was sampled by biological monitoring crews.

Figure 28. Photographic tour of Hellwig Creek monitoring stations highlighting habitat/channel stability assessment results, as well as the different natural background conditions. Station HC 3.2 represents the impaired biological monitoring reach.



Biological response to physical habitat conditions

Fish and macroinvertebrate communities typically demonstrate predictable responses to poor physical habitat conditions. A few common symptoms include; reduction in the number of sensitive taxa or individuals, a shift in community composition favoring habitat and/or trophic (feeding) generalists. In addition, taxa with specific spawning and rearing traits (e.g. fish that require clean gravel for spawning) are often eliminated or reduced in numbers.

Station HC 3.2 has been sampled several times for both fish and aquatic macroinvertebrates. In 2015 and 2016, fish and macroinvertebrate assessments were completed only on the natural channel portion of 98LS019 (Figure 27). The ditched portion of the reach was not sampled even though it regularly carries a significant portion of the streamflow. It is unlikely that the ditched portion was sampled during the 1998 sampling visits.

Fish community

FIBI scores surpassed the general use standard at station 98LS019 on two occasions (1998 and 2016), largely due the presence of several sensitive and/or riverine fish taxa. Mottled Sculpin, Finescale Dace, and Blacknose Dace were sampled in 1998 in relatively low numbers. These species reflect good habitat conditions and have a positive effect on FIBI scores. Mottled Sculpin and Blacknose Dace occupy riverine habitats, usually with moderate to swift current. Sculpin are associated with cobble or gravel riffle habitats and prefer colder water temperatures. Finescale Dace occur in small, confined habitat in places with permanent spring seeps, with optimal habitat described as a series of beaver ponds filled with a constant supply of cool groundwater (Stasiak and Cunningham, 1972, Schlosser et al. 1995, 1998). The diversity of species present in the 1998 sample suggests that an assortment of habitat types were present within or adjacent to the sampling reach. Less-sensitive fish taxa were present in the 1998 sample (e.g. Central Mudminnow, White Sucker), but those mentioned earlier offer evidence that quality habitat has been present in this reach within the past several decades.

The 2016 FIBI result also met the general use standard, but the fish community was dominated by species associated with wetland-influenced streams (Central Mudminnow, Golden Shiner, Northern Pike). A small beaver dam located at the downstream of the sampling reach in 2016 resulted in above-normal water levels and sluggish flows, which favor wetland-oriented species. The habitat fragmentation created by the beaver dam may have temporarily displaced some of the species observed during other sampling events, as fish taxa richness was much lower in 2016.

Beaver dams dictate physical habitat conditions, hydrology, and the distribution and diversity of aquatic life throughout Northeast Minnesota. Strong temporal dynamics in stream fish movement also have been reported by others (e.g.,Gowan and Fausch 1996b). During a decade-long study of fish movement adjacent to beaver ponds in Northern Minnesota, Shclosser (1995) found that considerable annual variation in fish densities occurred, and migration patterns were strongly linked to beaver dam locations and stream discharge. Moreover, during four summers of trapping fish moving through a weir just downstream of a beaver pond, Schlosser (1995b) found that nearly all the movement of several fish species occurred in a single pulse during only a few days over the entire four summers.

The FIBI result from the 2015 sampling visit was the impetus of the impairment listing. Low taxa richness and a high percentage of pioneer and/or tolerant taxa characterize the fish community observed during this visit. The four taxa present (Central Mudminnow, White Sucker, Creek Chub, Johnny Darter) are associated with poor or rapidly changing habitat conditions. Both of these scenarios are evident at 98LS019, as the sampling reach is in perpetual transition between impounded and free flowing, and offers elements of a channelized stream and natural channel.

In summary, the fish community at station HC 3.2 shows significant shifts over time, but long-term trends are not discernible due to the intermittent sampling of this station. A variety of species have been sampled, including both tolerant and sensitive species, wetland specialists, and even several that prefer coldwater and riffle habitats. The highly variable composition of the fish community reflects the frequent shifts in habitat types available at station HC 3.2, which can be largely attributed to recurring beaver dam construction and breaching and a stream channel that is adjusting due to historic channelization of the reach along Shipley Road.

Aquatic macroinvertebrate community

Similar to the fish community, major shifts in the macroinvertebrate community are apparent over the past several decades at Hellwig Creek station HC 3.2. However, the twenty-year span between sampling events makes it impossible to determine whether these shifts occur year to year (as the fish community does), or if a long-term change has taken place due to more sustained stressor.

The two MIBI results for station HC 3.2 vary by over 30 points, from 77 (fall of 1998) down to 34 (fall of 2015). The substantial decrease in MIBI score resulted from several major community shifts, including a significant decrease in taxa richness (50 taxa down to 22) and a reduction in “clinger” taxa, which require coarse substrates and often prefer riffle habitats. Another major difference between the 1998 and 2015 macroinvertebrate community is the balance, or level of dominance of few taxa. The macroinvertebrate community in 1998 was evenly balanced, as the five most-dominant taxa accounted for only 41% of the total individuals sampled. Conversely, the 2015 sample was highly dominated by very few taxon, with the dominant five taxa accounting for 87% of the total individuals sampled.

The 2015 macroinvertebrate sample was dominated by “mud snails” (Hydrobiidae). These snails are commonly found on aquatic plants, feed on algae, diatoms, and detritus, and can occur in large populations if conditions are favorable. Four additional snail taxa were abundant in the 2015, and overall, nearly 87% of the individuals collected during this sample were snails (compared to 21% in 1998). The macroinvertebrate sampling crew in August 2015 noted a complete lack of riffle habitat and very silty substrates. Abundant aquatic vegetation was reported during both 2015 visits, likely the results of slower than normal current velocities and soft substrates. No beaver dams within the sampling reach were reported in 2015, but site photos from that year show some smaller debris jams presumably caused by beaver activity.

Summary: Poor physical habitat conditions as a stressor in Hellwig Creek

Physical habitat conditions are contributing to the highly variable fish and macroinvertebrate communities observed within the impaired reach of Hellwig Creek (e.g. station HC 3.2). Habitat limitations can be considered one of the primary causes of the low FIBI and MIBI scores in 2015, yet other sampling visits to the same station provide evidence that station HC 3.2 can support a fish and macroinvertebrate community capable of meeting established FIBI and MIBI criteria under certain conditions (Table 13). Beaver dams and diversion of flow into the road ditch along Shipley Road are the only clear factors that influence habitat conditions within this reach.

Table 13. Summary of biological sampling results, community attributes, and habitat conditions during the numerous sampling visits to HC 3.2.

Sample Year	FIBI/MIBI Result*	Fish/Invert Community	General Reach Habitat Conditions
1998	FS/FS*	•High taxa richness • Variety of habitat specialists/ trophic/spawning traits • Mix of sensitive, neutral, and tolerant taxa	• Mosaic. Mostly free-flowing, some beaver activity nearby. Remnant dams within reach. • Normal to low water levels • Mix of substrate types (silt, gravel, cobble, wood)
2015	NS/NS*	•Low taxa richness • Community dominated by few taxa • Mostly tolerant/pioneer taxa	• Moderate streamflow, much of which is diverted from main channel by ditch. Beaver dams may or may not be present. • Abundant aquatic vegetation
2016	FS*/not sampled	• Low taxa richness • Dominated by wetland taxa • Fewer pioneer/tolerant taxa	• Homogenous. Mostly impounded, beaver dams within sampling reach • High water levels • Mostly fine substrates

FS = Full Support of IBI Criteria   NS=Non-support of IBI criteria (failed to meet standard)

6.3.4 Longitudinal connectivity / Aquatic organism passage

The ability of fish and other aquatic organisms to move freely within river systems plays a key role in assuring that all of the critical habitat components of a species are met. Critical habitats for spawning, rearing, feeding, and refugia are often limited and arranged in a patchwork pattern within a watershed, thus movement within and between these unique features becomes critical for sustaining wild fish populations. Barriers between main stem rivers and tributaries are especially damaging to brook trout, as habitat fragmentation is widely linked to local extinction of stream salmonid populations (Morita & Yamamoto, 2002; Letcher et al., 2007).

Improperly installed and/or poorly designed road and railroad crossings are negatively affecting aquatic connectivity (e.g. fish passage), water quality, and physical habitat in the Hellwig Creek Watershed. The observed detrimental effects of these crossings include;

- Barriers to fish migration and dispersal, one of which impedes access to a cold tributary that provides refugia, rearing, and spawning habitat
- Disruption of downstream transport of sediment, large and fine woody debris, all of which are critical for maintaining habitat diversity/complexity and trophic function

Loss of longitudinal connectivity is not considered a primary cause of the fish or macroinvertebrate impairment in Hellwig Creek. However, restoration activities directed at restoring these processes are likely to increase the potential for full recovery of biological potential in this watershed. The crossings referenced in this section are all candidates for restoration. A prioritization table for restoring connectivity in the Hellwig Creek Watershed is presented in Section 7.

Fish migration barriers

The DNR Stream Crossing Basic Assessment Form (Appendix C) was completed at thirteen stream crossings in the Hellwig Creek Watershed. All assessed crossings are mapped in Figure 29 and complete results can be provided upon request. Two of the thirteen crossings evaluated are span bridges. Both bridges were sized correctly (crossing/bankfull width ratio close to or greater than 1.0) and had natural substrate through the crossing. The bridges are properly aligned with the pattern and profile of the river, and do not have any negative effects on stream stability or aquatic organism passage. The remaining eleven crossings were culverts. The number of pipes at each crossing ranged from a single culvert up to four. Seven culvert crossings are considered “appropriately sized” and four are “undersized”.

Slightly over 20% (3 of 13) of the crossings evaluated in the Hellwig Creek Watershed were determined to be full or partial barriers to fish movement. As suggested by several scientific papers on watershed restoration (Roni, 2002; McKay et al., 2016; Petty et al., 2012) we recommend that restoration projects focus initially on reconnecting isolated high-quality fish habitats, such as instream (main stem and tributaries) or off-channel habitats (e.g. groundwater springs) made inaccessible by culverts or other artificial obstructions.

Stream temperature, physical habitat, and biological data indicate that the prime coldwater habitat in the Hellwig Creek is localized. Perennial inputs of coldwater from springs and several small tributary streams (Tributary 2 and Tributary 3; Figure 22) combined with high quality physical habitat conditions help sustain wild Brook Trout populations in several reaches of the main stem and the aforementioned tributaries. Replacing the two undersized culverts on Tributary 3 under US HWY 53 would allow Brook Trout and other coldwater species uninhibited movement between Hellwig Creek and approximately one mile of high quality habitat in Tributary 3. This tributary originates from a large spring, and water temperatures are significantly colder than the main stem of Hellwig Creek. In 2003 and 2004, temperatures remained within the “growth” range for Brook Trout 92-93 percentage of the summer (May-Sept). Brook Trout were sampled in very high density (0.84 BKT per foot of stream) in Tributary 3 downstream of HWY 53 in 2002, perhaps due to in part to the fact that the culverts under HWY 53 are difficult to pass through. This tributary clearly contains some of the highest quality Brook Trout habitat in the watershed, and restoration strategies should prioritize enhancing connectivity of this entire watershed to Hellwig Creek.

The Swan Lake Road crossing of Hellwig Creek was identified as a partial barrier to fish passage and priority for restoration action. This crossing is located just upstream of the confluence with the Cloquet River, and Brook Trout, Brown Trout, and a variety of other species in this river system are known to migrate in and out of tributaries seasonally. Given the size of Hellwig Creek at this location (bankfull width of 36 feet), we recommend that these culverts be removed and a span bridge be installed. A fully-passable crossing at this location would ensure connectivity between the Cloquet River and Hellwig Creek for all species and life-stages under all flow conditions.

Figure 29. All assessed stream crossings in the Beartrap Creek Watershed with ratings for sizing and fish passage.

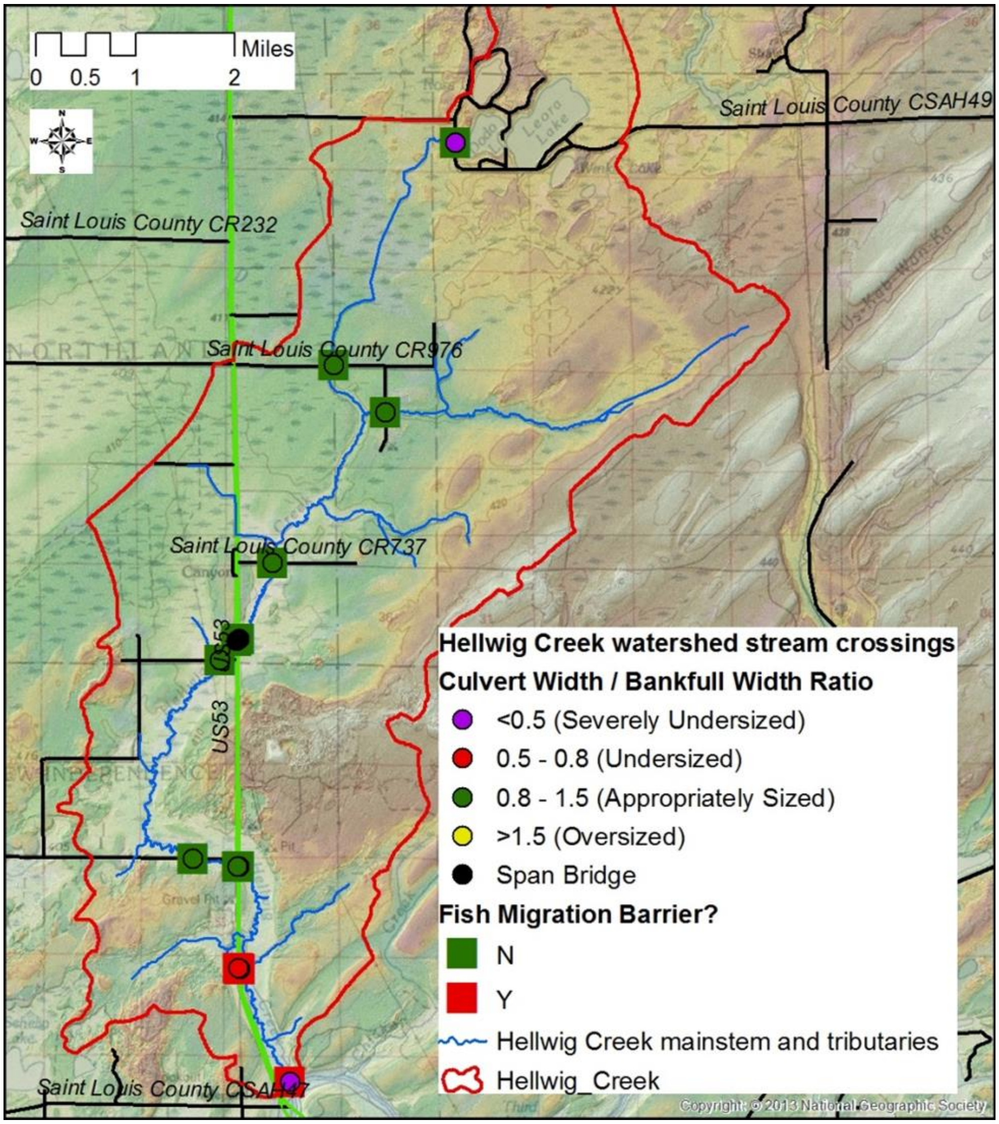
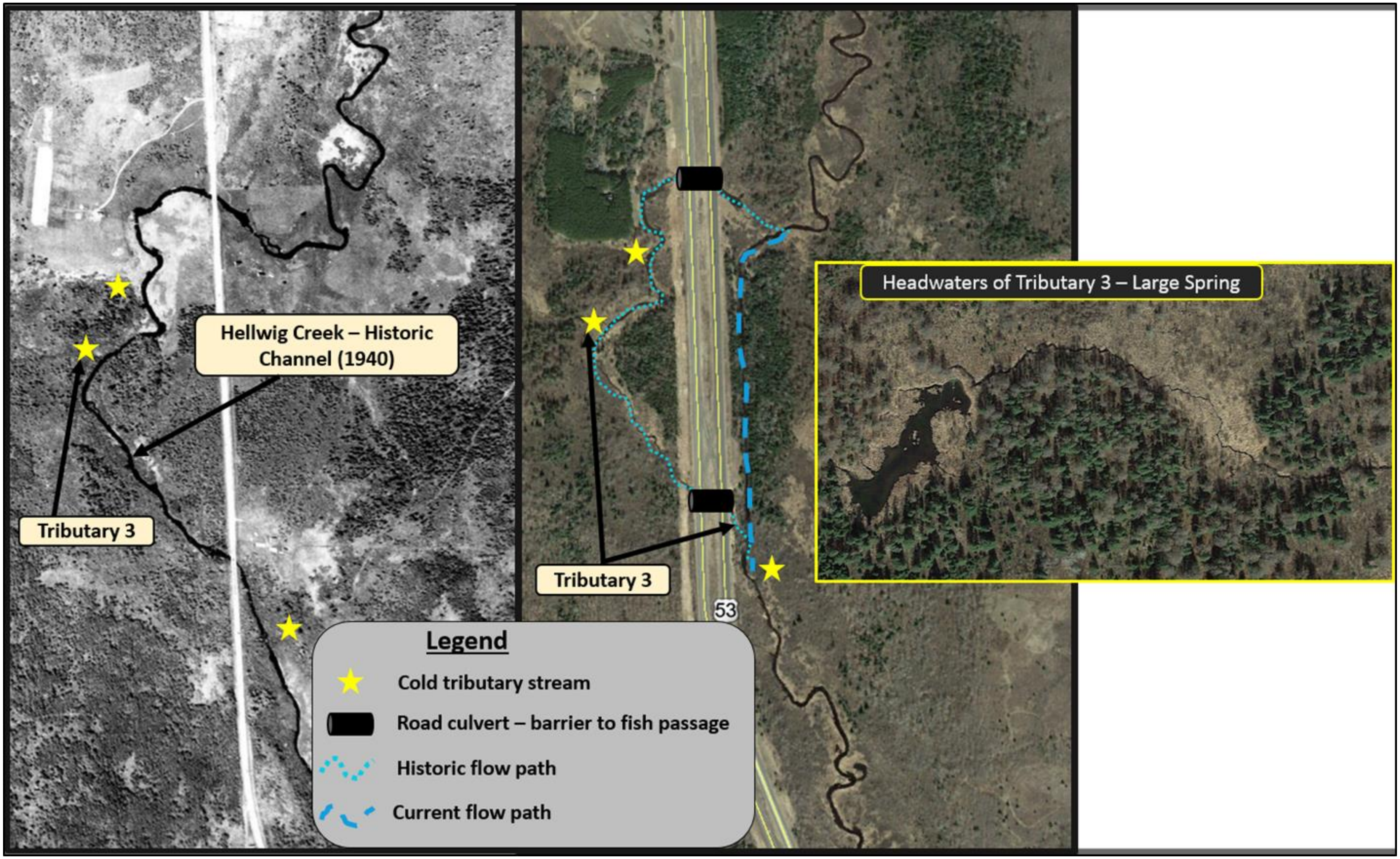


Figure 30. Historic path of Hellwig Creek prior to channelization along HWY 53. Removal of the meander on the west side of Hellwig Creek has shortened stream length, increased gradient, and reduced or eliminated access to a cold tributary stream (Tributary 3) that supports an abundant wild Brook Trout population.



Summary: Longitudinal connectivity / Aquatic organism passage as a stressor in Hellwig Creek

Loss of aquatic connectivity is not a direct cause of fish and macroinvertebrate IBI impairments in Hellwig Creek. However, restoring aquatic connectivity within this watershed would protect existing high quality coldwater habitat and increase thermal refugia and spawning and rearing habitat for Brook Trout populations in the lower reaches of Hellwig Creek. Restoration activities to achieve these goals must focus on replacing road culverts that act as full or partial barriers to fish movement in priority areas. Table 14 contains a prioritized list of recommended restoration projects related to aquatic connectivity and fish passage for the Hellwig Creek Watershed. Prioritization rankings are subject to change based on project feasibility, cost, and landowner cooperation.

Table 14. Prioritized list of restoration projects related to aquatic connectivity and fish passage in the Beartrap Creek Watershed.

Waterbody	Crossing Name	Location	Primary Impact	Priority
Hellwig Creek	Swan Lake Road	46.963828/ -92.460436	1	High
Tributary 3	HWY 53	46.980374 / -92.471029	1	High
Hellwig Creek	Three Lakes Road	47.100811 / -92.423633	2, 3	Low

1=Fish Migration Barrier **2**=Localized Habitat Impacts/Sedimentation **3**=Altered Hydrology

6.4 Stressor identification results: Hellwig Creek

Five stressors were evaluated to determine the cause(s) of FIBI and MIBI impairment in Hellwig Creek (Table 15). Ultimately, a lack of quality physical habitat within the impaired reach was cause supported by the most evidence. Loss of connectivity, or the ability of fish to move unimpeded between sections of Beartrap Creek and key tributaries, was also identified as a limiting factor that needs to be addressed by restoration and protection plans.

Restoration and protection project recommendations related to the causes of impairment are included in Section 7 of this report.

Table 15. Final stressor identification results for fish and macroinvertebrate impairments in Beartrap Creek.

Candidate Cause	FIBI Impairment	MIBI Impairment	Report Section
Low dissolved oxygen	○	○	**6.3.2**
Lack of quality physical habitat	•	•	**6.3.3**
Loss of connectivity	**X**	**X**	**6.3.4**
Elevated Total Suspended Solids (TSS)	**X**	**X**	**6.3.1**

Key: **• = confirmed stressor** **○ = potential stressor** **X = eliminated candidate cause**

7.0 Restoration/Protection recommendations

A variety of restoration techniques should be employed in the Beartrap Creek and Hellwig Creek watersheds to increase biological integrity and advance towards the goal of removing these streams from the impaired waters list. In addition, protection measures should be applied to the high quality habitats and intact watershed processes, as it is typically a more cost effective and successful strategy compared to the restoration approach. This section provides detailed recommendations for protection and restoration activities in the two impaired waters that were studied intensively. Additional recommendations are provided for non-impaired sub-watersheds of the Cloquet River will be provided in separate report to be released in 2019.

The two impaired streams share common stressors derived from similar sources, which include both natural background watershed conditions (e.g. the presence of beaver) and anthropogenic impacts (e.g. high number of road-stream intersections and ditching). Table 16 summarizes the impairments, the root causes of each stressor identified, and a general restoration and protection strategy to reduce the effects of the specific stressor.

Table 16. Summary of stressors, sources, and restoration strategies for impaired reaches of Hellwig Creek and Beartrap Creek.

Stream (Impairment)	Stressor/Limitation	Source	Restoration Strategy
Beartrap Ck (FIBI, MIBI)	Physical Habitat	Beaver Dams	Targeted removal of beaver dams
Beartrap Ck (FIBI, MIBI)	Connectivity	Beaver Dams	Targeted removal of beaver dams
Beartrap Ck (FIBI, MIBI)	Connectivity	Road culverts	Remove fish migration barriers
Beartrap Ck (FIBI, MIBI)	Physical Habitat	Lack of Riparian Veg.	Grazing management/Riparian plantings
Hellwig Ck (FIBI, MIBI)	Physical Habitat	Channelization	Plug ditch, return flow to natural channel
Hellwig Ck (FIBI, MIBI)	Connectivity	Road culverts	Remove fish migration barriers

7.1 Beartrap Creek protection and restoration recommendations

7.1.1 Restoration projects to improve physical habitat

Project 1: Establish “beaver-free” corridor to optimize coldwater fish/macroinvertebrate habitat

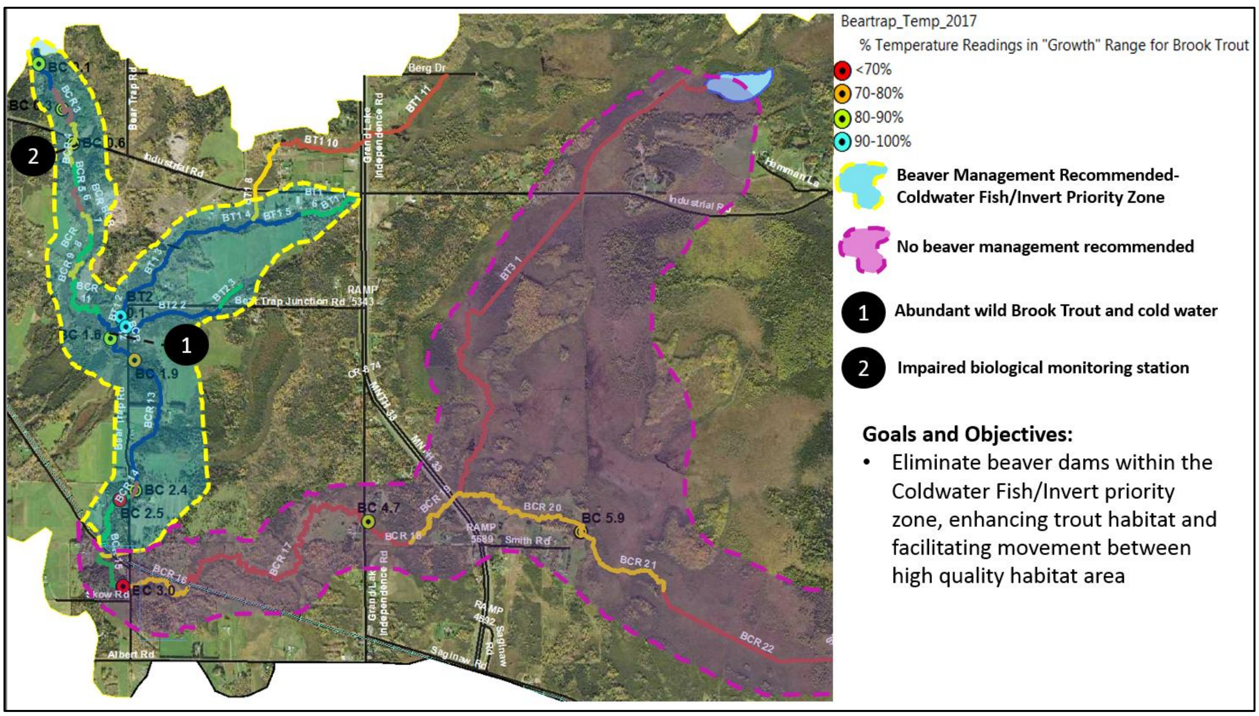
The impact of beaver on native salmonid populations varies spatially and temporally depending on a variety of local ecological characteristics (e.g. stream gradient, groundwater availability). A recent review paper (Johnson-Bice et al., 2018) concluded that beaver activity is often harmful to salmonids in low-gradient stream basins, but generally beneficial in high-gradient basins.

Beartrap Creek classifies as a rather low-gradient stream for most of its length, particularly near the impaired biological monitoring station. Beaver impoundments within and upstream of this reach have created a highly fragmented stream corridor and reduced riffle and glide habitat, resulting in minimal coarse substrates for spawning and benthic productivity. In addition, the impaired reach contains few off-channel springs or tributaries that can provide coldwater inputs and/or physical habitat complexity. These factors create challenging conditions for sustaining wild Brook Trout within the impaired reach, and likely reduce or eliminate Brook Trout movement to and from the higher quality habitat upstream where successful spawning and rearing is occurring.

The beaver management plan summarized in Figure 31 would establish a free-flowing, riverine corridor that extends from the Cloquet River upstream to river mile 3.0 of Beartrap Creek. Two management zones would be developed with different priorities for ecosystem management. The lower, free-flowing reach would be managed to optimize Brook Trout populations and allow movement between high quality and marginal habitats in this corridor. This zone of Beartrap Creek contains all of the habitat types required for Brook Trout to complete their life-cycle (i.e. spawning, rearing, feeding, refuge) and increased rates of movement are expected if beaver impoundments are eliminated. The upper zone of Beartrap Creek encompasses the low gradient, wetland dominated headwaters, an area already heavily influenced by beaver activity. No beaver management is recommended in this reach, as the water storage and bio-diversity created by beaver activity in this zone has ecological benefits.

This strategy has the potential to increase FIBI and MIBI scores in the impaired reach, and eventually remove the impairment listing for Beartrap Creek. Physical habitat conditions in the lower impaired reach will shift over time towards a riffle-run-pool morphology similar to the high quality trout habitat observed at station BC 1.6. The macroinvertebrate community should improve as more riffle and glide habitat return in areas that are currently impounded by beaver dams.

Figure 31. Beaver management strategy for Beartrap Creek that establishes a priority zone for increasing coldwater fish/macroinvertebrate IBI scores, and another where beaver activity is not managed (with the exception of special circumstances -- property owner complaints, road management, etc.)



Project 2: Riparian corridor enhancement: Cattle fencing, grazing management, and plantings

Agricultural land-uses within the Beartrap Creek Watershed include hay/pasture operations and open range cattle grazing. Several cattle grazing areas are located within the riparian corridor of Beartrap Creek. The riparian vegetation in these areas has been denuded of mature trees, shrubs, and native plants, all of which are critical for maintaining channel stability, shading, and inputs of organic matter (leaves, large wood debris, fine woody debris) that enhance fish cover and productivity. Priority areas for improving grazing management and re-vegetation projects are included in Table 17.

Table 17. Target areas for riparian corridor enhancements and possible cattle exclusion projects.

Beartrap Creek Reach (Coordinates)	Recommendations
BCR 13 (46.878092°/ -92.491193°)	Fencing - Reduce cattle access to stream
BCR 14 (46.876495°/ -92.490944°)	Fencing - Reduce cattle access to stream; Plantings of trees, shrubs, native grasses/plants
BCR 15 (46.872587°/-92.494279°)	Fencing - Reduce cattle access to stream; Plantings of trees, shrubs, native grasses/plants

7.1.2 Restoration projects to improve connectivity and fish passage

Four fish migration barriers (all undersized and/or perched road culverts) in the Beartrap Creek Watershed were identified as high priorities for removal. Only one of the identified barriers is located on the main stem of Beartrap Creek, with the remaining three located on tributary streams. Table 8 in Section 5.3.2 contains the general information and coordinates of these crossings. Removing all of the high priority migration barriers will allow Brook Trout and other species to access critical spawning, rearing, and refuge habitat under all streamflow conditions. Expected benefits following barrier removal include increased Brook Trout populations and genetic diversity, increased resiliency to floods/drought and water temperature increases related to climate chance, and localized habitat improvements as wood, sediment, and water pass through these crossings in a manner that closely resembles natural conditions.

7.2 Hellwig Creek protection and restoration recommendations

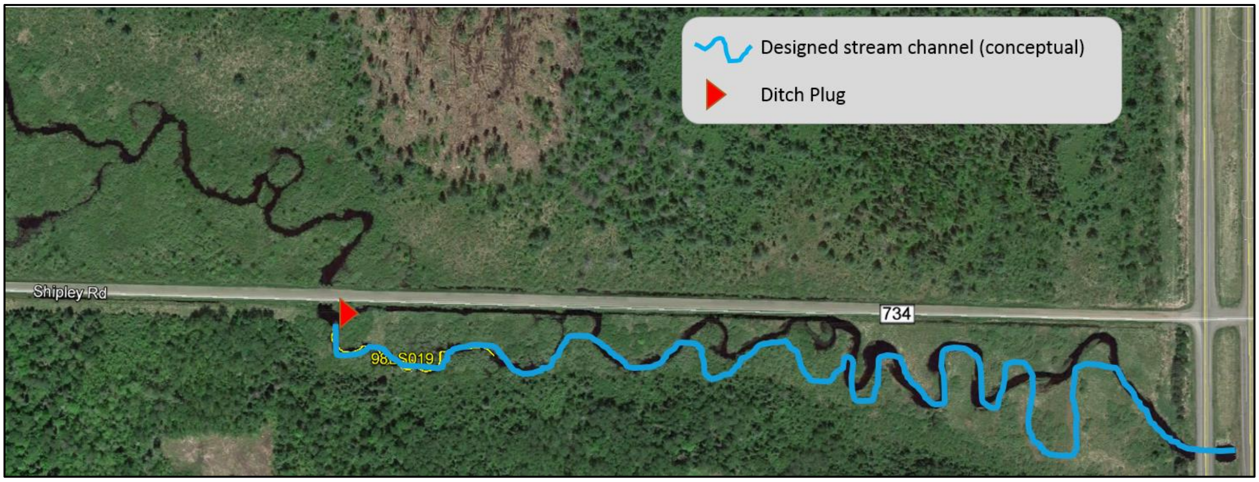
7.2.1 Restoration projects to improve physical habitat

Project 1: Shipley Road ditch plug and floodplain grading

Approximately 50% of the discharge of Hellwig Creek is diverted into a road ditch along Shipley Road for approximately 1,400 feet. This diversion has reduced stream power for maintaining deep pools and other channel facets in the natural stream channel. Substrate conditions appear to be trending towards fines (sand/silt), as a significant portion of the discharge is diverted down the channelized portion of the creek during higher flow events, which are critical for maintaining channel facets and a balance in sediment transport/deposition.

A project combining ditch plugging and minor stream channel restoration could return 100% of the streamflow back to the natural channel (Figure 32). A large portion of the existing channel would be utilized in this restoration approach. A new channel would need to be excavated in areas where ditching occurs, or the meander pattern infringes on the grade of Shipley Road. The dimensions, pattern, and profile of the new excavated channel would be derived from a stable reference reach upstream of the project site. Natural materials, such as rootwads and large wood would be used to stabilize several of the outside bends to prevent channel migration towards Shipley Road. This area routinely floods during spring snowmelt periods or after large rain events. A restoration project designed to store more water in the floodplain (off-channel wetlands, ponds) and pull the stream away from the road could alleviate infrastructure loss or public safety concerns related to frequent flooding, while also improve physical habitat conditions within the impaired reach.

Figure 32. Conceptual design for channel restoration, re-alignment, and road ditch plugging at station HC 3.2.



7.2.2 Restoration projects to improve connectivity/Fish passage

Two fish migration barriers (undersized road culverts) in the Hellwig Creek Watershed were identified as high priorities for removal. Only one of the identified barriers is located on the main stem of Hellwig Creek, with the remaining barrier located on cold tributary stream that supports a high quality native Brook Trout population. Table 14 in Section 6.3.4 contains the general information and coordinates of these crossings.

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Appendix A – Brook Trout Suitability Assessment

Example Data Form

Brook Trout Suitability Matrix

#	Category	Variable	0 points		1 points	2 points	3 points	Multiplier	Score
1	Floodplain Connectivity	Bank Height Ratio	3.0		2.0	1.5	1.0	2.00	
2	Water Temperature	Average number of days above 21 degrees water temperature on an annual basis	28		14	7	1	8.00	
3	Gravel Substrate	Substrate within the Spawning range for BKT (3-80 mm; Duff 1980)	5%		10%	25%	50%	2.00	
4	Fine Substrates and Embeddedness	% of riffle and glide area comprised of fine particles < 3mm	75%		50%	25%	5%	2.50	
5	Algae on the Gravel Substrates	% Large Gravels and Cobbles covered with Algae	50%		25%	10%	5%	1.00	
6	Aquatic Vegetation	% of Riffle with Aquatic Vegetation	25%		10%	5%	1%	1.00	
7	Bank Erosion	lbs of Bank Erosion per linear foot	0.90		0.09	0.04	0.009	2.00	
8	Bank Habitat	Percent of Pools with Stable Undercut Banks, Boulders, or LWD	5%		25%	50%	75%	1.00	
9	Longitudinal Connectivity	% of Channel with fish migration barriers at Low-Flow to Bankfull Flow	10%		1%	0.1%	0.01%	1.00	
10	Deep Pools	Max Depth Water in Pools at Low-Flow (ft)	0.5		1.0	2.0	3.0	4.00	
11	Morphological Energy Dissipation	Pool - Pool Spacing Ratio Relative to Reference Reach	3.0		2.0	1.5	1.0	1.00	
12	Riffle Complexity	Number of Habitat units within Riffle	1		2	3	4	1.00	
13	Riffle Length	Riffle Length Ratio Relative to Reference Reach	3.0		2.0	1.5	1.0	1.00	
14	Beaver Dams	Average # of Beaver Dams per 100 ft	0.5%		0.1%	0.05%	0.01%	1.00	
15	Offline Beaver Dams	% of Beaver Dams in the Reach that are off-line	10%	0	25%	75%	100%	1.00	
16	Side Channel Habitat	Average # of Side Channel Habitats within a Reference Meander Wavelength	0.01		0.1	0.25	1.0	1.00	
17	Channel Width to Depth Ratio	WDR Ratio Relative to Reference Reach	3.0		2.0	1.5	1.0	1.00	
18	Low Flow Width to Depth Ratio	WDR Ratio Relative to Reference Reach Inner Berm Channel	3.0		2.0	1.5	1.0	1.00	
19	Hyporheic Exchange	% Riffle that has Upwelling, Loose Gravels or noticeable groundwater exchange	1%		10%	25%	50%	1.00	
20	Riparian Vegetation	% Riparian Vegetative Cover	10%		25%	50%	75%	1.00	
21	Vegetative Shade	% of Channel with Vegetative Shade and cover	10%		25%	50%	75%	1.00	
22	Flow rates at Low-Flow	Stream Types, Ephemeral, Intermittent or Perennial	Ephemeral		Intermittent	Perennial Impaired	Perennial	5.00	
23	Large Woody Cover	Average # LWD habitat features within a reference meander wavelength	<1, or excessive (log jams / flow deflectors / sediment traps)		1	2	more than 3	2.50	
24	Fine Woody Debris	Relative abundance of fine woody debris (brush, branches, tree tops, fine roots, in-stream vegetative cover)	absent or very scarce		spotty	moderate	very common	1.50	
25	Riffle-Pool Ratio	Ratio of riffle to pool habitat available	complete lack of defined riffles or pools		2:1 ratio	1.5 to 1 ratio	1:1 riffle/pool ratio	1.00	
26	EPT Taxa	Optional: % Dominant in Common EPT Species with Reference	20%		40%	60%	100%	1.00	
27	Presence of Brook Trout	Optional: only score if BKT fish sampling data is availablefor the reach	None		Low Population	Average Population	High Population	1.50	
28	Presence of Predator Species	Optional: only score if fish sampling data is available for the reach	High Population		Average Population	Low Population	None	1.50	
								Total	**0**

Stream:			
Reach:		**Stream Type:**	
Observers:		**Valley Type:**	
Date:			

Appendix A – Brook Trout Suitability Assessment

Beartrap Creek (Main Stem) – Brook Trout Suitability Assessment (BTSA) Results

		BPS**	BCR 1	BCR 2	BCR 3	BCR 4	BCR 5	BCR 6	BCR 7	BCR 8	BCR 9	BCR 10	BCR 11	BCR 12	BCR 13	BCR 14	BCR 15	BCR 16	BCR 17	BCR 18	BCR 19	BCR 20	BCR 21	BCR 22
	Total Score	136.5	103.5	104.5	61	88	101	65.5	90	101.5	78.5	95.5	98	109.5	107	57.5	99	75	69	58.5	89.5	78.5	72.5	59.5
1	Floodplain Connectivity	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	4	6	6	6	6
2	Water Temperature	24	16	16	16	16	16	16	16	16	16	16	16	16	8	8	8	8	12	16	16	16	16	8
3	Gravel Substrate	6	4	5	0	2	5	0	4	4	0	4	2	4	6	2	4	2	0	0	2	0	0	0
4	Fine Substrates and Embeddedness	7.5	2.5	2.5	2.5	2.5	2.5	0	2.5	5	0	2.5	2.5	5	7.5	2.5	5	0	0	0	2.5	0	0	0
5	Algae on the Gravel Substrates	3	3	3	3	3	3	3	3	3	3	2	3	3	3	2	3	3	2	2	2	3	3	3
6	Aquatic Vegetation	3	2	2	1	1	3	3	3	3	3	3	3	3	3	3	3	3	2	2	2	2	2	2
7	Bank Erosion	6	6	6	4	4	4	4	4	6	6	6	4	6	6	2	4	2	2	2	4	4	4	4
8	Bank Habitat	3	2	2	1	2	3	0	2	3	3	1	3	3	2	0	2	2	2	1	2	2	1	1
9	Longitudinal Connectivity	3	3	3	1	3	3	2	3	3	3	3	3	3	3	2	2	0	0	3	2	1	1	1
10	Deep Pools	12	12	12	4	12	12	8	8	12	12	12	12	12	8	4	8	8	12	4	12	8	4	4
11	Morphological Energy Dissipation	3	2	2	0	2	2	1	2	3	0	1	2	3	3	1	3	1	2	0	2	2	1	0
12	Riffle Complexity	3	1	1	0	1	2	0	2	2	0	2	1	2	2	1	2	2	2	0	1	1	1	0
13	Riffle Length	3	2	2	0	1	1	0	2	3	0	1	3	3	3	2	3	1	1	0	2	2	2	0
14	Beaver Dams	3	3	3	0	1	3	1	3	3	0	1	3	3	3	3	3	2	2	2	1	1	1	3
15	Offline Beaver Dams	3	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
16	Side Channel Habitat	3	2	2	1	1	3	2	1	1	3	2	3	2	2	0	3	3	3	0	2	2	2	0
17	Channel Width to Depth Ratio	3	3	3	1	2	2	0	2	2	2	1	2	3	3	1	2	2	2	2	2	2	2	2
18	Low Flow Width to Depth Ratio	3	3	3	1	2	2	0	2	2	2	1	2	3	3	1	3	2	2	2	2	2	2	2
19	Hyporheic Exchange	3	2	2	1	2	2	1	2	2	0	2	2	2	3	1	1	1	0	0	1	1	1	1
20	Riparian Vegetation	3	3	3	1	2	2	2	3	3	3	2	2	3	3	0	2	2	2	1	2	2	2	2
21	Vegetative Shade	3	2	2	1	1	2	1	1	1	1	1	1	1	3	0	2	1	0	0	0	0	0	0
22	Flow rates at Low-Flow	15	15	15	10	15	15	10	15	15	10	15	15	15	15	15	15	15	10	15	15	15	15	15
23	Large Woody Cover	7.5	5	5	2.5	2.5	2.5	2.5	0	0	2.5	5	2.5	2.5	5	0	7.5	5	2.5	0	5	2.5	2.5	0
24	Fine Woody Debris	4.5	3	3	3	3	3	3	1.5	1.5	3	3	3	3	4.5	0	4.5	3	1.5	1.5	3	3	3	4.5
25	Riffle-Pool Ratio	3	1	1	1	1	2	0	2	2	0	1	2	3	2	1	3	1	1	1	1	1	1	1
	Total Score	136.5	103.5	104.5	61	88	101	65.5	90	101.5	78.5	95.5	98	109.5	107	57.5	99	75	69	58.5	89.5	78.5	72.5	59.5

*BPS = Best Possible Score

Appendix A – Brook Trout Suitability Assessment

Beartrap Creek Tributaries – Brook Trout Suitability Assessment (BTSA) Results

		BT1 1	BT1 2	BT1 3	BT1 4	BT1 5	BT1 6	BT1 7	BT1 8	BT1 9	BT1 10	BT1 11	BT2 1	BT2 2	BT2 3	BT3 1
	Total Score	105	108.5	109.5	106.5	106.5	96.5	96.5	72	72	59	57	103	104	101	58.5
1	Floodplain Connectivity	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
2	Water Temperature	24	24	24	24	24	24	24	16	16	16	16	24	24	24	8
3	Gravel Substrate	4	6	6	6	6	2	2	2	2	0	0	2	2	2	0
4	Fine Substrates and Embeddedness	2.5	5	5	5	5	5	5	5	5	2.5	2.5	2.5	2.5	2.5	2.5
5	Algae on the Gravel Substrates	3	3	3	3	3	3	3	3	3	3	3	3	3	3	1
6	Aquatic Vegetation	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2
7	Bank Erosion	4	6	6	6	6	6	6	6	6	6	6	6	6	6	6
8	Bank Habitat	2	1	1	0	0	0	0	0	0	0	0	1	1	1	1
9	Longitudinal Connectivity	3	1	1	1	1	1	1	0	0	0	0	2	3	0	2
10	Deep Pools	4	0	0	0	0	0	0	0	0	0	0	0	0	0	4
11	Morphological Energy Dissipation	3	2	3	3	3	3	3	0	0	0	0	3	3	3	2
12	Riffle Complexity	1	1	1	0	0	0	0	0	0	0	0	1	1	1	0
13	Riffle Length	3	3	3	3	3	3	3	3	3	0	0	3	3	3	2
14	Beaver Dams	3	3	3	3	3	3	3	3	3	3	1	3	3	3	1
15	Offline Beaver Dams	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	Side Channel Habitat	2	2	2	1	1	1	1	1	1	0	0	1	1	1	1
17	Channel Width to Depth Ratio	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2
18	Low Flow Width to Depth Ratio	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2
19	Hyporheic Exchange	3	3	3	3	3	3	3	1	1	0	0	3	3	3	0
20	Riparian Vegetation	3	3	3	3	3	3	3	2	2	2	2	3	3	3	2
21	Vegetative Shade	2	3	3	3	3	3	3	2	2	0	0	3	3	3	0
22	Flow rates at Low-Flow	15	15	15	15	15	15	15	10	10	10	10	15	15	15	10
23	Large Woody Cover	2.5	5	5	5	5	2.5	2.5	0	0	0	0	5	5	5	0
24	Fine Woody Debris	3	4.5	4.5	4.5	4.5	3	3	3	3	1.5	1.5	4.5	4.5	4.5	3
25	Riffle-Pool Ratio	3	3	3	3	3	1	1	0	0	0	0	3	3	3	1
	Total Score	105	108.5	109.5	106.5	106.5	96.5	96.5	72	72	59	57	103	104	101	58.5

*BPS = Best Possible Score

Appendix B – Pfankuch Stability Index

Example data form

Stream: Beartrap Creek			Location:		Valley Type:				Observers:	Date:
Location	**Key**	**Category**	**Excellent** Description	Rating	**Good** Description	Rating	**Fair** Description	Rating	**Poor** Description	Rating
Upper banks	1	Landform slope	Bank slope gradient <30%.	2	Bank slope gradient 30–40%.	4	Bank slope gradient 40–60%.	6	Bank slope gradient > 60%.	8
Upper banks	2	Mass erosion	No evidence of past or future mass erosion.	3	Infrequent. Mostly healed over. Low future potential.	6	Frequent or large, causing sediment nearly yearlong.	9	Frequent or large, causing sediment nearly yearlong OR imminent danger of same.	12
Upper banks	3	Debris jam potential	Essentially absent from immediate channel area.	2	Present, but mostly small twigs and limbs.	4	Moderate to heavy amounts, mostly larger sizes.	6	Moderate to heavy amounts, predominantly larger sizes.	8
Upper banks	4	Vegetative bank protection	> 90% plant density. Vigor and variety suggest a deep, dense, soil-binding root mass.	3	70–90% density. Fewer species or less vigor suggest less dense or deep root mass.	6	50–70% density. Lower vigor and fewer species from a shallow, discontinuous root mass.	9	<50% density plus fewer species and less vigor indicating poor, discontinuous, and shallow root mass.	12
Lower banks	5	Channel capacity	Bank heights sufficient to contain the bankfull stage. Width/depth ratio departure from reference width/depth ratio = 1.0. Bank-Height Ratio (BHR) = 1.0.	1	Bankfull stage is contained within banks. Width/depth ratio departure from reference width/depth ratio = 1.0–1.2. Bank-Height Ratio (BHR) = 1.0–1.1.	2	Bankfull stage is not contained. Width/depth ratio departure from reference width/depth ratio = 1.2–1.4. Bank-Height Ratio (BHR) = 1.1–1.3.	3	Bankfull stage is not contained; over-bank flows are common with flows less than bankfull. Width/depth ratio departure from reference width/depth ratio > 1.4. Bank-Height Ratio (BHR) > 1.3.	4
Lower banks	6	Bank rock content	> 65% with large angular boulders. 12"+ common.	2	40–65%. Mostly boulders and small cobbles 6–12".	4	20–40%. Most in the 3–6" diameter class.	6	<20% rock fragments of gravel sizes, 1–3" or less.	8
Lower banks	7	Obstructions to flow	Rocks and logs firmly imbedded. Flow pattern w/o cutting or deposition. Stable bed.	2	Some present causing erosive cross currents and minor pool filling. Obstructions fewer and less firm.	4	Moderately frequent, unstable obstructions move with high flows causing bank cutting and pool filling.	6	Frequent obstructions and deflectors cause bank erosion yearlong. Sediment traps full, channel migration occurring.	8
Lower banks	8	Cutting	Little or none. Infrequent raw banks <6".	4	Some, intermittently at outcurves and constrictions. Raw banks may be up to 12".	6	Significant. Cuts 12–24" high. Root mat overhangs and sloughing evident.	12	Almost continuous cuts, some over 24" high. Failure of overhangs frequent.	16
Lower banks	9	Deposition	Little or no enlargement of channel or point bars.	4	Some new bar increase, mostly from coarse gravel.	8	Moderate depostion of new gravel and coarse sand on old and some new bars.	12	Extensive deposit of predominantly fine particles. Accelerated bar development.	16
Bottom	10	Rock angularity	Sharp edges and corners. Plane surfaces rough.	1	Rounded corners and edges. Surfaces smooth and flat.	2	Corners and edges well-rounded in two dimensions.	3	Well-rounded in all dimensions, surfaces smooth.	4
Bottom	11	Brightness	Surfaces dull, dark, or stained. Generally not bright.	1	Mostly dull, but may have <35% bright surfaces.	2	Mixture dull and bright, i.e., 35–65% mixture range.	3	Predominantly bright, > 65%, exposed or scoured surfaces.	4
Bottom	12	Consolidation of particles	Assorted sizes tightly packed or overlapping.	2	Moderately packed with some overlapping.	4	Mostly loose assortment with no apparent overlap.	6	No packing evident. Loose assortment, easily moved.	8
Bottom	13	Bottom size distribution	No size change evident. Stable material 80–100%.	4	Distribution shift light. Stable material 50–80%.	8	Moderate change in sizes. Stable materials 20–50%.	12	Marked distribution change. Stable materials 0–20%.	16
Bottom	14	Scouring and deposition	<5% of bottom affected by scour or deposition.	6	5–30% affected. Scour at constrictions and where grades steepen. Some deposition in pools.	12	30–50% affected. Deposits and scour at obstructions, constrictions, and bends. Some filling of pools.	18	More than 50% of the bottom in a state of flux or change nearly yearlong.	24
Bottom	15	Aquatic vegetation	Abundant growth moss-like, dark green perennial. In swift water too.	1	Common. Algae forms in low velocity and pool areas. Moss here too.	2	Present but spotty, mostly in backwater. Seasonal algae growth makes rocks slick.	3	Perennial types scarce or absent. Yellow-green, short-term bloom may be present.	4
			Excellent Total =	**38**	**Good Total =**	**74**	**Fair Total =**	**114**	**Poor Total =**	**152**

Stream type	**A1**	**A2**	**A3**	**A4**	**A5**	**A6**	**B1**	**B2**	**B3**	**B4**	**B5**	**B6**	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**D3**	**D4**	**D5**	**D6**
Good (Stable)	38-43	38-43	54-90	60-95	60-95	50-80	38-45	38-45	40-60	40-64	48-68	40-60	38-50	38-50	60-85	70-90	70-90	60-85	85-107	85-107	85-107	67-98
Fair (Mod. unstable)	44-47	44-47	91-129	96-132	96-142	81-110	46-58	46-58	61-78	65-84	69-88	61-78	51-61	51-61	86-105	91-110	91-110	86-105	108-132	108-132	108-132	99-125
Poor (Unstable)	48+	48+	130+	133+	143+	111+	59+	59+	79+	85+	89+	79+	62+	62+	106+	111+	111+	106+	133+	133+	133+	126+
Stream type	**DA3**	**DA4**	**DA5**	**DA6**	**E3**	**E4**	**E5**	**E6**	**F1**	**F2**	**F3**	**F4**	**F5**	**F6**	**G1**	**G2**	**G3**	**G4**	**G5**	**G6**		
Good (Stable)	40-63	40-63	40-63	40-63	40-63	50-75	50-75	40-63	60-85	60-85	85-110	85-110	90-115	80-95	40-60	40-60	85-107	85-107	90-112	85-107		
Fair (Mod. unstable)	64-86	64-86	64-86	64-86	64-86	76-96	76-96	64-86	86-105	86-105	111-125	111-125	116-130	96-110	61-78	61-78	108-120	108-120	113-125	108-120		
Poor (Unstable)	87+	87+	87+	87+	87+	97+	97+	87+	106+	106+	126+	126+	131+	111+	79+	79+	121+	121+	126+	121+		

Grand Total =	
Existing Stream Type =	
***Potential Stream Type =**	
Modified channel stability rating =	

***Rating is adjusted to *potential* stream type, not existing stream type**

Appendix B – Pfankuch Stability Index

Hellwig Creek PSI Results

			HC 0.1	HC 0.4 (B3)	HC 0.4 (C4)	HC 3.2 (D)	HC 3.2 (NC)	HC 8.7	HT6 0.3
Upper banks	1	Landform slope	4	4	4	6	2	2	2
	2	Mass erosion	3	3	6	6	3	3	3
	3	Debris jam potential	2	2	4	4	4	4	4
	4	Vegetative bank protection	3	3	6	9	3	6	3
		Upper Banks Total	***12***	***12***	***20***	***25***	***12***	***15***	***12***
Lower banks	5	Channel capacity	1	1	2	4	2	2	1
	6	Bank rock content	2	2	6	8	8	8	8
	7	Obstructions to flow	2	2	2	4	2	4	4
	8	Cutting	4	4	6	6	4	4	4
	9	Deposition	4	4	8	8	4	4	4
		Lower Banks Total	***13***	***13***	***24***	***30***	***20***	***22***	***21***
Bottom	10	Rock angularity	1	1	3	2	2	1	2
	11	Brightness	1	1	2	2	2	1	2
	12	Consolidation of particles	2	2	4	8	6	4	2
	13	Bottom size distribution	4	4	8	8	8	4	8
	14	Scouring and deposition	6	6	12	24	18	18	6
	15	Aquatic vegetation	1	1	2	3	2	3	1
		Bottom Total	***15***	***15***	***31***	***47***	***38***	***31***	***21***
		Grand Total	**40**	**40**	**75**	**102**	**70**	**68**	**54**
		Modified Rating	Stable	Stable	Stable	Unstable	Stable	Mod. Unstable	Stable
		Existing Stream Type	B3c	C3b	C4	Ditch	E5	Ditch	E4/5
		Potential Stream Type	B3c	B3	C4	E5	E4/E5	E6	E4/5

Appendix C –DNR Stream Crossing Basic Assessment Form

Stream Survey

Stream Crossing Basic Assessment Form

All units are to be entered in feet. * = Mandatory field to complete

Location: Observer*:____________________Date*:___/___/____County:________T__R__S___

Stream name*:_________________ Stream mile:____UTM:* N_______________E_______________

Alt. name:_________________ Stream Kittle or AUID (circle which)*:_____________________

DNR Major watershed/HUC 8*(circle which):___________ Road/Path/Railway name*:__________

Elevation method*: ☐ Monument ☐ RTK ☐ Benchmark/LiDAR ☐ Handheld GPS Accuracy:__________

HI:________Notes:____

Crossing: Benchmark location:_______________________

Crossing type*: ☐ Span Bridge Total span* (sum of culverts):______

☐ Culvert(s) Num. (if multiple):____ Offset*?: ☐ Y ☐ N Outlet drop*:___

☐ Ford Crossing properly aligned*? ☐ Y ☐ N

Other:___________________ Year built:________

Openings* (left to right, facing downstream)

	Opening 1		Opening 2		Opening 3		Opening 4	
Type*	☐ Thalweg ☐Offset ☐Floodplain		☐ Thalweg ☐Offset ☐Floodplain		☐ Thalweg ☐Offset ☐Floodplain		☐ Thalweg ☐Offset ☐Floodplain	
Shape*	☐ Circular ☐ Box ☐ Pipe Arch ☐ Ellipse ☐ Open bottom arch		☐ Circular ☐ Box ☐ Pipe Arch ☐ Ellipse ☐ Open bottom arch		☐ Circular ☐ Box ☐ Pipe Arch ☐ Ellipse ☐ Open bottom arch		☐ Circular ☐ Box ☐ Pipe Arch ☐ Ellipse ☐ Open bottom arch	
Material*	☐ CMP ☐ SMP ☐ Concrete ☐ Wood ☐ Plastic		☐ CMP ☐ SMP ☐ Concrete ☐ Wood ☐ Plastic		☐ CMP ☐ SMP ☐ Concrete ☐ Wood ☐ Plastic		☐ CMP ☐ SMP ☐ Concrete ☐ Wood ☐ Plastic	
Length*								
Width *								
Height*								
Inlet invert	FS	El.	FS	El.	FS	El.	FS	El.
Outlet invert	FS	El.	FS	El.	FS	El.	FS	El.
Benchmark el.	FS	El.	FS	El.	FS	El.	FS	El.
Water depth								
Substrate present?*	☐ Y ☐ N		☐ Y ☐ N		☐ Y ☐ N		☐ Y ☐ N	
% plugged*								

Stream:

Bankfull width*:_____________ Bankfull estimate confidence*: ☐ High ☐ Medium ☐ Low

Scour Pool*: ☐ Y ☐ N Upstream pool*: ☐ Y ☐ N Upstream bars/deposition*: ☐ Y ☐ N

Bank erosion caused by crossing*: ☐ Y ☐ N

Summary:

Barrier to fish passage at some flows*? ☐ Y ☐ N Stream stability impact*: ☐ Y ☐ N Priority: ☐ High ☐ Med. ☐ Low

Limiting factor for passage*: ☐ Outlet drop ☐ Velocity ☐ Depth ☐ Substrate

Recommended corrective actions*: ____

Photos: Crossing, upstream and downstream views; Stream, upstream and downstream views from crossing

Appendix C –DNR Stream Crossing Basic Assessment Form

Stream Survey

Stream Crossing Initial Survey Instructions

Location:

UTM: Location should be taken as a single point at the upstream side of the crossing.

DNR Major Watershed/ HUC 8: Circle watershed class used; enter DNR major watershed as two digit number.

Road/path/railway name: Use the Federal/State/County name if applicable, rather than local names

Elevation method: If collected, invert elevations should be tied to real world elevations. If a monument is not available at the bridge and you do not have access to survey-grade GPS equipment, a laser level can be used to take invert elevations relative to a benchmark, preferably the crown of the road above the crossing, so that the elevation can later be determined in the office using LiDAR in ArcGIS. The approx. accuracy of this method is +/-0.6 feet.

Benchmark location: Describe detailed location where benchmark was measured.

Crossing:

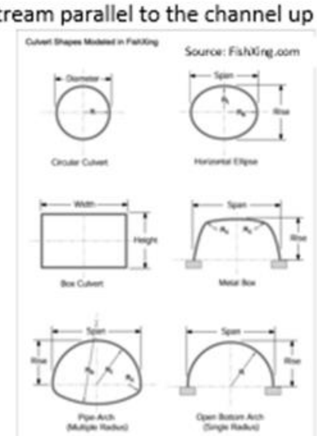
Offset culverts: If multiple culverts are present, are there baseflow and high flow culverts set at different elevations?

Total span: For crossings with multiple culverts, add the width of each culvert. Do not include the width of walls between culverts. For clear-span bridges, measure the total length of the bridge from abutment to abutment.

Outlet drop: If applicable, measure the drop in water surface elevation from the outlet of the culvert to the water surface of the scour pool.

Crossing alignment: Does the crossing allow the stream to progress downstream parallel to the channel up and down stream?

Openings: Record data on multiple culverts, starting with the furthest left culvert as you face downstream. Check box for thalweg culvert, offset channel culvert, or floodplain culvert type. Invert is measured by excavating down to below embedded substrate to the culvert, if present. If crossing is a bottomless structure, measure the highest thalweg elevation on the upstream and downstream side of the bridge. Substrate must be present throughout the culvert in order to check "yes" to that category. % plugged includes debris jams, substrate filling, or crushing.



Stream:

Bankfull width: Bankfull width should be measured at a riffle, away from the influence of the crossing. "High" confidence widths must be measured on streams with obvious bankfull features, and validated either by gage information or regional curves. "Medium" bankfull widths do not have strong agreement, but good bankfull features are present. "Low" confidence widths are based on regional curves and lack obvious instream features.

Summary:

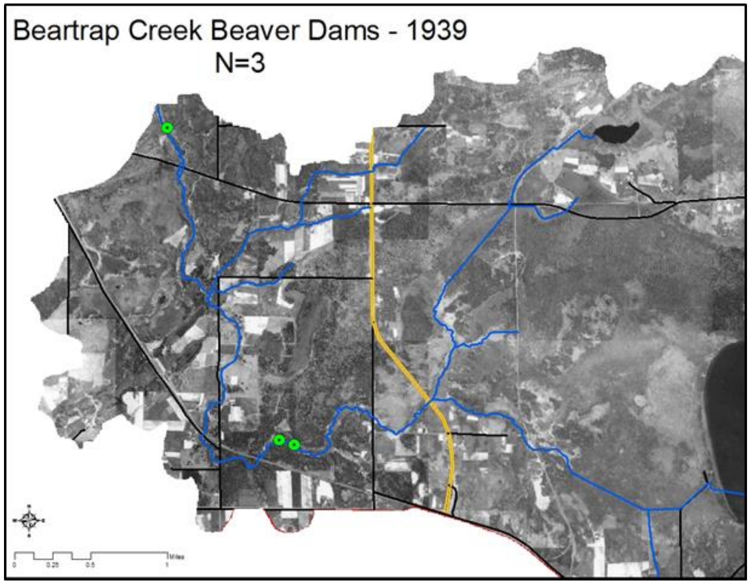
Barrier to fish passage: Does the crossing inhibit upstream fish passage at high or low flow?

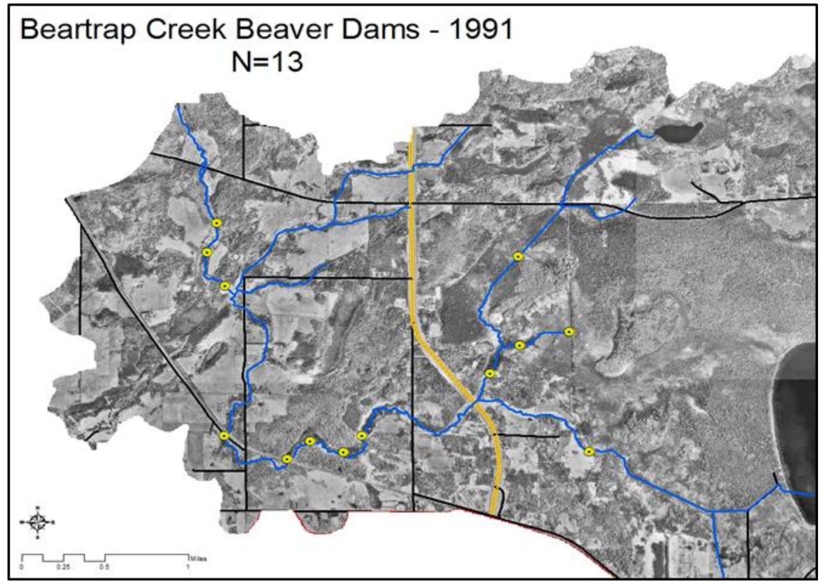
Priority: Priority ratings are based on the degree of impact, the relative impact to other crossings in the watershed, and the priority of stream based on potential aquatic resources.

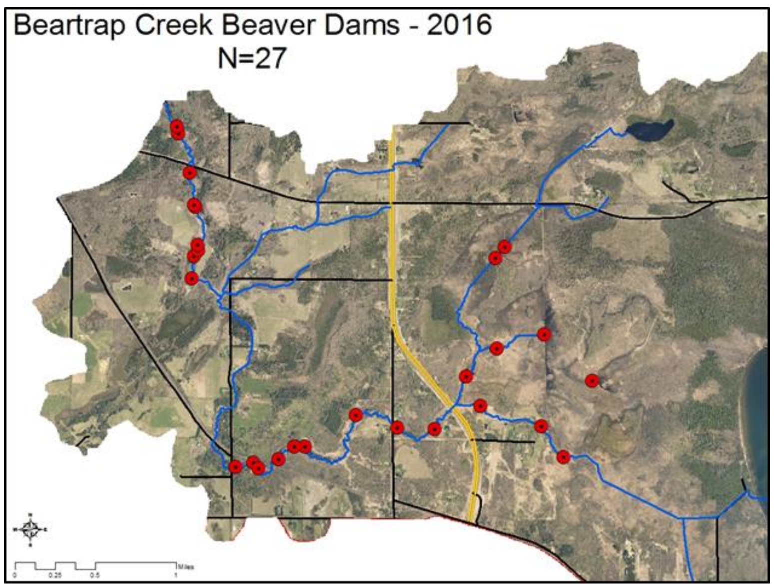
Appendix D – Beartrap Creek Water Temperature Summary

2017							
SID Station	**Growth**	**Stress**	**Lethal**	**No Growth**	**Summer Avg**	**July Avg**	**Summer Max**
BC 4.7	80.7%	19.3%	0.0%	0.0%	18.2	19.5	24.4
BC 3.0	67.6%	30.1%	2.3%	0.0%	18.8	20.3	26.9
BC 2.5	68.3%	30.8%	0.9%	0.0%	18.8	20.2	26.3
BC 1.9	72.0%	27.8%	0.2%	0.0%	18.5	19.9	25.3
BT2 0.1	99.3%	0.0%	0.0%	0.7%	11.7	12.1	17.1
BT1 0.1	100.0%	0.0%	0.0%	0.0%	14.4	15.6	18.7
BC 1.6	83.4%	16.6%	0.1%	0.0%	17.5	18.9	25.4
BC 0.1	87.7%	11.0%	0.0%	0.0%	17.4	18.9	24.2
2015							
SID Station	**Growth**	**Stress**	**Lethal**	**No Growth**	**Summer Avg**	**July Avg**	**Summer Max**
BC 0.6	81.8%	18.2%	0.0%	0.0%	17.7	19.3	
2003							
SID Station	**Growth**	**Stress**	**Lethal**	**No Growth**	**Summer Avg**	**July Avg**	**Summer Max**
BC 0.6	86.2%	13.8%	0.0%	0.0%	17.2	18.5	23.9
BC 4.6	94.3%	5.7%	0.0%	0.0%	17.0	16.7	21.7
2001							
SID Station	**Growth**	**Stress**	**Lethal**	**No Growth**	**Summer Avg**	**July Avg**	**Summer Max**
BC 0.6	81.1%	18.9%	0.1%	0.0%	17.8	17.8	25.6
BC 4.6	58.9%	39.4%	1.7%	0.0%	19.5	20.5	27.8
2002							
SID Station	**Growth**	**Stress**	**Lethal**	**No Growth**	**Summer Avg**	**July Avg**	**Summer Max**
BC 0.6	74.7%	23.7%	0.2%	0.2%	18.2	20.7	25.6
BC 4.6	64.3%	34.6%	1.1%	0.0%	19.4	21.0	26.7

Appendix E – Beartrap Creek Beaver Dam Densities, Historic vs. Current







Appendix F – Geological setting of Beartrap Creek

Bedrock geology

The entire watershed of Beartrap Creek is underlain by sedimentary and metasedimentary Precambrian rocks of the Animikie Group (Minnesota Geological Survey, 2011). These sediments were deposited in an inland sea between 2.5 and 1.8 billion years ago. Rocks of the Animikie Group extend from the Thompson formation (which outcrops at Jay Cooke State Park) to the economically-significant banded-iron formations in the Mesabi Range. Little, if any, of this formation can be seen from the surface in the Beartrap Creek watershed. The highest elevation in the watershed is around 1477 feet above sea level with the lowest at 1251 feet.

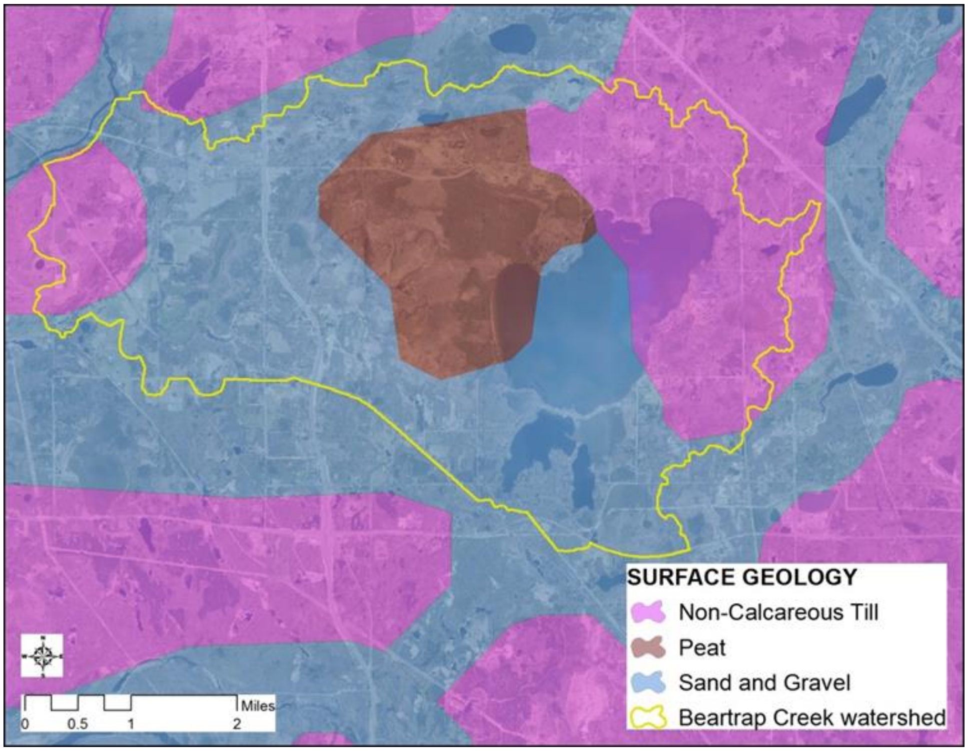
Surficial geology

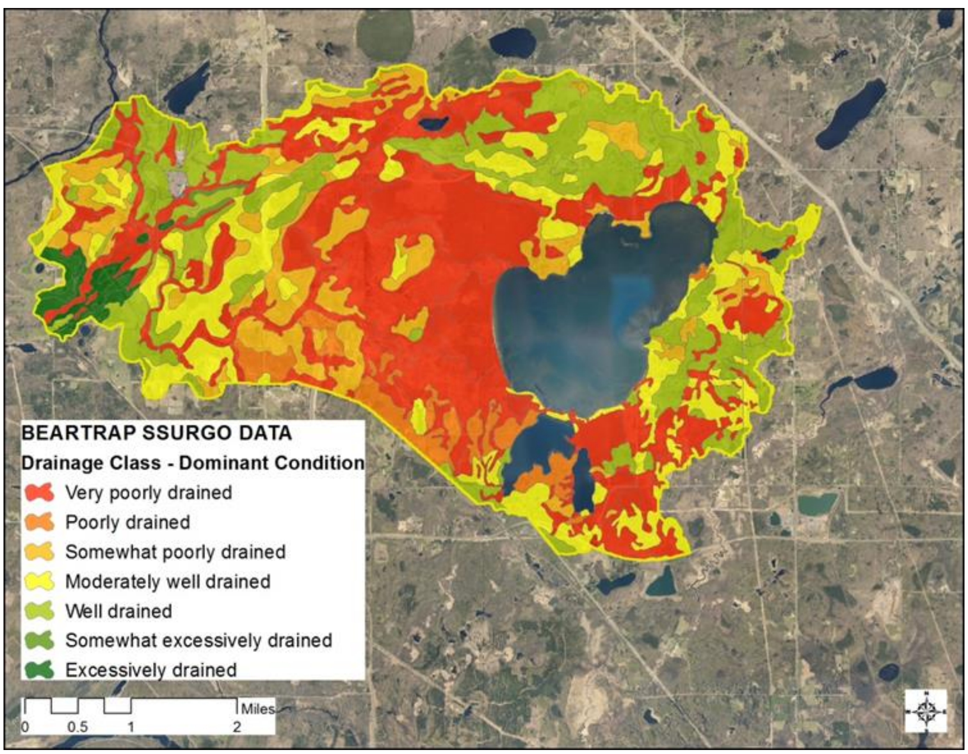
The surface geology is much more recent and is mostly the result of glacial and post-glacial deposition (Minnesota Geological Survey, 1982). This surficial geology, which includes non-calcareous glacial till, glacial outwash (sand and gravel), and biogenic deposits of peat, has a large impact on the hydrologic function of the watershed. Approximately 28% of the watershed is overlain by glacial till in the form of end moraines of the Superior Lobe. These moraines make up the far eastern and western portions of the watershed. The Minnesota Geological Survey texture modifier for these end moraines is "sandy", indicating a high potential for the infiltration capacity of these soils.

The center portion of the watershed – about 4 square miles immediately west-northwest of Grand Lake – is comprised mostly of peat that has been deposited in the Holocene. The remaining area of the watershed (53%) is mostly classified as gravelly glacial outwash. Glacial outwash deposits play a key role in stabilizing water temperatures and base flow in many northeast Minnesota streams (SOURCE NEEDED). These deposits were formed from glacial meltwater and are coarse and well sorted relative to the glacial tills from which they eroded. The permeability of areas of glacial outwash and thus the capacity for springs and groundwater discharge can be very high.

Soils

Soil Survey Geographic (SSURGO) data shows the spatial extent of the various soil drainage classes within the watershed. About 1.9% of the watershed is classified as "Excessively drained". These excessively drained soils occur primarily within the end moraine deposits in the far western portion of the watershed. Not surprisingly, this area is in close proximity to a significant spring that was observed by the authors. Reflecting the prevalence of wetlands in the watershed, almost 49% of the watershed is classified as "somewhat poorly drained", "poorly drained", or "very poorly drained".


SURFACE GEOLOGY
Non-Calcareous Till
Peat
Sand and Gravel
Beartrap Creek watershed
Miles
0 0.5 1 2


BEARTRAP SSURGO DATA
Drainage Class - Dominant Condition
Very poorly drained
Poorly drained
Somewhat poorly drained
Moderately well drained
Well drained
Somewhat excessively drained
Excessively drained
Miles
0 0.5 1 2

Appendix G – Geological setting of Hellwig Creek

Bedrock geology

Hellwig Creek's entire drainage area is underlain by the Animikie Group (Minnesota Geological Survey, 2011), which is composed of sedimentary and metasedimentary rocks that date to the Precambrian eon. The sediments that these rocks originated from were deposited in an inland sea between 2.5 and 1.8 billion years ago. The Animikie Group extends from the Thompson formation in Jay Cooke State Park to the banded-iron formations in the Mesabi Range. Very little, if any, of this formation actually outcrops within the Hellwig Creek watershed. The highest elevation in the watershed is around 1493 feet above sea level with the lowest elevation at 1285 feet ASL.

Surficial geology

Similar to other watersheds in the area, the origin of the Hellwig Creek watershed's surface geology is relatively recent. These deposits are mainly due to glacial and post-glacial activity (Minnesota Geological Survey, 1982), and include glacial outwash and till from the late Wisconsinan stage of glaciation as well as areas of peat, which have been deposited since the glaciers retreated. The peat deposits are located mostly in the bogs along the northwestern boundary of the watershed. The vast amount of the upper watershed is comprised of calcareous tills. These soils are part of the Culver Moraine which was deposited by the Des Moines Lobe, the most recent glacial advance in Minnesota (http://www.d.umn.edu/~mille066/Teaching/4100/MaG-Quaternary.pdf). The non-calcareous tills in the southern portion of the watershed were deposited by the Rainy and Superior Lobes, while the soils within the Hellwig Creek valley are mostly sands and gravels deposited by a larger glacial meltwater river that flowed through the same valley.

Soils

Soil Survey Geographic (SSURGO) data shows the spatial extent of the various soil drainage classes within the Hellwig Creek Watershed. Almost 40% of the watershed area is classified as "very poorly drained". Not surprisingly, these soils are primarily in the wetland-dominated headwaters region in the north and northwest parts of the watershed as well as the Hellwig river valley. With the exception of the river valley, the soils in the southern third of the watershed are mostly well-drained. The groundwater infiltration potential is especially high in the hills to the east of the river, where coarser glacial tills of the Culver Moraine are located. As expected, there is a large gravel mine operating here. Additionally, a few small areas of "excessively drained" soil are located to the north of Three Lakes Rd.

Excessively drained soils comprise only about 2% of the watershed. Overall, the watershed is heavily influenced by wetlands and poorly drained soils.

Figure X. Drainage class for Hellwig Creek Watershed soils, from Soil Survey Geographic (SSURGO) data

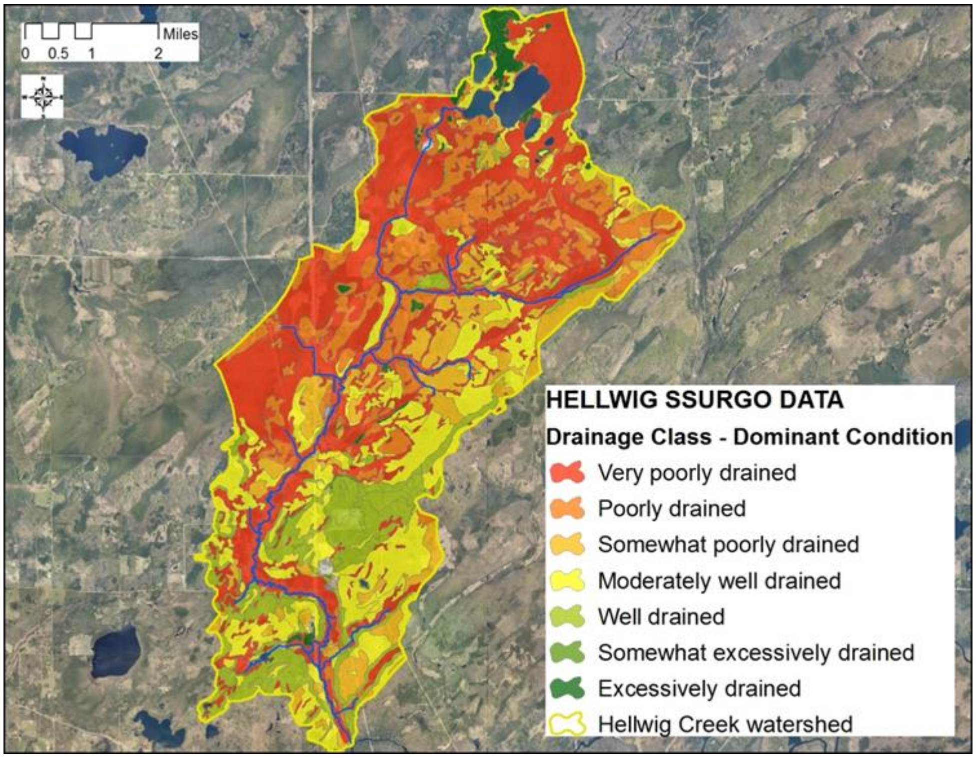


Figure X: The major surficial geologic units in the Hellwig Creek Watershed (MGS, 1982)