Northshore Mine Expansion and Mitigation Stream Inventory Report

Minnesota Pollution Control Agency
North Biological Monitoring Unit

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Introduction

In March and April of 2012, biological monitoring staff from MPCA's Environmental Outcomes Division characterized biological communities, aquatic habitat features, and water chemistry conditions at three streams in northeast Minnesota. The streams were chosen as part of a study to investigate the physical, chemical, and biological characteristics of each stream prior to an expansion at the Northshore/Peter Mitchell Mine near Babbitt, Minnesota. The mine expansion will result in the loss of a headwater stream that will be mitigated by re-meandering a channelized headwater stream north of Chisholm, Minnesota. This report describes the streams and inventory reaches, outlines the stream inventory methods, and summarizes results of the sampling effort.

Methods

Study Area and Site Reconnaissance

Three different streams (Impact, Mitigation and Reference) were characterized in the course of this project. All three sites were located in St. Louis County, within the Mixed Wood Shield Level 2 ecoregion and the Rainy River Basin. The Impact Site was part of the Rainy River Headwaters 8-digit HUC; the Mitigation and Reference Sites were part of the Little Fork River 8-digit HUC (Figure 1, Table 1).

Figure 1. Study Area, depicting study sites, hydrographic and road networks, major watersheds (shading), and cities.

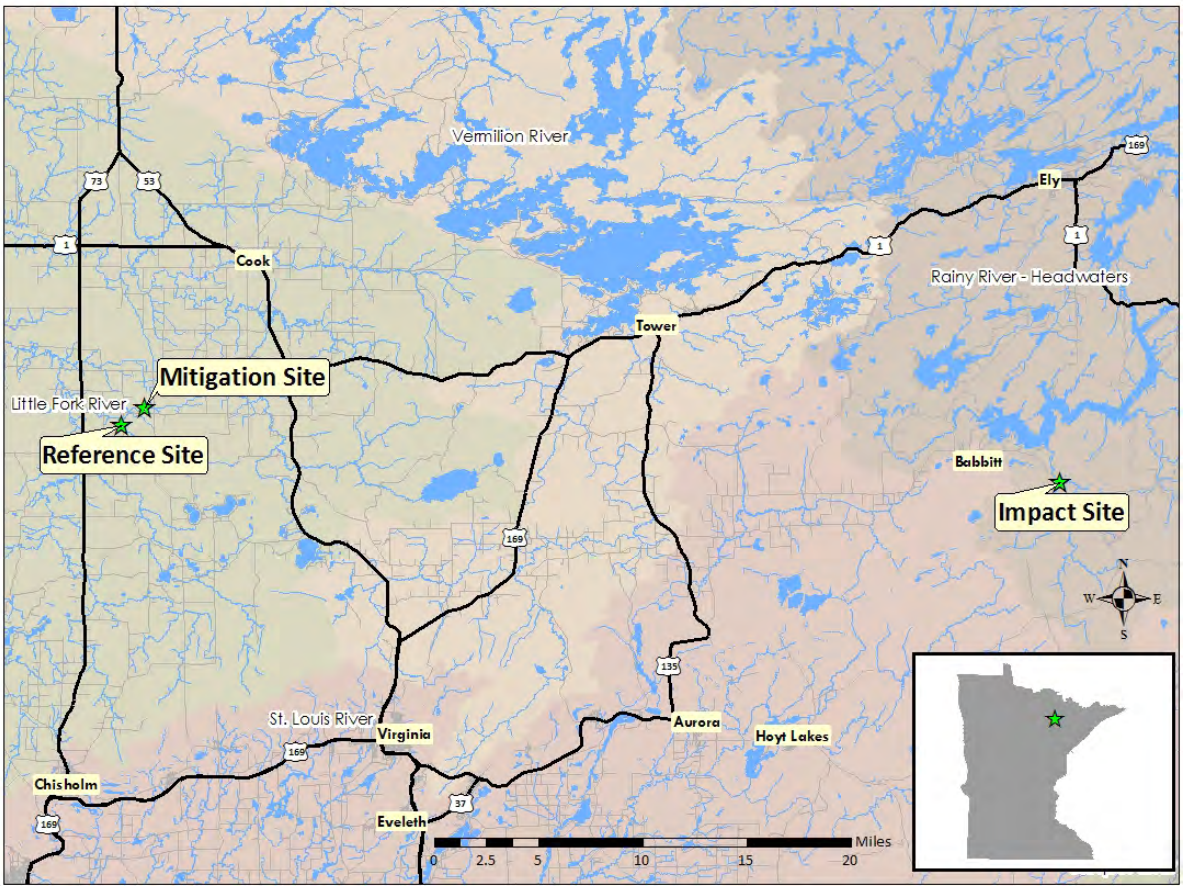


Table 1. Study sites, locations, and stream characteristics.

	Impact Site	Mitigation Site	Reference Site
Stream Name	Tributary to Dunka River	Gilmore Creek	Tributary to Gilmore Creek
Major Watershed	Rainy River Headwaters	Little Fork River	Little Fork River
Latitude (DD)	47.693	47.750	47.738
Longitude (DD)	-91.861	-92.803	-92.826
Township	60N	61N	61N
Range	12W	9W	20W
Section	9,10	20	25
Watershed Area (sq mi)	5.7	5.9	3.0
Stream Gradient (m/km)	11.9	1.5	1.5
Sinuosity	1.29	1.15	1.49

All three sites were visited by MPCA and Northshore Mining Company staff in late March. Inventory and biological monitoring reaches were established in each stream, following MPCA's stream monitoring site reconnaissance procedures (Feist 2011a). One biological monitoring reach was established at both the Impact and Reference Sites; two biomonitoring reaches were established at the Reference Site. The biomonitoring reaches were all 150 meters (m) in length, as stream width was less than 4m in all cases. Photos were taken at several locations on each stream during the initial site reconnaissance (Figure 2, Appendix A).

Figure 2. Photographs of (a) Impact Site, (b) Mitigation Site, (c) Reference Site

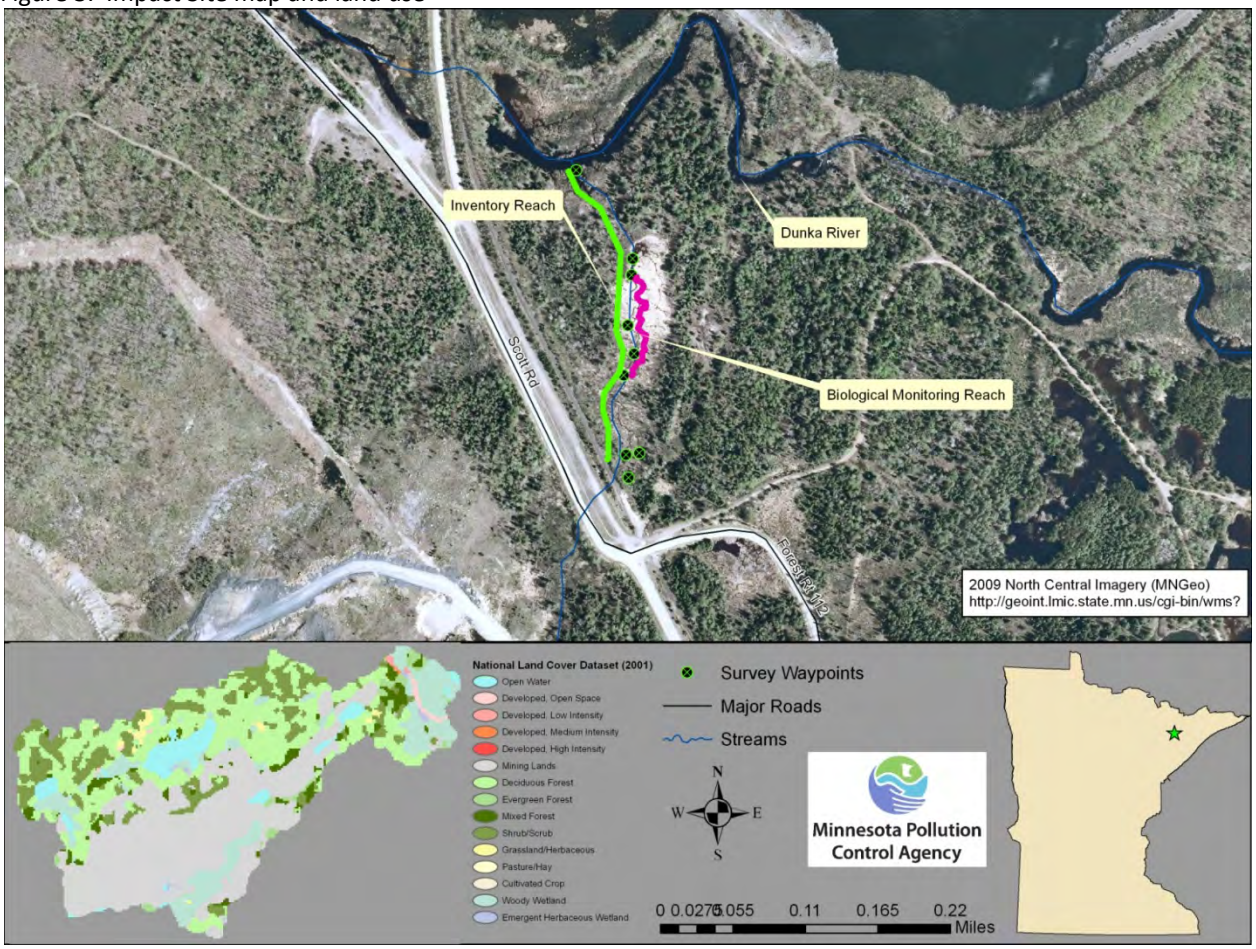
a.

b.

c.

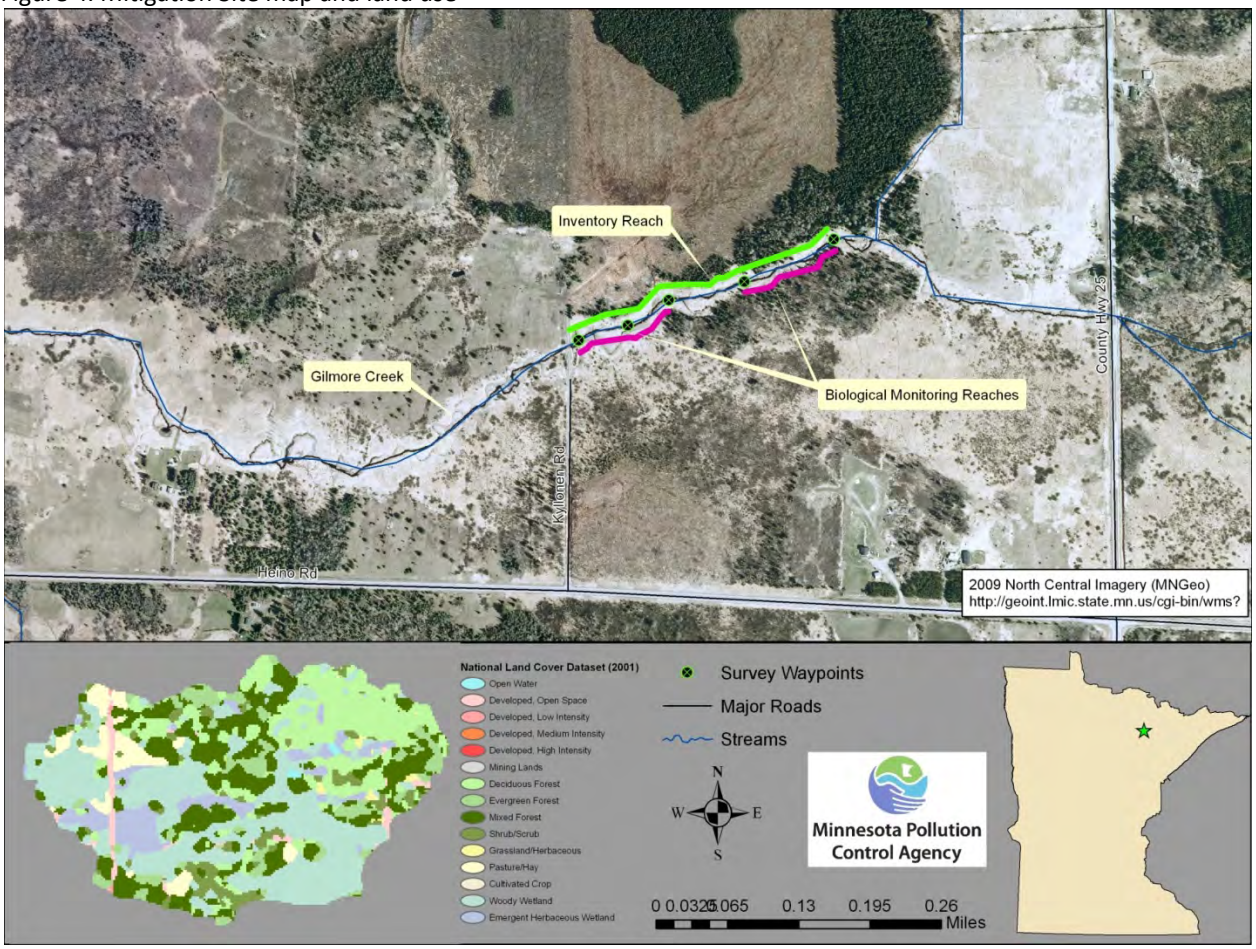
The Impact Site was located approximately four miles east of Babbitt, MN, part of an unnamed 1st-order tributary to the Dunka River. The Dunka River is a tributary to Birch Lake and, in turn, the Kawishiwi and Rainy River systems. The unnamed stream's watershed has been extensively altered through past mining activities, with much of its original drainage now lying within the Northshore/Peter Mitchell Mine. Forest, shrub/scrub, and wetland land cover also made up substantial proportions of the watershed's land use (Appendix B). The inventory reach fell between St. Louis County Road 623 and the Dunka River, measuring approximately 480meters (m) in length (Figure 3). The drainage area of the contributing watershed comprised 5.7 square miles (sq mi), with a reach gradient of approximately 12 meters/kilometer (m/km). An abandoned beaver dam was located near the downstream end of the reach and has, in the past, impounded a portion of this stream.

Figure 3. Impact Site map and land use



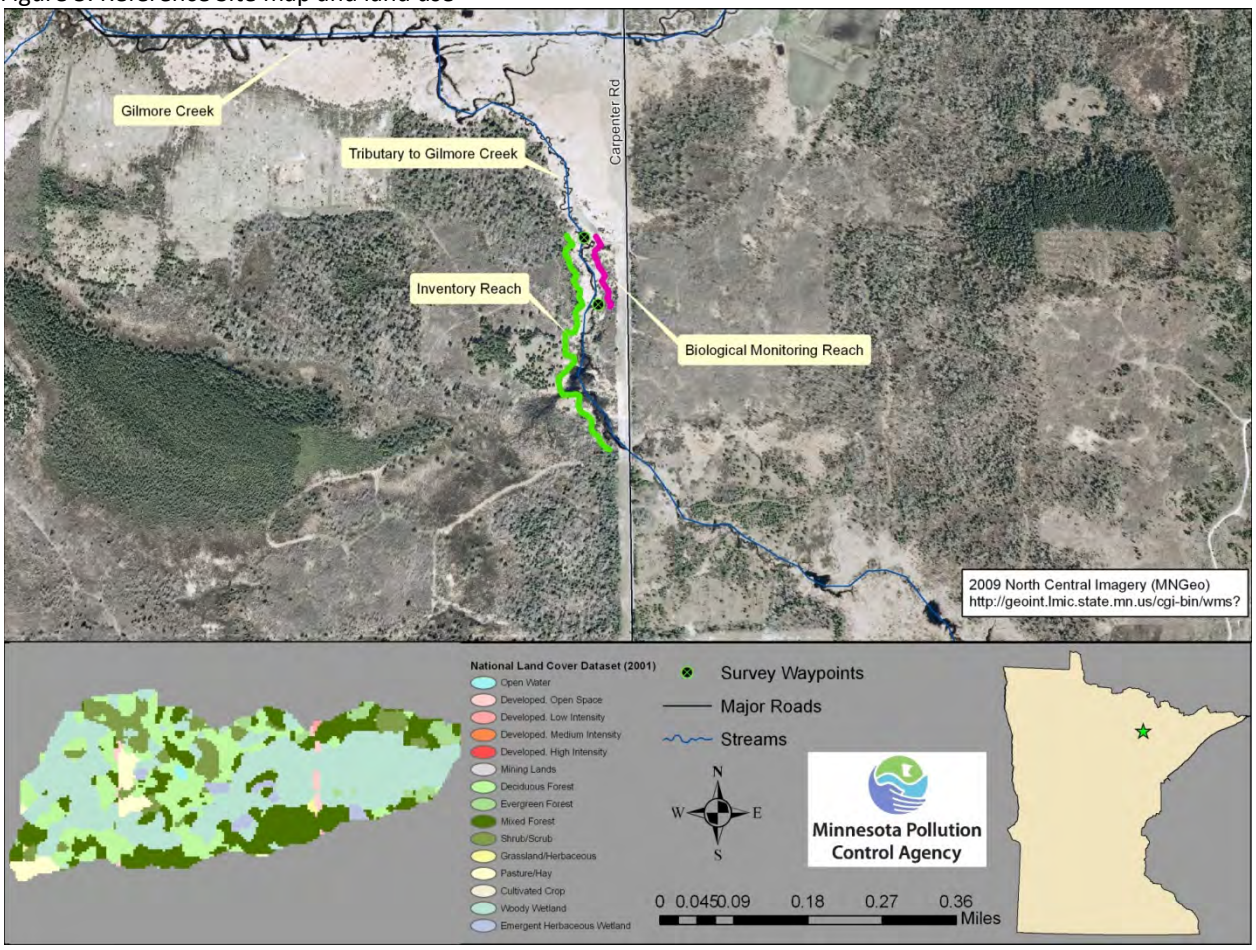
The Mitigation Site was located approximately nine miles southwest of Cook, MN. Gilmore Creek is a 2nd-order tributary to the Sturgeon River and, in turn, the Little Fork and Rainy River systems. Land use in the watershed was dominated by forest (46%) and wetland (39%) land cover, with a relatively small proportion (~8%) of disturbed lands (Appendix B). The inventory reach fell between an abandoned beaver dam at the upstream end and an old culvert at the downstream end, measuring approximately 550m in length (Figure 4). Two biomonitoring reaches were established at the Mitigation Site, each 150m in length. One biomonitoring reach was at the downstream end of the inventory reach (Bio1); the other biomonitoring reach was at the upstream end of the inventory reach (Bio2). The drainage area of the contributing watershed comprised 5.9 square miles, with a reach gradient of approximately 1.5 m/km. The reach was channelized at some point between 1939 and 1948, based on inspection of historic aerial photographs.

Figure 4. Mitigation Site map and land use



The Reference Site was part of an unnamed 1st order tributary to Gilmore Creek, located approximately eleven miles southwest of Cook, MN. Land use in the watershed was dominated by forest (41%) and wetland (44%) land cover, with a very small proportion of disturbed (~5%) lands (Appendix B). The inventory reach fell between an unnamed two-track road at the downstream end and County Road 481 (Carpenter Road) at the upstream end, measuring approximately 540m in length (Figure 5). The drainage area of the contributing watershed comprised 3.0 square miles, with a reach gradient of approximately 1.5 m/km. Aerial photographs indicate that the upstream portion of this reach was impounded by beaver activity as recently as 2010, though no flow obstruction was present during the 2012 inventory project.

Figure 5. Reference Site map and land use



Water Chemistry
A continuously-recording data sonde (YSI model 6920) was placed in each stream on March 29 to record water chemistry parameters at 15-minute intervals. Each water chemistry sonde was calibrated according to the manufacturer's specifications. Water chemistry grab samples were collected from each site during macroinvertebrate and fish sampling, and sent to a laboratory for analysis (Table 2).

Table 2. Water chemistry parameters collected at study sites

Parameter	Sonde	Grab Sample
Water temperature	X	
Dissolved oxygen	X	
Conductivity	X	
pH	X	
Phosphorus, total		X
Nitrogen, total		X
Ammonia		X
Total Suspended Solids		X

Habitat
Biological monitoring staff conducted both qualitative and quantitative habitat surveys at all three sites in early April. A qualitative habitat survey known as the Minnesota Stream Habitat Assessment (MSHA, Feist 2011b) was conducted for three longitudinally-contiguous segments of each inventory reach. The MSHA is scored on a 0-100 scale, with scores above 66 rating "good", scores between 45 and 66 rating "fair", and scores below 45 rating "poor". The composite MSHA score can also be broken down into normalized (0-100 scale) subcategory scores (Land Use, Riparian, Substrate, Cover, Channel Morphology) for individual habitat components.

In addition to the MSHA, the stream features component of the quantitative habitat assessment (Feist 2011c) was conducted along the entire inventory reach. This survey quantifies stream features such as riffles, runs, pools, bends, and logjams. Finally, a full quantitative habitat assessment was conducted within each biomonitoring reach. Photos were taken at several locations on each stream during the habitat assessments.

Macroinvertebrates
Macroinvertebrates were collected using D-frame kicknets from each inventory reach in early April, using standard MPCA protocols (Chirhart 2005). Samples were preserved in the field and shipped to a laboratory for sorting and identification.

Fish
In early April, fish were collected using backpack electrofishing gear from the entirety of the Impact Site inventory reach, and from the biomonitoring reaches at the Reference and Mitigation Sites, using standard MPCA protocols (Feist 2011d). All individuals were identified to the species level in the field, and voucher specimens preserved for verification.

Results

Impact Site – Water Chemistry
Dissolved oxygen, water temperature, conductivity and pH were measured every 15 minutes over a 15 day period (29 March – 12 April 2012) using a YSI (6920) data sonde, with a total of 1308 measurements collected. Dissolved oxygen concentrations (mg/L) ranged from 7.44 to 10.6 with an average concentration of 9.74. The average water temperature was 2.27°C and ranged from -0.09 to 8.58°C. Conductivity measurements ranged from 366.0 to 405.0

(µS/cm) with an average measurement of 379.2 (µS/cm). The average pH was 6.57 and ranged from 6.44 to 6.67 (Appendix C5).

Ammonia, Nitrate + Nitrite, Phosphorous, total suspended solids (TSS) and total suspended volatile solids (TSVS) were measured based on one grab sample collected on 5 April 2012. Ammonia (mg/L) was 0.11, Nitrate + Nitrite (mg/L) was 0.80, Phosphorous (mg/L) was 0.11, TSS (mg/L) was 4.0 and TSVS (mg/L) was 2.0 (Appendix C6).

Impact Site - Habitat

Habitat conditions at the Impact Site generally rated "good", with MSHA Total Score averaging 70 points. Channel Morphology and Riparian subcategory scores were particularly high, reflecting the stream's good depth variability, channel development, and sinuosity, as well as a relatively intact riparian zone surrounding the reach. A high density of bends was also noted during the quantitative habitat assessment. The lowest MSHA subcategory score was related to land use, reflecting the close proximity of mining activities in the upstream watershed. Nearly two-thirds of the reach consisted of Run habitat, though substantial proportions of pool and riffle were present. Substrates were dominated by sand and silt (82.7 percent fines), though boulder, cobble, and gravel were present in riffle habitats. Few flow-deflecting logjams were present but potential fish habitat in the form of woody cover comprised approximately 25 percent (%) of the reach (Appendix D).

Impact Site - Macroinvertebrates

Macroinvertebrates were collected from four major habitat types, which consisted of riffle/rock, undercut banks/overhanging vegetation, aquatic macrophytes, and woody debris. The riffle/rock habitats were sampled at the downstream portion of the reach just below an old beaver dam, while the remaining habitats were sample upstream of the old beaver dam. A total of 31 unique taxa were observed, of which, approximately 47% of these species are representative of tolerant species, mainly consisting of Dipteran taxa. Several sensitive taxa (~28 %) were observed and mainly consisted of aquatic beetles (Coleoptera), chironomids (Diptera) and caddisflies (Trichoptera); of which several of these are coldwater indicator taxa (Appendix E).

Impact Site - Fish

The fish community at the Impact Site consisted of 87 individuals, representing 9 taxa. Three Sensitive species were captured, making up 11.5% of the overall catch. Five Tolerant species were captured, making up 54% of the overall catch. Common shiner, of intermediate tolerance, was the most abundant species collected (Appendix F).

Mitigation Site – Water Chemistry

Dissolved oxygen, water temperature, conductivity and pH were measured every 15 minutes over a 15 day period (29 March – 12 April 2012) using a YSI (6920) data sonde, with a total of 1315 measurements collected. Dissolved oxygen concentrations (mg/L) ranged from 9.08 to 13.3 with an average concentration of 10.6. The average water temperature was 2.72°C and ranged from -0.23 to 7.23°C. Conductivity measurements ranged from 158.0 to 195.0 (µS/cm) with an average measurement of 173.0 (µS/cm). The average pH was 6.54 and ranged from 6.41 to 6.76 (Appendix C5).

Ammonia, Nitrate + Nitrite, Phosphorous, total suspended solids (TSS) and total suspended volatile solids (TSVS) were measured based on two grab samples collected on 4 April and 12 April 2012. Ammonia (mg/L) was 0.08 and 0.06, Nitrate + Nitrite (mg/L) was 3.4 and 2.9, Phosphorous (mg/L) was 0.019 and 0.018, TSS (mg/L) was 2.0 and less than the reporting limit, and TSVS (mg/L) was 1.6 and less than the reporting limit (Appendix C6).

Mitigation Site - Habitat

Habitat conditions at the Mitigation Site generally rated on the boundary between Poor and Fair, with MSHA Total Score averaging 44 points. Land Use and Riparian subcategory scores were high, reflecting a watershed dominated by forest and wetland land cover, as well as a relatively intact riparian zone surrounding the reach. The Channel Morphology subcategory score was low, reflecting a lack of depth variability, channel development, and sinuosity. These characteristics are consistent with the effects of ditching. Likewise, only one bend was observed along the entire 555m length of the Mitigation Site. The reach was dominated by run habitat (93%), with a small amount of pool comprising the remainder. There was no riffle habitat present in the reach. Substrates were dominated by

sand and silt (94% fines), with no coarse substrate present, resulting in a poor Substrate subcategory score. Eleven flow-deflecting logjams were present, but potential fish habitat in the form of woody cover comprised only 1% of the reach (Appendix D). While most of the riparian zone currently consists of grass/sedge meadow, several stumps, snags, and beaver dam logs were noted on and in the streambanks, suggesting that at some point in the past this reach was more heavily forested than it is today. Inspection of historic aerial photographs confirmed that a forested riparian corridor existed prior to 1939.

Mitigation Site - Macroinvertebrates

Macroinvertebrates were collected from two major habitat types, these consisted of undercut banks/overhanging vegetation and woody debris. A total of 36 unique taxa were observed. A majority of these species are representatives of one insect order: Diptera (Flies), while the remaining portions of the insect community were represented by Mayflies (Ephemeroptera) and Caddisflies (Trichoptera). The later are sensitive (intolerant) to stressors, while many Dipterans are tolerant of stressors. Of the Dipteran taxa collected, approximately 29 percent (%) are representative of the family Chironomidae. Approximately 4 percent (%) of the observed community were non-insect species consisting of fingernail clams, crayfish and snails. Several sensitive taxa (~29%) were observed and mainly consisted of mayfly, caddisfly and chironomid (Diptera) species (Appendix E).

Mitigation Site - Fish

The fish community at the Mitigation Site consisted of 309 individuals, representing 9 taxa. The two biomonitoring reaches produced similar fish lists, with finescale dace being the only species not common to both (found in the downstream reach but absent from the upstream reach). Three Sensitive taxa and five Tolerant taxa were observed across the two reaches. A slightly higher proportion of Tolerant individuals and slightly lower proportion of Sensitive individuals was captured at the upstream reach. In both reaches and in total, the most abundant species was the Tolerant central mudminnow (Appendix F).

Reference Site – Water Chemistry

Dissolved oxygen, water temperature, conductivity and pH were measured every 15 minutes over a 15 day period (29 March – 12 April 2012) using a YSI (6920) data sonde, with a total of 1315 measurements collected. The average dissolved oxygen concentration was 10.5 (mg/L), and ranged from 8.2 and 13.2 (mg/L). The average water temperature was 3.92°C with minimum and maximum temperatures of 0.01 and 10.3°C; respectively. The average conductivity measured was 128.2 (µS/cm), with measurements ranging from 116 to 138 (µS/cm). Measurements of pH ranged from 5.95 to 6.42 and the average pH was 6.10 (Appendix C5).

Ammonia, Nitrate + Nitrite, Phosphorous, total suspended solids (TSS) and total suspended volatile solids (TSVS) were measured based on two grab samples collected on 4 April and 12 April 2012. Ammonia (mg/L) was 0.06 and 0.05, Nitrate + Nitrite (mg/L) was 0.73 and 0.48, Phosphorous (mg/L) was 0.015 and 0.014, TSS (mg/L) was 1.6 and less than the reporting limit, and TSVS (mg/L) was 1.6 and less than the reporting limit (Appendix C6).

Reference Site - Habitat

Habitat conditions at the Reference Site rated near the low end of Fair, with MSHA Total Score averaging 48.5 points. Land Use and Riparian subcategory scores were high, reflecting a watershed dominated by forest and wetland land cover, as well as a relatively intact riparian zone surrounding the reach. The Channel Morphology subcategory score was low, reflecting poor depth variability, lack of riffle habitat, and fair channel development. However, sinuosity was good, with 14 bends observed along the reach. Substrates were dominated by sand and silt (96% fines), with no coarse substrate present, resulting in a poor Substrate subcategory score. Twenty-two flow-deflecting logjams were present, and potential fish habitat in the form of woody cover comprised 12% of the reach. Some longitudinal variability in habitat conditions was observed, as approximately the upper 40% of the reach was impounded by beaver activity in recent years; the previously-impounded section was notably shallower and had less cover than the rest of the reach (Appendix D).

Reference Site - Macroinvertebrates

Macroinvertebrates were collected from two major habitat types, these habitats consisted of undercut banks/overhanging vegetation and woody debris. A total of 29 unique taxa were observed of which the insect

community was dominated by two orders: Diptera (flies) and Trichoptera (caddisflies). Approximately 92% of the insect community was represented by five taxa. Over half of the insect community (51%) consisted of tolerant taxa. Several sensitive taxa were present and made up approximately 34% of the observed macroinvertebrate community, which mainly consisted of caddisflies. Non-insect species made up roughly 5% of the observed macroinvertebrate community. These species consisted of snails and fingernail clams (Appendix E).

Reference Site - Fish

The fish community at the Reference Site consisted of 70 individuals, representing five taxa. Two Sensitive taxa were captured, making up 4% of the total catch. Three Tolerant taxa were captured, making up 96% of the total catch. The most abundant species was the Tolerant central mudminnow (Appendix F).

Stream Comparison and Summary

Water chemistry was relatively similar across all sites, with the most notable differences observed in the conductivity measurements. The Impact Site had higher average conductivity than the Mitigation or Reference Sites and was above the normal range for small, undisturbed streams in the Rainy and Lake Superior Basins (typically <200 µS/cm, unpublished data). Water temperatures were very cold throughout the course of this study; a thin sheet of surface ice was observed at all three sites during fish and macroinvertebrate sampling. However, these conditions were not unexpected given the time of year the study was conducted. Dissolved oxygen concentrations indicated high oxygen saturation, which is probably reflective of the cold water temperatures.

Nutrients (ammonia, nitrate + nitrite and phosphorous) and suspended solids (TSS and TSVS) data were relatively consistent across all sampling reaches, the most notable difference was in nitrogen (as $NO_2^+ NO_3$) concentrations from the Mitigation reach (3.4 and 2.9 mg/L). Measured nitrogen values appear elevated within the Mitigation reach based on the normal range for small, undisturbed streams in the Rainy and Lake Superior Basins (typically 0.05 mg/L, unpublished data) (Appendix C7). However, all measured parameters are within current and proposed water quality standards (Heiskary et al. 2010) as well as within normal ranges for small, undisturbed streams in the region of the State (Appendix C7).

Qualitative and quantitative habitat surveys indicated greater habitat diversity at the Impact site than at the Mitigation and Reference sites. Stream gradient was much higher at the Impact site, which may explain many of the observed differences. While in-stream habitat at the Impact site appeared to be quite good, obvious impacts have occurred due to road building and loss of connectivity between the stream and its original watershed. Stream habitat at the Mitigation and Reference sites generally rated poor, but also somewhat typical for streams of this type. Characteristics such as the rarity or absence of riffle habitats, substrates dominated by sand and silt, and poor channel morphology attributes are frequently associated with low-gradient streams. In the case of the Mitigation Site, some of the poor habitat characteristics may be attributable to past channelization practices, and re-meandering will undoubtedly improve habitat complexity by adding bends and increasing depth variability. However, the site will likely continue to be dominated by fine substrates and lack riffle habitat, unless added as part of mitigation.

With respect to macroinvertebrate communities, it is important to note that this study occurred well outside of the MPCA's normal index period for macroinvertebrate monitoring (August-September). As a result, the observed communities can't be directly compared to the agency's extensive macroinvertebrate dataset, which is based on index period sampling. Other information regarding the macroinvertebrate communities present in small northeastern Minnesota streams in late winter/early spring is essentially non-existent, making it nearly impossible to draw conclusions regarding the biological condition of these streams. In addition, the macroinvertebrate samples contained many early instar or otherwise immature specimens, making fine-resolution taxonomic identification impossible. A broad overview of macroinvertebrate communities indicated that the Reference Site contained the highest relative abundances of very tolerant (33%) and tolerant taxa (50.5%), likely due in part to a high percentage of Chironomidae in the subsamples (38%). Approximately 92% of the macroinvertebrate community at the Reference Site was represented by only five taxa (Limnephilidae, *Prosimuliini*, *Limnophyes*,

Pseudosmittia and *Criocotopus*). Sensitive taxa were relatively uncommon at both the Reference and Mitigation Sites, possibly due to habitat homogeneity and lack of course substrates. Many Sensitive taxa are often found in coarse substrates and associated riffle/rock habitats. A relatively small number of macroinvertebrates were collected from the Impact Site (150 individuals) but the community exhibited good diversity and several Sensitive taxa were present. This may be attributed to the greater habitat complexity observed at the Impact Site.

Fish sampling also occurred outside of MPCA's biological monitoring index period (June-September), though closer to the appropriate timeframe than was the macroinvertebrate sampling. The same seasonality issues associated with interpretation of these streams' macroinvertebrate communities also apply to the fish communities. The fish taxa represented across the three sites were typical for streams of these types, though probably in lower abundance than would be seen during the normal index period. It's also possible that additional species would have been collected from these streams if sampling had occurred in the summer months. The Reference Site drained a very small watershed (3 sq. mi.) and may not support a robust fish population simply due to naturally-occurring low flow conditions. All three of these streams are very small (<6 sq mi watershed area), and probably experience harsh winter conditions (e.g. low flow, anchor ice, reduced habitat volume); their fish communities may be highly dependent on seasonal recolonization from refuge habitats in larger streams, lakes, wetlands, etc. It's also reasonable to expect that index period sampling would capture many young-of-the-year individuals which wouldn't be present in early spring. Sampling may simply have preceded these important recolonization and spawning events.

At the Impact Site, approximately 80% of the individual fish were captured in a small pool near the stream's confluence with the Dunka River, directly downstream of a newly-installed culvert and several silt fences associated with recent road construction. Upstream of this location, only three individuals were collected from the next 350m of the Impact Site, despite the presence of habitat that typically holds fish (e.g. deep pools, woody cover). At the extreme upstream end of the reach, an additional 15 individuals were captured in another culvert pool. Without detailed investigation of the fish passage potential of the downstream culvert and silt fences, it's impossible to know whether the near absence of fish from most of the Impact Site is due to natural factors, water quality, flow alteration, or loss of connectivity. As noted above, winter conditions in streams of this size can be very harsh for fish populations – it's possible that most fish migrate out of this stream during the fall/winter months and recolonize it during the spring/summer. The 15 individuals captured at the upstream end of the reach may represent a small group of fish that were able to either find suitable overwintering habitats or successfully negotiate the (potential) barriers introduced by recent road construction (culvert and silt fences).

References

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Feist, M. 2011a. Reconnaissance procedures for initial visit to stream monitoring sites. Minnesota Pollution Control Agency.

Feist, M. 2011b. MPCA stream habitat assessment (MSHA) protocol for stream monitoring sites. Minnesota Pollution Control Agency.

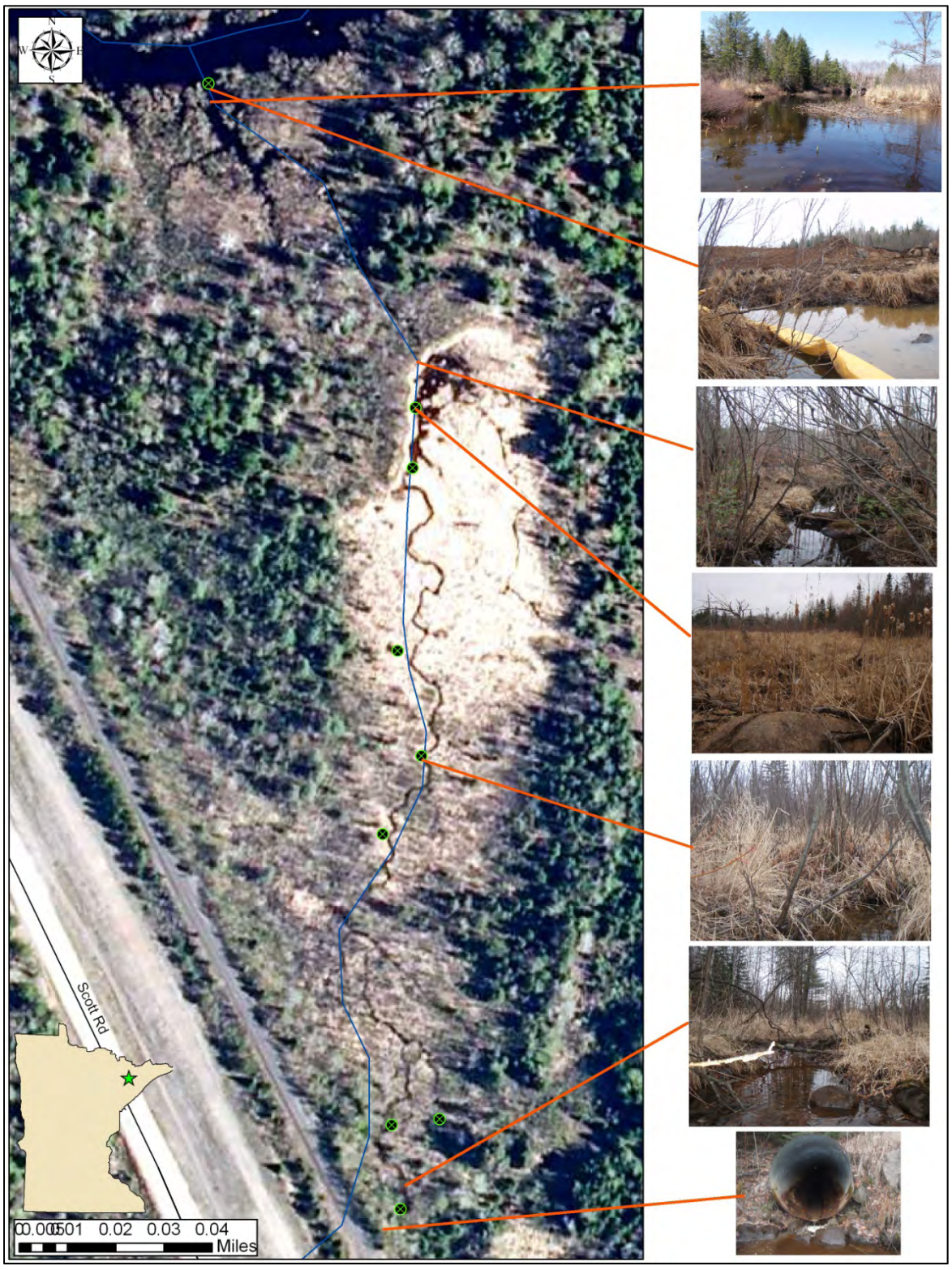
Feist, M. 2011c. Physical habitat and water chemistry assessment protocol for wadeable stream monitoring sites. Minnesota Pollution Control Agency.

Feist, M. 2011d. Fish community sampling protocol for stream monitoring sites. Minnesota Pollution Control Agency.

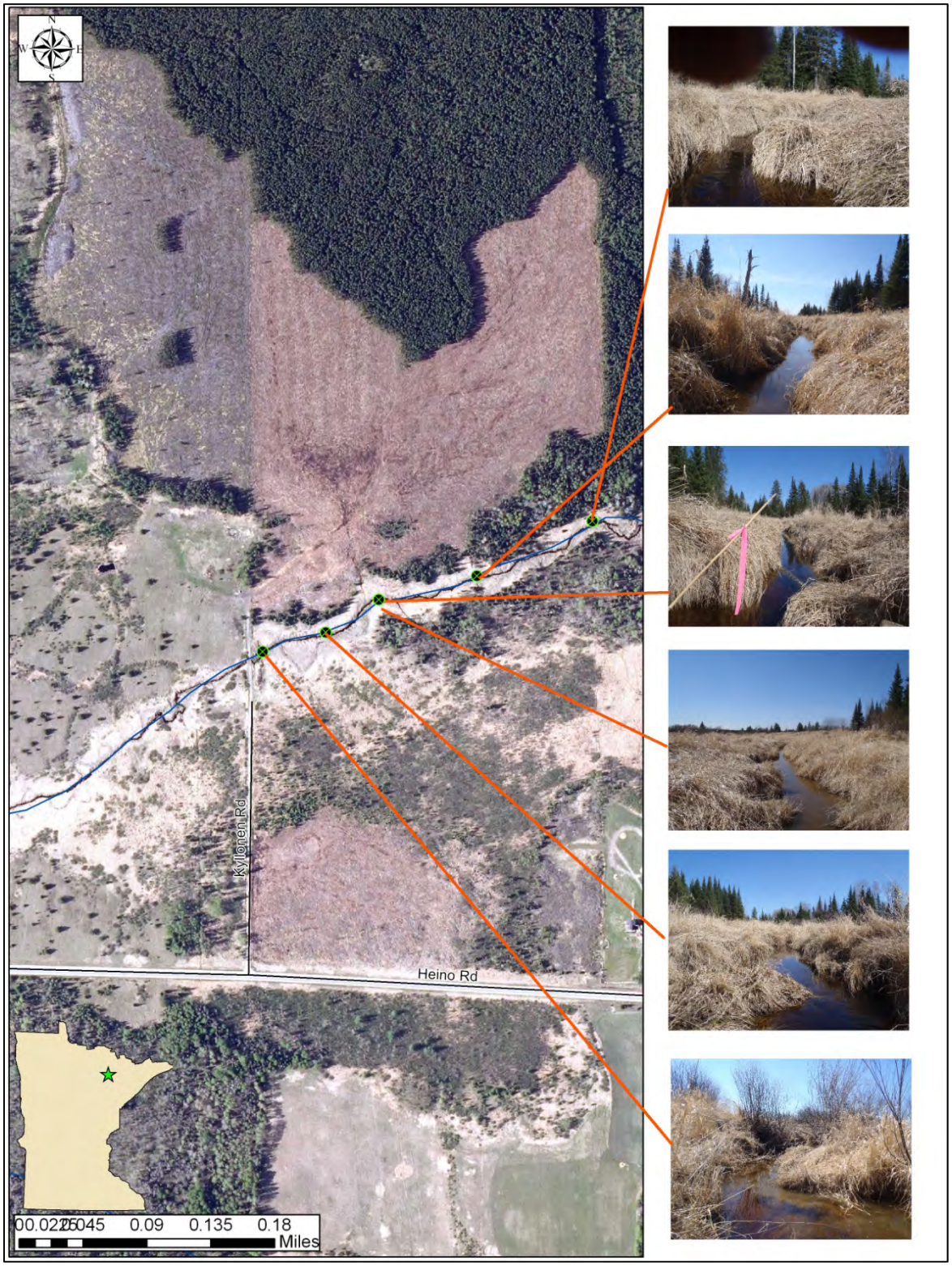
Heiskary, S., R. Bouchard, and H. Markus. 2010. Minnesota Nutrient Criteria Development for Rivers. Minnesota Pollution Control Agency (http://www.pca.state.mn.us/index.php/view-document.html?gid=14947).

Appendix A. Site Maps and Reach Photographs

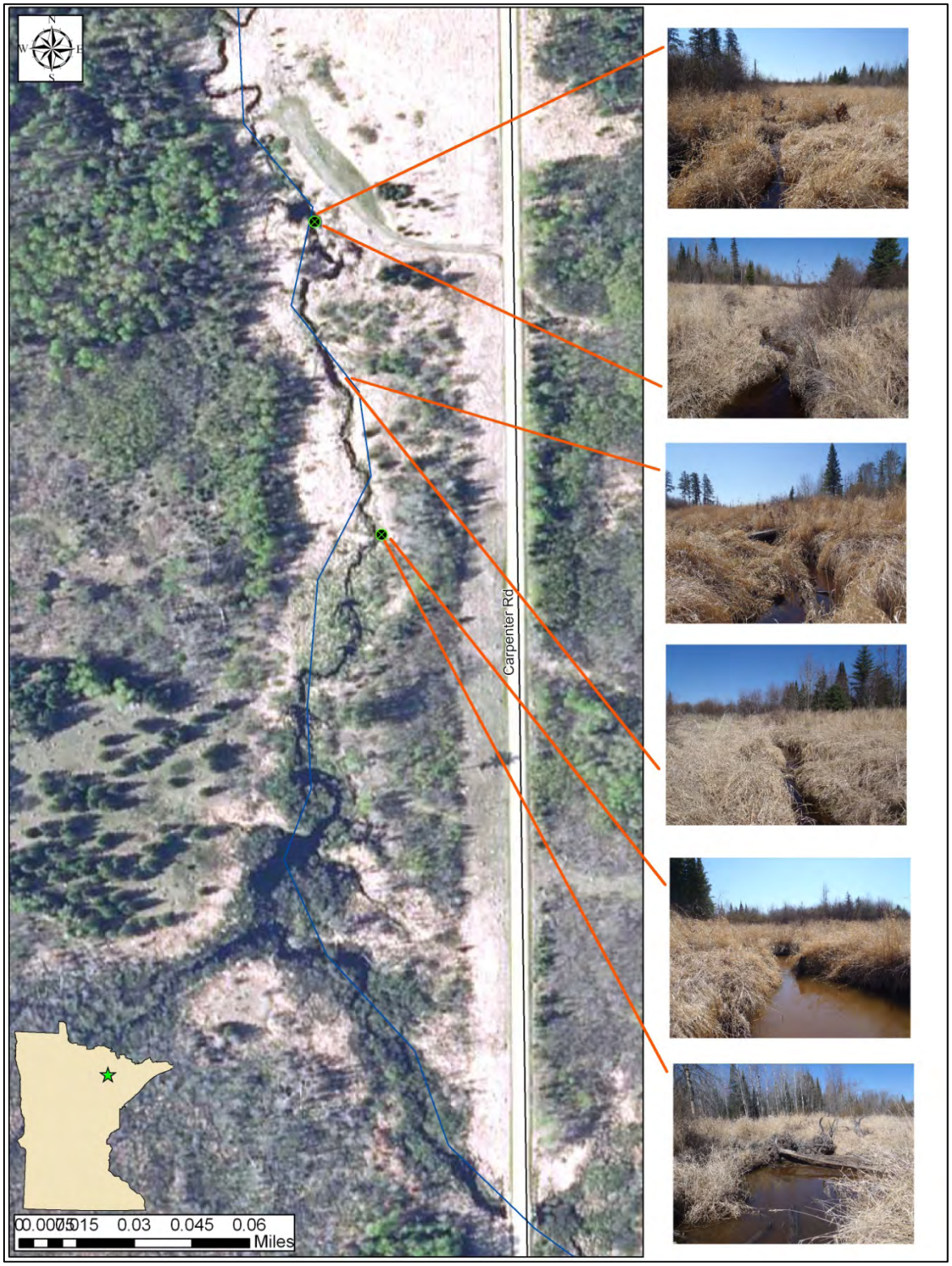
Appendix A1. Map of Impact Reach and Reach Photographs



Appendix A2. Map of Mitigation Reach and Reach Photos



Appendix A3. Map of Reference Reach and Reach Photographs.

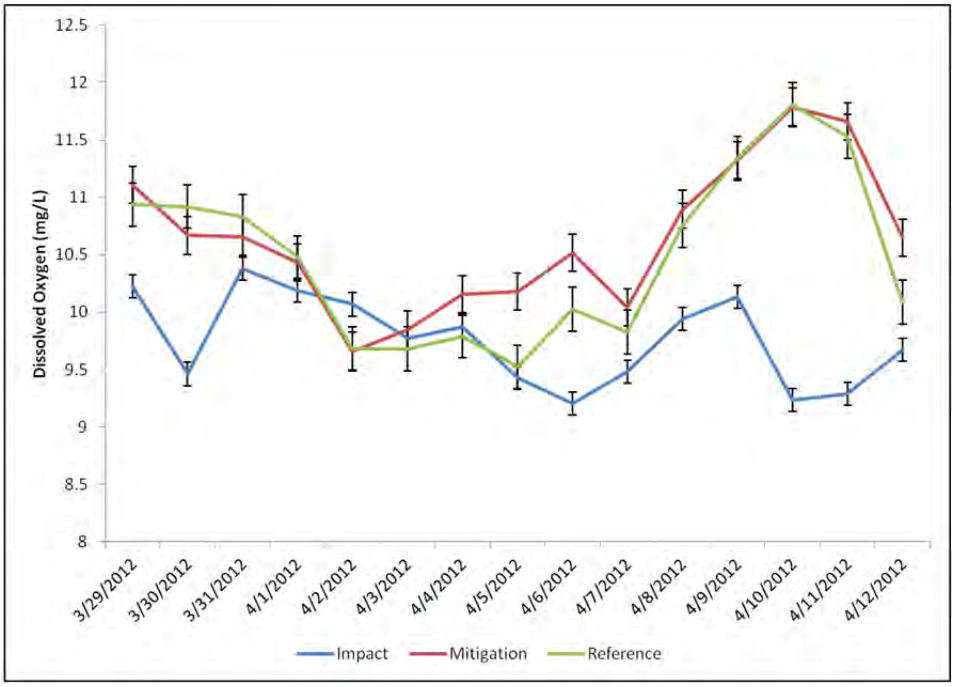


Appendix B. Landuse as a percentage (%) of the watershed; data based on National Landuse Classification Dataset (2001); disturbed lands reflect the sum of developed + pasture/hay + mining.

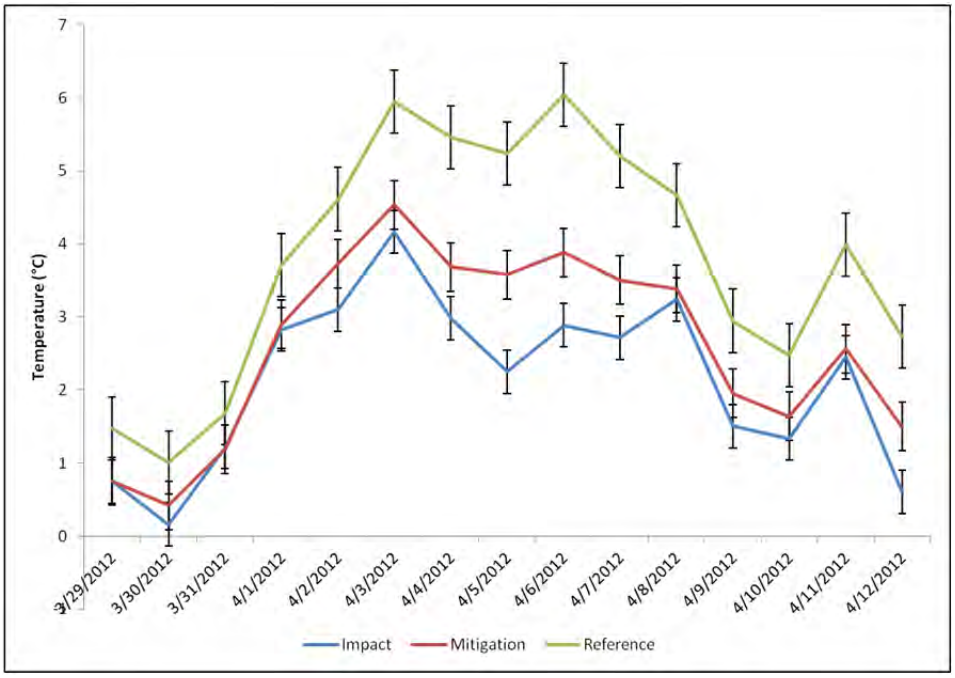
Land Use/Cover Type	Impact	Mitigation	Reference
Developed	0.9	3.0	1.8
Disturbed	36.0	7.7	4.9
Forests	29.5	45.7	40.7
Grasslands	1.2	0.7	0.3
Mining Lands	35.1	0.0	0.0
Open Water	5.4	0.3	0.2
Pasture/Hay	0.0	4.7	3.1
Shrub/Scrub	14.1	6.6	9.8
Wetlands	13.9	39.0	44.1

Appendix C. Water chemistry summary

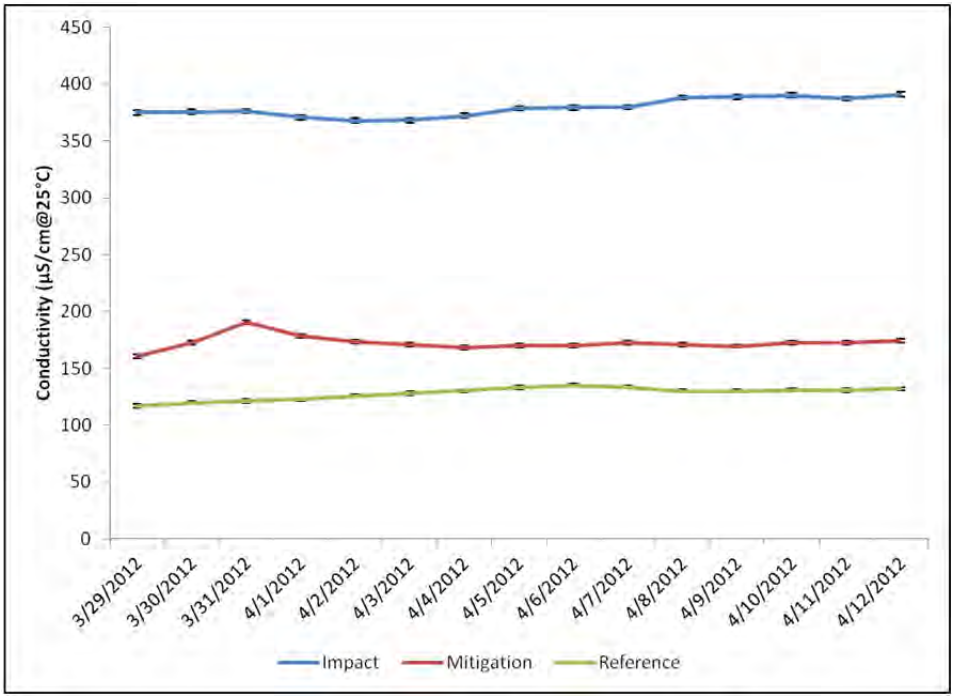
Appendix C1. Daily mean (± 1 S.E.) dissolved oxygen concentrations (mg/L) for all sampling reaches; respectively.



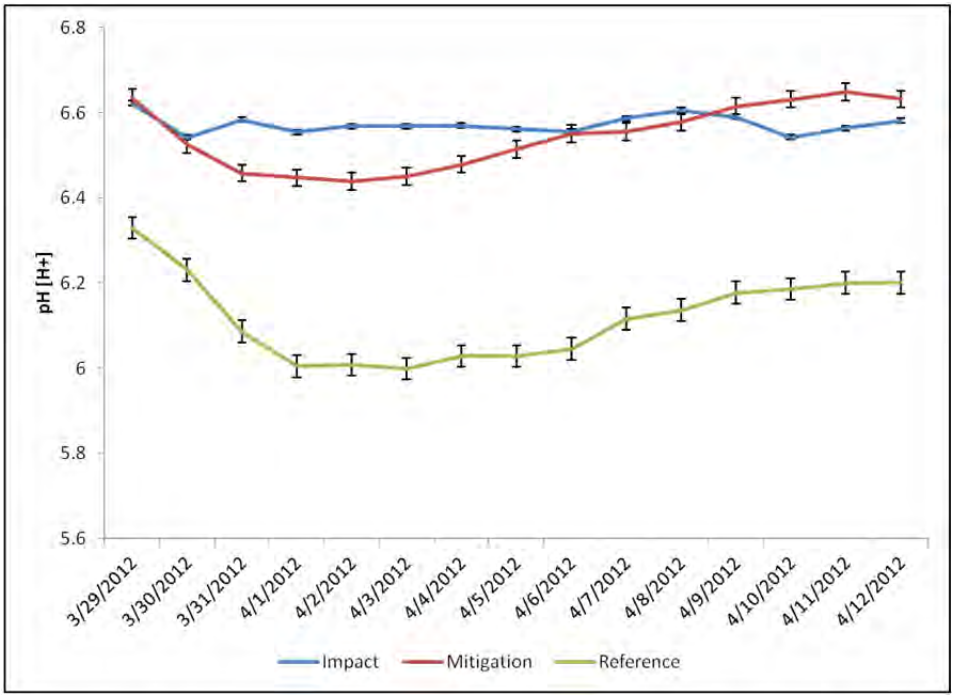
Appendix C2. Daily mean (± 1 S.E.) temperature (°C) for all reaches



Appendix C3. Daily mean (± 1 S.E.) conductivity measurements (µS/cm@25°C) for all reaches.



Appendix C4. Daily mean (± 1 S.E.) pH measurements for all reaches.



Appendix C5. Mean (± 1 S.D.) of each water chemistry parameter for each reach over the 15 days of continuous measurement.

Parameter	Impact	Mitigation	Reference
Dissolved Oxygen (mg/L)	9.74(0.6)	10.6(1.01)	10.5(1.0)
Temperature (°C)	2.3(2.20)	2.72(1.9)	3.92(2.40)
Conductivity (µS/cm@25°C)	379.2(9.30)	173.0(0.6)	128.2(5.17)
pH	6.6(0.03)	6.54(0.08)	6.10(0.09)

Appendix C6. One time water chemistry measurement summary. Values next to each parameter indicate reporting limit (ns = no sample, < = less than reporting limit).

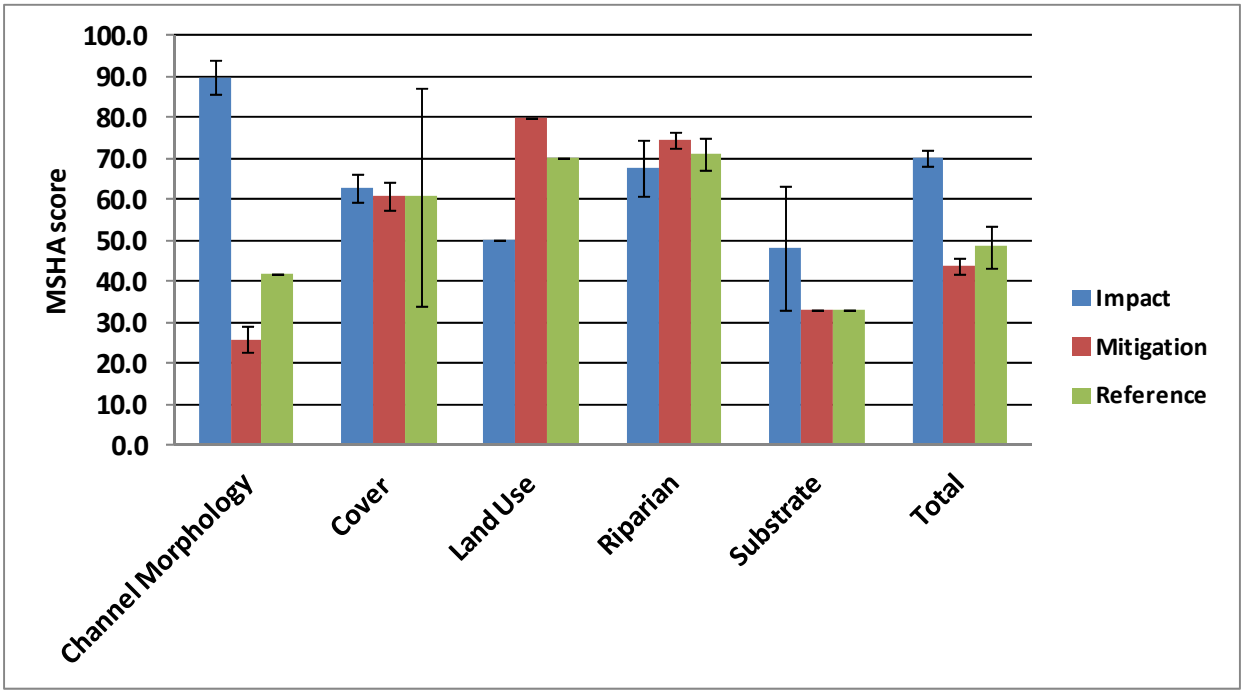
Parameter	Sample Date	Impact	Mitigation	Reference
Ammonia (mg/L) (0.05)	4/5/2012	0.11	0.08	0.06
	4/12/2012	*ns*	0.06	0.05
Nitrate + Nitrite (mg/L) (0.05)	4/5/2012	0.80	3.4	0.73
	4/12/2012	*ns*	2.9	0.48
Phosphorous (mg/L) (0.003)	4/5/2012	0.007	0.019	0.015
	4/12/2012	*ns*	0.018	0.014
TSS (mg/L) (1.0)	4/5/2012	4.0	2.0	1.6
	4/12/2012	*ns*	<	<
TSVS (mg/L) (1.0)	4/5/2012	2.0	1.6	1.6
	4/12/2012	*ns*	<	<

Appendix C7. Summary statistics for nutrient and suspended solids data from small (< 50 square miles), undisturbed (Human Disturbance Score ≥ 70) streams within the Little Fork, Rainy River and St. Louis Watersheds. Values are representative of one-time grab samples taken by MPCA biological monitoring staff as part of routine water chemistry monitoring over the last 10 years (u*npublished data*).

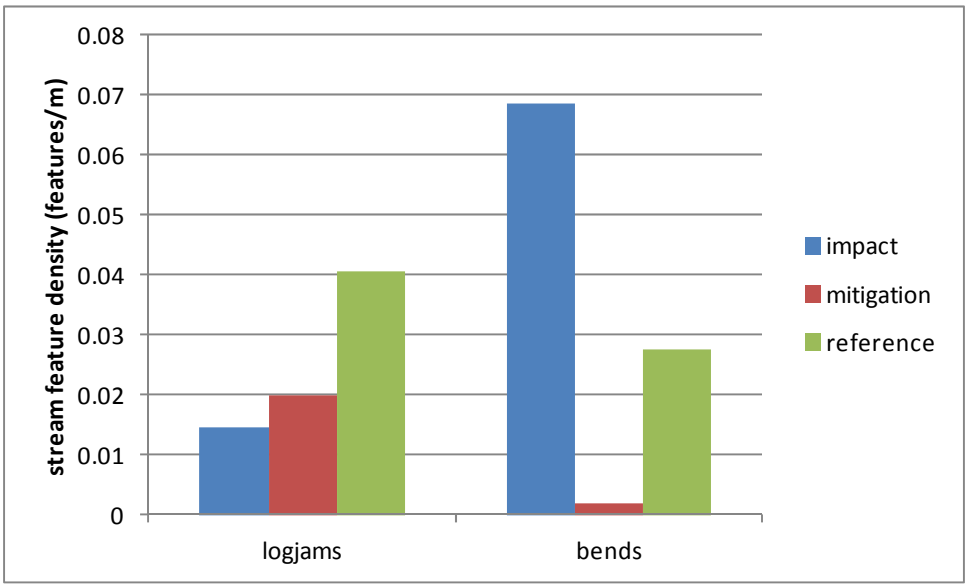
Parameter		
Ammonia	Mean	0.074
	S.D.	0.031
	Min	0.050
	Max	0.210
	n	87
Nitrogen	Mean	0.052
	S.D.	0.012
	Min	0.050
	Max	0.130
	n	87
Phosphorous	Mean	0.068
	S.D.	0.042
	Min	0.013
	Max	0.291
	n	87
TSS	Mean	9.843
	S.D.	12.403
	Min	1
	Max	76
	n	86
TSVS	Mean	3.482
	S.D.	2.42
	Min	1
	Max	17.6
	n	68

Appendix D. Stream Habitat and Feature Summary

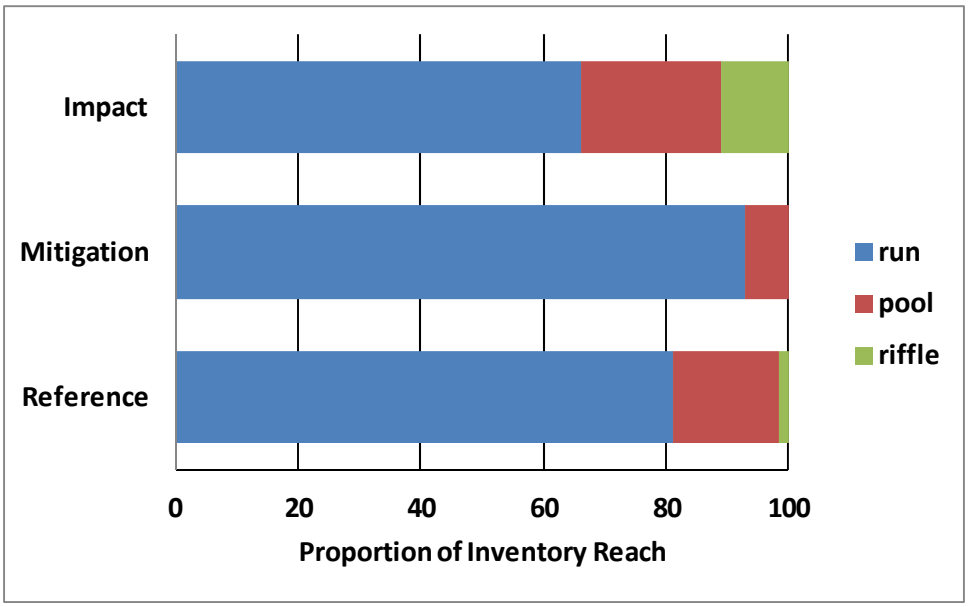
Appendix D1. MSHA normalized (0-100 scale) subcategory scores and total score. Values represent the mean (± 1 S.D.)



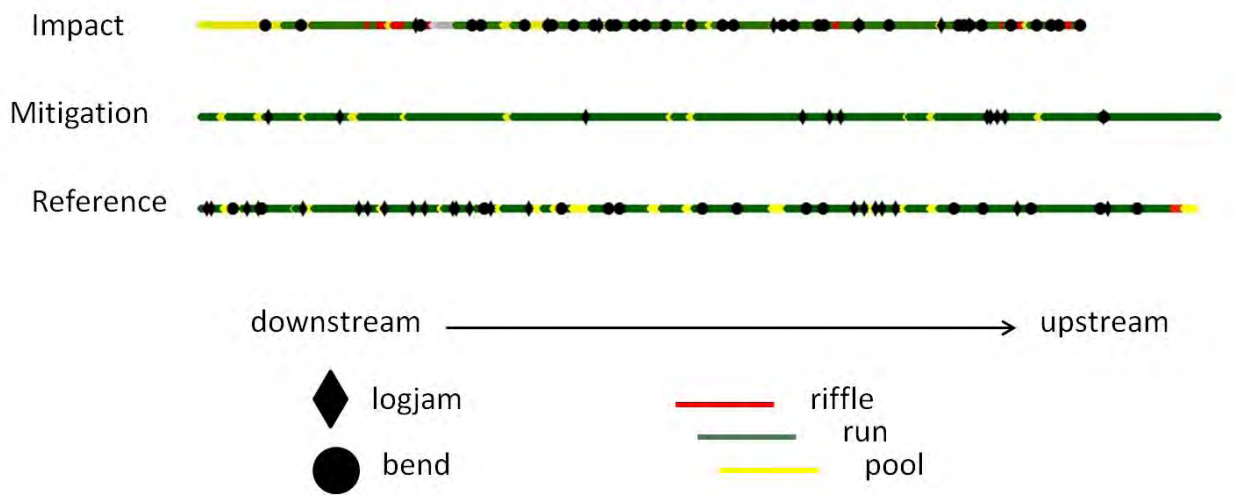
Appendix D2. Stream feature density.



Appendix D3. Proportion of different habitat types (run, pool, riffle) in each stream



Appendix D4. Longitudinal distribution of habitat types (riffle, run, pool) and stream features (bends, logjams) in each stream.



Appendix D5. Habitat data summary for each stream. MSHA scores are mean ± 1 S.D.

Measurement Type	Parameter	Impact Site	Mitigation Site	Reference Site
Flow	Flow (cubic meters/second)	N/A	0.19	0.06
Channel Type	Riffle percent	11	0	2
	Run percent	23	93	81
	Pool percent	66	7	17
Stream Features	Log jams	8	11	22
	Log jam density (number/meter)	0.017	0.020	0.041
	Bends	32	1	14
	Bend density (number/meter)	0.066	0.002	0.026
Qualitative Habitat (MSHA)	LandUse	50.0 (0.0)	80.0 (0.0)	70.0 (0.0.)
	Riparian	67.8 (6.9)	74.4 (1.9)	71.1 (3.8)
	Substrate	48.0 (15.1)	33.3 (0.0)	33.3 (0.0)
	Cover	62.7 (3.4)	60.8 (3.4)	60.8 (26.5)
	Channel Morphology	89.8 (4.2)	25.9 (3.2)	41.7 (0.0)
	Total Score	70.3 (2.0)	43.8 (1.8)	48.5 (5.0)
Quantitative Habitat	Substrate Percent Fines	82.7	94.2	96.2
	Percent Cover	60.4	29.2	37.3
	Percent Undercut	10.8	5.2	1.2
	Percent Overhanging Vegetation	23.9	22.7	23.1
	Percent Woody Cover	25.8	1.3	12.3
	Mean Thalweg Depth (cm)	28.0	71.3	50.0
	Mean Depth of Fines (cm)	7.7	14.4	16.1
	Mean Water Depth	16.6	50.1	35.1
	Coefficient of Depth Variation	35.4	16.3	18.8
	Mean Width (m)	1.3	2.6	1.8
	Width-To-Depth Ratio	6.3	2.5	4.3

Appendix E. Macroinvertebrate community summary for each stream. Values represent number of individuals unless otherwise noted. (Tolerance categories: S = Sensitive, T = Tolerant, and V = Very Tolerant)

Taxa List	Tolerance	Impact Reach	Reference Reach	Mitigation Reach
Bivalvia				
Sphaeriidae	v	20	2	3
Coleoptera				
Anacaena	S	1	1	
Colymbetes	T	2	-	-
Dubiraphia	T	-	-	1
Dytiscidae	T	1	1	-
Haliplus	T	-	7	-
Helophorus	T	1	1	-
Hydraena	T	3	1	-
Hydrocolus	T	1	-	-
Optioservus	S	4	-	-
Tropisternus	T	-	-	1
Diptera				
Ablabesmyia	T	-	1	2
Bezzia / Palpomyia	T	4	1	3
Ceratopogoninae	T	4	8	-
Cladotanytarsus	T	-	-	5
Corynoneura	T	-	-	8
Cricotopus	T	3	15	5
Cryptotendipes	T	-	1	-
Dicrotendipes	V	-	7	12
Diplocladius cultriger	S	1	-	3
Ephydridae	T	-	1	-
Eukiefferiella	V	3	-	-
Helodon	S	22	42	99
Heterotrissocladius	S	-	-	1
Hydrobaenus	V	1	4	-
Limnophila	S	-	-	1
Limnophyes	V	2	38	8
Paraphaenocladius	S	-	7	-
Paratanytarsus	T	-	15	7
Pericoma / Telmatoscopus	T	-	3	-
Phaenopsectra	T	2	-	-
Polypedilum	T	-	-	1
Potthastia	S	1	-	-
Procladius	V	-	-	6
Pseudosmittia	T	-	22	-
Rheotanytarsus	T	2	-	3
Sciomyzidae	T	1	-	-
Serromyia	T	3	-	-
Stempellinella	S	5	-	4
Stenochironomus	T	-	3	-
Stictochironomus	V	2	2	1
Tabanidae	T	12	-	1
Tanytarsus	T	-	-	8
Thienemannimyia Gr.	T	3	-	12
Tipula	S	4	-	-
Tipulidae	S	-	1	-

Xenochironomus xenolabis	S	-	2	-
Zavrelimyia	V	-	-	2
Ephemeroptera				
Caenis	T	-	-	6
Leptophlebia	S	-	-	7
Leptophlebiidae	S	-	-	10
Gastropoda				
Lymnaeidae	T	-	3	-
Promenetus exacuous	V	-	-	1
Stagnicola	V	-	-	1
Hemiptera				
Gerridae	V	2	-	-
Odonata				
Corduliidae	T	4	-	-
Libellulidae	V	-	1	-
Trichoptera				
Ceraclea	S	-	-	1
Cheumatopsyche	T	-	-	1
Leptoceridae	S	-	1	-
Limnephilidae	S	30	105	3
Limnephilus	T	-	-	64
Ptilostomis	T	1	-	1
Lepidoptera		2	-	-
Crambidae	S	2	-	-
Unclassified				
Acari	T	-	-	3
Oligochaeta	T	9	9	6
Total Count		**156**	**305**	**301**
Taxa Richness		31	29	36
Intolerant Taxa (percent)		27.6	34.4	29.6
Tolerant Taxa (percent)		42.1	50.5	32.9
Very Tolerant Taxa (percent)		6.6	33.1	16.9
EPT (percent)		20.4	34.8	30.9
Non-insect Taxa (percent)		19.1	4.6	4.7

Appendix F. Fish community summary for each stream. Values represent number of individuals unless otherwise noted. (Tolerance categories: S=Sensitive, I=Intermediate, T=Tolerant)

Common Name	Tolerance	Impact Site (484m)	Reference Site (150m)	Mitigation Site, Bio1 (150m)	Mitigation Site, Bio2 (150m)
brook stickleback	T	9	6	22	27
central mudminnow	T	14	51	48	81
creek chub	T	1	10	16	17
fathead minnow	T	3		4	1
finescale dace	S	1		7	
johnny darter	I			16	8
northern redbelly dace	S	7	2	24	19
pearl dace	S		1	7	8
white sucker	T			3	1
common shiner	I	30			
brassy minnow	T	20			
blacknose shiner	S	2			
Taxa Richness		9	5	9	8
Individuals		87	70	147	162
Sensitive Taxa		3	2	3	2
Sensitive Individuals (percent)		11.5	4.3	25.9	16.7
Tolerant Taxa		5	3	5	5
Tolerant Individuals (percent)		54.0	95.7	63.3	78.4