

Geomorphic and Hydrologic Influences on TMDL Impairments in the Grand Marais Creek Watershed (AUID 09020306)



May 30, 2014

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INTRODUCTION

Stream health can be grouped into five broad categories: hydrology, geomorphology, connectivity, water quality, and ecology (MN DNR 2014). While this section focuses on geomorphology, all five of these factors interact and can't be understood in isolation. Stream flow directly influences stream geomorphology and so hydrology is perhaps the most directly linked to geomorphology. Water quality is in turn directly influenced by sediment loading from fields and stream banks and varies by water level and season.

Many geomorphic factors influence the TMDL impairments. Turbidity and bedded sediment have different impacts on the biotic communities. Fine sediment load contributes to turbidity which is destructive to sight-predatory fish and filter-feeding invertebrates, for example. Silt and fine sand contribute to embeddedness on the streambed which reduces the substrate available for invertebrate colonization and fish nesting. Fine sediment stored on the stream bed also contributes to high turbidity during high flows when the fine materials are re-mobilized.

Channelization is the most widespread stream impact in the region and has many direct impacts on aquatic biota. The channel evolution state of streams is directly altered by ditch maintenance. Streams that are actively adjusting to changes in slope, width or depth tend to contribute more sediment to the local stream environment. Many ditches develop stable somewhat meandering low-flow channels on the bottom of the ditch trapezoid over many years. However ditch maintenance effectively sets the clock back on channel evolution. Channelization puts the stream into a state of active adjustment again. Construction of berms alongside the ditch and bed excavation has also disconnected the stream from its floodplain, greatly reducing lateral connectivity. Channelization also eliminates or greatly reduces pool-riffle sequences that are needed by certain fish and invertebrates for different life history functions. Hydrologic change has occurred throughout the region from changing land-use, sub-surface drainage increases and climate change. This has a large influence on geomorphology and subsequently on the conditions for aquatic life in streams. More specific information on the hydrologic setting and change in the region are discussed in the background section below.

Connectivity is also an important impact on aquatic biota that may be affected by stream geomorphology. Many, if not most, of the streams in this region are ephemeral. Without perennial streamflow, fish would need to migrate to refugia and deeper water areas during periods of low flow. There is perennial stream habitat in the Red River and the lower reaches of the larger tributaries. Upper stream reaches on the glacial ridge can have significant groundwater discharge creating permanent water pools (Cowdery et al. 2008). However connection between these habitats can limit the viability of aquatic life at least seasonally.

BACKGROUND

Site Setting

The geomorphic and hydrologic setting of Grand Marais Creek Watershed has a large influence on its water quality and aquatic communities. The Lake Agassiz glacial lake plain is drained by the Red River of the North and is very flat within the former lake bed although it is flanked by steeper glacial till and moraine areas. The Red River and major tributaries are very different than the smaller streams in the headwaters and the stressors leading to biotic impairment are likewise very different.

Hydrologic Setting

The Lake Agassiz Plain lies on the edge of the prairie-forest ecoregion boundary with forest in the eastern edge of basin and prairie historically covering most of the area. It has a semi-arid climate, with precipitation between 18 to 26 inches per year over most of the basin (UM - Soil Climate Water 2008). Mean annual runoff has been estimated at about 2 inches over most of the Red River Valley, with a range of 1-4 inches within the basin (Lorenz et al. 1997). Annual water balance calculations give values of 17-24 inches annual evapotranspiration (ET) and 2-4 inches of groundwater recharge (Lorenz et al. 1997). The vast majority of the streamflow occurs in the spring to early summer from snow-melt runoff when saturated soil conditions exist. Streamflow tends to be very flashy compared to streams in eastern Minnesota with a very high peak in spring followed by low flow to no streamflow in late summer through fall (Figure 1). Consequently many streams flow intermittently. In the Grand Marais-Lower Red hydrologic unit (09020306) there are 35.1 miles of perennial streams, 103.5 miles of intermittent streams, and 173.3 miles of “canals” or ditches (Figure 2) (ESG, 2014). The percentage of intermittent streams is actually higher in the Grand Marais watershed itself, since those statistics include a portion of the Red River which is perennial.

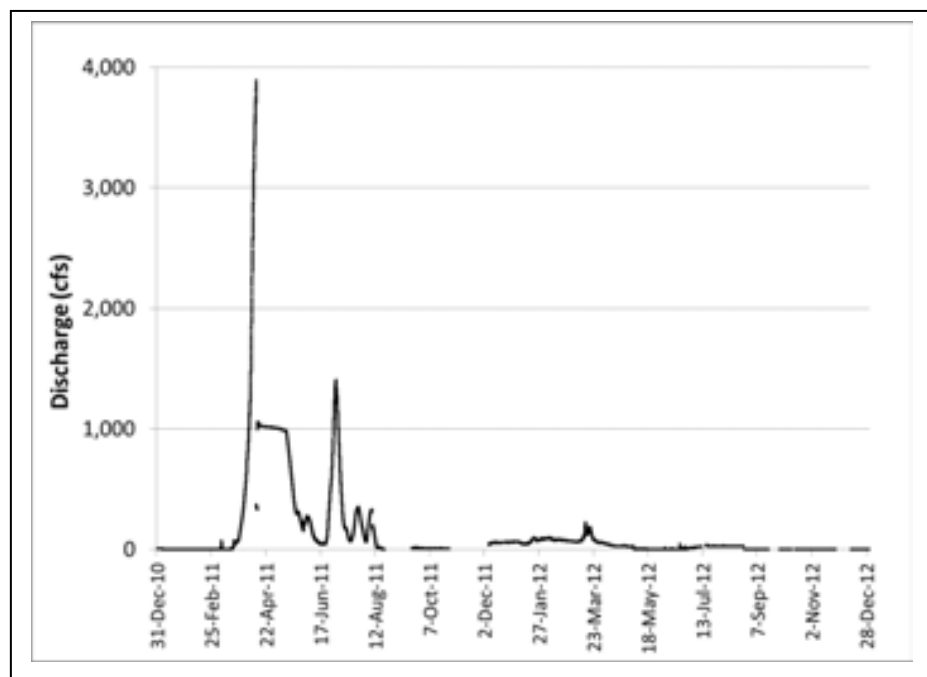


Figure 1. Hydrograph at Grand Marais Creek near for years 2011-2012, showing intermittent nature of flow and large spring streamflow peak in March of 2011. Water data collected by MN DNR and MPCA at near East Grand Forks, MN.

There has been significant hydrologic alteration since European settlement with the Red River basin now 90% agricultural land cover. Water that was once stored in wetlands and wet prairies is now mostly drained quickly to surface ditches or subsurface drainage pipes. The drained wetland areas are degraded and hydrologically disconnected to the stream network making them inhospitable as refugia for fish and invertebrates (Euliss and Mushet 1999).

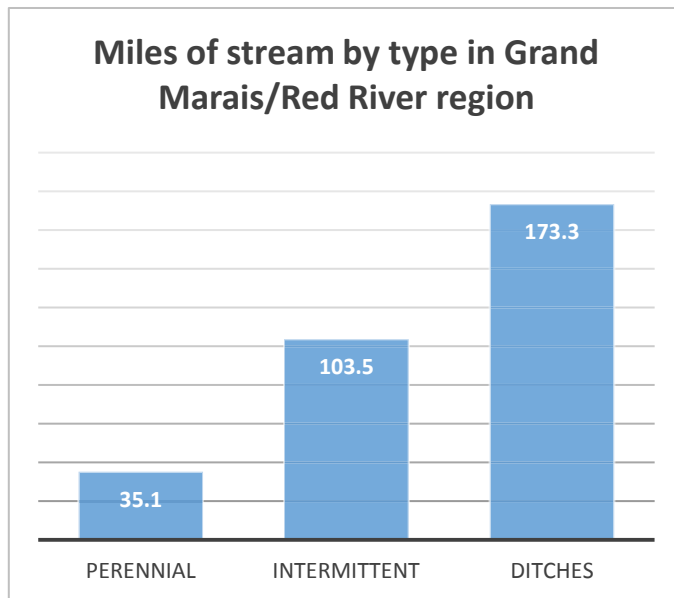


Figure 2. Miles of perennial, intermittent and ditched streams in the Grand Marais / Red River HUC (09030206).

Description of Channel Types and Existing Conditions

The vast majority of the stream network is either ditched natural streams or created channels for surface water drainage. There is little natural stream length remaining in the watershed. Channelized streams are usually very entrenched limiting their floodplain connectivity and function due to berm placement on the side of the ditches and channel down-cutting created by dredging and/or natural channel adjustment. Many of the streams prior to European settlement were more like broad swales that were well-connected to their floodplain (EOR 2009). Channelized stream conditions are detrimental to aquatic life as the stream bottom is homogenous with little structure or habitat available as colonization sites.

Most of the streams are low-gradient with a fine-textured (silt or clay) streambed. In the Rosgen system they are often classified as types E or C. Many existing streams, especially in the headwaters, were either swales or wetlands with more gradual sheet flow before channelization created larger, entrenched channels. In many cases the stream network was expanded by creating a network of ditches where channelized flow did not exist prior to the 1900s.

Relationship Between Geomorphology, Hydrology, Sediment Transport and Biotic Impairments

Channelization, hydrologic alteration, and intermittent flow are some of the primary physical stressors in ditched agricultural watersheds. An objective of this study is to understand how these stressors influence fish and invertebrate populations and IBI scores in this watershed. Impairments for the watershed are shown in Table 1. There are many known associations between geomorphology and fish and invertebrate health. High turbidity can stress filter-feeding invertebrates such as aquatic mussels and caddisflies (Newcombe and MacDonald 1991). Excess bed sediment can reduce the habitat available for invertebrates by burying coarse materials with fine sediment, reducing IBI but also overall invertebrate productivity. Sedimentation reduces the number of sensitive taxa such as mayflies and stoneflies and favor tolerant taxa such as black flies. In the fish community, turbidity reduces the ability of sight predators (*piscivores*) such as smallmouth bass, to obtain food. Fish that feed on invertebrates (*invertivores*) are directly negatively impacted by reduced invertebrate populations while omnivores such as white suckers are favored under these conditions. Following droughts or floods invertebrate populations are usually reduced and re-colonization must occur from “refugia” such as hyporheic zones

(areas of coarse sand and gravels beneath the streambed with groundwater-surface water exchange), longitudinal drift, or aerial deposition of eggs. Other factors related to geomorphology include the presence or absence of large pieces of wood. Removal of wood for ditch maintenance further reduces colonization sites for aquatic invertebrates reducing overall invertebrate numbers (Seger et al. 2012). Overall the most likely geomorphic stressors on aquatic life in the region include:

- In the long-term, land-cover change and channelization have led to increased sediment loading and reduced quality and quantity of in-stream habitat for invertebrates and fish
- Turbidity in streams is increased by sediment from field and gully erosion in farmland.
- Ditched streams tend to be fairly stable in terms of lateral erosion but are often aggrading because of low in-stream shear forces, over-widening and intermittent flow that are common in Red River basin channelized streams and ditches
- Sediment from wind and water-driven field erosion filling in channels

Table 1. Impairments in Grand Marais Watershed.

Assessment Unit	Description	Affected Use	Pollutant/Stressor	Year Listed
09020306-507	Grand Marais Creek: Headwaters to CD 2	Aquatic Life	DO Turbidity pH	2006 2006 2008
09020306-512	Grand Marais Creek: CD2 to Red River	Aquatic Life	Turbidity	2006
09020306-515	County Ditch 2: CD66 to Grand Marais Cr	Aquatic Life	Turbidity	2016**

** This stream reach does not meet the turbidity water quality standards for natural streams. However, this stream is more than 50% channelized and therefore will be assessed against Tiered Aquatic Life Use standards that are currently under development. This stream reach will not be included in the current TMDL study, but was included in this geomorphic study in the event that it is assessed as impaired in the future.

METHODS

Field geomorphic surveys, the Minnesota Agricultural Ditch Reach Assessment for Stability (MADRAS), and Minnesota Stream Health Assessment (MSHA) indices were completed at 21 sites in August and September of 2013. Geomorphic surveys were completed in more detail for Rosgen classification at a subset of 12 sites. Estimates of streambank erosion were calculated using the BANCS model which utilizes measurements of Bank Erosion Hazard Index (BEHI) and the Near Bank Shear Stress (NBS).

Water quality data was collected on August 26-27, 2013 during a period of low flow at 24 sites. Parameters measured included flow level (visual estimate), temperature, specific conductivity, and dissolved oxygen.

Data on the relationships between the geomorphic and hydrologic metrics and biotic impairments are presented in the results and examined in more detail in the discussion section.

RESULTS

Stream Health and Stability Indices

The Minnesota Stream Health Assessment (MSHA) scores showed poor conditions in all but 1 stream site, County Ditch 44 (Table 2). The streams scored lowest in the surrounding land-use category due to high agriculture use with an average score of 1 out of 5, and in the stream cover category with an average score of 3.4 out of 15. The riparian category score was moderate with an average score of 6.7 out of 15 due to lack of shade, but bank erosion was low. The substrate category score averaged 7.5 out of 27 due to fine sediment and high embeddedness. The channel morphology category scores were low with an average of 8.8 out of 27 due to low values in all sub-categories except stability. Overall, homogenization of the streambed from ditch maintenance and aggradation combined with lack of cover and predominantly fine sediment contribute to poor habitat conditions for fish and invertebrates. Substrate ranked very poor with a score of 7 of 27 or less at all but three sites. The highest ranked sites for substrate were the CD 44 site with a score of 15 while the two Brandt Creek sites scored 10 and 16 of 27. Stream cover was also low with 60% of sites scoring 0, 25% scoring an 8 or less and 15% scoring 11 of 16.

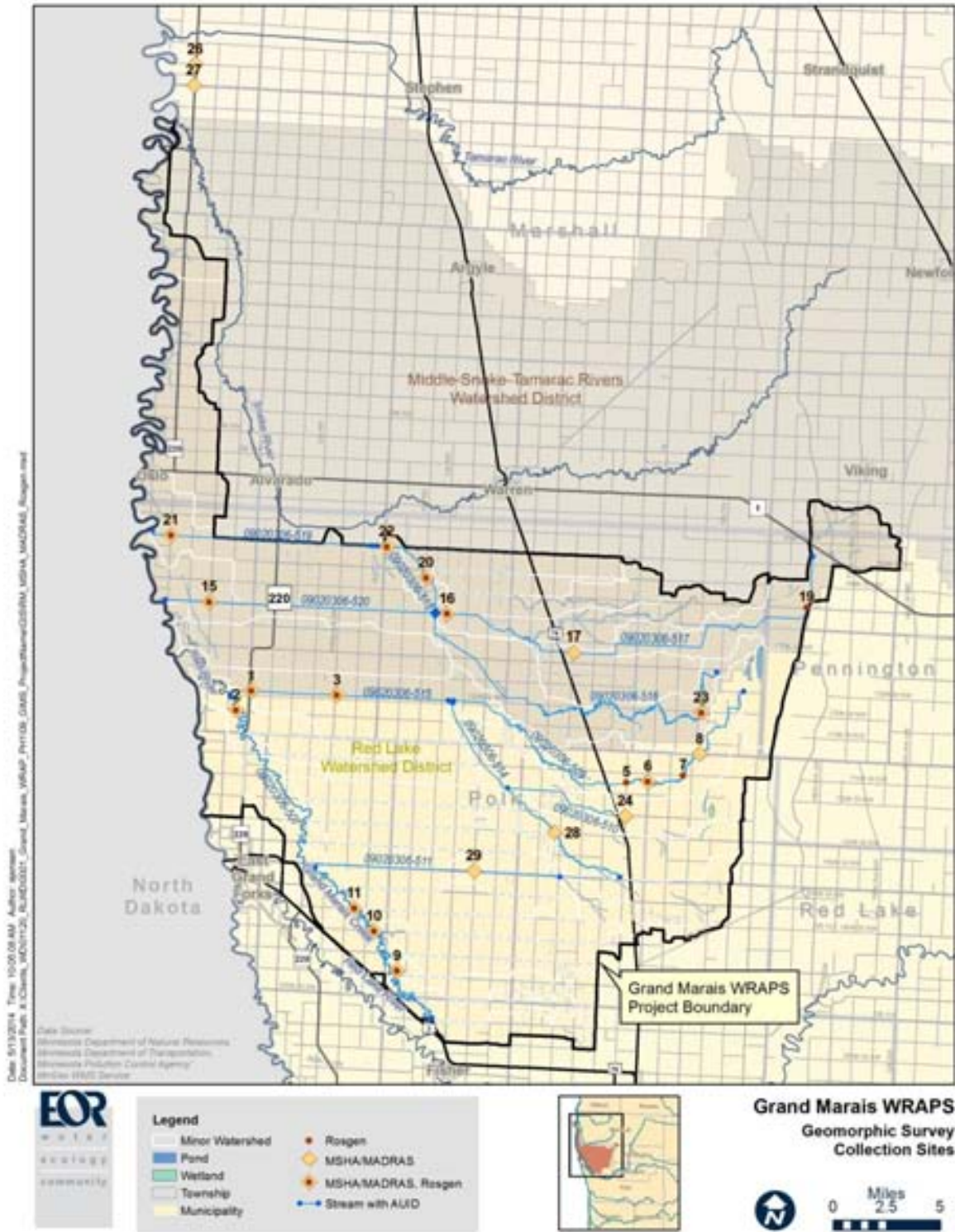


Figure 3. Geomorphic survey and stream index data collection locations. Data was collected to fill out MSHA and MADRAS worksheets and for Rosgen geomorphic classification and assessment in August and September, 2013.

Table 2. Minnesota Stream Health Assessment (MSHA) scores for Grand Marais Creek Watershed.

SITE (-AUID)	Category (score range)						Rating
	Surrounding Land use (0-5)	Riparian (0-15)	Substrate (0-27)	Cover (0-17)	Channel morphology (0-36)	Total (0-100)	
#1: CD2-Site 1 (-515)	0	5	7	0	7	19	poor
#2: GMC-Site 4 (-507)	5	10	6	0	12	33	poor
#3: CD2-Site 2 (-515)	0	6	7	11	7	31	poor
#6: Brandt Creek-Site 1b (-509)	0	9	10	0	15	34	poor
#8: Brandt Creek-Site 2b (-509)	5	6	16	5	2	34	poor
#9: GMC-Site 3 (-507)	3	9	6	0	12	30	poor
#10: GMC-Site 2 (-507)	0	7	7	0	7	21	poor
#11: GMC-Site 1(-507)	0	7	3	0	7	17	poor
#15: JD75-Site 1(-520)	0	5	7	8	7	27	poor
#16: JD75-Site 2(-517)	0	5	7	8	7	27	poor
#17: JD75-Site 3a (-517)	0	4	7	8	7	26	poor
#20: JD1-Site 2 (-518)	0	4	7	0	7	18	poor
#21: JD1-Site 1(-519)	0	4	7	0	7	18	poor
#22: JD1-Site 3(-519)	0	8	7	0	7	22	poor
#23: CD44 (-516)	5	12	15	8	19	59	fair
#24: CD66 (-510)	0	8	7	0	10	25	poor
#26: JD9(-999)	0	5	7	0	7	19	poor
#27: CD12 (-999)	0	7	7	0	7	21	poor
#28: CD66 (-514)	0	8	7	11	10	36	poor
#29: CD126 (-511)	0	4	3	11	13	31	poor
Median score	0	6	7	0	7	26	poor
Avg. score	1	6.7	7.5	3.4	8.8	27.2	poor

MSHA Qualitative habitat ratings:

Good: MSHA score above the median of the least-disturbed sites (MSHA>66)

Fair: MSHA score between the median of the least-disturbed sites and the median of the most-disturbed sites (45 < MSHA < 66)

Poor: MSHA score below the median of the most-disturbed sites (MSHA<45)

The MADRAS index, which measures geomorphic stability of man-made ditches and channelized natural streams, provided additional geomorphic information. Low MADRAS scores indicate greater geomorphic stability. MADRAS scores in the Grand Marais Creek watershed averaged 14.3 out of 60 which indicates the channels were fairly stable overall (Table 3). Bank condition, bank angle, scour, and road crossing scores averaged 2 out of 8 indicating good stability. Bed deposition scores averaged 2.1 out of 12, while channel slope scores averaged 3.2 out of 8.

Table 3. MADRAS summary of scores (21 sites in Grand Marais Watershed).

Variable	Avg. score	Scale*	Relationship to geomorphology and biotic stressors
Left Bank Condition	1.9	0 - 8	Slumping banks add to sediment load
Right Bank Condition	1.8	0 - 8	Slumping banks add to sediment load
Bed Deposition	2.1	0- 12	May cause embeddedness of streams reducing invertebrate IBI
Channel Slope	3.2	0 - 8	Flatter slope leads to deposition and lower IBI
Bank Angle	2.0	0 - 8	Higher bank angles are more erosion-prone
Scour	2.0	0 - 8	Bed scour may destabilize channel
Road Crossing	1.5	0 - 8	Perched Culverts or bridges may be indicative of stable or unstable conditions. Very old bridges are indicative of stable hydrology
Total	14.3	60	

*Low MADRAS scores indicate greater geomorphic stability.

Rosgen Stream Classification

Rosgen stream classification showed that most streams were either ditched or Type E and C streams with a fine sediment bed and therefore were classified as types E5-E6 and C5-C6 (Table 4). Fifty percent of the channels (7 out of 14) were entrenched to moderately entrenched with ratios ranging from 1.4 to 2.2. Eight sites had very low sinuosity values (1.0; indicating a straight channel with no meanders) while four streams had moderate sinuosity values (1.2 – 1.5) while one stream had high sinuosity values (1.5; indicating a sinuous channel with meanders). The appendix of this report includes summaries for each of the stream segments for which Rosgen stream classification data were collected.

In-stream hydraulics are indicative of a low energy ditch system where the channel is over-widened and there is not enough flow energy to transport all the sediment. The bankfull shear stress was low in most streams ranging between 0.01 to 0.17 lbs/ft². These conditions favor sediment aggradation.

Most of the streams were ditches that were technically Rosgen type B6c with little ecological value or floodplain function. While their entrenchment ratio and sinuosity level are similar to B types, their slope is much flatter so that the ditches don't fit neatly into any Rosgen category. Several of the natural stream survey locations on Grand Marais Creek and Brandt Creek were classified as E type streams. In addition, some of the ditches have developed into a more sinuous E type channel with floodplain benches that have developed within the larger, dredged trapezoid. This natural channel evolution process of re-meandering can be accelerated by the construction of 2-stage ditches.

Table 4. Rosgen Stream Assessment Data

Stream name (-AUD)	Type	Entrench. Ratio	W:D Ratio	Bed Traits	Discharge	Bankfull Shear Stress	Sinuosity
#5: Brandt Creek (-509)	E5-E6	14.3	11.3	silt /clay	100**	0.08	1.3
#6: Brandt Creek (-509)	E5	27.6	8.4	silt	57	0.11	1.6
#7: Brandt Creek (-509)	C	8.6	28.8	silt	58	0.12	1.4
#1: CD-2 (-515)	Ditch (E6)	2.1	10.7	silt /clay	204	0.02	1
#3: CD-2 (-515)	Ditch (Bc)	2.0	5.5	silt	79	0.01	1
#23: CD-44* (-516)	C4	5.9	16.3	gravel	26	0.07	1.3
#2: GMC (-512)	E6	8.9	17.2	clay	311	0.10	1.5
#11: GMC (-507)	E6	1.3	18.8	clay	12.2	0.01	1.2
#20: CD-7 (-518)	Ditch (B6c)	1.7	10.1	clay	231	0.14	1
#21: JD-1 (-519)	Ditch (B6c)	1.8	20.0	silt	640	0.12	1
#22: JD-1 (-519)	Ditch (B6c)	1.4	19.2	silt	186	0.03	1
#15: JD-75 (-520)	Ditch (B6c)	2.0	9.5	silt	682	0.13	1
#16: JD-75 (-517)	Ditch (E6)	3.1	10.0	silt	198	0.12	1
#19: JD-75 (-517)	Ditch (E6)	2.0	10.4	gravel	33	0.17	1

Sediment Sources in Streams

Overall estimates of streambank erosion from the BANCS equations were in the low to moderate range for most stream reaches surveyed. The bank erosion hazard index (BEHI) scores were generally low to moderate while the near bank shear stress (NBS) scores were typically low. Most of the small ditches in headwaters are very stable with low bank erosion rates (see Table 3 – MADRAS scores). However following ditch maintenance, localized gullies may form on the interface of the field and ditch due to the steepened gradient following removal of sediment from the streambed. Many of the ditches then act as sediment sinks for years after they have been dredged for maintenance as they aggrade or accumulate sediment coming from farm fields, gullies and other sources (Landwehr and Rhoads 2003)

Sediment source studies have shown field erosion to be the dominant source of sediment in small streams of this region (EOR 2009 and Lauer et al. 2006). Gully erosion is another likely pathway for sediment movement that has characteristics of field and channel erosion. Gullies have concentrated flow occurring in a narrow channel that often originates in farm fields. Aside from sheet, rill, and gully erosion driven by water, wind erosion is considered to be important in the flat, open Red River basin particularly during the late fall after crop harvest when soils are bare and dry.

Additional Data Collected During Field Surveys

Water quality data

Forty-six percent of the survey sites (11 out of 24) had no streamflow on August 28, 2013 while three sites had flows that were too low to measure, typical of intermittent streams. Of the ten sites that did have flow, water temperatures were moderate to high for fish tolerance ranging from 20-25 degrees C. Dissolved oxygen (DO) was low ranging from 0.11 to 6.29 mg/liter in the ten sites that had stream flow at the time of measurement. Only three of the ten sites had DO values above the 5.0 mg/liter standard for warm- or cool water fishery streams in Minnesota. Considering all physical and water quality parameters, only three of 24 sites had conditions suitable for fish life at the time of survey.

Stream geomorphology in the Grand Marais Creek Watershed influences water quality in numerous ways. Ditch over-widening tends to result in higher in-stream summer temperatures. Increased width relative to depth increases the average temperature throughout the water profile. There is also a lack of vegetative or other cover such as wood or bank overhangs as shown in the MSHA scores. There is a lack of deep pools, as shown in the longitudinal profile surveys, eliminating refugia for fish from high summer temperatures and low DO. Entrenchment limits connectivity to floodplain wetlands where some fish and invertebrates could find refuge. These areas could have formerly resupplied the streams with invertebrates after extended low-flow or drought periods. Now that this connection is largely cutoff, entrenchment likely contributes to reduced invertebrate IBI and overall productivity which in turn impacts fish IBI and productivity.

DISCUSSION

Connecting Geomorphic Variables to Aquatic Biota in the Grand Marais Creek Watershed

Sediment issues that contribute to the health of biotic communities include excess fine sediment that buries existing coarse bed substrates and increases turbidity. The turbidity is more prevalent in the lower reaches of Grand Marais Creek and the Red River itself than in headwaters reaches.

The most widespread impact on channel stability in the watershed is likely ditch maintenance. By over-widening the area within the ditch, many of them act as sinks for sediment until they are dredged again (Landwehr and Rhoads 2003), keeping them in a constant state of disequilibrium. The removal of sediment also increases the slope between the field and the ditch re-instigating local headcutting of field gullies into the ditch.

Connectivity between the lower Grand Marais Creek and the headwaters is poor due to intermittent flow preventing access in late summer to fall preventing fish and invertebrates access to “refugia” during periods of low flow. This might make it more difficult for fish and invertebrates to survive due to the lack of flow and poor stream bed conditions (i.e. lack of water and coarse bed materials). Lack of lateral connectivity to wetlands that have since been mostly drained may also be a contributing stressor for aquatic life. Wetlands would have provided habitat adjacent to streams for invertebrates over long time periods. The current channel geometry and connectivity contributes to low oxygen (DO) and impairment in headwaters reaches from the Headwaters to County Ditch 2. Low DO is a consequence of biological oxygen demand (BOD) which is worsened in over-widened ditches with shallow, warm water. In addition, vertical connection to groundwater fed hyporheic zones may also impact invertebrate populations. A hyporheic zone that stays wet in the summer with good interstitial space (i.e., gravely with coarse materials) would provide habitat for invertebrates to burrow into at low flow. Yet only 2 -3 % of the watershed has type A or A/D (sandy) soils that would typically have coarse substrates. Much of the watershed is comprised of lake bed clays limiting the availability of invertebrates to burrow into ground and survive through droughts.

Management Implications

Geomorphic and hydrologic management could improve conditions for fish and aquatic life in the Grand Marais Creek Watershed. With intermittent flow, a greater abundance of deep pools and variable stream depths in otherwise homogenous ditches would be beneficial to biota. Sediment sources to streams are thought to come mostly from fields in flat watersheds of the Red River basin with low streambank heights. Much of the field erosion likely occurs in gullied areas during high flows. Therefore control of field and gully erosion, both water and wind-driven, are important for stream health in this region. Data were collected in the field that made a visual estimation of the distance between the stream survey point and a wind-blocking stand of trees. This estimate was made in all directions at each

survey point and could guide future restoration projects that prevent wind-blown sediment from entering the stream and ditch channels.

Interrelationships between water quality and geomorphology suggest that stream geometry could be managed to promote lower water temperatures and higher DO levels. This could be done by allowing channelized streams to form more natural meandering stream that is narrow but deep (an E type channel) within the larger ditch trapezoid or constructing 2-stage ditches.

Connectivity could be improved both longitudinally and laterally. Laterally, two-stage ditches, either constructed or self-forming, allow for re-establishment of floodplain function in this intensively drained landscape. Longitudinally, fish blockages at dams and culverts could be modified to allow for aquatic life passage. Finally the reintroduction of large wood pieces (root wads or engineered logjams) could help improve invertebrate productivity by creating more surfaces for colonization and a variety of stream depths and velocities that are also beneficial to fish (Dolph 2012).

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APPENDIX A: STREAM SUMMARIES

REACH INFORMATION	
AUID	09020306-515
Stream/River	CD2
County	Polk
Drainage Area	104.0 sq. mi.
Date	8/26/13
Field/Site ID	1
Bio Monitoring	05RD098
MSHA Score	19

GEOMORPHIC SUMMARY	
Channel Type	Ditched (E6)
Est. Bankfull El.	809'
Channel Slope	0.015%
Sinuosity	1.0
Bankfull Width	27.6'
W/D Ratio	10.7
Material (D50)	0.06 mm
BEHI Rating	Moderate
NBS Rating	Moderate
MADRAS Score	15
Pfankuch Score	118 (Poor)



NOTES & OBSERVATIONS: As with many ditched systems, low instream habitat was observed throughout the study reach. This particular site was near dry during the assessment. A few stream features indicate that a small “E” channel is beginning to develop between the ditch banks.

REACH INFORMATION	
AUID	09020306-507
Stream/River	Grand Marais Crk
County	Polk
Drainage Area	184.5 sq. mi.
Date	8/27/13
Field/Site ID	2
Bio Monitoring	No
MSHA Score	33

GEOMORPHIC SUMMARY	
Channel Type	E6
Est. Bankfull El.	805.1'
Channel Slope	0.056%
Sinuosity	1.5
Bankfull Width	17.0'
W/D Ratio	17.2
Material (D50)	0.06 mm
BEHI Rating	Low
NBS Rating	Low
MADRAS Score	10
Pfankuch Score	61 (Good)



NOTES & OBSERVATIONS: This reach contains an “E” channel winding through a wide, low gradient historic channel. An accessible floodplain and well-vegetated stream banks limit bank erosion potential. This site was dry during the assessment.

REACH INFORMATION

AUID	09020306-515
Stream/River	CD2
County	Polk
Drainage Area	90.8 sq. mi.
Date	8/26/13
Field/Site ID	3
Bio Monitoring	12RD100
MSHA Score	31

GEOMORPHIC SUMMARY

Channel Type	Ditched (Bc)
Est. Bankfull El.	827.0'
Channel Slope	0.009%
Sinuosity	1.0
Bankfull Width	19.9'
W/D Ratio	5.5
Material (D50)	0.06 mm
BEHI Rating	Moderate
NBS Rating	Low
MADRAS Score	15
Pfankuch Score	125 (Poor)



NOTES & OBSERVATIONS: Similar to Site 1, this ditch contains dense vegetation that protects the channel and banks during flood events. Very little instream habitat exists in this ditch (i.e. lack of defined riffles, pools, no instream woody debris).

REACH INFORMATION

AUID	09020306-509
Stream/River	Brandt Creek
County	Polk
Drainage Area	23.3 sq. mi.
Date	8/27/13
Field/Site ID	5
Bio Monitoring	No
MSHA Score	N/A

GEOMORPHIC SUMMARY

Channel Type	E5
Est. Bankfull El.	886.6'
Channel Slope	0.07%
Sinuosity	1.3
Bankfull Width	21.1'
W/D Ratio	11.3
Material (D50)	0.08 mm
BEHI Rating	Low/Moderate
NBS Rating	Moderate
MADRAS Score	N/A
Pfankuch Score	81 (Fair)



NOTES & OBSERVATIONS: This study site occurs within the restored reach of Brandt Creek. Two beaver dams were documented within the reach, but the site was dry during the assessment. Limited pool and riffle structure was observed at this site.

REACH INFORMATION

AUID	09020306-509
Stream/River	Brandt Creek
County	Polk
Drainage Area	19.4 sq. mi.
Date	8/27/13
Field/Site ID	6
Bio Monitoring	No
MSHA Score	34

GЕOMORPHIC SUMMARY

Channel Type	E5
Est. Bankfull El.	895.0'
Channel Slope	0.13%
Sinuosity	1.55
Bankfull Width	14.6'
W/D Ratio	8.4
Material (D50)	0.08 mm
BEHI Rating	Low/Moderate
NBS Rating	Low/Very Low
MADRAS Score	13
Pfankuch Score	75 (Good)



NOTES & OBSERVATIONS: This reach is located immediately downstream of the impoundment in the restored segment of Brandt Creek. Similar to Site 5, the lack of water greatly affects available instream habitat for aquatic organisms.

REACH INFORMATION

AUID	09020306-509
Stream/River	Brandt Creek
County	Polk
Drainage Area	16.5 sq. mi.
Date	8/28/13
Field/Site ID	7
Bio Monitoring	No
MSHA Score	N/A

GЕOMORPHIC SUMMARY

Channel Type	C
Est. Bankfull El.	918.0'
Channel Slope	0.22%
Sinuosity	1.38
Bankfull Width	25.9'
W/D Ratio	28.8
Material (D50)	0.06 mm
BEHI Rating	Very Low
NBS Rating	Very Low
MADRAS Score	N/A
Pfankuch Score	62 (Good)



NOTES & OBSERVATIONS: This reach is located immediately upstream of the impoundment. The dense vegetation in this reach protects the banks from channel and bank erosion.

REACH INFORMATION

AUID	09020306-507
Stream/River	Grand Marais Creek
County	Polk
Drainage Area	27.2 sq. mi.
Date	8/26/13
Field/Site ID	9
Bio Monitoring	No
MSHA Score	30

GEOMORPHIC SUMMARY

Channel Type	N/A
Est. Bankfull El.	831.0'
Channel Slope	N/A
Sinuosity	3.02
Bankfull Width	N/A
W/D Ratio	N/A
Material (D50)	0.06 mm
BEHI Rating	Very Low
NBS Rating	Very Low
MADRAS Score	19
Pfankuch Score	N/A



NOTES & OBSERVATIONS: This reach is located near the headwaters of Grand Marais Creek. The study reach consisted of a sinuous, shallow, flow-through cattail marsh with no identifiable bankfull indicators; therefore, classification could not be completed for this site.

REACH INFORMATION

AUID	09020306-507
Stream/River	Grand Marais Crk
County	Polk
Drainage Area	51.5 sq. mi.
Date	8/26/13
Field/Site ID	10
Bio Monitoring	No
MSHA Score	21

GEOMORPHIC SUMMARY

Channel Type	N/A
Est. Bankfull El.	N/A
Channel Slope	N/A
Sinuosity	1.8
Bankfull Width	N/A
W/D Ratio	N/A
Material (D50)	0.06 mm
BEHI Rating	Very Low
NBS Rating	Very Low
MADRAS Score	1
Pfankuch Score	94 (Fair)



NOTES & OBSERVATIONS: Similar to Site 9, this reach consisted of a shallow, flow-through cattail marsh with no identifiable bankfull indicators; therefore, classification could not be completed for this site. The shallow-sloped, well-vegetated banks limit the erosion potential in this reach.

REACH INFORMATION

AUID	09020306-507
Stream/River	Grand Marais Creek
County	Polk
Drainage Area	61.4 sq. mi.
Date	8/26/13
Field/Site ID	11
Bio Monitoring	No
MSHA Score	17

GEOMORPHIC SUMMARY

Channel Type	E6
Est. Bankfull El.	821.6'
Channel Slope	0.031%
Sinuosity	1.2
Bankfull Width	11.5'
W/D Ratio	18.8
Material (D50)	0.06 mm
BEHI Rating	Low
NBS Rating	Low
MADRAS Score	1
Pfankuch Score	79 (Fair)



NOTES & OBSERVATIONS: Similar to Site 2, a small “E” channel is developing within the wide, low-gradient historic channel. An accessible floodplain and dense vegetation protect the stream banks during flood events. This site was dry during the assessment and little instream habitat was observed.

REACH INFORMATION

AUID	09020306-520
Stream/River	JD 75
County	Polk
Drainage Area	105.8 sq. mi.
Date	8/29/13
Field/Site ID	15
Bio Monitoring	12RD098
MSHA Score	27

GEOMORPHIC SUMMARY

Channel Type	Ditched (B6c)
Est. Bankfull El.	806.9'
Channel Slope	0.073%
Sinuosity	1.0
Bankfull Width	30.1'
W/D Ratio	9.5
Material (D50)	0.06 mm
BEHI Rating	Moderate
NBS Rating	Low
MADRAS Score	15
Pfankuch Score	69 (Good)



NOTES & OBSERVATIONS: A small “E” channel is beginning to develop between the ditch banks. Similar to other ditched systems, low instream habitat was observed throughout the study reach. Separate BEHI analyses were completed for two eroded banks measuring 71-foot long & 115-foot long and scored Moderate & High respectively.

REACH INFORMATION

AUID	09020306-517
Stream/River	JD 75
County	Polk
Drainage Area	64.5 sq. mi.
Date	8/28/13
Field/Site ID	16
Bio Monitoring	12RD087
MSHA Score	27

GEOMORPHIC SUMMARY

Channel Type	Ditched (E6)
Est. Bankfull El.	834.3'
Channel Slope	0.12%
Sinuosity	1.0
Bankfull Width	17.6'
W/D Ratio	10
Material (D50)	0.06 mm
BEHI Rating	Low
NBS Rating	Moderate
MADRAS Score	15
Pfankuch Score	62 (Good)



NOTES & OBSERVATIONS: A small “E” channel is beginning to develop within the ditch banks. A separate BEHI analysis was completed for a 156-foot long disturbed bank and scored Moderate. Very little instream habitat was observed in this ditch system.

REACH INFORMATION

AUID	09020306-517
Stream/River	JD 75
County	Pennington
Drainage Area	12.8 sq. mi.
Date	8/27/13
Field/Site ID	19
Bio Monitoring	07RD023
MSHA Score	N/A

GEOMORPHIC SUMMARY

Channel Type	Ditched (E6)
Est. Bankfull El.	992.6'
Channel Slope	0.26%
Sinuosity	1.0
Bankfull Width	11.7'
W/D Ratio	10.4
Material (D50)	20.0 mm
BEHI Rating	Moderate
NBS Rating	Low
MADRAS Score	N/A
Pfankuch Score	58 (Good)



NOTES & OBSERVATIONS: Unlike most sites assessed in the watershed, this reach contains a well-defined riffle/pool sequence with a coarse substrate. An “E4” channel is developing between the ditch banks and contains a small bankfull bench. This stream occurs within the beach ridge.

REACH INFORMATION

AUID	09020306-518
Stream/River	CD7
County	Polk
Drainage Area	18.2 sq. mi.
Date	8/28/13
Field/Site ID	20
Bio Monitoring	No
MSHA Score	18

GEOMORPHIC SUMMARY

Channel Type	Ditched (B6c)
Est. Bankfull El.	829.6'
Channel Slope	0.13%
Sinuosity	1.0
Bankfull Width	18.4'
W/D Ratio	10.1
Material (D50)	0.06 mm
BEHI Rating	Low
NBS Rating	Low
MADRAS Score	15
Pfankuch Score	57 (Good)



NOTES & OBSERVATIONS: This site was dry during the assessment and very little instream habitat was observed. A separate BEHI analysis was completed for a 40-foot long disturbed bank and was scored Moderate.

REACH INFORMATION

AUID	09020306-519
Stream/River	JD 1
County	Polk
Drainage Area	57.7 sq. mi.
Date	8/29/13
Field/Site ID	21
Bio Monitoring	No
MSHA Score	18

GEOMORPHIC SUMMARY

Channel Type	Ditched (B6c)
Est. Bankfull El.	803.4'
Channel Slope	0.086%
Sinuosity	1.0
Bankfull Width	44.4'
W/D Ratio	20.0
Material (D50)	0.06 mm
BEHI Rating	Low
NBS Rating	Moderate
MADRAS Score	15
Pfankuch Score	53 (Good)



NOTES & OBSERVATIONS: As with of most ditched systems, typical stream features (i.e. riffles, pools, point bars, bankfull bench) were not observed in this ditch. The site was dry during the assessment.

REACH INFORMATION

AUID	09020306-519
Stream/River	JD 1
County	Polk
Drainage Area	32.5 sq. mi.
Date	8/28/13
Field/Site ID	22
Bio Monitoring	No
MSHA Score	22

GEOMORPHIC SUMMARY

Channel Type	Ditched (B6c)
Est. Bankfull El.	819.9'
Channel Slope	0.023%
Sinuosity	1.0
Bankfull Width	34.8'
W/D Ratio	19.2
Material (D50)	0.06 mm
BEHI Rating	Low
NBS Rating	Low
MADRAS Score	15
Pfankuch score	52 (Good)



NOTES & OBSERVATIONS: Intermittent shallow pools of water were observed in this reach. The dense vegetation protects the channel and ditch banks during flood events.

REACH INFORMATION

AUID	09020306-516
Stream/River	CD 44
County	Polk
Drainage Area	3.4 sq. mi.
Date	8/27/13
Field/Site ID	23
Bio Monitoring	No
MSHA Score	59

GEOMORPHIC SUMMARY

Channel Type	C4
Est. Bankfull El.	938.0'
Channel Slope	0.11%
Sinuosity	1.3
Bankfull Width	16.2'
W/D Ratio	16.3
Material (D50)	23.0 mm
BEHI Rating	Low
NBS Rating	Moderate
MADRAS Score	11
Pfankuch Score	56 (Good)



NOTES & OBSERVATIONS : This reach occurs below a control structure for an impoundment. The stream channel appears to have been recently modified as indicated by excavator marks on the banks. This stream is located within the beach ridge and contains a gravel substrate. Separate BEHI analyses were completed for two eroded banks measuring 100-feet long and 30-feet long and scored Moderate and High respectively.