Knife River Implementation Plan for Turbidity

Total Maximum Daily Load

Anglers along the Knife River at spring water levels

Prepared by:
South St. Louis Soil and Water Conservation District

In conjunction with:
Knife River Forestry Stewardship Committee

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Preface

This implementation plan was written by the South St. Louis Soil and Water Conservation District (SWCD), with the assistance of the Knife River Stewardship Committee and guidance from the Minnesota Pollution Control Agency, based on the report *Total Maximum Daily Load Study of Turbidity on the Knife River Watershed*. The primary authors of the plan were Nathan Schroeder and Kate Kubiak (South St. Louis SWCD) with assistance from Greg Johnson (MPCA). Knife River Stewardship Committee members who participated in implementation plan discussions include:

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1. Introduction

The Knife River on the North Shore of Lake Superior has a unique character influenced most by historical human activities and distinct hydrologic qualities. The river's watershed was heavily logged in the past. This upland clearing, combined with the area's bedrock, makes the Knife a flashy, turbid river despite its cold water fishery. Fortunately, many agencies and citizens have long been involved with improving conditions in the Knife. The Knife River Implementation Plan for Turbidity TMDL represents a collaborative effort to identify, prioritize, budget and plan for future activities to reduce turbidity in the river.

Future development of restoration priorities and strategies should follow a natural channel design process. Activities in this implementation plan are coordinated to re-establish the general structure, function and self-sustaining behavior of the stream system. This holistic process requires an understanding of the physical and biological components of the stream system and its watershed, as well as the collaboration of public and private landowners and agencies who are its stewards.

2. TMDL Report Summary

A Total Maximum Daily Load study was completed for turbidity in the Knife River in 2010. The purpose of the Knife River Turbidity TMDL Study was to identify the amount of turbidity-causing pollutants that can be in the water and still meet the water quality standard for turbidity. The TMDL Study also described the sources and amounts of pollutants causing turbidity in the river and identified an initial strategy to achieve the water quality standard by reducing sediment loads to meet the source allocations. TMDLs are required under Section 303(d) of the Clean Water Act. The Knife River Turbidity TMDL Study was approved by the U.S. Environmental Protection Agency (EPA) on July 2, 2010. The approved TMDL Report can be found on the Minnesota Pollution Control Agency (MPCA) web site at: http://www.pca.state.mn.us/index.php/water/water-types-and-programs/minnesotas-impaired-waters-and-tmdls/tmdl-projects/lake-superior-basin-tmdl-projects/project-knife-river-turbidity.html

2.1. Project History

The TMDL Study included a comprehensive monitoring study carried out between 2004 and 2006 followed by data analysis and a group effort to interpret the results. The three years of water quality monitoring included four stations that recorded continuous data (temperature, conductivity, turbidity, DO, pH and stage). This continuous data was coupled with bi-weekly grab and storm event samples that were analyzed in a lab for TSS. Two additional monitoring efforts were also completed. The Natural Resources Research Institute (NRRI) completed sampling and analysis for macroinvertebrates in the Knife River watershed streams. The University of Minnesota Department of Bioproducts

and Biosystems Engineering completed a study of stream bank and bluff erosion in the watershed. Development of the TMDL and load allocations along with the other required elements of a TMDL report was begun in late 2006 and completed in spring 2010.

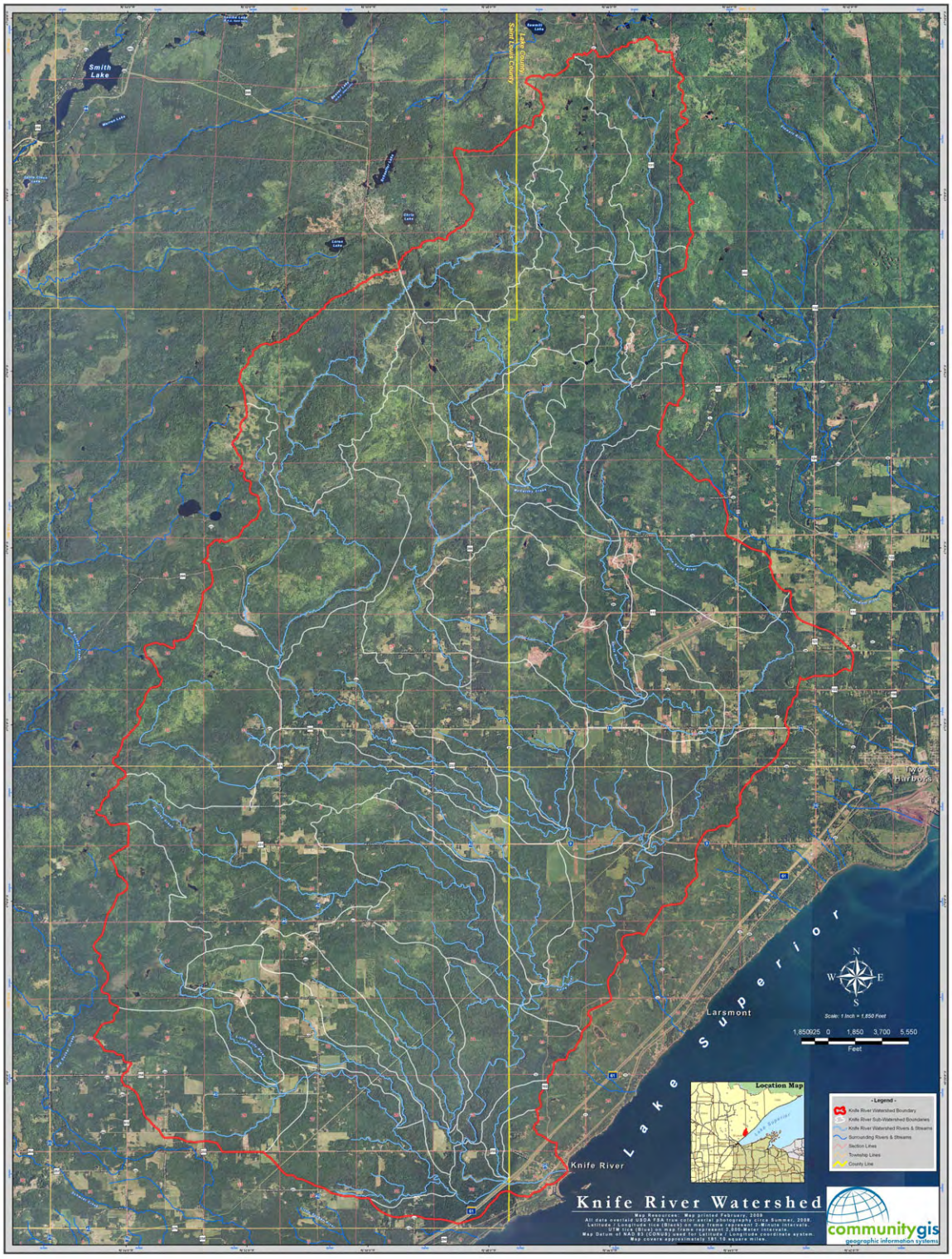
The TMDL Study was the most recent activity in a history of conservation efforts in the Knife River Watershed. The Knife River Watershed is an important resource for Lake Superior fisheries in that it provides a large portion of the spawning and fish rearing habitat for steelhead and other cold water game fish. The Knife River Forest Stewardship Committee and the Knife River Watershed Education Project have implemented projects "to minimize and/or prevent soil erosion and sedimentation in the Knife River Watershed, which directly impacts Lake Superior, and thus protect and improve water quality as well as wildlife and fish habitat" since 1991. These efforts have dwindled in the last few years, but the practices implemented by this group are continuing to have impacts on the Knife River watershed. Through past efforts, approximately 1,700 trees were planted on public and private land, riparian areas were planted and stabilized, GIS layers were created for use in planning and management activities, a newsletter was disseminated to more than 600 residents and almost 10,000 acres of private land in the watershed were enrolled under a forest stewardship plan.

2.2. Watershed Description

The Knife River watershed is a heavily forested watershed along the North Shore of Lake Superior, 15 miles northeast of Duluth, MN (Figure 2.1). Much of the Knife River flows along the St. Louis and Lake County border. The watershed is mostly upland deciduous forest (71%). The rest of the watershed consists of rural residential and some pasture land. Much of the land is owned and managed by the State of Minnesota, St. Louis County and Lake County. The headwaters begin in a sparsely populated and heavily forested area more than 25 river miles from the confluence. Two of the three main tributaries (Stanley Creek and the West Branch Knife River) also begin in this sparsely populated, forested region. The third main tributary, the Little Knife River, begins in a slightly more "developed" area and enters the mainstem near the river's confluence with Lake Superior. The only large developed area is the Two Harbors municipal airport. There are also 80 miles of county and township roads within the watershed. The confluence with Lake Superior lies within the Village of Knife River, a small residential area with several small businesses and a post office. This village is the only concentrated residential area in the 86.3 square mile watershed.

The geology and soils of the watershed play significant roles in hydrology and turbidity of the river. The presence of clay soils in the lower part of the watershed is a dominant feature contributing sediment to the river. Like most North Shore streams, the Knife has limited baseflow. As reported in the TMDL Study, "Flows in the Knife River are notoriously flashy."

Figure 2.1. Map of Knife River Watershed



2.3. 303(d) List Impairments

The Knife River was first listed as impaired on Minnesota's 1998 and again on the 2002 303(d) Lists for turbidity and pH, respectively. The Little East Branch Knife River was subsequently listed for turbidity and low dissolved oxygen in 2008. Table 2.1 provides the 303(d) listing details.

Table 2.1. Minnesota 303(d) listings in the Knife River watershed

Stream	Reach Name	Year Listed	Assessment Unit ID	Affected Use	Impairment
Knife River	Headwaters to Lk Superior	1996	04010102-504	Aquatic Life	Turbidity
Knife River	Headwaters to Lk Superior	2002	04010102-504	Aquatic Life	pH
Little Knife River (East Branch Little Knife River	Unnamed Cr to Knife R	2008	04010102-840	Aquatic Life	Turbidity
Little Knife River (East Branch Little Knife River	Unnamed cr to Knife R	2008	04010102-840	Aquatic Life	Oxygen, Dissolved

The TMDL approved for the Knife River only addressed the original turbidity listing. The pH listing was evaluated for possible de-listing and the MPCA has postponed a decision for additional evaluation. The listings for the Little Knife River were not incorporated into the TMDL given the progress of the TMDL Study and questions regarding the size of the stream.

2.4. Turbidity Source Assessment

The TMDL Study included an assessment of the sediment sources contributing to the turbidity problems in the river. There are no wastewater treatment facilities in the watershed, so all sources in the watershed are related to erosion and sediment transport from various land areas. The assessment of sediment sources involved field measurements, modeling and analysis to estimate the loads coming from the various sources. The 2008 report, *Assessment of Stream Bank and Bluff Erosion in the Knife River Watershed Final Report*, by the University of Minnesota Department of Bioproducts and Biosystems Engineering documenting this assessment, is included as Appendix E of the TMDL (Nieber et al., 2008).

Table 2.2 provides estimates of the net sediment erosion (in tons) by source and reaches along the mainstem of the Knife River for three storm events modeled in the assessment report. The three storm events were selected from the TMDL monitoring results to represent a range of flow conditions. Storm Event #1 represented a small storm event (0.9

inches in 4.5 hours); Storm Event #2 represented a medium storm event (1.3 inches in 12 hours); and Storm Event #3 represented near bankfull flow storm event (1.7 inches in 24 hours). Tables 2.3 and 2.4 summarize the load estimates as percentages of mainstem reaches for each source and sources for each reach, respectively.

Table 2.2. Estimated net sediment loads (tons) by mainstem reaches

Storm Event #	Source	Reach 1	2	3	4	5	Total
1 .9" in 4.5 hrs.	Bank	40	49	-38	113	180	344
	Bluff	0	0	0	93	57	150
	Trib & Overland	20	2	16	18	12	68
	Reach Total	60	51	-22	224	249	562
2 1.3" in 12 hrs.	Bank	10	10	9	19	50	98
	Bluff	0	0	0	27	24	51
	Trib & Overland	4	0.4	4	3	3	13
	Reach Total	14	10	13	49	77	162
3 1.7" in 24 hrs.	Bank	2	2.4	4	1	13	22
	Bluff	0	0	0	5	18	23
	Trib & Overland	4	0.4	3	3	2	12
	Reach Total	6	3	7	8	33	57

As expected, sediment loading increases with larger storm events. The assessment modeling also predicted relative changes in the source of sediment entering the Knife River between the storms (Table 2.3). Tributary and overland erosion loading was estimated to generally be low (about 10 percent) compared to bank and bluff erosion, but did represent more than 20 percent of the load in the smallest storm (Storm #3). The relative increase in this contribution may be a result of flow levels not affecting bank and bluff erosion processes. A comparison of the tributary and overland loads by stream reach shows a somewhat larger influence of this source in the upper stream reaches compared to the lower reaches. This likely is a result of smaller stream banks and bluffs in the upper watershed.

Sediment loading from stream banks and bluffs was estimated to be much greater than tributary and overland loading for the middle and upper storm events. Stream bank erosion accounted for 61, 60 and 38 percent of the predicted sediment load in storms 1, 2 and 3, respectively. And, bluff erosion was estimated to provide 27, 32 and 40 percent of the predicted sediment load in the 3 storms, respectively. Combined, bank and bluff

erosion was predicted to provide nearly 88, 92 and 78 percent of the net sediment load to the Knife River for the modeled storms. Bank and bluff erosion was predicted to be the greatest in the lower stream reaches given the presence of open banks and bluffs, steeper slopes and red clay soils.

Table 2.3. Estimated net sediment loads (percent) by sources for each reach

Storm Event #	Source	Reach 1	2	3	4	5	Total
1 .9" in 4.5 hrs.	Bank	67	96	173	50	72	61
	Bluff	0	0	0	42	23	27
	Trib & Overland	33	4	-73	8	5	12
	Reach Total	100	100	100	100	100	100
2 1.3" in 12 hrs.	Bank	71	96	72	39	65	60
	Bluff	0	0	0	55	31	32
	Trib & Overland	29	4	28	6	3	8
	Reach Total	100	100	100	100	100	100
3 1.7" in 24 hrs.	Bank	35	86	51	12	38	38
	Bluff	0	0	0	56	55	40
	Trib & Overland	65	14	49	32	7	22
	Reach Total	100	100	100	100	100	100

The modeling results also provided estimated erosion contributions by five stream reaches along the mainstem of the river (Table 2.4). The per reach breakdown of the sources provides a picture of which areas along the mainstem of the Knife River contribute the most sediment to the river. Reaches 1 and 2 contributed a relatively small amount of net bank erosion, together yielding 26, 21 and 20 percent in storms 1, 2 and 3, respectively. Reach 3 was predicted to be the section of the channel where the most deposition was occurring in storm 1, but contributed 9 and 16 percent of the net bank erosion in storms 2 and 3, respectively. Reaches 4 and 5 were predicted to each provide 30 to 50 percent of the sediment loads for the smaller events with Reach 5 contributing nearly 60 percent of the total load for the largest storm.

Overall, Reaches 4 and 5, representing the channel length from the West Branch tributary confluence to the model end-point, contributed 84 percent, 78 percent and 73 percent of the total predicted net sediment load (all sources) at the model end-point for storms 1, 2 and 3, respectively. The distribution of bluffs also contributed to the dominance of Reaches 4 and 5: Reach 4 possesses nine type-1 bluffs and Reach 5, four. Reach 3 possesses eight type-2 bluffs but overall these bluffs produced relatively negligible

amounts of erosion and are not reported or discussed in this report. Reaches 1 and 2 possessed no bluffs at all.

Table 2.4. Estimated net sediment loads (percent) by mainstem reaches for each source

Storm Event #	Source	Reach 1	2	3	4	5	Total
1 .9" in 4.5 hrs.	Bank	12	14	-11	33	52	100
	Bluff	0	0	0	62	38	100
	Trib & Overland	29	3	24	26	18	100
	Reach Total	11	9	-4	40	44	100
2 1.3" in 12 hrs.	Bank	10	10	9	19	51	100
	Bluff	0	0	0	53	47	100
	Trib & Overland	30	3	27	21	19	100
	Reach Total	9	6	8	30	47	100
3 1.7" in 24 hrs.	Bank	9	11	16	5	59	100
	Bluff	0	0	0	20	80	100
	Trib & Overland	30	3	27	21	19	100
	Reach Total	10	5	12	14	59	100

The results of this study illustrate with reasonable confidence the proportional contributions of different sources of sediment in the Knife River watershed. In particular, eroding banks and bluffs present on the Knife River downstream of the West Branch and Stanley Creek tributaries, by means of two distinct but interrelated mechanisms (fluvial bank erosion and raindrop/overland flow erosion), contribute the majority of sediment as a result of significant flow events. It is in these reaches that bank and/or bluff stability efforts would provide the greatest net benefit. However, more comprehensive data collection should be undertaken in developing specific restoration plans. Specifically, in situ measurements of soil geotechnical properties as well as observed rates of bank and bluff retreat would be crucial to confirm and more accurately quantify the results presented by Nieber et al. (2008).

2.5. TMDL Goals

The purpose of the Knife River Turbidity TMDL was to identify the amount of sediment that can be carried in the river and still meet the water quality standard for turbidity. The TMDL, or "carrying capacity" for the river, is divided into two types of allocations and a margin of safety (MOS). Wasteload allocations (WLAs) are assigned for permitted point

sources of pollution including stormwater runoff. Load allocations (LAs) are assigned for sources of pollution not regulated by the National Pollutant Discharge Elimination System permit program. Table 2.5 provides the TMDL and allocations for total suspended solids as the surrogate parameter for turbidity.

Table 2.5. Knife River TMDL, allocations and margin of safety for TSS

Knife River Assimilative Capacity by Flow Zone					
All values in tons/day					
	High Flows	Moist Conditions	Mid-Range Flows	Dry Conditions	Low Flows
TMDL	5.300	0.860	0.270	0.120	0.043
WLA - Construction	0.030	0.004	0.002	0.001	0.001
WLA – Duluth Township MS4 (Permit # MS400134)	0.427	0.066	0.031	0.011	0.004
LA	2.243	0.344	0.165	0.058	0.021
MOS	2.600	0.450	0.072	0.050	0.017

3. Implementation Plan Goals and Objectives

3.1. Goals

The overall goal of the Knife River Turbidity TMDL Implementation Plan is to restore and protect the aquatic life of the Knife River. Specifically, it is to implement best management practices (BMPs) to reduce the sediment load to the Knife River to meet the state water quality standard for turbidity as defined by the TMDL. However, stream flow and temperature are also recognized as critical stressors to the aquatic life of the river. Fortunately, watershed management practices for sediment reduction will also address the critical stream flow and temperature issues affecting the cold water fishery of the river.

3.2. Objectives

The objectives of the plan are defined following a five-component framework for evaluating the health (quality) of a stream system that has been adopted by the Minnesota Department of Natural Resources (DNR) in their *Watershed Assessment Tool* (http://www.dnr.state.mn.us/watershed_tool/index.html). The five components are hydrology, connectivity, biology, geomorphology and water quality. Objectives are presented for each of the components below.

3.2.1. Hydrology

The objective is to attain a hydrologic regime that better supports geomorphic stability and ecological function by restoring or increasing stream base flows and reducing storm event flows to more closely resemble the hydrologic patterns of a non-impacted watershed.

To improve hydrologic function we plan to:

- Evaluate the feasibility of using floodplain oxbow channels and perched floodplain areas for increased infiltration and storage;
- Design and implement these projects, if feasible;
- Increase infiltration in areas impacted by development through storm-water management BMPs;
- Identify and implement temporary storage options (road ditches, headwater storage, residential and commercial retention ponds) to control the rate of stormwater runoff;
- Increase and manage the forest cover and health in the Knife River watershed to reduce and delay runoff to the river through increased storage of water; and
- Implement stormwater BMPs in developed areas.

3.2.2. Connectivity

The objective is to restore the connectivity in the watershed system, including longitudinally (fish passage and sediment transport in the stream), laterally (water and sediment movement and storage in the watershed and floodplain areas) and vertically (ground and surface water interactions).

To improve connectivity within the watershed we plan to:

- Identify stream crossings that block fish passage and/or are contributing sediment or channel instability to the streams;
- Design and implement alternative stream crossings to simulate a natural stream's dimension, pattern and profile;
- Control beaver and remove dams that prevent fish passage into viable spawning areas of the main stem Knife River and lower portions of its main tributaries; and
- Incorporate the hydrology and geomorphology objectives relative to floodplain water storage and stream stability.

3.2.3. Biology

The biological objective is to improve the ecological function of the stream ecosystem. Specific to the TMDL, the objective is to support the aquatic life use for cold-water fish designated by Minnesota's water quality standards (MN R. 7050). The objective will involve maintaining or enhancing the current fishery and improving the invertebrate community.

To foster biological health of the ecosystem we plan to:

- Evaluate the ecological condition of the stream and identify functional needs for the ecosystem (pools, riffles, habitat, temperature regimes, channel and bank stability, etc.);
- Improve fish habitat features, especially large woody features in the river and tributary streams; and
- Implement the objectives of the four other watershed system components.

3.2.4. Geomorphology

The objective is to restore and maintain channel stability of the Knife River and its tributaries, where necessary and feasible. Stability is defined as maintaining the dimension, pattern and profile of stream channels so that the channel neither aggrades or degrades over time and is able to transport its water and sediment.

To restore geomorphological features we will plan to:

- Assess the vertical and horizontal stability of the channel through the use of permanent channel markers (bank pins, scour chains, etc.) at key locations as presented in Level 3 channel assessment by Rosgen (2006);
- Identify areas needing grade control and/or bank stabilization work through the channel assessments; and
- Implement stream channel restoration techniques to stabilize eroding clay banks.

3.2.5. Water Quality

The water quality objective is to support aquatic life in a cold-water ecosystem by reducing sediment concentrations in the Knife River to meet the TMDL targets and by managing stream temperatures.

To improve water quality in the river we will to:

- Implement sediment control practices including stream bank stabilization and stormwater runoff BMPs;
- Integrate water quality activities with geomorphology activities;

- Plant trees, where necessary;
- Implement infiltration practices as described under the hydrology objectives; and
- Complete site specific evaluations of the effect of beaver dams on stream temperature to better understand the range of effects present as they relate to fish and beaver management.

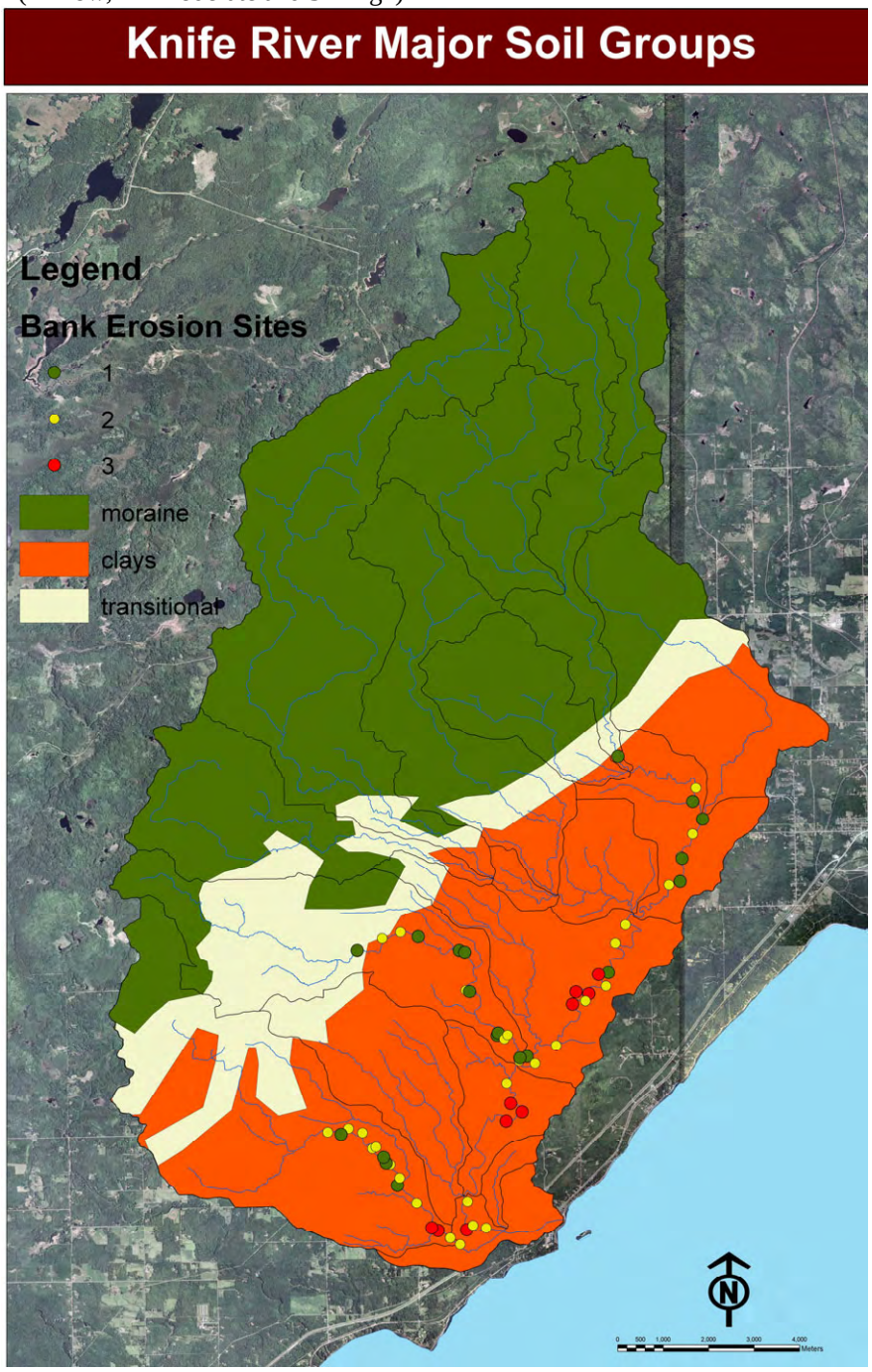
4. Identification of Priority Management Areas

With limited time, staff and funding resources for restoration efforts, it is important to target sediment reduction (and flow and temperature management) efforts to areas and pathways that are causing the greatest stresses on the aquatic life in the Knife River. The assessment report by the University of Minnesota (Nieber et al. 2008) identified the primary sources of sediment to be from stream banks and bluffs along the lower portions of the river; however, sediment from overland and upper tributary areas can account for ten to greater than 20 percent of the sediment carried in the river. While the location of the sediment sources is important, hydrologic pathways and processes in the watershed also must be considered in identifying priority management areas for the implementation plan.

The geology and resulting soils of the watershed are huge factors affecting the geographic location of the primary sediment sources eroding to the Knife River. The watershed can be split into three distinct areas of varying priority due to these characteristics. The approximate locations of the three areas are shown in Figure 4.1. The upper portion of the watershed is primarily glacial till material and contributes relatively little sediment to the river. The middle portion of the watershed is a transitional area composed of a mix of glacial till and lacustrine clay, contributing more sediment. The lower portion is mostly lacustrine clay with bedrock features, contributing the greatest sediment loads associated with the bank and bluff failures shown in the figure.

While the direct source of sediment is largely from the bank and bluff areas, the processes causing the erosion extend beyond the immediate location of the banks and bluffs. Stream flows likely increased following the historical logging of red and white pine trees and the resulting loss of the thick forest floor duff layer. Elevated stream flows would then be expected to cause added stream bank erosion. Continued bank erosion would be present with the destabilization of the stream channel with this historic change in hydrology. The dominance of aging aspen forests in the watershed also contribute to increased rates of surface runoff and lower rates of evapotranspiration and temporary subsurface water storage that increase the risk of bank and bluff erosion.

Figure 4. 1. General Geological Summary and Areas of Rated Bank Failure (1 – low, 2 – moderate and 3 – high)



Other sources of sediment include erosion from stormwater running off open fields, roads and ditches, construction areas and other developed areas. Although not dominant in the watershed, these sources are not insignificant and may be locally very important.

Given the sediment sources and hydrologic pathways present in the watershed, three types of priority management areas are described in this implementation plan. The first is

the actual source of much of the sediment eroded into the Knife River shown in Figure 4.1. The figure identifies the major bank and bluff erosion sites as well as the general vulnerability for erosion of the clay soils in the lower portion of the watershed. These areas should be the target of any direct channel, bank and/or bluff restoration work.

The second type of priority management area includes open areas that can be planted to a mix of evergreen and hardwood trees and aging aspen forests that can be sustainably managed to provide a healthy evergreen and mixed hardwood forest. The addition of evergreen trees and sustainable management of the forest in the watershed would eventually help reduce peak stream flows and provide increased base flows through temporary water storage. Figure 4.2 provides a GIS overview of the open areas in the watershed. Table 4.1 provides the acreage and percentage of the total area of open land in the Knife River and its sub-watersheds. The percentage of open lands potentially contributing to higher peak flows by quicker spring snowmelt and storm event runoff in each sub-watershed were ranked individually (Table 4.2) and by cumulative drainage area (Table 4.3) to provide a priority list of sub-watersheds to target for tree planting on open land. Figure 4.3 provides the ranking for the cumulative drainage areas of the watershed as four categories of open land. These figures and tables will be used to help prioritize reforestation efforts in open land areas. Priority areas for sustainable timber management on public lands should follow the St. Louis and Lake County Land Departments' plans.

The third type of priority management area includes those areas susceptible to direct upland soil erosion associated with human activities. These areas are associated with the open land areas shown in Figure 4.2 that have potential direct human-induced erosion features such as field tillage, impervious surface runoff and construction activities. They also encompass roads and ditches in the watershed that may directly erode or increase erosion from runoff from them.

Note: The tables and figures in this section can be used to prioritize projects, but should not be used to eliminate projects due to location constraints. The entire watershed should be considered when planning any type of project.

Figure 4.2. Open Land and Sub-Watersheds of the Knife River

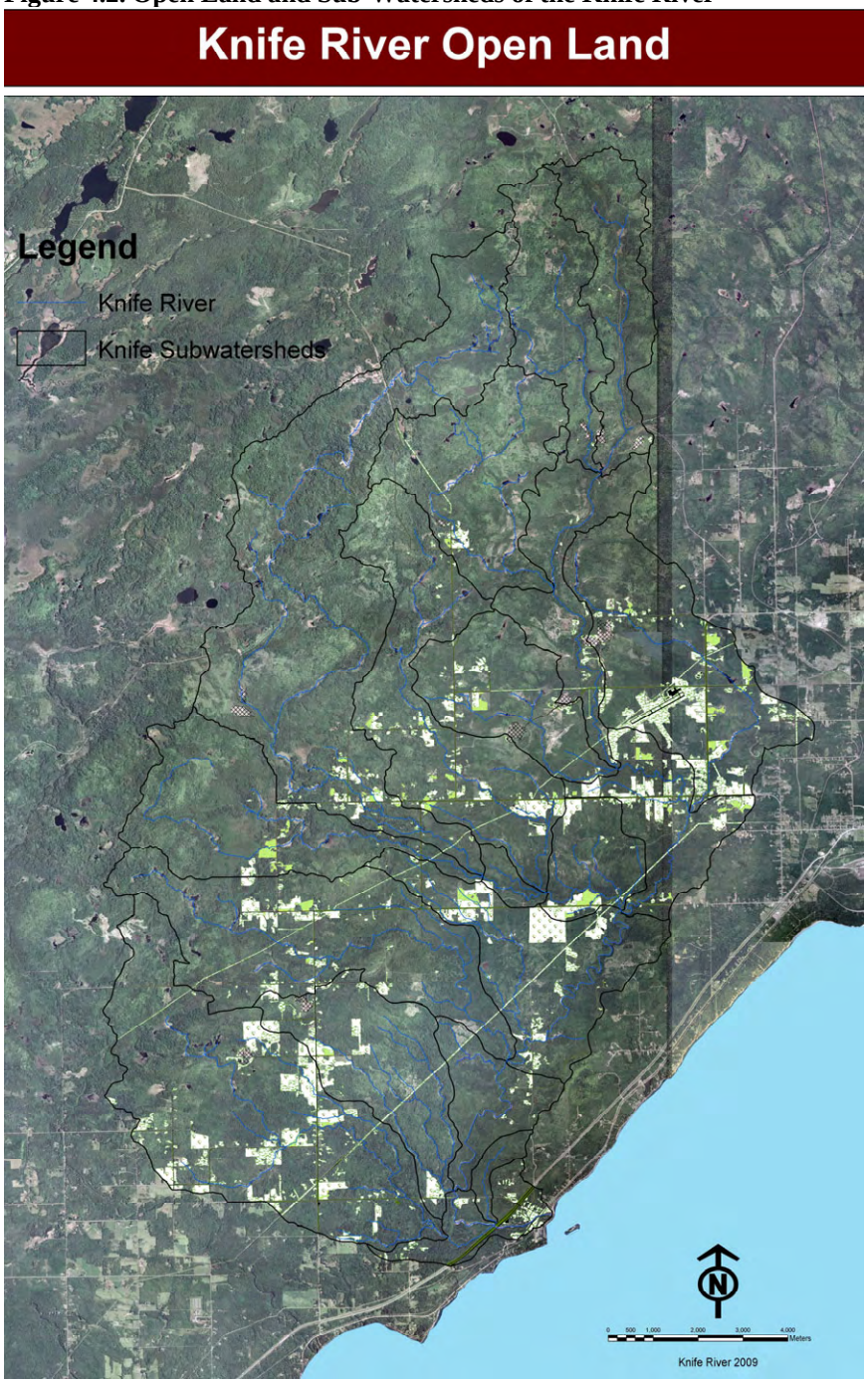


Table 4.1. Open land classification summary of entire watershed and by sub-watershed

(Top three sub-watersheds by percent for each category are highlighted in yellow)

Watershed	Agricultural Land	Percent	Grasslands	Percent	Gravel Pits	Percent	Non-open primarily forested	Percent	Pasture	Percent	Road Ditches	Percent	Roadway	Percent	Total	Percent of Watershed
Captain Jacobsen	16.68	0.51%	28.54	0.87%		0.00%	3158.48	96.70%	45.72	1.40%	10.46	0.32%	6.40	0.20%	3266.28	**5.91%**
Little East Knife	157.52	3.85%	389.49	**9.53%**	43.38	**1.06%**	3314.19	81.10%	61.81	**1.51%**	67.87	**1.66%**	52.22	**1.28%**	4086.50	**7.39%**
Little Knife	429.79	6.44%	303.45	4.55%	19.29	0.29%	5799.90	86.89%	15.07	0.23%	69.84	1.05%	37.41	0.56%	6674.76	**12.08%**
Little West Knife	140.35	3.28%	101.50	2.37%	3.50	0.08%	3918.71	91.55%	41.55	0.97%	53.60	1.25%	21.22	0.50%	4280.43	**7.75%**
Lower Main	9.48	1.08%	78.82	**8.98%**		0.00%	708.38	80.75%	0.64	0.07%	37.41	**4.26%**	42.51	**4.85%**	877.24	**1.59%**
Lower West Knife	87.98	**7.49%**	39.33	3.35%		0.00%	991.75	84.42%	29.40	**2.50%**	17.91	1.52%	8.36	**0.71%**	1174.74	**2.13%**
McCarthy Creek	28.72	0.91%	27.57	0.88%	6.88	0.22%	3054.94	97.27%	4.16	0.13%	11.76	0.37%	6.52	0.21%	3140.55	**5.68%**
Mid-Main Knife	0.32	0.02%	50.47	2.40%	19.37	**0.92%**	2014.61	95.85%		0.00%	8.13	0.39%	9.01	0.43%	2101.91	**3.80%**
Mid-Main 1	4.76	0.39%	19.48	1.61%		0.00%	1175.31	97.29%		0.00%	5.63	0.47%	2.93	0.24%	1208.11	**2.19%**
Mid-Main 2	282.68	**9.14%**	123.05	3.98%		0.00%	2623.19	84.85%	24.26	0.78%	28.10	0.91%	10.15	0.33%	3091.44	**5.59%**
Mid-Main 3	171.06	**9.45%**	178.02	**9.83%**	0.72	0.04%	1380.35	76.25%	45.39	**2.51%**	23.60	**1.30%**	11.26	0.62%	1810.39	**3.28%**
Mid-West Knife	6.76	2.49%		0.00%		0.00%	262.43	96.54%		0.00%	2.09	0.77%	0.56	0.21%	271.85	**0.49%**
Stanley Creek	140.46	2.91%	133.11	2.76%	1.07	0.02%	4465.25	92.59%	21.70	0.45%	42.65	0.88%	18.37	0.38%	4822.61	**8.73%**
Tributary 1		0.00%	1.33	0.52%		0.00%	253.96	**98.81%**		0.00%	1.07	0.42%	0.65	0.25%	257.01	**0.47%**
Tributary 2	143.53	5.45%	105.20	3.99%	14.70	0.56%	2340.31	88.87%	5.92	0.22%	14.77	0.56%	8.89	0.34%	2633.31	**4.77%**
Tributary 6	57.73	2.62%	48.53	2.20%	33.74	**1.53%**	2009.81	91.31%	14.02	0.64%	25.86	1.17%	11.32	0.51%	2201.01	**3.98%**
Tributary 9		0.00%	1.82	0.08%	14.45	0.66%	2163.68	**98.78%**		0.00%	5.18	0.24%	5.18	0.24%	2190.31	**3.96%**
Upper Main Knife		0.00%	4.16	0.19%	19.05	0.89%	2096.27	97.40%		0.00%	21.23	0.99%	11.59	0.54%	2152.30	**3.89%**
West Branch	58.60	0.65%	42.94	0.48%	28.66	0.32%	8819.18	**97.75%**	22.09	0.24%	33.21	0.37%	17.49	0.19%	9022.17	**16.33%**
Total	**1736.41**	**3.14%**	**1676.83**	**3.03%**	**204.80**	**0.37%**	**50550.71**	**91.47%**	**331.72**	**0.60%**	**480.38**	**0.87%**	**282.04**	**0.51%**	**55262.90**	

Table 4.2. Percent open area (score) and rank for individual sub-watersheds

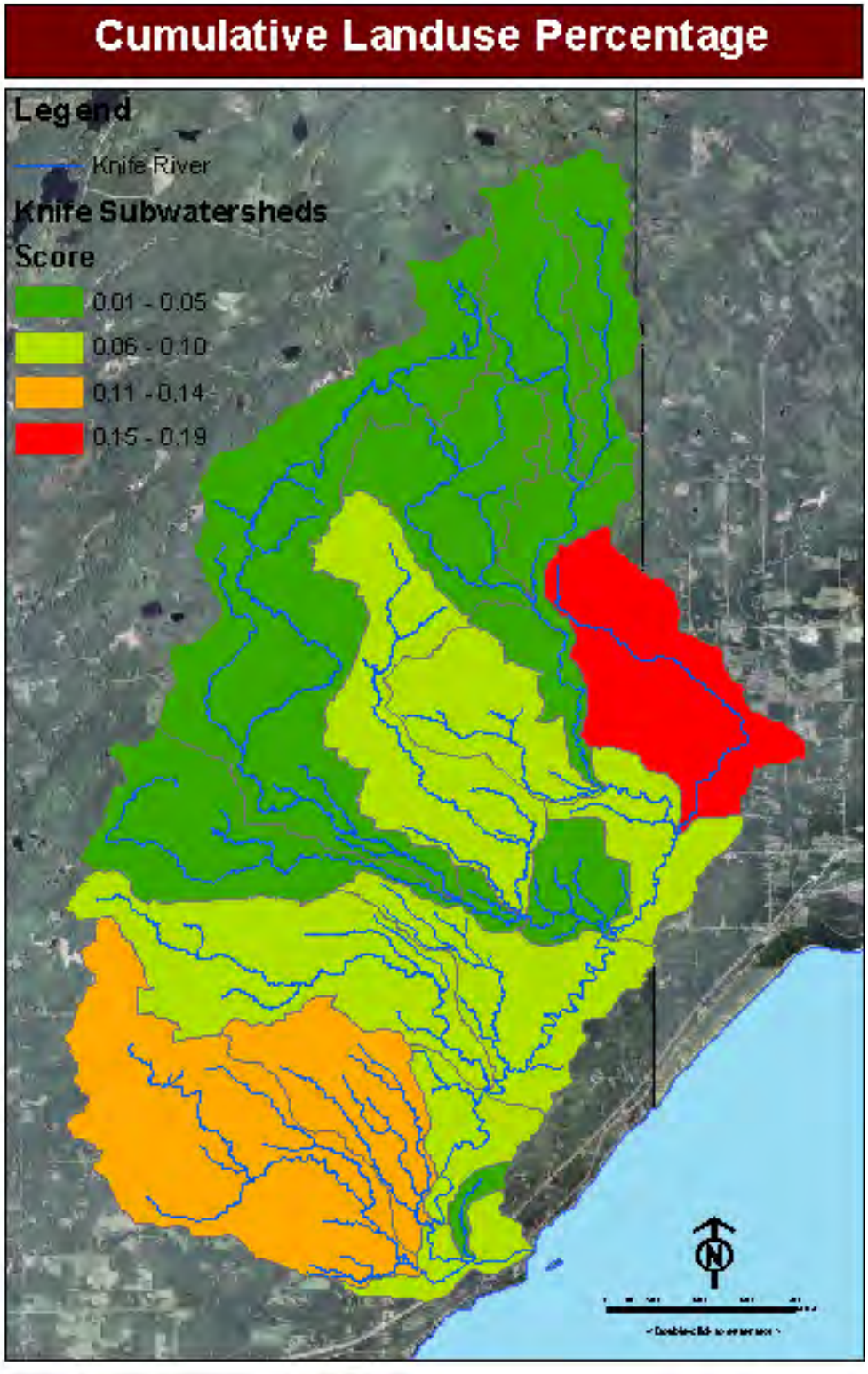
Watershed	Score	Rank
Mid-Main 3	0.24	1
Lower Main	0.19	2
Little East Knife	0.19	3
Lower West Knife	0.16	4
Mid-Main 2	0.15	5
Little Knife	0.13	6
Tributary 2	0.11	7
Tributary 6	0.09	8
Little West Knife	0.08	9
Stanley Creek	0.07	10
Mid-Main Knife	0.04	11
Mid-West Knife	0.03	12
Captain Jacobsen	0.03	13
McCarthy Creek	0.03	14
Mid-Main 1	0.03	15
Upper Main Knife	0.03	16
West Branch	0.02	17
Tributary 9	0.01	18
Tributary 1	0.01	19

Table 4.3. Cumulative open area, total acres, percent open area for Knife River sub-watersheds

(Sub-watersheds highlighted in yellow have upstream sub-watersheds contributing to them)

Subwatershed	Cumulative Open	Cumulative Acres	Percent
Little East Knife	776.72	4088	0.19
Little Knife	872.43	6711	0.13
Tributary #2	289.63	2633	0.11
Mid Main Knife 3	1654.8	17690	0.09
Tributary #6	198.09	2201	0.09
Lower Main Knife	4643.26	55356	0.08
Little West Branch	342.4	4280	0.08
Mid Main Knife 2	2936.61	38837	0.08
Mid Main Knife 1	3310.67	44871	0.07
Stanley Creek	337.82	4826	0.07
Lower West Branch	817.86	18054	0.05
McCarthy Creek	94.23	3141	0.03
Upper Main Knife	64.59	2153	0.03
Capt. Jacobsen	98.28	3276	0.03
Mid Main Knife 4	245.35	9590	0.03
Mid West Branch	287.46	12599	0.02
West Branch	181.02	9051	0.02
Tributary #9	21.94	2194	0.01
Tributary #1	2.57	257	0.01

Figure 4.3. Cumulative Percentage of Knife River Sub-Watersheds in Open Land



5. Best Management Practice Alternatives and Analysis

Several best management practices are available for use in the Knife River watershed to address the turbidity and other stressors (flow and water temperature) on aquatic life. The BMPs can largely be grouped into two categories, though their effects extend beyond their individual category. The first category involves land use and/or land cover changes to reduce soil erosion, decrease overland runoff and increase infiltration of precipitation and subsequently subsurface water contributions to the river. Best management practices in this category include tree planting, riparian area management and stormwater runoff controls. The second category involves direct reduction of sediment erosion from stream banks and bluffs through restoration activities designed to improve the stability of the stream channel, banks and flood plain. Specific BMPs for each category are listed and described in this section.

In identifying individual BMPs to implement, consideration was given to the site location, type of priority area present and the linkage of each aspect to the goals and objectives for the watershed. The number, size, location and timing of the BMPs will depend on several factors, including more data, funding, private landowner interest, local and state agency staff resources and volunteers.

While overall BMP prioritization for the watershed is described in Section 4, detailed surveys, inventories and evaluations of watershed conditions should be completed to more specifically prioritize BMPs and locations for implementation. This additional work is described in BMPs listed in 5.4, Survey, Inventory and Analysis Activities. Individual BMP descriptions indicate priority areas to the degree they are known at this time.

Estimating the effects on sediment reduction of these BMPs can be done with varying accuracy, depending on existing data and on the type of activity. As indicated in the Knife River Turbidity TMDL Study, “An important step in the implementation process will be on-going monitoring of flow, turbidity, TSS and transparency in the river to determine if the conditions are changing…” (Section 7.0, p. 56) As mentioned above, this implementation plan includes a survey, inventory and analysis section crucial to quantifying and prioritizing actions. Geographically localized BMP activities, like a grade-control/bankfull bench project, include estimates (in tons/year) of sediment reduction. Broader BMP activities, such as upland tree planting, include discussion of the complex, system-wide expected reductions in sediment.

In addition to implementing these BMPs, there are several restoration activities that should begin to be implemented in what are already recognized priority areas in the watershed. In the short term, implementation of BMPs and other restoration activities will aid in determining their effectiveness and re-directing activities accordingly. Implementation, along with ongoing watershed evaluations, provides the foundation for the use of an adaptive management approach for the Knife River.

5.1. Land Use/Cover Management Activities

A key to the long-term health of the Knife River is the restoration of the forests in the watershed to a healthy and sustainable condition. Much of the upland forest in the watershed is composed of declining quality stands of aspen. Upland open space is also an issue for mitigation here. Riparian tree cover, as well as beaver activity within the watershed, also plays a crucial role in stream turbidity and fishery health.

5.1.1. Tree planting in open land areas

Description:

Tree planting will be encouraged on open land, mostly former crop land and pasture, to convert the open areas back to forest cover. Most trees will be conifers but mixed hardwood species can also be included. Efforts will focus on sub-watersheds identified as having the most cumulative open areas in the watershed (Figure 4.3) but trees would be available for planting throughout the watershed.

Feasibility:

Planting would be done in conjunction with current SWCD tree planting programs.

Cost:

$2,100/acre for purchase, planting and maintenance

Sediment Reduction:

The sediment reduction will result from two stream sediment balance mechanisms. Lower peak flows will cause less sheer stress on the stream banks, thus reducing in-channel sediment sources. Upland tree roots will provide greater resistance to erosion than grasses.

Objectives Met:

Hydrology and water quality.

Evaluation:

Visual inspection of new plantings will be made for survival from deer browsing and weeds. Geographic information system tools and remote sensing imagery will be used to track changes in open land areas over time.

5.1.2. Miscellaneous runoff reduction activities in open land areas

Description:

Landowners throughout the watershed will be encouraged to manage open areas not to be planted to trees to reduce runoff through: reducing the size of lawns mowed, increasing buffer areas around agricultural areas and minimizing clearing of currently forested areas. This BMP includes providing more and clearer guidance to all (landowners, townships and municipalities) about the TMDL Implementation Plan practices, guidelines and requirements.

Feasibility:

Dependent on private landowner and municipality education and buy-in.

Cost:

Costs would be incorporated into the outreach activities cost.

Sediment Reduction:

Reductions would come from decreases in overland erosion and peak stream flows. Additional data will be required to quantify impacts on the sediment balance.

Objectives Met:

Hydrology and water quality.

Evaluation:

Geographic information system tools and remote sensing imagery will be used to track changes in open land areas over time.

5.1.3. Riparian area forest management

Description:

Given the large percentage of forest in the watershed, much of the riparian area management work will involve forest and timber harvest management practices on private and public lands. It is important that forest practices are consistent with goals set forth in this implementation plan. BMPs for open land in riparian areas will be implemented through 5.1.1 and 5.1.2 above. Riparian area management practices on private forest land will be encouraged through the review and updating of current forest management plans and the development of new forest management plans when possible. Riparian area management practices on public forest land will continue to be managed by the St. Louis and Lake County Land Departments. Forest management plans on both private and public land should follow the Minnesota Forest Resources Council (MFRC) Forest Management Guidelines with some additional recommendations to be considered on a site-specific basis. These recommendations include:

- Evaluate, and where feasible manage, on a site-specific basis, a “Long-Lived Tree zone” (LLT), extending 300 ft. from the stream for long-lived conifer and hardwood species (including red and white pine, white cedar, white and black spruce, tamarack and oak) through targeted timber harvesting and planting.
- Enhance collaboration with Department of Natural Resources Fishery staff on management of the LLT.

The forestry subcommittee of the Knife River Stewardship Committee will set general guidelines to direct implementation of site-specific activities. Factors likely to affect a site-specific plan include the size of the stream and its watershed, the effect and/or impact of the recommendations on the site-specific watershed versus the overall landscape (whole Knife River watershed). Revised and/or additional recommendations may be provided by the forestry subcommittee as the current MFRC guidelines are considered for revision.

A primary management goal for the riparian areas along the Knife River and its main tributaries is to develop a healthy, mature, long-lived and diverse forest. Achieving this goal will provide the large woody debris important to aquatic life and reduce the influence of beaver on the streams. It will also provide for a healthy sustainable forest that will benefit the whole ecosystem.

To enable more targeted management of the forest riparian areas in the Knife River watershed, the following resources are needed:

- A detailed inventory of the forest riparian conditions in the watershed,
- Staff support to evaluate the inventory and target riparian areas for forest management,
- Staff support available as a resource for developing site-specific LLT plans for public and private lands and
- Funds for trees, tree planting and tree maintenance (weed and animal control).

Feasibility: Funds would be needed for the SWCDs and/or other organizations; collaboration among agencies.

Cost:

- $38,000 / year—Staff support to work with private landowners and county foresters;
- $50,000—Inventory of the forest riparian conditions in the watershed;
- $2,100 / acre—Tree planting and maintenance.

Sediment Reduction:

The inventory included in this BMP, plus subsequent monitoring, will provide data for quantifying sediment reduction from tree planting over time.

Objectives Met:

Hydrology, biology and water quality.

Evaluation:

Geographic information system tools and remote sensing imagery will be used to maintain forest condition inventory.

5.1.4. Upland forest management

Description:

Conduct a detailed inventory of the forest stands in the watershed, including variables such as percent cover, stand health, tree species and tree age, size and density. The inventory would aid in the completion of a cooperative stand assessment. With a completed inventory, implementation plan resources would be used to increase the rate at which the forest condition is improved through additional tree planting and conversion to longer-lived tree species. Priority areas would be identified through the baseline forest inventory.

Feasibility:

Adoption of the MFRC forest management guidelines will be encouraged on private forest land through the review and updating of current forest management plans and the development of new forest management plans when possible. Public forest land

will continue to be managed by the St. Louis and Lake County Land Departments. Inventory will rely on collaboration of these agencies.

Cost:

- $38,000 / year—Staff support to work with private landowners and county foresters;
- $50,000—Inventory and analysis of upland forest stands.

Sediment Reduction:

Long-term sediment reductions would occur through restoration of the stream hydrology and geomorphologic condition.

Objectives Met:

Hydrology, connectivity and water quality.

Evaluation:

Geographic information system tools and remote sensing imagery will be used to maintain the forest condition inventory.

5.1.5. Beaver Dam Inventory, Monitoring and Evaluation

Description:

Two studies of beaver-related issues on the Knife River are being completed with the results to be available in 2012.

The Minnesota DNR Section of Fisheries has monitored water temperatures upstream and downstream of beaver impoundments since 2010 with final analysis to be completed in 2012. Initial results indicate that, where the surface area of the stream was increased by beaver impoundments, stream water temperatures increased below the beaver impoundments compared with water entering the impoundments. Initial results from eight out of ten of the sites monitored in the Knife River watershed had warmer stream temperatures directly below beaver impoundments compared to water entering the impoundments. (On a ninth site the stream bed was dry due to a lack of precipitation and the temperature logging device was recording ambient air temperature rather than stream temperature. The tenth site was at an old beaver dam which no longer impounds water nor increases the surface area of the stream.) Beaver dams that substantially increase the surface area of the stream behind them (create a large impoundment or series of impoundments) had the greatest increase in water temperatures exiting the impoundments.

The U.S. Army Corps of Engineers (USCOE) has completed the first phase of a sediment transport model for the Knife River as a tool to assist state and local agencies with the planning and implementation of measures for soil conservation and nonpoint source pollution prevention. A second phase in the development of the model will include modeling the relationship between beaver dams and sediment erosion and transport in the Knife River system.

Given the flow, sediment and temperature effects associated with beaver impoundments, BMPs will be considered following the completion of the two studies.

Feasibility:
Development of a management approach incorporating both beaver removal and protection, though difficult, is important to the water quality of the Knife.
Cost:
Annual cost is projected to be $35,000.
Sediment Reduction:
Direct sediment reductions would be minimal, but long-term indirect benefits would occur through stabilizing stream hydrology and protecting large woody debris. Benefits would relate more toward thermal and connectivity issues.
Objectives Met:
Connectivity, biology and water quality.
Evaluation:
The status of beavers and their dams in the watershed will be evaluated from annual Minnesota DNR aerial surveys. Site-specific effects of beaver dams would be evaluated with the use of longitudinal temperature monitoring. On-going efforts to balance steelhead and beaver interests would be reviewed.

5.2. Stream Bank and Bluff Restoration Activities

Erosion control for stream bank and bluff areas will follow a natural channel design approach such as that presented by Rosgen (2006). Staff from local, state and federal agencies has received training in the use of the Rosgen methods and is beginning to use them in stream restoration efforts. Based on the stream geomorphology study completed for the TMDL, preliminary discussions and initial design efforts, a three-step series of restoration activities would be designed and implemented along severely eroding reaches of the Knife River and its tributaries.

The three measures include:

- Grade control measures placed to reduce bank erosion,
- Bankfull benches developed in areas where the stream threatens the valley wall (bluffs) and
- Tree planting to stabilize the bluff areas once the bluff angle (slope) is reduced enough to support vegetation.

All work would require site-specific field measurements and evaluations to adequately plan, design and implement.

5.2.1. Grade control measures

Description:
Grade control activities may range from relatively simple toe of bank stabilization to the use of various cross vein designs for in-channel grade control to channel adjustment techniques. Projects would be prioritized according to bank failure ratings, as shown in Figure 4.1.
Feasibility: Requires funding and the technical assistance to implement
Cost:

See discussion below.

Sediment Reduction:

See discussion below.

Objectives Met:

Hydrology, biology, geomorphology and water quality.

Evaluation:

See discussion below.

5.2.2. Bankfull benches

Description:

A bankfull bench is created to separate bluff areas subject to collapse away from the energy of the stream flows. Benches are typically needed where a stream butts up against steep bluffs and/or when grade control structures are not adequate by themselves. The benches are designed to keep the bankfull flow away from the bluff and greatly reduce the flow power on the benches at higher flows. Areas with a bank failure rating of 'high' would receive priority. (Figure 4.1).

Feasibility:

Requires funding and the technical assistance to implement.

Cost:

See discussion below.

Sediment Reduction:

See discussion below.

Objectives Met:

Hydrology, geomorphology and water quality.

Evaluation:

See discussion below.

Cost and sediment reduction estimates for grade control and bankfull bench construction are combined, given that both will be influenced by the size of the bank and/or bluff areas and the degree to which near-bank shear stresses need to be reduced. The gross estimates were made based on a combination of these factors as mild, moderate and major erosion areas.

Cost estimates per erosion area (with sediment reduction estimate):

- Mild erosion areas (approx. 5 tons/year)--$25,000 ($10,000 for engineering, $15,000 for construction);
- Moderate erosion areas (approx. 30 tons/year)--$50,000 ($20,000 for engineering, $30,000 for construction;
- Major erosion areas (approx. 900 tons/year)--$150,000 ($50,000 for engineering, $100,000 for construction).

Evaluation of select grade control and bankfull bench BMPs would include placement of bank pins and chains to track sediment erosion and deposition along the stream banks and in the stream channel. A pre- and post- construction upstream and downstream water quality monitoring study may also be implemented as a part of an overall bank and bluff restoration

effort. Follow-up field measurements would also be made to track any changes in the dimension, pattern and profile of the stream.

5.2.3. Tree planting on bluffs

Description:

Following the development of bankfull benches along the stream, the exposed bluffs should begin to slump and erode onto the benches, reducing the surface slope of the bluffs. Once the bluff slopes (angle of repose) are small enough to support the establishment of trees, trees will be planted to further stabilize the bluffs. Priority will be given to bluffs at bankfull bench locations.

Feasibility:

Planting would be done in conjunction with current SWCD tree planting programs.

Cost:

$2,100/acre to purchase, plant and maintain trees.

Sediment Reduction:

Tree establishment on the bluffs would increase sediment reductions of the grade control and bankfull bench reductions by bolstering the counteracting forces that hold the stream banks and bluffs in place.

Objectives Met:

Geomorphology and water quality.

Evaluation:

Evaluation would be completed within evaluations of the grade control and bankfull bench BMPs.

5.2.4. Introduction of woody debris

Description:

Introduction of woody debris in riparian areas has been shown to create fish habitat and promote deposition of mobilized sediment. These types of projects would be carefully designed for specific locations, prioritizing small tributaries and main stem in the upper watershed.

Feasibility:

The SWCD has the technical staff and inventory data to effectively implement this.

Cost:

The cost would be $20.00 per lineal foot of shoreline.

Sediment Reduction:

This activity can have highly variable sediment reduction results depending on placement. On meander bends with high erosion rates, the reduction will be substantial. In areas of lower sheer stress, the rates would be lower but would still provide habitat and most likely some moderate sediment reduction capacity.

Objectives Met:

Biology and water quality.

Evaluation:

Visual inspection of installations should be completed regularly to make sure the woody debris is holding and that the installation is not creating new problems.

5.3. Upland Erosion Control Activities

Upland erosion control activities focus on stabilizing eroding gullies with structural BMPs. Other upland activities rely on education and enforcement of existing management practices for ditch maintenance, for stormwater runoff and for wetland preservation.

5.3.1. Gully stabilization

Description:

The gully stabilization method would be highly site specific, prioritizing gullies flowing directly into a stream. In some cases stabilization may require rip rap and in others it could be resolved with re-shaping and vegetation. These gullies are often associated with roads and sometimes the solution is up gradient of the gully, i.e., fixing culvert installations or installing energy dissipation measures.

Feasibility:

This BMP would require a significant reconnaissance portion to find gullies.

Cost:

A gross cost estimate is $4,000 per 50 feet of gully.

Sediment Reduction:

A gross sediment reduction estimate is 5 tons per year per 50 feet of gully.

Objectives Met:

Biology and geomorphology.

Evaluation:

Evaluation would consist of routine visual inspections after installation for two seasons.

5.3.2. Road ditch maintenance and re-vegetation (stormwater management)

Description:

Road ditches, which drain much of the Knife River watershed, can be significant pathways for sediment. An inventory of road ditch conditions— including culvert conditions, potential temporary storage areas and amount and duration of flow present—and workshops for road crews would help target areas for implementing existing road ditch BMPs (such as scour-reduction at culverts and check dams to reduce runoff velocities). Priority will be given to road ditches located near a stream.

Additional efforts should be made to fully support (funding, materials, education and expertise) the planting of native species and the utilization of current technologies along roadways. Counties and Townships could foster Adopt-a-Culvert or Adopt-a-Ditch efforts in the watershed for weed control and other maintenance.

Feasibility:

Ditch BMPs applicable to the Knife are already well defined in the Minnesota Stormwater Manual (Minnesota Stormwater Steering Committee, 2005) and the Highway 61 Stormwater Natural Drainage and Retrofit Identification Project report (Minnesota Board of Water and Soil Resources, 2008). Under a Great Lakes Restoration Initiative grant, a ditch construction and maintenance handbook specific to this region will be completed, also applicable to the Knife.

Cost:

- $10,000 to complete a road and road ditch inventory;
- $500 per year for workshops and other outreach training; and
- $18,000 per temporary storage for 6,000 cu.ft. of water ($4,000 for engineering and $14,000 for construction)

Sediment Reduction:

Ditch checks and increased vegetation will act to hold more water and reduce the peak flows and correspondingly reduce the sheer stress in the stream. In addition, increasing vegetation and adding ditch storage would decrease the sediment input directly from the ditches. More data is necessary to quantify the magnitude of sediment reduction from these mechanisms.

Objectives Met:

Hydrology and water quality.

Evaluation:

Evaluation would consist of completion of the inventory, completion of training and outreach and completion of a second inventory in five years to determine if ditch conditions have improved.

5.3.3. Stormwater BMPs Inventory, Training and Implementation

Description:

While the amount of stormwater runoff from impervious surfaces is relatively low in the Knife River watershed, this BMP focuses on providing an inventory of existing stormwater BMPs and training local contractors to follow them, focusing on all new development.

Feasibility:

Local ordinances and existing BMPs provide solid steps for controlling stormwater runoff from impervious surfaces. BMP inventorying, training and development will be integrated with other local government agencies and organizations, including the Regional Stormwater Protection Team.

Cost:

Support through staffing and/or contracting would cost approximately $4,000 (SWCD staff at 0.1 FTE for two years). No cost estimate was made for BMP implementation.

Sediment Reduction:

Watershed data collection and ongoing monitoring will help quantify impacts of this BMP.

Objectives Met:

Hydrology and water quality.

Evaluation:

Evaluation would consist of completion of: the BMP inventory, training and outreach and a second inventory in five years to determine if BMPs have been maintained properly. Follow-up with landowners and technical assistance beyond initial construction should encourage success and effectively monitor BMPs.

5.3.4. Wetland enhancement, creation and preservation

Description:

This BMP focuses on collaboration to encourage wetland enhancement, creation and preservation, identifying priority areas as outlined in Section 4. Stakeholders would work with existing county-level planning and zoning and through assuring any state- and federal-level wetland fill mitigation stays within the watershed.

Feasibility:

Though not likely to be commonly implemented, this BMP is important and requires collaboration with many agencies.

Cost:

There should be no cost for this activity beyond the current costs for administering the Minnesota Wetland Conservation Act. No cost estimate was made for BMP implementation.

Sediment Reduction:

Reductions would come from decreases in peak stream flows.

Objectives Met:

Hyrdology, biology and water quality.

Evaluation:

Existing wetland programs should provide all necessary monitoring.

5.4. Outreach and Education

This section provides information on and direction in achieving watershed landowner participation in this implementation plan. Five main elements are included in the section: education, outreach, training, civic engagement and regional collaboration. The assessments in each of the five elements will include a measure of their influence in attaining actual BMP implementation in the watershed.

5.4.1. Education activities

Description:

Through educational activities such as workshops, tours and site visits, this BMP focuses on teaching specific strategies landowners may use to improve conditions throughout the watershed. For instance, University of Minnesota-Extension 'Woodland Advisors' can be invited to help landowners review progress within their forest management plans. Specific BMPs on which education programs should focus

include tree planting in open land areas (5.1.1), miscellaneous runoff reduction activities in open land areas (5.1.2), riparian area management (5.1.3), upland forest management (5.1.4), gully stabilization (5.3.1) and stormwater BMPs (5.3.3).

Feasibility:

Could be contracted with community nonprofit group.

Cost:

$12,000 per year for 10 workshops, 2 tours and 20 site visits.

Sediment Reduction:

Refer to sediment reduction estimates for individual BMP activities.

Objectives Met:

All—hydrology, connectivity, biology, geomorphology and water quality.

Evaluation:

Assess impact of workshops, tours and site visits through immediate evaluations and 12-months-after follow-up.

5.4.2. Outreach through information dissemination

Description:

Implement outreach activities such as press releases, paid media, newsletters and a website to increase awareness among watershed residents of the connection between land use practices, run-off and turbidity. Also increase awareness of cost-share opportunities. Specific BMPS on which outreach programs should focus include stormwater BMPs (5.3.3.), as well as general behavior such as installing rain barrels and rain gardens to moderate flow.

Feasibility:

Requires some collaboration among agencies.

Cost:

Write, print and mail two issues of newsletter per year: $5,000

Sediment Reduction:

Refer to sediment reduction estimates for individual BMP activities.

Objectives Met:

All—hydrology, connectivity, biology, geomorphology and water quality.

Evaluation:

Assess impact of newsletter through annual evaluation.

5.4.3. Training for contractors, local government unit (LGU) staff and planning boards

Description:

Offer training workshops through which to teach strategies that contractors, agency personnel and landowners should or must legally use for road construction/maintenance, driveway permits, culverts, etc., to reduce flows and erosion. Efforts would prioritize the upper tributaries. Provide training and education about the TMDL for county planning and zoning boards and LGUs. This will help

with the following BMP activities: gully stabilization (5.3.1), road ditch maintenance and re-vegetation (5.3.2) and stormwater BMPs (5.3.3).

Feasibility:

Requires collaboration of private contractors, relevant agencies and boards.

Cost:

$3,000 for 1 training workshop

Sediment Reduction:

Refer to sediment reduction estimates for individual BMP activities.

Objectives Met:

Hydrology and water quality.

Evaluation:

Assess impact of workshops through immediate evaluations and one-year follow-up evaluation.

5.4.4. Civic engagement / organizing

Description:

Assist watershed residents and landowners in continued development of Advocates for the Knife River Watershed, a group which plans to become a non-profit organization. Encourage all residents of the watershed to be involved in its ongoing health, including volunteering their time for planting, bud-capping, fencing and other labor-intensive activities. Use door-knocking, house parties and peer-to-peer ambassadors to model and educate about good watershed citizenship, including yard signs to identify local watershed experts.

Feasibility:

Development of Advocates for the Knife River Watershed is under way, with a grant from Minnesota's Environmental Partnership. Residents already volunteer for projects.

Cost:

$5,000 per year for two years.

Sediment Reduction:

Refer to sediment reduction estimates for individual BMP activities.

Objectives Met:

All—hydrology, connectivity, biology, geomorphology and water quality.

Evaluation:

Assess impact of organization through immediate evaluations and annual follow-up evaluations.

5.4.5. Regional agency collaboration

Description:

Organize local governmental units from nearby watersheds, extension agents and interested private individuals and organizations in a format similar to the Regional Stormwater Protection Team. This will accomplish economies of scale and will maintain a robust response to emerging needs throughout the watershed.

Feasibility:
Requires concerted collaboration among stakeholders.
Cost:
$6,000/year for first two years, $1000/year afterward.
Sediment Reduction:
Refer to sediment reduction estimates for individual BMP activities.
Objectives Met:
All—hydrology, connectivity, biology, geomorphology and water quality.
Evaluation:
Assess impact of collaboration through annual evaluation.

5.5. Survey, Inventory and Analysis Activities

As indicated above, additional survey and inventory work along with analysis and evaluation is needed to prioritize and more specifically target areas for BMP implementation. Analysis and evaluation should consider the functions of all five of the watershed system components (hydrology, water quality, biology, geomorphology and connectivity). The survey and inventory work will include the compilation of existing data along with the collection of new data. Surveys, inventories and analyses are generally quite expensive, due to the large amount of staff time needed for field work. In addition, the Knife River watershed is large, increasing costs of these activities. Citizen input has placed priority on areas that have been or expect to be restored in order to make the most efficient use of limited staff and monetary resources.

Survey and Inventory Work

- Continuing analysis of soils, slopes, proximity to streams and land cover to identify the open land areas most sensitive to overland runoff and/or soil erosion (required for Sections 5.1.1 and 5.1.2). Forthcoming Light Detection and Ranging (LIDAR) data from the Minn. DNR and Soil Survey Geographic Database (SSURGO) data from the NRCS for the area will be available to help focus a continuing analysis of soils.
- Detailed inventory of riparian forest conditions in the watershed including hill slopes, stream slopes, soils and elevation, plus forest condition data as described below along (required for Section 5.1.3). Forthcoming LIDAR data from the Minn. DNR and SSURGO data from the NRCS for the area will be available to help focus a detailed inventory of riparian forest. The St. Louis Land Department also keeps records of their harvesting areas in a GIS. This can also aid an inventory.
- Detailed inventory of upland forest stands in the watershed, including percent cover, stand health, tree species and tree age, size and density (required for Section 5.1.4). Forthcoming LIDAR data and harvesting records housed at the St. Louis County Land Department can aid in this inventory.
- Additional surveys of the stream channels, banks and bluffs (using the Watershed Assessment of River Stability and Sediment Supply (WARSSS) or similar techniques) to identify and target unstable stream reaches and sediment sources for restoration. This would include the delineation of water surface slopes to identify and prioritize areas with high near-bank shear stresses and high Bank Erosion Hazard Index values (BEHIs).

- Electrical resistivity survey for the presence and depth of alluvium subsurface materials along the stream to determine the potential for increasing subsurface and groundwater storage through increased infiltration using grade control BMPs. Some Minnesota DNR infrared data is already available to inform this activity.
- Inventory of county and township roads, culverts and ditches to identify areas and conditions most susceptible to rapid runoff and erosion of sediment to streams. Duluth Township has started collecting this data. The other three townships, Alden in St. Louis County and two unorganized townships in Lake County, in addition to St. Louis and Lake County Land Departments should all work together on achieving this activity. The Rosgen road impact index can be used to assess the potential impact of roads in altering flow paths via their location and form in the watershed.
- Re-run Army Corps of Engineers sediment transport models for the Knife River using new data acquired with forthcoming LIDAR and SSURGO data.

As the surveys and inventories are completed, the data will help prioritize strategies in this implementation plan. Prioritization would occur within and between the various BMP categories and the functions of the watershed components to ensure the greatest impact of the implementation activities on restoring the Knife River and its aquatic life. Given the large task of implementation, it will be important to continue to refine and revise the implementation plan for on-going work in the watershed.

5.6. Short- and Long-term Effects of BMP Implementation on Stream Flow, Temperature and Habitat Stresses

Most of the BMPs presented in this implementation plan will reduce peak flows and temperatures in the Knife River, some more rapidly than others. Tree planting and forest management will tend to affect flow and temperature at a longer-term and broader geographic and hydrologic scale. The grade control and bankfull bench BMPs have a potential for near-term change to be seen more quickly through increased subsurface water storage at the BMP sites. This potential is dependent on the presence of adequate water-holding subsurface materials. Deep, alluvium subsurface materials could provide significant storage volume, yielding increased base flows and more stable water temperatures. The incorporation of natural channel design grade control structures will improve aquatic habitat by aiding in the creation of riffle and pool sequences in the stream. The long-term growth of trees on eroding bluffs will improve habitat through shading and providing a source of woody debris in the stream.

5.7. Implementation Approach

This implementation plan describes the restoration activities specific to the turbidity TMDL needed to improve the aquatic life of the Knife River. As such, it addresses the main drivers and sources of sediment to the river. More broadly, it identifies other main stressors on the cold-water fishery of the river. While initial implementation practices will focus on known priority areas, the plan also articulates the need for better inventories and additional field surveys for use in developing more specific restoration priorities and strategies.

Future development of restoration priorities and strategies should follow a natural channel design process. Activities are coordinated to re-establish the general structure, function and self-sustaining behavior of the stream system. This holistic process requires an understanding of the physical and biological components of the stream system and its watershed, as well as the collaboration of public and private landowners and agencies who are its stewards. Figure 5.1 shows how BMPs meet the objectives outlined in this implementation plan.

Figure 5.1. Chart of How BMPs Meet Implementation Objectives

BMPs	Land Use / Cover Management Activities					Stream Bank & Bluff Restoration Activities			Upland Erosion Control Activities					Outreach & Education					
Objectives	Tree planting in open lands 5.1.1	Misc. runoff reduction in open lands 5.1.2	Riparian area management 5.1.3	Upland forest management 5.1.4	Beaver dam removal 5.1.5	Grade control measures 5.2.1	Bankfull benches 5.2.2	Tree planting on bluffs 5.2.3	Gully stabilization 5.3.1	Road ditch maintenance 5.3.2	Stormwater BMPs 5.3.3	Introduction of wood debris 5.3.4	Wetland enhancement / preservation 5.3.5	Education activities 5.4.1	Outreach thru information dissemination 5.4.2	Training for contractors and LGU staff 5.4.3	Civic engagement / organizing 5.4.4	Regional agency collaboration 5.4.5	Survey , inventory & analysis activities 5.5
Attain a **hydrologic** regime that better supports geomorphic stability & ecological function	X	X	X	X		X	X			X	X		X	X	X	X	X	X	X
Restore the **connectivity** in the watershed longitudinally, laterally and vertically				X	X									X	X		X	X	X
Improve the **biological** health of the ecosystem to support cold water fish			X		X	X			X			X	X	X	X		X	X	X
Restore **geomorphological** features and maintain channel stability in the Knife and its tributaries						X	X	X	X					X	X		X	X	X
Improve **water quality** to support aquatic life in cold water ecosystem	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

6. Construction Stormwater and Municipal Separate Storm Sewer Systems (MS4s) Waste Load Allocations

The presence of a WLA in the Knife River turbidity TMDL warrants a separate section in the implementation plan to address implementation issues unique to permitted point sources of pollution. Following MPCA guidance, this section of the implementation plan describes the target loads, assumptions used in calculating the WLAs, the geographic area applicable to the WLAs, reduction estimates for the MS4 and the application of the stormwater management efforts in the watershed.

6.1. Construction Stormwater

The WLA for construction stormwater was calculated as one percent of the difference between the TMDL and the margin of safety. One percent was selected given the extremely small percentage of land in the watershed that was disturbed by construction activities in 2008 and the slight increase expected in population growth and subsequent construction activity (0.2 and 0.25 percent, respectively). Table 2.5 shows the WLA for construction stormwater as 0.03, 0.004, 0.002, 0.001 and 0.001 ton per year for high flows, moist conditions, mid-range flows, dry conditions and low flows on the load duration curve, respectively. Any permitted construction activity in the Knife River watershed is subject to this TMDL.

Construction stormwater activities are considered in compliance with the construction stormwater WLA if they obtain a Construction General Permit under the NPDES program and properly select, install and maintain all BMPs required under the permit, or meet local construction stormwater requirements if they are more restrictive than requirements of the State General Permit.

6.2. Duluth Township MS4

The WLA for the Duluth Township MS4 was determined as a percentage of the conveyance area subject to MS4 requirements relative to the whole watershed drainage area (16 percent) multiplied by the difference between the TMDL and the margin of safety and WLA for construction erosion. Table 2.5 shows the WLA for the MS4 as 0.43, 0.06, 0.03, 0.01 and 0.004 ton per year for high flows, moist conditions, mid-range flows, dry conditions and low flows on the load duration curve, respectively. The WLA applies only to the conveyance systems owned and managed by the township including approximately seven miles of township roads and their ditches, a town hall and a fire station that are located in the watershed (Figure 6.1).

A baseline total suspended solids load for use in determining the load reduction needed by an MS4 was based on the average TSS load calculated during the TMDL study for the years 2004, 2005 and 2006. Given that there was no data collected from solely MS4 areas, the baseline load for the MS4 was grossly estimated using the same areal percentage (16 percent) used in

determining the WLA from an estimated current upland or tributary load. The estimated current upland load was computed based on the estimate that the average upland or tributary component of the total TSS loading in the watershed was 12 percent (Section 6.5 of the TMDL). Table 6.1 provides a summary of the loads, allocations and percentages used in estimating a load reduction for the MS4.

The load reduction percentage for the MS4 using the general assumptions described above would be 28 percent only in the high flow category of the TMDL. The estimated baseline load for the MS4 in the moist conditions category is already less than its WLA for the category. No load reductions are estimated to be needed for the other three flow categories given that the TMDL is less than the current loading calculated during the TMDL study.

The Town of Duluth (Duluth Township) conducts regular road inspections, which include culvert inspections and identification of any areas of active erosion. All ditch/culvert maintenance or repair activities undertaken by the Town include re-seeding/re-vegetation, along with installation of rock armoring, ditch checks and diversions etc. where appropriate to prevent erosion and limit ditch flow/velocity. As of the most recent road inspection, the Town of Duluth does not have any known instances where poor ditch/culvert design or maintenance is leading to excessive erosion or other circumstance that would contribute inappropriately to suspended solids in road runoff entering the Knife River.

The Township does not have the financial resources to contract for professional engineering evaluation of its road ditches and culverts. If outside funds became available, such a study could be used to provide a quantitative determination as to whether there are areas where current visual inspection practices have failed to identify significant sources of suspended solids resulting from poor ditch/culvert design or maintenance. Logically, such a study should include all roads in the Township, not just those under Town control, so that an overall priority for possible road-related stormwater management efforts can be established. If such an analysis indicates likely contributions of suspended solids from Township roads/ditches in excess of the Town's wasteload allocation, a combination of outside funding and prioritization within the Town's road budget could be pursued to improve ditch/culvert performance and reduce the associated loads.

Duluth Township has been proactive in addressing potential stormwater problems through their MS4 Storm Water Pollution Prevention Plan, the Township's Comprehensive Plan and coordination with the St. Louis County Comprehensive Water Management Plan. Application of the SWPPP in the Knife River watershed and continuing coordination and participation with the county, city of Duluth and the Regional Stormwater Protection Team is expected to result in the attainment of the WLA. Stormwater BMPs and activities present in the SWPPP, comprehensive plan and county water management plan are included in this implementation plan by reference:

- Duluth Township, St. Louis County, 2008 Stormwater Pollution Prevention Plan – http://www.duluthtownship.org/pdf/stormwater_prevention_plan.pdf

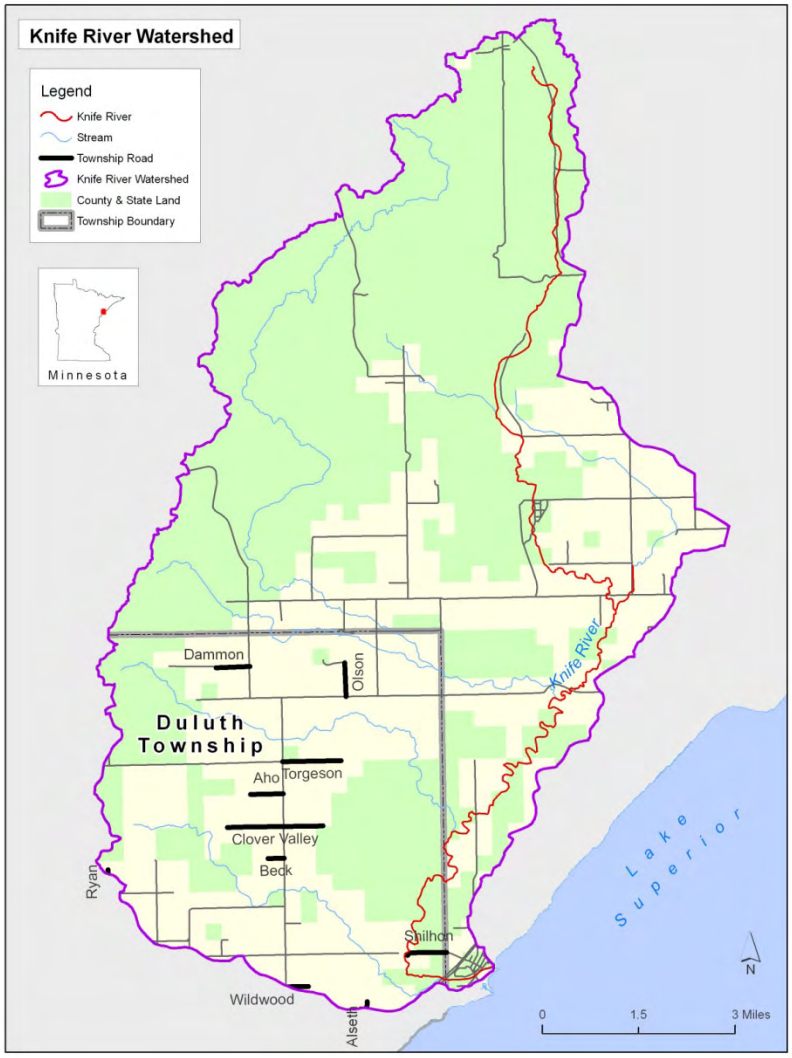
- Duluth Township Comprehensive Land Use Plan, 2002 – , http://www.duluthtownship.org/pdf/comp_land_use_plan.pdf

- St. Louis County, Minnesota, Comprehensive Water Management Plan, Update 2010 – 2020
  http://www.stlouiscountymn.gov/Portals/0/Library/government/County-Plans-Ordinances/2010-2020-Comprehensive-Water-Management-Plan.pdf

Table 6.1. Load reduction estimates for the TMDL and MS4 WLA

	High Flows	Moist Conditions	Mid-Range Flows	Dry Conditions	Low Flows
TMDL	5.3	0.86	0.27	0.12	0.04
Estimated Current Load	31	1.2	0.15	0.04	0.01
Overall Percent Reduction	90%	65%	n/a	n/a	n/a
(% Current load from tributary (upland) sources: 12%)					
Estimated Current Tributary (Upland) Load	3.7	0.14			
(% Watershed area in MS4: 16%)					
Estimated MS4 Current Load	0.6	0.02			
MS4 WLA	0.43	0.06			
MS4 Load Reduction	0.17	0			
% MS4 Load Reduction	28	0			

Figure 6.1. Township and Duluth Township Roads in the Knife River Watershed.



7. Monitoring

An important step in the implementation process will be on-going monitoring of flow, turbidity, Total Suspended Solids and transparency in the river to determine if conditions are changing and the effectiveness of pollution mitigation strategies. Partners in this process will include: citizen stream monitors, the MPCA, the South St. Louis SWCD, the Minnesota DNR and the United States Geological Survey (USGS). Funding for monitoring is a critical issue that needs to be addressed.

Key monitoring requirements and objectives include:

- Maintain the USGS flow monitoring station on the Knife River.

- Reestablish water quality monitoring at the Fish Trap site or the USGS gage site. Monitoring would include continuous sonde, grab sampling, field measurements and lab analyses.
- Ensure that all implementation activities—whether they occur through local, state, or federal programs, or other means—are tracked using a reporting database such as the Minnesota Board of Water and Soil Resources (BWSR) E-link database. This will be crucial for gauging general implementation progress.
- Continue to promote and expand citizen stream monitoring in the Knife River watershed.
- Coordinate with the University of Minnesota and MPCA to research soil erosion and sediment delivery processes and the effectiveness of particular BMPs. Apply results of sediment "fingerprinting" and other research that will be completed as part of the Lake Superior Streams Sediment Project.
- Maintain all monitoring activities for a period of no less than 10 years and preferably on a permanent basis.

Two broad categories of monitoring will be pursued through this implementation plan combined with other programs. These are needed to help attain the water quality goals for the Knife River and its watershed following the adaptive management strategy described in the next section. The two categories include long-term watershed monitoring and BMP effectiveness monitoring.

7.1. Long-term Watershed Monitoring

Long-term monitoring will primarily be completed following the MPCA ten-year major watershed monitoring and assessment cycle. The major watershed monitoring approach includes intensive biological monitoring throughout an eight-digit hydrologic unit code (HUC), followed by additional physical, biological and chemical monitoring at smaller scale watersheds (typically 12-digit HUCs), assessments of aquatic life conditions and the completion of a process called stressor identification to identify causes for water quality problems affecting aquatic life. The Knife River is located in the South Lake Superior 8-digit HUC. The first cycle of this monitoring begins in 2011. Subsequent cycles of monitoring repeated every ten years will provide data in which to evaluate if the water quality of the river has improved and to determine if the aquatic life use goals of the river are met. Between the MPCA monitoring efforts, volunteer stream monitoring through the MPCA Citizens Stream Monitoring Program (CSMP) will be encouraged to provide an annual check on stream conditions. The long-term monitoring efforts are identified in the timeline presented in Section 10 of the implementation plan.

There are no project-specific funds needed to complete the MPCA major watershed monitoring every ten years, given that it is part of MPCA-funded activities. Support for getting additional citizens to participate in the CSMP, maintaining citizen participation and evaluating the data each year is needed. Support through staffing and/or contracting would cost approximately $10,000 annually (SWCD staff at 0.25 FTE).

Given the large influence of stream banks and bluffs as sources of sediment to the river, long-term geomorphic monitoring should also be conducted in the watershed. This monitoring will range in cost from the relatively inexpensive placement of bank pins and chains at representative

locations to complete cross-section and longitudinal surveys conducted on a regular basis. Some of the cross-section and longitudinal surveys will be completed as part of the design procedures for bank and bluff restoration efforts. The cost for these surveys should decrease with the availability of LiDAR data in the next few years.

An estimated cost for the long-term placement and monitoring of bank pins and chains is $1,000 per cross-section per year. The cost would include materials, installation labor and annual monitoring measurements.

7.2. BMP Effectiveness Monitoring

BMP effectiveness monitoring will be BMP and site specific at a select number of locations if funding is available. BMP effectiveness monitoring should include methods to assess BMP impacts on hydrology, pollutant (sediment) loading, stream temperature and biology. The completion of appropriate monitoring for the effectiveness of BMPs implemented in a project is often difficult given timing and funding constraints. The ideal design for BMP effectiveness monitoring is usually a paired-watershed design: pre-BMP data is collected in two watersheds that are similar for a period of time, BMPs are implemented in one watershed and not the other watershed (or upstream-downstream sites) and post-BMP data is collected for another period of time. The pre- and post- implementation periods of monitoring should be at least two years each (preferably up to five years) (Clausen and Spooner, 1993; Spooner et al., 1995).

Effectiveness monitoring in the Knife River watershed should include biological, physical and water quality monitoring. A linkage to the long-term watershed monitoring should be made, if possible. A design and proposal for effectiveness monitoring should be developed in conjunction with proposals for BMP implementation funding. Goals for effectiveness monitoring would be to determine if changes in biologic, geomorphic, hydrologic and water quality conditions occur with BMP implementation.

8. Roles and Potential Responsibilities of Project Partners

Many units of government and organizations have been involved in drafting this implementation plan. The participation of these and others will be needed to successfully implement the plan. A list of the organizations along with their general roles and potential responsibilities is provided in the following table. The list is not intended to be a final list, as other groups and individuals step up to assist in the restoration efforts. The list of potential responsibilities is only that – potential – the list does not commit any group to the actions listed.

Figure 8.1. Chart of Partners' Potential Roles and Responsibilities

	Partner	General Roles	Potential Responsibilities
Citizen Groups	Knife River Stewardship Committee	– Provide a forum for broad implementation and management discussions – Help coordinate implementation efforts	– Maintain record of discussions – Organize meetings – Discuss implementation priorities
	Advocates for the Knife River Watershed	– Outreach & civic engagement – Pursue funding proposals – Provide volunteers	– Provide civic engagement – Generate project ideas – Volunteer time & labor – Act as ambassadors – Work w/ LUG on proposed activities
	Knife River Recreation Council	– Outreach & civic engagement	– Attend meetings – Share information – Tree planting – Ditch/culvert maintenance
	Landowners & Residents	– Serve on the Stewardship Committee – Provide input, information & feedback – Share information – Provide leadership	– Attend meetings – Share information – Monitor projects – Tree planting – Ditch/culvert maintenance
Non-Profit Organizations	Minnesota Environmental Partnership	- Lead in civic engagement	- Hold meetings - Assist Advocates' group - Provide links to other enviro. groups
	• Lake Superior Steelhead Assoc. • Save Lake Superior Assn. • Minnesota Environmental Partnership • Minnesota Trout Unlimited • Arrowhead Fly Fishermen • Izaak Walton League	– Serve on the Stewardship Committee – Pursue funding proposals – Provide outreach and civic engagement	– Generate ideas for projects – Provide civic engagement – Educate their members – Organize watershed resident meetings

	Partner	General Roles	Potential Responsibilities
Local Government	South St. Louis & Lake County Soil & Water Conservation Districts, Technical Service Area III Engineers	– Serve on the Stewardship Committee – Manage grant projects – Design and evaluate BMPs – Pursue and develop funding proposals – Initiate and maintain landowner contacts and relationships	– Maintain list of potential and finished projects – Provide technical assistance to landowners – Provide cost-share opportunities – Provide engineering assistance to projects – Write funding requests
	Lake and St. Louis Counties (Public Works, Planning and Development and Land Departments)	– Serve on the Stewardship Committee – Manage lands and forests – Oversee county roads – Enforce planning & zoning	– Manage land for sustainable forestry – Forest management education for landowners – Provide upland forest inventory – Maintain and construct transportation infrastructure – Consult implementation plan in zoning decisions
	Duluth and Alden Townships	– Serve on the Stewardship Committee – Oversee township roads – Enforce planning and zoning – Stormwater information	– Review proposed projects – Maintain roads and ditches – Consult implementation plan in zoning decisions – Stormwater education
State Government	Minnesota Board of Water and Soil Resources	– Serve on the Stewardship Committee – Administer MN Clean Water Fund Projects – Provide technical assistance	– Keep stewardship committee aware of opportunities – Provide project management
	Minnesota Department of Natural Resources (Divisions of Fisheries, Forestry and Ecological and Water Resources)	– Serve on the Stewardship Committee – Administer DNR programs – Provide technical assistance for hydrology, fisheries, geomorphology and forestry – Assist in development and evaluation of project proposals	– Review/approve projects under Minnesota DNR programs – Assist with project design – Provide technical comments on project design
	Minnesota's Lake Superior Coastal Program	– Provide grants of $5,000 - $100,000	– Grant program education and application review

	Partner	General Roles	Potential Responsibilities
	Minnesota Pollution Control Agency	– Serve on the Stewardship Committee – Administer MPCA and Section 319 funding programs – Provide technical assistance for hydrology, geomorphology and water quality – Assist in development and evaluation of project proposals	– Oversee implementation plan – Keep stewardship committee aware of opportunities – Provide data administration
	Minnesota Department of Transportation	– Oversee state highway	– Maintain Highway 61 corridor
	University of Minnesota (Duluth campus and NRRI)	– Provide technical review – Conduct Research – Pursue and develop funding proposals	– Lead needed research – Write funding requests – Provide 'Woodland Advisors'
Federal Government	Environmental Protection Agency	– Watershed monitoring	– Provide temperature loggers
	Natural Resources Conservation Service	– Serve on the Stewardship Committee – Provide technical review – Administer U.S. Department of Agriculture (USDA) funding programs	– Make Committee aware of funding opportunities – Assist with project design
	US Army Corps of Engineers	– Provide watershed modeling – Educate & inform about	– Update models with new data – Explain & educate local stakeholders

9. Current Agency Projects & Their Timelines

Many agencies are involved with protecting and improving water quality conditions on the Knife River. This is a listing of their current projects, both on-going and time-specific (grant-funded), organized by type of project: non-point source pollution, stormwater management, research or monitoring and public education.

Figure 9.1. Project Timeline

		Lead Agency	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Non-Point Source Management Programs	Direct Sediment Source Mitigation	All												
	Reducing Runoff through Good Land Use Practices	Residents, County Land Depts.												
	Clean Water Fund Implementation Projects	BWSR, SWCDs												
	Great Lakes Coalition Implementation Projects*	All												
Permitted Storm-water Mgmt Pgms	Duluth Township SWPPP Activities	Duluth Township												
	Construction Stormwater Permit Activities	MPCA												
Research Programs	DNR-Fisheries – Annual Fish Inventories	DNR												
	Univ. of MN (NRRI) – Lake Superior Stream Sediment	NRRI												
Monitoring Programs	DNR-Fisheries (biological monitoring)	DNR												
	US Geologic Survey (flow monitoring)	USGS												
	MPCA Citizen Stream Monitoring Program	MPCA												
	BMP Effectiveness Monitoring	All												
	MPCA 10-year Watershed Monitoring Cycle	MPCA, SWCDs												
	US Geologic Survey Statewide Sediment Network	USGS												
Public Educ. Out-reach	Knife River Newsletter	SWCDs, KR Advocates Group												
	Project Promotion	All												

*funding has been requested; projects pending.

10. Adaptive Management

Adaptive management is an approach to water quality restoration efforts where BMP implementation efforts are combined with an on-going evaluation of the water quality issues. Effects of implemented BMPs are reflected by adjustments to the resource goals, implementation plan and/or implementation efforts when needed. Adjustments are made to incorporate the knowledge gained through the combined efforts. Adaptive management—sometimes referred to as adaptive implementation—is critical when various uncertainties are significant in a watershed (Shabman et al., 2007). This approach is essentially a "learning while doing" approach. It means that uncertainty is not forgotten once implementation begins. Rather, a focus is placed on reducing the uncertainty present through implementation, monitoring and evaluation, research and experimentation. The knowledge gained through these efforts is then focused on reducing the uncertainties in the TMDL, the implementation approaches and/or water uses and criteria. The approach goes beyond just asking "when" in implementation to include "where, what, how and why" (Shabman et al., 2007).

Uncertainties related to the water quality criteria, TMDL numbers, sediment sources and aquatic life stressors are present in the Knife River Turbidity TMDL even though much was learned through the TMDL study. Through an adaptive management approach, this initial implementation plan has been developed to begin implementation activities, continue survey and inventory efforts and evaluate the progress toward meeting the aquatic life goals for the river. As this work is completed, the TMDL implementation goals, priorities and BMPs will be examined and revised, as needed.

11. Budget

The following table presents a general estimate of costs associated with this implementation plan. Firm costs for many of the BMPs cannot be determined until detailed proposals are developed. The implementation plan budget will be updated as better cost estimates are completed. Funding for the implementation plan will be sought through any funding programs in which activities in the Knife River watershed may be eligible. Current state and federal funding programs include Minnesota's Clean Water Fund, the EPA Section 319 program, USDA conservation programs and various Great Lakes targeted funding programs. Efforts will also be made to access local and private funds that may be available to assist in implementing the plan.

Figure 11.1 Five-Year Estimated Budget

Five-Year Estimated Budget (Knife River Turbidity TMDL Implementation Plan)

	Unit Cost	Number	Units	Total cost over five years
5. BMP Implementation				
5.1. Land Use/Cover Management Activities				
5.1.1. Tree planting in open land areas	$2,100	50	acre	$105,000
5.1.3. Riparian area management				
Riparian Forest Inventory	$50,000	1	item	$50,000
Staff Support	$38,000	0.5	FTE	$190,000
Tree planting	$2,100	50	acre	$105,000
5.1.4. Upland forest management				
Cooperative stand analysis and assessment	$50,000	1	item	$50,000
Staff Support	$38,000	0.5	FTE	$190,000
5.1.5 Beaver dam inventory, monitoring & evaluation	$35,000	1	year	$175,000
5.2. Streambank and Bluff Restoration Activities				
5.2.1. Grade control measures and 5.2.2. Bankfull benches				
Mild area	$25,000	3	item	$75,000
Moderate area	$50,000	3	item	$150,000
Major area	$150,000	3	item	$450,000
5.2.3. Tree planting on bluffs	$2,100	15	acre	$31,500
5.2.4. Introduction of woody debris	$20	5000	lineal foot	$100,000
5.3. Upland Erosion Control Activities				
5.3.1. Gully stabilization	$4,000	20	50 feet	$80,000
5.3.2. Road ditch maintenance and re-vegetation (stormwater management)				
Inventory	$10,000	1	item	$10,000
Staff support	$500	1	year	$2,500
Temporary water storage	$18,000	2	6,000 ft^3	$36,000
5.3.3. Stormwater BMPs				
Staff support	$4,000	1	item	$4,000
5.4. Outreach and Educational Activities				
5.4.1. Education activities	$12,000	10	year	$60,000
5.4.2. Outreach thru info dissemination (newsletter)	$2,500	2	year	$12,500
5.4.3. Training for contractors and LGU staff	$3,000	1	year	$15,000
5.4.4. Civic engagement / organizing	$5,000	10	year	$50,000
5.4.5. Regional collaboration ($6,000 for 2 years, $1,000 for 3 years)	$6,000	10	year	$15,000

5.5 Survey, Inventory & Analysis Activities				
Stream, bank and bluff surveys	$150,000	1	item	$150,000
Electrical resistivity survey	$20,000	1	item	$20,000
GIS support	$40,000	1	item	$40,000

7. Monitoring

7.1. Long-term watershed monitoring				
Water quality monitoring at Fishtrap/USGS site	$5,000	12	year	$25,000
Staff suppport for CSMP	$10,000	0.25	FTE	$50,000
Long-term bank pins and chains	$1,000	cross-section	year	$5,000
7.2. BMP effectiveness monitoring (pre- and post-)	$10,000	15	BMP	$150,000

Total estimated budget for 5 years of implementation	**$2,396,500**

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