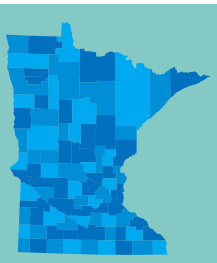
Grant

February 2023

Knife River Watershed NKE Plan

This nine key element (NKE) plan addresses the water quality concerns in the Knife River Watershed. If implemented as written, this plan will achieve the estimated reductions and water quality standards and goals in 10 years.

MINNESOTA POLLUTION CONTROL AGENCY



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Document number: wq-cwp2-45

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Executive summary

The Knife River and its tributaries are important stream resources along the North Shore of Lake Superior. The Knife River Watershed is a hydrological unit code (HUC) 10 watershed (Knife River 0401010203) that is approximately 84 square miles in area. The three HUC 12 watersheds in the HUC 10 watershed are listed in Table 1. It 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 River.

Table 1. HUC 12 watersheds in the Knife River watershed

HUC 12	Watershed name
040101020301	Upper Knife River
040101020302	West Branch Knife River
040101020303	Lower Knife River

The Knife River was assessed as impaired for mercury in the water column and turbidity (Table 2). The mercury impairment is addressed by the Implementation Plan for Minnesota's Statewide Mercury TMDL given the difficulty of addressing it at the local level. A total maximum daily load (TMDL) for total suspended solids (TSS) was developed due to the river 's impairment for the former turbidity water quality standard for cold-water streams in Minnesota (South St. Louis County SWCD, 2010). The turbidity standard has since been replaced with a TSS standard. Source concerns for sediment loading include failing streambanks and bluffs in the river system, forestry management activities, especially in riparian areas, roads and associated stream crossings that impact stream connectivity in addition to sediment loading, septic systems, and upland erosion areas. Other concerns include aquatic life habitat, stream water temperatures, groundwater contamination, and stresses on rare and threatened plant and animal species.

Table 2. Water quality impairments in the Knife River watershed

Name	Location	Stream ID	Affected designated use	Pollutant or stressor	Year Listed
Knife River	Headwaters to Lk Superior	04010102-504	Aquatic Consumption	Mercury in water column	2001
Knife River	Headwaters to Lk Superior	04010102-504	Aquatic Life	Impaired for turbidity	2001

This document is the nine key element (NKE) watershed plan for the Section 319 Small Watershed Program for the Knife River watershed. The plan builds on the monitoring and special studies completed for the TMDL, the TMDL, and the TMDL implementation plan. Stream restoration work will follow a natural channel design process. Activities in this plan will be 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. Implementation of this plan will reduce sediment loading to meet the TSS water quality standard.

Funding of projects proposed in this plan may be restricted to funding source. Only projects and practices that are allowable by the U.S. Environmental Protection Agency's (EPA's) 2014 program guidelines and Minnesota's Nonpoint Source Program Management Plan (NPSMPP) (except where noted in the MPCA's NPSMPP) will be funded by the Federal Clean Water Act Section 319 funds. Match funds and activities must also be eligible under the guidelines and plan.

Water quality conditions

The Knife River was identified as being impaired for aquatic life due to elevated levels of turbidity based on the turbidity water quality standard in place in 1998. A TMDL was completed using total suspended solids (TSS) as a surrogate for the turbidity standard in 2010. The turbidity water quality standard was replaced with TSS in 2010 after the TMDL was approved. The TMDL has not been revised and provides a conservative target to meet the TSS standard for the river given that the TSS surrogate of 5 milligrams per liter (mg/L) for the turbidity standard is slightly lower than the current 10 mg/L TSS standard for coldwater streams. The reduction target is based on the approved turbidity TMDL providing a greater load reduction than would be present for a revised TMDL for the current TSS standard.

The Lake Superior South Stressor Identification Report (MPCA, 2017) and the Minnesota Department of Natural Resources (DNR) describe the Knife River as having naturally reproducing brook trout populations, plus steelhead and brown trout that migrate from Lake Superior to use the river as a spawning and nursery area, especially because the Knife River has no natural barriers to fish passage. The Lake Superior South Monitoring and Assessment Report (MPCA, 2014) shows that the Knife River and its tributaries are meeting the Index of Biotic Integrity for both fish and macroinvertebrates; many tributaries to the Knife River have exceptional biology and water chemistry. The Minnesota DNR Steelhead status report from the most recent fish capture survey (2017), shows that steelhead populations fluctuate from year-to-year, with the 2017 steelhead population estimated between 20,000 and 25,000 individuals for all ages of fish. The assessment report discusses how streams with larger catchments and higher gradients will tend to have higher turbidity in lower reaches, which is typical of most Lake Superior streams. These conditions can be natural but result in stressful conditions for biological communities and can be amplified by poor land use practices.

Table 3 provides the TMDL using a load duration curve methodology (the flow duration curve is Figure 5.16 in the Knife River TMDL report). Load reductions of TSS were estimated for each flow duration interval (zone) based on a daily basis of the observed loads for sampled dates and the median load capacity in each flow interval. The loads used in estimating the needed load reductions are shown in Table 4. Assuming that the load duration curve is representative of an average year's daily flows, the annual load reduction is calculated as the average of 90% and 60% which equals 75% (Figure 1). An overview of how TMDLs are developed can be found here.

Figure 1. TMDL for Knife River as determined by load duration curve (MPCA, 2011).

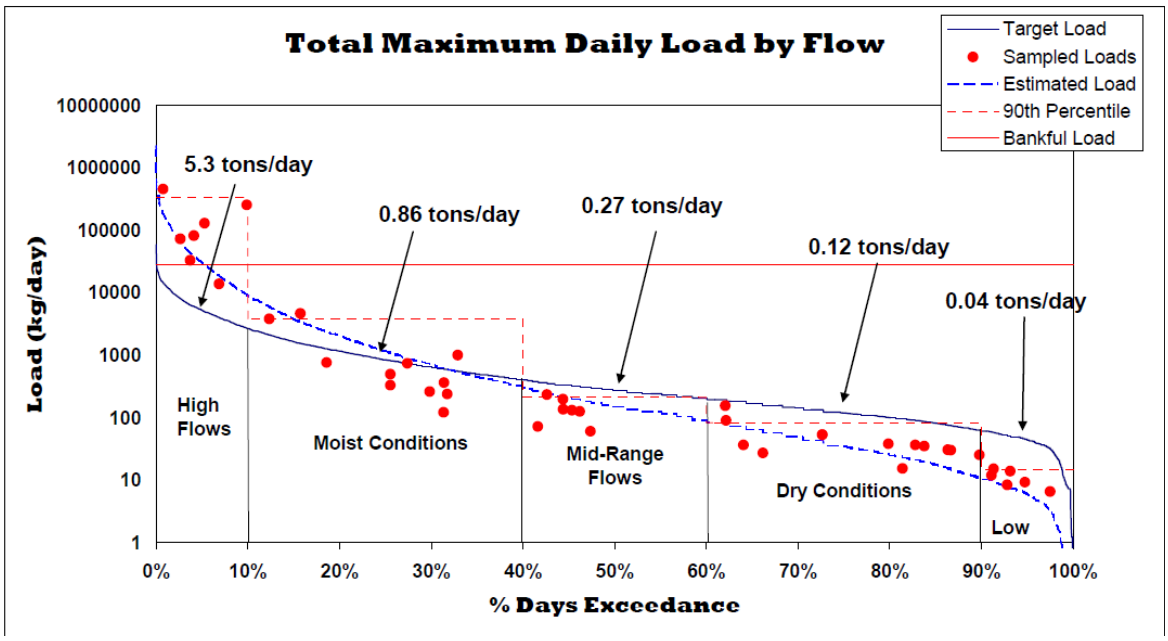


Table 3. Knife River turbidity TMDL (load capacity), waste load allocation, load allocation, and margin of safety for each flow interval of the load duration curve using TSS (Table 6.1 in TMDL).

Knife River Assimilative Capacity by Flow Zone

All values in tons per day of total suspended solids

	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	0.0004	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

- *WLA stands for wasteload allocation
- ±LA stands for Load Allocation
- ^MOS stands for Margin of Error

Table 4. Knife River TMDL, estimated current daily load, and percent reductions needed by Load Duration Curve (LDC) zone to meet the TMDL (Table 6.2 in TMDL)

Knife River TSS Load Reductions by Flow Zone

	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
Approximate Percent Reduction	90%	65%	n/a	n/a	n/a

All load values in units of tons per day of total suspended solids

The annual TSS load during the baseline period for the TMDL (2004-2006) was calculated using sampled TSS concentrations and mean daily flow data at the United States Geological Survey (USGS) gage near the outlet of the Knife River. As is expected, the estimated annual loads vary by year due to climate factors. The elevated load in 2005 may have been the result of higher number of moderate event flows compared to 2004. It is not the result of a particularly high flow year. The slightly lower loads of 2006 correspond with lower stream flows for the year. The annual and average estimates are shown in Table 5.

Table 5. Annual TSS load estimates for the Knife River.

Year	Annual TSS load (tons per year [TPY])
2004	2,800
2005	4,900
2006	2,500
Average	**3,400**

The annual load capacity to meet the TSS standard is 800 tons per year (TPY). If the average annual TSS load is 3,400 TPY, then the average annual load reduction needed to achieve the TMDL is 2,600 TPY (achieved by subtracting 800 TPY from the current 3,400 TPY). The reduction target is based on the approved turbidity TMDL providing a greater load reduction than would be present for a revised TMDL for the current TSS standard. It is important to note that these numbers represent estimates of the annual TSS load for use in identifying the expected level of best management practice (BMP) implementation and management activities needed to meet the water quality standard for TSS. The actual evaluation of whether the standard is met will be based on water quality monitoring and application of the standard. The standard being for the river to not exceed 10 mg/L on a daily basis more than 10% of the time between April 1 and September 30.

Water quality data from eight monitoring sites in the watershed provides a picture of geographic sources of sediment to the Knife River. Three sites downstream of U. S. Highway 61 are combined in a single data set. Two sites are located on the Little Knife River. Single sites are located on Captain Jacobsen Creek, West Branch Knife River, tributary at Nappa Road, Knife River at Airport Road, and East Little Knife River at Valley Road. Table 6 provides a summary of the TSS and transparency tube data for the sites between 2004 and 2021. The sites with low percentages of exceedance are all located above the red clay zone, while the Little Knife River sites are located in the transition zone between the uplands and red clay zone. The East Little Knife River is located in the red clay zone. The elevated Knife River outlet exceedances indicate that the majority of the sediment is occurring in the red clay zone along the mainstem below the upstream monitoring sites.

Table 6. Percent exceedances of TSS standard (10 mg/L) and estimated equivalent transparency tube depth (35 cm) for Knife River watershed monitoring sites

			Percent > 10 mg/L or < 35 cm	
Site name	Site IDs	Date range	TSS	Transparency
Outlet	S000-257, S003-642, S006-240	2004-2021	33%	23%
Little Knife River (downstream)	S005-394	2008-2012		11%
Little Knife River (upstream)	S005-473	2008-2015		14%
Captain Jacobsen Creek	S008-001 S008-069	2014-2020		0%
West Branch Knife River	S008-040	2014-2021		0%
Tributary at Nappa Road	S003-668	2004-2006	11%	0%
Knife River at Airport Road	S003-670	2004-2006	14%	0%
East Little Knife River at Valley Road	S003-669	2004-2006	27%	34%

Implementation strategies

The implementation strategies, schedule, milestones, assessments, and costs are described in Table 7 and are estimated to yield the reductions needed to reach water quality standards within 10 years using the Pollution Load Estimate Tool (PLET) model.

Table 7. Implementation strategies, schedule, milestones, assessment, costs, and TSS reductions estimated using the PLET model (2022)

	Milestones							
BMP/Practice/Activity	**2-year (2023)**	**4-year (2025)**	**6-year (2027)**	**8-year (2029)**	**10-year (2031)**	**Assessment**	**Cost**	**TSS reduction (tons/yr)**
Forest Stewardship plans on 5% of forest land (2,550 acres)	6 Stewardship plans (0.1 FTE)	6 Stewardship plans (0.1 FTE)	6 Stewardship plans (0.1 FTE)	6 Stewardship plans (0.1 FTE)	6 Stewardship plans (0.1 FTE)	# plans # acres	$75,000.00	3.2
Coordinate with county land departments on forest management along riparian areas on county land.	2 riparian forest management meetings per year (0.02 FTE)	2 riparian forest management meetings per year (0.02 FTE)	2 riparian forest management meetings per year (0.02 FTE)	2 riparian forest management meetings per year (0.02 FTE)	2 riparian forest management meetings per year (0.02 FTE)	# meetings # attendees # practices adopted in county riparian areas	$15,000.00	
Update, maintain, and analyze forest inventory within the watershed, especially in riparian areas, using GIS tools and remote sensing imagery. Use data for outreach targeting and forest management assistance. Evaluations, surveys and follow-up visits and mailings will be conducted.	Complete upper 1/3 of the watershed and target outreach and assistance to landowners along priority parcels (0.1 FTE)	Complete middle 1/3 of the watershed and target outreach and assistance to landowners along priority parcels (0.1 FTE)	Complete lower 1/3 of the watershed and target outreach and assistance to landowners along priority parcels (0.1 FTE)	Education and outreach to remaining Knife River watershed forest landowners (0.1 FTE)	Education and outreach to remaining Knife River watershed forested landowners (0.1 FTE)	# and type of GIS data layers # landowner contacts # interested landowners # landowners initiating forest management activity	$100,000.00	
SWCD to work with private landowners and collaborate with other natural resource agencies in implementing forestry activities. Evaluations, surveys and follow-up visits and mailings will be conducted.	5 landowners/yr (0.2 FTE)	5 landowners/yr (0.2 FTE)	5 landowners/yr (0.2 FTE)	5 landowners/yr (0.2 FTE)	5 landowners/yr (0.2 FTE)	# of landowners served # of new participants # acres	$200,000.00	

BMP/Practice/Activity	Milestones					Assessment	Cost	TSS reduction (tons/yr)
	2-year (2023)	4-year (2025)	6-year (2027)	8-year (2029)	10-year (2031)			
SWCD to work with private landowners and collaborate with other natural resource agencies in implementing terrestrial invasive plant management and treatment activities	5 landowners/yr (0.2 FTE)	5 landowners/yr (0.2 FTE)	5 landowners/yr (0.2 FTE)	5 landowners/yr (0.2 FTE)	5 landowners/yr (0.2 FTE)	# of landowners served # acres treated # acres without invasives regrowth # acres retreated	$200,000.00	
SWCD to work with private landowners and other professionals to offer site visits (consultation and resources) to individual landowners concerned with erosion, stormwater, drainage, native plants, buffer, and other best management practices addressing resource concerns on their property. Evaluations, surveys, follow-up visits and mailings will be conducted	5 landowners/yr (0.2 FTE)	5 landowners/yr (0.2 FTE)	5 landowners/yr (0.2 FTE)	5 landowners/yr (0.2 FTE)	5 landowners/yr (0.2 FTE)	# of landowners contacted determined by resource concern (tons of sediment, nutrients prevented from entering the watershed	$200,000.00	
Tree planting and tree maintenance (weed and fencing/animal browse protection) in open land areas described in the sources section and shown in Figure 8.	120 acres	120 acres	120 acres	120 acres	120 acres	# trees planted # acres planted	$2,100,000.00	6.63
Stabilize eroding road ditches and maintain vegetation in the road ditches by Duluth Township MS4	One road ditch/vegetation project	One road ditch/vegetation project	One road ditch/vegetation project	One road ditch/vegetation project	One road ditch/vegetation project	# projects # acres and/or length treated	$50,000.00	2.26
Stabilize eroding road ditches and maintain vegetation in the road ditches outside of Duluth Township MS4	Two road ditch/vegetation projects	Two road ditch/vegetation projects	Two road ditch/vegetation projects	Two road ditch/vegetation projects	Two road ditch/vegetation projects	# projects # acres and/or length treated	$100,000.00	4.51

BMP/Practice/Activity	Milestones 2-year (2023)	4-year (2025)	6-year (2027)	8-year (2029)	10-year (2031)	Assessment	Cost	TSS reduction (tons/yr)
Work with other townships and county road departments to track road and road ditch condition related to erosion risks (conduct ditch inventories, workshops for road crews)	Two meetings/ workshops. Conduct ditch inventories to track condition	Two meetings/workshops. Conduct ditch inventories to track condition	Two meetings/workshops. Conduct ditch inventories to track condition	Two meetings/workshops. Conduct ditch inventories to track condition	Two meetings/workshops. Conduct ditch inventories to track condition	# meetings/ workshops # participants # ditch inventories # ditches with improved and degraded conditions	$30,000.00	
Encourage use of erosion control practices by landowners through workshops and training, coordinate with local agencies and organizations including the Regional Stormwater Protection Team. Evaluations, surveys and follow-up visits and mailings will be conducted	Four workshops and individual contacts	Four workshops and individual contacts	Four workshops and individual contacts	Four workshops and individual contacts	Four workshops and individual contacts	# of workshops and meetings #of attendees # new attendees # individual contacts # practices adopted Participant surveys	$60,000.00	
Site-specific upland erosion control practices – cost share – 5 stormwater retention ponds (2 acres or more treated)	1 erosion control BMP	1 erosion control BMP	1 erosion control BMP	1 erosion control BMP	1 erosion control BMP	# completed # acres treated # tons sediment treated	$270,000.00	0.84
Site-specific upland erosion control practices – cost share – 10 ravine repairs (at least 5 acres treated per repair)	2 repairs	2 repairs	2 repairs	2 repairs	2 repairs	# completed # acres treated # tons sediment treated		2.3
Site-specific upland erosion control practices – cost share – 5 buffers (at least 10 acres treated per repair)	1 buffer	1 buffer	1 buffer	1 buffer	1 buffer	# completed # acres treated # tons sediment treated		1.29
Timber harvest using MFRC guidelines to reduce loading	Three harvests on total of 120 acres	Three harvests on total of 120 acres	Three harvests on total of 120 acres	Three harvests on total of 120 acres	Three harvests on total of 120 acres	# harvests # acres		0.58
Natural channel design restoration on 24,000 feet (4.5 miles) of stream	4,800 feet	4,800 feet	4,800 feet	4,800 feet	4,800 feet	# feet of streambank restored # tons sediment reduced	$10,000,000.00	972

BMP/Practice/Activity	Milestones					Assessment	Cost	TSS reduction (tons/yr)
	2-year (2023)	4-year (2025)	6-year (2027)	8-year (2029)	10-year (2031)			
Bluff restoration on 13 bluffs; stream bluff restoration activities: tree planting on bluffs when slopes decrease with bank restoration.	2 bluffs	2 bluffs	3 bluffs	3 bluffs	3 bluffs	# bluffs restored # trees planted # tons sediment reduced	$65,000.00	950
Stabilization of ravines	1,000 feet of ravine erosion stabilization	1,000 feet of ravine erosion stabilization Condition inspections of completed repairs for two years	1,000 feet of ravine erosion stabilization Condition inspections of completed repairs for two years	1,000 feet of ravine erosion stabilization Condition inspections of completed repairs for two years	1,000 feet of ravine erosion stabilization Condition inspections of completed repairs for two years	# feet stabilized # acres treated # inspections # ravines remaining stable	$1,500,000.00	500
Restore stream connectivity at road crossings with perched culverts for habitat enhancement and stream channel stabilization	Design and replace one culvert	Design and replace one culvert	Design and replace one culvert	Design and replace one culvert	Design and replace one culvert	# culverts replaced Amount of stream reconnected # feet stream channel stabilized	$2,500,000.00	
SSTS and groundwater workshops, including evaluations, surveys and follow-up visits and mailings	1 SSTS/Well workshop a year	1 SSTS/Well workshop a year	1 SSTS/Well workshop a year	1 SSTS/Well workshop a year	1 SSTS/Well workshop a year	# of workshops and attendees # participants upgrading SSTS or sealing well	$30,000.00	
Landowner workshop - conservation topics (wetlands, pollinators, etc.), including evaluations, surveys and follow-up visits and mailings	1 workshop a year	1 workshop a year	1 workshop a year	1 workshop a year	1 workshop a year	# of workshops and attendees # participants requesting additional information or technical assistance	$15,000.00	
						Total:	**$17,510,000**	**2,444**

Element a. Sources Identified

An identification of the causes and sources or groups of similar sources that will need to be controlled to achieve the load reductions estimated in this watershed-based plan (and to achieve any other watershed goals identified in the watershed-based plan), as discussed in item (b) immediately below. Sources that need to be controlled should be identified at the significant subcategory level with estimates of the extent to which they are present in the watershed (e.g., X numbers of dairy cattle feedlots needing upgrading, including a rough estimate of the number of cattle per facility; Y acres of row crops needing improved nutrient management or sediment control; or Z linear miles of eroded streambank needing remediation).

EPA Handbook for Restoring and Protecting Our Waters

Sediment Sources in the Knife River

The Knife River watershed drains 84.3 miles^2 and the river itself is 181 miles long. Ninety-four percent of the watershed is either forest or wetland. Developed lands, mostly hayfields and pastures, comprise about 6% of the watershed. Despite its rural nature, the Knife River watershed underwent extensive logging that converted the forest type and set hydrological processes in motion that caused the river to begin downcutting into the underlying clay streambed, creating ongoing sediment loading problems. The Knife River receives most of its water from surface runoff rather than groundwater inputs, making it a flashy stream prone to both large and small erosion events that contribute sediment to the stream. The Knife River TMDL Implementation Plan (South St. Louis County SWCD, 2011) and the Lake Superior Streams Sediment Assessment (Lahti et al., 2013) highlight the main sediment sources that lead to water quality impairment for turbidity in the river. Each of these sources are present within different reaches of the river and cause sediment release to the river under different flow regimes; Figure 2 shows the three HUC 12s for this watershed, while Table 8 shows the estimates for each type of sediment load for each of the Knife River's three HUC 12 watersheds. The main sediment sources are:

1. Bank and bluff erosion: the largest and most direct source of sediment comes from bank and bluff erosion, via both fluvial bank erosion and, to a lesser degree, overland flow. Bank and bluff erosion occurs primarily during spring snowmelt and larger storm events and accounts for about 90% of the average annual sediment load. The predicted modeled erosion total is approximately 1,800 TPY for bluffs and 600-700 TPY for stream banks (Hansen et al., 2016). Bank and bluff erosion are most prevalent in the Lower Knife River HUC 12, roughly the mainstem of the river downstream of the confluence with the West Branch Knife River (Figure 2). In addition to bank and bluff erosion, a large total number of river miles cut through clay till. Figure 3 shows the stream reaches assessed for bank and bluff erosion (Hansen et al., 2016); and concludes that reaches 4 and 5 contribute approximately 95% of the sediment load from bank and bluff erosion and will therefore be the highest priority critical areas for restoration and management.
2. Ravines: The Lake Superior Streams Sediment Stressor Investigation Phase 2 (Hansen et al., 2016) discusses how ravines appear to be most common where vegetation clearing has accelerated runoff; they are prevalent along steep slopes bordering elevation drops in areas along the North Shore of Lake Superior. They are also present in watersheds with abundant clay soil near the surface, like in the Knife River. GIS modeling showed that the Knife River watershed has 247 ravines totaling 243.9 acres in area. The modeled ravine erosion total was 126 TPY using the average rates from each slope category with a range from 44 to 438 TPY depending on slope, length, and land cover. The erosion rate of 126 TPY is small compared to that measured for banks and bluffs.

3. Open land: Open areas in the watershed that were previously forested before logging are a sediment source because forests capture and hold stormwater more effectively than grasslands. Much of the open land is in the clay till areas of the lower portions of the watershed, while open gravel pits are concentrated in morainal till areas in the upper watershed. Ten mapped gravel pits are very close to the mainstem of the Knife River.
4. Stormwater hotspots (critical areas): Site-specific upland erosion and runoff associated with human activities constitute stormwater hotspots, such as field tillage, impervious surfaces, construction sites and roads and ditches. Together, open land and stormwater hotspots (both related to overland flow) account for about 6-10% of the average annual sediment load and can account for up to 20% of sediment loading during smaller storms that don't affect bank and bluff erosion processes.

Figure 2. A map of the Knife River Watershed, showing the three Hydrologic Unit Code-12 watersheds.

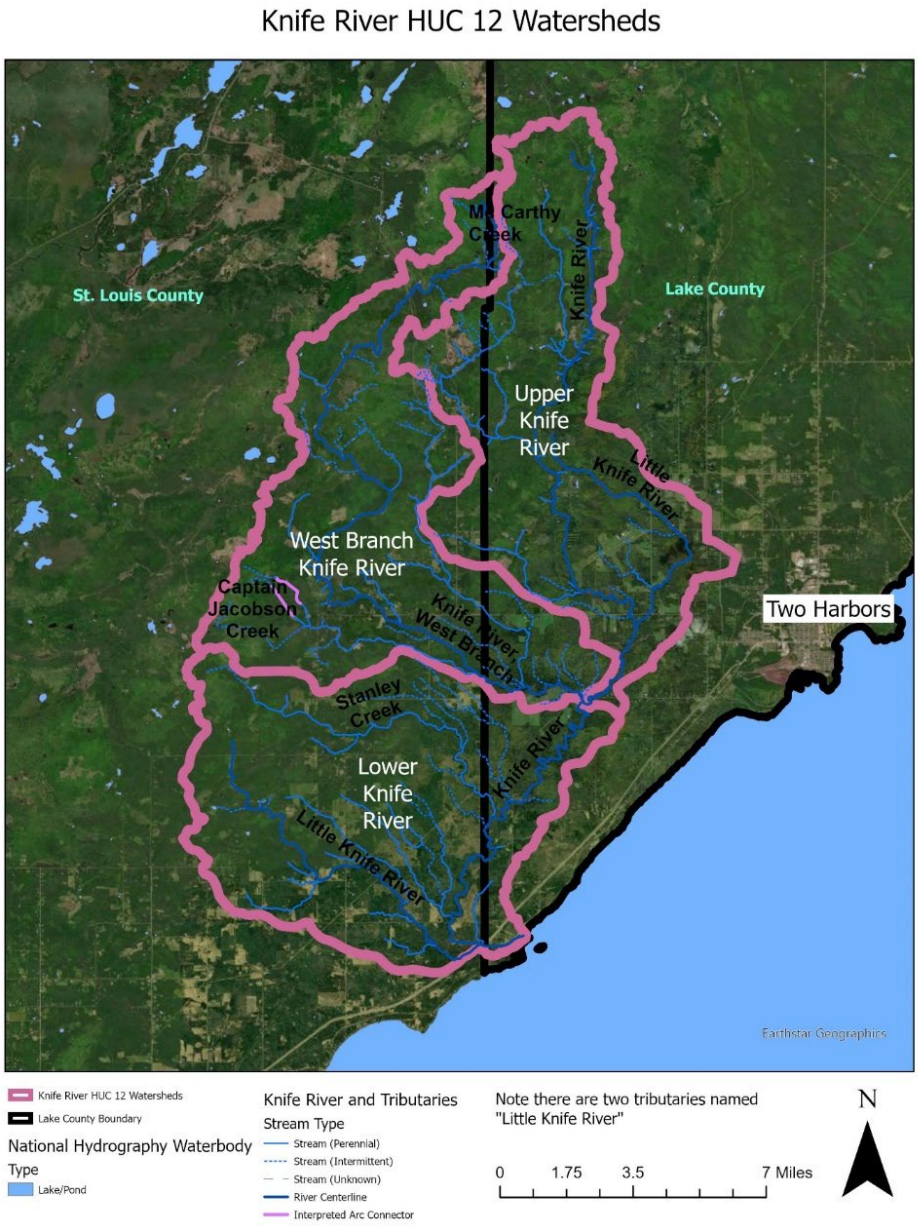
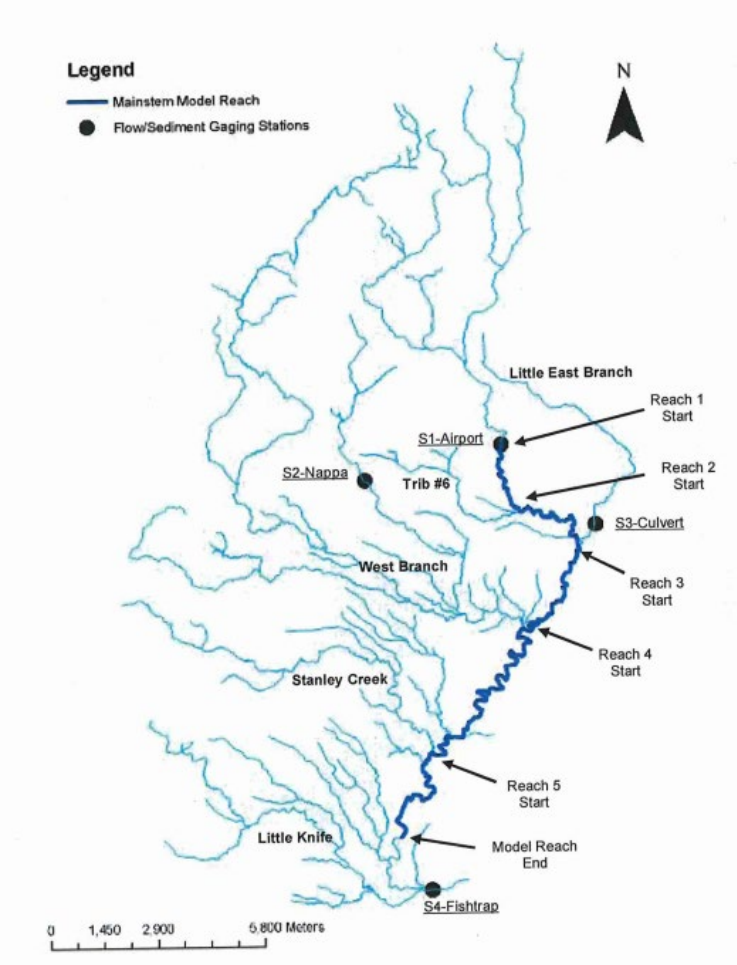


Table 8. Average sediment load (TPY) by source and HUC 12 watershed using PLET with streambank and bluff erosion (adapted from Nieber et al., 2008).

Watershed	Urban	Cropland	Pastureland	Forest	Streambank	Bluff	Total
040101020303 – Upper Knife River	35	1	13	24	654	--	727
040101020305 – Lower Knife River	36	7	22	28	1,568	1,021	2,681
040101020304 – West Branch Knife River	20	-	15	27	--	--	62
Total	90	8	50	79	2,222	1,021	3,470
% by source	3%	0%	1%	2%	64%	29%	

Figure 3. Stream reaches for streambank and bluff assessment (Nieber et al., 2008).



Factors affecting soil erosion in the Knife River

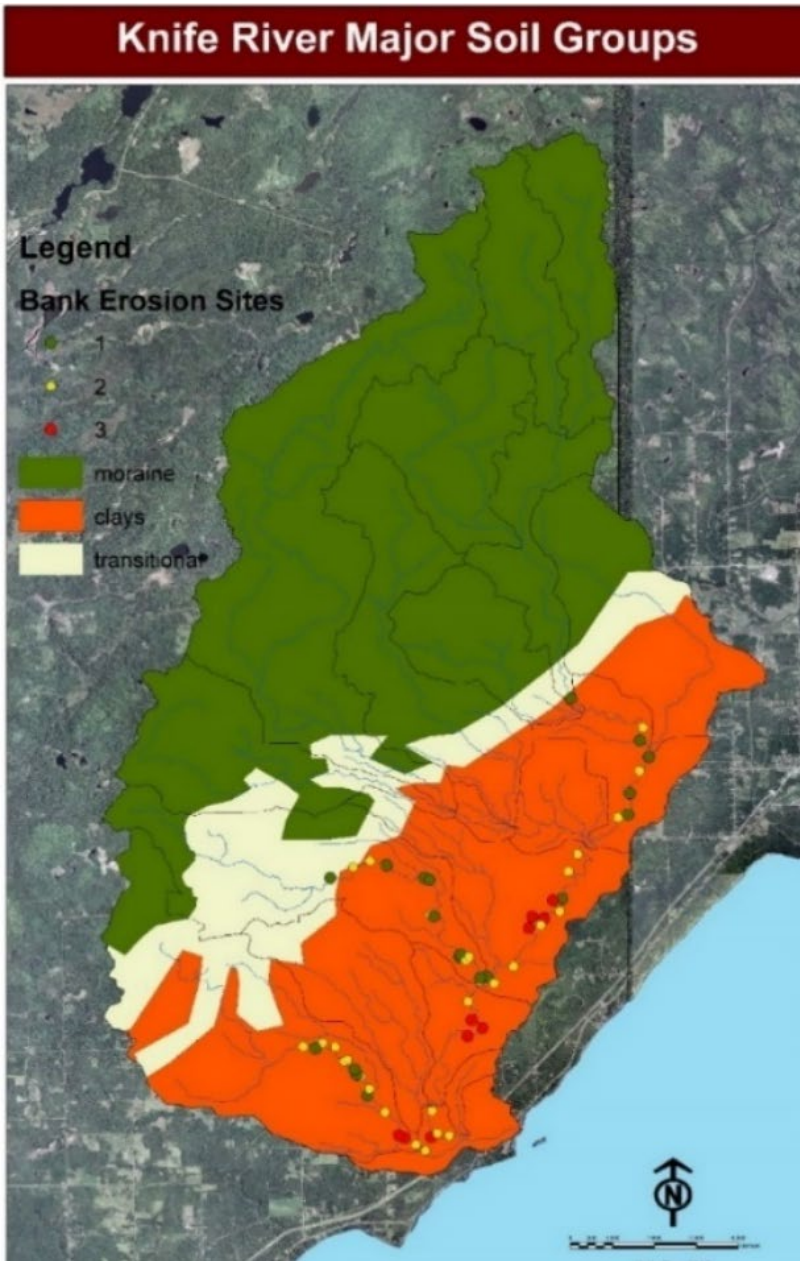
Soils, geology, and land use are the main factors affecting the amount of erosion and sediment transport in the river. The following information is drawn from the TMDL studies completed and the Knife River TMDL Implementation Plan (South St. Louis County SWCD, 2011).

Soils and geology

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 Knife River is unique among the North Shore of Lake Superior streams in that it runs perpendicular to the Lake Superior shoreline slope and parallel to the lake clay plain, increasing the number of river miles cutting through the clay till. Other North Shore streams run primarily parallel to the slope leading down to Lake Superior, which limits the number of river miles cutting through the clay tills. In addition, the proportion of clay tills in the watershed (36%) is high relative to the other North Shore streams. The Knife River also has the greatest total number of eroding bluffs (23) of all the North Shore study watersheds.

The presence of the clay till soils with very low permeability along with a seasonally high-water table increases the potential for surface stormwater runoff and ensuing high flows in the Knife River. The clay till is comprised mainly of fine clay and silt particles (70-98%) that settle out very slowly once they enter the river and are easily transported downstream. The clay till is dominant in the lower portion of the watershed resulting in a high risk of erosion and streambank failure. 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 three areas of the watershed are shown in Figure 4. The figure also identifies the location of bank erosion areas by bank failure potential. There are 10 severely eroded sites, 28 moderately eroded sites, and 18 slightly eroded sites on the Knife River, all of which are potential restoration sites (Figure 4).

Figure 4. General geological summary and areas rated for bank failure (1 – low, 2 – moderate, and 3 – high) (from South St. Louis County SWCD, 2011)



The mass erosion of fine sediment from the Knife River bluffs was estimated by extrapolating the results of a terrestrial laser scanning study of nearby Amity Creek and Lester River (Lahti et al., 2013). The estimated bluff erosion for the Knife River was 1,818 TPY accounting for 73% of the total sediment load for the Knife River. The clay till areas of the lower watershed are critical areas in the erosion and transport of sediment shown by erosion hotspot model mapping (Figure 5) and ravine mapping (Figure 6) for the watershed.

Figure 5. The erosional signature of the clay till shown on the erosional hotspot map of the Knife River (from Lahti et al., 2013).

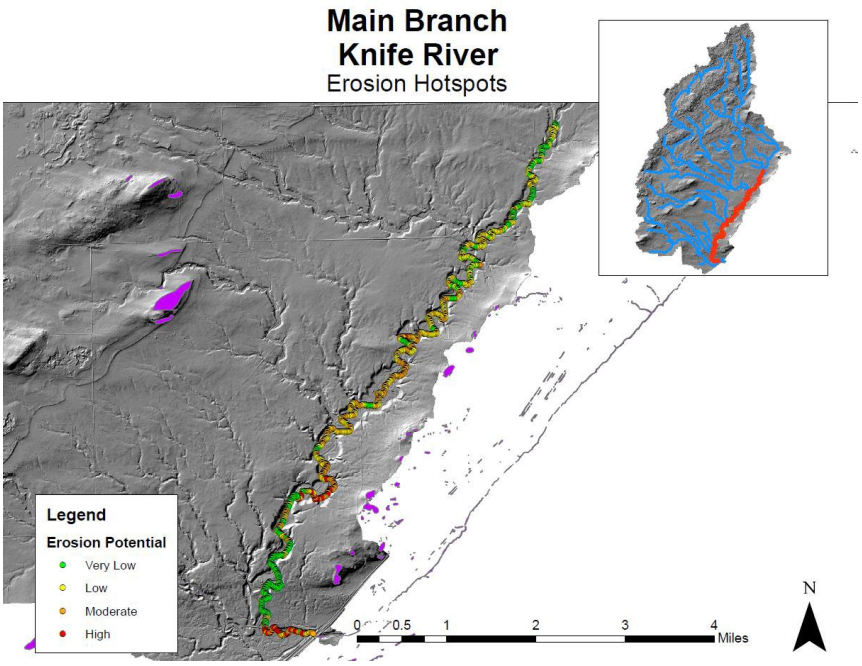
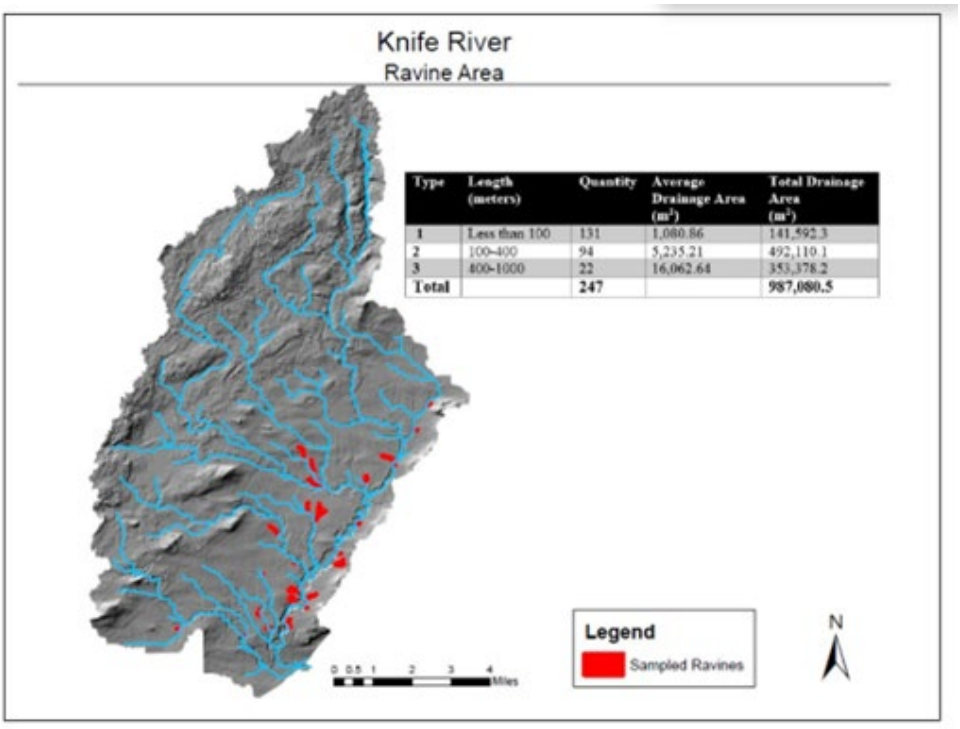


Figure 6. Ravine area in the Knife River watershed delineated in GIS (from Lahti et al., 2013).



Type	Length (meters)	Quantity	Average Drainage Area (m^2)	Total Drainage Area (m^2)
1	Less than 100	131	1,080.86	141,592.3
2	100-400	94	5,235.21	492,110.1
3	400-1000	22	16,062.64	353,378.2
Total		**247**		**987,080.5**

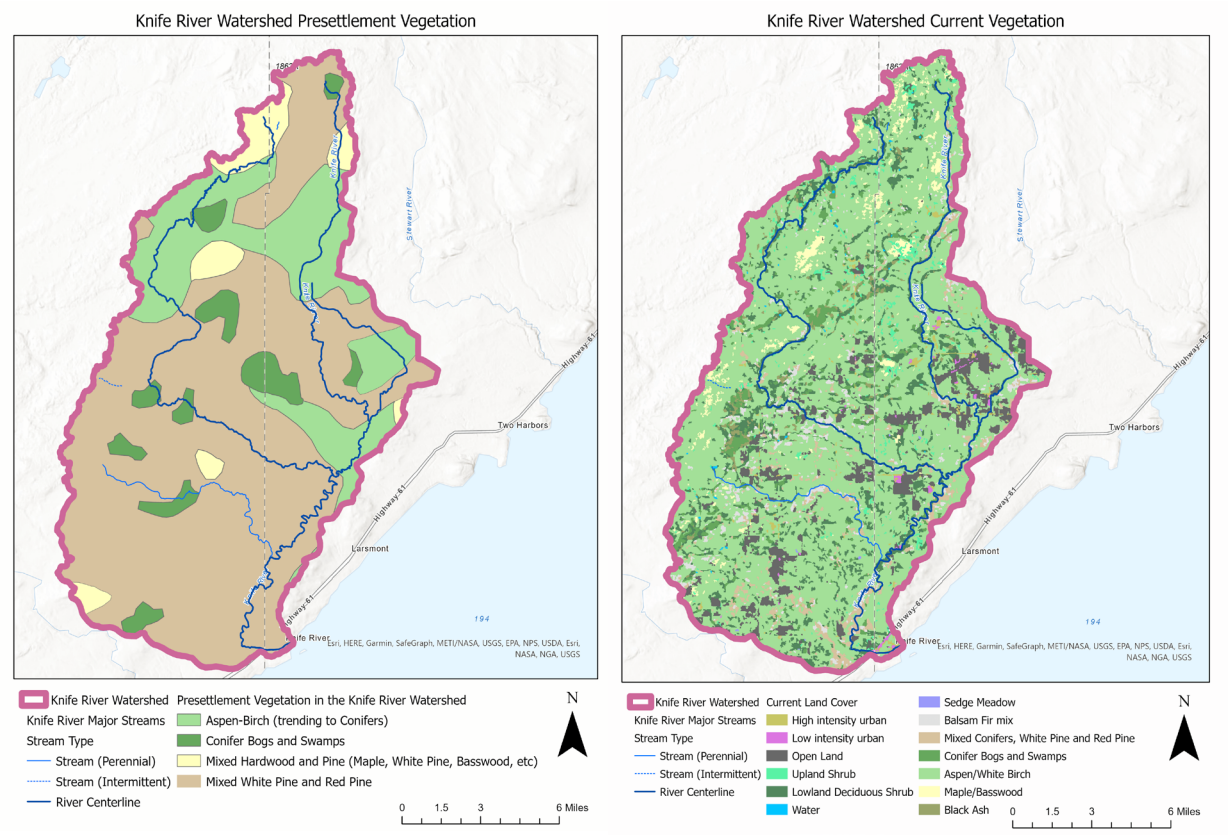
Erosion hotspot maps were also created for Captain Jacobson Creek, Stanley Creek, and the Little Knife River. The erosion hotspot maps were plotted on Light Detection and Ranging (LiDAR) images of the watersheds. Higher stream power and small bend curvature translates to more potential erosion. The Little Knife River had a higher average stream power than any of the main branches of the river even though it had a much smaller drainage area.

Land Use

Changes in land use have changed the hydrology of the watershed, but sustainable land management, including converting open land and aging aspen forests to a mixed conifer-hardwood system through tree disease management, timber harvest, and tree planting would eventually help reduce peak stream flows and provide increased base flows through temporary water storage. The two types of land use that have had the largest effect on Knife River hydrology are historic logging and conversion of forest to open land.

The Marschner presettlement vegetation map shows that the Knife River watershed was primarily white pine and red pine forest (Figure 7). Like much of northern Minnesota, the Knife River area was heavily logged in the late 1800s, changing the forest composition and the hydrology of the entire watershed into the present day. Stream flows likely increased following the historical logging of red pines and white pines and the resulting loss of the thick forest floor duff layer. Elevated stream flows during this period increased streambank erosion from what was historically experienced. This permanently increased the width/depth ratio and set in motion river downcutting processes that are still occurring today; channel destabilization and bank erosion are ongoing. The white pine and red pine mixed forest was replaced by hardwoods such as aspen (Figure 7), and 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 7. Change in Vegetation Types in the Knife River Watershed from the Public Land Survey (1847-1907) to the Present (1990s).



The conversion of forest to open space land increased overland runoff and erosion potential. Although not dominant in the watershed, these sources are not insignificant and may be locally very important. The open space land is classified as urban (developed) open space, cropland, and pastureland by the

National Land Cover Database (NLCD) but is mostly hay fields and pasture. The percentage of open land in the watershed is shown in Table 9. The open space lands are concentrated in the clay till area paralleling the North Shore, so that 13% of the land in the clay till area is open land. Figure 8 is a map of the open areas in the watershed. Gravel pits in morainal tills represent much of the open areas in the upper watershed.

Table 9. Open space land in the Knife River watershed.

Watershed	Percent open land
040101020303 - Upper Knife River	6%
040101020305 - Lower Knife River	8%
040101020304 - West Branch Knife River	6%
Total	7%

The upland open areas have potential direct human-induced erosion features such as field tillage, impervious surface runoff, and soil disturbance due to construction activities. In addition to the upland open areas, riparian open areas are critical places to plant vegetation to shade the river to reduce elevated water temperatures. Stormwater hotspots also encompass roads and ditches in the watershed that may directly erode or increase erosion from runoff from them. Numerous road crossings and their culverts can cause scouring of the riverbed or provide concentrated flow pathways which can lead to increases in peak flows. The critical stormwater hotspots for roads are sections of steep road ditches running downslope directly to a main branch or tributary of a stream. These sections were usually located where a road ran down the valley wall to a stream crossing. While many miles of ditches remain well vegetated, these sections of ditch have enough stream power as the result of a large enough drainage area enhanced by the concentrated flow paths to down-cut through the vegetation into the exposed till.

Figure 8. Open land and subwatersheds of the Knife River (from South St. Louis County SWCD, 2011).

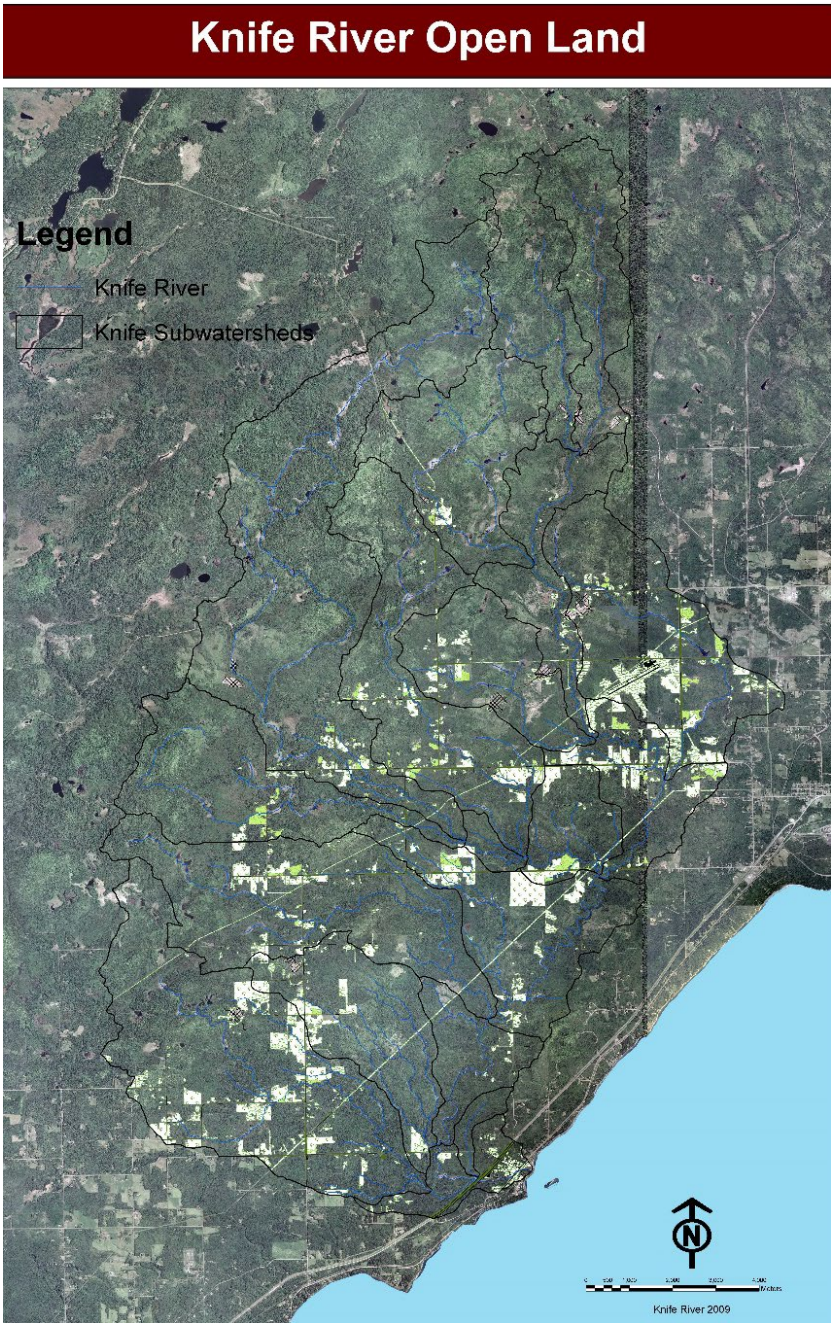
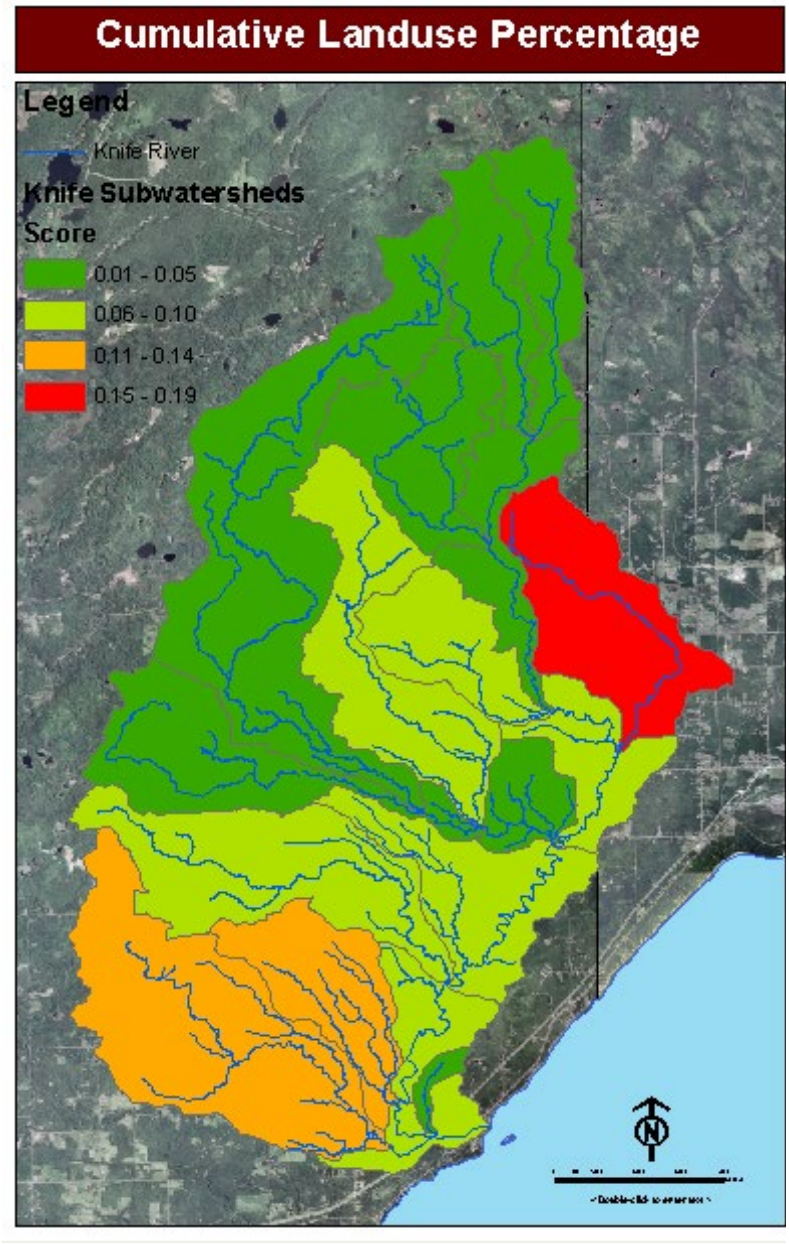


Figure 9 shows the percentage of open lands by catchment areas potentially contributing to higher peak flows by quicker spring snowmelt and storm event runoff ranked individually and by cumulative drainage area. The catchments with a high and moderate proportion (15-18% and 11-14%, respectively) of open land and stormwater hotspots provide a priority framework of sub-watersheds to target for tree planting on open land. The figure identifies the areas to prioritize for reforestation efforts in open land areas. Priority areas for sustainable timber management on public lands will follow the St. Louis County and Lake County Land Departments' plans.

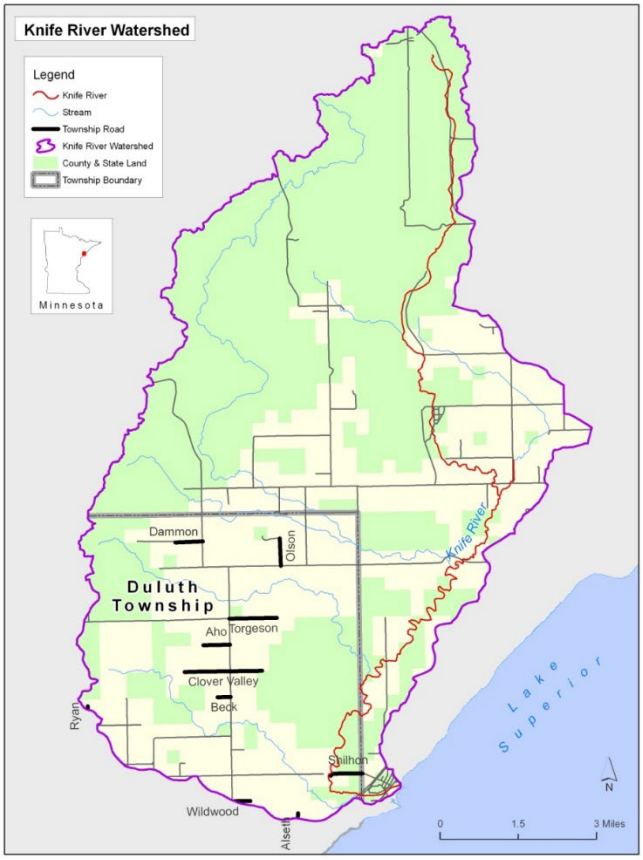
Figure 9. Percentage of open lands in Knife River watersheds (from South St. Louis County SWCD, 2011).



Wasteload Allocations in the Knife River Watershed

A wasteload allocation (WLA) was required for the Duluth Township MS4 in the Knife River TMDL. The township was designated an MS4 given its proximity to the city of Duluth even though it is wholly rural with the exception of some development near Lake Superior. The WLA applies only to the conveyance systems owned and managed by the township that include approximately seven miles of township roads and their ditches, a town hall and a fire station that are in the watershed (Figure 10).

Figure 10. Roads and Duluth Township roads in the Knife River watershed (from South St. Louis County SWCD, 2011).



A WLA was also assigned to construction stormwater. The amount of construction in any year is extremely small, so the one percent allocation is very conservative. Any permitted construction activity in the Knife River watershed is subject to the 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.

Element b. Estimated reductions

> *An estimate of the load reductions expected for the management measures described under paragraph (c) below (recognizing the natural variability and the difficulty in precisely predicting the performance of management measures over time). Estimates should be provided at the same level as in item (a) above (e.g., the total load reduction expected for dairy cattle feedlots; row crops; or eroded stream banks).*
>
> *EPA Handbook for Restoring and Protecting Our Waters*

Several BMPs have been implemented to reduce the TSS load since the TMDL was completed in 2010. Table 10 summarizes BMPs and actions completed with associated load reduction estimates as calculated using U.S. Environmental Protection Agency's Pollutant Load Estimation Tool (PLET), 2022.

Table 10. BMPs, management activities, and estimated TSS load reductions completed between 2010 and 2022 (PLET, 2022).

Activities	Sediment reduced (TPY)
Duluth Township road ditch repairs and stabilization and culvert replacements	7
Streambank restoration projects	742
Tree/shrub establishment	7
Riparian forest buffer	2
Forest management plans written	0.4
Forest stand improvement, critical area planting, habitat development, woody residue treatment	1
Total	760

The planned BMP implementation and stream restoration will result in the estimated sediment reductions shown in Table 11.

Table 11. Estimated sediment reductions with the planned BMP implementation and stream restoration activities (PLET, 2022).

Planned BMPs and activities	Sediment reduced (TPY)
Upland activities	22
Streambank restoration	972
Bluff restoration	950
Ravine restoration	500
Total	2,444

The total estimated sediment reductions from the completed and planned activities are summarized in Table 12. The completed activities combined with the activities in this plan will reduce the sediment loading to the Knife River an estimated average of 3,204 TPY, exceeding the amount required to achieve the Knife River turbidity TMDL (2,600 TPY). It is expected that the river will meet the water quality standard for total suspended solids when this plan is fully implemented.

Table 12. Summary of estimated sediment reductions for the Knife River watershed.

Activity	Sediment reduced (TPY)
Completed BMP reductions	760
Planned BMPs and activities	2,444
Total	3,204

Element c. Best management practices

> *A description of the BMPs (NPS management measures) that are expected to be implemented to achieve the load reductions estimated under paragraph (b) above (as well as to achieve other watershed goals identified in this watershed-based plan), and an identification (using a map or a description) of the critical areas (by pollutant or sector) in which those measures will be needed to implement this plan.*
>
> *EPA Handbook for Restoring and Protecting Our Waters*

The management measures that will be implemented to achieve the TSS load reductions to meet the TMDL follow the four types of critical areas described in Element a. The specific activities are listed in the implementation strategies table along with goals, milestones, and cost estimates (Table 7). The activities are described briefly in the following paragraphs.

The Lake Superior North One Watershed One Plan, which is the comprehensive watershed planning process in Minnesota, lists the Knife River as a Tier 1 priority watershed because of the river's value as a trout fishery and its turbidity impairment. The One Watershed One Plan includes implementation strategies to address existing erosion problems by conducting targeted erosion control projects. It focuses on using current natural resource engineering methods to reduce sediment loading into surface waters.

Streambank and Bluff Erosion Control and Restoration

Since streambank and bluff erosion are the largest sediment sources in the Knife River, priority will be given to projects that directly manage in-stream hydrologic processes in the river using the Natural Channel Design approach (Rosgen, 2011). The flashiness of the Knife River increases the risk of failure of restoration efforts such that extra caution is needed in the design process. Critical areas are also often difficult to access, which increases the cost and reduces the feasibility of completing restoration work. In many high-erosion sites, the river is downcutting into the clay soils of the streambank while also eroding valley walls and undercutting the toes of steep eroding bluffs. Successful past projects on the Knife River demonstrate the effectiveness of 1) correctly identifying bankfull elevation and installing grade control structures to reconnect the river to its floodplain and prevent further incision; and 2) routing the river away from slumping banks, installing bankfull benches with toewood and planting native trees and shrubs to prevent undercutting steep slopes. Bankfull benches allow the bluffs above them to slowly achieve angle of repose without releasing additional sediment into the river. Once the bluff slopes are stable, then they can be planted with trees.

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) are:

- Mild erosion areas (5 TPY) -- $25,000.00 ($10,000.00 for engineering, $15,000.00 for construction);
- Moderate erosion areas (30 TPY) -- $50,000.00 ($20,000.00 for engineering, $30,000.00 for construction; and

- Major erosion areas (900 TPY) -- $150,000.00 ($50,000.00 for engineering, $100,000.00 for construction).

For the purposes of the NKE plan, maintenance costs are assumed to be a part of construction costs. Actual costs for maintenance will be included as project designs are developed.

Grade Control Structures

Grade control activities may range from simple projects such as stabilizing the toe of the streambank to installing in-channel structures such as cross-veins, to channel adjustment techniques (which requires more intensive design). Projects will be prioritized according to bank failure ratings, as shown in Figure 4. Grade control structures are essential for reversing ongoing channel incision, raising the water level to reconnect the river with its floodplain, and raising the groundwater table. In addition to rock grade control structures, coarse organic material (i.e., woody debris) can be used in toewood installations and in cross-vein features such as J-hooks. Coarse organic material may also be placed in small tributaries and the mainstem of the Knife River in the upper watershed, creating fish habitat and promoting deposition of mobilized sediment. Sediment reduction results for grade control structures would be highly variable depending on placement. On meander bends with high erosion rates, sediment reduction will likely be substantial. In areas of lower shear stress, the rates would be lower but would still provide habitat and most likely some moderate sediment reduction capacity. Any work that decreases the width/depth ratio of the riverbed has the potential added benefit of creating conditions that support lower water temperatures.

Bankfull Benches

Bankfull benches can be installed where high-energy river cutbanks flow immediately against tall slumping clay bluffs, which can cause extreme erosion when steep valley walls can't support vegetation. Restoration activities involve reducing sinuosity and current velocity by straightening out these river cutbanks and creating a bankfull bench between the new river course and the eroding bluff. Benches are typically needed where a stream butts up against steep bluffs and/or when grade control structures are not adequate by themselves. If the shear stress of the river is great enough, toewood can also be included along the cutbanks of bankfull benches. In addition, native plants, shrubs and trees should be planted as soon as possible after bankfull bench installation. Areas with a bank failure rating of 'high' in Figure 4 are high priorities.

Once bankfull benches are installed, the exposed bluffs will slump and erode onto the benches, which are able to hold the eroding sediment in place and away from the river. As the bluff erodes, it will eventually reach its natural angle of repose and shrubs and trees can then be planted (or naturally recruited) to further stabilize the bluffs and reset these high-erosion areas into low or moderate erosion areas. Priority for tree-planting projects will be given to bluffs at bankfull bench locations. Costs for purchasing, planting, and maintaining trees is about $2,500.00 per acre.

Riparian and Upland Forest Management

A primary management goal for the riparian areas along the Knife River and its main tributaries, along with upland forest, is to develop a healthy, mature, long-lived and diverse forest. Priority for forest restoration and management will be given to open land and stormwater hotspots, since these are sediment sources identified in the Knife River TMDL. Riparian and upland forest management will reduce both the amount and velocity of overland stormwater runoff to the Knife River since forests capture and hold stormwater more effectively than existing grasslands or impervious/eroded surfaces. As open areas are converted to forest, and as existing aspen stands are converted to diverse forest

stands through timber stand improvement, two stream sediment-balance mechanisms will reduce sediment inputs into the river: 1) lower peak flows will cause less shear stress on stream banks, thus reducing in-channel sediment sources, and 2) tree roots will provide greater resistance to overland erosion compared to grass roots.

Forest management plans on both private land and public land should follow the Minnesota Forest Resources Council (MFRC) Forest Management Guidelines (MFRC, 2022) 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 feet from the stream for long-lived conifer and hardwood species (including red pine and white pine, white cedar, white spruce and black spruce, tamarack and oak) through targeted timber harvesting and planting.
- Enhance collaboration with Department of Natural Resources Fishery staff on LLT management.

Riparian Forest Management

Riparian area management practices on private forest land will be encouraged by reviewing and updating current forest management plans and developing new plans. Easements can also be used where feasible to encourage riparian buffers on private land and buffer recommendations will be implemented for timber harvests on public or private land. Trees planted in open areas near the river will contribute large woody debris important to aquatic life, and riparian forest management will also address potential black ash losses due to emerald ash borer by choosing alternative species that can grow in places of ash trees. Forest activities on private land will be coordinated by the SWCDs with DNR and Natural Resources Conservation Service (NRCS) programs. County forest land, both in riparian and upland areas, will continue to be managed by St. Louis County and Lake County Land Departments, and state land will be managed by DNR Forestry.

Upland Forest Management

Existing upland forest, which consists mostly of aging aspen stands, will be converted where possible to long-lived conifer and hardwood stands (planted with species likely to survive changing climate conditions, including tree seedlings from seed sources further south) through timber stand improvement efforts and harvests. Aspen will continue to be a dominant species on the landscape during this time of forest conversion, and aspen saplings and suckers provide the shade that species like white pine and white spruce need during their sapling stage. Much of the upland forest understory in the Knife River watershed consists of dead balsam fir that was impacted by the native spruce budworm forest pest. Upland forest management will involve balsam fir removal to allow for forest understory succession, and to reduce fire danger. Lake SWCD will follow site inspection guidelines used for cost-share tree planting projects, following Minnesota Board of Water and Soil Resources (BWSR) Operation, Maintenance, and Inspection of Practices Upland Erosion Control Activities

Upland soil erosion control practices will address specific erosion problems in the Knife River watershed due to gully and ravine erosion, road and ditch erosion, and stormwater hotspots due to bare soil, impervious surface runoff, and construction activities.

Ravine Stabilization

Ravine stabilization methods will be highly site-specific, prioritizing ravines flowing directly into a stream (Figure 4). In some cases, stabilization may require rip rap and in others it might be resolved with re-shaping and vegetation. These ravines are often associated with roads and sometimes the solution is upgradient of the gully or ravine, (e.g., fixing culvert installations or installing energy dissipation

measures). In terms of management, dramatic changes to land use could accelerate erosion in ravines, particularly deforestation and development on steep or long slopes directly above ravines. The maximum rates of soil loss predicted in ravines were quite high (up to 16.7 tons per acre per year) indicating that ravines do have potential to contribute large amounts of sediment to North Shore streams if changes to land-use and hydrology occur (Hansen et al., 2016).

Road Ditch/Culvert Maintenance and Re-vegetation

Road ditches, which drain much of the Knife River watershed, can be significant pathways for sediment. Lake County SWCD completed a culvert inventory that includes the Lake County portion of the Knife River watershed, and that database can be used to add additional information, such as culvert inventories in St. Louis County, plus an inventory of road ditch conditions and locations of potential temporary storage/flow attenuation areas, and the amount and duration of flow in ditches. Workshops for road crews can help target areas for implementing existing road ditch BMPs such as scour-reduction techniques at culverts and check dams to reduce runoff velocities in ditches. Priority will be given to road ditches located near a stream. Counties and townships may foster Adopt-a-Culvert or Adopt-a-Ditch efforts for weed control and other stormwater maintenance. Inventories and trainings focused on culvert maintenance will also prioritize fish passage, making sure that culvert replacement work follows the *Minnesota Guide for Stream Connectivity and Aquatic Organism Passage through Culverts* (DNR, 2019). The guide builds on a practical approach developed by U.S. Forest Service Hydrologist, E. Sandy Verry, referred to as MESBOAC (Table 13) for designing culverts that addressed a broad variety of potential aquatic organism passage problems associated with traditional culverts. The guide summarizes a set of best practices that includes critical design elements including 1) designing culverts to be similar to the stream channel by matching its slope, alignment, bankfull width, and flow depth; 2) providing a continuous sediment bed with roughness similar to the channel, while maintaining continuity of sediment transport and debris passage; and 3) designing for public safety, longevity, and resilience. Designing culverts in this way will improve stream connectivity and maintain sediment transport to reduce long-term maintenance costs and increase culvert life span.

Table 13. Summary of MESBOAC approach.

MESBOAC stands for:
Match culvert width to bankfull stream width.
Extend culvert length through the side slope toe of the road.
Set culvert slope the same as stream slope.
Bury the culvert.
Offset multiple culverts.
Align the culvert with the stream channel.
Consider headcuts and cutoffs.

Ditch checks and planting native vegetation will act together to hold water in-place longer along roadsides, promoting on-site infiltration and reducing peak flows and shear stress in the river. In addition, increasing vegetation and adding ditch storage will decrease the sediment input directly from the ditches.

Ditch BMPs applicable to the Knife are defined in the Minnesota Stormwater Manual, Highway 61 Stormwater Natural Drainage and Retrofit Identification Project report (McDonnell et al., 2008), and the Field Guide for Maintaining Rural Roadside Ditches.

Stormwater Hotpots

Stormwater hotspots are relatively small areas of the watershed that include field tillage, impervious surface runoff, construction activities and roads and ditches (Figure 7). Gravel pits, both during operation and after closure, are stormwater hotspots because gravel, sand and cobble are easily washed from open pits into nearby waterways. Deep gravel pits near or below the water table are also a potential source of groundwater contamination. The Lake Superior North One Watershed One Plan highlights the need for projects to restore and re-vegetate defunct gravel pits. The Richard Helgeson Municipal Airport is one of the largest contiguous open areas in the watershed and could potentially benefit from green infrastructure to slow and capture stormwater runoff. The unincorporated town of Knife River is at the outlet of the Knife River; it experiences flood damage and would benefit from the development and implementation of a stormwater management plan. A stormwater management plan would help Knife River update aging stormwater infrastructure, mitigate flood damage, and provide opportunities for stormwater demonstration projects such as rain gardens.

The first steps in managing stormwater hotspots include compiling an inventory of existing stormwater BMPs; training local contractors to use the BMPs; and supporting landowners in adopting them. 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.

Duluth Township MS4

The Town of Duluth (Duluth Township) conducts regular road inspections, which include culvert inspections and identifying any areas of active erosion. The Township uses a tracking system of GPS locations and photographs to track the condition of ditches and outfalls to ensure conditions are good or repairs are completed when needed. All ditch/culvert maintenance or repair activities undertaken by the Township include re-seeding/re-vegetation, along with installing rock armoring, ditch checks and diversions, etc. where appropriate to prevent erosion and limit ditch flow/velocity.

Duluth Township is proactive in addressing potential stormwater problems through their MS4 Stormwater Pollution Prevention Plan (SWPPP), 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 St. Louis County, the City of Duluth and the Regional Stormwater Protection Team is expected to result in the attainment of the WLA.

Terrestrial invasive species control

Invasive plant infestations can compete with native ground cover, which exposes a greater amount of bare soil, increasing the risk of erosion. Therefore, controlling these infestations is important to reduce sediment deposition and maintain the health and quality of the watershed. Terrestrial invasive plant management and treatment activities will target current and emerging invasive species populations. Control activities will often be coordinated with streambank, bluff, riparian and upland forest management, and upland erosion control activities in the watershed. Invasive species control is important in maintaining the health of the watershed. Workshops will be used to build understanding of the connections between terrestrial invasive species management and watershed health. Lake County SWCD oversees terrestrial invasive species management within Lake County through grants in association with a Cooperative Weed Management Area for Lake County, a grant and project with the Great Lakes Restoration Initiative and the U.S. Forest Service (USFS), and cooperation with the Lake County Invasives Team (LCIT), which includes the Minnesota Department of Transportation (MNDOT),

the USFS, DNR Forestry and Parks and Trails, Lake County Forestry and Highway Departments, Lake County SWCD, 1854 Treaty Authority, and participation from local organizations. Lake County SWCD recently started a rental program for buckthorn management equipment and other associated terrestrial invasive species equipment. Landowners in the Knife River watershed have expressed concerns over invasive species proliferation in hayfields and along energy transmission corridors, and the citizen group Advocates of the Knife River Watershed is focused on early eradication of terrestrial invasive species and implementing Integrated Vegetation Management practices.

Outcomes

Most of the BMPs presented in this implementation plan will reduce sediment loading, peak flows and temperatures in the Knife River, some more rapidly than others. BMPs aimed at streambank and bluff erosion have the greatest potential for altering the hydrologic processes that are contributing the most sediment to the river, with effects likely observable in the near-term. 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. Priority will be given to projects focused on both the channel and upland areas of the watersheds where steep slopes, clay tills and open land are present. Other priorities in the river, such as brook trout/steelhead spawning area, fish passage, or tributaries that would benefit from both sediment reduction and habitat enhancement, will be considered.

Long-term riparian forest management, especially on eroding bluffs, will improve habitat through shading and providing a source of woody debris to the stream. Upland forest management and erosion control activities will likely affect flow and temperature at a longer-term and broader geographic and hydrologic scale. This holistic stream restoration 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.

Element d. Expected costs and technical assistance

An estimate of the amounts of technical and financial assistance needed, associated costs, and/or the sources and authorities that will be relied upon, to implement the entire plan (include administrative, Information and Education, and monitoring costs). Expected sources of funding, States to be used Section 319, State Revolving Funds, USDA's Environmental Quality Incentives Program and Conservation Reserve Program, and other relevant Federal, State, local and private funds to assist in implementing this plan.

The estimated costs of the activities in this plan are shown in Table 7. The total estimated cost to attain the sediment reductions needed to achieve the TSS water quality standard in addition re-establishing the general structure, function and self-sustaining behavior of the Knife River watershed stream system is approximately $18 million.

Many units of government and organizations are important in the implementation of this plan. A list of the organizations along with their general roles and potential responsibilities is provided in Table 14. The list is not intended to be a final list, as other groups and individuals step up to assist in the restoration efforts.

Table 14. Partners' Potential Roles and Responsibilities

	Partner	General Roles	Potential Responsibilities
Citizen Groups	Knife River Stewardship Committee	It provides 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 with LGU on proposed activities
	Knife River Recreation Council	Outreach & civic engagement	Attend meetings Share information Tree planting Ditch/culvert maintenance
	North Shore Forest Collaborative	Focuses on the area from the shore of Lake Superior to 3.5 miles inland to restore and maintain a healthy and functioning forested ecosystem Outreach and civic engagement	Share information Tree planting
	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

	Partner	General Roles	Potential Responsibilities
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 Regional Stormwater Protection Team The Nature Conservancy	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 Support forest management and water quality goals through grant funds
Local Government	South St. Louis & Lake County Soil & Water Conservation Districts, Technical Service Area III Engineers	Lake County SWCD serves as project lead in partnership with MPCA Serve on the Stewardship Committee Manage grant projects Design and evaluate BMPs Pursue and develop funding proposals Initiate and maintain landowner contacts and relationships	Lake County SWCD implements Knife River Nine-Key Element Plan 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, Highway, and Land Departments)	Serve on the Stewardship Committee Manage lands and forests Oversee county roads Enforce planning & zoning Enforce wetland rules, construction setbacks and lot width, and SSTS. Highway Dept is the County weed inspector	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
	North Shore Management Board	Cooperative effort of the Minnesota DNR and local governments (counties, cities, townships) along the North Shore Support the North Shore Management Plan to guide and protect growth strategies	Assist with applying North Shore Management Plan along Lake Superior coast in the Knife River watershed Educate local officials

	Partner	General Roles	Potential Responsibilities
	Regional Stormwater Protection Team	Provide stormwater education, outreach and civic engagement for North Shore MS4s	Hold meetings Share information
	Lake County Invasives Team	Coordinate terrestrial invasives prevention, monitoring, control and restoration Outreach & education	Coordinate multi-agency terrestrial invasive species management, including project implementation.
State Government	Minnesota Board of Water and Soil Resources	Serve on the Stewardship Committee Administer Minnesota Clean Water Fund Projects Provide technical assistance Serves on County Technical Evaluation Panels for wetland permits	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, issue Public Waters Permits, conduct wetland rule enforcement 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 $5,000.00 - $100,000.00	Grant program education and application review
	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 (MNDOT)	Oversee state highway	Maintain Highway 61 corridor
	University of Minnesota (Duluth campus, Sea Grant, and NRRI)	Provide technical review Conduct research with a major focus on the Knife River Pursue and develop funding proposals Issue grant opportunities Civic engagement and training	Lead needed research Write funding requests Provide 'Woodland Advisors' Nonpoint Education for Elected Officials (NEMO)

	Partner	General Roles	Potential Responsibilities
Federal Government	U.S. Environmental Protection Agency (Region 5, ORD-Duluth laboratory)	Provide Section 319 grants and guidance Watershed monitoring	Provide temperature loggers
	Natural Resources Conservation Service (NRCS)	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
	U.S. Army Corps of Engineers	Provide watershed modeling	Update models with new data Explain & educate local stakeholders
	Federal Emergency Management Agency	Provide floodplain mapping Provide hazard mitigation funding and assistance	Updated floodplain maps Hazard mitigation planning and grants

Element e. Education and outreach

An information/education component that will be implemented to enhance public understanding of the project and encourage their early and continued participation in selecting, designing, implementing and maintaining the NPS management measures that will be implemented.

Outreach and Education

The various outreach and education activities in this plan are described below by audience type. In many cases, the individuals may be the same for some of the outreach and education activities – e.g., landowners within the Knife River watershed will also likely be members of Advocates for the Knife River Watershed. The effectiveness of the outreach and education activities will be assessed using evaluations, surveys and follow-up visits or mailings.

Landowner Education

Partnerships with landowners have been and will continue to be critical to the Knife River TMDL. Lake County SWCD will use broad public outreach strategies to garner landowner support throughout the watershed through mailings, workshops, tours and site visits. These types of outreach will also focus on increasing awareness of cost-share opportunities available to landowners to implement BMPs on their land; this may require expertise on BMP selection and implementation from local agencies or contractors. When working with specific landowners, the focus will be on teaching them the strategies they can use to improve erosion problems and decrease stormwater runoff conditions in their reach of the river, and how that affects the entire watershed. For instance, University of Minnesota-Extension 'Woodland Advisors' can be invited to help landowners review progress within their forest management plans; Lake County SWCD and County foresters can also connect landowners with opportunities to enact timber stand improvement actions on their land. Specific BMPs on which education programs should focus include tree planting in open land areas, miscellaneous runoff reduction activities in open land areas, riparian area management, upland forest management, gully/ravine stabilization and stormwater BMPs.

Public Outreach

Public outreach will focus on raising awareness of general water quality problems in the Knife River and the importance of protecting and improving conditions in the river, both to benefit wildlife and humans. Outreach will also focus on actions citizens can take to improve Knife River water quality (such as installing rain barrels and rain gardens to moderate flow) and will require some collaboration among agencies to help with outreach. This BMP will focus on implementing outreach activities such as press releases, paid media, school outreach activities, newsletters, and a tab on the Lake County SWCD website to increase awareness among watershed residents of the connection between land use practices, runoff and turbidity. Outreach will also provide contacts for landowners to request assistance from when planning work that could impact the Knife River, such as undertaking a construction project, replacing a culvert, installing a bridge, etc.

Training for Contractors and Local Government

This education BMP will have the most impact on sediment sources arising from stormwater hotspots (critical areas) coming from roadways and impervious surfaces. Agencies such as Lake County SWCD will offer training workshops, either virtual or in-person, to teach BMP implementation practices that contractors, business owners and local government departments, such as county highway maintenance workers, should or must legally use for road construction/maintenance, driveway permits, culverts, etc., to reduce stormwater runoff and erosion, and improve stream connectivity. Efforts would prioritize the upper tributaries. Lake County SWCD can also offer additional workshops for county planning and zoning boards and local governmental units (LGUs) that focus on including best practices for the Knife River TMDL in local ordinances and in governmental planning and policy documents. These activities will help with the following BMP activities: ravine stabilization, road ditch maintenance and revegetation and stormwater BMPs.

Civic Engagement

Multiple nonprofits and community groups are invested in improving water quality on the Knife River and protecting and restoring fish populations. The Advocates for the Knife River Watershed (AKRW) group is a key partner in outreach and education, as they organize regular meetings and outreach events to keep their members and the public informed about the latest research on the Knife River, promote ongoing conservation efforts and volunteer workdays, and provide a space for landowners and resource management agencies to share concerns and successes. The AKRW have a long history of inviting scientists and researchers to provide seminars/webinars to their group. These talks have led to citizen science research projects in the watershed, and have fostered new avenues of scientific inquiry, including ongoing research into the role of beaver dams in temperature dynamics in the Knife River. The AKRW also keep communication lines open with the Knife River Recreation Council and managers of the Knife River Community Forest. More broadly, groups such as The Lake Superior Steelhead Association and Gitche Gumme Chapter of Minnesota Trout Unlimited include members who are invested in protecting and restoring trout habitat on the Knife River, which includes supporting and implementing volunteer work and grant-funded projects to reduce erosion in the river. The Lake Superior Steelhead publishes a magazine, *Lake Superior Angler* and Trout Unlimited sends out an email newsletter, both of which can serve to encourage good Knife River watershed stewardship, highlight opportunities for collaboration with landowners and invite members to educational events such as tree sales or fly-casting clinics, while also celebrating successful implementation projects.

Regional Agency Collaboration

Concerted collaboration among stakeholders is important to overall project success, and includes counties, state agencies, road authorities, townships/MS4s that share jurisdiction in the Knife River watershed. Work will focus on organizing local governmental units from nearby watersheds, extension agencies and interested private individuals and organizations in a format like the Regional Stormwater Protection Team. This will accomplish economies of scale and will maintain a robust response to emerging needs throughout the watershed.

Element f. Reasonably expeditious schedule

A schedule for implementing the activities and NPS management measures identified in this plan that is reasonably expeditious.

The schedule for this watershed plan is designated in 2-year increments described in Table 7. When implemented as planned, the activities and BMPs described will reach the estimated reductions needed to meet water quality standards in 10 years.

Element g. Milestones

A description of interim, measurable milestones for determining whether NPS management measures or other control actions are being implemented.

The planned milestones for this watershed are designated in 2-year increments and will take place over the next 10 years (2022-2032). Specific milestones for each activity are captured in Table 7. The accomplishment of these milestones will be used to evaluate the implementation of this plan.

Element h. Assessment criteria

A set of criteria that can be used to determine whether loading reductions are being achieved over time and substantial progress is being made toward attaining water quality standards.

The assessment criteria for this watershed are designated in 2-year increments and the unit of measure is described in Table 7. The assessment criteria and achievement of milestone goals will be used to measure the accomplishment of this NKE plan.

Element i. Monitoring

The monitoring & evaluation component to track progress and evaluate the effectiveness of the implementation efforts over time, measured against the criteria established under item (h) immediately above.

Two categories of monitoring that will be used in the watershed include long-term watershed monitoring and BMP effectiveness monitoring. Long-term monitoring will primarily be completed following the MPCA ten-year major watershed monitoring and assessment cycle. BMP effectiveness monitoring will be completed specific to the Section 319 Small Watershed program.

Long-term monitoring

Ambient water quality

The MPCA ten-year 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, 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 in the South Lake Superior 8-digit HUC. The first and second cycles of this monitoring were completed in 2012 and 2022. Subsequent cycles of monitoring repeated every ten years will provide data in which to assess if the water quality of the river has improved and to determine if the aquatic life use goals of the river are met.

The Minnesota Pollution Control Agency (MPCA) surface water monitoring program includes TSS as part of a suite of water sample parameters used in the assessments. The MPCA biological monitoring includes macroinvertebrate and fish monitoring for the development of indices of biotic integrity (IBIs).

Hydrology and geomorphology

The base level hydrology monitoring comes from the streamflow gage operated by USGS, which provides real-time streamflow and water temperature data. The gauge also has a smaller dataset of continuous turbidity data and estimated daily suspended sediment concentrations and loads. Importantly, as climate change increases the potential for larger, more concentrated storm events, stream gauge monitoring data is vital to interpreting water quality data. Suspended sediment concentration (SSC) monitoring will provide information needed in evaluating the geomorphology of the river along with physical measurements of the profile of the streams. Connectivity will be evaluated with surveys of areas causing a disconnect in fish passage potential.

The following geomorphology-based survey and inventory work will provide the basis for evaluating progress and adapting implementation activities when needed:

- 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 incorporating Light Detection and Ranging (LiDAR) data and Soil Survey Geographic Database (SSURGO) data.

- Additional surveys of the stream channels, banks and bluffs (using the Watershed Assessment of River Stability and Sediment Supply (WARSSS) or similar techniques) to evaluate stream restoration projects and identify, target, and design restoration projects for unstable stream reaches and sediment sources.
- 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.
- 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.

Biology

Biological monitoring will evaluate the abundance and condition of the macroinvertebrates and fish communities in the river and its tributaries, and the Index of Biotic Integrity scores for both will be compiled for MPCA's ten-year recurring Watershed Stressor Identification Reports. Upland biological monitoring will include detailed inventories of riparian forest conditions in the watershed including hill slopes, stream slopes, soils and elevation, plus inventories of upland forest stands in the watershed (percent cover, stand health, tree species and tree age, size and density).

BMP effectiveness

BMP effectiveness monitoring in the Knife River watershed will include methods to assess BMP impacts on hydrology, pollutant (sediment) loading, stream temperature, biology, and stream condition. The extent of effectiveness monitoring will depend on the availability of funding. 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).

Ongoing monitoring of flow, turbidity, TSS, and transparency in the river and its tributaries will be conducted to determine the effectiveness of pollution mitigation strategies and if conditions are changing. Partners in this process will include citizen stream monitors, the MPCA, Lake County SWCD and South St. Louis County SWCD, the Minnesota DNR and the USGS. Funding for monitoring is a critical issue that needs to be addressed.

Key monitoring components include:

- Maintain the USGS flow monitoring station on the Knife River.
- Water quality grab sampling, field measurements, lab analyses, and continuous sonde measurements near the outlet of the river (Fish Trap or USGS gage site).
- Tracking all implementation activities in a database.
- Continue and expand citizen stream monitoring in the Knife River watershed.

Because climate change can lead to drought and extreme flooding, both can significantly alter the pollutant concentration/water discharge relationship and influence the ability of a given BMP to affect sediment loading in the Knife River. If a BMP is effective at reducing a sediment loading over time, but at the same time the Knife River watershed is experiencing high flows due to climate change, then the overall pollutant load may not decrease over time, even with the BMP in place. The important factor is to collect the correct data to be able to quantify any observed changes in pollutant loading as having a low, medium or high likelihood of being influenced by climatic differences. Because sediment loading is strongly driven by extreme flows in the Knife River, this needs to be considered during monitoring efforts. To keep a high level of statistical confidence that a BMP has been effective in reducing sediment loads, it can help to reduce variability in the data by including control sites/paired sites and monitoring for a suite of covariates that can influence data variability.

The proposed water quality monitoring program will include the streamflow, water sampling, and continuous turbidity measurements at the USGS gage site. One to two additional monitoring sites will be established with flow monitoring and water sampling. Streamflow monitoring will follow the DNR Cooperative Stream Gaging program procedures. Water monitoring procedures will follow the MPCA Watershed Pollutant Load Monitoring Network standard operating procedures. Streamflow monitoring will cost about $15,000.00 per year per gage site. Approximately 25 water samples will be collected at each monitoring site during storm events and base flows each year and analyzed for TSS at a cost of about $6,000.00 per year per site. The yearly cost for flow and water quality monitoring at three sites would be about $48,000.00 (no cost for streamflow at USGS gage site). The total cost for ten years of monitoring would be about $480,000.00. Given the estimated implementation cost for the NKE plan of $18 million, the monitoring cost represents less than 3% of the total cost.

Given the large influence of stream banks and bluffs as sources of sediment to the river, long-term geomorphic monitoring should be conducted in the watershed. This monitoring will range in cost from the relatively inexpensive placement of bank pins and chains, plus field cameras, 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. An estimated cost for the long-term placement and monitoring of bank pins and chains is $1,000.00 per cross-section per year. The cost would include materials, installation labor and annual monitoring measurements.

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.

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