Modeling sources of erosion for the Knife River

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Introduction

In 1998 the Knife River, tributary to Lake Superior just south of Two Harbors was placed on the impaired waters list for turbidity caused by sediment. Naturally questions arose about the sources of the sediment. How much is derived from each of the sources, upland areas, channel bottom and bank, ravines, and bluffs. During the period May to September 2007 the University of Minnesota conducted a study to assess these sediment sources.

Project Objective

The objective of the project was to identify and possibly quantify the potential sources generating the sediment measured at the mouth of the river. Study was in cooperation with the Minnesota Pollution Control Agency and the South St. Louis County Soil and Water Conservation District.

Methods

The approaches for identifying sediment sources, and quantifying the sediment generated from those sources included three modeling methods.

- University of Kentucky SEDIMOT II model – for overland flow erosion
- USDA CONCEPTS model – for channel erosion
- BEHI-NBS model – for channel erosion

Data requirements:

- Detailed flow data and sediment concentration data were available from four monitoring sites in the watershed; watershed areas ranging from
- Additional data about the channel were required for the CONCEPTS model and the BANCS model.
- Delineation of upland subwatershed boundaries, delineation of soil types, delineation of upland watershed stream channels.
- Identification and mapping of bluffs along the main stem of the river. There were 21 bluffs identified.

The models were applied to the prediction of sediment generated by three runoff producing events, all having estimated return periods less than one year. The predicted sediment amounts were then compared to the measured sediment amounts.

Hydrologic and sediment data

- Available from four gauging stations.
- S-1:Airport (3,764 ha), S-2:Nappa (1,687 ha), S-3:Culvert (958 ha), S_4:Fishtrap (22,116 ha).
- From 1974 to 2007
  - Peak flows: 1,410 to 9,100 cfs; annual mean of 3,147 cfs
  - Mean annual runoff = 14.71 inches

Channel data

Channel length studies – 21 km of lower part of river.

- Channel cross-sections were measured at 20 locations along the study reaches. Five were already available from the SSLC SWCD.
- Measured channel cross-sections and other Rosgen channel characteristics (pebble counts, bankfull depth, etc).
- Additional reaches were required for the CONCEPTS model; generated using regional curves and an established interpolation procedure.

Tributary data

- Delineated tributaries and derived channel slopes using ArcHydro.
- Delineated soil types.

Characteristics of the three storms used in the study.

Name	Total Precip Depth (in)	Duration (hr)	Peak 30 minute intensity (in)	Estimated Return Period (yr)	Observed Peak Flow (cfs)	Observed Sediment Mass (tons)[1]
Storm 1	1.73	24.0	0.59	0.7	1800	881
Storm 2	1.30	12.0	0.68	0.5	645	138
Storm 3	0.94	4.5	0.36	0.5	334	30

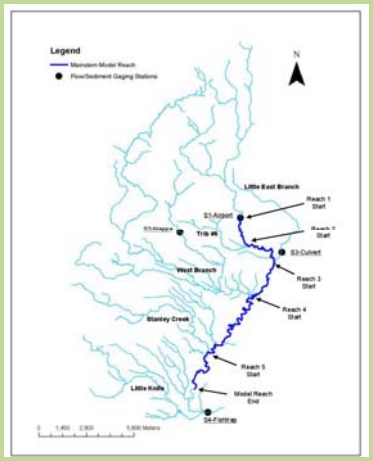
1 Estimated from regression relationship of average daily discharge vs. daily total sediment mass

Per storm sediment mass estimated for ungauged watersheds

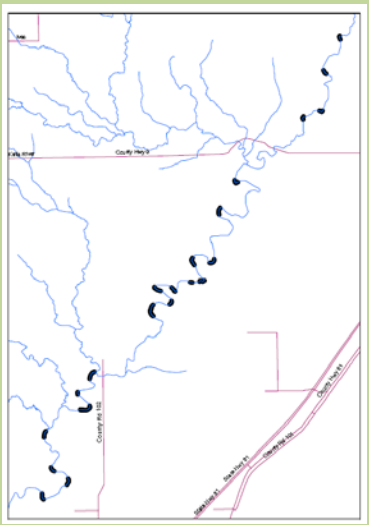
Input Name	Data Source	Storm 1 Sed. Mass (tons)	Storm 1 Gaging Station Used[2]	Storm 2 Sed. Mass (tons)	Storm 2 Gaging Station Used[2]	Storm 3 Sed. Mass (tons)	Storm 3 Gaging Station Used[2]
Airport Upstream Boundary	Observed	22	--	4.2	--	4.5	--
Little East Branch	Observed	16	--	3.5	--	1.3	--
MainStem Watershed	DAA[1]	17	Airport	3.2	Airport	2.3	Little East
West Branch	DAA[1]	15	Nappa	2.1	Nappa	1.5	Nappa
Stanley	DAA[1]	11	Airport	2.2	Airport	1.5	Little East

1 Per storm sediment mass generated using drainage area analysis (DAA)
2 Representative gaging station used for DAA of ungaged input

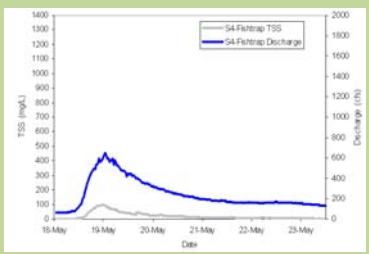
Knife River Watershed



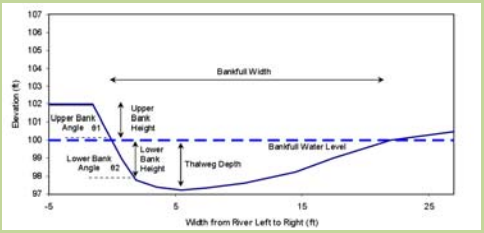
Locations of field study reaches



Mapped bluff locations



Flow and sediment graph, Storm 2

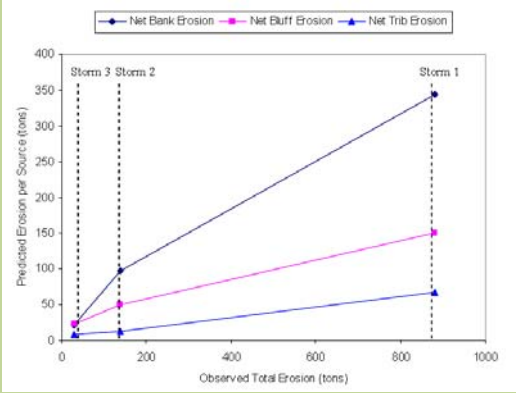


Channel geometric properties derived.

Storm	1	2	3
Bank Sources			
Bank Erosion (tons)	512.0	133.0	34.0
Bed Deposition (tons)	168.0	36.0	13.0
Calculated Yield Ratio[1]	0.67	0.73	0.62
Net Bank Erosion (tons)	344.0	97.0	21.0
Bank Source Percent	**61.1**	**60.3**	**39.7**
Bluff Sources			
No. of Type-1 Bluff	13	13	13
Type-1 Bluff Erosion Per (tons)	15.9	7.0	5.4
Bluff Erosion Type-1 total (tons)[2]	206.7	90.4	69.6
Applied Yield Ratio[3]	0.73	0.56	0.33
Net Bluff Erosion (tons)	150.9	50.6	23.0
Bluff Source Percent	**26.8**	**31.5**	**43.4**
Trib and Overland Sources			
Airport Upstream Boundary (tons)	22.0	4.2	4.5
Little East Branch TRIB (tons)	16.0	3.5	1.3
Main Stem Watershed (tons)	17.0	3.2	2.3
West Branch TRIB (tons)	15.5	2.1	1.5
Stanley TRIB (tons)	11.0	2.2	1.5
Sub-total (tons)	81.5	15.2	11.1
Applied Yield Ratio[4]	0.84	0.86	0.81
Net Tributary Erosion (tons)	68.1	13.1	8.9
Trib Source Percent	**12.1**	**8.2**	**16.9**
TOTAL SIMULATED (tons)[5]	**563.0**	**160.7**	**52.9**
TOTAL OBSERVED (tons)	**881.0**	**138.0**	**30.0**

1 Overall average bank sediment delivery ratios across all reaches calculated by CONCEPTS (See Tables 12-14)
2 Type-2 bluffs were omitted from the results as they were predicted to produce relatively insignificant amounts of erosion.
3 Average of delivery ratios for reaches 4 and 5 calculated by CONCEPTS; reaches correspond to locations of Type-1 bluffs (See Tables 12-14)
4 Estimated to be halfway between 100% delivery and the overall average delivery ratios calculated by CONCEPTS (see footnote 1)
5 Sum of net erosion estimates for bank, bluff, and tributary and overland sources to the modeled end point of the river.

Sediment erosion proportions predicted



Predicted erosion per source vs. total observed erosion
Storm 1: 563 tons predicted versus 881 tons observed
Storm 2: 161 tons predicted versus 131 tons observed
Storm 3: 53 tons predicted versus 30 tons observed

Conclusions

- Erosion amounts for the storms examined were in decreasing order; streambanks, bluffs and upland areas.
- Comparison between predicted and observed sediment loads appears to be reasonable.
- Additional field measurements would benefit in terms of improving predictive behavior of sediment sources.
- Bluff erosion did not account for possible mass wasting processes. Further work is needed to take this into account.