SOUTH FORK BIG NEMAHA RIVER WATERSHED EROSION ASSESSMENT

ArcGIS® Comparison Study: 1991 vs. 2008 Aerial Photography

Photo taken by: Anna Powell, Kansas Water Office; November 2010

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Table of Contents

Executive Summary

Wetlands and riparian areas are vital components of proper watershed function that, when wisely managed in context with a watershed system, can moderate and reduce sediment input into surface water supplies. Eroding streambanks have been recognized as a major contributor of sediment in Kansas waters.

The South Fork Big Nemaha River Watershed Assessment, an ArcGIS® based Comparison Study, identifies areas of streambank and streambank gully erosion concerns to provide a better understanding of the South Fork Big Nemaha River Watershed. This information is provided for the application of mitigation practices, a better understanding of watersheds and to reduce excessive sedimentation across Kansas. The comparison study was designed to guide prioritization of streambank restoration by identifying reaches of streams where erosion is most severe in the watershed.

The Kansas Water Office (KWO) 2011 assessment quantifies annual tons of sedimentation from streambank erosion between 1991 and 2008 within the South Fork Big Nemaha River Watershed in Kansas. A total of 83 streambank erosion sites were identified, covering 56,000 feet of unstable streambank and transporting 117,000 tons of sedimentation. Streambank erosion sites having an area of 1,500 sq. feet or more of streambank movement between 1991 and 2008 aerial photos were identified. A substantial quantity of this sediment is transported each year from the mainstem South Fork Big Nemaha River and identified stream reaches, BN1-a, BN1-b, BN2 and BN3; contributing approximately 16,736; 28,117; 17,125; 12,939 tons of sedimentation annually, respectively. These identified reaches account for an estimated 59% of the total stabilization cost needs in the watershed, totaling $3.3 million. Costs and percentages for BN1-a, BN1-b, BN2 and BN3: $462,844 (8%); $2,010,338 (36%); $503,699 (9%); and $306,601 (6%) respectively. Based on average cost estimate of streamabank stabilization practices, pulled from an assessment by The Watershed Institute (TWI) at $71.50 per linear foot, stabilizing all identified erosion site streambanks from this assessment would cost approximately $5.5 million.

Streambank gullies were also assessed. Gullies were analyzed for prioritization by indication of high, medium and low, and then grouped by stream reach for analysis. The assessment concluded that Turkey Creek stream reach 4 and South Fork Big Nemaha River stream reach 3, T4 and BN3, had the greatest number of high priority gullies. Calculating tons of soil erosion from gullies was not part of this assessment. It should be noted that gully erosion can contribute a tremendous amount of sediment at the watershed scale and can occur in both cropland and grassland. Not all gullies in the South Fork Big Nemaha River Watershed were identified due to the season at which NAIP aerial photos are taken, leaf on. Further assessments should be performed to identify all gullies and their contribution to sedimentation rates in streams and rivers throughout the watershed.

The KWO completed the South Fork Big Nemaha River Watershed Erosion Assessment for the South Fork Big Nemaha River Watershed Restoration and Protection Strategy (WRAPS) Stakeholder Leadership Team (SLT). Information contained in this assessment can be used by the South Fork Big Nemaha WRAPS SLT to target streambank stabilization and riparian restoration efforts toward high priority stream reaches in the South Fork Big Nemaha River Watershed. Similar assessments are ongoing in selected watersheds above reservoirs throughout Kansas and will be made available upon request to agencies and interested parties for the benefit of streambank and riparian restoration projects.

Introduction

Wetlands and riparian areas are vital components of proper watershed function that, when wisely managed in context of a watershed system, can moderate and reduce sediment input. There is growing evidence that a substantial source of sediment in streams in many areas of the country is generated from stream channels and edge of field gullies (Balch, 2007).

Streambank erosion is a natural process that contributes a large portion of annual sediment yield, but acceleration of this natural process leads to a disproportionate sediment supply, stream channel instability, land loss, habitat loss and other adverse effects. Many land use activities can affect and lead to accelerated bank erosion (EPA, 2008). In most Kansas watersheds, this natural process has been accelerated due to changes in land cover and the modification of stream channels to accommodate agricultural, urban and other land uses.

A naturally stable stream has the ability, over time, to transport the water and sediment of its watershed in such a manner that the stream maintains its dimension, pattern and profile without significant aggregation or degradation (Rosgen, 1997). Streams significantly impacted by land use changes in their watersheds or by modifications to streambeds and banks go through an evolutionary process to regain a more stable condition. This process generally involves a sequence of incision (downcutting), widening and re-stabilizing of the stream. Many streams in Kansas are incised (SCC, 1999).

Streambank erosion is often a symptom of a larger, more complex problem requiring solutions that may involve more than just streambank stabilization (EPA, 2008). It is important to analyze watershed conditions and understand the evolutionary tendencies of a stream when considering stream stabilization measures. Efforts to restore and re-stabilize streams should allow the stream to speed up the process of regaining natural stability along the evolutionary sequence (Rosgen, 1997). A watershed-based approach to developing stream stabilization plans can accommodate the comprehensive review and implementation.

Additional research in Kansas documents the effectiveness of forested riparian areas on bank stabilization and sediment trapping (Geyer, 2003; Brinson, 1981; Freeman, 1996; Huggins, 1994). Vegetative cover based on rooting characteristics can mitigate erosion by protecting banks from fluvial entrainment and collapse by providing internal bank strength. Riparian vegetative type is an important tool that provides indicators of erosion occurrence from land use practices. Forested riparian areas are superior to grassland in holding banks during high flows, when most sediment is transported. When riparian vegetation is changed from woody species to annual grasses and/or forbs, sub-surface internal strength is weakened, causing acceleration of mass wasting processes (extensive sedimentation due to sub-surface instability) (EPA, 2008). The primary threats to wetlands and forested riparian areas are agricultural production and suburban/urban development.

Another form of erosion contributing to sedimentation in many watersheds in Kansas is the development of streambank gullies. Gullies develop from the wearing away of the surface soil along drainage channels by surface water runoff. Gullies are associated with the loss of vegetation on the soil and down cuts forming deep widening channels. The potential for surface erosion is associated in part with the amount of bare, compacted soil exposed to rainfall and runoff. Other factors contributing to gully development are high soil erodability; little ground cover; steep, long, continuous slopes; high intensity storms; high drainage density of the slope and close proximity to streams.

In Kansas, monitoring the extent of erosion losses is difficult and current up-to-date inventories are needed. This assessment identifies areas with erosion concerns to provide a better understanding of the South Fork Big Nemaha River Watershed for mitigation purposes and for application of understanding to watersheds across Kansas.

Study Area

The Missouri River Basin covers some 1,600 square miles in the northeastern corner of Kansas including four 8-digit Hydrologic Unit Codes: 10240007, 10240008, 10240005 and 10240011. This represents a small fraction of the entire Missouri River watershed which covers all or part of ten states and extends into Canada. The basin covers all or part of Marshall, Nemaha, Brown, Doniphan, Atchison, Leavenworth and Wyandotte counties in Kansas and is the smallest of the 12 major basins in the state, accounting for about two percent of the total land area (KDHE, 2000).

The 8-digit Hydrologic Unit Code 10240007, South Fork Big Nemaha River Watershed, is located within the Missouri River Basin and covers approximately 368 square miles (Figure 1). Counties in the area include portions of Marshall and Nemaha. Land use within the South Fork Big Nemaha River Watershed is primarily agricultural and rangeland, with approximately 48% of the land area in row crop and 45% in grassland, while 6% is in wooded area and 6% in urban area.

There are approximately 6 public water supplies within the watershed, many of which draw water from the many streams and creeks, with a small number of supplies coming from small city and county lakes. There are no federal reservoirs in the basin. Groundwater resources include alluvial aquifers of the Big Nemaha River and its tributaries and Glacial aquifers. The South Fork Big Nemaha River, which along with other tributaries in Washington, Nemaha and part of Brown County, drains northward into Nebraska as part of the Big Nemaha River watershed which enters the Missouri River just upstream of the Kansas border. According to the Kansas Surface Water Register the most common designated uses for streams and rivers in the South Fork Big Nemaha River Watershed include: expected aquatic life uses, food procurement; recreation, and domestic water supply (KDHE, 2000) (Figure 2).

Figure 1: South Fork Big Nemaha River Watershed Assessment Area

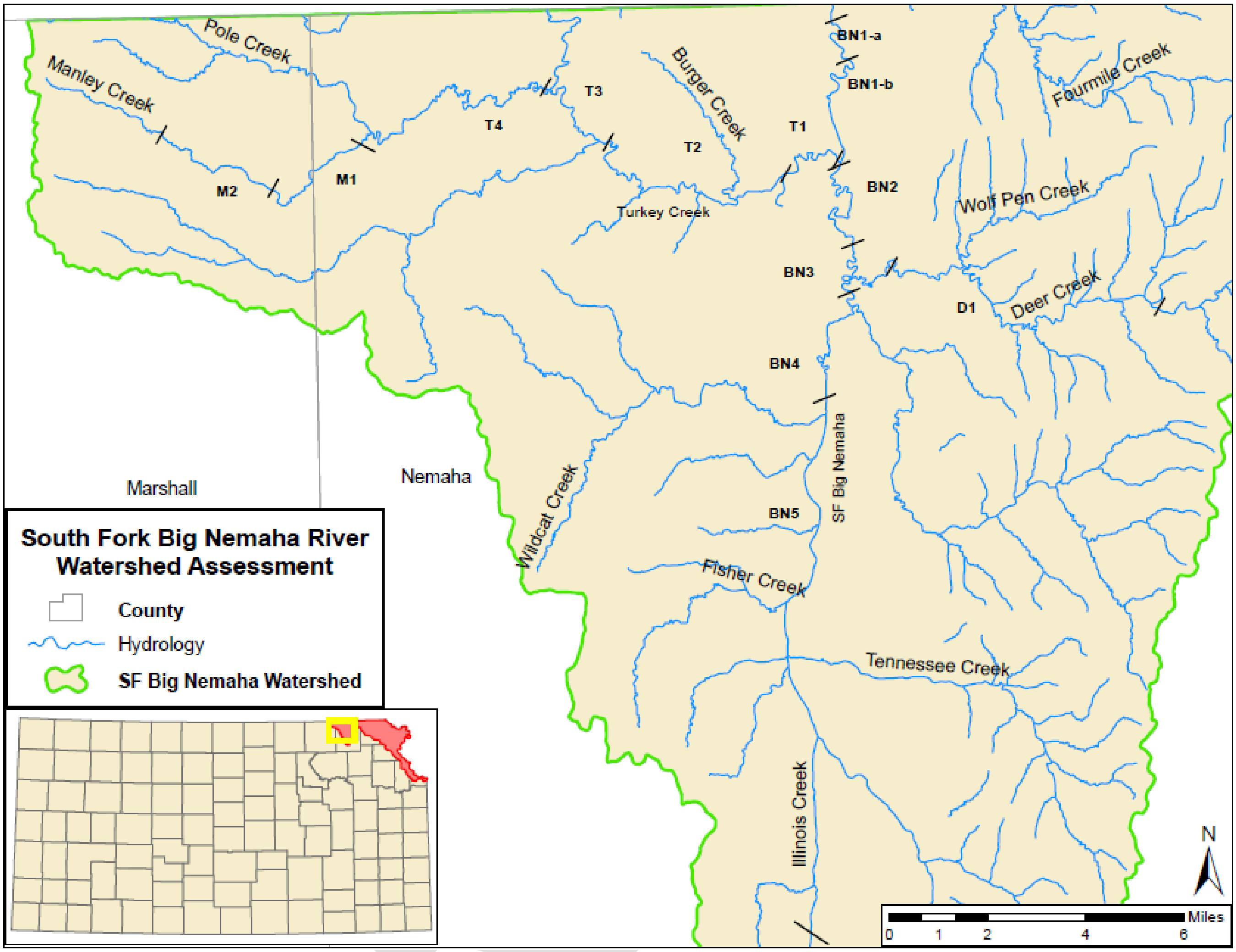
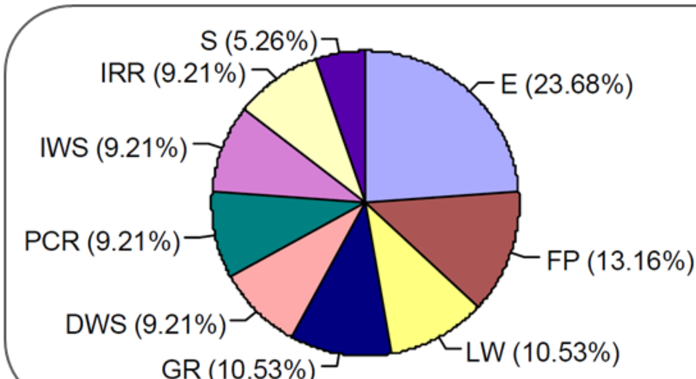


Figure 2: Surface Water Uses within the South Fork Big Nemaha River Watershed in 2000



- E=Expected Aquatic Life Use Water
- FP=Food Procurement
- DWS=Designated for domestic water supply use.
- GR=Designated for ground water recharge.
- LW=Designated for livestock watering use.
- IRR=Designated for irrigation use.
- IWS=Designated for Industrial Water Supply
- PCR=Designated for Contact Recreation
- S=Special Aquatic Life Use

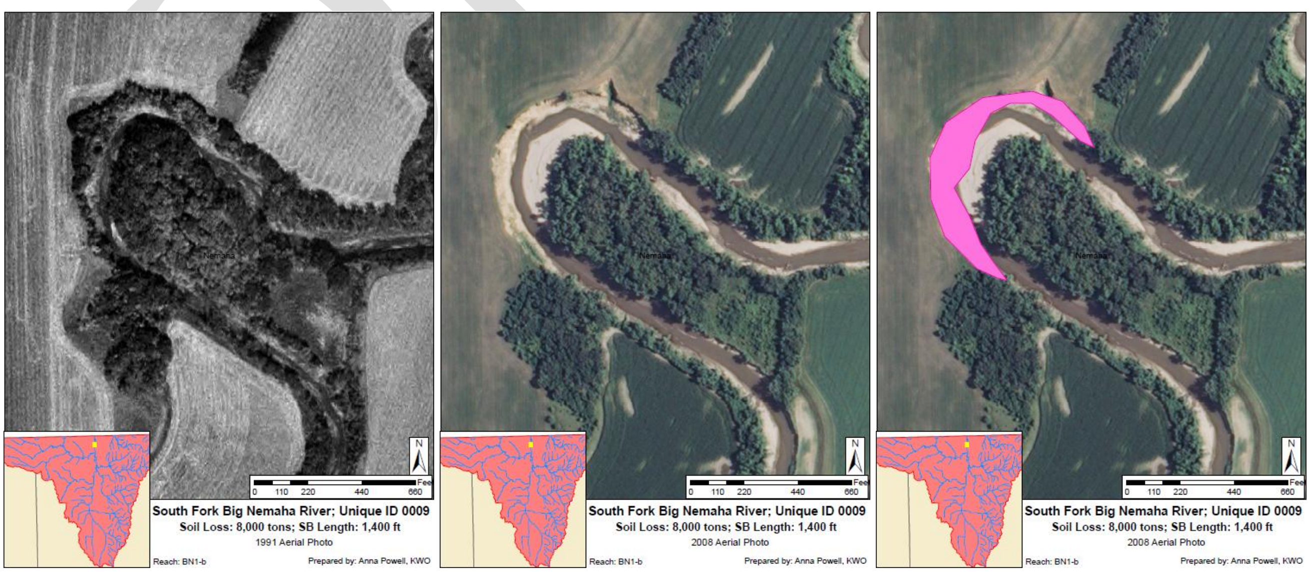
Data Collection Methodology

The South Fork Big Nemaha River Watershed streambank erosion assessment was performed using ArcGIS® software. The purpose of the assessment is to identify locations of streambank instability to prioritize restoration needs and slow sedimentation rates in South Fork Big Nemaha. ArcMap®, an ArcGIS® geospatial processing program, was utilized to assess color aerial photography from 2008, provided by National Agriculture Imagery Program (NAIP), and compare it with 1991 black and white aerial photography, provided by the State of Kansas GIS Data Access & Support Center (DASC). Erosion sites identified in this assessment include locations of streambank erosion and streambank gully erosion.

Streambank Erosion

The streambank assessment was performed by overlaying 2008 NAIP county aerial imagery onto 1991 DASC county aerial imagery (Figure 3). The assessment started on the South Fork Big Nemaha River mainsteam at the Kansas/Missouri boarder and proceeded upstream. Using ArcMap® tools, aggressive movement of the streambank between 1991DASC and 2008 NAIP aerial photos were identified as a site in need of rehabilitation at a 1:6,000 scale. Aggressive movement represents area of 1,500 sq. feet or more of streambank movement between 1991 DASC and 2008 NAIP aerial photos. Streambank erosion sites were denoted by geographic polygons features "drawn" into the ArcGIS® software program through the ArcMap® editor tool. The polygon features where created by sketching vertices following the 2008 streambank and closing the sketch by following the 1991 streambank at a 1:2,500 scale. Data provided, based on the geographic polygon sites include: watershed location, unique ID, stream name, type of stream and type of riparian vegetation.

Figure 3: 1991 DASC vs. 2008 NAIP Streambank Erosion Site on South Fork Big Nemaha River



The streambank erosion assessment data includes approximations of tons of soil loss from the erosion site. This portion of the assessment is performed with the use of the identified erosion site polygon features identified. Tons of soil loss was estimated by incorporating perimeter, area and streambank length of the polygons into a regression equation. Perimeter and area were calculated through the *field calculator* application within the ArcGIS® software. The streambank length of identified erosion sites was computed through the application of a regression equation formulated by the KWO office. This equation was developed by taking data from the *Enhanced Riparian Area/Stream Channel Assessment for John Redmond Feasibility Study* report prepared by TWI and relating the erosion area (in square feet) and perimeter length of that erosion area (in feet) to the unstable stream bank length (in feet). The multiple regression formula of that fit (R-square = .999) is ([Area_SqFt]*-.00067) + ([Perimtr_ft]*.5089609). The intercept of the model was forced to zero.

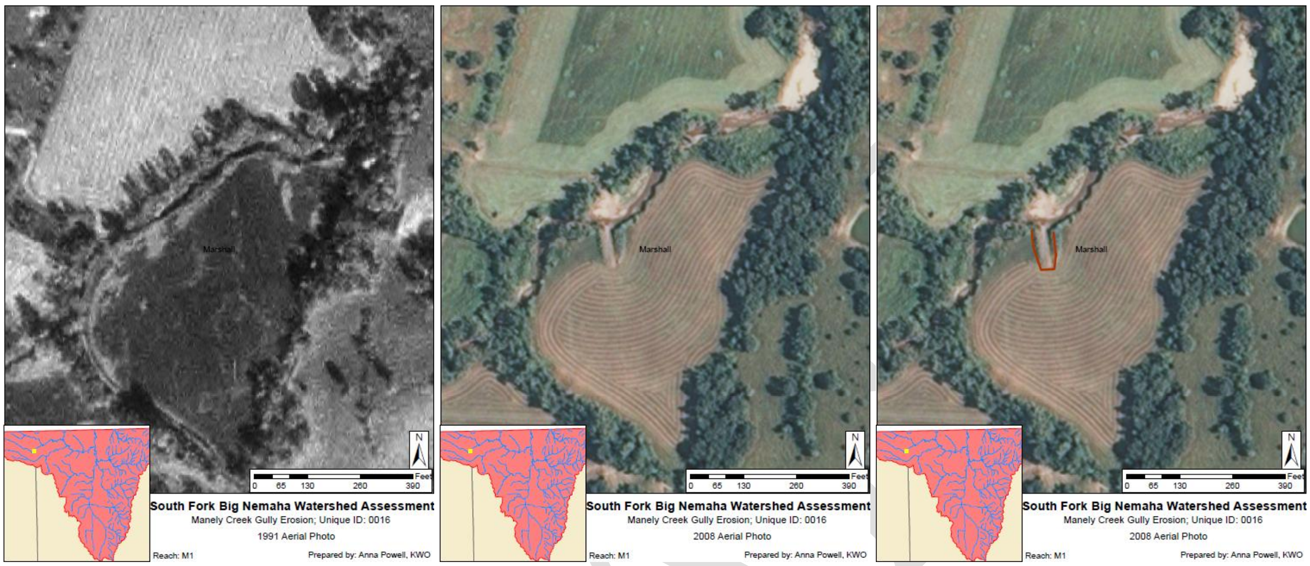
Tons of soil loss was estimated by first calculating the volume of sediment loss and then applying a bulk density estimate to that volume for the typical soil type of identified sites. The volume of sediment was found by multiplying out bank height, surface area lost over the 17 year period between the 1991 and 2008 aerial photos and soil bulk density. This calculated volume is then divided by the 17 year period, to get the average rate of soil loss in mass/year (Avg Soil Loss Rate(Tons/yr)=[Area_SqFt]*[BankHgtFt]*SoilDensity(lbs/ft^3) /2000 (lbs/ton) /([NAIP_ComparisonPhotoYear]- [BaseAerialPhotoYear]).

To complete the analysis for the equation above for tons of soil lost, streambank height measurements of select identified erosion sites were needed. Streambank height for identified streambank erosion sites were estimated by first performing on the ground measurements at ten selected sites throughout the watershed for their location. Landonwers were identified and contacted for access permission to selected sites by MO River Basin WRAPS members Carl Johnson and Carol Hughes. These ten sites were the basis for extrapolating streambank height measurements throughout the South Fork Big Nemaha River Watershed.

Streambank Gully Assessment

The streambank gully erosion assessment was performed with similar techniques and parallel to the streambank erosion assessment by overlaying 2008 NAIP county aerial imagery onto 1991 DASC county aerial imagery (Figure 3). However, calculating tons of soil erosion was not part of this assessment. Using ArcMap® tools, streambank gully erosion was indicated by line features "drawn" into the ArcGIS® software program at a 1:6,000 scale. Once sites were identified, watershed location, unique ID, stream name, type of stream and type of riparian vegetation data was compiled on gully sites and categorized by high, medium or low priority. Identification of a low priority gully indicates that sheet erosion has been identified and a gully could form in the area that is perpendicular to the stream. A low priority gully does not have visible channel cutting or any visible streambank riparian erosion. A medium priority gully identifies visible channel cutting perpendicular to the streambank but no visible erosion of the riparian area of the streambank (Figure 4). High priority gullies identify a deeply incised channel cutting perpendicular to the stream, including a significant portion of the riparian area eroded from the streambank. In some instances, gully priority ratings were increased to a medium or high priority, even if they exhibit “low priority” gully identifiers, if there was a visibly identified sizeable amount of land erosion or gullies identified in the same vicinity.

Figure 4: 1991 DASC vs. 2008 NAIP Gully Erosion Site on Manley Creek



Analysis

To adequately analyze streambank erosion sites, stream reach sections were delineated to better accommodate streambank rehabilitation project focus. Streambank erosion sites were analyzed for prioritization purposes by stream reach sections within the South Fork Big Nemaha River Watershed. Streambank erosion prioritization by stream reach sections include: BN1-a, BN1-b, BN2, BN3, BN4, BN5, D1, M1, M2, T1, T2, T3 and T4 (Figure 5). Reach sections were named by the stream reach they are located on and in numerical order from downstream to upstream. For example, stream reaches BN1-a to BN5 references six reaches identified on South Fork Big Nemaha River, proceeding from downstream to upstream along the river. Streambank erosion sites were analyzed by: streambank length (feet) of the eroded bank; annual soil loss (tons); percent of streambank length with poor riparian condition (riparian area identified as having cropland or grass/crop buffer); estimated sediment reduction through the implementation of streambank stabilization BMPs at an 85% efficiency rate; and streambank stabilization cost estimates for eroded streambank sites (Table1). Streambank stabilization costs were derived from an average cost of implement streambank stabilization BMPs pulled from the TWI *Kansas River Basin Regional Sediment Management Section 204 Stream and River Channel Assessment*; $71.50 per linear foot was used to calculate average streambank stabilizations costs (Figure 6).

Figure 5: South Fork Big Nemaha Streambank Assessment by Reach

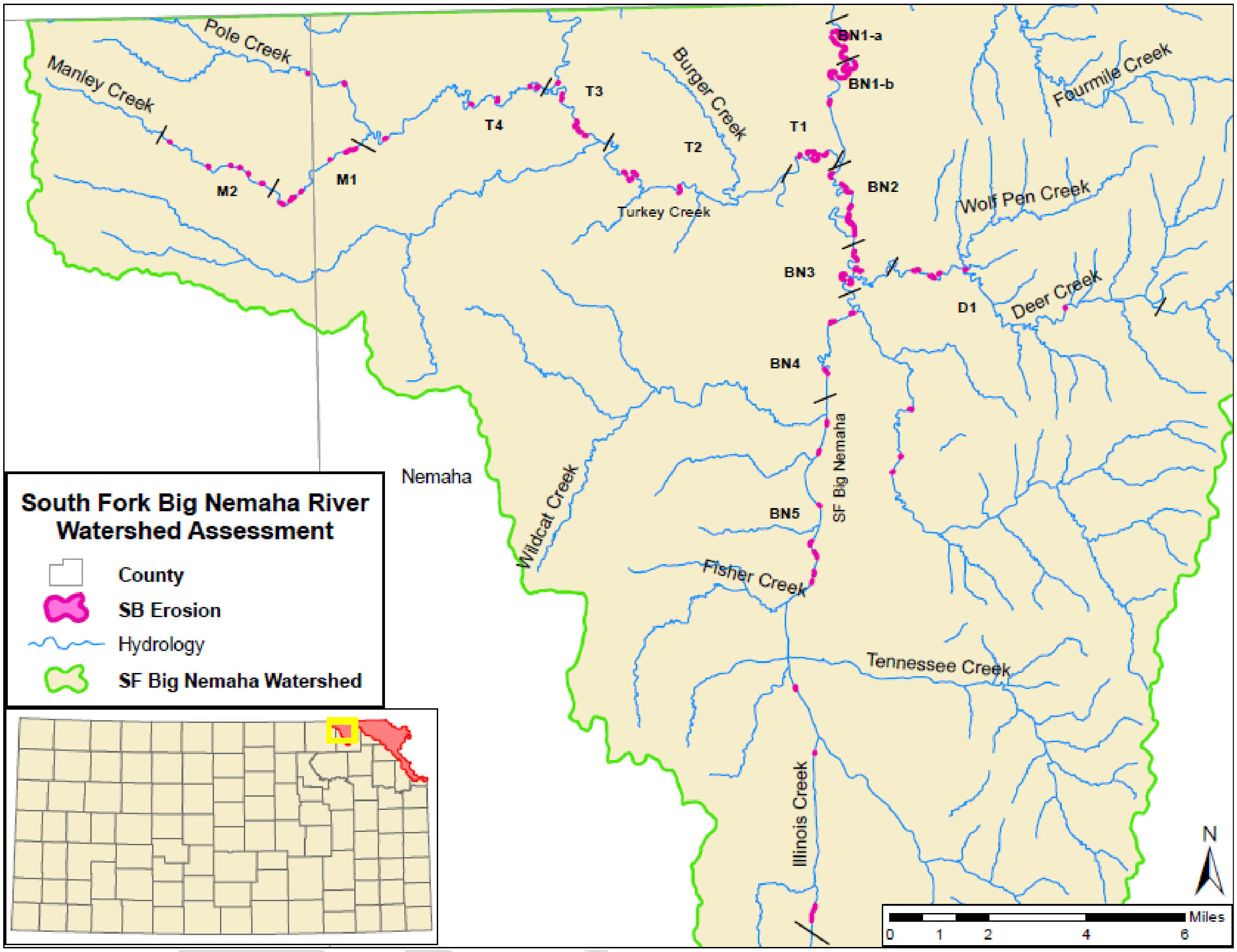
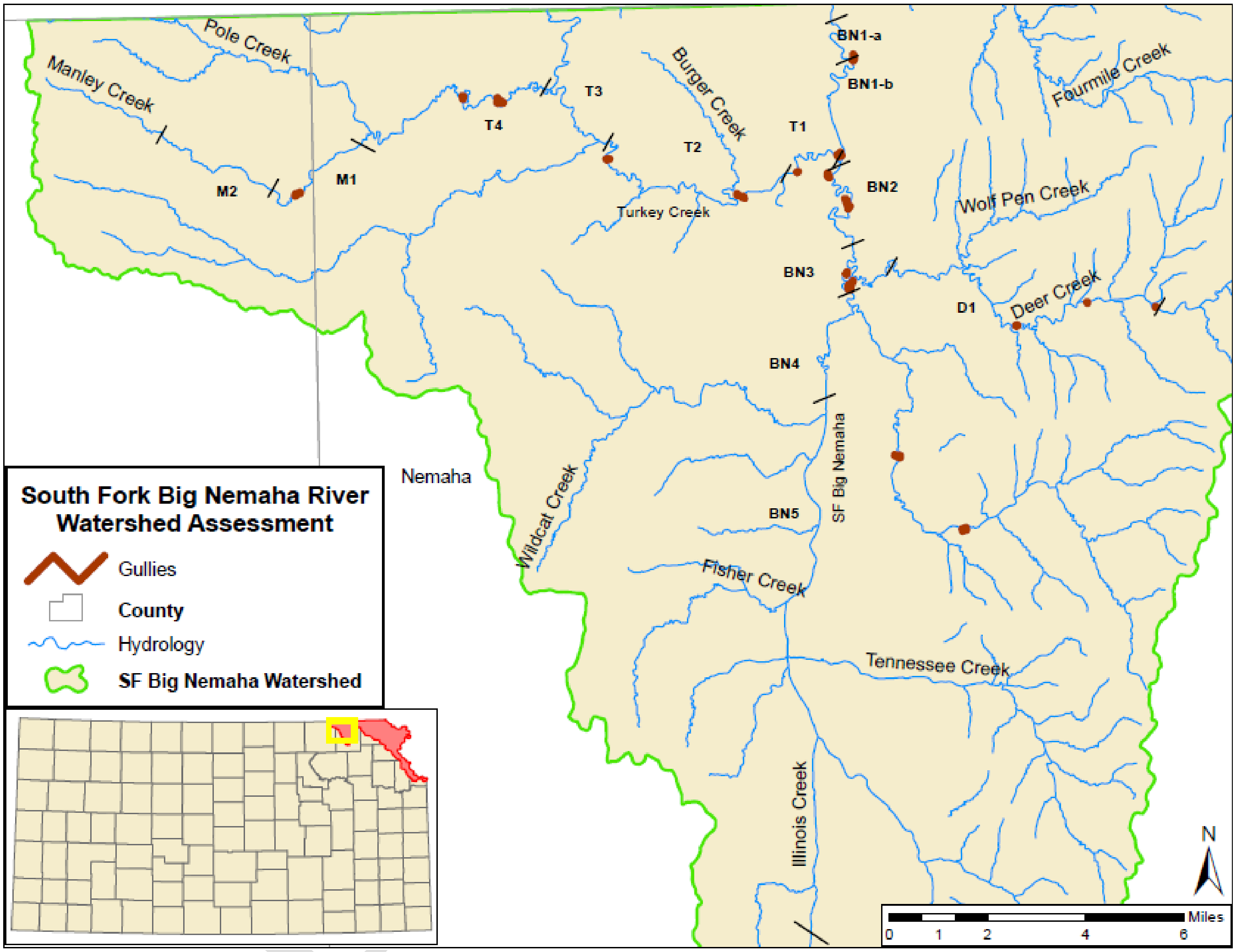


Figure 6: TWI Estimated Costs to Implement Streambank Stabilization BMPs

BMP Cost Description	Cost estimate per linear foot (in dollars)
1. Survey and design Rock delivery and placement As-built certification design Bank Shaping	\$50 - \$75
2. Vegetation (material and planting) Cover Crop Mulch Willow Stakes Bare root seedlings Grass filter strip	\$5
3. Contingencies Unexpected site conditions requiring extra materials and construction time	\$3 - \$5.5
TOTAL	\$58-\$85.5

Streambank gullies were assessed based on the proportion of high, medium and low priority identifications within stream reach sections, and can be used as supporting data for streambank erosion or streambank gully erosion rehabilitation prioritization (Figure 7). Explanation of prioritization is found in the data collection and methodology above. No further assessment was performed.

Figure 7: South Fork Big Nemaha River Watershed Gully Assessment



Results

The KWO 2011 assessment quantifies annual tons of sedimentation from streambank erosion between 1991 and 2008 within the South Fork Big Nemaha River Watershed in Kansas. A total of 83 streambank erosion sites, covering 56,000 feet of unstable streambank was identified; 89% of the unstable streambank was identified as having poor riparian condition (riparian area identified as having cropland or grass/crop buffer). Sediment transport from identified streambank erosion sites accounts for 117,000 tons of sediment transported from the South Fork Big Nemaha River watershed to the Missouri River in Nebraska annually. However, it should be noted that the identified streambank erosion locations are only a portion of all streambank erosion occurrences in the watershed. Only those streambank erosion sites covering an area 1,500 sq. feet, or more, were identified. A substantial quantity of this sediment is transported each year from the mainstem South Fork Big Nemaha River. Identified stream reaches contributing the greatest portion of sediment from the mainstem South Fork Big Nemaha River include: BN1-a, BN1-b, BN2 and BN3; contributing approximately 16,736; 28,117; 17,125; 12,939 tons of sedimentation annually, respectively (Figure 8). These identified reaches account for an estimated 59% or $3.3 million of total stabilization cost needs in the watershed. Costs and percentages for BN1-a, BN1-b, BN2 and BN3 are as follows: $462,844 (8%); $2,010,338 (36%); $503,699 (9%); $306,601 (6%) respectively. Based on the average stabilization costs of $71.50 per linear foot, conducting streambank stabilization practices for the entire watershed would cost approximately $5.5 million (Table 1).

Figure 8: South Fork Big Nemaha River Watershed Streambank Erosion Assessment Graph

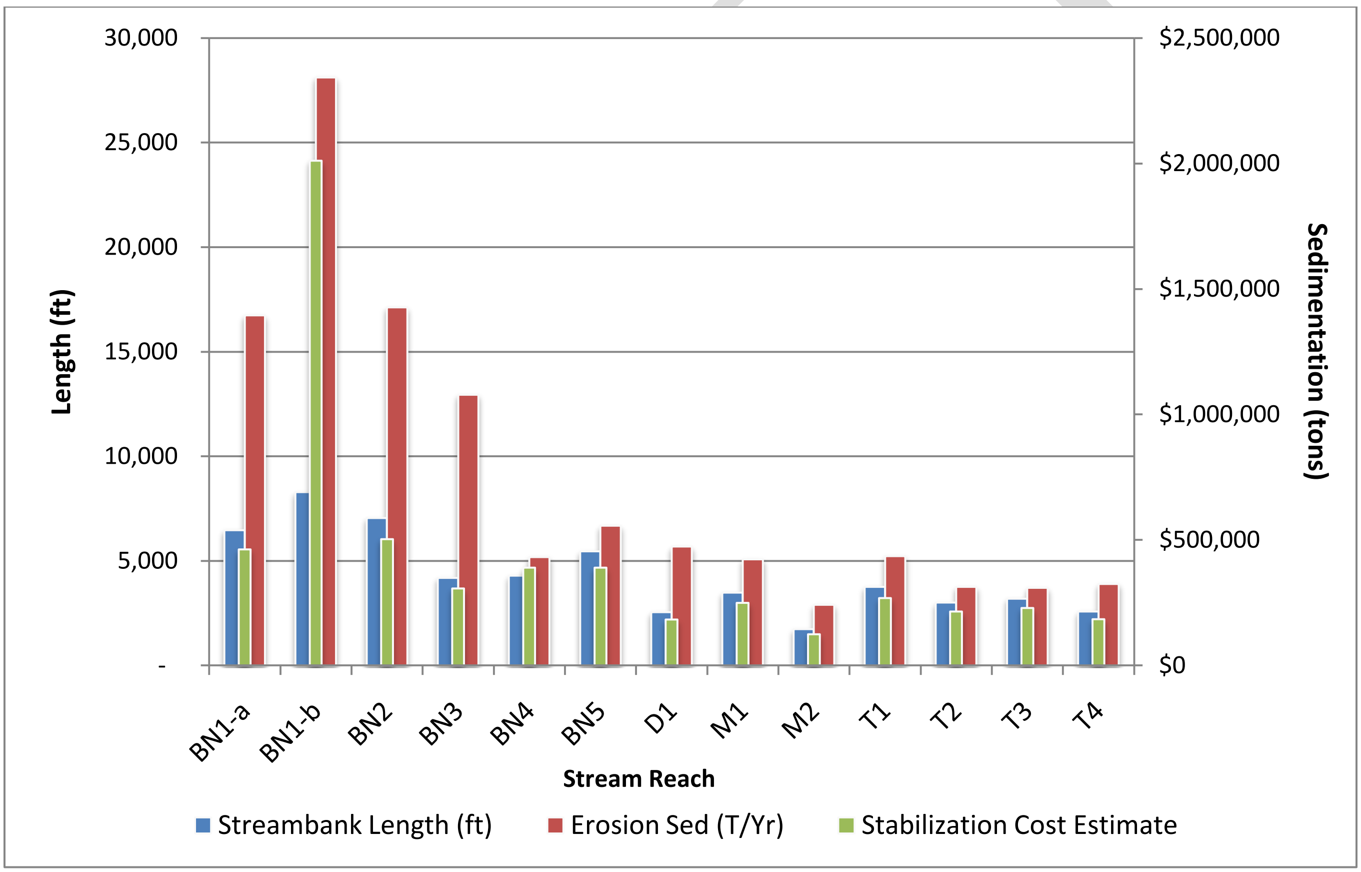
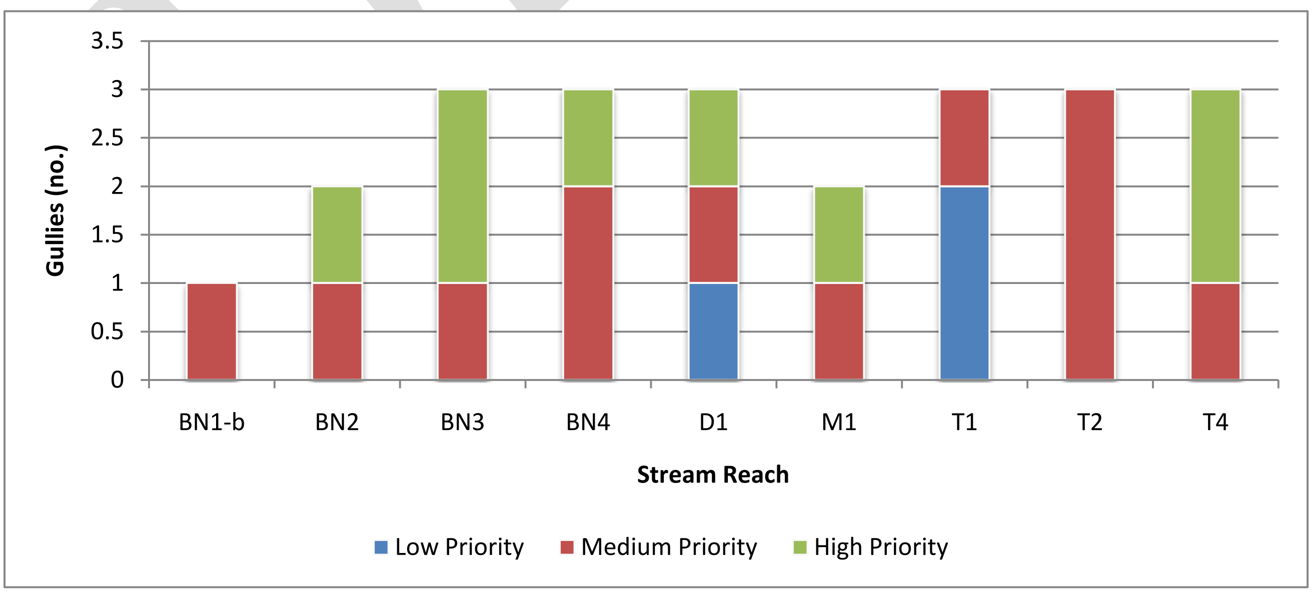


Table 1: South Fork Big Nemaha River Watershed Streambank Erosion Assessment Table

Reach	SB Length (ft)	Erosion Sed. (T/Yr)	Stabil. Cost Estimate	Erosion Sites (no.)	Yield Loss/ Bank Length	Poor Riparian Condition/SB Length (ft)	Est. Sed. Reduction (T/Yr)	% SB Length w/Poor Riparian Cond.
BN1-a	6,473	16,736	$462,844	4	0.39	4,106	14,226	63.42%
BN1-b	8,281	28,117	$2,010,338	6	0.29	8,281	23,899	100.00%
BN2	7,045	17,125	$503,699	6	0.41	3,912	14,556	55.53%
BN3	4,193	12,939	$306,601	6	0.32	4,193	10,998	100.00%
BN4	4,288	5,176	$389,819	8	0.83	4,288	4,400	100.00%
BN5	5,452	6,673	$389,819	9	0.82	5,452	5,672	100.00%
D1	2,553	5,679	$182,536	7	0.45	2,553	4,827	100.00%
M1	3,488	5,078	$249,379	7	0.69	3,488	4,316	100.00%
M2	1,739	2,893	$124,319	6	0.60	1,739	2,459	100.00%
T1	3,752	5,225	$268,244	5	0.72	3,752	4,441	100.00%
T2	3,005	3,757	$214,891	4	0.80	3,005	3,194	100.00%
T3	3,197	3,713	$228,558	6	0.86	3,197	3,156	100.00%
T4	2,576	3,902	$184,156	9	0.66	2,183	3,316	84.75%
Total	**56,040**	**117,014**	**$5,515,203**	**83**	**7.84**	**50,147**	**-99,462**	**89.48%**

Described in the data collection and methodology section above, streambank gullies where analyzed for high, medium and low priority. Figure 9 below identifies the extent of high, medium and low priority streambank gullies identified by stream reach; there were 23 total gullies identified. The assessment of streambank gullies by stream reach identified that six of the nine stream reaches identified three total gullies. Turkey Creek stream reach 4 and South Fork Big Nemaha River stream reach 3, T4 & BN3, had the greatest amount of high priority gullies identified (Figure 9).

Figure 9: South Fork Big Nemaha River Watershed Gully Assessment Graph



It should also be noted that gully erosion can contribute a tremendous amount of sediment at the watershed scale and can occur in both cropland and grassland. The amount of sediment input is based on rainfall/runoff and gully frequency within a given watershed. Not all gullies in the South Fork Big Nemaha River Watershed are identified through this assessment due to the timing at which aerial photos are taken, leaf on. Further assessments should be performed to identify all gullies and their contribution to sedimentation rates in streams and rivers throughout the watershed.

Conclusion

KWO completed this assessment for the South Fork Big Nemaha River Watershed Restoration and Protection Strategy (WRAPS) Stakeholder Leadership Team (SLT). Similar assessments are being conducted in watersheds above reservoirs throughout Kansas and will be made available to agencies and interested parties for the benefit of streambank and riparian restoration projects. Information contained in this assessment can be used by the South Fork Big Nemaha WRAPS SLT to target streambank stabilization and riparian restoration projects to the highest priority streams in the watershed.

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