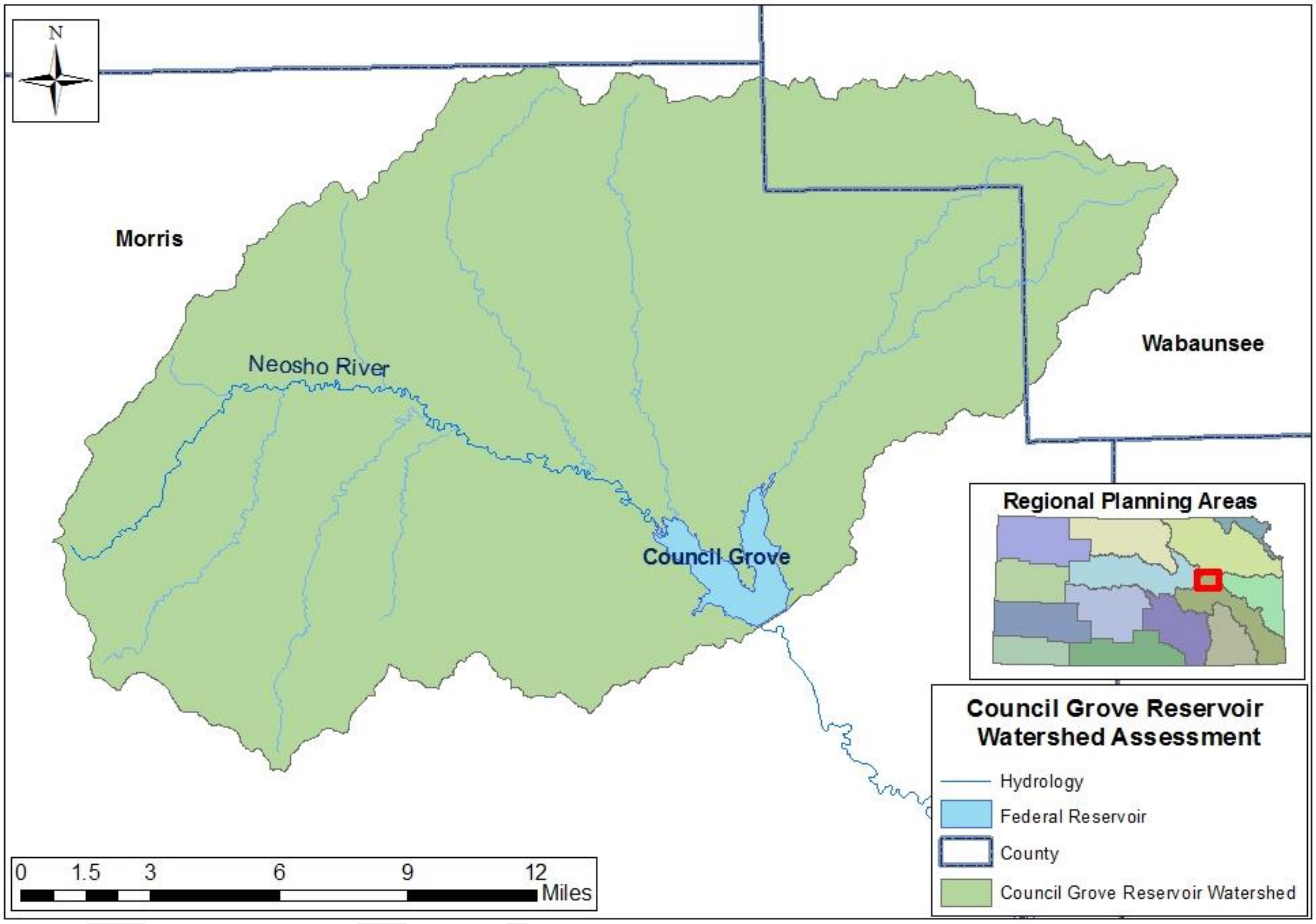
COUNCIL GROVE RESERVOIR WATERSHED STREAMBANK EROSION ASSESSMENT

ArcGIS® Comparison Study: 2002 vs. 2015 Aerial Photography

DRAFT: April 2017



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Executive Summary

Federal reservoirs are an important source of water supply in Kansas for approximately two-thirds of Kansas' citizens. The ability of a reservoir to store water over time is diminished as the capacity is reduced through sedimentation. In some cases reservoirs are filling with sediment faster than anticipated. Whether sediment is filling the reservoir on or ahead of schedule, it is beneficial to take efforts to reduce sedimentation to extend the life of the reservoir.

The Kansas Water Authority has established a *Reservoir Sustainability Initiative* that seeks to integrate all aspects of reservoir input, operations and outputs into an operational plan for each reservoir to ensure water supply storage availability long into the future. Reduction of sediment input is part of this initiative.

The Council Grove Reservoir Watershed Assessment, an ArcGIS® Comparison Study, was initiated to partially implement the *Reservoir Sustainability Initiative*. This assessment identifies areas of streambank erosion to provide a better understanding of the Council Grove Reservoir Watershed for streambank restoration purposes and to increase understanding of streambank erosion to reduce excessive sedimentation in reservoirs across Kansas. The comparison study was designed to guide prioritization of streambank restoration by identifying HUC12s where erosion is most severe in the watershed above Council Grove Reservoir.

The KWO 2017 assessment quantifies annual tons of sedimentation from streambank erosion over the period between 2002 and 2015 in the Council Grove Reservoir Watershed within the Neosho Regional Planning Area (NEO RPA). A total of 40 streambank erosion sites, covering 11,072 feet of unstable streambank were identified. Seventy-five percent of the identified streambank erosion sites were identified as having a poor riparian condition (riparian area identified as having cropland, grass/crop streamside vegetation or narrow woodland (single line of trees between stream and cropland/pastureland)). Sediment transport from identified streambank erosion sites accounts for 14,062 tons (11.4 acre-feet) of sediment per year transported from the Council Grove Reservoir Watershed streams to Council Grove Reservoir annually, accounting for roughly 6 percent of the total load estimated from the most recent bathymetric survey performed by a U.S. Army Corps of Engineers contractor in 2008.

Results by HUC12 indicate HUC12(10102) as the most active HUC12 for streambank degradation, accounting for 3,672 feet of unstable streambank; 6,352 tons (5.1 acre-feet) of sediment per year and 33 percent of total stabilization costs. Based on the average stabilization costs of $71.50 per linear foot, conducting streambank stabilization practices for the entire watershed would cost approximately $792,000.

The KWO completed this assessment for the Twin Lakes Watershed Restoration and Protection Strategy (WRAPS) Stakeholder Leadership Team (SLT). Information contained in this assessment can be used by the Twin Lakes WRAPS SLT to target streambank stabilization and riparian restoration efforts toward high priority HUC12s in the Council Grove Reservoir Watershed. Similar assessments are ongoing in selected watersheds above reservoirs throughout Kansas and are available on the KWO website at www.kwo.org, or may be made available upon request to agencies and interested parties for the benefit of streambank and riparian restoration projects.

Introduction

Wetland 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 into reservoirs. There is growing evidence that a substantial source of sediment in streams in many areas of the country is generated from stream channels (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 United States Geological Survey (USGS) study in the Perry Reservoir watershed in northeast Kansas showed that stream channels and banks are a significant contributor of reservoir sedimentation in addition to land surface erosion (Juracek, 2007). 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 either aggrading or degrading (Rosgen, 1997). Streams that have been significantly impacted by land use changes in their watersheds or by modifications to stream beds 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. Most streams in Kansas are in some stage of this process (SCC, 1999).

Streambank erosion is often a symptom of a larger more complex problem requiring solutions that frequently 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.

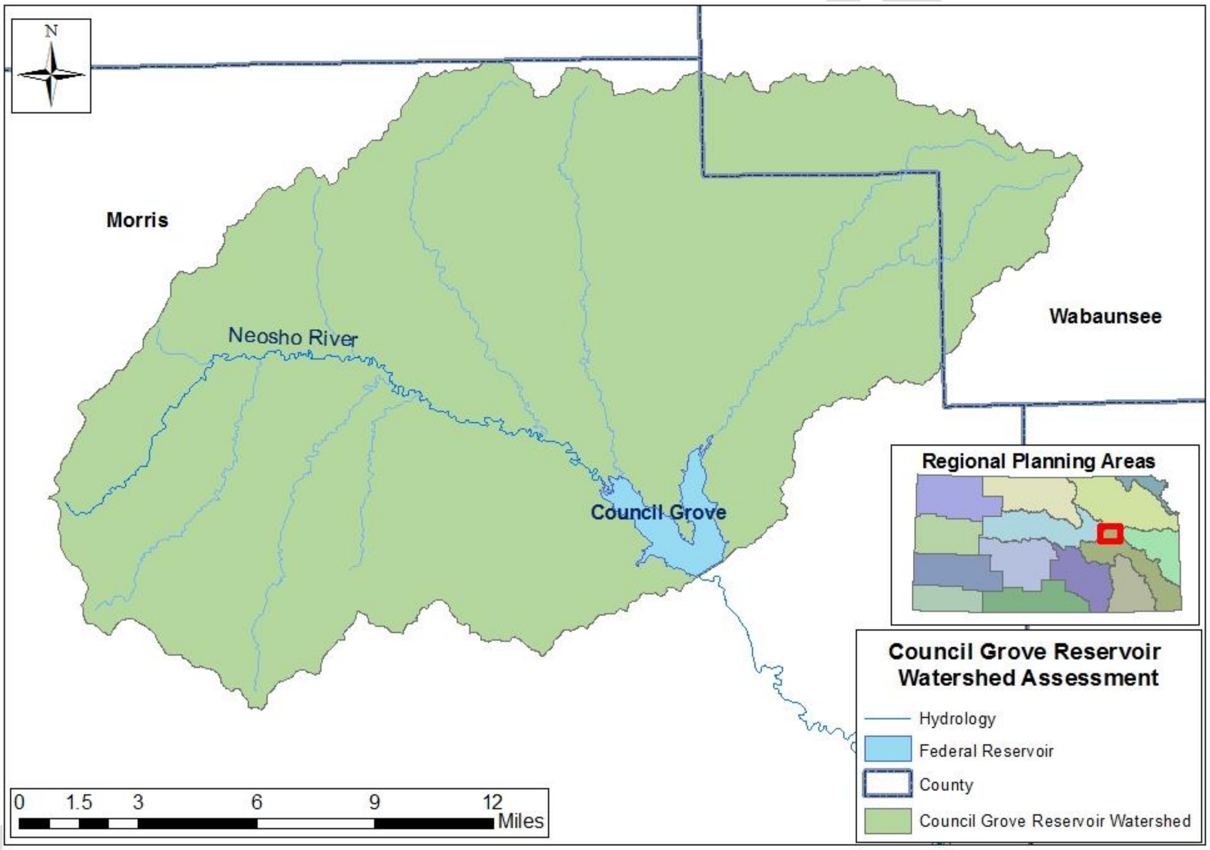
Other research in Kansas documents the effectiveness of forested riparian areas on bank stabilization and sediment trapping (Geyer, 2003; Brinson, 1981; Freeman, 1996; Huggins, 1994). Vegetative cover based on rooting characteristics can mitigate erosion by protecting banks from fluvial entrainment and collapse by providing internal bank strength. Riparian vegetative type is an important tool that provides indicators of erosion occurrence from land use practices. The riparian area is the interface between land and a river or stream. Riparian areas are significant in soil ecology, environmental management and because of their role in soil conservation, habitat biodiversity and the influence they have on aquatic ecosystems' overall health. Forested riparian areas are superior to grassland in holding bank stabilization 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.

Reservoir sedimentation is a major water quantity concern, particularly in reservoirs where the state owns water supply storage. Reservoirs are a vital source of water supply, provide recreational opportunities, support diverse aquatic habitat, and provide flood protection throughout Kansas. Excessive sediment can alter the aesthetic qualities of reservoirs and affect their water quality and useful life (Christensen, 2000). Sediment deposition in reservoirs can be attributed to many factors, including precipitation, topography, contributing-drainage area of the watershed and differing soil types. Decreases in reservoir storage capacity from sediment deposition can affect reservoir allocations used for flood control, drinking-water supplies, recreation and wildlife habitat. Land use has considerable effect on sediment loading in a reservoir. Intense agricultural use in the watershed, with limited or ineffective erosion prevention methods, can contribute large loads of sediment along with constituents (such as phosphorus) to downstream reservoirs (Mau, 2001).

Study Area

The Council Grove Reservoir is located on the Neosho River at river mile 449.9, approximately 2 miles northwest of Council Grove and approximately 22 miles northwest of Emporia in Morris County. Authorized purposes include flood control, water quality control, recreation and water supply. The watershed includes portions of Morris and Wabaunsee counties. The reservoir has a surface area of 3,316 acres and the watershed draining into it is 246 square miles. Reservoir construction started in 1960 by the U.S. Army Corps of Engineers and the multipurpose pool was filled in 1965. The original storage capacity of Council Grove Reservoir was 52,375 acre-feet with a design life of 100 years. The latest bathymetric survey, performed by the Kansas Biological Survey in 2008, reported capacity at Council Grove Reservoir was 43,984 acre-feet. Estimated current capacity is 43,984 acre-feet, with a sedimentation rate at 189 acre-feet per year. Since the reservoir was built, approximately 17.10% of the storage capacity has filled with sediment. The reservoir has high priority TMDLs for both eutrophication and siltation. Council Grove Reservoir is found in the Flint Hills Ecoregion. The predominate land cover in the watershed around Council Grove Reservoir includes 67% grasslands and 18% croplands, with the remaining 3% broken up into forests and urban development.

Figure 1: Council Grove Reservoir Watershed Assessment Area



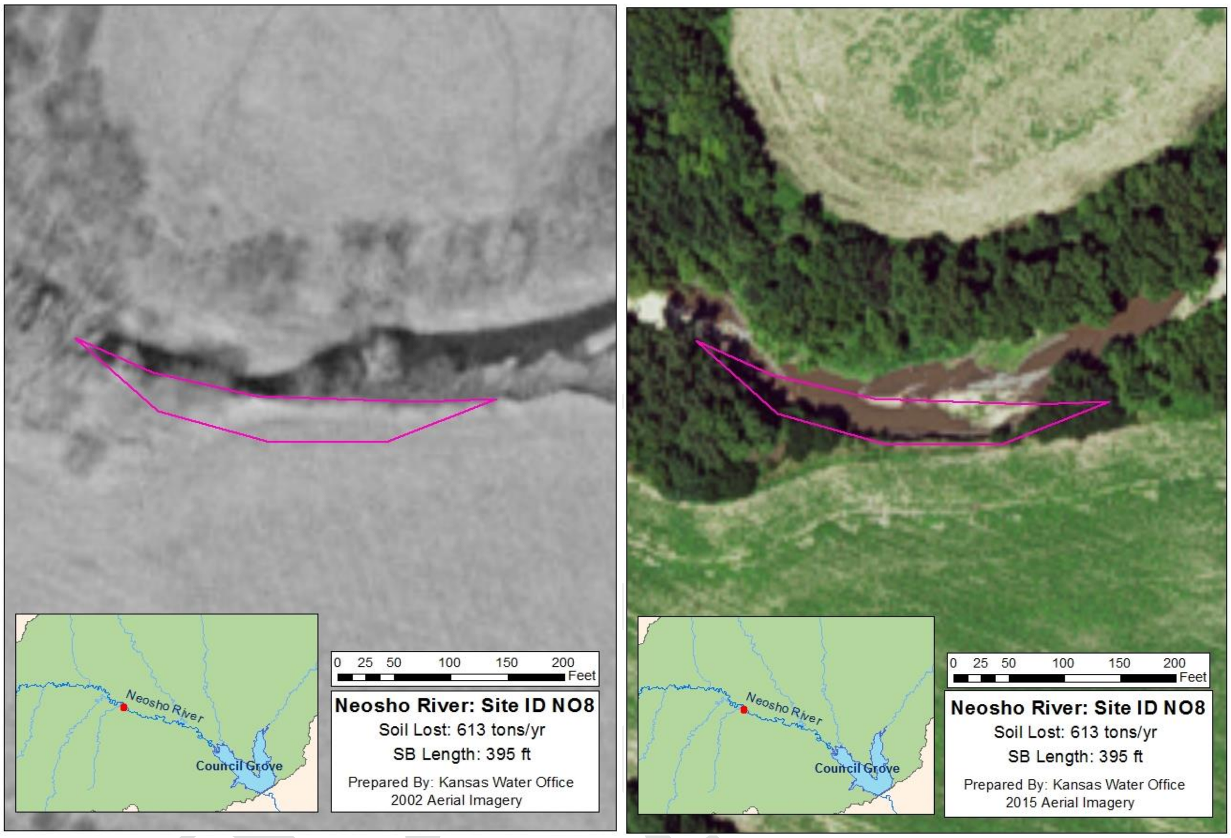
Data Collection Methodology

The Council Grove Reservoir watershed streambank erosion assessment was performed using desktop ArcGIS® software and on-the-ground field data verification and collection. The purpose of the assessment is to identify locations of streambank instability and estimate erosion rates to prioritize restoration needs along streambanks and to slow sedimentation rates in Council Grove Reservoir. ArcMap®, an ArcGIS® geospatial processing program, was utilized to assess color aerial photography from 2015 and compare it with 2002 black and white aerial photography provided by Data Access & Support Center (DASC).

Streambank erosion assessments were performed by overlaying 2015 aerial imagery onto 2002 aerial imagery. Using ArcMap® tools, "aggressive movement" of the streambank between 2002 and 2015 aerial photos were identified at a 1:2,500 scale, as a site of streambank erosion. "Aggressive movement" represents areas of 2,000 sq. feet or more of streambank movement between 2002 and 2015 aerial photos. Note that the identified streambank erosion sites are only a portion of all streambank erosion occurrences. Error can be attributed to shading interference from leafing of trees in aerial photos when photos are taken in spring, summer and early fall months. Leafing can affect the ability to locate streambanks and accurately calculate area of erosion.

Identified streambank erosion sites were denoted by geographic polygons features "drawn" into the ArcGIS® software program using ArcMap® editor tools (Figure 2). The polygon features were created by sketching vertices following the 2015 streambank and closing the sketch by following the 2002 streambank, at a 1:2,000 scale. Data provided, based on geographic polygon sites include: watershed location, stream name, type of stream and type of riparian vegetation.

Figure 2: 2002 FSA & 2015 NAIP of a Streambank Erosion Site on the Neosho River



The streambank erosion assessment data also includes approximations of tons of soil loss from the erosion site. This portion of the assessment is performed by utilizing the identified erosion site polygon features. 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*, a report prepared by The Watershed Institute (TWI) and Gulf South Research Corporation (GSCR), and relating the erosion area (in sq. feet) and perimeter length of that erosion area (in feet) to the unstable stream bank length (in feet). The intercept of the model was forced to zero.

$$\text{Estimated Streambank Length (ft)} = -0.00067A + 0.5089609P$$

Where:
A = Area (sq.ft)
P = Perimeter (ft)

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 bank height and surface area lost over the period between the 2002 and 2015 aerial photos and soil bulk density. This calculated volume is then divided by the year period, to get the average rate of soil loss in mass/year.

$$\text{Soil Loss Rate (ton/yr)} = \frac{(A \times BH \times \rho)/2000 \text{ (lb/ton)}}{\text{NAIP Comparison Photo (yr)} - \text{Base Aerial Photo (yr)}}$$

Where:
A = Area (sq.ft)
BH = Bank Height (ft)
P = Soil Density (lb/ft^3)

Soil Bulk Density, used in the average soil loss rate equation, was calculated by first determining the moist bulk density of the predominant soil in the study area, using the USDA Web Soil Survey website. The predominant soil type found at streambank erosion locations in the Council Grove Reservoir watershed consist mainly of Ivan and Kennebec soil series, with an average moist bulk density at 1.5 g/cc. This moist bulk density estimate was then converted into pounds per cubic foot and reduced by 15% to get a dry bulk density estimate at 79 lbs/ft^3. This dry bulk density is then compared to the dry bulk density on a soil texture triangle. Based on the two methods, 79 lbs/ft^3 was used for the typical bulk density of the predominant soil type in the Council Grove Reservoir watershed, and used in the average soil loss rate equation.

Streambank height measurements, also used in the average soil loss rate equation, were obtained through on the ground field verification in several locations throughout the watersheds (Figure 3). Of the total sites identified, 13 were selected, spread throughout the watershed, for field verification and streambank height measurements. These field verified streambank height measurements were the basis for extrapolating streambank height measurements for identified streambank erosion sites.

Figure 3: Streambank Height Measurement on the Neosho River

Analysis

Streambank erosion sites were analyzed by 12-digit Hydrologic Unit Codes (HUC12) that the Twin Lakes WRAPS SLT identified as high priority watersheds (Figure 4). Streambank erosion sites were analyzed for: 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, woodland, narrow woodland, or grass/crop streamside vegetation); estimated sediment reduction through the implementation of streambank stabilization BMPs at an 85% efficiency rate; and streambank stabilization cost estimates for eroded streambank sites. Streambank stabilization costs were derived from an average cost to implement streambank stabilization BMPs, as reported in 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 stabilization costs (Table 1).

Figure 4: Council Grove Reservoir Watershed Assessment by HUC12

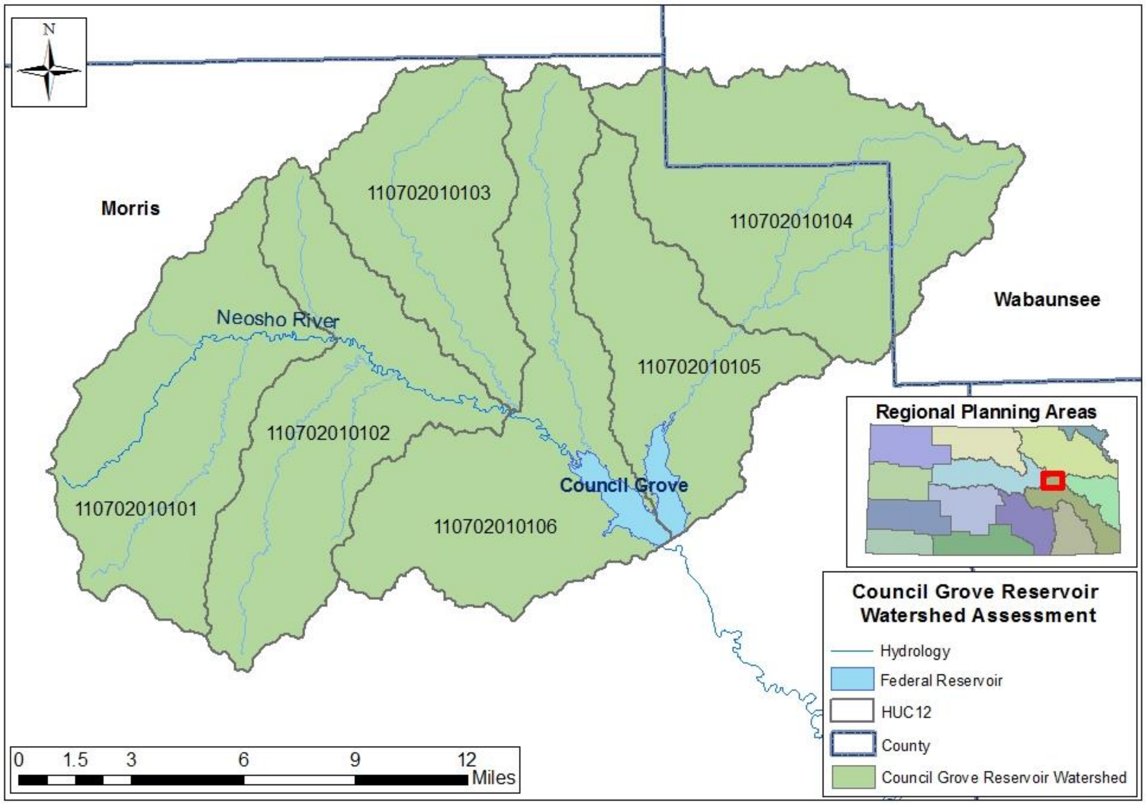


Table 1: TWI Estimated Costs to Implement Streambank Stabilization BMPs

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

Results

The KWO 2017 assessment quantifies annual tons of sedimentation from streambank erosion over the period between 2002 and 2015 in the Council Grove Reservoir Watershed within the Neosho Regional Planning Area (NEO RPA). A total of 40 streambank erosion sites, covering 11,072 feet of unstable streambank were identified. Seventy-five percent of the identified streambank erosion sites were identified as having a poor riparian condition (riparian area identified as having cropland, grass/crop streamside vegetation or narrow woodland (single line of trees between stream and cropland/pastureland)). Sediment transport from identified streambank erosion sites accounts for 14,062 tons (11.4 acre-feet) of sediment per year transported from the Tuttle Creek Watershed streams to Tuttle Creek Reservoir annually, accounting for roughly 6 percent of the total load estimated from the most recent bathymetric survey performed by a U.S. Army Corps of Engineers contractor in 2008.

Results by HUC12 indicate HUC12(10102) as the most active HUC12 for streambank degradation, accounting for 3,672 feet of unstable streambank; 6,352 tons (5.1 acre-feet) of sediment per year and 33 percent of total stabilization costs (Figure 5, 6, 7 and Table 2). Based on the average stabilization costs of $71.50 per linear foot, conducting streambank stabilization practices for the entire watershed would cost approximately $792,000.

Figure 5: Council Grove Reservoir Watershed Streambank Erosion Assessment Map by HUC12

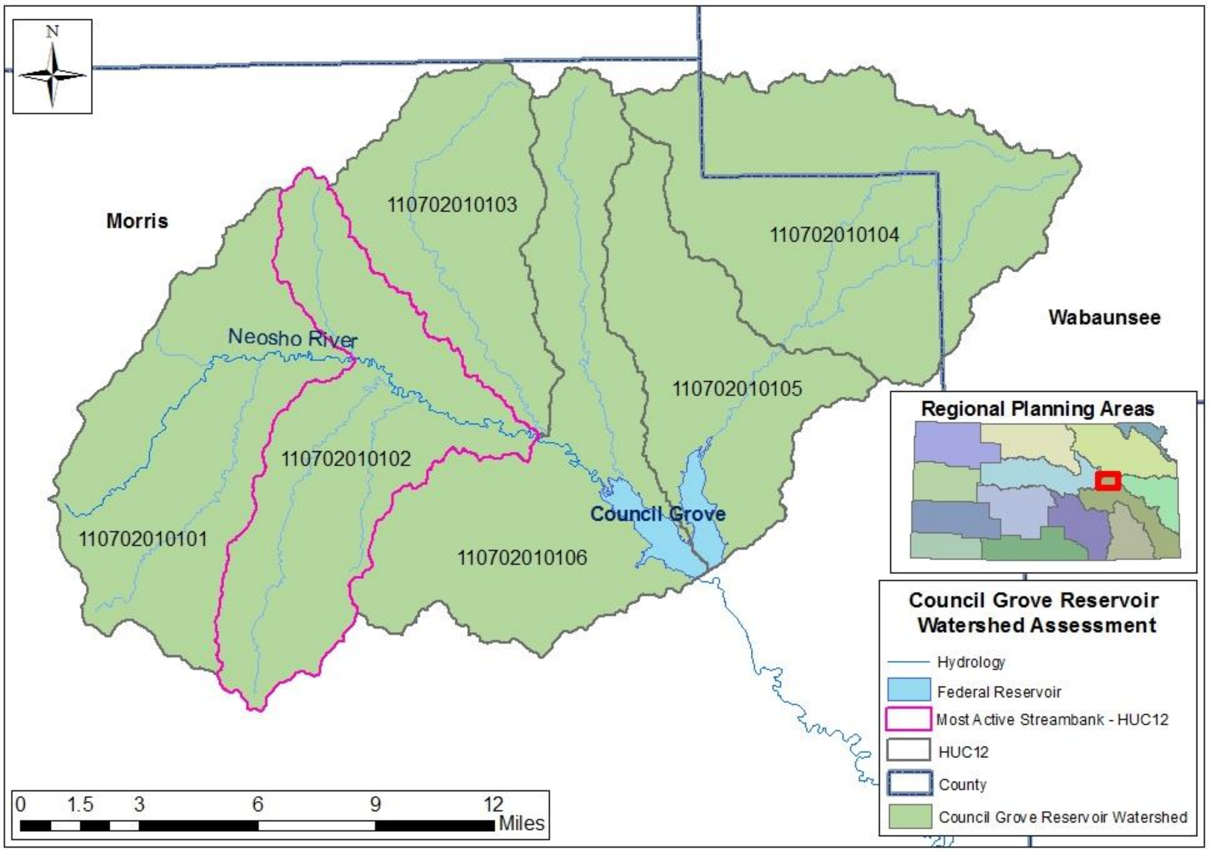


Table 2: Council Grove Reservoir Watershed Streambank Erosion Assessment Table by HUC12

HUC12 1107020...	Streambank Length (ft)	SB Erosion Site Total Soil Loss (T/Yr)	Stabilization Cost Estimate ($)	SB Erosion Sites (#)	Avg. Soil Loss/Bank Length (T/Yr/ft)	Poor Riparian Condition/SB Length (ft)	Est. Sed Reduction (T/Yr)	% SB Length w/ Poor Riparian Condition
HUC12(10101)	373	213	$26,670	2	0.57	163	-181	44%
HUC12(10102)	3,672	6,352	$262,534	11	1.73	2,989	-5,399	81%
HUC12(10103)	2,933	3,112	$209,742	10	1.06	2,386	-2,645	81%
HUC12(10104)	2,198	2,791	$157,183	8	1.27	1,790	-2,373	81%
HUC12(10105)	961	983	$68,738	4	1.02	-	-835	0%
HUC12(10106)	934	611	$66,799	5	0.65	934	-520	100%
Total	**11,072**	**14,062**	**$791,666**	**40**	**1.05**	**8,262**	**-11,953**	**74.62%**
Est Stabilization Cost/Linear Ft.			$71.50	Stablization/Restoration Efficiency			85%	

Figure 6: Council Grove Reservoir Watershed Assessment Graph by HUC12

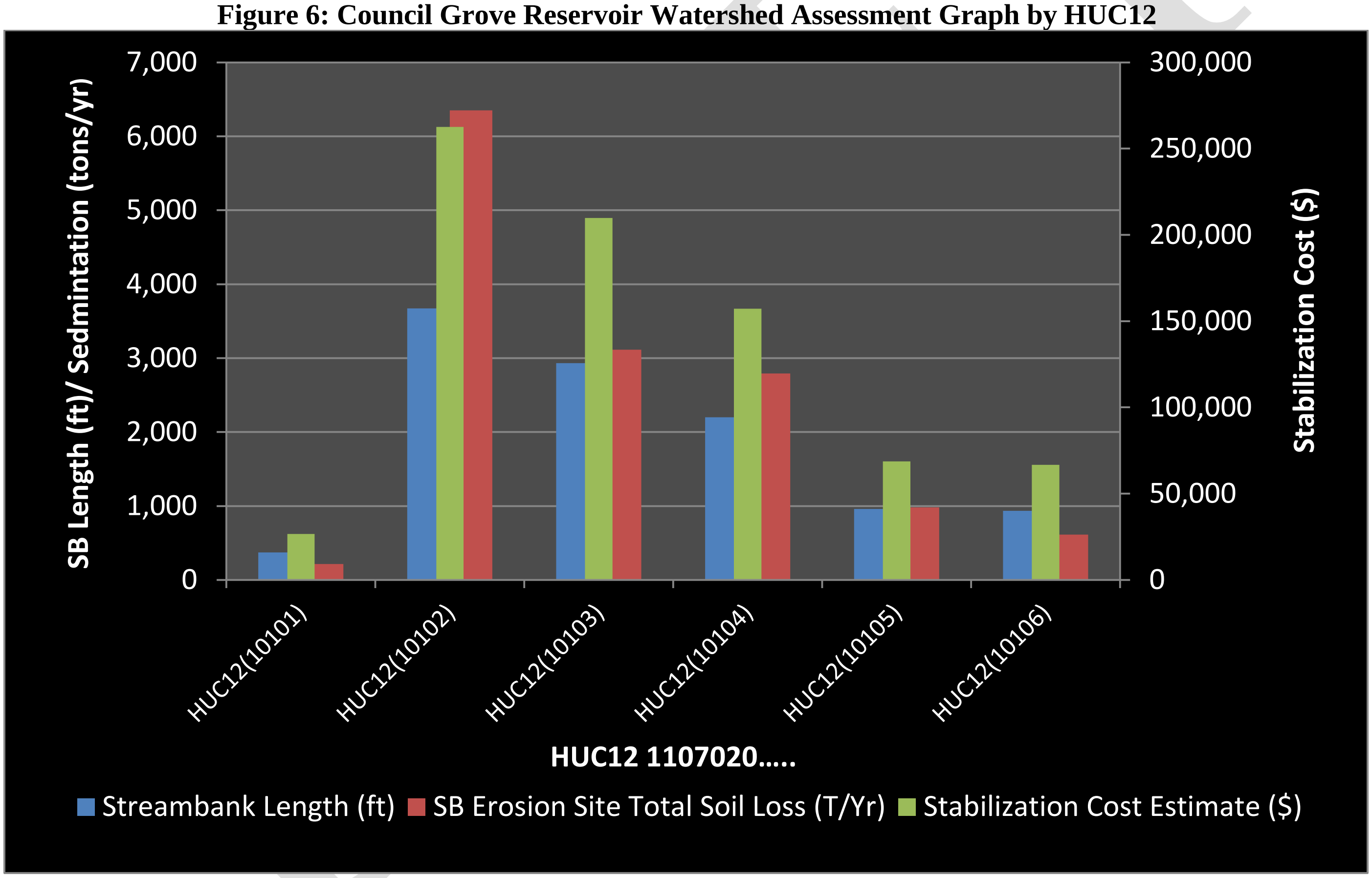
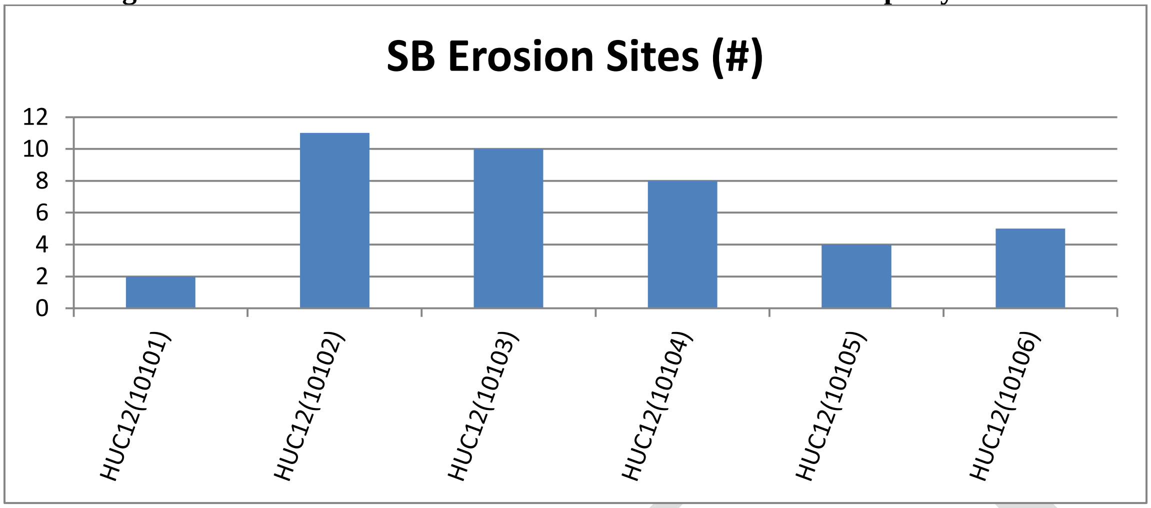


Figure 7: Council Grove Reservoir Watershed Assessment Graph by HUC12



Conclusion

The KWO completed this assessment in the Council Grove Reservoir watershed for the Twin Lakes WRAPS SLT. Information contained in the assessment may be used by the WRAPS SLT to target streambank stabilization and riparian restoration efforts toward high priority HUC12s within the Council Grove Reservoir watershed. Similar assessments have been 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.

References

1. Balch, P. (2007). *Streambank and Streambed Erosion: Sources of Sedimentation in Kansas Reservoirs*. Unpublished White Paper.

2. Brinsen, M. M., B. L. Swift, R. C. Plantico, and J.S. Barclay. 1981. Riparian Ecosystems: Their Ecology and Status. U.S.D.I., Fish and Wildlife Service. FWS/OBS-80/17, Washington, D.C., 91 pp.

3. Christensen, V. Mau, D. *Comparison of Sediment Deposition in Reservoirs of Four Kansas Watersheds.* August, 2000.

4. Freeman, Craig, Kansas Biological Survey. 1996. Importance of Kansas Forests and Woodlands, KS Walnut Council Annual Meeting, Topeka.

5. Geyer, W., Brooks, K., Neppl, T. 2003. Streambank Stability of Two Kansas River Systems During the 1993 Flood in Kansas, Transactions of the Kansas Academy of Science, Volume 106, no.1/2, p.48-53. (http://www.oznet.ksu.edu/library/forst2/srl122.pdf)

6. Huggins, D. G., Bandi, D. and Higgins, K. 1994. KBS Report # 60, Identifying riparian buffers that function to control nonpoint source pollution impacts to instream communities: feasibility study in the Delaware River Basin, Kansas.

7. Juracek, K.E. and Ziegler, A. (2007). *Estimation of Sediment Sources Using Selected Chemical Tracers in the Perry Lake and Lake Wabaunsee Basins, Northeast Kansas.*

8. Kansas State Conservation Commission. (1999). *Kansas River and Stream Corridor Management Guide*.

9. Kansas Water Plan. (2009). *Reservoir Sustainability Initiative.*

10. Mau, D.P., 2001, *Sediment depositional trends and transport of phosphorus and other chemical constituents, Cheney Reservoir watershed, south-central Kansas*: U.S. Geological Survey Water-Resources Investigations Report 01–4085, 40 p.

11. Nejadhashemi, A.P. Gali, R.K. Smith, C.M. Mankin, K.R. Wilson, R.M. Brown, S.P. Leatherman, J.C. Pomona *Lake Watershed Assessment: Preliminary Report*. 2009

12. Rosgen, D. L. (1997). *A Geomorphological Approach to Restoration of Incised Rivers*. Proceedings of the Conference on Management of Landscapes Disturbed by Channel Incision, 1997.

13. TWI. (2010). *Kansas River Basin Regional Sediment management Section 204 Stream and River Assessment.*

14. US Environmental Protection Agency. (2008). *Watershed Assessment of River Stability & Sediment Supply (WARSSS)* website: www.epa.gov/warsss/sedsource/streamero.htm