COUNCIL GROVE RESERVOIR WATERSHED STREAMBANK EROSION ASSESSMENT

ArcGIS® Comparison Study: 1991 vs. 2008 Aerial Photography

DRAFT: July 2011

Prepared by:

Anna Powell, Environmental Scientist
Kansas Water Office
901 S. Kansas Avenue, Topeka, KS 66612
(785) 296-3185, www.kwo.gov

Anna.Powell@kwo.ks.gov

Kansas Water Office

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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 reaches of streams where erosion is most severe in the watershed above Council Grove Reservoir.

The Kansas Water Office (KWO) 2011 assessment quantifies annual tons of sediment eroding from the Council Grove Reservoir Watershed over a 17 year period between 1991 and 2008. A total of 60 streambank erosion sites were identified, covering 19,164 feet of unstable streambank and transporting 22,751 tons of sediment downstream per year. Streambank erosion sites were analyzed by stream reach and 12-digit Hydrologic Unit Code (HUC12) subbasins. A substantial quantity of the identified eroded sediment in the watershed is transported annually from the mainstem Neosho River stream reaches two and three, Larids Creek stream reach one and Munkers Creek stream reach two. The four stream reach sections account for roughly 16,298 tons of sediment annually, roughly 72% of the sediment eroding from all identified streambank erosion sites. These identified reaches account for an estimated 51% or $703,300 of total stabilization cost needs for all identified streambank erosion sites. Results by HUC12 subbasins identified 110702010102, 110702010103 and 110702010104 as the most active HUC12 subbasins for streambank degradation, accounting for roughly 14,441 feet of unstable streambank, 19,877 tons of sediment per year and 75% of total stabilization costs. Based on the average stabilization costs of $71.50 per linear foot, as reported in The Watershed Institute (TWI) *Kansas River Basin Regional Sediment Management Section 204 Stream and River Channel Assessment*, conducting streambank stabilization practices for the entire watershed would cost approximately $1.4 million.

The KWO completed this assessment for the Council Grove Watershed Restoration and Protection Strategy (WRAPS) Stakeholder Leadership Team (SLT). Information contained in this assessment can be used by the Council Grove Reservoir Watershed WRAPS SLT to target streambank stabilization and riparian restoration efforts toward high priority stream reaches or 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 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 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 mil 449.9, approximately 2 miles northwest of Council Grove and approximately 22 miles northwest of Emporia in Morris County (Figure 1). 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. From the latest bathymetric survey, performed by the Kansas Biological Survey in 2008, reported capacity at Council Grove Reservoir was 43,781 acre-feet. Estimated current capacity is 43,394 acre-feet, with a sedimentation rate at 194 acre-feet per year. Since the reservoir was built, approximately 17.15% 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, 18% croplands, with the remaining 3% broken up into forests and urban development (Figure 2).

Figure 1. Council Grove Reservoir Watershed Assessment Area

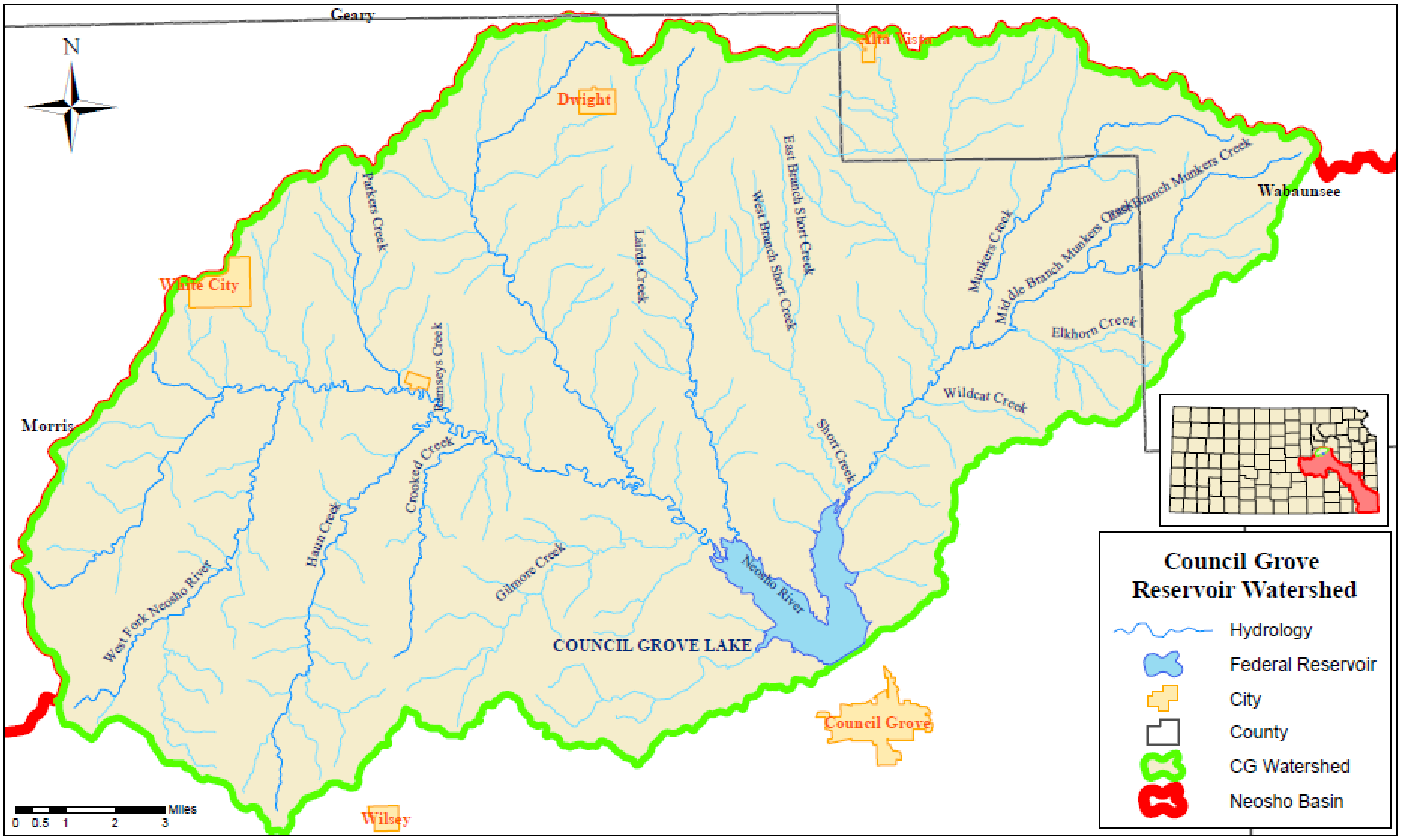
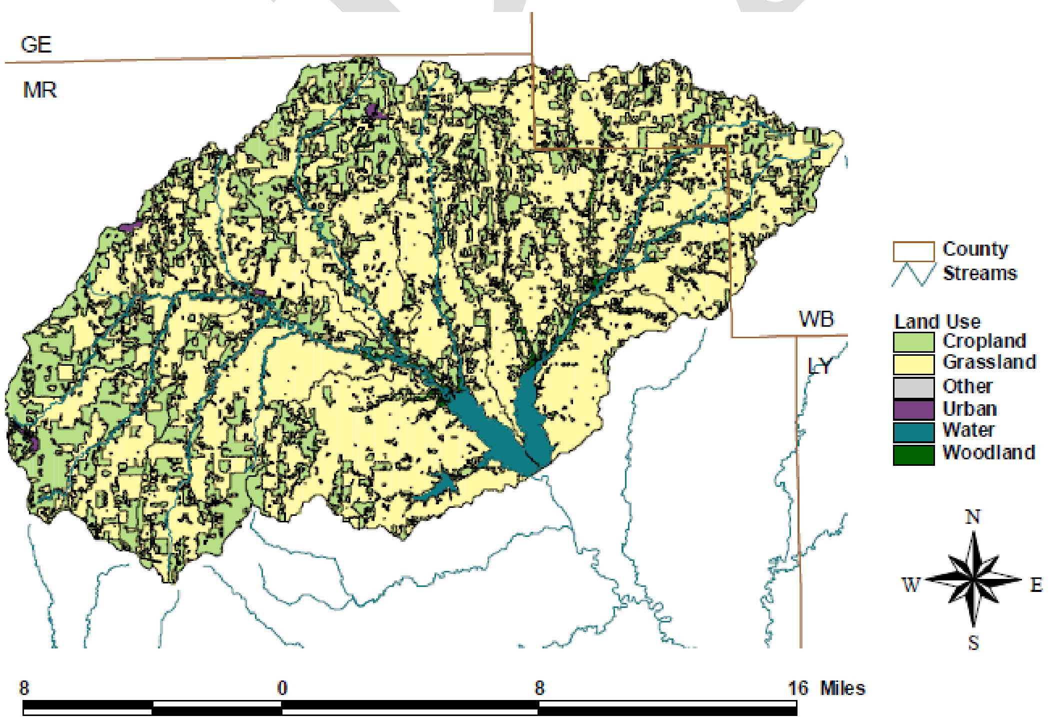


Figure 2. 2000 Land Use Land Cover Map



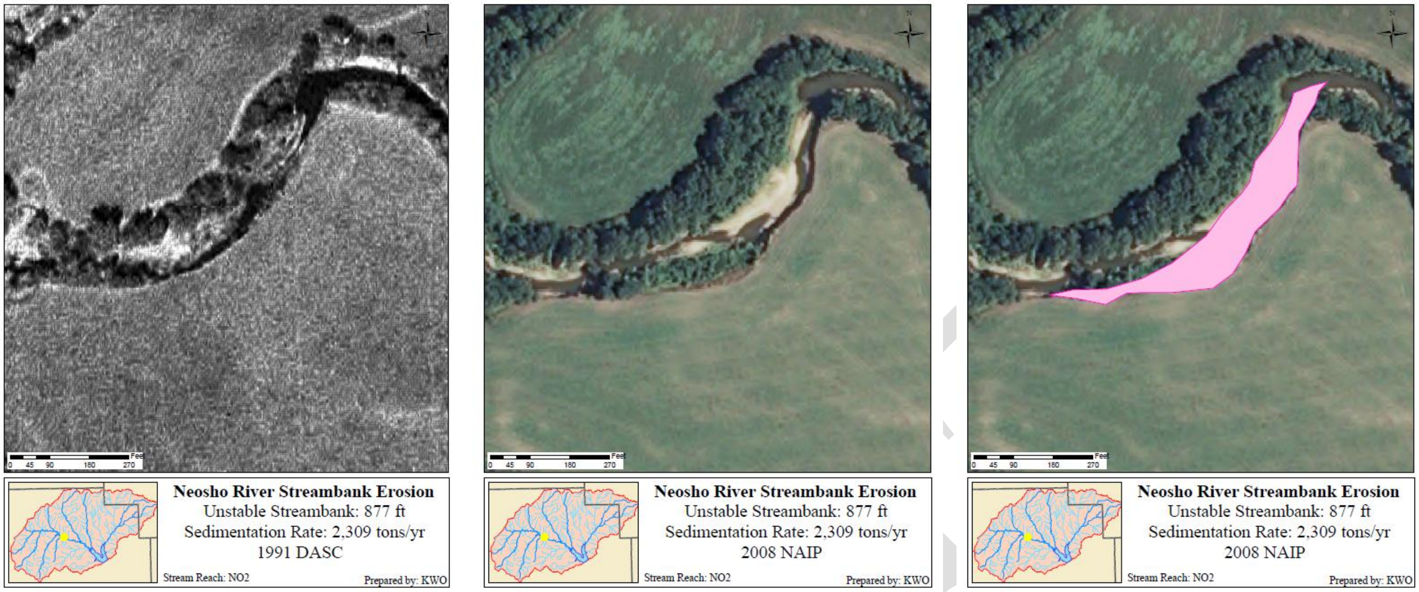
Data Collection Methodology

The Council Grove Reservoir watershed streambank erosion assessment was performed using desktop ArcGIS® ArcMap® 10 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® 10, 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 Data Access & Support Center (DASC).

Streambank erosion assessments were performed by overlaying 2008 NAIP county aerial imagery onto 1991 DASC county aerial imagery. Using ArcMap® tools, "aggressive movement" of the streambank between 1991 DASC and 2008 NAIP aerial photos were identified at a 1:6,000 scale, as a site of streambank erosion. "Aggressive movement" represents areas of 1,500 sq. feet or more of streambank movement between 1991 and 2008 aerial photos. Note that the identified streambank erosion sites are only a portion of all streambank erosion occurrences. Any erosion that covers an area smaller than roughly 1,500 sq. feet incurs a high margin of error, making calculations unreliable and is not included. This error can be attributed to some distortions between years when aerial photos are taken and years later when aerial photos are then digitally geo-referencing. Error can also 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 3). The polygon features were 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 geographic polygon sites include: watershed location, unique ID, stream name, type of stream and type of riparian vegetation.

Figure 3. 1991 DASC & 2008 NAIP of a Streambank Erosion Site; Neosho River



The streambank erosion assessment data also includes estimates of the average volume of soil loss, in tons per year, from streambank erosion sites. Estimation of average soil loss is performed utilizing the identified erosion site polygon features and calculating perimeter, area and streambank length into a regression equation. Perimeter and area were calculated through the *field calculator* application within the ArcGIS® software. Streambank length of identified erosion sites were computed through the application of a regression equation, formulated by the KWO. 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 multiple regression formula of that fit (R-square = 0.999) is:

Estimated SB Length = ([Area_SqFt]*-.00067) + ([Perimtr_ft]*.5089609)

The intercept of the model was forced to zero.

Average volume of soil loss was estimated by first calculating the volume of sediment loss and applying a bulk density estimate to that volume for the typical soil type of the eroding area. The volume of sediment was found by multiplying bank height, surface area lost over the 15 year period between the 1991 and 2008 and soil bulk density. This calculated volume is then divided by the 15 year period to get the average rate of soil loss in mass/year:

Average Soil Loss Rate (Tons/yr) =
[Area_SqFt]*[BankHgtFt]*SoilDensity(lbs/ft^3)/2000(lbs/ton)/([NAIP_ComparisonPhotoYear]-[BaseAerialPhotoYear])

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 4). 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 4. Streambank Height Measurement on the Neosho River

Analysis

To accommodate streambank rehabilitation project focus, the Council Grove Reservoir watershed study area was delineated into eight stream reaches (Figure 5) and ten 12-digit Hydrologic Unit Code subbasins (Figure 6). Streambank erosion prioritization by stream reach sections include: LC1, LC2, MC1, MC2, MR1, NO1, NO2, NO3 and NO4. Stream reach sections were identified by the stream name and in numerical order from downstream to upstream. For example, NO1 to NO4 are stream reach section on the Neosho River, starting at Council Grove Reservoir and heading upstream.

Figure 5. Council Grove Reservoir Watershed Streambank Assessment Stream Reaches

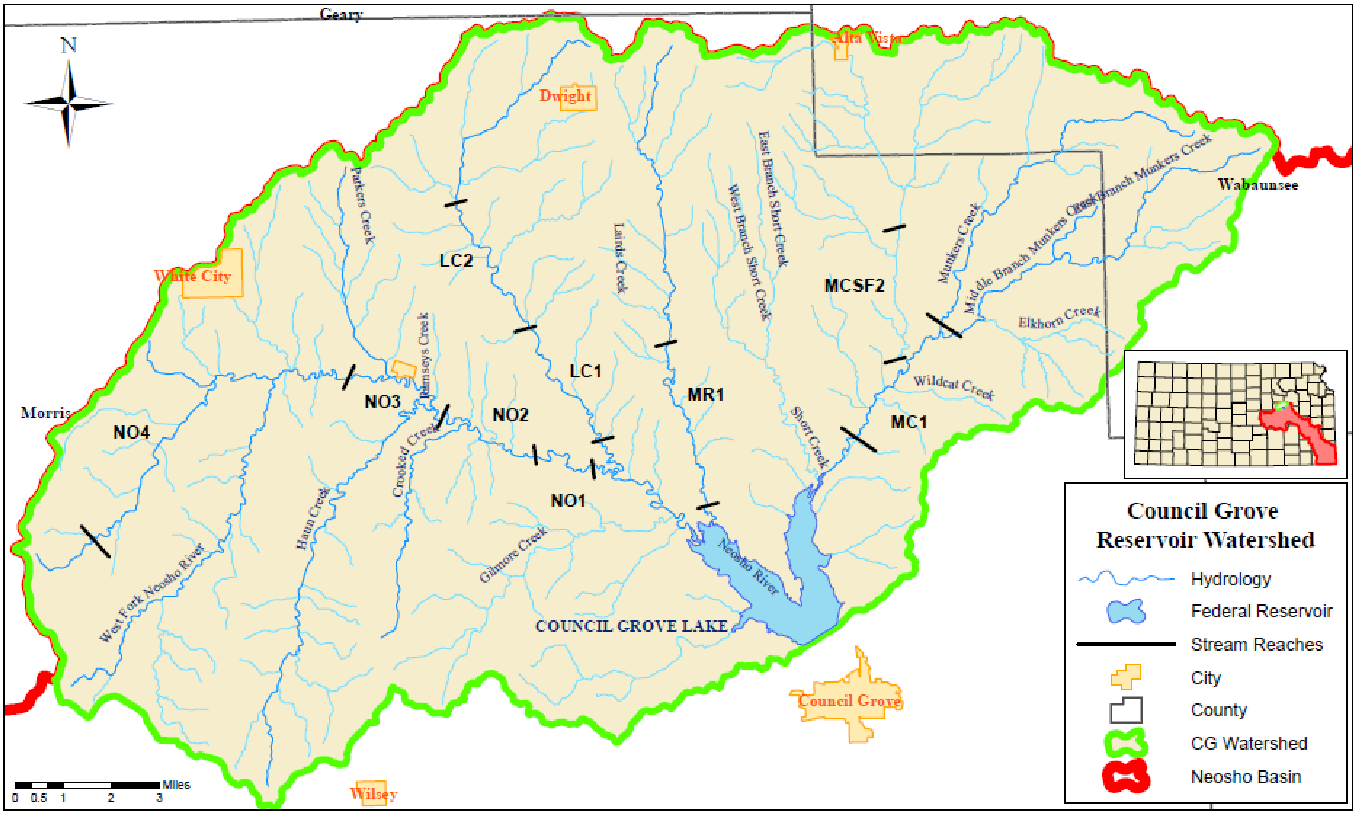
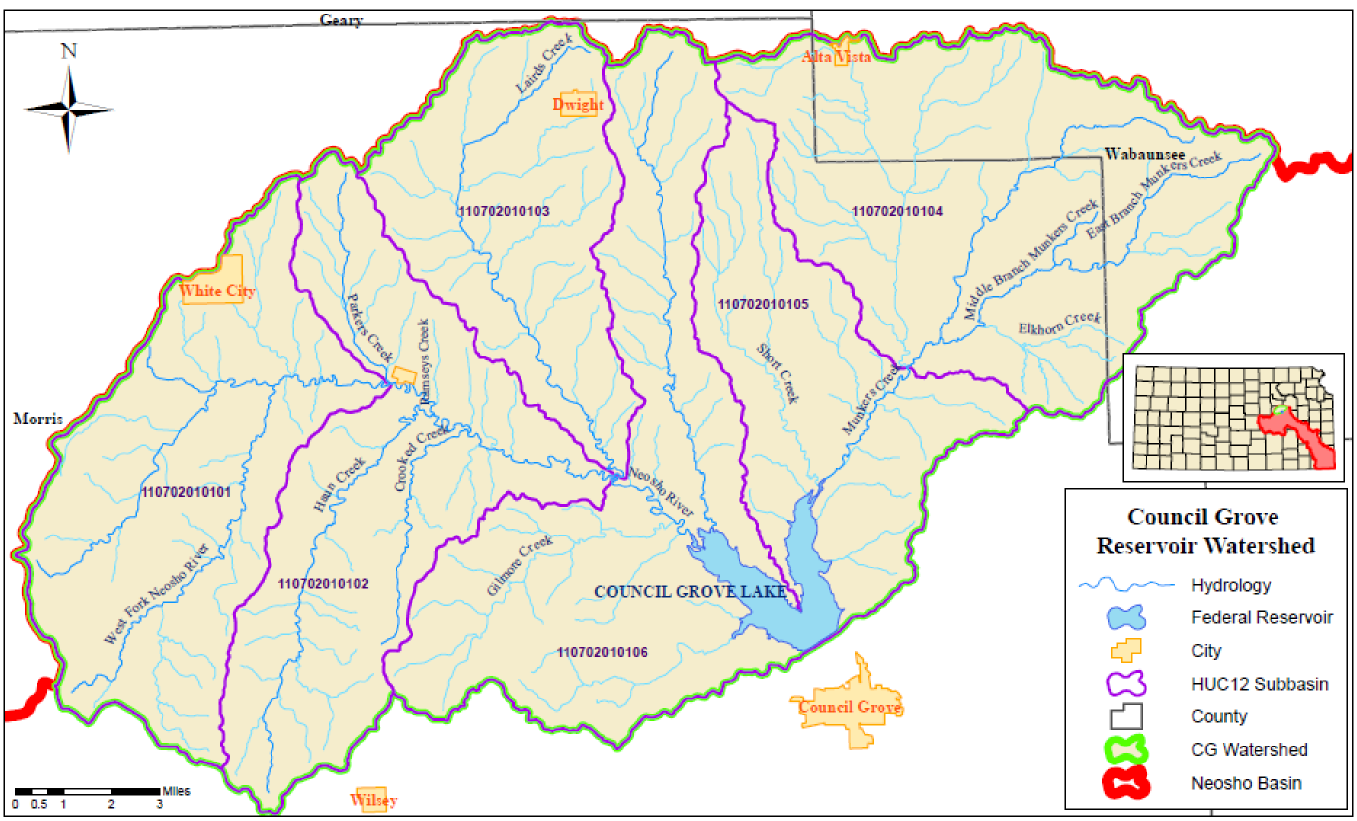


Figure 6. Council Grove Reservoir Watershed Assessment Area HUC12s



Streambank erosion sites were analyzed for: streambank length (in feet) of the eroded bank; annual soil loss (in tons/year); percent of streambank length with poor riparian condition (riparian area identified as being cropland, grassland or a grassed buffer BMPs for cultivated fields); estimated sediment reduction through the implementation of streambank stabilization Best Management Practices (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*; at $71.50 per linear foot (Figure 7). Streambank stabilization costs vary based on soil type and materials used for streambank stabilization BMPs and may differ from the estimates developed for the *Kansas River Basin Regional Sediment Management Section 204 Stream and River Channel Assessment* BMP estimates. Due to the lack of sufficient information to accurately develop streambank stabilization average costs in the Neosho River basin, TWI estimates were used.

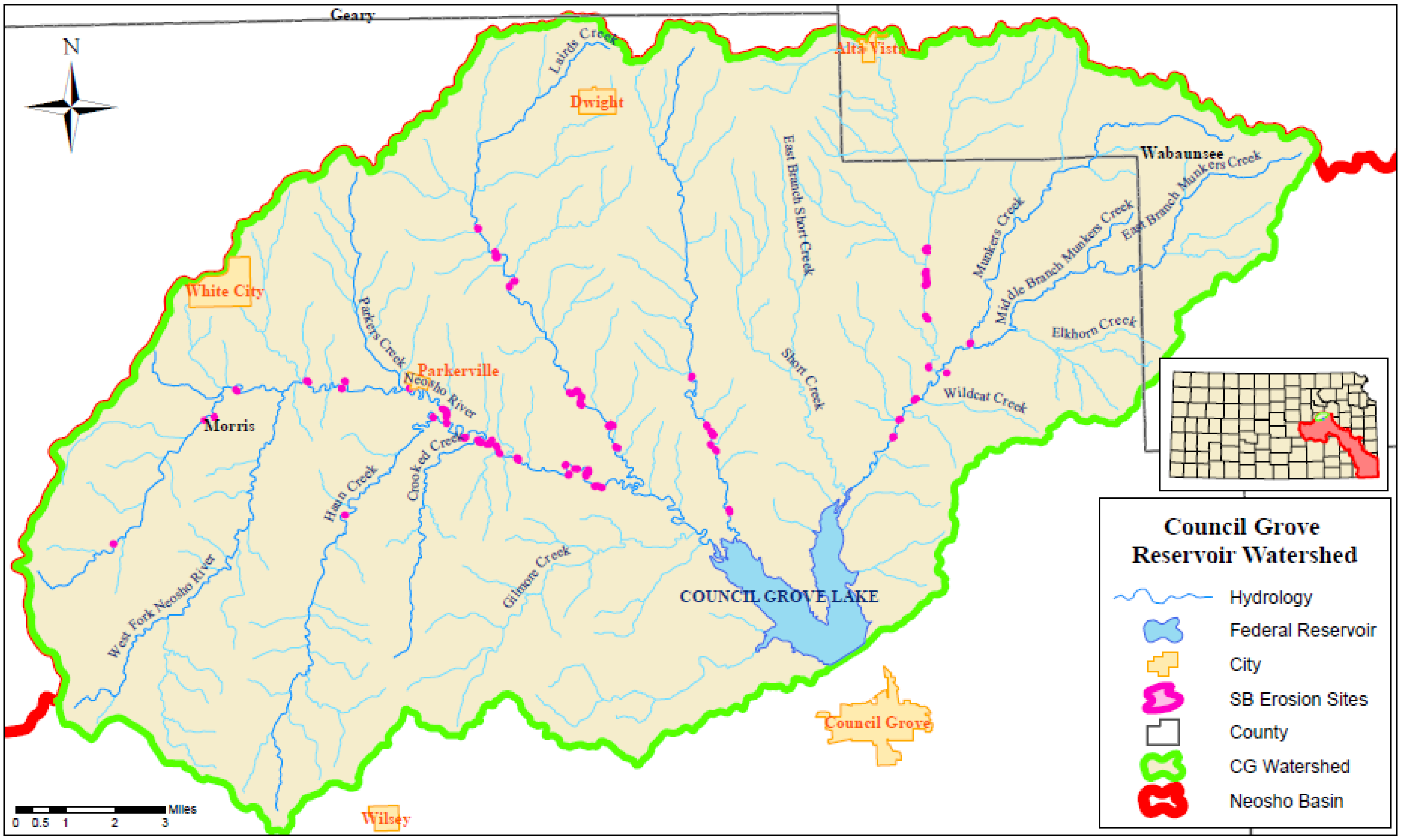
Figure 7. TWI Estimated Costs to Implement Streambank Stabilization BMPs

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 2011 assessment quantifies annual tons of sedimentation from streambank erosion sites between 1991 and 2008 in the Council Grove Reservoir watershed. A total of 60 streambank erosion sites, covering 19,164 feet of unstable streambank were identified through the assessment, with 72% of the unstable streambanks identified as having poor riparian condition (Figure 8). The assessment also identified estimates totaling approximately 22,751 tons of sediment being transported from the streambank erosion sites downstream annually.

Figure 8. Assessment Identified Streambank Erosion Sites

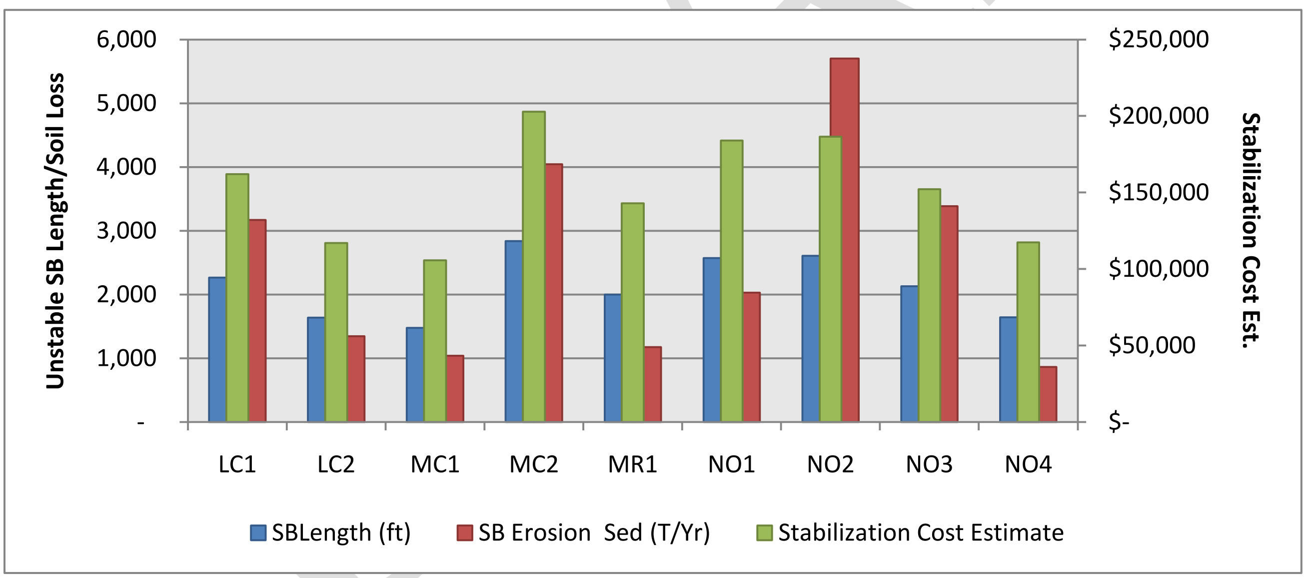


A majority of the identified 22,751 tons of eroded sediment is transported annually from the Neosho River stream reaches two and three (NO2 & NO3), Munkers Creek stream reach two (MC2) and Lairds Creek stream reach one (Table 1 & Figure 9). The Neosho River stream reach two was found to contribute approximately 5,702 tons of eroded sediment annually from roughly 2,608 feet of unstable streambank and accounts for an estimated 14% of the total stabilization cost needs in the watershed, totaling $186,476. Installing BMPs for all the identified sites within the Neosho River stream reach two would account for roughly 4,847 tons of annual sediment reduction at an 85% stabilization/restoration efficiency. The Neosho River stream reach three was found to contribute approximately 3,384 tons of eroded sediment annually from roughly 2,127 feet of unstable streambank and accounts for an estimated 11% of the total stabilization cost needs in the watershed, totaling $152,082. Installing BMPs for all the identified sites within the Neosho River stream reach three would account for roughly 2,876 tons of annual sediment reduction at an 85% stabilization/restoration efficiency. Munkers Creek stream reach two was found to contribute approximately 4,044 tons of eroded sediment annually from roughly 2,836 feet of unstable streambank and accounts for an estimated 15% of the total stabilization cost needs in the watershed, totaling $202,751. Installing BMPs for all the identified sites within Munkers Creek stream reach two would account for roughly 3,438 tons of annual sediment reduction at an 85% stabilization/restoration efficiency. Lairds Creek stream reach one was found to contribute approximately 3,168 tons of eroded sediment annually from roughly 2,266 feet of unstable streambank and accounts for an estimated 12% of the total stabilization cost needs in the watershed, totaling $161,988. Installing BMPs for all the identified sites within Lairds Creek stream reach one would account for roughly 2,693 tons of annual sediment reduction at an 85% stabilization/restoration efficiency.

Table 1. Council Grove Reservoir Watershed Assessment Table by Stream Reach

Stream Reach	SB Length (ft)	SB Erosion Sed (T/Yr)	Stabilization Cost Estimate	SB Erosion (no.)	Yield Loss/ Bank Length	Poor Riparian Cond/SB Length (ft)	Est. Sed Reduction (T/Yr)	% SB Length w/ Poor Riparian Cond.
LC1	2,266	3,168	$ 161,988	7	1.4	1,513	2,693	66.78%
LC2	1,635	1,346	$ 116,938	6	0.8	1,635	1,144	100.00%
MC1	1,478	1,038	$ 105,674	6	0.7	736	882	49.82%
MC2	2,836	4,044	$ 202,751	6	1.4	2,188	3,438	77.14%
MR1	2,000	1,175	$ 142,979	8	0.6	1,585	998	79.27%
NO1	2,572	2,030	$ 183,900	8	0.8	646	1,726	25.13%
NO2	2,608	5,702	$ 186,476	6	2.2	2,218	4,847	85.03%
NO3	2,127	3,384	$ 152,082	6	1.6	1,910	2,876	89.78%
NO4	1,642	864	$ 117,406	7	0.5	1,291	735	78.59%
Total	19,164	22,751	$1,370,194	60	10	13,721	19,339	71.60%
Est Stabilization Cost/Linear Ft.			$71.50	**Stabilization/Restoration Efficiency**			0.85	

Figure 9: Council Grove Reservoir Watershed Streambank Erosion Assessment Graph by Stream Reach

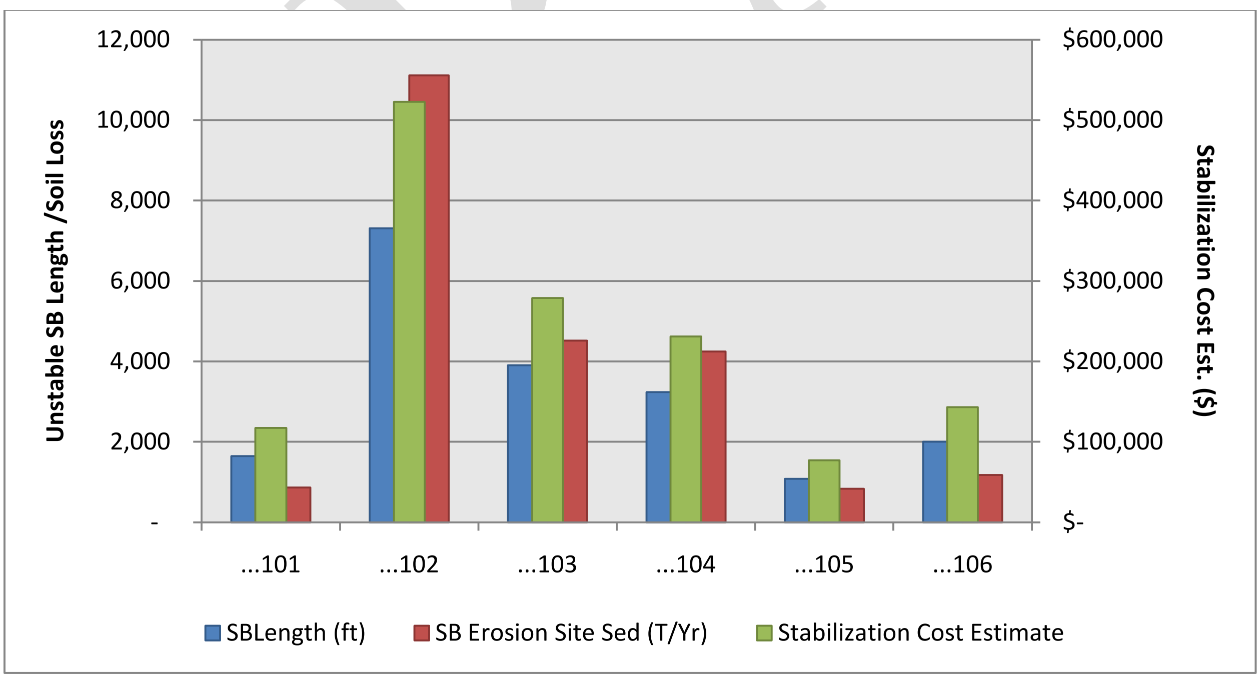


Results by HUC12 indicate that majority of the identified 42,588 tons of eroded sediment is transported annually from HUC12s (…102), (…103) and (…104) (Table 2 & Figure 10). HUC12 (…102) was found to contribute approximately 11,116 tons of eroded sediment annually from roughly 7,307 feet of unstable streambank and accounts for an estimated 38% of the total stabilization cost needs in the watershed, totaling $522,458. Installing BMPs for all the identified sites within HUC12 (…102) would account for roughly 9,499 tons of annual sediment reduction at an 85% stabilization/restoration efficiency. HUC12 (…103) was found to contribute approximately 4,515 tons of eroded sediment annually from roughly 3,901 feet of unstable streambank and accounts for an estimated 20% of the total stabilization cost needs in the watershed, totaling $278,926. Installing BMPs for all the identified sites within HUC12 (…103) would account for roughly 3,837 tons of annual sediment reduction at an 85% stabilization/restoration efficiency. HUC12 (…104) was found to contribute approximately 4,246 tons of eroded sediment annually from roughly 3,233 feet of unstable streambank and accounts for an estimated 17% of the total stabilization cost needs in the watershed, totaling $231,179. Installing BMPs for all the identified sites within HUC12 (…104) would account for roughly 3,609 tons of annual sediment reduction at an 85% stabilization/restoration efficiency.

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

HUC12 (110702010 …)	SB Length (ft)	SB Erosion Sed (T/Yr)	Stabil. Cost Estimate	SB Erosion Sites (No.)	Yield Loss/ Bank Length	Poor Riparian Cond/SB Length (ft)	Est. Sed Reduction (T/Yr)	% SB Length w/ Poor Riparian Cond.
...101	1,642	864	$117,406	7	0.5	1,291	-735	79%
...102	7,307	11,116	$522,458	20	1.5	5,118	-9449	70%
...103	3,901	4,515	$278,926	13	1.2	3,148	-3837	81%
...104	3,233	4,246	$231,179	8	1.3	2,585	-3609	80%
...105	1,080	836	$77,247	4	0.8	339	-710	31%
...106	2,000	1,175	$142,979	8	0.6	1,585	-998	79%
Total	**19,164**	**22,751**	**$1,370,194**	**60**	**5.9**	**14,066**	**19,339**	**73.40%**
Est Stabilization Cost/Linear Ft.			$71.50	**Stabilization/Restoration Efficiency**			0.85	

Figure 10. Council Grove Reservoir Watershed Assessment Graph by HUC12



Based on the average stabilization costs of $71.50 per linear foot, conducting streambank stabilization practices for the entire watershed of Council Grove Reservoir would cost approximately $1.4 million.

Conclusion

The KWO completed this Draft assessment in the Council Grove Reservoir watershed for the Council Grove Reservoir WRAPSSLT. The Draft and Final report will be submitted for internal review at the KWO. Information contained in the assessment may be used by the WRAPS SLT to target streambank stabilization and riparian restoration efforts toward high priority stream reaches on the within the Council Grove Reservoir watershed. The KWO continues to recommend streambank stabilization/riparian restoration projects as an effective method of reducing sediment delivery to these reservoirs from streambank sources. Continued land treatment as described in WRAPS plans and streambank protection with buffers is recommended for the Council Grove Reservoir watershed.

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