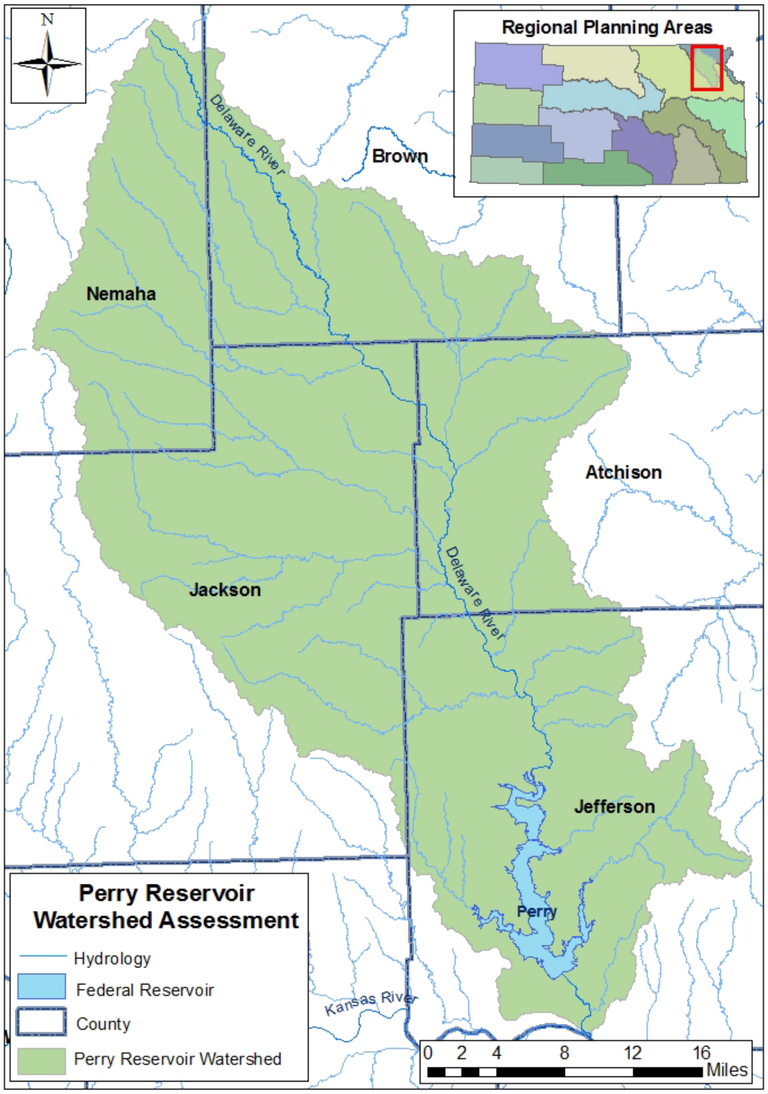
DELAWARE RIVER WATERSHED STREAMBANK EROSION ASSESSMENT

ArcGIS® Comparison Study: 1991, 2002, 2003 vs. 2015 Aerial Photography

UPDATED 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 Delaware River 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 Delaware River Watershed for streambank restoration purposes and to increase understanding of streambank erosion to reduce excessive sedimentation in reservoirs across Kansas.

The Kansas Water Office (KWO) 2017 assessment quantifies annual tons of sediment eroded over the period between 1991, 2002, or 2003 and 2015 within the Delaware River Watershed above Perry Reservoir in Kansas. A total of 81 streambank erosion sites, covering 55,437 linear feet of unstable streambank were identified. This sediment load accounts for roughly 9.6 percent of the mean annual sedimentation rate based on the most recent bathymetric survey performed by a U.S. Army Corps of Engineers contractor in 2009. 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 2,000 sq. feet, or more, were identified.

Results by HUC10 identified 1027010304 (HUC(304)) as the most active HUC10 for streambank degradation, accounting for 21,380 feet of unstable streambank; 56,762 tons (46 acre-feet of reservoir sedimentation) of sediment per year and 39 percent of total stabilization costs (Table 2 and Figure 5). While 1027010304 (HUC(304)) is the most active in terms of tons of sediment per year. Results by HUC12 identified 102701030408 as the most active HUC12 for streambank degradation, accounting for 19,809 feet of unstable streambank; 55,880 (45 acre-feet of reservoir sedimentation) of sediment per year and 36 percent of total stabilization costs (Table 3 and Figure 6). Based on the average stabilization costs of $71.50 per linear foot, conducting streambank stabilization practices for the entire watershed would cost approximately $3.9 million.

The KWO updated this assessment for the Kansas Regional Advisory Committee (KS RAC) and the Delaware River Watershed Restoration and Protection Strategy (WRAPS) Stakeholder Leadership Team (SLT). Information contained in this assessment can be used by the Delaware River Watershed WRAPS SLT to target streambank stabilization and riparian restoration efforts toward high priority HUC10s or HUC12s in the Delaware River 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

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 (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 forested riparian areas are agricultural production and suburban/urban development.

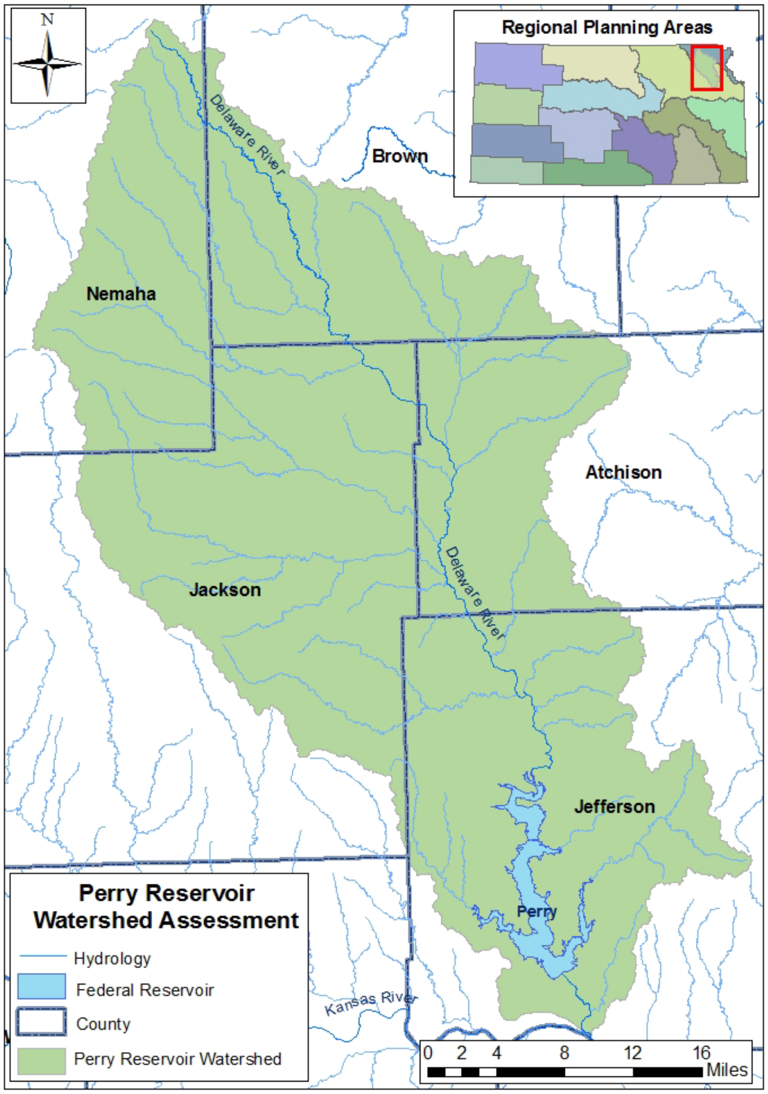
In Kansas, monitoring the extent of erosion losses is difficult, and current up-to-date inventories are needed. This assessment identifies areas with erosion concerns and estimates erosion losses to provide a better understanding of this watershed for mitigation purposes and for application of understanding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

Study Area

Perry Reservoir is located on the Delaware River, at river mile 5.8, 4.5 miles northwest of Perry, Kansas and 17 miles east of Topeka, Kansas. The Delaware River Watershed in the Kansas Regional Planning Area was assessed for streambank erosion with a primary focus on the Delaware River and its tributaries above Perry Reservoir (Figure 1). The Delaware River watershed drains approximately 1,117 mi^2, and includes portions of Atchison, Brown, Jackson, Jefferson, Nemaha and Shawnee county watersheds. Authorized purposes of Perry Reservoir are flood control, navigation, water supply, water quality, recreation and fish and wildlife. Major streams in the Perry Reservoir watershed include multiple tributaries that drain into the mainstem Delaware River.

The multipurpose pool of the reservoir was filled in 1970. The original design life for sediment storage was 100 years with a design sediment rate of 930 acre-ft/year with the original storage capacity set at 243,220 acre-feet. The most current bathymetric survey in 2009, performed by the U.S. Army Corps of Engineers contractor, concluded that 18.66 percent of the 100 year design life for sediment storage in Perry Reservoir has been lost to date, calculating the current sedimentation rate at 1,081 acre-feet per year (1,039,015 tons/yr). The bathymetric survey also concluded that the current storage capacity at the reservoir is estimated at 197,843 acre-feet to date.

Figure 1: Delaware River Watershed Assessment Area

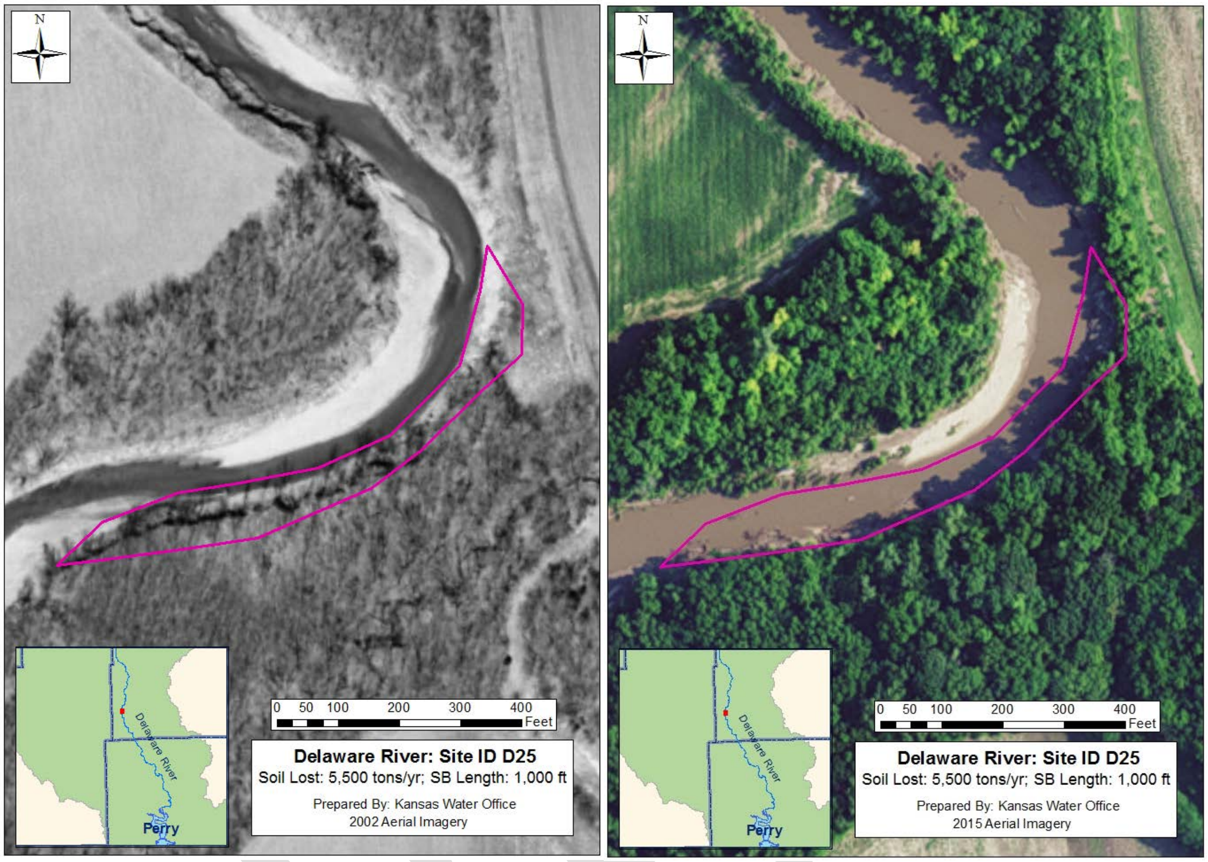


Data Collection Methodology

The Delaware 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 into Perry Reservoir. ArcMap®, an ArcGIS® geospatial processing program, was utilized to assess color aerial photography from 2015 and compare it with 1991 or 2002 black and white aerial photography or 2003 color aerial photography, provided by the State of Kansas GIS Data Access & Support Center.

The streambank erosion assessment was performed by overlaying 2015 county aerial imagery onto 1991, 2002, or 2003 county aerial imagery (Figure 2). Using ArcMap® tools, "aggressive movement" of the streambank between 1991, 2002 or 2003 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 1991, 2002 or 2003 and 2015 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 were created by sketching vertices following the 2015 streambank and closing the sketch by following the 1991, 2002, or 2003 streambank at a 1:2,000 scale. Data provided, based on the 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 Delaware 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 multiple regression formula of that fit is shown below. 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 1991, 2002, or 2003 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)

To complete the analysis for the equation above for tons of soil lost, streambank height measurements of select identified erosion sites were needed. The Kansas River Basin Regional Sediment Management Section, 204 Stream and River Channel Assessment, performed by the Gulf South Research Corporation (GRSC) and The Watershed Institute, Inc. (TWI), through contracts with the U.S. Army Corps of Engineers (Corps), was incorporated into this assessment. The assessments conducted stream channel morphologic and riparian assessments to identify future sediment control opportunities within the Kansas River basin, including streambank heights available from several surveyed locations within the Delaware River Watershed. Where no streambank elevations were available, Light Detection and Ranging (LiDAR) raster tiles available for the Delaware watershed were used to calculate streambank heights at actively eroding sites.

Analysis

Streambank erosion sites were analyzed by 10-digit Hydrologic Unit Codes (HUC10s) and 12-digit Hydrologic Unit Codes (HUC12s) (Figure 3 and 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 3: Delaware River Watershed Assessment Area HUC10s

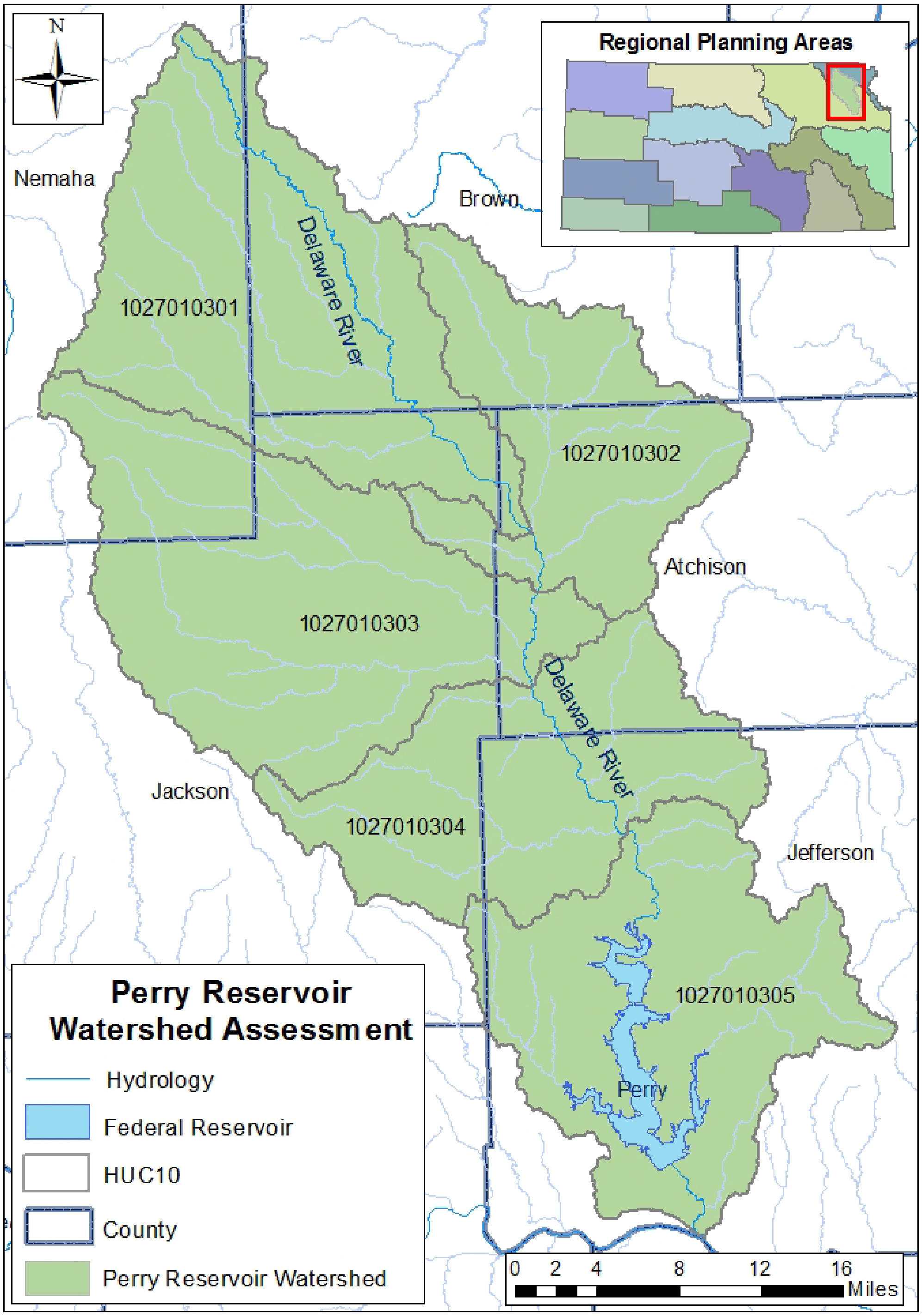


Figure 4: Delaware River Watershed Assessment Area HUC12s

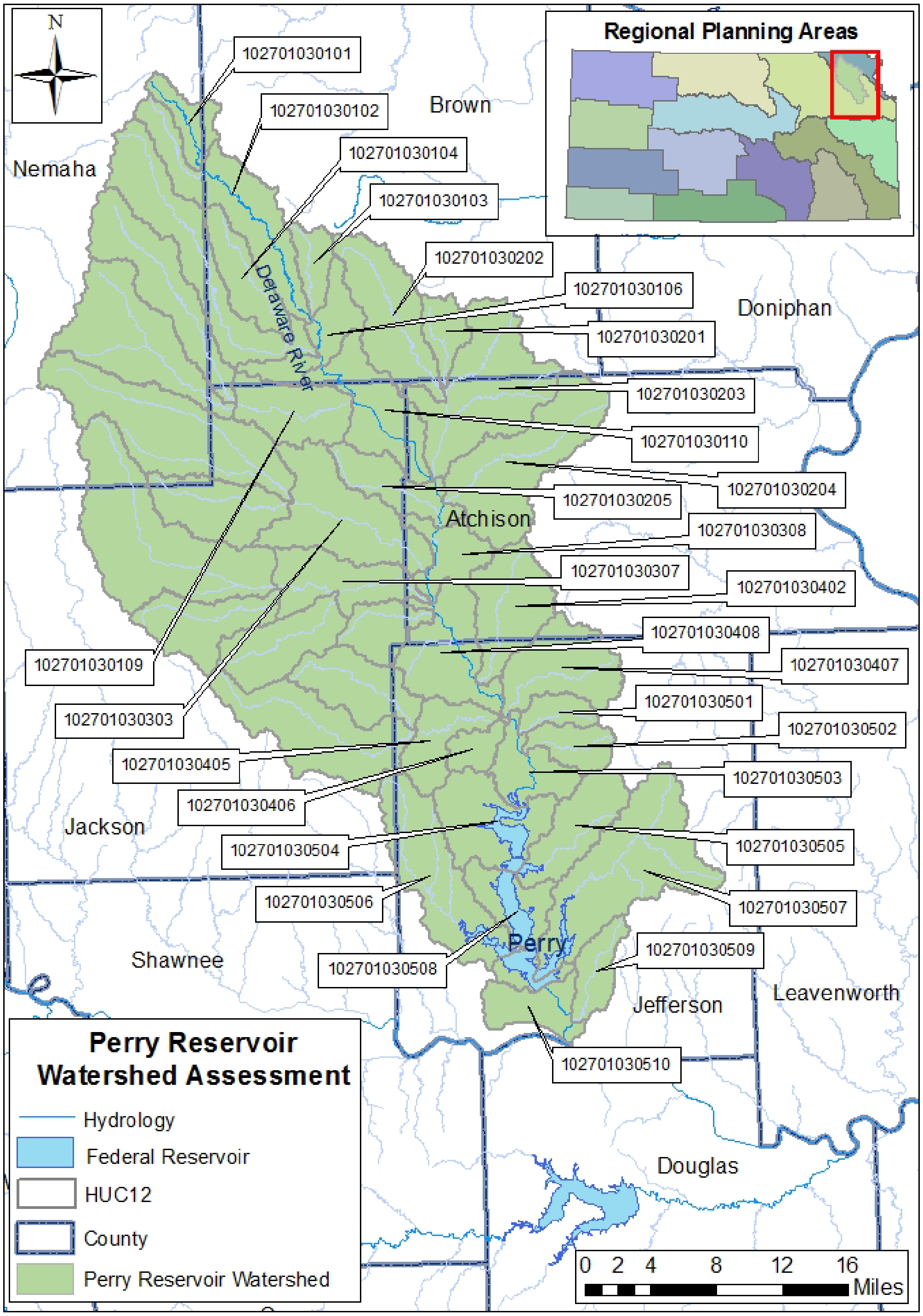


Table 1: TWI Estimated Costs to Implement Streambank Stabilization BMPs

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

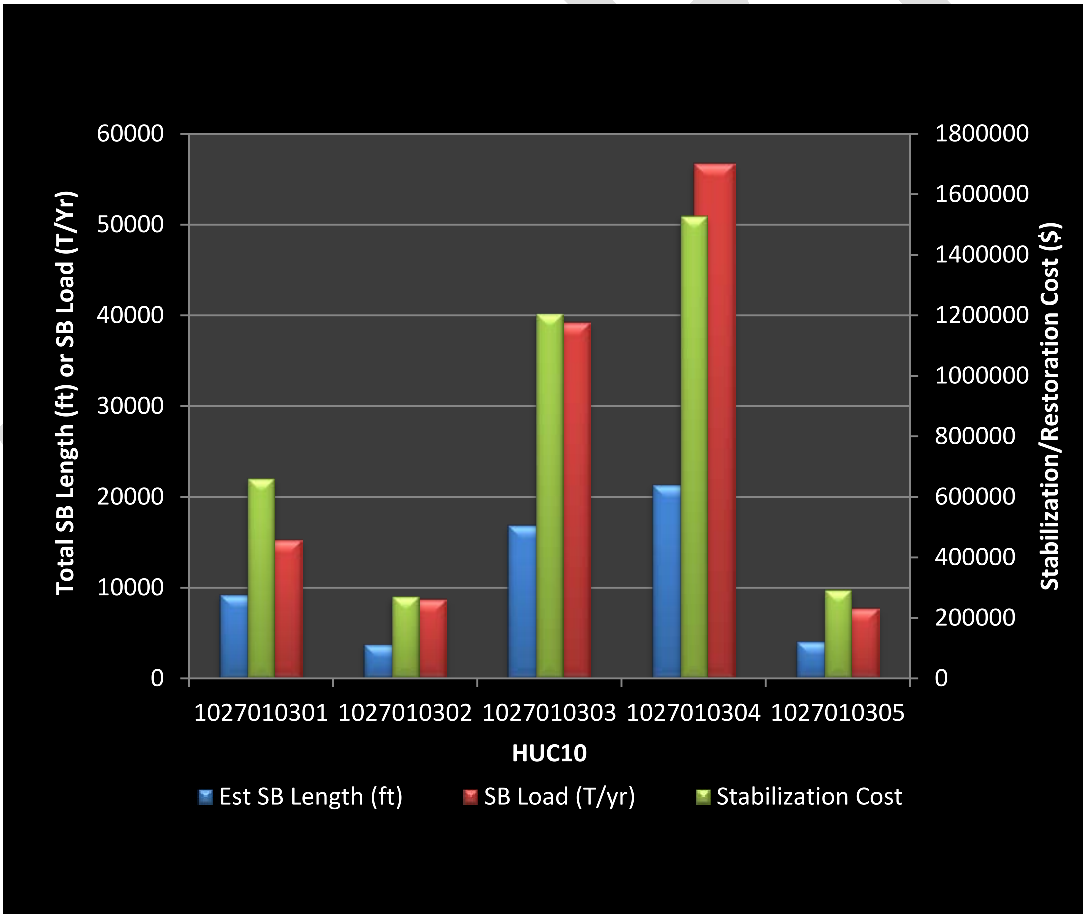
The Kansas Water Office (KWO) 2017 assessment quantifies annual tons of sediment eroding from the Delaware River Watershed over the period between 1991, 2002 or 2003 and 2015 within the Perry Reservoir Watershed in Kansas. A total of 81 streambank erosion sites, covering 55,437 linear feet of unstable streambank were identified. Seventy-seven 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 roughly 127,837 tons of sediment downstream per year, accounting for roughly 104 acre-feet per year of sediment transported from the Delaware River Watershed and deposited in Perry Reservoir. This sediment load accounts for roughly 9.6 percent of the mean annual sedimentation rate based on the most recent bathymetric survey performed by a U.S. Army Corps of Engineers contractor in 2009.

Results by HUC10 identified 1027010304 (HUC(304)) as the most active HUC10 for streambank degradation, accounting for 21,380 feet of unstable streambank; 56,762 tons (46 acre-feet of reservoir sedimentation) of sediment per year and 39 percent of total stabilization costs (Table 2 and Figure 5). While 1027010304 (HUC(304)) is the most active in terms of tons of sediment per year. Results by HUC12 identified 102701030408 as the most active HUC12 for streambank degradation, accounting for 19,809 feet of unstable streambank; 55,880 (45 acre-feet of reservoir sedimentation) of sediment per year and 36 percent of total stabilization costs (Table 3 and Figure 6). Based on the average stabilization costs of $71.50 per linear foot, conducting streambank stabilization practices for the entire watershed would cost approximately $3.9 million.

Table 2: Delaware River Watershed Streambank Erosion Assessment Table by HUC10

HUC10	Stream Bank Length (ft)	SB Erosion Site Total Soil Loss (T/Yr)	Stabilization Cost Estimate ($)	SB Erosion Sites (#)	Avg. Soil Loss/Bank Length (T/yr/ft)	Sum of Poor Riparian Con/SB length ft	Est. Sed Reduction (T/Yr)	% of SB Length w Poor Riparian Condition
1027010301	9,254	15,304	$661,671	16	26.9	7250	-13008	75.00%
1027010302	3,799	8,750	$271,639	7	15.0	3799	-7437	100.00%
1027010303	16,903	39,254	$1,208,532	26	51.7	14112	-33366	84.62%
1027010304	21,380	56,762	$1,528,667	25	55.9	18104	-48247	84.00%
1027010305	4,101	7,768	$293,241	7	12.3	294	-6602	14.29%
Total	**55,437**	**127,837**	**$3,963,750**	**81**	**161.8**	**43560**	**-108,661**	**77.78%**
Est. Stabilization Cost/Linear Ft.			$71.50	Stabilization/Restoration Efficiency			85%	

Figure 5: Delaware River Watershed Streambank Erosion Assessment Graph by HUC10



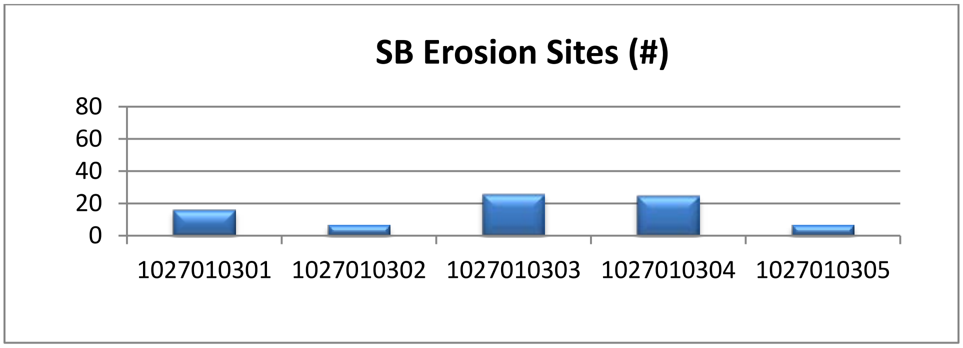
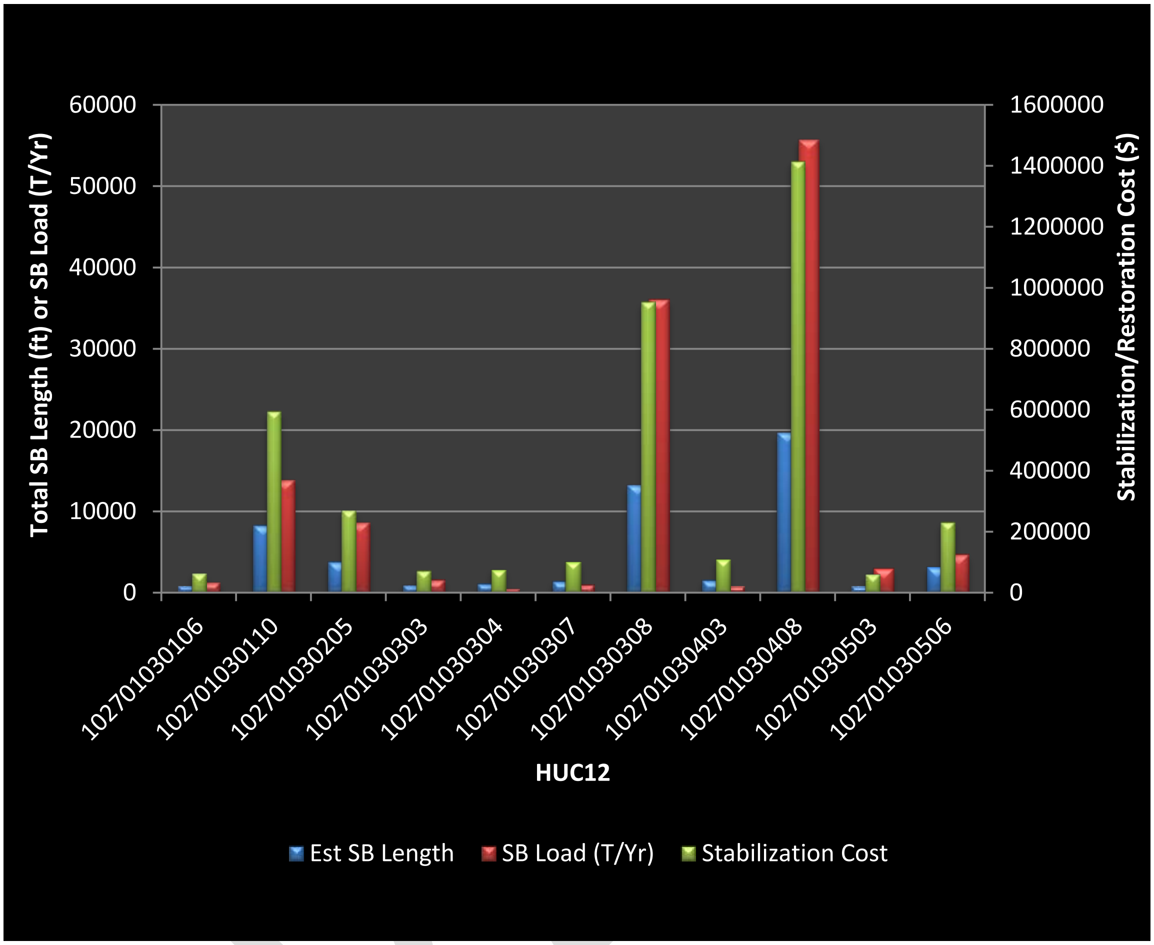
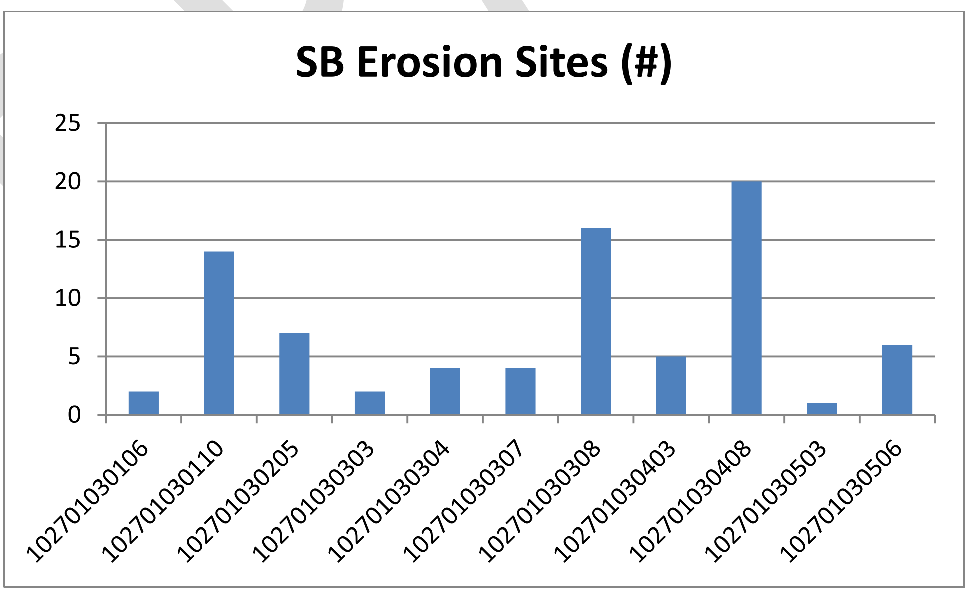


Table 3: Delaware River Watershed Streambank Erosion Assessment Table by HUC12

HUC12	Stream Bank 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 Con/SB length ft	Est. Sed Reduction (T/Yr)	% of SB Length w Poor Riparian Condition
102701030106	920	1,341	$65,789	2	2.9	0	-1,140	0.0%
102701030110	8,334	13,962	$595,881	14	24.0	7,250	-11,868	85.7%
102701030205	3,799	8,750	$271,639	7	15.0	3,799	-7,437	100.0%
102701030303	1,019	1,624	$72,844	2	3.2	572	-1,381	50.0%
102701030304	1,093	544	$78,181	4	2.1	1,093	-463	100.0%
102701030307	1,450	996	$103,695	4	2.7	1,450	-846	100.0%
102701030308	13,340	36,089	$953,812	16	43.6	10,997	-30,676	81.3%
102701030403	1,571	881	$112,333	5	2.9	979	-749	60.0%
102701030408	19,809	55,880	$1,416,335	20	53.0	17,125	-47,498	90.0%
102701030503	868	3,051	$62,030	1	3.5	0	-2,594	0.0%
102701030506	3,234	4,716	$231,211	6	8.8	294	-4,009	16.7%
Total	**55,437**	**127,837**	**$3,963,750**	**81**	**161.8**	**43,560**	**-108,661**	**77.8%**
Est. Stabilization Cost/Linear Ft.			$71.50	Stabilization/Restoration Efficiency			85%	

Figure 6: Delaware River Watershed Streambank Erosion Assessment Graph by HUC12





Conclusion

The KWO updated this assessment for the Kansas Regional Advisory Committee (KS RAC) and the Delaware River Watershed Restoration and Protection Strategy (WRAPS) Stakeholder Leadership Team (SLT). The Draft and Final report will be submitted for internal review at KWO. Information contained in the assessment can be used by the Delaware River WRAPS SLT to target streambank stabilization and riparian restoration efforts toward high priority HUC10s and HUC12s within the Delaware River Watershed above Perry Reservoir.

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