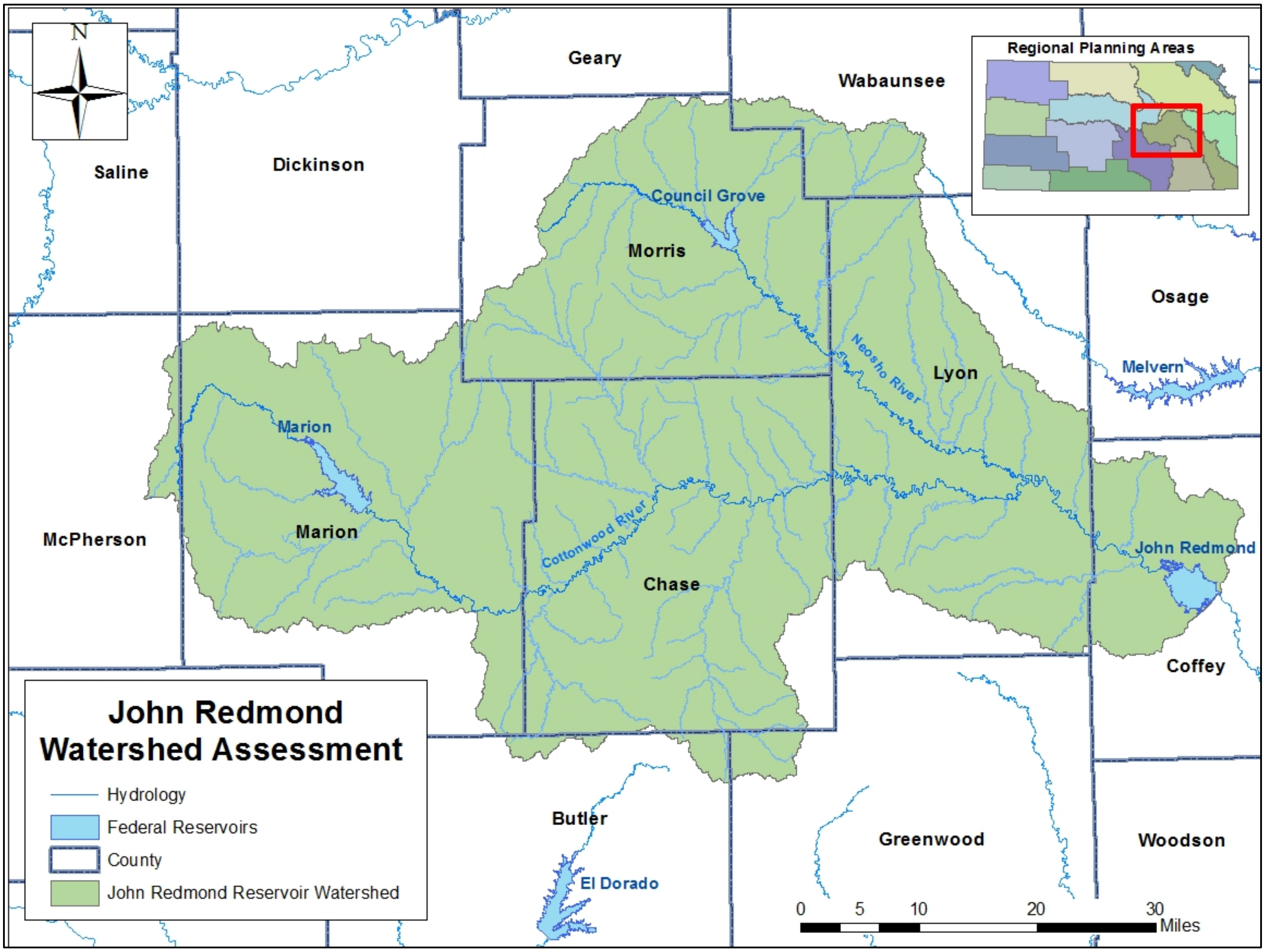
JOHN REDMOND WATERSHED STREAMBANK EROSION ASSESSMENT

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

UPDATED DRAFT March 2017



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Executive Summary

Federal reservoirs are an important source of water supply in Kansas for roughly 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 John Redmond Watershed Streambank Erosion 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 John Redmond 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 John Redmond Reservoir.

The Kansas Water Office (KWO) 2017 assessment quantifies annual tons of sediment eroded from the John Redmond Watershed. A total of 366 streambank erosion sites were identified, covering 197,470 feet of unstable streambank and transporting 525,447 tons (426 acre-feet) of sediment downstream per year, accounting for roughly fifty-five percent of the total sediment load estimated from the most recent bathymetric survey in 2014. 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.

Streambank erosion sites were analyzed by 10-digit Hydrologic Unit Codes (HUC10), 12-digit Hydrologic Unit Codes (HUC12). Results by HUC10 identified 1107020304 as the most active HUC10 for streambank degradation, accounting for 72,947 feet of unstable streambank, 260,507 tons of sediment per year, and 37 percent of total stabilization costs (Table 1 and Figure 6). Results by HUC12 identified 110702010305 as the most active HUC12 for streambank degradation, accounting for 29,720 feet of unstable streambank, 113,802 of sediment per year, and 15 percent of total stabilization costs (Table 2 and Figure 9). Based on the average stabilization costs of $71.50 per linear foot, conducting streambank stabilization practices for the entire watershed would cost approximately $14.1 million.

The KWO completed this assessment for the Neosho Regional Planning Area (Neosho RPA) and the Cottonwood Watershed Restoration and Protection Strategy (WRAPS) Stakeholder Leadership Team (SLT). Information contained in this assessment feeds into a number of sections and other assessments and can be used by the Cottonwood WRAPS SLT to target streambank stabilization and riparian restoration efforts toward high priority stream reaches in John Redmond watershed. Similar assessments are ongoing in selected watersheds above reservoirs throughout Kansas and are available on the KWO website at www.kwo.org under KWO Programs & Projects: Watershed Unit Projects, 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 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.

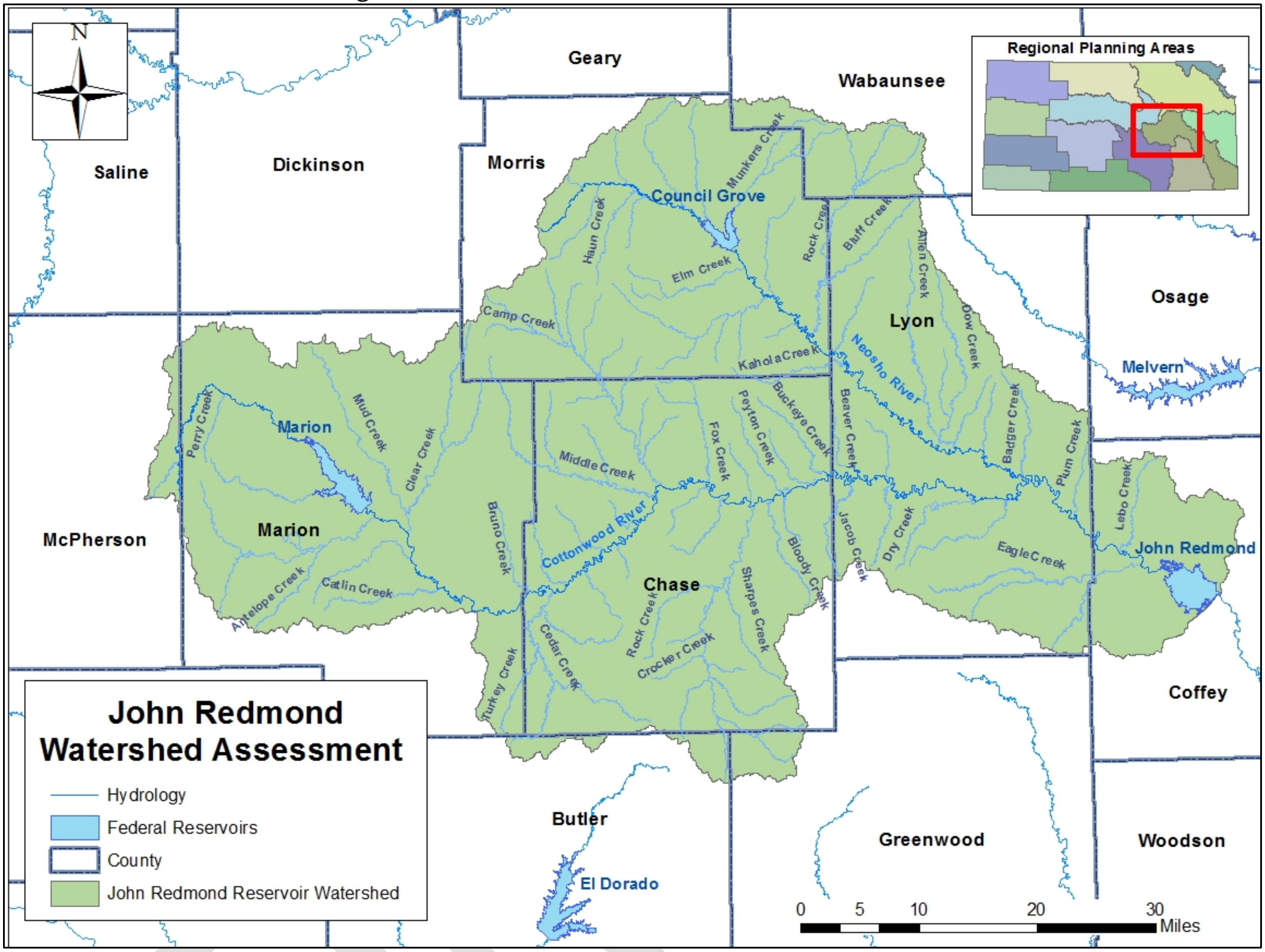
Additional research in Kansas documents the effectiveness of forested riparian areas on bank stabilization and sediment trapping (Geyer, 2003; Brinson, 1981; Freeman, 1996; Huggins, 1994). Riparian vegetative type is an important tool that provides indicators of erosion occurrence from land use practices. Vegetative cover based on rooting characteristics can mitigate erosion by protecting banks from fluvial entrainment and collapse by providing internal bank strength. 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.

Study Area

John Redmond Reservoir is located on the Neosho River, river mile 343.7 in Coffey County. The John Redmond watershed in the Neosho Regional Planning Area (Neosho RPA) was assessed for streambank erosion with a primary focus on the Neosho River mainstem and Cottonwood river tributary from roughly John Redmond Reservoir to Council Grove, Kansas and John Redmond Reservoir to Marion, Kansas (Figure 1). The Neosho River watershed above John Redmond Reservoir drains approximately 3,015 square miles through portions of Butler, Chase, Coffey, Greenwood, Harvey, Lyon, McPherson, Marion, Morris, Osage and Wabaunsee counties.

John Redmond Reservoir is a 9,400 acre impoundment located in eastern Kansas on the Neosho River. Construction began on the reservoir in 1959; the federally authorized purposes are flood control, water supply, navigation, recreation and fish and wildlife management. The original storage capacity of the reservoir was estimated to be 102,254 acre-ft. The most current bathymetric survey in 2014 concluded that 38.91 percent of the 50 year design life for sediment storage at John Redmond Reservoir has been lost to date, calculating the current sedimentation rate at 765 acre-feet per year (969,135 tons/yr). The bathymetric survey also concluded that the current storage capacity at the reservoir is estimated at 62,470 acre-feet to date.

Figure 1: John Redmond Watershed Assessment Area

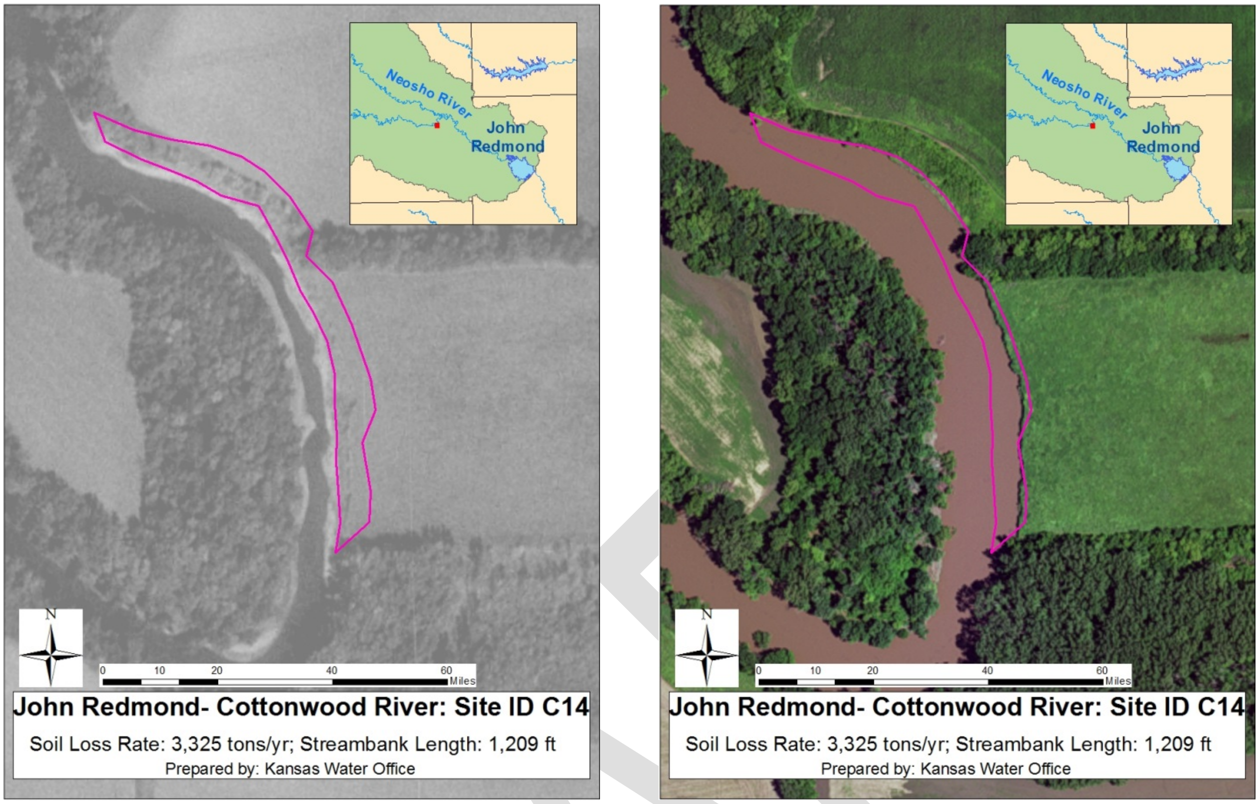


Data Collection Methodology

The John Redmond 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 the John Redmond Reservoir. ArcMap®, an ArcGIS® geospatial processing program, was utilized to assess color aerial photography from 2015, provided by National Agriculture Imagery Program (NAIP), and compare it with 1991 black and white or 2003 color aerial photography, each provided by the State of Kansas GIS Data Access & Support Center (DASC).

The streambank erosion assessment was performed by overlaying 2015 aerial imagery onto 1991 or 2003 aerial imagery (Figure 2). Using ArcMap® tools, "aggressive movement" of the streambank between 1991 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 and the more recent 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 were created by sketching vertices following the 2015 streambank and closing the sketch by following the 1991 or 2003 streambank at a 1:2,000 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 2: 1991 FSA & 2015 NAIP of a Streambank Erosion Site on the Cottonwood 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 21 year period between the 1991 or 2003 and 2015 aerial photos and soil bulk density. This calculated volume is then divided by the period between aerial photos to get 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 project assembled a number of previously installed streambank stabilization/riparian restoration projects in the state. Included with many of those projects is streambank height including many surveyed bank heights on the projects in the Neosho River basin. Where no streambank elevations were available, Light Detection and Ranging (LiDAR) raster tiles available for the John Redmond Reservoir watershed were used to calculate stream bank heights at actively eroding sites.

Analysis

Streambank erosion sites were analyzed by 10-digit Hydrologic Unit Codes (HUC10) and 12-digit Hydrologic Unit Codes (HUC12). 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 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 (Figure 5).

Figure 3: John Redmond Watershed Streambank Assessment by HUC10

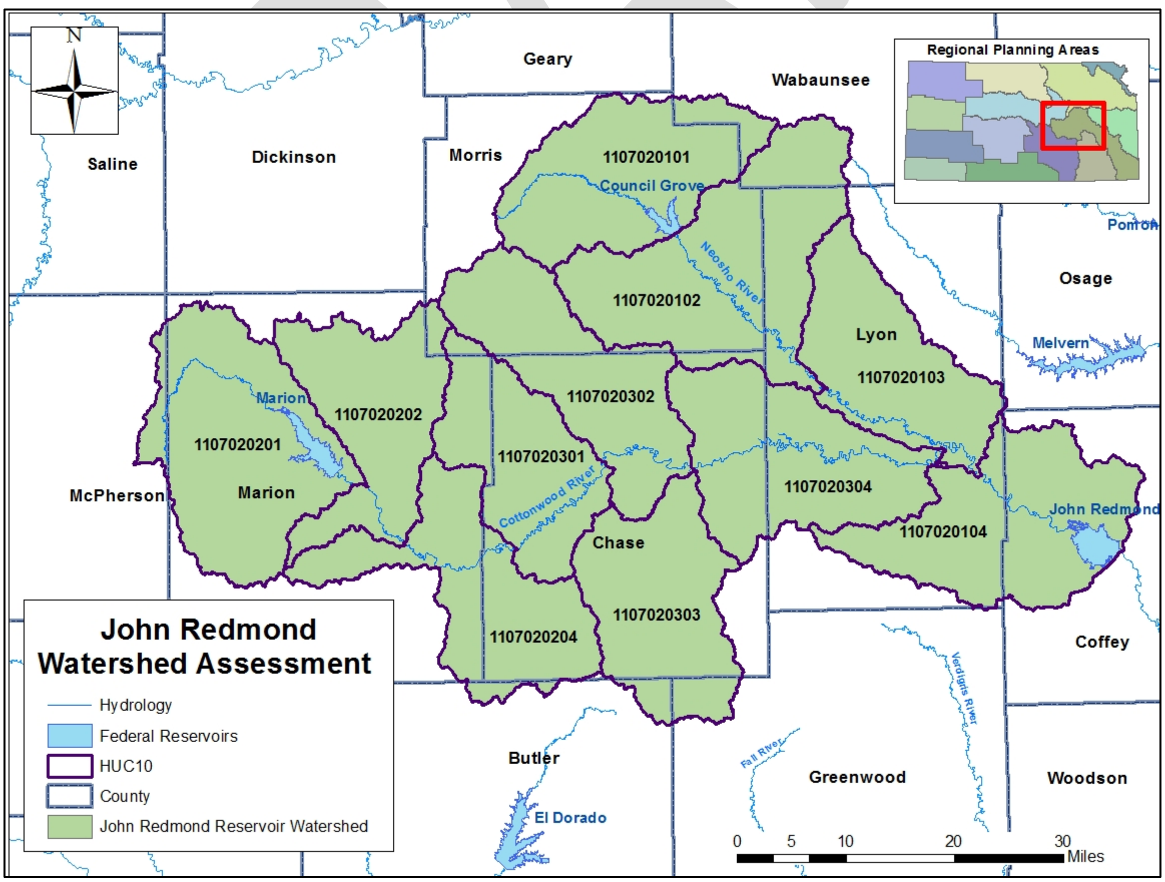


Figure 4: John Redmond Watershed Streambank Assessment by HUC12

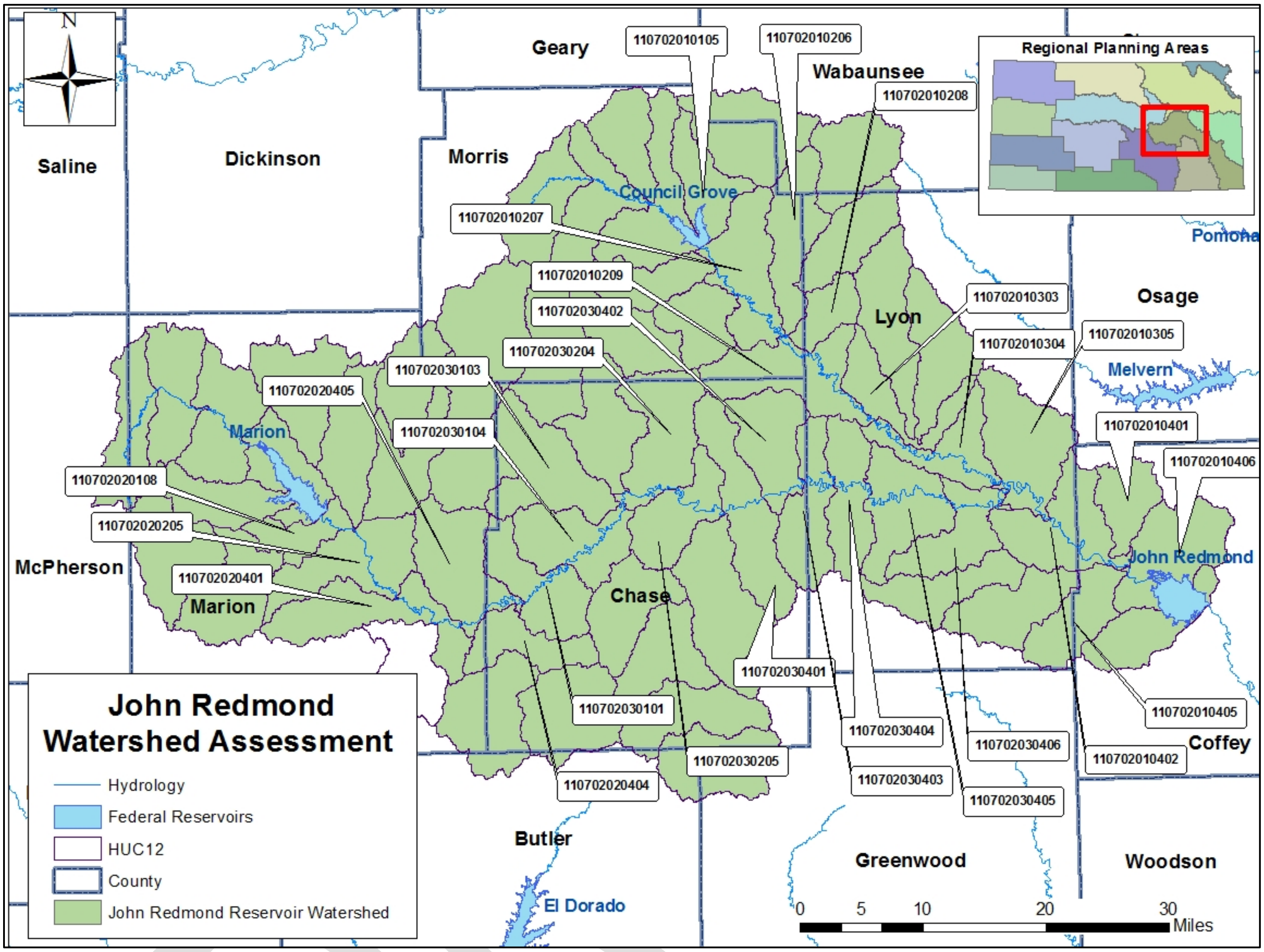


Figure 5: TWI Estimated Costs to Implement Streambank Stabilization BMPs

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 between 1991 or 2003 and 2015 in the John Redmond watershed. A total of 366 streambank erosion sites, covering 197,470 feet of unstable streambank were identified. Nearly eighty percent of the identified streambank erosion sites were identified as having a poor riparian condition (riparian area identified as having cropland or grass/crop streamside vegetation). Sediment transport from identified streambank erosion sites accounts for 525,447 tons (426 acre-feet) of sediment per year transported from the John Redmond watershed streams to John Redmond Reservoir annually, accounting for roughly 55 percent of the total load estimated from the most recent bathymetric survey, 2014.

Results by HUC10 identified 1107020304 as the most active HUC10 for streambank degradation, accounting for 72,947 feet of unstable streambank, 260,507 tons of sediment per year, and 37 percent of total stabilization costs (Table 1 and Figure 6). Results by HUC12 identified 110702010305 as the most active HUC12 for streambank degradation, accounting for 29,720 feet of unstable streambank, 113,802 of sediment per year, and 15 percent of total stabilization costs (Table 2 and Figure 9). Based on the average stabilization costs of $71.50 per linear foot, conducting streambank stabilization practices for the entire watershed would cost approximately $14.1 million.

Table 1: John Redmond 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 (#)	Average of Yield Loss/Bank Length (T/Yr/Ft)	Poor Rip Cond - SB Length (ft)	Est Sed Reduction (T/Yr)	Sum of % SB Length w poor riparian condition	% of SB Length w Poor Riparian Condition
1107020304	72,947	260,507	$ 5,215,728	113	2.9	66,958.3	-221,431	99	87.6%
1107020302	6,378	14,664	$ 456,039	17	1.6	4,865.2	-12,464	12	70.6%
1107020301	8,604	16,868	$ 615,183	21	1.8	7,811.5	-14,338	19	90.5%
1107020204	6,611	11,735	$ 472,705	17	1.8	4,702.5	-9,974	13	76.5%
1107020202	6,290	13,103	$ 449,733	18	1.9	5,739.3	-11,137	16	88.9%
1107020201	1,733	2,424	$ 123,886	5	1.4	1,732.7	-2,061	5	100.0%
1107020104	10,257	25,330	$ 733,384	7	2.3	9,649.3	-21,531	6	85.7%
1107020103	51,519	145,697	$ 3,683,587	82	2.1	46,231.3	-123,842	65	79.3%
1107020102	22,342	26,541	$ 1,597,487	57	1.1	12,413.0	-22,560	36	61.4%
1107020303	10,789	8,579	$ 771,415	29	0.8	8,163.8	-7,292	21	72.4%
Total	**197,471**	**525,448**	**$ 14,119,147**	**366**	**2.0**	**168,266.9**	**-446,631**	**292**	**79.8%**
Est. Stabilization Costs			**$71.50**	**Stabilization/Restoration Efficiency**				**85%**	

Figure 6: John Redmond Watershed Streambank Erosion Assessment Graph by HUC10

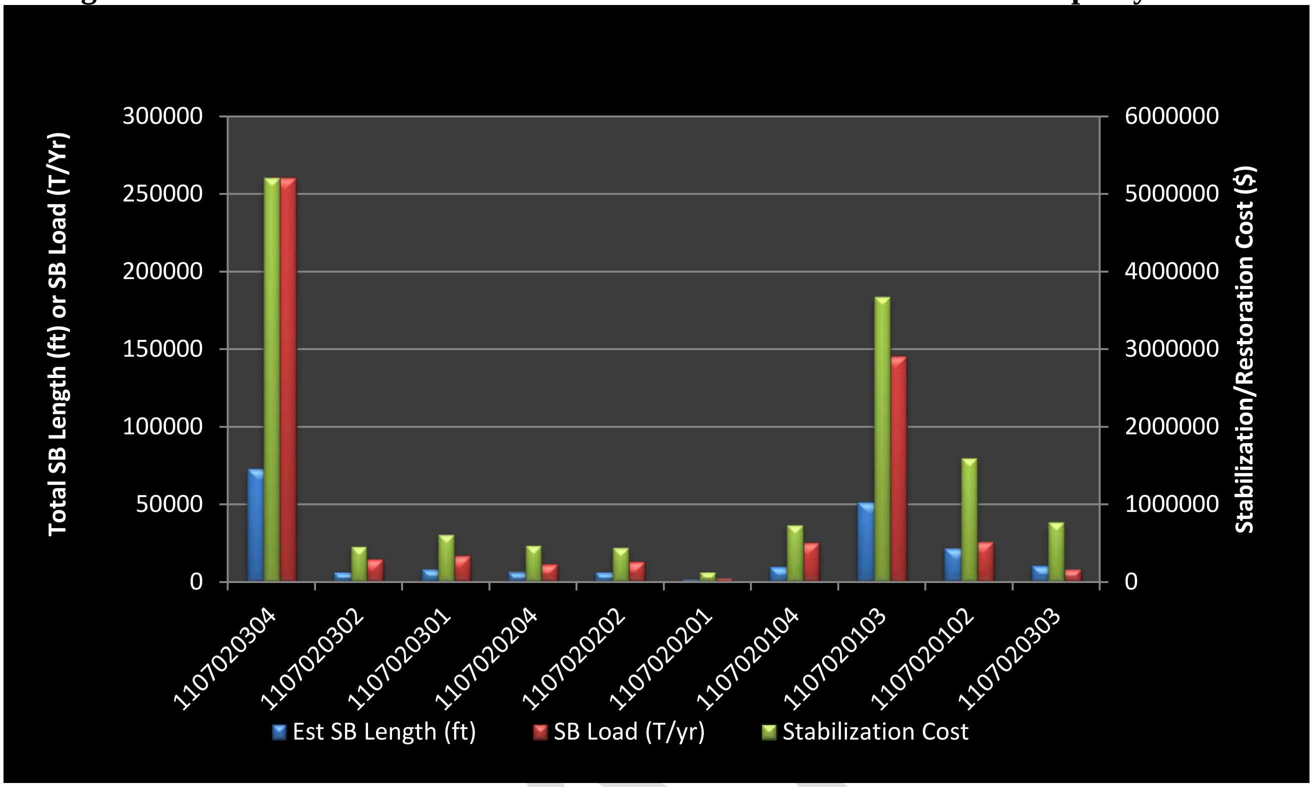


Figure 7: John Redmond Watershed Streambank Erosion Assessment Graph by HUC10

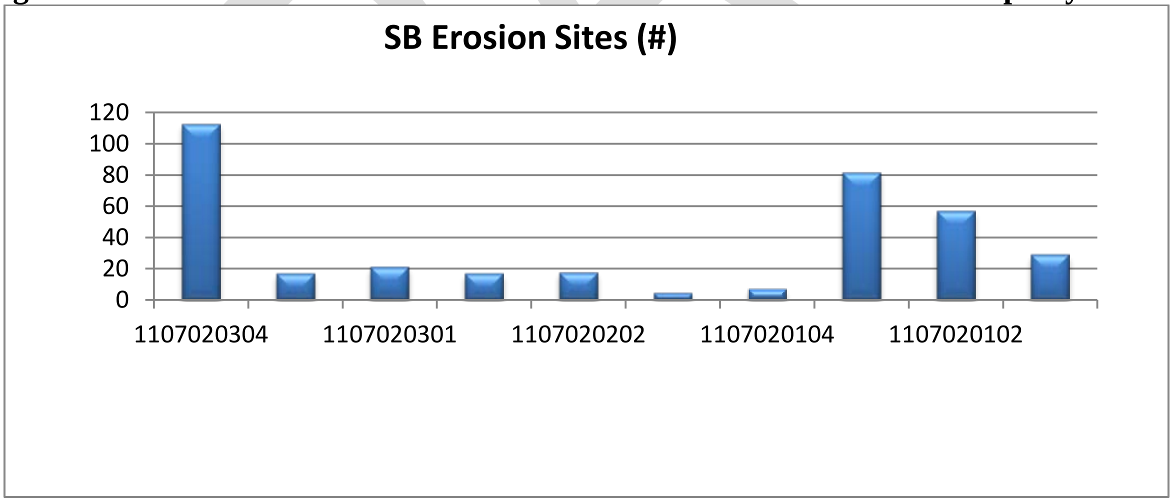


Figure 8: Tuttle Creek Watershed Streambank Erosion Assessment Map by HUC10

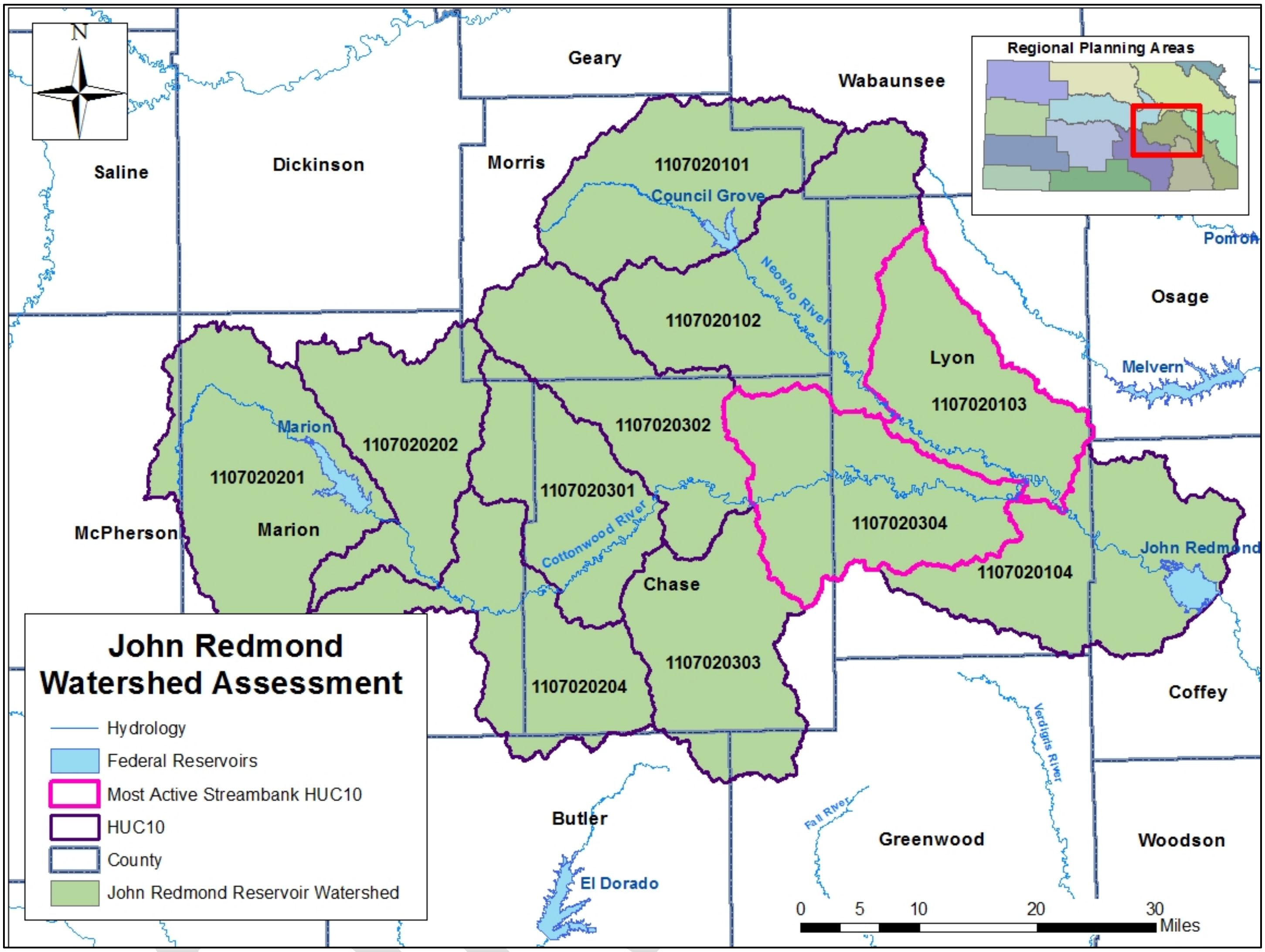


Table 2: John Redmond Watershed Streambank Erosion Assessment Table by HUC12

HUC12	Stream Bank Length (ft)	SB Erosion Site Total Soil Loss (T/Yr)	Stabilization Cost Estimate ($)	SB Erosion Sites (#)	Average Soil Loss/Bank Length (T/Yr/Ft)	Poor Riparian Cond - SB Length (ft)	Est Sed Reduction (T/Yr)	Sum of % SB Length w poor riparian condition	% of SB Length w Poor Riparian Condition
110702030406	21,888	94,657	$1,564,988	30	4.2	20,353.0	-80,458	27	90.0%
110702030405	20,280	78,153	$1,450,047	37	2.6	18,214.9	-66,430	31	83.8%
110702030404	8,505	20,368	$608,118	17	2.3	7,837.3	-17,313	15	88.2%
110702030403	11,217	31,204	$802,024	15	2.2	10,305.2	-26,523	13	86.7%
110702030402	4,553	15,898	$325,546	4	2.8	4,553.1	-13,513	4	100.0%
110702030401	5,695	17,283	$407,176	9	2.5	5,694.8	-14,690	9	100.0%
110702030205	3,106	10,954	$222,064	6	2.8	2,914.0	-9,311	5	83.3%
110702030204	1,772	2,535	$126,676	5	1.3	899.1	-2,154	3	60.0%
110702030104	5,460	10,486	$390,384	14	1.8	5,106.3	-8,913	13	92.9%
110702030101	3,144	6,382	$224,799	7	1.8	2,705.3	-5,425	6	85.7%
110702020405	4,143	6,432	$296,236	10	1.5	2,631.3	-5,468	7	70.0%
110702020401	2,468	5,302	$176,469	7	2.3	2,071.3	-4,507	6	85.7%
110702020205	5,854	12,963	$418,548	16	2.1	5,503.2	-11,018	15	93.8%
110702020108	1,733	2,424	$123,886	5	1.4	1,732.7	-2,061	5	100.0%
110702010402	10,257	25,330	$733,384	7	2.3	9,649.3	-21,531	6	85.7%
110702010305	29,720	113,802	$2,125,012	23	3.7	27,861.8	-96,732	21	91.3%
110702010209	17,971	22,173	$1,284,930	39	1.2	9,172.9	-18,847	23	59.0%
110702010304	20,038	33,352	$1,432,752	54	1.6	15,801.0	-28,349	38	70.4%
110702010207	2,649	3,569	$189,410	11	1.2	1,922.4	-3,034	8	72.7%
110702030203	1,501	1,175	$107,299	6	0.7	1,052.1	-999	4	66.7%
110702020203	436	140	$31,185	2	0.3	236.0	-119	1	50.0%
110702030305	10,478	8,374	$749,185	27	0.8	8,042.9	-7,118	20	74.1%
110702010206	1,105	464	$78,992	5	0.4	700.1	-394	3	60.0%
110702010203	618	335	$44,155	2	0.5	617.6	-285	2	100.0%
110702010303	1,318	852	$94,263	2	0.6	1,318.4	-724	2	100.0%
110702010301	916	526	$65,526	3	0.5	916.4	-447	3	100.0%
110702010302	334	110	$23,864	1	0.3	333.8	-94	1	100.0%
110702030303	190	161	$13,581	1	0.8	0.0	-137	0	0.0%
110702030301	121	44	$8,648	1	0.4	121.0	-38	1	100.0%
Total	**197,471**	**525,448**	**$14,119,147**	**366**	**2.0**	**168,266.9**	**-446,631**	**292**	**79.8%**
Est. Stabilization Costs			**$71.50**	**Stabilization/Restoration Efficiency**				**85%**	

Figure 9: John Redmond Watershed Streambank Erosion Assessment Graph by HUC12

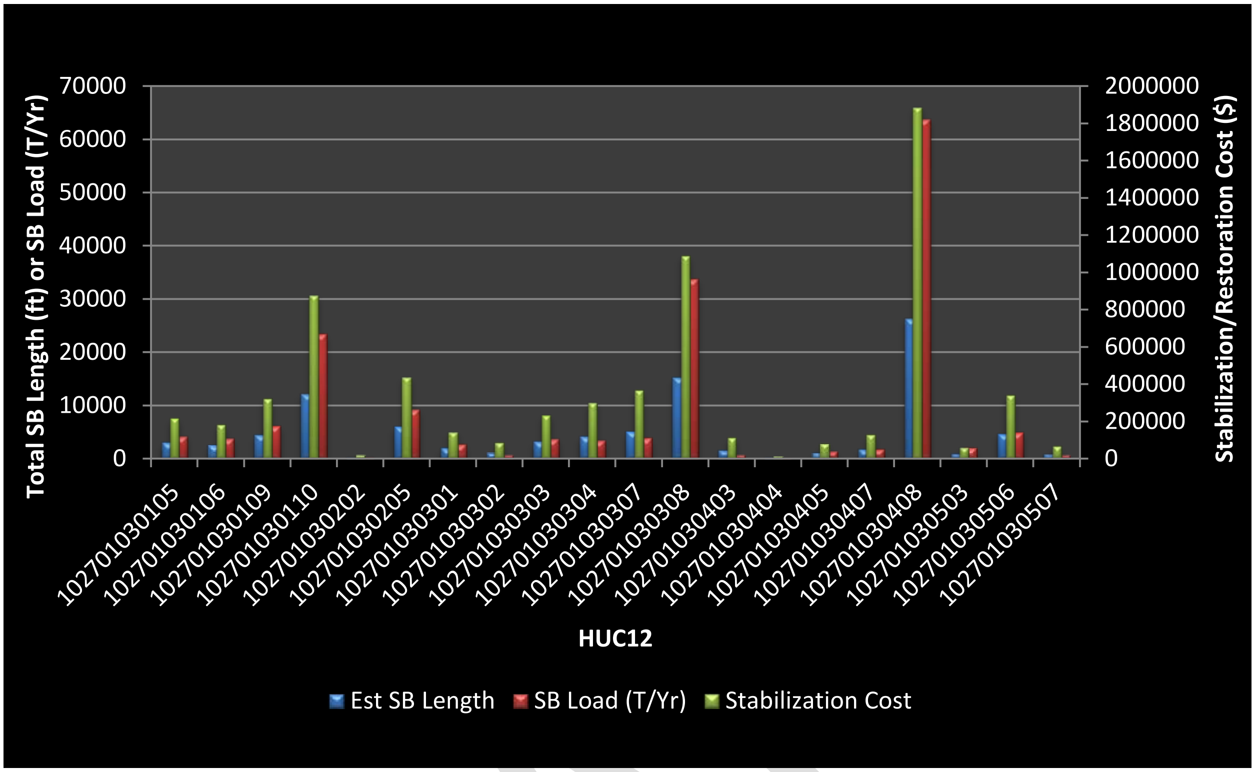


Figure 10: John Redmond Watershed Streambank Erosion Assessment Graph by HUC12

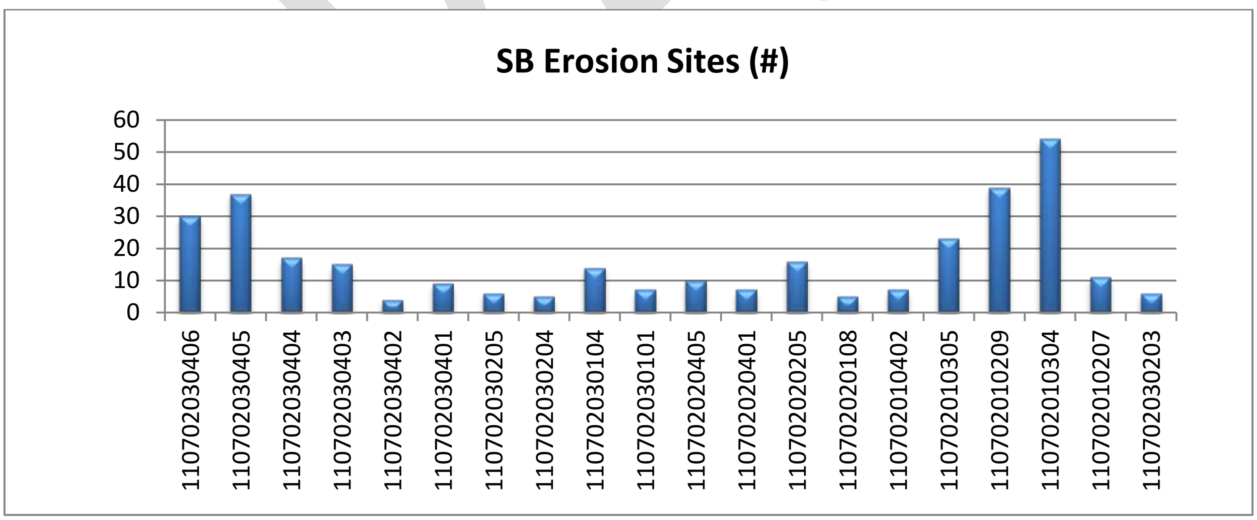
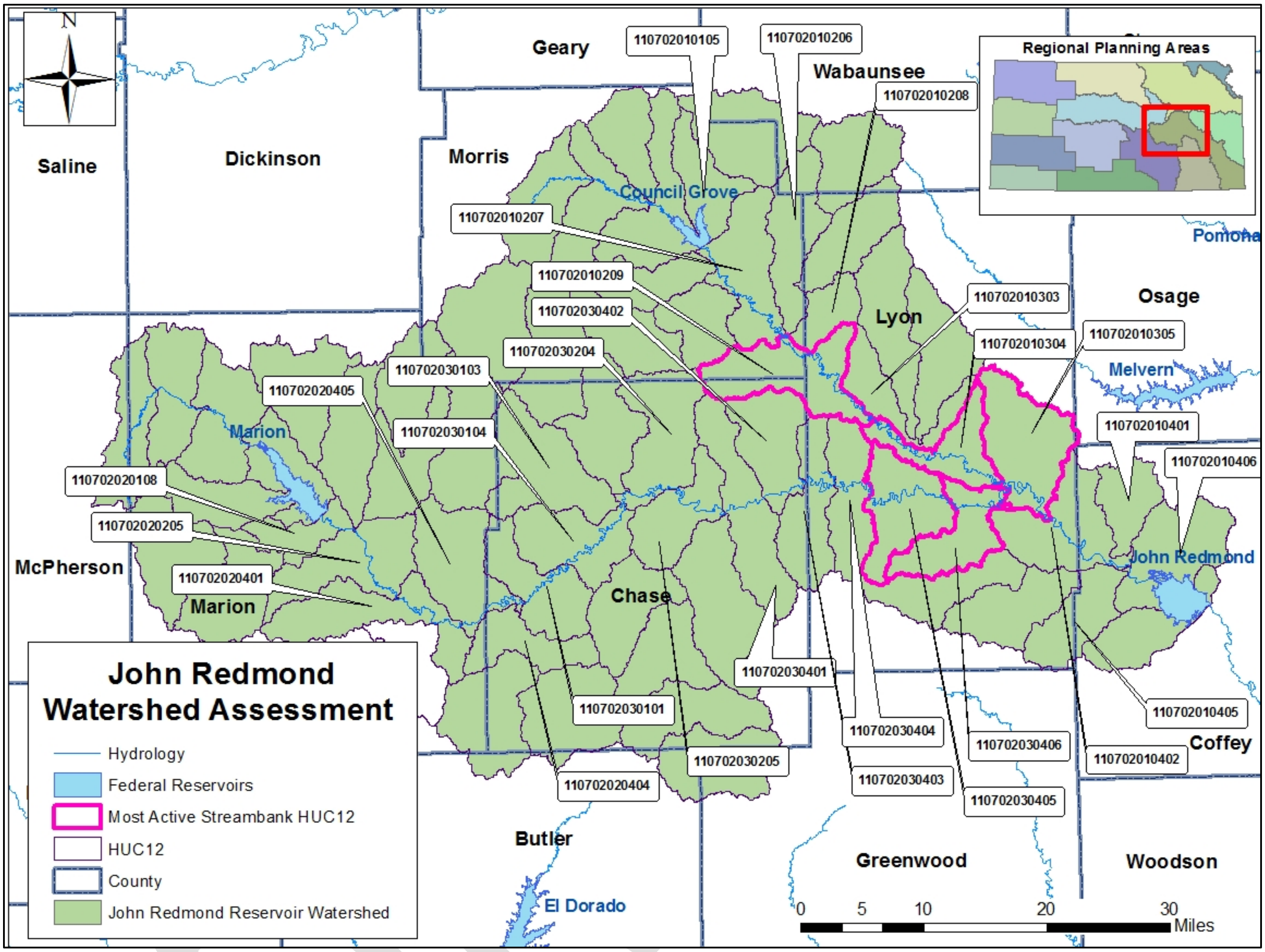


Figure 11: John Redmond Watershed Streambank Erosion Assessment Map by HUC12



Conclusion

KWO completed this assessment for the Neosho Regional Advisory Committee (RAC) and the Cottonwood Watershed Restoration and Protection Strategy (WRAPS) Stakeholder Leadership Team (SLT). 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. This report has identified priority reaches that can be used by the Cottonwood WRAPS SLT to target streambank stabilization and riparian restoration projects to the highest priority streams in the watershed.

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