MARAIS DES CYGNES – MELVERN RESERVOIR WATERSHED EROSION ASSESSMENT

ArcGIS® Comparison Study: 1991 vs. 2008 Aerial Photography

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

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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 Marais des Cygnes-Melvern Reservoir Watershed Assessment, an ArcGIS® Comparison Study, was initiated to partially implement the *Reservoir Sustainability Initiative*. This assessment identifies areas of streambank erosion and streambank gully erosion concerns to provide a better understanding of the Marais des Cygnes-Melvern Reservoir watershed. This information is provided for mitigation purposes, for application of understanding to watersheds and 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 Melvern Reservoir.

The Kansas Water Office (KWO) 2011 assessment quantifies annual tons of sedimentation from streambanks between 1991 and 2008 within the Marais des Cygnes-Melvern Reservoir watershed in Kansas. The assessment estimates about 26,671 tons of sediment is transported from the Marais des Cygnes-Melvern Reservoir watershed to the reservoir itself annually. It should be noted that identified areas of sedimentation from the streambank erosion assessment accounts for only a portion of all streambank erosion locations within the Marais des Cygnes-Melvern Reservoir watershed. Only those streambank erosion sites observed as having streambank movement covering an area roughly 1,500 sq. feet or more were identified within the assessment. The latest 2009 bathymetric survey indicated that storage capacity in the multi-purpose pool, which contains public water supply storage, had been reduced by roughly 2.07% since the reservoir was filled in 1975; original storage capacity totaling 154,370 acre-ft. A substantial portion of this sediment is transported from the main stem Marais des

Cygnes River and its major tributaries Elm Creek, Mud Creek, 142 Mile Creek, Duck Creek and Chicken Creek.

Based on estimated stabilization costs of $71.50 per linear foot from an assessment conducted by The Watershed Institute, Inc. (TWI), streambank stabilization for the entire watershed based on the 2011 assessment would cost approximately $2.2 million. The streambank gully erosion assessment did not quantify annual tons of soil loss. However, locations of gully erosion were identified for prioritization purposes using 2008 NAIP aerial imagery.

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

Introduction

Wetlands and riparian areas are vital components of proper watershed function that, when wisely managed in context of a watershed system, can moderate and reduce sediment input 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 Lake watershed indicated 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 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

(EPA, 2008). The primary threats to wetlands and forested riparian areas are agricultural production and suburban/urban development.

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

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

Study Area

Melvern Reservoir was constructed on the Marais des Cygnes River in Osage County at river mile 175.4. The watershed drains about 349 square miles and includes portions of Coffey, Lyon, Osage and Wabaunsee counties, with the majority in Osage County. The US Army Core of Engineers began construction of the reservoir in 1967 for flood control, water supply, recreation, fish and wildlife, and water quality control. Gates were closed in October of 1970 and the conservation pool filled in April of 1975. The original conservation pool and maximum storage capacities of the reservoir were 154,370 acre-ft and 362,814 acre-ft, respectively. Melvern Lake is situated on the eastern edge of Kansas' Flint Hills Region. Major tributaries in the watershed include Mud Creek, Hill Creek, Duck Creek, 142 Mile Creek, Elm Creek and Chicken Creek (Figure 1).

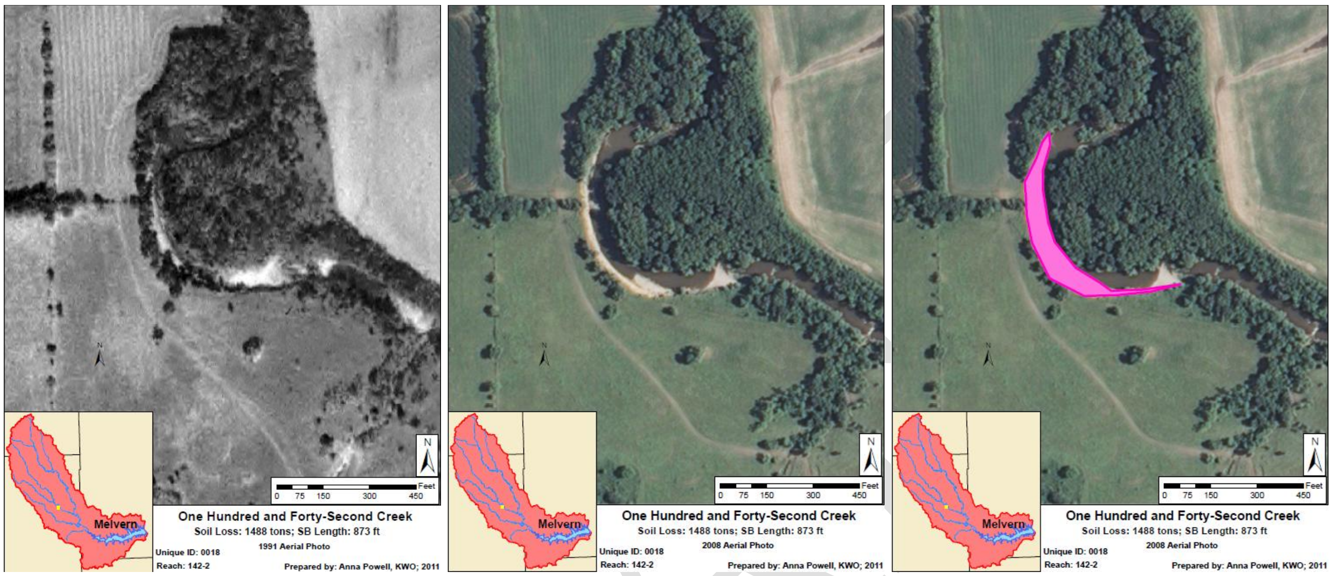
Figure 1: Marais des Cygnes-Melvern Reservoir Watershed Assessment Area

Data Collection Methodology

The Marais des Cygnes-Melvern Reservoir 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 along streambanks to slow sedimentation rates in Melvern Reservoir. ArcMap®, an ArcGIS® geospatial processing program, was utilized to assess color aerial photography from 2008, provided by National Agriculture Imagery Program (NAIP), and compare it with 1991 black and white aerial photography, provided by Data Access & Support Center (DASC). Erosion sites identified in this assessment include locations of streambank erosion and streambank gully erosion.

The streambank assessment was performed by overlaying 2008 county aerial imagery onto 1991 county aerial imagery (Figure 2). Using ArcMap® tools, streambank erosion sites were identified by locating aggressive movement of the streambank between the 1991 and 2008 aerial photos, the movement of a streambank covering an area roughly 1,500 sq. feet, or more, was identified. Streambank erosion sites were denoted by geographic polygons features "drawn" into the ArcGIS® software program. Data provided, based on geographic polygons include: watershed location, unique ID, stream name, type of stream and type of riparian vegetation. Tons of soil loss and streambank length of the erosion sites were also identified as part of the streambank erosion assessment.

Figure 2: 1991 DASC vs 2008 NAIP Streambank Erosion Site on 142 Mile Creek



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

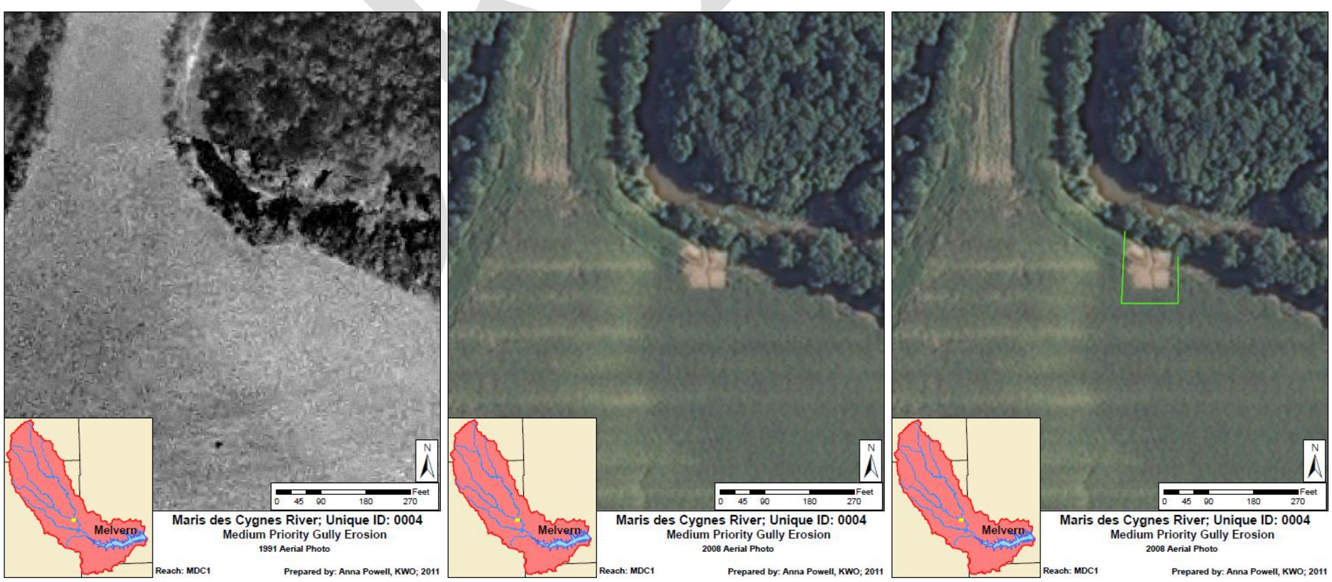
Tons of soil loss is estimated by first calculating the volume of sediment loss and then applying a bulk density estimate to that volume for the typical soil type of the streambank sites identified in the assessment. The volume of sediment was found by multiplying out bank height, surface area lost between the 1991 and 2008 aerial photos and soil bulk density. This volume is then used to divide by the number of years between the aerial photos used to identify streambank erosion sites, 1991 and 2008, to get the average rate of soil loss in mass/year (Avg Soil Loss

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

To complete the analysis for the equation above for tons of soil lost, streambank height measurements of the identified streambank erosion sites are needed. Streambank heights for each identified streambank erosion site were estimated by first performing on the ground measurements at ten identified streambank erosion sites throughout the watershed. These 10 sites were the bases for extrapolating streambank height measurements throughout the Marais des Cygnes-Melvern Reservoir watershed within Kansas.

The streambank gully erosion assessment was performed with similar techniques as the streambank erosion assessment. However, calculating tons of soil erosion was not part of this assessment. Using ArcMap® tools, streambank gully erosion was indicated by line features "drawn" into the ArcGIS® software program. Gully data was compiled and categorized by high, medium or low priority as another effort in rehabilitation prioritization. The identification of a low priority gully indicates that sheet erosion has been identified and a gully could form in the area that is perpendicular to the stream. A low priority gully does not indicate visible channel cutting or any visible streambank riparian erosion. A medium priority gully identifies visible channel cutting perpendicular to the streambank but no visible erosion of the riparian area of the streambank (Figure 3). High priority gullies identify a deeply incised channel cutting perpendicular to the stream, including a significant portion of the riparian area eroded from the streambank. In some instances, gullies were increased to a medium or high priority, even if they exhibit "low priority" gully identifiers, if there was a visibly identified sizeable amount of land erosion or gullies present in the same vicinity.

Figure 3: 1991 DASC vs 2008 NAIP Gully Erosion Site on Marais des Cygnes River



Analysis

To best assess sites indicated as having streambank erosion, watershed sections were delineated to better accommodate streambank rehabilitation project focus. Streambank erosion hotspots were analyzed for prioritization purposes by stream reach sections found within the Marais des Cygnes-Melvern Reservoir watershed area (Figure 4).

Figure 4: Marais des Cygnes-Melvern Lake Watershed Streambank Assessment

The streambank erosion prioritization by stream reach sections include: DC1, MDC1, 142-1, 142-2, EC1, EC2, EC3, EC4, EC5, and EC6. Reach sections are named by the stream reach they are located on and in numerical order from downstream to upstream. For example, stream reaches EC1-EC3 references three reaches identified on Elm Creek, proceeding from south (downstream) to north (upstream) along the river. Streambank erosion sites are assessed by the streambank length (feet) of the eroded bank, annual soil loss (tons) from the eroded area between 1991 and 2008, percent of streambank length with poor riparian condition (riparian area identified as having cropland or grass/crop buffer), estimated sediment reduction at an 85% efficiency rate with the use of buffers and filter strips and streambank stabilization cost estimates for eroded streambank sites.

Streambank gullies were assessed based on the proportion of high, medium and low priority identifications within stream reach sections, and can be used as supporting data for streambank erosion or streambank gully erosion rehabilitation prioritization (Figure 5). Explanation of prioritization is found in the data collection and methodology above. No further assessment was performed

Figure 5: Marais des Cygnes River-Melvern Lake Watershed Gully Assessment

Results

The KWO 2011 assessment quantifies annual tons of sedimentation from streambank erosion between 1991 and 2008 within the Marais des Cygnes-Melvern Reservoir watershed in Kansas. A total of 68 hot-spots covering 30,419 feet were identified. This 2011 assessment also identified estimates totaling approximately 26,671 tons of sediment being transported from the Marais des Cygnes-Melvern Reservoir watershed to the reservoir itself annually. However, it should be noted that the identified streambank erosion locations are only a portion of all streambank erosion occurrences in the watershed. Only those streambank erosion sites covering an area 1,500 sq. feet, or more, were identified. A substantial quantity of this sediment is transported each year from the mainstem Marais des Cygnes River, 142 Mile Creek (142-1), and Elm Creek stream reaches 3 and 5; contributing approximately 5,110; 4,340; 4,340 and 4,097 tons of sedimentation annually, respectively (Figure 6). The Marais des Cygnes mainstem accounts for an estimated 26% of the total stabilization cost needs in the watershed totaling $572,900. Costs and percentages for 142 Mile Creek (142-1) are $277,800 (13%); for Elm Creek stream reaches 3 and 5 $240,260 (11%) and $282,200 (13%), respectively. Based on estimated stabilization costs of $71.50 per linear foot from an assessment conducted by TWI, streambank stabilization for the entire watershed from the 2011 assessment would cost approximately $2.2 million (Table 1).

Figure 6: Marais des Cygnes River-Melvern Lake Watershed Streambank Assessment Graph

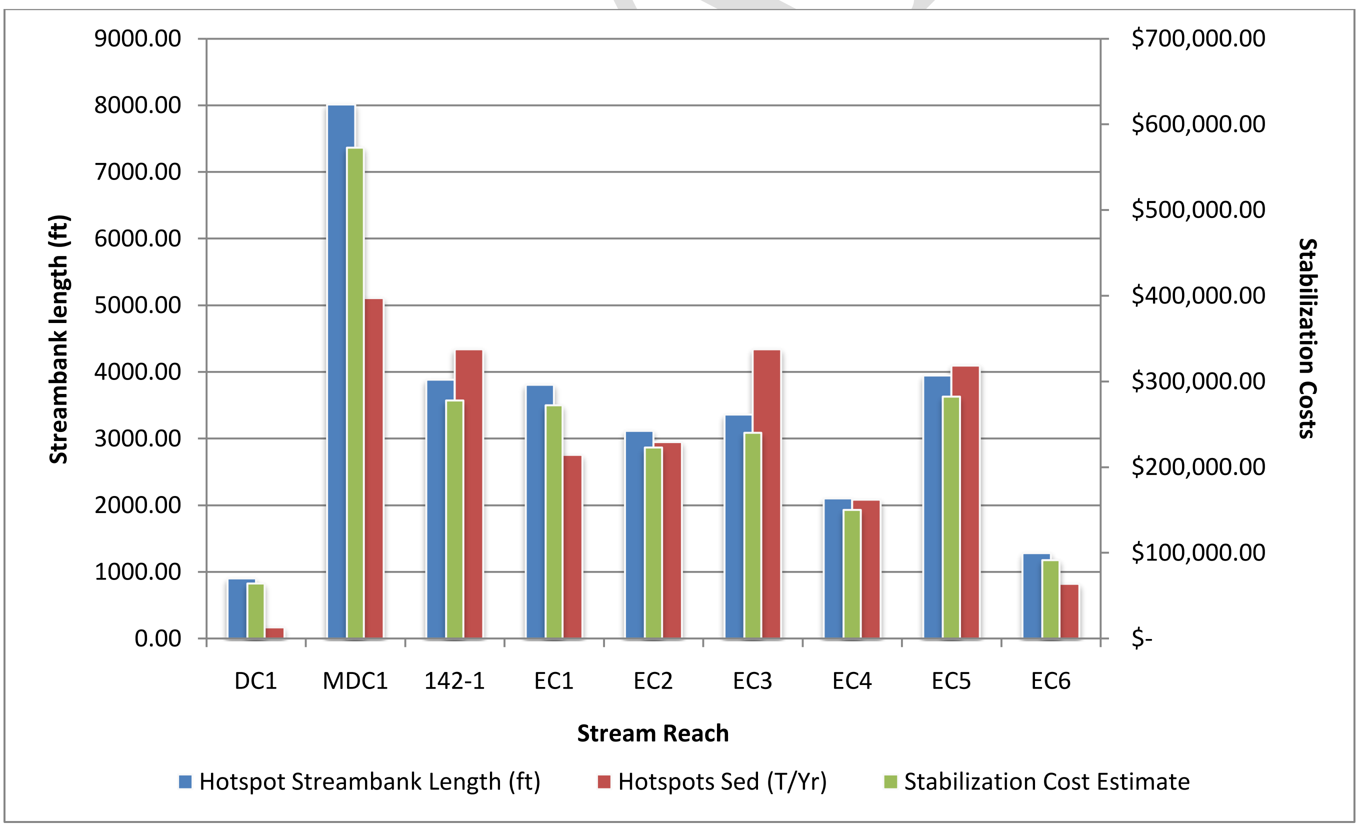
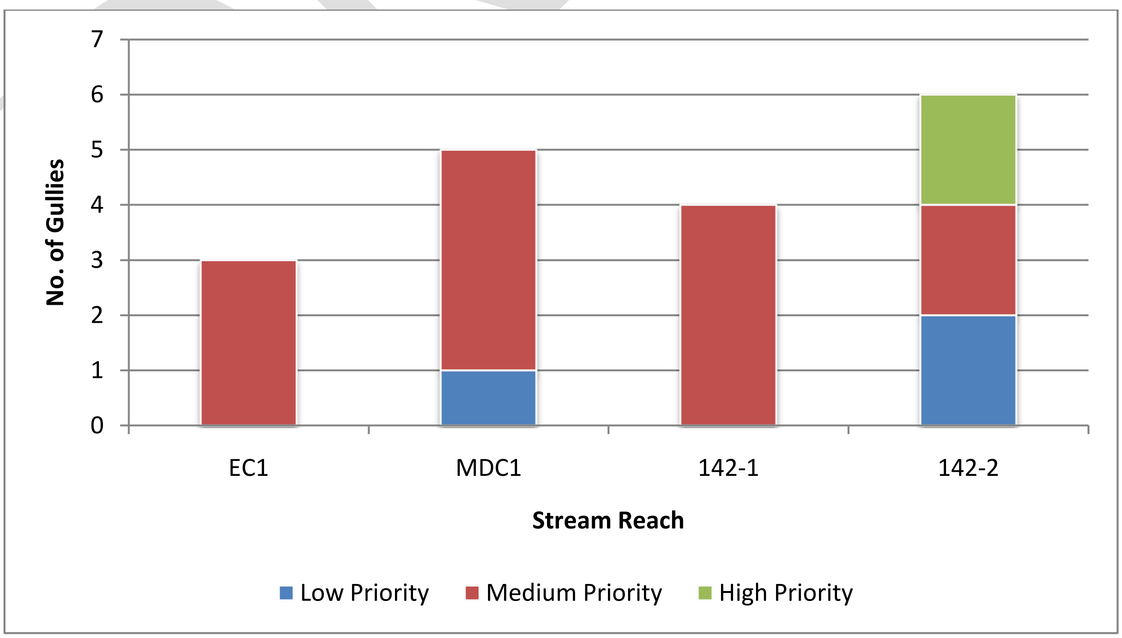


Table 1: Marais des Cygnes-Melvern Reservoir Watershed Streambank Erosion Assessment Table

Reach	Hotspot SB Length (ft)	Hotspot Sed (T/Yr)	Stabilization Cost Estimate	Hotspot (no.)	Yield Loss/ Bank Length	Poor Riparian Condition SB Length (ft)	Est. Sed Reduction (T/Yr)	% SB Length w/ Poor Riparian Cond.
DC1	901.75	169.52	$64,475.20	3	0.2	374.53	-144.09	41.53%
MDC1	8012.41	5110.40	$572,887.14	8	0.6	2740.89	-4343.84	34.21%
142-1	3884.95	4340.88	$277,774.10	9	1.1	1780.21	-3689.75	45.82%
EC1	3808.57	2754.56	$272,312.42	9	0.7	2244.80	-2341.38	58.94%
EC2	3118.91	2949.92	$223,001.73	11	0.9	2493.13	-2507.44	79.94%
EC3	3360.25	4340.74	$240,257.53	10	1.3	595.55	-3689.63	17.72%
EC4	2102.03	2084.81	$150,294.95	6	1.0	986.47	-1772.09	46.93%
EC5	3947.18	4097.16	$282,223.69	8	1.0	2793.27	-3482.59	70.77%
EC6	1283.06	822.76	$91,738.88	4	0.6	0.00	-699.35	0.00%
Total	**30,419**	**26,671**	**$2,174,966**	**68**	**7.6**	**14,009**	**22,670**	**46.05%**
Est Stabilization Cost/Linear Ft.			$71.50	**Stabilization/Restoration Efficiency**			0.85	

Described in the data collection and methodology section above, streambank gullies where analyzed for high, medium and low priority. Figure 7 below identifies the extent of high, medium and low priority streambank gullies identified by stream reach. The assessment of streambank gullies by stream reach identified 142-2 as contributing the highest amount of total streambank gullies (6), and MDC1 being the second with a total of 5 gullies identified.

Figure 7: Marais des Cygnes River-Melvern Lake Watershed Gully Assessment Graph



It should also be noted that gully erosion can contribute a tremendous amount of sediment at the watershed scale and can occur in both cropland and grassland. The amount of sediment input is based on rainfall/runoff and gully frequency within a given watershed. Buffer installation costs vary widely.

Conclusion

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

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