TORONTO RESERVOIR WATERSHED STREAMBANK EROSION ASSESSMENT

ArcGIS® Comparison Study: 1991 vs. 2006 Aerial Photography

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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 Toronto 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 Toronto 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 Toronto Reservoir.

The Kansas Water Office (KWO) 2011 assessment quantifies annual tons of sediment eroding from the Toronto Reservoir Watershed over a 15 year period between 1991 and 2006. A total of 87 streambank erosion sites were identified, covering 24,000 feet of unstable streambank and transporting 30,300 tons of sediment downstream per year; accounting for roughly 19 acre-feet per year of sediment accumulation in Toronto Reservoir. 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 of approximately 1,500 sq. feet or more were identified. 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 Verdigris River reaches one, two and three (VR1, VR2 and VR3) and West Creek stream reach two (WC2); accounting for estimates of 19,400 tons of sediment annually and 64% of sediment eroding from all identified streambank erosion sites. These identified reaches account for an estimated 50% or $850,800 of total stabilization cost needs of all identified streambank erosion sites. Results by HUC12 identified 110701010301 and 110701010201 as the most active HUC12s for streambank degradation; accounting for an estimated 7,942 feet of unstable streambank, 11,045 tons of sediment per year and 33% of total stabilization costs. Based on the average stabilization costs of $71.50 per linear foot, as reported in the 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 $1.7 million.

A streambank gully assessment was also performed. The streambank gully erosion assessment did not quantify annual tons of soil loss. However, locations of gully erosion were identified and prioritized by a high, medium or low priority using similar techniques as the streambank erosion assessment for identification. Gullies were also assessed by the same stream reaches. The gully assessment indicated that several reaches throughout the watershed had a significant number of gully sites, including West Creek stream reach two (WC2), Homer Creek stream reach one (HC1), Verdigris River stream reach three (VR3) and Verdigris River stream reach one (VR1). Each of these stream reaches contained eight or more identified gullies, with a significant percentage made of high priority streambank gully erosion sites.

The KWO completed this assessment for the Toronto Watershed Restoration and Protection Strategy (WRAPS) Stakeholder Leadership Team (SLT). Information contained in this assessment can be used by the WRAPS SLT to target streambank and gully stabilization and riparian restoration efforts toward high priority stream reaches or HUC12 subbasins in the Toronto 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).

Another form of erosion contributing to sedimentation in many watersheds in Kansas is the development of gullies alongside streams. Streambank gullies develop from the wearing away of the surface soil along drainage channels by surface water runoff. These 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. Increased risk of erosion and sediment delivery is associated with high soil erodability; little ground cover; steep, long, continuous slopes; high intensity storms; high drainage density of the slope; and close proximity to streams.

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. In each case, the gullies observed are unstable and will continue to be unless best management practices (BMPs) are implemented. A common BMP for gully erosion is the rock chute. Rock chute designs require bank shaping and the placement of erosion control fabric and sorted rock. Rock chutes are designed to direct flow down through the chute center. The rock creates flow resistance slowing down water velocities.

Study Area

The Toronto Watershed, which contains Toronto Reservoir, is located in the southeastern portion of Kansas in the Upper Verdigris Watershed of the Verdigris River basin (Figure 1). The U.S. Army Corps of Engineers began construction on the reservoir in November of 1954 and was completed in 1960. Toronto Reservoir is located on river mile 271.5 of the Verdigris River, about three miles south of Toronto, Kansas in Woodson County. The watershed drains an area of 458,395 acres (730 mi^2) and encompasses portions of Chase, Coffey, Greenwood, Lyon and Woodson Counties. The reservoir is federally authorized for flood control and conservation, water supply, water quality, fish and wildlife and recreation.

Toronto Reservoir was originally surveyed in 1960 with a multipurpose pool storage capacity at 27,320 acre-feet, a surface area of 2,879 acres and a design life of 50 years, with a 183 acre-feet/yr sedimentation rate. The most recent survey was performed in 1990, with storage capacity at 19,841 acre-feet and surface area at 2,580 acres; estimating the current sedimentation rate at 242 acre-feet/yr. The estimated capacity to date is 15,010 acre-feet with storage loss at 45%.

Primary land use in the Toronto Watershed is grassland covering 85% of the watershed. The remaining land uses in the watershed is woodlands (4%), water (1%) and other (3%) (Figure 2). Predominant soils found in the areas of streambank erosion sites in the Toronto Watershed consist mainly of the Chase and Reading soil series. The Chase series consists of deep, somewhat poorly drained, slowly permeable soils on low terraces. These soils formed in alluvium, with slopes ranging from zero to two percent. Chase soils are similar to Osage soils and commonly are adjacent to Ivan, Osage and Reading soils. The Reading series consists of deep, well drained, moderately slowly permeable soils on terraces. These soils formed in silty alluvium. Slopes range from zero to two percent. Reading soils are similar to Ivan and Newtonia soils and are commonly adjacent to Chase and Ivan soils.

Figure 1. Toronto Reservoir Watershed Assessment Area

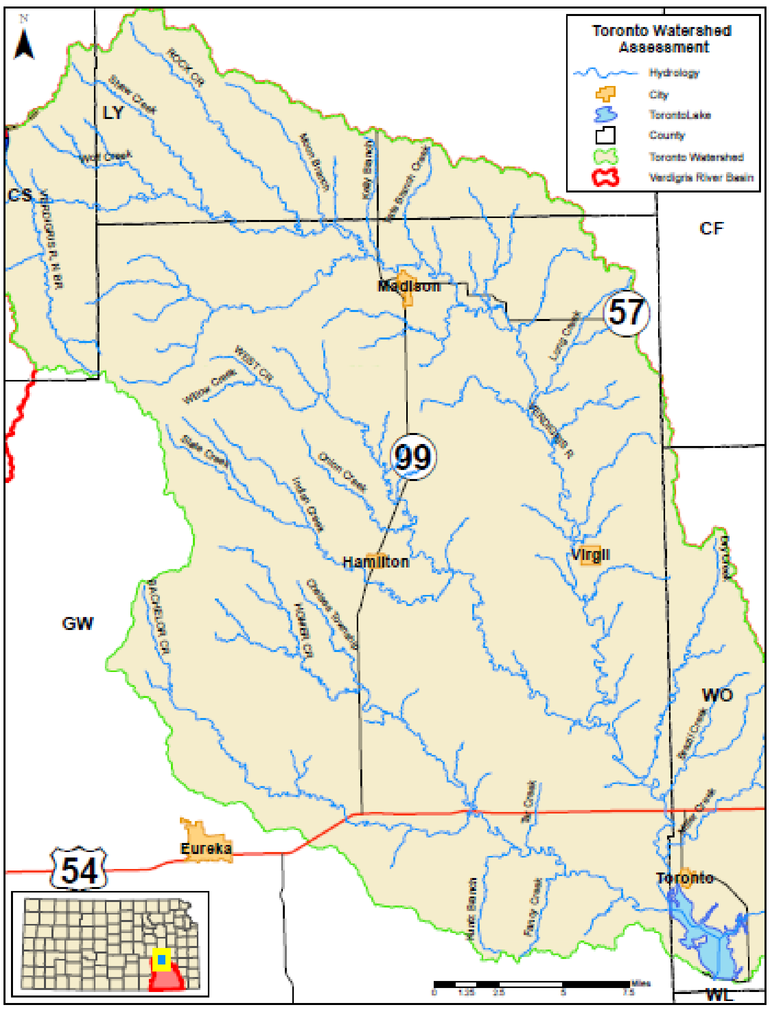


Figure 2. 2005 Land Use Land Cover Map, KGS

The Kansas Department of Health and Environment (KDHE) has developed one Total Maximum Daily Load (TMDL) for Toronto Reservoir; eutrophication with siltation and dissolved oxygen. Toronto Reservoir has high inorganic turbidity and high levels of siltation. The reservoir is shallow and sediment is re-suspended easily due to wind, motorboat traffic, and moderate to high inflow events. In addition, siltation is aggravated during large runoff events, when releases from Toronto Reservoir are minimized to accommodate flood control along the Verdigris River, which causes large silt deposits within the Reservoir and the inflowing river channels. Subsequent runoff events of moderate duration then facilitate the transport of that deposited sediment into the reservoir where it may settle out (KDHE, 2009).

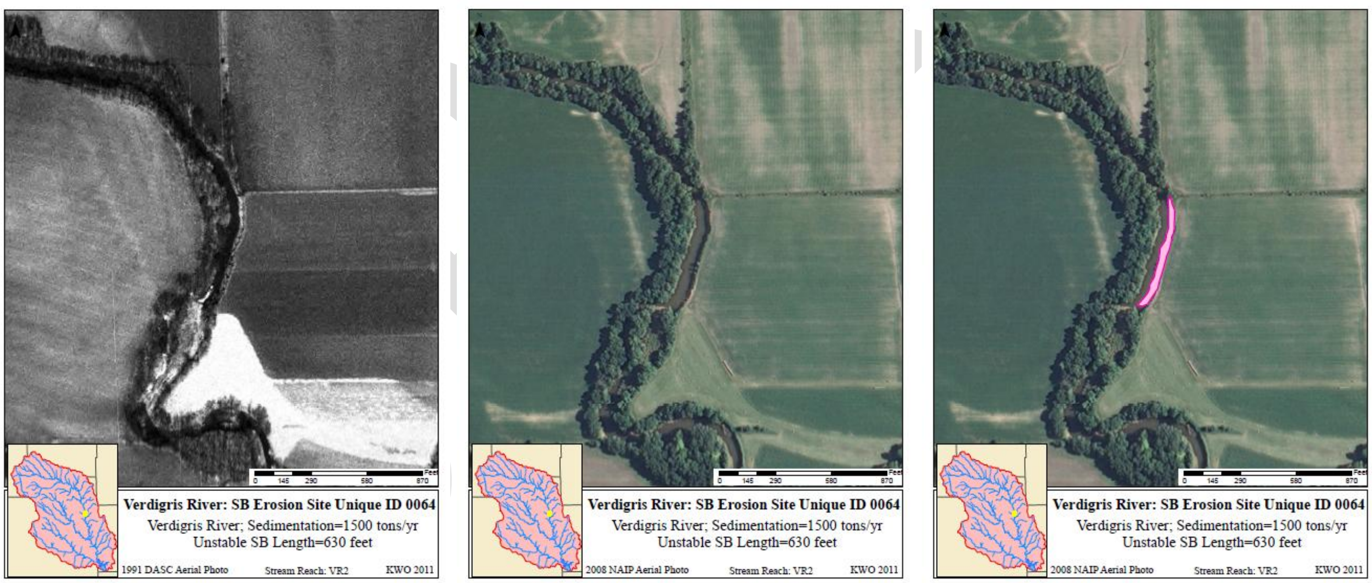
Data Collection Methodology

The Toronto 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, estimate erosion rates to prioritize restoration needs along streambanks and slow sedimentation rates in Toronto Reservoirs. ArcMap® 10, an ArcGIS® geospatial processing program, was utilized to assess color aerial photography from 2006, 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 2006 NAIP county aerial imagery onto 1991 DASC county aerial imagery. Using ArcMap® tools, "aggressive movement" of the streambank between 1991 and 2006 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 2006 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 when these photos are then digitally georeferenced. 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 and assess the condition of streambanks.

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 2006 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 & 2006 NAIP of a Streambank Erosion Site on the Verdigris River



The streambank erosion assessment data also includeestimates 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 2006 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) =

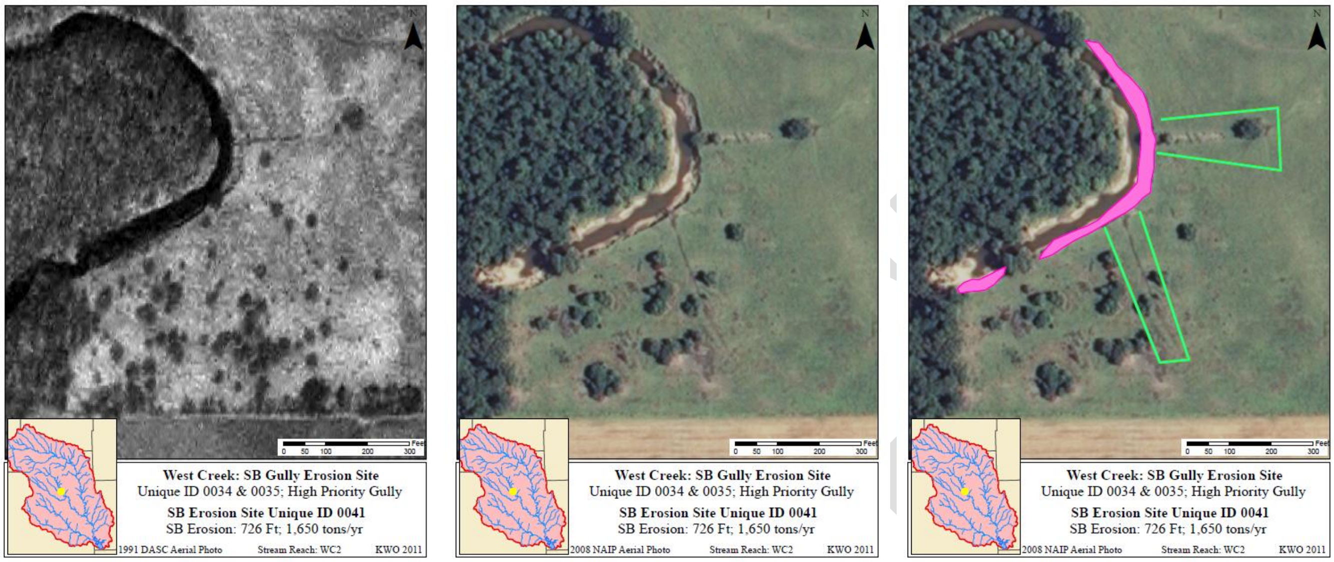
[Area_SqFt]*[BankHgtFt]*SoilDensity(lbs/ft^3)/2000(lbs/ton)/([NAIP_ComparisonPhotoYear]-[BaseAerialPhotoYear])

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 Toronto Reservoir watershed consists mainly of Chase and Reading 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 Toronto 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. Ten representative sites were selected that were 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.

The streambank gully erosion assessment was performed with similar techniques as the streambank erosion assessment. Using ArcMap® tools, streambank gully erosion was indicated by line features “drawn” into the ArcGIS® software program (Figure 4). Gully data were 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. 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 (Figure 4). 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 4. 1991 DASC & 2006 NAIP of two High Priority Streambank Gully Erosions Sites and a Streambank Erosion Site on West Creek



Analysis

To accommodate streambank rehabilitation project focus, the Toronto Reservoir watershed study area was delineated into 10 stream reaches (Figure 5) and fifteen 12-digit Hydrologic Unit Code subbasins (Figure 6). Streambank erosion prioritization by stream reach sections include: VR1 VR2, VR3, NBVR1, HC1, HC2, DC1, WC1, WC2 and OC1. Stream reaches were titled for the name of the stream it identifies and in numerical order from downstream to upstream. For example, VR1-VR3 are stream reach sections on the Verdigris River, starting at Toronto Reservoir and heading upstream.

Figure 5. Toronto Reservoir Watershed Streambank Assessment Stream Reaches

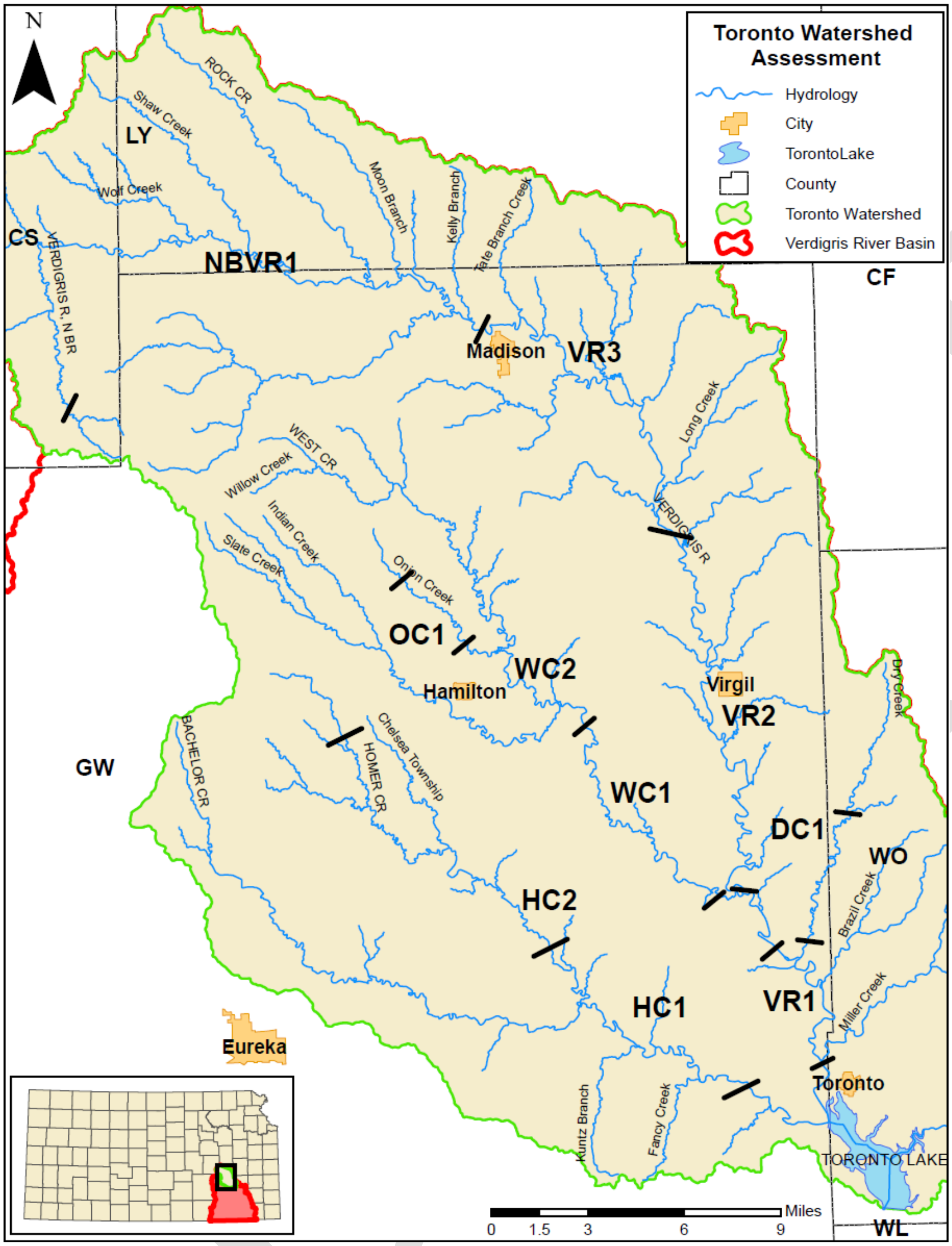
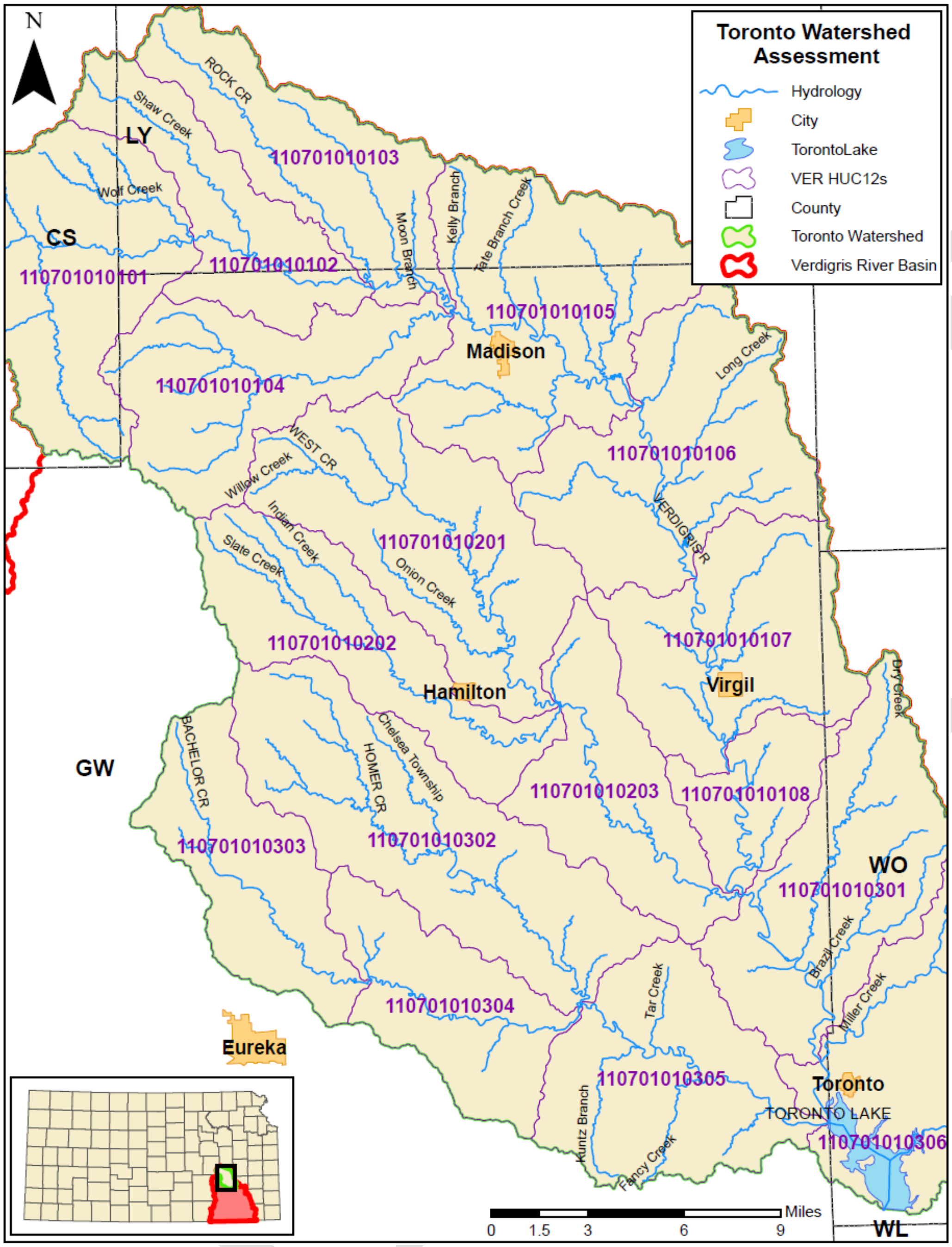


Figure 6. Toronto Reservoir Watershed Assessment Area HUC12s



Streambank erosion sites were analyzed for: unstable streambank length (in feet) of the eroded bank; average 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 Verdigris 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**

Identified streambank gully erosion sites were assessed based on the proportion of high, medium and low priority identifications; delineated by stream reach sections. The streambank gully site identification assessment can be used as supporting data for streambank erosion or streambank gully erosion rehabilitation prioritization. Explanation of prioritization is found in the data collection and methodology above. No further assessment was performed.

Results

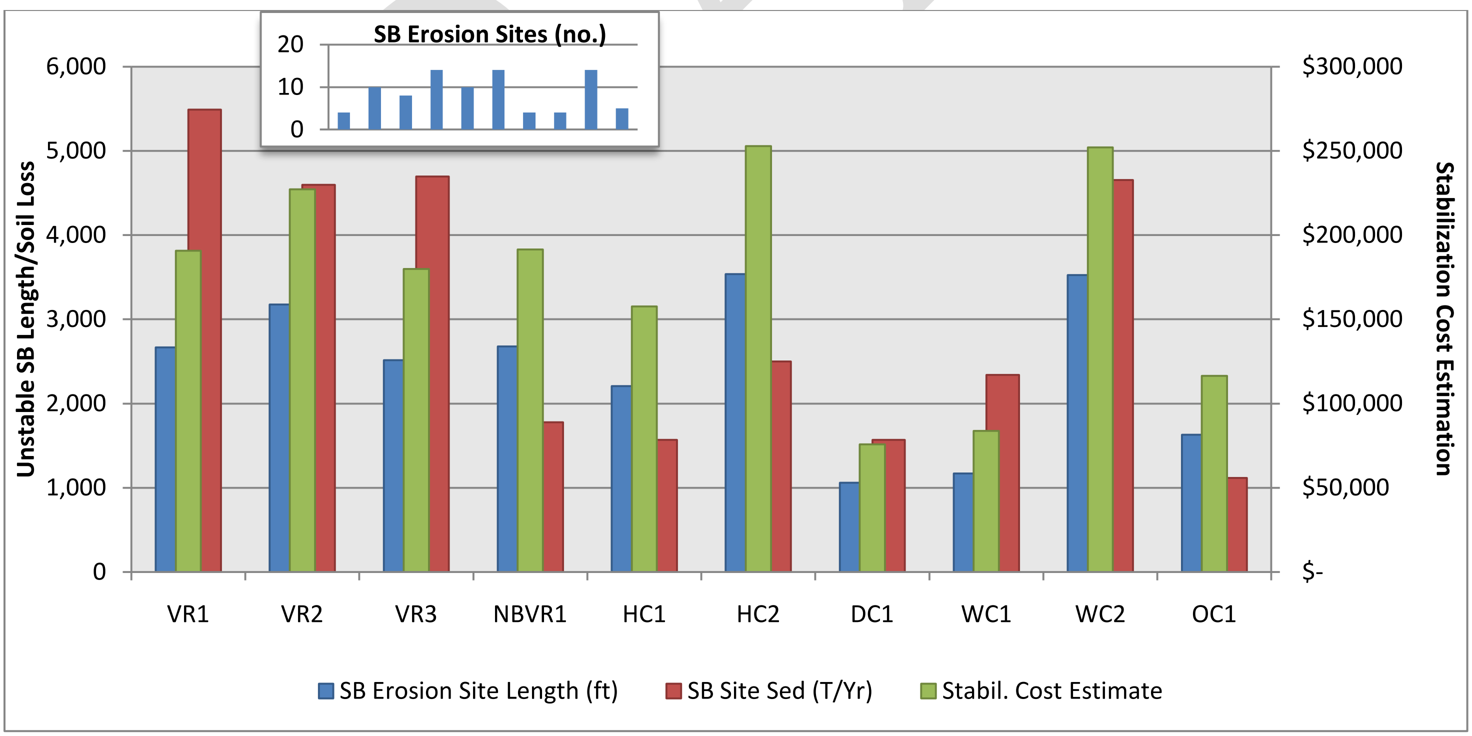
The KWO 2011 assessment quantifies annual tons of sediment from streambank erosion sites between 1991 and 2006 in the Toronto Reservoir watershed. A total of 87 streambank erosion sites, covering 24,166 feet of unstable streambank were identified through the assessment, with 73% of the unstable streambanks identified as having poor riparian condition. The assessment also identified estimates totaling approximately 30,310 tons of sediment being transported from the streambank erosion sites annually; accounting for about 30% of the load estimated in the identified TMDL.

A majority of the identified 30,310 tons of eroded sediment is transported annually from the mainstem Verdigris River stream reaches one, two and three (VR1, VR2 and VR3) and West Creek stream reach two (WC2); accounting for roughly 19,400 tons of sediment annually; accounting for 64% of sediment eroding from all identified streambank erosion sites (Table 1 & Figure 8). These identified reaches account for an estimated 50% and $850,800 of total stabilization cost needs for all identified streambank erosion sites.

Table 1. Toronto Reservoir Watershed Assessment Table by Stream Reach

Stream Reach	SB Erosion Site Length (ft)	SB Site 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.
VR1	2,668	5,491	$190,763	4	2.1	1,356	-4,667	51%
VR2	3,178	4,597	$227,221	10	1.4	2,107	-3,908	66%
VR3	2,515	4,695	$179,854	8	1.9	1,624	-3,990	65%
NBVR1	2,679	1,778	$191,565	14	0.7	2,222	-1,511	83%
HC1	2,206	1,570	$157,741	10	0.7	762	-1,334	35%
HC2	3,536	2,501	$252,809	14	0.7	3,084	-2,126	87%
DC1	1,059	1,570	$75,700	4	1.5	810	-1,334	76%
WC1	1,172	2,339	$83,765	4	2.0	1,172	-1,988	100%
WC2	3,525	4,653	$252,021	14	1.3	2,904	-3,955	82%
OC1	1,628	1,116	$116,420	5	0.7	1,628	-949	100%
Total	**24,166**	**30,310**	**$1,727,860**	**87**	**12.9**	**17,669**	**-25,763**	**73%**
Est Stabilization Cost/Linear Ft.			$71.50	**Stabilization/Restoration Efficiency**			0.85	

Figure 8: Toronto Reservoir Watershed Streambank Erosion Assessment Graph by Stream Reach

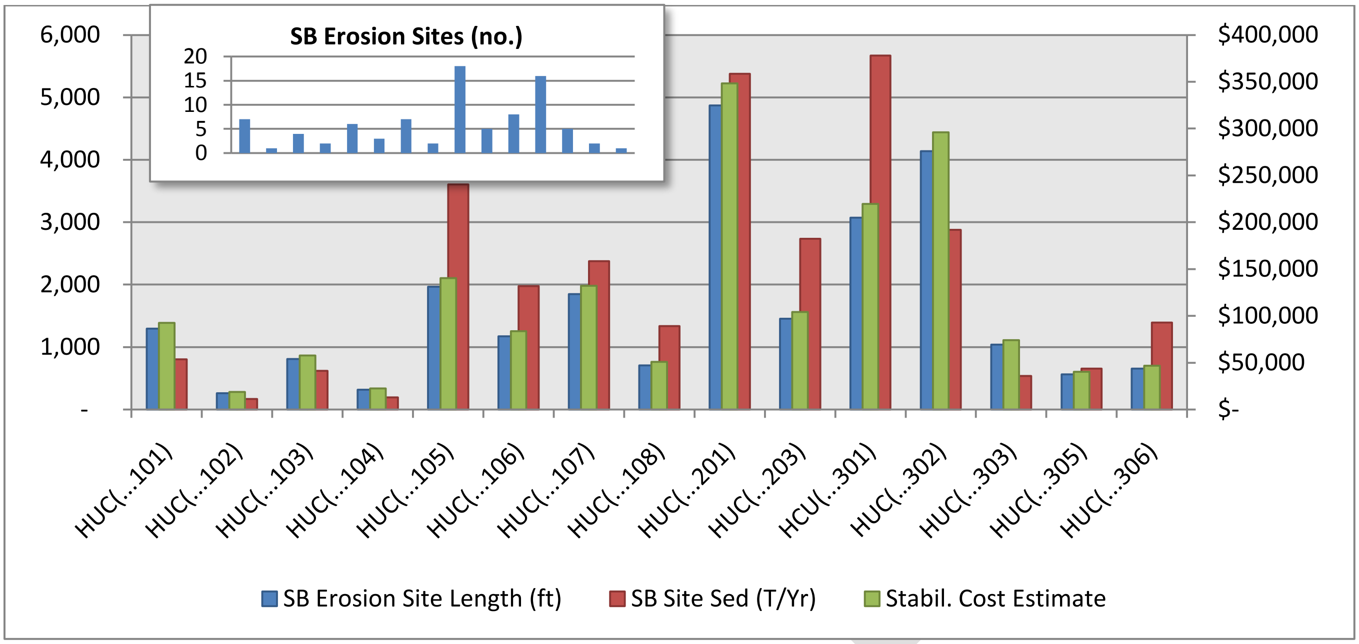


Results by HUC12 subbasins indicate that the majority of the identified 30,310 tons of eroded sediment is transported annually from HUC12s (…301), (…201), (…105) and (…302) (Table 2 & Figure 9). HUC12 (…301) was found to contribute approximately 5,669 tons of eroded sediment annually from roughly 3,073 feet of unstable streambank and accounts for an estimated 13% of the total stabilization cost needs in the watershed, totaling $219,686. Installing BMPs for all identified sites within HUC12 (…301) would account for roughly 4,819 tons of annual sediment reduction at an 85% stabilization/restoration efficiency. HUC12 (…201) was found to contribute approximately 5,376 tons of eroded sediment annually from roughly 4,869 feet of unstable streambank and accounts for an estimated 20% of the total stabilization cost needs in the watershed, totaling $348,139. Installing BMPs for all identified sites within HUC12 (…201) would account for roughly 4,570 tons of annual sediment reduction at an 85% stabilization/restoration efficiency. HUC12 (…105) was found to contribute approximately 3,603 tons of eroded sediment annually from roughly 1,965 feet of unstable streambank and accounts for an estimated 8% of the total stabilization cost needs in the watershed, totaling $140,470. Installing BMPs for all identified sites within HUC12 (…105) would account for roughly 3,063 tons of annual sediment reduction at an 85% stabilization/restoration efficiency. HUC12 (…302) was found to contribute approximately 2,876 tons of eroded sediment annually from roughly 4,140 feet of unstable streambank and accounts for an estimated 17% of the total stabilization cost needs in the watershed, totaling $295,981. Installing BMPs for all identified sites within HUC12 (…302) would account for roughly 2,444 tons of annual sediment reduction at an 85% stabilization/restoration efficiency.

Table 2. Toronto Reservoir Watershed Streambank Erosion Assessment Table by HUC12

HUC 12 (11070101010 …)	SB Site Length (ft)	SB Site Sed (T/Yr)	Stabil. Cost Estimate	SB Sites (No.)	Yield Loss/ Bank Length	Poor Riparian Cond/ SB Length (ft)	Est. Sed Reduction (T/Yr)	% SB Length w/ Poor Riparian Cond.
HUC(...101)	1,294	801	$92,523	7	0.6	827	-681	64%
HUC(...102)	262	167	$18,740	1	0.6	0	-142	0%
HUC(...103)	807	618	$57,719	4	0.8	807	-525	100%
HUC(...104)	316	192	$22,583	2	0.6	131	-163	41%
HUC(...105)	1,965	3,603	$140,470	6	1.8	1,624	-3,063	83%
HUC(...106)	1,171	1,978	$83,696	3	1.7	620	-1,681	53%
HUC(...107)	1,849	2,376	$132,216	7	1.3	1,487	-2,020	80%
HUC(...108)	709	1,335	$50,692	2	1.9	0	-1,135	0%
HUC(...201)	4,869	5,376	$348,139	18	1.1	4,248	-4,570	87%
HUC(...203)	1,455	2,733	$104,067	5	1.9	1,455	-2,323	100%
HCU(...301)	3,073	5,669	$219,686	8	1.8	2,166	-4,819	70%
HUC(…302)	4,140	2,876	$295,981	16	0.7	3,084	-2,444	74%
HUC(...303)	1,038	539	$74,192	5	0.5	641	-458	62%
HUC(...305)	565	656	$40,377	2	1.2	120	-558	21%
HUC(...306)	654	1,391	$46,777	1	2.1	0	-1,182	0%
Total	**24,166**	**30,310**	**$1,727,860**	**87**	**18.6**	**17,212**	**-25,763**	**71%**
Est Stabilization Cost/Linear Ft.			$71.50	**Stabilization/Restoration Efficiency**			0.85	

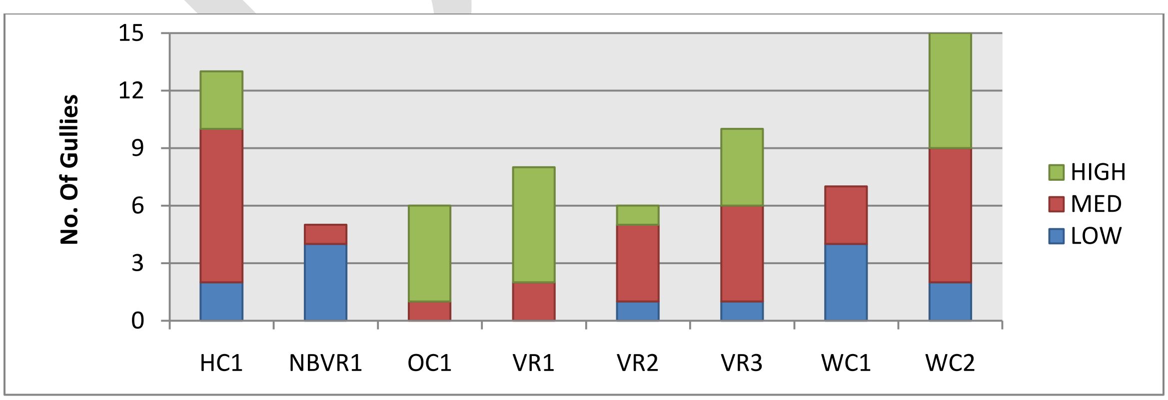
Figure 9. Toronto Reservoir Watershed Assessment Graph by HUC12



Based on the average stabilization costs of $71.50 per linear foot, conducting streambank stabilization practices for the entire watershed of Toronto Reservoir would cost approximately $1.7 million.

The streambank gully erosion assessment did not quantify annual tons of soil loss. However, locations of gully erosion were identified and prioritized by a high, medium or low priority using similar techniques as the streambank erosion assessment for identification. Streambank gully erosion sites were also assessed by the same stream reaches as the streambank erosion assessment. The streambank gully assessment indicated that several reaches throughout the watershed had significant numbers of gullies, including West Creek stream reach two (WC2), Homer Creek stream reach one (HC1), Verdigris River stream reach three (VR3) and Verdigris River stream reach one (VR1). Each of the stream reaches contained eight or more identified gullies, with a significant percent made up of high priority streambank gully erosion sites (Figure 10).

Figure 10. Toronto River Watershed Streambank Erosion Assessment Graph by Stream Reach



Conclusion

The KWO completed this Draft assessment in the Toronto Reservoir watershed for the Toronto Reservoir Watershed Restoration and Protection Strategy (WRAPS) Stakeholder Leadership Team (SLT). The Draft and Final report will be submitted for internal review at the KWO. Information contained in the assessment may be used by the Toronto Reservoir WRAPS SLT to target streambank stabilization and riparian restoration efforts toward high priority stream reaches on the within Toronto 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 Toronto Reservoir watershed. Additional evaluations of gullies are needed to determine the magnitude of sediment contribution from these sources.

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