Appendix B Protocol 1 Supplemental Details

Protocol 1 – Credit for Prevented Sediment during Storm Flow - is presented in Section 5 and an example using the protocol is presented in Section 6. This Appendix provides supplemental details for the protocol and example.

Bank and Nonpoint Source Consequences of Sediment (BANCS) Method

The BANCS Method, developed by Rosgen (2001) quantitatively predicts streambank erosion rates based on two commonly used bank erodibility tools: the Bank Erosion Hazard Index (BEHI) and Near Bank Stress (NBS).

The literature review in Table B-1 includes information from studies that have utilized the BANCS Method across the country. While many studies have applied the method, there are few that have collected actual measurements of streambank erosion to validate the results of the BANCS Method and establish a level of accuracy. The literature indicates that the BANCS Method generally predicts streambank erosion within an order of magnitude. Regional characteristics where the method is applied are important to consider and adjustments to the BEHI and NBS may be necessary to provide an adequate prediction of streambank erosion. For example, Sass and Keane (2012) found that woody vegetation plays a vital role in bank stability in Northeastern Kansas. By adjusting the vegetation portion of the BEHI they were able to improve the correlation between BEHI and streambank erosion.

The Panel identified a series of potential limitations to the BANCS method, including:

- The method is based on the NCD stream restoration approach, which uses assumptions regarding bank full storm frequency that are not shared in other design approaches (e.g., LGS, RSC).
- Some studies have found that frost heaving may be a better predictor of stream bank erosion than NBS.
- Estimates of BEHI and NBS can vary significantly among practitioners.
- Extrapolation of BEHI and NBS data to unmeasured banks may not be justified.
- The BANCS method is not effective in predicting future channel incision and bank erodibility in reaches upstream of active head cuts. These zones upstream of active head cuts, failing dams, or recently lowered culverts/utility crossings often yield the greatest potential for long-term sediment degradation and downstream sediment/nutrient pollution.
- The method estimates sediment supply and not transport or delivery.

Despite these concerns, the Panel felt that the use of a method that allows the estimation of stream bank erosion from an empirical relationship between standard assessment tools (BEHI and NBS) and in-stream measurements justified its use for the purposes of crediting stream restoration. Furthermore, the literature indicates that further refinements to this method that can improve the adequacy. The Panel recommended several steps to improve the consistency and repeatability of field scoring of BEHI and NBS, as follows:

- The development of a standardized photo glossary to improve standardization in selecting BEHI and NBS scores.

- Continued support for the development of regional stream bank erosion curves for the BANCS Method using local stream bank erosion estimates throughout the watershed and a statistical analysis of their predicted results. Ideally, measured bank erosion rates within each subwatershed or County would be used to validate the BANCS Method specific to that location. Given that this data may not be readily available, additional methodology for adjusting the BEHI and NBS scores to accommodate local subwatershed characteristics may be useful. For example, adjustments to the BEHI to account for areas with predominantly sandy soils, agricultural channels, or legacy sediment.

- Using other methods to validate the BANCS method such as aerial photographs that can be used to estimate historical erosion rates, dendro-geomorphic studies of exposed roots and new shoots, time series channel surveys, and/or bank pins.

- The BANCS method should only be performed by a qualified professional, as determined by each permitting authority.

- Extrapolation of BEHI and NBS to unmeasured banks should not be allowed unless photo documentation is used to provide the basis of extrapolation.

- If BEHI and NBS data are not available for *existing* stream restoration projects, the current CBP approved rate will apply.

Table B-1
Bank and Nonpoint Source Consequences of Sediment (BANCS) Method Literature Review

Source	Location	Application	Results/Recommendations
Shields River Watershed WQ Planning Framework & Sediment TMDLs (MDEQ, 2009a)	Shields River Watershed, south-central MT. Confined by mountains to the west and east and flows to the Yellowstone River	The BANCS Method was applied to HUC 6 watersheds at 16 reaches along Potter Creek and Shields River and in 13 additional tributary reaches within the TMDL Planning Area to estimate bank erosion for development of a sediment TMDL. The assessment method excluded 100% naturally eroding banks from the extrapolation and potential loads are assumed to be a combination of natural loads and anthropogenic loads	Bank erosion was found to contribute 103,000 tons of sediment annually to water bodies within the Shields River TMDL Planning Area. The bank erosion method focuses on both sediment production and sediment delivery and also incorporates large flow events via the method used to identify bank area and retreat rates. Therefore, a significant portion of the bank erosion load is based on large flow events versus typical yearly loading.

Table B-1 Bank and Nonpoint Source Consequences of Sediment (BANCS) Method Literature Review			
Source	**Location**	**Application**	**Results/Recommendations**
		associated with the use of reasonable land, soil, and water conservation practices.	Uncertainty in loading estimates is addressed through an adaptive management approach where the TMDL and allocations can be revised as additional information is collected.
Estimating Bank Erosion in the Wissahickon Creek Watershed - Conference Presentation (Haniman, 2009)	Wissahickon Creek Watershed near Philadelphia, PA	The BANCS Method was applied to 12 tributaries of the Wissahickon Watershed between Oct 2005 – Aug 2006. Bank pins were installed at 82 sites from 2006-2008.	The BANCS method predicted 4.2 million lbs of erosion/year. The bank pins estimated 2.3 million lbs of erosion/year (95% CI, +/- 2.5 million lbs/year). The BANCS Method predicts erosion within an order of magnitude. Bank erosion curves are difficult to develop. Understanding channel evolution is key.
Application of Rosgen's BANCS Model for NE Kansas and the Development of Predictive Streambank Erosion Curves (Sass and Keane, 2012)	The Black Vermillion Watershed, glaciated region of KS, northeast of the Flint Hills Ecoregion	3 subwatersheds were selected in the Vermillion Watershed with varied land uses and conservation practices, varied channel modification, and varied riparian corridor management. Each subwatershed included 3 study reaches. Streams in the watershed are low gradient (<0.01), typically entrenched, straightened through channelization, and have high vertical banks. The BANCS Method was conducted for the study reaches, in addition to streambank profiles (with erosion pins as a measurement check). The goal was to provide a tool that can accurately predict annual streambank erosion rates and sediment contributions from channel banks in Northeast Kansas.	The erosion prediction curves developed in this study displayed more variation than the original Yellowstone, Colorado, Piedmont, or Arkansas curves. Vegetation seems to play a vital role in maintaining bank stability in this region of NE KS. Erosion rates plotted against both BEHI score and NBS rating with each site's woody vegetation cover showed a clustering of sites with woody vegetation vs. sites without. Thus, the vegetation portion of the BEHI was modified and simplified, which resulted in consistent R^2 values of 0.84 and 0.88 and correct order of the BEHI adjective ratings. Bank materials may also play a vital role, as the soils are high in clay content that may act similar to bedrock when wetted.
Using BANCS Model to Prioritize Potential Stream Bank Erosion on	Birch Creek within Catskill State Park, NY	144 bank locations along 6.3 stream miles of Birch Creek (steep-gradient mountainous region) were assessed with the BANCS Method. Nine	The erosion processes accounted for in the BANCS model may differ in non-alluvial boundary conditions such as glacial till and/or glacio-lacustrine lake clays, and revetment

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Source	**Location**	**Application**	**Results/Recommendations**
Birch Creek, Shandaken, NY (Markowitz and Newton, 2011)		monumented stream bank cross-sections were installed and measured pre and post Hurricane Irene and Tropical Storm Lee flood events. The purpose of this investigation was to: 1) establish a baseline dataset to predict an annual stream bank erosion rate of Birch Creek using BANCS; 2) rank and prioritize site specific potential erosion; and 3) produce reach specific erosion ratings.	as observed in the study area. These boundary conditions may influence the erosion rates in ways not predicted by the BANCS model. No apparent trend was observed when data from the 9 monumented cross-sections were plotted against the BEHI and NBS ratings. The discrepancy appears to be because of the NBS method used. Only one out of the seven methods to assess NBS was applied to all geomorphic conditions along Birch Creek. When graphed separately it became apparent that the variables associated with the BEHI rating were a much more effective predictor of bank erosion than NBS.
Great Lakes Bank Erosion 516(e) Study – Conference Presentation (Creech, 2010)	Great Lakes Region	Used bank pins and bank profile measurements to develop regional curves for the BANCS method.	The presentation does not indicate how well the BANCS method predicted erosion found with the bank pins and profile measurements. It appears they are still doing measurements so may not have drawn conclusions yet.
Northwest Branch of the Anacostia River Bank Erosion Assessment – Conference Presentation (Crawford et al., 2009)	Anacostia River, Montgomery County, MD, 15.2 sq mile watershed that is 18% impervious. Streams have 700 – 1,000 ft forested floodplains.	Goal of the stream restoration project was to reconnect the channel with its floodplain. The BANCS method was used, along with bank profile surveys at 44 individual banks.	The calibrated NW-160 curve predicted 1,040 tons/year erosion, the Colorado curve predicted 1,298 tons/year, and the North Carolina curve predicted 910 tons/year. BANCS method seems to be a reasonable first estimate of bank erosion. Only utilized 2 NBS methods. Large woody debris is an important source of NBS. Trees on top of banks contribute to stability. BANCS method should not be used to calculate sediment delivered to downstream reaches as it does not take deposition into account.
Evaluating the BEHI on the Navajo Nation (Navajo Nation EPA, 2002)	Chuska Nation, Navajo Nation	Bank profiles and bank pins were surveyed and BEHI determined for 20 bank sites along 15 streams for the purpose of testing and calibrating the BANCS method.	Considerable error was found at most sites for the Yellowstone and Colorado regional curves. Although there is error, the model appears to operate qualitatively. All sites where erosion was predicted, experienced

Table B-1 Bank and Nonpoint Source Consequences of Sediment (BANCS) Method Literature Review			
Source	**Location**	**Application**	**Results/Recommendations**
			erosion. While considerable error exists at individual sites, values averaged or integrated across the project area were surprisingly accurate. The Yellowstone NP and Colorado USFS graphs underestimated erosion by 6% and 168% respectively. Given the great variability in bank composition, erosion mechanisms, and stream flow, it will take several additional years of data to determine the accurate predictive capability of the BEHI. Additional parameters may have to be developed to accurately characterize the Near Bank Stress in sand bed channels. Regardless of the quantitative merits of the BEHI, the field procedure provides a valuable qualitative assessment of stream bank stability for the technician, landowner, or manager.
Stony Run, Baltimore City, MD, Geomorphic Baseline Survey (Eng et al., 2007)	Stony Run, Baltimore City, MD	This study documents active channel adjustments, and will allow the City to compare pre- and post-restoration stream conditions to document the benefits of the restoration. 42 stream banks were assessed using the BANCS method. 9 existing monumented cross-sections were resurveyed, and 2 new cross-sections were surveyed.	A poor correlation was found between the measured erosion rates and the predicted erosion rate determined from the draft regional D.C. curve, which may have been due to changes in the BEHI and NBS procedures from Wildland Hydrology. Similar erosion rates were found at Moore's Run.
Impacts of land use on stream bank erosion in the NE Missouri Claypan region (Peacher, 2011)	Claypan region, NE Missouri	The goal of this project was to determine whether two ***modified*** Rosgen's Bank Erosion Hazard Index (BEHI) Procedures (SOP) used by the Michigan Department of Environmental Quality (MDEQ) would be applicable to streams in the Claypan region of NE Missouri.	The erosion rates for the eighteen treatment reaches were weakly negatively correlated with 2008 and 2011 SOP BEHI total scores, respectively. Both 2008 and 2011 total scores covered a fairly narrow range, which suggests that one or more of the variables were scored very similarly across the treatment

Table B-1
Bank and Nonpoint Source Consequences of Sediment (BANCS) Method Literature Review

Source	Location	Application	Results/Recommendations
		The procedures were tested using erosion pin data collected over three years in two sub-watersheds of the Salt River Basin. The first procedure uses a ratio of bank height to bankfull height and the 2nd procedure includes adjustment factors for bank material and soil layer stratification.	reaches. Another caveat to consider is that Rosgen's method incorporates near-bank velocity gradients and shear stress distributions, which are not incorporated into the survey methods of either MDEQ SOP examined here. No conclusions about the effectiveness of the BANCS method can be made.
Using a BEHI to Estimate Annual Sediment Loads from Streambank Erosion in the West Fork White River Watershed (Van Eps et al., 2004)	West Fork White River Watershed, NW Arkansas, 79,400 ac watershed	The Arkansas Department of Environmental Quality utilized a BEHI and data collected from surveys of streambank profile measurements to develop a graphical model to estimate streambank erosion rates and to estimate the annual sediment load due to accelerated streambank erosion. 24 permanent survey sites were established within 8 reaches for erosion measurement with bank pins from 2002-2003. 192 streambanks were assessed for BEHI and NBS (2002-2004). By relating the BEHI rating, the local NBSS, and the measured erosion rate at each permanent survey site, a graphical model to predict streambank erosion rates was developed.	The study did not provide accuracy estimates for how well the measured erosion rates correlated with the model they developed (regional curve). Bankfull discharge was met or exceeded on many instances during the study period. The survey data should represent erosion rates for years where bankfull flow is approached, equaled, or slightly exceeded. Lateral erosion rates predicted by the model were less than half the rates predicted by the Colorado model for a BEHI and NBSS combination rating of moderate and high. However, for other combinations of BEHI and NBSS, erosion rates predicted by the WFWR model were higher than those predicted by the other models by a factor ranging from 1.3 to 2.8 times.
Streambank Erosion Source Assessment, Upper Gallatin TMDL Planning Area (PBS&J, 2009)	West Fork Gallatin River watershed of the Upper Gallatin TMDL Planning Area, Gallatin and Madison counties, Montana	Sediment loads due to streambank erosion were estimated based on the BANCS Method at 30 monitoring sites (204 streambanks) covering 5.2 miles of stream between July and October of 2008. The reaches were located in low-gradient portions of the study streams where sediment deposition is likely to occur.	Average annual sediment load from the assessed streambanks was estimated at 397 tons/year. 30% of the erosion sediment load was attributed to accelerated streambank erosion caused by historic or current human activities, while approximately 70% was attributed to natural erosional processes and sources.

Table B-1
Bank and Nonpoint Source Consequences of Sediment (BANCS) Method Literature Review

Source	Location	Application	Results/Recommendations
			The watershed streambank sediment load was estimated at 1,821 tons/year based on the stream segment sediment load extrapolated from the assessed streambanks. 33% of this load is due to anthropogenic disturbances. Through the implementation of BMPs, it is estimated that the total sediment load from anthropogenically accelerated streambank erosion can be reduced by 31% (186 tons/year). Direct measurements of streambank erosion were not made, so no conclusions can be drawn about the accuracy of the results from the BANCS Method.
A Practical Method of Computing Streambank Erosion Rate (Rosgen, 2001)	Lamar Basin in Yellowstone National Park, Montana and the Front Range of Colorado on the USDA Forest Service, Arapaho and /Roosevelt and Pike/San Isabel National Forests.	The BANCS Method is presented and is based on the idea that streambank erosion can be traced to two major factors: stream bank characteristics (BEHI) and hydraulic / gravitational forces (NBS). In 1987 and 1988, direct measurements of annual erosion were made using bank pins and profiles to test the BEHI/NBS relationship. 49 sites were selected in the Front Range Colorado and 40 sites were selected in the Lamar River Basin, MT.	The coefficients of determination, or r^2 values, for the correlation of BEHI to NBS were found to be 0.92 for Colorado and 0.84 for Yellowstone. A subsequent study in NC found that the data plots closely to the Colorado dataset, possibly due to a similar alluvial bank composition. Research in the Illinois River in OK showed that either velocity gradients or shear stress ratios predict better than cross-sectional area ratio for NBS. This study also found that flows 4 times bankfull stage generated the measured erosion rate, compared to Colorado and Yellowstone, that are associated with flows at or near bankfull. Research in the Weminuche River found that data collected at low flow can provide comparable results to the higher flows associated with Colorado and Yellowstone. Stratification by geologic and soil types should be accomplished to establish a family of curves for various geologic and hydro-physiographic provinces. Once a

Table B-1 Bank and Nonpoint Source Consequences of Sediment (BANCS) Method Literature Review			
Source	**Location**	**Application**	**Results/Recommendations**
			quantitative relationship is obtained, mapping changes in the BEHI and NBS ratings can be used to estimate consequence of change in locations beyond where the measured bank erosion data is obtained.
Priority Setting for Restoration in Sentinel Watersheds (Lenhart et al., Ongoing)	Whitewater River in the Driftless Area in southeast Minnesota Elm Creek within Glacial Till Plains of the Blue Earth Basin in southern Minnesota Buffalo River within the Red River of the North Basin	This project will develop a modified BANCS model and calibrate it for different geomorphic regions of Minnesota using monitoring, modeling and historical data. BSTEM predicts erosion quantities from individual storm events, while CONCEPTS can model erosion, deposition and channel evolution over extended time periods. These analyses and assessments will be used to identify priority management zones for the intended purpose of reducing sediment and phosphorus loads in sentinel watersheds (areas that are representative of other watersheds in the same region).	This project is ongoing and is scheduled for completion December 2014.
Upper Jefferson River Tributary Sediment TMDLs and Framework Water Quality Improvement Plan (MDEQ, 2009b)	Impaired tributaries to the Upper Jefferson River - Big Pipestone, Little Pipestone, Cherry, Fish, Hells Canyon, and Whitetail creeks.	This document presents a TMDL and framework water quality improvement plan for six impaired tributaries to the Upper Jefferson River. Appendix G presents an assessment of sediment loading due to streambank erosion along stream segments listed as impaired due to sediment. The BANCS Method was done along 91 streambanks (3.89 miles of streambank).	A total sediment load of 742.4 tons/year was attributed to eroding streambanks within the monitoring sections. Erosion from the monitoring sites was extrapolated to the watershed scale. A total estimated sediment load of 44,576.3 tons/year was attributed to eroding streambanks. Direct measurements of streambank erosion were not made, so no conclusions can be drawn about the accuracy of the results from the BANCS Method.

TN and TP Concentration in Stream Bank Sediments

Table 5 in Section 5 shows the four Pennsylvania and Maryland studies in which the measured nutrient content of stream sediments consistently had higher nutrient content than upland soils, and were roughly comparable to the more enriched street solids and BMP sediments. Nutrient levels in stream sediments were variable. The Panel elected to use a value of 2.28 pounds of TN per ton of sediment and 1.05 pounds of TP per ton of sediment, as documented by Walters et al. (2007). These numbers align with recent findings from Baltimore County Department of Environmental Protection and Sustainability in comments to an earlier draft from Panelist Steve Stewart. Steve provided the data in Table B-2 collected from stream bed and bank samples from Powdermill Run and Scotts Level Branch in Baltimore County, MD.

Table B-2 Concentration of TN and TP in Stream Bed and Bank Samples from Powdermill Run and Scotts Level Branch in Baltimore County, MD

	Mean	**Median**	**Sample size**
TP (mg/L)	1.78	1.61	77
TN (mg/L)	5.41	3.81	89

Sediment Delivery Ratio

The scale at which the CBWM simulates sediment dynamics corresponds to basins that average about 60 to 100 square miles in area. The model does not explicitly simulate the contribution of channel erosion to enhanced sediment/nutrient loadings for smaller 1st, 2nd, and 3rd order streams not included as part of the CBWM reach network (i.e., between the edge-of-field and edge-of-stream), that is, scour and deposition with the urban stream channel network with these basins are not modeled.

Due to the scale issue, the CBWM indirectly estimates edge-of-stream sediment loads as a direct function of the impervious cover in the contributing watershed. The strong empirical relationships between impervious cover and sediment delivery for urban watersheds in the Chesapeake Bay were established from data reported by Langland and Cronin (2003), which included SWMM Model estimated sediment loads for different developed land use categories. A percent impervious was assigned to the land use categories to form a relationship between the degree of imperviousness and an associated sediment load (Section 2.5, Figure 1). These edge-of-stream loads were then converted to edge-of-field loads by comparing the average forest load estimates to Natural Resource Inventory average CBWM forest loads at the edge-of-field. For additional documentation, refer to Section 9 of U.S. EPA (2010).

The CBWM operates on the assumption that all sediment loads are edge-of-field and that transport and associated losses in overland flow and in low-order streams decrement the sediment load to an edge-of-stream input. Riverine transport processes are then simulated by HSPF as a completely mixed reactor at each time step of an hour to obtain the delivered load. Sediment can be deposited in a reach, or additional sediment can be scoured from the bed, banks, or other sources of stored sediment throughout the watershed segment. Depending on the location of the river-basin segment in the watershed and the effect of reservoirs, as much as 70 to 85% of the edge-of-field sediment load is deposited before it reaches the main-stem of the Bay (U.S. EPA, 2010).

The sediment loss between the edge-of-field and the edge-of-stream is incorporated into the CBWM as a sediment delivery ratio. This ratio is multiplied by the predicted edge-of-field erosion rate to estimate the eroded sediments actually delivered to a specific reach (U.S. EPA, 2010). Sediment delivery ratios in the Phase 5.3 CBWM range from 0.1 to 0.25. In the protocol 1 example in Section 6, the median of this range, 0.175, was used. Localities will not be required to apply the sediment delivery ratio when submitting the load reduction attributed to stream restoration projects. The ratio is incorporated into the CBWM and is subject to change based on further refinements of the modeling tools.

Supplemental information for the Protocol 1 Example

The example for Protocol 1 uses actual stream bank data collected for Hickey Run in Washington, D.C, by the USFWS. The data consisted of five reaches that were subdivided into a total of 28 banks for BEHI and NBS assessments. The BEHI and NBS scores were taken for each bank and an estimated stream erosion rate was derived using the curve developed by the USFWS in Figure B-1. The bank height and length were used to convert the erosion rate from feet per year to tons per year using the equation described under Protocol 1 in Section 6.

Table B-3
Bank Erosion Potential for Hickey Run

Reach ID	Bank Length (ft)	Bank Height (ft)	Bank Area (ft^2)	BKF Height (ft)	BEHI	Near Bank Stress	Predicted Erosion Rate (ft/yr)	Predicted Erosion Sub-Total (ft^3/yr)	Predicted Erosion Sub-Total (tons/yr)	Predicted Reach Total Reach Erosion (tons/yr)	Predicted Erosion Rate (tons/ft/yr)
Reach 6											
Bank 1	376	10	3760	1.7	High	Low	0.4	1504.00	93.89		
Bank 2	260	4.5	1170	1.7	Low	Low	0.017	19.89	1.24		
Bank 3	144	6.5	936	1.7	High	Low	0.4	374.40	23.37		
Bank 4	578	15	8670	1.7	High	Low	0.4	3468.00	216.49		
Bank 5	329	8	2632	1.7	High	Low	0.4	1052.80	65.72		
Bank 6	381	12	4572	1.7	Very High	Low	0.4	1828.80	114.16	514.87	0.25
Reach 5											
Bank 7	160.5	10	1605	2.01	High	Low	0.4	642.00	40.08		
Bank 8	192	8.5	1632	2.01	Very High	Low	0.4	652.80	40.75		
Bank 9	122.4	2.3	281.5	1.4	Low	Low	0.017	4.79	0.30		
Bank 10	55	7	385	1.4	Very High	Low	0.4	154.00	9.61	90.74	0.17
Reach 4											

Bank 11	263.5	6.5	1713	2.59	Very High	Low	0.4	685.10	42.77		
Bank 12	73	6.5	474.5	2.34	Very High	Low	0.4	189.80	11.85		
Bank 13	195	7.5	1463	2.59	High	Low	0.4	585.00	36.52		
Bank 14	151	7.5	1133	2.2	High	Low	0.4	453.00	28.28		
Bank 15	352.5	7	2468	2.27	Very High	Low	0.4	987.00	61.61		
Bank 16	323	7	2261	2.71	High	Low	0.4	904.40	56.46		
Bank 17	395	7.5	2963	2.59	High	Low	0.4	1185.00	73.97		
Bank 18	59.4	7.5	445.5	2.2	High	Low	0.4	178.20	11.12		
Bank 19	231.5	6.5	1505	2.2	Very High	Low	0.4	601.90	37.57		
Bank 20	95.5	6.5	620.8	2.26	Low	Moderate	0.074	45.94	2.87	363.02	0.17
Reach 3											
Bank 21	132	6.5	858	1.88	Very High	Extreme	2.65	2273.70	141.94		
Bank 22	100	6.5	650	1.88	High	Low	0.4	260.00	16.23		
Bank 23	62.5	8	500	1.23	N/A	N/A	0	0.00	0.00		
Bank 24	50	20	1000	1.73	Very High	Extreme	2.65	2650.00	165.43		
Bank 25	175	3.5	612.5	1.48	Moderate	Low	0.11	67.38	4.21		
Bank 26	162.5	7.5	1219	1.48	Very High	Low	0.4	487.50	30.43	358.23	0.53
Reach 2	***Concrete Channel***										
Reach 1											
Bank 27	1170	7.5	8775	3.76	Low	Low	0.017	149.18	9.31		
Bank 28	1170	10.5	12285	4	Low	Low	0.017	208.85	13.04	22.35	0.01
									TOTAL	**1349.22**	**0.17**

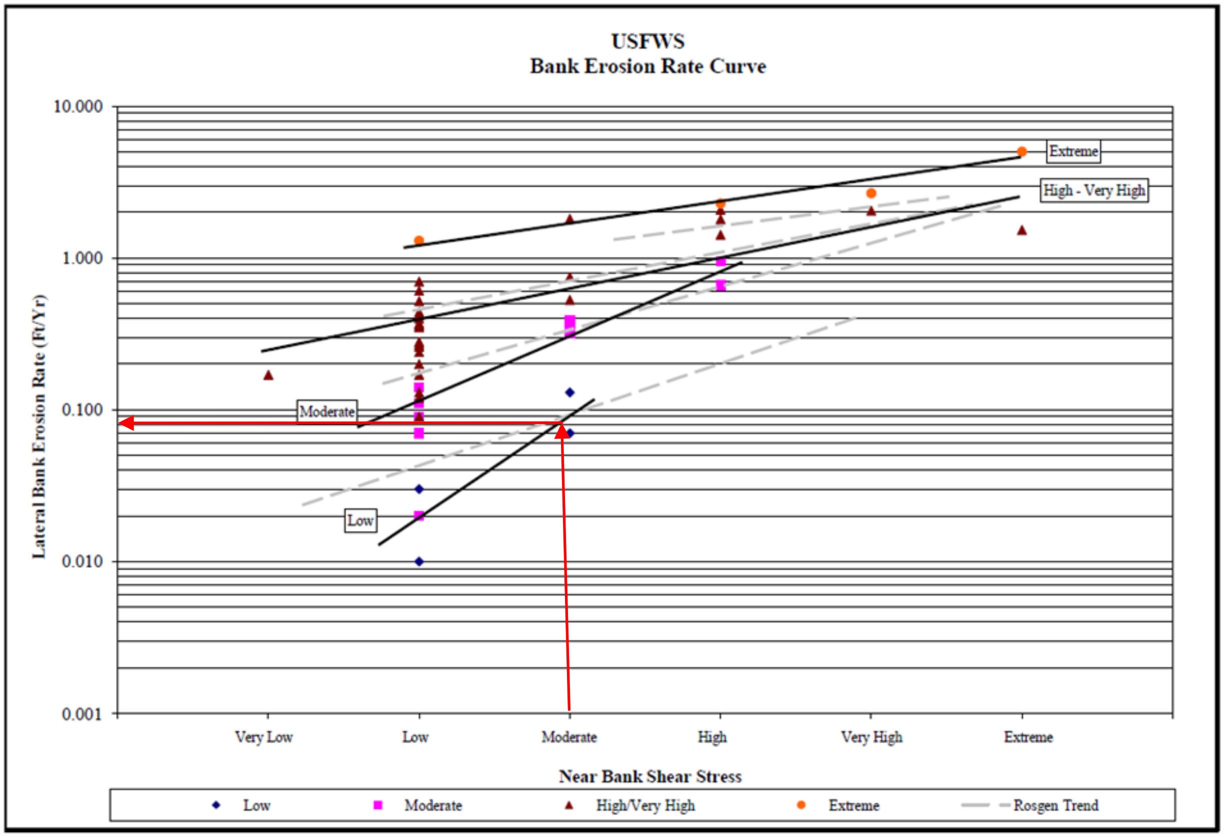

Figure B-1. Bank Erosion Rate Curve Developed by the USFWS

Stream bank erosion is predicted from the curve in Figure B-1 by first identifying the BEHI and NBS scores. For example, Bank 20 from Table B-3 had an NBS score of moderate and a BEHI score of low. By locating the moderate NBS score on the x axis of the Figure B-1 and following it straight up to the BEHI line for "low," the vertical axis shows a predicted erosion rate of 0.07 feet per year, as indicated by the red arrows on the figure.

To convert the erosion rate from feet per year to tons per year, a soil bulk density of 125 pounds/ft^3 was used. This estimate was obtained from a study by Van Eps et al. (2010) that sampled coarse and fine grain layers of stream banks in the West Fork White River watershed in Northwestern Arkansas to determine the in-situ bulk density and particle size distribution. The 125 pounds/ft^3 value used in the Protocol 1 example was calculated as the mean of the coarse and fine grain average bulk density measurements obtained by Van Eps et al. (2010). The bulk density from this study was used only as an example of typical values that might be found. The original bulk density data from the USFWS was not available. The protocol recommends that each project require its own bulk density analysis at several locations in the stream channel as bulk density can be highly variable.

From Van Eps et al. (2010):

"The average in-situ bulk density for fine grain material samples was 1.4 g/cm^3 (1.2 ton/yd^3). By weight, 8% of the particles in the fine material samples were greater than 2 mm in particle size. The average in-situ bulk density for coarse samples was 2.6 g/cm^3 (2.2 ton/yd^3). By weight, 80% of the particles in coarse samples were greater than 2 mm in particle size."

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