Lower Coeur d'Alene Riverbank Stabilization Prioritization

Prepared by:
Kootenai-Shoshone Soil and Water Conservation District
7830 Meadowlark Way, Suite C-1
Coeur d'Alene, Idaho 83815
(208) 762-4939
Craig Nelson and Bob Flagor

In Cooperation with Idaho Department of Environmental Quality
Coeur d'Alene Regional Office
2110 Ironwood Parkway
Coeur d'Alene, Idaho 83815
Kristin Keith and Thomas Herron

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Figures

(The following Figures may display a sample section within the extent. The scale for the entire Lower Coeur d'Alene River extent could not express the detail within the limitations of this report. The digital data that accompanies this report can be utilized using ESRI Software.)

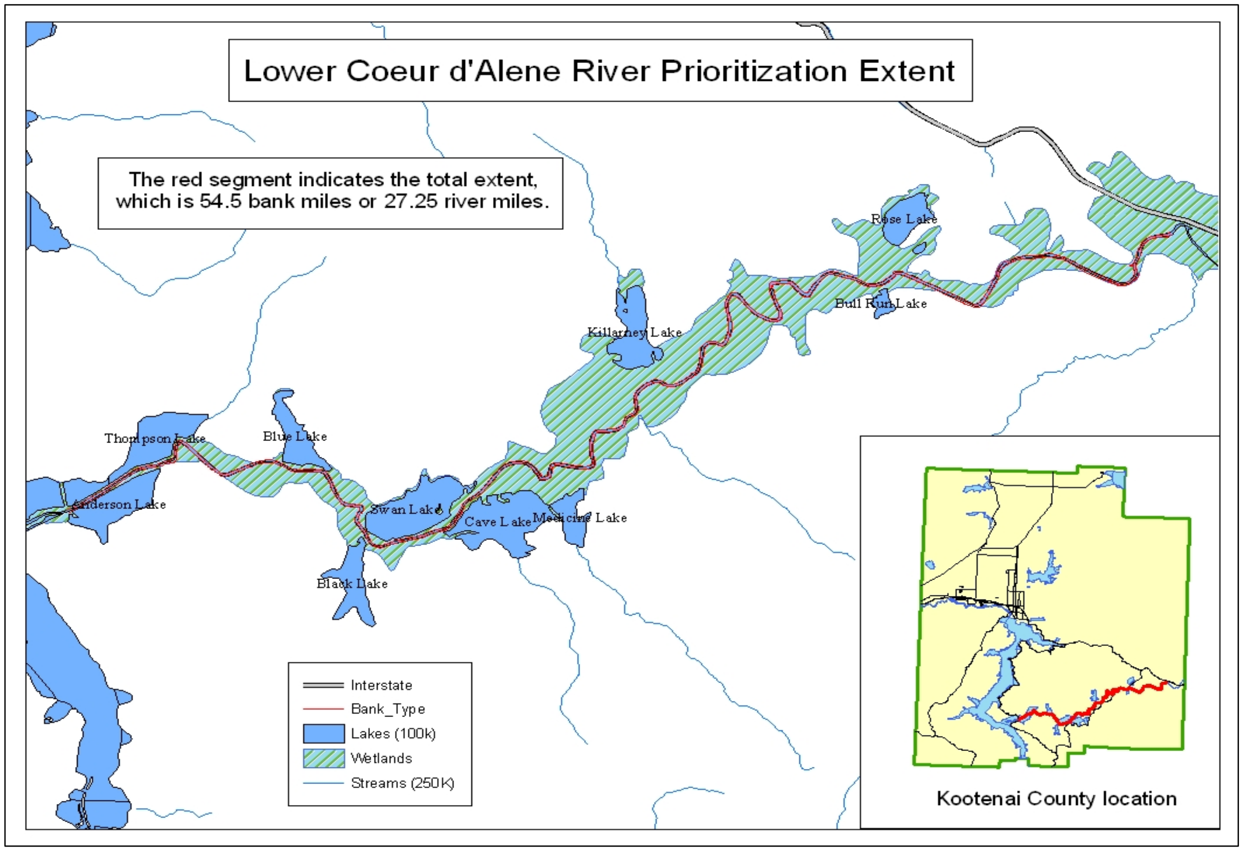
Tables

Purpose and Scope of the Study

The purpose of the study was twofold — first to estimate bank erosion rate, then to prioritize the future bank stabilization efforts along 27.25 miles of the Lower Coeur d'Alene River downstream of Cataldo to the mouth (Figure 1). The factors considered in this prioritization were the bank susceptibility to erosion, shear stress applied to the bank by erosion processes, and the amount of heavy metal contamination along the banks. These factors were used to produce a final Streambank Stabilization Prioritization Overlay (Prioritization Overlay) using ArcGIS.

The bank's susceptibility to erosion, or the Bank Erosion Hazard Index (BEHI), and the stress applied by erosion processes, or Near-Bank Stress (NBS) are two streambank erosion factors referenced in *Watershed Assessment of River Stability and Sediment Supply*, (Rosgen, 2006). By establishing the relationship between BEHI and NBS, the bank erosion, or recession rate (feet/year) can be estimated using the Bank Assessment for Non-point source Consequences of Sediment (BANCS) model (Rosgen, 2006). Estimation of bank recession rate is more efficient than monitoring bank erosion using other methods such as bank pins. This study lays the groundwork to determine if the Rosgen methodology for estimating bank recession rates is applicable to the Lower Coeur d'Alene River system. With repeated monitoring of the actual recession rate using bank pins, a correlation between the estimated bank recession rate and the measured recession rate can be established. If there is a weak correlation, then it will be determined that the Rosgen BANCS model for estimating bank recession rates does not apply to this system. In that case, the long term monitoring of the actual recession rate will provide a better understanding of the bank recession rate within this system.

Figure 1. Lower Coeur d'Alene River Prioritization Extent



Background

The Coeur d’Alene River is the second largest tributary to Coeur d’Alene Lake. It flows from the confluence of the North and South Forks of the Coeur d’Alene River near Enaville, Idaho westward to its mouth at Lake Coeur d’Alene near Harrison, Idaho. Mining and ore processing activity in the past 100 years, primarily in the South Fork Coeur d’Alene River Basin, has resulted in extensive deposits of metals-contaminated sediments along the bed, banks, and floodplain of the North and South Forks of the Coeur d’Alene River, the Coeur d’Alene River, the eleven lateral lakes, numerous wetlands located along the lower Coeur d’Alene River, the lakebed of Lake Coeur d’Alene, and the headwaters of the Spokane River. Annual precipitation and spring snowmelt runoff events continue to redistribute these contaminated sediments throughout the entire system. As a result, the Coeur d’Alene River exceeds state cadmium, lead and zinc water quality criteria protective of cold water aquatic life over its entire length. In addition, the entire length of the Coeur d’Alene River cold water aquatic life and salmonid spawning beneficial uses are impaired due to temperature exceedances, and cold water aquatic life use is impaired on the lower Coeur d’Alene River from Latour Creek to the mouth due to sediment.

Backwater conditions exist during May through September on the Coeur d’Alene River from Cataldo to the mouth due to control of surface elevation of Coeur d’Alene Lake at Post Falls Dam. The annual cycle of fluctuating water levels along with extensive deposits of contaminated sediments creates conditions prohibitive of vegetation establishment on the riverbanks, particularly from the zone of inundation down. In addition, the lower Coeur d’Alene River during May through September attracts seasonal recreational boaters, and boat wake action on the bare riverbanks has been a concern for additional erosive action on the river banks.

In addition to the more obvious impacts to the river from mining and backwater conditions, there are other general historical impacts within the watershed worth mentioning, due to their effect on erosional processes of the river:

- Deforestation caused by timber harvest, wildfires (primarily the 1910 fire), and land use conversion resulting in increased discharge rate of runoff;
- Channelization of streams by development;
- Decreased wetlands due to agricultural land conversion and development;

Previous Studies

Lower Coeur d’Alene River Valley Studies

The Lower Coeur d’Alene River Valley has been the focus of many studies related to the heavy metal contamination of the Coeur d’Alene Mining District and the impacts of the Post Falls Dam on the Spokane River. Studies relevant to this project are summarized below:

The United States Department of Agriculture Soil Conservation Service Document preliminary report, *Coeur d’Alene River Stream Bank Erosion* (1978) states, “The erosion is caused primarily by the wakes created by boat traffic on the river. There is no evidence of deposition taking place on the inside of sharp curves.” Four alternatives were discussed: 1) do nothing; 2) prohibit all boat traffic on the river;

3) install rock riprap; and 4) install a log breakwater. An inspection trip also documented the erosion damage along the banks and assigned a rating of low, moderate, severe, or critical.

The United States Geological Survey Open-File Report *Lead-Rich Sediments, Coeur d'Alene River Valley, Idaho: Area, Volume, Tonnage, and Lead Content*, (Bookstrom &.Box, *et al.*, 2001) provides estimates of the areas, volumes, and tonnages of lead-rich sediments present in the Coeur d'Alene River Valley. The report concluded that the median-based estimate of the total tonnage of lead in lead-rich sediments of the Lower Coeur d'Alene River Valley is 250, plus or minus seventy-five, kilotons of lead. With the mean background concentration of lead at thirty parts per million, the total would be around 1.4 kilotons. This impact is related to the mining activity upstream.

The Kootenai-Shoshone Soil and Water Conservation District compiled a report, *Riverbank Stabilization Inventory*, (2004). Twenty-four projects were inventoried on the Lower Coeur d'Alene River with a variety of stabilization methods employed. The report also contains a qualitative analysis on each of the projects.

Terrestrial Resources Work Group Spokane River Project Relicensing, under contract to Avista Corporation, completed the final Spokane River Hydroelectric Project Phase 2 Erosion Assessment in July 2004 (Earth Systems & Parametrix, 2004). Bank erosion pins were installed at four sites on the Lower Coeur d'Alene River from August until December. The extrapolated average would be about three feet of bank recession over thirty years or about six feet over fifty years. The assessment states, "Boat-generated wave erosion is the main force eroding the prominent ledge along the inside of the levees." If the future estimated erosion were based on the average ledge width of thirty feet since the creation of Post Falls Dam, the estimate would be higher — at about ten feet in thirty years or about sixteen feet in fifty years. The assessment also established the following:

> Boat waves erode the banks along the entire navigable reach, especially the lower reaches. In comparison, the stream currents only erode portions of the banks during floods. Boat waves mobilize and redistribute the stream bank sediment mostly during the summer months. This results in the coarser sediment settling on the ledge formed by the boat waves, with the fines remaining in suspension and slowly moving downstream. (Earth Systems & Parametrix 2004)

Alaska Boat Wake Study

A study documented in the United States Geological Survey Water-Resources Investigations Report, *Effects of Boatwakes on Streambank Erosion, Kenai River, Alaska,* (Dorava & Moore, 1997) estimated the amount of streambank erosion caused by boat wakes and evaluated methods to reduce erosion. Bank pins monitored the recession while wake gauges measured the boat activity. The investigation concluded the following:

> Erosion measured during the study at sites in the segment of the upper river that has restricted boat use is about 75 percent less than that measured in the most popular boating areas of the lower river and about 33 percent less than that in the least popular boating areas of the middle river. Comparisons of the amount of energy dissipated against the streambanks by river currents and boat wakes during this peak flow and peak boating period indicate that about 80 percent of the total energy came from boat wakes. (Dorava & Moore, 1997)

Bank stabilization techniques included spruce trees cabled to the bank, coconut-fiber logs, and live willows, which provided valuable fish habitat, and rock riprap and vertical wooden retaining wall, which did not provide valuable fish habitat.

Field Data Collection

Classification of the Riverbank Types

The first fieldwork completed was a classification of types of riverbanks based on characteristics identified by Rosgen's Bank Erosion Hazard Index (BEHI) (Rosgen, 2006). The Lower Coeur d'Alene River is unique and site specific, due to the historic impacts of the mining activity upstream, but these impacts affect the characteristics that are universal to all riverbanks. This classification may lead to a better understanding of how the characteristics of a riverbank impact the recession rate. The BEHI variables are as follows (Figure 2):

1. Study bank height/bankfull height (study bank-height ratio),
2. Root depth/bank height (root depth ratio),
3. Weighted root density,
4. Bank angle,
5. Surface protection,
6. Bank material, and
7. Stratification of bank material.

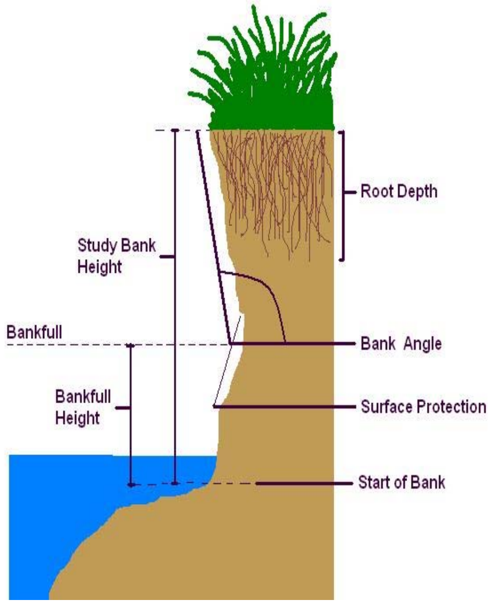
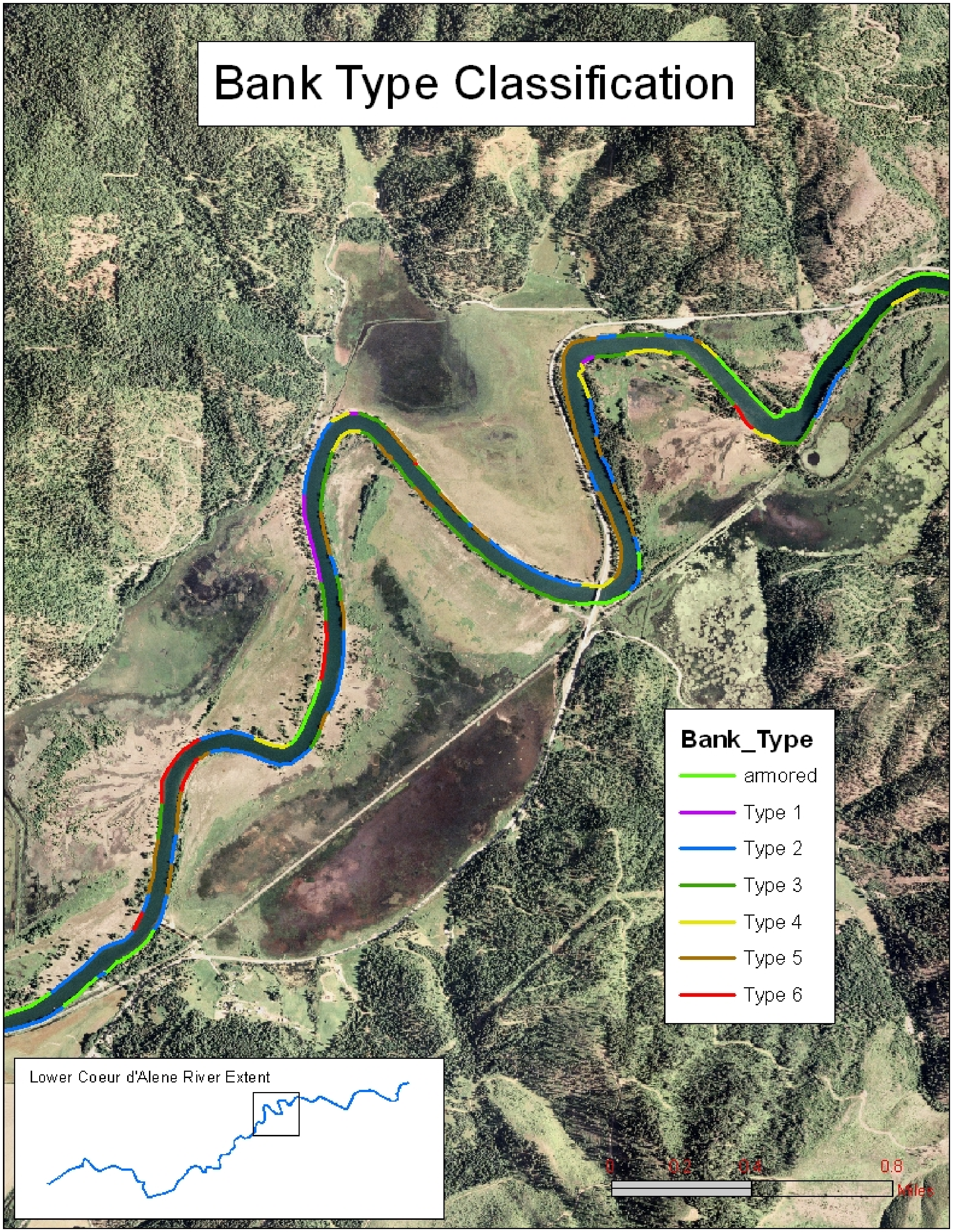


Figure 2. Illustration of BEHI variables

After establishing the distinct visual breaks along the river bank using the BEHI variables, a range could be defined within those variables to represent one bank type. Once riverbank types were defined, data was collected from a boat traversing the bank while using a Trimble GPS to track a line feature. The line was segmented through visual observation of the bank and a specific bank type was assigned as it was observed. Since the boat's course was not at the bank's edge, a line feature was digitized along the bank's edge using 2006 satellite imagery and ArcGIS. The data collected in the field was then transferred to the digitized bank, by segmenting the field line perpendicular to the bank using ArcGIS. A visual display is provided in Figure 3 and a definition of each bank type follows.

Figure 3. Bank Type classification

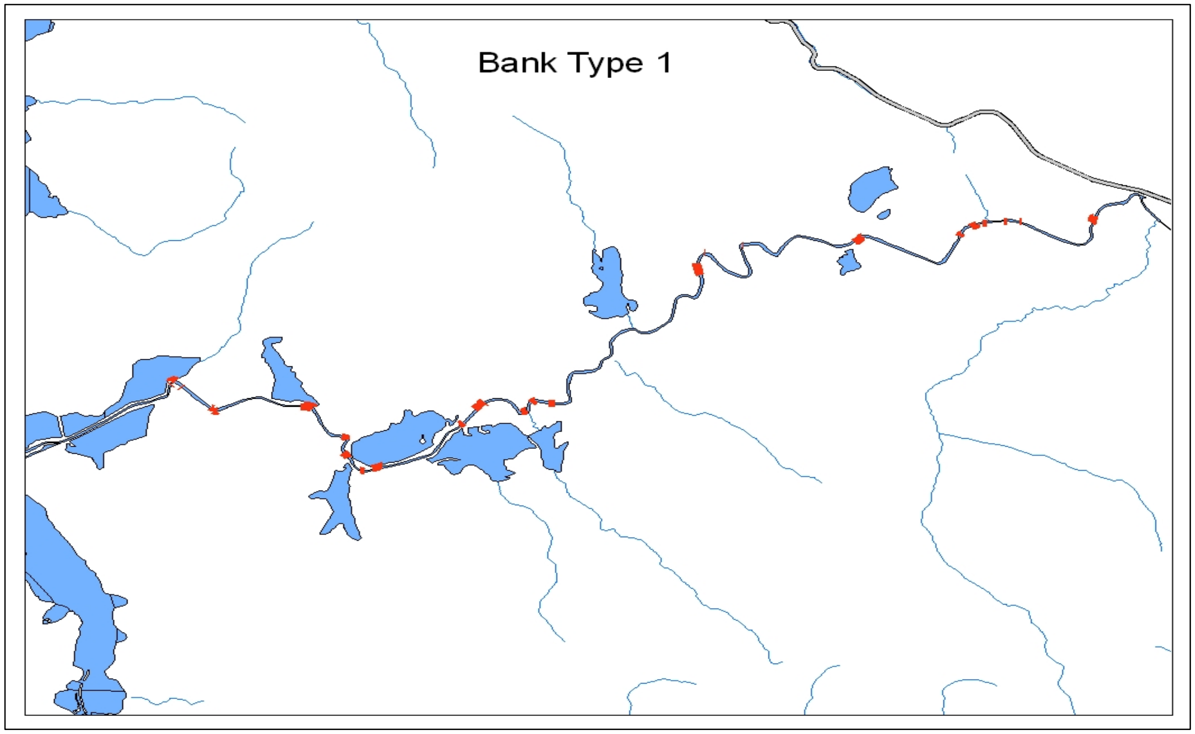


Bank Type 1

- Bank angle is typically 90 degrees.
- Root density is less than 5 percent.
- Root depth is no greater than two feet.
- Presence of mine tailings are prominent, causing typically "massive" structure of riverbank soils.
- An obvious distinction exists between tailings and pre-mining soils (when visible).

There are twenty-eight segments classified as Bank Type 1 which total 2.75 miles of bank and 5 percent of the total 54.5 riverbank miles. Figure 4 displays the distribution of Bank Type 1 within the project extent (indicated by red segments).

Figure 4. Distribution of Bank Type I within the project extent

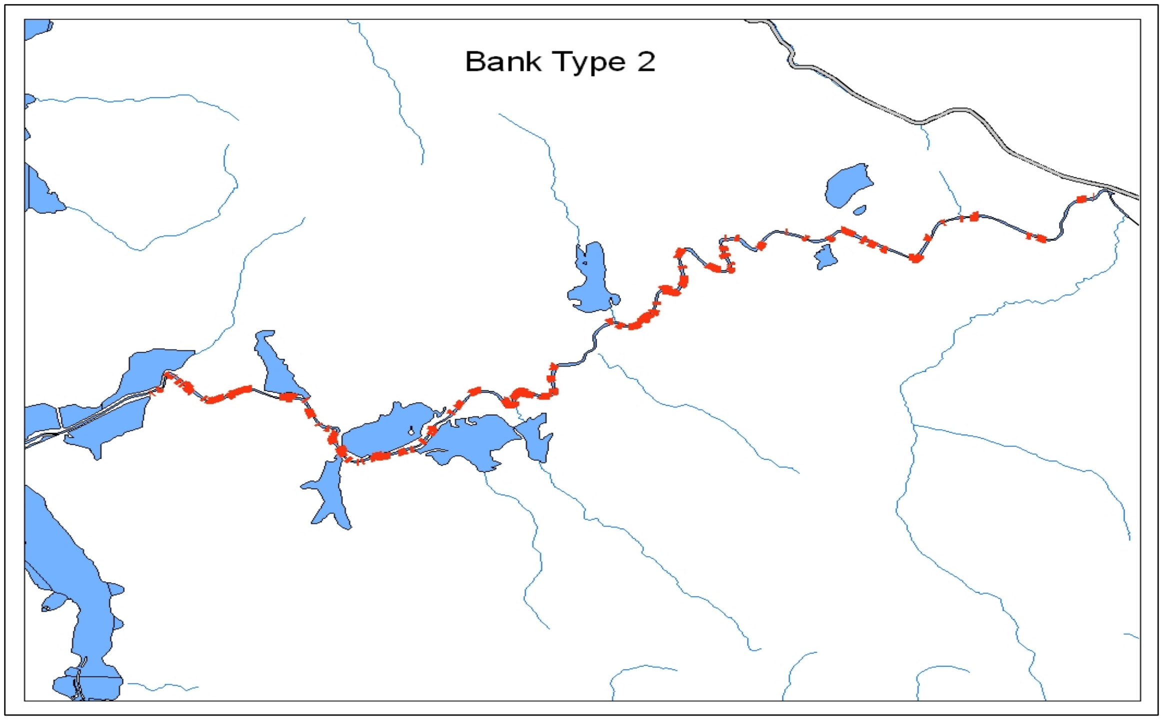


Bank Type 2

- Riverbank height is less than eight feet.
- Bank angle is greater than 90 degrees.
- Root density is 10-15 percent.
- Root depth is two to five feet.
- Presence of mine tailings are less obvious, and riverbank soils do not exhibit such a “massive” structure.

There are ninety-one segments classified as Bank Type 2 which total 11.25 miles of bank and 21 percent of the total 54.5 riverbank miles. Figure 5 displays the distribution of Bank Type 2 within the project extent (indicated by red segments)

Figure 5. Distribution of Bank Type 2 within the project extent

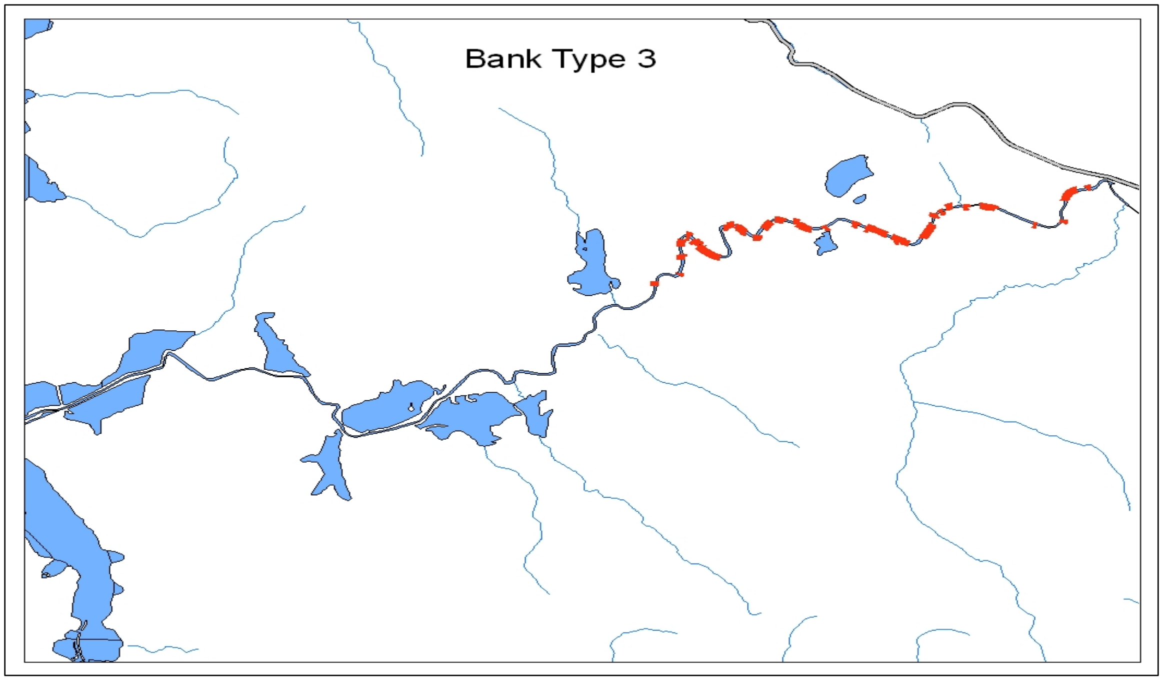


Bank Type 3

- Riverbank height is greater than eight feet.
- Bank angle is greater than 90 degrees.
- Root density is 10-15 percent.
- Root depth is two to five feet.
- Presence of mine tailings are less obvious, and riverbank soils do not exhibit such a “massive” structure.

There are thirty-six segments classified as Bank Type 3 which total 5.59 miles of bank and 10 percent of the total 54.5 riverbank miles. Figure 6 displays the distribution of Bank Type 3 within the project extent (indicated by red segments).

Figure 6. Distribution of Bank Type 3 within the project extent.

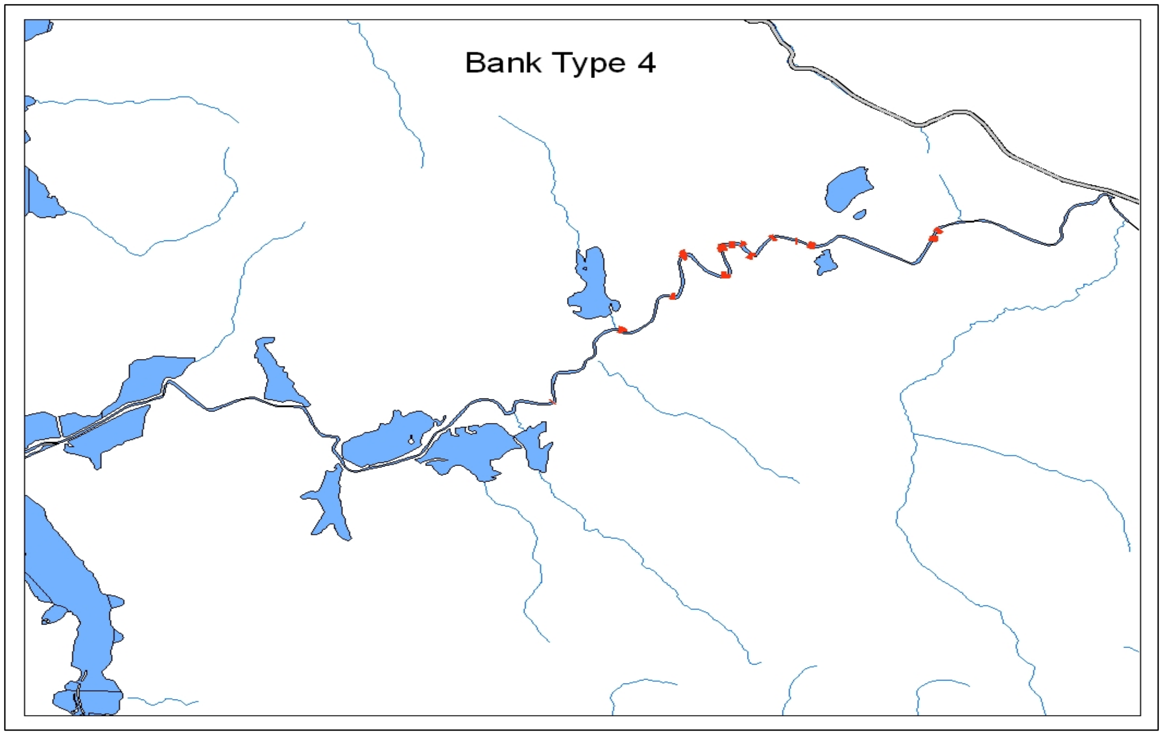


Bank Type 4

- Sandy bars are present.
- Lack of vegetation and root density exist.

There are fifteen segments classified as Bank Type 4 which total 1.40 miles of bank and 3 percent of the total 54.5 riverbank miles. Figure 7 displays the distribution of Bank Type 4 within the project extent (indicated by red segments).

Figure 7. Distribution of Bank Type 4 within the project extent.

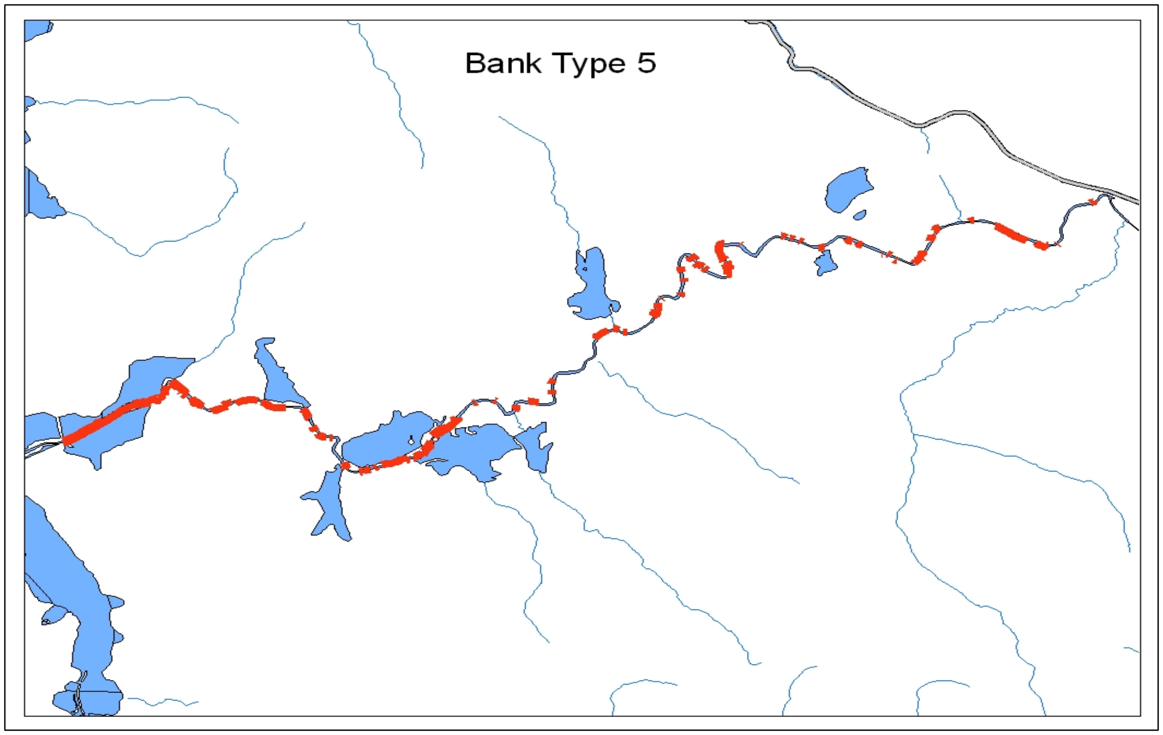


Bank Type 5

- Banks are highly vegetated with shrubs.
- Root density is greater than 30 percent.
- Root depth is typically the vertical extent of the bank.
- Bank angle is typically 90 degrees.

There are eighty-two segments classified as Bank Type 5 which total 14.67 miles of bank and 27 percent of the total 54.5 riverbank miles). Figure 8 displays the distribution of Bank Type 5 within the project extent (indicated by red segments).

Figure 8. Distribution of Bank Type 5 within the project extent.

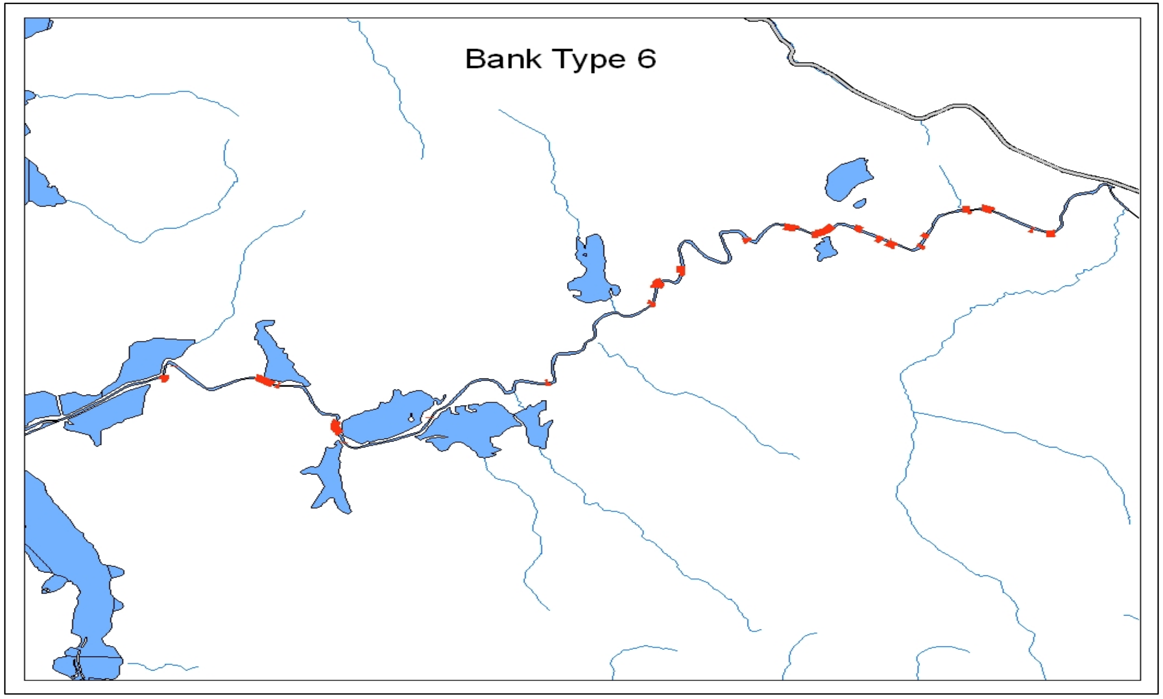


Bank Type 6

- Riverbank vegetation composed of grasses.
- Riverbank height is less than five feet.
- Root density is greater than 30 percent.
- Root depth is typically the vertical extent of the bank.

There are twenty-eight segments classified as Bank Type 6 which total 3.49 miles of bank and 6 percent of the total 54.5 riverbank miles. Figure 9 displays the distribution of Bank Type 6 within the project extent (indicated by red segments).

Figure 9. Distribution of Bank Type 6 within the project extent.



Armored Banks


8.18.2004

The Kootenai-Shoshone Soil and Water Conservation District report, *Riverbank Stabilization Inventory*, (June 2004), lists a number of stabilization projects installed along the Lower Coeur d'Alene River with varied designs. The majority of the banks on the Lower Coeur d'Alene River have been stabilized with riprap and riparian vegetation. The armored bank classification was visually assessed in July 2008, where 9.16 miles of riverbank were identified as stabilized. In June 2009, updates were done to include recent stabilization projects, which were an additional 6.18 miles of riverbank stabilization within the project extent. These updates included a few projects that were in the process, or would soon be implemented on the ground.

At the time of this report, there were fifty-one segments classified as Armored Banks which total 15.34 miles of bank and 28 percent of the total 54.5 riverbank miles. Figure 10 displays the distribution of armored bank within the extent (indicated by red segments).

Figure 10. Distribution of armored bank within the project extent.

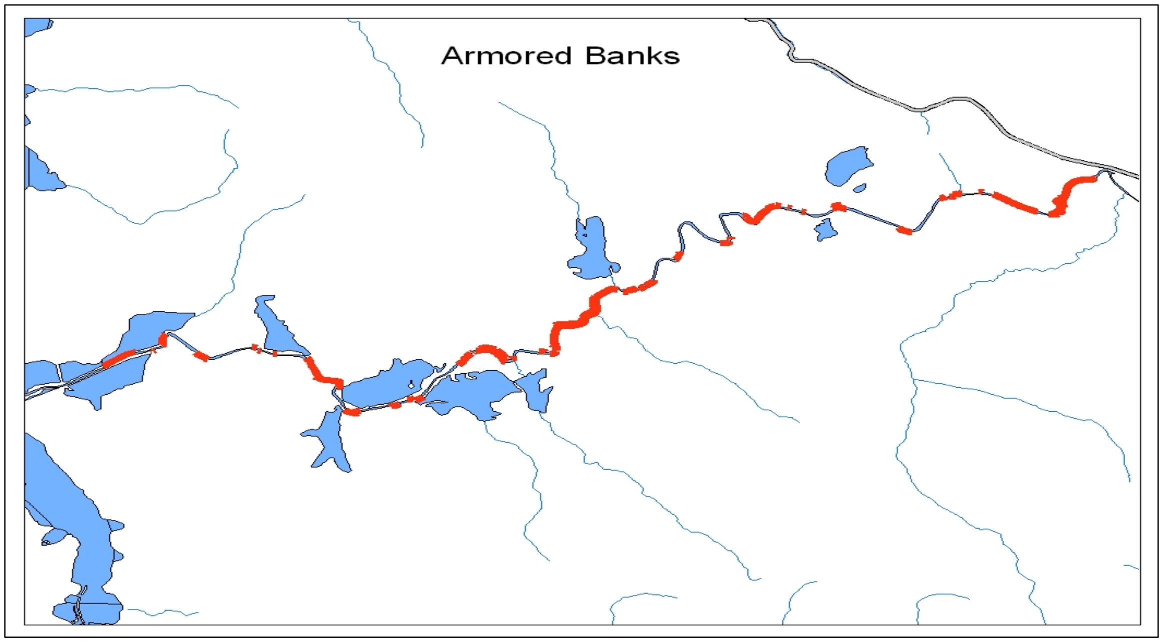
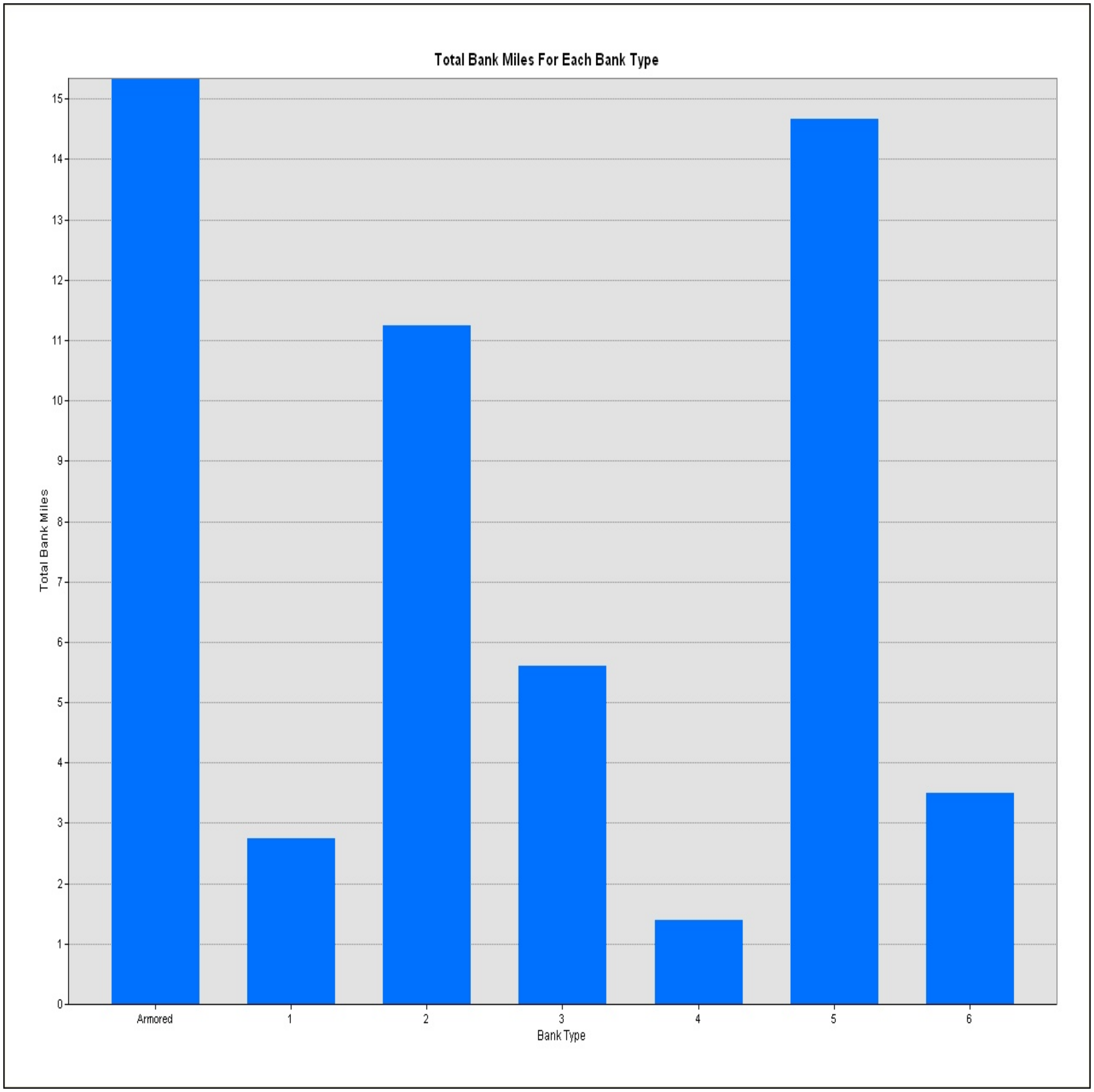


Figure 11 displays the total bank miles for each bank type within the extent of 54.5 riverbank miles.

Figure 11. Total bank miles for each bank type.



Riverbank Recession Rate Monitoring

Within each of the six bank types, multiple bank pin monitoring sites were established (Figure 12 and Table 1). With repeated monitoring of the actual recession rate (rate of erosion of the bank) at each site, we could gain an understanding of how the recession rate relates to the combination of BEHI variables and the Near-Bank Stress applied by erosion. Approximately five bank pin site locations were distributed for each bank type, totaling 36 sites.

Figure 12. Bank pin site locations (July 16, 2008):

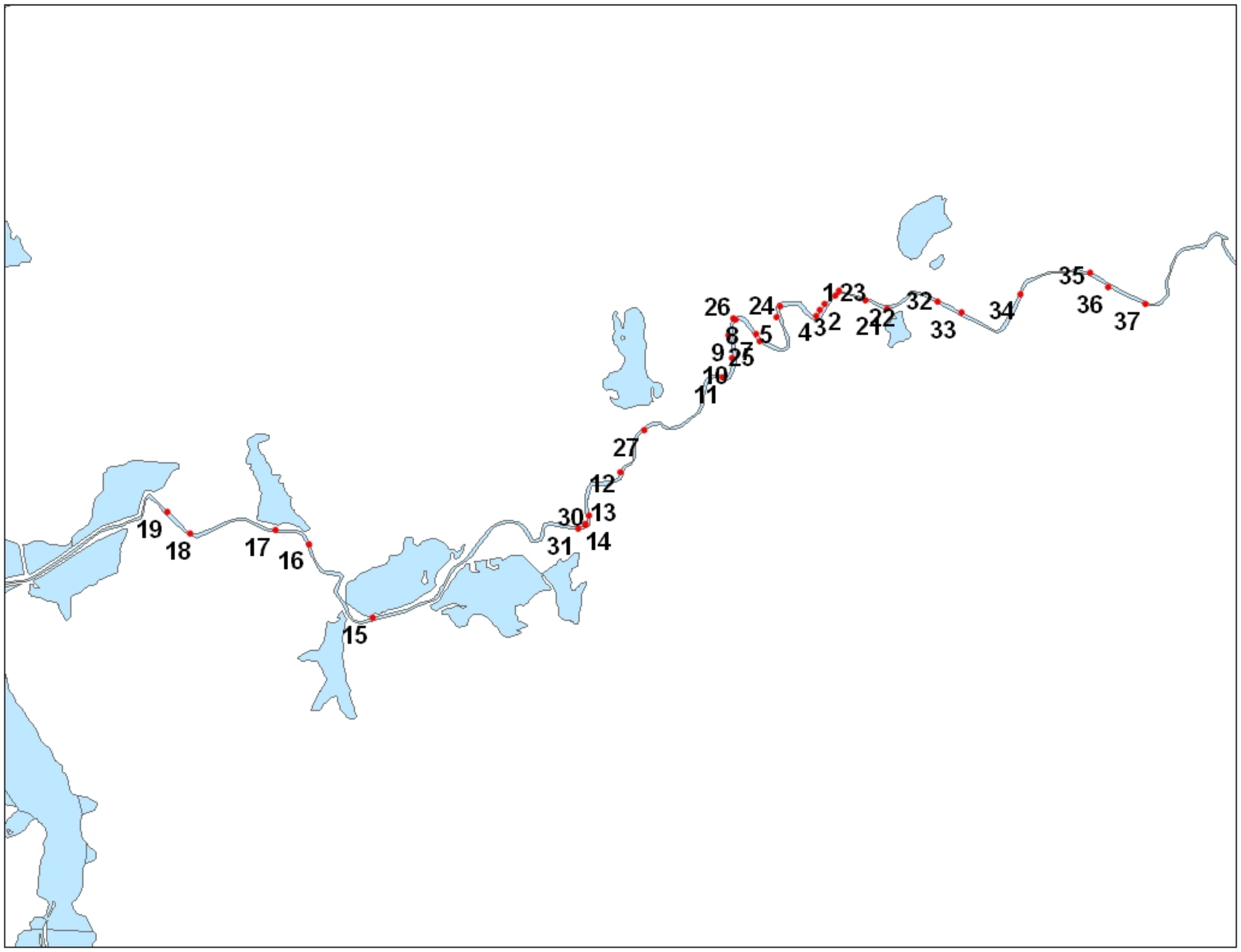
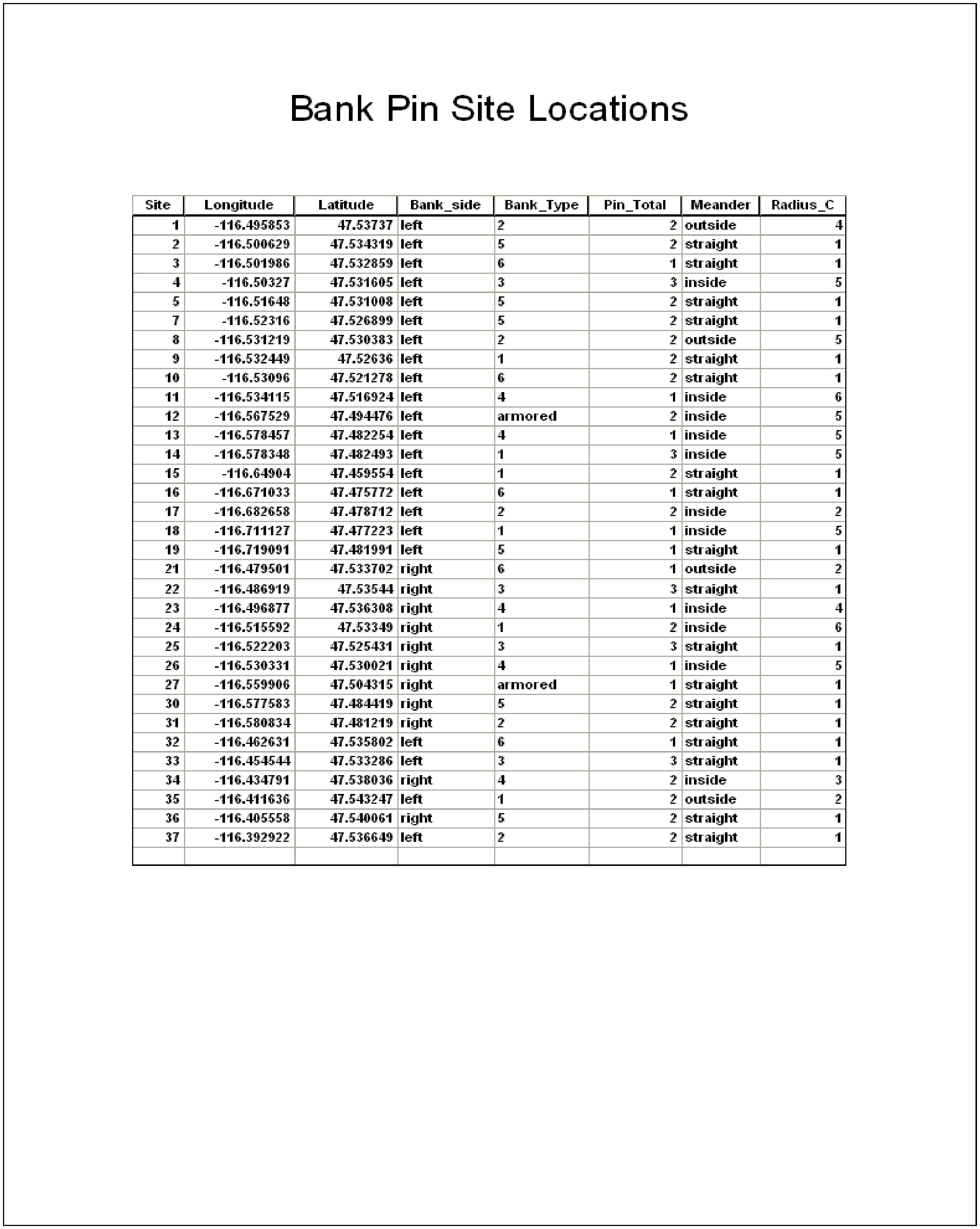


Table 1. Bank pin site locations (July 16, 2008):



Bank Pin Site Locations

Site	Longitude	Latitude	Bank_side	Bank_Type	Pin_Total	Meander	Radius_C
1	-116.495853	47.53737	left	2	2	outside	4
2	-116.500629	47.534319	left	5	2	straight	1
3	-116.501986	47.532859	left	6	1	straight	1
4	-116.50327	47.531605	left	3	3	inside	5
5	-116.51648	47.531008	left	5	2	straight	1
7	-116.52316	47.526899	left	5	2	straight	1
8	-116.531219	47.530383	left	2	2	outside	5
9	-116.532449	47.52636	left	1	2	straight	1
10	-116.53096	47.521278	left	6	2	straight	1
11	-116.534115	47.516924	left	4	1	inside	6
12	-116.567529	47.494476	left	armored	2	inside	5
13	-116.578457	47.482254	left	4	1	inside	5
14	-116.578348	47.482493	left	1	3	inside	5
15	-116.64904	47.459554	left	1	2	straight	1
16	-116.671033	47.475772	left	6	1	straight	1
17	-116.682658	47.478712	left	2	2	inside	2
18	-116.711127	47.477223	left	1	1	inside	5
19	-116.719091	47.481991	left	5	1	straight	1
21	-116.479501	47.533702	right	6	1	outside	2
22	-116.486919	47.53544	right	3	3	straight	1
23	-116.496877	47.536308	right	4	1	inside	4
24	-116.515592	47.53349	right	1	2	inside	6
25	-116.522203	47.525431	right	3	3	straight	1
26	-116.530331	47.530021	right	4	1	inside	5
27	-116.559906	47.504315	right	armored	1	straight	1
30	-116.577583	47.484419	right	5	2	straight	1
31	-116.580834	47.481219	right	2	2	straight	1
32	-116.462631	47.535802	left	6	1	straight	1
33	-116.454544	47.533286	left	3	3	straight	1
34	-116.434791	47.538036	right	4	2	inside	3
35	-116.411636	47.543247	left	1	2	outside	2
36	-116.405558	47.540061	right	5	2	straight	1
37	-116.392922	47.536649	left	2	2	straight	1

At each monitoring site, between one and three pins were driven horizontally into the bank, until the end of the pin was flush with the bank profile. The pins were half-inch diameter rebar, three feet long. As the bank receded from erosion, the pin was exposed. The length of the exposed pin was measured during each monitoring event then again driven flush with the bank profile. With repeated monitoring, a cumulative recession rate was calculated. This actual recession rate would help to answer whether there is a relationship between the recession rates for each bank type. Figure 13 displays an example of a bank pin site where bank recession has occurred, exposing an upper and lower pin.

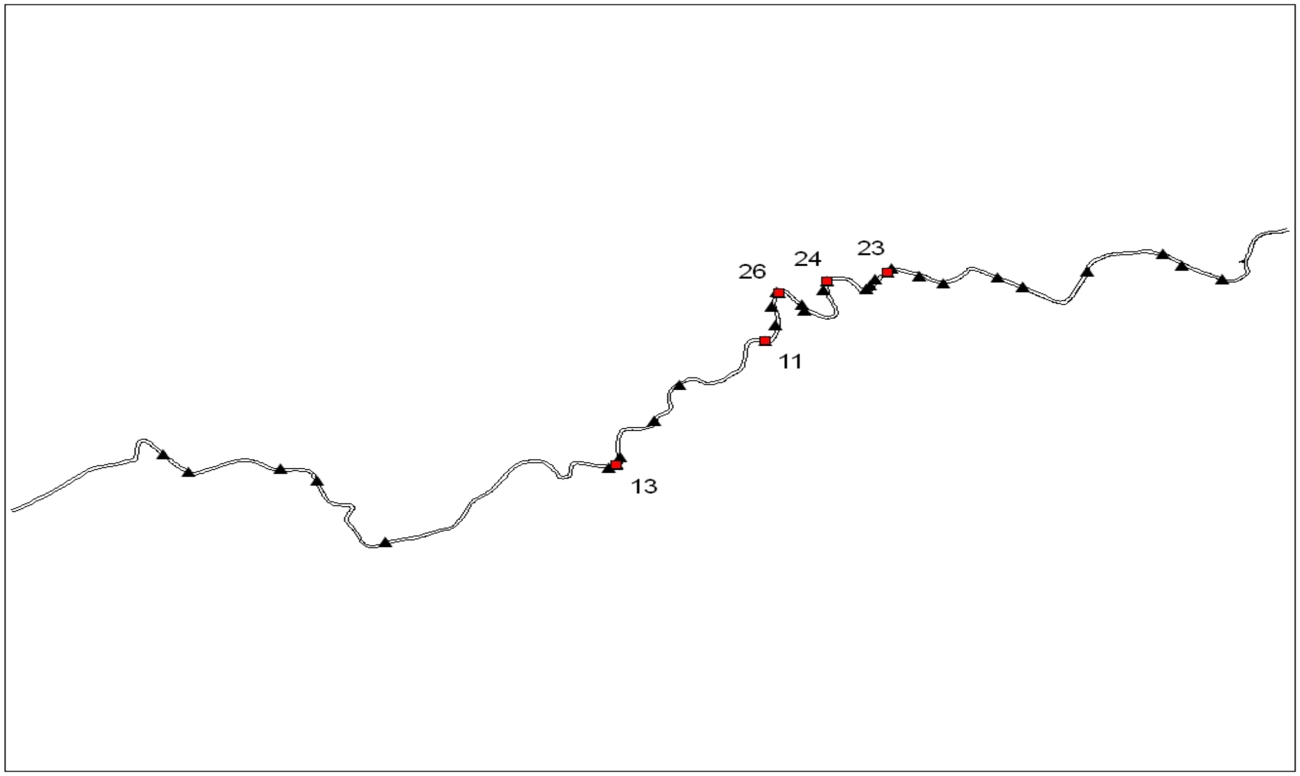
Figure 13. Photograph of exposed bank pins.

After the pins were installed on July 16, 2008, a partial monitoring event was performed on August 13, 2008. A complete monitoring of all 36 sites was accomplished on October 30, 2008, and November 19, 2008. Erosion observed during the July-August time frame would be primarily associated with bank erosion from boat wake activity. Table 2 displays the measured recession prior to spring runoff, with the unlisted sites having no measured recession. This recession occurred at the inside bank of a meander, where a sandy point bar exists (Bank Type 4) (Figure 14).

Table. 2. Measured recession during monitoring events prior to spring runoff.

Monitoring Event 8/13/08				
Site	Bank Type	Location		Recession in Inches
11	4	inside meander	only one pin	126
13	4	inside meander	only one pin	96
26	4	inside meander	only one pin	13.2
Monitoring Event 10/30/08				
Site	Bank Type	Location		Recession in Inches
11	4	inside meander	only one pin	21
13	4	inside meander	only one pin	24
24	1	inside meander	lower pin	0.25
Monitoring Event 11/19/08				
Site	Bank Type	Location		Recession in Inches
23	4	inside meander	only one pin	41
26	4	inside meander	only one pin	7.6

Figure 14. Site locations with measured recession prior to spring runoff:



After spring runoff, a complete monitoring event occurred between June 15 and June 17, 2009. A total of 36 sites were monitored. This monitoring event was designed to capture bank recession rate which occurred between November 19, 2008, and June 17, 2009 — a time period primarily associated with runoff. During this monitoring event, some of the pin sites were lost, and recession rate could not be measured for following reasons: 1) the site was covered with riprap stabilization during the winter months, (sites 4, 9, 12, 16, 17, and 27); 2) the site could not be located (sites 18 and 23). Despite this loss, bank recession rate was captured at 25 pin sites after the spring runoff. Table 3 displays the measured recession after spring runoff, Table 4 lists average recession rate by bank type, and Figure 15 shows site locations. Bank type 4 continued to show significant recession. Generally, bank types 1, 2, and 3 receded approximately one foot. Bank type 5 receeded less than half a foot and bank type 6 had no measured recession.

Table 3. Measured recession during monitoring event after spring runoff.

Monitoring Event 6/15/09 to 6/17/09				
Site	Bank Type	Location		Recession in Inches
14	1	inside meander	lower pin	0.75
15	1	generally straight	upper pin	12
15	1	generally straight	lower pin	7.5
24	1	inside meander	lower pin	5
35	1	outside meander	lower pin	15
35	1	outside meander	upper pin	11
1	2	outside meander	lower pin	0.5
8	2	outside meander	lower pin	42
8	2	outside meander	upper pin	42
31	2	generally straight	upper pin	12
31	2	generally straight	lower pin	11
37	2	generally straight	lower pin	0.75
25	3	generally straight	middle pin	3
33	3	generally straight	middle pin	12
33	3	generally straight	lower pin	10.5
33	3	generally straight	upper pin	2.5
11	4	inside meander	only one pin	98.4
26	4	inside meander	only one pin	36
34	4	inside meander	lower pin	14.5
34	4	inside meander	upper pin	1
5	5	generally straight	lower pin	5
5	5	generally straight	upper pin	2.5
7	5	generally straight	upper pin	2
30	5	generally straight	lower pin	0.75
36	5	generally straight	upper pin	0.75
36	5	generally straight	lower pin	0.5

Figure 15. Site locations with measured recession after spring runoff.

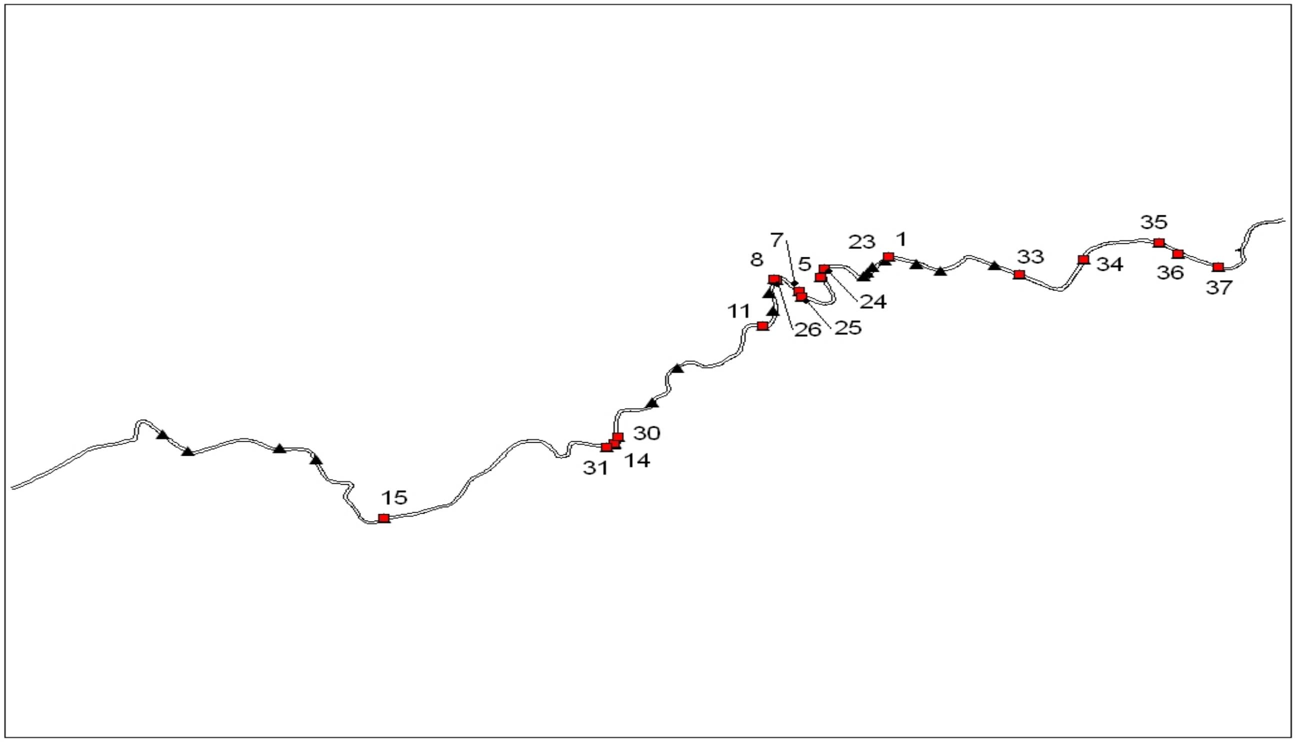


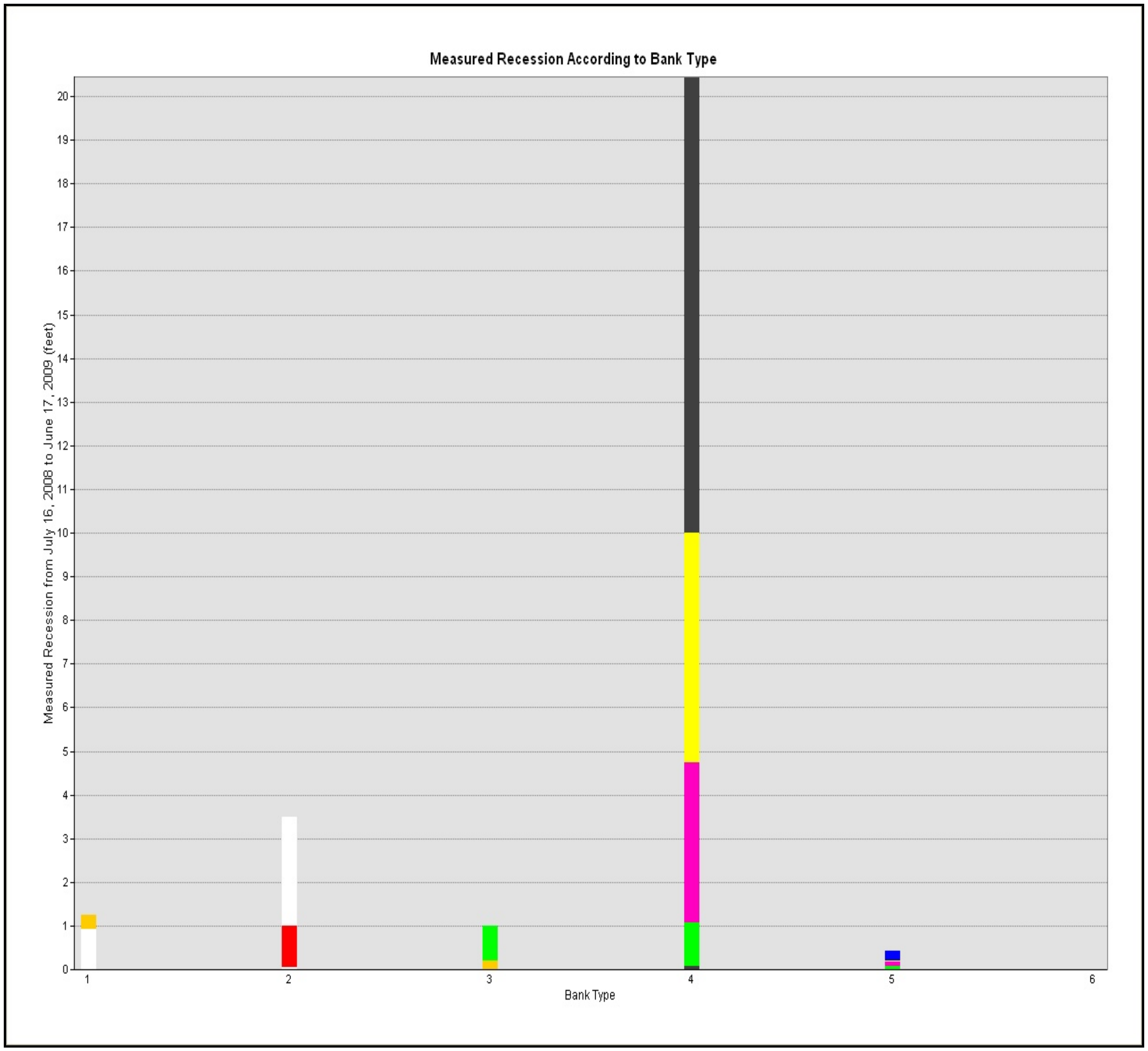
Table 4. Average recession by bank type

Bank Type	Average Recession Rate (inches)
1	10.3
2	18.0
3	7.0
4	37.5
5	1.9
6	0

Bank Type Recession Comparison

Figure 16 displays the measured recession from July 16, 2008 to June 17, 2009, according to the bank type. The color blocks indicate the total recession at different horizontal monitoring pin bank site locations. Significant recession occurred at bank type 4 locations, which are the dynamic inside meander sandy point bars. Bank type 1, 2, and 3 showed a measurable difference in recession compared to bank type 5 and 6. This difference seems to be attributed to the higher root density and depth from vegetation for bank type 5 and 6. The lack of a measurable recession for bank type 6 would be attributed to, not only the root density and depth, but the less severe bank angle.

Figure 16. Measured recession according to Bank Type



Riverbank Soil Sampling

Soil samples of the bank profile were collected at each of the 36 bank pin site locations for a total of four to six samples per bank type. The sample was obtained by scrapping an even distribution of soil from the full profile of exposed bank into a bucket and taking a subsample after the soil had been thoroughly mixed. Accurate Testing Labs, LLC, analyzed the samples for arsenic, lead, zinc, total phosphorus, organic phosphorus, and phosphate (Bray analysis). The results were graphed according to the six different bank types, (Figures 17-20). Lead concentration data were included in the control points used for interpolation of the Lead Concentration raster, which was a factor in the Prioritization Overlay.

Field portable x-ray fluorescence (XRF) is a fast, cost-effective method for determining metal concentration in soil. Given error is minimized in sample collection, handling, and preparation, it can correlate extremely well to lab results (Shefsky, 1997). To determine if there was a correlation with lab analysis results and XRF for lead, portions of the soil samples were dried and analyzed using a NITON XRF Analyzer. The XRF was borrowed from the Army Corps of Engineers, Model 723S and serial number U2151NW326. Four different recordings were done for each sample (moving the sample bag for each recording), with a duration of thirty nominal seconds for each recording. The four recordings were averaged and, conservatively, the highest plus-or-minus error was associated.

The lab analysis and the XRF analysis were compared using the data on lead (Figure 21). The correlation was acceptable ($R^2 = 0.9092$). This is useful knowledge if future soil analysis is needed to understand lead levels in banks during prioritization.

Figure 17. Lead levels according to Bank Type

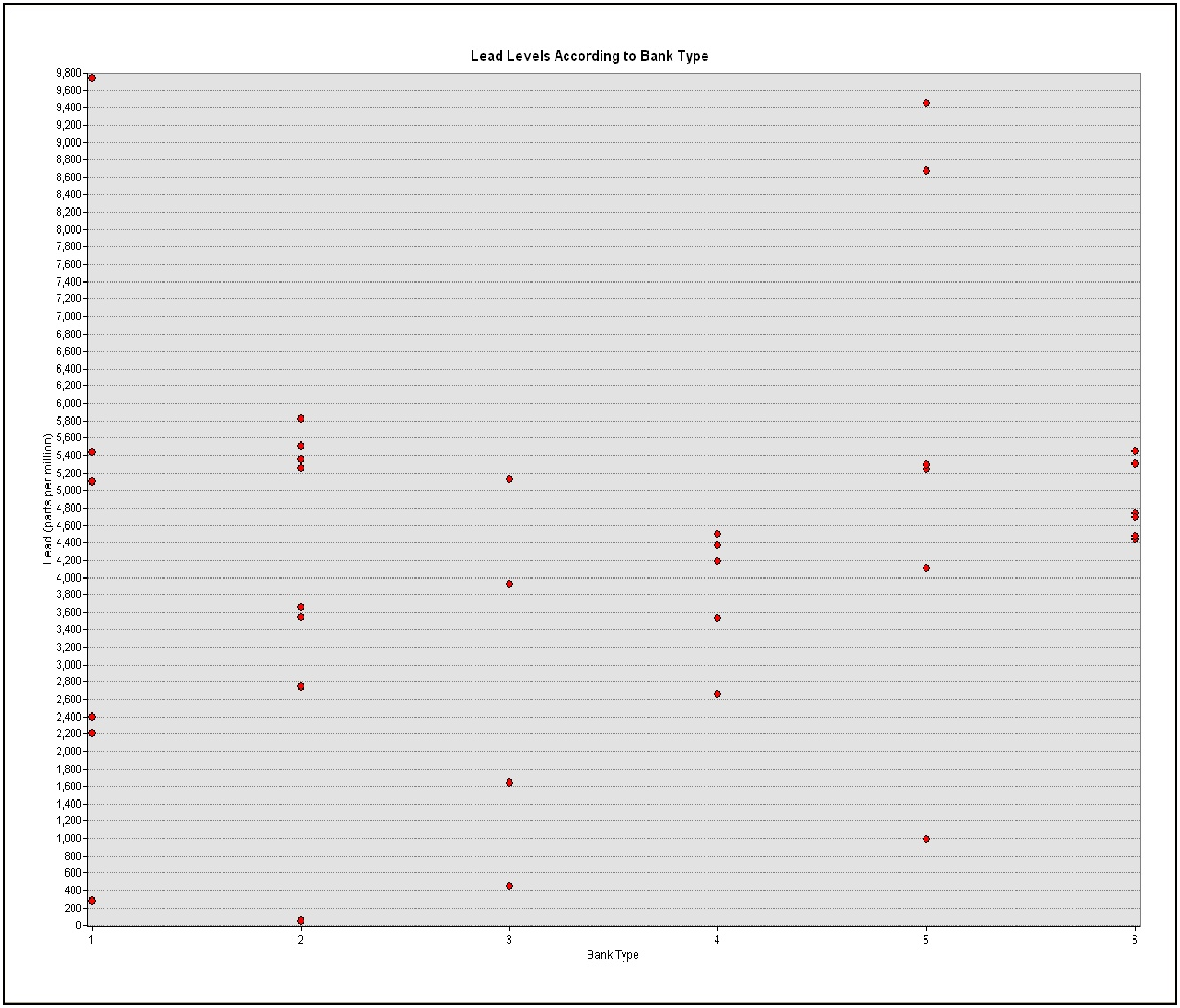


Figure 18. Arsenic levels according to Bank Type

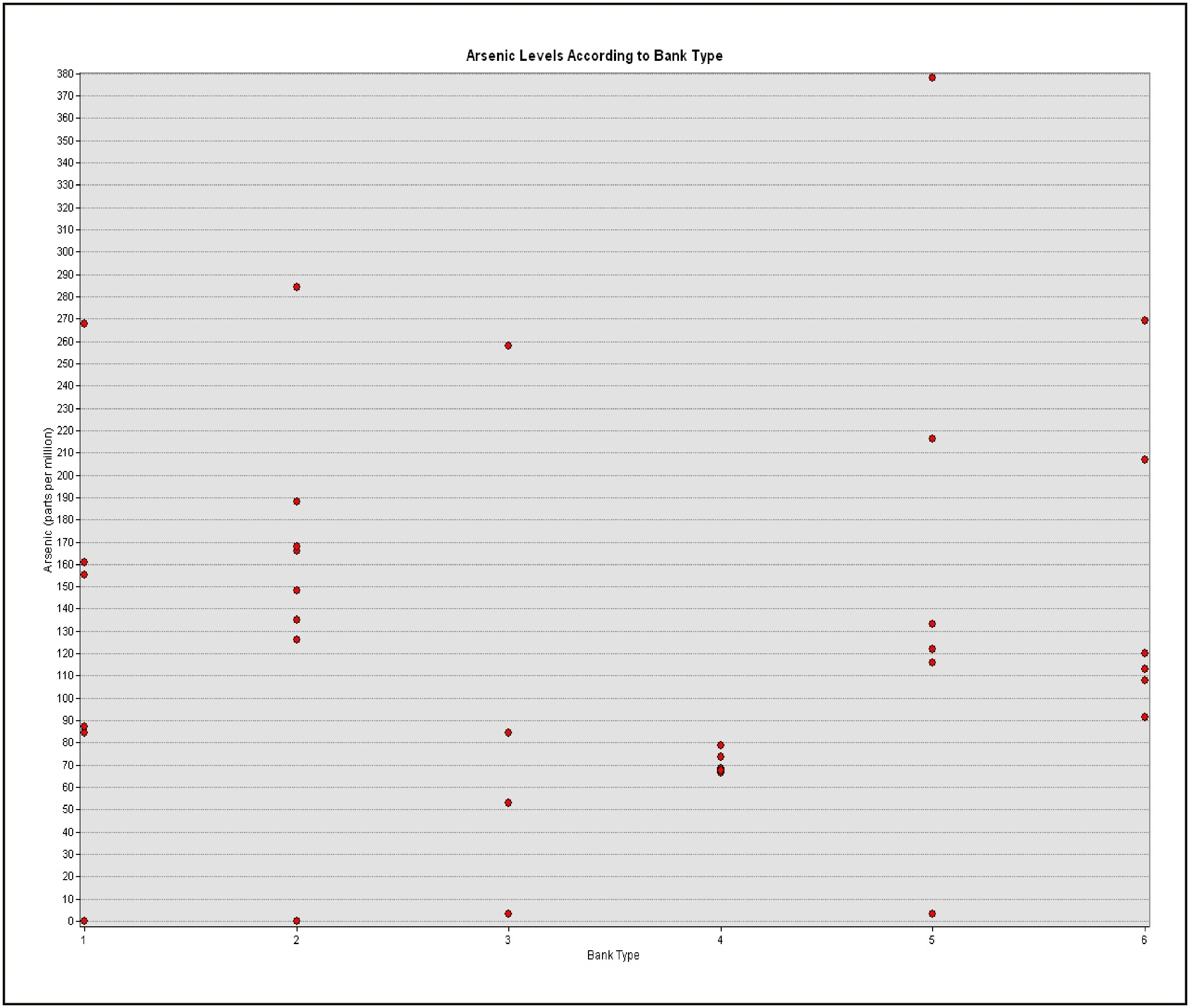


Figure 19. Zinc levels according to Bank Type

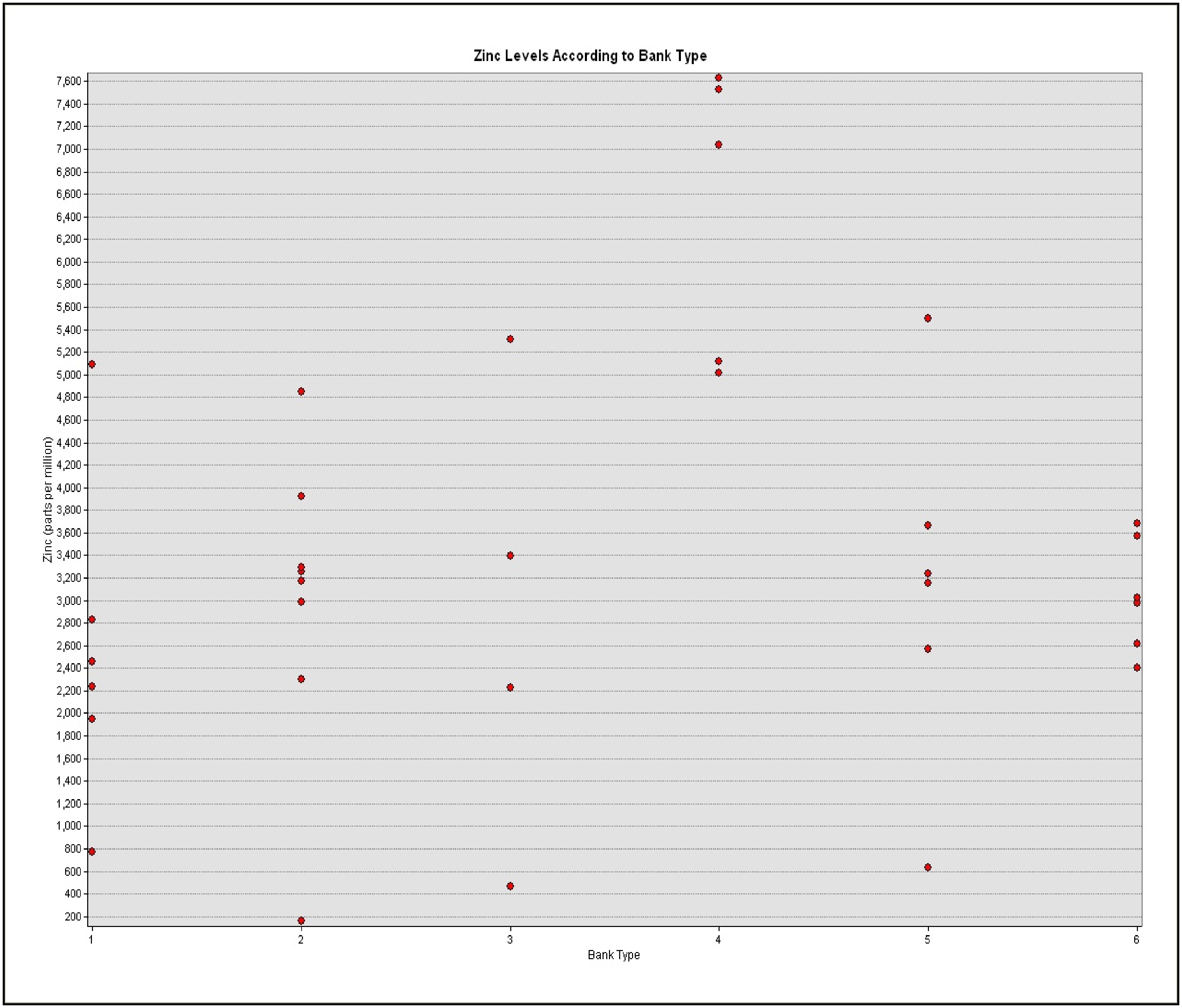
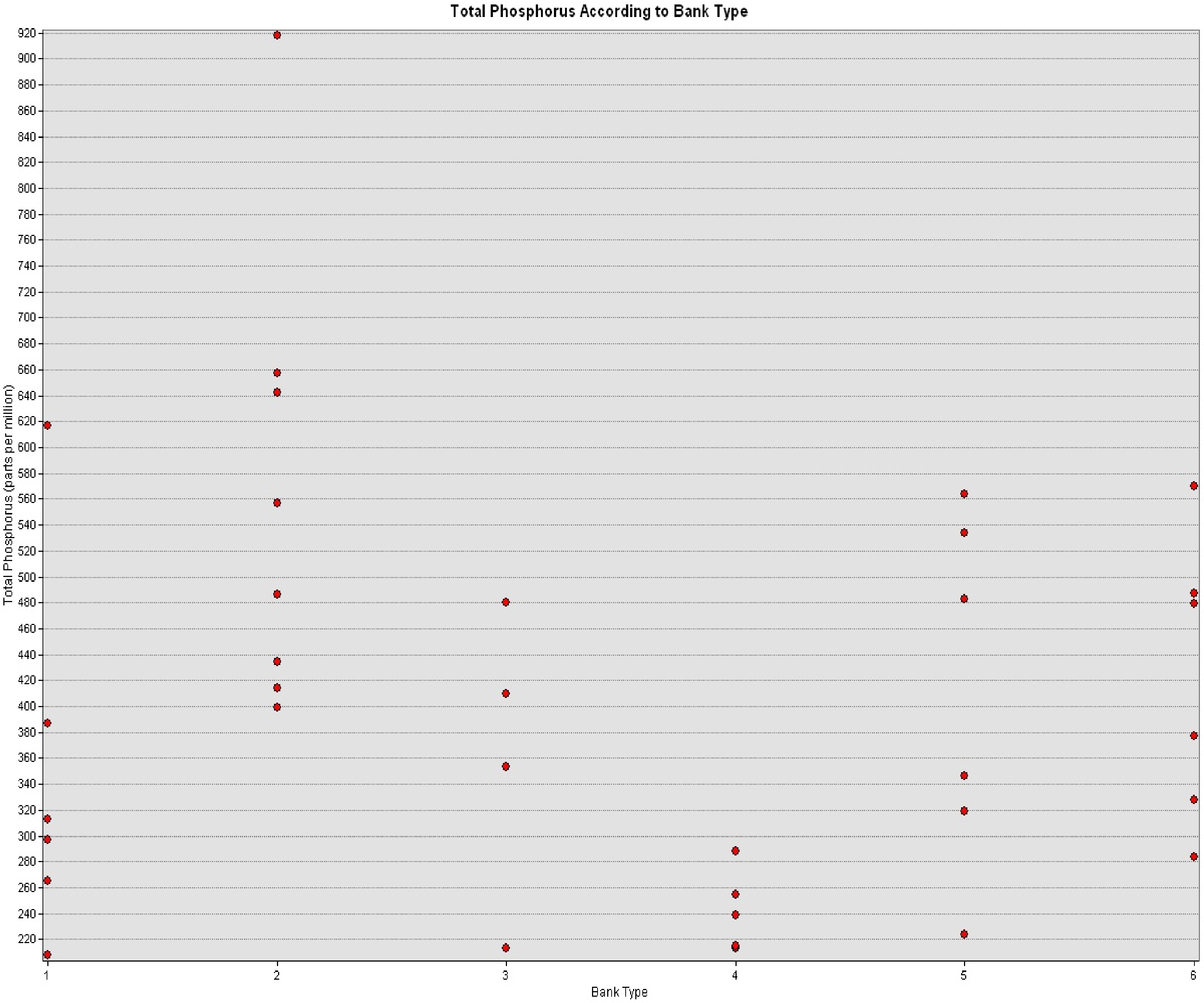


Figure 20. Total Phosphorus according to Bank Type



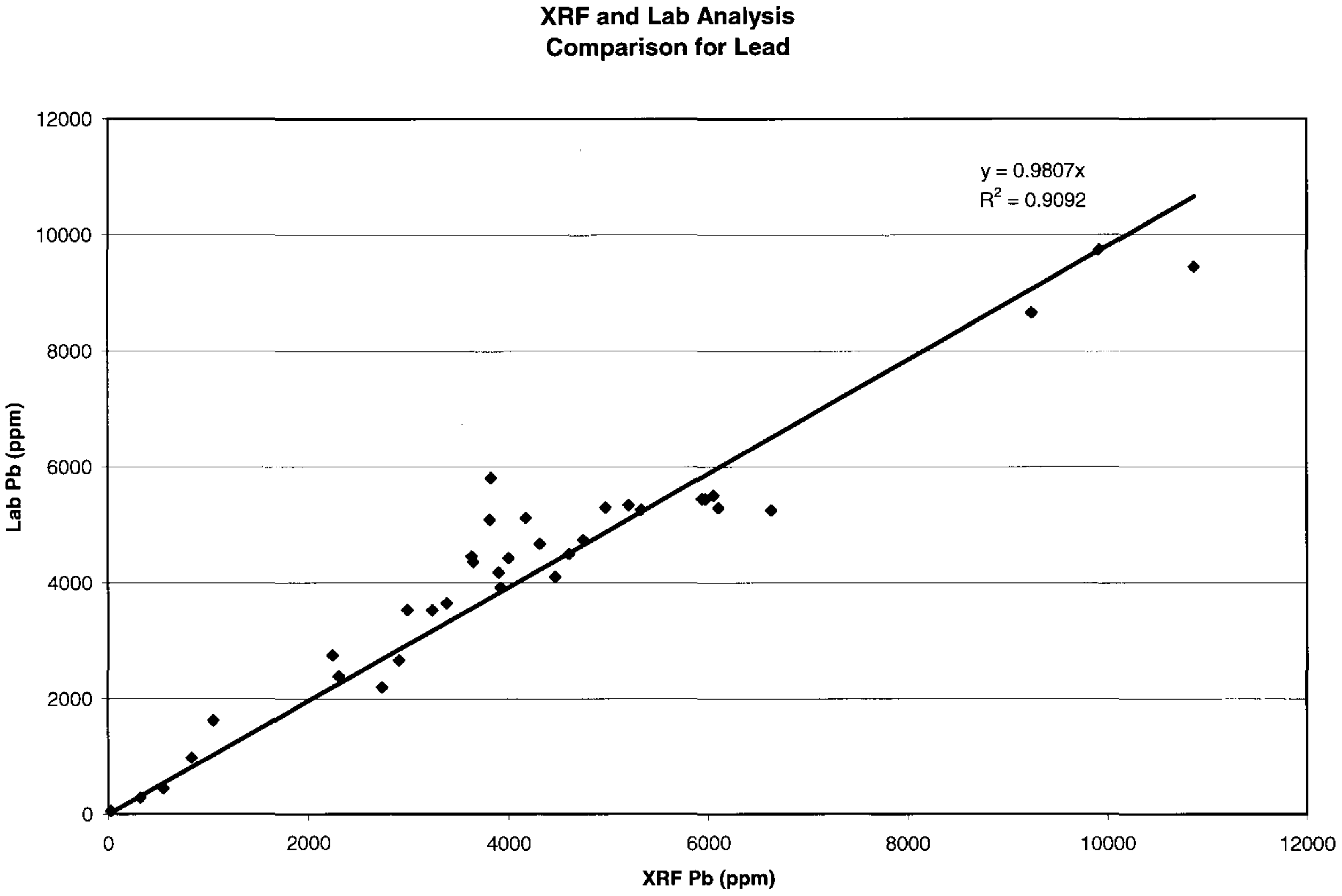
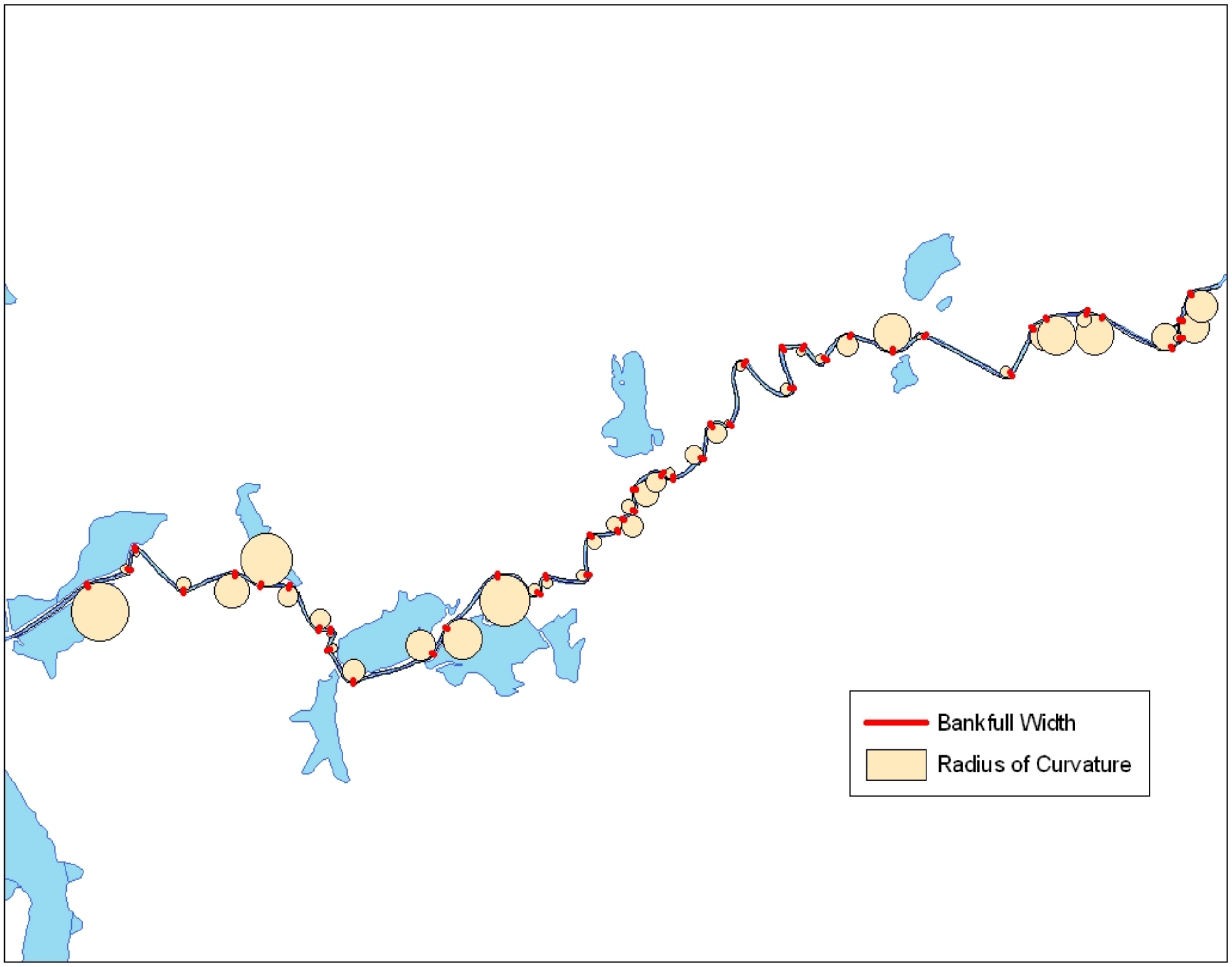


Figure 21. Comparison of XRF and lab analysis data for lead

Bankfull Width Measurements

On June 19, 2009, the bankfull width was measured at forty-four meanders using a Range Finder (Figure 22). The measurements were recorded and associated with the specific meander to be utilized in the bankfull width to radius of curvature ratio in the Near-Bank Stress assessment as described in *Watershed Assessment of River Stability and Sediment Supply*, (Rosgen, 2006).

Figure 22. Bankfull width measurement locations along with the associated meander (radius of curvature).



Estimated Recession Rate Analysis

(BANCS Model)

Bank Erosion Hazard Index (BEHI) and Near-Bank Stress (NBS) are two streambank erosion factors referenced in *Watershed Assessment of River Stability and Sediment Supply*, (Rosgen, 2006). By establishing the relationship between BEHI and NBS, bank recession rate (feet/year) can be estimated using the Bank Assessment for Non-point source Consequences of Sediment (BANCS) model (Rosgen, 2006).

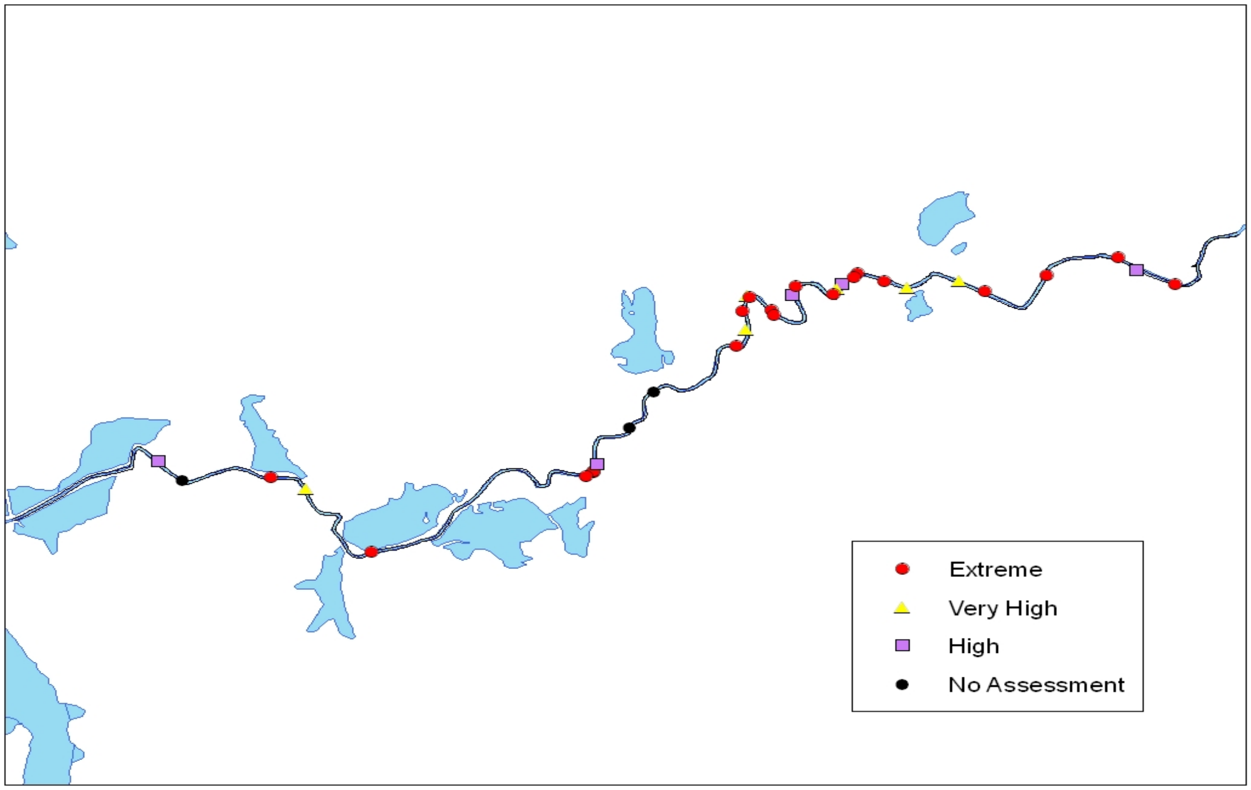
Bank Erosion Hazard Index (BEHI) Assessment

The BEHI assessment classified the riverbanks according to their susceptibility to erosion. The methodology and worksheet (worksheet 5-8, p. 5-56) are from *Watershed Assessment of River Stability and Sediment Supply*, (Rosgen, 2006). The assessment rates the following variables:

1. Study bank height/bankfull height (study bank-height ratio),
2. Root depth/bank height (root depth ratio),
3. Weighted root density,
4. Bank angle,
5. Surface protection,
6. Bank material, and
7. Stratification of bank material.

The sum of the individual variable rating scores produced a total score with an overall BEHI rating at each bank pin site (Figure 23).

Figure 23. BEHI rating at each bank pin site



This assessment was performed at each bank pin site location, excluding sites 12, 18, and 27. Site 12 and 27 were armored, and site 18 was missed in the assessment. The BEHI scores at each bank pin site location, with five site locations representing each bank type, were averaged to produce an average BEHI score and rating for each bank type (Table 5). According to this assessment, the Lower Coeur d'Alene riverbanks are all highly susceptible to erosion.

Table 5. BEHI rating score for Bank Types within the project extent.

Bank Type	Average BEHI Score	BEHI Rating
1	56.3	Extreme
2	50.3	Extreme
3	48.5	Extreme
4	58.2	Extreme
5	40.6	Very High
6	40.7	Very High

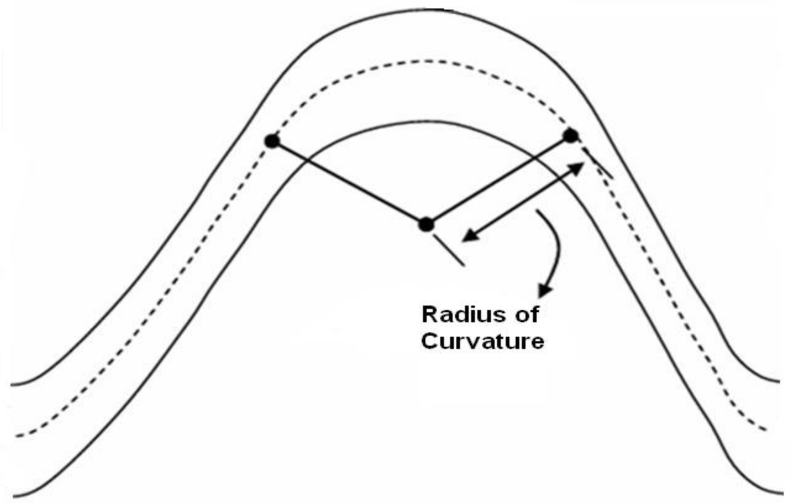
Near-Bank Stress (NBS) Assessment

Shear stress is the energy distribution from erosion processes acting on the banks and bottom of a channel. The main erosion processes on the lower Coeur d'Alene River banks is from river flow and boat wakes. These two processes act differently on the riverbanks. River flow is generally parallel to the banks and moves sediment toward and away from the bank, as well as downstream. Boat wakes impact the bank at an almost perpendicular angle, splashing up and down the bank. The sediment is dislodged from the impact, or if it is a permeable bank, also from the rapid inflow and outflow of water. Rosgen's Near-Bank Stress prediction methodology is more applicable to erosion from river flow, where there is a disproportionate distribution of shear stress in the near-bank region of flow. A higher near-bank stress correlates to a higher erosion rate on that near-bank region of the channel. There are seven different methods for determining an NBS rating in *Watershed Assessment of River Stability and Sediment Supply*, (Rosgen, 2006):

1. Channel pattern, transverse bar or split channel/central bar creating NBS/high velocity gradient,
2. Ratio of radius of curvature to bankfull width,
3. Ratio of pool slope to average water surface slope,
4. Ratio of pool slope to riffle slope,
5. Ratio of near-bank maximum depth to bankfull mean depth,
6. Ratio of near-bank shear stress to bankfull shear stress,
7. Velocity profiles/isovels/velocity gradient.

To determine NBS for erosion as a result of river flow on the lower Coeur d'Alene River, the ratio of radius of curvature to bankfull width was the preferred method since the radius of curvature can be determined using ArcGIS. The radius of curvature was created in ArcGIS. Using 2006 satellite imagery as a reference, the centerline of the river channel was determined. Circles were created within the inside meander and sized according to the tangency of the river channel centerline (Figure 24). The radius of the circle was calculated from the circumference. A visual display of the radius of curvature and bankfull width is provided in Figure 25, and Near-bank Stress rating in Figure 26.

Figure 24. Illustration of radius of curvature.



Previous studies, visual observations, and monitoring data suggested boat wakes create significant shear stress on banks in addition to that generated from river flow — especially on the inside meanders. Therefore, it was determined that NBS ratings along the entire banks of the project reach should not be less than "high" (Personal Communication, Dave Rosgen August 2009). Therefore, all NBS ratings less than "high" were adjusted to account for the high shear stress from boat wakes.

Figure 25. Radius of Curvature and Bankfull Width Display

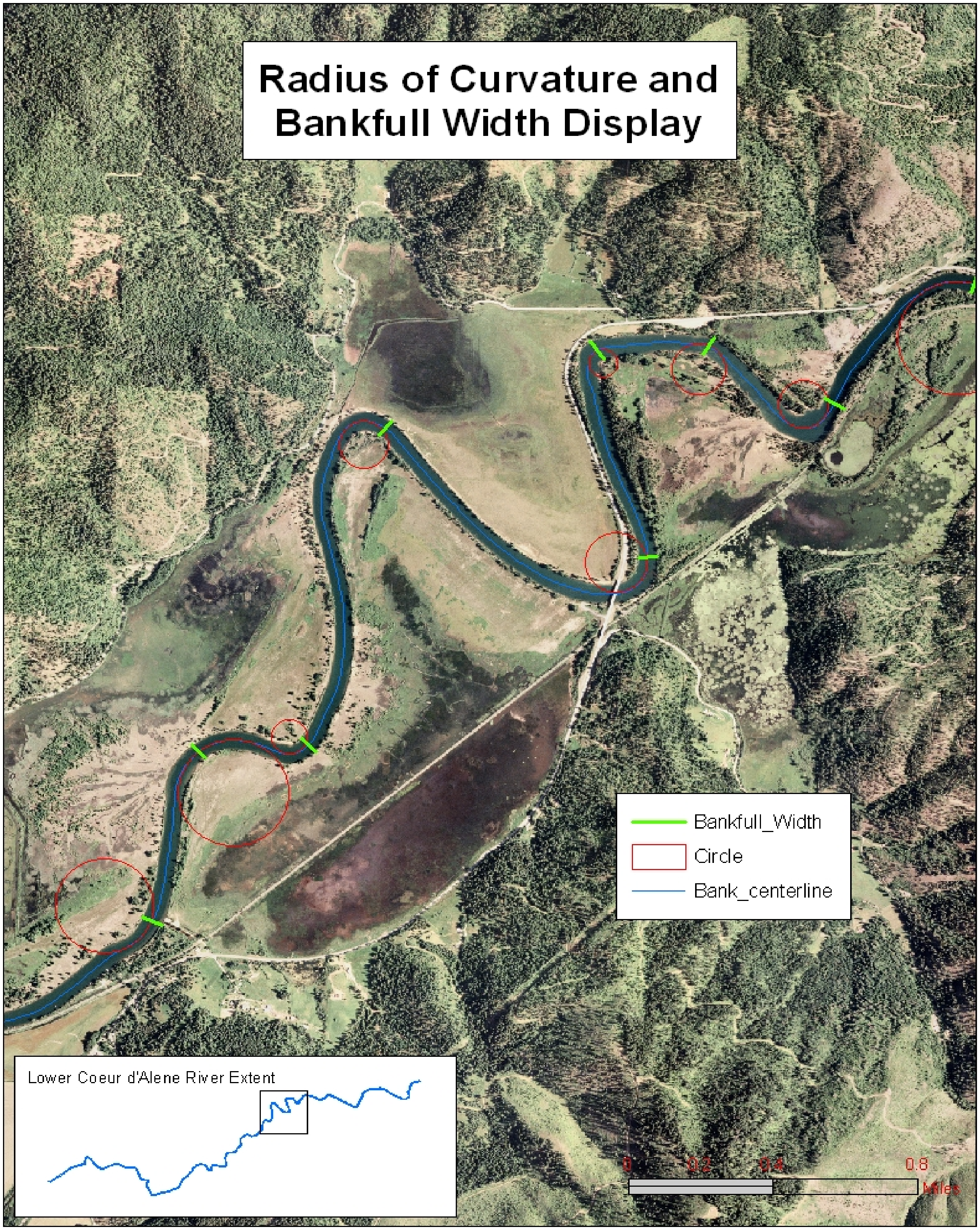
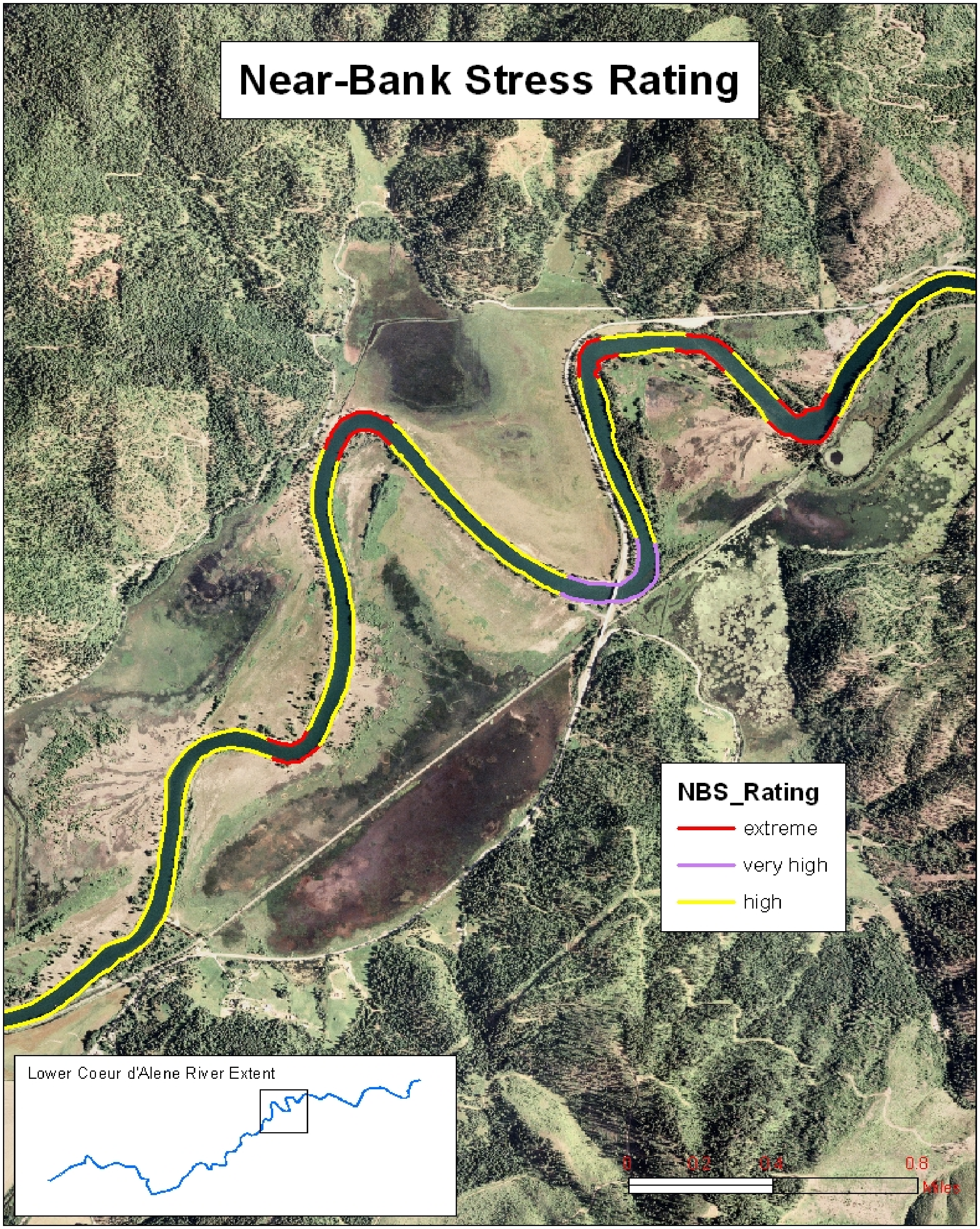


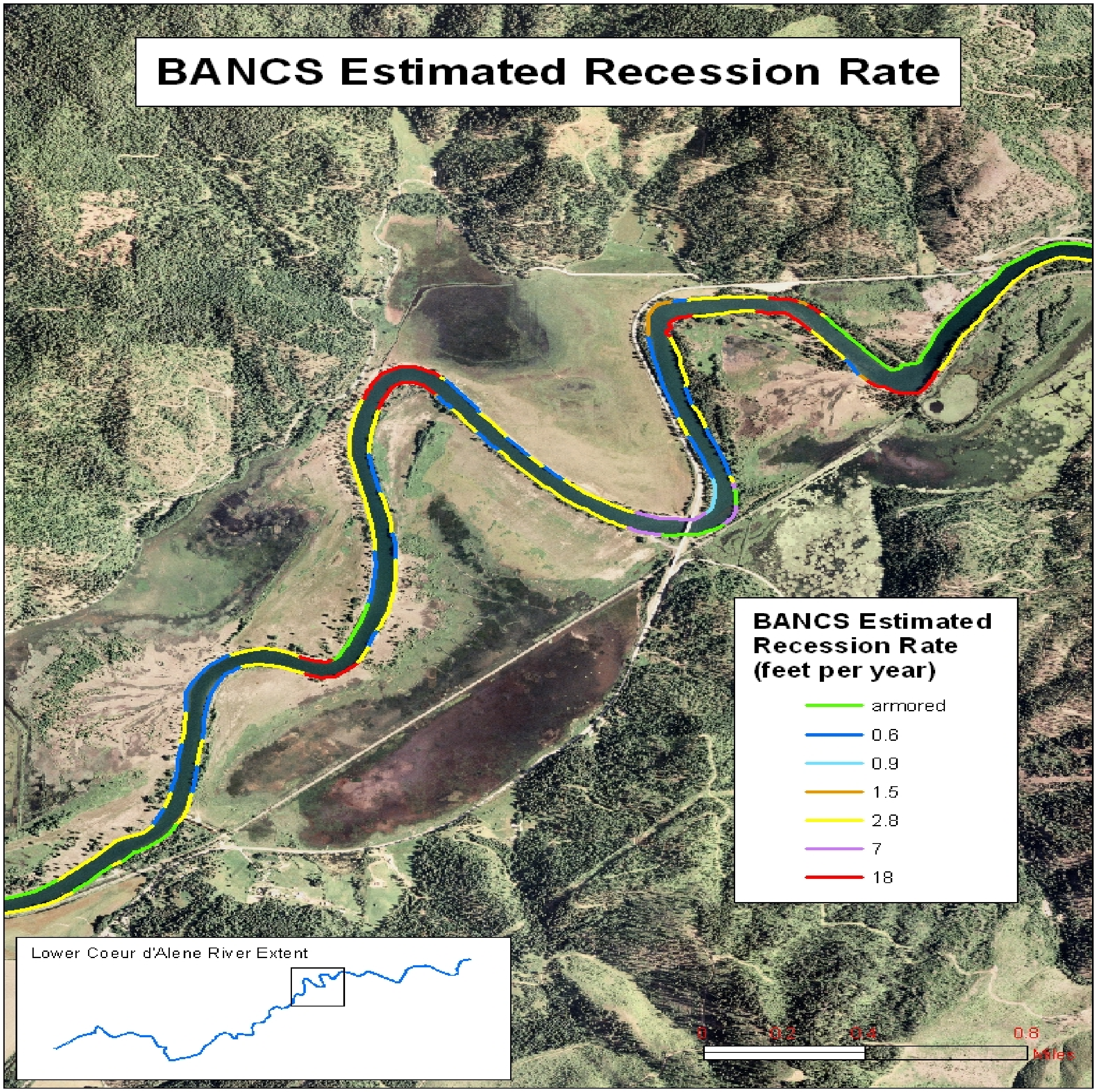
Figure 26. Near-Bank Stress rating for erosion as a result of river process. This rating was amended to account for erosion from boat wakes.



Estimated Recession Rate

The relationship between BEHI and NBS (ratio of radius of curvature to bankfull width) can establish an estimated bank recession rate (feet/year) for the Lower Coeur d'Alene River extent using the Bank Assessment for Non-point source Consequences of Sediment (BANCS) model (Rosgen, 2006). The prediction of annual streambank recession rates was based on Colorado United States Department of Agriculture Forest Service (1989) data for streams found in sedimentary or metamorphic geology. This estimated recession rate for the Lower Coeur d'Alene River was then evaluated for accuracy by comparing it with the actual recession rate measured at the pin site locations. A visual display of the estimated erosion rate is provided in Figure 27.

Figure 27. Estimated recession rate using the BANCS model



Comparison of Estimated Recession Rate and Measured Recession Rate

An important component of validation of the BANCS model estimate of recession rate on the Lower Coeur d'Alene River banks is a comparison with actual bank pin erosion monitoring data at select sites along the project extent. The scatter plot in Figure 28 compares the estimated bank recession rate (feet/year) using the BANCS model and the actual measured recession from July 16, 2008, to June 17, 2009, monitored using the horizontal bank pins. As evidenced in the graph, no solid relationship was established between the two methods.

Figure 28. Comparison of recession rate using BANCS model and measured recession rate

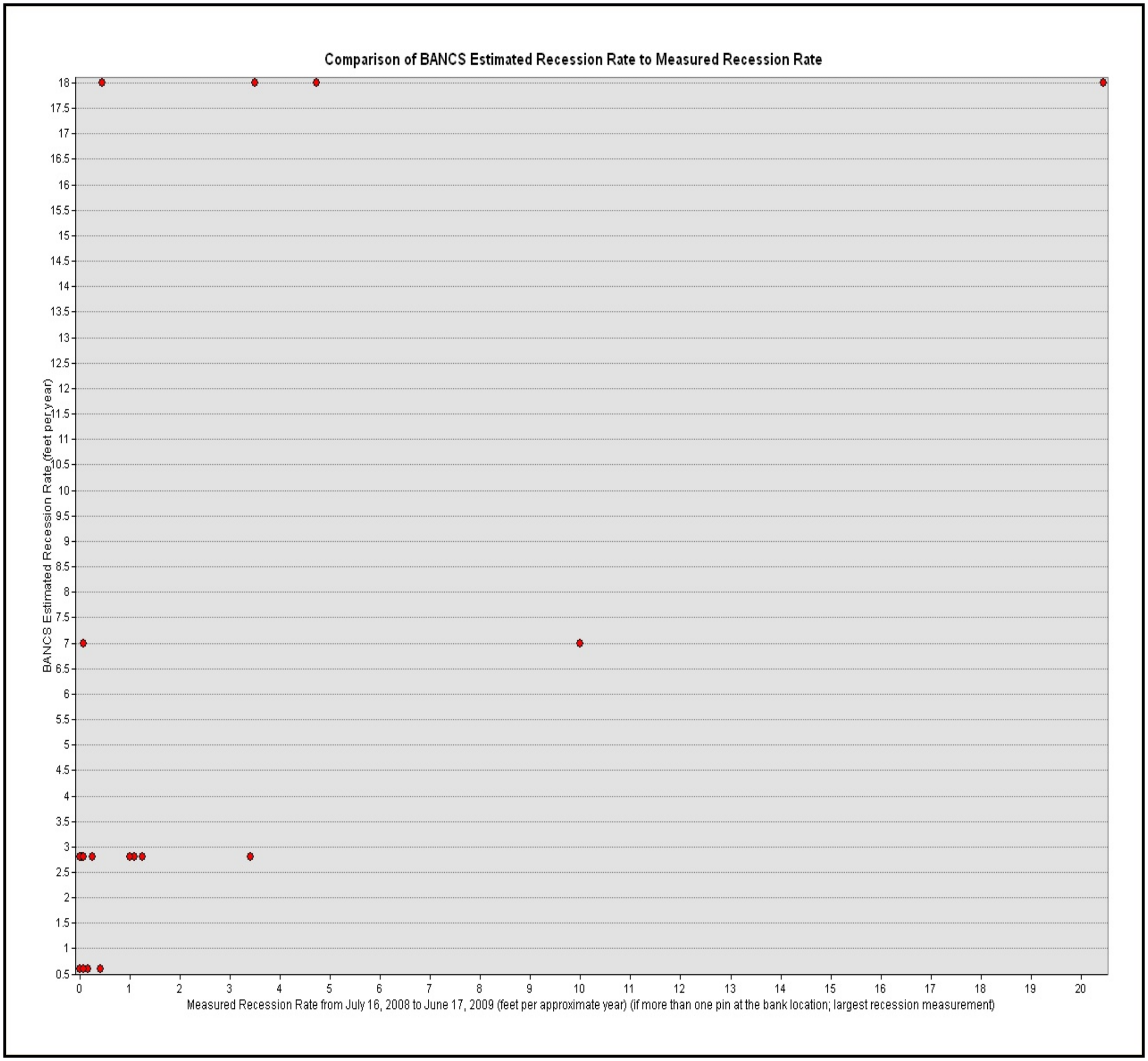
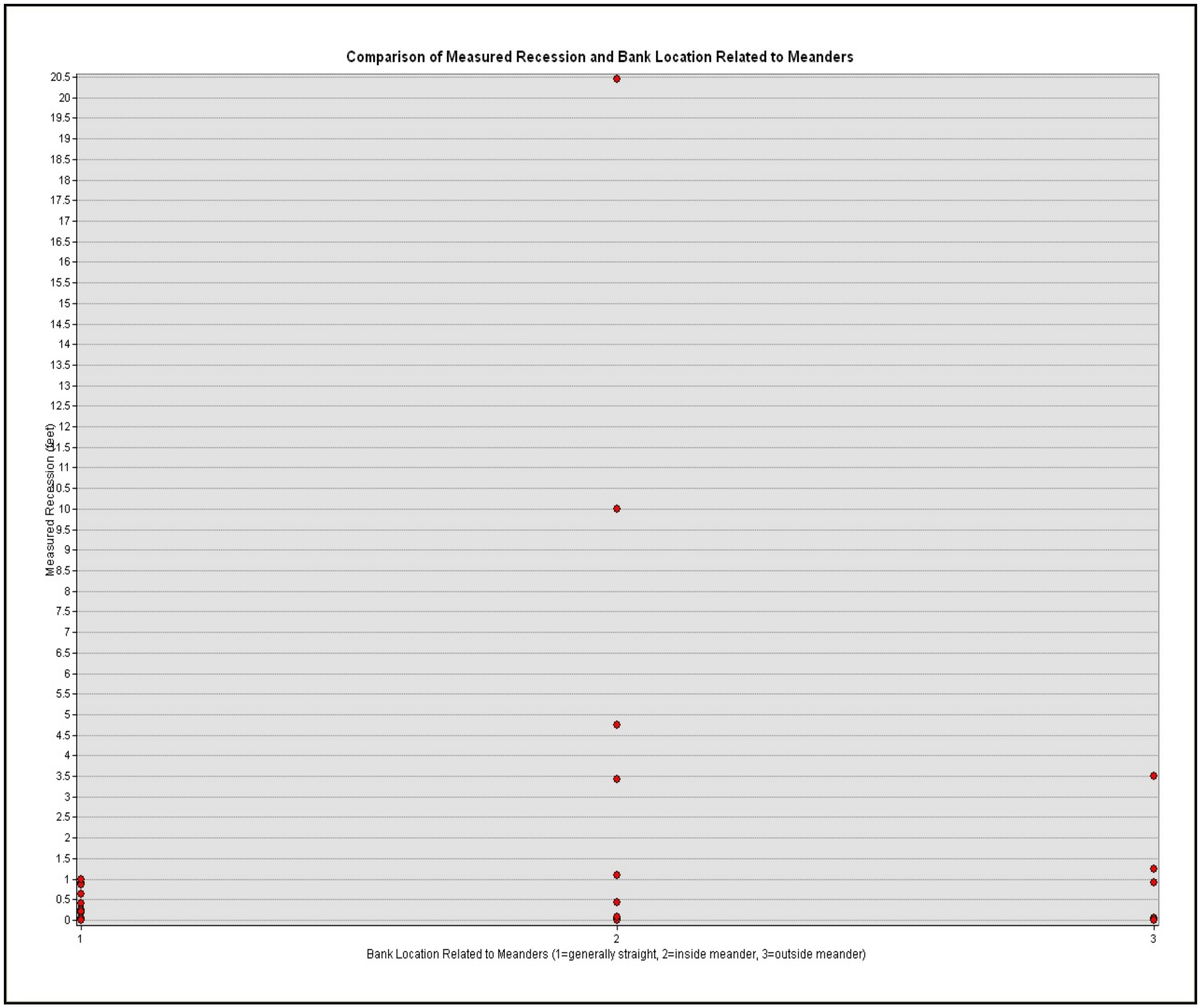
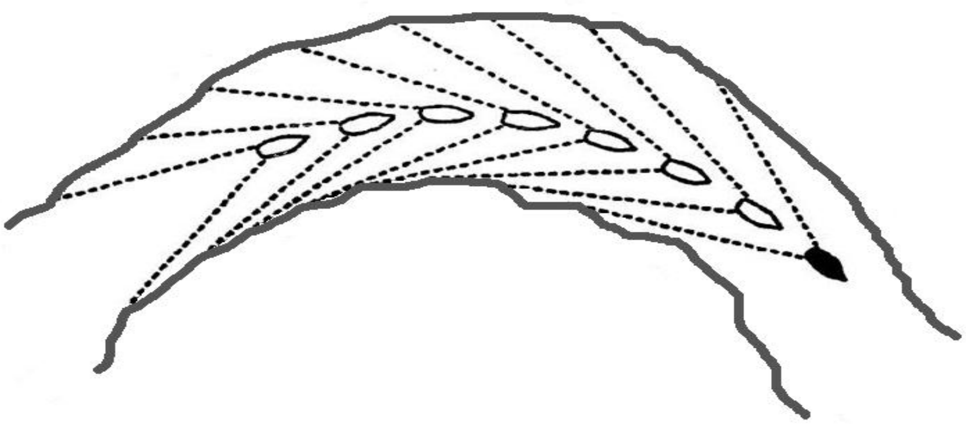


Figure 29. Comparison of measured recession and bank location related to meanders



This poor correlation can be attributed to several factors. The lower Coeur d'Alene River is a tailings-impacted, multi-stage channel due to upstream mining activity and backwater conditions during the summer. As such, Rosgen's Near Bank Stress prediction methodology and Bank Erosion Hazard Index may not apply to this system. The Near-Bank Stress methodology assumes disproportionate distribution of shear stress in the near-bank region of flow. However, during the season of inundation, erosion of the stream bank from boat wakes is a primary factor, with any shear stress from flow being relatively non-existent. This was evident on inside meanders of the river channel, which had a higher recession rate than the outside meanders during the first year of monitoring (Figure 29). In normal stream systems, the inside meanders are usually a depositional zone, creating sandy point bars. However, in systems that have high boat wake action, the highest stress is applied to the inside of the meander, where the wake energy is concentrated. This is illustrated in Figure 30. The inside meander in the Lower Coeur d'Alene system is therefore very dynamic.

Figure 30. Illustration of the concentration of boat wake energy on stream banks



In addition, Bank Type I had an Extreme Bank Erosion Hazard Index due to lack of vegetation and vertical banks. However, the tailings have created a cemented quality to the bank, which adds an element of protection of erosion thereby lowering the Bank Erosion Hazard Index. In the field, a unique erosion pattern was observed for the Type I, II and III banks, which were characterized by low root density and a bank angle of ninety degrees or greater. This erosion pattern was evidenced by undercutting, then slumping of bank in large blocks. Monitoring data suggests the frequency of this erosion pattern is likely greater than year time span. A few of the bank pin site locations did capture the loss of bank through slumping of a large block of bank, while others showed the undercutting phase of this pattern. The pictures in Figure 31 display two phases of this bank erosion pattern. In conclusion, more years of measured recession data will better capture and quantify this pattern and may validate the use of Rosgen BANCS methodology for estimating bank recession rates.

Figure 31. Undercutting and severe slumping of banks on the Lower Coeur d'Alene River.

Future Monitoring

Bank pin monitoring will continue along the lower Coeur d’Alene River to better understand the relationship between recession at the inside bank compared to the outside bank of a meander. Additional bank pins were installed during the last monitoring event on June 17, 2009. These new sites not only replaced some of the original sites that no longer exist, but were strategically located to optimize distributions among several variables. The variables include bank type, bank side, bank location with reference to meanders, and the radius of curvature classification. Future monitoring may explain the relationship of the variable to the recession rate. ArcGIS was used to represent a distribution within these variables while minimizing the amount of new sites, with the primary purpose for the new sites to be placed on the inside and outside bank of a meander. Nineteen new sites were added to the twenty-eight existing sites for a total of forty-seven current sites (eighty-three pins total). Within this total, twelve meanders have bank pin site locations capturing the recession on the inside and outside banks of the meander (Figure 32 and Table 6).

Figure 32. Current bank pin site locations (June 17, 2009).

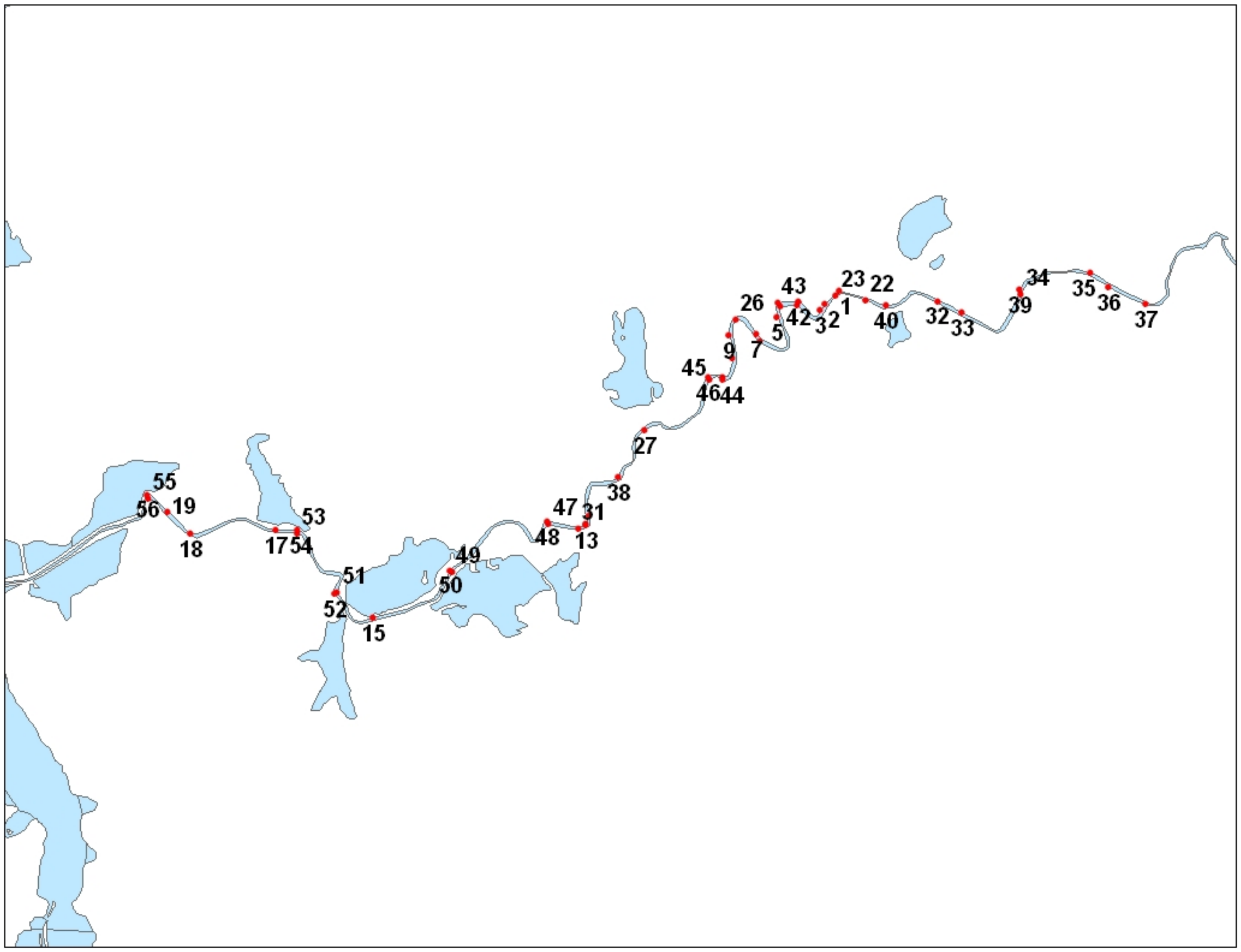
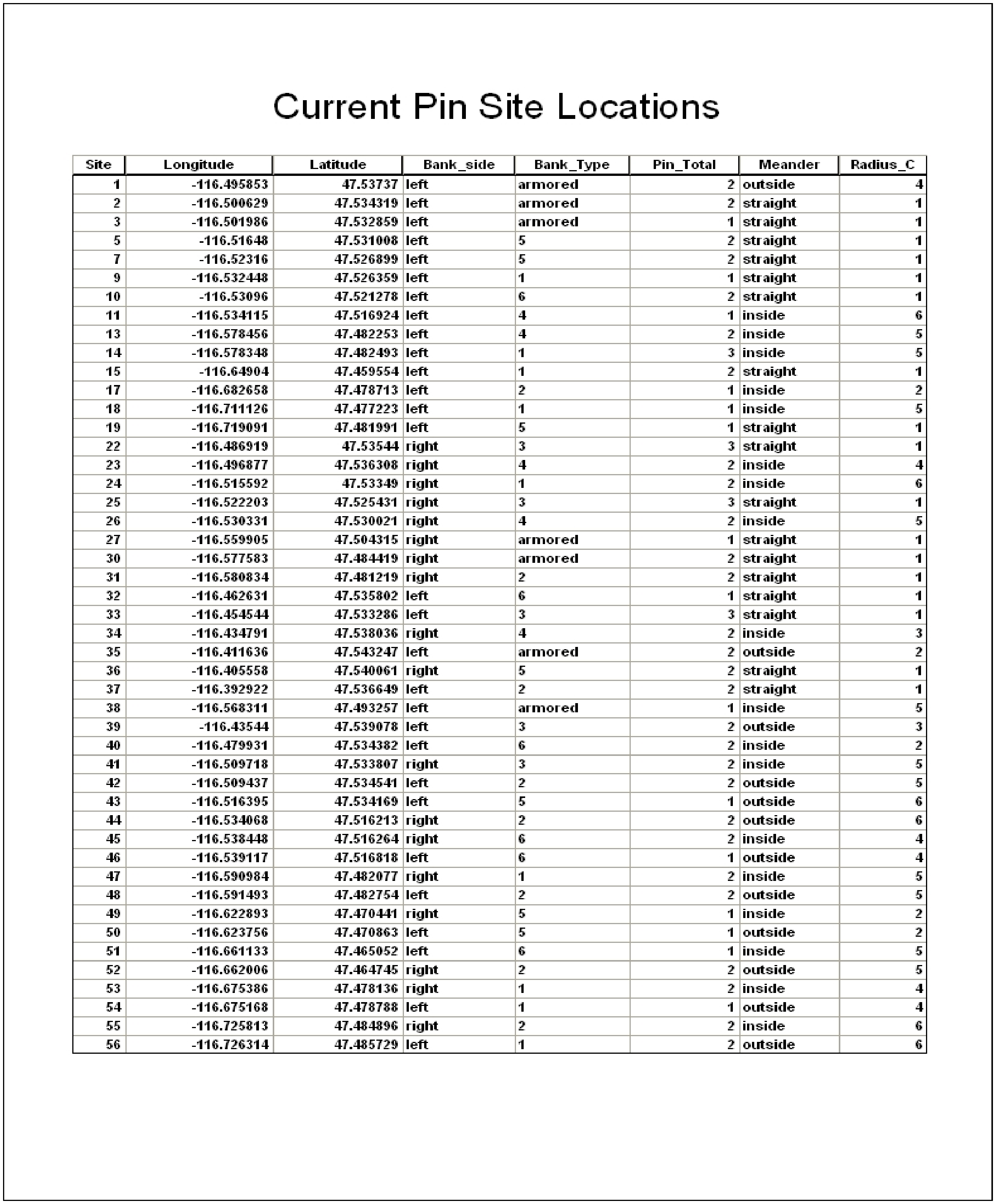


Table 6. Current bank pin site locations (June 17, 2009).



Current Pin Site Locations

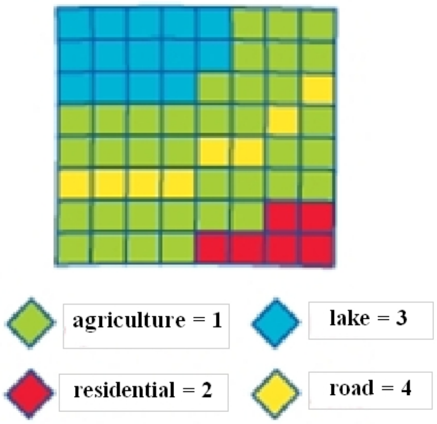
Site	Longitude	Latitude	Bank_side	Bank_Type	Pin_Total	Meander	Radius_C
1	-116.495853	47.53737	left	armored	2	outside	4
2	-116.500629	47.534319	left	armored	2	straight	1
3	-116.501986	47.532859	left	armored	1	straight	1
5	-116.51648	47.531008	left	5	2	straight	1
7	-116.52316	47.526899	left	5	2	straight	1
9	-116.532448	47.526359	left	1	1	straight	1
10	-116.53096	47.521278	left	6	2	straight	1
11	-116.534115	47.516924	left	4	1	inside	6
13	-116.578456	47.482253	left	4	2	inside	5
14	-116.578348	47.482493	left	1	3	inside	5
15	-116.64904	47.459554	left	1	2	straight	1
17	-116.682658	47.478713	left	2	1	inside	2
18	-116.711126	47.477223	left	1	1	inside	5
19	-116.719091	47.481991	left	5	1	straight	1
22	-116.486919	47.53544	right	3	3	straight	1
23	-116.496877	47.536308	right	4	2	inside	4
24	-116.515592	47.53349	right	1	2	inside	6
25	-116.522203	47.525431	right	3	3	straight	1
26	-116.530331	47.530021	right	4	2	inside	5
27	-116.559905	47.504315	right	armored	1	straight	1
30	-116.577583	47.484419	right	armored	2	straight	1
31	-116.580834	47.481219	right	2	2	straight	1
32	-116.462631	47.535802	left	6	1	straight	1
33	-116.454544	47.533286	left	3	3	straight	1
34	-116.434791	47.538036	right	4	2	inside	3
35	-116.411636	47.543247	left	armored	2	outside	2
36	-116.405558	47.540061	right	5	2	straight	1
37	-116.392922	47.536649	left	2	2	straight	1
38	-116.568311	47.493257	left	armored	1	inside	5
39	-116.43544	47.539078	left	3	2	outside	3
40	-116.479931	47.534382	left	6	2	inside	2
41	-116.509718	47.533807	right	3	2	inside	5
42	-116.509437	47.534541	left	2	2	outside	5
43	-116.516395	47.534169	left	5	1	outside	6
44	-116.534068	47.516213	right	2	2	outside	6
45	-116.538448	47.516264	right	6	2	inside	4
46	-116.539117	47.516818	left	6	1	outside	4
47	-116.590984	47.482077	right	1	2	inside	5
48	-116.591493	47.482754	left	2	2	outside	5
49	-116.622893	47.470441	right	5	1	inside	2
50	-116.623756	47.470863	left	5	1	outside	2
51	-116.661133	47.465052	left	6	1	inside	5
52	-116.662006	47.464745	right	2	2	outside	5
53	-116.675386	47.478136	right	1	2	inside	4
54	-116.675168	47.478788	left	1	1	outside	4
55	-116.725813	47.484896	right	2	2	inside	6
56	-116.726314	47.485729	left	1	2	outside	6

Streambank Stabilization Prioritization Overlay

Another goal of this project was to develop a prioritization schema, with which one could use to guide bank stabilization efforts on the lower Coeur d'Alene River. ArcGIS was utilized to prioritize the riverbank within the project extent for future stabilization efforts. The factors considered in this prioritization were the bank's susceptibility to erosion (Bank Erosion Hazard Index), the stress applied by erosion processes (Near-Bank Stress), and the amount of heavy metal contamination (lead concentration and depth). These factors were used to produce a final Streambank Stabilization Prioritization Overlay (Prioritization Overlay) using ArcGIS Each of the factors (BEHI, NBS, Lead Concentration, Lead Depth) required a common rating and geographic reference along the riverbank.

In order to use the weighted overlay in ArcGIS, the data needed to be represented in a raster. A raster is a grid of equally sized cells arranged in rows and columns, composed of single or multiple bands. Each cell contains a value and location coordinates. This is similar to pixels on a television or computer screen, with the pixel cells containing the color value (multiple bands: red, blue, and green). Figure 33 shows an example raster with cell values defining certain land features. The cell values are numeric, so the value of 1 would represent agriculture, 2 a residential designation, 3 a lake, and 4 a road.

Figure 33. Example raster grid



The cell size for the rasters used in the weighted overlay were five meters by five meters with a cell value based on a rating scale. This rating scale was used for each factor for a common numbering system in the weighted overlay and rating classification is based on the BEHI rating (Table 7).

Table 7. Raster rating scale for each factor

Raster Value	Raster Rating
1	Very Low
2	Low
3	Moderate
4	High
5	Very High
6	Extreme

Bank Erosion Hazard Index (BEHI) Raster

The BEHI raster to be used in the Prioritization Overlay was created from the line feature by assigning a raster value to segments of a line feature according to BEHI score (Table 8). Bank type 5 and 6 were given a value 5 (Very High) and types 1, 2, 3, and 4 were given the value 6 (Extreme). The armored banks were given a value of 0 and a score of NA (not applicable). The armored banks were excluded from the assessment and the overlay prioritization. A visual display is provided in Figure 34 and 35. A rating distribution graph visually displays the comparison among the raster values within the entire extent. The y value is the raster cell count. The tick marks are every one thousand cells.)

Table 8. Raster rating for BEHI scores within the project extent.

Raster Value	BEHI Score Range	BEHI Rating
6	>45	Extreme
5	40-45	Very High
1-4	None present in project extent	
0	NA	Armored

Figure 34. raster cell count for BEHI rating

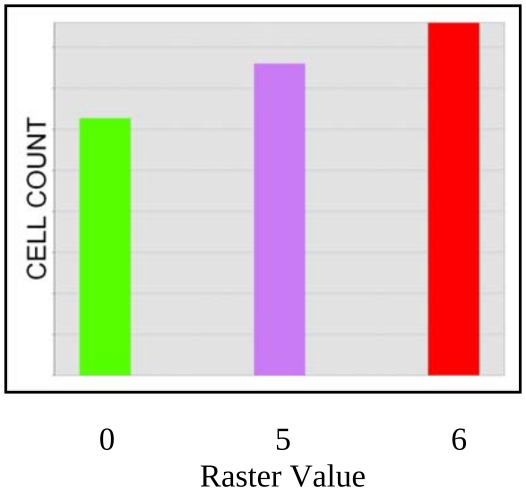
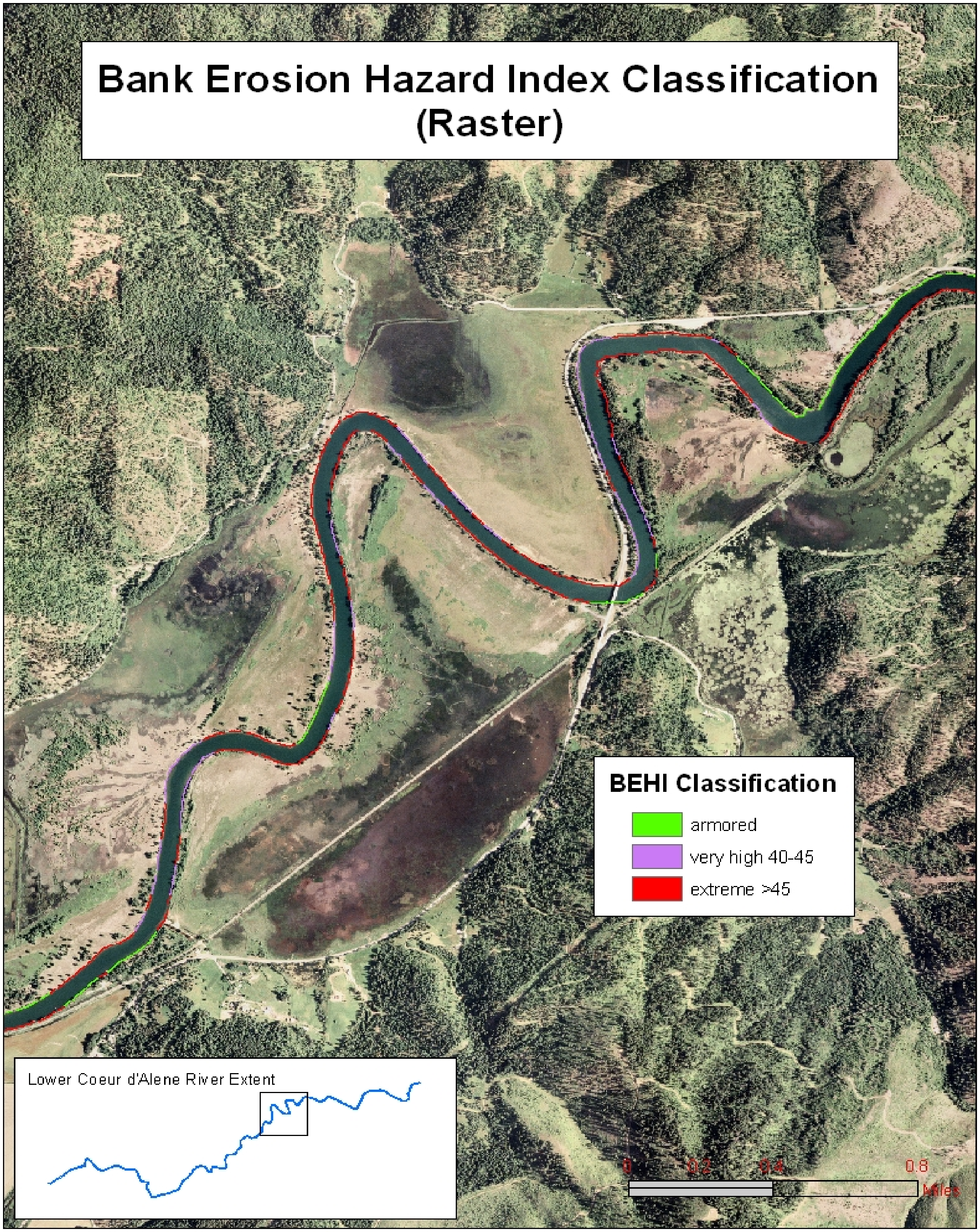


Figure 35. Bank Erosion Hazard Index classification



Radius of Curvature Raster

Because shear stress is applied both to the inside and outsite banks of a meander on the Coeur d'Alene River, Rosgen's Near Bank Stress could not be used as a factor in the Prioritization Overlay. Therefore, shear stress on both the inside and outside meander was weighted equally in the Prioritization Overlay, and radius of curvature became the only factor used to account for shear stress on the banks. To determine the radius of curvature of the meanders of the river, the bank line feature was segmented to represent three features: 1) the bank of an inside meander, 2) the bank of an outside meander, and 3) the bank along a generally straight section of the river (Table 9). The corresponding radius for that meander was also transferred to this line feature. Five classes were defined according to the radius, along with the banks in the generally straight sections of the river. The line feature was then converted to a raster to be used in the Prioritization Overlay. A visual display is provided in Figure 36 and 37.

Table 9. Raster rating for radius of curvature classification

Raster Value	Radius of Curvature Classification	Rating
1	generally straight	Very Low
2	400-750m radius	Low
3	300-400m radius	Moderate
4	200-300m radius	High
5	100-200m radius	Very High
6	50-100m radius	Extreme

Figure 36. Radius of Curvature Rating Distribution

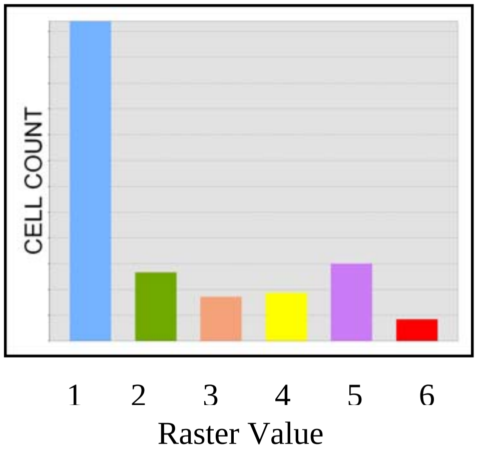
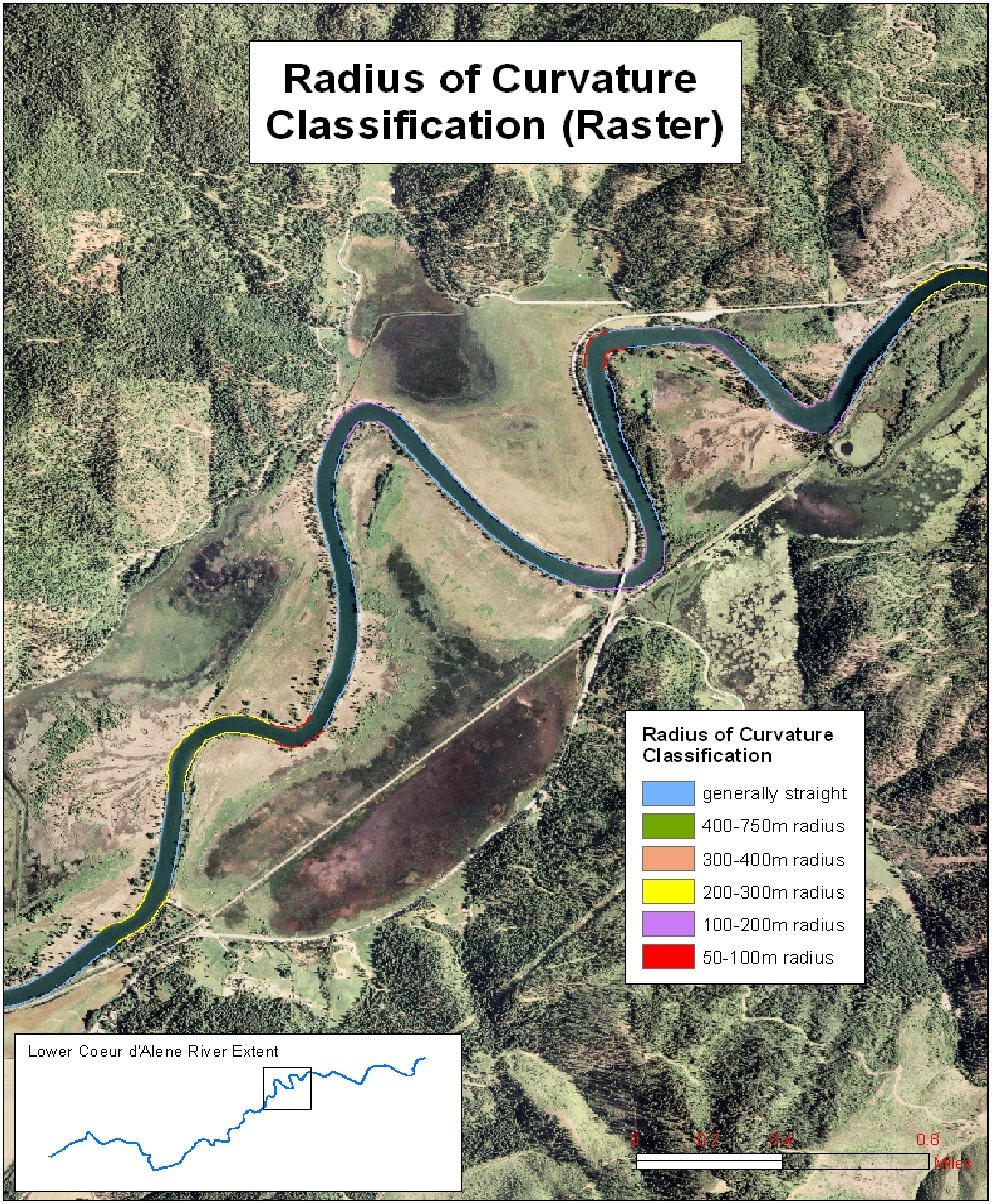


Figure 37. Radius of Curvature Classification (Raster)



Riverbank Lead Concentration and Depth Raster

The heavy metal contaminant lead was included in the Prioritization Overlay due to its negative impact to human health and the ecological environment. Other heavy metal contaminants could have been incorporated, but lead had the largest amount of soil sample data (control points), with an even distribution of those sites, thus providing a better interpolation of that data. The raster interpolation of the soil sample sites was created as a general depth-weighted average to represent lead concentration along the banks of the river.

In addition to the soil sample data collected at the bank pin site locations, the control points for the interpolation of lead concentration and depth were obtained from the USGS 2001 Open-File Report 01-140, *Lead-Rich Sediments, Coeur d'Alene River Valley, Idaho: Area, Volume, Tonnage, and Lead Content*, (Bookstrom & Box, 2001). The interpolation estimates a surface value based on the known value of the soil sample sites, or control points. The Kriging method was employed to weight the control points based on the distance between the points, the prediction locations, and the overall spatial arrangement among points. The end product is a surface distribution or raster based on the known values of the control points.

Riverbank Lead Concentration

Eighty-two soil sample sites, thirty-four sampled in this study and forty-eight in the 2001 USGS study, were interpolated from control pointsalong the riverbank to produce the lead concentration raster used in the Prioritization Overlay. The concentration is in parts per million (ppm). The interpolation was performed using ArcGIS to produce a Lead Concentration raster. This provides a depth-weighted average of the lead concentration of the banks within the study area (Table 10). A visual display is provided in Figure 38 and 39.

Table 10. Raster rating for lead concentration classification.

Raster Value	Lead Concentration Classification	Rating
1	2,200-2,500 ppm	Very Low
2	2,500-3,000 ppm	Low
3	3,000-4,000 ppm	Moderate
4	4,000-6,000 ppm	High
5	6,000-10,000 ppm	Very High
6	10,000-18,400 ppm	Extreme

Figure 38. Lead Concentration Rating Distribution

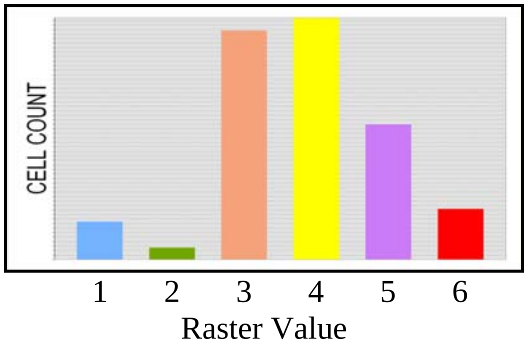
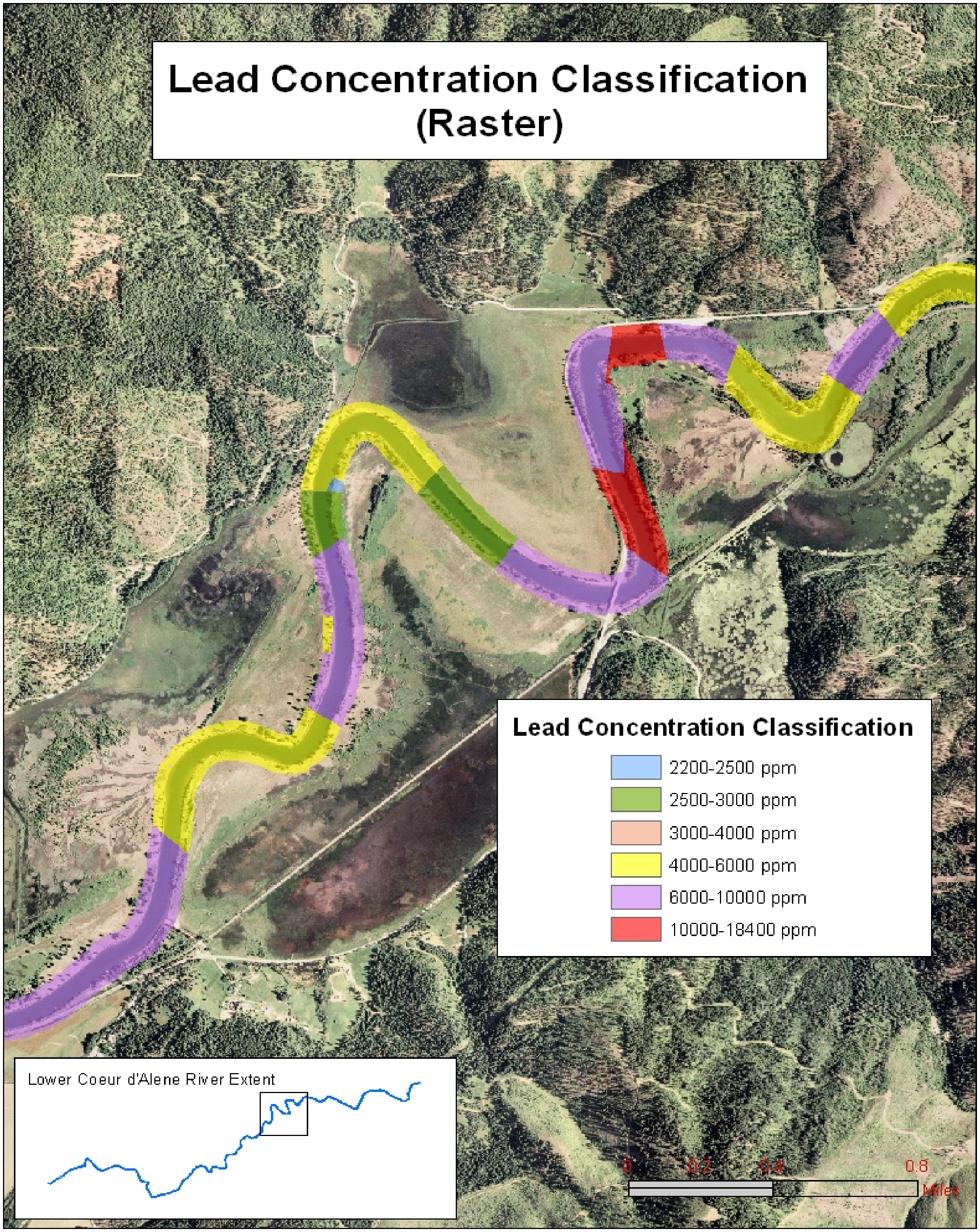


Figure 39. Lead concentration classification.



Riverbank Lead Depth Raster

Eighty-four soil sample sites, all from the 2001 USGS study, were interpolated along the riverbank to produce the lead depth raster used in the Prioritization Overlay. The depth was determined using a minimum threshold of one thousand ppm, which encompasses the sedimentation related to upstream mining activity. The depth does not represent the bank height, rather the depth of the sediment with a lead concentration of one thousand ppm or higher. The interpolation was performed using ArcGIS, based on the eighty-four samples, to produce a Lead Depth raster. This provides a general surface distribution of the lead depth for the banks within the study area (Table 11). A visual display is provided in Figure 40 and 41.

Table 11.Raster rating for radius of curvature classification

Raster Value	Lead Depth Classification	Rating
1	0.5-1 foot	Very Low
2	1-2 feet	Low
3	2-3 feet	Moderate
4	3-4 feet	High
5	4-5 feet	Very High
6	5-7 feet	Extreme

Figure 40. Lead Depth Rating Distribution

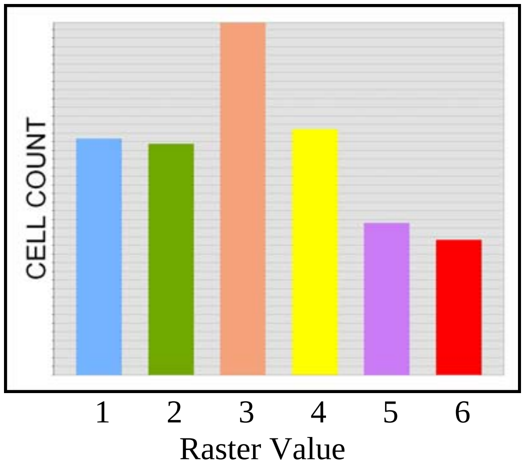
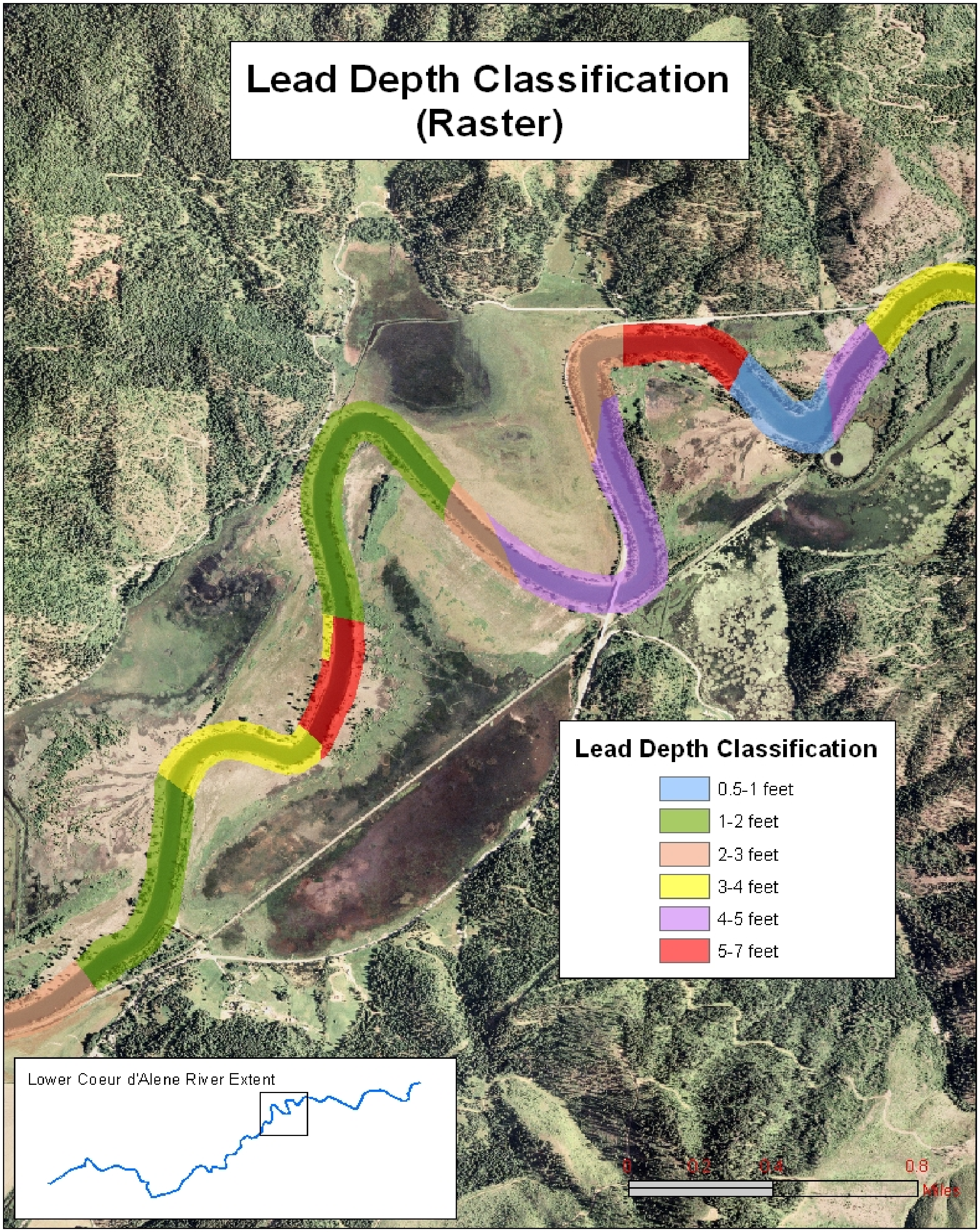


Figure 41. Lead depth classification.



Overlay

The factors in streambank stabilization prioritization were the bank’s susceptibility to erosion (Bank Erosion Hazard Index), the radius of curvature (which directly relates to shear stress), and the amount of heavy metal contamination (lead concentration and depth). These four factors determined the Prioritization Overlay using a weighted overlay in ArcGIS. Each factor is represented in a raster of five meter by five meter cells, which are all in alignment. The weighting was determined by classifying BEHI and radius of curvature as erosion factors and lead concentration and depth as heavy metal contaminant factors. It was established that the heavy metal contaminant factors had a high importance, so should receive a higher weighted percentile. The factors within those classes remained at equal importance. The percentile weighting is displayed in Table 12:

Table 12. Percentile weighting of prioritization factors.

Factor Classification	Percentile	Factor	Weighted Percentile
Erosion	40%	BEHI	20%
		NBS	20%
Heavy Metal Contaminant	60%	Lead Concentration	30%
		Lead Depth	30%

This next table shows an example of how the overlay cell is calculated for the four overlapping factor cells, similar to stacking blocks (five meters by five meters). Each block, or factor, has a raster value that is multiplied by its weighted percentile. The stack of blocks is then summed and rounded to the nearest whole number for the Prioritization Overlay output raster value, which is the single block that is left (Table 13).

Table 13. Raster weighted values for prioritization classification factors.

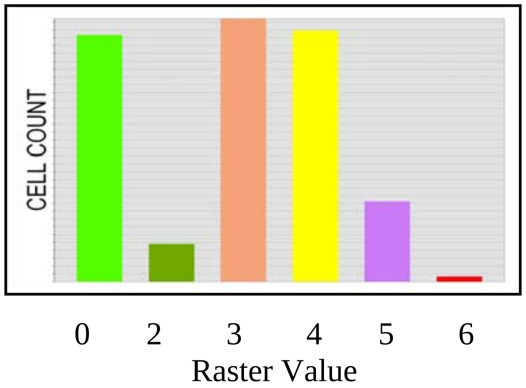
Factor	Raster Value	Raster Rating	Weighted Percentile	Weighted Value
BEHI	5	Very High	20%	1.0
NBS	3	Moderate	20%	0.6
Lead Concentration	5	Very High	30%	1.5
Lead Depth	2	Low	30%	0.6
Prioritization Overlay	4	High		sum of 3.7

The overlay output value is calculated for each cell and rated accordingly (Table 14). The armored banks were not rated, but were included as a separate class with a raster value of 0. A visual display is provided in Figure 42 and 43.

Table 14. Prioritization Overlay Rating

Raster Value	Raster Rating
0	Armored
1	Very Low
2	Low
3	Moderate
4	High
5	Very High
6	Extreme

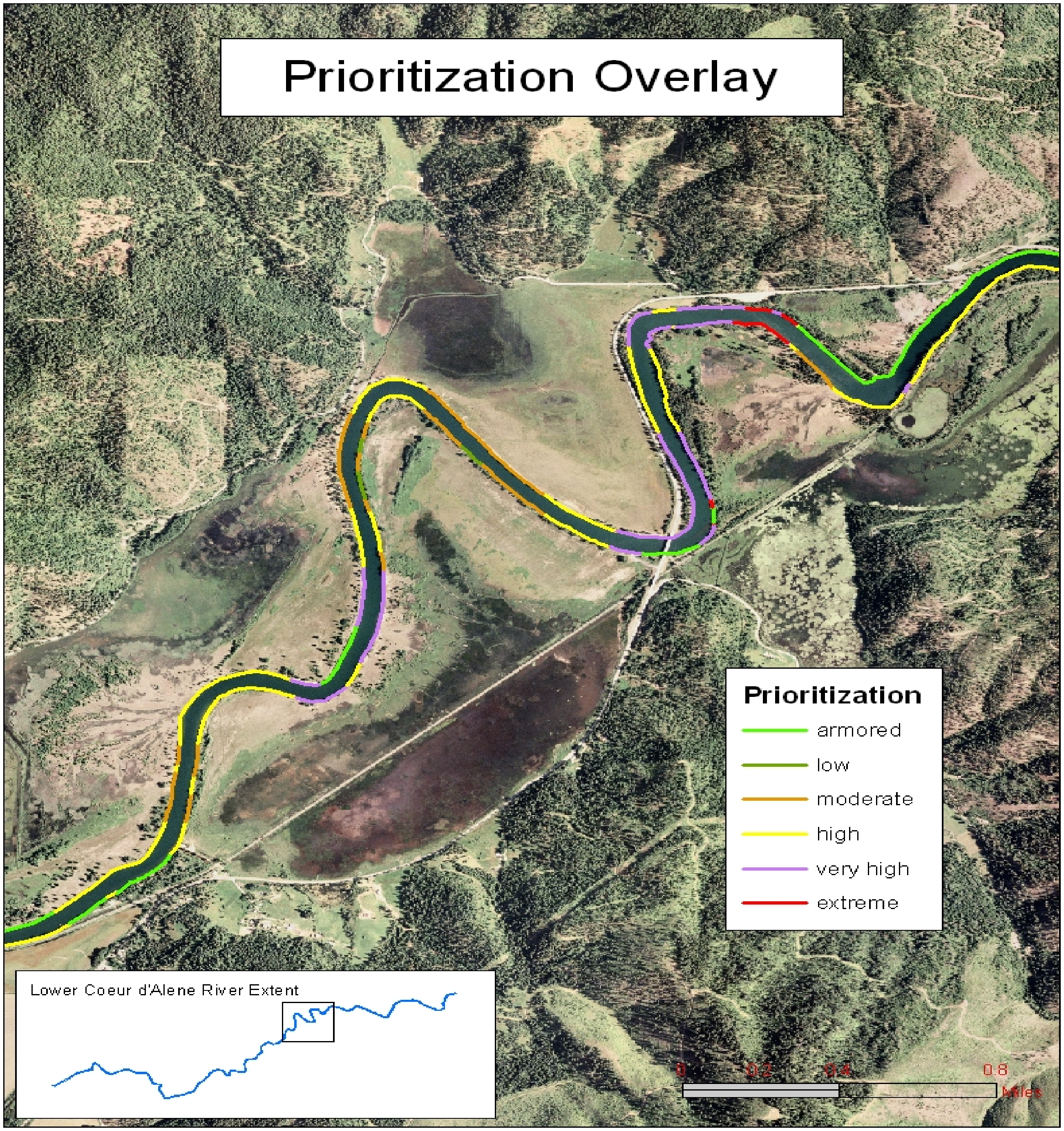
Figure 42. Prioritization Overlay Rating Distribution



Overlay Outcome

The final product for the Prioritization Overlay was a line feature, representing the banks along the Lower Coeur d'Alene River, which was rated from very low to extreme (Figure 43). The armored banks were included but not rated. This data can be utilized as a guide in determining where stabilization efforts could be focused. This data is available in digital format or could be produced on a hardcopy map from a plotter. The process could be used in other scenarios or additional factors could be added.

Figure 43. Prioritization Overlay for bank stabilization



Recommendations

This project was intended to start the process of monitoring the bank recession and not necessarily to conclude with a definitive answer on the topic. Several years of recession data would provide a better understanding of the bank recession and its relationship to bank characteristics. The ideal goal is that monitoring will be performed twice a year (two field days per monitoring) for at least another two years. The project was designed to be built on and utilized by others.

Past studies have attributed the majority of the recession to boat wake activity. The significant recession observed on the inside meander banks support that statement. This study focused more on the effects and not the causes of bank recession. A monitoring of boat frequency and boat wake height in combination with the recession rate would be beneficial. Future bank pin monitoring of the relationship between the recession on the inside and outside bank of a meander will provide supporting information.

Visual observation of the bench along the inside meander (bank pin site locations 11 and 13) of the river channel revealed that large portions had been swept away during the Spring 2009 runoff. A rough estimate at site 11 would be about forty cubic yards and site 13 would be over one hundred cubic yards of sediment (Figure 44 through 47, arrows point to bench). This bench should be monitored to understand the dynamics of the flow and sediment transport caused by the dual erosion action from boat wakes and river flow, both of which play an integral part in the erosion dynamics of the lower Coeur d'Alene River.

Figure 44. Site 11 on August 13, 2008

Figure 45. Site 11 on June 17, 2009

Figure 46. Site 13 on July 16, 2008 and August 13, 2008

Figure 47. Site 13 on June 17, 2009

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