*STATEMENT OF WORK*

# Spatial distribution, geochemistry, and storage of mining sediment in channel and floodplain deposits of streams draining the Viburnum Trend Mining District of Southeast Missouri, USA


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**INTRODUCTION**

The New Lead Belt in southeastern Missouri has been a major producer of lead (Pb) and other metals since 1960 when the first mine opened in Viburnum, Missouri (Seeger, 2008). To date, 10 mines have operated along a north-south line extending for almost 100 kilometers (km) from from Viburnum to south of Bunker, Missouri. This subdistrict of the Southeast Missouri Lead Mining District is referred to as the Viburnum Trend (VT). Seven mines are presently in operation in the VT: (i) Viburnum #29 Mine in Washington County which uses the Buick Mill; (ii) Casteel or Viburnum #35 Mine in Iron County which uses the Buick and Brushy Creek Mills; (iii) Buick Mine and Mill in Iron and Reynolds Counties; (iv) Fletcher Mine and Mill in Reynolds County which sometimes uses the Brushy Creek Mill; (v) Brushy Creek mine and mill in Reynolds County; (vi) West Fork Mine and Mill in Reynolds County; and (vii) Sweetwater Mine and Mill in Reynolds County (Seeger, 2008). In addition, three mines have been closed including Viburnum #27 Mine in Crawford County (1978), Magmont Mine in Iron County (1994), and the Viburnum #28 Mine in Iron County (2004). These mines used the Viburnum Central Mill near Viburnum #28 Mine which was closed in 2000. There were two smelters constructed in 1967 to handle VT ores. The Buick smelter located in Boss, Missouri processed ore until 1991 and now is used only for secondary lead recycling (Seeger, 2008). The other smelter closed in 2001 and is located 36 km to the east of the VT in the town of Glover in Iron County.

Missouri is the largest producer of Pb in the United States and generally ranks in the top five states in zinc (Zn) production (Seeger, 2008). The VT is the only Pb mining area active in the state. Total ore production for individual mines in the VT ranges from 20 to >50 million tons with a metal content of 8% Pb and 3% Zn. The primary ore in the VT is galena (Pb) with sphalerite (Zn) of secondary importance. Also of secondary importance, copper (Cu) is produced from chalcopyrite and bornite ores. Of minor importance, cobalt (Co) and nickel (Ni) are produced from siegenite and bravoite ores, sulfur from the iron sulfide, pyrite, and silver during the galena smelting process. The major gangue minerals in the VT are the carbonates dolomite and calcite, marcasite, another iron-sulfide, and quartz (Seeger, 2008).

There have been ongoing concerns about where and how mining activities in the Viburnum Trend affect the quality of stream water, sediment, and habitat (Besser et al., 2007 & 2009; Allert et al., 2008 a & b; Stroh et al. 2009; Weber, 2012). The VT is located within headwater areas of both the Black and Meramec Rivers and elevated concentrations of mining-related metals in runoff and sediment particles have been detected more than 30 km downstream from mining sites (Brumbaugh et al., 2007; Krizanich, 2008). It was recognized early on that mining, milling, and smelting operations in the VT presented a metal contamination risk to local streams, soils, livestock, and wildlife (Hardie et al., 1974; Dorn et al., 1975; Wixson, 1978; Gale and Wixson, 1979; Jennett and Foil, 1979).

Missouri's 2012 303(d) list contains 10 stream segments that are impaired by mining-related contaminants from VT mining and smelting operations including Pb, Zn, Cu, Ni, Cadmium (Cd), and

Arsenic (As) in water and sediment (http://www.dnr.mo.gov/env/wpp/waterquality/303d.htm). The listed segments are found in the following watersheds: Indian Creek including a portion of Courtois Creek and Crooked Creek in the Meramec Basin; Strother Creek and Middle Fork in the middle fork of the Black River Basin; Bee Fork and West Fork in the west fork of the Black River Basin; Logan Creek in the Black River Basin, and Big Creek and Scroggins Branch in the St. Francois Basin. Total Maximum Daily Loads (TMDLs) have already been approved for Indian Creek and Big Creek with TMDLs planned to be approved for most of the other listed stream segments between 2012 and 2013. Preassessment screen and determination reports have been released for several streams (USFWS, 2008 & 2009). The Final Phase I Assessment Plan has also been released for Adair Creek, Logan Creek, Sweetwater Creek, Black River, West Fork-Black River, Big Creek, and Scoggins Branch (Mosby et al., 2009). Moreover, mitigation and restoration plans for affected streams in the VT have been specified within the Doe Run Resources Corporation multi-media Consent Decree (USEPA, 2010).

In general, contaminated sediments <63 millimeter (mm) in diameter are the most mobile in the stream environment and can sorb metals to concentrations that are potentially toxic to aquatic life (Schmitt and Finger, 1982; Mosby et al., 2009). In VT streams, the highest concentrations of metals are typically found in the fine-grained fraction within channel bed deposits, typically <250 micrometers (um) or <63 um in diameter (Schmidt and Finger, 1982; Femmer, 2004; Wronkiewicz et al., 2006). The probable effects concentrations used to determine toxicity in VT sediments are as follows: 33 parts per million (ppm) for As, 5 ppm for Cd, 149 ppm for Cu, 49 ppm for Ni, 128 ppm for Pb, and 459 ppm for Zn (MacDonald et al., 2000). Various field sampling and laboratory methods have been applied to evaluate sediment contamination trends in the VT and they consistently support the finding that mining-related metals are transported in strong association with fine sediment particles and that toxic concentrations are often found at stream sites below mining areas (Jennett and Foil, 1979; Brumbaugh et al., 2007; Femmer, 2008; Lee, 2008; Hannon, 2012).

In contrast to sediment contamination trends in the VT, mining-related Pb concentrations are distributed across a wider range of particle sizes ranging from silt to fine gravel in the Big River which drains the Old Lead Belt about 40 km north of the VT (Pavlowsky et al., 2010a). Further, the contamination history and supply also differed between the two mining areas. Mining wastes in the Old Lead Belt were originally released directly to the river system as excessive sediment loads or slugs of chat and tailings between 1890 and 1940, before tailings impoundments were constructed. After introduction to the river channel, contaminated sediments were deposited within gravel bars and on floodplains to depths of 2 meters or more (Pavlowsky et al., 2010a). In contrast, mining contamination in the VT started relatively recently in 1960 and modern environmental controls including managed tailings impoundments were in-place from the start (Femmer, 2008). Therefore, metal contamination in VT streams is primarily associated with point discharges of mine and tailings impoundment water (Kleeschulte, 2008b; Schumacher, 2008), storm runoff from contaminated land and road areas (Jennett and Foil, 1979), and aerial deposition from smelter stacks (Gale and Wixson, 1979). Accidental releases of contaminated mill wastes and tailings directly into nearby channels were rare, but did occur (Duchrow, 1983; Mosby et al, 2009).

## PURPOSE AND OBJECTIVES

The purpose of this project is to improve our understanding of the spatial distribution, physical/geochemical mobility, and long-term storage of mining-related contaminated sediment and metals in VT stream sediments and alluvial deposits. Impairment and injury to water and geological resources in streams draining VT mining areas is well documented. However, more information is needed to help environmental managers to effectively plan restoration practices to address sediment contamination problems. First, a systematic evaluation of sediment contamination patterns at the watershed-scale is needed. Sediment sampling and analyses need to be coordinated with similar methods used in all affected watersheds. Conceptual and quantitative models describing the transport pathways and spatial distribution of contaminated sediment need to be developed. Second, contamination assessments need to focus on the role of fine-grained sediment in controlling the level and distribution of contamination in VT streams. Sediment sampling needs to address the variety of alluvial deposits present in affected streams and consider geomorphic and geochemical processes involved in fine-grained sediment transport and deposition, including floodplains. Finally, downstream trends in the mass storage of contaminated sediment and mining-related metals need to be quantified. Understanding the amount of contaminated sediment stored within the river system and available for reworking is critical for understanding the time-scales for geochemical recovery and long-term risk to aquatic life.

The primary concern of this study is focused on understanding the spatial distribution of sediment contamination and volumes of stored mining sediment in the channel and on floodplains and long-term mobility of contaminated sediment. In this study, contaminated channel sediments are defined as containing >128 ppm Pb and/or >458 ppm Zn (MacDonald et al. 2000). Contaminated floodplain soils are defined by US Environmental Protection Agency (USEPA) criteria for residential soils as >400 ppm Pb. Metal concentrations will be evaluated for both the <2 mm and <250 um sediment size fractions.

The <u>objectives</u> of this project are as follows:

(1) Quantify the spatial trends of mining-related metal contamination in channel bed and bar sediments and floodplain soils including downstream, lateral, and vertical variations in metal concentrations in mining-affected streams draining the Viburnum Trend;

(2) Quantify the downstream distribution and volume of alluvial deposits in mining affected streams including channel bed, bar, and bench deposits and floodplain deposits of different heights and ages with a focus on the patterns of storage and contamination of fine-grained sediment at both the reach- and watershed-scales within Viburnum Trend watersheds;

(3) Determine the spatial distribution of mass storage of mining-contaminated sediment and related metals in alluvial deposits in stream draining VT mining areas with an emphasis on sediment transport patterns and probable residence times; and

(4) For quality assurance and control purposes, complete a split-sample evaluation for particle size and metal concentration accuracy and precision where analytical results are compared between Missouri State University (MSU) and US Geological Survey (USGS) laboratories for a subset of sediment samples (n= 15).

## METHODS

### Study Area

Initially, stream segments will be selected for evaluation based on two criteria. First, streams where toxic concentrations of sediment Pb were observed by previous studies. Second, stream segments not yet sampled for sediment metals where there is a reasonable expectation of contamination. Information provided by the 2012 303(d) list for impaired stream lengths in VT watersheds, TMDL documentation, previous sediment contamination studies, mapped locations of mine and mill sites within the stream network, and communications with US Fish and Wildlife Service (USFWS) staff was also considered to determine the locations of stream segments for evaluation in this study. Karst influence on baseflow and emphemeral headwater segments was also evaluated in Logan Creek and other VT streams during sampling site selection (Kleeschulte 2008a). About 151 km of stream length will be evaluated for sediment contamination for this study as follows:

(1) Indian Creek Watershed (17 km) including Indian Creek (13 km) and Courtois Creek (4 km);

(2) Crooked Creek Watershed (25 km) including Crooked Creek (16 km), Huzzah Creek (3 km), and Mill Rock Creek (6 km);

(3) Strother Creek Watershed (37 km) including Left Fork-Neals Creek (2 km); Neals Creek (10 km), Strother Creek (12 km); and Middle Fork-Black River (13 km);

(4) West Fork Watershed (47 km) including Bills Creek (5 km), West Fork-Black River (27 km), and Bee Fork (15 km);

(5) Logan Creek Watershed (17 km) including Adair Creek (2 km); Logan Creek (10 km); and Sweetwater Creek (5 km); and

(6) Big Creek Watershed (8 km) including Big Creek (7 km) and Scoggins Branch (1 km)

**Sampling Design**

Geomorphic and sediment sampling will be completed in three phases. In the first or **screening-level phase** sediment samples will be collected from channel bed and bar areas and other deposits if readily available at locations with easy access. The entire 151 km study area will be sampled to evaluate sediment metal trends and degree of contamination. In the second or **geomorphic sampling phase** data on channel morphology and alluvial sediment storage will be collected only in stream segments where contamination is present in the <250 um sediment fraction. It is expected that after the screening phase, the total stream length that will be contaminated will be about 70 to 90 km and sample reach density will be one site per 1-2 km stream length. This estimate is based on preliminary work by MSU and a review of previously collected geochemical data by other workers. The final geomorphic sampling area will be based on the information generated by this study. In the third or **floodplain and bar texture sampling phase** about 20 sites will be selected for more in-depth examination of the vertical and lateral trends in contaminated overbank floodplain deposits. In addition, the textural properties of bed and bar features will be specifically tested to accurately determine the percentages of fine sediment (<2 mm & <250 um fractions) in the deposit and better understand the "within deposit" textural variability in VT streams.

**Field Methods**

Sampling reaches will be organized into several transects scaled according to active channel width. Field assessment activities will be divided into three components: (i) sediment sampling and characterization of bed, bar, bench, and floodplain deposits, (ii) geomorphic analysis of the channel and bank deposits and depth of sediment storage, and (iii) cross-valley coring of floodplain areas. For some floodplain transects, a total station will be used to accurately survey the channel and floodplain topography.

<u>Sampling Reach Layout.</u> A sampling reach consists of seven transects spaced out at 2 times the active channel width. The middle transect (#4) is located within a glide-riffle transition area within the channel and three transects are added up- and down-stream accordingly. A wooden stake is used as a monument to mark the location of transect 4 and flagging is used to mark each transect. This layout plan produces a sample length of the channel that is about 12 active channel widths long and equivalent to one full meander wavelength of the thalweg, on average. Each sampling reach is located by river-kilometer on the basemap according to the location of the middle transect.

<u>Sediment Sampling and Characterization.</u> Bed, bar, bench, and floodplain sediment samples are collected and bagged for laboratory analysis in order to determine textural and geochemical properties. It is difficult to collect Global Positioning System (GPS) coordinates in a consistent and accurate manner in the Viburnum Trend region due to satellite signal interference by high-relief terrain and riparian forest cover. Thus, each sample location is designated by river-kilometer from the

basemap and approximate latitude/longitude coordinates determined by manually locating sites on recent rectified aerial photographs.

*1. Bed sediment* samples are collected in glides or plane beds within the active bed of stream. These areas are typically inundated by low flows and are usually within the wetted width of the channel. A shovel is used to collect a grab sample of bed sediment to a depth of 15 to 20 centimeters (cm). Up to three channel samples are collected within each sample reach along different transects, if possible. Bed samples are typically collected in the center of the channel unit, dewatered by gravity while on the shovel blade, and placed in a 1-quart plastic freezer bag. Each sample location is marked with GPS coordinates or river-kilometer distance according to the base map.

*2. Bar sediment* samples are collected by shovel at a depth of 3x the maximum clast size in the immediate vicinity on the bar to exclude the influence of surface armoring on textural measurements. Bars are identified as gravel features deposited along the side or center of the channel with top surface elevations at 25 to 50 percent the bank height above the bed. They can be vegetated or bare. Typically 1 to 3 bar samples are collected at each sample reach on a transect line at the centerline of the bar at either head, middle, and tail locations. Samples are stored in 1-quart plastic freezer bags. Each sample location is marked with GPS coordinates, site and transect code, and/or river-kilometer from the basemap.

*3. Bench deposit samples* are collected by shovel to a depth of 10 to 20 cm. Benches are typically identified as relatively narrow surfaces occurring above the elevation of gravel bars, but below bankfull bank height. For the purposes of this study, a bench must have a layer of fine-grained sediment deposited on the surface to a depth of at least 5 cm. Benches indicate a change in deposition within the channel from lighter-colored gravel or coarse sand such as found on bar surfaces to darker materials containing more silt and clay.

*4. Floodplain or top bank deposits* are collected by shovel to a depth of 20 to 30 cm. Channel banks may represent floodplain features of various heights or lower terraces indicating a recently abandoned floodplain. In contrast to benches, floodplains are defined by wider surfaces at higher elevations that are indicative of the valley floor. They typically contain fine-grained material but can have varying amounts of sand and gravel mixed in. In some sampling reaches, both high and low floodplains are sampled if time permits. Samples are stored in 1-quart plastic freezer bags. Each core location is marked with GPS coordinates. Floodplain deposits can be contaminated by fine-grained sediment transported during floods as suspended load or aerial deposited particulates from previous smelter operations or road dust.

<u>Geomorphic Analysis of In-channel Alluvial Deposits.</u> The width and height (or thickness) of alluvial features including the channel bed, gravel bars, and benches are measured along each transect within the active channel. The active channel includes both the active bed and active bar/bench areas between the two floodplain banks. The height of each deposit is measured from the deepest point in

the channel on each transect (i.e., thalweg). The deepest point on the channel bed within 1 width up- and down-stream from the transect is also recorded. In addition, the depth of refusal by a tile probe is also recorded for the deepest point to determine the potential scour depth of the channel during flood flows to indicate the maximum thickness of alluvium potentially stored in the reach. The thickness of fine-grained sediment on benches and bank is also recorded either from visual inspection at cutbank exposures or depth of refusal by tile probe. These measurements will be used to determine the volume of alluvial sediment storage.

Cross-Valley Floodplain Coring. Floodplain deposits will be sampled at 3 to 5 cm intervals from the walls of 0.5 m pits dug with a shovel. It is not expected that floodplains will be contaminated below this level since mining contaminant have been released relatively recently (since 1960). Floodplain core samples may also be collected at exposed cut-bank locations where the stratigraphy is clearly shown and no slumping is indicated. Field notes on the stratigraphy (color, texture, structure, artifacts) of the exposed soil profile will be collected at each core site. The targeted deposits contain evidence of very little to no soil development indicating their relatively young age and formation during the historical or mining period. A portable X-ray fluorescence spectrometer (XRF) will be used in the field to measure lead and zinc concentrations in the sediment (USEPA, 1998). Selected samples maybe collected and brought back to the laboratory for further textural and geochemical analysis. Samples are stored in 1-quart plastic freezer bags. Each core location is marked with GPS coordinates.

Total Station Surveys. Where more accurate information is needed, topographic channel surveys will be completed using a total station or auto-level with at least three GPS control points (Rosgen, 1996; Pavlowsky et al., 2010a). Cross-sections are collected at up to 10 transects spaced out at one to two channel width intervals. A tile probe with extensions as needed may be used to determine the refusal depth in bed or bar areas at five to ten locations across the active channel to estimate the thickness of chat-sized sediment and scour depth in the channel (Pavlowsky et al., 2010a). Permanent monuments are set at the end of each transect and located with total station and/or GPS coordinates to allow for relatively precise repeat surveys in the future, if needed. Field data from channel surveys will be used to determine channel dimensions, size of channel bedforms, bank or floodplain heights, channel hydraulic parameters for bed load equations, and minimum/maximum depths of potential mining sediment (Ward and Trimble, 2004; Rosgen, 2006).

**Laboratory Methods**

Laboratory methods involve the preparation, physical analysis, and geochemical analysis of bed, bar, and overbank samples. All laboratory work is carried out by the Ozarks Environmental and Water Resources Institute at MSU.

Sample Preparation. All sediment samples are stored in labeled resealable plastic bags in the field with sample number, location, and field description verified according to field notes upon receipt by the laboratory. All samples are dried in an oven at $60^{o}$ Celsius, disaggregated with mortar and pestle (if needed), and put through a sieve set to isolate mining-related size-fractions for gravimetric and physical/chemical analysis.

Sediment Texture. The particle size distribution for sediment samples will be determined using two methods: gravimetric sieve analysis and laser diffraction.

*1.* Sieving is accomplished by manual methods to determine the particle distribution of the bulk sample for the following four fractions: >16 mm, 2-16 mm, <2 mm, and <250 um. Size fractions will be quantified as percent of total mass of the bulk sample. As used in this study, bulk sample refers to the entire sample mass delivered to the laboratory in the plastic sample bag.

*2. Laser Diffraction* will be used to measure the particle size distribution in the <250 um fraction. The standard operating procedure for this method can be found at http://oewri.missouristate.edu/58411.htm.

Geochemical Analysis. The geochemistry of selected sediment fractions is used to determine the contamination level of the sediment, indicate the influence of mining source inputs on sediment composition, and evaluate the chemical conditions prevalent within the deposit. The following geochemical data is collected for this study:

*1. Munsell Color and pH.* Color and pH will be determined for the <2 mm fraction of the overbank floodplain samples. Color can indicate stratigraphic units, source/provenance, and redox environment. The pH of the fine-grained portion of the sediment can indicate the potential chemical mobility of metals in the pore water/soil environment.

*2. Total and inorganic carbon analysis*. A Carbon/Nitrogen/Sulfur (CNS) analyzer will be used to determine the carbon content of selected samples and distinguish between the carbon in organic matter and mineral grains. “Total carbon” is determined on an untreated sample and “inorganic carbon” is determined after burning off the organic carbon as $CO_2$ in a muffle furnace at $400^o$ Celsius. Since the primary host rock of the mineralization in the district is dolomite, it is anticipated that tailings particles within alluvial sediment will have higher inorganic carbon content in the form of carbonate (Ca-Mg $CO_3$) compared to background sediment where weathering and leaching over time has removed the carbonate and lowered the inorganic C concentration. Ratios of mining sediment Carbon (C) to background sediment C will be used as an indicator of mining sediment contribution in the sample. The standard operating procedure for this method can be found at http://oewri.missouristate.edu/58411.htm.

*3. Elemental and metal analysis.* Levels of lead, zinc, cadmium, and barium found in the samples indicate the level mining pollution in relation to contamination thresholds. The content of mining-related metals and pathfinder elements in selected sediment samples and their specific size fractions will be used to calculate the mining contribution using a mixing model comparing contaminated and background samples in much the same way as the carbonate testing described above. Two methods are used for geochemical analysis: (i) XRF analysis in the field or laboratory (USEPA, 1998) and/or (ii) hot strong acid extraction (3:1 $HNO_3$:HCl or aqua regia) with Inductive Coupled Plasma-Atomic Emission Spectroscopy (ICP-AES) analysis in the laboratory (http://www.alsglobal.com/minerals.aspx., 2012 service schedule, p. 16). For bed and bar sediment, three size fraction are evaluated: (i) chat-size, 4 mm to 16 mm; (ii) flotation tailings-size, 63 um to 250 mm; and (iii) slime-size, <63 um. For overbank sediment, two size fractions are evaluated: (i) the entire sand, silt, and clay fraction, <2mm; and (ii) silt and clay fraction, <63 um. Chat-sized samples will first be powdered in a ball mall in preparation for geochemical analysis. High resolution XRF instrumentation may be used for cadmium and barium analysis in collaboration with the USFWS. The standard operating procedure for the XRF analysis method can be found at http://oewri.missouristate.edu/58411.htm.

*4. Cesium-137 radioisotope analysis.* Cesium-137 profiles in floodplain cores will be used to date the core with peak activity used to identify the 1963 sediment layer. The cesium peak should also coincide with the beginning of mining and related contamination in VT streams. The standard operating procedure for this method can be found at http://oewri.missouristate.edu/58411.htm.

**Geospatial Data and Analysis**

A geospatial data base and Geographic Information System (GIS) analysis is used to organize and analyze all the field and laboratory data evaluated in this study. High resolution 2007 aerial photographs are used as a base map for this study. Geospatial technologies and analysis are used in this study to evaluate sample reach characteristics, channel storage of mining sediment, floodplain contamination, historical records of channel change, and serial mapping borrow pit volume.

Sample Reach Location and Mapping. All channel survey data, sample site coordinates, and GPS points will be stored in a GIS and displayed on the 2007 base map. This includes site locations, channel bed and bar features, sediment sampling points, and channel and floodplain transects. High-resolution GPS or available Digital Elevation Models (DEMs) are used to determine an accurate true elevation for each channel survey. Laser total-station equipment is used to complete the longitudinal survey and some of the cross-channel transect lines with elevation data imported into the GIS. A total station or auto-level may be used to tie-in the transect surveys to monuments or datums. Within a topographic surveyed sample reach, several GPS control points are used to accurately locate the survey in the GIS.

Channel Storage Mapping. Reach-scale measurements of mine sediment storage will be modeled and spatially applied to the mining-affected watersheds. A continuous data set of active channel bed width and gravel bars will be created by digitizing of the 2007 photographs. Bed and bar areas can be calculated from these maps and combined with elevation or depth information from the reach surveys to determine volume of bed and bar sediment in the river. This study will use similar methods as reported in Martin and Pavlowsky (2011).

Floodplain Mapping. All the counties covering the Viburnum Trend have published soil surveys available along with GIS data layers of the soil series maps and soil attributes. The soil surveys for each county are: Brown (1981), St. Francois Co.; Brown and Greeg (1991), Iron Co.; Larson and Cook (2002), Crawford Co.; Simmons and Childress (2005), Shannon Co.; Simmons et al. (2006), Reynolds Co.; and Skaer and Cook (2005), Washington Co. These soil maps are used to identify floodprone soils and floodplain units on the valley floors of VT streams. Published soil descriptions and field evaluations by MSU are used to interpret the elevation and age of floodplain units that can be expected to contain contaminated mining sediment. Field sampling and assessment of metal contaminate profiles are used to verify floodplain interpretations.

## DATA ANALYSIS

### Channel volume of mining sediment

Potential mining sediment storage is calculated for each sampling reach based on channel surveys and height measurements. Potential storage will be partitioned according to bed, bar, bench deposits and related to depth or height above the bed. Carbonate and metal ratios based on comparisons of contaminated sediment to background sediment are used to refine the actual mining contribution as equal to or less than the total volume of sediment in the reach. Geomorphic and storage trends for each sample reach will be analyzed spatially using regression analysis to identify distance or drainage area relationships that model the downstream changes in mining sediment storage (for modeling procedures see Pavlowsky et al., 2010 a & b). Local storage calculations, either through the model or by reach up-scaling, will be applied to the entire river based on the GIS map of the channel bed and bar locations. Mining sediment volumes calculated from this process will be mapped and summed for the entire river.

### Floodplain volume of contaminated sediment

The depth of mining sediment and concentrations of metals deposited on floodplains of at least two different ages will be related to location in the drainage network using the soils database and modeled using a regression equation of concentration and depth over distance or drainage area. The resulting model will be applied to the entire Big River floodplain soil map in the GIS to sum the volume and metal mass stored in floodplain locations. This study will use similar methods as reported in Lecce and Pavlowsky (2001) and Owen et al. (2011).

**TIMELINE AND PRODUCTS**

This is a two year project from September 1, 2012 to August 31, 2014. Field work will commence as soon as possible and will be on-going through the Fall semester 2012 and possibly early Winter 2013. The main products of this project include:

1) December 15, 2012- Deliver samples for split testing to USGS

2) June 15, 2013- Draft report is delivered to USFWS.

**BUDGET**

This project has a proposed total budget of $88,113. Per Cooperative Ecosystems Studies Unit (CESU) requirements, indirect costs are calculated at 17.5% of the total direct costs. The distribution of the funds requested for this project is as follows:

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|---|---|
| Salary: | $54,935 (summary salary, graduate assistants, hourly labor) |
| Fringe: | $4,055 (only on 2 months summer salary) |
| Travel: | $11,000 |
| Supplies: | $5000 |
| Equipment | $0 |
| Indirect: | $13,123 |
| TOTAL | <u>$88,113</u> |

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