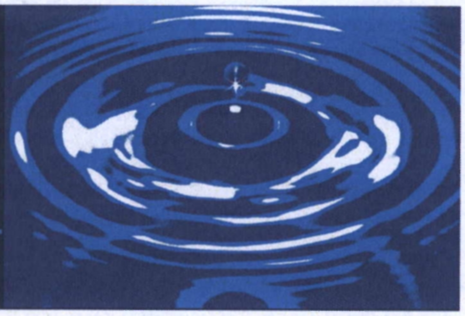

ECOLOGICAL RISK ASSESSMENT
BIG RIVER MINE TAILINGS SITE
ST. FRANCOIS COUNTY, MISSOURI
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1. INTRODUCTION

The purpose of this report is to provide an Ecological Risk Assessment (ERA) for the Big River Mine Tailings site. The United States Environmental Protection Agency (EPA) has standard guidance for the performance of ecological risk assessments at Superfund Sites (EPA, 1997). The process consists of the following eight steps:

1. Screening level problem formulation and effects evaluation
2. Screening level exposure and risk evaluation
3. Baseline risk assessment problem formulation
4. Study design and data quality objectives
5. Field verification of sampling design
6. Site investigation
7. Risk characterization
8. Risk management

A Site Description Report, Field Sampling Plan and Quality Assurance Project Plan (Black and Veatch, 2005) have been completed for this site, fulfilling steps 1 through 4 of the ERA process. Field verification of the sampling design and site investigations were completed in September 2005, fulfilling steps 5 and 6. This ERA incorporates the information from the *Site Description Report* with the results of field sampling and analytical activities that have been completed to date, essentially fulfilling step 7. The information provided herein will be used in the final step of the process to make risk management decisions for the site.

1.1. SITE LOCATION AND DESCRIPTION

The Big River Mine Tailings Site is located a half-mile northwest of the city of Desloge in St. Francois County, Missouri, which is a mining region approximately 70 miles south of St. Louis, Missouri known as the "Old Lead Belt." The site encompasses approximately 110 square miles and contains mine tailings rich in lead, cadmium, and zinc on over 600 acres ranging in depth from zero to more than 100 feet deep. The mine tailings are the result of 75 years (1890 to 1965) of dumping lead mining waste from several mine/mill operations. Six major tailings/chat piles exist at the site: Leadwood, Desloge, Federal, Elvins, National, and Bonne Terre. In addition, there are two smaller piles that are part of the site, Doe Run and Hayden Creek. The mine tailings/chat piles are potential contributors of fine sediment and heavy metals to portions of the Big River and Flat River watersheds. The site location is presented in Figure 1-1.

1.2 REPORTS AND DATA SOURCES REVIEWED

The habitat descriptions provided in Section 2 of this report are based on a review of the June 2003 aerial photography for St. Francois County used as a base map for the project Geographical Information System (GIS). The base map was supplemented by the cursory information recorded during the December 2004 reconnaissance visit and field sampling activities conducted in September 2005. Previous reports that were reviewed in preparation of this report include the following:

- St. Francois County Ecological Risk Assessment, Draft Technical Memorandum #1, Wildlife Exposure and Risk Calculations, May 2003.
- St. Francois County Ecological Risk Assessment, Draft Technical Memorandum #2, Risk Evaluation of Wildlife Species with Primarily Invertebrate Diets, April 2004.
- Field Sampling Plan for Ecological Risk Assessment for Focused Remedial Investigation/Feasibility Study, St. Francois County, Missouri, March 10, 1999.
- Biological Assessment and Fine Sediment Study, Flat River (Flat River Creek), St. Francois County, 2001.
- Biological Assessment and Fine Sediment Study, Big River (lower); Irondale to Washington State Park, St. Francois, Washington, and Jefferson Counties, Missouri, 2002 – 2003.
- Preliminary Public Health Assessment, Big River Mine Tailings Desloge (a.k.a. St. Joe Minerals) Desloge, St. Francois County, Missouri, August 14, 1996. 1.4 Summary of On-site Reconnaissance.
- Site Description Report, Big River Mine Tailings Site, St. Francois County, Missouri, March 2005.
- Field Sampling Plan, Big River Mine Tailings Site, St. Francois County, Missouri, March 2005.
- Quality Assurance Project Plan, Big River Mine Tailings Site, St. Francois County, Missouri, March 2005.

2. STUDY AREA CHARACTERISTICS

The following subsections provide a discussion of the physical conditions for each source area, contaminants of concern, migration pathways, associated habitats for each source area, critical/sensitive environments, and threatened and/or endangered species at the Big River Mine Tailings site.

2.1. PHYSICAL CONDITIONS OF EACH SOURCE AREA

The physical conditions for each source area generally fit into one of the following categories:

- Former tailings ponds in various levels of successional revegetation
- Open water former tailings ponds
- Chat piles in various levels of successional revegetation
- Mostly remediated chat piles (e.g., the western pile at Bonne Terre)

Tailings and chat are the wastes that result from two different methods that were used during ore production. The early method was a dry process which separated the ore from mined limestone by gravity separation. The later method separated the ore by the use of wet washing with chemicals.

The dry process produced a fine gravel waste commonly called "chat." The wet process resulted in the creation of tailings ponds where the material was dumped directly on the land surface or used to fill valleys. Once the water drained away, sand- and silt-sized particles, or "tailings" were left. Tailings generally contain higher concentrations of heavy metals than chat piles (EPA, 2001). The mine waste can also be classified according to grain size. The fine material generally has grain sizes of 0.004 to 0.06 mm, whereas the larger material has grain sizes of 0.06 to 2.4 mm.

Most of the chat piles and tailing ponds at the site are in various levels of successional revegetation in which various grasses and scrub-shrub vegetation are dominant. The western Bonne Terre chat pile has been remediated with a stone cover and vegetative cap on the top of the pile and several feet of stone cover around the base of the pile.

2.2. CONTAMINANTS OF CONCERN

The primary contaminants of concern at the Big River Mine Tailings Site are cadmium, lead, and zinc based on sampling events conducted during previous investigations. These contaminants are typically associated with mine wastes in the southeast lead belt of Missouri. Although relatively small quantities of various other metals are often found at these mining sites; cadmium, zinc, and especially lead are considered the primary risk drivers, and therefore are the focus of this risk assessment.

2.3. MIGRATION PATHWAYS

The primary sources of contamination at the Big River Mine Tailings site are the tailings and chat disposal areas. The source areas consist of mine tailings and chat that were dumped over time to form piles that in many cases are higher than the elevations of the original hillsides. Several source areas are uncapped exposed piles with some sparse vegetative cover. The western pile at Bonne Terre is capped with a layer of stone and vegetation. Based on the nature of the contamination at the Big River Mine Tailings site and the physical characteristics of the site, potential routes of contaminant migration likely include the following:

- Soil-to-Air Migration
- Soil-to-Surface Water/Sediment Migration
- Soil-to-Groundwater Migration
- Groundwater-to-Surface Water Migration
- Biological/Food Chain Bioaccumulation

The following subsections present a discussion of each potential route of contaminant migration for the site.

2.3.1. Soil-to-Air Migration. Fine-grained materials from source areas may be transported by the wind and released to the atmosphere. Constituents bound to surface soils may be transported as suspended particulates or dust to downwind locations. Factors influencing the potential for dust entrainment into the atmosphere include surface roughness, surface soil moisture, soil particle sizes, type and amount of vegetative cover, amount of soil surface exposed to the eroding wind force, physical and chemical properties of the soil, wind velocity, and other meteorological conditions (EPA, 1983). While some areas of the site are covered with vegetation, there are large areas on the sources with little or no cover where dust formation may be significant during extended periods of dry weather. As a result, contaminants from the source areas would be expected to be present in the air as dusts at certain times of the year.

2.3.2. Soil-to-Surface Water/Sediment Migration. Contaminants from source areas may be transported by the wind or surface water runoff and deposited in downgradient floodplains, surface waters and/or settle in surface water bodies as sediment. There are two major rivers potentially directly impacted by the six known source areas. Minor streams flow directly or through the Leadwood, Desloge, and Bonne Terre source areas and discharge into the Big River. Also, minor streams flow directly or through the National, Elvins, and Federal/St. Joe State Park sites and discharge into the Flat River. The Flat River flows into the Big River, which ultimately receives all drainage from all six known source areas. The locations of these source areas relative to the surface water drainage systems are presented in Figure 2-1. Shallow groundwater beneath the source areas is also likely to flow into these surface water systems. Sediment data shows impacts to the Big River appear downstream of the Leadwood pile and continues to the confluence of Mineral Fork. Approximately 5 miles of the Flat River may also be directly impacted. In addition, there are approximately 6.8 miles of minor streams and tributaries which may also be directly impacted.

2.3.2.1. Big River - In general, potentially impacted areas along Big River include the river itself and adjacent floodplain areas. Surrounding areas are generally agricultural or are undeveloped with several small towns within the overall watershed. Due to the hilly terrain of the region, floodplain areas along Big River are not extensive. The habitats associated with floodplain areas along the Big River are generally dominated by deciduous forest areas. In some isolated areas there are industrial operations adjacent to the river including active mining areas and gravel pits. In other areas there are agricultural areas (mostly pasture) encroaching up to the river's edge. Within and along the banks of the Big River there are numerous depositional areas (gravel and sand flats). Some of these areas contain visible deposits of tailings. Big River is a major river in the region and is approximately 60 feet wide and is generally less than 3 feet in depth, with the exceptions being shallow areas in riffles and deeper pools.

Flow in the Big River is variable and ranges from an average monthly flow of 74 cubic feet per second (cfs) in the summer months to an average monthly flow of 318 cfs during the spring due to rainfall and snowmelt. Big River is known to support over 100 fish species, 34 mussel species, 8 crayfish species, and 107 aquatic insect species (MDC, 2002).

2.3.2.2. Flat River - In general, potentially impacted areas along Flat River include the river itself and adjacent floodplain areas. Due to the hilly terrain of the region, floodplain areas along Flat River are not extensive. The Flat River watershed is much more developed than the Big River watershed and most of the nearby areas are urban areas associated with the towns of Desloge, Flat River, and Elvins. The habitats associated with floodplain areas along the Flat River include developed lands typical of urban centers (parks, lawns, industrial areas) and some areas of deciduous forest.

Some smaller areas have agricultural areas (mostly pasture) encroaching up to the river's edge. Most of the river is fringed by deciduous trees. There are some depositional areas along Flat River; however, these are relatively few when compared to Big River. A large depositional zone is located at the confluence of Flat River with Big River. Flat River is a smaller river ranging between 20 and 50 feet in width. The river is generally less than 2 feet in depth, with the exceptions being shallow areas in riffles and deeper pools. Flat River is known to support benthic invertebrates, crayfish, and fish communities.

2.3.2.3. Minor Tributaries and Streams - In general, potentially impacted areas along the minor tributaries and streams include the streams themselves and adjacent floodplain areas. Due to the hilly terrain of the region, and the small contributory flows into these streams, floodplain areas are not extensive.

Turkey Creek is the most significant of these tributaries and receives flow from the Bonne Terre source area. Turkey Creek also receives most of the runoff from the town of Bonne Terre. In Bonne Terre, Turkey Creek is typical of an urban stream and the associated habitats are those typical of urban centers (parks, lawns, and industrial areas). Most of the creek is fringed by deciduous trees. Near the Bonne Terre source area, Turkey Creek ranges from 8 to 10 feet in width and water depth ranges from a few inches to 1 foot. Turkey Creek contained areas of runs, riffles, and pools; however, there were signs of bank erosion and sedimentation.

Tributaries from the Leadville source area receive most of the runoff from the town of Leadville. These tributaries are less than 5 feet in width and contained less than 1 foot of water. In general, these tributaries do not support extensive stream habitat diversity. These tributaries are fringed by deciduous trees.

Other tributaries into the Big River contain drainage from the Bonne Terre source area; however, most of their watersheds are rural and agricultural. These tributaries are less than 5 feet in width and contained several inches of water. In general, these tributaries do not support extensive stream habitat diversity. Habitats along these tributaries are predominantly deciduous forest.

Shaw Branch is a tributary of the Flat River and is the outflow of the dam built to contain the main tailings pond at St. Joe State Park. There are extensive areas of tailings along this tributary and very little in-stream habitat diversity. This tributary was only a few feet in width and depth and water flow was very minimal. Habitat along and adjacent to this tributary is generally deciduous forest and shrub-scrub habitat.

2.3.2.4. Lakes - In general, there are significant lakes associated with the Federal/St. Joe Park and Leadwood sites. These lakes were historically formed by damming drainage ways to create settling ponds for mine tailings. Due to the hilly terrain of the region, these lakes are generally long and narrow with little floodplain fringe. None of the lakes associated with either of these sites receive drainage from upgradient mine waste sources; the sources of most waste is from the uses of the lakes as settling ponds themselves. The habitats associated with floodplain areas along with these lakes are open water habitats generally surrounded deciduous forest.

At Federal/St. Joe Park, several of these lakes are used for recreational purposes including swimming, sunbathing, and sport fishing. The lake at Leadwood does not appear to support any organized recreational uses. The lakes at Federal/St. Joe Park are of unknown depth and range in width up to several hundred feet. These lakes are known to support angler species of fish. The biological assemblage in the lake at Leadwood is unknown at this time; however, it would be expected to support fish and benthic invertebrates. Predatory species would be expected to feed on prey from these lakes as well.

2.3.3. Soil-to-Groundwater Migration. During periods of rainfall, water may infiltrate the source areas. A portion of the dissolved constituents are adsorbed by the soils underneath the affected surface soil zone. The remaining portion of the constituents, which is desorbed from the soil particles, continues to leach downward with infiltrating precipitation until it reaches the groundwater.

The potential for contaminants to move into groundwater from source material is dependent on several physical and chemical properties of the particular contaminants. Metals (or their related salts) may readily become soluble with infiltrating precipitation and are likely to contaminate groundwater.

Solubility, which is related to the affinity of a chemical to water, is another property that affects migration of contamination in water. Chemicals with a high solubility have the potential to rapidly dissolve into water (surface water or groundwater) and will therefore move with the water in which it is dissolved. Chemicals with a low solubility do not readily dissolve in water and will either float (if they have a low density) or sink (if they have a high density).

2.3.4. Groundwater-to-Surface Water Migration. The porous nature of mine tailings and chat piles and their location on top of native silty clay soils typically results in a mounded surficial groundwater table under these areas. Compression of the silty clay soils under the piles may create a somewhat effective barrier to downward groundwater migration. Groundwater flow beneath tailings and chat piles generally flows consistent with the original surface patterns and will generally flow towards and discharge to the nearest surface water features. Shallow groundwater under native soils in this region also typically flows toward the nearest stream and discharges to surface water; however, it is important to note that there are numerous bedrock outcrops in the area. When infiltrating groundwater from the source areas flows directly into bedrock, the flow direction has not been determined.

2.3.5. Biological/Food Chain Migration. Biological migration may occur through uptake, bioaccumulation, and food-chain transfer. The principal contaminants of concern identified at the site (cadmium, lead, and zinc) are listed in Table 4-2 of *Bioaccumulative Testing and Interpretation for the Purposes of Sediment Quality Assessment, Status and Needs* (EPA, 2000). EPA generally considered contaminants in this list to be of concern for biological transport.

2.4. SITE HABITATS

Six major source areas exist at the site: Leadwood, Desloge, Federal, Elvins, National, and Bonne Terre. The habitats associated with the source areas (barren and re-vegetating) range across the successional spectrum from herbaceous to forested areas. Former chat piles include remediated piles (the western pile at Bonne Terre) as well as non-remediated piles including barren and re-vegetating areas similar to the former tailing ponds.

The location and orientation of ecological habitats with respect to each of the source areas is presented in Figures 2-2 through 2-6. In general, the habitats observed at the site included the following:

- Tailings, barren – Barren tailings are located on all the former tailings ponds and are generally void of plant life.
- Tailings, herbaceous – Occur in most of the former tailings ponds where herbaceous plant species (grasses) appear to be re-vegetating.
- Tailings, shrub-scrub – Occur in most of the former tailings ponds where small shrub-scrub plant species appear to be re-vegetating.
- Tailings, forested.
- Tailings, open water.
- Chat, capped/barren – Occur on remediated chat piles where a stone cover was placed over the chat. Barren areas on the chat piles are generally void of plant life.
- Chat, capped/herbaceous - Occur on remediated chat piles where herbaceous vegetative cover was placed over the chat.
- Chat, barren - Barren chat piles are generally void of plant life.
- Chat, herbaceous - Occur on chat piles where herbaceous plant species (grasses) appear to be re-vegetating.
- Chat, shrub-scrub - Occur on chat piles where small shrub-scrub plant species appear to be re-vegetating.
- Chat, forested.
- Chat, wetland/herbaceous.
- Chat, industrial areas.

In addition to the tailings areas and chat piles, there are some adjacent areas located downgradient of these sources which could become contaminated by surface runoff from the sources. These areas include the following habitats:

- Open field/meadow
- Forested upland
- Rural residential-agricultural
- Urban industrial
- Urban residential

The following subsections provide a description of the specific habitats observed in each of the major source areas at the Big River Mine Tailings site.

2.4.1. **Leadwood.** The potentially impacted habitats associated with the Leadwood source area include upland forest, rural residential-agricultural areas, barren tailings, and former tailings ponds (herbaceous, shrub-scrub, forested, and open water). Figure 2-2 presents the habitats at the Leadwood source area and impacted stream segments downstream to the Desloge source area. Stands of red cedar trees constitute the tailings-forested habitat.

2.4.2. Desloge. The potentially impacted habitats associated with the Desloge source area include chat (barren, herbaceous, forested, shrub-scrub), upland forest, and urban residential. Figure 2-3 presents the habitats at the Desloge source area and impacted stream segments downstream to the Bonne Terre source area. Numerous animal tracks were observed along the floodplain of Big River including deer (*Odocoileus virginianus*), raccoon (*Procyon lotor*), coyote (*Canis latrans*), and turkey (*Meleagris gallopavo*). Common 3-ridge mussel (*Amblema neislerii*) shells were also observed on the banks. Most of the river is fringed by deciduous trees in this area.

2.4.3. Federal/St. Joe State Park. The potentially impacted habitats associated with the Federal/St. Joe State Park source area include tailings (barren, herbaceous, shrub-scrub, forested and open water), shrub-scrub chat, upland forest, and old field/meadow. Figure 2-4 presents the habitats at the Federal source area and impacted stream segments downstream to the National source area. Numerous deer tracks have been observed in this area.

2.4.4. Elvins (Rivermine). The potentially impacted habitats associated with the Elvins source area include chat (barren, herbaceous, shrub-scrub), upland forest, and urban residential. Figure 2-4 presents the habitats at the Elvins source area and impacted stream segments downstream to the National source area.

2.4.5. National (Flat River). The potentially impacted habitats associated with the National source area include chat (barren, herbaceous, shrub-scrub, wetland/herbaceous, and industrial), upland forest, old field/meadow, and urban residential. Figure 2-5 presents the habitats at the National source area and impacted stream segments downstream to the confluence of Flat River and Big River. A drainage area flows from the National chat pile towards Flat River. Dense stands of common reed (*Phragmites australis*) were observed growing in this drainage area.

2.4.6. Bonne Terre. The potentially impacted habitats associated with the Bonne Terre source area include tailings (capped/barren, capped/herbaceous, barren, herbaceous, shrub-scrub), upland forest, old field/meadow, and rural residential-agricultural. Figure 2-6 presents the habitats at the Bonne Terre source area and impacted stream segments downstream to the confluence of Turkey Creek and Big River.

2.5. SENSITIVE/CRITICAL HABITATS

While no sensitive or critical habitats were observed on the Big River Mines Tailings site, there are three sensitive natural communities that have been documented within St. Francois County and the Big River basin (MDC, 2002). Included in these communities are an example of an Ozark spring or spring branch (Coonville Creek) and two examples of fen (Coonville Creek Conservation Area and St. Francois State Park; MDC, 2002).

2.6. THREATENED AND ENDANGERED SPECIES

Four fish and three mussel species that have been known to occur in Big River are either endangered, rare, or on the State watch list (MDC, 2002). The fish species include the crystal darter (*Ammocrypta asprella*), which is on the State endangered list; Alabama shad (*Alos alabamae*), which is considered rare; and the western sand darter (*Ammocrypta clara*) and silverjaw minnow (*Ericymba buccata*) which are on the State watch list. The three mussel species of special concern include the pink mucket (*Lampsilis abrupta*) which is Federally-endangered; and the scale shell (*Leptodea leptodon*) and spectacle case (*Cumberlandia monodonta*), which are listed as rare (MDC, 2002). The cerulean warbler (*Dendroica* cerulean) and the plain spotted skunk (*Spilogale putorius*) are also listed on the State watch list for mammal species in St. Francois County, Missouri (MDC, 2002).

3. TOXICITY ASSESSMENT

3.1. CADMIUM

Cadmium is a naturally occurring element in the earth's crust. It is usually found as a mineral combined with other elements such as oxygen (cadmium oxide), chlorine (cadmium chloride), or sulfur (cadmium sulfate, cadmium sulfide). It does not have a definite taste or odor. All soils and rocks, including coal and mineral fertilizers, have some cadmium in them. Cadmium is often extracted during the production of other metals such as zinc, lead, and copper.

Orally ingested cadmium and its salts are poorly absorbed by the gastrointestinal tract in wildlife. In general, less than three percent of ingested cadmium is absorbed by the gastrointestinal tract of animals. Once in the blood, cadmium is distributed to all internal organs with the highest concentrations found in the liver and kidneys. Cadmium is not known to undergo metabolic conversion; however, it does bind with, and adversely affect the function of proteins such as metallothionein. Most cadmium ingested is rapidly cleared from the body, primarily through feces because its absorption efficiency is so low (ATSDR, 1993).

There is strong evidence for food chain bioaccumulation; however, the potential for biomagnification is presently unknown (ATSDR, 1993). EPA (2000) considers cadmium to be an important bioaccumulative compound in sediment.

A soil-to-invertebrate biotransfer factor (BTF) of 0.96 has been developed for cadmium based on the geometric mean of 22 laboratory studies using acute and chronic exposure (EPA, 1999).

A soil-to-plant BTF of 0.364 has been developed for cadmium based on empirical data from the EPA (EPA, 1999).

A water-to-invertebrate BTF of 3,461 has been developed for cadmium based on the geometric mean of data from eight field studies (EPA, 1999).

A water-to-fish BTF of 907 has been developed for cadmium based on the geometric mean of data from four field studies (EPA, 1999).

A sediment-to-invertebrate BTF of 3.4 has been developed for cadmium based on the geometric mean of data from eight field studies (EPA, 1999).

Aquatic Plants: Cadmium is not essential for plant growth. Exposure to cadmium can result in adverse growth effects. The lowest chronic value of 2.0 µg/L was established for aquatic plants by Conway (1977). A relatively low cadmium concentration reduced the population growth rate of *Asterionella formosa* by an order of magnitude.

Aquatic Invertebrates: A lowest chronic value of 0.15 µg/L was established for daphnids as a result of life-cycle tests performed by Chapman *et al.* (no date). A test EC20 value of 0.75 µg/L was established for daphnids by Elnabarawy *et al.* (1986).

A substantial toxicological database for effects on freshwater biota exposed to cadmium demonstrates that ambient cadmium concentrations in water exceeding 10 ppb are associated with high mortality, reduced growth, inhibited reproduction, and other adverse effects. Several species of freshwater aquatic insects, crustaceans, and teleosts exhibited significant mortality at cadmium concentrations of 0.8 to 9.9 plead during exposures of 4 to 33 days; mortality generally increased as exposure time increased, water hardness decreased, and organism age decreased.

Fish: A lowest chronic value of 1.7 µg/L was established for fish by Sauter *et al.* (1976) and was based on early life stage tests performed on brook trout. A test EC20 value of 1.8 µg/L was established by Carlson *et al.* (1982) based on freshwater fish studies.

Terrestrial Plants: Cadmium is not essential for plant growth. Exposure to cadmium at relatively low levels can result in adverse growth effects. If present in a bioavailable form, cadmium can be taken up by roots, translocated within the plant, and accumulated (Efroymson *et al.*, 1997a). Cadmium is chemically similar to zinc, an essential element. Competition between the two for organic ligands and enzyme binding sites may explain some of the toxic effects of cadmium and the ameliorative effects of zinc on cadmium toxicity. Cadmium depresses uptake of Fe, Mn, and probably Ca, Mg, and N. Cadmium is toxic at low concentrations. Symptoms resemble Fe chlorosis and include necrosis, wilting, reduced zinc levels, and reduction in growth. The mechanisms of toxicity include reduced photosynthetic rate, poor root system development, reduced conductivity of stems, and ion interactions in the plant. A benchmark value of 4 ppm was established for cadmium based on 74 studies. Approximately 40% of the concentrations responsible for greater than 20% reductions in plant growth parameters fall between 1 and 10 ppm cadmium added to soil. This range includes wild and cultivated plants such as legumes, trees, grasses, leafy vegetables and other dicotyledonous plants in soils with a relatively wide range of physical and chemical characteristics (Effroymson *et al.*, 1997a). EPA's Interim Ecological Soil Screening Guidance for cadmium indicates a soil screening level for plants of 32 mg/kg based on a review of 62 studies deemed acceptable (EPA, 2003).

Soil Invertebrates: Cadmium in surface soil has been shown to affect earthworm growth and survival, as well as reduce the number of earthworm cocoons produced. An Ecological Soil Screening Level (Eco-SSL) has been developed for cadmium based on ten suitable studies of toxicity of cadmium in soil to soil invertebrates. These studies identified the maximum acceptable toxicant concentrations and the EC20 for springtails and the earthworms. These values ranged from 6 to 600 mg/kg. The Eco-SSL of 142 mg/kg was based on the geometric mean of these values (EPA, 2003).

Birds: Cadmium has been shown to adversely effect reproduction in birds (Sample *et al.*, 1996). A study of oral dietary ingestion of cadmium (as cadmium chloride) by mallard ducks over a 90-day exposure period indicated that a dose of 1.45 (mg/kgBW/d) produced no adverse reproductive effects. This value is considered the No Adverse Effect Level (NOAEL). However, a dose of 20 mg/kgBW/d resulted in a decrease in egg production (White and Finley, 1978).

Mammals: A study of oral exposure in rats indicated that a dose of 1 mg/kgBW/day produced no adverse effects on reproduction (NOAEL). In this same study, a dose of 10 mg/kg/d produced reduced fetal implantations, fetal survivorship, and fetal resorptions and was identified as the Lowest Observed Adverse Effect Level (LOAEL) (Sutou *et al.*, 1980). EPA's Eco-SSL for cadmium has compiled a number of studies, many of which identify thresholds for reproductive effects. The Eco-SSL indicates a range of NOAELs for rodent species from 0.0069 to 50 mg/kgBW/d. The range of LOAELs is from 0.661 to 75 mg/kgBW/d.

3.2. LEAD

Lead is a naturally occurring bluish-gray metal found in small amounts in the earth's crust. It has no taste or smell. Lead is the product of many activities such as mining, manufacturing, and burning of fossil fuels.

In general, lead does not biomagnify in food chains. EPA (2000) considers lead to be an important bioaccumulative compound in sediment. Older organisms usually contain the greatest body burdens, and lead accumulations are highest in bony tissues (USGS, 1988).

A Soil-to-invertebrate transfer factor (BTF) of 0.03 has been developed for lead based on the geometric mean of 6 laboratory values (EPA, 1999).

A Soil-to-plant BTF of 0.045 has been developed for lead based on empirical data from Baes, Sharp, Sjoreen, and Shor (EPA, 1999).

A water-to-invertebrate BTF of 5,059 has been developed for lead based on the geometric mean of 6 field values (EPA, 1999).

A water-to-fish BTF of 0.09 has been developed for lead based on the geometric mean of 3 laboratory values (EPA, 1999).

A sediment-to-invertebrate BTF of 0.63 has been developed for lead based on the 14-day exposure *Chironomus tentans* Study conducted by Harrahy and Clements (EPA, 1999).

Aquatic Plants: The lowest chronic value of 500 µg/L was based on studies of growth inhibition in *Chlorella vulgaris* (EPA, 1985). Among aquatic biota lead concentrations are usually highest in algae although no significant biomagnification occurs in aquatic food chains (Demayo *et al.,* 1982). According to the US Fish and Wildlife Service (USFWS), growth inhibition of marine algae was reported at 5.1 µg Pb2+ while in freshwater algae at 5.0 µg Pb2+. The effects of lead contamination on sensitive species were most pronounced at elevated water temperatures, reduced pH, in comparatively soft waters, in younger life stages, and after long exposures.

Aquatic Invertebrates: The lowest chronic value of 2.6 µg/L was established for daphnids based on studies by Nebeker *et al.* (1983). The test EC20 value of <0.56 µg/L for daphnids was established by Elnabarawy *et al.* (1986).

Fish: The lowest chronic value of 1,888 µg/L was established for fish by Davies *et al.* (1976) based on an early life stage tests on rainbow trout. The effect concentrations (EC) value for fish is from Sauter *et al.* (1976). Lethal solutions of lead cause increased mucus formation in fishes. The excess coagulates over the entire body and is particularly prominent over the gills, interfering with respiratory function and resulting in death by anoxia (Aronson, 1971). Increasing waterborne concentrations of lead over 10 µg/L are expected to provide increasingly severe long-term effects on fish and fisheries (DeMayo *et al.*, 1982)

Terrestrial Plants: Uptake of lead by terrestrial plants is limited by the low bioavailability of lead from soils. A benchmark of 50 ppm was established for lead based on 17 studies conducted with a range of different plant species used for its derivation. (Efroymson *et al.*, 1997a). The most conservative of the available studies indicates that adverse effects are noted to tree growth at concentrations of 50 mg/kg; however, no adverse effects were noted at 20 mg/kg (Dixon, 1988). Lead is taken up passively by roots and translocation to shoots is limited. The phytotoxicity of lead is relatively low compared with other trace elements. It effects mitochondrial respiration and photosynthesis by disturbing electron transfer reactions. (Miles *et al.*, 1972). An Eco-SSL has been developed for lead based on five suitable studies of toxicity of lead in soil to plants. These studies identified the maximum acceptable toxicant concentrations, which ranged from 22 to 316 mg/kg. The Eco-SSL of 110 mg/kg was based on the geometric mean of these values (EPA, 2003).

Soil Invertebrates: An Eco-SSL has been developed for lead based on four suitable studies of toxicity of lead in soil to *Collembola*, a soil invertebrate. These studies identified the maximum acceptable toxicant concentrations and the EC20 for springtails and the earthworms. These values ranged from 894 to 3,162 mg/kg. The Eco-SSL of 1,682 mg/kg was based on the geometric mean of these values (EPA, 2003).

Birds: Lead has been shown to adversely effect reproduction in birds. A study of oral dietary ingestion of lead (as Acetate) over 12 weeks in Japanese Quails indicated a dose of 1.13 mg/kgBW/day produced no adverse reproductive effects (NOAEL); however, a dose of 11.3 mg/kgBW/day resulted in a decrease in egg hatching success (LOAEL) (Edens *et al.*, 1976).

Mammals: Orally ingested lead is not well absorbed through the gastrointestinal tract in adult animals; however, the rate of gastrointestinal absorption increases significantly in younger animals. Once absorbed, lead is widely distributed to soft tissues then redistributes and accumulates in bones. Lead is not metabolized or biotransformed in the body and therefore is either incorporated into tissue then bones or is excreted once ingestion. Older organisms tend to have the highest body burden concentrations of lead. Excretion is primarily through fecal excretion and through bile. Studies of lead ingestion in animals have indicated that lead can produce adverse reproductive effects; however, the mechanics of these effects are unknown. These reproductive effects include an increase incidence of spontaneous abortion, miscarriage, and stillbirths and effects to sperm and testicular tissue in males (ATSDR, 1993). Oral exposure studies of lead (in the form of lead acetate) in rats over three generations indicated a NOAEL of 8 mg/kgBW/d, while 80 mg/kgBW/d reduced offspring weights, and produced kidney damage in the young (LOAEL) (Azar *et al.*, 1973).

3.3. ZINC

Zinc is one of the most common elements in the earth's crust. It is found in air, soil, and water, and is present in all foods. Pure zinc is a bluish white shiny metal and combines with other elements to form zinc compounds. Common zinc compounds found at hazardous waste sites include zinc chloride, zinc oxide, zinc sulfate, and zinc sulfide. Zinc compounds are widely used in industry to make paint, rubber, dye, wood preservatives, and ointments.

Zinc is essential for normal metabolism in animals. Under normal conditions, 20 to 30 percent of ingested zinc is absorbed through the gastrointestinal tract. Once absorbed, zinc is widely distributed throughout the body with highest content in the muscle, bone, gastrointestinal tissue, kidney, and the brain. Zinc is excreted both in feces and urine (ATSDR, 1994).

Zinc accumulates in aquatic organisms, however, microcosm studies indicate that it does not biomagnify through aquatic food chains. Bioconcentration of zinc from soil by terrestrial wildlife and plants is insignificant. This indicates that zinc does not biomagnify through terrestrial food chains (ATSDR, 1994). EPA (2000) considers zinc to be an important bioaccumulative compound in sediment.

A soil-to-invertebrate biotransfer factor (BTF) of 0.56 has been developed for zinc based on the geometric mean of 5 laboratory values (EPA, 1999).

A soil-to-plant BTF of 0.0000000000012 has been developed for zinc based empirical data reported to EPA (EPA, 1999).

A water-to-invertebrate BTF of 4,578 has been developed for zinc based on the geometric mean of 9 field values (EPA, 1999).

A water-to-fish BTF of 2,059 has been developed for zinc based on the geometric mean of 4 field-derived values (EPA, 1999).

A sediment-to-invertebrate BTF of 0.57 has been developed for zinc based on the geometric mean of 8 field-derived values (EPA, 1999).

Aquatic Plants: Bartlett et al. (1974) ran 7-day tests on *Selenastrum capricornutum*. These aquatic plants showed incipient inhibition of growth.

Aquatic Invertebrates: The lowest chronic value of 46.73µg/L was established for daphnids by Chapman *et al.* (no date) based on life-cycle tests on *Jordanella floridae* and *Daphnia magna*. Zinc is important in pH regulation of sperm of marine invertebrates. Zinc reduction in semen to < 6.5 g/L adversely affected sperm pH and motility in sea urchins (*Strongylocentrotus purpuratus, Lytechnicus pictus*), horseshoe crab (*Limulus polyphemus*), and starfish (Clapper *et al.*, 1985a, 1985b).

Fish: A chronic value of 36.41 µg/L and test EC20 value of 47 µg/L for fish has been identified by Spehar (1976). Rainbow trout fry fed diets containing 1-4 mg/kg ration had poor growth, increased morality, cataracts, and fin erosion; supplementing the diet to 15-30 mg/kg alleviating these signs. Spry *et al.* (1988) also fed rainbow trout fry diets containing a 1, 90, or 590 mg/kg ration and simultaneously exposed them to a range of waterborne zinc concentrations of 7, 39, 148, or 529 µg/L. After 16 weeks, the 7 µg/L plus 1 mg/kg diet group showed clear signs of deficiency including a significantly reduced plasma zinc concentration (which was evident as early as the first week of exposure), reduced growth (with no growth after week 12), decreased hematocrit, and reduced plasma protein and whole body zinc concentration.

Terrestrial Plants: Zinc is an essential element for plant growth. It is actively absorbed by the roots and then widely distributed throughout the roots and shoots. Information concerning the ecological effects of zinc to plants is extensive. Excessive zinc in the soil may result in chlorosis and depressed plant growth by inhibiting CO_2 fixation, carbohydrate transport, and membrane permeability (Efroymson *et al.*, 1997a). A review of EPA's Ecotox database indicated no-effect thresholds for phytotoxicity ranging from 2.92 to 189 mg/kg; low-effect thresholds ranged from 58.8 to 1087 mg/kg.

Soil Invertebrates: An Eco-SSL has been developed for zinc based on six suitable studies of toxicity of zinc in soil, to soil invertebrates. These studies identified the maximum acceptable toxicant concentrations and the EC10 for a nematode and *F. candida*. These values ranged from 35 to 305 mg/kg. The Eco-SSL of 120 mg/kg was based on the geometric mean of these values (EPA, 2003).

Birds: A study of dietary ingestion of zinc (as zinc sulfate) over 44 weeks in white leghorn hens indicated that a dose of 14.5 mg/kgBW/d produced no adverse reproductive effects (NOAEL); however, a dose of 131 mg/kgBW/d decreased egg hatchability (LOAEL) (Stahl *et al.*, 1990).

Mammals: Ingested zinc has been shown to adversely effect reproduction in animals. A major effect is decreased embryonic implantations in mammals (Sample *et al.*, 1996). A study of dietary ingestion of zinc (as zinc oxide) during gestation of rats indicated that a dose of 160 mg/kgBW/d produced no adverse reproductive effects (NOAEL); however a dose of 320 mg/kgBW/d increased rates of fetal absorption and reduced fetal growth rates (LOAEL) (Schlicker and Cox, 1968).

4. PRELIMINARY RISK SCREEN

Steps 1 and 2 of the Ecological Risk Assessment Guidance for Superfund (ERAGS) are generally referred to as the screening-level ecological risk assessment (SLERA). The SLERA portion of this risk assessment was prepared by Black and Veatch in March 2005 as part of the *Site Description Report.* The results of the preliminary risk screen are included here and will be used in conjunction with additional site-specific information in the baseline problem formulation to determine the scope of the Ecological Risk Assessment (ERA).

4.1. CONCEPTUAL ECOLOGICAL EXPOSURE MODEL

The preliminary risk screening used the characterization of the exposure setting to identify potential or suspected exposure pathways for the Big River Mine Tailings site. The assessment of pathways by which ecological receptors may be exposed to chemical of potential concern (COPCs) from the Big River Mine Tailings Site included an examination of the source areas, existing migration pathways and potential exposure routes as well as those that may be reasonably expected in the future. The determination of exposure pathways was made by a careful evaluation of the current extent of affected media at the site in relation to habitats, and the results of a fate and transport assessment that evaluates constituent migration pathways.

For an exposure pathway to be complete, a chemical must be able to travel from the source to ecological receptors and be taken up by the receptors via one or more exposure routes (EPA, 1997). Incomplete exposure pathways are characterized by either a disruption in chemical transport to plants or animals or by the absence of chemicals in a medium to which an ecological receptor is exposed. Identifying complete exposure pathways before the analysis step focuses the exposure and ecological effects analyses on only those chemicals that can reach ecological receptors.

There are several potential areas where site-related contamination is known to occur:

- Bonne Terre Tailings Pile
- Desloge Chat Pile
- Elvins (Rivermine) Chat Pile
- Federal Tailings Pile (St. Joe State Park)
- Leadwood Tailings Pile
- National Chat Pile (Flat River)
- Doe Run Chat Pile
- Hayden Creek Chat Pile

The site conceptual exposure model for the Big River Mine Tailings site integrates and summarizes the information concerning sources, constituent migration pathways, exposure routes, and receptors into a combination of potential exposure pathways. The site conceptual exposure model, including a graphical representation of the complete exposure pathways to ecological receptors by direct exposure or through food-chain transfer, is presented in Figures 4-1a and 4-1b (Appendix C). This model identified the key potential release mechanisms, transport media, exposure media, exposure routes, and terrestrial and aquatic ecological receptors for the Big River Mine Tailings site. The identified potential exposure pathways included in this model are complete pathways (i.e., COPCs are expected to reach receptors). Table 4-1 (Appendix B) presents the assessment and measurement endpoints as well as the risk questions for the Big River Mine Tailings site.

Ecological endpoints are identified within ERA process to provide a basis for characterizing risks. Ecological endpoints are the types of actual or potential impacts a chemical stressor has on an ecological component. An assessment endpoint (AE) is "an explicit expression of the environmental value that is to be protected" (EPA, 1992). ERA involves multiple species that are likely to be exposed to differing degrees and to respond differently to the same contaminant. Nonetheless, it is not practical or possible to directly evaluate risks to all of the individual components of the ecosystem at a site. In the *Site Description Report,* assessment endpoints focused the preliminary risk screening on particular components of the ecosystem that could be adversely affected by contaminants from the site.

In the ERA, the preliminary assessment endpoints are refined based on the results of the initial screen and evaluated based on additional sampling and analyses. A measurement endpoint (ME) is defined as “a measurable ecological characteristic that is related to the valued characteristic chosen as the assessment endpoint” and is a measure of biological effects (e.g., mortality, reproduction, growth) (EPA, 1992). MEs are frequently numerical expressions of observations (e.g., toxicity test results, community diversity measures) that can be compared statistically to a control or reference site to detect adverse responses to a site contaminant.

The conceptual model established the complete exposure pathways that would be evaluated in the ERA and the relationship of the MEs to the AEs. MEs and the relationship of the selected MEs to the AEs are presented in Table 4-1.

Ecological risk questions are basically questions about the relationships among AEs and their predicted responses when exposed to contaminants. The risk questions are based on the AEs and provide a basis for recommendations regarding further study. The risk questions that were selected for the ERA are presented in Table 4-1.

Site-specific AEs for the Big River Mine Tailings site were developed based on the available information. These AEs include the following:

- AE No. 1 - Protection of terrestrial plant communities from the toxic effects (on survival and reproduction) of COPCs present in surface soils via direct exposure.

- AE No. 2 - Protection of terrestrial soil invertebrate communities from the toxic effects (on survival and reproduction) of COPCs present in surface soils via direct exposure.

- AE No. 3 - Protection of terrestrial herbivore communities from the toxic effects (on survival and reproduction) of COPCs present in vegetation.

- AE No. 4 - Protection of terrestrial vermivore communities from the toxic effects (on survival and reproduction) of COPCs present in terrestrial invertebrate tissue.

- AE No. 5 - Protection of terrestrial carnivore communities from the toxic effects (on survival and reproduction) of COPCs present in terrestrial wildlife prey tissue.

- AE No. 6 - Protection of aquatic communities from the toxic effects (on survival and reproduction) of COPCs present in surface water via direct exposure.

- AE No. 7 - Protection of benthic invertebrate communities from the toxic effects (on survival and reproduction) of COPCs present in sediment via direct exposure.

- AE No. 8 - Protection of aquatic herbivore communities from the toxic effects (on survival and reproduction) of COPCs present in vegetation.

- AE No. 9 - Protection of carnivore communities from the toxic effects (on survival and reproduction) of COPCs present in amphibian tissue.

- AE No. 10 - Protection of piscivore communities from the toxic effects (on survival and reproduction) of COPCs present in fish tissue.

- AE No. 11 - Protection of aquatic benthivore communities from the toxic effects (on survival and reproduction) of COPCs present in crayfish/invertebrates.

4.2. DIRECT EXPOSURE

Toxicity through direct exposure is measured by comparing the concentration of a COPC to direct exposure toxicity threshold concentrations for each receptor of concern obtained from the scientific literature or measured directly through site-specific bioassays. Specific toxicity threshold concentrations for receptors of concern are provided in the ecotoxicity profiles for each COPC provided in Section 3. The evaluation of direct exposure (AEs1, 2, 6 and 7) includes a comparison of the maximum and average concentrations of contaminants detected in soil, surface water, and sediment to the respective ecotoxicity screening values (ESVs). The following ESVs were used:

- EPA Eco Soil Screening Levels (Eco-SSLs) for soils
- Consensus Based Threshold Effect Concentrations (TECs) for sediments
- EPA National Ambient Water Quality Criteria (NAWQC) for surface waters

In this screening, risks to ecological receptors are evaluated by comparing the maximum and average contaminant concentrations to the specific ESV for that contaminant (Tables 4-2 and 4-5). When the concentration for a contaminant is below the ESV, that contaminant is unlikely to cause adverse ecological effects. The screening level risk calculation is a conservative estimate. The results of this screening calculation should serve only to determine whether a contaminant presents negligible risk or whether additional site-specific information needs to be collected and evaluated.

In this screening, only those contaminants that were detected in a media for each exposure unit were considered as potential contaminants of concern. There are two possible outcomes as follows:

- Outcome 1: The detected contaminant is below an accepted ESV (HQ<1). These contaminants are considered to present negligible risk.

- Outcome 2: Contaminant was detected at concentrations exceeding its accepted ESV(HQ>1). These contaminants may contribute to a significant risk at the site.

It is possible that reasonable maximum exposure (RME) concentrations will exceed the ecological screening value (ESV) while the central tendency exposure (CTE) will not. This is not the case with the preliminary data for this site (both RME and CTE concentrations exceed the ESVs); however, future data could result in this situation. At the screening phase of the risk assessment, when the RME concentration of any potential contaminant of concern exceeds the ESV, those contaminants will be retained for further evaluation.

4.2.1. Surface Soil. Surface soil samples were considered for each of six exposure areas selected to evaluate ecological receptors. These areas include the Bonne Terre Tailings pile, the Desloge chat pile, the Elvins (Rivermine) chat pile, the Federal tailings pile, the Leadwood tailings pile, and the National (Flat River) chat pile. The ranges of cadmium, lead and zinc concentrations in soils from these areas were compared to ESVs (Eco-SSLs), as presented in Tables 4-2 and 4-3 (Appendix B), respectively.

In general, lead and zinc were identified as preliminary COPC for direct exposure to plants in soil (AE 1). In addition, zinc was identified as a COPC for direct exposure to soil invertebrates (AE 2). Figures 4-2 through 4-7 (Appendix C) illustrate the occurrence and distribution of cadmium, lead, and zinc compared to the ESVs for each major source area.

For the Bonne Terre Tailings pile, maximum concentrations of lead (1,050 mg/kg) and zinc (161 mg/kg) exceed the ESVs, while the maximum concentration of cadmium (1.12 mg/kg) is below the screening value. Figures 4-2a, 4-2b, and 4-2c present the occurrence and distribution of cadmium, lead, and zinc in the vicinity of the Bonne Terre Tailings pile. Concentrations of lead were found to exceed the screening value in 70 percent of all samples analyzed and concentrations of zinc were found to exceed the screening value in 66 percent of all samples analyzed. Concentrations exceeding the screening levels were found up to 4,600 feet and 5,000 feet from the tailings pile for lead and zinc, respectively. There were no discernable trends in the detected concentrations with the distance from the tailings pile; however, the maximum concentrations of lead and zinc were detected at the same location (2,800 feet from the tailings pile).

For the Desloge chat pile, maximum concentrations of lead (882 mg/kg) and zinc (1,230 mg/kg) exceed the ESVs, while the maximum concentration of cadmium (24 mg/kg) is below the screening value. Figures 4-3a, 4-3b, and 4-3c present the occurrence and distribution of cadmium, lead and zinc in the vicinity of the Desloge chat pile. Concentrations of lead and zinc were found to exceed the screening value in all (100 percent) of the samples analyzed. Concentrations of lead and zinc exceeding the screening levels were found up to 1,650 feet from the chat pile. Generally, the highest concentrations of all three constituents were found either on or near (within 700 feet) the Desloge chat pile, with decreasing concentrations with increasing distance.

For the Elvins (Rivermine) chat pile, maximum concentrations of lead (1,540 mg/kg) and zinc (1,640 mg/kg) exceed the ESVs, while the maximum concentration of cadmium (18 mg/kg) is below the screening value. Figures 4-4a, 4-4b, and 4-4c present the occurrence and distribution of cadmium, lead and zinc in the vicinity of the Elvins (Rivermine) chat pile. Concentrations of lead and zinc were found to exceed the screening value in all (100 percent) of the samples analyzed. Concentrations of lead and zinc exceeding the screening levels were found up to 650 feet from the chat pile; however, there were no discernable trends in the concentrations with the distance from the chat pile. The maximum concentrations of all three constituents were detected at the same location on the chat pile, and the lowest concentrations for all three constituents were detected from a location 180 feet from the pile.

For the Federal Tailings pile (St. Joe State Park), maximum concentrations of lead (612 mg/kg) and zinc (341 mg/kg) exceed the ESVs, while the maximum concentration of cadmium (6.48 mg/kg) is below the screening value. Figures 4-5a, 4-5b, and 4-5c present the occurrence and distribution of cadmium, lead, and zinc in the vicinity of the Federal tailings pile. Concentrations of lead were found to exceed the screening value in 92 percent of the samples analyzed, and concentrations of zinc were found to exceed the screening value in 88 percent of the samples analyzed.

Concentrations of lead and zinc exceeding the screening levels were found up to 720 feet from the tailings pile. Generally, the highest concentrations of all three constituents were found on the tailings pile, with decreasing concentrations with increasing distance.

For the Leadwood tailings pile, maximum concentrations of lead (267 mg/kg) and zinc (337 mg/kg) exceed the ESVs, while the maximum concentration of cadmium (5.14 mg/kg) is below the screening value. Figures 4-6a, 4-6b, and 4-6c present the occurrence and distribution of cadmium, lead, and zinc in the vicinity of the Leadwood Tailings Pile. Concentrations of lead were found to exceed the screening value in 75 percent of the samples analyzed, and concentrations of zinc were found to exceed the screening value in all (100 percent) of the samples analyzed. Concentrations of lead and zinc exceeding the screening levels were found up to 1,000 feet and 1,200 feet from the tailings pile, respectively. Generally, the highest concentrations of all three constituents were found within 50 feet of the tailings pile, with decreasing concentrations with increasing distance.

For the National (Flat River) chat pile, maximum concentrations of lead (381 mg/kg) and zinc (381 mg/kg) exceed the ESVs, while the maximum concentration of cadmium (6.93 mg/kg) is below the screening value. Figures 4-7a, 4-7b, and 4-7c present the occurrence and distribution of cadmium, lead, and zinc in the vicinity of the National chat pile. Concentrations of lead and zinc were found to exceed the screening value in all (100 percent) of the samples analyzed. Since samples from only three locations were available, there were no discernable trends in the concentrations with the distance from the chat pile.

4.2.2. Sediment. Sediment samples were considered to evaluate potential concern for ecological receptors. The ranges of cadmium, lead and zinc concentrations in sediment from the Big River site were compared to Threshold Effects Concentrations (TECs)(MacDonald *et al.*, 2000). Contaminant concentrations in sediment samples from the Big River, Flat River and associated tributaries were compared to ESVs in Table 4-4 (Appendix B). In general, cadmium, lead, and zinc were identified as preliminary COPCs for direct exposure to sediment.

For sediment, maximum concentrations of cadmium (227 mg/kg), lead (6259 mg/kg) and zinc (6,295 mg/kg) exceed the consensus based TECs. Figures 4-8a, 4-8b, and 4-8c (Appendix C) present the occurrence and distribution of cadmium, lead, and zinc in Big River sediment. Concentrations of cadmium were found to exceed the screening value in 85 percent of the samples analyzed. Concentrations of lead were found to exceed the screening value in 94 percent of the samples analyzed, and concentrations of zinc were found to exceed the screening value in 67 percent of the samples analyzed. The highest concentrations of cadmium and lead were detected in sediment samples collected in the vicinity of the Desloge chat pile, however high concentrations of lead were also detected in the vicinity of the National chat pile. The highest concentrations of zinc detected in sediment were collected in the vicinity of the Elvins chat pile and Federal tailings pile, but high concentrations of zinc were also detected in the vicinity of the Desloge chat pile. The lowest concentrations reported were from sediment samples located in the vicinity of the Bonne Terre tailings pile. Generally higher concentrations of the COPCs were detected in low-energy stream segments and in those areas where streams join.

4.2.3. Surface Water. Surface water samples were considered to evaluate potential concern for ecological receptors. The ranges of cadmium, lead, and zinc concentrations in surface water from the Big River, Flat River and associated tributaries were compared to ESVs (chronic NAWQC). Contaminant concentrations in unfiltered surface water samples were compared to ESVs in Table 4-5 (Appendix B).

For surface water in the Big River, maximum concentrations of lead (52 µg/L) and zinc (575 µg/L) exceed the chronic NAWQC. No surface water samples containing detectable levels of cadmium were identified. Figures 4-9a and 4-9b present the occurrence and distribution of lead and zinc in Big River surface water. Concentrations of lead were found to exceed the screening value in 94 percent of the samples analyzed, and concentrations of zinc were found to exceed the screening value in 31 percent of the samples analyzed. The highest concentration of lead (52 µg/L) was detected in a surface water sample collected in Flat River Creek below the National tailings pile. The highest concentration of zinc (575 µg/L) was detected in a surface water sample collected in Flat River above Shaw Branch. The lowest concentrations of lead (still exceeding the screening value) were detected in surface water samples collected from a wetland and two lakes adjacent to the Federal tailings pile (St. Joe State Park). The lowest concentration of zinc (15 µg/L) was reported from a surface water sample located in the vicinity of the wetland adjacent to the Federal tailings pile (St. Joe State Park). There was no other discernable trend in the surface water data with respect to proximity to the tailings piles.

4.3. FOOD CHAIN EXPOSURE MODELS

To estimate the food chain exposure doses, ingestion dose exposure models for herbivorous, vermivorous, carnivorous, and piscivorous feeding guilds were developed. The ingestion dose exposure model used to estimate food chain exposure of specific constituents, derived from the *EPA Wildlife Exposure Factors Handbook* (EPA, 1993) is presented as follows:

$$ADD_C = \sum[(C_{PF} * FR_{PF} * N_{FIR})]_i + (C_M * N_{SIR}) * AUF$$

Where:
ADD_C = Average daily ingestion dose of constituent (mg/kgBW-day)
C_{PF} = Estimated concentration of contaminant in prey (mg/kg)
C_M = Concentration of contaminant in media (mg/kg or mg/L)
N_{FIR} = Normalized food ingestion rate (wet weight g/gBW-day)
N_{SIR} = Normalized incidental soil/sediment and surface water ingestion rate (g/gBW-day)
FR_{PF} = Dietary fraction comprised of prey/food item

i = Sum of number of types of food items consumed
AUF = Area Usage Factor of receptor species (default maximum of 1 used for all calculations)

The specific variables used for each receptor are presented in Appendix D. A brief description of each receptor, representing each AE, is provided below.

4.3.1. Herbivorous Mammal Exposure. A prairie vole (*Microtus ochrogaster*) was selected as a representative receptor of an herbivorous mammal that may be present in the terrestrial and wetland habitats of concern at the site. The prairie vole represents the ground-burrowing members of the rodent family and is found in the north and central plains of the United States and southern Canada. The prairie vole inhabits a wide variety of prairie plant communities and moisture regimes, including riparian as well as short-grass or tall-grass communities. Prairie voles prefer areas of dense vegetation, such as grass, alfalfa, or clover. Prairie voles are largely herbivorous, consuming primarily green succulent vegetation but also roots, bark, seeds, fungi, arthropods, and animal matter (EPA, 1993).

4.3.2. Herbivorous Bird Exposure. A mallard duck (*Anas platyrhynchos*) was selected as a representative receptor of an herbivorous bird that may be present in wetlands and aquatic habitats of concern at the site. Mallards prefer natural bottomland wetlands and rivers to reservoirs and farm ponds. Water depths of 20 to 40 centimeters are optimum for foraging. Nests are usually located within a few kilometers of water, and mallards prefer areas that provide concealment from predators such as dense grassy vegetation at least a half meter high. Mallards feed primarily on seeds but also on invertebrates associated with leaf litter and wetlands, mast, agricultural grains, and to a limited extent, leaves, buds, stems, rootlets and tubers. Laying females consume a higher proportion of animal foods during the breeding season than males or non-laying females (EPA, 1993).

4.3.3. Vermivorous Mammal Exposure. A short-tailed shrew (*Blarina brevicauda*) was selected as a representative receptor of a vermivorous mammal that may be present in terrestrial habitats of concern at the site. The northern short-tailed shrew ranges throughout the north-central and northeastern United States and into southern Canada. Short-tailed shrews inhabit a wide variety of habitats and are common in areas with abundant vegetative cover. Short-tailed shrews need cool, moist habitats because of their high metabolic and water-loss rates. The short-tailed shrew is primarily carnivorous. Stomach analyses indicate that insects, earthworms, slugs, and snails can make up most of the shrew's food, while plants, fungi, millipedes, centipedes, arachnids, and small mammals also are consumed. Small mammals are consumed more when invertebrates are less available. Shrews are able to prey on small vertebrates because they produce a poison secretion that is transmitted during biting (EPA, 1993).

4.3.4. Vermivorous Bird Exposure. The American woodcock (*Scolopax minor*) was selected as a representative receptor of a vermivorous bird that may be present in terrestrial habitats of concern at the site. Woodcocks inhabit both woodlands and abandoned fields, particularly those with rich and moderately to poorly drained loamy soils, which tend to support abundant earthworm populations. Woodcocks feed primarily on invertebrates found in moist upland soils by probing the soil with their long prehensile-tipped bill. Earthworms are the preferred diet, but when earthworms are not available, other soil invertebrates are consumed (EPA, 1993).

4.3.5. Carnivorous Mammal Exposure. A red fox (*Vulpes vulpes*) was selected as a representative receptor of a carnivorous mammal that may be present in terrestrial habitats of concern at the site. Red foxes are present throughout the United States and Canada except in the southeast, extreme southwest, and parts of the central states. As the most widely distributed carnivore in the world, the red fox can live in habitats ranging from arctic areas to temperate deserts. Red foxes utilize many types of habitat--cropland, rolling farmland, brush, pastures, hardwood stands, and coniferous forests. They prefer areas with broken and diverse upland habitats such as occur in most agricultural areas. The red fox feeds on animal and plant material, mostly small mammals, birds, insects, and fruit. Meadow voles are a major food in most areas of North America; other common prey includes mice and rabbits. Game birds (e.g., ring-necked pheasant and ruffed grouse) and waterfowl are seasonally important prey in some areas. Plant material is most common in red fox diets in summer and fall when fruits, berries, and nuts become available. Red foxes often cache food in a hole for future use. They also are noted scavengers on carcasses or other refuse. Most activity is nocturnal and at twilight (EPA, 1993).

4.3.6. Carnivorous Bird Exposure. A red-tailed hawk (*Buteo jamaicencis*) was selected as a representative receptor of a carnivorous bird that may be present in terrestrial habitats of concern at the site. The red-tailed hawk is the most common *Buteo* species in the United States. Breeding populations are distributed throughout most wooded and semi-wooded regions of the United States and Canada south of the tundra, although some populations are found in deserts and prairie habitats. Red-tails are found in habitats ranging from woodlands, wetlands, pastures, and prairies to deserts. They appear to prefer a mixed landscape containing old fields, wetlands, and pastures for foraging interspersed with groves of woodlands and bluffs and streamside trees for perching and nesting. Red-tails build their nests close to the tops of trees in low-density forests and often in trees that are on a slope. In areas where trees are scarce, nests are built on other structures, occasionally in cactus, on rock pinnacles or ledges, or manmade structures. In winter, night roosts usually are in thick conifers if available and in other types of trees otherwise. Red-tails hunt primarily from an elevated perch, often near woodland edges. Small mammals, including mice, shrews, voles, rabbits, and squirrels, are important prey, particularly during winter. Red-tails also eat a wide variety of foods depending on availability, including birds, lizards, snakes, and large insects. In general, red-tails are opportunistic and will feed on whatever species are most abundant. Winter food choices vary with snow cover;

when small mammals such as voles become unavailable (under the snow), red-tails may concentrate on larger prey, such as pheasants (EPA, 1993).

4.3.7. Carnivorous/Piscivorous Mammal Exposure. A river otter (*Lutra canadensis*) was selected as a representative receptor of a carnivorous/piscivorous mammal that may be present in or near wetlands and aquatic habitats of concern at the site. The river otter lives along streams and lakes. Only infrequently does it wander far from them when traveling from one water body to another. Its den is usually never more than a few hundred yards from water. A family group may hunt and fish over a waterway of 10 or more miles. The river otter feeds on crayfish, frogs, turtles, earthworms, aquatic insects, and fish (EPA, 1993).

4.3.8. Carnivorous/Piscivorous Bird Exposure. A belted kingfisher (*Ceryle alcyon*) was selected as a representative receptor of a carnivorous/piscivorous bird that may be present in near the wetland and aquatic habitats of concern at the site. Belted kingfishers are typically found along rivers and streams and along lake and pond edges. They prefer waters that are free of thick vegetation that obscures the view of the water and water that is not completely overshadowed by trees. Kingfishers also require relatively clear water in order to see their prey and are noticeably absent in areas when waters become turbid. Belted kingfishers nest in burrows within steep earthen banks devoid of vegetation beside rivers, streams, ponds, and lakes; they also have been found to nest in slopes created by human excavations such as road-cuts and landfills. Sandy soil banks, which are easy to excavate and provide good drainage, are preferred. In general, kingfishers nest near suitable fishing areas when possible but will nest away from water and feed in bodies of water other than the one closest to home (EPA, 1993).

4.3.9. Carnivorous/Herpivorous Bird Exposure. A great blue heron (*Ardea herodias*) was selected as a representative receptor of a carnivorous/herpivorous bird that may be present in aquatic/wetland habitats of concern at the site. Great blue herons inhabit a variety of freshwater and marine areas, including freshwater lakes and rivers, brackish marshes, lagoons, mangroves, and coastal wetlands, particularly where small fish are plentiful in shallow areas. They are often seen on tidal flats and sandbars and occasionally forage in wet meadows, pastures, and other terrestrial habitats. Fish are the preferred prey, but great blues also eat amphibians, reptiles, crustaceans, insects, birds, and mammals (EPA, 1993).

4.4. PRELIMINARY FOOD CHAIN RISK EVALUATION

Toxicity to ecological receptors from food chain exposure to the COPCs is evaluated by comparing an ingestion dose concentration to a dose concentration that is known to not produce adverse effects (NOAEL) and the lowest dose known to produce adverse effects (LOAEL). For the purposes of ecological risk assessment, effects are considered that translate into population or community-level effects such as growth and reproduction. The NOAEL and LOAEL for the COPCs are presented in the ecotoxicological profiles in Section 3.0.

Risks for each COPC through food chain exposure are expressed as a hazard quotient:

$$HQ = [\text{Exposure Dose}] \div [\text{NOAEL or LOAEL}]$$

An HQ of less than one indicates that the contaminant is unlikely to cause adverse ecological effects. It is important to note that actual tissue data from organisms collected at the site (vegetation, small mammal, amphibian, and earthworm) are used in the food chain risk evaluations.

4.4.1. Protection of Herbivore Communities. The initial evaluation of food chain exposure to herbivorous communities (AEs 3 and 8) included the development of HQs for the reasonable maximum exposure (RME) and the central tendency exposure (CTE) to soil, surface water, sediment, and vegetation. It was assumed that 100 percent of the diet for the representative bird and mammal (mallard and prairie vole) was composed of vegetation. In addition, the area use factor (AUF) was assumed to be 100 percent. The RME and CTE concentrations for the COPCs detected in the exposure media are presented in Table 4-6 (Appendix B).

The estimation of ADD and calculation of HQs for the herbivorous mammal and herbivorous bird are presented in Appendix E. The RME and CTE HQs for the herbivorous bird and mammal communities are summarized Table 4-7 (Appendix B).

Based on the evaluation of AE 3, concentrations of cadmium produced NOAEL HQ greater than 1 for the RME and the CTE prairie vole. Based on the preliminary risk screen, there is a risk to mammalian herbivores from cadmium. Approximately 76 percent of the HQ for the vole is due to uptake through measured concentrations of cadmium in vegetation, and 24 percent is due to ingestion of measured concentrations of cadmium in soil. Biota (vegetation) ingestion alone drives HQs above 1 for cadmium; therefore, biotransfer of contamination in vegetation to levels of ecological concern appears to occur at the site.

Based on the evaluation of AE 8, concentrations of lead and zinc produced NOAEL HQ greater than 1 for the RME mallard. In addition, concentrations of lead produced NOAEL HQ greater than 1 for the CTE mallard. Based on this information, there is a risk to avian herbivores from lead and zinc. Approximately 85 percent of the HQ for the mallard associated with lead is due to ingestion of measured concentrations of lead in sediment, and 14 percent is due to uptake through measured concentrations of lead in vegetation. Approximately 79 percent of the HQ for the mallard associated with zinc is due to uptake through measured concentrations of zinc in vegetation, and 21 percent is due to ingestion of measured concentrations of zinc in sediment. Biota (vegetation) ingestion alone drives HQs above 1 for zinc; therefore, biotransfer of contamination in vegetation to levels of ecological concern appears to occur at the site.

In summary, cadmium, lead, and zinc concentrations in vegetation may present an ecological risk to herbivore communities based on a comparison to NOAELs. There are no significant risks to the herbivore communities based on a comparison to LOAELs. Figures 4-10a, 4-10b and 4-10c illustrate the occurrence and distribution of cadmium, lead and zinc in vegetation at the various source areas of the Big River Mine tailings site.

4.4.2. Protection of Vermivore Communities. Earthworms may provide a source of food for vermivorous wildlife (primarily birds and mammals) that forage in the vicinity of the Big River Mine tailings site. The evaluation of food chain exposure to vermivorous communities (AE 4) includes the development of HQs for RME and CTE exposures to soil, surface water, and earthworm tissue. For purposes of this evaluation, it was assumed that 100 percent of the diet for the representative bird and mammal (short-tailed shrew and American woodcock) was composed of earthworms. In addition, AUF was assumed to be 100 percent. The RME and CTE concentrations for the COPCs detected in the exposure media are presented in Table 4-6 (Appendix B).

The estimation of ADD and calculation of HQs for the vermivorous mammal and bird are presented in Appendix E. The RME and CTE HQs for the vermivorous Mammal and Bird Communities are summarized in Table 4-8 (Appendix B).

Based on the evaluation of AE 4 for communities of vermivores, concentrations of cadmium, lead, and zinc produced NOAEL and LOAEL HQs greater than 1 for the RME woodcock. In addition, cadmium and lead produced NOAEL and LOAEL HQs greater than 1 for the CTE short-tailed shrew. Based on this information, there is a risk to mammalian vermivores from cadmium, lead, and zinc. For exposure to cadmium, approximately 99 percent of the HQ for the shrew is due to uptake through measured concentrations of cadmium in earthworms, and 1 percent is due to ingestion of measured concentrations of cadmium in soil. For exposure to lead, approximately 81 percent of the HQ for the shrew is due to uptake through measured concentrations of lead in earthworms, and 19 percent is due to ingestion of measured concentrations of lead in soil. For exposure to zinc, approximately 85 percent of the HQ for the shrew is due to uptake through measured concentrations of zinc in earthworms, and 15 percent is due to ingestion of measured concentrations of zinc in soil. Biota (earthworm) ingestion alone drives HQs above 1 for cadmium, lead, and zinc; therefore, biotransfer of contaminants in earthworms to levels of ecological concern appears to occur at the site.

Based on the evaluation of AE 4 for communities of birds, concentrations of cadmium, lead and zinc produced NOAEL and LOAEL HQs greater than 1 for the RME and CTE American woodcock. Based on this information, there is a risk to avian vermivores from cadmium, lead and zinc. For exposure to cadmium, approximately 99 percent of the HQ for the woodcock is due to uptake through measured concentrations of cadmium in earthworms, and 1 percent is due to ingestion of measured concentrations of cadmium in soil. For exposure to lead, approximately 89 percent of the HQ for the woodcock is due to uptake through measured concentrations of lead in earthworms, and 11 percent is due to ingestion of measured concentrations of lead in soil. For exposure to zinc, approximately 92 percent of the HQ for the woodcock is due to uptake through measured concentrations of zinc in earthworms, and 8 percent is due to ingestion of measured concentrations of zinc in soil. Biota (earthworm) ingestion alone drives HQs above 1 for cadmium, lead, and zinc; therefore, biotransfer of contamination in earthworms to levels of ecological concern appears to occur at the site.

In summary, cadmium, lead, and zinc concentrations in earthworms may present an ecological risk to vermivore communities based on NOAELs and LOAELs. The location of the earthworm samples collected in previous studies was not available; therefore, there are no figures to show the distribution of COPC in earthworms.

4.4.3. Protection of Terrestrial Carnivore Communities. Small mammals may provide a source of food for terrestrial carnivorous wildlife (primarily birds and mammals) that forage in the vicinity of the Big River Mine tailings site. The evaluation of food chain exposure to terrestrial carnivore communities (AE 5) includes the development of HQs for RME and CTE to soil, surface water, sediment, and small mammal tissue. For purposes of this evaluation, it was assumed that 100 percent of the diet for the representative bird and mammal (red fox and red-tailed hawk) was composed of small mammals. In addition, AUF was assumed to be 100 percent. The RME and CTE concentrations for the COPCs detected in the exposure media are presented in Table 4-6 (Appendix B). The estimation of ADD and calculation of HQs for the terrestrial carnivorous mammal and bird are presented in Appendix E. The RME and CTE HQs for the terrestrial carnivorous mammal and bird communities are summarized in Table 4-9 (Appendix B).

Based on the evaluation of AE 5 for communities of terrestrial mammals, concentrations of cadmium produced NOAEL HQs greater than 1 for the RME and CTE red fox. Based on this information, there is a risk to terrestrial mammalian carnivores from cadmium. Approximately 96 percent of the HQ for the fox is due to uptake through measured concentrations of cadmium in small mammals, and 4 percent is due to ingestion of measured concentrations of cadmium in soil. Biota (small mammal) ingestion alone drives HQs above 1 for cadmium; therefore, biotransfer of contamination in small mammals to levels of ecological concern appears to occur at the site.

Based on the evaluation of AE 5 for communities of terrestrial birds, concentrations of lead produced NOAEL HQs greater than 1 for the RME and CTE red-tailed hawk. Based on this information, there is a risk to terrestrial avian carnivores from lead. Approximately 91 percent of the HQ for the hawk is due to uptake through measured concentrations of lead in small mammals, and 9 percent is due to ingestion of measured concentrations of lead in soil. Biota (small mammal) ingestion alone drives HQs above 1 for lead; therefore, biotransfer of contamination in small mammals to levels of ecological concern appears to occur at the site.

In summary, cadmium and lead concentrations in small mammals may present an ecological risk to terrestrial carnivore communities based on a comparison to NOAELs. There is little significant risk to the terrestrial carnivore communities based on a comparison to LOAELs. Figures 4-11d, 4-11e and 4-11f illustrate the occurrence and distribution of cadmium, lead and zinc in small mammals at the various source areas of the Big River Mine tailings site.

4.4.4. Protection of Carnivore/Herpivore Communities. Amphibians (frogs) may provide a source of food for carnivorous wildlife (primarily birds) that forage in the vicinity of the Big River Mine tailings site. The evaluation of food chain exposure to carnivore/herpivore communities (AE 9) includes the development of HQs for RME and CTE to soil, surface water, sediment, and amphibian (frog) tissue. For purposes of this evaluation, it was assumed that 100 percent of the diet for the representative bird (heron) was composed of amphibians. In addition, AUF was assumed to be 100 percent. The RME and CTE concentrations for the COPCs detected in the exposure media are presented in Table 4-6 (Appendix B).

The estimation of ADD and calculation of HQs for the carnivorous/herpivorous bird are presented in Appendix E. The RME and CTE HQs for the carnivorous/ herpivorous bird communities are summarized in Table 4-10 (Appendix B).

Based on the evaluation of AE 9 for communities of carnivorous/ herpivorous birds, concentrations of lead produced NOAEL HQs greater than 1 for the RME and CTE heron. Concentrations of zinc produced NOAEL HQs greater than 1 for the RME. Based on this information, the primary risk to herpivorous avian carnivores is from lead. Approximately 58 percent of the HQ for the heron is due to uptake through measured concentrations of lead in amphibians (frogs), and 41 percent is due to ingestion of measured concentrations of lead in sediment. Biota (amphibian) ingestion alone drives HQs above 1 for lead; therefore, biotransfer of contamination in amphibians to levels of ecological concern appears to occur at the site.

In summary, lead concentrations in amphibians may present an ecological risk to aquatic herpivore communities based on a comparison to NOAELs. There are no significant risks to the terrestrial carnivore communities based on a comparison to LOAELs.

4.4.5. Protection of Carnivore/Piscivore Communities. Fish may provide a source of food for carnivorous wildlife (primarily birds and mammals) that forage in the vicinity of the Big River Mine tailings site. The evaluation of food chain exposure to carnivore/ piscivore communities (AE 10) includes the development of HQs for RME and CT exposures to soil, surface water, sediment, and fish tissue. For purposes of this evaluation, it was assumed that 100 percent of the diet for the representative bird and mammal (river otter and belted kingfisher) was composed of fish. In addition, AUF was assumed to be 100 percent. The RME and CTE concentrations for the COPCs detected in the exposure media are presented in Table 4-6.

The estimation of ADD and calculation of HQs for the carnivorous/piscivorous mammal and bird are presented in Appendix E. The RME and CTE HQs for the carnivorous/piscivorous mammal and bird communities are summarized in Table 4-11(Appendix B).

Based on the evaluation of AE 10 for communities of carnivorous/piscivorous mammals, concentrations of cadmium and lead produced NOAEL HQs greater than 1 for the RME river otter. In addition, concentrations of cadmium produced NOAEL HQs greater than 1 for the CTE river otter. Based on this information, there is a risk to piscivorous mammalian carnivores from cadmium and lead. For exposure to cadmium, approximately 64 percent of the HQ for the otter is due to uptake through measured concentrations of cadmium in fish, and 36 percent is due to ingestion of measured concentrations of cadmium in sediment. For exposure to lead, approximately 74 percent of the HQ for the otter is due to uptake through measured concentrations of lead in fish, and 26 percent is due to ingestion of measured concentrations of lead in sediment. Biota (fish) ingestion alone drives HQs above 1 for cadmium and lead; therefore, biotransfer of contamination in fish to levels of ecological concern appears to occur at the site.

Based on the evaluation of AE 10 for communities of carnivorous/piscivorous birds, concentrations of lead and zinc produced NOAEL HQs greater than 1 for the RME and CTE belted kingfisher. Based on this information, there is a risk to piscivorous avian carnivores from lead and zinc. Lead also produces a LOAEL HQ greater than 1 based on the RME. For exposure to lead, approximately 74 percent of the HQ for the kingfisher is due to uptake through measured concentrations of lead in fish, and 26 percent is due to ingestion of measured concentrations of lead in sediment. For exposure to zinc, approximately 92 percent of the HQ for the kingfisher is due to uptake through measured concentrations of zinc in fish, and 8 percent is due to ingestion of measured concentrations of zinc in sediment. Biota (fish) ingestion alone drives HQs above 1 for lead and zinc; therefore, biotransfer of contamination in fish to levels of ecological concern appears to occur at the site.

In summary, cadmium, lead, and zinc concentrations in fish may present an ecological risk to piscivore communities based on a comparison to NOAELs. Lead was the only contaminant present at levels in fish tissue that may present an ecological risk based on comparison to LOAELs.

4.4.6. Protection of Benthivore Communities. An evaluation of impacts to benthivore communities could not be made due to a lack of tissue data. Given the high concentrations of COPC in sediment and their bioaccumulative properties, communities that feed on aquatic invertebrates and crayfish may be exposed to potentially harmful concentrations. This is a data gap that will be addressed in Section 5.0 of this report.

5. SITE INVESTIGATION AND DATA ANALYSIS

The *Site Description Report* (Black & Veatch, 2005) addressed the degree to which the environments and ecological receptors associated with the Big River Mine tailings site are potentially at risk. Despite the site-specificity of the initial evaluation, many estimates and assumptions were required to fill gaps in needed knowledge and data to complete the evaluation of potential risk. The following sections discuss the scope and extent of additional investigations done to address the uncertainties inherent in the initial evaluation.

5.1. ASSESSMENT OF SOIL

Preliminary surface soil data was available from a total of 91 sample locations collected from the Big River Mine tailings site:

- Bonne Terre – 27 samples
- Desloge – 20 samples
- Elvins – 9 samples
- Federal – 24 samples
- Leadwood – 8 samples
- National – 3 samples

Considering the size of the geographic area encompassed by the Big River Mine tailings site, the range of concentrations used in this evaluation may not adequately characterize zones of exposure within the entire study area. Specifically, the preliminary soil data focused on transects coming off of each pile, but very little data was collected directly on the piles.

Therefore, an additional 93 surface soil samples (81 samples, 1 background sample and 11 duplicates) were collected from tailings piles, chat piles, off-site vegetated areas, and off-site unvegetated areas from the 0- to 12 inch depth interval. Ten background locations were originally selected at locations upwind from chat piles/tailings areas; however, only one of the samples collected met the criteria for a background lead concentration of 60 mg/kg. Therefore, the 9 original background locations that exceeded 60 mg/kg lead were included in the data set as *Off-pile Locations*. The one background sample that did not exceed 60 mg/kg lead remains a background sample. The additional soil sampling locations are presented in Figure 5-1 and include:

- Bonne Terre Pile – 14 samples
- Desloge Pile – 14 samples
- Elvins Pile – 8 samples
- Federal/St. Joe Pile – 13 samples
- Leadwood Pile – 13 samples
- National Pile – 7 samples
- Hayden Creek Pile – 3 samples

- Off-pile Locations – 9 samples
- Background – 1 sample

All surface soil samples were analyzed for total metals, percent moisture, total organic carbon and pH.

The preliminary screening identified lead and zinc as COPCs for direct exposure to plants in soil, and zinc as a COPC for direct exposure to earthworms in soil. Therefore, a subset of the soil samples was also assessed for toxicity. Toxicity tests (plant and earthworm) were conducted across a gradient of lead contamination, considered to be the primary risk contributor at the site. Plant and earthworm toxicity tests and earthworm tissue analysis targeted the following gradient: 100, 200, 400, 800, 1,200, 1,600, 2,400, and 3,200 milligrams per kilogram (mg/kg). Nine samples (eight sample locations plus a background location) were selected from the XRF results according to the targeted gradient and sent to the Region 7 EPA laboratory for toxicity testing and tissue analysis. Surface soil samples were assessed using plant germination toxicity tests according to American Society of Testing and Materials (ASTM) E1963-02 Standard Procedures for Conducting Terrestrial Plant Toxicity Tests. Earthworm toxicity samples were analyzed according to ASTM E 1676-04 42-Day Toxicity Test using Earthworms (*Eisenia fetida*).

5.2. ASSESSMENT OF SURFACE WATER

Preliminary surface water data was available from a total of 15 sample locations for lead and zinc:

- Big River - 5 samples (plus 1 background)
- Flat River - 3 samples
- Bonne Terre Wetland – 1 sample
- Leadwood Wetlands – 2 samples
- Federal Wetland – 1 sample
- Pim Lake – 1 sample
- Monsanto Lake – 1 sample

Considering the size of the geographic area encompassed by the Big River Mine tailings site, the range of concentrations used in the initial evaluation does not adequately characterize the entire study area. Further, the preliminary surface water data only included unfiltered samples (total metals) for lead and zinc, and hardness data was not available for all surface water data.

Therefore, an additional 62 surface water samples (61 samples including 1 duplicate) were collected at a 0- to 12-inch depth interval. Surface water samples were filtered in the field to represent the dissolved portion of metals, which provides a better estimation of the bioavailable concentrations of contaminants present in surface waters. It also enables a direct comparison to Missouri's Water Quality Criteria, which are based on dissolved metals, and are the same as the NAWQC. All surface water samples were analyzed for hardness, pH, temperature, specific conductance, turbidity, dissolved oxygen, and oxidation reduction potential. Surface water sampling locations are presented in Figure 5-2 and include the following:

- 46 samples from the river locations (34 samples from Big River, 12 samples from Flat River).
- Two Background samples on the Big River, upstream of the Leadwood pile (sample locations 33 and 34).
- Two additional background locations.
- Three samples from Hayden Creek.
- One sample from Koen Creek.
- Three samples from Mineral Fork
- Six samples from the on-site ponds. Because the Desloge pile does not contain any ponds and the Bonne Terre pile has already been well characterized, these six samples were taken from the following locations:
    - National Pile – 1 sample
    - Federal/St. Joe Pile

- 3 samples from the tailings beach area
- 1 sample from the lake
- 1 sample from the wetland/drainage area

5.3. ASSESSMENT OF SEDIMENT

Preliminary sediment data was available from a total of 33 sample locations collected from the Big River Mine Tailings Site:

- Big River – 9 samples
- Flat River – 4 samples
- Koen Creek – 1 sample
- Hayden Creek – 1 sample
- Owl Creek – 1 sample
- Bonne Terre Wetlands/Tributaries – 8 samples
- Federal Wetlands – 3 samples
- Leadwood Wetlands – 6 samples
- Background – 1 sample

Considering the size of the geographic area encompassed by the Big River Mine tailings site, the range of concentrations used in the initial evaluation does not adequately characterize the entire study area.

Therefore, an additional 62 sediment samples (61 samples including 1 duplicate) were collected at a 0- to 6-inch depth interval. The sediment samples were co-located with the surface water samples described above. All sediment samples were analyzed for total metals, TOC, Simultaneous Extractable Metals/Acid Volatile Sulfides

(SEM/AVS), and percent moisture. Sediment sampling locations are identified in Figure 5-2. All of the sediment samples collected for the purposes of background exceeded the TEC for lead; therefore, alternative background sites were identified based on the sampling results. Two sampling locations on the Big River upstream of the Leadwood pile appear to represent background (lead concentrations at these locations were found to be below the TEC); therefore, sample locations 33 and 34 on the Big River are considered background for the site.

5.3.1. Sieved Sediment and Pore Water Data. The bioavailable component of metals contamination in sediment is related to the fined grained materials (typically less than 0.5 mm in diameter). Further, benthic organisms are directly exposed to pore water, which is the water occupying the interstitial spaces in sediment. Therefore, to provide additional information regarding direct exposure to metals in sediments, co-located sieved sediment and pore water (dissolved fraction) was collected at a total of 12 locations (9 from the Big River, 2 from the Flat River and 1 from Mineral Fork).

For the purposes of the ERA, sediment toxicity was analyzed using the sediment quality triad (Chapman, 1990), which is a weight of evidence approach that includes not only chemical analysis of sediment, but also toxicity testing and an evaluation of the benthic invertebrate community structure.

Chemical analysis of sediment was accomplished through analysis of total metal concentrations in bulk sediment as well as through SEM/AVS analysis. SEM/AVS was used because the ecotoxicity of metals in sediment may be associated with the ratio of SEM to AVS. Because metals bind with AVS, it has been suggested that a SEM/AVS ratio may serve as an indicator of metal toxicity in sediments associated with other mining areas in Missouri (Besser *et al.*, 2003; Besser, 2005). If sediment has higher SEM levels than AVS, then the sediment is considered toxic. If the SEM/AVS ratio is less than one, it is considered to be nontoxic.

5.3.2. *Hyallela* Toxicity Tests. A variety of benthic invertebrate life is known to be present in Big River, Flat River and associated tributaries; therefore, to provide an additional line of evidence, a subset of the sediment samples were assessed for toxicity. Sediment samples for the invertebrate toxicity tests targeted the following gradient: 50, 100, 150, 300, 600, 800, 1,200, and 2,400 milligrams per kilogram (mg/kg). Nine samples (eight sample locations plus a background location) were selected from the XRF results according to the targeted gradient and sent to an EPA contract laboratory for toxicity testing. All sediment toxicity samples were analyzed according to the *Hyalella azteca* 42-day Test for Measuring the Effects of Sediment-associated Contaminants on Survival, Growth and Reproduction" (EPA Test Method100.4).

5.3.3. Macroinvertebrate Survey. A macroinvertebrate survey was performed at 8 locations across the site corresponding to a gradient of metal concentrations in sediment (EPA, 2005b). Three replicates, and one sample each in a run and a pool were taken at 6 locations on the Big River. Two additional locations, one on Hayden Creek and one on the Flat River were also sampled. These other two locations did not have adequate flow to sample replicates; therefore, sampling was restricted to one pool on Hayden Creek and one riffle, one run, and one pool on the Flat River. A total of 34 aquatic macroinvertebrate samples were collected and analyzed for seven metrics including total invertebrate counts, taxa richness, Ephemeroptera, Plecoptera, Trichoptera (EPT) Index, % EPT, % dominance, dominant taxa, EPT/Chironomidae ratio, and % Chironomidae.

5.4. ASSESSMENT OF BIOTA

5.4.1. Terrestrial Biota Sampling. The preliminary evaluations indicated that cadmium, lead, and zinc may present a risk to herbivore, vermivore, and carnivore communities. Based on the food chain exposure models, vermivore communities are subjected to the highest exposure concentrations (and, subsequently risks) through the food chain. Therefore, risk evaluation of the vermivore community focused on establishing protective levels of contamination would also be protective of the less highly exposed receptor guilds (herbivores and carnivores). Thus, since sufficient information currently exists to reasonably establish risk to herbivore and carnivore communities (vegetation samples from 33 locations and small mammal samples from 16 locations), biota sampling focused on estimating risk to vermivore communities. Remedial alternatives developed to be protective of vermivore communities will also be protective of herbivore and carnivore communities.

Earthworm tissue data was only available from a total of 3 samples from the vicinity of the Big River Mine tailings site. Considering the size of the geographic area encompassed by the site, the range of earthworm tissue concentrations used in the preliminary screen does not adequately characterize the entire study area. The sampling plan for the ERA included earthworm tissue collection at the nine soil sampling locations corresponding to the earthworm and plant toxicity tests; however, earthworms could not be found at any of the sampling locations along the gradient. Therefore, preliminary earthworm tissue concentrations as well as earthworm tissue concentrations measured at the conclusion of the earthworm toxicity tests were used as a means of estimating doses due to earthworm ingestion.

5.4.2. Aquatic Biota Sampling. Preliminary evaluations indicate lead may present a risk to the herpivore community. Herpetofauna (amphibian and reptile) tissue data was limited to a total of 7 frog tissue samples collected from the vicinity of the Big River Mine tailings site. The preliminary data was collected at the following sites:

- Leadwood Wetlands – 4 samples
- Bonne Terre Wetland – 3 samples

Considering the size of the geographic area encompassed by the site, the range of herpetofauna tissue concentrations used in the preliminary screen may not adequately characterize the entire study area. Preliminary herpetofauna tissue samples were not available from some of the areas with the highest concentrations of cadmium, lead and zinc in soil, surface water, and sediment. Therefore, 5 additional amphibian samples were collected from the following on-site pond locations:

- National – 1 sample
- Big River – 1 Sample
- Federal Wetlands/Tributaries – 3 samples

Aquatic insectivores were not evaluated in the initial screen due to lack of data. Crayfish are an important food source for several of the measurement receptors. Information on concentrations of COPCs in crayfish tissues would help refine exposure estimates to measurement receptors that obtain a significant portion of their diet from crayfish. Therefore, 13 crayfish samples were collected from the following locations:

- Flat River – 3 samples
- Big River – 7 samples
- Mineral Fork – 1 sample
- Hayden Creek – 2 samples

The preliminary screen indicated that cadmium, lead, and zinc may present a risk to the piscivorous communities. Fish tissue data (sunfish and bass [centrachids]) was available from 14 locations collected from the Big River/Flat River watershed.

Additional fish sampling was determined to be necessary to characterize conditions in the watershed. Therefore, 13 additional small fish samples were collected to further refine exposure estimates to measurement receptors that obtain a significant portion of their diet from fish. The targeted small fish species included those that feed on other fish and benthic invertebrates. Small fish samples were collected from the following locations:

- Mineral Fork – 1 sample
- Big River – 9 samples
- Flat River – 3 samples

6. RISK CHARACTERIZATION

In the ecological risk characterization, data on exposure and effects are integrated into a statement about risk to each assessment endpoint. A weight-of-evidence approach is used to interpret the implications of different studies and tests for each assessment endpoint. Risk characterization constitutes the final phase of the risk assessment process.

For the ecological risk characterization, the data used in the preliminary screen was combined with the data collected for the risk assessment, where appropriate. The central tendency exposure (CTE) and 95% UCL of the mean for each media are presented in Table 6-1 (Appendix B). The 95% UCL is used as the exposure point concentration (EPC) in the ecological risk characterization because it represents a conservative estimate of the average chemical concentration in an environmental medium. The 95% UCLs were calculated using ProUCL Version 3.00.02 Software (EPA, 2002), which recommends a value based on the distribution of the data. For non-detect data, one-half the Sample Quantitation Limit (SQL) was used to calculate the EPC. Duplicates were included in the statistical analysis; however, if precision was less than 25%, the duplicate was averaged with the sample. Further, where sample sizes were too low to calculate a 95% UCL, the CTE is used as the EPC.

For direct exposure, the EPC in the media is compared to an ecological benchmark. For food chain exposure, the EPCs for each media are used as input in the exposure models which are then compared to NOAELs and LOAELs. Where additional measurement endpoints have been specified, the data is provided and integrated into a statement regarding risk to the AE.

6.1. TERRESTRIAL RISK CHARACTERIZATION

6.1.1. Protection of Terrestrial Plant and Soil Invertebrate Communities Directly Exposed to Surface Soil. In the preliminary risk screen, cadmium, lead, and zinc concentrations in surface soil were compared to Eco-SSLs for plants and soil invertebrates. Lead and zinc were identified as COPCs for direct exposure to plants (AE 1), and zinc was identified as a COPC for direct exposure to soil invertebrates (AE 2). The preliminary soil data was collected primarily on transects coming off of the various piles (Figures 4-2 through 4-7). For the ERA, additional soil data was collected at a greater range of concentrations. For the ecological risk characterization, the soil data was re-analyzed using the data collected for the ERA in addition to the data used in the preliminary screen. Moreover, to further characterize the effects of cadmium, lead, and zinc on terrestrial plant and soil invertebrate communities, toxicity tests (plant and earthworm) were conducted across a gradient of lead contamination.

Figures 6-1 through 6-3 (Appendix C) present the occurrence and distribution of cadmium, lead and zinc in surface soil across the site. Table 6-2 (Appendix B) compares the surface soil concentrations of cadmium, lead and zinc at each sampling location to their respective Eco-SSL for plants. For cadmium, surface soil concentrations exceed the Eco-SSL for plants at locations on the Desloge, Elvins, and Leadwood Piles. None of the transect locations coming off of the piles exceed the Eco-SSL. Table 6-3 (Appendix B) compares the surface soil concentrations of cadmium, lead, and zinc at each sampling location to their respective Eco-SSL for soil invertebrates. Cadmium concentrations in surface soil only exceed the Eco-SSL at one location on the Leadwood Pile (the northern portion of the pile). Table 6-4 (Appendix B) compares the EPC for each pile to the Eco-SSL for plants and soil invertebrates. For cadmium, the HQ for plants is 2 at the Leadwood pile. Otherwise, HQs are below 1 for plants and soil invertebrates throughout the site for cadmium.

For lead, surface soil concentrations exceed Eco-SSLs for plants at 94% of the sampling locations (Table 6-2). However, surface soil concentrations only exceed the Eco-SSL for soil invertebrates at 16% of the sampling locations (Table 6-3). When the EPC for each pile is compared to the Eco-SSL for plants and soil invertebrates, HQs for plants are above 1 at every pile, and the HQ for the entire site is 30. HQs for soil invertebrates are above 1 at every pile except Hayden Creek, and the HQ for the site is 2. These results indicate that lead concentrations in soil are potentially impacting terrestrial plant and soil invertebrate communities at the site.

For zinc, surface soil concentrations exceed Eco-SSLs for plants at 93% of the sampling locations (Table 6-2). Surface Soil concentrations exceed Eco-SSLs for soil invertebrates at 71% of the sampling locations (Table 6-3). When the EPC for each pile is compared to the Eco-SSL for plants and soil invertebrates, HQs for plants are equal to or above 1 at every pile (Table 6-4), and HQs for soil invertebrates are equal to or above 1 at every pile except Hayden Creek. The HQs for the site for both plants and soil invertebrates are also above 1. These results indicate that zinc concentrations in soil are potentially impacting terrestrial plant and soil invertebrate communities at the site.

The re-analysis of the soil data generally agrees with the results of the preliminary screen, except that lead should be included as a COPC for soil invertebrates. Cadmium is not a significant risk driver at the Big River site for plants and soil invertebrates directly exposed to soil; however, lead, and zinc potentially are. Therefore, toxicity tests (plant and earthworm) were conducted across a gradient of lead contamination to provide additional information regarding the effects of these metals on terrestrial plant and soil invertebrate communities.

6.1.1.1. Earthworm Toxicity Test - Toxicity tests using earthworms (*Eisenia fetida*) were conducted by the Region 7 Laboratory to further assess the effects of metal exposure on earthworm survival (EPA, 2005a). At the conclusion of the test, soil was re-analyzed for lead and zinc concentrations. The soil concentrations and results of the toxicity test are presented In Table 6-4 (Appendix B).

No significant effects on earthworm survival were seen at any of the test soil concentrations after 14 days of exposure. Similar results were found in 14-day and

28-day toxicity tests using *Eisenia fetida* at the Jasper County Mining site (Sprenger, 2003).

The only locations where mortality was found (1 organism) both occurred in soil from the National pile. The lead and zinc concentrations were very different in these two samples; however, there may be additional physical or chemical factors in soils from the National pile that could impact earthworm survival.

These results indicate that earthworms can survive acute exposure to very high levels of lead and zinc. And, the results of this toxicity test are not in agreement with the results of the HQ calculations using the Eco-SSLs for soil invertebrates. However, the exposure period for this test was only 14-days and reproduction was not a measurement endpoint. Based on the results of the earthworm toxicity tests performed for the Jasper County Mining site, continuing the test to 28-days may not have provided any additional information. However, toxicity tests of an even longer duration (beyond 28-days) may be necessary to provide critical information on the effects of metal exposure on soil invertebrate survival.

It is important to note that earthworms are very difficult to find at the Big River Mine site. It is possible that long-term exposure to metals in soil affects survival, growth and reproduction of soil invertebrate communities. Or, there are additional chemical and/or physical properties of chat and tailings that are impacting earthworm populations (e.g. water holding capacities, organic carbon content, etc.).

6.1.2.2 Plant Toxicity Test - Toxicity tests using Oats (*Avena sativa*) were conducted by the Region 7 Laboratory to further assess the effects of metal exposure on plant communities (EPA, 2005a). Seed germination, root elongation and biomass production were measured after 7 days. No statistically significant differences were found between treatment soil and the control soil for seed germination and root elongation. However, statistically significant results were found for biomass production at three locations (NAT-02, EL-05, and FED-02).

The results of the plant toxicity tests are not in agreement with the results of the HQ calculations using the Eco-SSLs. Although, biomass production was reduced at higher concentrations of lead and zinc, no significant trend can be identified based on this data.

6.1.1.3. Summary of Plant and Soil Invertebrate Results - Lead and zinc were identified as COPCs for direct exposure to plants (AE 1), and soil invertebrates (AE 2) based on comparisons to Eco-SSLs. Although HQs indicated a potential impact to soil invertebrates due to direct exposure to lead and zinc, the earthworm toxicity test using *Eisenia fetida* did not show a significant effect of lead or zinc on earthworm survival. The HQs also indicated a potential impact to plant communities due to direct exposure to lead and zinc.

There is poor agreement between the measurement endpoints used to evaluate the effects of metals in soil on soil invertebrates. The Eco-SSL for lead for soil invertebrates is 1,700 mg/kg. However, the toxicity tests showed no earthworm mortality at lead concentrations as high as 5,270 mg/kg. Further, the anecdotal information from the field indicates that soil invertebrate populations are being affected since it is very difficult to locate these organisms in the soil at this site. It is possible that the earthworm toxicity tests were not conducted for a long enough period of time to capture the effects of metals on survival and reproduction. It is also possible that additional chemical or physical factors in the soil (water holding capacities, organic matter content, etc.) are impacting soil invertebrate populations.

There is also poor agreement between the measurement endpoints used to evaluate the effects of metals in soil on plants. The Eco-SSL for lead for plants is 110 mg/kg. However, the toxicity tests showed no decreases in seed germination or root elongation at lead concentrations as high as 5,270 mg/kg. Reduced biomass production in oats was the only significant effect found in the plant toxicity tests, and this effect was primarily found at the highest lead and zinc concentrations. Vegetation can be found growing at a range of metal concentrations across the site; however, there are areas of barren chat. This lack of vegetation may be due to high metal concentrations, but it could also be due to the physical properties of chat and tailings that render it unproductive for plant growth.

Because the measurement endpoints used to evaluate these AEs are not in agreement, it is difficult to make a conclusive statement regarding potential risks to plant and soil invertebrate communities directly exposed to metals in surface soil.

6.1.2. Protection of Carnivore and Herbivore Communities. The preliminary food chain evaluations indicated that cadmium, lead, and zinc may present a risk to terrestrial and aquatic herbivore communities (AEs 3 and 8) and terrestrial carnivore communities (AE 5). The preliminary HQs for the mallard duck and prairie vole are summarized in Table 4-7, and the preliminary HQs for the red fox and red-tailed hawk are summarized in Table 4-9.

Additional vegetation and small mammal data was not collected for the ERA because the results of the food chain exposure models indicated that vermivore communities are subjected to the highest exposure concentrations (and, subsequently risks) through the food chain. Therefore, a risk evaluation of the vermivore community focused on establishing protective levels of contamination would also be protective herbivores and carnivores. It stands to reason that remedial alternatives developed to be protective of vermivore communities will also be protective of herbivore and carnivore communities.

Therefore, since additional vegetation and small mammal data was not collected, and since the overall risk to these communities is not as significant as the risk to terrestrial vermivore communities, terrestrial carnivore, and terrestrial and aquatic herbivore communities were not re-analyzed in the ecological risk characterization.

6.1.3. Protection of Terrestrial Vermivore Communities. The preliminary food chain evaluations indicated that cadmium, lead, and zinc may present a risk to terrestrial vermivore communities (AE 4). The preliminary HQs for the short-tailed shrew and the American woodcock are summarized in Table 4-8. In the preliminary screen, NOAEL HQs for the shrew based on the CTE were 5,328 for cadmium and 10.8 for lead, and the LOAEL HQs were 55.6 for cadmium and 1.1 for lead. Zinc HQs were below 1. For the woodcock, NOAEL HQs based on the CTE were 31.4 for cadmium, 90.9 for lead, and 9.92 for zinc. LOAEL HQs were 2.28 for cadmium, 9.09 for lead, and 1.1 for zinc.

Hazard quotients for vermivore communities are very high for two reasons. First, these species are consuming a relatively higher percentage of soil (hence metals) in their diets. Second, soil invertebrates have relatively high metal concentrations in their tissue. However, these HQs are based on modeled exposure. To verify higher exposures it is necessary to look directly at the tissue of vermivores. Shrews were collected as part of the small mammal data for the site. If exposures are truly higher for shrews, metal concentrations in shrew tissue should be statistically different than the metal concentrations in voles and field mice (both of which are herbivores). A single factor ANOVA was performed to compare the mean tissue concentrations between shrews, mice and voles.

The results of the ANOVA are as follows:

Cadmium	*Count*	*Sum*	*Average*	*Variance*
Shrews	4	7.781	1.94525	4.31525
Voles	6	0.82	0.136667	0.001507
Mice	6	1.51	0.251667	0.031017

p-value = 0.03

Lead	*Count*	*Sum*	*Average*	*Variance*
Shrews	4	144.55	36.1375	274.036
Voles	6	36.71	6.118333	10.98322
Mice	6	75.62	12.60333	118.5622

p-value = 0.002

Zinc	*Count*	*Sum*	*Average*	*Variance*
Shrews	4	183.2	45.8	231.1467
Voles	6	223.2	37.2	6.34
Mice	6	262.1	43.68333	497.6697

p-value = 0.66

The results of the ANOVA verify that shrews have higher average cadmium and lead concentrations in their tissue in comparison to mice and voles, and that the difference is significant (p-values of 0.03 and 0.002, respectively). The ANOVA results also agree well with the LOAEL HQ results which indicate a risk due to cadmium and lead, but not zinc. In fact, zinc does not appear to accumulate in shrew tissue to any greater extent than it does in voles or mice.

Avian tissue was not collected on the site, so a similar comparison could not be done for the woodcock; however, given their diet (which is almost entirely composed of earthworms), similar results would be expected.

Additional earthworm tissue was not available in the field at the concentrations specified in the *Field Sampling Plan,* and the preliminary earthworm data only consisted of three locations of co-located earthworm and soil data. Additional earthworm samples are not necessary to further refine risk to a sensitive receptor such as an American woodcock exposed to lead, or a short-tailed shrew exposed to cadmium. However, additional data that allows for an ecological clean-up level to be calculated based on potential risk to sensitive terrestrial receptors is much needed. To that end, the earthworm tissue available from the toxicity tests that were performed may provide an additional means of identifying an appropriate clean-up level.

6.1.4. Summary of the Risk Characterization for Terrestrial Communities. Direct effects on plants and soil invertebrates exposed to soil at the Big River Site were evaluated. Because the plant and soil invertebrate toxicity tests showed no significant results (other than effects on biomass production in oats at the highest lead concentrations), the overall conclusion of the risk characterization for these receptors was that ecological clean-up levels based on risks to plants and soil invertebrates can not be established based on the available data.

However, food-chain level effects were also evaluated for terrestrial communities. The preliminary evaluation indicated vermivore communities are at a greater potential risk (due to higher exposures) relative to herbivores and carnivores. Therefore, ecological clean-up levels that are established to be protective of vermivore communities should also be protective of herbivore and carnivore communities.

6.2. AQUATIC RISK CHARACTERIZATION

6.2.1. Protection of Aquatic Communities Directly Exposed to Surface Water. In the preliminary risk screen, unfiltered surface water was compared to chronic NAWQC. Cadmium data was not available; however, lead and zinc were identified as preliminary COPCs for direct exposure to aquatic communities via surface water (AE 6). For the ERA, dissolved surface water was collected at a greater range of concentrations, and hardness data was collected so that the NAWQC could be adjusted to more accurately reflect potential exposure. Dissolved concentrations of cadmium, lead, and zinc in surface water were compared to chronic NAWQC in order to answer the question of whether concentrations of metals present in surface water are adversely impacting the survival and growth of aquatic organisms

Figures 6-4 through 6-6 (Appendix C) present the occurrence and distribution of cadmium, lead, and zinc in surface water throughout the site. Table 6-6 (Appendix B) shows the concentrations of cadmium, lead and zinc at each sampling location and compares those concentrations to the dissolved chronic NAWQC (adjusted for hardness). A hazard quotient above 1 indicates that the NAWQC is exceeded at a particular location. Table 6-7 compares the EPC for the Big River, Flat River, Mineral Fork, Hayden Creek, Koen Creek, National wetland, and Federal wetlands to NAWQC (adjusted based on the average hardness).

In general, cadmium concentrations in surface water were found to be below chronic NAWQC at the majority of sampling locations. Only 2 locations on the Flat River (FL04 and FL10) and 4 locations on the Big River (BR24, BR27, and BR28) exceed NAWQC for cadmium, with the highest concentration found on the Big River (BR24), near the Desloge pile (9.46 µg/L). However, when the EPCs for each water body are compared to the NAWQC, the HQ for the Big River is 9.0, and the HQ for the Flat River is 1.0. The site-wide HQ is 3.4. High concentrations of cadmium in surface water are not widespread throughout the site. However, there are locations in which very high levels were found, and these locations contribute to tremendous variability in the data, which results in HQs above 1 for the Big River and Flat River, as well as the site as a whole.

Lead concentrations, on the other hand, exceed NAWQC at all but 2 of the locations on the Flat River (FL10 and FL11), and all but 11 of the locations on the Big River. When EPCs for each water body are compared to the NAWQC, the HQ for the Big River is 4.5, and the HQ for the Flat River is 2.4. The HQ for the site is 2.7. Hayden Creek and Koen Creek are the only water bodies that do not exceed NAWQC for lead. These results indicate that lead contamination in surface water is widespread and likely to be a source of chronic stress on aquatic communities throughout the site.

Finally, zinc concentrations in surface water were generally found to be below NAWQC, except for at 3 locations on the Flat River (FL08, FL09, and FL10) and 2 locations on the Big River, with the highest concentration found on the Big River (BR24), near the Desloge pile. When the EPCs for each water body are compared to the NAWQC, the HQ for the Big River is less than 1, and the HQ for the Flat River is 1.2. The HQ for the site is also less than 1.

Hazard quotients based on chronic NAWQC predict potential impacts to aquatic communities at the site. No other measurement endpoints have been specified for assessing the effects of direct exposure to surface water on aquatic communities. However, this data will be used in conjunction with the sediment and aquatic biota data to describe the overall effects of metal contamination on aquatic communities at the Big River site.

6.2.2. Protection of Benthic Invertebrate Communities Directly Exposed to Sediment. In the preliminary risk screen, cadmium, lead, and zinc concentrations in sediment were compared to TECs, and all three metals were identified as COPCs for direct exposure to benthic invertebrate communities via sediment (AE 7). For the ERA, three additional measurement endpoints are specified for this assessment endpoint. These include the use of SEM/AVS analysis, *Hyallela* toxicity testing and a benthic invertebrate community survey.

Additional sediment chemistry data was collected for the ERA at a greater range of concentrations. Therefore, a good starting point at which to begin looking at sediment toxicity is to compare the bulk sediment concentration data to additional Sediment Quality Guidelines (SQGs) (MacDonald, *et al.*, 2000). In the preliminary screen, sediment concentrations were compared to TECs, which are SQGs that represent concentrations below which adverse effects are not expected to occur. The TEC is useful as a screening value. However, at the Big River site, the TEC for lead is exceeded at virtually every location. Therefore, bulk sediment concentrations were also compared to Probable Effect Concentrations (PECs), which are SQGs that represent a sediment concentration above which adverse effects on aquatic life are expected to occur more often than not. Although the PEC is a less conservative ecological benchmark, it is more useful than the TEC for identifying the magnitude and spatial patterns of sediment contamination at this particular site.

Figures 6-7 through 6-9 (Appendix C) present the occurrence and distribution of cadmium, lead and zinc in sediment throughout the site. Table 6-8 (Appendix B) shows the concentrations of cadmium, lead and zinc in sediment at each sampling location and compares those concentrations to the PEC. A hazard quotient above 1 indicates that the PEC was exceeded at a particular location. Based on the HQs, a Hazard Index (HI) is also presented. The HI_{PEC} is the sum of the HQs for cadmium, lead, and zinc, and provides additional information regarding the cumulative toxicity of metals in sediments at each sampling location. Figure 6-10 (Appendix C) presents the HI_{PEC} for each sediment sampling location. In addition, Table 6-9 compares the EPCs for individual water bodies on the site to the PEC.

Cadmium is above the PEC at 57% of the sediment sampling locations throughout the site. HQs exceed 1 on the Big River downstream of the Leadwood Pile, Flat River, National wetland, Federal tributaries and wetlands, and the Leadwood herbaceous wetland. The HQ for the entire site is 5, which indicates that not only is cadmium contamination in sediment widespread throughout the watershed, it is also at levels that are high enough to be expected to adversely affect aquatic life.

Lead is above the PEC at 87% of the sediment sampling locations throughout the site, including every location on the Flat River and all but 2 locations on the Big River downstream of the Leadwood Pile. HQs exceed 1 on the Big River downstream of the Leadwood Pile, Flat River, Mineral Fork, National wetland, Hayden Creek, Federal wetlands and tributaries, Bonne Terre herbaceous wetland, Leadwood herbaceous wetland, Owl Creek, and Koen Creek. The HQ for the entire site is 16, which indicates that not only is lead contamination in sediment widespread throughout the watershed, it is also at levels that are high enough to adversely affect aquatic life.

Zinc is above the PEC at 42% of the sediment sampling locations throughout the site. HQs exceed 1 on the Big River downstream of the Leadwood Pile, Flat River, and Leadwood herbaceous wetland. The HQ for the entire site is 3, which indicates that not only is zinc contamination in sediment widespread throughout the watershed, it is also at levels that are high enough to be expected to adversely affect aquatic life.

Based on the results from the bulk sediment analysis for individual metals, lead appears to be the primary risk driver at this site, although all three metals are potentially affecting benthic invertebrate communities. That being the case, it is also useful to look at a HI, or the sum of the HQs for each metal, since each metal contributes to a varying percentage of the risk at each location. When the HQs based on the PEC are summed into an HI_{PEC}, trends in sediment contamination at the site are easier to see.

There are only five areas throughout the site that do not have an HI_{PEC} above 1, these include both the Bonne Terre and Leadwood woody wetlands, three locations on the Big River upstream of the Leadwood Pile (BR32, BR33, and BR34), one additional location on the Big River (BR13), and one location on Mineral Fork (MF02). The lower metal concentrations in the woody wetlands are likely to be related to the more advanced successional stage of these wetlands. The lower metal concentrations may have allowed for greater vegetative development in these wetland areas, or metals may have been taken up by the vegetation over time. The lower concentrations upstream of the Leadwood Pile (two of the locations are considered background) reflect the fact that the contamination on the Big River begins once the river enters the mining impacted area, and that the Leadwood Pile contributes to metal contamination in sediments.

BR13 is a location on the Big River between the Desloge and Bonne Terre piles. High metal concentrations were found upstream and downstream of BR13; therefore, it is difficult to interpret this result. It may represent an outlier in the data, or it may be related to where the sediment sample was collected in the field. Finally, MF02 is one of three locations on Mineral Fork, which are the sediment/surface water sampling locations furthest downstream from the contamination at the site. It would be expected that metal contamination in sediment would begin to dissipate at these downstream locations.

In summary, the initial review of the sediment chemistry data indicates a significant potential ecological impact to aquatic life exposed to sediments on the site. However, additional information regarding sediment toxicity is available and will be incorporated into these results in the following sub-sections.

6.2.2.1. Sieved Sediment and Pore Water - Co-located sieved sediment and pore water was collected at a subset of the sediment sampling locations in order to gain a better understanding of direct exposure to metals within the sediments. Bulk sediment concentrations are useful indicators of potentially adverse effects to benthic organisms; however, a more significant source of exposure to benthic organisms is via the fine grained sediments, as well as via the pore-water, which is the water found in the interstitial spaces in sediments.

Table 6-10 shows the concentrations of cadmium, lead, and zinc in sieved sediment at each sampling location and compares those concentrations to the PEC. A HQ above 1 indicates that the PEC is exceeded at a particular location. Based on the HQs for each metal, an HI_{PEC} is also presented. Table 6-11 compares the EPCs for all of the individual water bodies sampled at the site to the PEC.

Cadmium concentrations in sieved sediments are above the PEC at all but 3 locations, and at those three locations, concentrations are very close to the PEC (4.98 mg/kg). The HQs based on a comparison of the EPC for individual water bodies to the PEC are above 1 on the Big River, Flat River, and Mineral Fork. The HQ for the entire site is 10, which indicates that cadmium in sieved sediment is at levels that are likely to adversely affect benthic organisms.

Lead concentrations in the sieved sediments are above the PEC at all of the sampling locations. The HQs based on a comparison of the EPC for individual water bodies to the PEC are above 1 on the Big River, Flat River, and Mineral Fork. The HQ for the entire site is 8, which indicates that lead in sieved sediment is at levels that are likely to adversely affect benthic organisms.

Zinc concentrations in the sieved sediments are at or above the PEC at 7 of the 12 sampling locations. The HQs based on a comparison of the EPC for individual water bodies to the PEC are above 1 on the Big River and Flat River, but not on Mineral Fork. The HQ for the entire site is 3, which indicates that zinc in sieved sediment is at levels that are likely to adversely affect benthic organisms.

Moreover, the data reveals an interesting trend. Three of the sampling locations selected for sieved samples also happen to be locations in which metal concentrations in bulk sediments did not exceed the PECs for cadmium, lead, and zinc (locations BR13, BR33 and MF02). However, at those same locations, the sieved fraction of the sediment does exceed the PEC for all three metals (except for zinc at locations BR33 and MF02). These results indicate that bulk sediment chemistry alone may not adequately reflect the true magnitude of exposure to benthic organisms to metals in sediment.

Table 6-10 shows the concentrations of cadmium, lead and zinc in pore water at each sampling location and compares those concentrations to the National Ambient Water Quality Criteria (NAWQC). A HQ above 1 indicates that the NAWQC is exceeded at a particular location. Based on the HQs for each metal, an HI is also presented. Table 6-11 compares the EPCs for individual water bodies sampled on the site to the NAWQC.

Cadmium in pore water exceeds the NAWQC at 6 of the 12 sampling locations. When the pore water data for cadmium is compared to the surface water data at each of the 12 locations, it is interesting to note that at many of the locations in which the surface water showed a non-detect for cadmium, the pore water exceeds the NAWQC.

In fact, cadmium only exceeds NAWQC in surface water at 1 of the 12 locations sampled for pore water (BR19).

Lead in pore water exceeds the NAWQC at 9 of the 12 sampling locations. When the pore water data for lead is compared to the surface water data at each of the 12 locations, surface water concentrations exceed NAWQC at 7 of those 12 locations. At 10 of the 12 locations, lead concentrations in pore water are higher than the concentrations in the overlying surface water.

Zinc in pore water exceeds the NAWQC at 2 of the 12 sampling locations. When the pore water data for zinc is compared to the surface water data at each of the 12 locations, zinc in surface water exceeds the NAWQC at 1 of the 12 locations. Zinc concentrations in pore water are not necessarily higher than the overlying surface water.

The pore water data indicates that exposure to cadmium and lead in pore water is a more significant pathway for benthic invertebrates than exposure via surface water. Not only are the organisms more directly exposed to pore water, the cadmium and lead concentrations appear to be higher as well. For zinc, trends in the pore water data generally agree with the trends in surface water data, and the effects of zinc in pore water on benthic organisms may be of less significance than the potential effects of cadmium and lead.

6.2.2.2. SEM/AVS Analysis - SEM/AVS data was analyzed for each of the bulk and sieved sediment samples. SEM/AVS analysis was incorporated into the ERA because the ecotoxicity of metals in sediment may be associated with the ratio of simultaneously extracted metals (SEM) to acid-volatile sulfide (AVS). Because metals bind with AVS, it has been suggested that a ratio of SEM to AVS may serve as an indicator of metal toxicity in sediments associated with mining areas in Missouri (Besser *et. al.*, 2003; Besser 2005). If sediment has higher SEM levels than AVS, then the sediment is considered toxic. If the SEM/AVS ratio is less than one, it is considered to be nontoxic. SEM/AVS ratios for each sediment sampling location are listed in Table 6-8.

At the Big River Site, the majority of the sediment samples contained insufficient levels of AVS for a valid numerical result to be obtained. This indicates that AVS levels are low in the sediments, and low AVS levels would indicate metal bioavailability. Numerical values were available for a total of 12 bulk sediment samples across the site, with a mean SEM/AVS ratio of 3.0, which indicates that metals in sediment are not being bound by AVS and are therefore bioavailable. For sieved sediments, SEM/AVS ratios were available at 2 locations (BR26 and FL09). At BR26, the ratio was 0.641, which indicates low metal bioavailability (low toxicity) and at FL09, the ratio was 4.03, which indicates that high metal bioavailability (higher toxicity).

6.2.2.3. Summary of Sediment Chemistry Results - The sediment chemistry data (bulk sediment, sieved sediment, pore water and SEM/AVS data) generally indicate significant potential effects of metals in sediment on benthic invertebrate communities via direct exposure. Probable effect concentrations for cadmium, lead, and zinc are regularly exceeded throughout the Big River site in both the bulk and sieved sediment. Moreover, at locations where metal concentrations in bulk sediment were low, the concentrations in the sieved sediment were found to be significantly higher. In addition to the fact that the HI_{PEC} results predict sediment toxicity due to metals throughout the site, the average SEM/AVS ratios for the site indicate that these metals are bioavailable in the sediment. Another significant source of exposure to benthic invertebrate communities is via dissolved concentrations of cadmium and lead in pore water. Metal concentrations in pore water regularly exceed NAWQC even when the overlying surface water does not.

In summary, the assessment of risk based on the chemistry data predicts significant potential effects to benthic invertebrates directly exposed to sediments. The following sub-sections incorporate biological data into this overall assessment, with the primary objective of evaluating the accuracy of the PEC sediment quality guidelines in predicting effects on benthic communities exposed to metals in sediment.

6.2.2.4. *Hyallela* Toxicity Tests - A variety of benthic invertebrate life is known to be present in Big River, Flat River, and associated tributaries; therefore, to provide an additional line of evidence, a subset of the sediment samples were assessed for toxicity. Sediment samples for the invertebrate toxicity tests targeted the following gradient: 50, 100, 150, 300, 600, 800, 1,200, and 2,400 milligrams per kilogram (mg/kg). Nine samples (eight sample locations plus a background location) were selected from the XRF results according to the targeted gradient and sent to an EPA contract laboratory for toxicity testing. All sediment toxicity samples were analyzed according to the *Hyalella azteca* 42-day Test for Measuring the Effects of Sediment-associated Contaminants on Survival, Growth and Reproduction" (EPA Test Method100.4). Results of the 42-day *Hyallela* toxicity tests are summarized in Table 6-12.

XRF was used to target the gradient in the field; however, the chemistry data did not agree well with the XRF results; therefore, the chemistry data is provided in Table 6-12, as these are the results used in the statistical analysis and graphs. One sampling location, BR32, had metal concentrations in the sediment below the TEC for cadmium and zinc, and below the PEC for lead. Therefore, this location was used as the "control."

One of the goals of the *Hyallela* toxicity tests is to determine how well the TEC and PEC sediment quality guidelines reflect the actual biological response of organisms exposed to sediments from the site. The following sub-sections describe the results of the *Hyallela* toxicity tests in terms of the sediment quality guidelines.

6.2.2.4.1. *Hyallela* Reproduction. Figures 6-14 through 6-16 (Appendix C) graph the effects of cadmium, lead, and zinc in sediment on reproduction in *Hyallela* (measured as # of juveniles per amphipod). Figure 6-17 graphs the relationship between the HIPEC and *Hyallela* reproduction. The results for cadmium and zinc show a similar trend. The highest rates of reproduction are found at concentrations below the TEC. Then, similar rates of reproduction can be seen at concentrations between the TEC and PEC. Finally, reproductive rates fall off dramatically at concentrations above the PEC.

For cadmium, reproduction is reduced by 46% at concentrations between the TEC and PEC in comparison to reproduction at the TEC concentration. Concentrations above the PEC further reduce reproduction by 73% in comparison to reproduction at the TEC concentration. For zinc, reproduction is reduced by 45% at concentrations between the TEC and PEC in comparison to reproduction at the TEC concentration. Concentrations above the PEC further reduce reproduction by 72% in comparison to reproduction at the TEC concentration.

Lead concentrations in sediment were all above the TEC, so the PEC was used to assess trends. Lead concentrations above the PEC reduce reproduction in *Hyallela* by 50%. Finally, when the HIPEC is compared to reproduction, reproduction is reduced by 51% at HIPEC values above 1.

6.2.2.4.2. *Hyallela* Growth. Figures 6-18 through 6-20 (Appendix C) graph the effects of cadmium, lead, and zinc in sediment on growth in *Hyallela* (measured as mg per amphipod). Figure 6-21 graphs the relationship between the HIPEC and *Hyallela* growth. Cadmium concentrations above the TEC reduce growth by 20%; however concentrations above the PEC do not appear to reduce growth any further in comparison to the concentrations that lie between the TEC and PEC. Zinc concentrations above the TEC reduce growth by 16%, and concentrations above the PEC further reduce growth by 32% when compared to growth at the TEC concentration

Lead concentrations above the PEC reduce growth by 20%. Finally, when the HIPEC is compared to growth, an HIPEC above 1 causes a reduction in growth of 20%.

6.2.2.4.3. *Hyallela* Survival. Figures 6-22 through 6-24 (Appendix C) graph the effects of cadmium, lead, and zinc in sediment on survival in *Hyallela* (measured as percent survival). Figure 6-25 graphs the relationship between the HIPEC and *Hyallela* survival. The results for cadmium indicate that survival at the TEC concentration is virtually the same as survival at concentrations between the TEC and PEC (88% and 90%, respectively). However, at concentrations above the PEC, survival is reduced from an average of 90% to an average of 65% (an overall reduction of 28%).

For lead, survival at concentration below the PEC was 88%; whereas average survival at lead concentrations above the PEC was 77% (a reduction of 13%). The results for zinc indicate that survival at the TEC concentration is virtually the same as survival at concentrations between the TEC and PEC (88% and 85%, respectively). However, at concentrations above the PEC, survival is reduced from an average of 85% to an average of 53% (an overall reduction of 38%). Finally, when the HI_{PEC} is compared to growth, an HI_{PEC} above 1 caused a reduction in survival of 13%.

6.2.2.4.4. Summary of *Hyallela* Toxicity Tests. The results of the *Hyallela* toxicity tests were analyzed in terms of how well they validate the sediment quality guidelines used throughout the ERA. Reductions in reproduction and growth are seen at concentrations above the TEC, which is in agreement with what the TEC would predict. Reductions in survival are seen at concentrations above the PEC. Again, this is in agreement with what the PEC would predict. Reproduction appears to be the biological response that is most severely impacted by metal concentrations in sediment at levels above the PEC. Reproduction in *Hyallela* is reduced by 51% when the HI_{PEC} exceeds 1. More importantly, rates of survival are also reduced at concentrations that exceed an HI_{PEC} of 1.

6.2.2.5. Aquatic Macroinvertebrate Survey - A benthic macroinvertebrate survey was performed in the Big River watershed to evaluate the effects of cadmium, lead, and zinc on benthic invertebrate communities directly exposed to sediment (EPA, 2005b). The results of the macroinvertebrate survey were analyzed in terms of how well they validate the sediment quality guidelines used throughout the ERA. The survey evaluated the following metrics at 8 different locations: total invertebrate counts, species richness, EPT Index, % EPT, % dominance, dominant taxa, EPT/Chironomidae ratio, and % Chironomidae.

Two of the metrics, taxa richness and the EPT Index, were used to evaluate the use the of PEC sediment quality guidelines. One sampling location, HC05 on Hayden Creek, was not included in these analyses because the survey results concluded that the habitat was insufficient for a comparison to be made between that location and the other locations in the survey. Table 6-13 shows the results of the macroinvertebrate survey.

Table 6-13: Macroinvertebrate Survey Results.

Site Metric	BR04	BR10	BR25	BR26	BR32	BKG11	FL09
Richness	24	17	26	26	36	36	18
EPT Index	4.6	3	5.2	4.8	6.2	8.6	3

Macroinvertebrate taxa richness was calculated for each sample (total number of taxonomic groups). Richness measures the number of distinctly different taxa found in a sample. Healthy waters tend to have greater diversity (greater richness) without dominant taxa. The chart below provides numeric guidance on how to interpret richness values found in Table 6-13.

Bioclassification Criteria for Taxa Richness Values (Lenat, 1988)

Bioclassification	Richness
Excellent	>31
Good	24-31
Good-Fair	16-23
Fair	8-15
Poor	0-7

The EPT Index represents the number of distinct genera found only among the Orders Ephemeroptera, Plecoptera, and Trichoptera (EPT). These three Orders are separated from other aquatic taxa because they generally represent the more pollution intolerant organisms present in rivers and streams. The chart below shows a numeric description of the EPT Index as it pertains to water quality (PSKF, 2000). It should be noted that Plecoptera are not abundant in warm water streams regardless of the water quality.

Bioclassification Critera for EPT Index

Bioclassification	EPT Index
Good	>8
Acceptable	6-8
Marginal	2-5
Poor	0-1

Figure 6-26 (Appendix C) graphs taxa richness values (as total number of taxonomic groups) at each of the locations sampled versus the HI_{PEC} for that location. Figure 6-27 (Appendix C) graphs the EPT Index of the locations sampled versus the HI_{PEC} for that location. Figure 6-26 shows excellent richness values at BCKG11 and BR32, both of which have HI_{PEC} values below 5. It should also be noted that the sediment sample for BKG11 was collected in a depositional area under a bridge. The macroinvertebrate survey was done downstream of the bridge. Since depositional areas tend to contain higher metal concentrations, the concentrations where the survey was completed are probably much lower. Good species richness was found at locations BR04, BR25, and BR26. The average HI_{PEC} for these locations is less than 10. Finally, fair-good richness was found at locations BR10 and FL09, both of which had HI_{PEC} values greater than 15. Figure 6-26 shows a good EPT Index at BCK11, which has a corresponding HI_{PEC} value below 5. The average HI_{PEC} value for sites that fall within the acceptable EPT Index range is below 10, and the average HI_{PEC} value for the sites that fall in the marginal EPT Index range is above 15.

In addition to evaluating sediment quality, the macroinvertebrate community survey can be used to evaluate surface water quality at the site. Figure 6-28 graphs species richness versus water quality at the site. An HI_{NAWQC} value, based on the HQs calculated for cadmium, lead and zinc, was compared to species richness. The results indicate that good to excellent species richness is found at sites with an HI_{NAWQC} value below 1.5. Figure 6-29 graphs the EPT Index versus water quality at the site. The results of this comparison indicate that the EPT Index declines with declining water quality. Acceptable to good EPT Indices were found at an HI_{NAWQC} below 1.5.

The results of the aquatic macroinvertebrate survey indicate that the PECs accurately predict the effects of metals in sediment on aquatic communities. Further, chronic NAWQC accurately predict the effects of metals in surface water on aquatic communities. Declines in taxa richness as well as the EPT Index were seen with declining sediment and surface water quality. Using an HI value based on the PEC, excellent taxa richness and good EPT indices are found at HI_{PEC} values below 5. Good to excellent species richness and acceptable to good EPT Indices were found at HI_{NAWQC} values below 1.5.

6.2.2.6. Summary of Sediment Results - The analysis of the sediment data began with a comparison of bulk sediment concentrations of metals to PEC sediment quality guidelines. As part of this analysis, a HI_{PEC}, calculated as the sum of the HQ_{PEC} values for cadmium, lead, and zinc, was also used to evaluate the cumulative toxicity of the metals of concern at the site. An HI_{PEC} value below 1 would indicate probable effect concentrations are not being exceeded, and that the quality of the sediment is potentially good. The HI_{PEC} results showed that only 5 areas throughout the Big River site had an HI_{PEC} value below 1. And at three locations in those areas (BR13, BR33, and MF02), the sieved fraction of the sediment actually contained higher metal concentrations in comparison to the bulk sediment, with the metal concentrations in the sieved fraction exceeding an HI_{PEC} of 1. Bulk and sieved sediment chemistry results indicate poor sediment quality at the site due to metal contamination, resulting in potentially adverse effects on benthic communities directly exposed to sediment.

Both the *Hyallela* toxicity tests and the macroinvertebrate survey results validate the use of sediment quality guidelines for predicting adverse effects on benthic communities directly exposed to metals in sediment. The results of the *Hyallela* toxicity tests show that at HI_{PEC} values above 1, reproduction in *Hyallela* is reduced by 51%, growth is reduced by 20% and survival is reduced by 13%. The results of the macroinvertebrate survey show that excellent taxa richness and good EPT indices are found at locations where the HI_{PEC} values were below 5, with the overall trend in the data showing a decline in the quality of the macroinvertebrate community with declining sediment quality.

The benthic macroinvertebrate community is a critical component of the aquatic food web. Reductions in the quality and quantity of macroinvertebrate communities directly impact the health and diversity of higher-trophic-level organisms. Therefore, protection of macroinvertebrate communities is critical to the protection of the aquatic community at the site. The results of this ERA indicate that the measurement endpoints used to evaluate the effects of direct exposure to metals in sediment on benthic invertebrate communities agree very well with the use of TEC/PEC sediment quality guidelines.

6.2.3. Protection of Aquatic Carnivore Communities. The preliminary risk screen calculated risk to piscivores and herpivores (AEs 9 and 10). And potential risk to benthivores was identified as a data gap (AE 11). Additional fish (forage), crayfish, and frog data was collected for the ERA in order to refine exposure estimates for aquatic carnivores. Figures 6-11 through 6-13 show the occurrence and distribution of cadmium, lead, and zinc in aquatic prey tissue.

The aquatic carnivorous birds and mammals selected as receptors for these assessment endpoints include the river otter, belted kingfisher and great blue heron. All three of these species are known to be opportunistic hunters that feed on a variety of prey depending on what is most available. Therefore, the refined risk calculations for these three receptors include a variety of food items in the diet that include both game (sunfish) and forage fish, as well as frogs and crayfish. The exposure factors for the otter, kingfisher and heron are presented in Appendix D, and the estimation of ADD and calculation of HQs are presented in Appendix E. The EPCs (based on the 95% UCLs) for cadmium, lead, and zinc detected in sunfish/bass, small (forage) fish, crayfish, and frog tissue are presented in Table 6-1. The EPCs for tissue from individual water bodies throughout the site are presented in Table 6-14 (Appendix B).

Area use factors (AUFs) are assumed to be 100% for the kingfisher and otter, since populations of kingfishers are likely to inhabit the site as long as open water is available, and otters are known to be year-round residents. The AUF for the heron was adjusted to 75% since they are migratory in the northern portion of their range.

The results of the refined risk characterization show that site-wide cadmium concentrations produced NOAEL HQs greater than 1 for the otter. Risk calculations for just the Big River produced NOAEL HQs greater than 1 for cadmium as well as for lead. Further, risk calculations for just the Flat River produced NOAEL HQs greater than 1 for cadmium as well as for lead.

The results of the refined risk characterization show that site-wide lead concentrations produced NOAEL HQs greater than 1 for the kingfisher. Risk calculations for just the Big River produced LOAEL HQs greater than 1 for lead. Further, risk calculations for just the Flat River produced LOAEL HQs greater than 1 for lead.

The results of the refined risk characterization show that site-wide lead concentrations produced NOAEL HQs greater than 1 for the heron. Risk calculations for just the Big River produced NOAEL HQs greater than 1 for lead. Further, risk calculations for just the Flat River produced NOAEL HQs greater than 1 for lead.

These results indicate that lead concentrations in aquatic prey tissue are a risk driver for higher-trophic level aquatic carnivores at the Big River site. Cadmium in prey tissue may also be potentially impacting otter populations. However, the most significant result of the risk calculations is the LOAEL HQ greater than 1 for kingfishers exposed to lead in prey items from the Big River and Flat River. Since LOAEL HQs were exceeded for the kingfisher, but not for the other two receptors, kingfishers are at a potentially higher risk. The greater potential risk to kingfishers may be due to their higher food ingestion rates. However, they also consume a relatively high percentage of crayfish in their diet. Of the three aquatic tissues sampled at the site (fish, frogs and crayfish), crayfish tend to have higher concentrations of lead in their tissue relative to fish or frogs. The 95% UCL for the crayfish data is 49 mg/kg, compared to 11 mg/kg for frogs, 17 mg/kg for sunfish, and 8 mg/kg for forage fish. The following shows the HQ results for lead for the Kingfisher.

Table 6-15: Kingfisher Hazard Quotients at the Big River and Flat River.

Kingfisher	ADD	NOAEL HQ	LOAEL HQ
Site	9.62	8.5	0.85
Big River	13.5	11.9	1.2
Flat River	11.8	10.4	1.0
Summer Diet - Site	16.8	14.9	1.5

The higher lead concentrations in crayfish become a significant factor when crayfish become an even more important food source. The Wildlife Exposure Factors Handbook (USEPA, 1993) provides information on dietary composition for wildlife based on a variety of studies. Studies indicate that crayfish may constitute up to 41% of the summer diet of kingfishers on Michigan streams, and up to 36% of the summer diet of river otters on the Mississippi River. When the ADD for a summer diet for kingfishers is calculated (Appendix E), the LOAEL HQ increases from 0.85 to 1.5 for the kingfisher (based on the EPC for the entire site). This summer LOAEL HQ for Kingfishers on the Big River increases to 2.

6.2.4. Summary of the Risk Characterization for Aquatic Communities.

Direct effects on aquatic communities exposed to surface water and sediment at the Big River site were evaluated. The conclusion of the risk evaluation for aquatic communities is that the chronic NAWQC and TEC/PEC sediment quality guidelines both accurately predict potential effects. NAWQC are ARARs and they should be used to established surface water clean-up levels. Sediment ARARs are not available; however, sediment clean-up levels can be established with a high degree of confidence using the sediment quality guidelines (SQGs).

Potential ecological risks were also identified for aquatic carnivorous communities. Kingfishers, in particular, may be particularly affected by lead. Cadmium NOAEL HQs for otters were also very high; however, the LOAEL HQs did not exceed 1. This is due to the two orders of magnitude difference between the cadmium NOAEL and LOAEL.

Unfortunately, no statistical trends exist between sediment concentrations and the concentrations in aquatic prey; therefore, sediment clean-up levels can not be back-calculated based on ADD calculations for kingfishers, otters, or herons. However, clean-up levels can be established based on direct effects to benthic invertebrates using the SQGs. And it is likely that the establishment of a healthy benthic community at the site will positively affect the health of the entire aquatic food-web, including kingfishers, herons, and otters.

For example, a variety of aquatic data is available on the Big River upstream of the Leadwood pile at locations BR32 and BR33. These locations have some of the lowest sediment lead concentrations at the site, and the HI_{PEC} values at both locations are below 1. Results of the *Hyallela* toxicity tests showed that reproduction and growth are higher at location BR32 compared to all of the other locations included in the toxicity test. The macroinvertebrate survey found excellent species richness at location BR33 (one of only two locations with excellent taxonomic richness). The lead concentration in crayfish collected at BR33 was 7.9 mg/kg, compared to an average of 48 mg/kg on the Big River downstream of the Leadwood pile. The lead concentration in forage fish collected at BR33 was 1.4 mg/kg, compared to an average of 6.2 mg/kg on the Big River downstream of the Leadwood pile. When HQs for Kingfishers are calculated based on data at location BR33, the summertime LOAEL HQ drops to 0.2, compared to 2.0 for the Big River downstream of the Leadwood pile. This area of the Big River not only has a healthy macroinvertebrate community, but the relative risk to higher-trophic level organisms due to metals in aquatic prey is low.

Looking at the other extreme, aquatic data is available at location FL09 on the Flat River. The HI_{PEC} at FL09 is 38.5. Results of the *Hyallela* toxicity tests showed that reproduction at FL09 was half of the reproductive rate at BR32, and *Hyallela* survival was only 69%. The macroinvertebrate survey (EPA, 2005b) gave this location a final bioclassification rating of poor. The lead concentration in crayfish collected at FL09 was 41.7 mg/kg and the forage fish concentration was 8.6 mg/kg. When HQs for Kingfishers are calculated based on data at location FL09, the summertime LOAEL HQ is 1.5. This area of the Flat River not only has a poor macroinvertebrate community, but there is a greater potential risk to higher-trophic level organisms due to metals in aquatic prey.

7. UNCERTAINTIES

There are inherent uncertainties in the risk assessment process; however, knowledge of the cause and potential effects of these uncertainties permits the risk assessor and risk manager to interpret and use the risk assessment in making site management decisions. Sources of uncertainty fall into several categories including analytical and sampling design, assumptions, natural variability, error, and insufficient knowledge. Risk assessment is essentially the integration of the exposure and hazard assessments. Sources of uncertainty associated with either of these elements may contribute to overall uncertainty. In addition, the risk assessment procedure itself can contribute to overall uncertainty. Each of these sources of uncertainty can be addressed differently; therefore, understanding how each of these sources of uncertainty is handled within the risk assessment is integral to the overall interpretation.

7.1. ANALYTICAL DATA

The analytical database has inherent uncertainties. For example, the contribution of chemical of potential concern (COPC) across the site was assumed to coincide with receptor contact with environmental media. The degree to which this assumption is met is not quantifiable and direction of bias can not be measured.

In some instances, results were reported as non-detect. In those cases, one-half the sample quantitation limit (SQL) was used to calculate concentration distribution statistics. However, except for cadmium in surface water, the percentage of non-detects in all media was very low. As a result, the impact of using one-half the SQL will not result in a statistically significant change to the calculated exposure or subsequent risk calculations.

When assessing the effect of specific COPCs and source areas on biological receptors, very specific and targeted sampling needs to be conducted to separate the contaminant effect from habitat effects or other stressors. This is probably most true for the effects of COPCs in soil on the site. The presence of chat and tailings results in the removal of habitat as well as the introduction of additional physical stressors to terrestrial communities. With regard to the aquatic assessment, this risk assessment incorporated SEM/AVS analysis, toxicity testing and a macroinvertebrate survey into the assessment of sediment and surface water toxicity, with the overall goal of validating the use of the NAWQC and sediment quality guidelines. This approach reduced the overall uncertainty regarding the effects of COPCs on aquatic communities. However, it is never possible to entirely separate habitat effects, or the effects of additional stressors, from the effects of COPCs.

7.2. UNCERTAINTY OF SCREENING ECOLOGICAL COPCS.

Other metals were detected in surface soil, surface water, and sediment samples collected at the site. Soil samples contained detectable levels of arsenic, barium, chromium, copper, iron, manganese, nickel, and vanadium. Surface water contained detectable levels of barium and nickel. Sediment contained detectable levels of barium, chromium, copper, iron, manganese, nickel and vanadium. These metals were screened from the ERA based on management decisions related to the site history and not quantitative analyses. Based on these decisions, these additional chemicals were not analyzed for in biotic samples. As a result, actual site risks may not be entirely represented. Several of the additional metals have different mechanisms of toxicity that could change risk conclusions.

Also, there known synergistic and antagonistic relationships between metals which could affect fate, transport, and ecotoxicity. There is currently no way to quantify those relationships or how they impact the overall toxicity of COPCs to receptors at the site.

7.3. UNCERTAINTY OF THE CONCEPTUAL MODEL.

Organisms use their environment unevenly, and differential habitat use based on habitat quality is a source of uncertainty. This is particularly true of this risk assessment, since portions of the study area are degraded and surrounded by a similarly degraded landscape. Natural variability is an inherent characteristic of ecological systems and stressors. Additionally, there is a limit to our understanding of the population dynamics of most species, and the community interactions that exist between species. Limited knowledge of population ecology is fundamental in the interpretation of measurement endpoints as they relate to the assessment endpoint.

Also, the exposure model is based on the "average" behavior of a species. As such, extremes of behavior are not incorporated into the overall exposure assessment. While these assumptions may not apply to all individuals, they are generally applicable at the population level and while not all of the biological variability is captured in the assessment, no directional bias is introduced.

Finally, an additional source of uncertainty is the exclusion of the air pathway due not only to lack of data, but also due to the lack of physiological and toxicological data necessary to evaluate this exposure pathway. Chat and tailings piles are a source for air-borne deposition of COPCs. Human activities, such riding recreational vehicles, are also likely to promote the dispersion of COPCs into the air. While this may not generate significant amounts of additional COPC exposure, it may be a contributor to overall risks.

7.4. UNCERTAINTIES ASSOCIATED WITH TOXICOLOGICAL STUDIES

7.4.1. Variable Toxicity in the Aquatic Environment. There are specific uncertainties related to toxicity of COPC in the aquatic environment. Temporal variations and variations related to climatic conditions can significantly increase or decrease the toxicity of COPCs. These variations may affect the concentration of individual COPCs, other essential nutrients, and hardness, which in turn affects metal toxicity and bioavailability. This uncertainty has been reduced to the maximum extent possible by incorporating SEM/AVS analysis into the assessment of sediment, and hardness data into the assessment of surface water.

7.4.2. Extrapolation of Laboratory Toxicity Tests to Natural Conditions. The toxicological data that were used to evaluate the implications of estimated doses of COPC to receptors of concern constitute a source of uncertainty in the assessment. For example, organisms used in toxicity tests conducted in laboratories are not necessarily subjected to the same degree of non-toxicant related stress as receptors under natural conditions. In general, laboratory toxicity tests use single toxicants while receptors in the field are exposed to multiple toxicants. Multiple toxicants can behave independently (such as when modes of action are very different), they may act additively (or synergistically), such that expression of effects is driven by several toxicants simultaneously, or they may interact antagonistically. Cumulative effects of multiple stressors are not necessarily the same. It is difficult to predict the direction of bias in this case as laboratory conditions and natural conditions each may stress organisms but the relative magnitude and physiological implications of these stresses are not actually comparable. Also, due to the differences in the health of laboratory and field populations, differences in genetic diversity (and hence resistance to stressors), and possible impacts of non-toxicant stressors, some unavoidable uncertainty exists when extrapolating laboratory derived data to field situations. Given these factors, the difference between conducting laboratory tests with single stressors as compared to natural conditions with multiple stressors adds to the uncertainty regarding the conclusions of this risk assessment. In addition, although it is believed that the important potential sources of toxicity have been addressed, it is possible that there are unmeasured or unconsidered stressors at the site.

7.4.3. Differences between Responses of Test Species and Receptor Species. Toxicological studies also use species that, while they may be related to the taxa being evaluated at the site, are rarely identical. In general, the greater the taxonomic difference, the greater the uncertainty associated with the application of study data to the receptors of potential concern.

7.4.4. Differences in Chemical Forms of COPCs. Many toxicological studies use chemical formulations and/or administration methods that do not relate well to field exposures. For example, many of the lead toxicology studies cited use lead acetate for exposures because it is known that this is one of the most bioavailable forms of lead. Lead in the environment at the site may not have similar bioavailability. Results from swine feeding studies at the Jasper County Superfund site indicate that some mill waste may have greater bioavailability in comparison to lead acetate. However, given the variability in bioavailability, the direction of bias is unknown.

7.4.5. Variability in NOAEL and LOAEL Values. In some case there may be up to an order of magnitude difference between the NOAEL and LOAELs used to estimate risk to a receptor. The actual point at which effects are seen could be anywhere in the range between the NOAEL and LOAEL. The greater the range between the two values, the greater the uncertainty associated with the conclusions.

7.4.6. Extrapolation of Individual Level Effects to Population-Level Effects. Laboratory based bioassays or toxicity tests measure the response of a laboratory "population" of organisms to the stressor under consideration. These populations generally represent a low diversity genetic stock and, as such, probably do not represent the range of sensitivities and tolerances characteristic of natural populations. As such, there is uncertainty associated with extrapolation of laboratory population responses to populations in natural systems. This uncertainty is probably not directionally biased as both sensitive and tolerant individuals may be missing from the laboratory populations.

7.5. UNCERTAINTIES ASSOCIATED WITH THE EXPOSURE ASSESSMENT

The area of this site is large enough that it is assumed that for most species, the area-use-factor is 100% (unless they are migratory). However, populations may not use the site evenly, and may concentrate their activities in areas of either higher or lower levels of relative exposure. Also, based on prior field observations and visual signs, chat and tailings areas are believed to provide functional habitat to some receptors. While the quality of this habitat may be in question, the chat and tailings areas were included in the overall exposure concentrations calculations. The most significant effect of the inclusion of chat areas in exposure calculations will be to the vermivore communities evaluated. For example, although earthworms did not appear to be impacted by high metal concentrations in the earthworm toxicity tests performed for the site, earthworms are not easily collected in vegetated chat at the site (suggesting that they are absent in the most highly contaminated areas). Vermivore populations may not utilize these areas if a food source is not available.

An additional source of uncertainty associated with exposure calculations is that feeding rates were assumed to not vary with season, breeding condition, or with other local factors. Reported feeding rates undoubtedly vary with all of these factors because metabolic needs change as does food availability. Conservative estimates of feeding rates were derived from studies that reported for multiple seasons.

Further, dietary compositions were assumed to not vary with season or local conditions. As with feeding rates, this assumption is unlikely to be met but the direction of bias is not measurable. Also, in some cases, dietary compositions were simplified due to lack of data. For example, some receptors at the site are known to ingest birds, since bird tissue was not collected at the site, it was not included in the exposure models. Substituting food types contributes to uncertainty, but the direction and magnitude of those substitutions is not measurable.

7.6. UNCERTAINTY IN EVALUATING ECOLOGICAL RISK

There is uncertainty associated with the interpretation of Hazard Quotients and Hazard Indices. The calculated HQs are based on a literature benchmark. Data are generally not available on the slope of the toxicity curve for most COPCs and little is known about the interaction of the contaminant on the slope of the Toxicity curve. For this reason, as well as others discussed in this section, the numerical value of a hazard quotient has little absolute meaning. For example, hazard quotients above 1 indicate a potential risk relative to the toxicological benchmark, but an HQ of 10 does not mean that the risk is 10 times greater.

There is also the issue of unmeasurable long-term effects and adaptations. Due to the complexity of community and population dynamics, it is not currently possible to evaluate all possible effects by implementation of even the most ambitious studies. The information presented, while complete and accurate, may miss long-term adverse effects of COPCs on receptors or may fail to address adaptation to conditions that impart some immunity to COPC effects. In addition, ecological functional redundancies contributed by unevaluated species (multiple species may fill the same niche) may provide resilience against adverse effects at the community and ecosystem levels and sensitivities may be present in other populations that have not been evaluated in the current risk assessment. In either case, the results presented are only snap-shots of conditions as they exist at the site and it is essentially certain that not all of the underlying variability and stressor effects have been quantified. As such, it is important for the reader to recognize that large uncertainties exist regarding community and population health, but that these uncertainties most likely do not directionally bias conclusions.

8. SUMMARY AND CONCLUSIONS

Based on the information provided in the previous sections, there appear to be several terrestrial and aquatic habitats at the Big River site that have been adversely impacted by mining activities.

Terrestrial receptors were considered to be at a significant risk if estimated exposure doses exceeded LOAELs. The terrestrial risk characterization found that vermivore communities are at significant risk. Any potential risk to herbivore and carnivore communities would be less significant in comparison. Therefore, PRGs that are established to be protective of vermivore communities should also be protective of herbivore and carnivore communities. The risk characterization also indicated potential risks to plants and soil invertebrates based on a comparison to Eco-SSLs. However, toxicity tests did not substantiate these results.

A weight-of-evidence approach was used to evaluate risk to aquatic communities through the use of the SQGs and NAWQC. The conclusion of the risk evaluation for aquatic communities is that the chronic NAWQC and TEC/PEC sediment quality guidelines both accurately predict potential effects. NAWQC are ARARs and they should be used to established surface water remediation goals. Sediment ARARs are not available; however, sediment PRGs can be established with a high degree of confidence using the SQGs.

Potential ecological risks were also identified for aquatic carnivorous communities, and significant risks to Kingfishers may exist. The risks to the kingfisher are most significant on the Big River and Flat River during the summer months when crayfish are a plentiful food source.

8.1. SIGNIFICANT HABITATS AT RISK

Although low to moderate levels of metal contamination exist in sediment and surface water throughout the site, the evaluation of the aquatic habitats and aquatic media indicate that surface water and sediment in the following stream reaches present a significant risk to aquatic communities:

- The Big River downstream of the Leadwood pile to the confluence of the Mineral Fork;
- The Flat River downstream from Bannister Branch to the confluence of the Big River;
- Lakes and wetlands on the Federal Pile; and
- Herbacous wetlands on the Bonne Terre and Leadwood Piles;

Significant levels of metal contamination can be found in soil throughout the site due to historical mining and smelting as well as the transportation of the mine-related material. In general, soil on the piles present the greatest significant risk to vermivore communities. However, soils sampled at locations directly near the piles as well as some background locations sampled along haul roads appear to present a significant risk to vermivore communities.

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APPENDIX A: SITE PHOTOGRAPHS

APPENDIX B: TABLES

Table 4-1
Ecological Risk Assessment Endpoints and Measurement Endpoints
Big River Mine Tailings Site
St. Francois County, MO

Exposure Medium	Exposure Scenario Description/Timeframe	Assessment Endpoint	Rationale for Selection	Risk Hypothesis	Exposure Route	Measurement Endpoint
Soil	Uptake of COPCs from soil by plants (current/future)	AE#1 – Protection of terrestrial plant communities from the toxic effects (on survival and reproduction) of COPCs present in soils via direct exposure.	Lead and zinc were identified as preliminary COPCs for direct exposure to plants.	Are concentrations of lead and zinc at levels that can adversely impact the terrestrial plant community?	Direct Exposure	Plant toxicity tests..
Soil	Uptake of COPCs from soil by terrestrial invertebrates (current/future)	AE#2 – Protection of terrestrial soil invertebrate communities from the toxic effects (on survival and reproduction) of COPCs present in soils via direct exposure.	Zinc was identified as a preliminary COPC for soil invertebrates.	Are concentrations of zinc at levels that can adversely impact the terrestrial invertebrate community?	Direct Exposure	Earthworm toxicity tests.
Soil	Ingestion of COPCs absorbed by plants (current/future)	AE#3 – Protection of terrestrial herbivore communities from the toxic effects (on survival and reproduction) of COPCs present in vegetation.	Cadmium was identified as a preliminary COPC for terrestrial herbivore communities.	Are concentrations of cadmium present in vegetation sufficient enough to cause adverse effects on herbivore communities through food chain transfer?	Ingestion – food chain	Use measured cadmium concentrations in plants for input in the exposure model for the prairie vole.

Soil	Ingestion of COPCs absorbed by terrestrial invertebrates (current/future)	AE#4 – Protection of terrestrial vermivore communities from the toxic effects (on survival and reproduction) of COPCs present in terrestrial invertebrate communities.	Cadmium, lead and zinc were identified as preliminary COPCs for terrestrial vermivore communities.	Are concentrations of cadmium, lead and zinc present in earthworms sufficient to cause adverse effects on vermivore communities through food chain transfer?	Ingestion – food chain	Use measured COPC concentrations in earthworms for input in exposure models for short-tailed shrew and American woodcock.
Soil	Ingestion of COPCs absorbed by soil small mammals (current/future)	AE#5 – Protection of terrestrial carnivore communities from the toxic effects (on survival and reproduction) of COPCs present in terrestrial wildlife prey tissue.	Cadmium and lead were identified as preliminary COPCs for terrestrial carnivore communities.	Are concentrations of cadmium and lead present in small mammals sufficient to cause adverse effects on carnivore communities through food chain transfer?	Ingestion – food chain	Use measured COPC concentrations in small mammals for input in exposure models for red fox and red-tailed hawk.
Surface Water	Uptake/ingestion of COPCs from surface water by aquatic organisms (current/future)	AE#6 – Protection of aquatic communities from the toxic effects (on survival and reproduction) of COPCs present in surface water via direct exposure.	Lead and zinc were identified as preliminary COPCs for aquatic communities exposed to surface water.	Are concentrations of lead and zinc present in surface water that can adversely impact survival and growth of aquatic organisms?	Direct Exposure	Measure COPC concentrations in surface water and compare to ecological benchmarks for aquatic organisms.

Sediment	Uptake/Ingestion of COPCs from sediment by benthic invertebrates (current/future)	AE#7 – Protection of benthic invertebrate communities from the toxic effects (on survival and reproduction) of COPCs present in sediment via direct exposure.	Cadmium, lead, and Zinc were identified as preliminary COPCs for benthic invertebrates exposed to sediment.	Are concentrations of cadmium, lead, and zinc present in sediment that can adversely impact survival and growth of aquatic organisms?	Direct Exposure	Measure AVS/SEM in sediment to determine bioavailability; *Hyallela* toxicity tests; Benthic invertebrate community analysis.
Surface Water/ Sediment /Soil	Ingestion of COPCs absorbed by plants (current/future)	AE#8 – Protection of aquatic herbivore communities from the toxic effects (on survival and reproduction) of COPCs present in vegetation.	Lead and zinc were identified as preliminary COPCs for aquatic herbivore communities.	Are concentrations of lead and zinc present in vegetation sufficient to cause adverse effects on aquatic herbivore communities through food chain transfer?	Ingestion – food chain	Use measured concentrations in plants for input in the exposure model for the mallard.
Surface Water/ Sediment /Soil	Ingestion of COPCs absorbed by amphibians (current/future)	AE#9 – Protection of carnivore communities from the toxic effects (on survival and reproduction) of COPCs present in amphibian prey tissue.	Lead was identified as a preliminary COPC for aquatic carnivore communites.	Are concentrations of lead present in amphibians sufficient to cause adverse effects on carnivore communities through food chain transfer?	Ingestion – food chain	Use measured concentrations of lead in amphibians (frogs) for input in the exposure model for the heron.
Surface Water/ Sediment /Soil	Ingestion of COPCs absorbed by fish (current/future)	AE#10 – Protection of piscivore communities from the toxic effects (on survival and reproduction) of COPCs present in fish.	Cadmium, lead, and zinc were identified as preliminary COPCs for piscivore communities.	Are concentrations of cadmium, lead, and zinc present in fish sufficient to cause adverse effects to piscivore communities?	Ingestion – food chain	Use measured cadmium, lead and zinc concentrations in fish for input in the exposure model for the river otter and kingfisher.

Surface Water/ Sediment /Soil	Ingestion of COPCs absorbed by crayfish/invertebrates (current/future)	AE#11 – Protection of aquatic benthivore communities from the toxic effects (on survival and reproduction) of COPCs present in crayfish/invertebrates.	COPCs in surface water/sediment may be taken up and accumulate in crayfish/invertebrates and may impact benthivore communities.	Are concentrations of COPCs/stressors present in crayfish sufficient to cause adverse effects on benthivore communities through food chain transfer?	Ingestion – food cahin	Use measured COPC concentrations in crayfish for input in the exposure model for benthivores.

Table 4-2: Occurrence, Distribution and Evaluation of Direct Exposure of Chemicals of Potential Concern to Plants in Soil.

Exposure Point	Chemical	RME (mg/kg)	CTE (mg/kg)	(Eco-SSLs) (mg/kg)	Direct Exposure Hazard Quotient		COPC (Y/N)	Rationale
					RME	CTE		
Soil	Cadmium	24	5.14	32	0.75	0.16	N	HQ < 1
	Lead	1,540	353	110	14.0	3.21	Y	HQ > 1
	Zinc	1,640	234	50	32.8	4.68	Y	HQ > 1

Table 4-3: Occurrence, Distribution and Evaluation of Direct Exposure of Chemicals of Potential Concern to Soil Invertebrates in Soil.

Exposure Point	Chemical	RME (mg/kg)	CTE (mg/kg)	(Eco-SSLs) (mg/kg)	Direct Exposure Hazard Quotient		COPC (Y/N)	Rationale
					RME	CTE		
Soil	Cadmium	24	5.14	140	0.17	0.04	N	HQ < 1
	Lead	1,540	353	1,700	0.91	0.21	N	HQ < 1
	Zinc	1,640	234	100	16.4	2.34	Y	HQ > 1

Table 4-4: Occurrence, Distribution and Evaluation of Direct Exposure of Chemicals of Potential Concern to Benthic Invertebrates in Sediment.

Exposure Point	Chemical	RME (mg/kg)	CTE (mg/kg)	TEC (mg/kg)	Direct Exposure Hazard Quotient		COPC (Y/N)	Rationale
					RME	CTE		
Sediment	Cadmium	227	23	0.99	229	23	Y	HQ > 1
	Lead	6,259	1,158	35.8	175	32	Y	HQ > 1
	Zinc	6,295	1,124	121	52	9	Y	HQ > 1

Table 4-5: Occurrence, Distribution and Evaluation of Direct Exposure of Chemicals of Potential Concern to Aquatic Life in Surface Water.

Exposure Point	Chemical	RME (µg/L)	CTE (µg/L)	NAWQC (µg/L)	Direct Exposure Hazard Quotient		COPC (Y/N)	Rationale
					RME	CTE		
Surface Water	Cadmium	NA	NA	0.00025	NA	NA	NA	NA
	Lead	52.0	25.3	2.5	21	10	Y	HQ > 1
	Zinc	575	156	120	5	1	Y	HQ > 1

Table 4-6
RME and CTE Exposure Concentrations - Preliminary Screen
Big River Mine Tailings Site
St. Francois County, MO

Media	Units	Exposure Point Concentrations	
		RME	CTE
Soil	mg/kg		
Cadmium		24	5.14
Lead		1,540	353
Zinc		1,640	234
Surface Water	µg/L		
Cadmium		ND	ND
Lead		52	25.3
Zinc		575	156
Sediment	mg/kg		
Cadmium		227	23
Lead		6,259	1,158
Zinc		6,295	1,121
Vegetation	mg/kg		
Cadmium		1.09	0.142
Lead		4.91	1.1
Zinc		109	15.4
Earthworms	mg/kg		
Cadmium		113	59.1
Lead		259	126
Zinc		370	182
Small Mammals	mg/kg		
Cadmium		5.06	0.632
Lead		54	16.1
Zinc		86.9	41.8
Frogs	mg/kg		
Cadmium		1.26	0.27
Lead		19.5	7.57
Zinc		81.9	37
Fish	mg/kg		
Cadmium		1	0.284
Lead		43.9	15.3
Zinc		173	51.8

Table 4-7: Preliminary Hazard Quotients for Herbivorous Bird and Mammal Communities.

Receptor	RME (Vegetation Only)		CTE (Vegetation Only)		Total RME		Total CTE	
	HQ_{NOAEL}	HQ_{LOAEL}	HQ_{NOAEL}	HQ_{LOAEL}	HQ_{NOAEL}	HQ_{LOAEL}	HQ_{NOAEL}	HQ_{LOAEL}
Prairie Vole								
Cadmium	22.1	0.23	2.88	0.03	29.0	0.30	4.35	0.05
Lead	0.09	0.009	0.02	0.002	0.47	0.05	0.11	0.01
Zinc	0.10	0.05	0.01	0.007	0.12	0.06	0.02	0.01
Mallard								
Cadmium	0.21	0.02	0.03	0.002	0.41	0.03	0.05	0.004
Lead	1.22	0.12	0.27	0.03	8.42	0.84	1.6	0.16
Zinc	2.1	0.23	0.3	0.03	2.67	0.30	0.40	0.04

HQs presented for RME (vegetation only) and CTE (vegetation only) were calculated based only on exposure through the vegetation ingestion pathway. Total RME and Total CTE HQs were calculated based on exposure through vegetation ingestion and soil or sediment, respectively.

Table 4-8: Preliminary Hazard Quotients for Vermivorous Bird and Mammal Communities.

Receptor	RME (Earthworm Only)		CTE (Earthworm Only)		Total RME		Total CTE	
	HQ_{NOAEL}	HQ_{LOAEL}	HQ_{NOAEL}	HQ_{LOAEL}	HQ_{NOAEL}	HQ_{LOAEL}	HQ_{NOAEL}	HQ_{LOAEL}
Shrew								
Cadmium	10,100	105	5,310	55.4	10,237	107	5,328	55.6
Lead	20.1	2.01	9.77	0.98	24.7	2.47	10.8	1.1
Zinc	1.43	0.717	0.705	0.35	1.68	0.84	0.7	0.4
Woodcock								
Cadmium	59.8	4.34	31.4	2.28	60.1	4.35	31.4	2.28
Lead	176	17.6	85.9	8.59	198	19.8	90.9	9.09
Zinc	19.6	2.17	9.66	1.07	21.4	2.37	9.92	1.1

HQs presented for RME (earthworm only) and CTE (earthworm only) were calculated based only on exposure through the earthworm ingestion pathway. Total RME and Total CTE HQs were calculated based on exposure through earthworm ingestion and soil.

Table 4-9: Preliminary Hazard Quotients for Carnivore Bird and Mammal Communities.

Receptor	RME (Small Mammal Only)		CTE (Small Mammal Only)		Total RME		Total CTE	
	HQ_{NOAEL}	HQ_{LOAEL}	HQ_{NOAEL}	HQ_{LOAEL}	HQ_{NOAEL}	HQ_{LOAEL}	HQ_{NOAEL}	HQ_{LOAEL}
Red Fox								
Cadmium	103	1.07	12.8	0.13	107	1.12	13.8	0.01
Lead	0.95	0.10	0.30	0.03	1.2	0.12	0.34	0.03
Zinc	0.08	0.04	0.04	0.02	0.0897	0.05	0.04	0.02
Hawk								
Cadmium	0.38	0.03	0.05	0.004	0.39	0.03	0.05	0.005
Lead	5.26	0.53	1.57	0.16	5.81	0.58	1.69	0.17
Zinc	0.70	0.07	0.32	0.04	0.707	0.08	0.32	0.04

HQs presented for RME (small mammal only) and CTE (small mammal only) were calculated based only on exposure through the small mammal ingestion pathway. Total RME and Total CTE HQs were calculated based on exposure through small mammal ingestion and soil.

Table 4-10: Preliminary Hazard Quotients for Carnivorous/Herpivorous Bird and Mammal Communities.

Receptor	RME (Frog Only)		CTE (Frog Only)		Total RME		Total CTE	
	HQ_{NOAEL}	HQ_{LOAEL}	HQ_{NOAEL}	HQ_{LOAEL}	HQ_{NOAEL}	HQ_{LOAEL}	HQ_{NOAEL}	HQ_{LOAEL}
Heron								
Cadmium	0.16	0.01	0.03	0.002	0.22	0.02	0.04	0.003
Lead	3.11	0.31	1.21	0.12	5.33	0.53	1.62	0.16
Zinc	1.02	0.11	0.46	0.05	1.19	0.13	0.49	0.05

HQs presented for RME (frog only) and CTE (frog only) were calculated based only on exposure through the frog ingestion pathway. Total RME and Total CTE HQs were calculated based on exposure through frog ingestion and sediment ingestion.

Table 4-11: Preliminary Hazard Quotients for Carnivorous/Piscivorous Bird and Mammal Communities.

Receptor	RME (Fish Only)		CTE (Fish Only)		Total RME		Total CTE	
	HQ_{NOAEL}	HQ_{LOAEL}	HQ_{NOAEL}	HQ_{LOAEL}	HQ_{NOAEL}	HQ_{LOAEL}	HQ_{NOAEL}	HQ_{LOAEL}
River Otter								
Cadmium	34.8	0.36	9.9	0.10	54.5	0.57	11.6	0.12
Lead	1.31	0.13	0.46	0.05	1.78	0.18	0.55	0.06
Zinc	0.26	0.13	0.08	0.04	0.28	0.14	0.08	0.04
Kingfisher								
Cadmium	0.35	0.03	0.10	0.007	0.53	0.04	0.12	0.01
Lead	19.4	1.9	6.8	0.68	26	2.6	8.0	0.80
Zinc	5.96	0.66	1.79	0.20	6.49	0.72	1.88	0.21

HQs presented for RME (fish only) and CTE (fish only) were calculated based only on exposure through the fish ingestion pathway. Total RME and Total CTE HQs were calculated based on exposure through fish ingestion and sediment ingestion.

Table 6-1
95% UCL and CTE Exposure Point Concentrations – Ecological Risk Characterization
Big River Mine Tailings Site
St. Francois County, MO

Media	Units	Exposure Point Concentrations	
		95% UCL	CTE
Soil	mg/kg		
Cadmium		16.4	11.5
Lead		3,271	1,579
Zinc		1,517	690
Surface Water	µg/L		
Cadmium	dissolved	1.5	0.4
Lead		16.4	8.9
Zinc		86.3	63.4
Sediment	mg/kg		
Cadmium		23.4	15.3
Lead		2,084	1,682
Zinc		1,226	872
Sieved Sediment	mg/kg		
Cadmium		47	18
Lead		987	778
Zinc		1,568	908
Pore Water	µg/L		
Cadmium	dissolved	37	4
Lead		56	27
Zinc		1,608	446
Vegetation	mg/kg		
Cadmium		0.6	0.1
Lead		2	1
Zinc		57	15
Earthworms	mg/kg		
Cadmium		NA	59.1
Lead		NA	126
Zinc		NA	182
Small Mammals	mg/kg		
Cadmium		4	0.6
Lead		25	16
Zinc		48	42
Frogs	mg/kg		
Cadmium		0.4	0.2
Lead		11	8
Zinc		43.7	34.2
Sunfish	mg/kg		
Cadmium		0.3	0.3
Lead		17.4	15
Zinc		57.1	52
Small Fish	mg/kg		
Cadmium		0.2	0.1
Lead		8	6
Zinc		39.5	32.6
Crayfish	mg/kg		
Cadmium		0.9	0.5
Lead		49	33
Zinc		64.3	48.1

Table 6-2
Direct Exposure to Surface Soil – Effect on Plants
Big River Mine Tailings Site
St. Francois County, MO

Station ID	Location	Cadmium (mg/kg)	Lead (mg/kg)	Zinc (mg/kg)	Cadmium HQ[1]	Lead HQ[2]	Zinc HQ[3]
BKG-SS01	South of Bonne Terre	2.94	3580	231	0.1	32.5	4.6
BKG-SS02	South of Desloge	1.06	165	69.9	0.0	1.5	1.4
BKG-SS02-FD	South of Desloge	1.02	162	65.9	0.0	1.5	1.3
BKG-SS03	Southwest of Leadwood	0.774	391	109	0.0	3.6	2.2
BKG-SS04	Southwest of Leadwood	0.34	546	532	0.0	5.0	10.6
BKG-SS05	South of Leadwood	0.35	147	62.5	0.0	1.3	1.3
BKG-SS06	Northwest of Federal	0.73	175	47.5	0.0	1.6	1.0
BKG-SS07	West of Federal	0.617	48	35.6	0.0	0.4	0.7
BKG-SS08	Southwest of Federal	0.35	252	63.1	0.0	2.3	1.3
BKG-SS09	South of Federal	0.35	121	47.2	0.0	1.1	0.9
BKG-SS10	East of Federal	22.6	10,900	886	0.7	99.1	17.7
BT-SS09	Bonne Terre - N corner	0.661	749	32.1	0.0	6.8	0.6
BT-SS10	Bonne Terre - NE of Pile	4.13	1,210	153	0.1	11.0	3.1
BT-SS14	Bonne Terre - NE of Pile	1.72	572	84.7	0.1	5.2	1.7
BT-SS01	Bonne Terre - NW of Pile	4.48	4,935	196	0.1	44.9	3.9
BT-SS01-FD	Bonne Terre - NW of Pile	4.62	4,935	175	0.1	44.9	3.5
BT-SS02	Bonne Terre - NW of Pile	9.25	4,650	539	0.3	42.3	10.8
BT-SS03	Bonne Terre - East of Pile	1.55	670	103	0.0	6.1	2.1
BT-SS04	Bonne Terre - SW corner	0.655	150	148	0.0	1.4	3.0
BT-SS05	Bonne Terre - SW corner	0.644	184	337	0.0	1.7	6.7
BT-SS06	Bonne Terre - SE corner	7	1,290	197	0.2	11.7	3.9
BT-SS06-FD	Bonne Terre - SE corner	5.83	1,100	196	0.2	10.0	3.9
BT-SS07	Bonne Terre - NW corner	4.68	1,550	154	0.1	14.1	3.1
BT-SS08	Bonne Terre - Center	3.78	1,280	106	0.1	11.6	2.1

Station ID	Location	Cadmium (mg/kg)	Lead (mg/kg)	Zinc (mg/kg)	Cadmium HQ[1]	Lead HQ[2]	Zinc HQ[3]
BT-SS11	Bonne Terre - NE of Pile	0.748	254	71.7	0.0	2.3	1.4
BT-SS12	Bonne Terre - NE of Pile	1.28	405	79.2	0.0	3.7	1.6
BT-SS13	Bonne Terre - NE of Pile	3.57	784	244	0.1	7.1	4.9
BTE-0	Bonne Terre - Off Pile East	1.12	549	119	0.0	5.0	2.4
BTE-1	Bonne Terre - Off Pile East	NA	369	80	0.0	3.4	1.6
BTE-2	Bonne Terre - Off Pile East	NA	77	64	0.0	0.7	1.3
BTE-3	Bonne Terre - Off Pile East	NA	65	57	0.0	0.6	1.1
BTE-4	Bonne Terre - Off Pile East	NA	116	59	0.0	1.1	1.2
BTE-5	Bonne Terre - Off Pile East	0.91	376	141	0.0	3.4	2.8
BTE-6	Bonne Terre - Off Pile East	NA	110	85	0.0	1.0	1.7
BTE-7	Bonne Terre - Off Pile East	NA	102	47	0.0	0.9	0.9
BTE-8	Bonne Terre - Off Pile East	NA	241	71	0.0	2.2	1.4
BTE-9	Bonne Terre - Off Pile East	NA	209	67	0.0	1.9	1.3
BTE-10	Bonne Terre - Off Pile East	NA	186	70	0.0	1.7	1.4
BTE-11	Bonne Terre - Off Pile East	NA	184	72	0.0	1.7	1.4
BTE-12	Bonne Terre - Off Pile East	0.33	1,050	161	0.0	9.5	3.2
BTE-13	Bonne Terre - Off Pile East	NA	188	105	0.0	1.7	2.1
BTE-14	Bonne Terre - Off Pile East	NA	148	81	0.0	1.3	1.6
BTE-15	Bonne Terre - Off Pile East	NA	258	112	0.0	2.3	2.2
BTE-16	Bonne Terre - Off Pile East	NA	99	48	0.0	0.9	1.0
BTE-Prison	Bonne Terre - Off Pile East	NA	100	67	0.0	0.9	1.3
BTN-1	Bonne Terre - Off Pile North	NA	213	33	0.0	1.9	0.7
BTN-2	Bonne Terre - Off Pile North	NA	1,030	99	0.0	9.4	2.0
BTN-3	Bonne Terre - Off Pile North	NA	113	37	0.0	1.0	0.7
BTN-4	Bonne Terre - Off Pile North	NA	155	49	0.0	1.4	1.0
BTN-5	Bonne Terre - Off Pile North	NA	111	45	0.0	1.0	0.9
BTN-6	Bonne Terre - Off Pile North	NA	78	42	0.0	0.7	0.8
BTN-7	Bonne Terre - Off Pile North	NA	103	35	0.0	0.9	0.7

Station ID	Location	Cadmium (mg/kg)	Lead (mg/kg)	Zinc (mg/kg)	Cadmium HQ[1]	Lead HQ[2]	Zinc HQ[3]
D1A	*Desloge - On-Pile*	10.2	568	582	0.3	5.2	11.6
D1B	Desloge - On-Pile	10.5	539	473	0.3	4.9	9.5
D1C	Desloge - On-Pile	12.4	715	727	0.4	6.5	14.5
D2A	Desloge - On-Pile	6.89	880	356	0.2	8.0	7.1
D3B	Desloge - On-Pile	6.2	882	317	0.2	8.0	6.3
D3C	Desloge - On-Pile	15.3	781	387	0.5	7.1	7.7
D-3	Desloge - Off-Pile	24	777	1,230	0.8	7.1	24.6
D-4	Desloge - Off-Pile	22.9	788	1,160	0.7	7.2	23.2
D-5	Desloge - Off-Pile	13.6	558	680	0.4	5.1	13.6
D-6	Desloge - Off-Pile	11.8	560	613	0.4	5.1	12.3
D-7	Desloge - Off-Pile	9.71	519	490	0.3	4.7	9.8
D-8	Desloge - Off-Pile	7.55	489	398	0.2	4.4	8.0
D-9	Desloge - Off-Pile	2.62	212	146	0.1	1.9	2.9
D-10	Desloge - Off-Pile	3.89	338	228	0.1	3.1	4.6
D-11	Desloge - Off-Pile	4.07	349	233	0.1	3.2	4.7
D-12	Desloge - Off-Pile	2.82	157	256	0.1	1.4	5.1
D-13	Desloge - Off-Pile	4.27	447	244	0.1	4.1	4.9
D-14	Desloge - Off-Pile	2.77	324	169	0.1	2.9	3.4
D-15	Desloge - Off-Pile	1.75	179	115	0.1	1.6	2.3
D-16	Desloge - Off-Pile	1.94	217	133	0.1	2.0	2.7
DL-SS02	Desloge - NE of Pile	36.3	935	1,580	1.1	8.5	31.6
DL-SS04	Desloge - West of Pile	13.8	1,550	743	0.4	14.1	14.9
DL-SS07	Desloge - East of Pile	25.4	1,000	1,290	0.8	9.1	25.8
DL-SS12	Desloge - East of Pile	34	1,110	1,690	1.1	10.1	33.8
DL-SS13	Desloge - SW of Pile	27.2	1,010	2,320	0.9	9.2	46.4
DL-SS14	Desloge - SE portion of Pile	30.4	6,040	9,700	1.0	54.9	194.0
DL-SS14	Desloge - SE portion of Pile	35.3	6,920	9,700	1.1	62.9	194.0
DL-SS11	Desloge - South portion of Pile	50	3,410	2,340	1.6	31.0	46.8
DL-SS10	Desloge - South portion of Pile	7.45	1,950	475	0.2	17.7	9.5

Station ID	Location	Cadmium (mg/kg)	Lead (mg/kg)	Zinc (mg/kg)	Cadmium HQ[1]	Lead HQ[2]	Zinc HQ[3]
DL-SS09	Desloge - Center	0.704	113	69.3	0.0	1.0	1.4
DL-SS08	Desloge - East portion of Pile	33.3	2,206	1,399	1.0	20.1	28.0
DL-SS08-FD	Desloge - East portion of Pile	33.3	2,206	1,399	1.0	20.1	28.0
DL-SS06	Desloge - North Portion of Pile	0.678	106	65.8	0.0	1.0	1.3
DL-SS05	Desloge - North Portion of Pile	27	1,390	1,340	0.8	12.6	26.8
DL-SS03	Desloge - North Portion of Pile	11.4	913	524	0.4	8.3	10.5
DL-SS01	Desloge - NE of Pile	1.03	204	114	0.0	1.9	2.3
ENE-1	Elvins - Off-Pile NE	14.9	616	982	0.5	5.6	19.6
ENE-2	Elvins - Off-Pile NE	7.57	388	459	0.2	3.5	9.2
ENE-3	Elvins - Off-Pile NE	6.82	378	453	0.2	3.4	9.1
ENE-4	Elvins - Off-Pile NE	5.16	411	358	0.2	3.7	7.2
ESW-1	Elvins - Off-Pile SW	18	1,540	1,640	0.6	14.0	32.8
ESW-2	Elvins - Off-Pile SW	5.25	384	316	0.2	3.5	6.3
ESW-3	Elvins - Off-Pile SW	2.93	419	221	0.1	3.8	4.4
ESW-4	Elvins - Off-Pile SW	1.52	287	138	0.0	2.6	2.8
ESW-5	Elvins - Off-Pile SW	0.7	254	95	0.0	2.3	1.9
EL-SS01	Elvins - N portion of Pile	28	1,150	1,170	0.9	10.5	23.4
EL-SS02	Elvins - N portion of Pile	33.3	3,160	1,330	1.0	28.7	26.6
EL-SS03	Elvins - W portion of Pile	7.58	484	385	0.2	4.4	7.7
EL-SS04	Elvins - E of Pile	5.16	447	282	0.2	4.1	5.6
EL-SS05	Elvins - Center	51.4	13,400	2,,100	1.6	121.8	42.0
EL-SS06	Elvins - SW portion of Pile	0.733	213	383	0.0	1.9	7.7
EL-SS07	Elvins - S of Pile	5.57	3,670	330	0.2	33.4	6.6
EL-SS08	Elvins - SE of Pile	1.71	650	138	0.1	5.9	2.8
EL-SS08-FD	Elvins - SE of Pile	1.84	794	147	0.1	7.2	2.9
HC-SS01	Hayden Creek Pile	0.32	83.8	41	0.0	0.8	0.8
HC-SS02	Hayden Creek Pile	0.31	152	56.8	0.0	1.4	1.1
HC-SS03	Hayden Creek Pile	0.31	223	87.7	0.0	2.0	1.8
F1A	Federal - NW portion of Pile	5.6	607	261	0.2	5.5	5.2

Station ID	Location	Cadmium (mg/kg)	Lead (mg/kg)	Zinc (mg/kg)	Cadmium HQ[1]	Lead HQ[2]	Zinc HQ[3]
F1B	Federal - NW portion of Pile	3.77	603	189	0.1	5.5	3.8
F1C	Federal - NW portion of Pile	5.69	608	239	0.2	5.5	4.8
F2A	Federal - N portion of Pile	3.9	573	193	0.1	5.2	3.9
F2B	Federal - N portion of Pile	5.57	612	2,668	0.2	5.6	53.4
F2C	Federal - N portion of Pile	3.93	556	205	0.1	5.1	4.1
F3A	Federal - N portion of Pile	3.85	600	195	0.1	5.5	3.9
F3B	Federal - N portion of Pile	4.32	582	214	0.1	5.3	4.3
F3C	Federal - N portion of Pile	3.67	547	186	0.1	5.0	3.7
F4A	Federal - E portion of Pile	1.3	310	96.7	0.0	2.8	1.9
F4B	Federal - E portion of Pile	1.25	259	92.2	0.0	2.4	1.8
F4C	Federal - E portion of Pile	1.12	278	93.3	0.0	2.5	1.9
F5A	Federal - S portion of Pile	6.48	482	341	0.2	4.4	6.8
F5B	Federal - S portion of Pile	5.3	361	257	0.2	3.3	5.1
F5C	Federal - S portion of Pile	0.58	97	97	0.0	0.9	1.9
FSE-1	Federal - Off-Pile SE	1.05	255	129	0.0	2.3	2.6
FSE-2	Federal - Off-Pile SE	0.11	102	50	0.0	0.9	1.0
FSE-3	Federal - Off-Pile SE	0.42	186	91	0.0	1.7	1.8
FSE-4	Federal - Off-Pile SE	0.11	232	130	0.0	2.1	2.6
FSE-5	Federal - Off-Pile SE	0.26	149	59	0.0	1.4	1.2
FSE-6	Federal - Off-Pile SE	0.46	194	86	0.0	1.8	1.7
FSE-7	Federal - Off-Pile SE	NA	132	41	0.0	1.2	0.8
FSE-8	Federal - Off-Pile SE	NA	115	44	0.0	1.0	0.9
FSE-9	Federal - Off-Pile SE	NA	116	86	0.0	1.1	1.7
FED-SS04	Federal - E portion of Tailings	1.11	778	72.1	0.0	7.1	1.4
FED-SS05	Federal - E portion of Tailings	8.65	488	355	0.3	4.4	7.1
FED-SS06	Federal - E portion of Tailings	5.12	2,820	340	0.2	25.6	6.8
FED-SS07	Federal - E portion of Tailings	10.4	879	471	0.3	8.0	9.4
FED-SS08	Federal - E portion of Tailings	1.68	406	119	0.1	3.7	2.4
FED-SS09	Federal - E portion of Tailings	8.91	894	371	0.3	8.1	7.4

Station ID	Location	Cadmium (mg/kg)	Lead (mg/kg)	Zinc (mg/kg)	Cadmium HQ[1]	Lead HQ[2]	Zinc HQ[3]
FED-SS10	Federal - E portion of Tailings	0.802	171	69.4	0.0	1.6	1.4
FED-SS11	Federal - Near SW Lake	10.7	863	1,180	0.3	7.8	23.6
FED-SS12	Federal - E portion of Tailings	9.5	680	407	0.3	6.2	8.1
FED-SS12-FD	Federal - E portion of Tailings	10.7	742	379	0.3	6.7	7.6
FED-SS13	Federal - Near S Lake	5.98	398	230	0.2	3.6	4.6
FED-SS01	Federal - N of Tailings	6.67	1,430	1,040	0.2	13.0	20.8
FED-SS02	Federal - NW of Tailings	19.4	18,700	780	0.6	170.0	15.6
FED-SS03	Federal - E of Tailings (forest)	10.3	2,290	441	0.3	20.8	8.8
N1A	National - Off-Pile NE	2.47	153	153	0.1	1.4	3.1
N1B	National - Off-Pile NE	2.22	149	149	0.1	1.4	3.0
N1C	National - Off-Pile NE	6.93	381	381	0.2	3.5	7.6
NAT-SS01	National - N of Pile	2.88	9,750	131	0.1	88.6	2.6
NAT-SS02	National - N of Pile	0.567	315	65.6	0.0	2.9	1.3
NAT-SS03	National - NE of Pile	5.49	2,970	292	0.2	27.0	5.8
NAT-SS03-FD	National - NE of Pile	4.95	2,230	255	0.2	20.3	5.1
NAT-SS04	National - N portion of Pile	4.31	1,610	225	0.1	14.6	4.5
NAT-SS05	National - E of Pile	6.37	4,095	646.5	0.2	37.2	12.9
NAT-SS05-FD	National - E of Pile	7.29	4,095	646.5	0.2	37.2	12.9
NAT-06	National - E of Pile	10.5	4,500	563	0.3	40.9	11.3
NAT-07	National - E of Pile	1.03	4,550	74.2	0.0	41.4	1.5
LE-1	Leadwood - Off-Pile E	5.14	267	337	0.2	2.4	6.7
LE-2	Leadwood - Off-Pile E	1.52	124	134	0.0	1.1	2.7
LE-3	Leadwood - Off-Pile E	3.25	246	245	0.1	2.2	4.9
LE-4	Leadwood - Off-Pile E	1.98	144	150	0.1	1.3	3.0
LE-5	Leadwood - Off-Pile E	1.37	102	100	0.0	0.9	2.0
LE-6	Leadwood - Off-Pile E	1.68	143	152	0.1	1.3	3.0
LE-7	Leadwood - Off-Pile E	2.14	198	159	0.1	1.8	3.2
LE-8	Leadwood - Off-Pile E	0.88	99	119	0.0	0.9	2.4
LW-SS01	Leadwood - N portion of Pile	230	8,330	12,135	7.2	75.7	242.7

Station ID	Location	Cadmium (mg/kg)	Lead (mg/kg)	Zinc (mg/kg)	Cadmium HQ[1]	Lead HQ[2]	Zinc HQ[3]
LW-SS01-FD	Leadwood - N portion of Pile	230	8,330	12,135	7.2	75.7	242.7
LW-SS02	Leadwood - W portion of Pile	42.3	3,220	2,020	1.3	29.3	40.4
LW-SS03	Leadwood - N portion of Pile	38.2	11,400	10,300	1.2	103.6	206.0
LW-SS04	Leadwood - SW of Tailings	36	31,700	1,570	1.1	288.2	31.4
LW-SS05	Leadwood - SW of Tailings	9.34	883	537	0.3	8.0	10.7
LW-SS06	Leadwood - E portion of Tailings	32.4	701	1,360	1.0	6.4	27.2
LW-SS07	Leadwood - Central portion of Tailings	25.8	1,240	2,320	0.8	11.3	46.4
LW-SS08	Leadwood - SE portion of Tailings	9.15	380	417	0.3	3.5	8.3
LW-SS09	Leadwood - SE portion of Tailings	13.9	858	586	0.4	7.8	11.7
LW-SS09-FD	Leadwood - SE portion of Tailings	13.8	1,040	581	0.4	9.5	11.6
LW-SS10	Leadwood - SW of Tailings	12.2	521	445	0.4	4.7	8.9
LW-SS11	Leadwood - S portion of Pile	13.4	1,180	595	0.4	10.7	11.9
LW-SS12	Leadwood - S portion of Pile	13.5	21,600	591	0.4	196.4	11.8
LW-SS13	Leadwood - NE of Pile	20	1,760	997	0.6	16.0	19.9
LW-SS14	Leadwood - NE of Pile	1.25	125	121	0.0	1.1	2.4

1 – Based on an Eco-SSL for cadmium for plants of 32 mg/kg.

2 – Based on an Eco-SSL for lead for plants of 110 mg/kg.

3 – Based on an Eco-SSL for zinc for plants of 50 mg/kg.

Table 6-3
Direct Exposure to Surface Soil – Effect on Soil Invertebrates
Big River Mine Tailings Site
St. Francois County, MO

Station ID	Location	Cadmium (mg/kg)	Lead (mg/kg)	Zinc (mg/kg)	Cadmium HQ[1]	Lead HQ[2]	Zinc HQ[3]
BKG-SS01	South of Bonne Terre	2.94	3,580	231	0.0	2.1	2.3
BKG-SS02	South of Desloge	1.06	165	69.9	0.0	0.1	0.7
BKG-SS02-FD	South of Desloge	1.02	162	65.9	0.0	0.1	0.7
BKG-SS03	Southwest of Leadwood	0.774	391	109	0.0	0.2	1.1
BKG-SS04	Southwest of Leadwood	0.34	546	532	0.0	0.3	5.3
BKG-SS05	South of Leadwood	0.35	147	62.5	0.0	0.1	0.6
BKG-SS06	Northwest of Federal	0.73	175	47.5	0.0	0.1	0.5
BKG-SS07	West of Federal	0.617	48	35.6	0.0	0.0	0.4
BKG-SS08	Southwest of Federal	0.35	252	63.1	0.0	0.1	0.6
BKG-SS09	South of Federal	0.35	121	47.2	0.0	0.1	0.5
BKG-SS10	East of Federal	22.6	10,900	886	0.2	6.4	8.9
BT-SS09	Bonne Terre - N corner	0.661	749	32.1	0.0	0.4	0.3
BT-SS10	Bonne Terre - NE of Pile	4.13	1210	153	0.0	0.7	1.5
BT-SS14	Bonne Terre - NE of Pile	1.72	572	84.7	0.0	0.3	0.8
BT-SS01	Bonne Terre - NW of Pile	4.48	4,935	196	0.0	2.9	2.0
BT-SS01-FD	Bonne Terre - NW of Pile	4.62	4,935	175	0.0	2.9	1.8
BT-SS02	Bonne Terre - NW of Pile	9.25	4,650	539	0.1	2.7	5.4
BT-SS03	Bonne Terre - East of Pile	1.55	670	103	0.0	0.4	1.0
BT-SS04	Bonne Terre - SW corner	0.655	150	148	0.0	0.1	1.5
BT-SS05	Bonne Terre - SW corner	0.644	184	337	0.0	0.1	3.4
BT-SS06	Bonne Terre - SE corner	7	1,290	197	0.1	0.8	2.0
BT-SS06-FD	Bonne Terre - SE corner	5.83	1,100	196	0.0	0.6	2.0
BT-SS07	Bonne Terre - NW corner	4.68	1,550	154	0.0	0.9	1.5
BT-SS08	Bonne Terre - Center	3.78	1,280	106	0.0	0.8	1.1

Station ID	Location	Cadmium (mg/kg)	Lead (mg/kg)	Zinc (mg/kg)	Cadmium HQ[1]	Lead HQ[2]	Zinc HQ[3]
BT-SS11	Bonne Terre - NE of Pile	0.748	254	71.7	0.0	0.1	0.7
BT-SS12	Bonne Terre - NE of Pile	1.28	405	79.2	0.0	0.2	0.8
BT-SS13	Bonne Terre - NE of Pile	3.57	784	244	0.0	0.5	2.4
BTE-0	Bonne Terre - Off Pile East	1.12	549	119	0.0	0.3	1.2
BTE-1	Bonne Terre - Off Pile East	NA	369	80	0.0	0.2	0.8
BTE-2	Bonne Terre - Off Pile East	NA	77	64	0.0	0.0	0.6
BTE-3	Bonne Terre - Off Pile East	NA	65	57	0.0	0.0	0.6
BTE-4	Bonne Terre - Off Pile East	NA	116	59	0.0	0.1	0.6
BTE-5	Bonne Terre - Off Pile East	0.91	376	141	0.0	0.2	1.4
BTE-6	Bonne Terre - Off Pile East	NA	110	85	0.0	0.1	0.9
BTE-7	Bonne Terre - Off Pile East	NA	102	47	0.0	0.1	0.5
BTE-8	Bonne Terre - Off Pile East	NA	241	71	0.0	0.1	0.7
BTE-9	Bonne Terre - Off Pile East	NA	209	67	0.0	0.1	0.7
BTE-10	Bonne Terre - Off Pile East	NA	186	70	0.0	0.1	0.7
BTE-11	Bonne Terre - Off Pile East	NA	184	72	0.0	0.1	0.7
BTE-12	Bonne Terre - Off Pile East	0.33	1,050	161	0.0	0.6	1.6
BTE-13	Bonne Terre - Off Pile East	NA	188	105	0.0	0.1	1.1
BTE-14	Bonne Terre - Off Pile East	NA	148	81	0.0	0.1	0.8
BTE-15	Bonne Terre - Off Pile East	NA	258	112	0.0	0.2	1.1
BTE-16	Bonne Terre - Off Pile East	NA	99	48	0.0	0.1	0.5
BTE-Prison	Bonne Terre - Off Pile East	NA	100	67	0.0	0.1	0.7
BTN-1	Bonne Terre - Off Pile North	NA	213	33	0.0	0.1	0.3
BTN-2	Bonne Terre - Off Pile North	NA	1,030	99	0.0	0.6	1.0
BTN-3	Bonne Terre - Off Pile North	NA	113	37	0.0	0.1	0.4
BTN-4	Bonne Terre - Off Pile North	NA	155	49	0.0	0.1	0.5
BTN-5	Bonne Terre - Off Pile North	NA	111	45	0.0	0.1	0.5
BTN-6	Bonne Terre - Off Pile North	NA	78	42	0.0	0.0	0.4
BTN-7	Bonne Terre - Off Pile North	NA	103	35	0.0	0.1	0.4

Station ID	Location	Cadmium (mg/kg)	Lead (mg/kg)	Zinc (mg/kg)	Cadmium HQ[1]	Lead HQ[2]	Zinc HQ[3]
D1A	Desloge - On-Pile	10.2	568	582	0.1	0.3	5.8
D1B	Desloge - On-Pile	10.5	539	473	0.1	0.3	4.7
D1C	Desloge - On-Pile	12.4	715	727	0.1	0.4	7.3
D2A	Desloge - On-Pile	6.89	880	356	0.0	0.5	3.6
D3B	Desloge - On-Pile	6.2	882	317	0.0	0.5	3.2
D3C	Desloge - On-Pile	15.3	781	387	0.1	0.5	3.9
D-3	Desloge - Off-Pile	24	777	1,230	0.2	0.5	12.3
D-4	Desloge - Off-Pile	22.9	788	1,160	0.2	0.5	11.6
D-5	Desloge - Off-Pile	13.6	558	680	0.1	0.3	6.8
D-6	Desloge - Off-Pile	11.8	560	613	0.1	0.3	6.1
D-7	Desloge - Off-Pile	9.71	519	490	0.1	0.3	4.9
D-8	Desloge - Off-Pile	7.55	489	398	0.1	0.3	4.0
D-9	Desloge - Off-Pile	2.62	212	146	0.0	0.1	1.5
D-10	Desloge - Off-Pile	3.89	338	228	0.0	0.2	2.3
D-11	Desloge - Off-Pile	4.07	349	233	0.0	0.2	2.3
D-12	Desloge - Off-Pile	2.82	157	256	0.0	0.1	2.6
D-13	Desloge - Off-Pile	4.27	447	244	0.0	0.3	2.4
D-14	Desloge - Off-Pile	2.77	324	169	0.0	0.2	1.7
D-15	Desloge - Off-Pile	1.75	179	115	0.0	0.1	1.2
D-16	Desloge - Off-Pile	1.94	217	133	0.0	0.1	1.3
DL-SS02	Desloge - NE of Pile	36.3	935	1,580	0.3	0.6	15.8
DL-SS04	Desloge - West of Pile	13.8	1,550	743	0.1	0.9	7.4
DL-SS07	Desloge - East of Pile	25.4	1,000	1,290	0.2	0.6	12.9
DL-SS12	Desloge - East of Pile	34	1,110	1,690	0.2	0.7	16.9
DL-SS13	Desloge - SW of Pile	27.2	1,010	2,320	0.2	0.6	23.2
DL-SS14	Desloge - SE portion of Pile	30.4	6,040	9,700	0.2	3.6	97.0
DL-SS14	Desloge - SE portion of Pile	35.3	6,920	9,700	0.3	4.1	97.0
DL-SS11	Desloge - South portion of Pile	50	3,410	2,,340	0.4	2.0	23.4
DL-SS10	Desloge - South portion of Pile	7.45	1,950	475	0.1	1.1	4.8

Station ID	Location	Cadmium (mg/kg)	Lead (mg/kg)	Zinc (mg/kg)	Cadmium HQ[1]	Lead HQ[2]	Zinc HQ[3]
DL-SS09	Desloge - Center	0.704	113	69.3	0.0	0.1	0.7
DL-SS08	Desloge - East portion of Pile	33.3	2,206	1,399	0.2	1.3	14.0
DL-SS08-FD	Desloge - East portion of Pile	33.3	2,206	1,399	0.2	1.3	14.0
DL-SS06	Desloge - North Portion of Pile	0.678	106	65.8	0.0	0.1	0.7
DL-SS05	Desloge - North Portion of Pile	27	1,390	,1340	0.2	0.8	13.4
DL-SS03	Desloge - North Portion of Pile	11.4	913	524	0.1	0.5	5.2
DL-SS01	Desloge - NE of Pile	1.03	204	114	0.0	0.1	1.1
ENE-1	Elvins - Off-Pile NE	14.9	616	982	0.1	0.4	9.8
ENE-2	Elvins - Off-Pile NE	7.57	388	459	0.1	0.2	4.6
ENE-3	Elvins - Off-Pile NE	6.82	378	453	0.0	0.2	4.5
ENE-4	Elvins - Off-Pile NE	5.16	411	358	0.0	0.2	3.6
ESW-1	Elvins - Off-Pile SW	18	1,540	1,640	0.1	0.9	16.4
ESW-2	Elvins - Off-Pile SW	5.25	384	316	0.0	0.2	3.2
ESW-3	Elvins - Off-Pile SW	2.93	419	221	0.0	0.2	2.2
ESW-4	Elvins - Off-Pile SW	1.52	287	138	0.0	0.2	1.4
ESW-5	Elvins - Off-Pile SW	0.7	254	95	0.0	0.1	1.0
EL-SS01	Elvins - N portion of Pile	28	1,150	1,170	0.2	0.7	11.7
EL-SS02	Elvins - N portion of Pile	33.3	3,160	1,330	0.2	1.9	13.3
EL-SS03	Elvins - W portion of Pile	7.58	484	385	0.1	0.3	3.9
EL-SS04	Elvins - E of Pile	5.16	447	282	0.0	0.3	2.8
EL-SS05	Elvins - Center	51.4	13,400	2,100	0.4	7.9	21.0
EL-SS06	Elvins - SW portion of Pile	0.733	213	383	0.0	0.1	3.8
EL-SS07	Elvins - S of Pile	5.57	3,670	330	0.0	2.2	3.3
EL-SS08	Elvins - SE of Pile	1.71	650	138	0.0	0.4	1.4
EL-SS08-FD	Elvins - SE of Pile	1.84	794	147	0.0	0.5	1.5
HC-SS01	Hayden Creek Pile	0.32	83.8	41	0.0	0.0	0.4
HC-SS02	Hayden Creek Pile	0.31	152	56.8	0.0	0.1	0.6
HC-SS03	Hayden Creek Pile	0.31	223	87.7	0.0	0.1	0.9
F1A	Federal - NW portion of Pile	5.6	607	261	0.0	0.4	2.6

Station ID	Location	Cadmium (mg/kg)	Lead (mg/kg)	Zinc (mg/kg)	Cadmium HQ[1]	Lead HQ[2]	Zinc HQ[3]
F1B	Federal - NW portion of Pile	3.77	603	189	0.0	0.4	1.9
F1C	Federal - NW portion of Pile	5.69	608	239	0.0	0.4	2.4
F2A	Federal - N portion of Pile	3.9	573	193	0.0	0.3	1.9
F2B	Federal - N portion of Pile	5.57	612	2,668	0.0	0.4	26.7
F2C	Federal - N portion of Pile	3.93	556	205	0.0	0.3	2.1
F3A	Federal - N portion of Pile	3.85	600	195	0.0	0.4	2.0
F3B	Federal - N portion of Pile	4.32	582	214	0.0	0.3	2.1
F3C	Federal - N portion of Pile	3.67	547	186	0.0	0.3	1.9
F4A	Federal - E portion of Pile	1.3	310	96.7	0.0	0.2	1.0
F4B	Federal - E portion of Pile	1.25	259	92.2	0.0	0.2	0.9
F4C	Federal - E portion of Pile	1.12	278	93.3	0.0	0.2	0.9
F5A	Federal - S portion of Pile	6.48	482	341	0.0	0.3	3.4
F5B	Federal - S portion of Pile	5.3	361	257	0.0	0.2	2.6
F5C	Federal - S portion of Pile	0.58	97	97	0.0	0.1	1.0
FSE-1	Federal - Off-Pile SE	1.05	255	129	0.0	0.2	1.3
FSE-2	Federal - Off-Pile SE	0.11	102	50	0.0	0.1	0.5
FSE-3	Federal - Off-Pile SE	0.42	186	91	0.0	0.1	0.9
FSE-4	Federal - Off-Pile SE	0.11	232	130	0.0	0.1	1.3
FSE-5	Federal - Off-Pile SE	0.26	149	59	0.0	0.1	0.6
FSE-6	Federal - Off-Pile SE	0.46	194	86	0.0	0.1	0.9
FSE-7	Federal - Off-Pile SE	NA	132	41	0.0	0.1	0.4
FSE-8	Federal - Off-Pile SE	NA	115	44	0.0	0.1	0.4
FSE-9	Federal - Off-Pile SE	NA	116	86	0.0	0.1	0.9
FED-SS04	Federal - E portion of Tailings	1.11	778	72.1	0.0	0.5	0.7
FED-SS05	Federal - E portion of Tailings	8.65	488	355	0.1	0.3	3.6
FED-SS06	Federal - E portion of Tailings	5.12	2,820	340	0.0	1.7	3.4
FED-SS07	Federal - E portion of Tailings	10.4	879	471	0.1	0.5	4.7
FED-SS08	Federal - E portion of Tailings	1.68	406	119	0.0	0.2	1.2
FED-SS09	Federal - E portion of Tailings	8.91	894	371	0.1	0.5	3.7

Station ID	Location	Cadmium (mg/kg)	Lead (mg/kg)	Zinc (mg/kg)	Cadmium HQ[1]	Lead HQ[2]	Zinc HQ[3]
FED-SS10	Federal - E portion of Tailings	0.802	171	69.4	0.0	0.1	0.7
FED-SS11	Federal - Near SW Lake	10.7	863	1,180	0.1	0.5	11.8
FED-SS12	Federal - E portion of Tailings	9.5	680	407	0.1	0.4	4.1
FED-SS12-FD	Federal - E portion of Tailings	10.7	742	379	0.1	0.4	3.8
FED-SS13	Federal - Near S Lake	5.98	398	230	0.0	0.2	2.3
FED-SS01	Federal - N of Tailings	6.67	1,430	1,040	0.0	0.8	10.4
FED-SS02	Federal - NW of Tailings	19.4	18,700	780	0.1	11.0	7.8
FED-SS03	Federal - E of Tailings (forest)	10.3	2,290	441	0.1	1.3	4.4
N1A	National - Off-Pile NE	2.47	153	153	0.0	0.1	1.5
N1B	National - Off-Pile NE	2.22	149	149	0.0	0.1	1.5
N1C	National - Off-Pile NE	6.93	381	381	0.0	0.2	3.8
NAT-SS01	National - N of Pile	2.88	9,750	131	0.0	5.7	1.3
NAT-SS02	National - N of Pile	0.567	315	65.6	0.0	0.2	0.7
NAT-SS03	National - NE of Pile	5.49	2,970	292	0.0	1.7	2.9
NAT-SS03-FD	National - NE of Pile	4.95	2,230	255	0.0	1.3	2.6
NAT-SS04	National - N portion of Pile	4.31	1,610	225	0.0	0.9	2.3
NAT-SS05	National - E of Pile	6.37	4,095	646.5	0.0	2.4	6.5
NAT-SS05-FD	National - E of Pile	7.29	4,095	646.5	0.1	2.4	6.5
NAT-06	National - E of Pile	10.5	4,500	563	0.1	2.6	5.6
NAT-07	National - E of Pile	1.03	4,550	74.2	0.0	2.7	0.7
LE-1	Leadwood - Off-Pile E	5.14	267	337	0.0	0.2	3.4
LE-2	Leadwood - Off-Pile E	1.52	124	134	0.0	0.1	1.3
LE-3	Leadwood - Off-Pile E	3.25	246	245	0.0	0.1	2.5
LE-4	Leadwood - Off-Pile E	1.98	144	150	0.0	0.1	1.5
LE-5	Leadwood - Off-Pile E	1.37	102	100	0.0	0.1	1.0
LE-6	Leadwood - Off-Pile E	1.68	143	152	0.0	0.1	1.5
LE-7	Leadwood - Off-Pile E	2.14	198	159	0.0	0.1	1.6
LE-8	Leadwood - Off-Pile E	0.88	99	119	0.0	0.1	1.2
LW-SS01	Leadwood - N portion of Pile	230	8,330	12,135	1.6	4.9	121.4

Station ID	Location	Cadmium (mg/kg)	Lead (mg/kg)	Zinc (mg/kg)	Cadmium HQ[1]	Lead HQ[2]	Zinc HQ[3]
LW-SS01-FD	Leadwood - N portion of Pile	230	8,330	12,135	1.6	4.9	121.4
LW-SS02	Leadwood - W portion of Pile	42.3	3,220	2,020	0.3	1.9	20.2
LW-SS03	Leadwood - N portion of Pile	38.2	11,400	10,300	0.3	6.7	103.0
LW-SS04	Leadwood - SW of Tailings	36	31,700	1,570	0.3	18.6	15.7
LW-SS05	Leadwood - SW of Tailings	9.34	883	537	0.1	0.5	5.4
LW-SS06	Leadwood - E portion of Tailings	32.4	701	1,360	0.2	0.4	13.6
LW-SS07	Leadwod - Central portion of Tailings	25.8	1,240	2,320	0.2	0.7	23.2
LW-SS08	Leadwood - SE portion of Tailings	9.15	380	417	0.1	0.2	4.2
LW-SS09	Leadwood - SE portion of Tailings	13.9	858	586	0.1	0.5	5.9
LW-SS09-FD	Leadwood - SE portion of Tailings	13.8	1,040	581	0.1	0.6	5.8
LW-SS10	Leadwood - SW of Tailings	12.2	521	445	0.1	0.3	4.5
LW-SS11	Leadwood - S portion of Pile	13.4	1,180	595	0.1	0.7	6.0
LW-SS12	Leadwood - S portion of Pile	13.5	21,600	591	0.1	12.7	5.9
LW-SS13	Leadwood - NE of Pile	20	1,760	997	0.1	1.0	10.0
LW-SS14	Leadwood - NE of Pile	1.25	125	121	0.0	0.1	1.2

1 – Based on an Eco-SSL for cadmium for soil invertebrates of 140 mg/kg.
2 – Based on an Eco-SSL for lead for soil invertebrates of 1700 mg/kg.
3 – Based on an Eco-SSL for zinc for soil invertebrates of 100 mg/kg.

Table 6-4: Results of Earthworm Toxicity Test.

XRF Target & Location	Soil Lead (mg/kg)	Soil Zinc (mg/kg)	Organisms Exposed	Mortality (# organisms)
Worm Bedding	NA	NA	30	0
Artificial Soil	NA	NA	30	0
Background	148	36.7	30	0
100 ppm Pb LW14	106	103.7	30	0
200 ppm Pb NAT02	204	57.4	30	1
400 ppm Pb DL10	344	168.7	30	0
800 ppm Pb DL13	780	1316	30	0
1200 ppm Pb NAT05	2435	415	30	1
1600 ppm Pb EL05	3567	1293.3	30	0
2400 ppm Pb BT01	5207	241	30	0
3200 ppm Pb FED02	3870	896.5	30	0

Table 6-5: Direct Exposure to Surface Soil – Hazard Quotients for Plants and Soil Invertebrates.

Pile/Site	Number of Sampling Locations	EPC (mg/kg)	Eco-SSL Plants	Eco-SSL Soil Invertebrates	HQ Plants	HQ Soil Invertebrates
CADMIUM						
Desloge	34	20.2	32	140	< 1	< 1
Elvins	17	18.3	32	140	< 1	< 1
National	10	6.1	32	140	< 1	< 1
Bonne Terre	41	4.4	32	140	< 1	< 1
Leadwood	22	55.0	32	140	2	< 1
Federal	37	6.6	32	140	< 1	< 1
Hayden Creek	3	0.3	32	140	< 1	< 1
Off-Pile Locations	9	16.7	32	140	< 1	< 1
Entire Site	173	16.4	32	140	< 1	< 1
Background	1	0.6	32	140	< 1	< 1

Pile/Site	Number of Sampling Locations	EPC (mg/kg)	Eco-SSL Plants	Eco-SSL Soil Invertebrates	HQ Plants	HQ Soil Invertebrates
LEAD						
Desloge	34	1,700.3	110	1,700	15.5	1
Elvins	17	8,874.8	110	1,700	81	5
National	10	5,708.4	110	1,700	52	3
Bonne Terre	41	2,187.9	110	1,700	20	1.3
Leadwood	22	10,550.8	110	1,700	96	6
Federal	37	5,883.9	110	1,700	54	3.5
Hayden Creek	3	152.9	110	1,700	1.4	< 1
Off-Pile Locations	9	8,396.9	110	1,700	76	5
Entire Site	173	3,270.5	110	1,700	30	2
Background	1	48	110	1,700	< 1	< 1

Pile/Site	Number of Sampling Locations	EPC (mg/kg)	Eco-SSL Plants	Eco-SSL Soil Invertebrates	HQ - Plants	HQ Soil Invertebrates
ZINC						
Desloge	34	1,928.5	50	100	39	19
Elvins	17	899.1	50	100	18	9
National	10	409.3	50	100	8	4
Bonne Terre	41	137.4	50	100	3	1
Leadwood	22	9,595.5	50	100	192	96
Federal	37	429.6	50	100	9	4
Hayden Creek	3	61.8	50	100	1	< 1
Off-Pile Locations	9	765.3	50	100	15	8
Entire Site	173	1,517	50	100	30	15
Background	1	35.6	50	100	< 1	< 1

Table 6-6
Direct Exposure to Surface Water
Big River Mine Tailings Site
St. Francois County, MO

Station ID	Location	Hardness (mg/L CaCo3)	CADMIUM (µg/L)	LEAD (µg/L)	ZINC (µg/L)	CADMIUM NAWQC	LEAD NAWQC	ZINC NAWQC	CADMIUM HQ	LEAD HQ	ZINC HQ
FL01	Flat River	217	0.075	10.7	35	0.421	5.784	151.910	0.2	1.8	0.2
FL02	Flat River	273	0.36	10.7	53.2	0.494	7.366	184.529	0.7	1.5	0.3
FL03	Flat River	242	0.431	13.3	63.6	0.454	6.490	166.614	0.9	2.0	0.4
FL04	Flat River	262	0.673	24.7	102	0.480	7.055	178.209	1.4	3.5	0.6
FL05	Flat River	252	0.261	24	138	0.467	6.772	172.429	0.6	3.5	0.8
FL06	Flat River, Near National	256	0.4	23.3	114	0.472	6.885	174.745	0.8	3.4	0.7
FL07	Flat River, Near National	259	0.075	16.7	132	0.476	6.970	176.479	0.2	2.4	0.7
FL08	Flat River	209	0.316	8.55	169	0.410	5.559	147.151	0.8	1.5	1.1
FL09	Flat River, Betewen Elvins and National	182	0.247	4.79	186	0.373	4.799	130.877	0.7	1.0	1.4
FL10	Flat River, Betewen Elvins and National	490	0.709	12	107	0.740	13.459	302.905	1.0	0.9	0.4
FL11	Flat River, Near Elvins	367	0.428	6.58	423	0.606	10.017	237.108	0.7	0.7	1.8
FL12	Flat River, Near Elvins	104	0.075	3.1	6.9	0.253	2.626	81.458	0.3	1.2	0.1
BR01	Big River	185	0.075	3	1.96	0.377	4.883	132.702	0.2	0.6	0.0
BR02	Big River	196	0.075	5.5	2.68	0.392	5.193	139.358	0.2	1.1	0.0
BR03	Big River	263	0.177	8.77	15.8	0.481	7.083	178.786	0.4	1.2	0.1
BR04	Big River	192	0.075	6.08	12.5	0.387	5.080	136.945	0.2	1.2	0.1
BR05	Big River	191	0.075	6.37	16.5	0.385	5.052	136.340	0.2	1.3	0.1
BR06	Big River	214	0.075	5.33	17.1	0.417	5.700	150.129	0.2	0.9	0.1
BR07	Big River	189	0.075	7.71	18.4	0.383	4.996	135.129	0.2	1.5	0.1
BR08	Big River	188	0.075	5.99	22.6	0.381	4.967	134.523	0.2	1.2	0.2

Station ID	Location	Hardness (mg/L CaCo3)	CADMIUM (µg/L)	LEAD (µg/L)	ZINC (µg/L)	CADMIUM NAWQC	LEAD NAWQC	ZINC NAWQC	CADMIUM HQ	LEAD HQ	ZINC HQ
BR09	Big River	232	0.075	8.66	36.9	0.441	6.208	160.761	0.2	1.4	0.2
BR10	Big River	201	0.222	7.52	29	0.399	5.333	142.365	0.6	1.4	0.2
BR11	Big River	184	0.184	10.4	31.1	0.376	4.855	132.094	0.5	2.1	0.2
BR12	Big River	180	0.075	10.1	28.8	0.370	4.743	129.657	0.2	2.1	0.2
BR13	Big River	233	0.075	11.3	43	0.442	6.236	161.348	0.2	1.8	0.3
BR14	Big River	179	0.295	29.6	32	0.369	4.714	129.047	0.8	6.3	0.2
BR15	Big River	199	0.17	7.48	32	0.397	5.277	141.163	0.4	1.4	0.2
BR16	Big River	204	0.2	7.8	37.5	0.403	5.418	144.163	0.5	1.4	0.3
BR17	Big River	204	0.176	6.55	40.7	0.403	5.418	144.163	0.4	1.2	0.3
BR18	Big River	204	0.22	7.88	51.7	0.403	5.418	144.163	0.5	1.5	0.4
BR19	Big River	187	1.4	45.3	124	0.380	4.939	133.917	3.7	9.2	0.9
BR20	Big River	189	0.284	8.46	63.7	0.383	4.996	135.129	0.7	1.7	0.5
BR21	Big River, Near Desloge	189	0.306	10.3	67.5	0.383	4.996	135.129	0.8	2.1	0.5
BR22	Big River, Near Desloge	213	0.208	7.18	41	0.416	5.672	149.534	0.5	1.3	0.3
BR23	Big River, Near Desloge	181	0.385	6.25	43	0.371	4.771	130.267	1.0	1.3	0.3
BR24	Big River, Near Desloge	249	9.46	9.81	751	0.463	6.688	170.688	20.4	1.5	4.4
BR25	Big River, Near Desloge	213	0.075	4.32	45.2	0.416	5.672	149.534	0.2	0.8	0.3
BR26	Big River, Near Desloge	203	0.075	2.96	20.9	0.402	5.390	143.564	0.2	0.5	0.1
BR27	Big River, Between Leadwood and Desloge	220	2.94	11.7	230	0.425	5.869	153.688	6.9	2.0	1.5
BR28	Big River, Between Leadwood and Desloge	194	1.42	4.19	72.2	0.390	5.136	138.152	3.6	0.8	0.5
BR29	Big River, Between Leadwood and Desloge	156	0.214	0.5	21.5	0.335	4.070	114.852	0.6	0.1	0.2

Station ID	Location	Hardness (mg/L CaCo3)	CADMIUM (µg/L)	LEAD (µg/L)	ZINC (µg/L)	CADMIUM NAWQC	LEAD NAWQC	ZINC NAWQC	CADMIUM HQ	LEAD HQ	ZINC HQ
BR30	Big River, Between Leadwood and Desloge	161	0.075	0.5	24	0.342	4.210	117.963	0.2	0.1	0.2
BR31	Big River, Between Leadwood and Desloge	153	0.075	0.5	17.4	0.331	3.986	112.978	0.2	0.1	0.2
BR32	Big River, Between Leadwood and Desloge	148	0.075	0.5	6.5	0.323	3.846	109.842	0.2	0.1	0.1
BR33	Big River, Upstream of Leadwood (background)	150	0.075	0.5	10.4	0.326	3.902	111.098	0.2	0.1	0.1
BR34	Big River, Upstream of Leadwood (background)	149	0.075	0.5	3.9	0.324	3.874	110.470	0.2	0.1	0.0
MF01	Mineral Fork	185	0.075	8.49	2.6	0.377	4.883	132.702	0.2	1.7	0.0
MF02	Mineral Fork	201	0.075	0.5	2.9	0.399	5.333	142.365	0.2	0.1	0.0
MF03	Mineral Fork	192	0.075	6.28	5.97	0.387	5.080	136.945	0.2	1.2	0.0
HC04	Hayden Creek	259	0.075	0.5	1.2	0.476	6.970	176.479	0.2	0.1	0.0
HC05	Hayden Creek	214	0.075	0.5	1.4	0.417	5.700	150.129	0.2	0.1	0.0
HC05 - dup	Hayden Creek	224	0.075	0.5	2.1	0.431	5.982	156.052	0.2	0.1	0.0
HC06	Hayden Creek	231	0.075	0.5	1.2	0.440	6.179	160.174	0.2	0.1	0.0
KC01	Koen Creek	339	0.075	2.12	3.7	0.574	9.228	221.688	0.1	0.2	0.0
NAT08	National Pile	387	0.15	40.7	70.7	0.629	10.579	248.011	0.2	3.8	0.3
FED15	Federal Pile	435	0.24	12.4	21.8	0.682	11.925	273.839	0.4	1.0	0.1
FED16	Federal Pile	645	0.447	13.7	33	0.895	17.730	382.335	0.5	0.8	0.1
FED17	Federal Pile	86.2	0.075	1.44	1	0.222	2.140	69.480	0.3	0.7	0.0
FED18	Federal Pile	72.8	0.075	0.5	1.9	0.197	1.778	60.213	0.4	0.3	0.0
FED19	Federal Pile	124	0.075	2.33	1	0.286	3.178	94.550	0.3	0.7	0.0
BKG11	Background	170	0.075	0.5	7.38	0.356	4.462	125.5	0.2	0.1	0.0
BKG12	Background	185	0.075	0.5	1	0.377	4.883	132.7	0.2	0.1	0.0

Table 6-7: Direct Exposure to Surface Water – Exposure Point Concentrations.

Waterbody	Locations	EPC	Average Hardness (mg/L CaCo3)	NAWQC (µg/L)	HQ
CADMIUM					
Big River - Downstream of Leadwood Pile	32	3.6	197	0.4	9.0
Flat River	12	0.5	259	0.48	1.0
National	1	ND	387	0.6	< 1
Mineral Fork	3	ND	193	0.4	< 1
Koen Creek	1	ND	339	0.6	< 1
Hayden Creek	3	ND	232	0.4	< 1
Federal Tributaries/Lakes	5	0.3	273	0.5	< 1
Site-Wide	57	1.5	224	0.4	3.4
Background	4	ND	163	0.35	< 1

Waterbody	Locations	EPC	Average Hardness (mg/L) CaCo3	NAWQC (µg/L)	HQ
LEAD					
Big River - Downstream of Leadwood Pile	32	23.3	197	5.2	4.5
Flat River	12	17.1	259	7.0	2.4
National	1	40.7	387	10.6	3.8
Mineral Fork	3	15.4	193	5.1	3.0
Koen Creek	1	2.12	339	9.2	< 1
Hayden Creek	3	ND	232	6.2	< 1
Federal Tributaries/Lakes	5	12.2	273	7.4	1.6
Site-Wide	57	16.4	224	6.0	2.7
Background	4	ND	163	4.3	< 1

Waterbody	Locations	EPC	Average Hardness (mg/L) CaCo3	NAWQC (µg/L)	HQ
ZINC					
Big River - Downstream of Leadwood Pile	32	92.7	197	139.8	< 1
Flat River	12	208.8	259	176.7	1.2
National	1	70.7	387	248	< 1
Mineral Fork	3	8.4	193	137	< 1
Koen Creek	1	2.12	339	221.7	< 1
Hayden Creek	3	ND	232	160.2	< 1
Federal Tributaries/Lakes	5	25.9	273	184.3	< 1
Site-Wide	57	86.3	224	156	< 1
Background	4	9.2	163	119.4	< 1

Table 6-8
Direct Exposure to Sediment
Big River Mine Tailings Site
St. Francois County, MO

Station ID	Location	SEM/AVS	Cadmium (mg/kg)	Lead (mg/kg)	Zinc (mg/kg)	Cadmium HQ_{PEC}^{1}	Lead HQ_{PEC}^{2}	Zinc HQ $_{PEC}^{3}$	HI_{PEC}
FL01	Flat River	No Value	9.39	1,850	348	1.9	14.5	0.8	17.1
FL02	Flat River	No Value	4.39	3,350	262	0.9	26.2	0.6	27.6
FL03	Flat River	No Value	3.4	3,240	156	0.7	25.3	0.3	26.3
FL04	Flat River	5.03	4.27	2,890	211	0.9	22.6	0.5	23.9
FL05	Flat River	No Value	5.43	1,730	387	1.1	13.5	0.8	15.4
FL06	Flat Rivr, Near National	No Value	7.26	2,900	505	1.5	22.7	1.1	25.2
FL07	Flat Rivr, Near National	10.7	6.23	3,540	479	1.3	27.7	1.0	30.0
FL08	Flat River	No Value	4.81	1,030	516	1.0	8.0	1.1	10.1
FL09	Flat River, Betewen Elvins and National	0.315	5.1	4,730	230	1.0	37.0	0.5	38.5
FL10	Flat River, Betewen Elvins and National	No Value	8.55	2,660	484	1.7	20.8	1.1	23.6
FL11	Flat River, Near Elvins	1.23	8.74	632	1,060	1.8	4.9	2.3	9.0
FL12	Flat River, Near Elvins	No Value	2.33	1,,040	196	0.5	8.1	0.4	9.0
FR4	Flat River at Derby (Background)	NA	3	361	263	0.6	2.8	0.6	4.0
FR5	Flat River above Shaw Branch	> 1	31	1,958	6,295	6.2	15.3	13.7	35.2
FR6	Flat River at City Park	No Value	18	2,685	3,318	3.6	21.0	7.2	31.8
FR7	Flat River, Downstream of National	No Value	24	5,558	1,707	4.8	43.4	3.7	52.0
BR01	Big River	No Value	7.86	1,520	629	1.6	11.9	1.4	14.8
BR02	Big River	No Value	5.82	1,140	569	1.2	8.9	1.2	11.3
BR03	Big River	No Value	3.48	863	247	0.7	6.7	0.5	8.0
BR04	Big River	No Value	1.88	339	163	0.4	2.6	0.4	3.4
BR05	Big River	No Value	2.5	649	229	0.5	5.1	0.5	6.1
BR06	Big River	No Value	12.1	1,530	610	2.4	12.0	1.3	15.7
BR07	Big River	No Value	2.34	887	188	0.5	6.9	0.4	7.8
BR08	Big River	No Value	16.9	1,550	820	3.4	12.1	1.8	17.3
BR09	Big River	No Value	0.905	167	138	0.2	1.3	0.3	1.8
BR10	Big River	No Value	4.5	2,000	242	0.9	15.6	0.5	17.1
BR11	Big River	No Value	6.34	2,850	396	1.3	22.3	0.9	24.4
BR12	Big River	No Value	2.33	1,040	196	0.5	8.1	0.4	9.0
BR13	Big River	No Value	0.3	38.6	34.2	0.1	0.3	0.1	0.4
BR14	Big River	No Value	4.41	842	298	0.9	6.6	0.6	8.1
BR15	Big River	No Value	26.3	2,200	1200	5.3	17.2	2.6	25.1
BR16	Big River	No Value	8.17	1,930	387	1.6	15.1	0.8	17.6
BR17	Big River	5.93	25	1,860	1,620	5.0	14.5	3.5	23.1
BR18	Big River	No Value	46.7	26,600	2,080	9.4	207.8	4.5	221.7
BR19	Big River	No Value	19.5	1,930	1,130	3.9	15.1	2.5	21.5

Station ID	Location	SEM/AVS	Cadmium (mg/kg)	Lead (mg/kg)	Zinc (mg/kg)	Cadmium HQ_{PEC}[1]	Lead HQ_{PEC}[2]	Zinc HQ $_{PEC}$[3]	HI_{PEC}
BR20	Big River	No Value	18.3	2,420	958	3.7	18.9	2.1	24.7
BR21	Big River, Near Desloge	No Value	14.8	983	847	3.0	7.7	1.8	12.5
BR22	Big River, Near Desloge	No Value	17	799	869	3.4	6.2	1.9	11.5
BR23	Big River, Near Desloge	5.09	88.5	5,890	4,370	17.8	46.0	9.5	73.3
BR24	Big River, Near Desloge	No Value	38.9	883	1,790	7.8	6.9	3.9	18.6
BR25	Big River, Near Desloge	No Value	19.6	710	830	3.9	5.5	1.8	11.3
BR26	Big River, Near Desloge	No Value	25.6	819	1,090	5.1	6.4	2.4	13.9
BR27	Big River, Between Leadwood and Desloge	0.11	4.57	418	311	0.9	3.3	0.7	4.9
BR28	Big River, Between Leadwood and Desloge	No Value	27.6	876	1,610	5.5	6.8	3.5	15.9
BR29	Big River, Between Leadwood and Desloge	No Value	5.97	168	319	1.2	1.3	0.7	3.2
BR30	Big River, Between Leadwood and Desloge	No Value	65.4	8,460	9,300	13.1	66.1	20.3	99.5
BR31	Big River, Between Leadwood and Desloge	1.73	4.15	266	244	0.8	2.1	0.5	3.4
BR32	Big River, Between Leadwood and Desloge	No Value	0.3	40.3	83	0.1	0.3	0.2	0.6
BR33	Big River, Upstream of Leadwood	No Value	0.28	19.1	41.6	0.1	0.1	0.1	0.3
BR34	Big River, Upstream of Leadwood	No Value	0.3	18.3	37.1	0.1	0.1	0.1	0.3
BR10	Big River at St. Francois State Park	NA	28	2,065	1,574	5.6	16.1	3.4	25.2
BR8	Big River below confluence with Flat River	NA	49	6,259	2,977	9.8	48.9	6.5	65.2
BR9	Big River above confluence with Flat River	NA	70	2,357	3,872	14.1	18.4	8.4	40.9
BR13	Big River at Desloge	NA	90	2,469	4,764	18.1	19.3	10.4	47.7
BR3	Big River at Bone Hole	NA	227	3,335	5,251	45.6	26.1	11.4	83.1
BR2	Big River at Leadwood	NA	34	1,550	1,980	6.8	12.1	4.3	23.3
BR3	Big River at Bone Hole	NA	12	705	812	2.4	5.5	1.8	9.7
UNSED-2	Mouth of tributary	NA	11	440	835	2.2	3.4	1.8	7.5
UNSED-1	Mouth of tributary	NA	3	818	278	0.6	6.4	0.6	7.6

Station ID	Location	SEM/AVS	Cadmium (mg/kg)	Lead (mg/kg)	Zinc (mg/kg)	Cadmium HQ$_{PEC}$[1]	Lead HQ$_{PEC}$[2]	Zinc HQ $_{PEC}$[3]	HI$_{PEC}$
MF01	Mineral Fork	0.823	11.8	1,900	710	2.4	14.8	1.5	18.8
MF02	Mineral Fork	No Value	0.5313	40.7	88.4	0.1	0.3	0.2	0.6
MF03	Mineral Fork	No Value	1.01	331	107	0.2	2.6	0.2	3.0
HC04	Hayden Creek	No Value	1.23	2,660	99	0.2	20.8	0.2	21.2
HC05	Hayden Creek	No Value	1.1	227	124	0.2	1.8	0.3	2.3
HC05 - dup	Hayden Creek	No Value	0.945	173	192	0.2	1.4	0.4	2.0
HC06	Hayden Creek	No Value	0.654	97.6	62.8	0.1	0.8	0.1	1.0
Hay	Mouth of Big River and Hayden Creek	NA		145	126	0.0	1.1	0.3	1.4
KC01	Koen Creek	0.174	3.85	904	167	0.8	7.1	0.4	8.2
Koen	Mouth of Koen Creek and Flat River	NA	1	191	101	0.2	1.5	0.2	1.9
NAT08	National Pile	No Value	6.78	1,930	326	1.4	15.1	0.7	17.1
FED15	Federal Pile	No Value	9.14	1,390	434	1.8	10.9	0.9	13.6
FED16	Federal Pile	No Value	9.54	1,020	461	1.9	8.0	1.0	10.9
FED17	Federal Pile	3.88	6.55	609	273	1.3	4.8	0.6	6.7
FED18	Federal Pile	No Value	4.3	791	216	0.9	6.2	0.5	7.5
FED19	Federal Pile	No Value	5.88	759	185	1.2	5.9	0.4	7.5
FED-SED1	Federal Wetland	NA	1	129	82	0.2	1.0	0.2	1.4
FED-SED2	Federal Wetland	NA	1	157	69	0.2	1.2	0.2	1.6
FED-SED3	Federal Wetland	NA	6	552	286	1.2	4.3	0.6	6.1
BT East	Creek draining Bonne Terre	NA	4	716	224	0.8	5.6	0.5	6.9
Owl-Cr	Head of pond 1/2 south of Big River and Owl Creek	NA	1	176	125	0.2	1.4	0.3	1.8
BT-SED1	Bonne Terre Wetland	NA		18	39	0.0	0.1	0.1	0.2
BT-SED2	Bonne Terre Wetland	NA		24	12	0.0	0.2	0.0	0.2
BT-SED3	Bonne Terre Wetland	NA		75	38	0.0	0.6	0.1	0.7
BT-SED4	Bonne Terre Wetland	NA		55	33	0.0	0.4	0.1	0.5
BT1A	Bonne Terre Herbacous Wetland	NA	3	613	109	0.6	4.8	0.2	5.6
BT1B	Bonne Terre Herbacous Wetland	NA	3	800	140	0.6	6.3	0.3	7.2
BT1C	Bonne Terre Herbacous Wetland	NA	2	907	124	0.4	7.1	0.3	7.8
LW-SED1	Leadwood Herbacous Wetland	NA	7	1490	357	1.4	11.6	0.8	13.8
LW-SED2	Leadwood Herbacous Wetland	NA	15	936	810	3.0	7.3	1.8	12.1
LW-SED3	Leadwood Herbacous Wetland	NA	4	411	199	0.8	3.2	0.4	4.4
LW-SED4	Leadwood Woody Wetland	NA	1	95	61	0.2	0.7	0.1	1.1

Station ID	Location	SEM/AVS	Cadmium (mg/kg)	Lead (mg/kg)	Zinc (mg/kg)	Cadmium HQ_{PEC}[1]	Lead HQ_{PEC}[2]	Zinc HQ $_{PEC}$[3]	HI_{PEC}
LW-SED5	Leadwood Woody Wetland	NA	1	74	50	0.2	0.6	0.1	0.9
LW-SED6	Leadwood Woody Wetland	NA	1	104	66	0.2	0.8	0.1	1.2
BKG11		0.154	2.42	432	206	0.5	3.4	0.5	4.4
BKG12		NA	44.3	925	2,060	8.9	7.2	4.5	20.6

1 – Based on a PEC for Cadmium of 4.98 mg/kg.
2 - Based on a PEC for Lead of 128 mg/kg.
3 – Based on a PEC for Zinc of 459 mg/kg.

Table 6-9: Direct Exposure to Sediment – Exposure Point Concentrations.

Waterbody	Locations	SEM/AVS	EPC	PEC	HQ_{PEC}
CADMIUM					
Big River - Downstream of Leadwood Pile	41	3.2	36.4	4.98	7
Flat River	16	4.3	13.0	4.98	3
National	1	NA	6.8	4.98	1
Mineral Fork	3	0.823	4.5	4.98	0.9
Hayden Creek	3	NA	1.3	4.98	< 1
Federal Tributaries/Lakes	8	3.88	7.6	4.98	2
Bonne Terre Wetlands/Tributaries	4	NA	4.0	4.98	< 1
Leadwood Wetlands	6	NA	14.9	4.98	3
Owl Creek	1	NA	1	4.98	< 1
Koen Creek	2	0.174	2.4	4.98	< 1
Site-Wide	85	3.0	23.4	4.98	5
Background – Upstream of Leadwood Pile	2	NA	0.3	4.98	< 1

Waterbody	Locations	SEM/AVS	EPC	PEC	HQ_{PEC}
LEAD					
Big River - Downstream of Leadwood Pile	41	3.2	3,976.7	128	31
Flat River	16	4.3	3,136.7	128	25
National	1	NA	1,930	128	15
Mineral Fork	3	0.823	757.2	128	6
Hayden Creek	4	NA	1,705.4	128	13
Federal Tributaries/Lakes	8	3.88	957.4	128	8
Bonne Terre Wetlands/Tributaries	8	NA	1,154.4	128	9
Leadwood Wetlands	6	NA	995	128	8
Owl Creek	1	NA	176	128	1
Koen Creek	2	0.174	547.5	128	4
Site-Wide	90	3.0	2,084.1	128	16
Background – Upstream of Leadwood Pile	2	NA	18.7	128	< 1

Waterbody	Locations	SEM/AVS	EPC	PEC	HQ_{PEC}
ZINC					
Big River - Downstream of Leadwood Pile	41	3.2	1,866.7	459	4
Flat River	16	4.3	5,056.6	459	11
National	1	NA	326	459	< 1
Mineral Fork	3	0.823	301.8	459	< 1
Hayden Creek	4	NA	165.9	459	< 1
Federal Tributaries/Lakes	8	3.88	347.7	459	< 1
Bonne Terre Wetlands/Tributaries	8	NA	138.32	459	< 1
Leadwood Wetlands	6	NA	770	459	2
Owl Creek	1	NA	125	459	< 1
Koen Creek	2	0.174	134	459	< 1
Site-Wide	90	3.0	1,225.6	459	3
Background – Upstream of Leadwood Pile	2	NA	53.9	459	< 1

Table 6-10: Direct Exposure to Sieved Sediment and Pore Water.

SIEVED SEDIMENT

Station ID	Location	AVS-SEM	CADMIUM (mg/kg)	LEAD (mg/kg)	ZINC (mg/kg)	CADMIUM HQ$_{PEC}$	LEAD HQ$_{PEC}$	ZINC HQ$_{PEC}$	HI$_{PEC}$
BR04	Big River		4.05	371	227	0.8	2.9	0.5	4.2
BR06	Big River		5.92	324	323	1.2	2.5	0.7	4.4
BR09	Big River		8.29	795	442	1.7	6.2	1.0	8.8
BR13	Big River		12.6	803	586	2.5	6.3	1.3	10.1
BR19	Big River		47.7	1,310	2,170	9.6	10.2	4.7	24.5
BR22	Big River, Near Desloge		4.56	628	1,280	0.9	4.9	2.8	8.6
BR25	Big River, Near Desloge		82	803	3,610	16.5	6.3	7.9	30.6
BR26	Big River, Near Desloge	0.641	14.9	364	713	3.0	2.8	1.6	7.4
BR33	Big River, Upstream of Leadwood		5.23	404	137	1.1	3.2	0.3	4.5
FL01	Flat River		15.1	997	713	3.0	7.8	1.6	12.4
FL09	Flat River, Betewen Elvins and National	4.03	4.57	1,630	383	0.9	12.7	0.8	14.5
MF02	Mineral Fork		5.71	912	316	1.1	7.1	0.7	9.0

PORE WATER

Station ID	Location	Hardness (mg/L CaCO3)	CADMIUM (µg/L)	LEAD (µg/L)	ZINC (µg/L)	NAWQC Cadmium (µg/L)	NAWQC Lead (µg/L)	NAWQC Zinc (µg/L)	CADMIUM HQ	LEAD HQ	ZINC
BR04	Big River	211	0.075	8.34	9.74	0.4	5.6	148.3	0.2	1.5	
BR06	Big River	210	0.522	3.53	31.2	0.4	5.6	147.7	1.3	0.6	
BR09	Big River	271	2.22	52.1	365	0.5	7.3	183.4	4.5	7.1	
BR13	Big River	228	0.694	17.7	49.1	0.4	6.1	158.4	1.6	2.9	
BR19	Big River	210	0.238	15.9	48.3	0.4	5.6	147.7	0.6	2.8	
BR22	Big River, Near Desloge	215	0.075	15.2	25.6	0.4	5.7	150.7	0.2	2.7	
BR25	Big River, Near Desloge	268	40	53.8	4540	0.5	7.2	181.7	82.1	7.4	

BR26	Big River, Near Desloge	204	0.075	5.34	6.93	0.4	5.4	144.2	0.2	1.0	
BR33	Big River, Upstream of Leadwood	183	0.764	1.65	48.7	0.4	4.8	131.5	2.0	0.3	
FL01	Flat River	215	0.676	20	98.5	0.4	5.7	150.7	1.6	3.5	
FL09	Flat River, Betewen Elvins and National	212	0.239	31.8	119	0.4	5.6	148.9	0.6	5.6	
MF02	Mineral Fork	197	0.075	1.06	3.63	0.4	5.2	140.0	0.2	0.2	

Table 6-11: Direct Exposure to Sediment (Sieved) and Pore Water - Exposure Point Concentrations.

Sieved Sediment	Locations	EPC	HQ_{TEC}	HQ_{PEC}
Big River – Cadmium	9	45.1	46	**9**
Big River – Lead	9	844.3	24	**7**
Big River – Zinc	9	2171.9	18	**5**
Flat River – Cadmium	2	9.8	10	**2**
Flat River – Lead	2	1,313.5	37	**10**
Flat River – Zinc	2	548	5	**1**
Mineral Fork – Cadmium	1	5.71	6	**1**
Mineral Fork – Lead	1	912	26	**7**
Mineral Fork – Zinc	1	316	3	**< 1**
Entire Site – Cadmium	12	47.3	48	**10**
Entire Site – Lead	12	987.1	28	**8**
Entire Site – Zinc	**12**	**1,567.7**	**13**	**3**

Pore Water	Locations	EPC	NAWQC (µg/L)	HQ_{NAWQC}
Big River – Cadmium	9	32.4	0.4	**81**
Big River – Lead	9	74.1	5.9	**13**
Big River – Zinc	9	2,059.9	154.9	**13**
Flat River – Cadmium	2	0.46	0.4	**1**
Flat River – Lead	2	25.9	5.7	**5**
Flat River – Zinc	2	108.8	150.1	**< 1**
Mineral Fork – Cadmium	1	0.15U	0.4	**< 1**
Mineral Fork – Lead	1	1.06	5.2	**< 1**

Mineral Fork – Zinc	1	3.63	140	**< 1**
Entire Site – Cadmium	12	36.6	0.4	**92**
Entire Site – Lead	12	55.8	5.8	**10**
Entire Site – Zinc	**12**	**1,607.8**	**153**	**11**

Table 6-12: Results of *Hyallela* Toxicity Tests.

Location	**XRF Lead (mg/kg)**	**Sediment Lead (mg/kg)**	**Sediment Cadmium (mg/kg)**	**Sediment Zinc (mg/kg)**	**HI_{PEC}**	**Reproduction # /*Hyallela***	**Growth mg/*Hyallela***	**Percent Survival**
Big River-Site 32	50	40.3	0.3	83	0.6	15.8	0.79	88
Hayden Creek Site 5	100	227	1.1	124	2.3	7.7	0.67	97
Big River Site 4	150	339	1.88	163	3.4	9.3	0.54	94
Federal Site 19	300	759	5.88	185	7.5	10.9	0.68	84
Big River Site 25	600	710	19.6	830	11.3	3.7	0.56	39
Big River Site 26	800	819	25.6	1,090	13.9	5.1	0.49	66
Big River Site 10	1,200	2,000	4.5	242	17.1	6.2	0.59	77
Flat River Site 9	2,400	4,730	5.1	230	38.5	7.6	0.77	69
Background BKG11	NA	432	2.42	206	4.4	10.9	0.72	91

Table 6-14
Fish, Crayfish and Frog Tissue Concentrations
Big River Mine Tailings Site
St. Francois County, MO

Water Body	EPC Small Fish	EPC Sunfish	EPC Crayfish	EPC Frogs
Cadmium				
Big River	0.3	0.4	2.8	NA
Flat River	0.03	0.2	0.32	NA
Mineral Fork	0.06	NA	0.08	NA
Hayden Creek	NA	NA	0.06	NA
Bonne Terre Wetland	NA	0.07	NA	NA
Monsanto Lake	NA	0.1	NA	NA
Owl Creek	NA	0.1	NA	NA
Site-Wide	0.2	0.3	0.9	0.4

Water Body	EPC Small Fish	EPC Sunfish	EPC Crayfish	EPC Frogs
Lead				
Big River	8.3	19.0	70.0	NA
Flat River	6.9	43.5	37.2	NA
Mineral Fork	7.55	NA	22.9	NA
Hayden Creek	NA	NA	1.3	NA
Bonne Terre Wetland	NA	7.7	NA	NA
Monsanto Lake	NA	2.7	NA	NA
Owl Creek	NA	1.1	NA	NA
Site-Wide	7.9	17.4	49.0	11.0

Water Body	EPC Small Fish	EPC Sunfish	EPC Crayfish	EPC Frogs
Zinc				
Big River	43.04	52.2	78.4	NA
Flat River	32.4	75.9	60.8	NA
Mineral Fork	30.6	NA	24.7	NA
Hayden Creek	NA	NA	23.7	NA
Bonne Terre Wetland	NA	36.2	NA	NA
Monsanto Lake	NA	22.3	NA	NA
Owl Creek	NA	22.4	NA	NA
Site-Wide	39.5	57.1	64.3	43.7

APPENDIX C
FIGURES

APPENDIX D
EXPOSURE FACTORS

Mallard Anus platyrhynchos				
Parameter	Symbol	Reported Value	Reference	Value for ERA
Body Weight (kg wet weight)	BW	1.225 – Adult Males throughout N. America 1.043 – Adult Females throughout N. America 1.134 – Average for Males and Females	USEPA, 1993	1.134
Normalized Food Ingestion Rate (kg wet weight/kg BW/day)	NIR_{food}	Species specific value is unavailable. Can be estimated from following equation: $IR_{fd} = (0.0582*BW^{0.651})/0.2$ Where 0.2 is the dry weight to wet weight conversion factor. $NIR_{fd} = IR_{fd}/BW$	USEPA, 1993	0.28
Normalized Water Ingestion Rate (L/kgBW/day)	NIR_w	0.058 – Adult Female 0.055 – Adult Males 0.057 – Average of Males and Females	USEPA, 1993	0.057
Normalized Sediment Ingestion Rate	NIR_{sed}	Ingestion of sediment (I_{sed}) as a percentage of diet (kg sediment dry weight/kg food dry weight) is reported as 3.3%. $IRsed = IR_{food}*0.145*I_{sed}$	Beyer, 1994	0.0015
Dietary Composition	FD	75% = Aquatic Invertebrates averaged across April – June in North Dakota Pot Holes 25% = Aquatic Plants averaged across April – June in North Dakota Pot Holes	USEPA, 1993	$FD_{INV} = 0.75$ $FD_{VEG} = 0.25$*
Home Range (ha)	HR	540 ha = Adult Female (Minnesota) 620 ha = Adult Male (Minnesota) 580 = Average for Males and Females	USEPA, 1993	580
Seasonal Use		In Missouri, mallards are found throughout the state, and they are known to over-winter on available open water/	MDC	

* In the preliminary risk screen, the AUF was assumed to be 100%.

Prairie Vole Microtus ochrogaster				
Parameter	Symbol	Reported Value	Reference	Value for ERA
Body Weight (kg wet weight)	BW	0.0313 = Adult Males Southern Indiana 0.0333 = Adult Females Southern Indiana 0.0323 = Average for Males and Females	USEPA, 1993	0.032
Normalized Food Ingestion Rate (kg wet weight/kgBW/day)	NIR_{food}	0.13-0.14 = Illinois Lab	USEPA, 1993	0.14
Normalized Water Ingestion Rate (L/kgBW/day)	NIR_w	0.37 = Adults Both Laboratory	USEPA, 1993	0.37
Normalized Soil Ingestion Rate	NIR_{soil}	Ingestion of soil (I_{soil}) as a percentage of diet (kg sediment dry weight/kg food dry weight) is reported as 2.4% for meadow vole. $IRsed = IR_{food}*0.53*I_{sed}$	USEPA, 1993	0.002
Dietary Composition	FD	Missouri Old Fields – leaves, stems, and seeds of mainly Fescue, Foxtail, and Brome grass.	USEPA, 1993	FD_{VEG} = 1.00
Home Range (ha)	HR	0.037 = Adult Males in Kansas 0.024 = Adult Females in Kansas 0.031 = Average Males and Females	USEPA, 1993	0.031
Seasonal Use		Active year around	USEPA, 1993	

* In the preliminary risk screen, the AUF was assumed to be 100%.

Red Fox Vulpes vulpes				
Parameter	Symbol	Reported Value	Reference	Value for ERA
Body Weight (kg wet weight)	BW	4.82 = Adult Males Iowa 3.94 = Adult Females Iowa 4.38 = Average for Males and Females	USEPA, 1993	4.38
Normalized Food Ingestion Rate (kg wet weight/kgBW/day)	NIR_{food}	0.14 – Captive Adult Females after whelp	USEPA, 1993	0.14
Normalized Water Ingestion Rate (L/kgBW/day)	NIR_w	0.084 = Adults Males 0.086 = Adult Females 0.085 = Average for Males and Females	USEPA, 1993	0.085
Normalized Soil Ingestion Rate	NIR_{soil}	Ingestion of sediment (I_{soil}) as a percentage of diet (kg sediment dry weight/kg food dry weight) is reported as 2.8%. $IRsed = IR_{food}*0.32*I_{sed}$	USEPA, 1993	0.0013
Dietary Composition	FD	Rabbits, mice, other small mammals, carrion, poultry, birds, invertebrates, and plants compose the diet of fox in Missouri. Diet composition varies across seasons; therefore fractions were averaged across seasons.	USEPA, 1993	$FD_{INS} = 0.04$ $FD_{VEG} = 0.05$ $FD_{SM} = 0.66$* $FD_{BIRD} = 0.25$
Home Range (ha)	HR	699 = Adult Female Minnesota Woods/fields	USEPA, 1993	699
Seasonal Use		Active year-round	USEPA, 1993	

* In the preliminary risk screen, the AUF was assumed to be 100%.

Heron
Ardea herodias

Parameter	Symbol	Reported Value	Reference	Value for ERA
Body Weight (kg wet weight)	BW	2.229 = Adults Both Eastern North America	USEPA, 1993	2.229
Normalized Food Ingestion Rate (kg wet weight/kgBW/day)	NIR_{food}	0.18	USEPA, 1993	0.18
Normalized Water Ingestion Rate (L/kgBW/day)	NIR_{w}	0.045	USEPA, 1993	0.045
Normalized Sediment Ingestion Rate	NIR_{sed}	Ingestion of sediment (I_{sed}) as a percentage of diet is not available. Assumed to be 1%. $IRsed = IR_{food}*0.24*I_{sed}$	USEPA, 1993	0.0004
Dietary Composition	FD	89% - Game fish (Michigan River) 5% - Forage Fish 1% - Crustaceans 4% - Amphibians 1% - Birds and Mammals	USEPA, 1993	$FD_{game} = 0.89$ $FD_{crayfish} = 0.01$ $FD_{frog}s = 0.05$* $FD_{forag}e = 0.05$
Home Range (ha)	HR	0.6 = Adult Both Fall 8.4 = Adult Both Winter	USEPA, 1993	0.6
Seasonal Use		Migratory in northern portion of range. Herons generally return to Missouri in February to early March.	MDC	.75*

* In the preliminary risk screen, the diet was assumed to be 100% frogs.
* In the preliminary risk screen, the AUF was assumed to be 100%.

Red-Tailed Hawk Buteo jamaicensis				
Parameter	Symbol	Reported Value	Reference	Value for ERA
Body Weight (kg wet weight)	BW	1.224 = Adults Females Michigan 1.028 = Adult Males Michigan 1.13 = Average for Males and Females	USEPA, 1993	1.13
Normalized Food Ingestion Rate (kg wet weight/kgBW/day)	NIR_{food}	0.11 = Adult Females (Michigan captive) 0.10 = Adult Males (Michigan captive)	USEPA, 1993	0.11
Normalized Water Ingestion Rate (L/kgBW/day)	NIR_{w}	0.055 = Adult Females 0.059 = Adult Males 0.057 = Average Males and Females	USEPA, 1993	0.057
Normalized Soil Ingestion Rate	NIR_{soil}	Ingestion of soil (I_{sed}) as a percentage of diet is not available. Assumed to be 1%. $IR_{soil} = IR_{fd}*0.32*I_{soil}$	USEPA, 1993	0.0004
Dietary Composition	FD	In farms and woodlands, they are known to consume various small mammals and birds.	USEPA, 1993	$FD_{SM} = 0.74$* $FD_{BIRD} = 0.26$
Home Range (ha)	HR	381-989 Michigan Fields/Woodlots	USEPA, 1993	381
Seasonal Use		Southerly populations are year-round residents.	USEPA, 1993	

* In the preliminary risk screen, the AUF was assumed to be 100%.

Belted Kingfisher Ceryle alcyons				
Parameter	Symbol	Reported Value	Reference	Value for ERA
Body Weight (kg wet weight)	BW	0.158= Adults Both Ohio	USEPA, 1993	0.158
Normalized Food Ingestion Rate (kg wet weight/kgBW/day)	NIR_{food}	0.50 = Adult Both (Michigan)	USEPA, 1993	0.50
Normalized Water Ingestion Rate (L/kgBW/day)	NIR_w	0.11	USEPA, 1993	0.11
Normalized Sediment Ingestion Rate	NIR_{sed}	Ingestion of soil (I_{sed}) as a percentage of diet is not available. Assumed to be 1%. $IR_{soil} = IR_{fd}*0.24*I_{soil}$	USEPA, 1993	0.0012
Dietary Composition	FD	In Ohio creeks, kingfishers are known to take crayfish, forage fish, and game fish.	USEPA, 1993	$FD_{game} = 0.10$* $FD_{crayfish} = 0.14$ $FD_{forage} = 0.77$
Home Range (ha)	HR	1.03 = km shoreline (Ohio Creek)	USEPA, 1993	1.03 km
Seasonal Use		Arrive in Late February in Missouri.	USEPA, 1993	

* In the preliminary risk screen, the diet was assumed to be 100% game fish (sunfish/bass).

* In the preliminary risk screen, the AUF was assumed to be 100%.

River Otter
Lutra Canadensis

Parameter	Symbol	Reported Value	Reference	Value for ERA
Body Weight (kg wet weight)	BW	8.13 = Adult Male Michigan 6.73 = Adult Female Michigan 7.43 = Average Males and Females	USEPA, 1993	7.43
Normalized Food Ingestion Rate (kg wet weight/kgBW/day)	NIR_{food}	Species specific value is unavailable. Can be estimated from following equation: $IR_{fd} = (0.0687*BW^{0.822})/0.2$ Where 0.2 is the dry weight to wet weight conversion factor. $NIR_{fd} = IR_{fd}/BW$	USEPA, 1993	0.24
Normalized Water Ingestion Rate (L/kgBW/day)	NIR_w	0.082 = Estimated	USEPA, 1993	0.082
Normalized Sediment/Soil Ingestion Rate	NIR_{sed}	Ingestion of soil (I_{sed}) as a percentage of diet is not available. Assumed to be 1%. $IR_{soil} = IR_{fd}*0.24*I_{soil}$	USEPA, 1993	0.0006
Dietary Composition	FD	Fish, crayfish, frogs, insects, and occasionally birds and mammals in NW Illinois Stream. Diet composition is estimated for major food sources across seasons.	USEPA, 1993	$FD_{gane} = 0.75$* $FD_{crayfish} = 0.18$ $FD_{frogs} = 0.07$
Home Range (ha)	HR	400 – 1,900 = Adult Males in Missouri marsh/stream	USEPA, 1993	400 ha
Seasonal Use		Year-round residents.	USEPA, 1993	

* In the preliminary risk screen, the diet was assumed to be 100% game fish (sunfish/bass).
* In the preliminary risk screen, the AUF was assumed to be 100%.

Short-Tailed Shrew Blarina brevicauda				
Parameter	Symbol	Reported Value	Reference	Value for ERA
Body Weight (kg wet weight)	BW	0.015 = Adult Both New Hampshire	USEPA, 1993	0.015
Normalized Food Ingestion Rate (kg wet weight/kgBW/day)	NIR_{food}	0.62 = Wisconsin Lab	USEPA, 1993	0.62
Normalized Water Ingestion Rate (L/kgBW/day)	NIR_{w}	0.223 = Illinois Lab	USEPA, 1993	0.223
Normalized Soil Ingestion Rate	NIR_{soil}	Ingestion of soil (I_{sed}) as a percentage of diet (kg dry weight/kg dry weight food) is reported to be to be 13%. $IR_{soil} = IR_{fd}*0.30*I_{soil}$	Talmage and Walton, 1993	0.024
Dietary Composition	FD	Earthworms, beetle larvae (grubs), vegetable matter, and small mammals. Diet composition is estimated for major food sources from data presented for the eastern United States.	USEPA, 1993	$FD_{EW} = 0.27$* $FD_{INS} = 0.60$ $FD_{SM} = 0.03$ $FD_{VEG} = 0.10$
Home Range (ha)	HR	<0.1 – 0.36 = Adult Females <0.1 – 1.8 = Adult Males	USEPA, 1993	<0.1 ha
Seasonal Use		Year-round residents.	USEPA, 1993	

American Woodcock Scolopax Minor				
Parameter	Symbol	Reported Value	Reference	Value for ERA
Body Weight (kg wet weight)	BW	0.176 = Adult Male Throughout Range 0.218 = Adult Female Throughout Range 0.20 = Average Male and Female	USEPA, 1993	0.20
Normalized Food Ingestion Rate (kg wet weight/kgBW/day)	NIR_{food}	0.77 = Louisiana Captive	USEPA, 1993	0.77
Normalized Water Ingestion Rate (L/kgBW/day)	NIR_w	0.10 = Estimated	USEPA, 1993	0.10
Normalized Sediment/Soil Ingestion Rate	NIR_{soil}	Ingestion of soil (I_{soil}) as a percentage of diet (kg dry weight/kg dry weight food) is reported to be to be 10.4%. $IR_{soil} = IR_{fd}*0.20*I_{soil}$	Talmage and Walton, 1993	0.016
Dietary Composition	FD	Earthworms are the preferred food choice, but other soil invertebrates will be taken when earthworms are not available.	USEPA, 1993	$FD_{EW} = 0.87$* $FD_{INS} = 0.13$
Home Range (ha)	HR	0.3-6.0 = Adult Male Inactive	USEPA, 1993	<0.3 ha
Seasonal Use		Fall migration occurs in late September to mid-December and spring migration occurs mid-February to April.	USEPA, 1993	0.75 of year

* In the preliminary risk screen, the AUF was assumed to be 100%.

APPENDIX E
EXPOSURE AND RISK CALCULATIONS

Preliminary Exposure and Risk Calculations for RME Birds - Cadmium
Big River Mine Tailings Site

Receptor	C_{sw}	NIR_w	NIR_d	NIR_{soil}	C_{soil}	C_{sed}	FD_{veg}	C_{veg}	FD_{ew}	C_{ew}	FD_{sm}	C_{sm}	FD_F	C_F	FD_{Bl}	C_{Bl}	C_{frog}	Fd_{frog}	AUF	ADD	TRV NOAEL	TRV LOAEL	HQ_{NOAEL}	HQ_{LOAEL}
Heron	0	0.045	0.18	0.0004	24	227	0	1.09	0	113	0	5.06	0	1	0	0	1.26	0.99	1.00	0.32	1.45	20	0.2	0.0
Mallard	0	0.057	0.28	0.0013	24	227	1	1.09	0	113	0	5.06	0	1	0	0	1.26	0	1.00	0.60	1.45	20	0.4	0.0
Woodcock	0	0.1	0.77	0.016	24	227	0	1.09	1	113	0	5.06	0	1	0	0	1.26	0	1.00	87.09	1.45	20	60.1	4.4
Hawk	0	0.057	0.11	0.0004	24	227	0	1.09	0	113	1	5.06	0	1	0	0	1.26	0	1.00	0.57	1.45	20	0.4	0.0
Kingfisher	0	0.11	0.5	0.0012	24	227	0	1.09	0	113	0	5.06	1	1	0	0	1.26	0	1.00	0.770	1.45	20	0.5	0.0

Preliminary Exposure and Risk Calculations for RME Birds - Lead
Big River Mine Tailings Site

Receptor	C_{sw}	NIR_w	NIR_d	NIR_{soil}	C_{soil}	C_{sed}	FD_{veg}	C_{veg}	FD_{ew}	C_{ew}	FD_{sm}	C_{sm}	FD_F	C_F	FD_{Bl}	C_{Bl}	C_{frog}	Fd_{frog}	AUF	ADD	TRV NOAEL	TRV LOAEL	HQ_{NOAEL}	HQ_{LOAEL}
Heron	0.1	0.045	0.18	0.0004	1,540	6,259	0	4.91	0	259	0	54	0	43.8	0	0	19.5	1	1.00	6.02	1.13	11.3	5.3	0.5
Mallard	0.1	0.057	0.28	0.0013	1,540	6,259	1	4.91	0	259	0	54	0	43.8	0	0	19.5	0	1.00	9.51	1.13	11.3	8.4	0.8
Woodcock	0.1	0.1	0.77	0.016	1,540	6,259	0	4.91	1	259	0	54	0	43.8	0	0	19.5	0	1.00	224.08	1.13	11.3	198.0	19.8
Hawk	0.1	0.057	0.11	0.0004	1,540	6,259	0	4.91	0	259	1	54	0	43.8	0	0	19.5	0	1.00	6.56	1.13	11.3	5.8	0.6
Kingfisher	0.1	0.11	0.5	0.0012	1,540	6,259	0	4.91	0	259	0	54	1	43.8	0	0	19.5	0	1.00	29.41	1.13	11.3	26.0	2.6

Preliminary Exposure and Risk Calculations for RME Birds - Zinc
Big River Mine Tailings Site

Receptor	C_{sw}	NIR_w	NIR_d	NIR_{soil}	C_{soil}	C_{sed}	FD_{veg}	C_{veg}	FD_{ew}	C_{ew}	FD_{sm}	C_{sm}	FD_F	C_F	FD_{Bl}	C_{Bl}	C_{frog}	Fd_{frog}	AUF	ADD	TRV NOAEL	TRV LOAEL	HQ_{NOAEL}	HQ_{LOAEL}
Heron	0.6	0.045	0.18	0.0004	1,640	6,295	0	109	0	370	0	86.9	0	173	0	0	81.9	1	1.00	17.29	14.5	131	1.2	0.1
Mallard	0.6	0.057	0.28	0.0013	1,640	6,295	1	109	0	370	0	86.9	0	173	0	0	81.9	0	1.00	38.74	14.5	131	2.7	0.3
Woodcock	0.6	0.1	0.77	0.016	1,640	6,295	0	109	1	370	0	86.9	0	173	0	0	81.9	0	1.00	311.20	14.5	131	21.5	2.4
Hawk	0.6	0.057	0.11	0.0004	1,640	6,295	0	109	0	370	1	86.9	0	173	0	0	81.9	0	1.00	10.25	14.5	131	0.7	0.1
Kingfisher	0.6	0.11	0.5	0.0012	1,640	6,295	0	109	0	370	0	86.9	1	173	0	0	81.9	0	1.00	94.05	14.5	131	6.5	0.7

Preliminary Exposure and Risk Calculations for CTE Birds - Cadmium
Big River Mine Tailings Site

Receptor	C_{sw}	NIR_w	NIR_d	NIR_{soil}	C_{soil}	C_{sed}	FD_{veg}	C_{veg}	FD_{ew}	C_{ew}	FD_{sm}	C_{sm}	FD_F	C_F	FD_{BI}	C_{BI}	C_{frog}	Fd_{frog}	AUF	ADD	TRV NOAEL	TRV LOAEL	HQ_{NOAEL}	HQ_{LOAEL}
Heron	0	0.045	0.18	0.0004	5.14	23	0	0.142	0	59.1	0	0.63	0	0.28	0	0	0.27	1	1.00	0.06	1.45	20	0.04	0.003
Mallard	0	0.057	0.28	0.0013	5.14	23	1	0.142	0	59.1	0	0.63	0	0.28	0	0	0.27	0	1.00	0.07	1.45	20	0.05	0.004
Woodcock	0	0.1	0.77	0.016	5.14	23	0	0.142	1	59.1	0	0.63	0	0.28	0	0	0.27	0	1.00	45.59	1.45	20	31.44	2.28
Hawk	0	0.057	0.11	0.0004	5.14	23	0	0.142	0	59.1	1	0.63	0	0.28	0	0	0.27	0	1.00	0.07	1.45	20	0.05	0.004
Kingfisher	0	0.11	0.5	0.0012	5.14	23	0	0.142	0	59.1	0	0.63	1	0.28	0	0	0.27	0	1.00	0.170	1.45	20	0.12	0.009

Preliminary Exposure and Risk Calculations for CTE Birds - Lead
Big River Mine Tailings Site

Receptor	C_{sw}	NIR_w	NIR_d	NIR_{soil}	C_{soil}	C_{sed}	FD_{veg}	C_{veg}	FD_{ew}	C_{ew}	FD_{sm}	C_{sm}	FD_F	C_F	FD_{BI}	C_{BI}	C_{frog}	Fd_{frog}	AUF	ADD	TRV NOAEL	TRV LOAEL	HQ_{NOAEL}	HQ_{LOAEL}
Heron	0.0253	0.045	0.18	0.0004	353	1,158	0	1.1	0	126	0	16.1	0	15.3	0	0	7.57	1	1.00	1.83	1.13	11.3	1.62	0.16
Mallard	0.0253	0.057	0.28	0.0013	353	1,158	1	1.1	0	126	0	16.1	0	15.3	0	0	7.57	0	1.00	1.81	1.13	11.3	1.61	0.16
Woodcock	0.0253	0.1	0.77	0.016	353	1,158	0	1.1	1	126	0	16.1	0	15.3	0	0	7.57	0	1.00	102.67	1.13	11.3	90.86	9.09
Hawk	0.0253	0.057	0.11	0.0004	353	1,158	0	1.1	0	126	1	16.1	0	15.3	0	0	7.57	0	1.00	1.91	1.13	11.3	1.69	0.17
Kingfisher	0.0253	0.11	0.5	0.0012	353	1,158	0	1.1	0	126	0	16.1	1	15.3	0	0	7.57	0	1.00	9.04	1.13	11.3	8.00	0.80

Preliminary Exposure and Risk Calculations for CTE Birds - Zinc
Big River Mine Tailings Site

Receptor	C_{sw}	NIR_w	NIR_d	NIR_{soil}	C_{soil}	C_{sed}	FD_{veg}	C_{veg}	FD_{ew}	C_{ew}	FD_{sm}	C_{sm}	FD_F	C_F	FD_{BI}	C_{BI}	C_{frog}	Fd_{frog}	AUF	ADD	TRV NOAEL	TRV LOAEL	HQ_{NOAEL}	HQ_{LOAEL}
Heron	0.156	0.045	0.18	0.0004	234	1,121	0	15.4	0	182	0	41.8	0	51.8	0	0	37	1	1.00	7.12	14.5	131	0.49	0.05
Mallard	0.156	0.057	0.28	0.0013	234	1,121	1	15.4	0	182	0	41.8	0	51.8	0	0	37	0	1.00	5.78	14.5	131	0.40	0.04
Woodcock	0.156	0.1	0.77	0.016	234	1,121	0	15.4	1	182	0	41.8	0	51.8	0	0	37	0	1.00	143.90	14.5	131	9.92	1.10
Hawk	0.156	0.057	0.11	0.0004	234	1,121	0	15.4	0	182	1	41.8	0	51.8	0	0	37	0	1.00	4.70	14.5	131	0.32	0.04

Kingfisher	0.156	0.11	0.5	0.0012	234	1,121	0	15.4	0	182	0	41.8	1	51.8	0	0	37	0	1.00	27.26	14.5	131	1.88	0.21

Preliminary Exposure and Risk Calculations for RME Mammals - Cadmium
Big River Mine Tailings Site

Receptor	C_{sw}	NIR_{w}	NIR_{d}	NIR_{soil}	C_{soil}	C_{sed}	FD_{veg}	C_{veg}	FD_{ew}	C_{ew}	FD_{sm}	C_{sm}	FD_{F}	C_{F}	FD_{BI}	C_{BI}	C_{frog}	Fd_{frog}	AUF	ADD	TRV NOAEL	TRV LOAEL	HQ NOAEL	HQ LOAEL
Shrew	0	0.223	0.62	0.024	24	227	0	1.09	1	113	0	5.06	0	1	0	0	1.26	0	1.00	70.64	0.0069	0.66	10,237	107
Otter	0	0.082	0.24	0.0006	24	227	0	1.09	0	113	0	5.06	1	1	0	0	1.26	0	1.00	0.38	0.0069	0.66	55	0.57
Fox	0	0.085	0.14	0.0013	24	227	0	1.09	0	113	1	5.06	0	1	0	0	1.26	0	1.00	0.74	0.0069	0.66	107	1.12
Vole	0	0.37	0.14	0.002	24	227	1	1.09	0	113	0	5.06	0	1	0	0	1.26	0	1.00	0.20	0.0069	0.66	29	0.30

Preliminary Exposure and Risk Calculations for RME Mammals - Lead
Big River Mine Tailings Site

Receptor	C_{sw}	NIR_{w}	NIR_{d}	NIR_{soil}	C_{soil}	C_{sed}	FD_{veg}	C_{veg}	FD_{ew}	C_{ew}	FD_{sm}	C_{sm}	FD_{F}	C_{F}	FD_{BI}	C_{BI}	C_{frog}	Fd_{frog}	AUF	ADD	TRV NOAEL	TRV LOAEL	HQ NOAEL	HQ LOAEL
Shrew	0.1	0.223	0.62	0.024	1,540	6,259	0	4.91	1	259	0	54	0	43.8	0	0	19.5	0	1.00	198	8	80	24.7	2.47
Otter	0.1	0.082	0.24	0.0006	1,540	6,259	0	4.91	0	259	0	54	1	43.8	0	0	19.5	0	1.00	14	8	80	1.78	0.18
Fox	0.1	0.085	0.14	0.0013	1,540	6,259	0	4.91	0	259	1	54	0	43.8	0	0	19.5	0	1.00	10	8	80	1.20	0.12
Vole	0.1	0.37	0.14	0.002	1,540	6,259	1	4.91	0	259	0	54	0	43.8	0	0	19.5	0	1.00	8	8	80	0.47	0.047

Preliminary Exposure and Risk Calculations for RME Mammals - Zinc
Big River Mine Tailings Site

Receptor	C_{sw}	NIR_{w}	NIR_{d}	NIR_{soil}	C_{soil}	C_{sed}	FD_{veg}	C_{veg}	FD_{ew}	C_{ew}	FD_{sm}	C_{sm}	FD_{F}	C_{F}	FD_{BI}	C_{BI}	C_{frog}	Fd_{frog}	AUF	ADD	TRV NOAEL	TRV LOAEL	HQ_{NOAEL}	HQ_{LOAEL}
Shrew	0.6	0.223	0.62	0.024	1,640	6,295	0	109	1	370	0	86.9	0	173	0	0	81.9	0	1.00	268.89	160	320	1.68	0.84
Otter	0.6	0.082	0.24	0.0006	1,640	6,295	0	109	0	370	0	86.9	1	173	0	0	81.9	0	1.00	45.34	160	320	0.28	0.14

Fox	0.6	0.085	0.14	0.0013	1,640	6,295	0	109	0	370	1	86.9	0	173	0	0	81.9	0	1.00	14.35	160	320	0.09	0.04
Vole	0.6	0.37	0.14	0.002	1,640	6,295	1	109	0	370	0	86.9	0	173	0	0	81.9	0	1.00	18.75	160	320	0.12	0.06

Preliminary Exposure and Risk Calculations for CTE Mammals - Cadmium
Big River Mine Tailings Site

Receptor	C_{sw}	NIR_w	NIR_d	NIR_{soil}	C_{soil}	C_{sed}	FD_{veg}	C_{veg}	FD_{ew}	C_{ew}	FD_{sm}	C_{sm}	FD_F	C_F	FD_{BI}	C_{BI}	C_{frog}	Fd_{frog}	AUF	ADD	TRV_{NOAEL}	TRV_{LOAEL}	HQ_{NOAEL}	HQ_{LOAEL}
Shrew	0	0.223	0.62	0.024	5.14	23	0	0.142	1	59.1	0	0.632	0	0.284	0	0	0.27	0	1.00	36.77	0.0069	0.66	5,328.3	55.6
Otter	0	0.082	0.24	0.0006	5.14	23	0	0.142	0	59.1	0	0.632	1	0.284	0	0	0.27	0	1.00	0.08	0.0069	0.66	11.9	0.1
Fox	0	0.085	0.14	0.0013	5.14	23	0	0.142	0	59.1	1	0.632	0	0.284	0	0	0.27	0	1.00	0.10	0.0069	0.66	13.8	0.1
Vole	0	0.37	0.14	0.002	5.14	23	1	0.142	0	59.1	0	0.632	0	0.284	0	0	0.27	0	1.00	0.03	0.0069	0.66	4.4	0.05

Preliminary Exposure and Risk Calculations for CTE Mammals - Lead
Big River Mine Tailings Site

Receptor	C_{sw}	NIR_w	NIR_d	NIR_{soil}	C_{soil}	C_{sed}	FD_{veg}	C_{veg}	FD_{ew}	C_{ew}	FD_{sm}	C_{sm}	FD_F	C_F	FD_{BI}	C_{BI}	C_{frog}	Fd_{frog}	AUF	ADD	TRV_{NOAEL}	TRV_{LOAEL}	HQ_{NOAEL}	HQ_{LOAEL}
Shrew	0.0253	0.223	0.62	0.024	353	1,158	0	1.1	1	126	0	16.1	0	15.3	0	0	7.57	0	1.00	86.60	8	80	10.8	1.1
Otter	0.0253	0.082	0.24	0.0006	353	1,158	0	1.1	0	126	0	16.1	1	15.3	0	0	7.57	0	1.00	4.37	8	80	0.5	0.1
Fox	0.0253	0.085	0.14	0.0013	353	1,158	0	1.1	0	126	1	16.1	0	15.3	0	0	7.57	0	1.00	2.72	8	80	0.3	0.03
Vole	0.0253	0.37	0.14	0.002	353	1,158	1	1.1	0	126	0	16.1	0	15.3	0	0	7.57	0	1.00	0.87	8	80	0.1	0.01

Preliminary Exposure and Risk Calculations for CTE Mammals – Zinc
Big River Mine Tailings Site

Receptor	C_{sw}	NIR_w	NIR_d	NIR_{soil}	C_{soil}	C_{sed}	FD_{veg}	C_{veg}	FD_{ew}	C_{ew}	FD_{sm}	C_{sm}	FD_F	C_F	FD_{BI}	C_{BI}	C_{frog}	Fd_{frog}	AUF	ADD	TRV_{NOAEL}	TRV_{LOAEL}	HQ_{NOAEL}	HQ_{LOAEL}

Shrew	0.156	0.223	0.62	0.024	234	1,121	0	15.4	1	182	0	41.8	0	51.8	0	0	37	0	1.00	118.49	160	320	0.7	0.4
Otter	0.156	0.082	0.24	0.0006	234	1,121	0	15.4	0	182	0	41.8	1	51.8	0	0	37	0	1.00	13.12	160	320	0.08	0.04
Fox	0.156	0.085	0.14	0.0013	234	1,121	0	15.4	0	182	1	41.8	0	51.8	0	0	37	0	1.00	6.17	160	320	0.04	0.02
Vole	0.156	0.37	0.14	0.002	234	1,121	1	15.4	0	182	0	41.8	0	51.8	0	0	37	0	1.00	2.68	160	320	0.02	0.01

Exposure and Risk Calculations for Aquatic Carnivorous Birds and Mammals – 95% UCL EPCs
Big River Mine Tailings Site

Receptor	C_{sw}	NIR_w	NIR_d	NIR_{soil}	C_{sed}	FD_F	C_F	FD_{BI}	C_{BI}	Fd_{frog}	C_{frog}	FD_{smf}	C_{smf}	AUF	ADD	TRV NOAEL	TRV LOAEL	HQ_{NOAEL}	HQ_{LOAEL}
Otter-Cd	0.0015	0.082	0.24	0.0006	23.4	0.75	0.3	0.18	0.9	0.07	0.4	0.00	0.2	1.0	0.11	0.0069	0.7	16.487	0.172
Otter-Pb	0.0164	0.082	0.24	0.0006	2,084	0.75	17	0.18	49	0.07	11	0.00	8	1.0	6.61	8	80	0.827	0.083
Otter-Zn	0.0863	0.082	0.24	0.0006	1,226	0.75	57	0.18		0.07		0.00		1.0	11.00	160	320	0.069	0.034

Receptor	C_{sw}	NIR_w	NIR_d	NIR_{sed}	C_{sed}	FD_F	C_F	FD_{BI}	C_{BI}	Fd_{frog}	C_{frog}	FD_{smf}	C_{smf}	AUF	ADD	TRV NOAEL	TRV LOAEL	HQ_{NOAEL}	HQ_{LOAEL}
Kingfisher-Cd	0.0015	0.11	0.5	0.0012	23.4	0.10	0.3	0.13	0.9	0	0.4	0.77	0.2	1.0	0.18	1.45	20.00	0.123	0.009
Kingfisher-Pb	0.0164	0.11	0.5	0.0012	2,084	0.10	17	0.13	49	0	11	0.77	8	1.0	9.62	1.13	11.30	8.511	0.851
Kingfisher-Zn	0.0863	0.11	0.5	0.0012	1,226	0.10	57	0.13		0		0.77		1.0	4.33	14.50	131.00	0.299	0.033

Receptor	C_{sw}	NIR_w	NIR_d	NIR_{soil}	C_{sed}	FD_F	C_F	FD_{BI}	C_{BI}	Fd_{frog}	C_{frog}	FD_{smf}	C_{smf}	AUF	ADD	ADD*AUF	TRV NOAEL	TRV LOAEL	HQ_{NOAEL}	HQ_{LOAEL}
Heron-Cd	0.0015	0.045	0.18	0.0004	23.4	0.89	0.3	0.01	0.9	0.05	0.4	0.05	0.2	0.75	0.06	0.05	1.45	20.00	0.044	0.003
Heron-Pb	0.016	0.045	0.18	0.0004	2084	0.89	17	0.01	49	0.05	11	0.05	8	0.75	3.80	2.85	1.13	11.30	3.362	0.336
Heron-Zn	0.086	0.045	0.18	0.0004	1226	0.89	57	0.01		0.05		0.05		0.75	9.63	7.22	14.50	131.00	0.664	0.073

Exposure and Risk Calculations for Aquatic Carnivorous Birds and Mammals –CTE EPCs
Big River Mine Tailings Site

Receptor	C_{sw}	NIR_w	NIR_d	NIR_{soil}	C_{sed}	FD_F	C_F	FD_{BI}	C_{BI}	Fd_{frog}	C_{frog}	FD_{smf}	C_{smf}	AUF	ADD	TRV NOAEL	TRV LOAEL	HQ_{NOAEL}	HQ_{LOAEL}
Otter-Cd	0.0004	0.082	0.24	0.0006	15.3	0.75	0.3	0.18	0.5	0.07	0.2	0.00	0.1	1.0	0.09	0.0069	0.7	12.779	0.134
Otter-Pb	0.0089	0.082	0.24	0.0006	1,682	0.75	15	0.18	33	0.07	8	0.00	6	1.0	5.27	8	80	0.659	0.066
Otter-Zn	0.063	0.082	0.24	0.0006	872	0.75	52	0.18		0.07		0.00		1.0	9.89	160	320	0.062	0.031

Receptor	C_{sw}	NIR_w	NIR_d	NIR_{soil}	C_{sed}	FD_F	C_F	FD_{BI}	C_{BI}	Fd_{frog}	C_{frog}	FD_{smf}	C_{smf}	AUF	ADD	TRV NOAEL	TRV LOAEL	HQ_{NOAEL}	HQ_{LOAEL}
Kingfisher-Cd	0.0004	0.11	0.5	0.0012	15.3	0.10	0.3	0.14	0.5	0	0.2	0.77	0.1	1.0	0.11	1.45	20.00	0.074	0.005
Kingfisher-Pb	0.0089	0.11	0.5	0.0012	1682	0.10	15	0.14	33	0	8	0.77	6	1.0	7.39	1.13	11.30	6.539	0.654
Kingfisher-Zn	0.063	0.11	0.5	0.0012	872	0.10	52	0.14		0		0.77		1.0	3.65	14.50	131.00	0.252	0.028

Receptor	C_{sw}	NIR_w	NIR_d	NIR_{soil}	C_{sed}	FD_F	C_F	FD_{BI}	C_{BI}	Fd_{frog}	C_{frog}	FD_{smf}	C_{smf}	AUF	ADD	ADD*AUF	TRV NOAEL	TRV LOAEL	HQ_{NOAEL}	HQ_{LOAEL}
Heron-Cd	4E-04	0.045	0.18	0.0004	15.3	0.89	0.3	0.01	0.5	0.05	0.2	0.05	0.1	0.75	0.06	0.04	1.45	20.00	0.040	0.00
Heron-Pb	0.009	0.045	0.18	0.0004	1,682	0.89	15	0.01	33	0.05	8	0.05	6	0.75	3.25	2.44	1.13	11.30	2.874	0.28
Heron-Zn	0.063	0.045	0.18	0.0004	872	0.89	52	0.01		0.05		0.05		0.75	8.68	6.51	14.50	131.00	0.599	0.06

Exposure and Risk Calculations for Piscivorous Birds and Mammals –Big River
Big River Mine Tailings Site

Receptor	C_{sw}	NIR_w	NIR_d	NIR_{soil}	C_{sed}	FD_F	C_F	FD_{BI}	C_{BI}	Fd_{frog}	C_{frog}	FD_{smf}	C_{smf}	AUF	ADD	TRV NOAEL	TRV LOAEL	HQ_{NOAEL}	HQ_{LOAEL}
Otter-Cd	0.0036	0.082	0.24	0.0006	36.4	0.75	0.4	0.18	2.8	0.07	0.4	0.00	0.3	1.0	0.22	0.0069	0.7	32.147	0.336
Otter-Pb	0.023	0.082	0.24	0.0006	3,977	0.75	19	0.18	70	0.07	11	0.00	8.3	1.0	9.02	8	80	1.127	0.113
Otter-Zn	0.0927	0.082	0.24	0.0006	1,867	0.75	52.2	0.18		0.07		0.00		1.0	10.52	160	320	0.066	0.033

Receptor	C_{sw}	NIR_w	NIR_d	NIR_{soil}	C_{sed}	FD_F	C_F	FD_{BI}	C_{BI}	Fd_{frog}	C_{frog}	FD_{smf}	C_{smf}	AUF	ADD	TRV NOAEL	TRV LOAEL	HQ_{NOAEL}	HQ_{LOAEL}
Kingfisher-Cd	0.0036	0.11	0.5	0.0012	36.4	0.10	0.4	0.13	2.8	0	0.4	0.77	0.3	1.0	0.36	1.45	20.00	0.249	0.018
Kingfisher-Pb	0.023	0.11	0.5	0.0012	3,977	0.10	19	0.13	70	0	11	0.77	8.3	1.0	13.47	1.13	11.30	11.921	1.192
Kingfisher-Zn	0.0927	0.11	0.5	0.0012	1,867	0.10	52.2	0.13		0		0.77		1.0	4.86	14.50	131.00	0.335	0.037

Receptor	C_{sw}	NIR_w	NIR_d	NIR_{soil}	C_{sed}	FD_F	C_F	FD_{BI}	C_{BI}	Fd_{frog}	C_{frog}	FD_{smf}	C_{smf}	AUF	ADD	ADD*AUF	TRV NOAEL	TRV LOAEL	HQ_{NOAEL}	HQ_{LOAEL}
Heron-Cd	0.0036	0.045	0.18	0.0004	36.4	0.89	0.4	0.01	2.8	0.05	0.4	0.05	0.3	0.75	0.09	0.07	1.45	20.00	0.062	0.004
Heron-Pb	0.023	0.045	0.18	0.0004	3,977	0.89	19	0.01	70	0.05	11	0.05	8.3	0.75	4.92	3.69	1.13	11.30	4.351	0.435
Heron-Zn	0.0927	0.045	0.18	0.0004	1,867	0.89	52.2	0.01		0.05		0.05		0.75	9.11	6.84	14.50	131.00	0.629	0.070

Exposure and Risk Calculations for Piscivorous Birds and Mammals –Flat River

Big River Mine Tailings Site

Receptor	C_{sw}	NIR_w	NIR_d	NIR_{soil}	C_{sed}	FD_F	C_F	FD_{BI}	C_{BI}	Fd_{frog}	C_{frog}	FD_{smf}	C_{smf}	AUF	ADD	TRV NOAEL	TRV LOAEL	HQ_{NOAEL}	HQ_{LOAEL}
Otter-Cd	0.0005	0.082	0.24	0.0006	13	0.75	0.2	0.18	0.9	0.07	0.4	0.00	0.03	1.0	0.09	0.0069	0.7	12.962	0.136
Otter-Pb	0.0171	0.082	0.24	0.0006	3,137	0.75	43.5	0.18	49	0.07	11	0.00	6.9	1.0	12.02	8	80	1.502	0.150
Otter-Zn	0.21	0.082	0.24	0.0006	5,057	0.75	75.9	0.18		0.07		0.00		1.0	16.71	160	320	0.104	0.052

Receptor	C_{sw}	NIR_w	NIR_d	NIR_{soil}	C_{sed}	FD_F	C_F	FD_{BI}	C_{BI}	Fd_{frog}	C_{frog}	FD_{smf}	C_{smf}	AUF	ADD	TRV NOAEL	TRV LOAEL	HQ_{NOAEL}	HQ_{LOAEL}
Kingfisher-Cd	0.0005	0.11	0.5	0.0012	13	0.10	0.2	0.13	0.9	0	0.4	0.77	0.03	1.0	0.10	1.45	20.00	0.066	0.005
Kingfisher-Pb	0.0171	0.11	0.5	0.0012	3,137	0.10	43.5	0.13	49	0	11	0.77	6.9	1.0	11.78	1.13	11.30	10.427	1.043
Kingfisher-Zn	0.21	0.11	0.5	0.0012	5,057	0.10	75.9	0.13		0		0.77		1.0	9.89	14.50	131.00	0.682	0.075

Receptor	C_{sw}	NIR_w	NIR_d	NIR_{soil}	C_{sed}	FD_F	C_F	FD_{BI}	C_{BI}	Fd_{frog}	C_{frog}	FD_{smf}	C_{smf}	AUF	ADD	ADD*AUF	TRV NOAEL	TRV LOAEL	HQ_{NOAEL}	HQ_{LOAEL}
Heron-Cd	0.0005	0.045	0.18	0.0004	13	0.89	0.2	0.01	0.9	0.05	0.4	0.05	0.03	0.75	0.04	0.03	1.45	20.00	0.029	0.002
Heron-Pb	0.017	0.045	0.18	0.0004	3,137	0.89	43.5	0.01	49	0.05	11	0.05	6.9	0.75	8.46	6.34	1.13	11.30	7.485	0.748
Heron-Zn	0.21	0.045	0.18	0.0004	5,057	0.89	75.9	0.01		0.05		0.05		0.75	14.19	10.64	14.50	131.00	0.979	0.108

Exposure and Risk Calculations for Piscivorous Birds and Mammals –Summer Diets
Big River Mine Tailings Site

Receptor	C_{sw}	NIR_w	NIR_d	NIR_{sed}	C_{sed}	FD_F	C_F	FD_{BI}	C_{BI}	Fd_{frog}	C_{frog}	FD_{smf}	C_{smf}	AUF	ADD	TRV NOAEL	TRV LOAEL	HQ_{NOAEL}	HQ_{LOAEL}
Otter-Cd	0.0015	0.082	0.24	0.0006	23.4	0.50	0.3	0.36	0.9	0.13	0.4	0.00	0.2	1.0	0.14	0.0069	0.7	20.348	0.213
Otter-Pb	0.0164	0.082	0.24	0.0006	2,084	0.50	17	0.36	49	0.13	11	0.00	8	1.0	7.87	8	80	0.984	0.098
Otter-Zn	0.0863	0.082	0.24	0.0006	1,226	0.50	57	0.36		0.13		0.00		1.0	7.58	160	320	0.047	0.024

Receptor	C_{sw}	NIR_w	NIR_d	NIR_{sed}	C_{sed}	FD_F	C_F	FD_{BI}	C_{BI}	Fd_{frog}	C_{frog}	FD_{smf}	C_{smf}	AUF	ADD	TRV NOAEL	TRV LOAEL	HQ_{NOAEL}	HQ_{LOAEL}
Kingfisher-Cd	0.0015	0.11	0.5	0.0012	23.4	0.43	0.3	0.41	0.9	0	0.4	0.16	0.2	1.0	0.29	1.45	20.00	0.202	0.015
Kingfisher-Pb	0.0164	0.11	0.5	0.0012	2,084	0.43	17	0.41	49	0	11	0.16	8	1.0	16.84	1.13	11.30	14.905	1.490
Kingfisher-Zn	0.0863	0.11	0.5	0.0012	1,226	0.43	57	0.41		0		0.16		1.0	13.74	14.50	131.00	0.947	0.105