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U.S. Environmental Protection Agency
Madison County Mines Site
Final OU5 FS Report

B&V Project No. 44775
B&V File E.1
June 12, 2012

Mr. Dan Kellerman
TOPO
U.S. Environmental Protection Agency
901 North 5th Street
Kansas City, Kansas 66101

Subject: Final Feasibility Study Report, Madison County Mines OU5 Site

Dear Mr. Kellerman:

Please find enclosed one copy of the Final Feasibility Study Report for the Madison County Mines Site, Operable Unit 5. We are also enclosing one disk containing the pdf file for the report.

If you have any questions, please call me at 913-458-6605.

Very truly yours,

BLACK & VEATCH Special Projects Corp.

H. David Sanders
Site Manager

Enclosures

30246252

Prepared for:
U.S. Environmental Protection Agency
Region 7
901 North 5th Street
Kansas City, Kansas 66101

Final
Feasibility Study Report

Operable Unit 5

Madison County Mines Site
Madison County, Missouri

June 2012

EPA Contract No.: EP-S7-05-06
EPA Task Order No.: 0103
BVSPC Project No.: 044775

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ENERGY WATER INFORMATION GOVERNMENT

Prepared by:
Black & Veatch Special Projects Corp.
6601 College Blvd.
Overland Park, Kansas 66211

Professional
Environmental Engineers, Inc.

Prepared for:
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Appendix A Risk-Based Preliminary Remediation Goals

List of Acronyms

AC	Acres
AES	Architect and Engineering Services
ATV	All Terrain Vehicle
ARARs	Applicable or Relevant and Appropriate Requirements
ASTDR	U.S. Agency for Toxic Substances and Disease Registry
ASTM	American Society for Testing and Materials
bgs	Below Ground Surface
BHHRA	Baseline Human Health Risk Assessment
BVSPC	Black and Veatch Special Projects Corp
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
CERCLIS	Comprehensive Environmental Response, Compensation, and Liability Information System
CFR	Code of Federal Regulations
COC	Contaminants of Concern
COPC	Contaminant of Potential Concern
CSM	Conceptual Site Model
CTE	Central Tendency Exposure
Cu yd	Cubic Yards
DOT	U. S. Department of Transportation
EPA	US Environmental Protection Agency
ERA	Ecological Risk Assessment
FS	Feasibility Study
Ft	Feet
GCL	Geosynthetic Clay Liner
gpm	Gallons per minute
GPS	Global Positioning System
GRA	General Response Action
HASP	Health and Safety Plan
HDPE	High Density Polyethylene
HELP	Hydraulic Evaluation of Landfill Performance model
HI	Hazard Index
HQ	Hazard Quotient
IC	Institutional Control
ICP	Inductively Coupled Plasma
IEUBK	Integrated Exposure Uptake Biokinetic Model

LDPE	Low Density Polyethylene
LSFR	Little St. Francis River
MCL	Maximum Contaminant Level
mg/kg	milligram per kilogram
mg/L	milligrams per liter
MDNR	Missouri Department of Natural Resources
MLMRA	Mine La Motte Recreation Association
MNA	Monitored Natural Attenuation
MNR	Monitored Natural Recovery
NCP	National Oil & Hazardous Substances Contingency Plan
NPDES	National Pollutant Discharge Elimination System
NPL	National Priority List
OSHA	Occupational Safety and Health Administration
OSWER	Office of Solid Waste and Emergency Response
OU	Operable Unit
O&M	Operation and Maintenance
PAH	Polycyclic Aromatic Hydrocarbon
PCB	Polychlorinated Biphenyls
PEC	Probable Effect Concentration
POTW	Publicly Owned Treatment Works
PRB	Permeable Reactive Barrier
PRG	Preliminary Remediation Goal
ppm	parts per million
PVC	Polyvinyl Chloride
QAPP	Quality Assurance Project Plan
RAO	Remedial Action Objectives
RCRA	Resource Conservation and Recovery Act
RI	Remedial Investigation
RME	Reasonable Maximum Exposure
ROD	Record of Decision
SAP	Sampling and Analysis Plan
SARA	Superfund Amendments and Reauthorization Act
Sq ft	Square Feet
S/S	Solidification/Stabilization
s.u.	Standard Units
SVOC	Semivolatile Organic Compound
TAL	Target Analyte List

TBC	To Be Considered
TEC	Threshold Effects Concentration
TCLP	Toxic Characteristic Leachate Procedure
TRV	Toxicity Reference Value
TSCA	Toxic Substances Control Act
USC	United States Code
ug/dL	micrograms per deciliter
ug/L	micrograms per liter
WQS	Water Quality Standard
XRF	X-ray Florescence
ZVI	Zero Valent Iron

Executive Summary

The U.S. Environmental Protection Agency (EPA) has initiated a remedial investigation and feasibility study (RI/FS) for Madison County Mines Site, Madison County, Missouri. The RI/FS process is the methodology authorized by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980 as amended by the Superfund Amendments and Reauthorization Act (SARA) of 1986 (i.e., the Superfund program) for characterizing the nature and extent of risks posed by uncontrolled hazardous waste sites and for evaluating potential remedial options.

This Feasibility Study (FS) for remediation of Operable Unit (OU) Number 5 at the Madison County Mines Site (Site), Madison County, Missouri has been prepared to assist in the selection of a remedial action for cleanup of the mine wastes at the OU as well as surface water and sediments affected by the mine waste, possible mine waste pile wind-blown contamination, groundwater impacts, and mine works. This FS has been prepared by Black & Veatch Special Projects Corp. (BVSPC) for the U.S. Environmental Protection Agency (EPA) under the Region 7 Architect & Engineering Services (AES) Contract, Task Order 0103.

Site Location, History, and Extent of Contamination

Site Location and History

The Madison County Mines Site, Comprehensive Environmental Response, Compensation, and Liability Information System (CERCLIS) identification number MOD098633415, is located near Fredericktown in southeastern Missouri. The Site is located at the southern end of the Old Lead Belt where heavy metal mining has occurred since the early 1700s. The Site is located about 80 miles south of St. Louis, Missouri, on the southeastern edge of the Ozark Uplift. Past mining operations have left at least 13 identified major mine waste areas, in the form of tailings and chat deposits, from smelting and mineral processing operations in Madison County. The Madison County Mines Site was placed on the National Priorities List (NPL) on September 29, 2003.

The Madison County Mines site was historically defined by six operable units. OU1 is located in northern Madison County and consists of the Mine La Motte Recreation Association (MLMRA) subsite that contains approximately 250 acres of tailings; the Slime Pond, a 100-acre lake that adjoins the MLMRA; the Harmony Lake area, the Copper Mines mine waste; the Old Jack Mine; the Lindsey Mine; the small gage feeder rail right-of-way to the abandoned Black Mountain spur; and all other areas affected by these mining activities. OU1 also includes the Offset Mine. OU2 consists of

the area adjoining and just southeast of the City of Fredericktown, Missouri, and includes the A B, C, D, and E Tailings Areas (historically called the Madison Mine); the metallurgical pond; remnants of an old mill and smelter; headframe and abandoned shafts; a mine decline; a refinery complex; a chat pile; the abandoned Black Mountain spur right-of-way through Fredericktown; and all other areas affected by these mining activities. In 2006, EPA re-designated the former OU3 (Ruth and Park City (Conrad Site)), OU4 (Catherine Site), OU5 (Skaggs Site), and OU6 (Little St. Francis River [LSFR Site]) as follows:

- OU3 – includes all residential properties including public areas in Madison County as well as the entire cities of Fredericktown, Junction City, and Cobalt Village, and the LSFR subsite. Within and around the cities and the LSFR areas, OU3 also includes all streets, road right-of-ways, public drainage ways, possible smelter stack and mine waste pile wind-blown contamination, groundwater, surface water and sediments in Goose Creek and Tollar Branch, and mine works locations and outflows.
- OU4 – includes the entire Conrad subsite with its mine waste as well as the adjoining Ruth mine and mill complex; surface water and sediments affected by the mine waste; eroded materials to the LSFR from the Conrad subsite, road right-of-ways and public drainage ways; possible smelter stack and mine waste pile wind-blown contamination; groundwater impacts; and mine works locations and outflows. The FS for OU4 was prepared as a separate document that was submitted to EPA in May 2011 (BVSPC 2011a). OU4 will not be addressed in this FS.
- OU5 – includes the Catherine Mine with its mine waste, pond, and repository; the Skaggs mine waste; and any areas affected by the overhead tram from the Catherine Mine to the LSFR subsite. OU5 also includes surface water, sediments, road right-of-ways, public drainage ways, and groundwater affected by the Catherine or Skaggs mine waste as well as nearby mine works locations and outflows.
- OU6 – includes all other known and undiscovered mining-related contaminated areas including, but not limited to, the Silver Mines area, nearby groundwater, surface waters and sediments in the unnamed runoffs to the LSFR, road right-of-ways, public drainage ways, and mine works locations and outflows.

The FS for OU4 was prepared as a separate document that was submitted to EPA in May 2011 (BVSPC 2011a). OU4 will not be addressed in this FS. The FS for OUs 1,

2, 3, and 6 will also be prepared as a separate document.

The Catherine subsite (OU5) is located on the west side of Highway H, about 2 miles northwest of Fredericktown. The Catherine subsite presently consists of remnant chat piles, most of which have been excavated and removed, and a 3.5 acre pond that receives runoff and drainage from the chat area. Most of the remnant chat is being covered by approximately 205,000 cubic yards of lead-contaminated soil excavated from residential properties in Fredericktown and clean soil excavated as overburden from a developing gravel quarry about 1,000 feet south of the Catherine property. It is estimated that the area of the chat at the Catherine subsite is approximately 10.9 acres and approximately 44,000 cubic yards of chat are present at the site. Surface runoff from the northern part of the site drains northeastward along perennially flowing Logtown Branch, a tributary to the LSFR. Runoff from the southern part of the site flows through an unnamed tributary to Plum Creek, a tributary to the LSFR.

The Skaggs subsite (OU5) is located near the intersection of Highways H and 67, about 2 miles northwest of Fredericktown. The Skaggs subsite presently consists of remnant chat piles, most of which have been excavated and removed, piles of sawdust that locally cover chat, an active garage/shop area, a small scrap yard, and a few miscellaneous buildings that are not in use. The western chat pile is estimated to be 3.1 acres, the central chat pile is estimated to be 8.7 acres, and the eastern chat pile is estimated to be 0.36 acres. It is estimated that there are approximately 5,000 cubic yards of chat in the western chat pile, 56,500 cubic yards of chat in the central chat pile, and 580 cubic yards of chat in the eastern chat pile. Runoff from the western portion of the site drains southwestward through an ephemeral drainage to the unnamed Plum Creek tributary that flows south from the Catherine subsite, and thence to the LSFR. Runoff from the eastern portion of the site drains eastward through an unnamed intermittent stream that discharges to the LSFR.

Extent of Contamination

Catherine Subsite

Continuous 5-foot core samples through the chat were collected at three locations during the 2006 RI. The chat samples were analyzed for TAL metals. One sample was analyzed for metals using the TCLP test. All three of the chat samples collected from the Catherine subsite contained lead concentrations that exceeded the EPA screening level of 400 mg/kg for residential properties. The highest concentration was 2,100 mg/kg. The chat samples also contained moderate to elevated concentrations of other metals including arsenic, cobalt, copper, iron, nickel, and zinc. Results of the TCLP test

indicated that the chat has the characteristic of metals toxicity for lead.

Shallow groundwater collected from the chat area contained low to moderate concentrations of cobalt, iron, lead, manganese, nickel, and zinc. Groundwater concentrations for arsenic, iron, lead, manganese, and sulfate exceeded the EPA MCLs. In addition, the groundwater concentrations exceeded applicable surface water quality criteria for nickel, chloride, and sulfate.

Surface soil samples were collected from five locations surrounding the Catherine subsite and analyzed for TAL metals. None of the 9 soil samples exceeded the EPA screening level for lead.

In general, WQSs were met for all of the contaminants of potential concern in the surface water of the Catherine pond. Sediment in the Catherine pond exceeded human health benchmarks for arsenic, cobalt, iron, lead, manganese, and nickel and exceeded the ecological probable effects concentration for copper, lead, and nickel. The sediment sample in Logtown Branch slightly exceeded the ecological probable effects concentration for lead.

Skaggs Subsite

Continuous 5-foot core samples through the chat were collected at 2 locations during the 2006 RI. In addition, core samples through the chat in the eastern and western piles were collected using a hand auger. The chat samples were analyzed for TAL metals. One sample was analyzed for metals using the TCLP test. All 6 of the samples collected from the chat contained lead concentrations that exceeded the EPA screening level for residential soils. The highest concentration was 28,400 mg/kg in the sample from the east pile. The chat samples also contained moderate to elevated concentrations of other metals including arsenic, cobalt, copper, iron, nickel, and zinc. Results of the TCLP test indicated that the chat has the characteristic of metals toxicity for lead.

Shallow groundwater collected from the Skaggs area contained low to moderate concentrations of cobalt, iron, lead, manganese, nickel, and zinc. Groundwater concentrations for arsenic, iron, lead, and manganese exceeded EPA MCLs. In addition, the groundwater concentrations exceeded applicable surface water quality criteria for iron, lead, nickel, and zinc.

Surface and subsurface soil samples were collected from five locations surrounding the Skaggs subsite. Lead concentrations in 5 of the 10 surface and subsurface soil samples exceeded the EPA screening level for residential soils.

Four surface soil samples were collected from the floodplain of the unnamed tributary stream that drains south-southwest from the Skaggs area to Plum Creek and one surface soil sample was collected from the floodplain of an unnamed tributary that drains

eastward from the Skaggs area to the LSFR. The samples were collected from 15 to 30 ft from the channel and analyzed for TAL metals. Two of the 5 floodplain soil samples exceeded the residential screening levels for lead.

Surface water and sediment samples were collected in an unnamed tributary that drains south from the Skaggs Mine area toward Plum Creek and one sample was collected from a stock pond immediately southwest of the site. One measurable sample for dissolved lead in the stock pond exceeded the WQS for aquatic life.

The data from the eleven sediment samples that were collected suggest that arsenic, copper, iron, lead, manganese, and nickel are of concern in the Skaggs area sediments. Lead is of most concern because it exceeded the human health value in 9 of 11 samples and the ecological benchmark value in 10 of 11 samples. Nickel exceeded the ecological benchmark value of 49 mg/kg in 9 of the samples. Arsenic was slightly elevated in sample 56300 near the center site. In general, the highest concentrations occur in the drainage east of the site.

Human Health Risk Assessment

A baseline human health risk assessment (BHHRA) was conducted for Madison County Mines site (Syracuse, 2007) to assess the potential risks to humans, both now and in the future, from site-related contaminants present in environmental media, including surface soil, indoor dust, sediment, surface water, groundwater, and fish tissue. The BHHRA assumes that no steps are taken to remediate the environment or to reduce human contact with contaminated environmental media. The original BHHRA addressed OU3, OU4, OU5, and portions of OU6. A supplemental Human Health Risk Assessment (BVSPC, 2011) was conducted for OUs 1 and 2, the Hickory Nut Mine in OU6, and the small streams that flow through Fredericktown. The results of these risk assessments are intended to help inform risk managers and the public about potential human risks attributable to site-related contaminants and to help determine if there is a need for action at the site. The following discussion summarizes the risks at OU5.

Risks to Future Residents

If shallow groundwater from the mine areas were used for drinking by future residents, non-cancer risks would be above a level of concern to both child and adult residents at both of the two wells at the Catherine subsite and at all three of the wells at the Skaggs subsite. This non-cancer risk is attributable to a variety of different metals, including lead, arsenic, cobalt, manganese, and nickel. For cancer risks, excess risks in the range of 3E-04 to 4E-04 occur at one well at the Catherine subsite and two wells at

the Skaggs subsite. In all cases, this risk is attributable to the presence of arsenic. Concentrations of lead in groundwater result in P10 values that exceed EPA's health-based goal of 5% for future child residents at both subsites.

Cancer risks to a hypothetical future resident from the ingestion of both soil and shallow groundwater at the Catherine and Skaggs subsites range from about 2E-05 to 4E-04. These risks are driven mainly by the ingestion of groundwater pathway, with smaller contributions from the ingestion of soil. For both media, risks are entirely attributed to concentrations of arsenic.

Concentrations of lead in groundwater result in P10 values that exceed EPA's health-based goal of 5% for future child residents at both subsites, ranging from 6 percent to 99 percent at the Catherine subsite and 7 percent to 97 percent at the Skaggs subsite.

Risks to Commercial Workers

If hypothetical future workers used shallow groundwater from mine waste areas for drinking in the future, non-cancer risks would be below a level of concern at most wells, with the exception of one well located at the Skaggs subsite. At this well, risks are attributable to arsenic. Concentrations of lead in groundwater result in P10 values that exceed EPA's health-based goal of 5% for children at the Catherine and Skaggs subsites. Excess cancer risks from the concentration of arsenic in groundwater do not exceed EPA's usual level of concern (1E-04).

The risks to commercial workers from exposure to soil combined with the risks from hypothetical future ingestion of groundwater were determined for both the Catherine and Skaggs subsites. Non-cancer risks and cancer risks were below a level of concern at the Catherine subsite, but were above a level of concern at one well located at the Skaggs subsite. The risks were attributable to arsenic.

Exposure of a pregnant commercial worker to the combined intake of lead from soil and groundwater from the Catherine subsite would result in blood lead levels that would be of concern to a fetus, with P10 values ranging from 6 to 31 percent for the dissolved fraction and from 15 to 100 percent for the total fraction. At the Skaggs subsite, the blood lead levels would also be of concern to a fetus, with P10 values ranging from 13 to 33 percent for the dissolved fraction and from 5 to 94 percent for the total fraction.

There were no excess cancer risks to commercial workers associated with the combined intake of surface soil and groundwater.

Risks to All Terrain Vehicle (ATV) Riders

Non-cancer risks are above a level of potential concern to both CTE and RME individuals at both the Catherine and Skaggs subsites. These elevated non-cancer risks

are due almost exclusively to inhalation of manganese in airborne dusts generated during ATV riding. Cancer risks are below EPA's usual level of concern (1E-04) at both subsites. Risks from lead are above EPA's health based goal for lead (P10 < 5%) at both locations, with typical P10 values ranging from 6 percent at the Catherine subsite to 42 percent at the Skaggs subsite. Upper bound P10 estimates range from 39 percent at the Catherine subsite to 92 percent at the Skaggs subsite. These risks are primarily attributed to the soil ingestion and dust inhalation pathways.

Risks to Recreational Visitors

Risks for adult recreational visitors are below a level of concern for cancer and non-cancer effects at both the Catherine and Skaggs subsites. Risks from lead exceed EPA's health based goal (P10 < 5%) at the Catherine and Skaggs subsites. This is attributed mainly to concentrations of lead in soil and sediment.

Non-cancer hazards for child recreational visitors are below a level of concern for a CTE child recreational visitor at both locations, but are above a level of concern (1.6E+00) for a RME recreational visitor at the Skaggs subsite. The non-cancer hazards are attributed to the ingestion of a variety of metals in sediment, soil and/or surface water, including: antimony, manganese, thallium, and vanadium. Cancer risks are below EPA's usual level of concern at both subsites. Risks from lead are above a level of concern at the Catherine subsite. Exposures to lead in soil and sediment at these areas would result in P10 values exceeding EPA's health based goal for lead (P10 < 5%).

Ecological Risk Assessment

EPA prepared a streamlined Ecological Risk Assessment (ERA) for the former Madison County Mines OU3 Site (EPA 2006). A supplemental ERA (BVSPC, 2011) was conducted for OUs 1 and 2, the Hickory Nut Mine in OU6, and the small streams that flow through Fredericktown. The purpose of the ERAs was to describe the likelihood, nature, and severity of adverse effects that environmental chemical contamination may be having on local ecosystems.

The ERAs concluded that there is ample evidence that both the aquatic and the terrestrial environments in the Madison County Mine Site are contaminated by mine wastes, that living organisms in both environments have elevated exposure to mining-related metals, and that the metals cause adverse effects on at least some receptors in each environment.

Specific conclusions regarding the impact of these elevated exposures are summarized below.

Catherine Subsite

Aquatic Ecosystem

- Fish collected from the Catherine Mine Pond had levels of metals in their tissues that indicated little or no risk to piscivores.
- HQ values are greater than 1 for aquatic life exposed to concentrations of lead, manganese and silver in surface water.
- HQ values are greater than 1 for benthic invertebrates exposed to concentrations of antimony, arsenic, barium, cadmium, cobalt, copper, iron, lead, manganese, nickel and thallium in sediment.

Terrestrial Ecosystem

- There is clear evidence of phytotoxicity to terrestrial plants in mine waste areas. Concentrations of chromium, cobalt, lead, manganese, nickel, thallium and vanadium in soil affected by mine waste may have adverse effects on plant germination, growth and/or reproduction.
- HQ values are greater than 1 for protection of terrestrial herbivores due to concentrations of cobalt, lead and nickel in soil affected by mine waste.
- HQ values are greater than 1 for protection of terrestrial vermivores due to concentrations of antimony, copper, lead and vanadium in soil affected by mine waste.
- HQ values are greater than 1 for protection of terrestrial carnivores due to concentrations of lead and nickel in soil affected by mine waste.

Skaggs Subsite

Aquatic Ecosystem

- HQ values are greater than 1 for aquatic life exposed to concentrations of lead, manganese, and silver in surface water.
- HQ values are greater than 1 for benthic invertebrates exposed to concentrations of antimony, arsenic, barium, cobalt, copper, iron, lead, manganese, nickel and thallium in sediment.

Terrestrial Ecosystem

- There is clear evidence of phytotoxicity to terrestrial plants in mine waste areas. Concentrations of chromium, cobalt, copper, lead, manganese,

nickel, thallium, vanadium, and zinc in soil affected by mine waste may have adverse effects on plant germination, growth and/or reproduction.

- HQ values are greater than 1 for protection of terrestrial herbivores due to concentrations of lead and vanadium in soil affected by mine waste.
- HQ values are greater than 1 for protection of terrestrial vermivores due to concentrations of antimony, chromium, copper, lead, manganese and vanadium in soil affected by mine waste.
- HQ values are greater than 1 for protection of terrestrial carnivores due to concentrations of lead in soil affected by mine waste.

Remedial Action Objectives and Action Levels

Based on current site data and evaluations of potential risk, lead was identified as being a contaminant of concern and the primary cause of human health risk from mine wastes and soils at the site is through direct ingestion and dermal contact. Additional metals that present a risk to human health include antimony, arsenic, cobalt, manganese, nickel, thallium, and vanadium. Metals that present a risk to ecological receptors include aluminum, antimony, arsenic, cadmium, cobalt, copper, chromium, lead, manganese, nickel, thallium, vanadium, and zinc.

Remedial Action Objectives (RAOs) were established for the site to control risks to human receptors from exposure to the mine wastes, surface soils, floodplain soils, surface water, sediment, and groundwater. RAOs were also established for the site to control risks to ecological receptors from exposure to mine wastes, floodplain soils, surface water, and sediments.

Preliminary remediation goals were established for various metals in mine wastes, surface soils, floodplain soils, surface water, sediments, and groundwater at the site.

Remedial Alternatives

General response actions and various remedial technologies were evaluated and screened based on effectiveness, implementability, cost, and short and long-term risk. The following remedial alternatives were developed following the screening and evaluation of remedial technologies.

OU5 – Catherine Subsite

Alternative 1 – No Action. Under this alternative, the site would remain in its

present condition, with no actions being taken to control or mitigate contamination or to prevent exposure to contaminants in the environment. This remedial action is required by the NCP.

Alternative 2 – Institutional Controls. Under Alternative 2, RAOs would be addressed solely through the application of a variety of institutional controls that include a combination of land use, deed restrictions, fencing and signs. Groundwater, surface water and sediments in the vicinity of the site would be monitored for at least 5 years.

Alternative 3 – Sediment Excavation, On-Site Disposal, Low Permeable Cap and Monitored Natural Recovery. Under Alternative 3, the Catherine chat area would be graded, contoured, and covered with a low permeable cap. The cap would consist of a 1-foot thick clay liner and a 6-inch vegetative soil layer. The vegetation selected would be compatible with the local climate and require low maintenance. Mine waste and chat would not be excavated and moved as part of this alternative, however, prior to capping contaminated sediment in the Catherine Pond would be excavated and transported to the chat area for placement under the cap. Following removal of contaminated material from the Catherine Pond, bank restoration/stabilization measures would be implemented and damaged areas would be backfilled with topsoil and vegetated or seeded with native species. Access to the capped area would be controlled by fences and signs, and legal controls (deed restrictions) would be placed on the property to prevent uses that could disturb the cap. A cap monitoring program would be designed and implemented to ensure establishment of vegetation and the continued integrity of the facility. Periodic maintenance would be required and groundwater use restrictions would be employed to prevent future consumptive use. Groundwater monitoring would be performed for at least 5 years to determine if the shallow groundwater was migrating from the site. Monitored natural recovery would be implemented at Logtown Branch to determine if the lead concentration in the sediment will achieve the action level without active remediation. The surface water and sediment in Logtown Branch and Catherine Pond would be sampled annually for approximately 10 years to determine whether the monitored natural recovery is successful.

Alternative 4 – Sediment Excavation, On-Site Disposal, Engineered Cap, and Monitored Natural Recovery. Under Alternative 4, the Catherine chat area would be graded, contoured, and covered with an engineered low permeable cap. The cap would consist of a low permeability (less than 1×10^{-7} cm/sec) two foot thick natural clay or amended soil liner or geosynthetic clay liner (GCL) as a substitute; a geomembrane 60

mil HDPE, low density polyethylene (LDPE) or 30 mil polyvinyl chloride (PVC); a drainage layer; a protective soil cover; a vegetative soil layer; and a vegetated cover. The vegetation selected would be compatible with the local climate and require low maintenance. Mine waste and chat would not be excavated and moved as part of this alternative, however, prior to capping contaminated sediment in the Catherine Pond would be excavated and transported to the chat area for placement under the cap. Following removal of contaminated material from the Catherine Pond, bank restoration/stabilization measures would be implemented and damaged areas would be backfilled with topsoil and vegetated or seeded with native species. Access to the capped area would be controlled by fences and signs, and legal controls (deed restrictions) would be placed on the property to prevent uses that could disturb the cap. A cap monitoring program would be designed and implemented to ensure establishment of vegetation and the continued integrity of the facility. Periodic maintenance would be required and groundwater use restrictions would be employed to prevent future consumptive use. Groundwater monitoring would be performed for at least 5 years to determine if the shallow groundwater was migrating from the site. Monitored natural recovery would be implemented at Logtown Branch to determine if the lead concentration in the sediment will achieve the action level without active remediation. The surface water and sediment in Logtown Branch and Catherine Pond would be sampled annually for approximately 10 years to determine whether the monitored natural recovery is successful.

OU5 – Skaggs Subsite

Alternative 1 – No Action. Under this alternative, the site would remain in its present condition, with no actions being taken to control or mitigate contamination or to prevent exposure to contaminants in the environment. This remedial action is required by the NCP.

Alternative 2 – Institutional Controls. Under Alternative 2, RAOs would be addressed solely through the application of a variety of institutional controls that include a combination of land use, deed restrictions, fencing and signs. Groundwater and surface water/sediments in the vicinity of the site would be monitored for 5 years.

Alternative 3 – Permeable Cover and Monitored Natural Recovery. This alternative would create a permeable soil and vegetation cover over the central chat area at the Skaggs subsite to prevent wind and water erosion. Contaminated material in the central chat area would not be excavated but would be covered in place with a permeable

soil and vegetation cover. Chat and contaminated soil in the eastern and western chat areas would be excavated and included under the permeable cover placed on the central chat area. Floodplain soil would also be excavated and disposed at the central chat area. Clean soil would be used to backfill the excavated areas. Sediment in the unnamed pond southwest of the chat area would be excavated and the sediment would also be placed at the central chat area prior to placement of the permeable cover. The covered area would be seeded with native species for added stability. Fencing and signage would be used to prohibit or restrict access to the permeable cover to prevent damage by off-road vehicles. In addition, land use and deed restrictions would be used to prevent future excavation into the cover and groundwater use restrictions would be employed to prevent future consumptive use. Groundwater monitoring would be performed for at least 5 years to determine if the shallow groundwater was migrating from the site. Monitored natural recovery would be implemented at the two unnamed tributaries at the Skaggs subsite to determine if the lead concentration in the sediment will achieve the action level without active remediation. The surface water and sediment would be sampled annually for approximately 10 years to determine whether the monitored natural recovery is successful.

Alternative 4 – Excavation, On-Site Disposal, Low Permeable Cap and Monitored Natural Recovery. This alternative would create a low permeable cap over the central chat area at the Skaggs subsite to reduce precipitation infiltration and to prevent wind and water erosion. Most of the contaminated material in the central chat area would not be excavated but would be covered in place with the low permeable cap. A portion of the central chat area would be consolidated prior to construction of the cap. Chat and contaminated soil in the eastern and western chat areas would be excavated and included under the low permeable cap placed on the central chat area. Floodplain soil would also be excavated and disposed at the central chat area. Clean soil would be used to backfill the excavated areas. Sediment in the unnamed pond southwest of the chat area would be excavated and the sediment would also be placed at the central chat area prior to placement of the low permeable cap. The covered area would be seeded with native species for added stability. Fencing and signage would be used to prohibit or restrict access to the capped area to prevent damage by off-road vehicles. In addition, land use and deed restrictions would be used to prevent future excavation into the cap and groundwater use restrictions would be employed to prevent future consumptive use. Groundwater monitoring would be performed for at least 5 years to determine if the shallow groundwater was migrating from the site. Monitored natural recovery would be implemented at the two unnamed tributaries at the Skaggs subsite to determine if the lead

concentration in the sediment will achieve the action level without active remediation. The surface water and sediment would be sampled annually for approximately 10 years to determine whether the monitored natural recovery is successful.

Analysis of Remedial Alternatives

Detailed evaluations of the remedial alternatives for OU5 were performed using seven of the nine EPA evaluation criteria. The detailed evaluations are summarized in Tables ES-1 and ES-2. The evaluation criteria are:

- Protection of Human Health and the Environment
- Compliance with Applicable or Relevant and Appropriate Requirements (ARARs)
- Long-Term Effectiveness and Performance
- Reduction of Toxicity, Mobility, or Volume
- Short-Term Effectiveness
- Implementability
- Cost

Two of the criteria, state and community acceptance, cannot be adequately addressed until after the FS Report is released for regulatory and public review. These criteria will be assessed in the Record of Decision (ROD) responsiveness summary.

1.0 Introduction

This Feasibility Study (FS) for remediation of Operable Unit (OU) Number 5 at the Madison County Mines Site (Site), Madison County, Missouri has been prepared under the authority of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA). The purpose of this FS is to assist in the selection of a remedial action for cleanup of the mine wastes at OU5 as well as surface water and sediments affected by the mine waste, possible mine waste pile wind-blown contamination, and groundwater impacts. This FS has been prepared by Black & Veatch Special Projects Corp. (BVSPC) for the U.S. Environmental Protection Agency (EPA) under the Region 7 Architect & Engineering Services (AES) Contract, Task Order 0103.

1.1 Purpose and Organization of the Report

The FS process is the procedure used to develop, evaluate, and select a remedial action. The FS report provides documentation for this process. This FS report addresses OU5 at the Madison County Mines Site. The goals of this FS include the following:

- Providing a framework for evaluating and selecting technologies and remedial actions.
- Satisfying environmental review requirements for a remedial action.
- Complying with administrative record requirements for documentation of remedial action selection.

The purpose of the report is to present and evaluate the remedial alternatives that may be used to address the risks posed by the OU5 at the Site. This FS, the remedial investigation (RI), the baseline human health risk assessment (BHHRA), and the ecological risk assessment (ERA) form the basis from which a Proposed Plan will be developed. This FS does not propose preferred remedial actions. In the Proposed Plan, the EPA will indicate which type of cleanup action it prefers for each OU and seek public input on what types of cleanup actions should take place. Once the public has had an opportunity to review and comment on the Proposed Plan, a Record of Decision (ROD) will be issued by the EPA selecting the remedial action.

In addition to this introduction, this report is organized into the following sections:

- Section 2 – Potential ARARs
- Section 3 – Remedial Action Objectives and Action Levels
- Section 4 – General Response Actions and Screening Criteria

- Section 5 – Identification and Screening of Applicable Technologies and Process Options
- Section 6 - Development of Alternatives
- Section 7 - Detailed Evaluation of Remedial Alternatives
- Section 8 - Comparative Analysis of Alternatives
- Section 9 – Bibliography

1.2 Background Information

1.2.1 Madison County Mines Site Location and Description

The Madison County Mines Site, Comprehensive Environmental Response, Compensation, and Liability Information System (CERCLIS) identification number MOD098633415, is located near Fredericktown in southeastern Missouri. The Site is located at the southern end of the Old Lead Belt where heavy metal mining has occurred since the early 1700s. The Site is located about 80 miles south of St. Louis, Missouri, on the southeastern edge of the Ozark Uplift (Figure 1-1). Past mining operations have left at least 13 identified major mine waste areas, in the form of tailings and chat deposits, from smelting and mineral processing operations in Madison County. Chat deposits include sand to gravel sized material resulting from the crushing, grinding, and dry separation of the ore material. Tailings deposits include sand and silt sized material resulting from the wet washing or floatation separation of the ore material. The mine waste contains elevated levels of lead and other heavy metals which pose a threat to human health and the environment. These deposits appear to have contaminated soils, sediments, surface water, and groundwater. These materials may also have been transported by wind and water erosion or relocated to other areas throughout the county. It has been reported that mine waste may have been used on residential property for fill material and private driveways. It has also been reported that mine waste may have been used as aggregate for road construction and placed on public roads around Fredericktown to control snow and ice. The Madison County Mines Site was placed on the National Priorities List (NPL) on September 29, 2003.

The Madison County Mines Site was historically defined by six OUs. OU1 is located in northern Madison County and consists of the Mine La Motte Recreation Association (MLMRA) subsite that contains approximately 250 acres of tailings; the Slime Pond, a 100-acre lake that adjoins the MLMRA; the Harmony Lake area; the Copper Mines mine waste; the Old Jack Mine; the Lindsey Mine; the small gage feeder rail right-of-way to the abandoned Black Mountain spur; and all other areas affected by these mining activities (EPA 2001). OU1 also includes the Offset Mine. OU2 consists of the area adjoining and just southeast of the City of Fredericktown, Missouri, and includes the A B, C, D, and E Tailings Areas (historically called the Madison

Mine); the metallurgical pond; remnants of an old mill and smelter; headframe and abandoned shafts; a mine decline; a refinery complex; a chat pile; the abandoned Black Mountain spur right-of-way through Fredericktown; and all other areas affected by these mining activities (BE&K/TERRANEXT 2000).

In 2006, EPA re-designated the former OU3 (the Ruth and Park City Site, now commonly referred to as the Conrad subsite), OU4 (Catherine subsite), OU5 (Skaggs subsite), and OU6 (Little St. Francis River (LSFR) subsite) as follows:

- OU3 – includes all residential properties including public areas in Madison County as well as the entire cities of Fredericktown, Junction City, and Cobalt Village, and the LSFR subsite. Within and around the cities and the LSFR areas, OU3 also includes all streets, road right-of-ways, public drainage ways, possible smelter stack and mine waste pile wind-blown contamination, groundwater, surface water and sediments in Goose Creek and Tollar Branch, and mine works locations and outflows.
- OU4 – includes the entire Conrad subsite with its mine waste as well as the adjoining Ruth mine and mill complex; surface water and sediments affected by the mine waste; eroded materials to the LSFR from the Conrad subsite, road right-of-ways and public drainage ways; possible smelter stack and mine waste pile wind-blown contamination; groundwater impacts; and mine works locations and outflows.
- OU5 – includes the Catherine Mine with its mine waste, pond, and repository; the Skaggs mine waste; and any areas affected by the overhead tram from the Catherine Mine to the LSFR subsite. OU5 also includes surface water, sediments, road right-of-ways, public drainage ways, and groundwater affected by the Catherine or Skaggs mine waste as well as nearby mine works locations and outflows.
- OU6 – includes all other known and undiscovered mining-related contaminated areas including, but not limited to, the Silver Mines area, nearby groundwater, surface waters and sediments in the unnamed runoffs to the LSFR, road right-of-ways, public drainage ways, and mine works locations and outflows.

All of the areas discussed above are shown on Figure 1-2. The FS for OU4 was prepared as a separate document that was submitted to EPA in May 2011 (BVSPC 2011a). OU4 will not be addressed in this FS. The FS for OUs 1, 2, 3, and 6 will also be prepared as a separate document.

1.2.2 Madison County Mines Operational History and Waste Characteristics

Lead ore was discovered in the area of Mine La Motte (north of Fredericktown) by French explorers around 1715 (Hall, 1939). The area was already known to and likely was being exploited by local natives. Mining commenced in the early 1720s and continued intermittently on a comparatively small basis through the 18th century (Shoemaker, date unknown). Mining and beneficiation activities increased significantly at Mine La Motte and what is now known as the Madison Mine beginning in the mid-1840s and expanded throughout Madison County in the period following the Civil War, when the diamond drill became available as an exploration tool (Anonymous). Mining in Madison County has produced copper, lead, cobalt, nickel, iron, and small amounts of zinc, silver, and tungsten (Tolman, 1933; James, 1949; USGS et al., 1967).

Visual observations during the 2006 RI (BVSPC, 2008) and the October 2010 Supplemental RI (BVSPC, 2011b) indicated that ore crushing and beneficiation activities took place at many sites in Madison County, including the Conrad subsite (OU4), Catherine subsite (OU5), Skaggs subsite (OU5), LSFR subsite (OU3), and the Einstein and Apex Mines (OU6), in addition to Mine La Motte (OU1) and what is now known as the Madison Mine (OU2). Smelting was accomplished at Mine La Motte (ESC, 2000), the Madison Mine (ATSDR, 2005), and for a very brief time, the Einstein Mine (Payne, 1893). Ore grinding and flotation concentration occurred at Mine La Motte, the Madison Mine, and the Ruth (Park City) Mine at the Conrad subsite.

1.3 Catherine and Skaggs Subsites (OU5)

1.3.1 Catherine Subsite (OU5)

The Catherine Mine site is located on the west side of Highway H, about 2 miles northwest of Fredericktown in Section 2, Township 33N, Range 6E (Figure 1-3). The site is about 2,500 feet north of the intersection of Highways H and 67. The Catherine Mine site is accessed from Highway H and is presently owned by Delta Asphalt Company and the Bobby Hufford Trust.

The Catherine subsite presently consists of remnant chat piles, most of which have been excavated and removed, and a 3.5 acre pond that receives runoff and drainage from the chat area. Most of the remnant chat has been covered by lead-contaminated soil excavated from residential properties in Fredericktown and clean soil excavated as overburden from a developing gravel quarry about 1,000 feet south of the Catherine property. Using ArcMap software, it is estimated that the area of the chat at the Catherine subsite is approximately 10.9 acres. Based on the limited amount of borings installed at the Catherine subsite, it is estimated that approximately 44,000 cubic yards of chat were present at the site at the time of the RI. EPA contractors subsequently

transported approximately 205,000 cubic yards of lead impacted soil and chat that was removed from residential property to the Catherine subsite (EPA 2010a). The level of certainty in the estimated volume of chat is low because of the excavated soil that has been placed at the site and additional investigations are necessary to collect information that can be used to provide a more reliable estimate of the volume of chat at the site.

Surface runoff from the northern part of the site drains northeastward along perennially flowing Logtown Branch, a tributary to the LSFR. Runoff from the southern part of the site flows through an unnamed tributary to Plum Creek, a tributary to the LSFR. The extreme upper reaches of the unnamed tributary are ephemeral, but it is a perennial stream along most of its length. From its northern edge, the site is about 5,000 feet from the LSFR. From the southern edge of the chat, the site is about 1.75 miles from Plum Creek and about 2.75 miles from the LSFR.

1.3.1.1 Operational History

Mineralization in the Catherine Mine area was discovered by the Schulte brothers in the early 1890s (Anonymous). The property was first worked by the Catherine Lead Company beginning around 1900 (MBMMI, 1904). These owners sunk a shaft (the Catherine Mine) and constructed a mill to process their ore on the banks of the LSFR. Ore was hauled to the mill via an aerial tramway 9,150 ft long (MBMMI, 1904). The mine was developed at a depth of about 100 feet from which drifts were driven to the east and west (MBMMI, 1904). The east drift encountered a fault and a second shaft was driven on this fault until the ore body was located at a depth of 60 feet below the original (MBMMI, 1904). The drifts encountered soft ground that was extremely expensive to mine and in 1904, the Catherine Company declared bankruptcy (MBMMI, 1904). The property was purchased by the Madison Lead and Land Company in 1904. Little is known of the operations of this company. Plate 2 of James (1949) depicts five shafts in the Catherine Mine area. Shafts No. 1 through 5 extend southward from the Catherine Mine (presumably the No. 1 shaft), roughly following the trend of a small tributary drainage to Plum Creek. Based on aerial photos, an ore beneficiation plant was constructed at the Catherine subsite prior to 1939; the buildings were dismantled prior to 1971 (EPA, 2003). The available aerial photos show that the Catherine chat piles grew in size from 1939 through 1955, but appeared to decrease in volume thereafter. The lifespan and operation of the ore processing facility and the disposition of the chat material are not known, although the county highway department reportedly used material from this former pile on icy roads, and possibly as aggregate in asphalt.

Observations of the Catherine Mine area made during a site visit in October 2004 identified only small remnants of the original chat piles, although chat was observed over a comparatively wide area. The area was being vigorously worked by heavy equipment as part of

the quarry development and this activity hindered observations. Much of the former chat disposal area has been covered with soil, either lead-contaminated soil removed from residential properties in Fredericktown or quarry overburden. Chat was identified extending into a wooded area west of the chat disposal area; this chat is covered with a few inches of forest duff and soil. Chat was also exposed along the southern shore of the settling pond on the north side of the chat piles. It is unknown if the entire pond is underlain by chat. Observations of the surface drainages at that time indicated that both Logtown Branch and the unnamed Plum Creek tributary were free of visible chat.

1.3.1.2 Nature and Extent of Contamination at Catherine Subsite

The nature and extent of contamination in the area of the Catherine subsite is discussed by geographic area: the Catherine chat area, the surrounding land, and surface water and sediment pathways leading from the site.

1.3.1.2.1 Character of the Catherine Chat

The chat contained within the Catherine subsite was investigated by collecting continuous core samples through the chat section at three locations. Sample locations are shown in Figure 1-4. Chat or its reworked equivalent was exposed at the surface at one of the coring sites (Station 28001). Sample locations 28002 and 28003 had been covered by contaminated residential property soil. Contaminated residential property soil was placed at the Catherine subsite following the sampling and the boundary of the residential property soil shown on Figure 1-4 is approximate. The maximum thickness of chat encountered in these holes was four feet. The areal distribution of chat in 2006, to the extent that it could be determined, is shown on Figure 1-4. Thicknesses of the chat throughout the site were not determined.

1.3.1.2.2 Chemistry of the Catherine Chat

Samples of chat were collected from three locations at the Catherine subsite as part of the coring program. The locations from which chat samples were collected are shown on Figure 1-4. Because of ongoing quarry development, soil disposal, and timbering activities at the site during sampling in early 2006, samples were collected only from the margins of the former chat storage area. Consequently, the representativeness of the three samples collected from this site is unknown.

Table 1-1 summarizes results for selected metals in 3 samples of chat; complete analytical results are presented in Table 1-3. As shown in Table 1-11, chat samples have moderate to elevated concentrations of numerous trace metals including arsenic, cobalt, copper, iron, lead, nickel, and zinc.

Results of a TCLP leach test on one sample from the Catherine subsite indicated that the chat exceeded the TCLP criterion for lead (Table 1-2) (the leach extract contained 36.8 mg/L lead compared to the regulatory criterion of 5.0 mg/L).

Analytical results for chat samples from the Catherine subsite were compared to EPA screening levels for industrial and residential soils in Table 1-4. All samples (3 total) exceeded the industrial and residential screening values for lead and the residential screening values for cobalt and manganese.

1.3.1.2.3 Chemistry of Shallow Groundwater

Shallow groundwater was collected from two boring locations (28001 and 28004) at the Catherine subsite as part of the coring program. The sample locations are shown on Figure 1-4. Shallow groundwater collected from the Catherine subsite contained low to moderate concentrations of cobalt (max. 68.1 ug/L dissolved), iron (max. 108 ug/L dissolved), lead (max. 57.6 ug/L dissolved), manganese (max. 4,640 ug/L dissolved), nickel (max. 388 ug/L dissolved), zinc (max. 55.5 ug/L dissolved), sulfate (max. 747 mg/L total), and hardness (max. 1,153 mg/L dissolved) (see Table 1-5 for complete results). Samples were alkaline, with near-neutral pH (7.13 to 7.81) and high specific conductance (1,610 to 1,830 umhos/cm as measured in the field).

The concentrations of numerous constituents in shallow groundwater from the Catherine subsite are compared to primary and secondary MCLs for drinking water and to applicable surface water criteria for the LSFR in Table 1-6. Although detection limits for numerous metals were above water quality criteria, the results indicate that shallow groundwater at the Catherine subsite locally exceeds MCLs for arsenic, iron, lead, manganese, and sulfate. In addition, this water locally exceeds applicable surface water criteria for nickel, chloride, and sulfate and could adversely affect streams in areas where it might gain to surface water.

1.3.1.2.4 Surrounding Area

Soil samples were collected from the five locations surrounding the Catherine subsite shown in Figure 1-4. Analytical results for soil samples from the area surrounding the Catherine chat are shown in Table 1-7. These samples contain low concentrations of most metals. At every location, lead is consistently higher in surface soil samples (0 to 1 inch) than in subsurface soils (1 to 6 inch). Surface soil from Station 28110, located in a wooded area approximately 500 feet east of the Catherine chat piles, had a lead concentration of 82.9 mg/kg. This sample was taken in one of the primary downwind directions and may indicate that windborne dispersal of fines from the chat may have caused low levels of contamination in areas surrounding the former piles. The highest soil lead concentration (84.9 mg/kg) was measured at Station 28130, approximately 150 feet from the former chat piles. The lowest soil lead concentration (20.4

mg/kg) was measured in the subsurface soil sample collected at Station 28120, which is considered to be upwind of the Catherine subsite. Subsurface soils from other locations have lead concentrations ranging from 28.8 to 59.6 mg/kg, with the highest value occurring at Station 28110. Analytical results for soils from the Catherine subsite indicate that cobalt and manganese concentrations exceeded screening levels for residential soils in one sample (Table 1-8).

Figure 1-4 shows the distribution of lead in soils and chat at the Catherine subsite. Samples are lacking from the south side of the site due to soil disturbances associated with quarry development and ongoing disposal of contaminated property soil. Using the available data, the map illustrates that lead concentrations exceeding the EPA screening criteria for residential soils are confined primarily to areas underlain by chat.

1.3.1.2.5 Surface Water and Sediment

In general, WQS were met for all the COPCs, including lead, in the surface water of the Catherine pond. This sample exhibited a relatively high hardness level of 531 mg/L which resulted in slightly less stringent WQS than other surface water bodies in the Madison County area. The analytical reporting limits for cadmium and arsenic were slightly higher than the WQS in this sample, but these differences are not significant.

The sediment sample from the Catherine pond (Station 65100) contained concentrations of arsenic (27.1 mg/kg), cobalt 2,380 mg/kg), iron (25,300 mg/kg), lead 4,440 mg/kg), manganese (3,180 mg/kg), and nickel (2,530 mg/kg) that exceed the human health benchmarks. The metal concentrations in the sample also exceeded the probable effects concentration (PEC) for copper, lead, and nickel. The sediment sample in Logtown Branch (Station 52300) slightly exceeded the PEC concentration for lead (128 mg/kg). This tributary is mostly ephemeral and only flows water during storm events and is not capable of supporting aquatic life. The sediment sampling locations and metal concentrations are presented in Figure 1-5. The complete surface water and sediment analytical results for the Catherine subsite are presented in Tables 1-9 and 1-10.

1.3.2 Skaggs Subsite (OU5)

The Skaggs property is located near the intersection of Highways H and 67, about 2 miles northwest of Fredericktown in Section 2, T33N, R6E (Figure 1-3). The site is about a quarter mile south of the Catherine Mine subsite and possibly was part of the original Catherine Mine subsite.

The Skaggs subsite presently consists of remnant chat piles, most of which have been excavated and removed, piles of sawdust that locally cover chat, an active garage/shop area, a small scrap yard, and a few miscellaneous buildings that are not in use. Runoff from the western

portion of the site drains southwestward through an ephemeral drainage to the unnamed Plum Creek tributary that flows south from the Catherine subsite, and thence to the LSFR. Runoff from the eastern portion of the site drains eastward through an unnamed intermittent stream that discharges to the LSFR. From the western edge of the chat, the site is about 6,000 feet from Plum Creek and about 2.2 miles from the LSFR. From the eastern edge of the chat, the site is about 1.25 miles distant from the LSFR.

1.3.2.1 Operational History

Little is known about the mining and processing operations that occurred at the Skaggs subsite. Plate 2 of James (1949) depicts two shafts in the Skaggs area. Shafts Fed. No. 1 and Fed. No. 2 are depicted as occurring in the east-central part of the property, near the highway intersection and at least one of these is indicated on a 1939 aerial photo (EPA, 2003). Based on aerial photos, an ore processing plant was constructed at the Skaggs subsite prior to 1939; the buildings were dismantled prior to 1955 (EPA, 2003). Chat was disposed of in three areas: a western chat pile extended along a tributary drainage to Plum Creek, a central chat pile was present between the processing facility and Highway H, and an eastern pile occurred east of Highway 67. The available aerial photos show that the Skaggs chat piles were reworked as early as 1955 and began to decrease in volume thereafter. The lifespan and operation of the ore processing facility and the disposition of the chat material upon excavation are not known.

ArcMap software was used to estimate area of the chat piles. The western chat pile is estimated to be 3.1 acres, the central chat pile is estimated to be 8.7 acres, and the eastern chat pile is estimated to be 0.36 acres. Based on the limited amount of borings installed at the Skaggs subsite, it is estimated that there is approximately 5,000 cubic yards of chat in the western chat pile, 56,500 cubic yards of chat in the central chat pile, and 580 cubic yards of chat in the eastern chat pile. The level of certainty in the estimated volume of chat is low and additional investigations are necessary to collect information that can be used to provide a more reliable estimate of the volume of chat at the site.

Observations of the Skaggs subsite in 2004 identified only small remnants of the original chat piles, although chat was observed over a comparatively wide area. Chat was identified extending westward along the base of the sawdust piles into a grassy meadow where it is covered with a few inches of soil. Barren chat was exposed throughout most of the central and northern Skaggs subsite at depths ranging from a few inches to a few feet and the southern margin of the chat extended into a wooded area. The eastern extent of the chat was not determined during investigations for the RI and only a small amount of remnant chat was located in the area of this former pile.

Observations of the surface drainages show that both the western ephemeral drainage and the eastern intermittent drainage contain visible chat in the areas from which chat was excavated;

downstream of the historic piles, the streams are generally free of chat.

1.3.2.2 Nature and Extent of Contamination at the Skaggs Subsite

The nature and extent of contamination in the area of the Skaggs subsite is discussed by geographic area: the Skaggs chat pile areas, the surrounding land, and surface water and sediment pathways leading from the site.

Figure 1-6 shows the distribution of lead in soils and chat at the Skaggs subsite as determined by sampling conducted for this investigation. Samples are lacking from the northeast, south, and northwest sides of the area. Map symbols are color-coded with respect to the residential and industrial screening values for lead. Based on the available data, the map illustrates that soil lead concentrations exceeding the residential screening value are confined primarily to areas immediately adjacent to the Skaggs chat piles. The residential screening value is also exceeded on the floodplain of the unnamed tributary to Plum Creek in the area downstream of the confluence with the ephemeral drainage flowing from the Skaggs west chat pile.

1.3.2.2.1 Skaggs Chat Disposal Areas

The Skaggs subsite comprises three former chat piles: a western pile that extended along a tributary drainage to Plum Creek, a central chat pile that was present between the processing facility and Highway H, and an eastern pile occurred east of Highway 67. These piles have largely been excavated and removed from the site.

Chat comprising the western pile is covered by a large pile of sawdust. The thickness of the chat in this area ranges from 0.5 to about 1.5 feet. The central pile consists of exposed areas of barren to sparsely vegetated chat and areas where chat has been buried beneath vegetated fill in a small valley. Chat was exposed on the surface at one of the coring sites (Station 30004) and was covered by fill soil at two other sites (Stations 30005 and 30010). The maximum thickness of chat encountered in these holes was 7.5 feet. Chat also was found in a wooded area south of the meadow. Remnants of the eastern pile were found in heavily wooded terrain east of Highway 67 where it locally occurs beneath a few inches of soil. Chat forming the eastern pile remnants varies in thickness from a few inches to 1.5 feet. In all cases, chat rests on native soil.

Chat contained within the Skaggs chat disposal areas was investigated by collecting continuous core samples through the chat section at two locations (Stations 30004 and 30005) within the central pile and by hand augering through the chat section at 4 locations (Stations 30001, 30002, 30003, and 30006) in the eastern, western, and central piles. Sample locations are shown in Figure 1-6.

Table 1-1 summarizes results for selected metals in 6 samples of chat from the Skaggs

area; complete analytical results are presented in Table 1-11. As shown in Table 1-1, chat samples have moderate to elevated concentrations of numerous trace metals including arsenic, cobalt, copper, iron, lead, nickel, and zinc. Lead in the Skaggs chat samples varies by more than one order of magnitude. The sample collected from the remnant of the eastern chat pile (Station 30006), which was composed of sandy to silty material that was apparently eroded from the chat, had the highest lead concentration measured in the Skaggs chat samples (28,400 mg/kg).

Results of the TCLP leach test (Table 1-2) shows that the chat sample from the central Skaggs pile exceeded the TCLP criterion for lead (the leach extract contained 105 mg/L lead compared to the regulatory criterion of 5.0 mg/L). Consequently, the Skaggs chat has the characteristic of metals toxicity for lead.

Analytical results for chat samples from the Skaggs chat piles are compared to EPA screening levels established for industrial and residential soils in Table 1-4. All samples (6 total) exceeded the industrial and residential screening values for lead and the residential screening values for cobalt and manganese. Two of the samples (one each from the central and eastern piles) exceeded the non-cancer screening value for arsenic of 22 mg/kg.

Samples of soil were collected from beneath the central Skaggs chat pile in two locations as part of the coring program. Table 1-12 summarizes results for metals in soils from beneath the central Skaggs chat pile; complete analytical results are presented in Table 1-13. As shown in Table 1-12, the two soil samples have substantially different compositions, with lead values of 84 mg/kg and 33,800 mg/kg (Stations 30004 and 30005, respectively). The extremely high lead value at Station 30005 may be attributed at least partly to contamination of the underlying clay in this area. It is unknown if lead contamination occurred directly (e.g., by dumping lead-rich liquid or solid wastes) or indirectly (by fixation of lead leached from the overlying chat or conveyed by surface or groundwater by sorption onto clay or and partly decayed organic detritus).

Shallow groundwater was collected from two locations (Stations 30005 and 30100) within the central Skaggs chat pile as part of the coring program and at a surface seep (Station 30022) down-gradient of the central chat pile. Coring location 30004 did not produce sufficient water for sampling. Consequently, a new location (Station 30100) was sited approximately 30 meters southwest of Station 30004 to collect a sample of groundwater.

Shallow groundwater collected from the Skaggs area contained low to moderate concentrations of cobalt (max. 841 ug/L dissolved), iron (max. 3,230 ug/L dissolved), lead (max. 61.3 ug/L dissolved), manganese (max. 1,680J ug/L dissolved), nickel (max. 469 ug/L dissolved), zinc (max. 488J ug/L dissolved), sulfate (max. 114 mg/L total), and hardness (max. 385 mg/L dissolved) (see Table 1-14 for complete results). Samples were alkaline, with near-neutral pH (7.02 to 7.62) and high specific conductance (605 to 683 umhos/cm as measured in the field).

The concentrations of numerous constituents in shallow groundwater from the Skaggs subsite are compared to primary and secondary MCLs for drinking water and to applicable surface water criteria for the LSFR in Table 1-15. The results indicate that shallow groundwater at the Skaggs subsite locally exceeds MCLs for arsenic, iron, lead, and manganese. In addition, this water locally exceeds applicable surface water criteria for iron, lead, nickel, and zinc and could adversely affect streams in areas where it might gain to surface water.

1.3.2.2.2 Areas Immediately Surrounding the Chat Piles

Soil samples were collected from five locations surrounding the Skaggs subsite in order to determine whether these soils were impacted by the contamination from the three chat disposal areas. Surface (0 to 1 inch depth) and subsurface soils (1 to 6 inches depth) were collected at four of these locations (Stations 30010, 30011, 30013, and 30014) and submitted for laboratory analysis of total metals. At the fifth site (Station 30012), only a surface soil sample was collected and analyzed by XRF. Sample locations are shown in Figure 1-6.

Analytical results for soil samples from the area surrounding the Skaggs subsite are summarized in Table 1-12 (see Table 1-13 for complete results). Surface and subsurface soil samples contain low to moderate concentrations of most metals.

Analytical results for soils from the Skaggs subsite, including surface soils, subsurface soils, and soil from beneath the chat piles, show that metals concentrations are above screening values for residential and industrial soils for some of the metals (Table 1-8). Surface soils from Stations 30011 and 30013 and soil beneath the central chat pile at Station 30005 exceeded numerous screening values, including the industrial values for lead and residential values for cobalt and manganese. The soil sample collected from beneath chat at Station 30004 exceeded the residential values for cobalt. The surface soil sample from Station 30010 exceeded the residential screening value for lead; and the surface and subsurface soils from Station 30014 exceeded the residential manganese values.

1.3.2.2.3 Floodplain Soils Downstream of the Chat Piles

Four surface soil samples (0 to 1 inch) were collected from the floodplain of the unnamed tributary stream that drains south-southwestward from the Skaggs area to Plum Creek (tributary to the LSFR) and one surface soil sample was collected from the floodplain of an unnamed tributary that drains eastward from the Skaggs area to the LSFR. These samples were collected distances of 15 to 30 feet from the channel. Sample locations are shown in Figure 1-6 and complete analytical results are presented in Table 1-13.

Table 1-16 summarizes results for the five floodplain soil samples (the median and range of values is shown in Table 1-12). These samples illustrate that erosion from the Skaggs area has

caused downstream effects on floodplain soil. As shown in Table 1-16, floodplain soils draining from the Skaggs chat pile (Station 57200) have moderate to high concentrations of metals (e.g., lead of 1,410 mg/kg). Transport of these soils has caused the concentrations of cobalt, copper, iron, lead, manganese, nickel, and zinc in the floodplain soils of the unnamed tributary to Plum Creek to spike to higher values from above to below this confluence (e.g., lead of 67.5 to 644 mg/kg at Stations 57500 and 57300). Metals concentrations decrease downstream from this point as the contaminated floodplain soil is diluted by clean soil entering other parts of this drainage. Nevertheless, floodplain soil above the Plum Creek confluence (Station 57700) has concentrations of copper, lead, and zinc that are higher than at Station 57500 by 27 to 49 percent.

Floodplain soils from the Skaggs area are compared to EPA screening levels for residential and industrial soils in Table 1-17. All samples exceeded the residential screening value for manganese. Two of the five floodplain soil samples (from the Skaggs tributary and the unnamed Plum Creek tributary immediately downstream of the Skaggs confluence) also exceeded the residential screening levels for lead; the Skaggs tributary sample also exceeded the industrial lead screening value. Three samples exceeded the residential screening value for cobalt.

1.3.2.2.4 Surface Water and Sediment

Surface water and sediment samples were collected in an unnamed tributary that drains south from the Skaggs subsite toward Plum Creek (Stations 57300 and 57600) and one sample was collected from a pond immediately southwest of the site (Station 65600). Additional sediment samples were also collected from the unnamed tributary at Stations 57200, 57500, and 57700 and one sediment sample (57100) was collected from a dry stream bed near the chat area. The analytical data for the surface water and sediment samples are presented in Tables 1-18 and 1-19. The sampling locations are shown on Figure 1-7.

One sample (Station 65600) for dissolved lead in the pond (16.4 µg/L) exceeded the WQS of 2.61 µg/L for aquatic life; however, this is a manmade stock pond that was not built to support fish. The pond met all State WQS for livestock and wildlife watering.

The unnamed tributary that drains east from the Skaggs subsite under State Highway 67 to the LSFR is primarily ephemeral to intermittent in its upper reaches. Sediment samples were obtained from Stations 56100, 56200, 56250, and 56300 in this tributary to assess potential downstream migration of chemicals from the site.

These data suggest that arsenic, copper, iron, lead, manganese, and nickel are of concern in the Skaggs subsite sediments. Lead is of most concern because it exceeded the human health value in 9 of 11 samples and the ecological benchmark value in 10 of 11 samples. Nickel exceeded the ecological benchmark value of 49 mg/kg in 9 of the samples. Arsenic was slightly elevated at Station 56300 in the eastern flowing tributary. In general, the highest concentrations

occur in the unnamed tributary draining east from the site.

1.4 Baseline Risk Assessment

1.4.1 Human Health Risk Assessment

A BHHRA was conducted for the Madison County Mines Site in 2008 to assess the potential risks to humans, both now and in the future, from site-related contaminants present in environmental media, including mine waste, soil, sediment, surface water, groundwater, and fish tissue (Syracuse Research Corporation, 2007). The 2008 BHHRA addressed potential risks to humans at OU3, OU4, OU5 and a portion of OU6. In addition, a supplemental BHHRA was prepared in 2011 to address the potential risks to humans from site-related contaminants present in environmental media at OU1, OU2, a portion of OU6 and other streams and drainages in the Fredericktown area (BVSPC, 2011). The BHHRA assumes that no steps are taken to remediate the environment or to reduce human contact with contaminated environmental media. The results of the risk assessment are intended to help inform risk managers and the public about potential human risks attributable to site-related contaminants and to help determine if there is a need for action at the Site. A summary of the human health risks at OU5 of the Madison County Site is presented in Table 1-20.

There are four steps in the baseline risk assessment process: data collection and evaluation; exposure assessment; toxicity assessment; and risk characterization. Each of these steps is summarized below, along with how they were conducted for the Madison County Mines Site.

Step 1: Data collection and evaluation involves gathering and analyzing the Site data relevant to the human health evaluation, as well as identifying the contaminants present at the Site that are the focus of the risk assessment process.

Samples were collected to determine the magnitude and extent of metals contamination in mine waste piles, soil, groundwater, surface water, sediment, and fish tissues. Based on the environmental sampling results, the risk assessment identified the following metals as COPCs in one or more environmental media: aluminum, antimony, arsenic, barium, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, nickel, selenium, silver, thallium, vanadium, zinc and polynuclear aromatic hydrocarbons (PAHs). COPCs are chemicals which exist in the environment at concentration levels that might be of potential health concern to humans and which are or might be derived, at least in part, from Site-related sources. While numerous metals were identified as COPCs, lead is the contaminant of primary health concern at the Site. All COPCs were quantitatively evaluated to determine their potential impacts on human health.

Step 2: Exposure assessment is conducted to estimate the magnitude of actual and/or

potential human exposures, the frequency and duration of these exposures, and the pathways by which humans are potentially exposed.

The human populations most likely to be exposed to site-related chemicals include child and adult residents, commercial workers in and around Fredericktown, child and adult recreational visitors that may utilize tailing areas for activities such as all terrain vehicle (ATV) riding, and child and adult recreational visitors that utilize riparian areas for activities such as fishing, swimming, wading, picnicking, and/or hiking.

There is normally a wide range of exposure to site-related contaminants between different members of an exposed population. Thus, the risk assessment estimated the magnitude of exposures or intakes that are "average" or are otherwise near the central portion of the range, and the intakes that are near the upper end of the range (e.g., the 95th percentile). These two exposure estimates are referred to as Central Tendency Exposure (CTE) and Reasonable Maximum Exposure (RME) estimates, respectively. The RME represents the highest the exposure that is reasonably expected to occur at a site, but that is still within the range of possible exposures. For each receptor (i.e., child or adult resident, commercial worker, recreational visitor, etc.), the exposure assessment estimated the intake of contaminants specific to an area within which a receptor is likely to spend most of their time, which is called the exposure unit or exposure area.

Step 3: Toxicity assessment identifies the types of adverse health effects associated with exposure to a contaminant and how the appearance of these adverse health effects is related to the exposure level. Human health risk assessments typically characterize potential non-cancer and cancer health effects separately. They are evaluated separately because for non-cancer health effects it is assumed there is a level or "threshold" which will not result in adverse health effects, while for cancer effects it is typically assumed that exposure to any level will increase the risk or probability of developing cancer (i.e., no threshold exists).

Step 4: Risk characterization integrates the exposure and toxicity assessments to quantify the risks or potential for adverse non-cancer and cancer health effects. This final step also discusses the uncertainties of each step of the risk assessment and their impact on the risk estimates.

For most chemicals, the potential for non-cancer effects is evaluated by comparing the estimated daily intake of the contaminant over a specific time period with a level not associated with adverse health effects for that contaminant. This comparison results in a non-cancer Hazard Quotient (HQ), while a Hazard Index (HI) is calculated when an individual is exposed to more than one chemical or exposure pathway, such as eating and breathing a contaminant. If the HQ or HI for a contaminant(s) is equal to or less than one, it is believed that there is no appreciable risk that non-cancer health effects will occur, including sensitive subpopulations. If an HQ exceeds one, there is a possibility that non-cancer effects may occur and a level of concern has

been exceeded, although the probability of adverse health effects is unknown.

For contaminants that EPA considers potentially carcinogenic in humans, the risk assessment estimates the risk or probability that an individual will develop cancer over a lifetime as a result of exposure to site-related contaminants. For example, the cancer risk is expressed as a probability of 1 in 10,000 in an individual or for every 10,000 people exposed to the contaminant, one extra or excess cancer case may occur beyond what would normally be expected from all other causes of cancer. The cancer risks are summed across all chemicals of concern and all exposure pathways that contribute to exposure of an individual in a given population. In general, EPA considers excess cancer risks that are below 1 in 1,000,000 or 1E-06 to be so small as to be negligible, and risks above 1 in 10,000 or 1E-04 to be sufficiently large that some sort of remediation is desirable. Excess cancer risks that range between 1 in 10,000 and 1 in 1,000,000 are generally considered to be acceptable, although this is evaluated on a case by case basis.

The risks or potential for adverse health effects for lead are evaluated using a different approach than for most other metals. Because lead is widespread in the environment, exposure can occur by many different pathways. Thus, lead risks are based on consideration of total exposure (all pathways) rather than just site-related exposure. In addition, because most studies of lead exposures and resultant health effects in humans have traditionally been described in terms of blood lead level (PbB, expressed in units of micrograms per deciliter or μg/dL), lead exposures and risks are typically assessed using mathematical models.

The risk assessment for the Madison County Mines Site used EPA's Integrated Exposure Uptake Biokinetic (IEUBK) Model for Lead in Children and the Adult Lead Methodology to estimate the distribution of blood lead levels in a population of children and adults, respectively, exposed to lead at the Site. EPA has established a health protection goal that there be no more than a 5% chance that an exposed individual (a child less than 7 years of age or a woman of child-bearing age) will have a blood lead level that exceeds 10 μg/dL. For convenience, this probability is referred to as P10.

1.4.1.1 OU5 - Catherine Subsite

1.4.1.1.1 Risk Estimates for Future Residents

Risks from Groundwater

Risks from ingestion of groundwater were determined for future residents from the ingestion of groundwater if the shallow groundwater from the mine areas were used in the future for drinking water.

If the shallow groundwater at the Catherine Subsite were used for drinking by future residents, non-cancer hazards would be above a level of concern to both child and adult residents

at both of the two wells at the subsite. In most cases, concentrations of metals, and thus estimated hazards, are higher in the total fraction than the dissolved fraction. Using the total fraction of metals in the wells, the non-cancer hazards for child residents range from 1E+00 to 2E+00 for a CTE resident and from 5E+00 to 9E+00 for a RME resident. The non-cancer hazards for adult residents range from 9E-01 to 2E+00 for a CTE resident and from 2E+00 to 3E+00 for a RME resident. This non-cancer hazard is primarily attributable to arsenic, manganese and nickel.

Concentrations of lead in groundwater result in P10 values that exceed EPA's health-based goal of 5% for future child residents at the Catherine subsite, ranging from 6 percent to 99 percent for the total fraction.

The excess cancer risk from the concentration of metals in the dissolved fraction are above EPA's usual level of concern (1E-04) at one well (3E-04) for the RME scenario at the Catherine subsite. This risk is attributable to the presence of arsenic. Excess cancer risks from the concentration of metals in the total fraction could not be determined, because all results were non-detect and the detection limits were too high to be useful in calculating risk estimates. If concentrations in the total fraction are similar or higher than those observed in the dissolved fraction, then excess cancer risks may also be above EPA's usual level of concern from concentrations of arsenic in the total fraction (unfiltered groundwater).

These results indicate that the concentrations of several metals in both filtered and unfiltered fractions of shallow groundwater at the Catherine subsite would pose unacceptable non-cancer hazards and cancer risks if it were used as drinking water by future residents.

Combined Risks from Soil and Groundwater

The risks to future child and adult residents from ingestion and direct contact with soil combined with the risks from the hypothetical future ingestion of shallow groundwater near the Catherine subsite were determined. Non-cancer hazards to residential children from exposure to both soil and groundwater exceed a level of concern for a hypothetical future CTE child resident at both of the 2 wells at the Catherine subsite. Non-cancer hazards to a hypothetical future child resident for the RME scenario range from 7E+00 to 1E+01 for both the dissolved and total fractions, and exceed a level of concern at both of the wells at the Catherine subsite. For the adult residents, the non-cancer hazards from exposure to both soil and groundwater exceed a level of concern for a hypothetical future CTE at one of the wells (well 28004) and exceed a level of concern for a hypothetical RME resident at both wells. Non-cancer hazards to a hypothetical adult resident for the RME scenario range from 2E+00 to 3E+00 for the dissolved fraction and from 2E+00 to 4E+00 for the total fraction. This non-cancer hazard is primarily attributable to arsenic, manganese and nickel.

Concentrations of lead in groundwater result in P10 values that exceed EPA's health-based goal of 5 percent for future child residents at the Catherine subsite, ranging from 7 percent

to 100 percent for the total fraction.

Cancer risks to a hypothetical future resident (child and adult) from the ingestion of both soil and shallow groundwater near the Catherine subsite are below a level of concern for a CTE resident and range up to 3E-04 for a RME resident at one well (well 28001). These risks are driven mainly by the ingestion of groundwater pathway, with smaller contributions from the ingestion of soil. For both media, risks are entirely attributed to concentrations of arsenic.

1.4.1.1.2 Risks to Commercial Workers

Risks from Groundwater

Risks from ingestion of groundwater were determined for hypothetical future workers from the ingestion of groundwater if the shallow groundwater from the Catherine subsite were used in the future for drinking water. If this water were used for drinking in the future, non-cancer hazards would be below a level of concern (HI < 1E+00) at both wells. Concentrations of lead in groundwater result in P10 values that exceed EPA's health-based goal of 5 percent for children at one location for the dissolved fraction (24 percent at well 28001) and in both locations for the total fraction (8 to 100 percent).

Excess cancer risks from the concentration of arsenic in the dissolved fraction are below EPA's usual level of concern (1E-04) at both locations. Excess cancer risks from the concentration of arsenic in the total fraction could not be determined, since all results were non-detect and the detection limits were too high to be reliable.

These results indicate that the concentrations of lead in both filtered and unfiltered fractions of shallow groundwater at the Catherine subsite would pose unacceptable risks if it were used as drinking water in the future.

Combined Risks from Surface Soil and Groundwater

The risks to commercial workers from exposure to soil combined with the risks from hypothetical future ingestion of groundwater from the mine waste areas were also determined. Non-cancer hazards and cancer risks to commercial workers from exposure to both soil and groundwater are below levels of concern (HI>1E+00) and (1E-04) at the Catherine subsite.

Exposure of a pregnant commercial worker to the combined intake of lead from soil and shallow groundwater from the Catherine subsite would result in blood lead levels that would be of concern to a fetus, with P10 values ranging from 6 to 31 percent for the dissolved fraction and from 15 to 100 percent for the total fraction. These risks are primarily attributed to the groundwater ingestion exposure pathway due to elevated levels of lead in both the filtered and unfiltered groundwater.

1.4.1.1.3 ATV Riders at Mine Areas

The risks to ATV riders from ingestion, inhalation, and dermal exposure to soil and mine wastes at and near the Catherine subsite were determined. Non-cancer hazards are above a level of potential concern to both CTE (3E+00) and RME (8E+00) individuals in all exposure areas. These elevated non-cancer hazards are due almost exclusively to inhalation of manganese in airborne dusts generated during ATV riding.

Risks from lead were determined for a typical ATV rider and also a conservative, upper bound risk for ATV riders that may have higher levels of exposure. Risks to typical ATV riders from lead are above EPA's health based goal (P10<5%) at the Catherine subsite with a P10 value of 6 percent. The upper bound P10 estimate for ATV riders with higher levels of exposure is 39 percent. Risks from lead are primarily attributed to the soil ingestion pathway, with roughly 10% of the risk attributed to inhalation of airborne particulates.

Cancer risks are below EPA's usual level of concern (1E-04) at the Catherine subsite. These results indicate that ATV riders that utilize the Catherine subsite for recreation are exposed to levels of manganese in soil that would result in non-cancer hazards and levels of lead that would result in risks that exceed EPA's typical levels of concern.

1.4.1.1.4 Recreational Visitors at Area Streams and Ponds

Risks to a Recreational Adult

Both cancer risks and non-cancer hazards are below a level of concern (non-cancer HI < 1E+00 and cancer risk < 1E-04) at all locations from exposure to sediment, surface water, floodplain soil, and fish tissue.

Risks from lead (P10 values) exceed EPA's health based goal (P10 $\leq$ 5%) at the Catherine subsite with a typical exposure of 9 percent and an upper bound exposure of 50 percent. These risks are attributed to concentrations of lead in sediment. Concentrations of lead in this media would result in an exposure of a pregnant recreational visitor that would be of concern to a fetus.

These results indicate that there is no significant health risk to adult recreational visitors who may have contact with surface water, sediment, and floodplain soil along streams and creeks within and around the Catherine subsite, with the exception of exposure to lead in sediment that may be incidentally ingested.

Risks to a Recreational Child

Total non-cancer hazards at the Catherine subsite are below a level of concern for both a CTE and RME child recreational visitor. The probability of a recreational child having a blood lead level above10 μg/dL is 9 percent which slightly exceeds EPA's health based goal of 5

percent.

The total cancer risks from exposure to surface water, sediment, floodplain soil, and fish tissue are below EPA's typical level of concern (1E-04) to a CTE and a RME recreational visitor, with estimated total risks of 7E-07 and 1E-05, respectively.

These results indicate that there is no significant health risk to child recreational visitors who may have contact with surface water, sediment, and floodplain soil along streams and creeks within and around the Catherine subsite, with the exception of exposure to lead in sediment that may be incidentally ingested.

1.4.1.2 OU5 – Skaggs Subsite

1.4.1.2.1 Risk Estimates for Future Residents

Risks from Groundwater

Risks from ingestion of groundwater were determined for future residents if the shallow groundwater from the Skaggs subsite were used in the future for drinking water.

If the shallow groundwater were used for drinking by future residents, non-cancer hazards would be above a level of concern to both child and adult residents at all three of the wells at the Skaggs subsite. Using the dissolved fraction of metals in the wells, the non-cancer hazards to RME child residents range from 4E+00 to 1E+01. Using the total fraction of metals in the wells, the non-cancer hazard for RME child residents is 4E+00 at one of the wells. For adult residents, the non-cancer hazards associated with the dissolved fraction of metals in the wells range from 7E-01 to 2E+00 for a CTE resident and from 1E+00 to 5E+00 for a RME resident. Using the total fraction of metals in the wells, the non-cancer hazard for RME adult residents is 2E+00 at one of the wells. This non-cancer hazard is primarily attributable to arsenic, cobalt, manganese and nickel.

Concentrations of lead in groundwater result in P10 values that exceed EPA's health-based goal of 5% for future child residents at the Skaggs subsite, ranging from 3 to 27 percent for the dissolved fraction and ranging from 6 percent to 96 percent for the total fraction.

The excess cancer risks from the concentration of metals in the dissolved fraction are above EPA's usual level of concern (1E-04) at two wells at the Skaggs subsite with RME risks at 4E-04 and 3E-04, respectively. This risk is attributable to the presence of arsenic. Excess cancer risks from the concentration of metals in the total fraction could not be determined, because all results were non-detect and the detection limits were too high to be useful in calculating risk estimates. If concentrations in the total fraction are similar or higher than those observed in the dissolved fraction, then excess cancer risks may also be above EPA's usual level of concern from concentrations of arsenic in the total fraction (unfiltered groundwater).

These results indicate that the concentrations of several metals (including lead) in both

filtered and unfiltered fractions of shallow groundwater at the Skaggs subsite would pose unacceptable non-cancer hazards and cancer risks if it were used as drinking water by future residents.

Combined Risks from Soil and Groundwater

The risks to future child and adult residents from ingestion and direct contact with soil combined with the risks from the hypothetical future ingestion of shallow groundwater near the Skaggs subsite were determined. Non-cancer hazards to residential children from exposure to both soil and groundwater exceed a level of concern for a hypothetical future CTE child resident at all 3 wells at the Skaggs subsite. Non-cancer hazards to a hypothetical future child resident for the RME scenario range from 6E+00 to 1E+01 for the dissolved fraction and from 2E+00 to 6E+00 for the total fraction and exceed a level of concern at all of the wells at the Skaggs subsite. For the adult residents, the non-cancer hazards from exposure to both soil and groundwater exceed a level of concern for a hypothetical future RME resident at all 3 wells. Non-cancer hazards to a hypothetical adult resident for the RME scenario range from 2E+00 to 5E+00 for the dissolved fraction and from 2E-01 to 2E+00 for the total fraction. This non-cancer hazard is primarily attributable to arsenic, cobalt, manganese and nickel.

Concentrations of lead in groundwater result in P10 values that exceed EPA's health-based goal of 5 percent for future child residents at the Skaggs subsite, ranging from 6 to 28 percent for the dissolved fraction and ranging from 7 percent to 97 percent for the total fraction.

Cancer risks to a hypothetical future resident (child and adult) from the ingestion of both soil and shallow groundwater near the Skaggs subsite range from 2E-05 to 4E-04 for a RME resident. These risks are driven mainly by the ingestion of groundwater pathway, with smaller contributions from the ingestion of soil. For both media, risks are entirely attributed to concentrations of arsenic.

1.4.1.2.2 Risks to Commercial Workers

Risks from Groundwater

Risks from ingestion of groundwater were determined for hypothetical future workers from the ingestion of groundwater if the shallow groundwater from the Skaggs subsite were used in the future for drinking water. If this water were used for drinking in the future, non-cancer hazards would be above a level of concern (HI > 1E+00) at one of the 3 wells. Non-cancer hazard to a hypothetical commercial worker for the RME scenario was 2E+00 for the dissolved fraction at well 30005. Non-cancer hazards are primarily attributable to arsenic. Concentrations of lead in groundwater result in P10 values that exceed EPA's health-based goal of 5 percent at all locations and ranged from 6 to 26 percent for the dissolved fraction and ranged from 1 to 94 percent for the total fraction.

Excess cancer risks from the concentration of arsenic in the dissolved fraction are below EPA's usual level of concern (1E-04) at all locations, with estimated risks for the RME worker in the range of 7E-05 to 9E-05. Excess cancer risks from the concentration of arsenic in the total fraction could not be determined, since all results were non-detect and the detection limits were too high to be reliable. If concentrations in the total fraction are similar or higher than those observed in the dissolved fraction, then excess cancer risks may also be above EPA's usual level of concern at several locations from concentrations of arsenic in the total fraction (unfiltered groundwater).

These results indicate that the concentrations of arsenic and lead in both filtered and unfiltered fractions of shallow groundwater at the Skaggs subsite would pose unacceptable non-cancer hazards if it were used as drinking water in the future.

Combined Risks from Surface Soil and Groundwater

The risks to commercial workers from exposure to soil combined with the risks from hypothetical future ingestion of groundwater from the mine waste areas were also determined. Non-cancer hazards from exposure to both soil and groundwater are above a level of concern (HI>1E+00) to a RME worker at one well located at the Skaggs subsite (2E+00). The non-cancer hazards are driven by the groundwater ingestion pathway and are attributed to the concentrations of arsenic in the dissolved fraction.

Exposure of a pregnant commercial worker to the combined intake of lead from soil and shallow groundwater from the mine areas would result in blood lead levels that would be of concern to a fetus, with P10 values ranging from 13 to 33 percent for the dissolved fraction and ranging from 5 to 94 percent for the total fraction. These risks are primarily attributed to the groundwater ingestion exposure pathway due to elevated levels of lead in both the dissolved and total fractions of groundwater.

The cancer risks to commercial workers from the future ingestion of arsenic in soil combined with the risks from ingestion of shallow groundwater from the Skaggs subsite were also determined. There were no cancer risks to commercial workers that exceeded EPA's usual level of concern (1E-04).

1.4.1.2.3 ATV Riders at Mine Areas

The risks to ATV riders from ingestion, inhalation, and dermal exposure to soil and mine wastes at and near the Skaggs subsite were determined. Non-cancer hazards are above a level of potential concern to both CTE (4E+00) and RME (1E+01) individuals in all exposure areas. These elevated non-cancer hazards are due almost exclusively to inhalation of manganese in airborne dusts generated during ATV riding.

Risks from lead were determined for a typical ATV rider and also a conservative, upper

bound risk for ATV riders that may have higher levels of exposure. Risks to typical ATV riders from lead are above EPA's health based goal (P10<5%) at the Skaggs subsite with a P10 value of 42 percent. The upper bound P10 estimate for ATV riders with higher levels of exposure is 92 percent. Risks from lead are primarily attributed to the soil ingestion pathway, with roughly 10% of the risk attributed inhalation of airborne particulates.

Cancer risks are below EPA's usual level of concern (1E-04) at the Skaggs subsite. These results indicate that ATV riders that utilize the mine areas for recreation are exposed to levels of manganese in soil that would result in non-cancer hazards and are exposed to lead in soil that exceed EPA's typical levels of concern.

1.4.1.2.4 Recreational Visitors at Area Streams and Ponds

Risks to a Recreational Adult

Both cancer risks and non-cancer hazards are below a level of concern (non-cancer HI < 1E+00 and cancer risk < 1E-04) at all locations from exposure to sediment, surface water, floodplain soil, and fish tissue.

Risks from lead (P10 values) exceed EPA's health based goal (P10 ≤ 5%) at the Skaggs subsite with an upper bound of 18 percent. These risks are attributed to concentrations of lead in sediment. Concentrations of lead in this media would result in an exposure of a pregnant recreational visitor that would be of concern to a fetus.

These results indicate that there is no significant health risk to adult recreational visitors who may have contact with surface water, sediment, and floodplain soil along streams and creeks within and around the Skaggs subsite, with the exception of exposure to lead in sediment that may be incidentally ingested.

Risks to a Recreational Child

Total non-cancer hazards at the Skaggs subsite are below a level of concern for a CTE child recreational visitor and are above a level of concern (1.6E+00) for a RME child recreational visitor. The non-cancer hazards are attributed to the ingestion of a variety of metals in sediment, soil and/or surface water, including: antimony, manganese, thallium, and vanadium. The probability of a recreational child having a blood lead level above10 μg/dL does not exceed EPA's health based goal of 5 percent.

The total cancer risks from exposure to surface water, sediment, floodplain soil, and fish tissue are below EPA's typical level of concern (1E-04) to a CTE and a RME recreational visitor, with estimated total risks of 5E-07 and 8E-06, respectively.

These results indicate that there is little potential risk to the average child recreational visitor at the Skaggs subsite. Recreational children who visit the Skaggs subsite at a high frequency may be exposed to levels of metals that may result in unacceptable levels of non-

cancer hazard.

1.4.2 Ecological Risk Assessment

EPA prepared a streamlined ERA for the former Madison County Mines OU3 Site (EPA 2006). EPA also collected surface water, sediment, and fish tissue samples in 2009 from the Catherine Pond at OU5 (EPA 2010b). In addition, a supplemental ecological risk assessment was prepared in 2011 to address the potential risks to ecological receptors from site-related contaminants present in environmental media at OU1, OU2, a portion of OU6 and other streams and drainages in the Fredericktown area (BVSPC, 2011). The baseline ecological risk assessment assumes that no steps are taken to remediate the environment or to reduce ecological exposures to contaminated environmental media. The results of the risk assessment are intended to help inform risk managers and the public about potential ecological risks attributable to site-related contaminants and to help determine if there is a need for action at the Site. A summary of the ecological risks at OU5 of the Madison County Site is presented in Table 1-20.

The purpose of the ERA was to describe the likelihood, nature, and severity of adverse effects that environmental chemical contamination may be having on local ecosystems. The information is used by EPA to make decisions on whether remedial activities are needed at the Site to protect the environment.

The ecological risks from the contaminants of concern were determined by comparing the contaminant concentration to the appropriate toxicity reference concentration. The ratio of these values results in a hazard quotient (HQ). If the value of the HQ is less than or equal to one (1), it is believed that no unacceptable impacts will occur in the exposed population of receptors. If the value of the HQ exceeds 1, an unacceptable impact may occur, with the predicted likelihood and/or severity of the impacts increasing as the value of the HQ increases.

If an environmental medium is contaminated with more than one chemical, or if a receptor is exposed to more than one contaminated environmental medium, a screening-level estimate of total hazard may be derived by summing the chemical-specific and/or medium-specific HQ values. The result is termed the HI. If the value of the HI is less than or equal to one (1), it is believed that no unacceptable impacts will occur in the exposed population of receptors. If the value of the HI exceeds 1, an unacceptable impact may occur, with the predicted likelihood and/or severity of the impacts increasing as the value of the HI increases.

1.4.2.1 OU5 – Catherine Subsite

<u>Aquatic Ecosystem</u>

- Fish collected from the Catherine Mine Pond had levels of metals in their tissues that indicated little or no risk to piscivores.

- HQ values are greater than 1 for aquatic life exposed to concentrations of lead, manganese and silver in surface water.
- HQ values are greater than 1 for benthic invertebrates exposed to concentrations of antimony, arsenic, barium, cadmium, cobalt, copper, iron, lead, manganese, nickel and thallium in sediment.

Terrestrial Ecosystem

- There is clear evidence of phytotoxicity to terrestrial plants in mine waste areas. Concentrations of chromium, cobalt, lead, manganese, nickel, thallium and vanadium in soil affected by mine waste may have adverse effects on plant germination, growth and/or reproduction.
- HQ values are greater than 1 for protection of terrestrial herbivores due to concentrations of cobalt, lead and nickel in soil affected by mine waste.
- HQ values are greater than 1 for protection of terrestrial vermivores due to concentrations of antimony, copper, lead and vanadium in soil affected by mine waste.
- HQ values are greater than 1 for protection of terrestrial carnivores due to concentrations of lead and nickel in soil affected by mine waste.

1.4.2.2 OU5 – Skaggs Subsite

Aquatic Ecosystem

- HQ values are greater than 1 for aquatic life exposed to concentrations of lead, manganese, and silver in surface water.
- HQ values are greater than 1 for benthic invertebrates exposed to concentrations of antimony, arsenic, barium, cobalt, copper, iron, lead, manganese, nickel and thallium in sediment.

Terrestrial Ecosystem

- There is clear evidence of phytotoxicity to terrestrial plants in mine waste areas. Concentrations of chromium, cobalt, copper, lead, manganese, nickel, thallium, vanadium, and zinc in soil affected by mine waste may have adverse effects on plant germination, growth and/or reproduction.
- HQ values are greater than 1 for protection of terrestrial herbivores due to concentrations of lead and vanadium in soil affected by mine waste.

- HQ values are greater than 1 for protection of terrestrial vermivores due to concentrations of antimony, chromium, copper, lead, manganese and vanadium in soil affected by mine waste.
- HQ values are greater than 1 for protection of terrestrial carnivores due to concentrations of lead in soil affected by mine waste.

2.0 Potential ARARs

Pursuant to Section 121(d) of CERCLA, 42 United States Code (U.S.C.) § 9621(d), remedial actions shall attain a degree of cleanup of hazardous substances, pollutants, and contaminants released into the environment and control of further release which, at a minimum, assures protection of human health and the environment. In addition, remedial actions shall, upon their completion, reach a level or standard of control for such hazardous substances, pollutants, or contaminants which at least attains legally applicable or relevant and appropriate federal standards, requirements, criteria, or limitations, or any promulgated standards, requirements, criteria, or limitations under a state environmental or facility siting law that is more stringent than any federal standard. These are termed as applicable or relevant and appropriate requirements (ARARs). In instances where the remedial actions do not achieve ARARs, the EPA must provide the basis for a waiver. An ARARs waiver is not contemplated for any of the alternatives evaluated in this FS.

Applicable requirements are those standards, requirements, criteria, or limitations promulgated under federal, state, or local law that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site. Relevant and appropriate requirements are those standards, requirements, criteria, or limitations promulgated under federal, state, or local law that address problems or situations similar to those encountered at the CERCLA site; and therefore, are well suited for that site. Although not legally applicable, these requirements may nonetheless be relevant and appropriate for a particular CERCLA site.

EPA Region 7 and the State of Missouri determine which requirements are ARARs by considering the type of remedial actions contemplated, the hazardous substances present, the waste characteristics, the physical characteristics of the site, and other appropriate factors. Only the substantive portions of the requirements need to be followed for on-site actions; CERCLA procedural and administrative requirements require safeguards similar to those provided under other laws. Under Section 121(e) of CERCLA, 42 United States Code (U.S.C.) § 9621(e), and the National Oil and Hazardous Substances Contingency Plan (NCP), 40 Code of Federal Regulations (CFR) § 300.400(e), federal, state, and local permits are not required for the portions of CERCLA cleanups that are conducted entirely onsite, as long as the actions are selected and carried out in compliance with Section 121 of CERCLA.

There are three types of ARARs. The first type includes chemical-specific requirements. These ARARs set limits on concentrations of specific hazardous substances, pollutants, and contaminants in the environment. Examples of these types of ARARs are drinking water standards and ambient water quality criteria. Frequently, the chemical-specific ARARs constitute

a basic level of protectiveness for certain hazardous substances. However, for some media, chemical-specific ARARs are not available.

A second type of ARAR includes location-specific requirements that set restrictions on certain types of activities such as those in wetlands, floodplains, and historic sites. Location specific ARARs generally apply to most alternatives under consideration because they are based on the location of the site.

The third type of ARAR includes action-specific requirements. These are technology-based restrictions that are triggered by the type of remedial action under consideration. Examples of action-specific ARARs are RCRA regulations for waste treatment, storage and disposal. Action-specific ARARs may vary depending on the remedial alternative under consideration. Potential federal and state action-specific ARARs are identified in Section 7 as each alternative is subjected to detailed analysis.

The potential federal and state chemical, location, and action-specific ARARs for the Madison County Mines OU5 subsite, identified by the EPA, respectively, are presented in Tables 2-1 through 2-6. These tables cite the requirements identified, state whether the requirements are applicable or relevant and appropriate, or to be considered and summarize the substantive standards to be met. To be considered (TBC) criteria consist of advisories, criteria, or guidance that were developed by the EPA, other federal agencies, or states that may be useful in developing CERCLA remedies. TBCs do not meet the definition of ARAR, but may be necessary to determine what is protective and are useful when ARARs are not available.

2.1 Potential Chemical-Specific ARARs

The potential chemical-specific ARARs identified for the Madison County Mines Site relate to protection of future residents, commercial workers, recreational visitors, and ecological receptors from exposure to mine wastes, soils, groundwater, surface water and sediments. As discussed above, the principal contaminant is lead from mining related operations.

Federal and Missouri governments have not promulgated standards, requirements, criteria or limitations to control the level of hazardous substances, pollutants, or contaminants in the mine waste and soil. Therefore, the alternatives evaluated for this FS do not have chemical-specific ARARs for contaminated mine wastes and soils. However, the human health risk assessment and other federal and state guidance are available to evaluate each alternative for its ability to achieve a basic level of protectiveness for hazardous substances in mine waste and soil.

Federal and state regulations are available to evaluate each alternative for its ability to achieve a basic level of protectiveness for hazardous substances in groundwater, surface water, and sediments. Tables 2-1 and 2-2 identify the potential federal and state chemical-specific ARARs for the Madison County Mines Site.

2.2 Potential Location-Specific ARARs

Physical characteristics of the site may influence the type and location of remedial responses considered for this FS. Potential federal and state location-specific ARARs, presented in Tables 2-3 and 2-4, relate to historic preservation, fish and wildlife coordination procedures, wetlands protection, floodplains protection, and work in navigable waters.

2.3 Potential Action-Specific ARARs

Action-specific requirements are not established for a specific contaminant, but rather by the activities that are selected to accomplish the remedy. Action-specific ARARs may establish performance levels, actions, or technologies as well as specific levels for discharged or residual contaminants. Tables 2-5 and 2-6 present the potential action-specific ARARs for the Madison County Mines Site. The action-specific ARARs for each alternative will vary depending on the technologies employed. A discussion of when the ARAR would be applicable or relevant and appropriate is included in Tables 2-5 and 2-6.

2.4 Summary of ARARs

Contamination at the Madison County Mines Site poses a potential threat to human health and to ecological receptors. CERCLA requires that any remedial action selected shall attain a degree of cleanup, which at a minimum assures protection of human health and the environment.

The BHHRA, ERA, and the EPA and state regulations and guidance are to be used for the effective evaluations of the remedial alternatives herein. Based on present knowledge, protection of human health and the environment can be provided by attaining the levels of protectiveness described in the BHHRA, ERA, and the EPA and state regulations and guidance documents.

3.0 Remedial Action Objectives and Action Levels

The purpose of this section is to develop remedial action objectives (RAOs) and action levels for the remedial actions at OU5 of the Madison County Mines Site.

3.1 Remedial Action Objectives

This section defines the goals of the remedial action and identifies the RAOs for the mine wastes/source materials and transition surface soils, floodplain soils, surface water and sediments, and shallow groundwater. RAOs specific to all of the above site-specific media are presented separately in this section. RAOs are developed by reviewing site characterization data, BHHRA results, ERA results, ARARs, and other relevant site information.

EPA guidance states that RAOs should be medium-specific goals for protecting human health and the environment and must specify the following:

- Contaminants of concern.
- Exposure routes and receptors.
- Acceptable contaminant level or range of levels for each identified exposure route.

3.1.1 Contaminants of Concern

The BHHRAs prepared by the Syracuse Research Corporation and BVSPC identified the following metals as contaminants of concern (COCs) to human receptors in one or more environmental media: antimony, arsenic, cobalt, lead, manganese, nickel, thallium, and vanadium.

The ERAs prepared by the EPA and BVSPC identified the following metals as COCs to ecological receptors: antimony, arsenic, barium, cadmium, chromium, cobalt, copper, iron, lead, manganese, nickel, thallium, vanadium, and zinc.

3.1.2 Exposure Routes and Receptors

As described in the BHHRAs, the following exposure pathways and receptors were used for quantitative assessments of the risks to human receptors at OU5.

- Future Residents – Ingestion of and direct contact with surface soils combined with hypothetical future ingestion of shallow groundwater near the mine waste. In addition, hypothetical future ingestion of shallow groundwater only near the mine waste was evaluated.
- Commercial Workers - Ingestion of and direct contact with surface soils combined with hypothetical future ingestion of shallow groundwater near the mine waste. In addition, hypothetical future ingestion of shallow groundwater only near the mine

waste was evaluated.

- ATV Riders – Ingestion, inhalation, and dermal exposure to mine wastes and surface soils.
- Adult Recreational Visitor – Ingestion of and dermal exposure to floodplain surface soil, sediment, surface water, and ingestion of locally caught fish.
- Child Recreational Visitor – Ingestion of and dermal exposure to floodplain surface soil, sediment, surface water, and ingestion of locally caught fish.

As described in the ERAs, the following exposure pathways and receptors were used for quantitative assessments of the risks to ecological receptors.

- Aquatic biotas are exposed to contaminants in surface water. Contaminants are transported to surface water via runoff from mine waste source materials and possible groundwater discharge from the shallow aquifer beneath the mine wastes.
- Aquatic biotas are exposed to contaminants in sediment. Contaminants in mine wastes are mobilized during rainfall events and deposited as sediments in nearby surface waters.
- Terrestrial plants and soil invertebrates are exposed to contaminants in mine waste soils via direct contact or metals uptake.
- Terrestrial herbivores are exposed to contaminants through their direct ingestion of soil and consumption of plant tissue.
- Terrestrial vermivores are exposed to contaminants through their direct ingestion of soil and consumption of earthworms.
- Terrestrial carnivores are exposed to contaminants through their direct ingestion of soil and consumption of small mammals or fish.

3.1.3 Media Specific Remedial Action Objectives

The media-specific RAOs are described in this section of the FS.

3.1.3.1 Mine Waste/Source Materials RAOs

The source material RAOs are designed to address the potential risks associated with direct exposure of human and ecological receptors to contaminants in mine wastes/source materials, chat, and in the affected transition zone soils in the vicinity of the source materials. The RAOs for the mine wastes/source materials are as follows:

- Control risks to human receptors from exposure to contaminants (arsenic, cobalt, lead, manganese, and nickel) in mine wastes such that the excess cancer risk is less than 1×10^{-4}, the HQ and HI values are less than 1.0, and there is no more than a 5

percent chance that an exposed individual (a child less than 7 years of age or a woman of child-bearing age) will have a blood lead level that exceeds 10 µg/dL.

- Control risks to ecological receptors from exposure to contaminants (antimony, arsenic, cadmium, chromium, cobalt, lead, manganese, nickel, thallium, vanadium, and zinc) from mine wastes such that HQ or HI values are less than or equal to 1.0.

3.1.3.2 Surface Soils RAOs

The surface soils include the soils beneath the chat piles and soils contaminated by wind-blown chat. The RAOs for the surface soils are as follows:

- Control risks to human receptors from exposure to contaminants (antimony, arsenic, cobalt, lead, manganese, nickel and thallium) in soil such that the excess cancer risk is less than 1×10^{-4}, the HQ and HI values are less than 1.0, and there is no more than a 5 percent chance that an exposed individual (a child less than 7 years of age or a woman of child-bearing age) will have a blood lead level that exceeds 10 µg/dL.
- Control risks to ecological receptors from exposure to contaminants (antimony, arsenic, cadmium, chromium, cobalt, copper, iron, lead, manganese, nickel, thallium, vanadium, and zinc) in soil such that HQ or HI values are less than or equal to 1.0.

3.1.3.3 Floodplain Soils RAOs

The floodplain soils include the soils along the unnamed tributaries at OU5. The floodplain RAOs are designed to address the potential risks associated with direct exposure of human and ecological receptors to contaminants in the floodplain soils.

There were no significant health risks to adult human receptors from contact with floodplain soils at OU5. Total non-cancer hazards to child recreational visitors are above a level of concern for a reasonable maximum exposure visitor at OU5. The unacceptable hazard at OU5 is attributed to the ingestion of manganese and thallium in soil; however, contributions to the total non-cancer hazard are also due to constituents in surface water and sediment. The total cancer risks from exposure to floodplain soils are below EPA's typical level of concern for a child recreational visitor. Based on this information, the RAOs for the floodplain soils are as follows:

- Control risks to human receptors from exposure to lead from floodplain soils such that there is no more than a 5 percent chance that an exposed individual (a child less than 7 years of age or a woman of child-bearing age) will have a blood lead level that exceeds 10 µg/dL.
- Control risks to child receptors from exposure to contaminants (manganese and thallium) in floodplain soils such that the HQ and HI values are less than 1.0.

- Control risk of exposure of terrestrial receptors to contaminants in floodplain soils such that the HQ and HI values are less than 1.0.

3.1.3.4 Surface Water RAOs

The surface water RAOs are designed to address the potential risks associated with direct exposure of human and ecological receptors to contaminants in surface streams and their tributaries resulting from surface runoff of source materials. There were no significant health risks to adult human receptors from contact with surface water at OU5.

Total non-cancer hazards to child recreational visitors at OU5 are above a level of concern for a reasonable maximum exposure visitor. The risks at OU5 are attributed to the ingestion of antimony and vanadium in surface water; however, contributions to the total non-cancer hazard are also due to constituents in soil and sediment. The probability of a recreational child having a blood lead level above 10 µg/dl exceeds EPA's health based goal of 5 percent at OU5, although the risk is primarily due to ingestion of sediment. Based on this information, the RAOs for surface water are as follows:

- Control risks to adult and child receptors from exposure to contaminants (antimony, manganese and vanadium) in surface water such that the HQ and HI values are less than 1.0.
- Control exposure of aquatic biota to contaminants (aluminum, cobalt, copper, lead, and nickel) released and transported from the mine wastes where federal surface water quality criteria are exceeded.

3.1.3.5 Sediment RAOs

The sediment RAOs are designed to address the potential risks associated with direct exposure of human and ecological receptors to contaminants in sediments from the transport of source materials to surface streams and their tributaries.

There were no significant non-cancer hazards or cancer risks to adult human receptors from contact with sediments at OU5. The probability of the fetus of an adult recreational visitor having a blood lead level above 10 µg/dl exceeds EPA's health based goal of 5 percent at OU5.

Total non-cancer hazards to child recreational visitors are above a level of concern for a reasonable maximum exposure visitor at OU5. The risks are attributable the ingestion of manganese in sediment at OU5; however contributions to the total non-cancer hazard are also due to constituents in soil and surface water. The total cancer risks from exposure to sediments are below EPA's typical level of concern for a child recreational visitor. The probability of a recreational child having a blood lead level above 10 µg/dl exceeds EPA's health based goal of 5 percent at OU5. These risks are attributable to ingestion of lead in sediment and soil. Based on

this information, the RAOs for sediment are as follows:

- Control risks to adult and child receptors from exposure to contaminants (manganese) in sediments such that the HQ and HI values are less than 1.0.
- Control risks to human receptors from exposure to lead from sediments such that there is no more than a 5 percent chance that an exposed individual (a child less than 7 years of age or a woman of child-bearing age) will have a blood lead level that exceeds 10 µg/dL.
- Control risk of exposure of aquatic biota to contaminants (antimony, arsenic, barium, cadmium, chromium, cobalt, copper, iron, lead, manganese, nickel, thallium and zinc) in sediments by controlling the transport of mine waste from source areas to streams along the tailings and chat piles.

3.1.3.6 Shallow Groundwater RAOs

The groundwater RAOs are designed to address the potential risks associated with direct exposure of human receptors to contaminants from the ingestion of shallow groundwater at OU5. In addition, the groundwater RAOs are designed to address the exposure of aquatic biota to contaminants in streams that receive discharges from the source areas. The RAOs for the shallow groundwater are as follows:

- Control risks to human receptors from ingestion of contaminants (arsenic, cobalt, lead, and manganese) in groundwater such that the excess cancer risk is less than 1×10^{-4}, the HQ and HI values are less than 1.0, and there is no more than a 5 percent chance that an exposed individual (a child less than 7 years of age or a woman of child-bearing age) will have a blood lead level that exceeds 10 µg/dL.
- Prevent exposure of aquatic biota to contaminants in releases of shallow groundwater from the source areas where surface water quality criteria are exceeded.

3.2 Development of Preliminary Remediation Goals

The 2008 and 2011 BHHRAs indicated that the principal threats to human health at OUs 1, 2, 3, 5, and 6 were to future residents from the ingestion of shallow groundwater and the combined risk from ingestion and direct contact with soil and ingestion of shallow groundwater; risks to hypothetical future workers from ingestion of groundwater and the combined risks from ingestion of surface soil and groundwater; risks to ATV riders from ingestion, inhalation, and dermal exposure to soil and mine wastes; and risks to recreational visitors from exposures to soil, surface water, sediments, and fish.

BVSPC prepared a memorandum that developed preliminary remediation goals (PRGs) for OUs 1, 2, 3, 5 and 6 to address both human health risks and ecological risks. This memorandum is presented in Appendix A. The memorandum addresses human health risks and presents PRGs for residential soil, tailings, sediment/soils, and groundwater. The memorandum also addresses ecological risks and presents PRGs for soil, sediment and surface water.

The site specific PRGs developed to protect human health from ingestion of shallow groundwater include the federal MCLs for arsenic and lead. In addition, PRGs were developed for cobalt and manganese to protect human health from non-cancer hazards. The PRGs for groundwater at OU5 are presented in Table 3-1 at the end of this section.

The final 2008 BHHRA determined that the PRG that would protect residents from ingestion and contact with lead in soils was 400 ppm using an XRF instrument or 466 ppm using the inductively coupled plasma (ICP) analytical method. These PRGs were presented in the FS for OU4 (the Conrad subsite) and were also adopted for OU5. The human health and ecological PRGs for the remaining COCs in surface soils were developed in the BVSPC memorandum and are summarized in Table 3-2.

The FS for OU4 (the Conrad subsite) established the PRG for lead concentrations in mine waste/tailings at 1,461 ppm using the ICP analytical method and 1,370 ppm using an XRF instrument. For consistency, these PRGs for lead were also adopted for OU5. The PRGs for arsenic, cobalt, manganese and nickel are based on non-cancer effects as established in the BVSPC memorandum and are summarized in Table 3-3.

The BVSPC memorandum established PRGs for the protection of human health and ecological receptors exposed to floodplain soils. The floodplain soils include the soils along the unnamed tributaries at OU5. The floodplain RAOs are designed to address the potential risks associated with direct exposure of human and ecological receptors to contaminants in the floodplain soils. The PRGs for floodplain soils are presented in Table 3-4.

The BHHRA indicated that concentrations of antimony, manganese, and vanadium were associated with unacceptable non-cancer hazards to recreational visitors at OU5. The RI Report and the ERA also indicated that aluminum, cobalt, copper, lead, nickel, and silver concentrations were above the acute/chronic ambient water quality criteria in the water column in the various creeks and tributaries of the LSFR watershed located downstream from the mine waste areas of OUs 1, 2, 3, 5, and 6 at the Madison County Mine Site. PRGs for surface water were established either as concentrations protective of human health or as the site specific water quality criteria for these metals based on the available average water hardness data for the LSRF watershed in Madison County (231 mg/L $CaCO_3$). These PRGs for surface water are presented in Table 3-5.

The BVSPC memorandum established the PRGs for protection of human health and ecological receptors exposed to the sediments of the creeks and tributaries of the LSFR watershed located downstream from mine waste areas of OUs 1, 2, 3, 5, and 6 at the Madison

County Mine Site. The human health PRGs are protective of exposures through ingestion and dermal contact with sediments. The ecological PRGs are based on the PEC or equivalent value from the available literature. The PRGs for sediment are presented in Table 3-6.

Table 3-1 Preliminary Remediation Goals for Groundwater Operable Unit 5

COC	*MCL*
Arsenic	10*
Cobalt	4.7**
Lead	15*
Manganese	375**
All concentrations are in µg/L. * Primary MCL. ** Non-Cancer Risk.	

Table 3-2 Preliminary Remediation Goals for Surface Soils Operable Unit 5

COC	Human Health PRG	Ecological PRG
Antimony	31	0.27 – 5.67
Arsenic	23	18 – 180
Cadmium	--	7.31 – 95
Chromium	--	58
Cobalt	23	13 – 130
Copper	1564	70 – 700
Iron	27375	27700
Lead	400*; 466**	219 - 400**
Manganese	1877	220 – 2200
Mercury	--	0.3 – 3
Nickel	1564	38 – 380
Selenium	--	0.63 – 1.26
Silver	--	4.2 – 42
Thallium	5	1 – 10
Vanadium	--	86.4
Zinc	--	120 – 1200
PAHs	--	1.1
All concentrations are in mg/kg *Bulk – XRF Readings ** Fine ICP Methods		

Table 3-3 Preliminary Remediation Goals for Mine Wastes/Tailings Operable Unit 5

COC	Bulk-XRF Readings	Fine – ICP Method
Arsenic	--	113
Cobalt	--	47
Lead	1,370	1,461
Manganese	--	446
Nickel	--	771
All concentrations are in mg/kg		

Table 3-4 Preliminary Remediation Goals for Floodplain Soils Operable Unit 5

COC	Human Health PRG	Ecological PRG
Antimony	--	0.27 – 5.67
Arsenic	--	18 – 180
Cadmium	--	7.31 – 95
Chromium	--	58
Cobalt	319	13 – 130
Copper	--	70 – 700
Iron	--	27700
Lead	1250**	219 - 400**
Manganese	49681	220 – 2200
Mercury	--	0.3 – 3
Nickel	--	38 – 380
Selenium	--	0.63 – 1.26
Silver	--	4.2 – 42
Thallium	75	1 – 10
Vanadium	--	86.4
Zinc	--	120 – 1200
PAHs	--	1.1
All concentrations are in mg/kg **Fine ICP Method		

Table 3-5 Preliminary Remediation Goals for Surface Water Operable Unit 5

COC	*Human Health PRG* [1]	*Site-Specific Water Quality Standard* [2]	
		Acute	*Chronic*
Aluminum	--	750	87
Antimony	127	--	--
Cobalt	198	24	24
Copper	--	30	18
Lead	--	158	6.2
Manganese	3015	--	--
Nickel	--	951	106
Silver	--	13.6	--
Vanadium	87	--	--

All concentrations in µg/L.
[1] – Human Health PRG based on recreational exposure scenario
[2] – Site-Specific Water Quality Standards (Missouri Code of State Regulations, Title 10, Division 20, Chapter 7) are in dissolved form and based on a measured water hardness of 231 mg/L $CaCO_3$.

Table 3-6 Preliminary Remediation Goals for Sediments Operable Unit 5

COC	*Human Health PRG*	*Ecological Benchmark**
		PEC or Equivalent
Antimony	--	2
Arsenic	--	33
Barium	--	554 **
Beryllium	--	1.25 **
Cadmium	--	4.98
Chromium	--	111
Cobalt	319	137 **
Copper	--	149
Iron	--	28300 **
Lead	1250	150
Manganese	49681	460
Mercury	--	1.1
Nickel	--	167 **
Selenium	--	2
Silver	--	4 **
Thallium	75	1
Zinc	--	5980 **

All concentrations in mg/kg.
*PEC – Probable Effect Concentration. (McDonald, 2000)
** Mean background

4.0 General Response Actions and Screening Criteria

4.1 Delineation of Areas and Volumes of Contaminated Media

4.1.1 Catherine Subsite

This subsection delineates the areas and volumes of contaminated media at the Catherine subsite. Contaminated media include chat material, solids and subsurface soils below the chat, shallow groundwater within and beneath the chat pile; surface soils and tailings that have eroded from the chat piles, the pond north of the chat pile, and sediments along Logtown Branch. The estimated areas and volumes of contaminated media are based on the information obtained during the 2008 RI and are considered to be preliminary estimates.

The area of the chat is estimated to be approximately 10.9 acres. Based on the limited number of borings installed at the Catherine subsite, it is estimated that approximately 44,000 cubic yards of chat are present at the subsite. In addition, approximately 205,000 cubic yards of contaminated soil from the remediation of residential yards in Madison County were disposed at the Catherine subsite.

The area and volume of contaminated shallow groundwater within and beneath the Catherine subsite is unknown. Groundwater was found in 2 of the 3 borings installed in the Catherine chat pile. (1 ft to 4 ft at boring 28001 and 17 ft to 21 ft at boring 28004).

The Catherine Pond is approximately 3.5 acres. The sediment in the pond contains multiple metals that exceed the action levels including cobalt, copper, lead, manganese, and nickel. Assuming that the sediment is contaminated to a depth of 0.5 ft., approximately 2,800 cubic yards of sediment in the Catherine Pond would require remediation.

The length of Logtown Branch that contains lead concentrations above the action levels is not known. A sediment sample collected approximately 500 ft. east of Highway H contained a lead concentration of 190 mg/kg which is above the action level of 150 mg/kg. The cadmium concentration is this sample was below the action level. Assuming that sediments in approximately 500 feet of Logtown Branch contain lead concentrations above the action level, the width of the stream bed is 8 ft. and the sediment would be remediated to a depth of 0.66 ft., approximately 98 cubic yards of sediment would require remediation.

4.1.2 Skaggs Subsite

This subsection delineates the areas and volumes of contaminated media at the Skaggs subsite. Contaminated media include chat material, solids and subsurface soils below the chat, shallow groundwater within and beneath the chat pile; surface soils and tailings that have eroded from the chat piles, floodplain soil and sediments along the unnamed tributary flowing south-

southwest from the Skaggs area to Plum Creek, and floodplain soil and sediments along the unnamed tributary flowing east from the Skaggs area. The estimated areas and volumes of contaminated media are based on the information obtained during the 2008 RI and are considered to be preliminary estimates.

Based upon the limited number of borings installed in the Skaggs subsite, the western chat pile is estimated to be 3.1 acres and contain approximately 5,000 cubic yards of chat; the central chat pile is estimated to be 8.7 acres and contain approximately 56,500 cubic yards of chat; and the eastern chat pile is estimated to be 0.36 acres and contain 580 cubic yards of chat.

The area and volume of contaminated shallow groundwater within and beneath the Skaggs subsite is unknown. Groundwater was found in 2 of the 5 borings installed in the Skaggs chat pile (0 to 4.6 ft at boring 30004 and 10 ft to 14 ft at boring 30005).

The length of the unnamed tributary from the Skaggs subsite to Plum Creek is approximately 8,300 feet. Lead concentrations in the sediment exceeded action levels in 4 of the 5 sediment samples collected from the unnamed tributary. The volume of contaminated sediment in the unnamed tributary is unknown, but the limited data indicate much of the stream may contain sediment with lead concentrations above the action level of 150 mg/kg. For the purpose of developing remedial alternatives for the Skaggs subsite, it is estimated that sediments in 5,000 ft of the unnamed tributary may contain lead concentrations above the action level. It is assumed that the average width of the unnamed tributary is approximately 8 feet and the average depth of the contaminated sediment is 8 inches. Using these assumptions, approximately 1,760 cubic yards of sediment contain metal concentrations above the action levels.

Lead concentrations exceeded the action level in all 4 of the sediment samples collected from the unnamed tributary east of the Skaggs subsite. The volume of contaminated sediment in the unnamed tributary is unknown, but the limited data indicate a portion of the stream contains sediment with lead concentrations above the action level. For the purpose of developing remedial alternatives for the Skaggs subsite, it is estimated that sediments in 2,000 ft of the unnamed tributary may contain lead concentrations above the action level. It is assumed that the average width of the unnamed tributary is approximately 8 feet and the average depth of the contaminated sediment is 8 inches. Using these assumptions, approximately 390 cubic yards of sediment contain metal concentrations above the action levels.

The length of the unnamed tributary south-southwest of the Skaggs subsite with floodplain soils above the action levels is unknown. Data indicate that samples collected from the floodplain at Stations 57200 and 57300 contain lead concentrations above the action level of 219 mg/kg. For the purpose of developing remedial alternatives for the floodplain soil, it is assumed that 1,000 ft of the unnamed tributary have floodplain soils with lead concentrations above the action level. It is assumed that an average of ten feet on each side of the stream contains soil above the action level and that the soil is contaminated to a depth of 0.66 ft. Using

these assumptions, approximately 488 cubic yards of floodplain soil along the unnamed tributary would be remediated.

4.2 General Response Actions

General Response Actions (GRA) describe gross categories of actions that can be employed to meet the RAOs. GRAs are intended to mitigate risks by reducing or eliminating exposure to contaminants, controlling their transport, or treating or remediating wastes to the point the wastes no longer present unacceptable risks. The GRAs that will address risks to human and ecological receptors identified in the RI are summarized below and include:

- No action
- Institutional controls
- Monitored natural attenuation/monitored natural recovery
- Containment
- *In situ* treatment
- Collection and treatment
- Removal and disposal
- Removal and treatment.

4.2.1 No Action

"No Action" is both a GRA and a separate alternative. The NCP at 40 CFR §300.430(e)(6) requires that the "No Action" or "No Further Action" alternative must be considered at every site. The "no action" alternative does not include any treatment, engineering controls, or institutional controls. Monitoring may be a condition included within a "no action" alternative in cases where the baseline risk is acceptable but the site still contains known contaminants (for example buried contaminants) that do not result in exposure to human or ecological receptors. In practice, where residual risks have been identified, the "no action" alternative serves as the basis for comparison for all other alternatives and actions.

4.2.2 Institutional Controls

Institutional controls (IC) are non-engineering measures or actions, such as legal controls, that help minimize the potential exposure of humans or ecological receptors to hazardous materials by usually restricting land or resource use. The NCP emphasizes that ICs are meant to supplement engineering controls and that ICs will rarely be the sole remedy at a site. Examples of ICs are public health education, legal restrictions, and access restrictions. Types of legal

restrictions include land deed restrictions, land use restrictions, ground water use restrictions, surface water use restrictions, and fish advisories.

4.2.3 Monitored Natural Recovery/Monitored Natural Attenuation

Monitored Natural Recovery (MNR) and Monitored Natural Attenuation (MNA) are remedies that use ongoing, naturally occurring processes to contain, destroy, or reduce the bioavailability or toxicity of contaminants without active intervention. MNR applies to contaminated sediment and relies on slightly different natural mechanisms to attenuate contaminants than MNA, which applies to contaminated groundwater and soil. In both cases, however, natural processes include physical, biological, and chemical mechanisms that act together to reduce the risk of contaminants to human or ecological receptors. Both cases would also include monitoring to measure and document risk reduction that occurred over time. An important aspect to MNR and MNA are the establishment of a time frame over which attenuation is expected to reduce risk to acceptable levels. Consequently, MNR and MNA are not the same as monitoring that could occur under a "no action" alternative. Where a risk to human or ecological receptors has been identified, MNR and MNA are used either alone or with other action technologies to assess potential remediation success and/or reduction in exposure.

4.2.4 Containment

Containment is an approach where contaminated soil, sediment, or waste materials are contained either by covering them, instituting erosion control measures, or solidifying and stabilizing them. Caps and covers fall into two general categories that include those that permit water and air infiltration (permeable covers) and those that limit or exclude air and water infiltration (impermeable or low permeability caps). Capping materials may include soil, gravel or rock, clay, vegetation, synthetic materials, water, or a combination of these. Caps reduce contaminant mobility and the likelihood that terrestrial and aquatic organisms will interact with contaminants. Capping is generally appropriate when the contaminant source has been contained, the costs or environmental effects of moving or treating contaminated materials cannot be justified, and hydraulic conditions will not disturb the cap. Subaerial caps are placed in accordance with engineering designs while those used to address instream sediment can be placed or allowed to form through natural or induced sedimentation to develop a barrier between contaminants and ecological receptors.

Drainage and erosion control measures typically include precipitation runoff controls (storm water management), slope stabilization through surface contouring, slope stabilization through other physical means, streambed and bank stabilization, and establishing vegetation to reduce wind erosion and sheet wash, and promote evapotranspiration. Precipitation runoff controls include features such as run-on diversion ditches and hydraulic controls such as cross-

vanes and retention ponds that are used to direct precipitation runoff or reduce the velocity of surface flows. Physical slope stabilization employs a variety of techniques to hold up unstable slopes (e.g., retention walls, sheet piling, or cribbing) or to cover them with stable materials such as rip rap or shotcrete.

Solidification/stabilization (S/S) involves physically binding or enclosing contaminants into a stabilized mass and reducing contaminant mobility by inducing chemical reactions between the stabilizing agent and the contaminants. Technologies related to S/S act to reduce the physical mobility of contaminants and typically create a monolithic mass that remains on-site. The pozzolan/portland cement process is a common S/S technology using fly ash, kiln dust (or similar materials) and portland cement that reacts with water to form a cement-like matrix that helps to precipitate and immobilize some heavy metals.

4.2.5 In Situ Treatment

In situ treatment is an approach that involves the chemical, biological, or physical treatment of contaminated solid waste, sediment, or groundwater in place. Treatment destroys or converts contaminants to less toxic forms. In solid matrices (e.g., tailings or sediment), treatment is typically accomplished by injecting chemicals into the subsurface and permitting them to disperse through the contaminated area or by tilling or otherwise mixing chemicals into the contaminated area. In water matrices, treatment is accomplished by injecting chemicals into the subsurface or directing groundwater flow through areas where treatment chemicals have been placed (e.g., reactive barrier technology). Chemicals used to treat solids contaminated with heavy metals include phosphate salts or phosphoric acid and Bauxsol®, a by-product of aluminum refining. Treatment of acid-generating solids or acidic water uses chemicals to neutralize acid and precipitate or tie up metals in solid mineral forms that are less biologically available and less toxic.

4.2.6 Removal or Collection and Disposal

This category of actions includes technologies to remove or collect contaminants for disposal. For contaminated soil, sediment, and solid waste materials, removal is accomplished through excavation or dredging. Contaminated material is then transported to a suitable disposal location either on-site or off-site. TCLP tests of soil at the former ore processing area at OU1 indicated that the material possesses the characteristic of hazardous waste (BVSPC, 2011b) and would require appropriate handling and disposal techniques. On-site disposal would require construction of a suitable repository to handle these materials. Saturated sediment dredged from streambeds and portions of chat piles that are below the water table would likely require dewatering either before or after transport. Liquid from dewatering would require treatment prior to discharge to an appropriate water body. Sediments that might require removal from the

floodplains and channels of streams could likely be moved using standard dry land equipment (as opposed to a dredge).

Contaminated surface water or groundwater would be collected through the use of diversions, pumps, or similar means. This water would then be disposed of into an appropriate water body, through land application, or evaporation.

4.2.7 Removal or Collection and Treatment

For contaminated soil, sediment, and mine wastes, this approach involves employing dredging or excavation options, as discussed above, but the contaminated solids would be treated prior to disposal. Treatment of lead-contaminated solids could create material that would not require handling and disposal as hazardous waste. Treatment options are similar to those listed in Section 4.2.5 and disposal could occur either on-site or at an off-site landfill. Contaminated surface water and groundwater would be collected as described above and under this category would be treated prior to discharge. Treatment could be accomplished in an on-site chemical treatment plant, by disposal into a sanitary sewer (and be treated by a publicly owned treatment works (POTW)), or by using passive techniques such as wetlands or bioreactors to remove heavy metals. Treated water could be discharged to an appropriate water body.

4.3 Screening Criteria

For each identified general response action, technologies and associated process options have been identified as potentially applicable for use at the Madison County Mines Site. Section 5 screens the process options through an initial assessment of the feasibility and applicability of the technology or process option in meeting RAOs. Technologies and best process options that are retained will be used to develop formal remedial alternatives. Screening criteria of effectiveness, implementability, and short- and long-term risk were used in accordance with EPA guidance (EPA 1988a). However, process option screening also considered approaches such as Adaptive Management which calls for well-reasoned iterative actions to be accompanied by a comprehensive monitoring program aimed at quantifying well-articulated performance-based measures. This approach was recommended by the National Research Council in its review of the remedial decision process at the Coeur d'Alene, Idaho mining site (NRC, 2005). The developed screening criteria or screening questions are:

- **Effectiveness** – determines if the method has been reasonably proven to be effective in reducing the quantities or bioavailability of heavy metals. Evaluates how soon the benefits of the method would accrue, and what level of maintenance or reapplication may be necessary.

- **Implementability** – evaluates all factors associated with implementation, such as general equipment needs, availability, space, and time requirements. Considers if there are special considerations or limitations. Compares site access requirements and remoteness. Defines any substantive permitting or other administrative constraints which may affect implementing the technology.
- **Cost** – A relative cost analysis, based on engineering judgment, is used to evaluate whether the costs for each process is high, low, or medium relative to other process options in the same technology type.
- **Short- and Long-Term Risk** – supports both effectiveness and implementability evaluations. Evaluates the expected short- and long-term risk to humans and the environment. Defines short-term risks to humans or other receptors that could be expected during project implementation or construction. Along with effectiveness, this evaluation identifies expected long-term residual risk and permanence.

5.0 Identification and Screening of Applicable Technologies and Process Options

This section presents summaries of the screening-level assessment of the technologies and process options identified for each RAO. Technology type and any associated process option(s) are grouped into their general response action (GRA) categories where they are generally described and then evaluated with respect to the screening criteria defined in Section 4.3. This is followed by a summary assessment of whether or not each technology or process option is considered feasible and therefore retained for the development of alternatives. The screening process is summarized by environmental medium in Table 5-1.

5.1 GRA: Institutional Controls

Institutional controls (ICs) are non-engineering measures or actions that help to minimize potential exposure of human or ecological receptors to hazardous materials. Three types of institutional controls are evaluated in this section: public health education, legal controls, and access restrictions.

5.1.1 Technology – Public Health Education

Public health education involves distributing information about metal exposure to the public in areas affected by metals in waste, soil, groundwater, and other environmental media. Education can alert the public to the issues of exposure routes, sources of metals, people at risk, and preventative measures. Educating citizens visiting, recreating, working, or living in or near affected areas can be used as a supplemental action to reduce exposure and decrease risk. Public health education is an ongoing activity in Madison County and aims to educate residents about the risks from exposure to lead contaminated soils. As such, additional public health education efforts are unlikely to be warranted for residents, workers, and frequent visitors to most affected areas of OU5.

Public Health Education – Screening Assessment	
Effectiveness	Participation in public health education is voluntary and successful programs are ongoing cooperative efforts between the public and public health institutions. Education increases awareness of sources, exposure routes, people at risk, and preventative measures and can help the public take steps to reduce or control their exposure. Typically, public health education is not a stand-alone remedy, but is used in conjunction with engineered actions as a supplemental activity.
Implementability	Implementing education programs requires the cooperation of public health institutions but can be easily accomplished through meetings with area physicians to inform family practitioners, public meetings, literature distribution, and exercising appropriate intervention when patients are identified as having elevated blood-lead levels. Although public health education is more suitable for reaching large numbers of people, it can also be effective for educating visitors to recreational areas by providing information to assist them in recognizing risks and mitigating exposures.
Cost	Low.
Short- and Long-Term Risk	There are no short- or long-term risks to implementing this technology. Used as a supplemental action, public health education can reduce exposure and decrease risk. Because public concern and awareness tend to wane with time, education must be a continuing process if it is to be successful over the long term.
Summary of Assessment	Public health education concerning the risks to exposure to lead contaminated soil is an ongoing activity in Madison County. Public health education would be expected to be effective in alerting infrequent visitors to recreational areas to potential risks and providing them with information to reduce exposures.
Retained for Development of Alternatives?	No.

5.1.2 Technology – Legal Restrictions

Legal restrictions are a form of institutional control that can be used to restrict how property is used and developed in the future and to restrict the consumption and use of environmental resources. Three types of legal restrictions are considered: land use and deed restrictions, groundwater use restrictions, and surface water use restrictions.

5.1.2.1 Process Option – Land Use and Deed Restrictions

Land use and deed restrictions are an effective tool to place limits on the use of a property. Legal restrictions include restrictive covenants, deed notices, zoning, and building codes. Legal restrictions may be required to address contamination left on site at the completion of the remedial action. These controls could include restrictions such as zoning or permit requirements for future construction to ensure that contaminated material is properly addressed. Land use and deed restrictions also can be used to place specific restrictions to prevent soil disturbances in certain areas (for example, where wastes have been buried and capped) or prevent effects to engineering controls (for example, breaching surface run-on control ditches). The effectiveness of legal restrictions is limited by enforcement of the specific control.

Land Use and Deed Restrictions – Screening Assessment	
Effectiveness	Land use and deed restrictions are an effective means for providing long-term risk reduction by prohibiting activities that could potentially cause exposure. They can be used to institute zoning requirements, restrict access, and protect engineered remedial actions to retain function.
Implementability	Implementing land use and deed restrictions will require cooperation of the community and appropriate branches of local and county government.
Cost	Low.
Short- and Long-Term Risk	None.
Summary of Assessment	Land use and deed restrictions could be useful for restricting future site activities and use.
Retained for Development of Alternatives?	Yes.

5.1.2.2 Process Option – Groundwater Use Restrictions

Groundwater use restrictions can be effective in reducing exposure to contaminants through the ingestion of contaminated groundwater. The restriction would define the vertical and horizontal dimensions of the area to be restricted and the uses that are prohibited (for example, an ordinance could prohibit human consumption but permit industrial use). Groundwater use restrictions are appropriate when other remedial actions are not feasible or cannot provide the required level of risk reduction.

Groundwater Use Restrictions – Screening Assessment	
Effectiveness	Groundwater use restrictions are an effective tool for providing long-term risk reduction by prohibiting the installation of wells and usage of groundwater for consumptive and other purposes. Enforcement of local or state ordinances codifying the usage restriction is key to the effective protection of public health, safety, and welfare.
Implementability	Implementing groundwater use restrictions will require cooperation of the community and appropriate branches of government.
Cost	Low.
Short- and Long-Term Risk	None.
Summary of Assessment	Groundwater use restrictions are expected to be useful for restricting exposure to contaminants through the groundwater ingestion pathway.
Retained for Development of Alternatives?	Yes.

5.1.2.3 Process Option – Surface Water Use Restrictions

Surface water use restrictions may be used to reduce exposure to contaminants through contact with or the ingestion of contaminated surface water. These restrictions could take the form of a state regulation enacted to protect public health, safety, and welfare or a change in the

beneficial uses designated by the State under the Clean Water Act. The restriction would define the portions of the surface water bodies to be restricted and the uses that are prohibited (for example, a stream could be restricted for water supply and human recreation but permit irrigation). Surface water use restrictions are appropriate when other remedial actions are not feasible or cannot provide the required level of risk reduction.

Surface Water Use Restrictions – Screening Assessment	
Effectiveness	Surface water use restrictions are an effective means to provide long-term risk reduction by prohibiting certain surface water uses that cause exposure. Enforcement of local ordinances or state regulations codifying the usage restriction is key to the effective protection of public health, safety, and welfare. The effectiveness of a surface water use restriction depends on the public's willingness to understand and follow the restriction.
Implementability	Implementing surface water use restrictions will require cooperation of the community and appropriate branches of local, county, or state government. It may be difficult to implement and control use of surface water.
Cost	Low.
Short- and Long-Term Risk	None.
Summary of Assessment	Low levels of risk are present in surface water at the pond on the Skaggs property in OU5, and in other area streams and ponds. Access restrictions (locked gates) are in place at the Skaggs property. Risk reduction related to sediment may be more appropriately addressed through public health education. Consequently, surface water use restrictions are not considered to be necessary at this time.
Retained for Development of Alternatives?	No.

5.1.2.4 Process Option – Fish Consumption Advisories

Fish consumption advisories are informational devices that may be selected as part of site remedies. A fish advisory informs the public that they should not eat fish or consume more than a specified number of fish meals over a specific time from a particular area or water body. This technology could be used to address risks posed by the consumption of fish containing elevated concentrations of arsenic in the LSFR. Because of the limited data available, the risks from arsenic are uncertain due to the unknown form of arsenic present in the fish; it is assumed that much of the arsenic in fish tissue exists in an organic form that is much less toxic than inorganic arsenic. Based on this assumption, fish consumption advisories would not be necessary.

Fish Consumption Advisories – Screening Assessment	
Effectiveness	Following a risk advisory is voluntary but would eliminate any potential human health risk from fish consumption. Consumption advisories are not enforceable and their effectiveness depends on the public's willingness to understand and follow the advisory.
Implementability	The Missouri Department of Health and Senior Services is the regulating authority for fish consumption advisories in Missouri. When implemented, advisories are publicized through public announcements in newspapers and on the internet, signs posted at popular fishing locations, and the distribution of pamphlets, and other outreach materials as needed. Due to limited data on the form of arsenic present in fish tissue, the risk posed by fish consumption is uncertain.
Cost	Low.
Short- and Long-Term Risk	The risk associated with fish consumption is uncertain due to the unknown form of arsenic present in fish tissue. If most arsenic is present in an organic form, then a fish advisory would not be necessary.
Summary of Assessment	The level of risk posed by the consumption of fish in the LSFR is uncertain. Implementation of a fish advisory is unwarranted until further data can be gathered to clarify risk.
Retained for Development of Alternatives?	No.

5.1.3 Technology – Access Restrictions

Access restrictions are a form of institutional control that can be used to prevent physical access to hazardous areas or to areas where engineered remedies have been completed. The most common method is to install secure fencing to block access and signage to alert the public to hazards. Other methods of access restriction include vegetation barriers (e.g., thickets of brush that are difficult to penetrate), boulder clusters, metal piling, and earthen berms and ditches that cannot be crossed with automobiles. Because vegetation barriers are difficult to establish (and can be compromised by wildfire) and boulder clusters, metal pilings, and earthen berms are viable only for blocking automobile access on roads, these process options were deemed inappropriate for OU5 and have not been evaluated.

5.1.3.1 Process Option – Fencing and Signage

Fencing is a proven method to restrict access to hazardous areas. A chain-link fence with attached signs also could be used to restrict access to areas where engineered remedies have been completed. For example, if a vegetated cap is placed atop the mine waste, it would be appropriate to enclose this area to prevent access by all-terrain vehicles so that the integrity and function of the cap are preserved. Landowners in Madison County have already restricted access (at least partially) by vehicular traffic to many site areas using locked gates and/or fences. These include the Skaggs and Catherine Mine OU5 sites. Fences are subject to vandalism and will require periodic maintenance to ensure the fence and signage remains intact and functional.

Fencing and Signage – Screening Assessment	
Effectiveness	When properly maintained, fences and signs are effective in restricting access to hazardous or sensitive areas. Galvanized chain-link fences are durable and require minimal maintenance. However, fences and signs are subject to vandalism and can be compromised. Consequently, periodic inspection and maintenance may be required to maintain integrity and function. Fences and signs that become compromised through vandalism or neglect would lose their ability to provide the intended protections.
Implementability	Fencing and signs are easy to install and can be moved if necessary to protect additional areas. It is a proven technology.
Cost	Low.
Short- and Long-Term Risk	Short-term risks include potential exposure to workers installing the fence. There are no long-term risks to this option. Preventing access to hazardous or sensitive areas using fences and signs is effective in helping to maintain the integrity and function of certain engineered remedies. Fences and signs will require periodic inspection and maintenance; failure to maintain fences would render them ineffective.
Summary of Assessment	Fences and signs are a proven technology to restrict access. Inspection and maintenance are required to continue function. This option is easily implemented.
Retained for Development of Alternatives?	Yes.

5.2 GRA: Monitored Natural Attenuation/Monitored Natural Recovery

MNA and MNR are similar concepts that differ in the types of natural processes that cause reductions in contaminant concentrations and toxicity. Selection of either must be accompanied by the expectation that they would achieve remedial objectives within a specific time frame, with progress toward the objectives measured by a monitoring program.

5.2.1 Technology – Monitored Natural Attenuation

MNA is a remedy for contaminated groundwater and soil in which natural attenuation processes are used to achieve site-specific remediation objectives within a time frame that is reasonable compared to that offered by other methods (EPA 1999). Natural processes include various physical, chemical, and biological mechanisms that act without human intervention to reduce the mass, toxicity, mobility, volume, or concentrations of contaminants and the risk posed by contaminants to human or ecological receptors. Most prominent among these processes (applicable to metals) are biodegradation, dispersion, dilution, and sorption. Other potential processes include chemical or biological stabilization, transformation, or destruction of contaminants. EPA's expectation is that MNA will be appropriate only for sites with low potential for contaminant migration where it typically will be used in conjunction with active remedial actions (EPA 1999).

Natural attenuation may reduce the risk posed by contaminants by transforming them to less toxic forms, reducing their concentration, or reducing their mobility and bioavailability. Studies conducted as part of the RI (Black & Veatch, 2008) showed that lead in residential soils in the Madison County area remains in a highly bioavailable form (typically more than 70% at concentrations greater than 500 mg/kg). This suggests that natural attenuation processes are not reducing lead concentrations or toxicity in soil.

Less is known about natural attenuation of shallow groundwater at the site. In general, attenuation of metals in shallow groundwater occurs as water migrates through pore spaces in soil and rock and sorbs to clays or organic detritus or precipitates as insoluble phases in response to changed chemical conditions (possibly biologically mediated). Mine wastes have little capacity to attenuate metals due to low concentrations of clays and organic material. As a result, most attenuation would occur in underlying or surrounding soils. It is uncertain whether these soils would have the ability to transmit and attenuate shallow groundwater.

Monitored Natural Attenuation – Screening Assessment	
Effectiveness	MNA can be effective at reducing contaminant concentrations, availability, and toxicity in soil and groundwater if ambient chemical and biological conditions permit. In general, MNA is used in conjunction with active remedial components, such as source control, to achieve the desired level of risk reduction. Evidence from residential yards in the Madison County area suggests that MNA is not effective in reducing the bioavailability of lead in soils. The potential effectiveness of MNA in shallow groundwater could not be evaluated from the available data.
Implementability	MNA is easy to implement because it does not require human intervention to initiate the remedy. However, MNA does require that EPA develop and implement a robust monitoring plan to determine whether MNA is achieving remedial goals in the desired time frame.
Cost	Low.
Short- and Long-Term Risk	There is no short-term risk in implementing MNA because it does not require active intervention. Although the timing and extent of long-term risk reduction are unknown, MNA is not expected to occur instantaneously. Once established, continued function of MNA depends on maintaining the desired chemical or biological processes. Changes in the capacity of the environment to attenuate contaminants (for example a soil may lose its ability to continue to sorb metals from groundwater) could lead to increases in contaminant concentrations, mobility, and toxicity. In addition, “hot spots” of unacceptable risk could potentially remain for the long-term.
Summary of Assessment	MNA is a tool that can be used in conjunction with source control and other active remedial measures to achieve desired remedial goals. It requires no intervention to operate. MNA cannot be demonstrated to be effective at the site to reduce metal concentrations in groundwater.
Retained for Development of Alternatives?	Soil – No. Groundwater – No.

5.2.2 Technology – Monitored Natural Recovery

MNR is a remedy for contaminated sediment that uses ongoing, naturally occurring

processes to contain, destroy, or reduce the bioavailability or toxicity of contaminants (EPA 2005). Natural processes include various physical, chemical, and biological mechanisms that act alone or in combination to reduce the risk posed by contaminants to human or ecological receptors. Mechanisms include conversion to less toxic chemical forms, reduction in chemical mobility or bioavailability, decreases in chemical concentrations by burial or mixing with clean sediment, and decreases in chemical concentrations by dispersion or dissolution to the water column. MNR generally occurs over a specified time frame during which site-specific remedial goals are expected to be attained. Selecting MNR as a remedial technology or as part of a remedial alternative requires knowledge that contaminant sources have been controlled, that natural processes affecting contaminants are understood, and that there is a reasonable expectation that risks can be reduced to acceptable levels through natural processes. The choice of MNR requires a monitoring program to evaluate and track risk reduction over time.

The main advantages of MNR are that it can be implemented at low cost and does not require disruption by construction activities that can increase short-term exposure risks. As such, it is advantageous for sensitive environments where harm to the ecological community by active measures outweighs risk reduction. However, MNR leaves contaminants in place, may be slow to achieve remedial goals, and carries the risk that buried contaminants may become re-exposed.

Monitored Natural Recovery – Screening Assessment	
Effectiveness	Contaminated sediment present in many small streams draining areas of mine waste includes tailings and chat. Mechanisms providing effective MNR include conversion to less toxic forms and reductions in mobility and bioavailability. Lead, which is the main contaminant of concern in sediment, cannot be converted to a less toxic form and studies of lead-contaminated soil in Madison County indicate that it does not quickly become less bioavailable. Consequently, to be an effective solution, MNR would require burial or mixing with clean sediment or downstream dispersion. MNR may not be effective in small tributary streams that contain sediment with a significant proportion of tailings or chat because they lack sufficient input of clean sediment. However, on small streams with high gradients, storm runoff could help to disperse these materials over time and MNR could be effective providing that source control measures successfully reduce or eliminate input. Similarly, MNR would not be effective in static waters such as the small ponds at the Catherine and Skaggs OU5 site that do not receive significant clean sediment.
Implementability	MNR is easy to implement because it does not require human intervention to initiate the remedy. However, MNR does require that EPA develop and implement a robust monitoring plan to determine whether MNR is achieving remedial goals in the desired time frame.
Cost	Low.

Short- and Long-Term Risk	There is no short-term risk in implementing MNR because it does not require active intervention. Although the timing and extent of long-term risk reduction are unknown, MNR is not expected to occur instantaneously. Once established, continued function of MNR would depend on maintaining the sediment configuration. Changes in stream configuration especially during large flow events could potentially lead to re-exposure of contaminants. In addition, "hot spots" of unacceptable risk could potentially remain for the long-term.
Summary of Assessment	MNR is unlikely to be effective in the smaller streams and tributaries and the ponds due to the paucity of clean sediment and the geochemical cycle of lead in the environment. Nevertheless, this process option is easily implemented.
Retained for Development of Alternatives?	No for static waters such as the Catherine and Skaggs Ponds (OU5). Yes for small streams draining waste piles when used in conjunction with source control or containment measures.

5.3 GRA: Containment

Containment actions include a variety of technologies to contain contaminants and minimize or prohibit their migration through the environment. Three technologies are screened for their applicability to sites in OU5: caps and covers, solidification/stabilization, and erosion control. Another containment strategy, encapsulation, is discussed in a following section on disposal technologies. Containment actions can be applied to the Catherine and Skaggs chat piles, areas of soil contamination, and contaminated sediment in small streams.

5.3.1 Technology – Caps and Covers

Caps and covers consist of stable layers of soil, rock, synthetic materials, or water placed atop contaminated soil, sediment, or waste to decrease the potential for exposure to human and ecological receptors and the mobility of contaminants in the environment. These are engineered systems that include measures to ensure that the contaminant mass stays physically stable over the long-term and steps to control surface and groundwater flow across and through the capped mass. In all cases, the capped material is left in place without benefit of a basal liner or prepared base material.

Caps and covers are proven technologies and include process options of permeable covers, low permeability covers, and water covers.

5.3.1.1 Process Option – Permeable Covers

Permeable covers are those that permit water to infiltrate through the cover and into underlying contaminated materials. Their primary functions are to decrease the potential for human and ecological receptors to be exposed to contaminants and to limit the physical transport of contaminants through the environment by wind and water erosion. Permeable covers typically consist of a layer of vegetated topsoil or amended borrow soil spread across the upper surface of the contaminated materials; they may also consist of layers of gravel or larger rock. Rock covers

may be used to cap contaminated subaqueous sediment to prohibit downstream transport. An advantage of permeable covers is that they can be installed with standard equipment and do not require significant excavation or movement of contaminated material. A disadvantage is that they permit water infiltration, which can potentially leach contaminants that may then be conveyed to groundwater and surface water in dissolved form. For contaminants that are subject to oxidation reactions (such as iron sulfide minerals), permeable caps may slow but will not prohibit the oxidation process.

Permeable Cover – Screening Assessment	
Effectiveness	Permeable covers are effective at reducing exposures to human and ecological receptors and limiting erosion and transport of contaminants by wind and flowing water. Because precipitation is able to penetrate through the cover into the underlying contaminated material, these covers do not effectively reduce contaminant leaching to groundwater or surface water.
Implementability	Permeable covers are easy to implement and require a source of suitable borrow soil, top soil, or rock. Installation requires standard earthmoving equipment. Vegetation can range from simple grass covers to covers designed to improve wildlife habitat by supplying a diverse mix of grasses, forbs, and other vegetation. Borrow soil, especially subsurface soil, typically requires chemical amendment with fertilizer to promote vegetation growth over the long term.
Cost	Low to medium.
Short- and Long-Term Risk	Short-term risks include potential exposure to contaminants during grading and compaction. Long-term risks arise from the fact that contaminants are not removed from the environment and are isolated only from physical transport. Precipitation infiltration through the cap can leach contaminants and convey them in dissolved form to groundwater and surface water. In addition, contaminant degradation and release through oxidation will continue to occur within the contaminated mass although at a slower rate than with no cap. Permeable caps require installation and maintenance of access controls to prevent damage to the cap that may be caused by foot or vehicular traffic, and periodic maintenance to ensure that erosion or loss of vegetation does not compromise the integrity and function of the cap. Rock caps placed over contaminated sediment are more difficult to inspect and maintain since they are under water and are subject to compromise during flood events exceeding those of the engineering design or during events causing channel migration.
Summary of Assessment	Permeable covers could be easily implemented if a suitable source of cover material is identified. They would be effective in reducing the spread of contamination from tailings and chat by mechanisms such as wind erosion, but would do little to halt the oxidation of iron sulfide minerals in the tailings and leaching of tailings that release heavy metals to groundwater.
Retained for Development of Alternatives?	Yes.

5.3.1.2 Process Option – Low Permeability Caps

Low permeability caps are those that severely restrict or prohibit water infiltration into underlying contaminated materials. Their primary functions are to decrease the potential for human and ecological receptors to be exposed to contaminants, limit the physical transport of contaminants through the environment by wind and water erosion, and significantly reduce contaminant migration by preventing infiltration and leaching and reducing oxidative

weathering.

Low permeability caps typically consist of three layers: an upper layer of vegetated soil, an intermediate drainage layer, and a lower low permeability layer. Most commonly, the low permeability layer consists either of compacted clay, geotextile fabric or geomembranes, a geosynthetic clay liner (GCL), or asphalt. GCL is a manufactured product comprised of bentonite clay sandwiched between two geotextile layers. Drainage layers serve to wick away moisture that penetrates through the vegetation layer to prevent it from pooling atop the low permeability layer. A variety of materials can be used for the drainage layer depending on the amount of water that must be handled. The upper vegetated layer provides protection for the low permeability cap and stability for the entire cap system. Advantages of low permeability covers are that they can be installed with standard equipment, do not require significant excavation or movement of contaminated material, and provide protection against the spread of contamination by leaching and oxidative weathering. A disadvantage is that they are more costly to install, require additional engineering considerations to secure the liner system, and require periodic inspection and maintenance to ensure that trees or other large plants do not establish roots that could penetrate the low permeability layer and compromise the cap system.

Low Permeability Cap – Screening Assessment	
Effectiveness	Low permeability caps are effective at reducing exposures to human and ecological receptors, limiting erosion and transport of contaminants by wind and flowing water, and reducing oxidative weathering and contaminant leaching to groundwater.
Implementability	Low permeability caps require engineering to ensure they function as intended. This includes grading and drainage control as well as engineered anchors to keep the cap in place. Installation can be accomplished with standard equipment. The upper protective vegetated soil layer requires a source of suitable borrow soil, top soil, or rock. Vegetation can range from grass to mixed covers designed to provide wildlife habitat. Borrow soil, especially subsurface soil, typically requires chemical amendment with fertilizer to promote vegetation growth over the long term.
Cost	Medium to high.
Short- and Long-Term Risk	Short-term risks include potential exposure to contaminants during grading and compaction. Long-term risks arise from the fact that contaminants are not removed from the environment. Low permeability caps require that access controls be installed and maintained to prevent damage to the cap that may be caused by foot or vehicular traffic. These caps require periodic inspection and maintenance to ensure their integrity over the long-term. Failure to inspect and maintain these caps could lead to their compromise and failure from tree roots penetrating the low permeability layer, saturation and slumping of vegetation layers, or erosion.
Summary of Assessment	Low permeability caps are implementable and are expected to be effective in reducing the spread of contamination from tailings and chat piles by wind and water erosion and in limiting the oxidation of iron sulfide minerals in the tailings and leaching of heavy metals to groundwater. Engineering is required to design and install these liners. They would require a suitable source of topsoil or borrow to construct the upper protective vegetated layer.
Retained for Development of Alternatives?	Yes.

5.3.1.3 Process Option – Water Covers

Water covers are used to minimize the oxidation of iron sulfide minerals and decrease the amount of acid generated by oxidation. This, in turn, reduces the release of metals from tailings solids. Water covers have been used as a wet closure option for tailings impoundments in numerous locations worldwide. Implementing this option requires that tailings dams be physically stable and capable of maintaining a pool of water a few to several feet deep. Water management is key to the successful function of a water cover. A disadvantage of water covers is that water floods into contaminated material. This can cause seepage of poor quality water until accumulated oxidation products are flushed from the system and physical instability caused by increased pore pressures. If the quality of the impounded surface water is degraded by contact with the underlying contaminants, then it provides a route by which waterfowl and other terrestrial and aquatic species can become exposed to contaminants.

Water Cover – Screening Assessment	
Effectiveness	Water covers have been demonstrated to be effective in reducing oxidation of iron sulfide minerals and the consequent generation of acid and leaching of metals from tailings. In addition, they reduce contaminant exposure to human and ecological receptors and erosion of contaminants by wind and water. Seepage penetrating through contaminated materials can potentially affect groundwater and surface water resources.
Implementability	Water covers require determination of a site water balance, water management practices, and engineering studies to assure the stability of tailings dams. Creating the water cover requires only a source of water that can be used to flood the area and maintain the proper amount of water under all conditions.
Short- and Long-Term Risk	Short-term risks include potential exposure to contaminants during grading and work to stabilize the tailings dam. Long-term risks arise from the fact that contaminants are not removed from the environment. Initial flooding of the tailings could lead to flushing accumulated contaminants in the tailings that could affect groundwater and surface water resources. The duration over which this flushing process would continue is unknown. This process option would increase the risk of heavy metal exposure to terrestrial and aquatic species. Water covers require water management and control; failure to maintain a minimum pool level could lead to oxidation of contaminants and failure to maintain a maximum pool level could lead to instability and failure of the dam. The dam would require periodic inspection to ensure its integrity.
Cost	Medium to high.
Summary of Assessment	Water covers are demonstrated to be effective in reducing oxidation of tailings at mine sites worldwide. However, to implement this process option at OU5 would require extensive engineering and construction work to provide a stable impoundment to hold the water cap, identification of a water source, and infrastructure to manage and maintain the water cap.
Retained for Development of Alternatives?	No.

5.3.1.4 Process Option – Induced Sedimentation

Contaminated streambed sediment, such as that existing in portions of the LSFR, could

be capped using natural stream processes. This type of containment typically involves altering stream flow to encourage the deposition of clean sediment carried from upstream locations to the contaminated areas. The clean sediment provides a barrier to reduce contaminant exposures to aquatic biota. Sediment transport in a stream is a function of stream velocity, bed shear strength, and particle size and density. Most typically, induced sedimentation involves installing structures in the stream to locally alter stream velocity and promote sedimentation on the downstream side. The types of structures may include, among others, cross vanes, j-hooks, spur dikes, and boulder clusters. Boulders are generally used in construction, but large woody debris may be substituted in some instances. An advantage to induced sedimentation is that it uses natural processes to form and maintain the cap. A disadvantage is that streams are dynamic environments and changes in channel position over time may decrease the effectiveness of structures installed to promote capping or cause portions of the cap to become entrained and eroded, especially during high flow events. In addition, the option requires a sufficient and comparatively stable input of clean sediment from upstream and streams with sufficient average sediment carrying capacity. Consequently, induced sedimentation is unsuitable for use in intermittent streams, headwater streams with little clean sediment input or carrying capacity, and static waters such as ponds and lakes.

Induced Sedimentation – Screening Assessment	
Effectiveness	A variety of techniques could be used to induce sedimentation in streams to cover contaminated sediment in the stream bed. Forming a cap of clean sediment over contaminated areas can form a barrier to reduce contaminant exposures to aquatic biota. Sediment trapping effects would be limited to a relatively short distance downstream requiring numerous structures to be built. The types of structures suitable for use and their design would require knowledge of stream flow variations to ensure stability of the structure and preservation of function under a variety of flow conditions. Such structures typically are designed for a range of conditions; flow events exceeding the design could lead to loss of function and potentially bed scour and downstream migration of contaminants from the capped area. Very large flow events could potentially cause changes in channel position that could render the engineered structures ineffective. Since effectiveness depends on a stream having sufficient capacity to carry clean sediment, this process option would be less effective or ineffective in intermittent streams or headwaters reaches where low flow velocity under base flow conditions minimizes stream capacity. Similarly, the technology could not be used to address contaminated sediment in static waters such as ponds and lakes, where water velocity is essentially zero.
Implementability	Implementing this process option requires identifying the types of structures that would be most advantageous in each stream reach and securing a source of boulders, large woody debris, and other materials to create the structures. Structures could be built with standard earthmoving equipment, but may require construction of access roads to some locations; this may involve access agreements with landowners. Implementing this option also would require meeting substantive requirements of a Clean Water Act §404 permit from the Corps of Engineers and potentially other permits from the State of Missouri.
Cost	Medium.

Short- and Long-Term Risk	Implementing this option could cause short-term effects during and shortly following construction that include disturbing and potentially entraining contaminated sediment that would be carried downstream. These effects would subside shortly afterward. Long-term risk reduction provided by the process option would be local and moderately effective. High flow/high velocity events could temporarily remove and transport accumulated sediment downstream. The structures would again trap new sediment as flow velocity subsides.
Summary of Assessment	Induced sedimentation is moderately effective in forming caps to cover contaminated sediment over relatively short distances. The option can be implemented given that access agreements can be reached and sources of construction materials can be identified. The process option requires perennial streams with sufficient flow to carry clean sediment; it is not suitable for intermittent streams, headwaters streams, or ponds and lakes such as those found at OU5.
Retained for Development of Alternatives?	No.

5.3.2 Technology – Drainage and Erosion Control

Drainage and erosion control includes a variety of measures to reduce the spread of contaminants by wind and water erosion and to reduce sedimentation in receiving waters. These measures could be applicable to numerous areas in OU5 including the chat piles at the Skaggs subsite, the residential soil repository at the Catherine subsite, and on various floodplains and channels of perennial and intermittent streams. Three types of erosion control that are applicable to many areas include planting vegetation, grading and contouring, and runoff management. Options applicable primarily to the bed and banks of streams include channelization, bank stabilization with gabion walls, revetments, or rip rap, and grade control structures such as weirs, cross vanes, and check dams.

5.3.2.1 Process Option – Planting New Vegetation or Enhancing Existing Vegetation

Planting new vegetation or enhancing the growth and cover of existing vegetation can be used to reduce wind and water erosion from areas of chat and contaminated soil in OU5. In areas where existing vegetation has already taken hold, this vegetation can be enhanced through additional seeding and fertilization. In barren areas lacking sufficient soil structure, such as tailings or chat piles,, placement of new top soil may be required to provide a suitable growth medium. Fertilization or other soil amendment could be accomplished by broadcasting chemical fertilizer, applying biosolids, or applying compost and other types of organic material. Seeding may be accomplished using standard equipment such as seed drills, broadcast spreaders, or hydroseeders. Alternatively, poor soil structure can be enhanced *in situ* using penned cattle to increase soil tilth and nutrients, promote water retention, and encourage seed germination and growth. This technique, used to promote vegetative growth on barren tailings piles in the western U.S., employs a dedicated herd of cattle that are penned in small areas for a few days at a time and rotated through the affected area to incorporate organic matter and provide soil

nutrients. The cattle trample hay, manure, and urine into the tailings, providing organic matter and nutrients to otherwise barren materials. Nutrient incorporation is likely to not be effective on contaminated soil (likely too compact) and less effective for coarse-grained materials such as chat.

Vegetative covers can consist of native grasses, shrubs, and/or trees and can be created to provide wildlife habitat. This process option may be used alone or in combination with other technologies such as capping.

Vegetation – Screening Assessment	
Effectiveness	Established vegetation with well developed root systems is effective in adding cohesion to soil and other unconsolidated materials and reducing raindrop impact thereby reducing erosion by wind and water. Selecting native plants with high germination rates and that thrive under the prevailing soil moisture, sunlight, and nutrient conditions will ensure success. Effectiveness depends on having adequate nutrients and soil structure to promote growth over the long term. Vegetation enhances long-term effectiveness of removal actions and capping.
Implementability	Implementing the vegetation option requires the use of standard equipment to scarify, till, and prepare soil, spread seed, and if necessary place additional growth medium. Nutrient analyses of the area to be seeded would be used to determine whether fertilization is required to assist in growth over the long-term. Fertilizers can be standard chemical additives, biosolids, or various types of compost. Biosolids would need to meet applicable criteria for land application. Areas may require grading and drainage control to prevent seedlings from washing out before they become established and to control soil moisture conditions. *In situ* soil enhancement using cattle would require securing a dedicated herd of 40 to 100 cattle; daily care and maintenance of the herd; installation of temporary, movable electrical fencing; hay, water, and nutrients for the herd; and veterinary care for the herd, including periodic tests for metals in blood and tissue, Since the method utilizes cattle to incorporate nutrients into the affected ground, it is likely to be implementable only on barren tailings.
Cost	Low to medium
Short- and Long-Term Risk	Short-term risks potentially include increased wind and water erosion on freshly graded surfaces and increased exposure of site workers to contaminants during scarifying, soil preparation activities, and seeding. Risks from increased erosion could be mitigated using best management practices and those to workers could be mitigated through health and safety protocols. Long-term risks are few. However, planted vegetation could potentially die due to inadequate moisture, nutrients, or poor germination and this would require monitoring and potential reseeding. Studies of dedicated herds working on copper mine tailings have shown little to no uptake of metals by the cattle but this would require monitoring to ensure health.
Summary of Assessment	Planting vegetation is an established method to provide erosion control for unconsolidated materials and would have wide applicability to barren tailings, chat piles, and contaminated soil areas in all OUs. Depending on the area to be seeded, measures to control drainage and enhance soil nutrients and tilth may be required.
Retained for Development of Alternatives?	Yes.

5.3.2.2 Process Option – Grading and Contouring

Grading and contouring are used to control water runoff, reduce slope angles, assist in controlling soil moisture, and to prepare sites for other actions, such as placing caps and covers.

Grading to control runoff is discussed in the following section. Grading and contouring is accomplished using standard earthmoving equipment. For fine-grained, unconsolidated materials such as tailings, grading and contouring alone are likely to be only partly effective at controlling erosion and typically are implemented in conjunction with other actions such as planting vegetation.

Grading and Contouring – Screening Assessment	
Effectiveness	By themselves, grading and contouring are only partly effective in controlling erosion. In general, this option is commonly used in conjunction with other process options as part of a comprehensive erosion control program.
Implementability	Easily implemented for areas of tailings, chat, and other soil areas using standard earthmoving equipment. Grading and contouring are likely to require use of best management practices to reduce sediment impact to surface waters during implementation until other erosion control measure, such as vegetation, are installed or become effective.
Cost	Medium.
Short- and Long-Term Risk	Short-term risks include potentially increased wind and water erosion on freshly graded surfaces and potential exposures of site workers to contaminants during grading actions. Risks from increased erosion could be mitigated using best management practices and those to workers could be mitigated through health and safety protocols. Potential long-term risks could potentially include increased erosion if grading and contouring are not coupled with other options to stabilize surface soils, such as vegetation.
Summary of Assessment	Grading and contouring are established methods to control erosion, but to be effective must be used in conjunction with other process options. It would have wide applicability in all OUs and could be easily implemented.
Retained for Development of Alternatives?	Yes.

5.3.2.3 Process Option – Precipitation Runoff Management

Precipitation runoff management is a type of grading and contouring action aimed at controlling runoff. This is accomplished by grading upland areas to funnel storm water to engineered swales, ditches, and channels that flow to other surface water bodies. Precipitation runoff management is a common component of many remedial actions, such as caps and covers, solidification/stabilization, erosion control, and *in situ* treatment. In most cases, conveyance features are sized to handle storms up to a specified design runoff event, for example the 10-year, 24-hour storm. Discharges exceeding the design event could potentially cause erosion or other damage.

Precipitation Runoff Management – Screening Assessment	
Effectiveness	Managing storm water is an effective means to provide protection to remedial actions such as caps and covers and to decrease erosion. Systems are typically designed to convey discharges up to a pre-determined runoff event. The effectiveness of the management system decreases when the design capacity is exceeded.

Implementability	Implementing effective storm water management systems requires a level of design that includes determinations of rainfall-runoff relationships and estimates of flow velocity so that conveyance systems can be properly sized and designed to function without deleterious effect. Construction requires standard earthmoving equipment. Implementing storm water controls would likely require use of best management practices to prevent erosion during construction.
Cost	Medium.
Short- and Long-Term Risk	Short-term risks include potentially increased wind and water erosion on freshly graded surfaces and potential exposures of site workers to contaminants during grading actions. Risks from increased erosion could be mitigated using best management practices and those to workers could be mitigated through health and safety protocols. Potential long-term risks include potential effects in the downstream receiving water that arise from increased volume and flow velocity. These risks could be mitigated by increasing channel size and constructing engineered structures to decrease flow and stabilize the bed and banks of the receiving stream. Other potential long-term risks could arise if the design capacity of the system was exceeded. Conveyance structures would require inspection and repair following large flow events.
Summary of Assessment	Storm water management is a common process option used in conjunction with other remedial options. It would have wide applicability in all OUs and could be easily implemented. These systems would require engineering designs that include an analysis of the capacity of the receiving water to handle increased flows. Storm water systems would require periodic inspection and potential maintenance following large flow events.
Retained for Development of Alternatives?	Yes.

5.3.2.4 Process Option – Stream Channel and Bank Stabilization

Chat and contaminated soils are present in the bed and on the banks of perennial and ephemeral streams. Preventing continued erosion of these materials could potentially be accomplished by stabilizing the channel to minimize or prevent channel migration and stabilizing stream banks to prevent erosion. This would be combined with upstream actions to control further erosion of tailings and chat into the streams, and possibly combined with in-stream removal actions to remove contaminant hotspots from the stream substrate and banks. Options include channelization, bank stabilization with gabions or rip rap revetments, and grade control structures such as weirs, cross vanes, and check dams. Channelization could potentially include measures to straighten or deepen the exiting channel. Bank stabilization with gabions (rock-filled baskets) or rip rap (large boulders) would be applied primarily to the outside of river bends to absorb stream energy and deflect flows around corners. Grade control structures are used to pool water within the channel to reduce stream velocity and bed scour.

Stream Channel and Bank Stabilization – Screening Assessment	
Effectiveness	Measures to stabilize the channel and banks of impacted perennial and ephemeral streams can be effective in controlling the erosion and downstream migration of contaminants present in the stream channel and on the floodplain of the stream. Stabilization measures are generally engineered with respect to a maximum design storm. Discharges exceeding the design of the stabilization system can potentially cause a decrease in the effectiveness of the system.

Implementability	Most stream stabilization features can be constructed using standard earthmoving equipment. Features such as gabions, rip rap revetments, weirs, cross vanes, and check dams could require that a suitable source of rock be identified. Work in the stream would require meeting the substantive requirements of a §404 permit.
Cost	Medium
Short- and Long-Term Risk	Short-term risks include potentially increased erosion during and shortly following stabilization actions and potential exposure of site workers to contaminants during construction. Risks from increased erosion could be mitigated using best management practices and those to workers could be mitigated through health and safety protocols. Long-term risks could result from storm flows that exceed the design capacity of the stabilization, which could cause erosion and potentially damage stream control features. Interfering with the natural dynamics of a stream by preventing channel migration or down cutting (through channelization) could potentially increase erosion in downstream locations where stabilization features were not installed. Grade control features could potentially cause flooding during high flow events.
Summary of Assessment	Stream channel and bank stabilization measurements are expected to be moderately effective in reducing the erosion and transport of contaminants from streambeds under low or moderate flow conditions and from the banks of streams under all but the highest flow conditions. Under high flow, streambed scour could occur. These measures require engineering to ensure proper function and protect downstream reaches.
Retained for Development of Alternatives?	Yes.

5.3.3 Technology – Solidification/Stabilization

Solidification/stabilization (S/S) involves physically binding or enclosing contaminants into a stabilized mass and reducing contaminant mobility by inducing chemical reactions between the stabilizing agent and the contaminants. Technologies related to S/S act to encapsulate or otherwise reduce the physical mobility of contaminants and typically create a monolithic mass that remains on-site. There are a wide range of S/S processes available for use, however, only the pozzolan/cement process is considered for use in Madison County.

5.3.3.1 Process Option – Pozzolan/Cement Stabilization

The pozzolan/portland cement process is a common S/S technology that utilizes fly ash, kiln dust (or similar materials), and portland cement that reacts with water to form a cement-like matrix that helps to precipitate and immobilize some heavy metals. The process can be accomplished *in situ* or *ex situ*. *In situ* stabilization involves injecting the pozzolan/cement mixture into the contaminated area so that it penetrates the area prior to hardening (*i.e.*, the contaminated material is not excavated, but is solidified in place). The *ex situ* process involves excavating contaminated soil, sediment, or waste materials, mixing these with the binding agents and water, and placing the mixture in a location where it will harden and remain in perpetuity. Both processes create a stable, monolithic mass.

Pozzolan/Cement Stabilization – Screening Assessment	
Effectiveness	This form of stabilization is a proven technology for physically and chemically immobilizing metals. The effectiveness of the process depends partly on how it is implemented. *In situ* solidification may be locally incomplete, and depends on the ability of the injected grout to fully penetrate the contaminated mass prior to solidification. *Ex situ* solidification ensures more complete mixing but requires excavation and handling of the contaminated material.
Implementability	Chat piles are likely to be more amenable to in situ S/S due to the larger pore spaces within the material.
Cost	High.
Short- and Long-Term Risk	Short-term risks associated with both implementation methods include potential exposure to contaminants (very high likelihood for ex situ) and potential mobilization of contaminants by wind erosion as material is excavated and handled. In addition, short-term risks also include potential exposure to the binding agents. Short-term risks can be mitigated by proper health and safety procedures. Long-term risks cannot be evaluated but depend in part on the success of the process in creating a stable mass.
Summary of Assessment	S/S is expected to be moderately effective in creating a stable mass that reduces contaminant mobility. The result would be a very large volume of concrete-like material that would remain on-site. For tailings impoundments, S/S would be difficult to implement and likely be cost prohibitive, but it could potentially be used in small chat piles.
Retained for Development of Alternatives?	No.

5.4 GRA: *In Situ* Treatment

In situ treatment actions include technologies to treat, destroy, or tie up contaminants in place in order to minimize or prohibit their migration through the environment. Technologies are screened for both contaminated solids (applicable to soil, tailings, and sediment) and contaminated groundwater. Process options screened for their applicability to contaminated solids are phosphate stabilization and Bauxsol® addition. Process options applicable to contaminated shallow groundwater include injection of neutralizing agents and permeable reactive barrier technology.

5.4.1 Technology – In Situ Treatment of Contaminated Soil and Mine Waste

In situ treatment of contaminated soil and mine waste involves mixing appropriate chemical additives into the solids without excavating or removing them. This technology has shown limited success in treating mining wastes at several sites. Additives can be injected into the solids in liquid or slurried form, sprayed onto the surface of the solids and permitted to infiltrate, or tilled into the upper surface using standard earth moving equipment. The effectiveness of the technology depends on site-specific chemistry and the completeness of the mixing process.

5.4.1.1 Process Option – Phosphate Stabilization

Phosphate stabilization has been shown in laboratory settings to be capable of reducing the production and release of acid and dissolved metals from partly oxidized mine wastes. The process was demonstrated using commercial water-soluble fertilizer as a phosphate source and readily available industrial chemicals as an oxidizer and pH buffer (Harris and Lottermoser, 2006). These chemicals were applied in liquid form to the surface of test columns and created stable phosphate mineral coatings on sulfide grains in the interior of the mine waste, prohibiting further oxidation and release of copper, lead, and zinc (arsenic was not treated by this method). To date, this technique has apparently not been applied to full scale remediation and consequently remains unproven under field conditions.

***In Situ* Phosphate Stabilization – Screening Assessment**	
Effectiveness	Unknown. Under small lab tests, the process was shown effective in reducing the release of most base metals (arsenic was an exception) and in forming stable mineral coatings on sulfide grains prohibiting further oxidation. The effectiveness depends on the degree to which the treatment mix saturates the wastes and the presence of groundwater within tailings piles could decrease the effectiveness of this option.
Implementability	Could be implemented with relative ease, requiring commercial fertilizer and widely available industrial chemicals. Implementing would require a means to solubilize large quantities of these dry chemicals and apply the mix across the impoundment.
Cost	High.
Short- and Long-Term Risk	Unknown; potential risks associated with storing and handling large quantities of chemicals, including potassium permanganate, an oxidizer.
Summary of Assessment	A promising but unproven technology.
Retained for Development of Alternatives?	No.

5.4.1.2 Process Option – Bauxsol®

Bauxsol® (also referred to as "red mud") is a water and soil conditioner made by Virotec, an Australian company. It is the alkaline, solid residue from aluminum refining using the Bayer process that has been treated and partly neutralized. A variety of Bauxsol® reagents are available to treat acidic mine spoils and most work to bind metals into insoluble or less soluble forms. A formulation called ViroBind is designed to treat acid-sulfate soils contaminated with heavy metals. This formulation can be combined with various organic and inorganic additives on a site-specific basis to neutralize acid and bind metals into more insoluble, less bioavailable forms.

Similar to phosphate stabilization, this process has a limited case history to demonstrate its effectiveness. Results of applications on acidic copper mine tailings in EPA Region 1 found that it promoted vegetation growth. Studies in which Bauxsol® was applied to contaminated soil without additional biosolids amendments indicated that it increased soil salinity and had negative

impacts on the physical structure of soil (Maddocks et al., 2004). A test conducted on an acid-generating road cut in Pennsylvania found minor amounts of hexavalent chromium in leachate from a Bauxsol®-treated test plot, although the chromium was not definitively tied to the Bauxsol® reagent (Joseph, 2005).

***In Situ* Bauxsol® – Screening Assessment**	
Effectiveness	Unknown. Test plots indicate promising results, but full-scale application has not been attempted on sites in the U.S. (it has been used at mine sites in Australia, but data are unavailable to fully evaluate the effectiveness). Due to difficulty incorporating the reagent throughout the vertical extent of the tailings (see below) it would be effective only as a surface amendment, where it could potentially aid vegetation growth, decrease erosion, and reduce exposures.
Implementability	The reagent can be applied as a powder, slurry, or pellets. Solids are treated by spreading the reagent across the surface of the contaminated area, then incorporating it by tilling or mixing. This would make it difficult to mix the reagent into the deeper parts of the tailings deposit (including the portion below the water table).
Cost	High.
Short- and Long-Term Risk	Short-term risk includes increased exposure to site contaminants to workers during spreading and incorporating the reagent. These effects could be mitigated through health and safety protocols (health effects of the reagent are unknown, but not expected to be significant).
Summary of Assessment	A promising but unproven technology.
Retained for Development of Alternatives?	No.

5.4.2 Technology – In Situ Treatment of Shallow Groundwater

In situ treatment of shallow groundwater involves injecting appropriate chemical additives into contaminated groundwater within an aquifer or intercepting the flow of groundwater and directing it to flow through an area where treatment chemicals have been placed (reactive barriers). These technologies are used in a variety of settings to treat a range of inorganic and organic contaminants (EPA 1998; Blowes et al., 2003). The chemical character of shallow groundwater sampled in shallow soil borings in numerous locations in Madison County exhibits generally similar characteristics. These waters typically have neutral pH, concentrations of lead and arsenic that slightly exceed primary MCL and Action Level values, and concentrations of iron, manganese, and sulfate that slightly exceed secondary MCL values. Groundwater in the Catherine and Skaggs chat area has elevated concentrations of numerous metals, most notably cobalt, iron, lead, manganese, nickel, and zinc.

Treating shallow groundwater to lower the concentrations of metals in different locations would require a multi-step process. Since shallow groundwater has neutral pH, precipitation of iron may be accomplished by oxidizing the iron with or without further neutralization. The precipitation of ferric iron hydroxides would likely also reduce the concentrations of copper,

lead, and zinc through sorption or co-precipitation. However, metals such as cobalt, manganese, and nickel would likely require raising pH of the oxidized water to values above 8 or 9 s.u. (and possibly even more). Treatability studies would need to be conducted to determine an optimal treatment strategy.

5.4.2.1 Process Option – Injection of Treatment Agents

An oxidizing agent such as peroxide could be injected into shallow groundwater to oxidize iron into the ferric state. Alkaline agents such as sodium hydroxide or slurried lime could subsequently be injected to raise pH and remove other metals from solution. Injecting treatment agents directly into contaminated groundwater has been used at sites where changes in the oxidation state of the water are required to effect treatment (e.g., EPA 2000). In these cases, a grid of injection wells is created across the area of contamination, with grid spacing based on the hydrogeologic properties of the aquifer (closer spacing for less transmissive materials). Multiple injections were required to affect treatment.

For shallow groundwater in Madison County, the addition of an oxidizing agent could potentially increase the release of metals by increasing the rate of sulfide mineral oxidation, especially in tailings solids. This would require additional treatment and potentially higher doses of alkaline agents. This treatment process removes metals by the formation of stable hydroxides that precipitate in pore spaces within the aquifer. Consequently, precipitants may, over time, fill pore spaces and reduce transmissivity, making it more difficult to disperse treatment agents through the area of groundwater contamination.

Injection of Treatment Agents – Screening Assessment	
Effectiveness	The effectiveness of injecting treatment agents depends on the ability to disperse the agents throughout the vertical and horizontal extent of contamination. Because tailings material is comparatively fine grained, this may require closely spaced injection wells. Treating water to remove or reduce the concentrations of manganese, cobalt, and zinc may require raising pH to values above the MCL for pH and would leave extremely basic water. Reacidifying to bring pH into an acceptable range could potentially destabilize precipitated metal hydroxides causing dissolution. Issues with respect to iron oxidation discussed in the text also limit the effectiveness of this option as do potential issues of metal precipitation in the pore spaces of the aquifer.
Implementability	Implementation would require studies to determine minimum grid spacing for injection wells, installation of these wells, and means to mix and inject treatment agents into contaminated shallow groundwater. Slurried lime would be difficult to use as a neutralizing agent due the difficulty in dispersing the suspension through aquifer pore spaces. Injection systems require monitoring of the system and down-gradient groundwater to assess performance.
Cost	High.
Short- and Long-Term Risk	Short-term risk includes increased exposure to site contaminants to workers during well installation and potential exposures to treatment chemicals. These effects could be mitigated through health and safety protocols. Long-term effects could potentially include additional mobilization of metals during the oxidation step of treatment, potential plugging of pore spaces with precipitated metals which would reduce the ability to inject and disperse treatment chemicals over time, and the

	potential that treated water would have a pH above the MCL value.
Summary of Assessment	Injecting treatment agents could potentially be used to reduce metals concentrations in groundwater, but would require multiple treatment steps that would be difficult to monitor and control. Treatment is likely to require continuing actions, the success of which would be difficult to predict.
Retained for Development of Alternatives?	No.

5.4.2.2 Process Option – Permeable Reactive Barriers

Permeable reactive barrier (PRB) technology has been used to treat shallow contaminated groundwater at numerous sites (EPA 1998). In this process, treatment chemicals are placed into the path of migrating contaminated groundwater so that groundwater flows through the chemicals and receives treatment. Chemicals are contained by placement into excavated trenches or using other types of subsurface confinement such as grout walls. Groundwater flow may be directed through the barrier using funnel and gate or similar technology. The use of PRBs to treat groundwater in tailings impoundments is described by Blowes *et al*. (2003); the technology would be applied similarly in chat disposal areas.

PRBs use a variety of treatment techniques either singularly or in combination. General classes of treatment (and barrier technology) include chemical reduction, biologically mediated reduction, and adsorption. Chemical reduction barriers most commonly use the corrosion of zero valent iron (ZVI, also known as elemental iron) to cause chemical reduction and precipitation of metals as hydroxide and carbonate phases. Because iron is solubilized in the barrier, this treatment option can increase dissolved ferrous iron down-gradient. This technology could be expected to decrease the groundwater concentrations of most metals of concern, including manganese which may be precipitated as a carbonate.

Permeable Reactive Barriers – Screening Assessment	
Effectiveness	Varies depending on the type of barrier technology employed and site-specific chemistry. Biologically mediated reduction barriers and zero valent iron systems are likely to be most effective, but treatability studies are needed to determine whether these systems are capable of treating water to achieve remedial goals.
Implementability	Soil borings installed as part of the RI indicate that the water table is sufficiently shallow to permit use of this technology in some locations. PRBs can be installed with standard earthmoving equipment. Implementing this option requires bench- and pilot-scale testing to optimize barrier design. To treat shallow groundwater within tailings impoundments would require constructing a barrier perpendicular to the flow of groundwater which means building a barrier or funnel-and-gate system at least several hundred feet long at most sites. Implementing this technology also would require a relatively stable water table and sufficient hydraulic head so that water will continue to flow through the treatment system. Reactive barrier systems require monitoring of the system and down-gradient groundwater to assess performance.

Cost	High.
Short- and Long-Term Risk	Short-term risk includes increased exposure to site contaminants to workers during well installation and potential exposures to treatment chemicals. These effects could be mitigated through health and safety protocols. Long-term effects could potentially include failure of the system if it becomes plugged with precipitates or if treatment agents become exhausted. This would lead to no treatment of the groundwater. In addition, some systems may not treat all contaminants in the groundwater and they would continue to provide a source of long-term risk.
Summary of Assessment	Permeable reactive barrier technology could potentially be used to decrease the concentrations of many metals in area groundwater. To capture water flowing through the chat and tailings areas may require an extremely long system that would be very expensive to install and maintain. It is unclear that PRB technology would be capable of treating all contaminants found in groundwater at the site and whether site groundwater has a sufficiently stable water table elevation and sufficient head to enable the PRB to function properly.
Retained for Development of Alternatives?	No.

5.5 GRA: Collection and Treatment

Collection and treatment actions are applicable to surface water and groundwater and include a variety of technologies to collect contaminated water and treat it. The collection strategy for shallow groundwater would be to install one or more extraction wells. The collection strategy for surface water would be to divert surface water to a collection area from which it would be pumped or allowed to flow by gravity to treatment facilities. Two treatment technologies are screened for their applicability to the Madison Mine area: active treatment, in which water is chemically treated in an existing or constructed wastewater treatment plant and passive treatment, in which water is treated in a passive, biologically mediated treatment system.

5.5.1 Technology – Collection and Active Treatment

Active water treatment involves adding chemicals to either a continuous flow or batch of water to remove contaminants. Most treatment plants accepting water contaminated with heavy metals from mine sites use aeration, neutralization, flocculation, and clarification to remove metals. These processes generate a sludge that requires management and disposal; in some cases, sludge must be handled and disposed of as a hazardous waste. Treated water is typically released to an appropriate receiving stream through a permitted outfall.

5.5.1.1 Process Option – On-Site Treatment

A treatment plant constructed specifically to treat contaminated surface water and groundwater at any particular location would require a system to collect contaminated water and route it to the treatment plant; storage for chemical reagents; tanks and piping to effect the treatment; a settling basin or clarifier; a process for collecting, handling, and disposing of sludge; and a system to dispose of the treated water. Treatability study testing would be required to

determine the optimal process to treat water to within acceptable limits. Plants at many other mining-impacted sites use aeration and neutralization with either lime or sodium hydroxide to precipitate metals. Manganese removal may require a multi-step treatment process in which pH is raised to values of 9 to 11 standard units (s.u.) to precipitate manganese hydroxide. This would require pH adjustment (acidification) to lower pH to acceptable levels prior to discharge to nearby surface water. Metal-rich sludge that settles in the bottom of a settling basin or clarifier would require leach testing to determine if it possesses the characteristics of a hazardous waste. Non-hazardous sludge could be disposed in an on-site landfill or dried and shipped to a permitted landfill. If the sludge were deemed hazardous, disposal would require construction of an on-site hazardous waste repository or shipment to an off-site hazardous waste landfill. Discharge of treated water would require meeting the substantive requirements of a new source National Pollutant Discharge Elimination System (NPDES) permit.

Contaminated groundwater at most locations in the Madison Mine area has neutral pH but concentrations of arsenic, lead, iron, manganese, and sulfate that exceed their primary or secondary MCL or Action Level values. Plants that remove metals by aeration and neutralization typically achieve reductions in arsenic, lead, and certain other base metals by sorption onto precipitating iron and aluminum hydroxide minerals or co-precipitation as hydroxide phases. Aeration and neutralization processes are only partly effective in removing manganese unless operating pH is raised to values above 9 s.u. and they are generally ineffective in removing sulfate. To some extent, the nucleation of iron and aluminum hydroxides during neutralization and their effective settling is related to the concentrations of these metals in the untreated feed water. The low to moderate concentrations of iron and aluminum in site groundwater may inhibit effective settling of sludge, requiring use of coagulants and flocculants to aid separation.

An on-site ion exchange treatment plant could also be used to remove metals. The contaminated water would be pumped through ion exchange columns containing resins that remove the metals. After the resin has been exhausted and cannot accomplish any further ion exchange, the columns with the spent resin would be transported back to the supplier to be regenerated. The ion exchange process would not generate sludge and may require less operation than treatment processes that use pH adjustment and precipitation of metals. At low flows, an ion exchange process may be less expensive than a process that uses pH adjustment and metals precipitation.

Alternatively, treatment plants could be constructed using technologies such as reverse osmosis (semi-permeable membrane separation) or activated charcoal filtration to treat contaminated water on-site. Although capable of generating treated water with lower constituent concentrations, these systems pose alternative issues to resolve. A reverse osmosis system would generate a waste stream of concentrated solute that would require disposal and a charcoal

filtration plant would require reactivation or replenishment of spent charcoal and the consequent handling and disposal of reactivated chemicals and charcoal waste. Capital costs and operating costs for reverse osmosis and charcoal filtration plants are expected to be significantly higher than for an aeration and neutralization plant.

On-Site Active Treatment – Screening Assessment	
Effectiveness	These technologies could be used to treat contaminated groundwater generated from dewatering activities during excavation of the chat. Expected to range from being moderately effective to highly effective in removing metals and other contaminants depending on the technology used. The effectiveness of a neutralization plant is unclear due to low iron concentrations in contaminated water.
Implementability	Implementing this option would require constructing a new treatment plant on-site, including the required collection system and piping, retention and settling ponds, clarifiers, and discharge piping. It would also require meeting the substantive requirements of a new source NPDES permit. These options also would require a dedicated amount of funding for O&M, including salary for a plant operator, reagent purchase, and sludge disposal costs. Treatability testing would be required to select the best technology to use and all technologies will produce a waste stream that must be handled and disposed of.
Cost	Medium.
Short- and Long-Term Risk	Short-term risk includes increased exposure to site contaminants to workers installing the collection system, particularly for groundwater. These effects could be mitigated through health and safety protocols. Long-term effects are not expected to be significant but cannot be quantified at this point.
Summary of Assessment	Some active treatment technologies would likely be effective in removing contaminants, others less so. All require substantial capital outlays and significant operational budgets making them an unattractive option. Active treatment produces one or more waste streams that would require handling and disposal and would require a new source NPDES permit to permit discharge of treated water.
Retained for Development of Alternatives?	Yes.

5.5.1.2 Process Option – Off-Site Treatment at POTW

Contaminated surface water and groundwater in the Madison Mine area could be collected and pumped to the Fredericktown municipal wastewater treatment plant. This plant uses oxidation ditch technology to treat municipal waste and disposes of treatment sludge by land application (MDNR, 2005b). This would require constructing one or more pipelines to the nearest tie-in point to the municipal system and one or more pumping stations to push water through the piping system.

Off-Site Active Treatment – Screening Assessment	
Effectiveness	Decreases in metal concentrations are expected to occur, although the effectiveness of oxidation ditch technology in treating heavy metals is unknown. Metals would sorb to the sludge and could potentially be released to the environment as the sludge breaks down under land application conditions.
Implementability	Implementing this option would require collecting surface and groundwater for treatment and pumping this water through a newly constructed pipeline of a mile or more in length to tie into the municipal wastewater system.

Cost	High
Short- and Long-Term Risk	Short-term risk includes increased exposure to site contaminants to workers installing the collection system, particularly for groundwater. These effects could be mitigated through health and safety protocols. Long-term effects are not expected to be significant but cannot be quantified at this point.
Summary of Assessment	The Fredericktown POTW could be used to treat contaminated water from the site but would require constructing a mile or more of pipeline and a pumping station to convey water for treatment. The effectiveness of the oxidation ditch technology at the POTW for removing metals is unknown but is expected to provide some benefit. However, removed metals would sorb to the sludge and might be re-released to the environment as the sludge breaks down during land application.
Retained for Development of Alternatives?	No.

5.5.2 Technology – On-Site Passive Treatment

Passive water treatment describes technologies that can function for significant periods of time (years to decades) without substantial operation and maintenance. Passive treatment is used increasingly to treat mine drainage associated with metal mines and, especially coal mines. Unlike active systems that use chemical processes to generate a heavy metal sludge, passive systems rely primarily on biochemical processes to precipitate metals that remain within the passive treatment structure (e.g., Walton-Day, 2003). Because contaminated groundwater within most areas of Madison County is net alkaline, passive systems such as anoxic limestone drains, sulfate-reducing bioreactors, and similar technologies used for treating acidic water will not be considered. The only treatment option that will be considered for use at the Madison County Mines sites is a constructed wetlands-based system. Similar to active systems, treated water from passive systems is typically released to an appropriate receiving stream through a permitted outfall. Passive systems commonly have a design life of 25 years and would require cleanout and reconstruction after that time.

5.5.2.1 Process Option – Compost Wetlands and Aerobic Rock Filter

Passive treatment of contaminated groundwater and surface water at the Catherine and Skaggs OU5 site could be accomplished using a multi-step passive process to remove metals and sulfate. Water from the affected areas could be collected using a seepage collection system that would convey water by gravity to the treatment system. In the first step of the treatment process, water would flow into a compost wetland that consists of a constructed pond with a substrate mix of various types of organic material (common mixtures use composted manure, straw, wood chips, and similar materials) and limestone. Water flow is directed vertically down through the substrate. Naturally occurring bacteria in the substrate create reducing conditions that break down sulfate into aqueous sulfide which then combines with iron and other metals to form stable sulfide precipitates within the substrate. This process will remove sulfate and metals such as arsenic, lead, and iron from solution. Water discharged from the compost wetland would be

routed to an aerobic pond to gain dissolved oxygen and permit precipitation of remaining iron as a hydroxide. Oxygenated water would then be sent to a rock filter in which manganese would be removed as oxide precipitates by certain strains of bacteria and algae. Water passing through the rock filter would be released to an appropriate surface water body.

Passive systems have comparatively high initial construction costs (typically higher than comparable active systems) but require significantly less maintenance and upkeep. Passive treatment systems are constructed in accordance with engineered designs that are based on treatability studies that evaluate the effectiveness and longevity of various substrate mixes, required residence times, and other design criteria. These systems require comparatively steady influent flows and, depending on the quality of influent water, a significant amount of land (several acres is not uncommon). Passive systems require periodic monitoring to ensure that they continue to function as intended.

Passive Treatment – Screening Assessment	
Effectiveness	Passive systems have been demonstrated to provide effective treatment for water contaminated with heavy metals and sulfate in mine settings. Treatment typically requires a several step process to achieve reductions in the metals of concern. Effective treatment requires that the flow of water and load of metals into the system remain relatively constant; systems that dry out due to lack of water can fail and those that are overloaded with metals can provide only partial treatment. Treatability study tests are required to determine whether passive treatment would be capable of lowering all metals in Madison Mine water to concentrations that could be discharged to surface water.
Implementability	Implementing this option would require treatability studies to assist in the engineering design of the system, construction of seepage collection systems, and construction of the treatment cells. Discharge of treated water to an appropriate receiving water would require meeting the substantive requirements of a new source NPDES permit. Periodic monitoring (perhaps quarterly) would be required to ensure continued function.
Cost	Medium.
Short- and Long-Term Risk	Short-term risk includes increased exposure to site contaminants to workers installing the collection system, particularly for groundwater. These effects could be mitigated through health and safety protocols. Long-term effects are not expected to be significant but cannot be quantified at this point. However, failure of the system would lead to the discharge of untreated or partly treated water and the system would need to be reconstructed at the end of its design life.
Summary of Assessment	Passive treatment technologies would likely be effective in removing most contaminants found in shallow groundwater. This option would require a substantial capital outlay but only a modest operational budget (primarily for monitoring). Passive treatment does not produce a continuous waste stream, but would require periodic reconstruction as the substrate fills with precipitated metals (removal of the spent substrate would require appropriate handling and disposal). A passive system would require a significant amount of land and a new source NPDES permit to permit discharge of treated water.
Retained for Development of Alternatives?	Yes.

5.6 GRA: Removal and Disposal

Removal and disposal actions are applicable to contaminated soil, mine waste, and sediment. Removal actions are limited to excavation and hauling using standard earthmoving equipment. Disposal actions include off-site hazardous and non-hazardous waste landfills and an on-site waste repository.

5.6.1 Technology – Disposal in an Off-Site Non-Hazardous Waste Landfill

Removal and disposal in an off-site non-hazardous waste landfill could be used to reduce exposures to chat and other mine waste materials. Tailings, chat and other mine wastes produced through the extraction and beneficiation of ore are exempt from regulation under Subtitle C of the RCRA as a hazardous waste by the Bevill Amendment. Consequently, chat could be transported to a non-hazardous waste landfill for disposal. However, it is unlikely that a non-hazardous waste landfill would accept these materials because, except for the exemption from RCRA by the Bevill amendment, they may be a characteristic hazardous waste.

Off-Site Non-Hazardous Waste Landfill Disposal – Screening Assessment	
Effectiveness	Excavation of tailings, chat, or contaminated soil and their disposal in a non-hazardous waste landfill would be effective in reducing exposure to site contaminants.
Implementability	Excavation could be accomplished using standard earthmoving equipment. Transport to a non-hazardous waste landfill would require haul trucks. The large volume of chat would require a large number of round trips. Depending on the site layout, some amount of clean soil may be required for backfilling and seeding.
Cost	Medium.
Short- and Long-Term Risk	Short-term risk includes increased exposure to site contaminants to workers excavating, loading, and transporting chat. These effects could be mitigated through health and safety protocols. Long-term risks could occur from tailings that are blown from the loads during transport and deposited along roadways. Long-term risks could occur from leaching of lead from the chat after placement in a non-hazardous landfill.
Summary of Assessment	Removal of contaminants from the site and sequestering them in a regulated landfill setting would be an effective means to reduce exposure to site contaminants. The large estimated volume of chat would take a significant amount of time to complete the removal action.
Retained for Development of Alternatives?	No.

5.6.2 Technology – Disposal in an Off-Site Hazardous Waste Landfill

Samples of tailings, chat, and other materials collected at the Skaggs and Catherine OU5 sites that exhibited the characteristic of hazardous waste could be disposed of in a landfill permitted under RCRA to accept this type of waste. The nearest RCRA-permitted hazardous

waste landfills are in Illinois and Alabama. These materials would be excavated to a depth where contamination is not known to be present and transported to the RCRA landfill.

Hazardous Waste Landfill Disposal – Screening Assessment	
Effectiveness	Excavation of chat, contaminated soil, and sediment and their disposal in a permitted hazardous waste landfill would be effective in reducing exposure to these hazardous site contaminants.
Implementability	Excavation of soil could be accomplished using standard earthmoving equipment. Transport to a hazardous waste landfill would require haul trucks and compliance with all applicable DOT, EPA, and state regulations during excavation, transport, and disposal.
Cost	High.
Short- and Long-Term Risk	Short-term risk includes increased exposure to contaminants to workers excavating, loading, and transporting contaminated material. These effects could be mitigated through health and safety protocols. Long-term risks are not anticipated.
Summary of Assessment	Removal of contaminants from the site and sequestering them in a regulated landfill setting would be an effective means to reduce exposure to site contaminants.
Retained for Development of Alternatives?	Yes.

5.6.3 Technology – Disposal in an On-Site Repository

Excavation and disposal in an on-site repository could be used to reduce exposures to the majority of the chat, soils, and sediment in OU5. Since these materials are exempt from regulation under RCRA Subtitle C, they would not have to be managed as a hazardous waste. Consequently, the on-site repository base liner could be designed to meet the requirements of a Subtitle D landfill.

The onsite repository would include a basal liner system with leachate collection, and an upper Subtitle C cap that consists of a low permeability liner, geomembrane, drainage layer, protective soil layer, and vegetated cover, and a leakage monitoring system. This process creates a structure in which the hazardous materials are “entombed” and leakage from the repository can be detected and monitored.

On-Site Repository – Screening Assessment	
Effectiveness	Excavation of tailings and contaminated soils and sediments and their disposal in an on-site repository constructed to RCRA Subtitle C or Subtitle D landfill standards would be effective in reducing exposure to these site contaminants.
Implementability	Construction of a repository could be accomplished using standard earthmoving equipment. A repository would require identifying an appropriate parcel of land on the site, completing an engineering design for the repository, and constructing the facility using appropriate materials and construction techniques. A repository located at an existing tailings impoundment or chat pile, would require these materials to be moved and temporarily relocated while the repository was constructed. This would increase the difficulty of constructing the repository. The engineering design would also specify monitoring requirements.
Cost	High.

Short- and Long-Term Risk	Short-term risk includes increased exposure to contaminants to workers excavating, loading, and transporting contaminated soil. These effects could be mitigated through health and safety protocols. Long-term risks could occur if the containment system fails or if the monitoring program is not carried out in a manner that permits any leakage to be detected and dealt with in a timely manner.
Summary of Assessment	Removal of contaminants from the site and sequestering them in an on-site repository would be an effective means to reduce exposure to site contaminants. This option would permanently remove a portion of the site from beneficial reuse since the repository would require access restrictions.
Retained for Development of Alternatives?	Yes.

5.7 GRA: Removal, Treatment, and Disposal

Removal, treatment, and disposal actions are applicable to contaminated soil, mine waste, sediment, groundwater, and surface water. Those actions applicable to groundwater and surface water are discussed in Section 5.5. Removal actions for solids (soil, mine waste, and sediment) are limited to excavation and hauling using standard earthmoving equipment. Disposal actions are similar to those described in Section 5.6 and include off-site hazardous and non-hazardous waste landfills and an on-site hazardous waste repository. Treatment options are considered for mill tailings and sediment and soil contaminated with tailings, and soil contaminated with other chemicals.

5.7.1 Technology – Ex Situ Treatment of Tailings and Chat, Tailings and Chat-Contaminated Soil and Sediment

Ex situ treatment of contaminated soil and chat involves excavating and removing the mine wastes, mixing appropriate chemical additives into these materials, and disposing of the treated solids either in the same location or in a new location on-site. The intent of treating the solids prior to their disposal is to bind heavy metals into less soluble or mobile forms, permitting a lower level of capping technology to be used in their final placement.

Case studies where entire chat piles have been excavated, treated, and replaced have not been found. However, the process at OU5 could be accomplished using standard earthmoving equipment. *Ex situ* treatment permits the mixing and treatment process to be managed and controlled to ensure complete incorporation of treatability reagents with the tailings solids.

5.7.1.1 Process Option – Phosphate Stabilization

Phosphate stabilization is described in Section 5.4.1.1. *Ex situ* application of phosphate and other stabilizing agents would permit more complete mixing of treatment reagents with chat solids.

Ex Situ Phosphate Stabilization – Screening Assessment	
Effectiveness	Unknown. Under small lab tests, the process was shown effective in reducing the release of most base metals (arsenic was an exception) and in forming stable mineral coatings on sulfide grains prohibiting further oxidation.
Implementability	Implementation would require considerable effort to excavate, mix, and replace the large volume of chat present in OU5. The lower portions of the mine waste could require de-watering so that the mine waste could be excavated and handled. This would require managing an unknown quantity of contaminated groundwater derived from the dewatering process. Treatment could be effected using commercial fertilizer and widely available industrial chemicals.
Cost	High.
Short- and Long-Term Risk	Unknown; potential risks associated with storing and handling large quantities of chemicals, including potassium permanganate, an oxidizer.
Summary of Assessment	A promising but unproven technology.
Retained for Development of Alternatives?	No.

5.7.1.2 Process Option – Bauxsol® Stabilization

Bauxsol® stabilization is described in Section 5.4.1.2. *Ex situ* application of Bauxsol® would permit its more complete incorporation into the mine waste solids.

Ex Situ Bauxite® Stabilization – Screening Assessment	
Effectiveness	Unknown. Test plots indicate promising results, but full-scale application has not been attempted on sites in the U.S. *Ex situ* stabilization is expected to be more effective than *in situ* application because the reagent (which is a solid) could be combined more completely through the vertical extent of the mine waste.
Implementability	Implementation would require considerable effort to excavate, mix, and replace the large volume of mine waste present in OU5. The lower portions of the mine waste could require de-watering so that the mine waste could be excavated and handled. This would require managing an unknown quantity of contaminated groundwater derived from the dewatering process. The reagent can be applied as a powder, slurry, or pellets and mechanically mixed into the mine waste.
Cost	High.
Short- and Long-Term Risk	Short-term risk includes increased exposure to site contaminants to workers during spreading and incorporating the reagent. These effects could be mitigated through health and safety protocols (health effects of the reagent are unknown, but not expected to be significant).
Summary of Assessment	A promising but unproven technology.
Retained for Development of Alternatives?	No.

6.0 Development of Alternatives

This section describes alternatives that are recommended for detailed analysis. These alternatives were developed using technologies and process options that passed the screening analysis in Section 5. The alternatives include a "No Action" alternative which is required for all sites by the NCP in 40 CFR §300.430(e)(6). The FS will analyze each of these alternatives in detail using the nine criteria specified by EPA (EPA 1988a).

6.1 OU5 - Catherine and Skaggs Subsites

6.1.1 Catherine Subsite

The following sections review the technologies and process options passing the screening analysis that can be applied to the three sub-areas at the Catherine subsite. Alternatives are then developed using options applicable to each of the three sub-areas. The three sub-areas are shown on Figure 6-1 and include:

- Sub-Area No. 1 - The chat pile including the subsoil below the chat, groundwater below the chat area and chat eroded from the chat pile.
- Sub-Area No. 2 - The Catherine Pond and the sediment within the pond.
- Sub-Area No. 3 - The channel and floodplain of Logtown Branch to the point where contaminant concentrations in floodplain soil and sediment are below action levels.

Sub-Area 1: Catherine Chat Pile

Table 6-1 summarizes the technologies and process options that passed initial screening that could be applied to the chat area, including contaminated groundwater below the chat.

Table 6-1 Remedial Technologies and Process Options Retained for Inclusion in Alternatives for the Catherine Chat Area		
GRA	**Remedial Technology**	**Process Option**
Chat, Eroded Chat, and Contaminated Soil		
No Action	None	
Institutional Controls	Legal Restrictions	Land Use & Deed Restrictions
	Access Restrictions	Fencing & Signage
Containment	Cap and Cover	Permeable Cover
		Low Permeable Cap
	Drainage and Erosion Control	Grade & Contour
		Runoff Management
		Vegetation
Groundwater		
No Action	None	
Institutional Controls	Legal Restrictions	Groundwater Use

Sub-Area 2: Catherine Pond

Table 6-2 summarizes the technologies and process options that passed initial screening that could be applied to the Catherine Pond.

Table 6-2 Remedial Technologies and Process Options Retained for Inclusion in Alternatives for the Catherine Pond		
GRA	**Remedial Technology**	**Process Option**
Sediment		
No Action	None	
Institutional Controls	Legal Restrictions	Land Use & Deed Restrictions
	Access Restrictions	Fencing & Signage
Removal and Disposal	Excavation; Disposal at Catherine Repository	Low Permeable Cap
		Permeable Cap

Sub-Area 3: Logtown Branch

Table 6-3 summarizes the technologies and process options that passed initial screening that could be applied to Logtown Branch. It includes contaminated surface water, sediment, and floodplain soil.

Table 6-3 Remedial Technologies and Process Options Retained for Inclusion in Alternatives for Logtown Branch		
GRA	**Remedial Technology**	**Process Option**
No Action	None	
Institutional Controls	Legal Restrictions	Land Use & Deed Restrictions
	Access Restrictions	Signage
Containment	Drainage and Erosion Control	Grade & Contour
		Runoff Management
		Stream Channel and Bank Stabilization
		Vegetation
Removal and Disposal	Excavation; Disposal at Local Repository	Low Permeable Cap
		Permeable Cap
Monitored Natural Recovery	Monitoring Prior to and Following Source Control	Surface Water and Sediment Monitoring

6.1.1.1 Proposed Alternatives for the Catherine Subsite

This section describes alternatives for the Catherine subsite that have been developed from the process options for each of the three sub-areas described above. Since the Catherine subsite is an existing repository for approximately 205,500 cu yd of lead contaminated soil from residential properties in Madison County, the alternatives for this subsite include an engineered low permeable cap to cover the repository. The alternatives are summarized in Table 6-4.

6.1.1.1.1 Alternative 1 – No Action

Under a No Action alternative, the site would remain in its present condition, with no actions being taken to control or mitigate contamination or to prevent exposure to contaminants in the environment.

6.1.1.1.2 Alternative 2 – Institutional Controls

Under the Institutional Controls alternative, RAOs would be addressed solely through the application of a variety of institutional controls. A combination of land use and deed restrictions, and fencing and signage would be used to restrict access and limit exposure to chat and contaminated soil at the Catherine subsite.

The Catherine Pond would be fenced and signs would be placed at the fence to restrict access to the contaminated sediments. Signs would not be required along the Logtown Branch since the metal concentrations do not exceed the action levels for protection of human health.

Groundwater use restrictions would be used to limit exposure to contaminated shallow groundwater within the Catherine chat area.

Groundwater monitoring would be performed to determine if shallow contaminated groundwater was migrating from the site. It is assumed that one upgradient monitoring well and 3 downgradient monitoring wells would be installed. All of the monitoring wells would be sampled semi-annually for the first 2 years and annually thereafter for 3 years unless EPA determined that the shallow groundwater was migrating from the site. In that event, the groundwater monitoring would be continued. It is assumed that the groundwater monitoring wells would be approximately 20 feet deep and groundwater samples would be analyzed for TAL metals.

Surface water and sediment samples would be collected from two locations on Logtown Branch and from one location in the Catherine Pond. The surface water and sediment in Logtown Branch and the Catherine Pond would be sampled annually for 5 years unless EPA determined that they were still impacted by the chat. Surface water samples would be analyzed for total and dissolved TAL metals and sediment samples would be analyzed for TAL metals.

6.1.1.1.3 Alternative 3 – Low Permeable Cap, Sediment Excavation and Onsite Disposal, Monitored Natural Recovery

Under Alternative 3, the chat area would be graded, contoured, and covered with a low permeable cap. Chat would not be excavated and moved as part of this alternative. Prior to capping, contaminated sediment in the Catherine Pond would be excavated, dewatered, and transported to the chat area for placement under the cap.

The low permeable cap would consist of the following components:

- A 1-foot thick clay liner (A low permeable GCL may be substituted if sufficient clay is not available locally).
- A 6-inch vegetative soil layer.
- Vegetated cover.

The site area would be cleared and grubbed and the chat pile would be graded to the appropriate slope and shape for closure. Grading the site would remove localized fingers along the perimeter of the chat. This would be performed by excavating the material from the chat or placement of additional contaminated material excavated on-site. The chat would be graded to the contours necessary to direct storm water from the capped area to natural drainage.

The subgrade for the clay liner would be compacted to support the cap system and a clay liner would be placed over the prepared subgrade. A 6-inch soil layer with sufficient organics to support vegetation would be placed over clay liner. The top of the cover would be vegetated to

provide long term erosion control. The vegetation selected would be compatible with the local climate and require low maintenance. Construction of the low permeable cap would require 7 to 9 months.

Access to the capped area would be controlled by fences and signs, and legal controls (deed restrictions) would be placed on the property to prevent uses that could disturb the cap. A cap monitoring program would be designed and implemented to ensure establishment of vegetation and the continued integrity of the facility. Periodic maintenance would be required to repair the cap and maintain the vegetation on the cap. Groundwater use restrictions would be employed to prevent future consumptive use.

Following removal of contaminated material from the Catherine Pond, bank restoration/stabilization measures would be implemented and damaged areas would be backfilled with topsoil and vegetated or seeded with native species.

MNR would be implemented at Logtown Branch to determine if the lead concentration in the sediment will achieve the action level without active remediation. There is insufficient information at the present time to determine whether the sediment in the stream would achieve action levels without additional remedial actions such as dredging or the installation of barriers in the stream to encourage the deposition of clean sediment. However, until the mine wastes from the source area are controlled, use of these technologies to remediate the streams would not be appropriate because the streams would continue to be contaminated by mine wastes from the source area. Implementation of MNR would enable the natural recovery process to be evaluated until the source area is controlled. After the source area is controlled, additional remedial actions at the stream would be evaluated if MNR does not appear to be successful. Surface water and sediment samples would be collected from one location in Logtown Branch to determine if the mine wastes were continuing to impact the surface water and sediment. The surface water and sediment would be sampled annually for at least 5 years (10 years total assuming that the source areas are controlled within 5 years) following control of the source areas to determine whether the MNR is successful. Surface water samples would be analyzed for total and dissolved TAL metals and sediment samples would be analyzed for TAL metals.

Groundwater monitoring would be performed to determine if shallow contaminated groundwater was migrating from the site. It is assumed that one upgradient monitoring well and three downgradient monitoring wells would be installed. All of the monitoring wells would be sampled semi-annually for the first 2 years and annually thereafter for 3 years or until EPA determined that the shallow groundwater was not migrating from the site. It is assumed that the groundwater monitoring wells would be approximately 20 ft. deep and groundwater samples would be analyzed for TAL metals.

Surface water and sediment samples would be collected from one location in Catherine Pond. The surface water and sediment would be sampled annually for 5 years or until EPA

determined that surface water and sediment at the site were not impacted by the chat. Surface water samples would be analyzed for total and dissolved TAL metals and sediment samples would be analyzed for TAL metals.

6.1.1.1.4 Alternative 4 – Engineered Low Permeable Cap, Sediment Excavation and Onsite Disposal, Monitored Natural Recovery

Under Alternative 4, the chat area would be graded, contoured, and covered with an engineered low permeable cap. Chat would not be excavated and moved as part of this alternative. Prior to capping, contaminated sediment in the Catherine Pond would be excavated and transported to the chat area for placement under the cap.

The low permeable cap would consist of the following components:

- A low permeability, less than 1 x 10^{-7} cm/sec, two foot thick natural clay or amended soil liner or geosynthetic clay liner (GCL) as a substitute.
- A geomembrane, 60 mil HDPE, low density polyethylene (LDPE) or 30 mil polyvinyl chloride (PVC).
- Drainage layer.
- A protective soil cover.
- A vegetative soil layer.
- Vegetated cover.

The site area would be cleared and grubbed and the chat pile would be graded to the appropriate slope and shape for closure. Grading the site would remove localized fingers along the perimeter of the chat. This would be performed by excavating the material from the chat or placement of additional contaminated material excavated on-site. The chat would be graded to the contours necessary to direct storm water from the capped area to natural drainage.

The subgrade for the clay liner or GCL would be compacted to support the cap system and a clay liner or GCL would be placed over the prepared subgrade. The geomembrane would be placed and seamed over the clay liner/GCL. The geomembrane material is anticipated to be a 60 mil HDPE or LDPE. A drainage system would be installed over the geomembrane to reduce the hydraulic head on the lining system due to infiltration through the soil cover. The drainage layer may consist of a granular layer with geotextile cushion and filter layer or a geocomposite drainage layer along with the drainage piping system. The drainage layer would cover the entire geomembrane cap.

An 18-inch thick protective soil cover would be placed over the drainage layer. The material would be placed in lifts to prevent damage to the underlying cap materials. A soil layer with sufficient organics to support vegetation would be placed over the protective soil layer. The

top of the cover would be vegetated to provide long term erosion control. The vegetation selected would be compatible with the local climate and require low maintenance. Construction of the low permeable cap would require 9 to 10 months.

Access to the capped area would be controlled by fences and signs, and legal controls (deed restrictions) would be placed on the property to prevent uses that could disturb the cap. A cap monitoring program would be designed and implemented to ensure establishment of vegetation and the continued integrity of the facility. Periodic maintenance would be required to repair the cap and maintain the vegetation on the cap. Groundwater use restrictions would be employed to prevent future consumptive use.

Following removal of contaminated material from the Catherine Pond, bank restoration/stabilization measures would be implemented and damaged areas would be backfilled with topsoil and vegetated or seeded with native species.

MNR would be implemented at Logtown Branch to determine if the lead concentration in the sediment will achieve the action level without active remediation. There is insufficient information at the present time to determine whether the sediment in the stream would achieve action levels without additional remedial actions such as dredging or the installation of barriers in the streams to encourage the deposition of clean sediment. However, until the mine wastes from the source area are controlled, use of these additional technologies to remediate the stream would not be appropriate because the stream would continue to be contaminated by mine wastes from the source area. Implementation of MNR would enable the natural recovery process to be evaluated until the source area is controlled. After the source area is controlled, additional remedial actions at the stream would be evaluated if MNR does not appear to be successful. Surface water and sediment samples would be collected from one location in Logtown Branch to determine if the mine wastes were continuing to impact the surface water and sediment. The surface water and sediment would be sampled annually for at least 5 years (10 years total assuming that the source areas are controlled within 5 years) following control of the source areas to determine whether the MNR is successful. Surface water samples would be analyzed for total and dissolved TAL metals and sediment samples would be analyzed for TAL metals.

Groundwater monitoring would be performed to determine if the shallow groundwater at was migrating from the site. It is assumed that one upgradient monitoring well and three downgradient monitoring wells would be installed. All of the monitoring wells would be sampled semi-annually for the first 2 years and annually thereafter for 3 years or until EPA determined that the shallow groundwater was not migrating from the site. It is assumed that the groundwater monitoring wells would be approximately 20 ft. deep and groundwater samples would be analyzed for TAL metals.

Surface water and sediment samples would be collected from one location in Catherine Pond. The surface water and sediment would be sampled annually for 5 years or until EPA

determined that surface water and sediment at the site were not impacted by the chat. Surface water samples would be analyzed for total and dissolved TAL metals and sediment samples would be analyzed for TAL metals.

6.1.2 Skaggs Subsite

The following sections review the technologies and process options passing the screening analysis that can be applied to the two sub-areas at the Skaggs subsite. Alternatives are then developed using options applicable to each of the two sub-areas. The two sub-areas are shown on Figure 6-2 and include:

- Sub-Area No. 1 – The east, west, and central chat piles including the subsoil below the chat, groundwater below the chat areas and chat eroded from the chat piles.
- Sub-Area No. 2 - The sediments and the floodplain soils in and along the unnamed tributary stream south-southwest of the chat pile from its headwaters to the confluence with Plum Creek and the sediments of the unnamed tributary stream east of the Skaggs pile from its headwaters east to the point where contaminant concentrations in sediments are below the action levels. Also included are the sediments in the small pond southwest of the chat pile.

<u>Sub-Area 1: Skaggs Chat Piles</u>

Table 6-5 summarizes the technologies and process options that passed initial screening that could be applied to the chat area, including contaminated groundwater below the chat.

Table 6-5 Remedial Technologies and Process Options Retained for Inclusion in Alternatives for the Skaggs Chat Area

GRA	Remedial Technology	Process Option
Tailings, Eroded Tailings and Sediment, Contaminated Soil		
No Action	None	
Institutional Controls	Legal Restrictions	Land Use & Deed Restrictions
	Access Restrictions	Fencing & Signage
Containment	Cap and Cover	Permeable Cover
		Low Permeable Cap
	Drainage and Erosion Control	Grade & Contour
		Runoff Management
		Vegetation
Removal and Disposal	Off-Site Non-Hazardous or Hazardous Waste Landfill	

Groundwater		
No Action	None	
Institutional Controls	Legal Restrictions	Groundwater Use

Sub-Area 2: Unnamed Tributaries

Table 6-6 summarizes the technologies and process options that passed initial screening that could be applied to the unnamed tributaries that drain south-southwest and east from the Skaggs chat area. It includes contaminated surface water, sediment, and floodplain soil.

Table 6-6 Remedial Technologies and Process Options Retained for Inclusion in Alternatives for the Unnamed Tributaries and Unnamed Pond at the Skaggs Subsite

GRA	Remedial Technology	Process Option
No Action	None	
Institutional Controls	Legal Restrictions	Land Use & Deed Restrictions
	Access Restrictions	Signage
Containment	Drainage and Erosion Control	Grade & Contour
		Runoff Management
		Stream Channel and Bank Stabilization
		Vegetation
Removal and Disposal	Off-Site Non-Hazardous or Hazardous Waste Landfill	
	Excavate and Cap	Low Permeable Cap
		Permeable Cap
Monitored Natural Recovery	Monitoring Prior to and Following Source Control	Surface Water and Sediment Monitoring

6.1.2.1 Proposed Alternatives for the Skaggs Subsite

This section describes alternatives for the Skaggs subsite that have been developed from the process options for each of the two sub-areas described above. The alternatives are summarized in Table 6-7.

6.1.2.1.1 Alternative 1 – No Action

Under a No Action alternative, the site would remain in its present condition, with no actions being taken to control or mitigate contamination or to prevent exposure to contaminants in the environment.

6.1.2.1.2 Alternative 2 – Institutional Controls

Under the Institutional Controls alternative, RAOs would be addressed solely through the application of a variety of institutional controls. A combination of land use and deed restrictions, and fencing and signage would be used to restrict access and limit exposure to chat and contaminated soil at the Skaggs subsite.

Signs would be placed along the unnamed tributaries to discourage exposure to contaminated soils and sediments. Groundwater use restrictions would be used to limit exposure to contaminated shallow groundwater within the Skaggs chat areas.

Groundwater monitoring would be performed to determine if the shallow groundwater was migrating from the site. It is assumed that one upgradient monitoring well and 3 downgradient monitoring wells would be installed. All of the monitoring wells would be sampled semi-annually for the first 2 years and annually thereafter for 3 years unless EPA determined that the shallow groundwater was migrating from the site. In that event, the groundwater monitoring would be continued. It is assumed that the groundwater monitoring wells would be approximately 20 feet deep and groundwater samples would be analyzed for TAL metals.

Surface water and sediment samples would be collected from two locations on both of the unnamed tributaries at the Skaggs subsite. The surface water and sediment would be sampled annually for five years. Sampling would continue after the initial five year period if EPA determined that the unnamed tributaries were continuing to be impacted by the chat. Surface water samples would be analyzed for total and dissolved TAL metals and sediment samples would be analyzed for TAL metals.

6.1.2.1.3 Alternative 3 – Permeable Cover, Excavation and Disposal, and Monitored Natural Recovery

Alternative 3 would create permeable soil and vegetation covers over areas where chat is present to prevent wind and water erosion; contaminated material in the 8.7 acre central chat area would not be excavated but would be covered in place with a 6-inch layer of clean soil. Approximately 14,000 cu yd of clean soil would be required to cover the central chat area. Chat and contaminated soil in the eastern and western chat areas would be excavated and moved under the permeable cover placed on the central chat area. Approximately 3.1 acres of the western chat would be excavated and 5,000 cu yds of material would be moved to the central chat area for capping. Approximately 0.36 acres of the eastern chat area would be excavated and 580 cu yds of material would be moved to the central chat area. Approximately 488 cu yd of floodplain soil would be excavated and disposed at the central chat area. Clean soil would be used to backfill the excavated areas.

Sediment in the unnamed 0.25 acre pond southwest of the chat area would be excavated and the sediment placed on the central chat area prior to placement of the permeable cover.

Grading and contouring of the cover and areas around the cover would be tied to runoff management controls to provide long-term erosion protection. The covered area would be seeded with native species for added stability. Fencing and signage would be used to prohibit or restrict access to the permeable cover to prevent damage by off-road vehicles. In addition, land use and deed restrictions would be used to prevent future excavation into the cover and groundwater use restrictions would be employed to prevent future consumptive use.

MNR would be implemented at the two unnamed tributaries at the Skaggs subsite to determine if the lead concentration in the sediment will achieve the action level without active remediation. There is insufficient information at the present time to determine whether the sediment in the streams would achieve action levels without additional remedial actions such as dredging or the installation of barriers in the streams to encourage the deposition of clean sediment. However, until the mine wastes from the source area are controlled, use of these technologies to remediate the streams would not be appropriate because the streams would continue to be contaminated by mine wastes from the source area. Implementation of MNR would enable the natural recovery process to be evaluated until the source area is controlled. After the source area is controlled, additional remedial actions at the streams would be evaluated if MNR does not appear to be successful.

Surface water and sediment samples would be collected from two locations in each of the unnamed tributaries to determine if the mine wastes were continuing to impact the surface water and sediment. The surface water and sediment would be sampled annually for at least 5 years (10 years total assuming that the source areas are controlled within 5 years) following control of the source areas to determine whether the MNR is successful. Surface water samples would be analyzed for total and dissolved TAL metals and sediment samples would be analyzed for TAL metals.

Groundwater monitoring would be performed to determine if the shallow groundwater at the site was migrating away from the site. It is assumed that one upgradient monitoring well and three downgradient monitoring wells would be installed. All of the monitoring wells would be sampled semi-annually for the first 2 years and annually thereafter for 3 years unless EPA determined that the shallow groundwater was migrating from the site. In that event, the groundwater monitoring would be continued. It is assumed that the groundwater monitoring wells would be approximately 20 feet deep and groundwater samples would be analyzed for TAL metals.

6.1.2.1.4 Alternative 4 – Low Permeable Cap, Excavation and Disposal, and Monitored Natural Recovery

Under Alternative 4, the central chat area would be graded, contoured, and covered with a low permeable cap. Most of the mine waste in the central chat area would not be excavated and moved as part of this alternative. A portion of the central chat area would be consolidated prior to construction of the cap. Chat and contaminated soil in the eastern and western chat areas would be excavated and moved under the low permeable cap placed on the central chat area. Approximately 3.1 acres of the western chat would be excavated and 5,000 cu yds of material would be moved to the central chat area for capping. Approximately 0.36 acres of the eastern chat area would be excavated and 580 cu yds of material would be moved to the central chat area. Approximately 488 cu yd of floodplain soil would be excavated and disposed at the central chat area. Clean soil would be used to backfill the excavated areas.

The central chat area is approximately 8.7 acres and contains approximately 56,000 cu yds of mine waste. The average depth of the chat over the 8.7 acres is approximately 4 ft. deep. The cap would be constructed by consolidating 4 ft. of material from the central, eastern, and western chat areas over a portion of the central chat area. Using these assumptions, the low permeable cap would be approximately 4.5 acres. Approximately 27,100 cu yds of material in the central chat area would be excavated and consolidated under the cap.

Sediment in the unnamed 0.25 acre pond southwest of the chat area would be excavated and the sediment placed on the central chat area prior to placement of the low permeable cap.

The low permeable cap would consist of the following components:

- A 1-foot thick clay liner (A low permeable GCL may be substituted if sufficient clay is not available locally).
- A 6-inch vegetative soil layer.
- Vegetated cover.

The site area would be cleared and grubbed and the chat pile would be graded to the appropriate slope and shape for closure. Grading the site would remove localized fingers along the perimeter of the chat. This would be performed by excavating the material from the chat or placement of additional contaminated material excavated on-site. The chat would be graded to the contours necessary to direct storm water from the capped area to natural drainage.

The subgrade for the clay liner would be compacted to support the cap system and a clay liner would be placed over the prepared subgrade. A 6-inch soil layer with sufficient organics to support vegetation would be placed over clay liner. The top of the cover would be vegetated to provide long term erosion control. The vegetation selected would be compatible with the local climate and require low maintenance. Construction of the low permeable cap would require 6 to

8 months.

Access to the capped area would be prevented by fences and signs, and there would be legal controls (deed restrictions) to prevent uses that could disturb the cap. A cap monitoring program would be designed and implemented to ensure establishment of vegetation and the continued integrity of the facility. Periodic maintenance would be required to repair the cap and maintain the vegetation on the cap. Groundwater use restrictions would be employed to prevent future consumptive use.

MNR would be implemented at the two unnamed tributaries at the Skaggs subsite to determine if the lead concentration in the sediment will achieve the action level without active remediation. There is insufficient information at the present time to determine whether the sediment in the streams would achieve action levels without additional remedial actions such as dredging or the installation of barriers in the streams to encourage the deposition of clean sediment. However, until the mine wastes from the source area are controlled, use of these technologies to remediate the streams would not be appropriate because the streams would continue to be contaminated by mine wastes from the source area. Implementation of MNR would enable the natural recovery process to be evaluated until the source area is controlled. After the source area is controlled, additional remedial actions at the streams could be evaluated if MNR does not appear to be successful.

Surface water and sediment samples would be collected from two locations in each of the unnamed tributaries to determine if the mine wastes were continuing to impact the surface water and sediment. The surface water and sediment would be sampled annually for at least 5 years (10 years total assuming that the source areas are controlled within 5 years) following control of the source areas to determine whether the MNR is successful. Surface water samples would be analyzed for total and dissolved TAL metals and sediment samples would be analyzed for TAL metals.

Groundwater monitoring would be performed to determine if the shallow groundwater at the site was migrating away from the site. It is assumed that one upgradient monitoring well and three downgradient monitoring wells would be installed. All of the monitoring wells would be sampled semi-annually for the first 2 years and annually thereafter for 3 years unless EPA determined that the shallow groundwater was migrating from the site. In that event, the groundwater monitoring would be continued. It is assumed that the groundwater monitoring wells would be approximately 20 feet deep and groundwater samples would be analyzed for TAL metals.

7.0 Detailed Evaluation of Remedial Alternatives

The NCP, 40 C.F.R. Section 300 et. seq., requires the EPA to evaluate selected remedial alternatives against nine criteria. A selected or preferred alternative should best satisfy all nine criteria before it can be implemented. The first step is to ensure that the remedial alternatives satisfy the threshold criteria. The two threshold criteria are overall protection of public health and the environment and compliance with the ARARs. In general, alternatives that do not satisfy these two criteria are rejected and not evaluated further. However, compliance with ARARs may be "waived" if site-specific circumstances warrant such a "waiver" as described in Section 300.430(f)(1)(ii)(C) of the NCP, 40 C.F.R. § 300.430(f)(1)(ii)(C).

The second step is to compare the remedial alternatives against a set of balancing criteria. The NCP establishes five balancing criteria, which include long-term effectiveness and permanence; reduction in toxicity, mobility, or volume achieved through treatment; implementability; short-term effectiveness; and cost. The third and final step is to evaluate the remedial alternatives on the basis of modifying criteria. The two modifying criteria are state and community acceptance. These final two criteria cannot be evaluated fully until the state and public have commented on the preferred alternative in the Proposed Plan and their comments have been analyzed.

7.1 Alternative Analysis Criteria

Each of the alternatives is subjected to nine evaluation criteria described in the NCP. The factors considered for each evaluation criterion and a brief description of each criterion follow.

7.1.1 Threshold Criteria

Overall Protection of Human Health and the Environment

This criterion provides a final check to assess whether each alternative meets the requirement that it is protective of human health and the environment. The overall assessment of protection is based on a composite of factors assessed under the evaluation criteria, especially long-term effectiveness and permanence, short-term effectiveness, and compliance with ARARs.

Compliance With ARARs

This criterion is used to decide how each alternative meets applicable or relevant and appropriate federal, state, and local requirements, as defined in CERCLA Section 121.

Compliance is judged with respect to:

- chemical-specific ARARs,
- action-specific ARARs,
- location-specific ARARs, and
- appropriate criteria, advisories and guidance (TBCs).

Potential chemical- and location-specific ARARs are identified in Tables 2-1 through 2-4. Potential federal and state action-specific ARARs relating to the remedial alternatives are identified in Tables 2-5 and 2-6.

7.1.2 Balancing Criteria

Long-Term Effectiveness

This criterion addresses the results of a remedial action in terms of the risk remaining at the site after the RAOs have been met. The primary focus of this evaluation is to determine the extent and effectiveness of the controls that may be required to manage the risk posed by treatment residuals and/or untreated wastes. The factors to be evaluated include:

- magnitude of risk remaining at the site after the remedial objectives are met,
- adequacy of controls, and
- reliability of controls (i.e., assessment of potential failure of the technical components).

Short-Term Effectiveness

This criterion addresses the effects of the alternative during the construction and operation phase until the remedial actions have been completed and the selected level of protection has been achieved. Each alternative is evaluated with respect to:

- protection of community during remedial actions,
- protection of workers during remedial actions,
- time until remedial response objectives are achieved, and
- environmental impacts.

Reduction of Toxicity, Mobility, or Volume

This criterion addresses the statutory preference for selecting remedial actions that employ treatment technologies that permanently and significantly reduce toxicity, mobility, or volume of the contaminants. The factors to be evaluated include:

- treatment process and remedy,
- amount of hazardous material destroyed or treated,
- reduction in toxicity, mobility or volume of the contaminants,
- irreversibility of the treatment, and
- type and quantity of treatment residuals.

Implementability

This criterion addresses the technical and administrative feasibility of implementing an alternative and the availability of various services and materials required during its implementation. Technical feasibility considers:

- the ability to construct the technology,
- reliability of the technology,
- ease of undertaking additional remedial actions if necessary,
- monitoring considerations,
- coordination with other agencies (e.g., state and local) to obtain permits or approvals for implementing remedial actions,
- availability of treatment, storage capacity, and disposal services,
- availability of necessary equipment and specialists, and
- availability of prospective technologies.

Cost

This criterion addressees the capital costs, annual operation and maintenance (O&M) costs, and present worth analysis. Capital costs consist of direct (construction) and indirect (non-construction and overhead) costs. Direct costs include expenditures for the equipment, labor and material necessary to perform remedial actions. Indirect costs include expenditures for engineering, financial and other services that are not part of actual installation activities but are required to complete the installation of remedial alternatives. Annual O&M costs are post-construction costs necessary to ensure the continued effectiveness of a remedial action. A

present worth analysis is used to evaluate expenditures that occur over different time periods by discounting all future costs to a common base year, usually the current year. This allows the cost of remedial action alternatives to be compared based on a single figure representing the amount of money that would be sufficient to cover all costs associated with the remedial action over its planned life. A discount rate of 7.0 percent was used. The cost estimates are expected to provide an accuracy of +50 percent to -30 percent.

7.1.3 Modifying Criteria

State Acceptance

This criterion evaluates the technical and administrative issues and concerns the state may have regarding each of the alternatives. The factors to be evaluated include those features of alternatives that the state supports, reservations of the state, and opposition of the state.

Community Acceptance

This criterion incorporates public concerns into the evaluation of the remedial alternatives. Typically, community acceptance cannot be determined during development of the FS. Evaluation of this criterion will be postponed until the FS has been released for review by the public. Community acceptance will also be evaluated by comments on the Proposed Plan, where the alternatives will be summarized and a preferred alternative put forward to the public. This criterion will then be addressed in the ROD and the responsiveness summary.

7.2 Alternative Analysis OU5 – Catherine Subsite

The following sub-sections present the individual analyses of the alternatives against the nine criteria.

7.2.1 Alternative 1 - No Action

The no-action alternative would not involve any remedial actions, and the Catherine subsite would remain in its present condition. Alternative 1, required by the NCP and CERCLA, is a baseline alternative against which the other alternatives can be compared. EPA would still perform 5-year reviews at the Catherine subsite.

Overall Protection of Human Health and the Environment

Because no remedial or monitoring activities would be conducted as part of Alternative 1,

the RAOs would not be met. This alternative does not provide protection for the environment or human health in Madison County because no actions are taken to mitigate the exposure to lead-contaminated soil and sediment.

The human population most likely to be exposed at the site includes recreational visitors that may utilize the contaminated area for activities such as hiking and fishing. In addition, changes in site use could result in exposures to workers of commercial businesses potentially located on the site or adult and child residents of homes potentially located on the site. Current conditions are not protective of ATV riders primarily due to ingestion of lead in soil and the potential inhalation of lead and manganese in airborne dusts generated by the ATV. Additionally, children who visit the site frequently may be exposed to unacceptable risks due to potential ingestion of lead in sediment. Potential ingestion of lead in sediment may also result in adverse health effects to a fetus of an adult pregnant recreational visitor at the Catherine subsite.

Organisms within both the aquatic and terrestrial environments have elevated exposure to mining-related metals, which cause adverse effects on at least some receptors in each ecosystem. Conditions within the terrestrial ecosystem cause phytotoxicity to plants within the mine waste areas and result in potential hazards to terrestrial herbivores (dove, vole), terrestrial vermivores (woodcock, shrew), and terrestrial carnivores (red-tailed hawk, weasel). Decreases in terrestrial plants in mine waste areas and other locations of stressed or absent vegetation likely result in a decrease in the abundance of terrestrial receptors which utilize the habitat for food or cover. Further, the exposed mine waste is open to erosion and wind which will increase the size of the contaminated site if the mine waste is not remediated.

Within the aquatic ecosystem concentrations of lead, manganese and silver in surface water pose a risk to aquatic life and concentrations of several metals in sediment pose a risk to sediment dwelling organisms. Additionally, areas of sparse vegetation serve as a source of sediment runoff into the Catherine Pond and nearby creeks, increasing sediment loading and substrate embeddedness, ultimately impacting the availability of suitable spawning areas for fish and habitats for benthic macroinvertebrates and algae.

Compliance With ARARs

This alternative does not meet the potential state or federal chemical- specific or location-specific ARARs listed in Table 2-1 through 2-4. This alternative does not include any remedial actions; therefore, no action-specific ARARs are triggered.

Long-Term Effectiveness

The residual risk to human health and the environment associated with this alternative

would be the same as the current risk. An evaluation of the adequacy and reliability of controls is not applicable to this alternative because the alternative does not include any remedial actions.

Short-Term Effectiveness

Because no actions would be conducted, there would be no increase in the short-term risk to the workers, the community, or the environment.

Reduction of Toxicity, Mobility, or Volume

There is no reduction in the toxicity, mobility, or volume of contamination under the No Action alternative. Remedial actions would not be conducted; therefore, no mechanism would exist to evaluate any reductions in toxicity, mobility, and volume.

Implementability

The implementability criterion is not applicable because no remedial activities would occur. Services, materials, and activities normally needed to coordinate with other agencies would not be necessary. This alternative does not require implementation.

Cost

Table 7-1 presents the costs for Alternative 1 at the Catherine subsite. There are no capital costs associated with this alternative because no remedial actions would be conducted. There will be costs associated with EPA's 5-year review of the project. The present worth cost of the 5-year reviews is $53,900.

State Acceptance

It is assumed that this alternative is not acceptable to the State.

Community Acceptance

Community acceptance will be evaluated after the public comment period closes for the Proposed Plan and this final FS.

7.2.2 Alternative 2 - Institutional Controls

This alternative would address RAOs strictly through the application of institutional controls including signage, restricting access, and land use restrictions. This alternative does not include any active remedial technologies.

Overall Protection of Human Health and the Environment

This alternative would protect human health strictly through the application of institutional controls including placement of signs, fencing, as well as land and groundwater use restrictions. Adverse health risks to recreational visitors associated with exposure to lead in soil as well as risks associated with inhalation of metals to ATV riders would be controlled through placement of restricted access signs around contaminated soil and mine wastes at the Catherine subsite. The Catherine Pond would be fenced and signs would be placed at the fence to restrict access to the contaminated sediments. Signs would not be required along the Logtown Branch. Deed restrictions would be used to limit future land use and groundwater use restrictions would be used to limit exposure to shallow groundwater at the Catherine subsite.

Institutional controls would not address ecological exposures to impacted media; therefore, this alternative would not be protective of the environment. Adverse impacts to terrestrial and aquatic organisms would be as described in Section 7.2.1.

Compliance With ARARs

This alternative does not meet the potential state or federal chemical- specific or location-specific ARARs listed in Table 2-1 through 2-4. This alternative does not include any remedial actions; therefore, no action-specific ARARs are triggered.

Long-Term Effectiveness

The long-term effectiveness of this alternative would depend on periodic maintenance and public cooperation. Because fences and signs are subject to vandalism and weathering, periodic inspection and maintenance would be required. Failure to maintain fences would render them ineffective. Despite best efforts, institutional controls are not expected to completely mitigate potential exposures at the site. A portion of recreational visitors to the site would be expected to disregard warnings represented by signs and fences.

Long-term effectiveness of land use restrictions would be dependent on the ability of the local government to track and enforce the restrictions. This alternative is not effective in meeting RAOs aimed at protecting environmental receptors.

Short-Term Effectiveness

Workers may be exposed to contaminated media while installing and maintaining signs and fencing. Due to the short exposure periods, risks to these workers are expected to be minimal. Potential worker exposure would be mitigated by development and adherence to a HASP. No short-term risks would be associated with implementation of the land use restrictions.

Reduction of Toxicity, Mobility, or Volume

Because this alternative does not include any treatment, no reduction in toxicity, mobility, or volume would occur.

Implementability

Fences and signs are readily implemented using locally available materials and services. Restrictions on land use at the site would require cooperation with local and county governments. A deed restriction controlling future land development at the site and filed with the local government may be required to ensure future protectiveness.

Cost

Table 7-2 presents the costs for Alternative 2 at the Catherine subsite. The total capital cost for this alternative is estimated to be $499,000. Total O&M costs for Alternative 2 are estimated to be $437,380. The present worth value of Alternative 2 is estimated to be $721,700.

State Acceptance

State acceptance will be evaluated after the public comment period closes for the Proposed Plan and this FS.

Community Acceptance

Community acceptance will be evaluated after the public comment period closes for the Proposed Plan and this final FS.

7.2.3 Alternative 3 – Low Permeable Cap, Sediment Excavation and Onsite Disposal, Monitored Natural Recovery

This alternative would meet RAOs through excavation of sediment, onsite disposal, construction of a low permeable cap, MNR and institutional controls.

Overall Protection of Human Health and the Environment

Potential exposures to recreational visitors at areas contaminated with chat and soil at the Catherine subsite would be controlled by installation of a low permeable cap and vegetation cover. Adverse health risks to recreational visitors associated with exposure to lead in soil as well as risks associated with inhalation of metals to ATV riders would be controlled through installation of the low permeable cap and the soil and vegetation cover. Fencing and signage would be used to prohibit or restrict access to the cap and would also reduce the potential for human exposure and risk. Deed restrictions would be used to limit future land use, control future excavation at the area, and control groundwater use at the site.

Risks to adult and child recreational visitors exposed to lead in the sediment at the Catherine Pond would be controlled through excavation and disposal of the pond sediment under the low permeable cap at the Catherine Repository.

The installation of a low permeable cap would also reduce potential adverse exposures to terrestrial organisms including herbivores (voles, doves), vermivores (woodcocks, shrews) and carnivores (red-tailed hawks, weasels). Installation and grading of a soil and vegetation cover would provide a favorable environment for plant growth, effectively eliminating the phytotoxicity that is currently observed at the site. Establishment of healthy vegetation at the site would increase habitat for terrestrial organisms, and reduce erosion by wind and storm water runoff.

Excavation of sediment from the Catherine Pond would reduce or control adverse effects on benthic invertebrates exposed to concentrations of metals in the sediment. Aquatic life in the Catherine Pond would also be protected by this alternative as the source control measures (sediment removal and the low permeability cap) should result in a reduction of surface water metal concentrations.

MNR in Logtown Branch could also address potential ecological exposures to aquatic organisms. Over time, adverse impacts to aquatic life and benthic invertebrates should be mitigated by a reduction of metal concentrations in the surface water and sediment. The surface water and sediment would be sampled annually for at least 10 years to determine if the MNR is successful.

Compliance With ARARs

The state and federal chemical-specific ARARs for sediment in Catherine Pond listed in Tables 2-1 and 2-2 are expected to be met with this alternative. Installation of the low permeable cap would also be expected to meet the state or federal chemical-specific ARARs for soil, mine wastes, and sediments listed in Tables 2-1 through 2-2. Placement of a low permeability cap and soil cover at contaminated sources should control erosion and discharge to the Catherine Pond; however, there is presently insufficient information to determine whether the surface water quality in these waters will achieve action levels without additional remedial actions. Similarly, there is insufficient information at the present time to determine whether source control measures will achieve surface water and sediment action levels in Logtown Branch or if additional remedial actions will be needed.

This alternative is expected to meet all potential state and federal location- and action-specific ARARs listed in Tables 2-3 through 2-6. Compliance with Executive Order 11988 (Protection of Floodplains), Executive Order 11990 (Protection of Wetlands), the Clean Water Act, the Fish and Wildlife Conservation Act of 1980, and the Fish and Wildlife Coordination Act, along with controls to prevent adversely impacting ecological receptors within and downstream of these sensitive environments will be required.

Excavation activities would require compliance with the Clean Air Act, the Missouri Fugitive Particulate Matter Regulations, the Missouri Clean Water Law, the Missouri Hazardous Substances Emergency Response, and the use of appropriate controls to monitor and mitigate emissions of airborne particulates and prevent storm water releases. Disposal of contaminated media at the Catherine Repository may require compliance with Subtitle C of RCRA, TSCA, the Missouri Solid Waste Disposal Law, and the Missouri Hazardous Waste Management Law.

Long-Term Effectiveness

A low permeability cap at the Catherine chat pile is expected to be effective at reducing exposures to human and ecological receptors, limiting erosion and transport of contaminants by wind and water, and reducing infiltration. The long-term effectiveness of the low permeability cap would depend on proper design and construction to direct surface water away from the waste, ensure containment of the waste, and ensure the integrity of the low permeability layer. Cap maintenance will be required, including repair of damage caused by erosion; removal of invasive plant species with root systems that may damage the integrity of the impermeable layer; and potentially periodic replanting, fertilization, or watering of vegetation. Periodic maintenance of fencing would be required to prevent damage to the cap by foot or vehicular traffic.

The long-term effectiveness of MNR is uncertain because there is presently insufficient information to determine whether the surface water quality and sediment in Logtown Branch will achieve human health and ecological action levels without additional remedial actions. If MNR is not effective, additional remedial actions such as dredging or the installation of barriers in the streams to encourage the deposition of clean sediments could be implemented. Surface water and sediment monitoring is required to determine whether this alternative will be effective.

The long-term effectiveness of this alternative would also depend on periodic maintenance and public cooperation. Because fencing and signs are subject to vandalism and weathering, periodic inspection and maintenance would be required. Despite best efforts, installation of fencing and signs is not expected to completely mitigate potential exposures at the site. A portion of recreational visitors to the site would be expected to disregard warnings represented by the signs.

Short-Term Effectiveness

Short-term risks to workers include exposure to contaminants and heavy machinery during excavation, disposal, installation of the low permeability cap, fencing, and signs. The potential risks would be managed through the use of OSHA certified workers, development and compliance with HASPs, required attendance at safety meetings, and the use of best management practices for construction sites.

Risks to nearby residents include the potential for exposure to contaminants in dust generated during construction activities, increased noise at the site due to heavy machinery, and increased truck traffic on local roads. The potential risks would be mitigated through application of water or dust suppressants as needed to control release of particulates into the air, limiting operation of heavy machinery to daylight or standard work hours (if noise is an issue), and by restricting site access and egress by trucks to roads which would result in the least impacts to local traffic flows.

Environmental risks during implementation include the potential for releases of sediment or impacted surface water during storm events. Mitigation measures such as silt fences, hay bales, and construction of temporary ditches to direct surface water away from the work areas would be used to minimize environmental impacts.

Reduction of Toxicity, Mobility, or Volume

This remedial alternative would result in a substantial reduction in contaminant mobility through placement of a low permeability cap over the contaminated soils and chat at the Catherine area which will prevent wind and water erosion. However, installation of a low

permeability cap would not result in a decrease of toxicity or volume of the mine wastes and soil.

This remedial alternative would result in a substantial reduction in contaminant mobility, and volume of sediment in Catherine Pond through excavation and disposal. Placement of excavated materials under the low permeability cap will contain the contaminated sediment, effectively eliminating potential exposures by human and ecological receptors and restricting the mobility of 2,800 cubic yards of sediment.

Over time, MNR could result in a reduction of contaminant toxicity by decreasing the concentrations of metals in surface water and sediment in Logtown Branch to which human and ecological receptors would be exposed. However, monitoring would be required for at least 10 years to determine whether this alternative is successful. A reduction in mobility or volume is not expected to occur with MNR.

Implementability

Excavation and disposal, as well as construction of the low permeability cap and its soil cover could be accomplished using standard earth moving equipment. Transport of cover materials would be accomplished using standard dump trucks or truck and trailer combinations. Construction of the low permeability caps and placement of soil cover would require a source of natural low permeable clay, clean borrow, topsoil and vegetation. Clean borrow and topsoil are available locally. Vegetation may also be available locally or is readily available as seed, plugs, or potted plants from nurseries. All required material and services for the low permeability cap and soil cover, fencing and signage are available locally.

Groundwater, surface water and sediment sampling can be easily implemented using standard collection and analysis methods. A SAP, QAPP, and HASP would be required for the monitoring program. Signs are readily implemented using locally available materials and services.

Restrictions on future use of land and groundwater at the site would require cooperation with local and county governments. Deed restrictions that limit land and groundwater use filed with the local government may be required to ensure future protectiveness.

Cost

Table 7-3 presents the costs for Alternative 3 at the Catherine subsite. The total capital cost for this alternative is estimated to be $2,269,530. Total O&M costs for Alternative 3 are estimated to be $802,630. The present worth value of Alternative 3 is estimated to be $2,653,540.

State Acceptance

State acceptance will be evaluated after the public comment period closes for the Proposed Plan and this FS.

Community Acceptance

Community acceptance will be evaluated after the public comment period closes for the Proposed Plan and this final FS.

7.2.4 Alternative 4 – Engineered Low Permeability Cap, Excavation, Onsite Disposal, Monitored Natural Recovery

This alternative would meet RAOs through a combination of excavation, disposal, on-site containment through the installation of an engineered low permeable cap, MNR, and institutional controls.

Overall Protection of Human Health and the Environment

This alternative would be protective of human health and the environment. The overall protectiveness of this alternative would be very similar to the protectiveness of the low permeability cap described in Section 7.2.3 with the exception that the engineered cap included in this alternative is expected to substantially reduce infiltration into the contained waste. Fencing and signage would be used to prohibit or restrict access to the engineered cap which would also reduce the potential for human exposure and risk. Deed restrictions would be used to limit future land use to recreational activities and to control future excavation at the area.

Risks to adult and child recreational visitors exposed to lead in the sediment at the Catherine Pond would be controlled through excavation and disposal under the engineered low permeable cap at the Catherine Repository.

Excavation of sediment from the Catherine Pond would also reduce or control adverse effects on benthic invertebrates exposed to concentrations of metals in the sediment. Aquatic life in the Catherine Pond would also be protected by this alternative as the source control measures (sediment removal and the engineered low permeability cap) should result in a reduction of surface water metal concentrations.

MNR in Logtown Branch could also address potential ecological exposures to aquatic organisms. Over time, adverse impacts to aquatic life and benthic invertebrates should be mitigated as metal concentrations in surface water and sediment decline. The surface water and sediment would be sampled annually for at least 10 years to determine if the MNR is successful.

Compliance With ARARs

Compliance with chemical-specific ARARs for this alternative is similar to compliance described in Section 7.2.3 with the exception that this alternative is likely to meet chemical-specific ARARs for groundwater. Although attainment of groundwater cleanup levels is generally required throughout the contaminated plume, attainment at the edge of the waste management area is allowed when waste is left in place (EPA 1988b). This alternative would prevent on-going leaching of contaminants from the mine wastes and control groundwater recharge within the chat area. It is likely that contaminants in the groundwater would not migrate beyond the containment boundaries within the water table or by discharge through seeps.

Compliance with location- and action-specific ARARs for this alternative are identical to compliance described in Section 7.2.3.

Long-Term Effectiveness

The long-term effectiveness of this alternative is very similar to the long-term effectiveness of the low permeability cap described in Section 7.2.3 with the exception that the engineered low permeability cap included in this alternative is expected to further reduce infiltration to the groundwater under the cap.

Short-Term Effectiveness

The short-term effectiveness of this alternative is identical to the short-term effectiveness of the low permeability cap described in Section 7.2.3.

Reduction of Toxicity, Mobility, or Volume

The degree of reduction in toxicity, mobility, and volume of this alternative is similar to the degree of reduction of the low permeable cap described in Section 7.2.3; however, preventing precipitation from infiltrating into the chat is expected to control contaminant mobility within the containment area. Because this alternative does not include treatment, no reduction in toxicity would be achieved.

Implementability

Implementation of this alternative is similar to implementation of the low permeability

cap described in Section 7.2.3.

Cost

Table 7-4 presents the costs for Alternative 4 at the Catherine subsite. The total capital cost for this alternative is estimated to be $15,883,350. Total O&M costs for Alternative 4 are estimated to be $844,350. The present worth value of Alternative 4 is estimated to be $16,284,620.

State Acceptance

State acceptance will be evaluated after the public comment period closes for the Proposed Plan and this FS.

Community Acceptance

Community acceptance will be evaluated after the public comment period closes for the Proposed Plan and this final FS.

7.3 Alternative Analysis OU5 – Skaggs Subsite

The following sub-sections present the individual analyses of the alternatives against the nine criteria.

7.3.1 Alternative 1 - No Action

The no-action alternative would not involve any remedial actions, and the Skaggs subsite would remain in its present condition. Alternative 1, required by the NCP and CERCLA, is a baseline alternative against which the other alternatives can be compared. EPA would still perform 5-year reviews at the Skaggs subsite.

Overall Protection of Human Health and the Environment

Because no remedial or monitoring activities would be conducted as part of Alternative 1, the RAOs would not be met. This alternative does not provide protection for the environment or human health in Madison County because no actions are taken to mitigate the exposure to lead-contaminated soil and sediment.

The human population most likely to be exposed at the site includes recreational visitors that may utilize the contaminated area for activities such as hiking. In addition, changes in site use could result in exposures to workers of commercial businesses potentially located on the site or adult and child residents of homes potentially located on the site. Current conditions are not protective of ATV riders primarily due to the potential ingestion of lead in soil as well as the inhalation of lead and manganese in airborne dusts generated by the ATV. Additionally, child recreational visitors who visit the site at a high frequency may be exposed to unacceptable risks due to potential ingestion of several metals in sediment, soil and/or surface water. Potential ingestion of lead in sediment may also result in adverse health effects to a fetus of an adult pregnant recreational visitor at the Skaggs subsite.

Organisms within both the aquatic and terrestrial environments have elevated exposure to mining-related metals, which cause adverse effects on at least some receptors in each ecosystem. Conditions within the terrestrial ecosystem cause phytotoxicity to plants within the mine waste areas and result in potential hazards to herbivores, vermivores, and carnivores. Decreases in terrestrial plants in mine waste areas and other locations of stressed or absent vegetation likely result in a decrease in the abundance of terrestrial receptors which utilize the habitat for food or cover. Further, the exposed mine waste is open to erosion and wind which will increase the size of the contaminated site if the mine waste is not remediated.

Within the aquatic ecosystem concentrations of lead, manganese and silver in surface water pose a risk to aquatic life and concentrations of several metals in sediment pose a risk to sediment dwelling organisms. Additionally, areas of sparse vegetation serve as a source of sediment runoff into nearby creeks and rivers, increasing sediment loading and substrate embeddedness, ultimately impacting the availability of suitable spawning areas for fish and habitats for benthic macroinvertebrates and algae.

Compliance With ARARs

This alternative does not meet the potential state or federal chemical- specific or location-specific ARARs listed in Table 2-1 through 2-4. This alternative does not include any remedial actions; therefore, no action-specific ARARs are triggered.

Long-Term Effectiveness

The residual risk to human health and the environment associated with this alternative would be the same as the current risk. An evaluation of the adequacy and reliability of controls is not applicable to this alternative because the alternative does not include any remedial actions.

Short-Term Effectiveness

Because no actions would be conducted, there would be no increase in the short-term risk to the workers, the community, or the environment.

Reduction of Toxicity, Mobility, or Volume

There is no reduction in the toxicity, mobility, or volume of contamination under the No Action alternative. Remedial actions would not be conducted; therefore, no mechanism would exist to evaluate any reductions in toxicity, mobility, and volume.

Implementability

The implementability criterion is not applicable because no remedial activities would occur. Services, materials, and activities normally needed to coordinate with other agencies would not be necessary. This alternative does not require implementation.

Cost

Table 7-5 presents the costs for Alternative 1 at the Skaggs subsite. There are no capital costs associated with this alternative because no remedial actions would be conducted. There will be costs associated with EPA's 5-year review of the project. The present worth cost of the 5-year reviews is $53,900.

State Acceptance

It is assumed that this alternative is not acceptable to the State.

Community Acceptance

Community acceptance will be evaluated after the public comment period closes for the Proposed Plan and this final FS.

7.3.2 Alternative 2 - Institutional Controls

This alternative would address RAOs strictly through the application of institutional controls including signage, restricting access, groundwater and surface water monitoring, and land and groundwater use restrictions. This alternative does not include any active remedial

technologies.

Overall Protection of Human Health and the Environment

This alternative would protect human health strictly through the application of institutional controls including placement of signs, fencing, groundwater and surface water monitoring, and land and groundwater use restrictions. Adverse health risks to recreational visitors associated with exposure to lead in soil as well as risks associated with inhalation of metals to ATV riders would be controlled through placement of restricted access signs around contaminated soil and mine wastes at the Skaggs subsite. Deed restrictions would be used to limit future land and groundwater use. Signs and fencing would be placed around the chat pile to indicate that the mine waste is present and may present a risk to human health. Signs would also be placed along the two unnamed tributaries and unnamed pond to discourage exposure to sediment.

Institutional controls would not address ecological exposures to impacted media; therefore, this alternative would not be protective of the environment. Adverse impacts to terrestrial and aquatic organisms would be as described in Section 7.3.1.

Compliance With ARARs

This alternative does not meet the potential state or federal chemical- specific or location-specific ARARs listed in Table 2-1 through 2-4. This alternative does not include any remedial actions; therefore, no action-specific ARARs are triggered.

Long-Term Effectiveness

The long-term effectiveness of this alternative would depend on periodic maintenance and public cooperation. Because fences and signs are subject to vandalism and weathering, periodic inspection and maintenance would be required. Failure to maintain fences would render them ineffective. Despite best efforts, institutional controls are not expected to completely mitigate potential exposures at the site. A portion of recreational visitors to the site would be expected to disregard warnings represented by signs and fences.

Long-term effectiveness of land and groundwater use restrictions would be dependent on the ability of the local government to track and enforce the restrictions. This alternative is not effective in meeting RAOs aimed at protecting environmental receptors.

Short-Term Effectiveness

Workers may be exposed to contaminated media while installing and maintaining signs and fencing. Due to the short exposure periods, risks to these workers are expected to be minimal. Potential worker exposure would be mitigated by development and adherence to a HASP. No short-term risks would be associated with implementation of the land and groundwater use restrictions.

Reduction of Toxicity, Mobility, or Volume

Because this alternative does not include any treatment, no reduction in toxicity, mobility, or volume would occur.

Implementability

Fences and signs are readily implemented using locally available materials and services. Restrictions on land and groundwater use at the site would require cooperation with local and county governments. A deed restriction controlling future land development at the site and filed with the local government may be required to ensure future protectiveness.

Cost

Table 7-6 presents the costs for Alternative 2 at the Skaggs subsite. The total capital cost for this alternative is estimated to be $811,700. Total O&M costs for Alternative 2 are estimated to be $522,650. The present worth value of Alternative 2 is estimated to be $1,066,700.

State Acceptance

State acceptance will be evaluated after the public comment period closes for the Proposed Plan and this FS.

Community Acceptance

Community acceptance will be evaluated after the public comment period closes for the Proposed Plan and this final FS.

7.3.3 Alternative 3 – Permeable Cover, Excavation, Onsite Disposal, Monitored Natural Recovery

This alternative would meet RAOs through a combination of excavation, onsite disposal, the installation of a permeable soil cover, MNR, and institutional controls.

Overall Protection of Human Health and the Environment

Potential exposures to recreational visitors at areas contaminated with chat and soil at the Skaggs subsite would be controlled by installing a permeable soil and vegetation cover. Adverse health risks to human receptors including current recreational visitors and ATV riders as well as potential future residents and commercial workers would be controlled through excavation of the chat and contaminated soil at the eastern and western chat areas. Excavated materials would be consolidated at the central chat area and placed under a permeable soil and vegetative cover. The permeable cover would isolate the contaminated materials and consequently reduce or control exposure to human receptors. The installation of fencing and signage would discourage access to the permeable covers and prevent off-road vehicle use. In addition, deed restrictions would be used to prevent exposures associated with future development of the site or excavation of the cover. Exposures and risks to groundwater would be prevented by deed restrictions that would prohibit future use of the groundwater as a source for drinking water.

Potential exposures to terrestrial plants, herbivores, vermivores and carnivores at the eastern and western chat areas contaminated with soil would be controlled by excavation and onsite disposal at the central chat area. Installation and grading of a permeable cover would provide a favorable environment for plant growth, effectively eliminating the phytotoxicity that is currently observed at the site. Establishment of healthy vegetation at the site would increase habitat for terrestrial organisms, and reduce erosion by wind and storm water runoff.

Adverse effects to aquatic life in the unnamed pond would be reduced or controlled through sediment removal. MNR could also address potential ecological exposures to aquatic organisms in the unnamed tributaries. Over time, adverse impacts to aquatic life and benthic invertebrates should be mitigated as metal concentrations in surface water and sediment decline. The surface water and sediment would be sampled annually for at least 10 years to determine if the MNR is successful.

Compliance With ARARs

This alternative is expected to meet the potential state or federal chemical-specific ARARs for mine wastes and soil at the eastern and western chat areas and for sediment in the unnamed pond listed in Tables 2-1 and 2-2 through source removal and disposal. This alternative

is expected to meet the state or federal chemical-specific ARARs for soil and mine wastes listed in Tables 2-1 and 2-2 through installation of the permeable cover at the central chat area. Since MNR does not include sediment removal from the unnamed tributaries, the state or federal chemical-specific, action-specific or location-specific ARARs for surface water and sediment listed in Tables 2-1 through 2-6 would not initially be met. However, this alternative could eventually meet the potential state and federal chemical-specific ARARs if the MNR is successful in reducing concentrations of metals in surface water and sediment.

This alternative is expected to meet all potential state and federal location- and action-specific ARARs listed in Tables 2-3 through 2-6. Compliance with Executive Order 11988 (Protection of Floodplains), Executive Order 11990 (Protection of Wetlands), the Clean Water Act, the Fish and Wildlife Conservation Act of 1980, the Fish and Wildlife Coordination Act, along with controls to prevent adversely impacting ecological receptors within and downstream of these sensitive environments will be required.

Excavation activities would require compliance with the Clean Air Act, the Missouri Fugitive Particulate Matter Regulations, the Missouri Clean Water Law, the Missouri Hazardous Substances Emergency Response, and the use of appropriate controls to monitor and mitigate emissions of airborne particulates and prevent storm water releases. Transporting excavated chat and contaminated soil and sediment would require compliance with the Hazardous Materials Transportation Regulation and the DOT Hazardous Materials Transportation Regulations. Disposal of mine wastes may require compliance with Subtitle C of RCRA, TSCA, the Missouri Solid Waste Disposal Law, and the Missouri Hazardous Waste Management Law.

Long-Term Effectiveness

Excavation and onsite disposal would ensure that RAOs are permanently achieved at the eastern and western chat areas and the unnamed pond at the Skaggs subsite. Permeable covers are effective at reducing exposures to human and ecological receptors and limiting erosion and transport of contaminants by wind and water. The long-term effectiveness of the covers would depend on proper design and construction to prevent slumping of the cover over time and on-going maintenance. Erosion of the soil cover at the central chat area could expose residual contaminated materials resulting in exposures to both human and ecological receptors. Cap maintenance, consisting of repair of damage caused by erosion; removal of invasive plant species with root systems that may damage the integrity of the cover; and periodic replanting, fertilization, or watering of vegetation would be required.

The long-term effectiveness of MNR is uncertain because there is presently insufficient information to determine whether the surface water quality and sediment in the unnamed tributaries will achieve human health and ecological action levels. If MNR is not effective,

additional remedial actions such as dredging or the installation of barriers in the streams to encourage the deposition of clean sediments could be implemented. Surface water and sediment monitoring is required to determine whether this alternative will be effective.

The long-term effectiveness of this alternative would also depend on periodic maintenance and public cooperation. Because fencing and signs are subject to vandalism and weathering, periodic inspection and maintenance would be required. Despite best efforts, installation of signs is not expected to completely mitigate potential exposures at the site. A portion of recreational visitors to the site would be expected to disregard warnings represented by the signs.

Short-Term Effectiveness

Short-term risks to workers include exposure to contaminants and heavy machinery during excavation, loading, and transporting contaminated material and construction of the soil and vegetation cover. The potential risks would be managed through the use of OSHA certified workers, development and compliance with HASPs, required attendance at safety meetings, and the use of best management practices for construction sites.

Risks to nearby residents include the potential for exposure to contaminants in dust generated during excavation activities, increased noise at the site due to heavy machinery, and increased truck traffic on local roads. The potential risks would be mitigated through application of water or dust suppressants as needed to control release of particulates into the air, limiting operation of heavy machinery to daylight or standard work hours (if noise is an issue), and by restricting site access and egress by trucks to roads which would result in the least impacts to local traffic flows.

Environmental risks during implementation include the potential for releases of sediment or impacted surface water during storm events. Mitigation measures such as silt fences, hay bales, dewatering of mine wastes, and construction of temporary ditches to direct surface water away from the work areas would be used to minimize environmental impacts.

Reduction of Toxicity, Mobility, or Volume

This remedial alternative would result in a substantial reduction in contaminant mobility, and volume through excavation and disposal of waste materials from the eastern and western chat areas as well as from the unnamed pond. Approximately 5,000 cubic yards of material from the western chat area and an additional 580 cubic yards of material from the eastern chat area would be excavated and included under the permeable cover at the central chat area. Consolidation of excavated materials at the central chat area would contain the waste, effectively

eliminating potential exposures by human and ecological receptors and restricting the mobility of approximately 62,000 cubic yards of chat and contaminated media (this total includes materials from the eastern and western chat areas, about 200 cubic yards of sediment from the unnamed pond, and approximately 56,000 cubic yards of mine waste at the central chat area that will not be excavated).

Over time, MNR could result in a reduction of contaminant toxicity by decreasing the concentrations of metals in surface water and sediment to which human and ecological receptors would be exposed. However, monitoring would be required for at least 10 years to determine whether this alternative is successful. A reduction in mobility or volume is not expected to occur with MNR.

Implementability

Excavation, disposal, and construction of a permeable soil cover are commonly employed technologies. All three technologies use standard earth moving equipment which is readily available locally. Construction of a permeable soil cover would require a source of clean borrow, topsoil and vegetation. Clean borrow and topsoil are available locally. Vegetation may also be available locally or is readily available as seed, plugs, or potted plants from nurseries. Coordination with the local government would be required to place deed restrictions preventing future excavation or disturbance of the soil cover.

Surface water and sediment sampling can be easily implemented using standard collection and analysis methods. A SAP, QAPP, and HASP would be required for the monitoring program. Signs are readily implemented using locally available materials and services.

Restrictions on future use of land and groundwater at the site would require cooperation with local and county governments. Deed restrictions that limit land and groundwater use filed with the local government may be required to ensure future protectiveness.

Cost

Table 7-7 presents the costs for Alternative 3 at the Skaggs subsite. The total capital cost for this alternative is estimated to be $2,389,470. Total O&M costs for Alternative 3 are estimated to be $724,050. The present worth value of Alternative 3 is estimated to be $2,737,300.

State Acceptance

State acceptance will be evaluated after the public comment period closes for the Proposed Plan and this FS.

Community Acceptance

Community acceptance will be evaluated after the public comment period closes for the Proposed Plan and this final FS.

7.3.4 Alternative 4 – Low Permeable Cap, Excavation, Onsite Disposal, Monitored Natural Recovery

This alternative would meet RAOs through a combination of excavation, onsite disposal, installation of a low permeable cap, MNR, and institutional controls.

Overall Protection of Human Health and the Environment

Potential exposures to recreational visitors at areas contaminated with chat and soil at the Skaggs subsite would be controlled by installation of a low permeable cap. Adverse health risks to recreational visitors associated with exposure to lead in soil as well as risks associated with inhalation of metals to ATV riders would be controlled through installation of the low permeable cap and its soil and vegetation cover. Fencing and signage would be used to prohibit or restrict access to the cap and would also reduce the potential for human exposure and risk. Deed restrictions would be used to limit future land and groundwater use at the Skaggs subsite and to control future excavation at the area.

The installation of a low permeable cap would also reduce potential adverse exposures to terrestrial organisms including herbivores, vermivores, and carnivores. Installation and grading of a soil and vegetation cover would provide a favorable environment for plant growth, effectively eliminating the phytotoxicity that is currently observed at the site. Establishment of healthy vegetation at the site would increase habitat for terrestrial organisms, and reduce erosion by wind and storm water runoff.

Adverse effects to aquatic life in the unnamed pond would be reduced or controlled through sediment removal. MNR could also address potential ecological exposures to aquatic organisms. Over time, adverse impacts to aquatic life and benthic invertebrates should be mitigated as metal concentrations in surface water and sediment decline. The surface water and sediment would be sampled annually for at least 10 years to determine if the MNR is successful.

Compliance With ARARs

This alternative, through source removal and disposal, is expected to meet the potential state or federal chemical-specific ARARs for mine wastes and soil at the eastern and western chat areas and for sediment in the unnamed pond listed in Tables 2-1 and 2-2. This alternative is expected to meet the state or federal chemical-specific ARARs for soil and mine wastes listed in Tables 2-1 and 2-2 through installation of the low permeable cap at the central chat area. Since MNR does not include sediment removal from the unnamed tributaries, the state or federal chemical-specific, action-specific or location-specific ARARs for surface water and sediment listed in Tables 2-1 through 2-6 would not initially be met. However, this alternative could eventually meet the potential state and federal chemical-specific ARARs if the MNR is successful in reducing concentrations of metals in surface water and sediment.

This alternative is expected to meet all potential state and federal location- and action-specific ARARs listed in Tables 2-3 through 2-6. Compliance with Executive Order 11988 (Protection of Floodplains), Executive Order 11990 (Protection of Wetlands), Clean Water Act, Fish and Wildlife Conservation Act of 1980, and the Fish and Wildlife Coordination Act along with controls to prevent adversely impacting ecological receptors within and downstream of these sensitive environments will be required.

Excavation activities would require compliance with the Clean Air Act, the Missouri Fugitive Particulate Matter Regulations, the Missouri Clean Water Law, the Missouri Hazardous Substances Emergency Response, and the use of appropriate controls to monitor and mitigate emissions of airborne particulates and prevent storm water releases. Transporting excavated chat and contaminated soil and sediment would require compliance with the Hazardous Materials Transportation Regulation and the DOT Hazardous Materials Transportation Regulations. Disposal of contaminated media may require compliance with Subtitle C of RCRA, TSCA, the Missouri Solid Waste Disposal Law, and the Missouri Hazardous Waste Management Law.

Long-Term Effectiveness

A low permeability cap at the Skaggs subsite is expected to be effective at reducing exposures to human and ecological receptors, limiting erosion and transport of contaminants by wind and water, and reducing infiltration. The long-term effectiveness of the low permeability cap would depend on proper design and construction to direct surface water away from the waste, ensure containment of the waste, and ensure the integrity of the low permeability layer. Cap maintenance, including repair of damage caused by erosion; removal of invasive plant species with root systems that may damage the integrity of the impermeable layer; and potentially periodic replanting, fertilization, or watering of vegetation will be required. Periodic

maintenance of fencing would be required to prevent damage to the cap by foot or vehicular traffic.

The long-term effectiveness of MNR is uncertain because there is presently insufficient information to determine whether the surface water quality and sediment in the unnamed tributaries will achieve human health and ecological action levels. If MNR is not effective, additional remedial actions such as dredging or the installation of barriers in the streams to encourage the deposition of clean sediments could be implemented. Surface water and sediment monitoring is required to determine whether this alternative will be effective.

The long-term effectiveness of this alternative would also depend on periodic maintenance and public cooperation. Because fencing and signs are subject to vandalism and weathering, periodic inspection and maintenance would be required. Despite best efforts, installation of signs is not expected to completely mitigate potential exposures at the site. A portion of recreational visitors to the site would be expected to disregard warnings represented by the signs.

Short-Term Effectiveness

Short-term risks to workers include exposure to contaminants and heavy machinery during excavation, disposal, installation of the low permeability cap, fencing, and signs. The potential risks would be managed through the use of OSHA certified workers, development and compliance with HASPs, required attendance at safety meetings, and the use of best management practices for construction sites.

Risks to nearby residents include the potential for exposure to contaminants in dust generated during construction activities, increased noise at the site due to heavy machinery, and increased truck traffic on local roads. The potential risks would be mitigated through application of water or dust suppressants as needed to control release of particulates into the air, limiting operation of heavy machinery to daylight or standard work hours (if noise is an issue), and by restricting site access and egress by trucks to roads which would result in the least impacts to local traffic flows.

Environmental risks during implementation include the potential for releases of sediment or impacted surface water during storm events. Mitigation measures such as silt fences, hay bales, dewatering of mine wastes, and construction of temporary ditches to direct surface water away from the work areas would be used to minimize environmental impacts.

Reduction of Toxicity, Mobility, or Volume

This remedial alternative would result in a substantial reduction in contaminant mobility,

through excavation and disposal of waste materials from the eastern and western chat areas as well as from the unnamed pond. Approximately 5,000 cubic yards of material from the western chat area, approximately 580 cubic yards of material from the eastern chat area, and about 200 cubic yards of sediment from the unnamed pond would be excavated and included under the low permeable cap at the central chat area. Consolidation of excavated materials at the central chat area would contain the waste, effectively eliminating potential exposures by human and ecological receptors and restricting the mobility of approximately 62,000 cubic yards of chat and contaminated media (this total includes the excavated material from the eastern and western chat areas, the unnamed pond, and approximately 56,000 cubic yards of mine waste at the central chat area that will not be excavated). However, installation of a low permeability cap would not result in a decrease of toxicity or volume of the contaminated material.

Over time, MNR could result in a reduction of contaminant toxicity by decreasing the concentrations of metals in surface water and sediment to which human and ecological receptors would be exposed. However, monitoring would be required for at least 10 years to determine whether this alternative is successful. A reduction in mobility or volume is not expected to occur with MNR.

Implementability

Excavation, disposal, as well as construction of the low permeability cap and soil cover could be accomplished using standard earth moving equipment. Transport of cover materials would be accomplished using standard dump trucks or truck and trailer combinations. Construction of the low permeability caps and placement of soil cover would require a source of natural low permeable clay, clean borrow, topsoil and vegetation. Clean borrow and topsoil are available locally. Vegetation may also be available locally or is readily available as seed, plugs or potted plants from nurseries. All required material and services for the low permeability cap and soil cover, fencing and signage are available locally.

Groundwater, surface water and sediment sampling can be easily implemented using standard collection and analysis methods. A SAP, QAPP, and HASP would be required for the monitoring program. Signs and fencing are readily implemented using locally available materials and services.

Restrictions on future use of land and groundwater at the site would require cooperation with local and county governments. Deed restrictions that limit land and groundwater use filed with the local government may be required to ensure future protectiveness.

Cost

Table 7-8 presents the costs for Alternative 4 at the Skaggs subsite. The total capital cost for this alternative is estimated to be $2,984,950. Total O&M costs for Alternative 4 are estimated to be $562,150. The present worth value of Alternative 4 is estimated to be $3,268,620.

State Acceptance

State acceptance will be evaluated after the public comment period closes for the Proposed Plan and this FS.

Community Acceptance

Community acceptance will be evaluated after the public comment period closes for the Proposed Plan and this final FS.

8.0 Comparative Analysis of Alternatives

A comparative analysis of alternatives using each of the nine evaluation criteria, as required by federal regulation, is presented in this section. The purpose of this analysis is to identify the advantages and disadvantages of each alternative relative to the other alternatives. A separate comparison of the alternatives is presented under the heading of each criterion.

8.1 OU5 – Catherine Subsite

8.1.1 Protection of Human Health and the Environment

Alternatives 3 (Low Permeable Cap, Sediment Excavation, Onsite Disposal, and Monitored Natural Recovery) and 4 (Engineered Low Permeable Cap, Sediment Excavation, Onsite Disposal, and Monitored Natural Recovery) would be protective of human health and the environment. Both of these alternatives primarily rely on on-site containment of media exceeding action levels to attain RAOs. The major difference in these two alternatives is that compared to the cap in Alternative 3, the engineered cap in Alternative 4 is expected to substantially reduce infiltration through the contained waste. Both alternatives include excavation of the contaminated sediments which should reduce or eliminate exposures to human and ecological receptors from the sediments in the Catherine Pond. Both alternatives also include MNR in Logtown Branch, which, over time, may be protective of ecological exposures to aquatic life.

Alternative 2 (Institutional Controls) would achieve a moderate degree of protectiveness for human health, but would not be protective of the environment. Institutional controls such as installation of signs, fencing, and deed restrictions would not prevent exposures to ecological organisms.

Alternative 1 (No Action) would not be protective of human health or the environment.

8.1.2 Compliance with ARARs

Alternatives 3 (Low Permeable Cap, Sediment Excavation, Onsite Disposal, and Monitored Natural Recovery) and 4 (Engineered Low Permeable Cap, Sediment Excavation, Onsite Disposal, and Monitored Natural Recovery) are expected to comply with chemical-specific ARARs for soil, mine waste, and sediment in the Catherine Pond. Alternatives 3 and 4 are likely to meet chemical-specific ARARs for groundwater. Because the engineered cap is expected to provide a greater reduction in the infiltration of precipitation through the chat, Alternative 4 should be more likely to meet chemical-specific ARARs for groundwater. There is presently insufficient information to determine whether surface water and sediment quality of

Logtown Branch will meet action levels without additional remedial actions for either alternative. Both of these alternatives would meet all location- and action-specific ARARs.

Alternative 1 (No Action) and Alternative 2 (Institutional Controls) would not comply with chemical- or location-specific ARARs. Because neither alternative includes active remedial technologies, action-specific ARARs would not be triggered.

8.1.3 Long-Term Effectiveness and Permanence

The long-term effectiveness of Alternatives 3 (Low Permeable Cap, Sediment Excavation, Onsite Disposal, and Monitored Natural Recovery) and 4 (Engineered Low Permeable Cap, Sediment Excavation, Onsite Disposal, and Monitored Natural Recovery) would be very similar. The primary difference between the two alternatives is that the engineered low permeable cap in Alternative 4 is expected to achieve a higher degree of groundwater protection. Both alternatives rely on proper design, construction, and maintenance of the cap.

Alternative 2 (Institutional Controls) would be less effective and reliable because it relies on maintenance of signs and fences in addition to the public's willingness to heed warnings. This alternative is not effective in preventing exposures to the environment.

Alternative 1 (No Action) is not reliable or effective in preventing exposures to humans or the environment.

8.1.4 Reduction of Toxicity, Mobility or Volume

Alternatives 3 (Low Permeable Cap, Sediment Excavation, Onsite Disposal, and Monitored Natural Recovery) and 4 (Engineered Low Permeable Cap, Sediment Excavation, Onsite Disposal, and Monitored Natural Recovery) would both contain the contaminated mine wastes, soil, and sediment. The containment will substantially reduce contaminant mobility for these media, especially from wind and surface water runoff. Compared to Alternative 3 that has a low permeable cap, Alternative 4 (Engineered Low Permeability Cap) would further reduce contaminant mobility by reducing the amount of precipitation infiltrating through the mine wastes and leaching contaminants to the groundwater.

Alternatives 1 (No Action) and 2 (Institutional Controls) would not achieve any reductions in toxicity, mobility, or volume at the site.

8.1.5 Short-Term Effectiveness

Because no remedial actions would be implemented, there are no short-term risks to the community, workers, or the environment associated with Alternative 1 (No Action). Similarly, minimal short-term risks would be associated with Alternative 2 (Institutional Controls).

Alternatives 3 (Low Permeable Cap, Sediment Excavation, Onsite Disposal, and

Monitored Natural Recovery) and 4 (Engineered Low Permeable Cap, Sediment Excavation, Onsite Disposal, and Monitored Natural Recovery) would have similar short-term risks to the community, workers, and environment. These risks include the physical hazards associated with heavy equipment operation and potential human and environmental exposures to contaminants during excavation activities. The use of best management practices would significantly minimize potential adverse effects during implementation of these alternatives.

8.1.6 Implementability

No remedial actions would be implemented with Alternative 1 (No Action). Similarly, minimal remedial actions needed to implement Alternative 2 (Institutional Controls) are straight forward. Implementation of Alternative 2 would require coordination with local agencies to prevent future use of groundwater for drinking water.

Implementation of Alternatives 3 (Low Permeable Cap, Sediment Excavation, Onsite Disposal, and Monitored Natural Recovery) and 4 (Engineered Low Permeable Cap, Sediment Excavation, Onsite Disposal, and Monitored Natural Recovery) primarily rely on standard earthmoving and construction technologies. Supplies and materials are readily available locally or through specialized companies (e.g., geomembranes or GCL required for engineered low permeability cap). Alternatives 3 and 4 would also require on-going maintenance of the cap containing mine wastes and coordination with local agencies to prevent disturbance of the containment areas.

8.1.7 Cost

Table 8-1 presents a summary of the capital costs, O&M costs, and present worth costs for each alternative. Alternative 4 (Engineered Low Permeable Cap, Sediment Excavation and Onsite Disposal, Monitored Natural Recovery) has the highest present worth cost at $16,284,620. The capital cost of this alternative is $15,883,350 and the total O&M costs are $844,350. Alternative 3 (Low Permeability Cap, Sediment Excavation and Onsite Disposal, Monitored Natural Recovery) has the next highest present worth cost of $2,653,540 with total O&M costs of $802,630.

Alternative 2 (Institutional Controls) has a present worth cost of $721,700 with total O&M costs of $437,380. Alternative 1 (No Action) has a present worth cost of $53,900 that is associated with the EPA five year reviews at the site.

8.1.8 State Acceptance

State acceptance on the alternatives will be fully determined after the public comment

period closes for the Proposed Plan and this FS.

8.1.9 Community Acceptance

Community acceptance of the alternatives will be fully determined after the public comment period closes for the Proposed Plan and this FS.

8.2 OU5 – Skaggs Subsite

8.2.1 Protection of Human Health and the Environment

Alternative 4 (Low Permeable Cap, Excavation, Onsite Disposal, and Monitored Natural Recovery) would provide more protection of human health and the environment than Alternative 3 (Permeable Cover, Excavation, Onsite Disposal, and Monitored Natural Recovery). Both alternatives control exposures to human and ecological receptors from contaminants in the eastern and western chat areas at the Skaggs subsite. Both of these alternatives primarily rely on on-site containment of media exceeding action levels to attain RAOs at the central chat area. The major difference in these two alternatives is that the low permeable cap included in Alternative 4 is expected to substantially reduce infiltration through the contained mine waste. Both alternatives include excavation of contaminated sediments in the onsite pond which is expected to reduce or eliminate exposures to human and ecological receptors from these sediments. Both alternatives also include MNR in the unnamed tributaries, which, over time, should be equally protective of ecological exposures to aquatic life.

Alternative 2 (Institutional Controls) would achieve a moderate degree of protectiveness for human health, but would not be protective of the environment. Institutional controls such as installation of signs, fencing, and deed restrictions would not prevent exposures by ecological organisms.

Alternative 1 (No Action) would not be protective of human health or the environment.

8.2.2 Compliance with ARARs

Alternatives 3 (Permeable Cover, Excavation, Onsite Disposal, and Monitored Natural Recovery) and 4 (Low Permeable Cap, Excavation, Onsite Disposal, and Monitored Natural Recovery) would be almost equally compliant with chemical-specific ARARs for soil, mine wastes, and sediments from the unnamed pond. Because the low permeability cap is expected to achieve a higher reduction in the amount of precipitation infiltrating through the mine waste, Alternative 4 would be more likely to achieve groundwater ARARs. There is presently insufficient information to determine whether surface water and sediment quality of unnamed

tributaries will meet action levels without additional remedial actions for either alternative. Both of these alternatives would meet all location- and action-specific ARARs.

Alternative 1 (No Action) and Alternative 2 (Institutional Controls) would not comply with chemical- or location-specific ARARs. Because neither alternative includes active remedial technologies, action-specific ARARs would not be triggered.

8.2.3 Long-Term Effectiveness and Permanence

The long-term effectiveness of Alternatives 3 (Permeable Cover, Excavation, Onsite Disposal, and Monitored Natural Recovery) and 4 (Low Permeable Cap, Excavation, Onsite Disposal, and Monitored Natural Recovery) would be very similar. The main difference between the two alternatives is that the low permeable cap in Alternative 4 would be expected to achieve a higher degree of groundwater protection than Alternative 3 by reducing precipitation infiltrating through the mine waste to a higher degree.

Alternative 2 (Institutional Controls) would be less effective and reliable because it relies on maintenance of signs and fences in addition to the public's willingness to heed warnings. This alternative is not effective in preventing exposures to the environment.

Alternative 1 (No Action) is not reliable or effective in preventing exposures to humans or the environment.

8.2.4 Reduction of Toxicity, Mobility or Volume

Alternatives 3 (Permeable Cover, Excavation, Onsite Disposal, and Monitored Natural Recovery) and 4 (Low Permeable Cap, Excavation, Onsite Disposal, and Monitored Natural Recovery) would both contain approximately 62,000 cy yd of contaminated mine wastes, soil, and sediment. The containment will substantially reduce the contaminant mobility for these media, especially from wind and surface water runoff. Alternative 4 would further reduce the mobility of contaminants by reducing the amount of precipitation infiltrating through the consolidated mine wastes and leaching contaminants to the groundwater. The reduction in surface water and sediment contaminant concentrations in the unnamed tributaries are expected to be similar for Alternatives 3 and 4. Both alternatives would use MNR to reduce the mobility and toxicity of metals in these media.

Alternatives 1 (No Action) and 2 (Institutional Controls) would not achieve any reductions in toxicity, mobility, or volume at the site.

8.2.5 Short-Term Effectiveness

Because no remedial actions would be implemented, there are no short-term risks to the community, workers, or the environment associated with Alternative 1 (No Action). Similarly,

only minimal short-term risks would be associated with Alternative 2 (Institutional Controls).

Alternatives 3 (Permeable Cover, Excavation, Onsite Disposal, and Monitored Natural Recovery) and 4 (Low Permeable Cap, Excavation, Onsite Disposal, and Monitored Natural Recovery) would have similar short-term risks to the community, workers, and environment. These risks include the physical hazards associated with heavy equipment operation and potential human and environmental exposures to contaminants during excavation activities. The use of best management practices would significantly minimize potential adverse effects during implementation of these alternatives.

8.2.6 Implementability

No remedial actions would be implemented with Alternative 1 (No Action). Similarly, minimal remedial actions needed to implement Alternative 2 (Institutional Controls) are straight forward. Implementation of Alternatives 2, 3, and 4 would require coordination with local agencies to prevent future use of groundwater for drinking water.

Implementation of Alternatives 3 (Permeable Cover, Excavation, Onsite Disposal, and Monitored Natural Recovery) and 4 (Low Permeable Cap, Excavation, Onsite Disposal, and Monitored Natural Recovery) primarily rely on standard earthmoving and construction technologies. Supplies and materials are readily available locally. Alternative 4 would require a source of natural low permeable clay for the low permeable cap. Alternatives 3 and 4 would also require on-going maintenance of the cap/cover and coordination with local agencies to prevent disturbance of the containment area.

8.2.7 Cost

Table 8-2 presents a summary of the capital costs, O&M costs, and present worth costs for each alternative. Alternative 4 (Low Permeable Cap, Excavation and Disposal, Monitored Natural Recovery) has the highest present worth cost at $3,268,620. The capital cost of this alternative is $2,984,950 and the total O&M costs are $562,150. Alternative 3 (Permeable Cover, Excavation and Disposal, Monitored Natural Recovery) has the next highest present worth cost of $2,737,300 with total O&M costs of $724,050.

Alternative 2 (Institutional Controls) has a present worth cost of $1,066,700 with total O&M costs of $522,650. Alternative 1 (No Action) has a present worth cost of $53,900 that is associated with the EPA five year reviews at the site.

8.2.8 State Acceptance

State acceptance on the alternatives will be fully determined after the public comment period closes for the Proposed Plan and this FS.

8.2.9 Community Acceptance

Community acceptance of the alternatives will be fully determined after the public comment period closes for the Proposed Plan and this FS.

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Tables

Table ES-1
Comparative Analysis of Alternatives
OU5 – Catherine Subsite
Madison County Mines Site
Madison County, Missouri

Evaluation Criteria	**Alternative 1** **No Action**	**Alternative 2** **Institutional Controls**	**Alternative 3** **Low Permeable Cap, Sediment Excavation and Onsite Disposal, Monitored Natural Recovery**	**Alternative 4** **Engineered Low Permeable Cap, Sediment Excavation and Onsite Disposal, Monitored Natural Recovery**
Overall Protection of Human Health and the Environment	This alternative would not provide protection of human health or the environment. No remedial action objectives would be satisfied.	This alternative would provide some protection to human health by restricting access to the Catherine chat area and pond. Land use restrictions would limit exposure to the shallow groundwater at the Catherine subsite. The alternative would not be protective of the environment because risks to ecological receptors would continue to exist.	Human and ecological receptor exposure to contaminated mine wastes and soils would be controlled by the low permeable cap and fencing. Exposure to contaminated sediments in the Catherine pond would be controlled by excavating the sediments and disposal under the low permeable cap. Water percolation through the cap would be decreased. Risks from exposure to groundwater would be controlled by land use restrictions. Monitored natural recovery may address potential ecological exposure to sediment, but there is insufficient information to determine whether it will be successful.	Human and ecological receptor exposure to contaminated mine wastes and soils would be controlled by the engineered low permeable cap and fencing. Exposure to contaminated sediments in the Catherine pond would be controlled by excavating the sediments and disposal under the cap. Water percolation through the cap would be nearly eliminated, thereby reducing risks from additional contaminants entering the groundwater. Risks from exposure to groundwater would be controlled by land use restrictions. Monitored natural recovery may address potential ecological exposure to sediment, but there is insufficient information to determine whether it will be successful.
Compliance with Applicable or Relevant and Appropriate Requirements (ARARs)	This alternative would not meet potential federal or state chemical-specific or location- specific ARARs. Action- specific ARARS would not be applicable because there is no action.	This alternative would not meet potential federal or state chemical-specific or location-specific ARARs. Action-specific ARARs would not be applicable because there is no remedial action.	This alternative would be expected to meet the potential federal and state chemical-specific ARARS for mine wastes, soils, and sediments. It would not be expected to meet chemical-specific ARARs for groundwater. Monitored natural recovery may not result in attainment of surface water and sediment ARARs. The alternative would be expected to meet federal and state location-specific and action-specific ARARs.	This alternative would be expected to meet the potential federal and state chemical-specific ARARS for mine wastes, soils, and sediments. It may not meet chemical-specific ARARs for groundwater, although additional recharge of the groundwater would be controlled. Monitored natural recovery may not result in attainment of surface water and sediment ARARs. The alternative would be expected to meet federal and state location-specific and action-specific ARARs.
Long-Term Effectiveness	This alternative would not provide active reduction in long-term risks. No long-term controls would be implemented.	Long term effectiveness would be dependent upon periodic maintenance of fences, public compliance with warning signs, and implementation of land use restrictions. The alternative would not be effective in meeting ecological RAOs.	A low permeable cap would be effective in controlling exposure to mine wastes and contaminated soils from direct contact and ingestion. Water percolation through a low permeable cap would be reduced. Excavation and onsite disposal of sediment from the Catherine pond would be effective in controlling exposure to the contaminated sediment. If monitored natural recovery is not effective in controlling exposure to contaminated sediments, additional remedial actions may be necessary to achieve action levels in surface water and sediments. Long-term effectiveness of groundwater use restrictions would be dependent upon ability of local government to enforce restrictions.	An engineered low permeable cap would be effective in controlling exposure to mine wastes and contaminated soils from direct contact and ingestion. Water percolation through an engineered low permeable cap would be nearly eliminated. Excavation and onsite disposal of sediment from the Catherine pond would be effective in controlling exposure to the contaminated sediment. If monitored natural recovery is not effective in controlling exposure to contaminated sediments, additional remedial actions may be necessary to achieve action levels in surface water and sediments. Long-term effectiveness of groundwater use restrictions would be dependent upon ability of local government to enforce restrictions.
Reduction of Toxicity, Mobility, and Volume	There would be no reduction in the toxicity, mobility, or volume of contamination.	This alternative would not include treatment and there would be no reduction in toxicity, mobility, or volume of waste material.	The alternative would not treat mine waste materials and would not reduce toxicity or volume of waste material. A low permeable cap would reduce the mobility of the mine wastes and the sediments from the Catherine pond that would be placed under the cap.	The alternative would not treat mine waste materials and would not reduce toxicity or volume of waste material. An engineered low permeable cap would further reduce the mobility of mine wastes and the sediments from the Catherine pond that would be placed under the cap.

Table ES-1 (Continued)
Comparative Analysis of Alternatives
OU5 – Catherine Subsite
Madison County Mines Site
Madison County, Missouri

Short-Term Effectiveness	Because no actions would be conducted, there would be no increase in the short-term risk to the workers, the community, or the environment.	This alternative would be protective in the short term. Contaminant exposure to workers installing fencing and signs would be controlled through adherence to a Health & Safety (H&S) plan.	There would be short-term risks to workers from exposure to contaminants and physical hazards during construction of the cap and fencing. Exposure of workers to contaminants at the site would be controlled through implementation of a H&S plan. Exposure of the public to dust would be controlled through application of water or dust suppressants. Environmental risks from storm water runoff during implementation of the remedial action would be controlled by following Best Management Practices.	There would be short-term risks to workers from exposure to contaminants and physical hazards during construction of the cap and fencing. Exposure of workers to contaminants at the site would be controlled through implementation of a H&S plan. Exposure of the public to dust would be controlled through application of water or dust suppressants. Environmental risks from storm water runoff during implementation of the remedial action would be controlled by following Best Management Practices.
Implementability	The implementability criterion is not applicable because no remedial activities would occur.	This alternative would be fully implementable using locally available materials and services. Restrictions on use of property would be implementable.	Construction of a low permeable cap and fencing and excavation and disposal of sediment in the Catherine pond are commonly employed technologies. Restrictions on use of property are implementable.	Construction of an engineered low permeable cap and fencing and excavation and disposal of sediment in the Catherine pond are commonly employed technologies. Restrictions on use of property are implementable.
Cost (Total Present Worth)	$53,900	$721,700	$2,653,540	$16,284,620

Table ES-2
Comparative Analysis of Alternatives
OU5 – Skaggs Subsite
Madison County Mines Site
Madison County, Missouri

Evaluation Criteria	Alternative 1 No Action	Alternative 2 Institutional Controls	Alternative 3 Permeable Cover, Excavation and Disposal, Monitored Natural Recovery	Alternative 4 Low Permeable Cap, Excavation and Disposal, Monitored Natural Recovery
Overall Protection of Human Health and the Environment	This alternative would not provide protection of human health or the environment. No remedial action objectives would be satisfied.	This alternative would provide some protection to human health by restricting access to the Skaggs chat areas and pond. Land use restrictions would limit exposure to the shallow groundwater at the Skaggs subsite. Signs would be placed along the unnamed tributaries to control exposure to contaminated sediments. The alternative would not be protective of the environment because risks to ecological receptors would continue to exist.	Human and ecological receptor exposure to contaminated mine wastes and soils would be controlled by the permeable cover and fencing. Exposure to contaminated sediments in the Skaggs pond would be controlled by excavating the sediments and disposal under the permeable cover. Water percolation through the cover would be decreased to some extent. Risks from exposure to groundwater would be controlled by land use restrictions. Monitored natural recovery may address potential ecological exposure to sediment, but there is insufficient information to determine whether it will be successful.	Human and ecological receptor exposure to contaminated mine wastes and soils would be controlled by the low permeable cap and fencing. Exposure to contaminated sediments in the Skaggs pond would be controlled by excavating the sediments and disposal under the cap. Water percolation through the cap would be reduced to a large extent, thereby reducing risks from additional contaminants entering the groundwater. Risks from exposure to groundwater would be controlled by land use restrictions. Monitored natural recovery may address potential ecological exposure to sediment, but there is insufficient information to determine whether it will be successful.
Compliance with Applicable or Relevant and Appropriate Requirements (ARARs)	This alternative would not meet potential federal or state chemical-specific or location- specific ARARs. Action- specific ARARS would not be applicable because there is no action.	This alternative would not meet potential federal or state chemical-specific or location-specific ARARs. Action-specific ARARs would not be applicable because there is no remedial action.	This alternative would be expected to meet the potential federal and state chemical-specific ARARS for mine wastes, soils, and sediments. It would not be expected to meet chemical-specific ARARs for groundwater. Monitored natural recovery may not result in attainment of surface water and sediment ARARs. The alternative would be expected to meet federal and state location-specific and action-specific ARARs.	This alternative would be expected to meet the potential federal and state chemical-specific ARARS for mine wastes, soils, and sediments. It may not meet chemical-specific ARARs for groundwater, although additional recharge of the groundwater would be controlled. Monitored natural recovery may not result in attainment of surface water and sediment ARARs. The alternative would be expected to meet federal and state location-specific and action-specific ARARs.
Long-Term Effectiveness	This alternative would not provide active reduction in long-term risks. No long-term controls would be implemented.	Long term effectiveness would be dependent upon periodic maintenance of fences, public compliance with warning signs, and implementation of land use restrictions. The alternative would not be effective in meeting ecological RAOs.	Excavation and consolidation of mine wastes from the east and west chat areas under a permeable cover at the central chat area would control long term exposure to mine wastes at the east and west chat areas. A permeable cover would be effective in controlling exposure to mine wastes and contaminated soils from direct contact and ingestion. Water percolation through a permeable cover would be reduced to some extent. Excavation and onsite disposal of sediment from the Skaggs pond would be effective in controlling exposure to the contaminated sediment. If monitored natural recovery is not effective in controlling exposure to contaminated sediments, additional remedial actions may be necessary to achieve action levels in surface water and sediments. Long-term effectiveness of groundwater use restrictions would be dependent upon ability of local government to enforce restrictions.	Excavation and consolidation of mine wastes from the east and west chat areas under a low permeable cap at the central chat area would control long term exposure to mine wastes at the east and west chat areas. A low permeable cap would be effective in controlling exposure to mine wastes and contaminated soils from direct contact and ingestion. Water percolation through a low permeable cap would be nearly eliminated. Excavation and onsite disposal of sediment from the Skaggs pond would be effective in controlling exposure to the contaminated sediment. If monitored natural recovery is not effective in controlling exposure to contaminated sediments, additional remedial actions may be necessary to achieve action levels in surface water and sediments. Long-term effectiveness of groundwater use restrictions would be dependent upon ability of local government to enforce restrictions.
Reduction of Toxicity, Mobility, and Volume	There would be no reduction in the toxicity, mobility, or volume of contamination.	This alternative would not include treatment and there would be no reduction in toxicity, mobility, or volume of waste material.	The alternative would not treat mine waste materials and would not reduce toxicity or volume of waste material. A permeable cover would reduce the mobility of the mine wastes and the sediments from the Skaggs pond that would be placed under the cover.	The alternative would not treat mine waste materials and would not reduce toxicity or volume of waste material. A low permeable cap would further reduce the mobility of mine wastes and the sediments from the Skaggs pond that would be placed under the cap.

Table ES-2 (Continued)
Comparative Analysis of Alternatives
OU5 – Skaggs Subsite
Madison County Mines Site
Madison County, Missouri

Short-Term Effectiveness	Because no actions would be conducted, there would be no increase in the short-term risk to the workers, the community, or the environment.	This alternative would be protective in the short term. Contaminant exposure to workers installing fencing and signs would be controlled through adherence to a Health & Safety (H&S) plan.	There would be short-term risks to workers from exposure to contaminants and physical hazards during construction of the cover and fencing. Exposure of workers to contaminants at the site would be controlled through implementation of a H&S plan. Exposure of the public to dust would be controlled through application of water or dust suppressants. Environmental risks from storm water runoff during implementation of the remedial action would be controlled by following Best Management Practices.	There would be short-term risks to workers from exposure to contaminants and physical hazards during construction of the cap and fencing. Exposure of workers to contaminants at the site would be controlled through implementation of a H&S plan. Exposure of the public to dust would be controlled through application of water or dust suppressants. Environmental risks from storm water runoff during implementation of the remedial action would be controlled by following Best Management Practices.
Implementability	The implementability criterion is not applicable because no remedial activities would occur.	This alternative would be fully implementable using locally available materials and services. Restrictions on use of property would be implementable.	Construction of a permeable cover and fencing and excavation and disposal of sediment in the Skaggs pond are commonly employed technologies. Restrictions on use of property are implementable.	Construction of a low permeable cap and fencing and excavation and disposal of sediment in the Skaggs pond are commonly employed technologies. Restrictions on use of property are implementable.
Cost (Total Present Worth)	$53,900	$1,066,700	$2,737,300	$3,268,620

Table 1-1. Summary of Concentrations of Selected Metals in Chat Samples from the Catherine, Skaggs, and Little St. Francis River Sites

		Catherine Chat (3 samples)			Skaggs Chat (6 samples)			Little St. Francis River-West (10 samples)			Little St. Francis River-East (8 samples)		
		median	**min**	**max**	**median**	**min**	**max**	**median**	**min**	**max**	**median**	**min**	**max**
Aluminum	mg/kg	6300	595	7110	890	556	3000	1230	502	8140	663	585	988
Arsenic	mg/kg	11.7	7.1	12.5	16.5	12.6	40.5	14.1	6.7	21.6	<7.9	3.1 U	14.3
Cadmium	mg/kg	<0.58	0.54 U	0.59 U	<1.2	0.53 UJ	4.2	<0.53	0.5 U	2.7	<0.52	0.52 U	0.54
Cobalt	mg/kg	108	89.1	245	145	72.6	280	82.4	50.4	147	115	60.6	236
Copper	mg/kg	105	32.4	111	515	125	1050	79.0	15.9	1020	55.6	18.8	255
Iron	mg/kg	23800	17900	25200	26400	25600	35700	29400	17100	33400	26500	22800	30000
Lead	mg/kg	2090	1420	2100	5660	2560	28400	5255	2780	7440	7475	2030	26400
Manganese	mg/kg	2580	1990	4200	3700	3390	4200	3715	2000	5140	3515	3140	3870
Nickel	mg/kg	93.5	82.7	219	150	102	296	92.3	53.9	143	113	64.5	279
Vanadium	mg/kg	18.7	3.4	18.8	3.3	1.4	9.4	<1.33	0.52 U	14.6	<0.76	0.52 U	2.1
Zinc	mg/kg	<36.9	23.1 U	40	337	173	811	<56.4	13.3 U	655	<18.9	9.5 U	82.1

U -- Analyte not detected, value shown is the detection limit
J -- Value is estimated
< -- One or more values not detected; detection limit used for nondetects

Table 1-2. TCLP Leach Test Results for Chat and Soil Samples from the Catherine, Skaggs, and Little St. Francis River Sites

		Metals Toxicity Values*	Catherine		Skaggs		LSFR West Chat		LSFR East Soil	
Station ID			**28001**		**30003**		**25003**		**26101**	
Sample ID Collection Date Collection Time Depth (bgs)			ZTGPLF-28001 2/23/2006 14:55 0 - 2 ft		ZTGPLF-30003 3/1/2006 16:10 0 - 0.85 ft		ZTGPLJ-25003 2/28/2006 14:35 8 to 10 ft		ZTCPLC-26101 3/3/2006 15:15 0 to 1 ft	
Leach Extract										
Arsenic	mg/L	5.0	0.03	U	0.03	U	0.03	U	0.03	U
Barium	mg/L	100	0.11		0.11		0.13		0.95	
Cadmium	mg/L	1.0	0.005	U	0.016		0.005	U	0.013	
Chromium	mg/L	5.0	0.0055		0.005	U	0.005		0.0066	
Lead	mg/L	5.0	36.8		105		112		0.12	
Mercury	mg/L	0.2	na		na		na		na	
Selenium	mg/L	1.0	0.04	U	0.04	U	0.04	U	0.04	U
Silver	mg/L	5.0	0.005	U	0.005	U	0.005	U	0.005	U

U -- Analyte not detected, value shown is the detection limit
na -- Not analyzed
* 40 CFR 264.21

Table 1-3. Analytical Results for Metals in Chat Samples from the Catherine Site

		Chat Samples					
		28001		**28003**		**28004**	
Sample ID		ZTGPLF-28001		ZTGPLK-28003		ZTGPLM-28004	
Collection Date		2/23/2006		2/23/2006		2/23/2006	
Collection Time		14:55		13:45		10:30	
Depth (bgs)		0 to 2 ft		11.1 to 12.3 ft		13.8 to 17.8 ft	
Sample Type		Grab		Grab		Grab	
Metals							
Aluminum	mg/kg	595		6300		7110	
Antimony	mg/kg	3.3	U	3.6	U	3.5	U
Arsenic	mg/kg	12.5		7.1		11.7	
Barium	mg/kg	2.4		71.7		213	
Beryllium	mg/kg	0.52		0.45		0.84	
Cadmium	mg/kg	0.54	U	0.59	U	0.58	U
Calcium	mg/kg	134000		45100		76400	
Chromium	mg/kg	2.1		8.1		11.3	
Cobalt	mg/kg	89.1		108		245	
Copper	mg/kg	105		32.4		111	
Iron	mg/kg	25200		17900		23800	
Lead	mg/kg	2100		1420		2090	
Magnesium	mg/kg	63700		23700		40600	
Manganese	mg/kg	4200		1990		2580	
Mercury	mg/kg	na		na		na	
Nickel	mg/kg	93.5		82.7		219	
Potassium	mg/kg	417		371		601	
Selenium	mg/kg	4.3	U	4.7	U	4.7	U
Silver	mg/kg	0.81		0.59	U	0.81	
Sodium	mg/kg	271	U	153	U	276	U
Thallium	mg/kg	7	U	7.7	U	7.6	U
Vanadium	mg/kg	3.4		18.7		18.8	
Zinc	mg/kg	23.1	U	36.9		40	
Solids	%	na		na		na	

U -- Analyte not detected, value shown is the detection limit
J -- Value is an estimate
na -- Not analyzed

Table 1-4. Comparison of Chat from the Catherine and Skaggs Sites to EPA Human Health Screening Criteria for Soil

		Region 9 PRG		Catherine Chat			Skaggs Chat		
		Residential Soil	Industrial Soil	Max. Value	n ≥ Res. PRG	n ≥ Ind. PRG	Max. Value	n ≥ Res. PRG	n ≥ Ind. PRG
Aluminum	mg/kg	77,000	990,000	7,110	0 of 3	0 of 3	3,000	0 of 6	0 of 6
Antimony	mg/kg	31	410	3.6 U	0 of 3	0 of 3	6.49 UJ	0 of 6	0 of 6
Arsenic	mg/kg	22	---	12.5	0 of 3	---	40.5	2 of 6	---
Barium	mg/kg	15,000	190,000	213	0 of 3	0 of 3	28.3	0 of 6	0 of 6
Beryllium	mg/kg	160	2,000	0.84	0 of 3	0 of 3	1.19	0 of 6	0 of 6
Cadmium	mg/kg	70	800	0.59 U	0 of 3	0 of 3	4.2	0 of 6	0 of 6
Cobalt	mg/kg	23	300	245	3 of 3	0 of 3	280	6 of 6	0 of 6
Copper	mg/kg	3,100	41,000	111	0 of 3	0 of 3	1,050	0 of 6	0 of 6
Iron	mg/kg	55,000	720,000	25,200	0 of 3	0 of 3	35,700	0 of 6	0 of 6
Lead	mg/kg	400	800	2,100	3 of 3	3 of 3	28,400	6 of 6	6 of 6
Manganese	mg/kg	1,800	23,000	4,200	3 of 3	0 of 3	4,200	6 of 6	0 of 6
Mercury	mg/kg	23	310	n/a	---	---	n/a	---	---
Molybdenum	mg/kg	390	5,100	n/a	---	---	n/a	---	---
Nickel	mg/kg	1,600	20,000	219	0 of 3	0 of 3	296	0 of 6	0 of 6
Selenium	mg/kg	390	5,100	4.7 U	0 of 3	0 of 3	5 U	0 of 6	0 of 6
Silver	mg/kg	390	5,100	0.81	0 of 3	0 of 3	4	0 of 6	0 of 6
Vanadium	mg/kg	390	5,200	18.8	0 of 3	0 of 3	9.4	0 of 6	0 of 6
Zinc	mg/kg	23,000	310,000	40	0 of 3	0 of 3	811	0 of 6	0 of 6

* Chromium analyzed as total chromium
** Detection limit for thallium exceeded the residential PRG
n/a not analyzed
U Analyte not detected; value shown is the detection limit
J Value is estimated

Table 1-5. Analytical Results for Shallow Ground Water at the Catherine Site

		Shallow Ground Water From Beneath Chat											
Station ID		28001								28004			
Sample ID		ZGGPLP-28001				ZGGDLP-28001				ZGGPLS-28004			
Collection Date		2/23/2006				2/23/2006				2/23/2006			
Collection Time		15:10				16:00				11:00			
Depth (bgs)		1 to 4 ft				Duplicate				17 to 21 ft			
		Total		*Dissolved*		*Total*		*Dissolved*		*Total*		*Dissolved*	
Metals													
Aluminum	ug/L	723	U	37	U	50	U	37	U	876	U	37	U
Antimony	ug/L	50	U	17	U	50	U	17	U	50	U	17	U
Arsenic	ug/L	25	U	12.4		25	U	7	U	25	U	7	U
Barium	ug/L	83		73.7		81.5		75.1		83.1	J	66.1	J
Beryllium	ug/L	3	U	1	U	3.74		1	U	3	U	1	U
Cadmium	ug/L	3	U	1	U	3	U	1	U	3	U	1	U
Calcium	mg/L	241		221		230		219		172		178	
Chromium	ug/L	15	U	4	U	15	U	4	U	15	U	4	U
Cobalt	ug/L	119		51.5		54.7		57.3		75.4		68.1	
Copper	ug/L	83.3		3.24		6.45		2.49		12.2		2	U
Iron	ug/L	6400		108		50	U	89.7		1480	U	29	U
Lead	ug/L	1650		57.6		57.6		50.2		50	U	10	U
Magnesium	mg/L	134		66.1		124		118		84.1		82.7	
Manganese	ug/L	913		123		82		85		4870		4640	
Mercury	ug/L	na		na		na		na		na		na	
Molybdenum	ug/L	15	U	5	U	15	U	5	U	15	U	11.1	
Nickel	ug/L	457		388		395		377		60.2		44.6	
Potassium	mg/L	4.69		3.91		3.51		3.85		7.27		7.48	
Selenium	ug/L	50	U	40	U	50	U	40	U	50	U	40	U
Silver	ug/L	25	U	7	U	25	U	7	U	25	U	7	U
Sodium	mg/L	10.8		12.1		10.9		12		90.6	J	102	J
Thallium	ug/L	50	U	37	U	50	U	37	U	50	U	37	U
Titanium	ug/L	20	U	4	U	20	U	4	U	20	U	4	U
Vanadium	ug/L	10	U	3	U	10	U	3	U	10	U	3	U
Zinc	ug/L	69.2		55.5		51.9		55.5		40.6		35.3	
Hardness as CaCO3	mg/L	1153	cal	824	cal	1085	cal	1033	cal	776	cal	785	cal
Other Constituents													
Acidity as CaCO3	mg/L	5	U			5	U			5	U		
Alkalinity	mg/L	260				261				319			
Chloride	mg/L	12.1				6.81				297			
Sulfate	mg/L	728				747				319			
Hardness as CaCO3	mg/L	1150				1080				776			
Non-Filterable Solids	mg/L	62				2	U			63			
Total Dissolved Solids	mg/L	1320				1200				1160			
Conductivity	umhos/cm	1610				1700				1830			
Field Parameters													
pH	s.u.	7.19				7.13				7.81			
Specific conductance	umhos/cm	1516				1534				1678			
Temperature	C	8.4				7.8				13.4			
Turbidity	NTU	4.02				7.42				92			

Table 1-6. Comparison of Shallow Ground Water from the Catherine Site to Water Quality Criteria

		Ground Water Criteria (10 CSR 60-4)*		Surface Water Criteria (10 CSR 20-7)**		Shallow Ground Water Collected from Beneath Catherine Chat by GeoProbe (2 samples)					
		Primary MCL	Secondary MCL	Criteria	Designated Use	Max. Value Total		Max. Value Dissolved		n>MCL	n>SW criteria
Aluminum	ug/L		50-200	750-acute	AQL	876	U	37	U	0 of 1	0 of 1
Antimony	ug/L	6		6	DWS	50	U	17	U	0 of 0	0 of 0
Arsenic	ug/L	10		20	AQL	25	U	12.4		1 of 2 (diss.)	0 of 2
Barium	ug/L	2,000		2,000	DWS	83.1	J	75.1		0 of 2	0 of 2
Beryllium	ug/L	4		4	DWS	3.74		1	U	0 of 2	0 of 2
Cadmium	ug/L	5		**0.24**	AQL	3	U	1	U	0 of 2	0 of 2
Chromium	ug/L	100		**74.1-Cr^{III}**	AQL	15	U	4	U	0 of 2	0 of 2
Cobalt	ug/L			1,000	LWW	119		68.1		---	0 of 2
Copper	ug/L	1,300(action)	1,000	**7.3**	AQL	83.3		3.24		0 of 2	0 of 2
Iron	ug/L		300	1,000	AQL	6,400		108		1 of 1	0 of 2
Lead	ug/L	15 (action)		**2.5**	AQL	1,650		57.6		1 of 1	0 of 1
Manganese	ug/L		50			4,780		4,640		2 of 2	---
Mercury	ug/L	2		0.5	AQL	na		na		---	---
Nickel	ug/L			**52**	AQL	457		388		---	1 of 2
Selenium	ug/L	50		**5**	AQL	50	U	40	U	0 of 2	0 of 0
Silver	ug/L		100	**3.2-acute**	AQL	25	U	7	U	0 of 2	0 of 0
Thallium	ug/L	2		2	DWS	50	U	37	U	0 of 0	0 of 0
Zinc	ug/L		5,000	**107**	AQL	69.2		55.5		0 of 2	0 of 2
Other Constituents											
Chloride	mg/L		250	230	AQL	297				1 of 2	1 of 2
Sulfate	mg/L		250	250	DWS	747				2 of 2	2 of 2
Cyanide, Total	mg/L	0.2-CN^{Free}		5-CN^{ATC}	AQL	na				---	---
Total Dissolved Solids	mg/L		500			1,320				2 of 2	---
pH	s.u.		6.5-8.5	6.5-9.0	General	7.13-7.81				0 of 2	0 of 2

MCL -- values shown for copper and lead are action levels
Cyanide -- MCL for free cyanide; surface water criterion for cyanide amenable to chlorination
Chromium -- surface water criterion for chromium(III).
Surface water aquatic life criteria are chronic, unless otherwise stated; most stringent value shown for designated uses of Little St. Francis River
Surface water criteria in bold are computed at water hardness of 100 mg/L
AQL = aquatic life criteria; LWW = livestock watering
Nondetects with detection limits exceeding criteria values not included in the number of samples exceeding criteria
MCL values compared to total metal analyses unless otherwise noted; surface water criteria for metals compared to dissolved metals analyses

*Missouri Code of State Regulations: Title 10, Division 60, Chapter 4

**Missouri Code of state Regulations: Title 10, Division 20, Chapter 7

Table 1-7. Analytical Results for Metals in Surface and Subsurface Soil Samples from the Catherine Site

		Adjacent to W of Chat Pile		1200 feet NE of Chat Pile				500 feet E of Chat Pile				SW of Chat Pile				150 feet W of Chat Pile			
Station ID		28002		28100				28110				28120				28130			
Sample ID		ZTGPLB-28002		ZSGPLA-28100		ZSGPLB-28100		ZSGPLA-28110		ZSGPLB-28110		ZSGPLA-28120		ZSGPLB-28120		ZSGPLA-28130		ZSGPLB-28130	
Collection Date		3/2/2006		3/2/2006		3/2/2006		3/2/2006		3/2/2006		3/1/2006		3/1/2006		3/2/2006		3/2/2006	
Collection Time		12:25		14:55		15:00		14:30		14:35		13:00		13:05		12:40		12:45	
Depth (bgs)		1 to 6 in.		0 to 1 in.		1 to 6 in.		0 to 1 in.		1 to 6 in.		0 to 1 in.		1 to 6 in.		0 to 1 in.		1 to 6 in.	
Sample Type		Grab		Grab		Grab		Grab		Grab		Grab		Grab		Grab		Grab	
Metals																			
Aluminum	mg/kg	4410		5500		6330		5010		6510		7130		9370		9800		7680	
Antimony	mg/kg	3.8	U	2	U	2	U	2	U	2	U	8.04	UJ	7.43	UJ	2	U	2	U
Arsenic	mg/kg	8		5	U	5	U	5	U	5	U	3.86	UJ	4.27	UJ	5	U	5	U
Barium	mg/kg	25.3		150		93.4		121		70.2		87		68.3		218		121	
Beryllium	mg/kg	0.13	U	1	U	1	U	1	U	1	U	0.67	U	0.62	U	1	U	1	U
Cadmium	mg/kg	0.63	U	1		1	U	1	U	1	U	0.67	UJ	0.62	UJ	1	U	1	U
Calcium	mg/kg	152	U	1920		285		1010		118		1060		620	U	3350		1440	
Chromium	mg/kg	7.7		9.24		7.74		5.82		10.7		10.9		13.4		10.8		11.7	
Cobalt	mg/kg	5.1		7.21		7.57		7.28		9.09		6.7	U	7.37		23.8		11.1	
Copper	mg/kg	5.1		4.35		2.73		8.18		5.63		6.41		6.12		47.9		13.7	
Iron	mg/kg	5740		8510		8790		5770	J	8720		8370		10600		17000		11700	
Lead	mg/kg	48.4		52.9		28.8		82.9		59.6		39.2		20.4		84.9		37.4	
Magnesium	mg/kg	479		772		708		747	J	714		951		1100		1840		1110	
Manganese	mg/kg	289		1450		655		1520		1340		758		589		3180		1790	
Mercury	mg/kg	na		na		na		na		na		na		na		na		na	
Molybdenum	mg/kg	na		2	U	2	U	2	U	2	U	na		na		2	U	2	U
Nickel	mg/kg	3.6		5.9		5.2		6.29		6.25		5.82		6.53		15.9		9.05	
Potassium	mg/kg	299		403		313		305		280		850		756		513		254	
Selenium	mg/kg	5.1	U	10	U	10	U	10	U	10	U	4.69	UJ	4.34	UJ	10	U	10	U
Silver	mg/kg	0.63	U	2	U	2	U	2	U	2	U	1.34	UJ	1.24	UJ	2	U	2	U
Sodium	mg/kg	79.7	U	50		50	U	50	U	50	U	670	U	620	U	50.1		50	U
Thallium	mg/kg	8.2	U	10	U	10	U	10	U	10	U	3.35	UJ	3.1	UJ	10	U	10	U
Vanadium	mg/kg	13.7		16.6		17.2		11.6		17.4		19.4		24.3		26.6		25.5	
Zinc	mg/kg	14.3	U	33.5		25.3		33.3		26.7		29.1	UJ	26.5	UJ	37.4		20.7	
Solids	%	na		70.6		79.8		67.2		76.7		na		na		56.2		75.3	

U -- Analyte not detected, value shown is the detection limit
J -- Value is an estimate
na -- Not analyzed

Table 1-8. Comparison of Surface and Subsurface Soils from the Catherine and Skaggs Sites to EPA Human Health Screening Criteria for Soil

		Region 9 PRG		Catherine Soils			Skaggs Soils		
		Residential Soil	Industrial Soil	Max. Value	n ≥ Res. PRG	n ≥ Ind. PRG	Max. Value	n ≥ Res. PRG	n ≥ Ind. PRG
Aluminum	mg/kg	77,000	990,000	9,800	0 of 9	0 of 9	18,300	0 of 10	0 of 10
Antimony	mg/kg	31	410	8.04 UJ	0 of 9	0 of 9	8.77 UJ	0 of 10	0 of 10
Arsenic	mg/kg	22	---	8	0 of 9	---	20.4	0 of 10	---
Barium	mg/kg	15,000	190,000	218	0 of 9	0 of 9	359	0 of 10	0 of 10
Beryllium	mg/kg	160	2,000	1 U	0 of 9	0 of 9	1.4	0 of 10	0 of 10
Cadmium	mg/kg	70	800	1 U	0 of 9	0 of 9	0.837 UJ	0 of 10	0 of 10
Cobalt	mg/kg	23	300	23.8	1 of 9	0 of 9	307	5 of 10	1 of 10
Copper	mg/kg	3,100	41,000	47.9	0 of 9	0 of 9	574	0 of 10	0 of 10
Iron	mg/kg	55,000	720,000	17,000	0 of 9	0 of 9	30,600	0 of 10	0 of 10
Lead	mg/kg	400	800	85	0 of 9	0 of 9	33,800	5 of 10	3 of 10
Manganese	mg/kg	1,800	23,000	3,180	1 of 9	0 of 9	4,600	6 of 10	0 of 10
Mercury	mg/kg	23	310	n/a	---	---	n/a	---	---
Molybdenum	mg/kg	390	5,100	n/a	---	---	n/a	---	---
Nickel	mg/kg	1,600	20,000	15.9	0 of 9	0 of 9	293	0 of 10	0 of 10
Selenium	mg/kg	390	5,100	10 U	0 of 9	0 of 9	5.12 UJ	0 of 10	0 of 10
Silver	mg/kg	390	5,100	2 U	0 of 9	0 of 9	2.05	0 of 10	0 of 10
Vanadium	mg/kg	390	52,000	26.6	0 of 9	0 of 9	48.5	0 of 10	0 of 10
Zinc	mg/kg	23,000	310,000	37.4	0 of 9	0 of 9	265 J	0 of 10	0 of 10

n/a not analyzed
U Analyte not detected; value shown is the detection limit
J Value is estimated

Table 1-9
Surface Water Data
Catherine Site
Madison County Mines Site
Fredericktown, Missouri

Surface Water Data

BVID	Sample_ID	Sample Type	Note/comment	N_Coordinates	W_Coordinates	Date/Time	Pb (ug/L)	ID	As (ug/L)	ID	Zn (ug/L)	ID	Ag (ug/L)	ID	Al (ug/L)	ID	Ba (ug/L)	ID	Be (ug/L)	ID	Ca (mg/L)	ID	Cd (ug/L)	ID
52100	ZAGPLB-52100	Metals in Water by ICP	Unnamed east tributary to Logtown Creek upstream of Copper Mine Tailings	37.59677	90.32909	23-Feb-06	50.0	U	25.0	U	25.0	U	25.0	U	607		27.0		3.00	U	27.5		3.00	U
52100	ZAGPLB-52100	Metals - Dissolved, in Water by ICAP	Unnamed east tributary to Logtown Creek upstream of Copper Mine Tailings	37.59677	90.32909	23-Feb-06	10.0	U	7.00	U	4.00	U	7.00	U	46.6	U	19.2		1.07		26.2		1.00	U
52200	ZAGPLB-52200	Metals in Water by ICP	Unnamed east tributary to Logtown Branch downstream of Copper Mine Tailings	37.59753	90.32944	23-Feb-06	50.0	U	25.0	U	25.0	U	25.0	U	50.0	U	39.0		3.00	U	45.7		3.00	U
52200	ZAGPLB-52200	Metals - Dissolved, in Water by ICAP	Unnamed east tributary to Logtown Branch downstream of Copper Mine Tailings	37.59753	90.32944	23-Feb-06	10.0	U	7.00	U	4.00	U	7.00	U	50.3	U	39.6		1.11		44.0		1.00	U
65100	ZAGPLB-65100	Metals in Water by ICP	Sample collected at Catherine Tailings Pond ~4 ft from south shore.	37.59462	90.34050	23-Feb-06	79.0		25.0	U	25.0	U	25.0	U	397		78.2		3.00	U	47.6		3.00	U
65100	ZAGPLB-65100	Metals - Dissolved, in Water by ICAP	Sample collected at Catherine Tailings Pond ~4 ft from south shore.	37.59462	90.34050	23-Feb-06	10.0	U	7.00	U	4.00	U	7.00	U	51.5	U	73.8	J	1.30		45.1	J	1.00	U

Table 1-9
Surface Water Data
Catherine Site
Madison County Mines Site
Fredericktown, Missouri

Surface Water Data

BVID	Sample_ID	Co (ug/L)	ID	Cr (ug/L)	ID	Cu (ug/L)	ID	Fe (ug/L)	ID	K (mg/L)	ID	Mg (mg/L)	ID	Mn (ug/L)	ID	Mo (ug/L)	ID	Na (mg/L)	ID	Ni (ug/L)	ID	Sb (ug/L)	ID	Se (ug/L)	ID	Ti (ug/L)	ID	Tl (ug/L)	ID	V (ug/L)	ID	Acidity (as CaCO3) (mg/L)	ID	Alkalinity, bicarbonate (mg/L)	ID	Chloride (mg/L)	ID	Hardness (mg/L)	ID	Solids, nonfilterable (mg/L)	ID	Conductivity (umhos/cm)	ID	Sulfate (mg/L)	ID	Solids, Total dissolved (mg/L)	ID
52100	ZAGPLB-52100	10.0	U	15.0	U	5.00	U	901		2.00	U	14.8		230		15.0	U	5.00	U	20.0	U	50.0	U	50.0	U	20.0	U	50.0	U	10.0	U	5	U	117		4.00	U	130		2	U	242		7.1	J	68	
52100	ZAGPLB-52100	3.00	U	4.00	U	2.00	U	29.0	U	1.00	U	13.4		5.45		5.00	U	2.74		6.00	U	17.0	U	40.0	U	4.00	U	37.0	U	3.00	U																
52200	ZAGPLB-52200	19.0		15.0	U	5.00	U	105		2.00	U	23.2		280		15.0	U	5.00	UJ	35.8		50.0	U	50.0	U	20.0	U	50.0	U	10.0	U	5	U	174		4.16		210		2	U	396		35.8		114	J
52200	ZAGPLB-52200	21.2		4.00	U	2.00	U	42.4		1.00	U	21.9		262		5.00	U	3.93		33.7		17.0	U	40.0	U	4.00	U	37.0	U	3.00	U																
65100	ZAGPLB-65100	28.9		15.0	U	7.00		476		2.00	U	31.3		175		15.0	U	5.00	U	39.2		50.0	U	50.0	U	20.0	U	50.0	U	10.0	U	5	U	96.7		5.63		531		7		445		180		189	
65100	ZAGPLB-65100	20.1		4.00	U	2.93		29.0	U	2.38		28.6		85.2		5.00	U	5.40	J	24.4		17.0	U	40.0	U	4.00	U	37.0	U	3.00	U																

Table 1-10
Sediment Data
Catherine Site
Madison County Mines Site
Fredericktown, Missouri

Sediment Data																											
BVID	Sample_ID	Sample Type	Note/comment	N_Coordinates	W_Coordinates	Date/Time	Pb (mg/kg)	ID	As (mg/kg)	ID	Zn (mg/kg)	ID	Ag (mg/kg)	ID	Al (mg/kg)	ID	Ba (mg/kg)	ID	Be (mg/kg)	ID	Ca (mg/kg)	ID	Cd (mg/kg)	ID
52100	ZBGPLB-52100	Metals in Solids by ICP	Co-located with surface water in unnamed east tributary to Logtown Creek upstream of Copper Mine Tailings; sieved into two splits for analysis.	37.59677	90.32909	23-Feb-06	5890	J	56.3	J	499		1.81	UJ	425	J	36.3	U	0.907	UJ	156000		2.22	
52100	ZBGPLBX-52100	Metals in Solids by ICP	Co-located with surface water in unnamed east tributary to Logtown Creek upstream of Copper Mine Tailings; sieved with 35 mesh sieve.	37.59677	90.32909	23-Feb-06	1420	J	14.5	J	50.7		1.76	UJ	4740	J	188		1.47	UJ	10700		0.882	U
52200	ZBGDLB-52200	Metals in Solids by ICP	Duplicate of Sample ZBGPLB-52000	37.59753	90.32944	23-Feb-06	14700	J	15.7	J	11.3		1.28	UJ	534	J	25.6	U	0.929	UJ	117000		0.640	U
52200	ZBGPLB-52200	Metals in Solids by ICP	Co-located with surface water in unnamed east tributary to Logtown Branch downstream of Copper Mine Tailings; sieved into two splits for analysis.	37.59753	90.32944	23-Feb-06	21900	J	25.4	J	13.3		1.76	UJ	608	J	28.2		0.911	UJ	114000		0.667	U
52200	ZBGPLBX-52200	Metals in Solids by ICP	Co-located with surface water in unnamed east tributary to Logtown Branch downstream of Copper Mine Tailings; sieved with 35 mesh sieve.	37.59753	90.32944	23-Feb-06	13200	J	24.2	J	11.4		1.95	UJ	536	J	26.9	U	0.813	UJ	76600		0.673	U
52300	ZBGPLB-52300	Metals in Solids by ICP	Collected from center of partially dry creek bed	37.59695	90.33935	23-Feb-06	190	J	7.01	J	22.0		1.48	UJ	5610	J	102		0.758	UJ	1980		0.741	U
65100	ZBGPLB-65100	Metals in Solids by ICP	Sample collected at Catherine Tailings Pond ~4 ft from south shore.	37.59462	90.34050	23-Feb-06	4440	J	27.1	J	325		3.37	UJ	5500	J	244		1.68	UJ	74100		1.68	U

Table 1-10
Sediment Data
Catherine Site
Madison County Mines Site
Fredericktown, Missouri

Sediment Data																													
BVID	Sample_ID	Co (mg/kg)	ID	Cr (mg/kg)	ID	Cu (mg/kg)	ID	Fe (mg/kg)	ID	K (mg/kg)	ID	Mg (mg/kg)	ID	Mn (mg/kg)	ID	Na (mg/kg)	ID	Ni (mg/kg)	ID	Sb (mg/kg)	ID	Se (mg/kg)	ID	Tl (mg/kg)	ID	V (mg/kg)	ID	Total Organic Carbon (%)	ID
52100	ZBGPLB-52100	163	J	1.99	U	2700		35700		907	UJ	81900		4760	J	907	UJ	249		10.9	UJ	6.35	UJ	4.54	UJ	9.07	U	0.43	
52100	ZBGPLBX-52100	40.6	J	19.6		94.6		32100		882	UJ	5060		2760	J	882	UJ	50.0		10.6	UJ	6.17	UJ	4.41	UJ	27.9			
52200	ZBGDLB-52200	101	J	6.27		654		28900		640	UJ	67000		3500	J	640	UJ	123		7.68	UJ	4.48	UJ	3.20	UJ	6.40	U	2.1	
52200	ZBGPLB-52200	203	J	1.85	U	1650		33200		667	UJ	60200		3410	J	667	UJ	228		8.00	UJ	4.67	UJ	3.33	UJ	6.67	U	1.4	
52200	ZBGPLBX-52200	153	J	2.60	U	2020		26600		673	UJ	43500		2790	J	673	UJ	185		8.07	UJ	4.71	UJ	3.36	UJ	6.73	U		
52300	ZBGPLB-52300	15.4	J	12.1		9.89		15400		740	UJ	1260		1060	J	740	UJ	20.7		8.89	UJ	5.18	UJ	3.70	UJ	29.2		0.84	
65100	ZBGPLB-65100	2380	J	9.04		225		25300		1680	UJ	20500		3180	J	1680	UJ	2530		20.2	UJ	11.8	UJ	8.42	UJ	21.7		3.4	

Table 1-11. ICP Analytical Results for Metals in Chat Samples from the Skaggs Site

		West Pile				Central Pile										East Pile	
Station ID		**30001**		**30002**		**30003**		**30004**				**30005**		**30006**			
Sample ID		ZTCPLF-30001		ZTCPLF-30002		ZTGPLF-30003		ZTGPLP-30004		ZTGDLP-30004		ZTGPLR-30005		ZTCPLC-30006			
Collection Date		3/1/2006		3/1/2006		3/1/2006		2/24/2006		2/24/2006		2/24/2006		3/2/2006			
Collection Time		10:25		12:00		16:10		11:05		11:20		14:40		9:45			
Depth (bgs)		0 - 1.1 ft		0 - 2 ft		0 - 0.85 ft		0 - 4.6 ft		0 - 4.6 ft		9.3 - 14 ft		0 - 1.6 ft			
Sample Type		3 pt composite		3 pt composite		Grab		Grab		Duplicate		Grab		3 pt composite			
Metals																	
Aluminum	mg/kg	2220		3000		556		904		632		890		847			
Antimony	mg/kg	6.36	UJ	6.49	UJ	3.1	U	3.2	U	3.2	U	3.5	U	3.8	U		
Arsenic	mg/kg	12.8	J	19.9	J	12.9		12.6		24.9		16.5		40.5			
Barium	mg/kg	21.2	U	28.3		4		3.8		2.9		6.8		6.9			
Beryllium	mg/kg	1.19		1.14		0.95		0.58		0.55		0.68		0.59			
Cadmium	mg/kg	0.53	UJ	0.541	UJ	0.53		3.2		1.2		2.2		4.2			
Calcium	mg/kg	156000		145000		158000		137000		135000		113000		115000			
Chromium	mg/kg	6.01		6.89		2.1		2.4		2.1		2.7		2.7			
Cobalt	mg/kg	72.6		181		145		137		157		130		280			
Copper	mg/kg	131		565		125		167		875		515		1050			
Iron	mg/kg	35700		34700		25600		25700		26400		26300		27100			
Lead	mg/kg	2860		4510		7550		2560		18600		5660		28400			
Magnesium	mg/kg	77600		71900		78400		65800		64500		60100		61000			
Manganese	mg/kg	4200		4200		3670		3740		3700		3490		3390			
Mercury	mg/kg	na		na		na		na		na		na		na			
Nickel	mg/kg	102		160		120		130		153		150		296			
Potassium	mg/kg	1110		1160		407		349		282		487		531			
Selenium	mg/kg	3.71	UJ	3.78	UJ	4.2	U	4.3	U	4.2	U	4.7	U	5	U		
Silver	mg/kg	1.06	UJ	1.08	UJ	1.7		0.9		1.8		1.1		4			
Sodium	mg/kg	530	U	541	U	340	U	249	U	240	U	250	U	191	U		
Thallium	mg/kg	11.5	J	11.8	J	6.8	U	6.9	U	6.8	U	7.6	U	8.2	U		
Vanadium	mg/kg	7.55		9.4		1.4		3.3		2.4		3.6		2.6			
Zinc	mg/kg	173	J	361	J	182		648		289		337		811			

U -- Analyte not detected, value shown is the detection limit
J -- Value is an estimate
na -- Not analyzed

Table 1-12. Summary of Analytical Results for Metals in Soil Samples from the Skaggs Site

		Soil From Beneath Chat				Surface and Subsurface Soils Surrounding Skaggs Chat Piles (8 samples)			Floodplain Soils (5 samples)		
Station ID		**30004**		**30005**		**median**	**min**	**max**	**median**	**min**	**max**
Sample ID Depth (bgs)		ZSGPLZ-3004 4.6 - 5.1 ft.		ZSGPLZ-30005 14.0 - 14.5 ft.							
Aluminum	mg/kg	18300		2820		8895	4060	10800	8640	5940	12100
Arsenic	mg/kg	12.1	J	20.4		<7.06	4.1	14.9 J	11.4 J	7.84 J	17.3 J
Cadmium	mg/kg	0.602	U	0.729		<0.638	0.531 UJ	0.837 UJ	<0.669	0.614 U	0.694 UJ
Cobalt	mg/kg	116		307		20.6	6.19	135	23.7	13.3	69.7
Copper	mg/kg	17.1		70.9		19.3	11.3	574	30	8.74	80.2
Iron	mg/kg	27600		30600		14450	12500	27800	21800	14800	35600
Lead	mg/kg	84		33800		365	91.7	4490	101	46.2 J	1410
Manganese	mg/kg	221		3460		2855	153	4600	2730	2310	5980
Nickel	mg/kg	75.5		293		22.3	9.44	137	24.2	10.7 J	71.1
Vanadium	mg/kg	48.5		6.34		24.6	12.5	28.6	30	19.3	34.3
Zinc	mg/kg	69.1		145		<42.7	26.2 UJ	265 J	71.9 J	29.5	115

U -- Analyte not detected, value shown is the detection limit
J -- Value is an estimate
< -- One or more values were nondetects
na -- Not analyzed

Table 1-13. Analytical Results for Metals in Soil Samples from the Skaggs Site

		Soil From Beneath Chat		Surface and Subsurface Soils Surrounding Skaggs Chat Piles								Floodplain Soils				
Station ID		30004	30005	30010		30011		30013		30014		56300	57200	57300	57500	57700
Sample ID		ZSGPLZ-3004	ZSGPLZ-30005	ZSGPLA-30010	ZSGPLB-30010	ZSGPLA-30011	ZSGPLB-30011	ZSGPLA-30013	ZSGPLB-30013	ZSGPLA-30014	ZSGPLB-30014	ZSGPLB-56300	ZSGPLB-57200	ZSGPLB-57300	ZSGPLB-57500	ZSGPLB-57700
Collection Date		2/24/2006	2/24/2006	3/1/2006	3/1/2006	3/1/2006	3/1/2006	3/2/2006	3/2/2006	3/2/2006	3/2/2006	2/28/2006	3/1/2006	3/1/2006	3/1/2006	3/1/2006
Collection Time		11:30	14:45	16:35	16:40	10:50	11:00	11:05	11:10	10:15	10:30					
Depth (bgs)		4.6 - 5.1 ft.	14.0 - 14.5 ft.	0 - 1 in.	1 - 6 in.	0 - 1 in.	1 - 6 in.	0 - 1 in.	1 - 6 in.	0 - 1 in.	1 - 6 in.					
Sample Type		Grab	Grab	Grab	Grab	Grab	Grab	Grab	Grab	Grab	Grab	Grab	Grab	Grab	Grab	Grab
Aluminum	mg/kg	18300	2820	7940	10800	9330	10300	4060	8300	8460	9470	5940	6840	8640	12100	11000
Antimony	mg/kg	7.23 UJ	7.6	6.38 UJ	6.97 UJ	8.77 UJ	7.48 UJ	7.29 UJ	7.18 UJ	8.38 UJ	7.82 UJ	8.32 U	7.37 UJ	7.89 UJ	8.03 UJ	8.25 UJ
Arsenic	mg/kg	12.1 J	20.4	4.1 UJ	4.46 UJ	12.4 J	6.94 UJ	14.9 J	7.83 UJ	7.17 UJ	6.85 UJ	7.84 J	11.4 J	17.3 J	11.1 J	12.9 J
Barium	mg/kg	67.3 J	25.3	37.3	48	232	359	46.7	73.2	227	245	186	93.1 J	341 J	188 J	230
Beryllium	mg/kg	0.602 U	1.4	0.531 U	0.581 U	0.914	1.12	0.761 J	0.643 J	0.865	0.881	0.693 U	0.87	1.55	1.34	1.56
Cadmium	mg/kg	0.602 U	0.729	0.531 UJ	0.581 UJ	0.731 UJ	0.623 UJ	0.837 UJ	0.598 UJ	0.698 UJ	0.652 UJ	0.694 UJ	0.614 U	0.658 U	0.669 U	0.688 UJ
Calcium	mg/kg	3190	132000	2750	3280	27300	1300	96500	37500	1200	661	2150 J	31800	14200	4610	7670
Chromium	mg/kg	31	1.89	11.4	13.1	21.3	15.9	8.71	13.1	14.6	16.2	14	20.1	52.4	14.3	16.8
Cobalt	mg/kg	116	307	6.83	6.19	99.7	27	135	132	14.1	14.1	23.7	53.3	69.7	13.3	15
Copper	mg/kg	17.1	70.9	13.6	12.8	125	25	574	110	11.6	11.3	8.74	79.8	80.2	18.1	30
Iron	mg/kg	27600	30600	12700	12500	20200	15700	27800	18400	12900	13200	14800	23300	35600	21200	21800
Lead	mg/kg	84	33800	541	147	4490	188	1310	629	118	91.7	46.2 J	1410	644	67.5	101
Magnesium	mg/kg	2630	67200	1850	2620	12400	1070	47600	19200	1020	1010	837	16000	7100	1720	2330
Manganese	mg/kg	221	3460	211	153	2540	4600	3360	1500	3230	3170	2730	2600	5980	2310	2920
Mercury	mg/kg	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
Nickel	mg/kg	75.5	293	9.44	9.94	97.9	26.2	137	114	18.4	17.4	10.7 J	54.8	71.1	19.5	24.2
Potassium	mg/kg	920 J	1820	531 U	581 U	1530	1410	870	787	768	833	693 UJ	882 J	816 J	1630 J	1830
Selenium	mg/kg	4.22 U	4.44	3.72 UJ	4.07 UJ	5.12 UJ	4.36 UJ	4.25 UJ	4.19 UJ	4.89 UJ	4.56 UJ	4.85 U	4.30 U	4.61 U	4.69 U	4.81 UJ
Silver	mg/kg	1.2 UJ	2.05	1.06 UJ	1.16 UJ	1.46 UJ	1.25 UJ	1.22 UJ	1.2 UJ	1.4 UJ	1.3 UJ	1.39 UJ	1.23 UJ	1.32 UJ	1.34 UJ	1.38 UJ
Sodium	mg/kg	602 U	634	531 U	581 U	731 U	623 U	608 U	598 U	698 U	652 U	693 U	614 U	658 U	669 U	688 U
Thallium	mg/kg	3.01 U	7.69	2.66 UJ	2.9 UJ	7.4 J	12.7 J	9.62 J	5.17 J	8.69 J	8.9 J	3.47 UJ	3.71 J	16.4 U	3.49 J	8.61 J
Vanadium	mg/kg	48.5	6.34	23.1	26.3	25.1	28.6	12.5	22.6	24.1	25.9	30	19.3	34.3	30.3	29.9
Zinc	mg/kg	69.1	145	26.2 UJ	29 UJ	198 J	44.2 UJ	265 J	165 J	41.2 UJ	35.4 UJ	29.5	90.6	115	55	71.9 J

U -- Analyte not detected, value shown is the detection limit
J -- Value is an estimate
na -- Not analyzed

Table 1-14. Analytical Results for Shallow Ground Water and Surface Seeps at the Skaggs Site

		Shallow Ground Water from Beneath Chat Collected by GeoProbe						Surface Seeps			
Station ID		**30005**		**30100**				**30022**			
Sample ID		ZGGPLR-30005		ZGGPLH-30100				ZGGPLB-30022			
Collection Date		2/24/2006		2/24/2006				3/1/2006			
Collection Time		15:25		11:50				17:10			
Depth (bgs)		10 - 14 ft.		4 - 8 ft.				4 in. below water surface			
Metals		*Dissolved*		*Total*		*Dissolved*		*Total*		*Dissolved*	
Aluminum	ug/L	37	U	86.6		37	U	50	U	37	U
Antimony	ug/L	17	U	50	U	17	U	50	U	17	U
Arsenic	ug/L	18		25	U	7	U	25	U	13.1	
Barium	ug/L	103		60.4		65.4		83.9		94	
Beryllium	ug/L	1.25		3	U	1.27		3	U	1.62	
Cadmium	ug/L	1	U	3	U	1	U	3	U	1	U
Calcium	mg/L	99.3	J	98		89.4		96		85.2	
Chromium	ug/L	4	U	15	U	4	U	15	U	4	U
Cobalt	ug/L	841		503		496		13.7		14.2	
Copper	ug/L	2	U	12.7		4.99		5.69		4.66	
Iron	ug/L	3230	J	818		228		50	U	29	U
Lead	ug/L	36.4		416		61.3		50	U	22.3	
Magnesium	mg/L	33.4		32.3		31.8		38.1		37.8	
Manganese	ug/L	1680	J	577		562		6.26		4.99	
Mercury	ug/L	na		na		na		na		na	
Molybdenum	ug/L	5.62		15	U	5	U	15	U	9.04	
Nickel	ug/L	469		184		173		37.3		37.8	
Potassium	mg/L	7.29		7.38		7.55		21.2	J	5.23	
Selenium	ug/L	40	U	50	U	40	U	50	U	40	U
Silver	ug/L	7	U	25	U	7	U	25	U	7	U
Sodium	mg/L	3.54	J	5	U	3.99		5	U	4.13	
Thallium	ug/L	37	U	50	U	37	U	50	U	37	U
Titanium	ug/L	4	U	20	U	4	U	20	U	4	U
Vanadium	ug/L	3	U	10	U	3	U	10	U	3	U
Zinc	ug/L	488	J	372		350		28		27.4	
Hardness as CaCO3	mg/L	385	cal	378	cal	354	cal	397	cal	368	cal
Other Constituents											
Acidity as CaCO3	mg/L			5	U			5	U		
Alkalinity	mg/L			320				340			
Chloride	mg/L			7.08				4	U		
Sulfate	mg/L	114		95.6	J			111			
Cyanide	mg/L	na		0.003	U			na			
Hardness as CaCO3	mg/L	na		640				238			
Non-Filterable Solids	mg/L	136		23				2	U		
Total Dissolved Solids	mg/L	420		370				374			
Conductivity	umhos/cm	723		673				717			
Field Parameters											
pH	s.u.	7.12		7.02				7.62			
Specific conductance	umhos/cm	649		605				683			
Temperature	C	11.4		9.8				15.3			
Turbidity	NTU	758		95.5				2.14			

U -- Analyte not detected, value shown is the detection limit
J -- Value is an estimate
na -- Not analyzed
cal -- Value is calculated

Table 1-15. Comparison of Shallow Ground Water from the Skaggs Chat Area to Water Quality Criteria

		Ground Water Criteria (10 CSR 60-4)*		Surface Water Criteria (10 CSR 20-7)**		Shallow Ground Water Collected from Skaggs Chat Area (3 samples)					
		Primary MCL	Secondary MCL	Criteria	Designated Use	Max. Value Total		Max. Value Dissolved		n>MCL	n>SW criteria
Aluminum	ug/L		50-200	750-acute	AQL	86.6		37	U	0 of 3	0 of 3
Antimony	ug/L	6		6	DWS	50	U	17	U	0 of 0	0 of 0
Arsenic	ug/L	10		20	AQL	25	U	18		2 of 3	0 of 3
Barium	ug/L	2,000		2,000	DWS	83.9		103		0 of 3	0 of 3
Beryllium	ug/L	4		4	DWS	3	U	1.62		0 of 3	0 of 3
Cadmium	ug/L	5		**0.24**	AQL	3	U	1	U	0 of 3	0 of 0
Chromium	ug/L	100		**74.1-Cr^{III}**	AQL	15	U	4	U	0 of 3	0 of 3
Cobalt	ug/L			1,000	LWW	503		841		---	0 of 3
Copper	ug/L	1,300(action)	1,000	**7.3**	AQL	12.7		4.99		0 of 2	0 of 3
Iron	ug/L		300	1,000	AQL	818		3,230		1 of 3	1 of 3
Lead	ug/L	15 (action)		**2.5**	AQL	416		61.3		3 of 3	3 of 3
Manganese	ug/L		50			577		1,680		2 of 3	---
Mercury	ug/L	2		0.5	AQL	na		na		---	---
Nickel	ug/L			**52**	AQL	184		469		---	2 of 3
Selenium	ug/L	50		**5**	AQL	50	U	40	U	0 of 3	0 of 0
Silver	ug/L		100	**3.2-acute**	AQL	25	U	7	U	0 of 3	0 of 0
Thallium	ug/L	2		2	DWS	50	U	37	U	0 of 0	0 of 0
Zinc	ug/L		5,000	**107**	AQL	372		488		0 of 3	2 of 3
Other Constituents											
Chloride	mg/L		250	230	AQL	7.08				0 of 2	0 of 2
Sulfate	mg/L		250	250	DWS	114				0 of 3	0 of 3
Cyanide, Total	mg/L	$0.2\text{-}CN^{Free}$		$5\text{-}CN^{ATC}$	AQL	0.003	U			0 of 1	---
Total Dissolved Solids	mg/L		500			420				0 of 3	---
pH	s.u.		6.5-8.5	6.5-9.0	General	7.02-7.62				0 of 3	0 of 3

MCL -- values shown for copper and lead are action levels
Cyanide -- MCL for free cyanide; surface water criterion for cyanide amenable to chlorination
Chromium -- surface water criterion for chromium(III).
Surface water aquatic life criteria are chronic, unless otherwise stated; most stringent value shown for designated uses of Little St. Francis River
Surface water criteria in bold are computed at water hardness of 100 mg/L
AQL = aquatic life criteria; LWW = livestock watering
Nondetects with detection limits exceeding criteria values not included in the number of samples exceeding criteria
MCL values and surface water criteria for metals compared to dissolved metals analyses

*Missouri Code of State Regulations: Title 10, Division 60, Chapter 4
*Missouri Code of State Regulations: Title 10, Division 20, Chapter 7

Table 1-16. Summary of Floodplain Soil Samples from Skaggs Site

		Tributary to Plum Creek						Tributary from Skaggs		Tributary to LSFR	
		Above Skaggs Tributary		Below Skaggs Tributary		Above Plum Creek		Above Plum Creek Trib.		W. of H Road	
Station ID		**57500**		**57300**		**57700**		**57200**		**56300**	
Sample ID		**ZSGPLB-57500**		**ZSGPLB-57300**		**ZSGPLB-57700**		**ZSGPLB-57200**		**ZSGPLB-56300**	
Arsenic	mg/kg	11.1	J	17.3	J	12.9	J	11.4	J	7.84	J
Cobalt	mg/kg	13.3		69.7		15		53.3		23.7	
Copper	mg/kg	18.1		80.2		30		79.8		8.74	
Iron	mg/kg	21200		35600		21800		23300		14800	
Lead	mg/kg	67.5		644		101		1410		46.2	J
Manganese	mg/kg	2310		5980		2920		2600		2730	
Nickel	mg/kg	19.5		71.1		24.2		54.8		10.7	J
Vanadium	mg/kg	30.3		34.3		29.9		19.3		30	
Zinc	mg/kg	55		115		71.9	J	90.6		29.5	

Table 1-17. Comparison of Floodplain Soils from the Skaggs Site to EPA Human Health Screening Criteria for Soil

		Region 9 PRG		Skaggs Floodplain Soils		
		Residential Soil	Industrial Soil	Max. Value	n ≥ Res. PRG	n ≥ Ind. PRG
Aluminum	mg/kg	77,000	990,000	12,100	0 of 5	0 of 5
Antimony	mg/kg	31	410	8.32 U	0 of 5	0 of 5
Arsenic	mg/kg	22	---	17.3 J	0 of 5	---
Barium	mg/kg	15,000	190,000	341 J	0 of 5	0 of 5
Beryllium	mg/kg	160	2,000	1.56	0 of 5	0 of 5
Cadmium	mg/kg	70	800	0.694 UJ	0 of 5	0 of 5
Cobalt	mg/kg	23	300	69.7	3 of 5	0 of 5
Copper	mg/kg	3,100	41,000	80.2	0 of 5	0 of 5
Iron	mg/kg	55,000	720,000	35,600	0 of 5	0 of 5
Lead	mg/kg	400	800	1,410	2 of 5	1 of 5
Manganese	mg/kg	1,800	23,000	5,980	5 of 5	0 of 5
Mercury	mg/kg	23	310	n/a	---	---
Molybdenum	mg/kg	390	5,100	n/a	---	---
Nickel	mg/kg	1,600	20,000	71.1	0 of 5	0 of 5
Selenium	mg/kg	390	5,100	4.85 U	0 of 5	0 of 5
Silver	mg/kg	390	5,100	1.39 UJ	0 of 5	0 of 5
Vanadium	mg/kg	390	52,000	34.3	0 of 5	0 of 5
Zinc	mg/kg	23,000	310,000	115	0 of 5	0 of 5

n/a not analyzed
U Analyte not detected; value shown is the detection limit
J Value is estimated

Table 1-18
Surface Water Data
Skaggs Site
Madison County Mines Site
Fredericktown, Missouri

Surface Water Data																							
BVID	Sample_ID	Sample Type	Note/comment	N_Coordinates	W_Coordinates	Date/Time	Pb (ug/L)	ID	As (ug/L)	ID	Zn (ug/L)	ID	Ag (ug/L)	ID	Al (ug/L)	ID	Ba (ug/L)	ID	Be (ug/L)	ID	Ca (mg/L)	ID
57300	ZAGPLB-57300	Metals in Water by ICP	Unnamed tributary south of Skaggs tailings.	37.58297	90.34056	24-Feb-2006	10.0	U	10.0	UJ	60.0	U	10.0	U	200	U	200	U	5.00	U	31.3	
57300	ZAGPLB-57300	Metals - Dissolved, in Water by ICAP	Unnamed tributary south of Skaggs tailings.	37.58297	90.34056	24-Feb-2006	10.0	U	10.0	UJ	60.0	U	10.0	U	200	U	200	U	5.00	U	32.4	
57600	ZAGPLB-57600	Metals in Water by ICP	Unnamed tributary draining south to Plum Creek from Skaggs tailings area.	37.57313	90.34153	26-Feb-2006	10.0	U	10.0	UJ	60.0	U	10.0	U	200	U	200	U	5.00	U	40.4	
57600	ZAGPLB-57600	Metals - Dissolved, in Water by ICAP	Unnamed tributary draining south to Plum Creek from Skaggs tailings area.	37.57313	90.34153	26-Feb-2006	10.0	U	10.0	UJ	60.0	U	10.0	U	200	U	200	U	5.00	U	42.6	
65600	ZAGPLB-65600	Metals in Water by ICP	Collected 10 ft from shore in unnamed stock pond south of Skaggs tailings.	37.58475	90.33743	24-Feb-2006	10.0	U	10.0	UJ	60.0	U	10.0	U	200	U	222		5.00	U	48.8	
65600	ZAGPLB-65600	Metals - Dissolved, in Water by ICAP	Collected 10 ft from shore in unnamed stock pond south of Skaggs tailings.	37.58475	90.33743	24-Feb-2006	16.4		10.0	UJ	60.0	U	10.0	U	200	U	209		5.00	U	43.2	

Table 1-18
Surface Water Data
Skaggs Site
Madison County Mines Site
Fredericktown, Missouri

Surface Water Data

BVID	Sample_ID	Cd (ug/L)	ID	Co (ug/L)	ID	Cr (ug/L)	ID	Cu (ug/L)	ID	Fe (ug/L)	ID	K (mg/L)	ID	Mg (mg/L)	ID	Mn (ug/L)	ID	Na (mg/L)	ID	Ni (ug/L)	ID	Sb (ug/L)	ID	Se (ug/L)	ID	Tl (Ug/L)	ID	V (ug/L)	ID	Acidity (as CaCO3) (mg/L)	ID	Alkalinity, bicarbonate (mg/L)	ID	Chloride (mg/L)	ID	Hardness (mg/L)	ID	Solids, nonfilterable (mg/L)	ID	Conductivity (umhos/cm)	ID	Sulfate (mg/L)	ID	Solids, Total dissolved (mg/L)	ID
57300	ZAGPLB-57300	5.00	UJ	50.0	U	10.0	U	25.0	U	100	U	5.00	U	17.0		34.5		5.00	UJ	40.0	U	60.0	UJ	35.0	UJ	25.0	UJ	50.0	U	5	U	131		4.35		154		2	U	296		26.7		52	
57300	ZAGPLB-57300	5.00	UJ	50.0	U	10.0	U	25.0	U	100	U	5.00	U	17.7		46.9		5.00	UJ	40.0	U	60.0	UJ	35.0	UJ	25.0	UJ	50.0	U																
57600	ZAGPLB-57600	5.00	UJ	50.0	U	10.0	U	25.0	U	119		5.00	U	20.4		40.8		5.00	UJ	40.0	U	60.0	UJ	35.0	UJ	25.0	UJ	50.0	U	5	U	166		4.43		195		9		341		22.6		194	
57600	ZAGPLB-57600	5.00	UJ	50.0	U	10.0	U	25.0	U	100	U	5.00	U	21.5		15.0	U	5.00	UJ	40.0	U	60.0	UJ	35.0	UJ	25.0	UJ	50.0	U																
65600	ZAGPLB-65600	5.00	UJ	50.0	U	10.0	U	25.0	U	100	U	5.00	U	24.5		364		5.00	UJ	40.0	U	60.0	UJ	35.0	UJ	25.0	UJ	50.0	U	5	U	184		4.00	U	198		2	U	366		37.0		190	
65600	ZAGPLB-65600	5.00	UJ	50.0	U	10.0	U	25.0	U	765		5.00	U	21.8		328		5.00	UJ	40.0	U	60.0	UJ	35.0	UJ	25.0	UJ	50.0	U																

Table 1-19
Sediment Data
Skaggs Site
Madison County Mines Site
Fredericktown, Missouri

Sediment Data																							
BVID	Sample_ID	Sample Type	Note/comment	N_Coordinates	W_Coordinates	Date/Time	Pb (mg/kg)	ID	As (mg/kg)	ID	Zn (mg/kg)	ID	Ag (mg/kg)	ID	Al (mg/kg)	ID	Ba (mg/kg)	ID	Be (mg/kg)	ID	Ca (mg/kg)	ID
56100	ZBGPLB-56100	Metals in Solids by ICP	Sample collected from stream east of Skaggs tailings.	37.58741	90.33176	23-Feb-2006	5260	J	17.5	J	145	J	1.41	U	881		57.4	J	0.737	UJ	94500	J
56200	ZBGPLB-56200	Metals in Solids by ICP	Sample collected from dry stream bed east of Skaggs tailings.	37.58709	90.33040	23-Feb-2006	5250	J	12.8	J	271	J	1.11	U	2080		108	J	0.837	UJ	110000	J
56250	ZBGPLB-56250	Metals in Solids by ICP	Sample collected from dry stream bed east of Skaggs tailings.	37.58754	90.32924	23-Feb-2006	3950	J	17.2	J	263	J	1.32	U	2460		45.3	J	0.898	UJ	86000	J
56300	ZBGPLB-56300	Metals in Solids by ICP	Sample collected east of Skaggs tailings	37.58859	90.32212	23-Feb-2006	1590	J	34.5	J	184	J	3.36	J	5380		2030	J	2.86	J	16300	J
57100	ZBGPLB-57100	Metals in Solids by ICP	Collected from dry stream bed SW of Skaggs chat/tailing area.	37.58628	90.33617	24-Feb-2006	1770		19.1	J	231	J	1.20	U	3270	J	192	J	1.49	UJ	79600	
57200	ZBGPLB-57200	Metals in Solids by ICP	Unnamed tributary southwest of Skaggs tailings.	37.58392	90.33990	24-Feb-2006	1290		11.9	J	69.3	J	1.34	U	2540	J	96.9	J	0.742	UJ	29400	
57200	ZBGPLBX-57200	Metals in Solids by ICP	Unnamed tributary southwest of Skaggs tailings. Sample sieved with 35 mesh sieve.	37.58392	90.33990	24-Feb-2006	1450		10.7	UJ	57.9	J	1.46	U	2110	J	42.3	J	0.730	UJ	37000	
57300	ZBGPLB-57300	Metals in Solids by ICP	Co-located with surface water in unnamed tributary south of Skaggs tailings.	37.58297	90.34056	24-Feb-2006	416		20.7	J	112	J	1.98	J	4170	J	1540	J	1.93	UJ	9840	
57300	ZBGPLBX-57300	Metals in Solids by ICP	Co-located with surface water in unnamed tributary south of Skaggs tailings. Sample sieved with 35 mesh sieve.	37.58297	90.34056	24-Feb-2006	402		13.5	J	61.0	J	1.40	U	3200	J	112	J	0.895	UJ	15000	
57500	ZBGDLB-57500	Metals in Solids by ICP	Duplicate of Sample ZBGPLB-57500	37.58664	90.34067	24-Feb-2006	1010		19.2	J	120	J	1.46	J	3780	J	395	J	1.76	UJ	34800	
57500	ZBGPLB-57500	Metals in Solids by ICP	Unnamed NW tributary south of Skaggs tailings near headwaters.	37.58664	90.34067	24-Feb-2006	860		28.4	J	179	J	1.94	J	4950	J	784	J	1.94	UJ	32000	
57500	ZBGPLBX-57500	Metals in Solids by ICP	Unnamed NW tributary south of Skaggs tailings near headwaters. Sample sieved with 35 mesh sieve.	37.58664	90.34067	24-Feb-2006	545		15.4	J	104	J	1.37	U	4540	J	144	J	1.01	UJ	25700	
57600	ZBGPLB-57600	Metals in Solids by ICP	Co-located with surface water sample from unnamed tributary draining south to Plum Creek from Skaggs tailings area.	37.57313	90.34153	26-Feb-2006	362		18.7	J	70.3	J	1.60	U	7590	J	184	J	1.48	UJ	7580	
57700	ZBGPLB-57700	Metals in Solids by ICP	Collected from dry stream bed of unnamed tributary to main channel of Plum Creek from Skaggs chat area.	37.57381	90.34100	26-Feb-2006	99.7		14.4	J	65.2	J	3.19	J	6940	J	221	J	1.51	UJ	7090	
65600	ZBGPLB-65600	Metals in Solids by ICP	North side of unnamed stock pond south of Skaggs tailings.	37.58475	90.33743	26-Feb-2006	5880		18.2	J	254	J	2.13	U	2310	J	79.4	J	1.07	UJ	76200	

Table 1-19
Sediment Data
Skaggs Site
Madison County Mines Site
Fredericktown, Missouri

Sediment Data																															
BVID	Sample_ID	Cd (mg/kg)	ID	Co (mg/kg)	ID	Cr (mg/kg)	ID	Cu (mg/kg)	ID	Fe (mg/kg)	ID	K (mg/kg)	ID	Mg (mg/kg)	ID	Mn (mg/kg)	ID	Na (mg/kg)	ID	Ni (mg/kg)	ID	Sb (mg/kg)	ID	Se (mg/kg)	ID	Tl (mg/kg)	ID	V (mg/kg)	ID	Total Organic Carbon (%)	ID
56100	ZBGPLB-56100	0.704	UJ	104	J	5.11	J	88.5		31000		704	UJ	51900		3460		704	UJ	92.3	J	8.45	UJ	4.93	UJ	3.52	UJ	10.4	J		
56200	ZBGPLB-56200	1.23	J	129	J	18.9	J	149		31800		586	J	56600		4110		555	UJ	165	J	6.66	UJ	3.88	UJ	2.77	UJ	17.5	J		
56250	ZBGPLB-56250	0.873	UJ	154	J	13.0	J	239		30300		660	UJ	47400		3480		660	UJ	109	J	7.92	UJ	4.62	UJ	3.30	UJ	19.8	J		
56300	ZBGPLB-56300	1.89	J	119	J	38.0	J	111		57100		653	UJ	7900		17600		653	UJ	82.9	J	7.83	UJ	4.57	UJ	14.2	J	61.6	J		
57100	ZBGPLB-57100	0.600	UJ	197		6.70		67.3	J	35600		694	J	45400		4510	J	600	UJ	206	J	7.20	UJ	4.20	UJ	3.00	UJ	16.0			
57200	ZBGPLB-57200	0.668	UJ	37.8		27.6		44.5	J	24200		668	UJ	14500		2650	J	668	UJ	40.7	J	8.02	UJ	4.68	UJ	3.34	UJ	20.0			
57200	ZBGPLBX-57200	0.730	UJ	35.7		9.64		76.1	J	19800		730	UJ	18800		1780	J	730	UJ	40.5	J	8.76	UJ	5.11	UJ	3.65	UJ	12.4			
57300	ZBGPLB-57300	0.629	UJ	75.6		28.6		28.3	J	38700		629	UJ	4460		10600	J	629	UJ	75.6	J	7.55	UJ	4.40	UJ	9.20	UJ	40.9		0.18	
57300	ZBGPLBX-57300	0.701	UJ	30.7		28.7		23.4	J	23900		701	UJ	7290		2410	J	701	UJ	33.1	J	8.42	UJ	4.91	UJ	3.51	UJ	24.0			
57500	ZBGDLB-57500	0.714	UJ	74.9		34.9		21.1	J	40900		714	UJ	17400		6330	J	714	UJ	61.8	J	8.57	UJ	5.00	UJ	4.97	UJ	39.5		0.24	
57500	ZBGPLB-57500	0.689	UJ	103		54.4		32.9	J	55800		689	UJ	15700		8950	J	689	UJ	112	J	8.26	UJ	4.82	UJ	8.88	UJ	48.7		0.86	
57500	ZBGPLBX-57500	0.684	UJ	46.8		17.5		18.7	J	24600		684	UJ	13300		3330	J	684	UJ	40.7	J	8.20	UJ	4.79	UJ	3.42	UJ	24.4			
57600	ZBGPLB-57600	0.799	UJ	25.6		14.3		35.2	J	25200		799	UJ	3190		2620	J	799	UJ	33.1	J	9.58	UJ	5.59	UJ	8.21	UJ	28.4			
57700	ZBGPLB-57700	0.664	UJ	18.5		22.5		30.6	J	23500		807	J	3180		2730	J	664	UJ	26.2	J	7.97	UJ	4.65	UJ	6.60	UJ	29.9		0.76	
65600	ZBGPLB-65600	1.07	UJ	157		4.75		245	J	24900		1070	UJ	39100		3010	J	1070	UJ	179	J	12.8	UJ	7.47	UJ	5.33	UJ	10.8			

Table 1-20
Summary of Contaminants Presenting Risk Above a Level of Concern
Operable Unit 5
Madison County Mines Site
Fredericktown, Missouri

Operable Unit 5					
	Ingestion of Groundwater near Mine Waste Areas	Ingestion/Contact with Mine Waste	Ingestion/Contact with Groundwater and Soils near Mine Waste Areas	Ingestion/Contact with Flood Plain Soil/Sediment/Surface Water/Fish Tissue	
Future Residents	Variety of metals including arsenic, cobalt, lead, manganese, and nickel	No Pathway	Variety of metals including arsenic, cobalt, lead, manganese, and nickel	No Pathway	
Commercial Workers	Arsenic, lead	No Pathway	Arsenic, lead	No Pathway	
ATV Riders	No Pathway	Lead, manganese	No Pathway	No pathway	
Recreational Visitors	No Pathway	No Pathway	No Pathway	Antimony, lead, manganese, thallium, and vanadium.	
Ecological Receptors	No Pathway	No Pathway	No Pathway	Aquatic Ecosystem	Terrestrial Ecosystem
				Antimony, arsenic, barium, cadmium, cobalt, copper, iron, lead, manganese, nickel, silver, thallium	Antimony, chromium, cobalt, copper, lead, manganese, nickel, thallium, vanadium, zinc

Table 2-1
Potential Federal Chemical-Specific ARARs

	Citations	Description
A. Potential ARARs		
1. Safe Drinking Water Act	National Primary Drinking Water Standards 40 C.F.R. Part 141 Subpart B and G	Establishes maximum contaminant levels (MCLs), which are health based standards for public waters systems.
2. Safe Drinking Water Act	National Secondary Drinking Water Standards 40 C.F.R. Part 143	Establishes secondary maximum contaminant levels (SMCLs) which are non-enforceable guidelines for public water systems to protect the aesthetic quality of the water. SMCLs may be relevant and appropriate if groundwater is used as a source of drinking water.
3. Safe Drinking Water Act	Maximum Contaminant Level Goals (MCLGs) 40 C.F.R. Part 141, Subpart F	Establishes non-enforceable drinking water quality goals. The goals are set to levels that produce no known anticipated adverse health effects. The MCLGs include an adequate margin of safety.
4. Clean Water Act	Water Quality Criteria 40 C.F.R. Part 131 Water Quality Standards	Establishes non-enforceable standards to protect aquatic life. May be relevant and appropriate to surface water discharges, or may be a TBC.
5. Clean Air Act	National Primary and Secondary Ambient Air Quality Standards 40 C.F.R. Part 50	Establishes standards for ambient air quality to protect public health and welfare.
B. To Be Considered		
1. EPA Revised Interim Soil-lead Guidance for CERCLA Sites and RCRA Corrective Action Facilities	Office of Solid Waste and Emergency Response (OSWER) Directive 9355.4-12, July 14, 1994 OSWER Directive 9200.4-27P, August 1988	Establishes screening levels for lead in soil for residential land use, describes development of site-specific preliminary remediation goals, and describes a plan for soil-lead cleanup at CERCLA sites. This guidance recommends using the EPA Integrated Exposure Uptake Biokinetic Model (IEUBK) on a site-specific basis to assist in developing cleanup goals.
2. EPA Strategy for Reducing Lead Exposures	EPA, February 21, 1991	Presents a strategy to reduce lead exposure, particularly to young children. The strategy was developed to reduce lead exposure to the greatest extent possible. Goals of the strategy are to 1) significantly reduce the incidence above 10 Fg Pb/dL in children; and 2) reduce the amount of lead introduced into the environment.
3. Human Health Risk Assessment Reports (HHRA)	"Area-Wide Human Health Risk Assessment for the Madison County Mines Site, Madison County, Missouri" – prepared by Syracuse Research Corp., July 2007 "Draft Supplemental Remedial Investigation Report, Madison County Mines Site, prepared by Black & Veatch Special Projects Corp, April 2011	Evaluates baseline health risk due to current site exposures and established contaminant levels in environmental media at the site for the protection of public health. The risk assessment approach using this data should be used in determining cleanup levels because ARARs are not available for contaminants in mine wastes and soils.
4. Ecological Risk Assessment Report (ERA)	"Madison County Mine Site Ecological Risk Assessment, Final Report" – prepared by EPA, May 24, 2006. "Draft Supplemental Remedial Investigation Report, Madison County Mines Site, prepared by Black & Veatch Special Projects Corp, April 2011	Evaluates baseline risks to ecological receptors due to current site exposures and established contaminant levels in environmental media at the Madison County Mines Site.
5. Superfund Lead-Contaminated Residential Sites Handbook	EPA OSWER 9285.7-30, August 2003.	Handbook developed by EPA to promote a nationally consistent decision making process for assessing and managing risks associated with lead contaminated residential sites across the country.

Table 2-1 (Continued)
Potential Federal Chemical-Specific ARARs

6. Preliminary Remediation Goals	Preliminary Remediation Goals for Lead in Soil at the Madison County Mines, Operable Unit 3 Site, Madison County Missouri, January 31, 2008.	Establishes preliminary remediation goals for protection of residents from lead in surface soil at the Madison County Mines, Operable Unit 3.
7. Preliminary Remediation Goals	Final draft preliminary remediation goals for lead in multiple media at the Madison County Mines, Operable Unit 4 Site, Madison County Missouri, December 11, 2008.	Establishes preliminary remediation goals for protection of ATV riders, recreational visitors, and residents from lead in tailings, floodplain soils, sediments, surface water, and groundwater at the Madison County Mines, Operable Unit 4 subsite.

Table 2-2
Potential State Chemical-Specific ARARs

	Citation	Description
A. Potential ARARs		
1. Missouri Air Conservation Law	Missouri Department of Natural Resources RSMo 643.010 10 CSR 10-6.010	Sets ambient air quality standards for a variety of constituents, including particulate matter and lead. Provides long range goals for ambient air quality throughout Missouri in order to protect the public health and welfare.
2. Hazardous Waste Management Law	Missouri Department of Natural Resources Identification and Listing of Hazardous Waste 10 CSR 25-4.261	Defines those solid wastes which are subject to regulations as hazardous wastes under 10 CSR 25.
3. Missouri Clean Water Law	Missouri Department of Natural Resources RSMo 644.006 10 CSR 20-7.015 (1) (2) (3) (4) (5) (6) (7) (9)	Sets forth the limits for various pollutants which are discharged to the various waters of the state. Sets effluent standards that will protect receiving streams.
4. Missouri Clean Water Law	Missouri Department of Natural Resources RSMo 644.006 10 CSR 20-7.031 (2) (3) (4) (5); Tables (A) (B)	Identifies beneficial uses of waters of the State, criteria to protect their uses, and defines the antidegradation policy.
B. To Be Considered	None	

Table 2-3
Potential Federal Location-Specific ARARs

	Citation	Description
A. Potential ARARs		
1. Historic project owned or controlled by a federal agency	National Historic Preservation Act: 16 U.S.C. 470, et.seq; 40 C.F.R. § 6.301; 36 C.F.R. Part 1.	Property within areas of the Site is included in or eligible for the National Register of Historic Places. The remedial alternatives will be designed to minimize the effect on historic landmarks.
2. Site within an area where action may cause irreparable harm, loss, or destruction of artifacts.	Archeological and Historic Preservation Act; 16 U.S.C. 469, 40 C.F.R. 6.301.	Property within areas of the site may contain historical and archaeological data. The remedial alternative will be designed to minimize the effect on historical and archeological data.
3. Site located in area of critical habitat upon which endangered or threatened species depend.	Endangered Species Act of 1973, 16 U.S.C. 1531-1543; 50 C.F.R. Parts 17; 40 C.F.R. 6.302. Federal Migratory Bird Act; 16 U.S.C. 703-712.	Determination of the presence of endangered or threatened species. The remedial alternatives will be designed to conserve endangered or threatened species and their habitat, including consultation with the Department of Interior and U.S. Fish and Wildlife Service if such areas are affected.
4. Site located within a floodplain soil.	Protection of Floodplains, Executive Order 11988; 40 C.F.R. Part 6.302, Appendix A.	Remedial action may take place within a 100-year floodplain. The remedial action will be designed to avoid adversely impacting the floodplain in and around the soil repositories to ensure that the action planning and budget reflects consideration of the flood hazards and floodplain management.
5. Wetlands located in and around tailings, chat piles, or soil repositories.	Protection of Wetlands; Executive Order 11990; 40 C.F.R. Part 6, Appendix A.	Remedial actions may affect wetlands. The remedial action will be designed to avoid adversely impacting wetlands wherever possible including minimizing wetlands destruction and preserving wetland values.
6. Waters in and around the tailings, chat piles and soil repositories.	Clean Water Act, (Section 404 Permits) Dredge or Fill Substantive Requirements, 33 U.S.C. Parts 1251-1376; 40 C.F.R. Parts 230,231.	Capping, dike stabilization, construction of berms and levees, and disposal of contaminated soil, waste material or dredged material are examples of activities that may involve a discharge of dredge or fill material. Four conditions must be satisfied before dredge and fill is an allowable alternative: 1. There must not be a practical alternative. 2. Discharge of dredged or fill material must not cause a violation of State water quality standards, violate applicable toxic effluent standards, jeopardize threatened or endangered species or injure a marine sanctuary. 3. No discharge shall be permitted that will cause or contribute to significant degradation of the water. 4. Appropriate steps to minimize adverse effects must be taken. Determine long- and short-term effects on physical, chemical, and biological components of the aquatic ecosystem.

Table 2-3 (Continued)
Potential Federal Location-Specific ARARs

	Citation	Description
7. Area containing fish and wildlife habitat in and around the removal repository.	Fish and Wildlife Conservation Act of 1980, 16 U.S.C. Part 2901 et seq.; 50 C.F.R. Part 83.9 and 16 U.S.C. Part 661, et seq. Federal Migratory Bird Act, 16 U.S.C. Part 703.	Activity affecting wildlife and non-game fish. Remedial action will conserve and promote conservation of non-game fish and wildlife and their habitats.
8. Fish and Wildlife Coordination Act	16 U.S.C Section 661 et seq.; 33 C.F.R Parts 320-330; 40 C.F.R 6.302	Requires consultation when a Federal department or agency proposes or authorizes any modification of any stream or other water body, and adequate provision for protection of fish and wildlife resources.
9. 100-year floodplain	Location Standard for Hazardous Waste Facilities- RCRA; 42 U.S.C. 6901; 40 C.F.R. 264.18(b).	RCRA hazardous waste treatment and disposal. Facility located in a 100-year floodplain must be designed, constructed, operated, and maintained to prevent washout during any 100-year/24 hour flood.
10. Historic Site, Buildings, and Antiquities Act	16 USC Section 470 et seq. 40 CFR Sect. 6.301(a), and 36 CFR, Part1.	Requires Federal agencies to consider the existence and location of landmarks on the National Registry of Natural Landmarks and to avoid undesirable impacts on such landmarks.
11. Clean Air Act	National Ambient Air Quality Standards/ NESHAPS 42 U.S.C. 74112; 40 C.F.R. 50.6 and 50.12	Emissions standards for particular matter and lead.
B. To Be Considered	None	

Table 2-4
Potential State Location-Specific ARARs

	Citation	Description
A. Applicable Requirements		
Missouri Well Construction Code	Missouri Department of Natural Resources RSMo 256.606, 256.626 10 CSR 23-3	Addresses the construction of new residential wells. Well construction standards are specific to location. For some sites where shallow contamination exists, Special Areas have been developed as an institutional control to prevent exposure to c ontaminants.
B. To Be Considered	None	

Table 2-5
Potential Federal Action-Specific ARARs

A. Potential ARARs	Citation	Description
1. Disposal of Solid Waste in a Permanent Repository.	Subtitle D of RCRA, Section 1008, Section 4001, et seq., 42 U.S.C. '6941, et seq.	State or Regional Solid Waste Plans and implementing federal and state regulations to control disposal of solid waste. The mine wastes and soils disposed in the repositories may not exhibit the toxicity characteristic and therefore, are not hazardous waste. However, these mine wastes and soils may be solid waste. Soils failing TCLP were contaminated by mining wastes so all wastes are exempt from definition of hazardous per the Bevill exemption. Contaminated residential soils and mine wastes will be consolidated onto the existing tailings and chat piles at the OU1, OU4, and OU5 sites. The disposal of this waste material should be in accordance with regulated solid waste management practices.
2. Clean Water Act	Water Quality Criteria 40 C.F.R. Part 131 Water Quality Standards	Establishes non-enforceable standards to protect aquatic life.
3. Clean Air Act	National Ambient Air Quality Standards/ NESHAPS 42 U.S.C. 74112; 40 C.F.R. 50.6 and 50.12	Emissions standards for particular matter and lead.
4. Hazardous Materials Transportation Act	Hazardous Materials Transportation Regulations 49 C.F.R. Parts 107, 171-177	Regulates transportation of hazardous materials.
5. NPDES Storm Water Discharge for Permanent Repositories.	40 C.F.R. Part 122.26; 33 U.S.C 402 (p)	Establishes discharge regulations for storm water. Required management of repository where waste materials come into contact with storm water. Also required during construction of the repository.
6. Transportation of excavated mine wastes and soils.	DOT Hazardous Material Transportation Regulations, 49 C.F.R. Parts 107, 171-177	Regulates transportation of hazardous wastes.
7. Waters in and around the soil repositories.	Clean Water Act, (Section 404 Permits) Dredge or Fill Substantive Requirements, 33 U.S.C. Parts 1251-1376; 40 C.F.R. Parts 230,231.	Capping, dike stabilization, construction of berms and levees, and disposal of contaminated soil, waste material or dredged material are examples of activities that may involve a discharge of dredge or fill material. Four conditions must be satisfied before dredge and fill is an allowable alternative: 1. There must not be a practical alternative. 2. Discharge of dredged or fill material must not cause a violation of State water quality standards, violate applicable toxic effluent standards, jeopardize threatened or endangered species or injure a marine sanctuary. 3. No discharge shall be permitted that will cause or contribute to significant degradation of the water. 4. Appropriate steps to minimize adverse effects must be taken. Determine long- and short-term effects on physical, chemical, and biological components of the aquatic ecosystem.
8. Subtitle C of RCRA 42 U.S.C. 6921, et seq.	40 C.F. R. Parts 260 – 268 Hazardous Waste Management	Establishes requirements for the transportation and disposal of hazardous wastes, including those wastes that are hazardous because they exhibit the toxicity characteristic. May be relevant and appropriate for wastes exhibiting the toxicity characteristic that are transported and disposed off site.
9. Toxic Substances and Control Act 15 U.S.C. 2601, et Seq.	40 C.F.R Part 761.61 PCB Remediation Waste	Establishes cleanup levels and disposal requirements for bulk PCB-contaminated remediation waste, including PCB-contaminated soils.
B. To Be Considered		

Table 2-6
Potential State Action-Specific ARARs

A. Potential ARARs	Citation	Description
1. Missouri Fugitive Particulate Matter Regulations	Missouri Department of Natural Resources 10 CSR 10-6.170	The Missouri fugitive particulate matter regulations contain restrictions on the release of particulate matter to ambient air. These regulations are applicable to any dust emissions that occur as a result of remedial actions taken at the site.
2. Missouri Clean Water Law – Storm Water Regulations	Missouri Department of Natural Resources 10 CSR 20-6.200	These regulations define Best Management Practices for land disturbances, including practices or procedures that would reduce the amount of metals in soils and sediments available for transport to waters of the state. Permits would not be required for actions taken under CERCLA, but the substantive provisions of these regulations would be applicable. The Missouri standards would be considered ARARs only if they are more stringent than the Federal standards. Requires permits for metal and non-metal mining facilities and land uses or disturbances that create point source discharges of storm water.
3. Missouri Hazardous Substances Emergency Response	Missouri Department of Natural Resources RSMo 260.520 10 CSR 24-3.010	Establishes a statewide emergency telephone number to notify the State whenever a hazardous substance emergency occurs and specifies the requirements for emergency notification and follow up written notice.
4. Missouri Solid Waste Disposal Law	Missouri Department of Natural Resources RSMo 260.225 10 CSR 80-5.010 (2)	Contains requirements for determining what solid wastes will be accepted at landfills and identifying any special handling requirements.
5. Missouri Solid Waste Disposal Law	Missouri Department of Natural Resources RSMo 260.225 10 CSR 80-5.010 (5) (A), (B) 1-4, (C)	Requires all waters discharged from solid waste processing facilities to be sufficiently treated to meet applicable water quality standards, including those established under the authority of the Federal Water Pollution Control Act.
6. Missouri Hazardous Waste Management Law	Missouri Department of Natural Resources RSMo 260.370 10 CSR 25-5.262	Sets forth standards for generators of hazardous waste, incorporates 40 CFR Part 262 by reference, and sets forth additional state standards.
7. Missouri Hazardous Waste Management Law	Missouri Department of Natural Resources RSMo 260.385 and 260.395 10 CSR 25-6.263	Sets forth standards for transporters of hazardous waste, incorporates 40 CRF Part 263 and certain regulations in 49 CFR by reference, and sets forth additional state standards.
8. Missouri Hazardous Waste Management Law	Missouri Department of Natural Resources RSMo 260.370 , 260.390, and 260.395 10 CSR 25-7.264(2)(A) through (2)(G), (2)(K) through (2)(N), and/or (2)(S)	Sets forth the standards for owners and operators of hazardous waste treatment, storage and disposal facilities; incorporates and modifies the federal regulations in 40 CFR Part 264 by reference, and sets forth additional state requirements.
9. Missouri Hazardous Waste Management Law	Missouri Department of Natural Resources RSMo 260.370, 260.390, 260.395, and 260.400 10 CSR 25-7.268	Establishes standards and requirements that identify hazardous wastes that are restricted from land disposal.
10. Missouri Monitoring Well Construction Code	Missouri Department of Natural Resources RSMo 256.603, 256.606, 256.626 10 CSR 23-4	Specifies requirements for installation of groundwater monitoring wells.
11. Missouri Well Construction Rules	Missouri Department of Natural Resources RSMo 256.606, 256.626 10 CSR 23-3	Specifies requirements for newly construction potable water wells from known contamination sources.
B. To Be Considered	None	

Table 5-1. Summary of Technology Screening Process by Environmental Medium

Medium	Remedial Action Objective	General Response Actions	Remedial Technology Types	Process Options
Mine Waste and Source Materials	Human Health: Control risks to human receptors from exposure to contaminants so that excess cancer risk is <10E-4, the HQ and HI values are <1.0, and there is ≤5 % chance that an exposed individual will have a blood lead level >10 µg/dL. Ecological: Control risks to ecological receptors from exposure to contaminants such that the HQ and HI values are ≤1.0.	No Action Institutional Control Actions Containment Actions *In situ* Treatment Actions Removal and Disposal Actions Removal and Treatment Actions	Institutional Controls: • Legal restrictions • Public health education • Access restrictions Containment: • Caps and covers • Solidification/Stabilization • Drainage & erosion control *In Situ* Treatment: • Treatment of soil & tailings Removal and Disposal: • Off-site landfill • On-site repository Removal and Treatment: • *Ex situ* treatment of tailings & soil	Legal Restrictions: • Land use & deed restrictions Access Restrictions: • Fencing & signage Caps and Covers: • Permeable covers • Low permeability caps • Water cover Solidification/Stabilization: • Pozzolan/Portland Cement Drainage & Erosion Control: • Grading & contouring • Tailings dam stabilization • Precipitation runoff management • Vegetation *In Situ* Treatment of Soil & Tailings: • Phosphate Stabilization • Bauxsol Stabilization Off-Site Disposal: • Non-hazardous waste landfill *Ex Situ* Treatment of Soil & Tailings: • Phosphate Stabilization • Bauxsol Stabilization
Surface Soil/Flood Plain Soils	Human Health: Control risks to human receptors from surface soils such that that excess cancer risk is <10E-4, the HQ and HI values are <1.0, and there is ≤5 % chance that an exposed individual will have a blood lead level >10 µg/dL. Ecological: Control risks to ecological receptors from exposure to contaminants such that the HQ and HI values are ≤1.0.	No Action Institutional Control Actions Monitored Natural Attenuation Actions Containment Actions *In situ* Treatment Actions Removal and Disposal Actions Removal and Treatment Actions	Institutional Controls: • Legal restrictions • Public health education • Access restrictions Monitored Natural Attenuation: • Monitoring following source removal or containment Containment: • Caps and covers • Drainage & erosion control *In Situ* Treatment: • Treatment of soil & tailings Removal and Disposal: • Off-site landfill • On-site repository	Legal Restrictions: • Land use & deed restrictions Access Restrictions: • Fencing & signage Caps and Covers: • Permeable covers • Low permeability caps Solidification/Stabilization: • Pozzolan/Portland Cement Drainage & Erosion Control: • Grading & contouring • Precipitation runoff management • Vegetation

Table 5-1. Summary of Technology Screening Process by Environmental Medium				
Medium	**Remedial Action Objective**	**General Response Actions**	**Remedial Technology Types**	**Process Options**
Surface Soil/Flood Plain Soils (Continued)			Removal and Treatment: • *Ex situ* treatment of tailings & soil • Treatment of PAH-contaminated soil	*In Situ* Treatment of Soil & Tailings: • Phosphate Stabilization • Bauxsol Stabilization Off-Site Disposal: • Non-hazardous waste landfill • Hazardous waste landfill *Ex Situ* Treatment of Soil & Tailings: • Phosphate Stabilization • Bauxsol Stabilization
Surface Water	Human Health: Control risks to adult and child receptors from exposure to contaminants such that the HQ and HI values are <1.0. Ecological: Control exposure of aquatic biota to contaminants released and transported from mine waste where surface water quality criteria are exceeded.	No Action Institutional Control Actions Collection and Treatment Actions	Institutional Controls: • Legal restrictions • Public health education • Access restrictions Collection and Treatment: • Collection and active treatment • Collection and passive treatment	Legal Restrictions: • Land use & deed restrictions • Surface water use restrictions Access Restrictions: • Fencing & signage Active Treatment: • On-site • Off-site Passive Treatment: • Wetlands & rock filter
Sediment	Human Health: Control risks to child receptors from exposure to contaminants such that the HQ and HI values are <1.0 and there is ≤5 % chance that an exposed individual will have a blood lead level >10 µg/dL. Ecological: Control exposure of aquatic biota to contaminants by controlling the transport of mine wastes to streams.	No Action Institutional Control Actions Monitored Natural Recovery Actions Containment Actions Removal and Disposal Actions Removal and Treatment Actions	Institutional Controls: • Legal restrictions • Public health education • Access restrictions Monitored Natural Recovery: • Monitoring following source removal or containment Containment: • Caps & covers • Drainage & erosion control Removal and Disposal: • Off-site landfill • On-site repository Removal and Treatment: • *Ex situ* treatment of tailings & soil	Legal Restrictions: • Land use & deed restrictions Access Restrictions: • Fencing & signage Caps and Covers: • Permeable covers • Induced sedimentation Drainage & Erosion Control: • Grading & contouring • Precipitation runoff management • Stream bank and channel stabilization Off-Site Disposal: • Non-hazardous waste landfill *Ex Situ* Treatment of Soil & Tailings: • Phosphate Stabilization • Bauxsol Stabilization

Table 5-1. Summary of Technology Screening Process by Environmental Medium				
Medium	**Remedial Action Objective**	**General Response Actions**	**Remedial Technology Types**	**Process Options**
Groundwater	Human Health: Control risks to human receptors from ingestion of contaminants so that excess cancer risk is <10E-4, the HQ and HI values are <1.0, and there is ≤5 % chance that an exposed individual will have a blood lead level >10 µg/dL. Ecological: Prevent exposure of aquatic biota to contaminants in releases of groundwater where surface water quality criteria are exceeded.	No Action Institutional Control Actions Monitored Natural Recovery Actions *In Situ* Treatment Actions Collection and Treatment Actions	Institutional Controls: • Legal restrictions • Public health education Monitored Natural Attenuation: • Monitoring following source removal or containment *In Situ* Treatment: • Treatment of shallow groundwater Collection and Treatment: • Active treatment • Passive treatment	Legal Restrictions: • Groundwater use restrictions *In Situ* Treatment: • Injection of treatment agents • Permeable reactive barrier Active Treatment: • On-site • Off-Site Passive Treatment: • Wetlands & rock filter

Table 6-4. Summary of Alternatives for Detailed Screening at the Catherine Chat Area			
Alternative	**Catherine Chat Area**	**Catherine Pond and Sediment in Pond**	**Sediment in Logtown Branch**
1. No Action	• No Action	• No Action	• No Action
2. Institutional Controls	• Land Use & Deed Restrictions • Signage and Fencing	• Land Use & Deed Restrictions • Signage and Fencing	• Signage
3. Low Permeable Cover, Sediment Excavation and Onsite Disposal, Monitored Natural Recovery	• Low Permeable Cover at Chat Pile • Grade & Contour • Runoff Management • Vegetation • Land Use & Deed Restrictions • Fencing and Signage	• Excavation & Disposal Under Cap at Catherine Repository • Runoff Management	• Monitored Natural Recovery • Excavation of Stream Sediment Hot Spots and Disposal at Catherine Repository • Stream Bank & Channel Stabilization • Runoff Management • Vegetation • Signage
4. Engineered Cap, Sediment Excavation and Onsite Disposal, Monitored Natural Recovery	• Engineered Low Permeable Cap • Grade & Contour • Runoff Management • Vegetation • Land Use & Deed Restrictions • Fencing and Signage	• Excavation & Disposal Under Cap at Catherine Repository • Runoff Management	• Monitored Natural Recovery • Excavation of Stream Sediment Hot Spots and Disposal at Catherine Repository • Stream Bank & Channel Stabilization • Runoff Management • Vegetation • Signage

Table 6-7. Summary of Alternatives for Detailed Screening at the Skaggs Subsite		
Alternative	**Chat Piles and Soil**	**Sediments in Two Unnamed Tributaries and Unnamed Pond**
1. No Action	• No Action	• No Action
2. Institutional Controls	• Land Use & Deed Restrictions • Signage and Fencing	• Signage
3. Permeable Cover, Excavation and Disposal, Monitored Natural Recovery	• Permeable Cover • Grade & Contour • Runoff Management • Vegetation • Land Use & Deed Restrictions • Fencing and Signage	• Monitored Natural Recovery • Excavation of Stream Sediment Hot Spots and Disposal at Local Repository • Stream Bank & Channel Stabilization • Runoff Management • Vegetation • Signage
4. Low Permeable Cap, Excavation and Disposal, Monitored Natural Recovery	• Low Permeable Cap • Grade & Contour • Runoff Management • Vegetation • Land Use & Deed Restrictions • Fencing and Signage	• Monitored Natural Recovery • Excavation of Stream Sediment Hot Spots and Disposal in Local Repository • Stream Bank & Channel Stabilization • Runoff Management • Vegetation • Signage

Table 7-1
Alternative 1 - No Action
Present Worth Cost Estimate
OU5 - Catherine Subsite
Madison County Mines FS Report

Cost Estimate Component	Quantity	Units	Unit Cost	Capital Cost	O&M Cost
CAPITAL COSTS				$0	
DIRECT CAPITAL COST SUBTOTAL				$0	
Bid Contingency (10%)				$0	
Scope Contingency (15%)				$0	
TOTAL DIRECT CAPITAL COST				$0	
Permitting and Legal (5%)				$0	
Construction Services (5%)				$0	
CONSTRUCTION COSTS TOTAL				$0	
Engineering Design (8%)				$0	
TOTAL CAPITAL COST				$0	
ANNUAL OR PERIODIC O&M COSTS					
Five-Year Review @ 5, 10, 15, 20, 25, and 30 yrs	1	LS	$25,000		$25,000
TOTAL PRESENT WORTH O&M COST				$53,900	
TOTAL PRESENT WORTH				$53,900	

7 percent discount rate used to calculate present worth.
LS - Lump Sum

Table 7-1 (Continued)
Alternative 1 - No Action
Present Worth Cost Estimate
OU5 - Catherine Subsite
Madison County Mines FS Report

Year	Yearly O&M Cost*	Intermittent O&M Costs	Total Annual O&M Costs	O&M Costs Include:
1	$0	$0	$0	
2	$0	$0	$0	
3	$0	$0	$0	
4	$0	$0	$0	
5	$0	$25,000	$25,000	5 yr review
6	$0	$0	$0	
7	$0	$0	$0	
8	$0	$0	$0	
9	$0	$0	$0	
10	$0	$25,000	$25,000	5 yr review
11	$0	$0	$0	
12	$0	$0	$0	
13	$0	$0	$0	
14	$0	$0	$0	
15	$0	$25,000	$25,000	5 yr review
16	$0	$0	$0	
17	$0	$0	$0	
18	$0	$0	$0	
19	$0	$0	$0	
20	$0	$25,000	$25,000	5 yr review
21	$0	$0	$0	
22	$0	$0	$0	
23	$0	$0	$0	
24	$0	$0	$0	
25	$0	$25,000	$25,000	5 yr review
26	$0	$0	$0	
27	$0	$0	$0	
28	$0	$0	$0	
29	$0	$0	$0	
30	$0	$25,000	$25,000	5 yr review
Total Cost of Annual O&M			$150,000	
Present Worth of Annual O&M			$53,900	

* There are no yearly O&M costs for this alternative.

Table 7-2
Alternative 2 - Institutional Controls
Present Worth Cost Estimate
OU5 - Catherine Subsite
Madison County Mines FS Report

Cost Estimate Component	Quantity	Units	Unit Cost	Capital Cost	O&M Cost
CAPITAL COSTS					
Deed Restrictions will be provided at no cost by local governm	1	LS	$0	$0	
Install 8 ft chain link fence and signage around pond and repository	4,100	FT	$80	$328,000	
Install/abandon 4 - 20 ft deep GW monitoring wells	1	LS	$8,000	$8,000	
DIRECT CAPITAL COST SUBTOTAL				$336,000	
Bid Contingency (10%)				$33,600	
Scope Contingency (15%)				$50,400	
TOTAL DIRECT CAPITAL COST				$420,000	
Permitting and Legal (5%)				$21,000	
Construction Services (5%)				$21,000	
CONSTRUCTION COSTS TOTAL				$462,000	
Engineering Design (8%)				$37,000	
TOTAL CAPITAL COST				$499,000	
ANNUAL OR PERIODIC O&M COSTS					
Capital O&M					
Repair chain link fence (annually)	1	LS	$3,280		$3,300
Replace signs (every 5 years)	1	LS	$445		$400
Sampling					
Prepare Health & Safety Plan (Year 1 only)	1	LS	$3,200		$3,200
Prepare QAPP/Sampling Plan (Year 1 only)	1	LS	$4,800		$4,800
Semi Annual GW sampling (Yrs 1-2) at 4 wells	1	LS	$17,100		$17,100
Annual GW sampling (Yrs 3-5) at 4 wells	1	LS	$8,550		$8,600
Annual SW & sediment sampling (Yrs 1-5) at 3 locations	1	LS	$11,530		$11,500
Public Mtg & 5 Yr Reviews					
5 year review (Every 5 yrs)	1	LS	$25,000		$25,000
Prepare Newsletter (Every 5 yrs)	1	LS	$4,000		$4,000
Newsletter Publication & Local Newspaper (Every 5 yrs)	1	LS	$1,500		$1,500
Public Information Mtg (Every 5 years)	1	LS	$4,600		$4,600
TOTAL PRESENT WORTH O&M COST				$222,700	
TOTAL PRESENT WORTH				$721,700	

7 percent discount rate used to calculate present worth.
LS - Lump Sum
FT - Feet

Table 7-2 (Continued)
Alternative 2 - Institutional Controls
Present Worth Cost Estimate
OU5 - Catherine Subsite
Madison County Mines FS Report

Year	Yearly O&M Cost	Intermittent O&M Costs	Total Annual O&M Costs	O&M Costs Include:
1	$31,900	$8,000	$39,900	Fence Repair, sampling, QAPP/SAP, HASP.
2	$31,900	$0	$31,900	Fence Repair, sampling
3	$23,360	$0	$23,360	Fence Repair, sampling
4	$23,360	$0	$23,360	Fence Repair, sampling
5	$23,360	$35,500	$58,860	Fence Repair , Sign Repair, sampling, 5 yr review and informational meeting.
6	$3,300	$0	$3,300	Fence Repair
7	$3,300	$0	$3,300	Fence Repair
8	$3,300	$0	$3,300	Fence Repair
9	$3,300	$0	$3,300	Fence Repair
10	$3,300	$35,500	$38,800	Fence Repair, Sign Repair, 5 yr review and informational meeting
11	$3,300	$0	$3,300	Fence Repair
12	$3,300	$0	$3,300	Fence Repair
13	$3,300	$0	$3,300	Fence Repair
14	$3,300	$0	$3,300	Fence Repair
15	$3,300	$35,500	$38,800	Fence Repair, Sign Repair, 5 yr review and informational meeting
16	$3,300	$0	$3,300	Fence Repair
17	$3,300	$0	$3,300	Fence Repair
18	$3,300	$0	$3,300	Fence Repair
19	$3,300	$0	$3,300	Fence Repair
20	$3,300	$35,500	$38,800	Fence Repair, Sign Repair, 5 yr review and informational meeting
21	$3,300	$0	$3,300	Fence Repair
22	$3,300	$0	$3,300	Fence Repair
23	$3,300	$0	$3,300	Fence Repair
24	$3,300	$0	$3,300	Fence Repair
25	$3,300	$35,500	$38,800	Fence Repair, Sign Repair, 5 yr review and informational meeting
26	$3,300	$0	$3,300	Fence Repair
27	$3,300	$0	$3,300	Fence Repair
28	$3,300	$0	$3,300	Fence Repair
29	$3,300	$0	$3,300	Fence Repair
30	$3,300	$35,500	$38,800	Fence Repair, Sign Repair, 5 yr review and informational meeting
Total Costs of Annual O&M			$437,380	
Present Worth of Annual O&M			$222,720	

Table 7-3
Alternative 3 - Low Permeable Cap, Sediment Excavation and Onsite Disposal,
Monitored Natural Recovery
Present Worth Cost Estimate
OU5 - Catherine Subsite
Madison County Mines FS Report

Cost Estimate Component	Quantity	Units	Unit Cost	Capital Cost	O&M Cost
CAPITAL COSTS					
Mobilization/Demobilization	1	LS	$72,780	$72,780	
Clearing & grubbing	10.9	AC	$6,765	$73,730	
Excavate contaminated material from pond and move to repository	2,900	CY	$17	$49,140	
Soil confirmation sampling	1	LS	$14,784	$14,780	
Stabilization of Catherine Pond	22,000	FT	$2.21	$48,630	
Install low permeable cap at repository consisting 1 ft clay layer, 6 inch topsoil layer, and vegetation.	52,756	SY	$17.69	$933,240	
Install 8 ft chain link fence and signs around pond and repository	4,100	FT	$80	$328,000	
Deed Restrictions will be provided at no cost by local government	1	LS	$0	$0	
Install/abandon 4 - 20 ft deep GW monitoring wells	1	LS	$8,000	$8,000	
DIRECT CAPITAL COST SUBTOTAL				$1,528,300	
Bid Contingency (10%)				$152,830	
Scope Contingency (15%)				$229,250	
TOTAL DIRECT CAPITAL COST				$1,910,380	
Permitting and Legal (5%)				$95,520	
Construction Services (5%)				$95,520	
CONSTRUCTION COSTS TOTAL				$2,101,420	
Engineering Design (8%)				$168,110	
TOTAL CAPITAL COST				$2,269,530	

Table 7-3
Alternative 3 - Low Permeable Cap, Sediment Excavation and Onsite Disposal,
Monitored Natural Recovery
Present Worth Cost Estimate
OU5 - Catherine Subsite
Madison County Mines FS Report

Cost Estimate Component	Quantity	Units	Unit Cost	Capital Cost	O&M Cost
ANNUAL OR PERIODIC O&M COSTS					
Maintenance & Repairs					
Annual low permeable cap maintenance	10.9	AC	$947		$10,319
Annual repair chain link fence	1	LS	$3,280		$3,280
Replace signs every 5 years (thru Year 10)	1	LS	$445		$445
Sampling					
Prepare Health & Safety Plan (Year 1 only)	1	LS	$3,200		$3,200
Prepare QAPP/Sampling Plan (Year 1 only)	1	LS	$4,800		$4,800
Semi Annual GW sampling (Yrs 1-2) at 4 wells	1	LS	$17,100		$17,100
Annual GW sampling (Yrs 3-5) at 4 wells	1	LS	$8,550		$8,550
Annual SW & sediment sampling (Yrs 1-10) at 3 locations	1	LS	$11,530		$11,530
Public Meetings & 5-Yr Reviews					
Prepare Newsletter (Every 5 yrs)	1	LS	$4,000		$4,000
Newsletter Publication & Local Newspaper (Every 5 yrs)	1	LS	$1,500		$1,500
Public Information Mtg (Every 5 years)	1	LS	$4,600		$4,600
5 year review (Every 5 yrs)	1	LS	$25,000		$25,000
TOTAL PRESENT WORTH O&M COST				$384,010	
TOTAL PRESENT WORTH				$2,653,540	

7 percent discount rate used to calculate present worth.

LS - Lump Sum
AC - Acre
CY - Cubic Yards
FT - Feet
SY - Square Yards

Table 7-3 (Continued)
Alternative 3 - Low Permeable Cap, Sediment Excavation and Onsite Disposal, Monitored Natural Recovery
Present Worth Cost Estimate
OU5 - Catherine Subsite
Madison County Mines FS Report

Year	Yearly O&M Cost*	Intermittent O&M Costs	Total Annual O&M Costs	O&M Costs Include:
1	$42,229	$8,000	$50,230	Cap Maintenance, Fence Repair, Sampling, QAPP/SAP, HASP.
2	$42,229		$42,230	Cap Maintenance, Fence Repair, Sampling
3	$33,679		$33,680	Cap Maintenance, Fence Repair, Sampling
4	$33,679		$33,680	Cap Maintenance, Fence Repair, Sampling
5	$33,679	$35,545	$69,220	Cap Maintenance, Fence Repair, Sign Repair, Sampling, 5-year Review.
6	$25,129		$25,130	Cap Maintenance, Fence Repair, Sampling
7	$25,129		$25,130	Cap Maintenance, Fence Repair, Sampling
8	$25,129		$25,130	Cap Maintenance, Fence Repair, Sampling
9	$25,129		$25,130	Cap Maintenance, Fence Repair, Sampling
10	$25,129	$35,545	$60,670	Cap Maintenance, Fence Repair, Sign Repair, Sampling, 5-year Review.
11	$13,599		$13,600	Cap Maintenance, Fence Repair
12	$13,599		$13,600	Cap Maintenance, Fence Repair
13	$13,599		$13,600	Cap Maintenance, Fence Repair
14	$13,599		$13,600	Cap Maintenance, Fence Repair
15	$13,599	$35,100	$48,700	Cap Maintenance, Fence Repair, 5-year Review.
16	$13,599		$13,600	Cap Maintenance, Fence Repair
17	$13,599		$13,600	Cap Maintenance, Fence Repair
18	$13,599		$13,600	Cap Maintenance, Fence Repair
19	$13,599		$13,600	Cap Maintenance, Fence Repair
20	$13,599	$35,100	$48,700	Cap Maintenance, Fence Repair, 5-year Review.
21	$13,599		$13,600	Cap Maintenance, Fence Repair
22	$13,599		$13,600	Cap Maintenance, Fence Repair
23	$13,599		$13,600	Cap Maintenance, Fence Repair
24	$13,599		$13,600	Cap Maintenance, Fence Repair
25	$13,599	$35,100	$48,700	Cap Maintenance, Fence Repair, 5-year Review.
26	$13,599		$13,600	Cap Maintenance, Fence Repair
27	$13,599		$13,600	Cap Maintenance, Fence Repair
28	$13,599		$13,600	Cap Maintenance, Fence Repair
29	$13,599		$13,600	Cap Maintenance, Fence Repair
30	$13,599	$35,100	$48,700	Cap Maintenance, Fence Repair, 5-year Review.
Total Costs of Annual O&M			$802,630	
Present Worth of Annual O&M			$384,010	

Table 7-4
Alternative 4 - Engineered Low Permeable Cap, Sediment Excavation and Onsite Disposal, Monitored Natural Recovery
Present Worth Cost Estimate
OU5 - Catherine Subsite
Madison County Mines FS Report

Cost Estimate Component	Quantity	Units	Unit Cost	Capital Cost	O&M Cost
CAPITAL COSTS					
Mobilization/Demobilization	1	LS	$509,330	$509,330	
Clearing & grubbing	10.9	AC	$6,765	$73,730	
Excavate contaminated material from pond and move to repository	2,900	CY	$16.94	$49,140	
Soil confirmation sampling	1	LS	$14,784	$14,780	
Stabilization of Catherine Pond	22,000	FT	$2.21	$48,630	
Install engineered, low permeable cap at repository	474,804	SF	$20.35	$9,664,250	
Install 8 ft chain link fence and signs around pond and repository	4,100	FT	$80	$328,000	
Deed Restrictions will be provided at no cost by local government	1	LS	$0	$0	
Install/abandon 4 - 20 ft deep GW monitoring wells	1	LS	$8,000	$8,000	
DIRECT CAPITAL COST SUBTOTAL				$10,695,860	
Bid Contingency (10%)				$1,069,590	
Scope Contingency (15%)				$1,604,380	
TOTAL DIRECT CAPITAL COST				$13,369,830	
Permitting and Legal (5%)				$668,490	
Construction Services (5%)				$668,490	
CONSTRUCTION COSTS TOTAL				$14,706,810	
Engineering Design (8%)				$1,176,540	
TOTAL CAPITAL COST				$15,883,350	

Table 7-4
Alternative 4 - Engineered Low Permeable Cap, Sediment Excavation and Onsite Disposal, Monitored Natural Recovery
Present Worth Cost Estimate
OU5 - Catherine Subsite
Madison County Mines FS Report

Cost Estimate Component	Quantity	Units	Unit Cost	Capital Cost	O&M Cost
ANNUAL OR PERIODIC O&M COSTS					
Maintenance & Repairs					
Annual cap maintenance	10.9	AC	$1,075		$11,714
Annual repair chain link fence	1	LS	$3,280		$3,280
Replace signs every 5 years (thru Year 10)	1	LS	$445		$445
Sampling					
Prepare Health & Safety Plan (Year 1 only)	1	LS	$3,200		$3,200
Prepare QAPP/Sampling Plan (Year 1 only)	1	LS	$4,800		$4,800
Semi Annual GW sampling (Yrs 1-2) at 4 wells	1	LS	$17,100		$17,100
Annual GW sampling (Yrs 3-5) at 4 wells	1	LS	$8,550		$8,550
Annual SW & sediment sampling (Yrs 1-10) at 3 locations	1	LS	$11,530		$11,530
Public Meetings & 5-Yr Reviews					
5 year review (Every 5 yrs)	1	LS	$25,000		$25,000
Prepare Newsletter (Every 5 yrs)	1	LS	$4,000		$4,000
Newsletter Publication & Local Newspaper (Every 5 yrs)	1	LS	$1,500		$1,500
Public Information Mtg (Every 5 years)	1	LS	$4,600		$4,600
TOTAL PRESENT WORTH O&M COST				$401,270	
TOTAL PRESENT WORTH				$16,284,620	

7 percent discount rate used to calculate present worth.

LS - Lump Sum
AC - Acre
CY - Cubic Yards
FT - Feet
SF - Square Feet

Table 7-4 (Continued)
Alternative 4 - Engineered Low Permeable Cap, Sediment Excavation
and Onsite Disposal, Monitored Natural Recovery
Present Worth Cost Estimate
OU5 - Catherine Subsite
Madison County Mines FS Report

Year	Yearly O&M Cost	Intermittent O&M Costs	Total Annual O&M Costs	O&M Costs Include:
1	$43,624	$8,000	$51,620	Cap Maintenance, Fence Repair, Sampling, QAPP/SAP, HASP
2	$43,624		$43,620	Cap Maintenance, Fence Repair, Sampling
3	$35,074		$35,070	Cap Maintenance, Fence Repair, Sampling
4	$35,074		$35,070	Cap Maintenance, Fence Repair, Sampling
5	$35,074	$35,545	$70,620	Cap Maintenance, Fence Repair, Sign Repair, Sampling, 5-year Review
6	$26,524		$26,520	Cap Maintenance, Fence Repair, Sampling
7	$26,524		$26,520	Cap Maintenance, Fence Repair, Sampling
8	$26,524		$26,520	Cap Maintenance, Fence Repair, Sampling
9	$26,524		$26,520	Cap Maintenance, Fence Repair, Sampling
10	$26,524	$35,545	$62,070	Cap Maintenance, Fence Repair, Sign Repair, Sampling, 5-year Review
11	$14,994		$14,990	Cap Maintenance, Fence Repair
12	$14,994		$14,990	Cap Maintenance, Fence Repair
13	$14,994		$14,990	Cap Maintenance, Fence Repair
14	$14,994		$14,990	Cap Maintenance, Fence Repair
15	$14,994	$35,100	$50,090	Cap Maintenance, Fence Repair, 5-year Review
16	$14,994		$14,990	Cap Maintenance, Fence Repair
17	$14,994		$14,990	Cap Maintenance, Fence Repair
18	$14,994		$14,990	Cap Maintenance, Fence Repair
19	$14,994		$14,990	Cap Maintenance, Fence Repair
20	$14,994	$35,100	$50,090	Cap Maintenance, Fence Repair, 5-year Review
21	$14,994		$14,990	Cap Maintenance, Fence Repair
22	$14,994		$14,990	Cap Maintenance, Fence Repair
23	$14,994		$14,990	Cap Maintenance, Fence Repair
24	$14,994		$14,990	Cap Maintenance, Fence Repair
25	$14,994	$35,100	$50,090	Cap Maintenance, Fence Repair, 5-year Review
26	$14,994		$14,990	Cap Maintenance, Fence Repair
27	$14,994		$14,990	Cap Maintenance, Fence Repair
28	$14,994		$14,990	Cap Maintenance, Fence Repair
29	$14,994		$14,990	Cap Maintenance, Fence Repair
30	$14,994	$35,100	$50,090	Cap Maintenance, Fence Repair, 5-year Review
Total Costs of Annual O&M			$844,350	
Present Worth of Annual O&M			$401,270	

Table 7-5
Alternative 1 - No Action
Present Worth Cost Estimate
OU5 - Skaggs Subsite
Madison County Mines Site FS Report

Cost Estimate Component	Quantity	Units	Unit Cost	Capital Cost	O&M Cost
CAPITAL COSTS				$0	
DIRECT CAPITAL COST SUBTOTAL				$0	
Bid Contingency (10%)				$0	
Scope Contingency (15%)				$0	
TOTAL DIRECT CAPITAL COST				$0	
Permitting and Legal (5%)				$0	
Construction Services (5%)				$0	
CONSTRUCTION COSTS TOTAL				$0	
Engineering Design (8%)				$0	
TOTAL CAPITAL COST				$0	
ANNUAL OR PERIODIC O&M COSTS					
Five-Year Review @ 5, 10, 15, 20, 25, and 30 yrs	1	LS	$25,000		$25,000
TOTAL PRESENT WORTH O&M COST				$53,900	
TOTAL PRESENT WORTH				$53,900	

7 percent discount rate used to calculate present worth.
LS - Lump Sum

Table 7-5 (Continued)
Alternative 1 - No Action
Present Worth Cost Estimate
OU5 - Skaggs Subsite
Madison County Mines Site FS Report

Year	Yearly O&M Cost*	Intermittent O&M Costs	Total Annual O&M Costs	O&M Costs Include:
1	$0	$0	$0	
2	$0	$0	$0	
3	$0	$0	$0	
4	$0	$0	$0	
5	$0	$25,000	$25,000	5 yr review
6	$0	$0	$0	
7	$0	$0	$0	
8	$0	$0	$0	
9	$0	$0	$0	
10	$0	$25,000	$25,000	5 yr review
11	$0	$0	$0	
12	$0	$0	$0	
13	$0	$0	$0	
14	$0	$0	$0	
15	$0	$25,000	$25,000	5 yr review
16	$0	$0	$0	
17	$0	$0	$0	
18	$0	$0	$0	
19	$0	$0	$0	
20	$0	$25,000	$25,000	5 yr review
21	$0	$0	$0	
22	$0	$0	$0	
23	$0	$0	$0	
24	$0	$0	$0	
25	$0	$25,000	$25,000	5 yr review
26	$0	$0	$0	
27	$0	$0	$0	
28	$0	$0	$0	
29	$0	$0	$0	
30	$0	$25,000	$25,000	5 yr review
Total Cost of Annual O&M			$150,000	
Present Worth of Annual O&M			$53,900	

* There are no yearly O&M costs for this alternative.

Table 7-6
Alternative 2 - Institutional Controls
Present Worth Cost Estimate
OU5 - Skaggs Subsite
Madison County Mines Site FS Report

Cost Estimate Component	Quantity	Units	Unit Cost	Capital Cost	O&M Cost
CAPITAL COSTS					
Deed Restrictions will be provided at no cost by local government	1	LS	$0	$0	
Install 8 ft chain link fence and signage around 3 chat piles	6,700	FT	$80	$533,300	
Install signs along 2 Unnamed tributaries at 200 ft increments	35	EA	$148	$5,200	
Install/abandon 4 - 20 ft deep GW monitoring wells	1	LS	$8,000	$8,000	
DIRECT CAPITAL COST SUBTOTAL				$546,500	
Bid Contingency (10%)				$54,700	
Scope Contingency (15%)				$82,000	
TOTAL DIRECT CAPITAL COST				$683,200	
Permitting and Legal (5%)				$34,200	
Construction Services (5%)				$34,200	
CONSTRUCTION COSTS TOTAL				$751,600	
Engineering Design (8%)				$60,100	
TOTAL CAPITAL COST				$811,700	
ANNUAL OR PERIODIC O&M COSTS					
Capital O&M					
Repair chain link fence (annually)	1	LS	$5,333		$5,300
Replace signs (every 5 years)	1	LS	$5,200		$5,200
Sampling					
Prepare Health & Safety Plan (Year 1 only)	1	LS	$3,200		$3,200
Prepare QAPP/Sampling Plan (Year 1 only)	1	LS	$4,800		$4,800
Semi Annual GW sampling (Yrs 1-2) at 4 wells	1	LS	$17,100		$17,100
Annual GW sampling (Yrs 3-5) at 4 wells	1	LS	$8,550		$8,600
Annual SW & sediment sampling (Yrs 1-5) at 4 locations	1	LS	$10,750		$10,800
Public Mtg & 5 Yr Reviews					
5 year review (Every 5 yrs)	1	LS	$25,000		$25,000
Prepare Newsletter (Every 5 yrs)	1	LS	$4,000		$4,000
Newsletter Publication & Local Newspaper (Every 5 yrs)	1	LS	$1,500		$1,500
Public Information Mtg (Every 5 years)	1	LS	$4,600		$4,600
TOTAL PRESENT WORTH O&M COST				$255,000	
TOTAL PRESENT WORTH				$1,066,700	

7 percent discount rate used to calculate present worth.
LS - Lump Sum
FT - Feet
EA - Each

Table 7-6 (Continued)
Alternative 2 - Institutional Controls
Present Worth Cost Estimate
OU5 - Skaggs Subsite
Madison County Mines Site FS Report

Year	Yearly O&M Cost	Intermittent O&M Costs	Total Annual O&M Costs	O&M Costs Include:
1	$33,200	$8,000	$41,200	Fence Repair, Sampling, QAPP/SAP, HASP.
2	$33,200	$0	$33,200	Fence Repair , Sampling
3	$24,650	$0	$24,650	Fence Repair , Sampling
4	$24,650	$0	$24,650	Fence Repair , Sampling
5	$24,650	$40,300	$64,950	Fence Repair , Sign Repair, Sampling, 5 yr review and informational meeting.
6	$5,300	$0	$5,300	Fence Repair
7	$5,300	$0	$5,300	Fence Repair
8	$5,300	$0	$5,300	Fence Repair
9	$5,300	$0	$5,300	Fence Repair
10	$5,300	$40,300	$45,600	Fence Repair , Sign Repair,5 yr review and informational meeting.
11	$5,300	$0	$5,300	Fence Repair
12	$5,300	$0	$5,300	Fence Repair
13	$5,300	$0	$5,300	Fence Repair
14	$5,300	$0	$5,300	Fence Repair
15	$5,300	$40,300	$45,600	Fence Repair , Sign Repair,5 yr review and informational meeting.
16	$5,300	$0	$5,300	Fence Repair
17	$5,300	$0	$5,300	Fence Repair
18	$5,300	$0	$5,300	Fence Repair
19	$5,300	$0	$5,300	Fence Repair
20	$5,300	$40,300	$45,600	Fence Repair , Sign Repair,5 yr review and informational meeting.
21	$5,300	$0	$5,300	Fence Repair
22	$5,300	$0	$5,300	Fence Repair
23	$5,300	$0	$5,300	Fence Repair
24	$5,300	$0	$5,300	Fence Repair
25	$5,300	$40,300	$45,600	Fence Repair , Sign Repair,5 yr review and informational meeting.
26	$5,300	$0	$5,300	Fence Repair
27	$5,300	$0	$5,300	Fence Repair
28	$5,300	$0	$5,300	Fence Repair
29	$5,300	$0	$5,300	Fence Repair
30	$5,300	$40,300	$45,600	Fence Repair , Sign Repair,5 yr review and informational meeting.
Total Costs of Annual O&M			$522,650	
Present Worth of Annual O&M			$255,000	

Table 7-7
Alternative 3 - Permeable Cover, Excavation and Disposal, Monitored Natural Recovery
Present Worth Cost Estimate
OU5 - Skaggs Subsite
Madison County Mines Site FS Report

Cost Estimate Component	Quantity	Units	Unit Cost	Capital Cost	O&M Cost
CAPITAL COSTS					
Mobilization/Demobilization	1	LS	$76,620	$76,620	
Clearing & grubbing assumed for East, Central, and West Chat areas.	12.2	AC	$6,765	$82,530	
Excavate, dewater, and load sediment from 0.25 acre pond	1,210	SY	$1.79	$2,160	
Excavate and consolidate soil from East and West Chat Piles	5,580	CY	$10.90	$60,840	
Alt 3 soil confirmation sampling in eastern and western chat piles (3.5 acres)	1	LS	$4,704	$4,700	
Backfill, grading, and seeding eastern and western chat piles (3.5 acres)	16,940	SY	$25	$418,580	
Install complete permeable cover consisting of 6 inch topsoil layer and vegetation (seeded). [Assumes 8.7 acres covered].	42,108	SY	$13.85	$583,350	
Install 8 ft chain link fence and signage around central chat area	4,600	FT	$80	$367,080	
Install signs along 2 Unnamed tributaries at 200 ft increments	35	EA	$148	$5,200	
Deed Restrictions will be provided at no cost by local government	1	LS	$0	$0	
Install/abandon 4 - 20 ft deep GW monitoring wells	1	LS	$8,000	$8,000	
DIRECT CAPITAL COST SUBTOTAL				$1,609,060	
Bid Contingency (10%)				$160,910	
Scope Contingency (15%)				$241,360	
TOTAL DIRECT CAPITAL COST				$2,011,330	
Permitting and Legal (5%)				$100,570	
Construction Services (5%)				$100,570	
CONSTRUCTION COSTS TOTAL				$2,212,470	
Engineering Design (8%)				$177,000	
TOTAL CAPITAL COST				$2,389,470	

Table 7-7

Alternative 3 - Permeable Cover, Excavation and Disposal, Monitored Natural Recovery

Present Worth Cost Estimate

OU5 - Skaggs Subsite

Madison County Mines Site FS Report

Cost Estimate Component	Quantity	Units	Unit Cost	Capital Cost	O&M Cost
ANNUAL OR PERIODIC O&M COSTS					
Maintenance & Repairs					
Annual permeable cover maintenance	8.7	AC	$764		$6,644
Annual repair chain link fence	1	LS	$3,670		$3,670
Replace signs every 5 years (thru Year 10)	1	LS	$5,200		$5,200
Sampling					
Prepare Health & Safety Plan (Year 1 only)	1	LS	$3,200		$3,200
Prepare QAPP/Sampling Plan (Year 1 only)	1	LS	$4,800		$4,800
Semi Annual GW sampling (Yrs 1-2) at 4 wells	1	LS	$17,100		$17,100
Annual GW sampling (Yrs 3-5) at 4 wells	1	LS	$8,550		$8,550
Annual SW & sediment sampling (Yrs 1-10) at 4 locations	1	LS	$10,750		$10,750
Public Meetings & 5-Yr Reviews					
Prepare Newsletter (Every 5 yrs)	1	LS	$4,000		$4,000
Newsletter Publication & Local Newspaper (Every 5 yrs)	1	LS	$1,500		$1,500
Public Information Mtg (Every 5 years)	1	LS	$4,600		$4,600
5 year review (Every 5 yrs)	1	LS	$25,000		$25,000
TOTAL PRESENT WORTH O&M COST				$347,830	
TOTAL PRESENT WORTH				$2,737,300	

7 percent discount rate used to calculate present worth.

LS - Lump Sum

AC - Acre

SY - Square Yards

CY - Cubic Yards

FT - Feet

EA - Each

Table 7-7 (Continued)
Alternative 3 - Permeable Cover, Excavation and Disposal, Monitored Natural Recovery
Present Worth Cost Estimate
OU5 - Skaggs Subsite
Madison County Mines Site FS Report

Year	Yearly O&M Cost*	Intermittent O&M Costs	Total Annual O&M Costs	O&M Costs Include:
1	$38,164	$8,000	$46,160	Maintenance & Repairs, Sampling, QAPP/SAP, HASP.
2	$38,164		$38,160	Maintenance & Repairs, Sampling.
3	$29,614		$29,610	Maintenance & Repairs, Sampling.
4	$29,614		$29,610	Maintenance & Repairs, Sampling.
5	$29,614	$40,300	$69,910	Maintenance & Repairs, Sampling, 5-year Review.
6	$21,064		$21,060	Maintenance & Repairs, Sampling.
7	$21,064		$21,060	Maintenance & Repairs, Sampling.
8	$21,064		$21,060	Maintenance & Repairs, Sampling.
9	$21,064		$21,060	Maintenance & Repairs, Sampling.
10	$21,064	$40,300	$61,360	Maintenance & Repairs, 5-year Review.
11	$10,314		$10,310	Maintenance & Repairs.
12	$10,314		$10,310	Maintenance & Repairs.
13	$10,314		$10,310	Maintenance & Repairs.
14	$10,314		$10,310	Maintenance & Repairs.
15	$10,314	$39,700	$50,010	Maintenance & Repairs, 5-year Review.
16	$10,314		$10,310	Maintenance & Repairs.
17	$10,314		$10,310	Maintenance & Repairs.
18	$10,314		$10,310	Maintenance & Repairs.
19	$10,314		$10,310	Maintenance & Repairs.
20	$10,314	$39,700	$50,010	Maintenance & Repairs, 5-year Review.
21	$10,314		$10,310	Maintenance & Repairs.
22	$10,314		$10,310	Maintenance & Repairs.
23	$10,314		$10,310	Maintenance & Repairs.
24	$10,314		$10,310	Maintenance & Repairs.
25	$10,314	$39,700	$50,010	Maintenance & Repairs, 5-year Review.
26	$10,314		$10,310	Maintenance & Repairs.
27	$10,314		$10,310	Maintenance & Repairs.
28	$10,314		$10,310	Maintenance & Repairs.
29	$10,314		$10,310	Maintenance & Repairs.
30	$10,314	$39,700	$50,010	Maintenance & Repairs, 5-year Review.
Total Costs of Annual O&M			$724,050	
Present Worth of Annual O&M			$347,830	

Table 7-8

Alternative 4 - Low Permeable Cap, Excavation and Disposal, Monitored Natural Recovery

Present Worth Cost Estimate

OU5 - Skaggs Subsite

Madison County Mines Site FS Report

Cost Estimate Component	Quantity	Units	Unit Cost	Capital Cost	O&M Cost
CAPITAL COSTS					
Mobilization/Demobilization	1	LS	$95,720	$95,720	
Clearing & grubbing assumed for East, Central, and West Chat areas.	12.2	AC	$6,765	$82,530	
Excavate, dewater, and load sediment from 0.25 acre pond	1,210	SY	$1.79	$2,160	
Excavate and consolidate soil from East, West, and Central Chat Piles	32,680	CY	$10.90	$356,300	
Alt 4 soil confirmation sampling in eastern and western chat piles (7.7 acres)	1	LS	$10,349	$10,350	
Backfill, grading, and seeding eastern, western, and portion of central chat piles (7.7 acres)	37,268	SY	$25	$920,880	
Install low permeable cap consisting 1 ft clay layer, 6 inch topsoil layer, and vegetation (seeded). [Assumes 4.5 acres capped.]	21,780	SY	$17.69	$385,280	
Install 8 ft chain link fence and signage around capped area	1,800	FT	$80	$143,640	
Install signs along 2 Unnamed tributaries at 200 ft increments	35	EA	$148	$5,200	
Deed Restrictions will be provided at no cost by local government	1	LS	$0.00	$0	
Install/abandon 4 - 20 ft deep GW monitoring wells	1	LS	$8,000	$8,000	
DIRECT CAPITAL COST SUBTOTAL				$2,010,060	
Bid Contingency (10%)				$201,010	
Scope Contingency (15%)				$301,510	
TOTAL DIRECT CAPITAL COST				$2,512,580	
Permitting and Legal (5%)				$125,630	
Construction Services (5%)				$125,630	
CONSTRUCTION COSTS TOTAL				$2,763,840	
Engineering Design (8%)				$221,110	
TOTAL CAPITAL COST				$2,984,950	

Table 7-8

Alternative 4 - Low Permeable Cap, Excavation and Disposal, Monitored Natural Recovery

Present Worth Cost Estimate

OU5 - Skaggs Subsite

Madison County Mines Site FS Report

Cost Estimate Component	Quantity	Units	Unit Cost	Capital Cost	O&M Cost
ANNUAL OR PERIODIC O&M COSTS					
Maintenance & Repairs					
Annual low permeable cap maintenance	4.5	AC	$947		$4,260
Annual repair chain link fence	1	LS	$1,440		$1,440
Replace signs every 5 years (thru Year 10)	1	LS	$5,200		$5,200
Sampling					
Prepare Health & Safety Plan (Year 1 only)	1	LS	$3,200		$3,200
Prepare QAPP/Sampling Plan (Year 1 only)	1	LS	$4,800		$4,800
Semi Annual GW sampling (Yrs 1-2) at 4 wells	1	LS	$17,100		$17,100
Annual GW sampling (Yrs 3-5) at 4 wells	1	LS	$8,550		$8,550
Annual SW & sediment sampling (Yrs 1-10) at 4 locations	1	LS	$10,750		$10,750
Public Meetings & 5-Yr Reviews					
Prepare Newsletter (Every 5 yrs)	1	LS	$4,000		$4,000
Newsletter Publication & Local Newspaper (Every 5 yrs)	1	LS	$1,500		$1,500
Public Information Mtg (Every 5 years)	1	LS	$4,600		$4,600
5 year review (Every 5 yrs)	1	LS	$25,000		$25,000
TOTAL PRESENT WORTH O&M COST				$283,670	
TOTAL PRESENT WORTH				$3,268,620	

7 percent discount rate used to calculate present worth.

LS - Lump Sum
AC - Acre
SY - Square Yards
CY - Cubic Yards
FT - Feet
EA - Each

Table 7-8 (Continued)
Alternative 4 - Low Permeable Cap, Excavation and Disposal, Monitored Natural Recovery
Present Worth Cost Estimate
OU5 - Skaggs Subsite
Madison County Mines Site FS Report

Year	Yearly O&M Cost	Intermittent O&M Costs	Total Annual O&M Costs	O&M Costs Include:
1	$33,550	$8,000	$41,550	Maintenance & Repairs, Sampling, QAPP/SAP, HASP.
2	$33,550		$33,550	Maintenance & Repairs, Sampling.
3	$25,000		$25,000	Maintenance & Repairs, Sampling.
4	$25,000		$25,000	Maintenance & Repairs, Sampling.
5	$25,000	$40,300	$65,300	Maintenance & Repairs, Sampling, 5-year Review.
6	$16,450		$16,450	Maintenance & Repairs, Sampling.
7	$16,450		$16,450	Maintenance & Repairs, Sampling.
8	$16,450		$16,450	Maintenance & Repairs, Sampling.
9	$16,450		$16,450	Maintenance & Repairs, Sampling.
10	$16,450	$35,100	$51,550	Maintenance & Repairs, Sampling, 5-year Review.
11	$5,700		$5,700	Maintenance & Repairs.
12	$5,700		$5,700	Maintenance & Repairs.
13	$5,700		$5,700	Maintenance & Repairs.
14	$5,700		$5,700	Maintenance & Repairs.
15	$5,700	$35,100	$40,800	Maintenance & Repairs, 5-year Review.
16	$5,700		$5,700	Maintenance & Repairs.
17	$5,700		$5,700	Maintenance & Repairs.
18	$5,700		$5,700	Maintenance & Repairs.
19	$5,700		$5,700	Maintenance & Repairs.
20	$5,700	$35,100	$40,800	Maintenance & Repairs, 5-year Review.
21	$5,700		$5,700	Maintenance & Repairs.
22	$5,700		$5,700	Maintenance & Repairs.
23	$5,700		$5,700	Maintenance & Repairs.
24	$5,700		$5,700	Maintenance & Repairs.
25	$5,700	$35,100	$40,800	Maintenance & Repairs, 5-year Review.
26	$5,700		$5,700	Maintenance & Repairs.
27	$5,700		$5,700	Maintenance & Repairs.
28	$5,700		$5,700	Maintenance & Repairs.
29	$5,700		$5,700	Maintenance & Repairs.
30	$5,700	$35,100	$40,800	Maintenance & Repairs, 5-year Review.
Total Costs of Annual O&M			$562,150	
Present Worth of Annual O&M			$283,670	

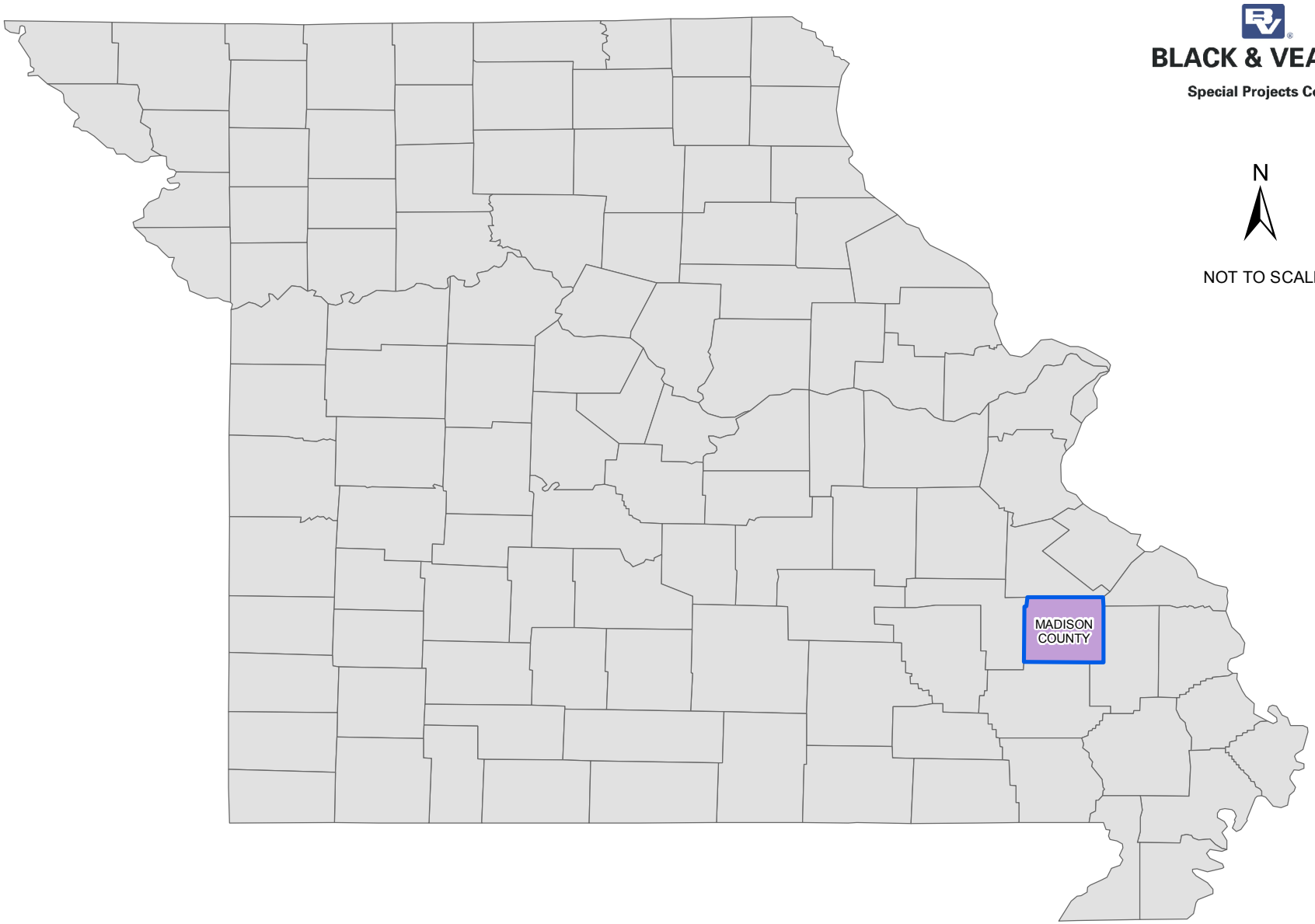
Table 8-1
Alternative Cost Summary Table
OU5 - Catherine Subsite
Madison County Mines FS Report

Alternative	Capital Cost	Present Worth of O&M Costs	Total Present Worth	Total O&M Costs
Alternative 1 - No Action	$0	$53,900	$53,900	$150,000
Alternative 2 - Institutional Controls	$499,000	$222,700	$721,700	$437,380
Alternative 3 - Low Permeable Cap, Sediment Excavation and Onsite Disposal, Monitored Natural Recovery	$2,269,530	$384,010	$2,653,540	$802,630
Alternative 4 - Engineered Low Permeable Cap, Sediment Excavation and Onsite Disposal, Monitored Natural Recovery	$15,883,350	$401,270	$16,284,620	$844,350
7 percent discount rate				

Table 8-2
Alternative Cost Summary Table
OU5 - Skaggs Subsite
Madison County Mines Site FS Report

Alternative	Capital Cost	Present Worth of O&M Costs	Total Present Worth	Total O&M Costs
Alternative 1 - No Action	$0	$53,900	$53,900	$150,000
Alternative 2 - Institutional Controls	$811,700	$255,000	$1,066,700	$522,650
Alternative 3 - Permeable Cover, Excavation and Disposal, Monitored Natural Recovery	$2,389,470	$347,830	$2,737,300	$724,050
Alternative 4 - Low Permeable Cap, Excavation and Disposal, Monitored Natural Recovery	$2,984,950	$283,670	$3,268,620	$562,150
7 percent discount rate				

Figures



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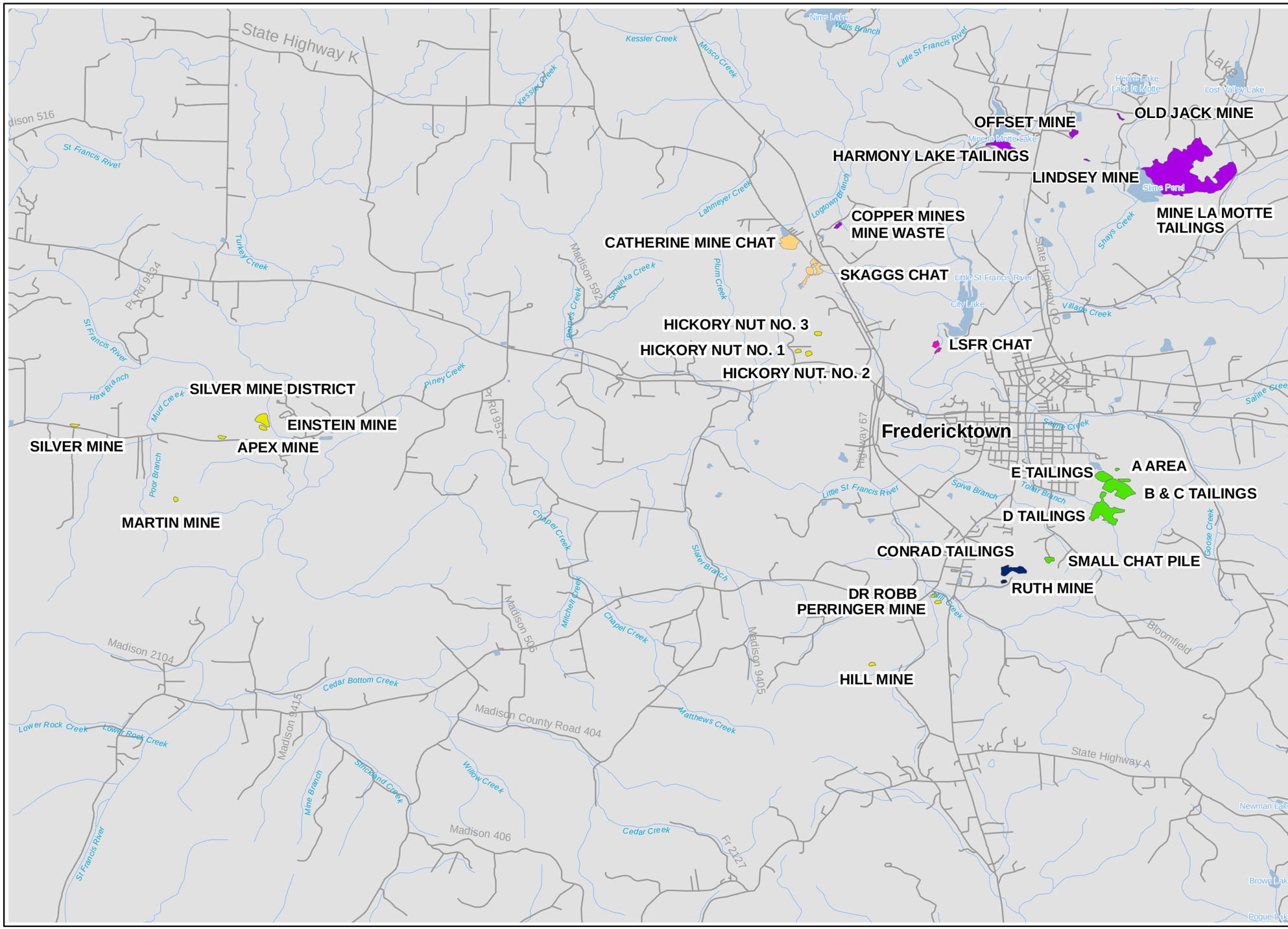
Special Projects Corp.

N

NOT TO SCALE

FIGURE 1-1:
LOCATION MAP

MADISON COUNTY MINES
FREDERICKTOWN, MISSOURI



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Legend

- Mine Waste OU1
- Mine Waste OU2
- Mine Waste OU3
- Mine Waste OU4
- Mine Waste OU5
- Mine Waste OU6
- streets
- streams
- lakes

LSFR - Little St. Francis River

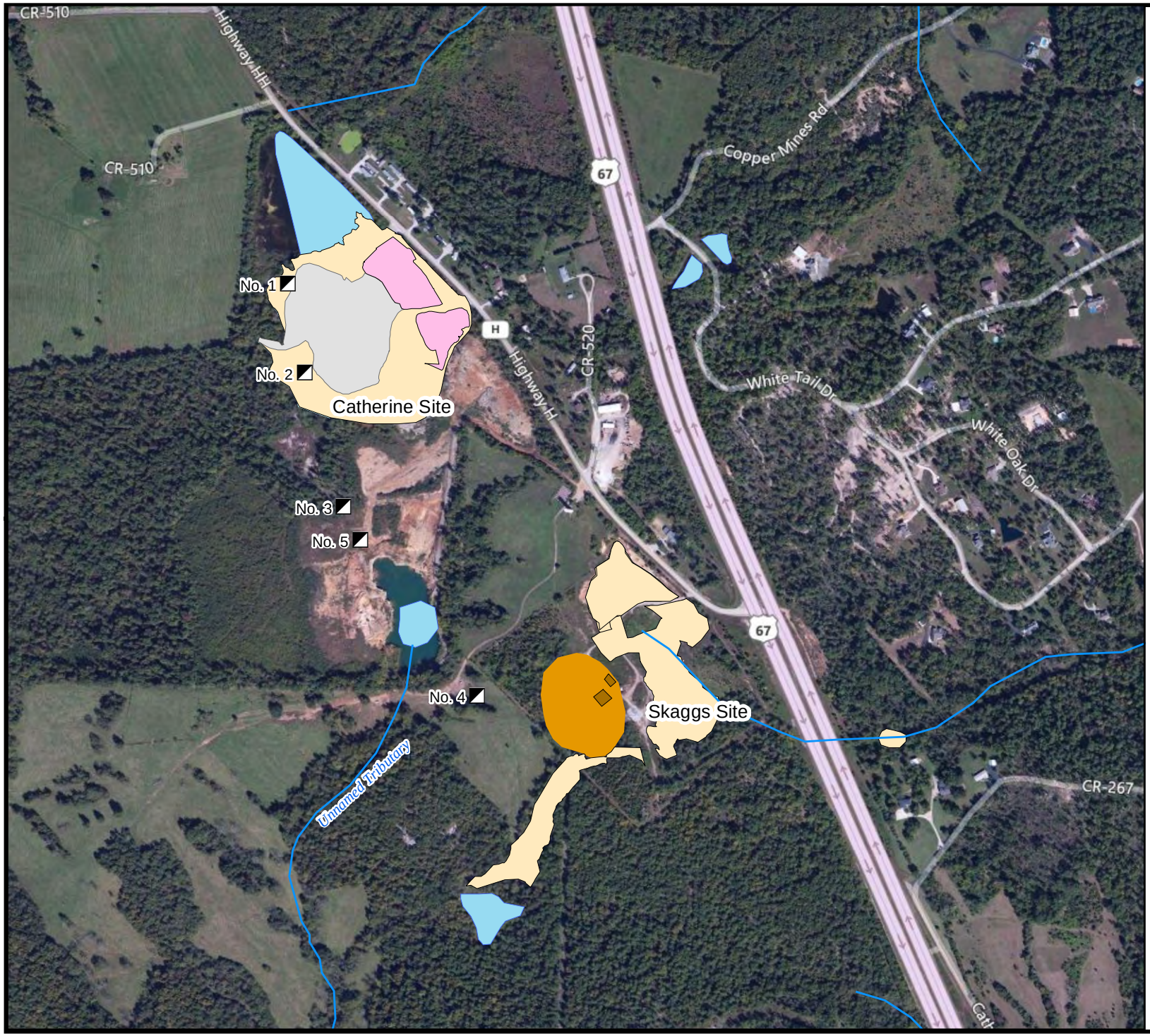
N

0 3,750 7,500 15,000

Feet

FIGURE 1-2:
SITE MAP

MADISON COUNTY MINES
FREDERICKTOWN, MISSOURI



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Legend

- Mine Shaft
- Street
- Stream
- Lake
- Approximate Boundary
- Chat
- Clean Soil Over Chat
- Sawdust
- Excavated Yard Soil Over Chat
- Shop Buildings

N

0 200 400 800
Feet

FIGURE 1-3:
FEATURES OF CATHERINE AND SKAGGS SITES

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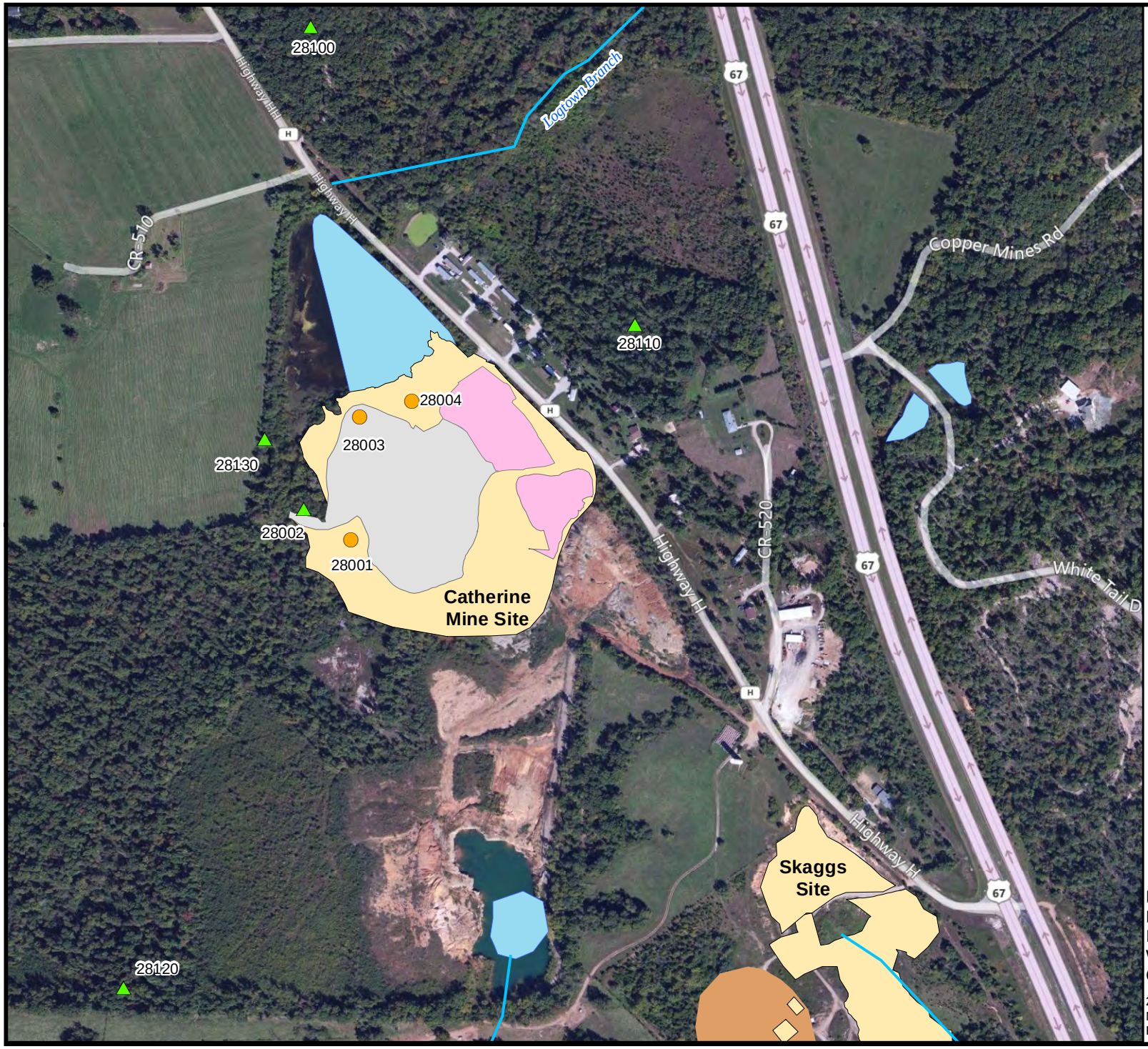
MADISON COUNTY MINES
FREDERICKTOWN, MISSOURI



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Special Projects Corp.

Legend

Lead Concentration in Soil

< 400 mg/kg

Lead Concentration in Mine/Mill Waste

800 - 4,000 mg/kg

Street/Road

Stream

Excavated Yard Soil Over Chat

Lake

Chat

Clean Soil Over Chat

N

0 125 250 375 500
Feet

FIGURE 1-4:
LEAD CONCENTRATIONS IN SOIL AND MINING WASTE AT THE CATHERINE SITE

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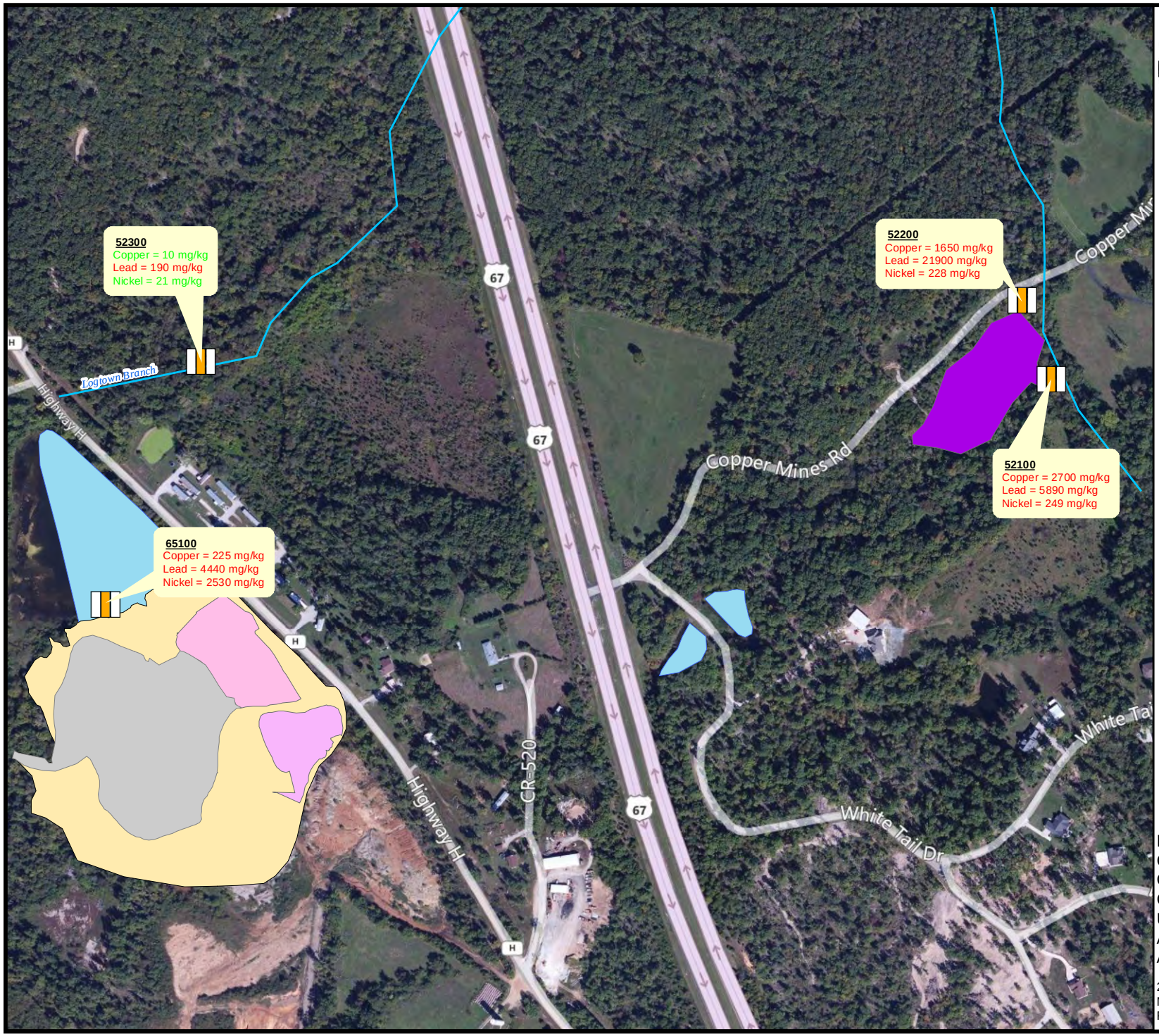
FREDERICKTOWN, MISSOURI



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Special Projects Corp.

Legend

Sediment

Floodplain Soil

Surface Water

Mine Waste OU1

Chat

Clean Soil Over Chat

Excavated Yard Soil Over Chat

Street

Stream

Lake

Does not exceed Screening Criteria

Exceeds Screening Criteria

N

0 62.5 125 250 375 500
Feet

FIGURE 1-5: CONCENTRATIONS OF SELECTED CONSTITUENTS IN UNSIEVED SEDIMENTS AT CATHERINE MINE AREA

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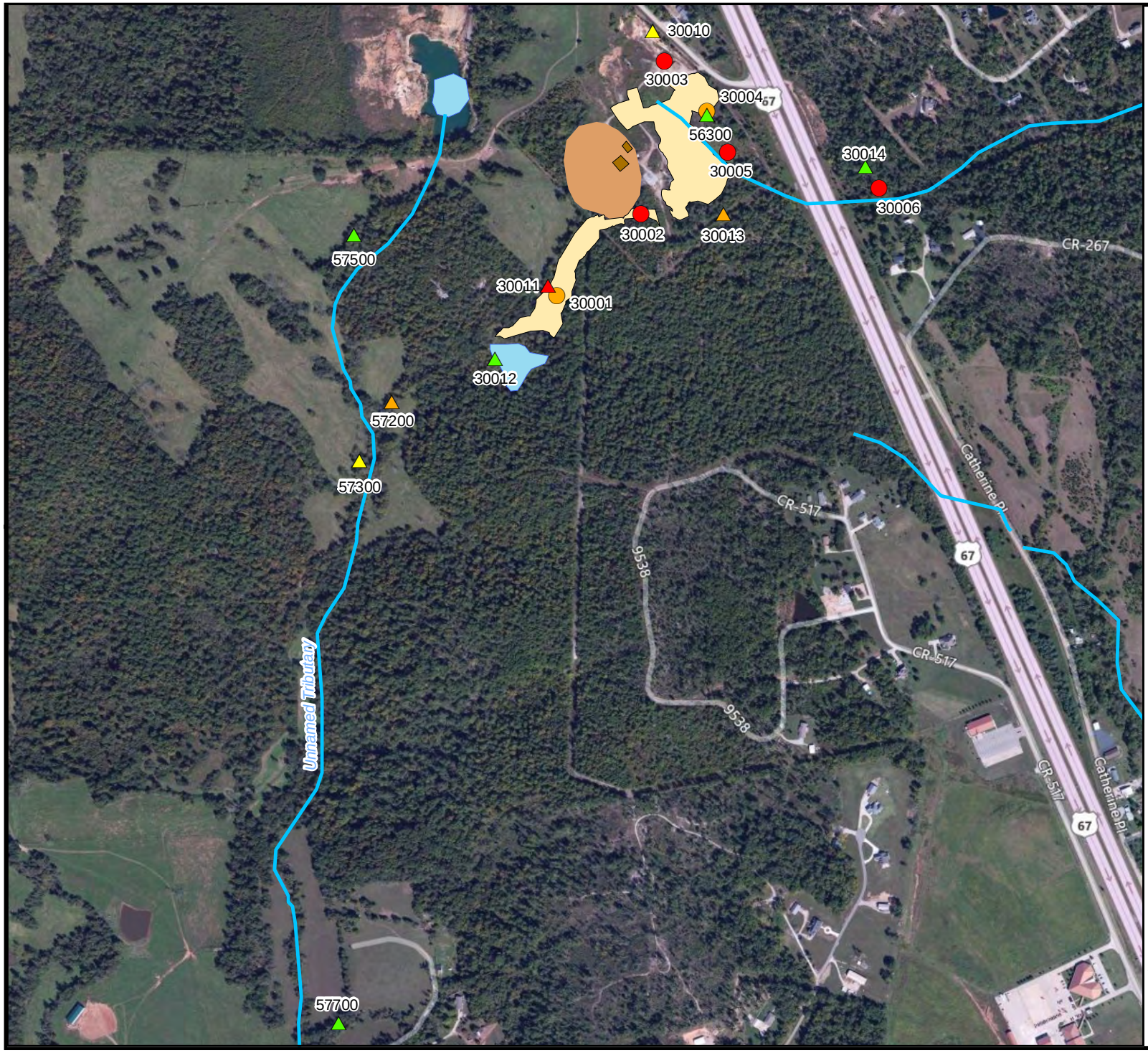

BLACK & VEATCH
Special Projects Corp.

Legend

Lead Concentration in Soil
- < 400 mg/kg
- 400 - 799 mg/kg
- 800 - 4,000 mg/kg
- > 4,000 mg/kg

Lead Concentration in Mine/Mill Waste
- 800 - 4,000 mg/kg
- > 4,000 mg/kg

- Street/Road
- Stream
- Lake/Pond
- Chat
- Sawdust
- Shop Buildings

N

0 250 500 750 1,000
Feet

FIGURE 1-6:
LEAD CONCENTRATIONS IN SOIL AND MINING WASTE AT SKAGGS SITE

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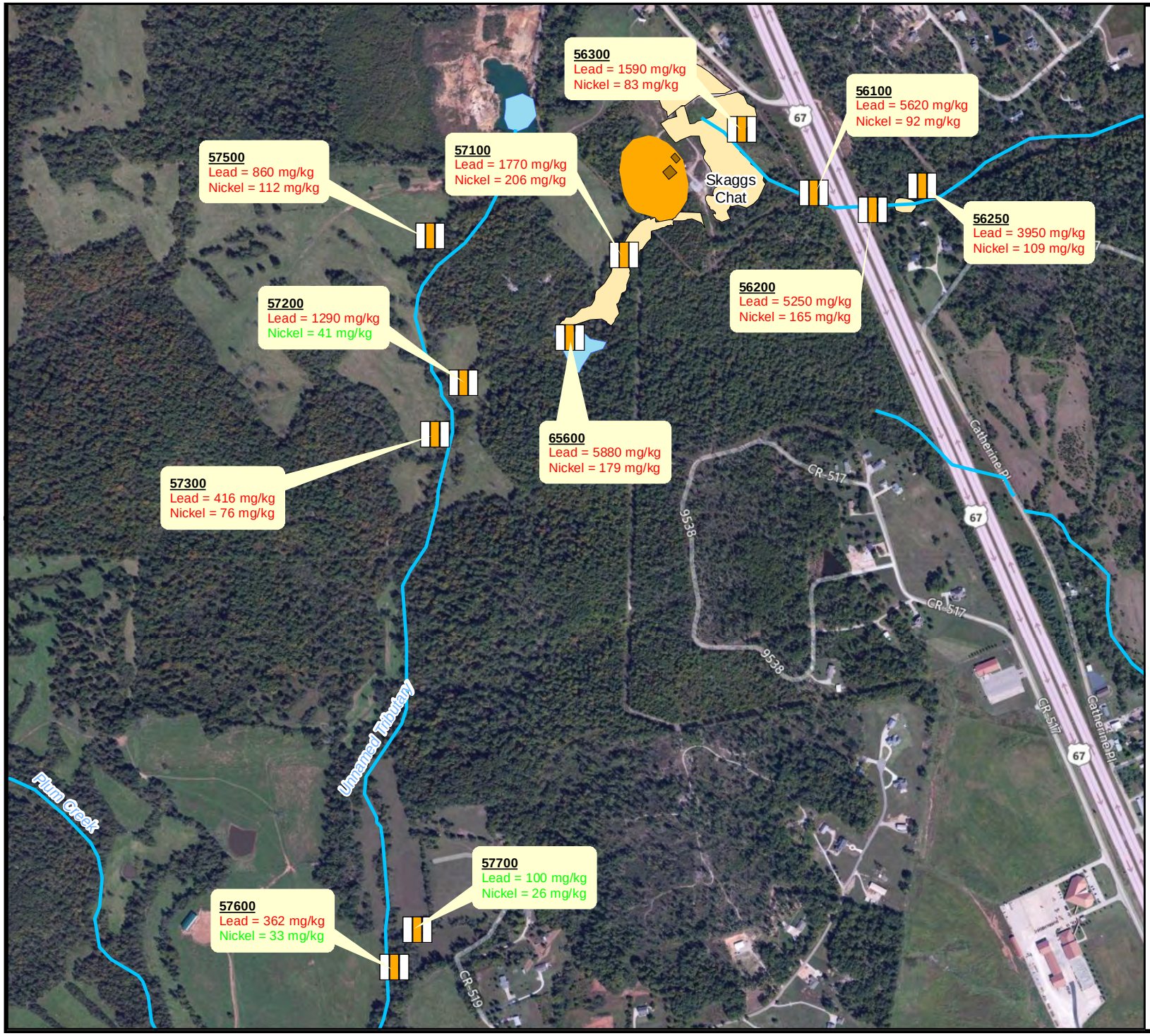
MADISON COUNTY MINES
FREDERICKTOWN, MISSOURI



BLACK & VEATCH
Special Projects Corp.

Legend

Sediment

Floodplain Soil

Surface Water

- Sawdust
- Chat
- Shop Buildings
- Street
- Stream
- Lake

Does not exceed Screening Criteria

Exceeds Screening Criteria

N

0 255 510 1,020
Feet

FIGURE 1-7: CONCENTRATIONS OF SELECTED CONSTITUENTS IN SEDIMENTS - SKAGGS AREA

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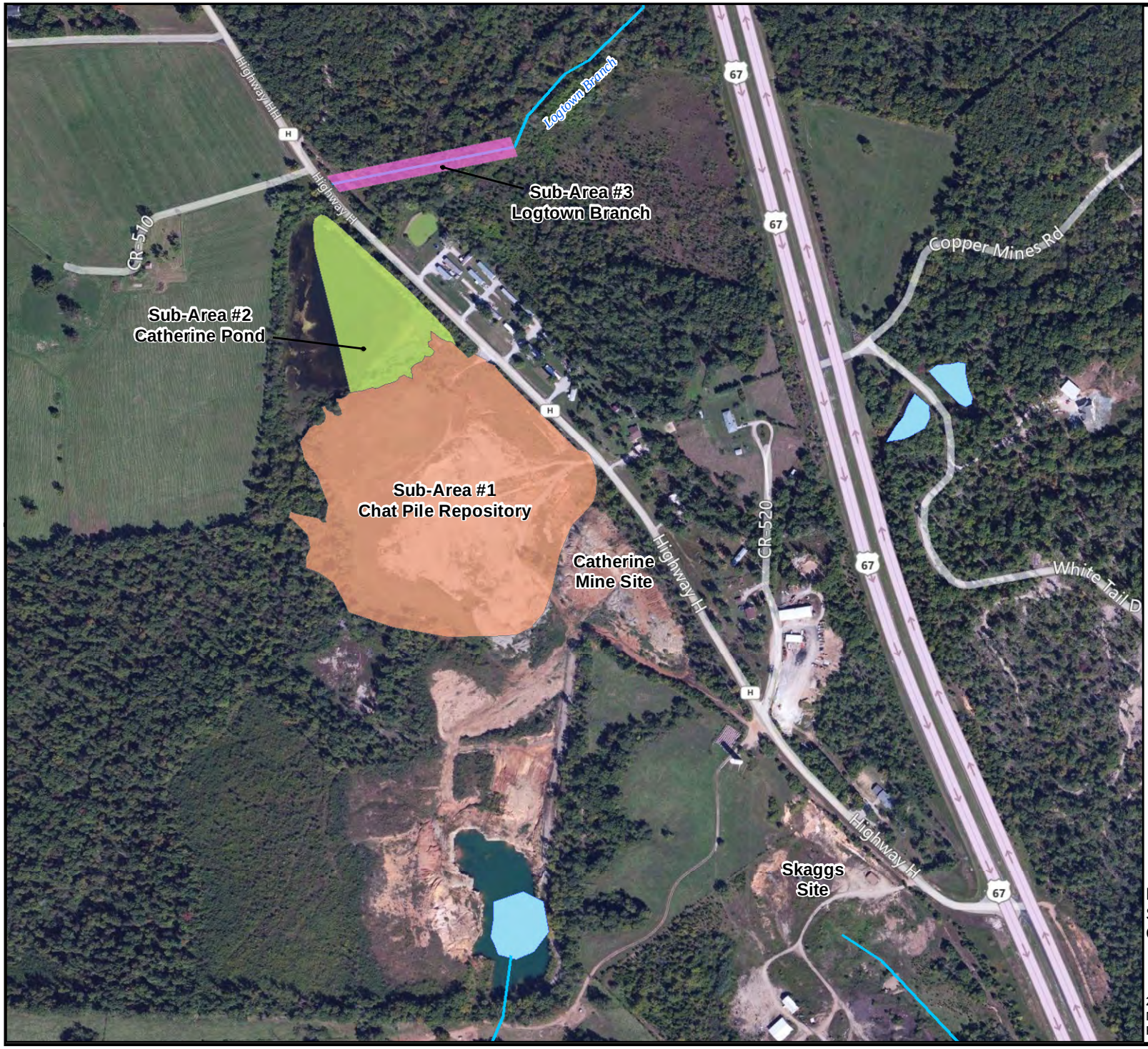
MADISON COUNTY MINES
FREDERICKTOWN, MISSOURI



BLACK & VEATCH
Special Projects Corp.

Legend

Stream

Lake/Pond

N

0 150 300 600
Feet

FIGURE 6-1:
SUB-AREAS AT THE
CATHERINE SUBSITE

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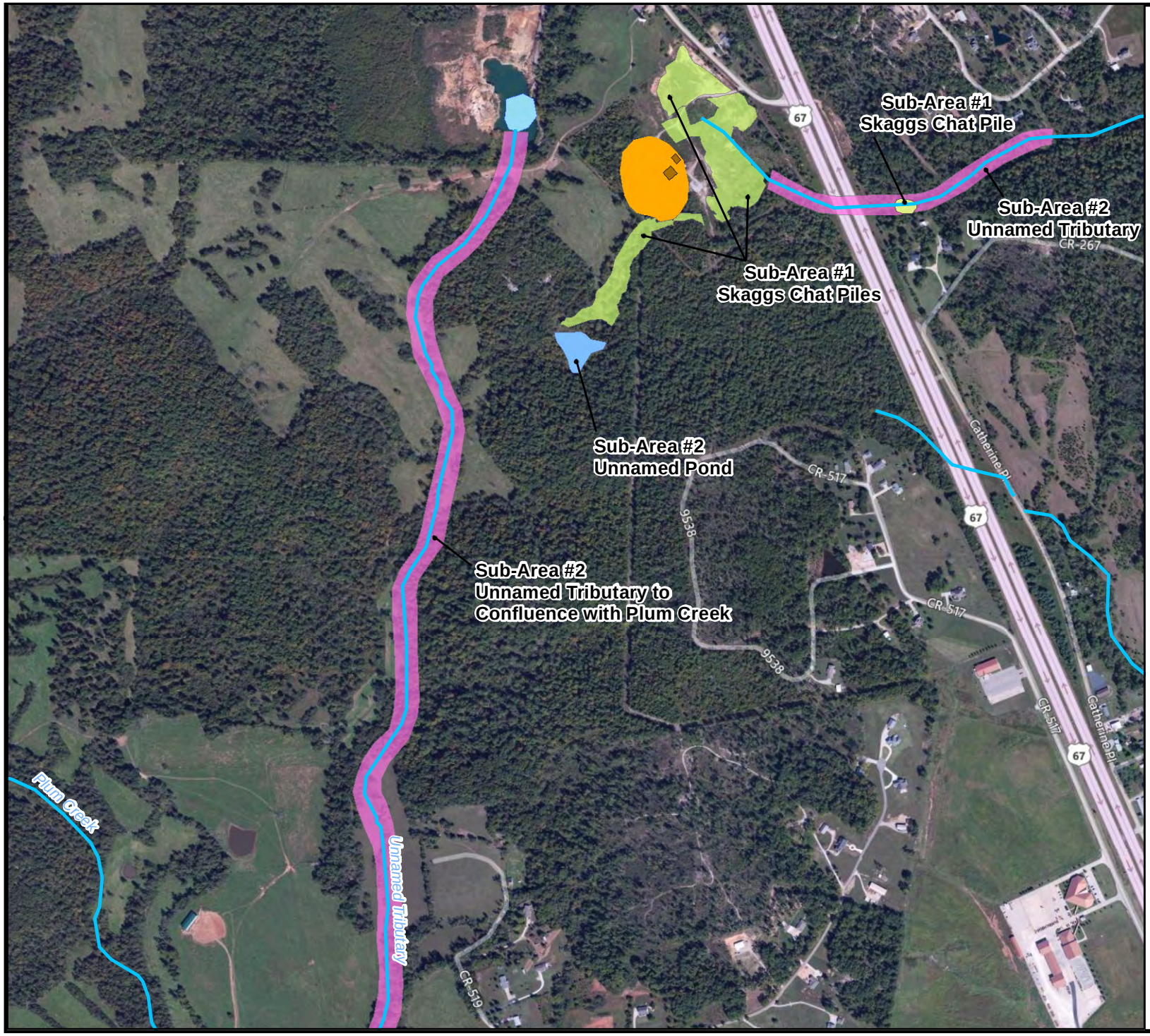

BLACK & VEATCH
Special Projects Corp.

Legend

Sediment

Floodplain Soil

Surface Water

- Sawdust
- Shop Buildings
- Street
- Stream
- Lake

Does not exceed Screening Criteria

Exceeds Screening Criteria

N

0 250 500 1,000
Feet

FIGURE 6-2:
SUB-AREAS AT THE
SKAGGS SUBSITE

2008 RI Report
MADISON COUNTY MINES
FREDERICKTOWN, MISSOURI

Appendix A
Risk Based Preliminary Remediation Goals

APPENDIX A

DRAFT MEMORANDUM

DATE: May 12, 2011

SUBJECT: Preliminary Remediation Goals (PRGs)
Madison County Mines Site
Operable Units 1, 2, 3, 5, 6
Madison County, Missouri

FROM: Black & Veatch Special Projects Corp. (BVSPC)

TO: Mr. Dan Kellerman
Remedial Project Manager
Special Emphasis and Remediation Branch
USEPA Region 7

At EPA's request, BVSPC developed PRGs for the Madison County Mines Site, located in Madison County, Missouri. Soil, surface water, sediment, and groundwater PRGs were developed to address contamination resulting from past mining activities at the Madison County Mines Site Operable Units 1, 2, 3, 5, and 6. The PRGs were developed for chemicals of concern (COCs) contributing to unacceptable current and/or potential future health risks (e.g. Hazard Index (HI) > 1). Consideration must be given to the protection of both human health and ecological receptors, as evaluated in either the July 2007 Baseline Human Health Risk Assessment (BRA) for the Madison County Mines Site (Syracuse Research Corporation, 2007); the 2011 Supplemental Human Health Risk Assessment for the Madison County Mines Site (BVSPC, 2011); the May 2006 Ecological Risk Assessment for the Madison County Mine Site (EPA, 2006); and the 2011 Supplemental Ecological Risk Assessment for the Madison County Mines Site (BVSPC, 2011). The media specific PRGs account for the exposure scenarios that contributed to the greatest human health or ecological risk in each defined exposure unit. PRGs developed herein are consistent with the PRGs developed for the Madison County Operable Unit (OU) 4 to the maximum extent possible. The residential PRGs for lead presented in this memorandum are consistent with the residential PRGs developed for OU4. Please note that the values presented in this document are considered preliminary remediation goals, which are subject to change and are not final remediation levels.

Preliminary Remediation Goals
For Madison County Mines Site
Operable Units 1, 2, 3, 5, and 6
Madison County, Missouri

1.0 Site Location and Description

The Madison County Mines Site, Comprehensive Environmental Response, Compensation, and Liability Information System (CERCLIS) identification number MOD098633415, is located near Fredericktown in southeastern Missouri. The Site is located at the southern end of the Old Lead Belt where heavy metal mining has occurred since the early 1700s. The Site is located about 80 miles south of St. Louis, Missouri, on the southeastern edge of the Ozark Uplift. Past mining operations have left at least 13 identified major mine waste areas, in the form of tailings and chat deposits, from smelting and mineral processing operations in Madison County. The Madison County Mines Site was placed on the National Priorities List (NPL) on September 29, 2003.

The Madison County Mines Site is defined by six operable units. OU1 is located in northern Madison County and consists of the Mine La Motte Recreation Association (MLMRA) subsite that contains approximately 250 acres of tailings; the Slime Pond, a 100-acre lake that adjoins the MLMRA; the Harmony Lake area, the Copper Mines mine waste; the Old Jack Mine; the Lindsey Mine; the small gage feeder rail right-of-way to the abandoned Black Mountain spur; and all other areas affected by these mining activities. OU2 consists of the area adjoining and just southeast of the City of Fredericktown, Missouri, and includes the A B, C, D, and E Tailings Areas (historically called the Madison Mine); the metallurgical pond; remnants of an old mill and smelter; headframe and abandoned shafts; a mine decline; a refinery complex; a chat pile; the abandoned Black Mountain spur right-of-way through Fredericktown; and all other areas affected by these mining activities.

In 2006, EPA re-designated the former OU3 ((Ruth and Park City (Conrad Site)), OU4 (Catherine Site), OU5 (Skaggs Site), and OU6 (LSFR Site) as follows:

- OU3 – includes all residential properties including public areas in Madison County as well as the entire cities of Fredericktown, Junction City, and Cobalt Village, and the LSFR subsite. Within and around the cities and the LSFR areas, OU3 also includes all streets, road right-of-

ways, public drainage ways, possible smelter stack and mine waste pile wind-blown contamination, groundwater, surface water and sediments in Goose Creek and Tollar Branch, and mine works locations and outflows.

- OU4 – includes the entire Conrad subsite with its mine waste as well as the adjoining Ruth mine and mill complex; surface water and sediments affected by the mine waste; eroded materials to the LSFR from the Conrad subsite, road right-of-ways and public drainage ways; possible smelter stack and mine waste pile wind-blown contamination; groundwater impacts; and mine works locations and outflows.
- OU5 – includes the Catherine Mine with its mine waste, pond, and repository; the Skaggs mine waste; and any areas affected by the overhead tram from the Catherine Mine to the LSFR subsite. OU5 also includes surface water, sediments, road right-of-ways, public drainage ways, and groundwater affected by the Catherine or Skaggs mine waste as well as nearby mine works locations and outflows.
- OU6 – includes all other known and undiscovered mining-related contaminated areas including, but not limited to, the Silver Mines area, the Hickory Nut Mine, nearby groundwater, surface waters and sediments in the unnamed runoffs to the LSFR, road right-of-ways, public drainage ways, and mine works locations and outflows.

2.0 Baseline Human Health Risk Assessment and Selection of Chemicals of Concern (COCs)

A Baseline Human Health Risk Assessment (BHHRA) for the Madison County Mines Site was completed in July 2007. In addition, a supplemental BRA was completed in April 2011. These two documents have identified several chemicals of concern (COCs) that contribute to health risks that exceed EPA levels of concern (cancer risks greater than 1E-04; non-cancer hazard index (HI) greater than 1; and in the case of lead, a P10 value (probability that blood lead levels exceed 10 ug/dL) greater than 5 percent. Table 1 lists the human health COCs for soil, sediment, groundwater, surface water and fish. Table 1 also includes the exposure scenarios contributing to unacceptable risks under the reasonable maximum exposure (RME) scenario. In regards to non-cancer health hazards, only COCs contributing to target organ-specific HIs greater than one were retained for PRG development.

3.0 Exposure Assessment

3.1 Exposure Pathways

Consistent with the 2007 BHHRA and 2011 supplemental human health risk assessment, the media-specific PRGs account for the receptor with the greatest exposure under the current and future land-use scenarios. The PRGs for cancer and non-cancer effects are based on reasonable maximum exposure (RME) scenarios, while the PRGs for lead are based on central tendency exposure (CTE) scenarios. The human receptors and exposure pathways accounted for in the media-specific PRGs are listed in Table 2 and are consistent with the 2007 BHHRA and 2011 supplemental human health risk assessment. The PRGs account for the complete exposure pathways that are also presented in Table 2.

3.2 Exposure Factors

Table 3 provides the exposure factors used to derive the PRGs for protection of human health. The exposure factors used to derive the PRGs are consistent with the exposure factors used in the 2007 BHHRA and 2011 supplemental human health risk assessment. Consistent with EPA lead risk assessment guidance, the exposure factors used to calculate PRGs for lead are based on assumptions for the CTE, whereas exposure factors for cancer and non-cancer COCs are generally based on assumptions for the RME.

4.0 Toxicity Assessment

The toxicity values used to derive the PRGs were obtained according to the hierarchy recommended by USEPA's Office of Solid Waste and Emergency Response (OSWER) Directive 9285.7-53. Table 4 provides the cancer and non-cancer toxicity values for each COC. The information presented includes the weight-of-evidence classification for carcinogenicity and target organs for non-cancer health effects. It should be noted that some of the toxicity values for several COCs have been updated since the 2007 BHHRA (i.e., arsenic, cobalt, manganese and vanadium).

5.0 Calculation of PRGs for Protection of Human Health

5.1 Non-Lead COCs

With the exception of lead, PRGs were calculated for tailings, soil, groundwater, surface water, sediment and fish tissue using formulas from the 2007 BHHRA and 2011 supplemental human health risk assessment reports. The equations used to characterize exposure and risk to carcinogenic and non-carcinogenic COCs were set to equal target hazard quotients and target cancer risks and were solved for the media-specific PRG concentrations.

For Non-carcinogens:

$$PRG_{i\text{-}nc} = (EPC_i / HQ_i) * THQ$$

Where:

$PRG_{i\text{-}nc}$ = non-cancer PRG for COC i
EPC_i = exposure point concentration for COC i used to characterize non-cancer hazard in the BHHRA
HQ_i = Hazard Quotient for COC i presented in the BHHRA
THQ = Target Hazard Quotient

For Carcinogens:

$$PRG_{i\text{-}c} = (EPC_i / CR_i) * TR$$

Where:

$PRG_{i\text{-}c}$ = cancer PRG for COC i
EPC_i = exposure point concentration for COC i used to characterize cancer risk in BHHRA
CR_i = Cancer Risk for COC i presented in the BHHRA
TR = Target Risk

5.2 Lead PRGs

Lead PRGs are derived using the Integrated Exposure Uptake and Biokinetic (IEUBK) Model for exposures to children between the ages of 0 and 84 months. For exposures not involving children that are less than 84 months of age, the Adult Lead Methodology (ALM) is used to derive PRGs. The ALM is directly applicable to women exposed to lead contaminated soils but may also be applied to other media. Both models are used to predict the distribution of blood lead (PbB) values in an exposed population and the probability that an individual will have a blood lead level that exceeds the level of

health concern (10 ug/dL). This probability is referred to as the P10 value. EPA has established a health-based goal that there should be no more than a 5 percent probability that a child (or fetus *in utero*) will have a blood lead level higher than 10 ug/dL.

5.2.1 Residential PRG for Lead

The residential PRG for lead was calculated using the IEUBK Model for exposures to children. Soil PRGs for lead were previously calculated (EPA, 2008c) for the residential land use scenario at Operable Unit 4 of the Madison County Mines Site (the Conrad Subsite). For consistency, the value calculated for OU4 was adopted for OUs 1, 2, 3, 5, and 6.

5.2.2 Commercial Worker PRG for Lead

The commercial worker PRG for lead was calculated using the ALM. Soil PRGs for lead were not previously calculated for the commercial worker scenario at OU4. For the commercial worker, exposure to lead was assumed to occur through ingestion of soil. The exposure factors that were used to back calculate the PRG are consistent with the exposure factors that were used to characterize risks associated with lead exposure in the 2007 BHHRA and 2011 supplemental human health risk assessment.

5.2.3 ATV Rider PRG for Lead

The ATV Rider PRG for lead was calculated using the ALM. The exposure factors that were used to back calculate the PRG are consistent with the factors used in the 2007 BHHRA and 2011 supplemental human health risk assessment. Soil PRGs for lead were previously calculated (EPA, 2008c) for the ATV rider land use scenario at OU4 of the Madison County Mines Site (the Conrad Subsite). For consistency, the value calculated for OU4 was adopted for OUs 1, 2, 3, 5, and 6.

5.2.4 Recreational Visitor PRG for Lead

The recreational visitor PRGs for lead were calculated using both the IEUBK Model and the ALM. The IEUBK model was used to calculate PRGs for the child recreational visitor and the ALM was used to calculate PRGs for the adult recreational visitor. Sediment/soil PRGs for lead were previously calculated (EPA, 2008c) for the child recreational visitor land use scenario at OU4 of the Madison County Mines Site (the

Conrad Subsite), however, these values were not used for OUs 1, 2, 3, 5, and 6 because the values for OU4 were based on some assumptions such as surface water concentration that were specific to OU4. The exposure factors that were used to back calculate the PRG are consistent with the factors used in the 2007 BHHRA and 2011 supplemental human health risk assessment.

The sediment and soil PRGs for lead account for most of the risk to the child recreational visitor. Although exposure to surface water contributed to a P10 value that was greater than 5%, the overall exposure to surface water is negligible compared to the overall impact the exposure to sediment and soils had on the total P10 value. Therefore, a surface water PRG for lead is not calculated. However, the intake of lead via surface water is accounted for when deriving the sediment and soil PRGs. Furthermore, while the total ingestion rate for sediment and soil were evenly divided in the risk assessment, the exact fraction of the total daily intake for soils and sediments is uncertain. In order to be health protective, the PRGs assume that up to 100% of the daily intake may be from sediment. For the purposes of deriving the PRGs, the daily intake rate for sediment and soil were combined.

Since the child recreational visitor scenario includes children below the age of 84 months, the IEUBK Model is used to derive the PRG. Through a process of successive approximations, various lead intake values were inserted into the alternate source intake input module, which accounts for exposures to lead in sediment, soil, surface water and fish, to achieve a P10 of 5%. Note that the alternate source intake is in addition to the lead intake from other sources including the diet, water, air, soil, and indoor dust. However, since the absolute bioavailability of lead in sediments/flood plain soil (35%) differ from that of surface water (50%), an absorbed dose rather than intake value was used in the model assuming 100% bioavailability. The absolute bioavailability (ABA) values were instead taken into account outside of the model when estimating the PRG.

Upon running the model, an alternate source absorbed dose value of 7.5 µg/day resulted in a P10 of 5% (see Attachment 1). Using that lead intake value, sediment and soil PRGs for lead can be estimated assuming a constant surface water and fish concentration (i.e., exposure point concentrations used in the risk assessment). All other lead intakes (e.g., diet) in the IEUBK also remained constant and are consistent with current lead risk assessment guidance and site-specific values used in the 2007 and 2011 BHHRA (for additional information see Attachment 1). The following equation was used to estimate the PRGs for sediment and soil.

$$PbI(\frac{\mu g}{day}) = \left(PRG_{sed/soil} \times IR_{sed/soil} \times \frac{EF_{crec}}{AT_{crec}} \times ABA_s \right) + \left(C_w \times IR_w \times \frac{EF_{crec}}{AT_{crec}} \times ABA_w \right) + \left(C_f \times IR_f \times ABA_f \right)$$

Solving for $PRG_{sed/soil}$ results in the following PRG equation

$$PRG_{sed/fsoil} = \frac{\left(7.5\frac{\mu g}{day} - \left(C_w \times IR_w \times \frac{EF_{crec}}{AT_{crec}} \times ABA_w\right) - \left(C_f \times IR_f \times ABA_f\right)\right)}{\left(IR_{sed/fsoil} \times \frac{EF_{crec}}{AT_{crec}} \times ABA_s\right)}$$

5.3 Human Health PRGs

The target risk level used in calculating the non-lead PRGs equate to excess individual lifetime cancer risks of 1E-04 or a non-cancer hazard index (HI) of 1. When COCs have the same target organ(s), then their target hazard index is set equal to 1 divided by the number of COCs with the same target organ. In regards to the PRGs, for residential soils, copper and iron in soil share the same target organ (GI tract). Therefore, the non-cancer PRGs for these two constituents were developed by setting the target HI equal to 0.5. As discussed previously, the target P10 value for lead is 5 percent. For groundwater, the available primary MCL values were used as the recommended PRGs. Tables 5 through 14 present the calculated PRGs for the identified COCs for each media. A summary of the recommended PRGs for protection of human health is presented in Table 15.

6.0 Baseline Ecological Risk Assessment and Selection of Chemicals of Concern (COCs)

An Ecological Risk Assessment (ERA) for the Madison County Mines Site was completed in May 2006. In addition, a supplemental ERA was completed in April 2011. These two documents have identified several chemicals of concern (COCs) that contribute to ecological risks at the Madison County Mines Site. Table 16 lists the ecological COCs for tailings/soil, surface water and sediment. Table 16 also provides the ecological assessment endpoints that are a concern for each COC.

7.0 Ecological Exposure Assessment

Consistent with the 2006 and 2011 ERAs, the media-specific PRGs account for the receptor with the greatest exposure to the COCs. The PRGs for ecological receptors are based on reasonable maximum exposure (RME) scenarios. The receptors and exposure pathways accounted for in the media-specific PRGs are presented in Table 17

and are consistent with the 2006 and 2011 ERAs. The PRGs account for the assessment endpoints that are also presented in Table 17. The assessment endpoints for the ecological receptors at the Madison County Mine Site include:

- AE 1 – Protection and Maintenance of Proper Nutrient Cycling and Function of Soils in Terrestrial Habitats
- AE 2 – Protection of Terrestrial Herbivores
- AE 3 – Protection of Terrestrial Vermivores
- AE 4 – Protection of Terrestrial Carnivores
- AE 5 – Protection of Aquatic Life Communities in Surface Water
- AE 6 – Protection of Aquatic Life Communities in Sediment

8.0 Calculation of PRGs for Protection of Ecological Receptors

8.1 Calculation of PRGs for Tailings/Soil

The ecological PRGs for tailings/soil at the Madison County Mines Site were developed by applying the appropriate ecotoxicity criteria and the site-specific exposure assumptions to generate concentrations of the COCs that were protective for each assessment endpoint for terrestrial receptors (AEs 1, 2, 3, and 4). Target PRGs were developed for each COC and for each assessment endpoint. A range of PRGs were developed for each COC and each AE using no observed adverse effect level (NOAEL) and lowest observed adverse effect level (LOAEL) based toxicity reference values (TRVs). The target risk level used in calculating the ecological PRGs equate to a hazard quotient (HQ) of 1 for each COC. The selected PRG for each COC was the lowest of the PRGs developed for the assessment endpoints. For purposes of consistency, the ecological PRG for lead, that was previously developed for the Conrad subsite of the Madison County Mines Site (EPA, 2008d), was adopted for OUs 1, 2, 3, 5, and 6.

PRGs for AE1 were the NOAEL and LOAEL based criteria for protection of terrestrial plants and soil invertebrates. PRGs for AEs 2, 3, and 4, were developed separately for both mammals and birds. PRGs for AEs 2 and 3 were developed using available site-specific adjustments for uptake of the COCs in plant and earthworm tissues If the lowest of the available PRGs was lower than background, then the mean background concentration was selected as the target PRG for that COC. For this evaluation, the mean background concentrations measured in the eight counties adjacent

to Madison County (Bollinger, Iron, Jefferson, Perry, St. Francois, St. Genevieve, Washington, and Wayne), reported by the USGS Pluto Database for Soil (USGS, 2011) were selected for this comparison.

Table 18 presents the ecological PRGs for the COCs in tailings and soil.

8.2 Calculation of PRGs for Surface Water

The PRGs for surface water were developed by using the available acute and chronic water quality criteria for the protection of aquatic life from the National Ambient Water Quality Criteria and Missouri Water Quality Standards. The chronic water quality criterion was selected as the NOAEL surface water PRG value and the acute water quality criterion was selected as the LOAEL value. Values for copper, lead, nickel, and silver were calculated based on the average water hardness data available for the Little St. Francis River watershed (231 mg/L CaCO3). Values were calculated separately for dissolved and total metal concentrations when the necessary conversion factors were available. Values for aluminum and cobalt are not hardness dependent and were also obtained from the National Water Quality Criteria and Missouri Water Quality Standards.

The equations, assumptions, and conversion factors used to calculate surface water PRGs for copper, lead, nickel and silver are presented in Table 19. Table 20 presents the ecological PRGs for the COCs in surface water.

8.3 Calculation of PRGs for Sediment

The PRGs for sediment were developed by using the available consensus based sediment quality guidelines (McDonald et al, 2000). The threshold effect concentration (TEC) was selected as the NOAEL PRG value and the probable effect concentration (PEC) was selected as the LOAEL PRG value.

Consensus based sediment quality criteria were not available for all COCs in sediments at the Madison County Mines site. Consequently, PRGs were also obtained from the available literature. PRGs for sediment include the EPA Region 3 benchmarks for sediment and the National Oceanic and Atmospheric Administration (NOAA) sediment guidelines for protection of freshwater sediment. NOAAs freshwater sediment values included four categories: (1) lowest threshold effects level (TEL) based on *Hyalella azteca*; (2) TELs based on other biota; (3) probable effects levels (PELs); and (4) upper effect threshold levels (UETs). Some NOAA sediment guidelines were used as PRGs when available and appropriate. Table 21 presents the ecological PRGs for the COCs in sediment.

8.4 Ecological PRGs

A summary of the recommended ecological PRGs is presented in Table 22.

9.0 Uncertainties

Many of the uncertainties discussed in the 2006 ERA, 2007 BRA and 2011 supplemental risk assessment apply to the PRGs, including, but not limited to, human and ecological exposure parameters, chemical absorption, and risk estimates. For additional discussion please see Section 6.0 of the 2007 BRA and sections 6.1.6 and 6.2.6 of the 2011 Supplemental RI as well as the brief discussion below on uncertainties with the use of the IEUBK for evaluating "short-term" exposures.

There is uncertainty with the use of the IEUBK model for evaluating a "short-term" exposure. The IEUBK model is designed to project PbB concentrations from sustained daily exposure over the first 84 months of childhood. Based on this assumption, it does not allow for a wash-out period between short-term exposures, such as the child recreational visitor scenario where the child is exposed to sediments, surface water, and floodplain soil for a period of 4 months (May – September) rather than the whole year. Although pseudo-steady-state PbB concentrations can be met during short-term exposures of greater than 90 days in duration, the IEUBK may overestimate blood lead predictions for the child recreational visitor.

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Table 1. Media-Specific COCs Identified in 2007 and 2011 Human Health Risk Assessments

Environmental Media	COCs	Exposure Scenarios
Mine Waste Tailings	Arsenic	Adolescent/Adult ATV Rider
	Cobalt	Adolescent/Adult ATV Rider
	Lead	Adolescent/Adult ATV Rider
	Manganese	Adolescent/Adult ATV Rider
	Nickel	Adolescent/Adult ATV Rider
Soil	Antimony	Child Resident
	Arsenic	Adult/Child Resident
	Cobalt	Adult/Child Resident, Commercial Worker, Adult/Child Recreational Visitor
	Copper	Child Resident
	Iron	Child Resident
	Lead	Child Resident, Commercial Worker, Adult/Child Recreational Visitor
	Manganese	Child Resident, Child Recreational
	Nickel	Child Resident
	Thallium	Child Resident, Child Recreational
Groundwater	Arsenic	Adult/Child Resident
	Cobalt	Adult/Child Resident
	Lead	Child Resident and Commercial Worker
	Manganese	Child Resident
Surface Water	Antimony	Child Recreational Visitor
	Cobalt	Adult/Child Recreational Visitor
	Manganese	Child Recreational Visitor
	Vanadium	Child Recreational Visitor
Sediment	Cobalt	Adult/Child Recreational Visitor
	Lead	Adult/Child Recreational Visitor
	Manganese	Child Recreational Visitor
Fish	Arsenic	Adult/Child Recreational Visitor

Table 2. PRGs' Receptors and Exposure Pathways for Human Health Risk Assessments

Environmental Media	Receptor	Exposure Pathways
Mine Waste Tailings	ATV Rider	Incidental Ingestion of Tailings Dermal Contact with Tailings Inhalation of Tailings-derived Dust
Soil	Residential Commercial Worker Recreational Visitor	Incidental Ingestion of Soil Dermal Contact with Soil
Groundwater	Residential Commercial Worker	Hypothetical Incidential Ingestion of Shallow Groundwater
Surface Water	Recreational Visitor	Incidental Ingestion of Surface Water Dermal Contact with Surface Water
Sediment	Recreational Visitor	Incidental Ingestion of Sediment Dermal Contact with Sediment
Fish	Recreational Visitor	Ingestion of Fish

Table 3. Exposure Factors Used in the Human Health Risk Assessment

Exposure Factor	Definition	Value	Source
THQ	Target Hazard Quotient	1	2007 and 2011 BHHRA
TR	Target Risk	1E-06 to 1E-04	2007 and 2011 BHHRA
BW_a	Body Weight - Adult	70 kg	2007 and 2011 BHHRA
BW_c	Body Weight - Child	15 kg	2007 and 2011 BHHRA
BW_{atv}	Body Weight - ATV Rider	43 kg	2007 and 2011 BHHRA
BW_{crec}	Body Weight - child recreational visitor	28 kg	2007 and 2011 BHHRA
AT_c	Carcinogenic Averaging Time	25550 days	2007 and 2011 BHHRA
AT_{nca}	Non-cancer Averaging Time-adult	8760 days	2007 and 2011 BHHRA
AT_{ncc}	Non-cancer Averaging Time-child	2190 days	2007 and 2011 BHHRA
AT_{nccw}	Non-cancer Averaging Time-Commercial Worker	1825 days	2007 and 2011 BHHRA
AT_{ncatv}	Non-cancer Averative Time-ATV	3650 days	2007 and 2011 BHHRA
AT_{ncarec}	Non-cancer Averaging Time-adult recreational visitor	10950 days	2007 and 2011 BHHRA
AT_{nccrec}	Non-cancer Averaging Time-child recreational visitor	2555 days	2007 and 2011 BHHRA
EF_r	Exposure Frequency - resident	350 days/yr	2007 and 2011 BHHRA
EF_{cw}	Exposure Frequency - Commercial Worker	250 days/yr	2007 and 2011 BHHRA
EF_{atv}	Exposure Frequency - ATV	68 days/yr	2007 and 2011 BHHRA
EF_{rec}	Exposure Frequency - recreational visitor	96 days/yr	2007 and 2011 BHHRA
EF_{fish}	Exposure Frequency - Fish Ing	350 days/yr	2007 and 2011 BHHRA
ED_a	Exposure Duration - adult	24 years	2007 and 2011 BHHRA
ED_c	Exposure Duration - child	6 years	2007 and 2011 BHHRA
ED_{cw}	Exposure Duration - Commercial Worker	25 years	2007 and 2011 BHHRA
ED_{atv}	Exposure Duration - ATV	10 years	2007 and 2011 BHHRA
ED_{arec}	Exposure Duration - adult recreational visitor	30 years	2007 and 2011 BHHRA
ED_{crec}	Exposure Duration - child recreational visitor	7 years	2007 and 2011 BHHRA
IRw_a	Ingestion Rate - Water - Adult Resident	2 L/day	2007 and 2011 BHHRA
IRw_c	Ingestion Rate - Water - Child Resident	1 L/day	2007 and 2011 BHHRA
$IRsw_a$	Ingestion Rate - Surface Water - Adult Recreational Visitor	30 ml/hour	2007 and 2011 BHHRA
$IRsw_c$	Ingestion Rate - Surface Water - Child Recreational Visitor	50 ml/hour	2007 and 2011 BHHRA
IRs_a	Ingestion Rate - Soil - Adult	100 mg/day	2007 and 2011 BHHRA
IRs_c	Ingestion Rate - Soil - Child	200 mg/day	2007 and 2011 BHHRA
IRs_{atv}	Ingestion Rate - Soil - ATV Rider	200 mg/day	2007 and 2011 BHHRA
$IRarec_{sed/soil}$	Ingestion Rate - Sediment/Soil Adult Recreational Visitor	50 mg/day	2007 and 2011 BHHRA
$IRcrec_{sed/soil}$	Ingestion Rate - Sediment/Soil - Child Recreational Visitor	100 mg/day	2007 and 2011 BHHRA

Table 3. Exposure Factors Used in the Human Health Risk Assessment

Exposure Factor	Definition	Value	Source
$IRarec_{fish}$	Ingestion Rate - Fish - Adult Rec	93 g/day	2007 and 2011 BHHRA
$IRcrec_{fish}$	Ingestion Rate - Fish - Child Rec	37 g/day	2007 and 2011 BHHRA
ET_{atv}	Exposure Time - ATV Rider	2 hrs/day	2007 and 2011 BHHRA
ET_{arec}	Exposure Time - Adult Rec	2 hrs/day	2007 and 2011 BHHRA
ET_{crec}	Exposure Time - Child Rec	3 hrs/day	2007 and 2011 BHHRA
PEF_{atv}	Particulate Emission Factor - ATV Rider	1.39E+05 m^3/kg	2007 and 2011 BHHRA
$I_{nh}R$	Inhalation Rate	1.6 m^3/day	2007 and 2011 BHHRA
SA_a	Surface Area - Adult	5700 cm^2	2007 and 2011 BHHRA
SA_c	Surface Area - Child	2800 cm^2	2007 and 2011 BHHRA
SA_{cw}	Surface Area - Commercial Worker	3300 cm^2	2007 and 2011 BHHRA
SA_{atv}	Surface Area - ATV Rider	3550 cm^2	2007 and 2011 BHHRA
SA_{arec}	Surface Area - Adult recreational visitor	5700 cm^2 (all media)	2007 and 2011 BHHRA
SA_{crec}	Surface Area - Child recreational visitor	2346 cm2 (soil) 2674 cm^2 (sediment) 9300 cm^2 (water)	2007 and 2011 BHHRA
AF_a	Dermal Adherence Factor - Adult	0.07 mg/cm^2	2007 and 2011 BHHRA
AF_c	Dermal Adherence Factor - Child	0.2 mg/cm^2	2007 and 2011 BHHRA
AF_{cw}	Dermal Adherence Factor - Commercial worker	0.2 mg/cm^2	2007 and 2011 BHHRA
AF_{atv}	Dermal Adherence Factor - ATV Rider	0.2 mg/cm^2	2007 and 2011 BHHRA
ABS_d	Dermal Absorption Fraction	chemical specific	2007 and 2011 BHHRA
Kp	Dermal Permeability Coefficient	chemical specific	2007 and 2011 BHHRA
$tevent_{arec}$	Event Duration - Adult Recreational Visitor	2 hrs/event	2007 and 2011 BHHRA
$tevent_{crec}$	Event Duration - Child Recreational Visitor	3 hrs/event	2007 and 2011 BHHRA
$AT_{cw\text{-}Pb}$	Lead Averaging Time - Worker	365 days/yr	2007 and 2011 BHHRA
$AT_{atv\text{-}Pb}$	Lead Averaging Time - ATV	238 days/yr	2007 and 2011 BHHRA
$AT_{crec\text{-}Pb}$	Lead Averaging Time-child recreational visitor	168 days/yr	2007 and 2011 BHHRA
$EF_{crec\text{-}Pb}$	Lead Exposure Frequency - child recreational visitor	48 day/yr	2007 and 2011 BHHRA
GSD_i	Geometric Standard Deviation - Midwest Region All Races/Ethnicities	2.18 (unitless)	2007 and 2011 BHHRA
PbB_0	Baseline Blood Lead - Midwest Region All Races/Ethnicities	1.5 ug/dL	2007 and 2011 BHHRA
BKSF	Biokinetic Slope Factor	0.4 ug/dL per ug/day	2007 and 2011 BHHRA
AFs	Absolute Gastrointestinal Absorption Fraction - ALM	soil/sed = 0.14 air/sw/fish = 0.2	2007 and 2011 BHHRA
$ABA_{s/w/f}$	Absolute Bioavailability - IEUBK Model	soil/sed = 35% surface water/fish = 50%	2007 and 2011 BHHRA
R	Fetal/Maternal Blood Lead Ratio	0.9 (unitless)	2007 and 2011 BHHRA
$PbB_{fetal,0.95}$	95th Percentile PbB in Fetus	10 ug/dL	2007 and 2011 BHHRA
CF1	Conversion Factor 1	1E-06 kg/mg	2007 and 2011 BHHRA
CF2	Conversion Factor 2	1E-03 kg/g	2007 and 2011 BHHRA
CF3	Conversion Factor 3	1E+03 ug/mg	2007 and 2011 BHHRA

Table 4. Summary of Carcinogenic and Noncarcinogenic Toxicity Criteria for COCs

COCs	Carcinogenicity			Non-Cancer			
	Oral Slope Factor $(mg/kg\text{-}day)^{-1}$	Inhalation Unit Risk $(ug/m^3)^{-1}$	Weight-of-Evidence Classification	Reference Dose (mg/kg-day)	Target Organ	Reference Concentration (mg/m^3)	Target Organ
Antimony	-	-	NA	4.0E-04	Blood	-	-
Arsenic	1.5E+00	4.3E-03	A	3.0E-04	Skin	1.5E-05	Dev, CNS,Heart
Cobalt	-	9.0E-03	"Likely to be carcinogenic"	3.0E-04	Thyroid	6.0E-06	Lung
Copper	-	-	D	4.0E-02	GI	-	-
Iron	-	-	"Inadequate Data"	7.0E-01	GI	-	-
Lead	-	-	B2	-	-	-	-
Manganese	-	-	D	2.4E-02	CNS	5.0E-05	CNS
Nickel	-	2.6E-04	A	2.0E-02	Body Weight	9.0E-05	Respiratory Sys.
Thallium	-	-	NA	7.0E-05	Liver	-	-
Vanadium	-	-	NA	5.00E-03	Hair	-	-

Table 5. PRGs for Non-Cancer COCs Associated with Residential Child Scenario

COC	Groundwater (ug/L)	Soil (mg/kg)
Antimony	NC	31
Arsenic	10*	23
Cobalt	4.7**	23
Copper	NC	1564
Iron	NC	27375
Lead	15*	466***
Manganese	375**	1877
Nickel	NC	1564
Thallium	NC	5

* Primary MCL

** Non-Cancer Risk - value from EPA as reported in OU4 Feasibility Study Report for Conrad Subsite Madison County Mines (B&V, 2009)

*** Lead Risk - value from EPA as reported in OU4 Feasibility Study Report for Conrad Subsite Madison County Mines (B&V, 2009) Fine ICP Method

NC = not calculated. Chemical is not a non-cancer concern for this media.

Table 6. PRGs for Non-Cancer COCs Associated with Residential Adult Scenario

COC	Groundwater (ug/L)	Soil (mg/kg)
Arsenic	10*	NC
Cobalt	4.7**	219

* Primary MCL
** Non-Cancer Risk - value from EPA as reported in OU4 Feasibility Study Report for Conrad Subsite Madison County Mines (B&V, 2009)
NC = not calculated. Chemical is not a non-cancer concern for this media.

Table 7. PRGs for Carcinogenic COCs Associated with Residential Scenario

COC	Groundwater (ug/L)	Soil * (mg/kg)
Arsenic	10**	39

* Target Cancer Risk of 1E-04
** Primary MCL

Table 8. PRGs for Non-Cancer COCs Associated with Commercial Worker Scenario

COC	Groundwater (ug/L)	Soil (mg/kg)
Cobalt	NC	307
Lead	15*	940 **

* Primary MCL
** Fine ICP Method
NC = not calculated. Chemical is not a non-cancer concern for this media.

Table 9. PRGs for Carcinogenic COCs Associated with Commercial Worker Scenario

COC	Groundwater (ug/L)	Soil (mg/kg)
None	NC	NC

NC = not calculated. There are no carcinogenic chemicals of concern for this media.

Table 10. PRGs for Non-Cancer COCs Associated with ATV Rider Scenaric

COC	Soil/ Tailings * (mg/kg)
Arsenic	113
Cobalt	47 **
Lead	1461 ***
Manganese	446 **
Nickel	771

* Target Hazard Index of 1.0.
** Non-Cancer Risk - value from EPA as reported in OU4 Feasibility Study Report for Conrad Subsite, Madison County Mines (B&V, 2009)
*** Lead Risk - value from EPA as reported in OU4 Feasibility Study Report for Conrad Subsite Madison County Mines (B&V, 2009)
Fine ICP Method

Table 11. PRGs for Carcinogenic COCs Associated with ATV Rider Scenario

COC	Soil/ Tailings * (mg/kg)
Arsenic	119
Cobalt	222

* Target Cancer Risk of 1E-04

Table 12. PRGs for Non-Cancer COCs Associated with Recreational Child Scenario

COC	Sediment (mg/kg)	Surface Water (ug/L)	Soil (mg/kg)	Fish (mg/kg)
Antimony	NC	127	NC	NC
Arsenic	NC	NC	NC	0.24
Cobalt	319	198	319	NC
Lead	1250	NC	1250	NC
Manganese	49681	3015	49681	NC
Thallium	NC	NC	75	NC
Vanadium	NC	87	NC	NC

NC = not calculated. Chemical is not a non-cancer concern for this media.

Table 13. PRGs for Non-Cancer COCs Associated with Recreational Adult Scenario

COC	Sediment (mg/kg)	Surface Water (ug/L)	Soil (mg/kg)	Fish (mg/kg)
Arsenic	NC	NC	NC	0.24
Cobalt	1597	1237	1597	NC
Lead	1350	NC	1350	0.128

NC = not calculated. Chemical is not a non-cancer concern for this media.

Table 14. PRGs for Carcinogenic COCs Associated with Recreational Scenario

COC	Sediment (mg/kg)	Surface Water (ug/L)	Soil (mg/kg)	Fish * (mg/kg)
Arsenic	NC	NC	NC	0.12

* Target Cancer Risk of 1E-04
NC = not calculated. Chemical is not a cancer concern for this media.

Table 15. Summary of Recommended PRGs for Protection of Human Health

COC	Residential Soil (mg/kg)	Worker Soil (mg/kg)	Groundwater (ug/L)	Tailings (mg/kg)	Recreational Sediment/Soil (mg/kg)	Recreational Surface Water (ug/L)	Fish Tissue (mg/kg)
Antimony	31	NC	NC	NC	NC	127	NC
Arsenic	23	NC	10*	113	NC	NC	0.12
Cobalt	23	307	4.7**	47 **	319	198	NC
Copper	1564	NC	NC	NC	NC	NC	NC
Iron	27375	NC	NC	NC	NC	NC	NC
Lead	466***	940	15*	1461 ***	1250	NC	0.128
Manganese	1877	NC	375**	446 **	49681	3015	NC
Nickel	1564	NC	NC	771	NC	NC	NC
Thallium	5	NC	NC	NC	75	NC	NC
Vanadium	NC	NC	NC	NC	NC	87	NC

* Primary MCL
** Non-Cancer Risk - value from EPA as reported in OU4 Feasibility Study Report for Conrad Subsite Madison County Mines (B&V, 2009)
*** Lead Risk - value from EPA as reported in OU4 Feasibility Study Report for Conrad Subsite Madison County Mines (B&V, 2009) Fine ICP Method
NC = not calculated. Chemical is not a concern for this media.

Table 16. Media-Specific COCs Identified in 2007 and 2011 Ecological Risk Assessments

Environmental Media	COCs	Assessment Endpoints
Soil/Mine WasteTailings	Antimony	AE 1, AE 2, AE 3, AE 4
	Arsenic	AE 1, AE 2, AE 4
	Cadmium	AE 3
	Chromium	AE 1
	Cobalt	AE 1, AE 2, AE 3, AE 4
	Copper	AE 1, AE 2, AE 3, AE 4
	Iron	AE 1, AE 2, AE 3, AE 4
	Lead	AE 1, AE 2, AE 3, AE 4
	Manganese	AE 1
	Mercury	AE 1
	Nickel	AE 1, AE 2, AE 4
	Selenium	AE 1, AE 3
	Silver	AE 1, AE 2, AE 3
	Thallium	AE 1
	Vanadium	AE 1
	Zinc	AE 1
	PAHs	AE 3
Surface Water	Aluminum	AE 5
	Cobalt	AE 5
	Copper	AE 5
	Lead	AE 5
	Nickel	AE 5
	Silver	AE 5
Sediment	Antimony	AE 6
	Arsenic	AE 6
	Barium	AE 6
	Beryllium	AE 6
	Cadmium	AE 6
	Chromium	AE 6
	Cobalt	AE 6
	Copper	AE 6
	Iron	AE 6
	Lead	AE 6
	Manganese	AE 6
	Mercury	AE 6
	Nickel	AE 6
	Selenium	AE 6
	Silver	AE 6
	Thallium	AE 6
	Zinc	AE 6

AE 1 = Protection of Nutrient Cycling
AE 2 = Protection of Terrestrial Herbivores
AE 3 = Protection of Terrestrial Vermivores
AE 4 = Protection of Terrestrial Carnivores
AE 5 = Protection of Aquatic Life (Surface Water)
AE 6 = Protection of Benthos (Sediment)

Table 17. PRGs' Receptors and Exposure Pathways for Ecological Risk Assessments

Environmental Media	Receptor	Assessment Endpoints
Mine Waste Tailings	Plants, Soil Invertebrates, Herbivores, Vermivores, Carnivores	AE 1, 2, 3, and 4
Soil	Plants, Soil Invertebrates, Herbivores, Vermivores, Carnivores	AE 1, 2, 3, and 4
Surface Water	Aquatic Life	AE 5
Sediment	Benthos	AE 6

AE 1 = Protection of Nutrient Cycling
AE 2 = Protection of Terrestrial Herbivores
AE 3 = Protection of Terrestrial Vermivores
AE 4 = Protection of Terrestrial Carnivores
AE 5 = Protection of Aquatic Life (Surface Water)
AE 6 = Protection of Benthos (Sediment)

Table 18. PRGs for Tailings and Soil

COC	Site Specific Terrestrial Plants AE 1 (mg/kg)	Soil Invertebrates AE 1 (mg/kg)	Avian Herbivores AE 2 (mg/kg)	Avian Vermivores AE 3 (mg/kg)	Avian Carnivores AE 4 (mg/kg)	Mammalian Herbivores AE 2 (mg/kg)	Mammalian Vermivores AE 3 (mg/kg)	Mammalian Carnivores AE 4 (mg/kg)	Mean * Background (mg/kg)	EPA PRG (mg/kg)	Selected PRG (mg/kg)
Antimony	5 - 50	78 - 780	NA	NA	NA	10 - 210	0.27 - 5.67	4.9 - 104	NA	NA	0.27 - 5.67
Arsenic	18 - 180	60 -600	150 - 840	318 - 1800	1100 - 6286	370 - 450	340 - 414	170 - 206	15.96	NA	18 - 180
Cadmium	32 - 320	140 - 1400	156 - 2180	15.6 - 219	630 - 8570	406 - 5278	7.31 - 95	84 - 1091	1.3	4.98	7.31 - 95
Chromium	1 - 10	380 - 3800	78 - 147	26 - 49	780 - 1466	380 - 3800	34 - 340	180 - 1800	58	NA	58
Cobalt	13 - 130	2100 - 21000	113 - 1134	200 - 2000	1300 - 13000	880 - 8800	384 - 3840	470 - 4700	11.2	NA	13 - 130
Copper	70 - 700	80 - 800	147 -1470	160 - 1600	1600 - 16000	2130 - 6400	280 - 840	560 - 1540	30	NA	70 - 700
Iron	Soil pH	Soil pH	Soil pH	Soil pH	Soil pH	Soil pH	Soil pH	Soil pH	27700	NA	27700
Lead	120 - 1200	1700 - 17000	117 - 818	60 - 422	510 - 3536	3048 - 51800	307 - 5200	460 - 7830	210	219 - 400	219 - 400
Manganese	220 - 2200	450 - 4500	4300 - 43000	4300 - 43000	65000 - 650000	5300 - 29227	4000 - 22058	6200 - 34190	NA	NA	220 - 2200
Mercury	0.3 - 3	170 - 170	100 - 100	75 - 75	375 - 375	170 - 170	70 - 70	33 - 33	0.07	NA	0.3 - 3
Nickel	38 - 380	280 - 2800	147 - 1470	NA	2800 - 28000	238 - 11186	NA	130 - 6118	20.8	NA	38 - 380
Selenium	0.52 - 5.2	4.1 - 41	2.95 - 8.84	1.2 - 3.6	83 - 286	3.62 - 7.24	0.63 - 1.26	2.8 - 6.0	0.36	NA	0.63 - 1.26
Silver	560 - 5600	50 - 500	69 - 690	4.2 - 42	930 - 9300	1500 - 15000	14 - 140	990 - 9900	0.6	NA	4.2 - 42
Thallium	1 - 10	NA	NA	NA	NA	NA	NA	NA	NA	NA	1 - 10
Vanadium	2 - 20	20 - 200	20.8 - 208	7.8 - 78	140 - 1400	2080 - 20800	280 - 2800	580 - 5800	86.4	NA	86.4
Zinc	160 - 1600	120 - 1200	9975 - 19950	9410 - 18800	30000 - 59455	71400 - 285600	16163 - 64650	10000 - 100000	326	NA	120 - 1200
High Mol Wt PAHs	NA	18	NA	NA	NA	39	1.1	110	NA	NA	1.1

* Mean Background Soil for 8 counties adjacent to Madison County (Bollinger, Iron, Jefferson, Perry, St. Francois, St. Genevieve, Washington, and Wayne) reported by the USGS Pluto Database for Soil (USGS, 2011)

Table 19 Equations Used for Calculation of Surface Water PRGs

COC	Acute	Chronic
Copper (Total)	EXP(0.9422*LN(Hardness)-1.7003)	EXP(0.8545*LN(Hardness)-1.702)
Copper (Dissolved)	EXP(0.9422*LN(Hardness)-1.7003)*0.96	EXP(0.8545*LN(Hardness)-1.702)*0.96
Lead (Total)	EXP(1.273*LN(Hardness)-1.460448)	EXP(1.273*LN(Hardness)-4.704797)
Lead (Dissolved)	EXP(1.273*LN(Hardness)-1.460448)*(1.46203-(LN(Hardness)*0.145712))	EXP(1.273*LN(Hardness)-4.704797)*(1.46203-(LN(Hardness)*0.145712))
Nickel (Total)	EXP(0.846*LN(Hardness)+2.255647)	EXP(0.846*LN(Hardness)+0.058978)
Nickel (Dissolved)	EXP(0.846*LN(Hardness)+2.255647)*0.998	EXP(0.846*LN(Hardness)+0.058978)*0.997
Silver (Total)	EXP(1.72*LN(Hardness)-6.588144)	NA
Silver (Dissolved)	EXP(1.72*LN(Hardness)-6.588144)*0.85	NA

* Hardness Dependent values. Average hardness of 231 mg/L $CaCO_3$ assumed based on available data for Little St. Francis River Watershed.

Table 20 Calculated PRGs for Surface Water

COC	AWQC Chronic (ug/L)	AWQC Acute (ug/L)
Aluminum (Total)	87	750
Cobalt (Total)	24	24
Cobalt (Dissolved)	24	24
Copper (Total) *	19	31
Copper (Dissolved) *	18	30
Lead (Total) *	9.2	237
Lead (Dissolved) *	6.2	158
Nickel (Total) *	106	953
Nickel (Dissolved) *	106	951
Silver (Total) *	NA	16
Silver (Dissolved) *	NA	13.6

* Hardness Dependent values. Average hardness of 231 mg/L $CaCO_3$.

Table 21 PRGs for Sediment

COC	Eco SQG TEC (mg/kg)	Eco SQG PEC (mg/kg)	Source	EPA PRG	Background Sediment * (mg/kg)	Selected PRG (mg/kg)
Antimony	2	2	b	NA	1.15	2
Arsenic	9.79	33	a	NA	11.3	11.3 - 33
Barium	20	60	c	NA	554	554
Beryllium	1.1	1.1	d	NA	1.25	1.25
Cadmium	0.99	4.98	a	4.98	23.5	4.98
Chromium	43.4	111	a	NA	27.2	43.4 - 111
Cobalt	50	50	b	NA	137	137
Copper	31.6	149	a	NA	106	106 - 149
Iron	20000	20000	b	NA	28300	28300
Lead	35.8	128	a	150	2870	150
Manganese	460	460	b	NA	NA	460
Mercury	0.18	1.1	a	NA	0.05	0.18 - 1.1
Nickel	22.7	48.6	a	NA	167	167
Selenium	2	2	e	NA	0.4	2
Silver	1	2.2	f	NA	4	4
Thallium	1	1	d	NA	NA	1
Zinc	121	459	a	NA	5980	5980

SQG = Sediment Quality Guideline
TEC = Threshold Effect Concentration
PEC = Probable Effect Concentration

* Mean Background Sediment for 8 counties adjacent to Madison County (Bollinger, Iron, Jefferson, Perry, St. Francois, St. Genevieve, Washington, and Wayne) reported by the USGS Pluto Database for Sediment (USGS, 2011)

a - MacDonald et al (2000) Development and Evaluation of Consensus-based Sediment Quality Guidelines
b - NOAA Screening Quick Reference Table for Inorganics in Sediment (NOAA 2008)
c - USEPA, 1977. Guidelines for the pollution classification of Great Lakes Harbor sediments
d - Dutch Ministry of Housing, Spatial Planning and Environment (MHSPE) 1994
e - EPA Region 3 Sediment Benchmarks (USEPA, 2006)

Table 22 Summary of Recommended PRGs for Protection of Ecological Receptors

COC	Soil (mg/kg)	Sediment (mg/kg)	Surface Water (ug/L)
Aluminum	NC	NC	87 - 750
Antimony	0.27 - 5.67	2	NC
Arsenic	18 - 180	11.3 - 33	NC
Barium	NC	554	NC
Beryllium	NC	1.25	NC
Cadmium	7.31 - 95	4.98 **	NC
Chromium	58	43.4 - 111	NC
Cobalt	13 - 130	137	24
Copper	70 - 700	106 - 149	18 - 30
Iron	27700	28300	NC
Lead	219 - 400 *	150 **	6.2 - 158
Manganese	220 - 2200	460	NC
Mercury	0.3 - 3	0.18 - 1.1	NC
Nickel	38 - 380	167	106 - 951
Selenium	0.63 - 1.26	2	NC
Silver	4.2 - 42	4	13.6
Thallium	1 - 10	1	NC
Vanadium	86.4	NC	NC
Zinc	120 - 1200	5980	NC
High Mol Wt PAHs	1.1	NC	NC

NC = not calculated. Chemical is not a concern for this media.

Values for chromium, iron, and vanadium in soil are mean background concentrations.
Values for barium, beryllium, cobalt, iron, nickel, silver, and zinc
in sediment are mean background concentrations.

* EPA PRG for Soil (from EPA, 2008 Memo regarding Conrad Site)
** EPA PRG for Sediment (from EPA, 2008 Memo regarding Conrad Site)

Appendix A
Attachment 1

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Model Version: 1.1 Build11
User Name: EPA Region 7
Date: 03/17/11
Site Name: Madison County Mines
Operable Unit: OU1 and OU2
Run Mode: PRG

==========

****** Air ******

Indoor Air Pb Concentration: 30.000 percent of outdoor.
Other Air Parameters:

Age	Time Outdoors (hours)	Ventilation Rate (m^3/day)	Lung Absorption (%)	Outdoor Air Pb Conc (µg Pb/m^3)
.5-1	1.000	2.000	32.000	0.100
1-2	2.000	3.000	32.000	0.100
2-3	3.000	5.000	32.000	0.100
3-4	4.000	5.000	32.000	0.100
4-5	4.000	5.000	32.000	0.100
5-6	4.000	7.000	32.000	0.100
6-7	4.000	7.000	32.000	0.100

****** Diet ******

Age	Diet Intake(µg/day)
.5-1	2.260
1-2	1.960
2-3	2.130
3-4	2.040
4-5	1.950
5-6	2.050
6-7	2.220

****** Drinking Water ******

Water Consumption:

Age	Water (L/day)
.5-1	0.200
1-2	0.500
2-3	0.520
3-4	0.530
4-5	0.550
5-6	0.580
6-7	0.590

Drinking Water Concentration: 0.000 µg Pb/L

****** Soil & Dust ******

Multiple Source Analysis Used
Average multiple source concentration: 75.280 µg/g

Mass fraction of outdoor soil to indoor dust conversion factor: 0.320

Outdoor airborne lead to indoor household dust lead concentration: 100.000
Use alternate indoor dust Pb sources? No

Age	Soil (µg Pb/g)	House Dust (µg Pb/g)
.5-1	204.000	75.280
1-2	204.000	75.280
2-3	204.000	75.280
3-4	204.000	75.280
4-5	204.000	75.280
5-6	204.000	75.280
6-7	204.000	75.280

****** Alternate Intake ******

Age	Alternate (µg Pb/day)
.5-1	7.500
1-2	7.500
2-3	7.500
3-4	7.500
4-5	7.500
5-6	7.500
6-7	7.500

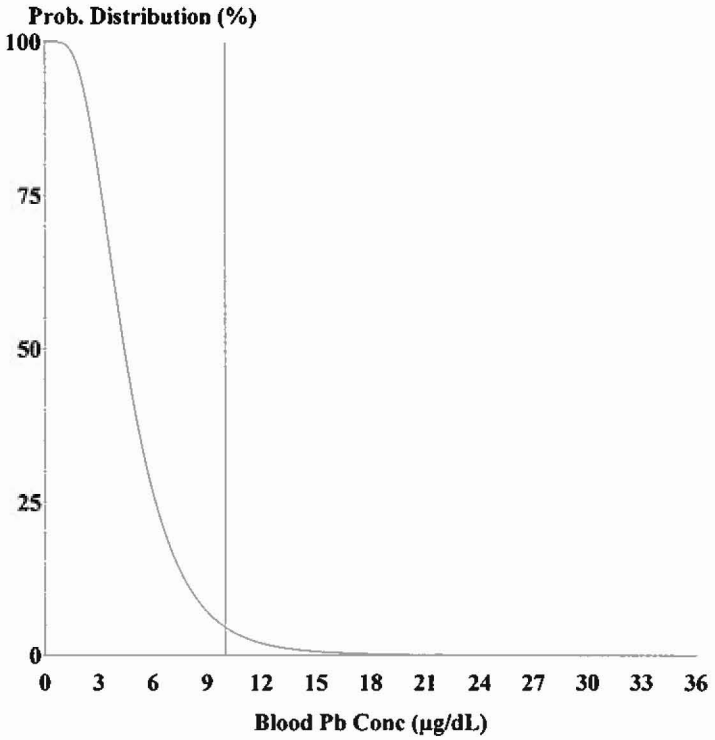
****** Maternal Contribution: Infant Model ******

Maternal Blood Concentration: 1.000 µg Pb/dL

****
CALCULATED BLOOD LEAD AND LEAD UPTAKES:
****

Year	Air (µg/day)	Diet (µg/day)	Alternate (µg/day)	Water (µg/day)
.5-1	0.021	0.994	6.600	0.000
1-2	0.034	0.872	6.675	0.000
2-3	0.062	0.963	6.780	0.000
3-4	0.067	0.935	6.876	0.000
4-5	0.067	0.911	7.010	0.000
5-6	0.093	0.967	7.074	0.000
6-7	0.093	1.052	7.111	0.000

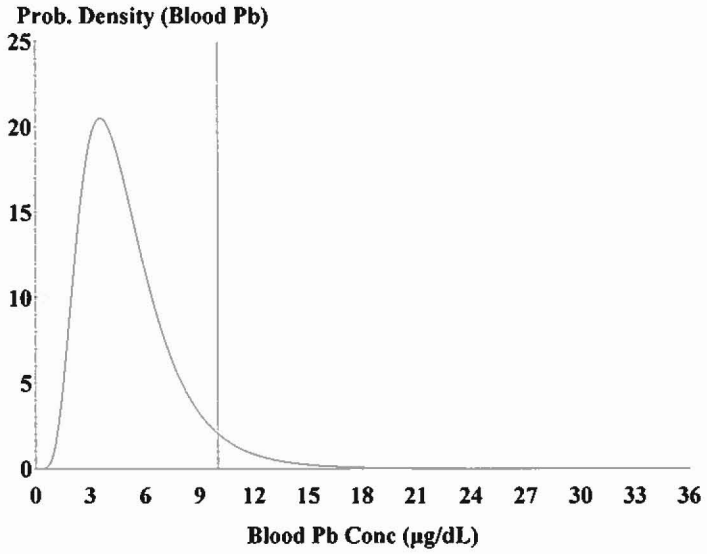
Year	Soil+Dust (µg/day)	Total (µg/day)	Blood (µg/dL)
.5-1	3.487	11.102	5.9
1-2	5.602	13.183	5.6
2-3	5.690	13.495	5.0
3-4	5.770	13.647	4.8
4-5	4.357	12.345	4.2
5-6	3.958	12.091	3.8
6-7	3.757	12.014	3.4



Cutoff = 10.000 µg/dl
Geo Mean = 4.611
GSD = 1.600
% Above = 4.978

Age Range = 0 to 84 months

Run Mode = Research
Comment = Child Rec RAO



Cutoff = 10.000 µg/dl
Geo Mean = 4.611
GSD = 1.600
% Above = 4.978
% Below = 95.022

Age Range = 0 to 84 months

Run Mode = Research
Comment = Child Rec RAO