Final

Current Status Conceptual Site Model Operable Unit 2

Bunker Hill Mining and Metallurgical Complex Superfund Site

Prepared for

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Executive Summary

Purpose

This document presents an updated conceptual site model (CSM) for Operable Unit 2 (OU2) of the Bunker Hill Mining and Metallurgical Complex Superfund Site. The purpose of this CSM is provide a representation of the current status of the environmental system within OU2 following the implementation of Phase I remedial actions.

This revision of the CSM focuses on updating the current level of knowledge and understanding of the OU2 environmental system. Updates to the CSM include refinements to interpretations presented in the original CSM (Dames & Moore, 1989a) based on new site information that has become available in recent years. Updates to the CSM are critical to aid in the assessment of the protectiveness of the selected remedy required as part of the Five-Year Record of Decision (ROD) Review process (EPA, 2001a). Evaluation of the effectiveness of Phase I remedial actions is required as part of the phased approach to remedy implementation presented in the State Superfund Contract (SSC) (IDHW, 1995). Another important goal of the CSM is to identify the level of knowledge regarding OU2 and the level to which understanding of the environmental system cannot be further developed because of a lack of information (data gaps).

This CSM is intended to function as a living document that will be periodically updated by the U.S. Environmental Protection Agency (EPA) as new information becomes available, ongoing analyses are completed, and the OU2 environmental system is better understood. Regular updates to the CSM will enable improved decisionmaking by EPA and site stakeholders as data gaps are filled by information gained through continued site activities.

Background

The Bunker Hill Mining and Metallurgical Complex Superfund Site (Figure ES-1) was listed on the National Priorities List (NPL) in 1983. The site includes mining-contaminated areas in the Coeur d'Alene River corridor, adjacent floodplains, downstream water bodies, tributaries, and fill areas, as well as the 21-square-mile Bunker Hill "Box" located in the area surrounding historic smelting operations. The site has been divided into three operable units:

- The populated areas of the Bunker Hill Box (OU1)
- The non-populated areas of the Bunker Hill Box (OU2)
- Mining-related contamination in the broader Coeur d'Alene Basin (OU3)

The focus of this CSM is the environmental system within OU2. OU2 includes the non-populated areas of the Bunker Hill Box not addressed by the 1991 OU1 ROD (EPA, 1991). The South Fork Coeur d'Alene River (SFCDR) and the Pine Creek drainage are not part of OU2 and are addressed as part of OU3. In addition, the 1992 OU2 ROD did not include an ecological remedy for OU2 because of the general lack of habitat and ecological receptors at the time of remedy development. However, monitoring potential exposure of ecological receptors within OU2 after the establishment of habitat is required.

In 1995, with the bankruptcy of the major potentially responsible party (PRP) for OU2, the EPA and State of Idaho defined a path forward for phased remedy implementation. Phase I of remedy implementation includes extensive source removal and stabilization efforts, all demolition activities, all community development initiatives, development and initiation of an Institutional Controls Program (ICP), future land use development support, and public health response actions. Also included in Phase I are additional investigations to provide necessary information to resolve long-term water quality issues, including technology assessments and pilot studies, evaluation of the success of source control efforts, development of site-specific water quality and effluent-limiting performance standards, and development of a defined operations and maintenance (O&M) plan and implementation schedule. Interim control and treatment of contaminated water and acid mine drainage (AMD is also included in Phase I remedy implementation.

Phase II of the OU2 remedy will be implemented following completion of source control and removal activities and evaluation of the impacts of these activities on meeting water quality improvement objectives. Phase II will consider any shortcomings encountered in implementing Phase I and will specifically address long-term water quality and environmental management issues.

Site History

Mining and milling activities began within OU2 in the 1880s. A total of 52 mine-related sites have been identified within OU2 (BLM, 1999) with a total ore production near 48 million tons. The primary ore mined in the area during early mining activities was galena for lead and silver. Zinc was also present in great quantities in the area. However, zinc ores were not actively mined during the early stages of mining activity because of inefficiencies associated with the zinc ore concentration process and a lack of zinc refining capabilities in the area. The largest mine within OU2 is the Bunker Hill Mine. The Bunker Hill Mine was in operation from 1885 to 1991. Currently, the Bunker Hill Mine is in operation to produce crystal specimens and small quantities of high-grade ore.

Historical records indicate the presence of at least nine mills (ore concentrators) within OU2. During the early stages of mining within the area, ore was concentrated using the jigging process, which is a relatively inefficient method of ore concentration. It has been estimated that up to half of the lead ore was lost during the jigging process and disposed of as tailings. More efficient flotation concentration methods were introduced to the area in 1913 and became the principal form of ore concentration by 1938.

In the early stages of mining and milling activity within OU2, all tailings and mine wastes resulting from mining, milling, and other processing activities were discharged to either the SFCDR, its tributaries, or the immediate areas surrounding mine workings, mills, and other processing facilities. These materials were eroded and transported in the SFCDR and its tributaries and deposited in downstream channels and floodplains. Initial attempts to contain a portion of these wastes occurred in the early 1900s with the construction of several dams along the SFCDR to impound the majority of these wastes. These dams included a plank and pile dam constructed in the Pinehurst Narrows in the western portion of OU2. This dam resulted in tailings being impounding in the SFCDR floodplain in the Smelterville Flats area. In 1933, flooding resulted in the failure of the plank and pile dam at Pinehurst Narrows. Tailings and other mine wastes that had been impounded behind the dam were redistributed downstream and within the OU2 SFCDR floodplain alluvium. In 1926 and 1928, the Page Pond and Central Impoundment Area (CIA) tailings impoundments were constructed, ending the direct discharge of tailings from OU2 sources to the SFCDR. Upstream mills continued to dispose of tailings directly to the SFCDR until 1968.

Prior to 1917, all concentrated ores produced at Bunker Hill were smelted at Wickes, Montana. In 1917, the Bunker Hill Lead Smelter began operation. In 1928, the electrolytic Zinc Plant located in Government Gulch began production. In 1939, an antimony plant was added to the Lead Smelter, followed by a zinc fuming plant in 1943 and a cadmium plant in 1945. Sulfuric acid plants were added to the Zinc Plant in 1954 and a phosphoric acid and fertilizer plant were added in 1954 and 1965, respectively.

Physical Setting

This section provides a brief summary of the groundwater and surface water systems within OU2.

Groundwater

Groundwater within OU2 occurs in both the main valley and upland tributary valleys. The areal extent of these groundwater systems is presented in Figure ES-2. These groundwater systems can generally be described as follows:

Main Valley Groundwater System – The main valley groundwater system contains four distinct hydrogeologic units:

- A relatively thick, unconfined alluvial sand and gravel unit that is present only in the eastern portion of OU2 where the confining unit is not present
- An upper, unconfined alluvial sand and gravel unit associated with the main SFCDR valley and defined by the presence of the confining unit that underlies this upper alluvial unit
- A middle lacustrine silt/clay confining unit associated with the main SFCDR valley that separates the upper and lower coarse-grained alluvial sand and gravel units
- A lower, confined alluvial sand and gravel unit associated with the main SFCDR valley and defined by the presence of the confining unit that overlies this lower alluvial unit

In general, groundwater within the main valley flows from east to west across OU2. In the upper aquifer, interactions with upland tributary groundwater systems (described below) and the SFCDR and its tributaries result in varying localized groundwater flow pathways and directions.

Upland Tributary Groundwater Systems – The upland tributary groundwater systems are located in the gulches that discharge to the main valley groundwater system. These systems are generally unconfined or semi-confined colluvial/alluvial units.

Groundwater in the tributary groundwater systems generally flows north-south following tributary valley alignment at relatively steep hydraulic gradients. Hydraulic conductivities measured in the upland tributary groundwater systems are generally much lower than those observed in the main valley aquifers.

Surface Water

The SFCDR is the major surface water feature within OU2. The SFCDR flows from east to west through OU2, and is currently located near the northern margin of the main valley. The current alignment of the SFCDR is the result of forced channel changes caused by mining-related activities, community development, highway and railroad corridor development, natural channel migration, and remedial actions. The SFCDR both gains and loses discharge as it passes through OU2. These gains and losses of discharge are dictated by main valley morphology. Where the valley is wide, the SFCDR loses discharge to the single unconfined and upper unconfined aquifers. Where the valley narrows, the SFCDR gains discharge from the upper unconfined aquifer.

Tributaries to the SFCDR within OU2 are shown in Figure ES-3. Tributaries that discharge directly to the SFCDR within OU2 include Milo, Italian, Jackass, Bunker, Government, and Pine creeks. The Page Swamp wetland complex also discharges directly to the SFCDR from the West Page Swamp. Bunker Creek receives discharge from several smaller tributaries including Portal, Railroad, Deadwood, and Magnet creeks. The Central Treatment Plant (CTP) discharges treated mine water under an expired National Pollutant Discharge Elimination System (NPDES) permit to Bunker Creek. The Page Swamp wetland complex receives discharge from Grouse and Humboldt creeks. Two wastewater treatment plants, the Page and Smelterville wastewater treatment plants, discharge directly to the SFCDR.

In general, the discharge of the SFCDR increases as the river flows through OU2. Under higher flow conditions, the majority of discharge contributed to the SFCDR comes from surface water tributaries. Under base-flow conditions, groundwater is the source of most of the discharge contributed to the SFCDR within OU2. Tributaries within OU2 tend to gain discharge from their associated upland tributary groundwater systems and lose discharge to the upper aquifer as they traverse the valley floor.

Contaminant Sources

For the purpose of this document, the term contaminant is used to describe hazardous substances (e.g., dissolved and total metals) present in OU2 surface water and groundwater in concentrations above ambient water quality criteria (AWQC) or maximum contaminant levels (MCLs), respectively. Contaminant sources within OU2 can be placed into the following broad categories:

Tailings – Metal-rich tailings from mining activities are widespread throughout OU2. Tailings have become mixed with natural alluvium on the main valley floor and in some tributary valleys over time. In general, the tailings/alluvium mixture is between 4 and 7 feet thick across the main valley floor. Tailings were also widely used as fill for construction projects within OU2 including residential areas, industrial facilities, railroad grades and roadway fill.

Impoundments and Stockpiles – Impoundments were used to consolidate and contain tailings and other process wastes within OU2. The two major tailings impoundments within OU2 are Page Ponds and the CIA. In addition, mined ore, processed concentrates, finished materials, waste rock and other mine wastes were stockpiled at several locations within OU2.

Soils and Sediments – Stack emissions and windblown contamination from material storage and waste piles contributed to the contamination of soils within OU2. Contaminated sediment is also generated from erosion of contaminated soils and other materials located within OU2.

Mine Water – A significant amount of AMD is produced within the Bunker Hill Mine. Most of the AMD produced by the Bunker Hill Mine is treated in the CTP. Metal-rich mine water from other adits and uncaptured portions of the Bunker Hill Mine discharge to tributaries and hillsides within OU2.

Contaminant Release Mechanisms

The primary contaminant release mechanisms for OU2 are:

Inflow from Upstream – Metals in both dissolved and particulate phases enter OU2 in surface water and groundwater at the eastern, upstream boundary from sources upstream of OU2.

Dissolution – The most widespread and highly concentrated contaminants found in sources within OU2 are cadmium, lead, and zinc. All three metals have the common attribute of occurring as insoluble sulfide minerals and are classified as hazardous substances. The most common sulfide ores of cadmium, lead, and zinc do not form acid upon oxidation, but they do release soluble metals in the presence of water and atmospheric oxygen. Lead is released in soluble (dissolved) form from galena, but is quickly sorbed to organic and inorganic materials such as sediment and suspended solids. Cadmium and zinc released in soluble form tend to stay dissolved in OU2 surface water and groundwater.

The movement of water through sources within OU2 results in the release of dissolved cadmium and zinc and, to a lesser extent, dissolved lead. Typically, water moving through source materials within OU2 is the result of the following:

- Infiltration of precipitation and snowmelt
- Infiltration of surface water
- Groundwater discharge to surface water
- Groundwater elevation fluctuations

Infiltration of precipitation and surface water through contaminant sources is a predominant mechanism for release of dissolved metal to groundwater within OU2.

Erosion and Sediment Transport – Contaminant sources that are exposed to surface water and direct precipitation are potential sources for erosion and resultant sediment transport.

Direct Release of Mine Water – As stated earlier, not all mine water within OU2 is captured and treated. Mine water that is not captured and treated eventually discharges to tributaries and shallow groundwater systems within OU2.

OU2 Phase I Remedial Actions

A significant number of large- and small-scale remedial actions have been performed as part of Phase I of OU2 remedy implementation. Understanding the magnitude and extent of Phase I remedial actions with respect to contaminant sources and release mechanisms is critical for the further refinement of the CSM. Currently, the State of Idaho is assembling a detailed description of Phase I remedial activities conducted within OU2 to include depths of excavation and estimates of volumes of contaminants removed. When this effort is completed, this information will be incorporated in the CSM to provide a better understanding of contaminant nature and extent and contaminant fate and transport within OU2. As part of the Second Five-Year Review for OU2 (EPA, 2005), Phase I remedial actions were revisited to evaluate the protectiveness of the remedy. The Phase I remedial actions conducted within OU2 are shown in Figure ES-4.

Contaminant Transport and Migration Pathways

Contaminants within OU2 are transported primarily in the groundwater and surface water systems after release from their sources. Contaminants in groundwater are primarily in the dissolved phase. Contaminants in surface water are present in both the dissolved and particulate phases. Fate and transport of metals within OU2 is complicated by the heterogeneous nature of the physical system, the varied and widespread nature of contaminant sources, and the long timeframe over which contaminants have been present in the OU2 environmental system. Groundwater/surface water interaction plays a significant role in both contaminant release from sources and the transport and migration of contamination within OU2.

Ecological Exposure

Exposure Media

The following media were identified as exposure media for ecological receptors within OU2:

- Sediment
- Soil
- Surface water
- Groundwater

The 1992 OU2 ROD does not address sediment cleanup as part of the selected remedy. However, sediment is addressed under the OU3 ROD (EPA, 2002), which includes the SFCDR as it passes through OU2. In addition, soil/sediment monitoring is included in the OU2 Environmental Monitoring Plan (EMP) (CH2M HILL, 2006a) to further characterize potential biological receptor exposure.

Exposure Pathways

Exposure pathways are the routes by which humans and living natural resources (receptors) may be exposed to metals from mining-related sources. In general, exposure pathways within OU2 include:

- Birds and mammals – ingestion of soil-sediment, surface water, and food
- Fish – ingestion and direct contact with sediment and surface water
- Benthic invertebrates – ingestion and direct contact with sediment and surface water
- Aquatic plants – root uptake and direct contact with sediment and surface water
- Amphibians – direct contact with surface water and soil-sediment
- Terrestrial plants – root uptake from soil-sediment
- Soil processes – direct contact of microbes with soil-sediment

Habitats and Receptors

Within OU2, ecological risks to plants and animals associated with mining-related hazardous substances occur within four habitat types.

Riverine habitat includes the wetlands and deepwater habitats within the channels of creeks and rivers of OU2.

Palustrine habitat includes wetlands that are dominated by trees, shrubs, and other persistent emergent wetland plants.

Riparian habitat is terrestrial habitat that is associated with one of the previously mentioned wetland habitats, most often the riverine habitat. It occurs along stream channels and water bodies within OU2.

Upland habitat occurs outside the floodplains of tributaries and the SFCDR within OU2.

Data Gaps

During the development of this revision of the CSM, data gaps that prevented further development of the level of understanding regarding the OU2 environmental system were identified. It is important to note that the level of uncertainty and importance of data gaps associated with this CSM may be significantly different from the acceptable level of uncertainty associated with Phase I remedial action specific assessment and other site activities.

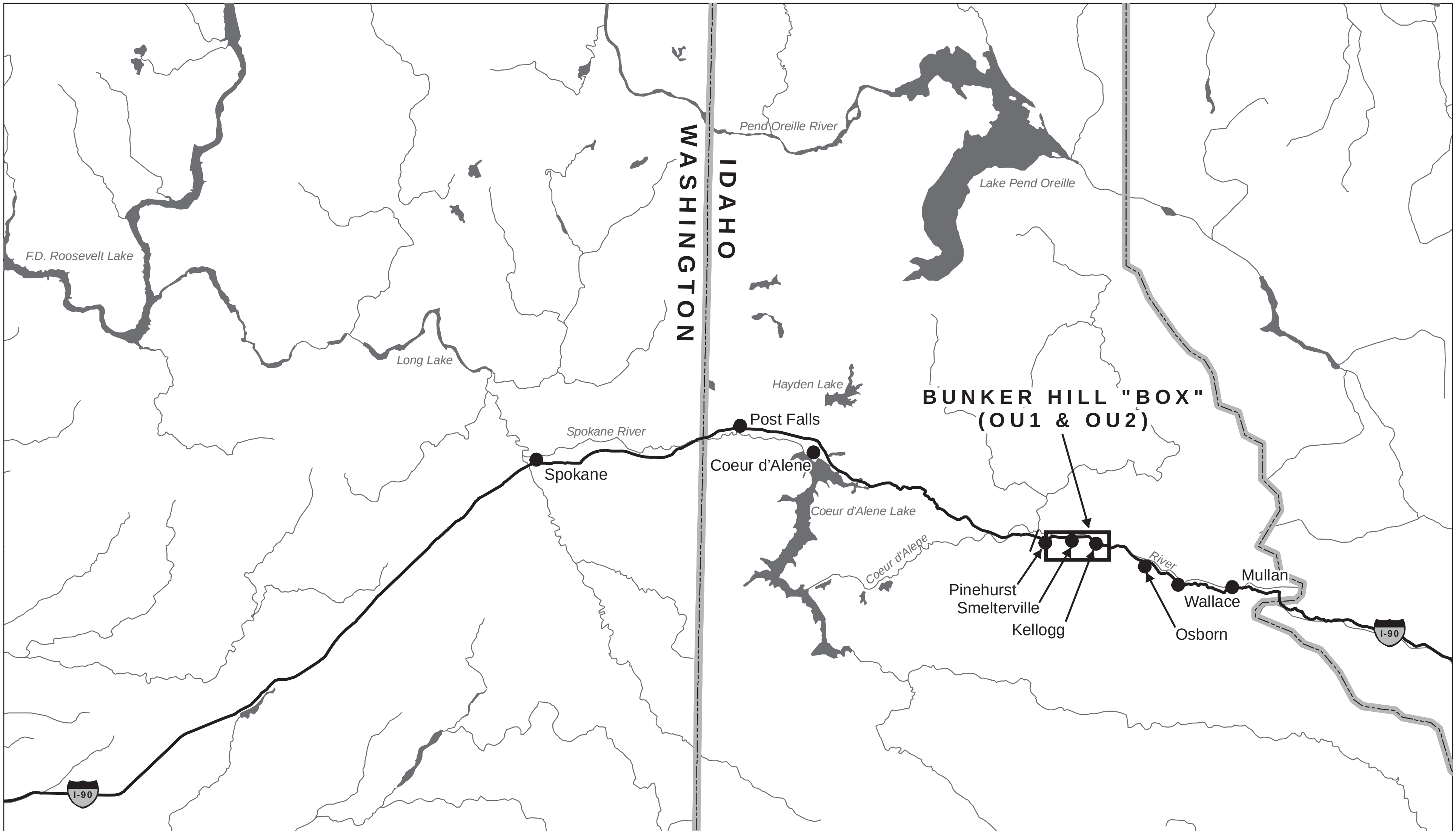
Data gaps identified in this CSM based on the current understanding of the physical setting, contaminant nature and extent, and contaminant fate and transport mechanisms for the environmental system within OU2 are summarized in Table ES-1. The data gaps presented in Table ES-1 are not intended to be exhaustive or complete; rather, the list reflects the limitations of current site knowledge that may inhibit an adequate assessment of recent remedial actions and planning for future cleanup activities. As stated previously, the CSM is intended to be a living document that is updated periodically as new information becomes available.

TABLE ES-1
Data Gaps
Conceptual Site Model
Bunker Hill Superfund Site OU2

Data Gap	Location	Significance
Physical Setting and Processes		
Depth to Bedrock	All of OU2	The depth to bedrock beneath unconsolidated deposits throughout much of the SFCDR valley and tributary valleys is unknown. The bedrock surface may have significant impacts on groundwater flow in the lower aquifer and may effect relationships between the upper and lower aquifers.
Confining Unit	Eastern Portion of OU2	The eastern extent of the confining unit is assumed to be between Transect 2 and well BH-SF-E-0201. The actual location of the eastern boundary of the confining unit is not known with great certainty. Identifying the location would allow for a better understanding of contaminant transport from sources upstream of this location.
Confining Unit	All of OU2	The thickness of the confining unit could act as a control on groundwater flow in the upper and lower aquifers and interaction between the two aquifers. The confining unit is assumed to be continuous throughout the western portion of OU2. The top elevation of the confining unit could dictate groundwater flow and contaminant transport in the upper aquifer and surface water/groundwater interaction.
Subsurface Geology	All of OU2	Geologic cross-sections have been developed in the more data rich areas within OU2 (e.g., at and near groundwater transects). Even in these relatively data rich areas, information is spatially limited and requires the development of generalized cross-sections limited to three units. Potential correlations between data points indicating other possible relationships cannot be verified at this scale.
Subsurface Geology	Eastern Portion of OU2	The subsurface geology of OU2 beneath the populated areas is poorly understood due to a lack of site-specific data. The occurence and behavior of groundwater in this area cannot be refined without additional information.
Subsurface Geology	Tributary Mouths	The geology within and at the mouths of tributary gulches at their connection with the main SFCDR valley is only partially defined at Government Gulch. Limited subsurface information is available for other gulches.The interaction of the main valley aquifer system with tributary groundwater systems may have a significant impact on contaminant fate and transport within these areas.
Historic SFCDR Channel	All of OU2	The impacts of the pre-1900s SFCDR channel and other paleochannels of the SFCDR on groundwater flow in the upper aquifer throughout OU2 is poorly understood due to the minimal number of monitoring wells that intercept the historic channel.
Tributary Discharge	All Tributaries	With the exception of Pine, Government, and Deadwood creeks, continuous discharge data to develop hydrographs are not available. Development of hydrographs for other major tributaries within OU2 is critical to the evaluation of tributary surface water systems within OU2.
Tributary/Groundwater Interaction	All Tributaries	Interactions between tributaries and their upland tributary aquifers has not been evaluated. The interaction between tributaries and the upper aquifer as the tributaries traverse the valley floor has only been partially evaluated.
Production Wells	All of OU2	Large-diameter production wells that penetrate the confining unit between the upper and lower aquifers. The effects of these wells with respect to potential vertical leakage they may cause is not well understood.
Groundwater Flow Paths	All of OU2	Groundwater elevation data throughout OU2 is limited by the number and density of groundwater monitoring wells. The spatial distribution of these wells precludes the refinement of groundwater flow pathways and therefore contaminant migration pathways throughout much of OU2.

TABLE ES-1
Data Gaps
Conceptual Site Model
Bunker Hill Superfund Site OU2

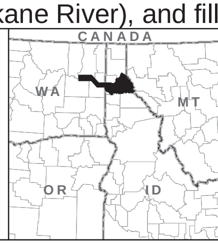
Data Gap	Location	Significance
Physical Setting and Processes		
Vertical Head Differences	Pinehurst Narrows	The presence of a downward vertical gradient between the upper and lower aquifers at Pinehurst Narrows is unexpected and not understood. This downward vertical gradient suggests the presence of a control on groundwater flow in this area that has not been identified.
Gaining and Losing Reaches of the SFCDR	All of OU2	Gaining and losing reaches of the SFCDR are only understood under base flow conditions. It would be expected that the boundaries of gaining and losing reaches would shift in response to different stream stages and groundwater elevations.
Nature and Extent of Contamination		
Extent of Tailings	All of OU2	The vertical and horizontal extent of tailings and tailings/alluvium mixtures within OU2 has not been fully defined. The lack of vertical extent information prohibits a full evaluation and characterization of contaminant release mechanisms that may be potentially acting on these source materials (e.g., groundwater elevation fluctuations, infiltration of surface water)
Groundwater Fluctuations	All of OU2	The potential for groundwater table fluctuations to act as a significant release mechanism for contaminants is poorly understood.
Phase I Remedial Actions	All of OU2	Full characterization of the nature and extent of Phase I remedial actions are in the process of being refined. Information regarding the horizontal and vertical extent of contaminated material removals and the amount and depth of contamination that may have been left behind are critical to refine the understanding of contaminant sources, release mechanisms, and fate and transport within OU2.
Dishcarge from Mine Workings	All of OU2	The location, quantity, and quality of water discharging from mine adits within OU2 has not been fully inventoried.
Sediment	SFCDR and Tributary Channels	The quality of sediment in the SFCDR and tributary channels has only been evaluated at the upstream and downstream boundaries of OU2. Sediment quality is also needed to determine the potential impacts of flooding on remediated areas.
Contaminant Fate and Transport		
Groundwater Contribution to the SFCDR	All of OU2	The contribution of contamination to the SFCDR from groundwater within OU2 has only been evaluated under base flow conditions. The effects of different hydrologic conditions on contaminant contributions have not been evaluated.
High discharge	All Tributaries	The effect of elevated discharge on contaminant contributions from tributaries to the SFCDR has not been fully evaluated.
Groundwater Contamination	Western end of OU2	The cause of the relatively smaller MCL exceedence frequencies and contaminant metal concentrations observed in both the upper and lower aquifers at the western end of OU2 with respect to areas upgradient is not understood.
Receptors		
Soil and Sediment Contamination	All of OU2	There is a lack of post-remediation soil and sediment confirmation sampling data within OU2. This lack of data makes it diffucult to evaluate potential impacts to and exposure pathways for receptors within OU2.



NOTE: OU3 consists of mining-contaminated areas in the Coeur d'Alene River corridor outside of OU1 and OU2, primarily adjacent flood-plains, downstream water bodies, tributaries (including Coeur d'Alene Lake and the Spokane River), and fill areas.

Legend

- Operable Units
- Cities
- State Boundaries
- Water Features



N

0 10 20 Miles

FIGURE ES-1
BUNKER HILL MINING AND METALLURGICAL COMPLEX SUPERFUND SITE MAP CONCEPTUAL SITE MODEL
BUNKER HILL SUPERFUND SITE OU2

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Legend

- Approximate Main Valley Alluvial Aquifer
- Approximate Upland Tributary Alluvial Aquifers
- OU2 Boundary
- Transects
- Water Features

N

0 2,500 5,000 Feet

FIGURE ES-2
UPLAND AQUIFER AND ALLUVIAL AQUIFER EXTENT CONCEPTUAL SITE MODEL
BUNKER HILL SUPERFUND SITE OU2

CH2MHILL

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Legend

OU2 Boundary

Water Features

N

0 1,750 3,500 Feet

FIGURE ES-3

OU2 HYDROLOGY CONCEPTUAL SITE MODEL

BUNKER HILL SUPERFUND SITE OU2

CH2MHILL

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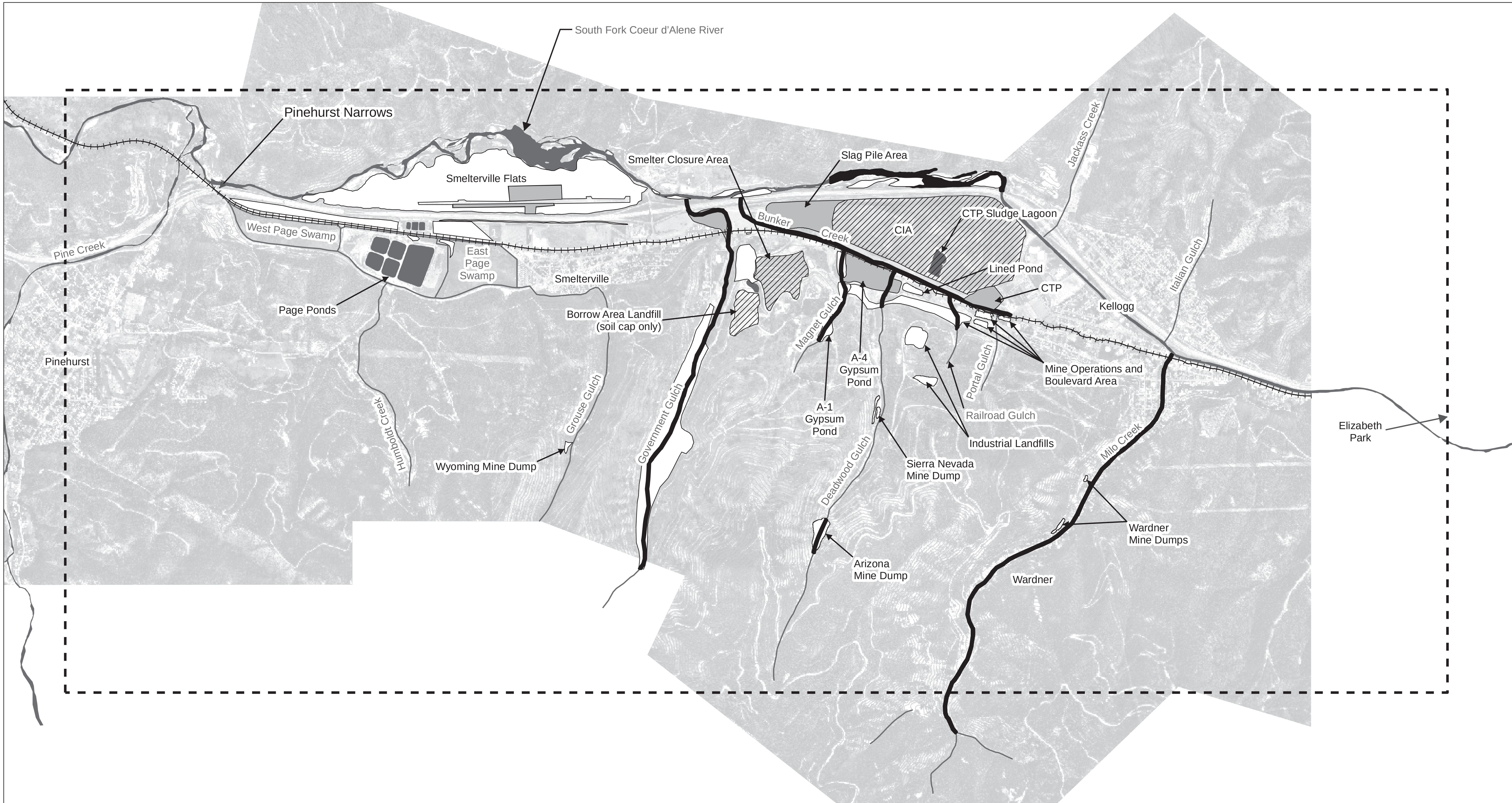

Legend

- Consolidation and Impermeable Capping
- Removal and Capping
- Soil Capping
- Channel Restoration
- OU2 Boundary
- Union Pacific RR Right-of-Way
- Water Features

N

0 2,500 5,000 Feet

FIGURE ES-4
OU2 PHASE I REMEDIAL ACTIONS CONCEPTUAL SITE MODEL
BUNKER HILL SUPERFUND SITE OU2

CH2MHILL

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