Source Areas of Concern Report
Operable Unit 2
Bunker Hill Mining and Metallurgical Complex Superfund Site

Prepared for

U.S. Environmental Protection Agency
Region 10

March 24, 2008

AES10
Architect and Engineering Services Contract
Contract No. 68-S7-04-01

Prepared by

CH2MHILL

Contents

Tables

Figures

Acronyms and Abbreviations

AMD	acid mine drainage
ARARs	applicable or relevant and appropriate requirements
AWQC	Ambient Water Quality Criteria
BEMP	Basin Environmental Monitoring Plan
cfs	cubic feet per second
CIA	Central Impoundment Area
CSM	Conceptual Site Model
CTP	Central Treatment Plant
EMP	Environmental Monitoring Plan
EPA	U.S. Environmental Protection Agency
ICP	Institutional Controls Program
IDEQ	State of Idaho Department of Environmental Quality
INL	Idaho National Laboratory
MCL	Maximum Contaminant Level
mg/L	milligrams per liter
NPDES	National Pollutant Discharge Elimination System
OU	Operable Units
PRP	potentially responsible party
ROD	Record of Decision
SFCDR	South Fork Coeur d’Alene River
USGS	U.S. Geological Survey
WQA	Water Quality Assessment

1.0 Introduction

1.1 Background

The implementation of the selected remedy for Operable Unit 2 (OU2) of the Bunker Hill Mining and Metallurgical Complex Superfund Site identified in the Record of Decision (ROD) for OU2 (EPA, 1992) is being performed by the U.S. Environmental Protection Agency (EPA) and the State of Idaho using a phased approach developed and agreed upon by the EPA and the State of Idaho following the bankruptcy of the major potentially responsible parties (PRPs) for the site in 1994. The phased approach to remedy implementation is detailed in the State Superfund Contract (Idaho Department of Health and Welfare, 1995) and its supporting documents.

Phase I of remedy implementation in OU2 includes extensive source removal and stabilization efforts, all demolition activities, closure of the two primary waste consolidation areas within OU2 (the Smelter Closure Area and the Central Impoundment Area [CIA]), all community development initiatives, development and initiation of an Institutional Controls Program (ICP), future land use development support, and several public health response actions. Phase I also includes additional investigations to provide necessary information to resolve long-term water quality and effluent-limiting performance standards, and development of a defined operations and maintenance and implementation schedule. Interim treatment of contaminated water at the Central Treatment Plant (CTP) is also included in Phase I (EPA, 2005).

Phase II of remedy implementation begins after the completion of Phase I source control and removal activities and evaluation of the effectiveness of these activities in meeting water quality objectives. In Phase II, remedy shortcomings are to be addressed, followed by a coordinated program to address long-term water quality, ecological, and environmental management issues. In addition, the ICP and future development programs will be reevaluated as part of Phase II (EPA, 2005).

In order to facilitate implementation of the phased approach to remediation and to ensure that activities conducted within OU2 are mindful of the activities occurring in OU3, the EPA and State of Idaho initiated the OU2 Water Quality Assessment Team (WQA Team). The WQA Team is comprised of representatives from EPA and the State of Idaho Department of Environmental Quality (IDEQ). The WQA Team developed a work plan (EPA and IDEQ, 2007) to guide their activities. The work plan identifies tasks that need to be accomplished in order to move from Phase I to Phase II of remedy implementation. The major tasks identified in the WQA Team work plan are listed below.

Task 1 – Define the current environmental system and status of OU2 following the implementation of Phase I remedial actions.

Task 2 – Develop methods to evaluate the impacts of Phase I remedial actions and the overall OU2-wide remedy on the environmental system.

Task 3 – Develop and implement the OU2 Environmental Monitoring Plan (OU2 EMP).

Task 4 – Plan for Phase II remedy implementation.

Task 5 – Provide formal documentation for Phase II remedy implementation.

The first three tasks have been completed and are documented in the following documents:

- Task 1 - *Current Status Conceptual Site Model (CSM), Operable Unit 2, Bunker Hill Mining and Metallurgical Complex Superfund Site* prepared for EPA by CH2M HILL (January 2006a)
- Task 2 - *Phase I Remedial Action Characterization Report for the Bunker Hill Mining and Metallurgical Complex, Operable Unit 2* prepared for IDEQ by Terragraphics Environmental Engineering, Inc and Ralston Hydrologic Services (January 2006)
- Task 2 - *Phase I Remedial Action Assessment Report, Operable Unit 2, Bunker Hill Mining and Metallurgical Complex Superfund Site* prepared for EPA by CH2M HILL (October 2007)
- Task 3 - *Environmental Monitoring Plan, Operable Unit 2, Bunker Hill Mining and Metallurgical Complex Superfund Site* prepared for EPA by CH2M HILL (January 2006b)

The WQA Team is currently beginning work on Task 4 of the work plan, which entails planning for Phase II remedy implementation. This document, the OU2 Source Areas of Concern Report, is the first deliverable under Task 4.

1.2 Purpose and Scope

This document identifies contaminant source areas present within OU2 following the implementation of Phase I remedial actions. This document is intended to serve as one of the tools used by decision makers to identify significant source areas of contamination to groundwater and surface water in OU2 and the South Fork Coeur d'Alene River (SFCDR). The findings of this document will be used by decision makers to identify areas for additional data collection, and to consider the need for potential Phase II remedial actions.

In the 1992 OU2 ROD (EPA, 1992), the following OU2-wide remedial action objectives are identified:

- Compliance with ambient water quality criteria (AWQC) in tributaries to the SFCDR within OU2.
- Compliance with maximum contaminant levels (MCLs) in groundwater within OU2.

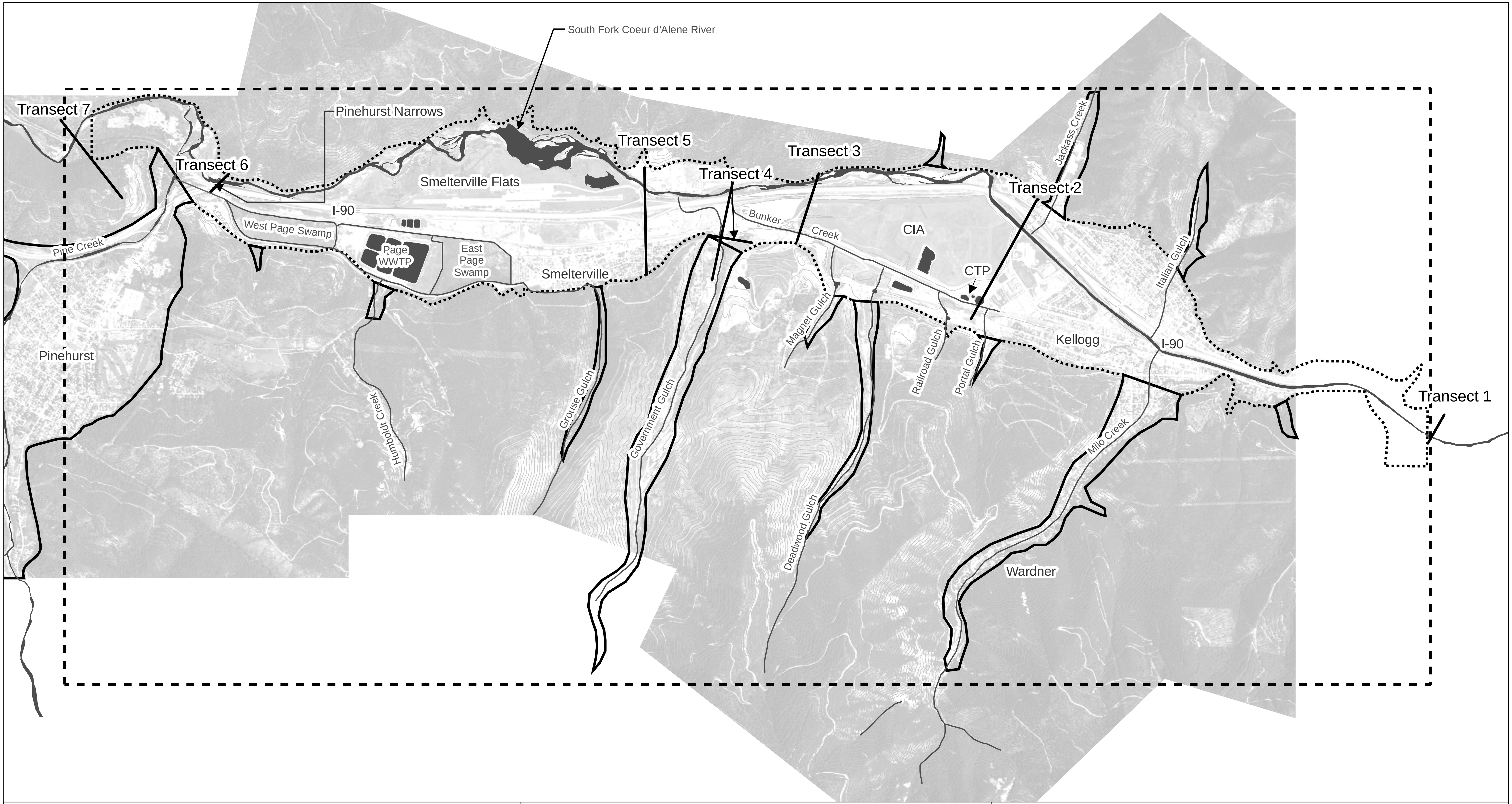
The SFCDR was not included in OU2 because of the large amount of contamination entering OU2 in the SFCDR from upstream sources; therefore, the SFCDR is included in the larger OU3 (Coeur d'Alene Basin or Basin). However, one of the overall goals for remedial actions conducted within OU2 is to protect the SFCDR from AWQC exceedences resulting from OU2 sources (EPA, 1992).

OU2 is a part of the larger Coeur d'Alene Basin, and future decisions regarding the need for potential Phase II remedial actions within OU2 will need to be balanced and considered with respect to the overall goals and objectives for remediation of both OU2 and OU3. For this reason, the identification and ranking of source areas of concern within OU2 presented in this document is based on the relative impact of these source areas on water quality in the SFCDR as it passes through OU2. The SFCDR acts as the integrator for contaminants from the majority of groundwater and surface water sources within OU2. Therefore, the most practical method to identify and rank contaminant sources within OU2 is to evaluate their relative impact on SFCDR water quality. The methods used to perform the identification and ranking of contaminant sources are discussed in Section 2 of this report.

1.3 Document Organization

This document is organized into four sections.

- **Section 1.0 Introduction** – This section identifies the purpose, scope, and organization of this document.
- **Section 2.0 Methodology** – This section presents an overview of the methodology used to evaluate and assess source areas and data gaps and a summary of CSM for OU2.
- **Section 3.0 Source Areas of Concern Data Analysis** – This section presents the analysis of water quality data used to identify source areas of concern within OU2.
- **Section 4.0 Summary and Next Steps** – This section presents a summary of the findings of the source area of concern analysis and identifies the next steps to evaluate potential Phase II remedial actions.



Legend

- ⋯ Approximate Main Valley Alluvial Aquifer
- ▭ Approximate Upland Tributary Alluvial Aquifers
- ╌ OU2 Boundary
- ▬ Transects
- — Water Features

N

0 2,500 5,000 Feet

FIGURE 1-1

OU2 SITE MAP

SOURCE AREAS OF CONCERN REPORT

BUNKER HILL SUPERFUND SITE OU2

CH2MHILL

2.0 Methodology

This section presents the parameters evaluated, the data used in the evaluation, the methodology employed to evaluate the relative impact of contaminant sources on SFCDR water quality, and the methodology used to identify data gaps with respect to the identification and delineation of source areas of concern. A brief summary of the OU2 CSM is also presented in this section.

2.1 Parameters Evaluated

The most widespread and highly concentrated contaminants found in sources within OU2 are cadmium, lead, and zinc. Dissolved cadmium and zinc are indicators of groundwater contamination, and surface water contamination under base-flow conditions. Total metals, especially total lead, are indicators of surface water contamination under high-flow conditions (CH2M HILL, 2006b). This document uses dissolved zinc in surface water and groundwater and total lead in surface water as indicators to identify potential source areas resulting in negative impacts on SFCDR water quality within OU2. Potential phosphorous source areas were also evaluated. Dissolved zinc and total lead are contaminants of concern within OU2 (EPA, 1992) and OU3 (EPA, 2002). Although phosphorous is not identified as a contaminant of concern for OU2, it was included in this evaluation because of its relevance to SFCDR water quality in the Coeur d'Alene Basin. Nutrient loading is a concern for the Coeur d'Alene Basin (EPA, 2002); therefore, an evaluation of phosphorous in the SFCDR as it passes through OU2 is included in this document. This evaluation is intended to provide a general picture of potential areas where nutrient loading to the SFCDR may be occurring within OU2.

Applicable or relevant and appropriate requirements (ARARs) for the above-listed metals in groundwater and surface water are listed in Table 2-1.

For the purpose of this document, the AWQC referred to in this document are the SFCDR Sub-Basin Specific Water Qualtiy Criteria (IDAPA 58.01.02.284) developed by the State of Idaho and adopted by the EPA in January 2003. MCLs for groundwater are the federal Safe Drinking Water Act Maximum Contaminant Levels. Although compliance with MCLs is usually measured as total metals, for the purpose of this report and for consistency when comparing groundwater and surface water concentrations, dissolved metals concentrations are presented and compared with MCLs.

Dissolved zinc has been identified as an indicator parameter for dissolved metal contamination in groundwater and in surface water, especially during low flow conditions, within OU2 (CH2M HILL, 2006b) and the Coeur d'Alene Basin (EPA, 2004). Because dissolved zinc is used as an indicator parameter, other dissolved metals were not evaluated in this document. However, further evaluation of other dissolved metals may be warranted pending future investigations of particular source areas, or as additional information becomes available.

Total lead has been identified as an indicator parameter for particulate metal contamination of surface water under high flow conditions within OU2 (CH2M HILL, 2006b) and the Coeur d'Alene Basin (EPA, 2004). Similar to dissolved zinc, total lead is the only total metal evaluated in this document and further evaluation of other total metals may be warranted pending the results of future investigations.

As noted earlier, phosphorous is not included as a contaminant of concern within OU2. However, because of its identification as a contaminant of concern for OU3, and its negative impacts to Lake Coeur d'Alene and downgradient into Washington State, it has been evaluated in this document to the extent that data are available.

2.2 Data Used in this Evaluation

Source areas within OU2 were identified by reviewing water quality data collected from groundwater and surface water monitoring locations within OU2 and the SFCDR between 2006 and 2007. The data collected between 2006 and 2007 were selected because they represent the most current conditions, and they coincide with the initiation of sampling at all four SFCDR Basin Environmental Monitoring Plan (BEMP) (EPA, 2004) monitoring locations within OU2. The BEMP monitoring locations on the SFCDR within OU2 are shown in Figure 2-1. In addition to the BEMP monitoring locations, low-flow groundwater/surface water interaction monitoring is conducted on the SFCDR within OU2 during the late summer base-flow time period as part of the OU2 EMP. The low-flow groundwater/surface water interaction monitoring locations are also shown on Figure 2-1. Groundwater monitoring in OU2 occurs on a semi-annual basis at the majority of shallow groundwater monitoring wells. Several OU2 tributary surface water monitoring locations are also monitored on a semi-annual basis. The semi-annual sampling events are conducted during the spring high-flow and late summer base-flow time periods. These data were incorporated into this evaluation to assist in the delineation of source areas of concern.

Available monitoring data used in this document are summarized in Table 2-2 and Figure 2-2. Data are available from a total of 11 monitoring events for the BEMP SFCDR monitoring locations under differing flow conditions between 2006 and 2007. In addition to the BEMP data, four of these monitoring events include data for surface water and/or groundwater within OU2. Low-flow monitoring data collected in October 2003 are also included inthis evaluation. These data represent a significant source of data that are useful in evaluating water quality under low-flow conditions.

Available data were subdivided based on flow tiers determined from SFCDR discharge recorded at Pinehurst (SF-271). This allows the data to be evaluated based on flow conditions that affect the release and transport of contaminants. As noted earlier, under low-flow conditions, dissolved metals are the major contaminant of concern, while under high-flow conditions, total metals are the major contaminant of concern. Of the 12 monitoring events, three monitoring event was conducted at low-flow conditions (less than 25th percentile flow tier), three were conducted at below normal (between 25th and 50th percentile flow tier), two were conducted at above normal (between 50th and 75th percentile flow tier), and four were conducted at high-flow conditions (greater than 75th percentile flow tier), with two of the four collected at discharges above the 90th percentile flow tier.

2.3 Summary of the OU2 Physical Setting

This section provides a brief summary of the groundwater and surface water systems within OU2. A more detailed discussion of the physical setting of OU2 is available in the OU2 CSM (CH2M HILL, 2006a). Contaminant release and transport mechanisms are also provided in this section.

2.3.1 Groundwater

Groundwater within OU2 occurs in both the main valley and upland tributary valleys. 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. Figures 3-1 and 3-5 in Section 3.0 show interpreted groundwater contours and flow directions for the October 2006 low flow (less than 25th percentile) and the March 2007 high flow (greater than 75th percentile) monitoring events.

Upland Tributary Groundwater Systems – The upland tributary groundwater systems are located in the hillsides and 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.

2.3.2 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. Gaining and losing reaches of the SFCDR are further discussed in Section 3.0.

Tributaries to the SFCDR within OU2 are shown in Figure 2-1. 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 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.

2.3.3 Contaminant Release Mechanisms

The mechanisms that result in the release of contaminants from sources within OU2 are not well understood. Recent work completed by the Idaho National Laboratory (INL) in Canyon Creek (INL, 2007) regarding mechanisms of release from sources within Canyon Creek to groundwater and surface water are summarized by Johnson (2008) in Appendix A. Overall, it appears that approximately 40 percent of the metals in contaminant sources located within the Canyon Creek valley floor were in the fraction that was easily leachable by water and a weak acid of pH 5. Another 40 percent of the metals were associated with metal hydrous oxide compounds and organic matter that were leachable under more acidic conditions. The remaining 20 percent of metals were contained in difficult to leach sulfide or other residual minerals.

The contaminant sources and water quality conditions in Canyon Creek are somewhat similar to conditions observed within OU2. Therefore, the release of contaminants from OU2 source materials would be expected to be similar to those observed for source materials in Canyon Creek. Therefore, the major contaminant release mechanism in OU2 would appear to be the result of desorption of the very easily leachable fraction followed by desorption of metals from the various metal hydrous oxide compounds and organic matter.

In order for desorption to occur, water must come into contact source materials. The movement of water through source materials results in the release of dissolved metals to groundwater and surface water. 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

The infiltration of precipitation and surface water through contaminant source within is likely the predominant mechanism by which contaminants are released from sources to the groundwater and surface water systems within OU2.

2.3.4 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.

2.4 Source Area Identification

The SFCDR is considered to be the integrator of the bulk of contamination from sources within OU2. All tributaries within OU2 eventually discharge to the SFCDR, and the shallow groundwater system within OU2 is highly interconnected with the SFCDR. The interaction of surface water and groundwater within OU2 represents a major contaminant release and transport mechanism within both OU2 and the Coeur d'Alene Basin.

SFCDR and tributary surface water quality and discharge data and corresponding groundwater quality and elevation data were evaluated to identify source areas in OU2 that affect SFCDR water quality. Previous evaluations of water quality in the SFCDR have focused on annual averages and changes in those annual averages between monitoring locations to identify the relative impact of contaminant sources. The use of annual averages may not be the most appropriate method for evaluating the potential impact of sources of contamination within OU2 on SFCDR water quality because the release and transport of contaminants from sources to groundwater and surface water change in response to climatic, discharge, and groundwater elevation conditions.

In this report, source areas were identified by evaluating changes in SFCDR water quality and discharge between monitoring locations for synoptic sampling events conducted under different discharge conditions. For each monitoring event, SFCDR water quality data collected at each monitoring location were tabulated and compared between upstream and downstream locations to determine changes in discharge, concentration, load, and AWQC ratio (dissolved zinc only). Although each of these represent important information by themselves, it is critical they all be taken into account to determine the location of source areas and their relative impact on SFCDR water quality.

Discharge data collected at SFCDR monitoring locations coupled with valley morphology allow for the identification of gaining and losing reaches of the SFCDR as it passes through OU2 (see Figure 2-1). The locations of gaining and losing reaches of the SFCDR, tributary inflows, and estimated groundwater flow pathways provide the basis for identifying the location of potential source areas within OU2.

Increases in concentrations between SFCDR monitoring locations indicate the presence of a source of contamination. However, increases in contaminant concentrations can be masked by dilution from the input of relatively clean water sources. In general, dissolved and total metal concentrations are related to discharge (EPA, 2004). Dissolved metal concentrations are generally higher under low-flow conditions and lower under high-flow conditions. Total metals (particularly lead) are generally greater under high-flow conditions.

Changes in contaminant loading between monitoring locations are driven by changes in both discharge and concentration. Similar to increases and decreases in concentration, changes in loading can also be misleading when evaluated alone. This is a result of loading being a function of both discharge and concentration. A significant increase in loading can be the result of a large increase in discharge with a relatively low concentration, or a small increase in discharge with a relatively high concentration. The root cause of the loading increase (discharge or concentration) must be understood in order to determine if it is the result of a high concentration contaminant source or an input of relatively clean discharge.

Similar to the relationship between discharge and metal concentration, hardness is also controlled to a degree by discharge conditions. This is important because the AWQC for dissolved cadmium, dissolved lead, and dissolved zinc are hardness-dependant. Therefore, AWQC ratios (measured concentration divided by the hardness-dependant AWQC) are evaluated between monitoring locations. The comparison of AWQC ratios removes much of the variability associated with dissolved metal concentrations under differing flow conditions and also allows for a representative evaluation of changes in surface water quality between monitoring locations. This evaluation is limited in areas where inputs of high hardness water (CTP effluent at Bunker Creek) occur, and these areas must be accounted for in the evaluation to ensure that the presence of a potential source is not masked by AWQC ratio improvements.

Following the evaluation of SFCDR water quality and quantity data, areas where discernible changes in water quality occurred in the SFCDR were identified. Within these areas, potential sources of contamination were identified and quantified to the extent practicable using water quality data collected from tributaries and groundwater within OU2 by tracking contamination upstream/upgradient. Using this process, source areas within OU2 were identified and categorized based on their relative impact on SFCDR water quality.

2.5 Data Gap Identification

During the evaluation and identification of source areas within OU2, data gaps were identified with respect to the delineation of the location, relative impact, and/or characteristics of source areas. These data gaps have been identified in this report to the extent practicable for each potential source area identified. These data gaps should not be considered an exhaustive list of data needs for each source area. The identification and prioritization of data needs for a particular source area will be driven by data needs identified as each source area is further evaluated against remedial technologies, and priorities for potential Phase II remedial actions are refined.

TABLE 2-1

OU2 Groundwater and Surface Water ARARs

Source Areas of Concern Report

Bunker Hill Superfund Site OU2

Groundwater

Metal	**Maximum Contaminant Level (µg/L)[a]**
Arsenic	10[b]
Cadmium	5
Lead	15
Zinc	5,000[c]

Surface Water

Metal	**National Ambient Water Quality Criteria (µg/L)[d]**
Arsenic	0.018

Hardness Dependent Surface Water ARARs (µg/L)

	EPA-Approved Idaho Water Quality Standards[e]						**Idaho Site-Specific Criteria[f]**						**National Ambient Water Quality Criteria[d]**					
Metal	**Acute**			**Chronic**			**Acute**			**Chronic**			**Acute**			**Chronic**		
Hardness	**30**	**50**	**100**	**30**	**50**	**100**	**30**	**50**	**100**	**30**	**50**	**100**	**30**	**50**	**100**	**30**	**50**	**100**
Cadmium	1.0	1.7	3.7	0.42	0.62	1.0	0.61	1.0	2.1	0.42	0.62	1.0	0.62	1.0	2.0	0.11	0.15	0.25
Lead	17	30	65	0.66	1.2	2.5	80	129	248	9.1	15	28	17	30	65	0.66	1.2	2.5
Zinc	41	64	114	38	58	105	88	123	195	88	123	195	42	65	117	43	66	118

a/ Safe Drinking Water Act Maximum Contaminant Level (MCL).

b/ Arsenic MCL revised from 50 µg/L to 10 µg/L on January 22, 2002 (66 CFR 7061).

c/ Secondary MCL

d/ National Ambient Water Quality Criteria are from the National Toxics Rule 40 CFR 131.36.

e/ EPA-approved Idaho Water Quality Standards, IDAPA 58.01.02.210, as submitted by Idaho to EPA on May 30, 2000.

f/ Idaho site-specific criteria for SFCDR Sub-Basin (IDAPA 58.01.02.284).

g/ Hardness in milligrams of calcium carbonate per liter (mgCaCO3/L). Maximum hardness allowed for calculation of criteria is 400 mg/L.

Equations used to calculate water quality standards and criteria

Metal	**Acute Criteria Equation**	**Chronic Criteria Equation**
Cadmium (EPA-Approved State Standard)	{1.136672-(ln(H)*0.041838)}*{exp(1.128*ln(H)-3.828)}	{1.101672-(ln(H)*0.041838)}*{exp(0.7852*ln(H)-3.49)}
Cadmium (Idaho Site-Specific Criteria)	0.973*exp(1.0166*ln(H)-3.924)	{1.101672-(ln(H)*0.041838)}*{exp(0.7852*ln(H)-3.49)}
Cadmium (National AWQC)	{1.136672-(ln(H)*0.041838)}*{exp(1.0166*ln(H)-3.924)}	{1.101672-(ln(H)*0.041838)}*{exp(0.7409*ln(H)-4.719)}
Lead (EPA-Approved State and National AWQC)	{1.46203-(ln(H)*0.145712)}*{exp(1.273*ln(H)-1.46)}	{1.46203-ln(H)*0.145712)}*{exp(1.273*ln(H)-4.705)}
Lead (Idaho Site-Specific Criteria)	exp(0.9402*ln(H)+1.1834)	exp(0.9402*ln(H)-0.9875)
Zinc (EPA-Approved State Standard)	0.978*exp(0.8473*ln(H)+0.8604)	0.986*exp(0.8473*ln(H)+0.7614)
Zinc (Idaho Site-Specific Criteria)	exp(0.6624*ln(H)+2.2235)	Same as acute
Zinc (National AWQC)	0.978*exp(0.8473*ln(H)+0.884)	0.986*exp(0.8473*ln(H)+0.884)

TABLE 2-2

Summary of 2006 and 2007 Monitoring Data

Source Areas of Concern Report

Bunker Hill Superfund Site OU2

Monitoring Event	SFCDR Flow Tier (Percentile)	BEMP Monitoring Data	SFCDR Low Flow Monitoring Data	SFCDR Tributary Monitoring Data[1]	Groundwater Monitoring Data
Oct-03	<25	X	X	X	X
Jan-06	50 to 75	X	--	X	X
Feb-06	25 to 50	X	--	--	--
Apr-06	>75	X	--	X	X
May-06	>75*	X	--	--	--
Jun-06	50 to 75	X	--	--	--
Jul-06	25 to 50	X	--	--	--
Aug-06	<25	X	--	--	--
Oct-06	<25	X	X	X	X
Nov-06	>75	X	--	--	--
Feb-07	25 to 50	X	--	--	--
Mar-07	>75*	X	--	X	X

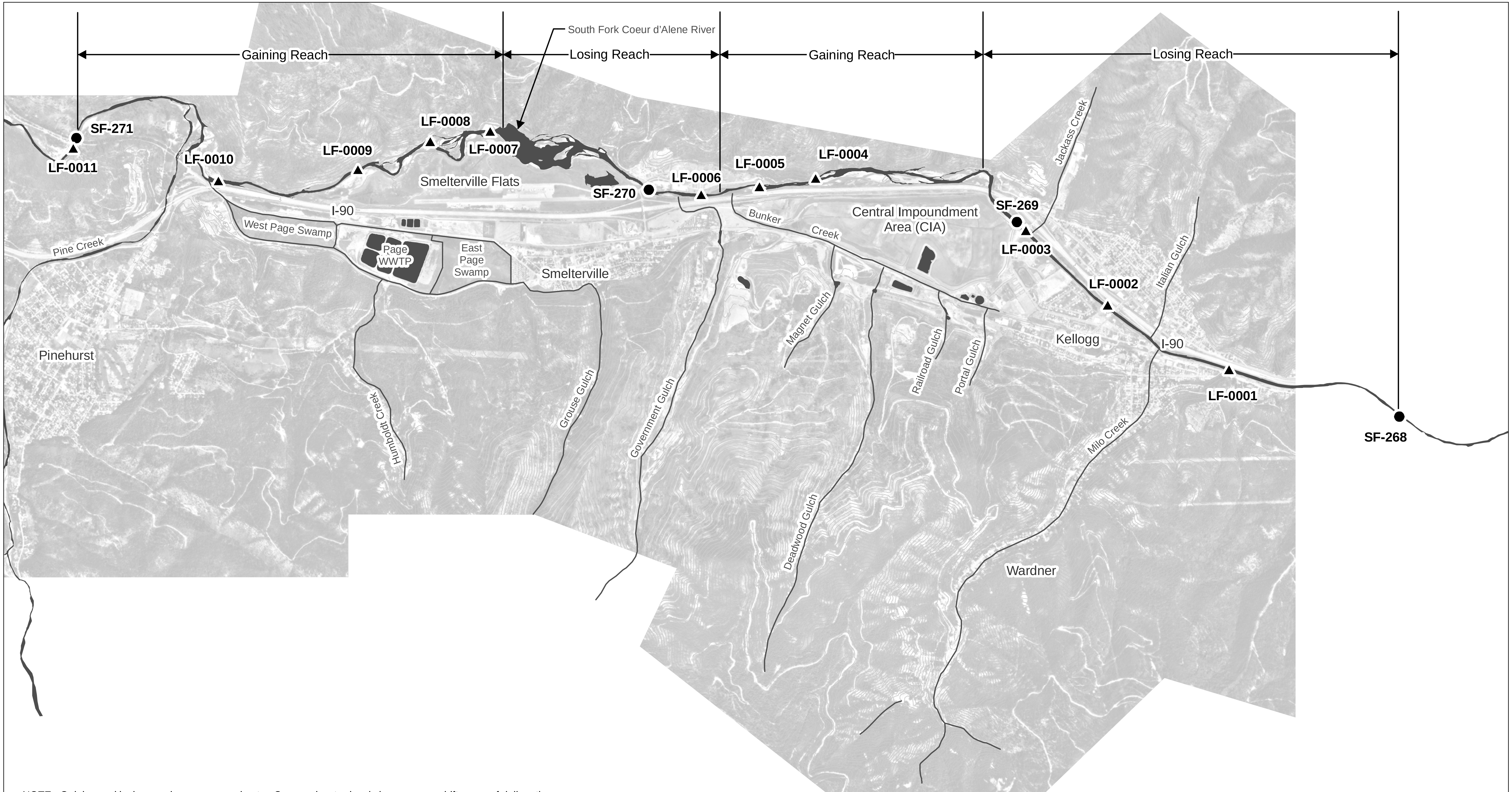
Notes:

-- = Not sampled, not measured, or insufficient data.

>75* = Discharge greater than 90th percentile.

X = Data available for listed monitoring event.

[1] Data are incomplete for the January and April 2006 monitoring events.



NOTE: Gaining and losing reaches are approximate. Seasonal water level changes may shift areas of delineation.

Legend

▲ OU2 EMP Groundwater\Surface Water Interaction Monitoring Location ("BH-SF-" has been truncated from BH-SF-LF-00XX locations)

● BEMP Surface Water Monitoring Locations

N

0 2,500 5,000 Feet

FIGURE 2-1

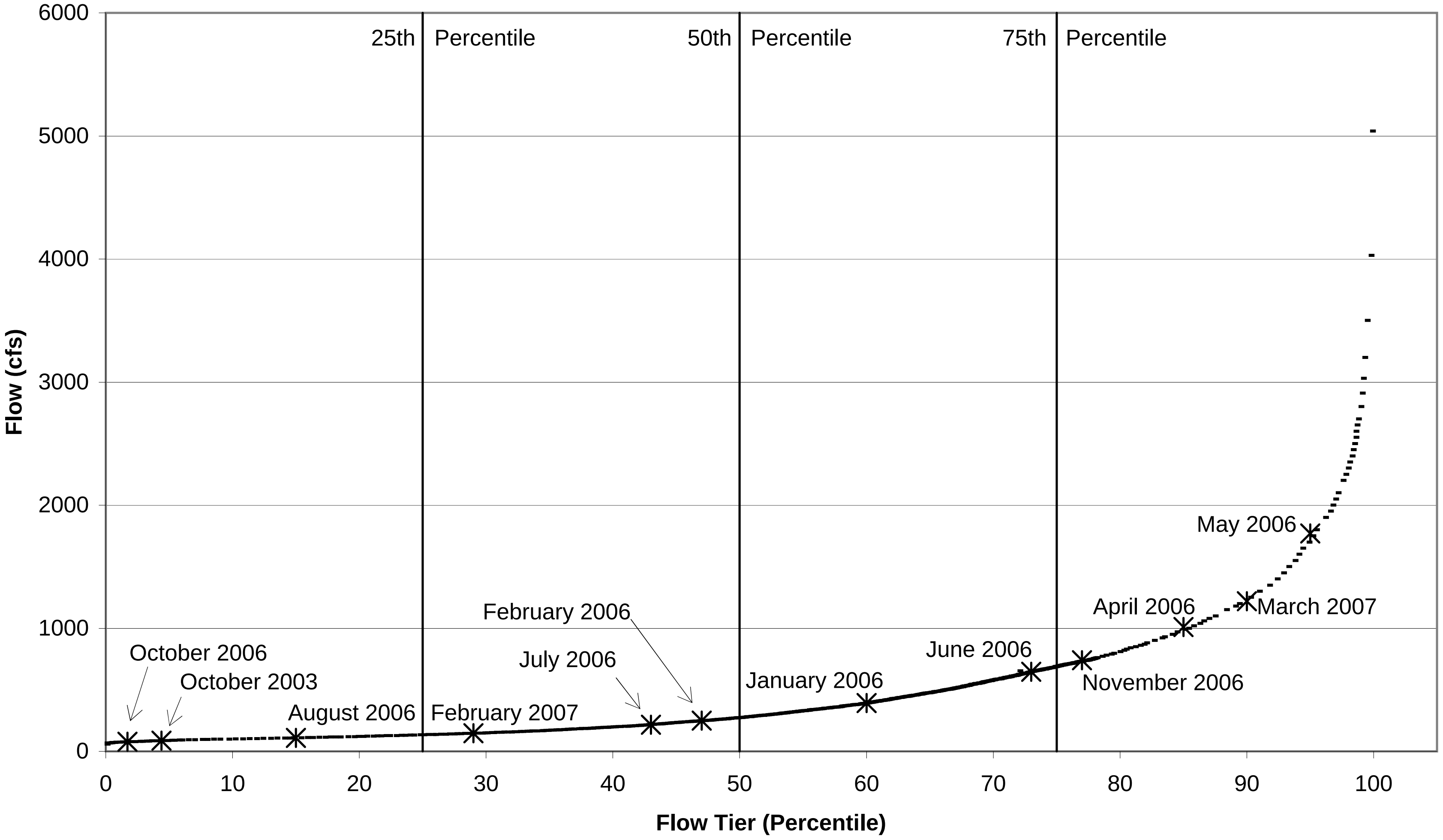
SFCDR SURFACE WATER MONITORING LOCATIONS

SOURCE AREAS OF CONCERN REPORT

BUNKER HILL SUPERFUND SITE OU2

CH2MHILL

Figure 2-2
SFCDR Discharge Curve at SF-271: 1987 - 2007
Source Areas of Concern Report
Bunker Hill Superfund Site OU2



3.0 Source Areas of Concern Data Analysis

This section presents the analysis of water quality data collected in OU2 and from the SFCDR between 2006 and 2007 performed to evaluate potential source areas of concern with regard to SFCDR water quality. The analysis is presented for each parameter (dissolved zinc, total lead, and phosphorous) under different flow conditions. At the end of each parameter-specific section, potential source areas are categorized and prioritized based on available information, and data gaps are identified.

3.1 Dissolved Zinc

This section presents an analysis of potential sources of dissolved zinc contamination to the SFCDR within OU2 under different flow conditions. The dissolved zinc data set used in this report is far more comprehensive than the total lead and phosphorous data sets. Therefore, the discussion of potential sources of dissolved zinc contamination is more detailed than for other parameters discussed in this report.

3.1.1 Less than 25th Percentile Flow Tier

For the 2006 to 2007 time period, two sampling events (August 2006 and October 2006) were conducted when flow conditions in the SFCDR measured at Pinehurst (SF-271) were below the 25th percentile for the period of record (1987 to present). In August 2006 and October 2006, the U.S. Geological Survey (USGS) collected samples from the SFCDR BEMP monitoring locations (SF-268, SF-269, SF-270, and SF-271). In addition to the BEMP monitoring conducted on the SFCDR, OU2 EMP groundwater/surface water interaction monitoring was also conducted in October 2006 over a 3-day period at locations on the SFCDR and at the mouths of flowing tributaries within OU2. The data from the BEMP and OU2 groundwater surface water interaction monitoring are presented in Table 3-1. Data from the October 2006 monitoring events and groundwater monitoring data collected in October 2006 are shown on Figure 3-1. Dissolved zinc data from OU2 tributary surface water monitoring locations are presented in Table 3-2.

In addition to the 2006 to 2007 time period monitoring data, an additional groundwater/surface water interaction monitoring event was conducted in October 2003 using the same monitoring locations as the OU2 EMP groundwater/surface water interaction monitoring program. The results of the October 2003 groundwater/surface water interaction monitoring event have been included in this report for the basis of comparison of contaminant and hydrologic conditions with the October 2006 monitoring data. As noted in the *Phase I Remedial Action Assessment Report* (CH2M HILL, 2007) changes in contaminant conditions have been occurring over time following the implementation of Phase I remedial actions in OU2. The data from the October 2003 sampling event are presented in Table 3-3. Dissolved zinc loading diagrams for both the October 2003 and October 2006 groundwater/surface water interaction monitoring events are provided in Figure 3-2.

When comparing the BEMP and OU2 EMP groundwater/surface water interaction monitoring data, it is important to note that the BEMP monitoring data represent a single measurement and the OU2 EMP groundwater/surface water interaction data are presented as the average of three measurements collected over three consecutive days.

SF-268 to SF-269

Under low-flow conditions, the SFCDR is believed to be a losing stream between SF-268 and SF-269. Losing conditions are believed to continue downstream of SF-269, but the full extent of the losing reach of the SFCDR to the west has not been fully delineated.

For the August 2006 and October 2006 monitoring events, discharge measurements increased by 2 cubic feet per second (cfs) and 3 cfs, respectively, between stations SF-268 and SF-269. These data indicate that the SFCDR was actually gaining between these locations. Subtracting the October 2006 gain in discharge associated with the input of Milo Creek between these locations (3 cfs) results in no net gain or loss of discharge. Tributary data were not collected during August 2006.

It is important to note that the measurement error associated with discharge measurements is typically on the order of 8 to 10 percent (Buchannon and Somers, 1969). The measurement error under low-flow conditions in this area of the SFCDR is likely greater than this as a result of SFCDR channel conditions (large cobbles) and relatively shallow flow depths.

Between SF-268 and SF-269, there are four tributaries to the SFCDR. Italian Gulch and Jackass Creek located to the north of the SFCDR were dry during the October 2006 sampling event. Milo Creek was discharging approximately 3 cfs to the SFCDR. Montgomery Creek is located on the north side of the SFCDR near SF-268. Montgomery Creek is not monitored, and it is unknown if it was discharging to the SFCDR in October 2006.

Review of BEMP SFCDR water quality data collected at SF-268 and SF-269 in comparison to OU2 EMP groundwater/surface water interaction data collected in the SFCDR at BH-SF-LF-0001, BH-SF-LF-0002, and BH-SF-LF-0003 shows that dissolved zinc concentrations were typically higher for the BEMP samples than for the OU2 groundwater/surface water interaction samples. The differences in concentrations between the sampling events may be the result of diel changes in water quality (diel = a 24-hour period that includes a day and the adjoining night). Diel changes in dissolved metal concentrations appear to be caused primarily by natural changes in temperature, pH, oxidation reduction potential, and photosynthetic processes in the streambed environment that affect in-stream geochemical conditions in the SFCDR system (Nimick et. al, 2003). Diel changes were further evaluated in Canyon Creek (CH2M HILL, 2007). The results of the diel evaluations performed by Nimick and others (2003) and CH2M HILL (2007) show that dissolved zinc concentrations are typically greater in the early morning hours and decrease throughout the day. Dissolved zinc concentrations in the SFCDR fluctuated by 58 percent (Nimick et. al, 2003).

BEMP monitoring conducted at the SF-268 and SF-269 stations occurred during the early portion of the day, while sampling of the OU2 EMP groundwater/surface water interaction monitoring locations occurred during the later part of the day during each of the three days that sampling was conducted. Therefore, it is possible that diel changes are responsible for the difference in dissolved metal concentrations. By comparison, BEMP monitoring of stations SF-270 and SF-271 occurred during roughly the same times of the day as OU2 EMP groundwater/surface water interaction monitoring in this area, and dissolved zinc concentrations at these locations are much more similar to each other.

In October 2006, the dissolved zinc concentration at SF-268 was 0.924-milligram per liter (mg/L). This is higher than dissolved zinc concentrations measured in monitoring wells located at nearby groundwater monitoring Transect 1 (see Figure 3-1), which ranged from 0.0113 mg/L and 0.187 mg/L.

Between SF-268 and downstream monitoring location BH-SF-LF-0001, a decrease in discharge and dissolved zinc concentration was measured. As noted earlier, the difference in dissolved zinc concentrations between SF-268 and BH-SF-LF-0001 may be a result of diel changes in concentration.

In October 2003, discharge between BH-SF-LF-0001 and BH-SF-LF-0002 was approximately 74 cfs at both locations. Italian Gulch and Milo Creek discharge to the SFCDR between these locations. In October 2003, Italian Gulch was dry and Milo Gulch was discharging approximately 2.3 cfs at a dissolved zinc concentration of 1.05 mg/L. The input of discharge and dissolved zinc concentration from Milo Creek to the SFCDR would be expected to increase the 74 cfs discharge and 0.771 mg/L dissolved zinc concentration measured at BH-SF-LF-0001 to 76 cfs discharge and a dissolved zinc concentration of 0.779 mg/L. This is a greater discharge and lower dissolved zinc concentration than measured downstream at BH-SF-LF-0002 (74 cfs and 0.769 mg/L).

In October 2006, dissolved zinc concentrations and discharge increased between BH-SF-LF-0001 and BH-SF-LF-0002. During this time, Italian Gulch was dry and Milo Gulch was discharging approximately 3 cfs to the SFCDR at a dissolved zinc concentration of 1.271 mg/L. The input of discharge and dissolved zinc concentration from Milo Creek would be expected to increase the 74 cfs and 0.746 mg/L discharge and dissolved zinc concentration observed at BH-SF-LF-0001 to 77 cfs and 0.766 mg/L. This is lower than the 81 cfs and 0.783 mg/L discharge and dissolved zinc concentration measured downstream at BH-SF-LF-0002.

As noted earlier, the error band associated with discharge measurements under low-flow conditions makes it difficult to create a definitive discharge balance. The decrease in dissolved zinc concentrations in October 2003 between BH-SF-LF-0001 and BH-SF-LF-0002 indicates that a potential source of relatively clean discharge may have been present in this area in October 2003. The increase in dissolved zinc concentrations between BH-SF-LF-0001 and BH-SF-LF-0002 observed in October 2006 indicates that there are other sources of contamination to the SFCDR in addition to Milo Creek in this area. Potential sources of contamination include riverbed sources of contamination, release of bank storage with elevated metal concentrations, and the potential discharge of groundwater to the SFCDR. However, little data are available to evaluate these potential sources of contamination.

During the October 2003 and October 2006 groundwater/surface water interaction studies, temporary piezometers were advanced into the channel bottom at SFCDR monitoring locations to evaluate head differences between the SFCDR and underlying groundwater. In October 2003, the head difference at BH-SF-LF-0001 was 0.9-foot downward, and at BH-SF-LF-0002 the head difference was 3.2 feet downward. In October 2006, the head difference was 0.013-foot downward at BH-SF-LF-0001, and at BH-SF-LF-0002 the head difference was

0.8-foot downward. This supports the conclusion that the SFCDR is losing to groundwater in this area.

BH-SF-E-0101 is a groundwater monitoring well located between the SFCDR and the mouth of Milo Gulch between BH-SF-LF-0001 and BH-SF-LF-0002 (see Figure 3-1). In October 2003 and October 2006, the dissolved zinc concentration at this monitoring well was 2.37 mg/L and 2.58 mg/L, respectively. These concentrations are higher than dissolved zinc concentrations in groundwater measured upgradient at Transect 1 in October 2006 (no monitoring wells were present at Transect 1 in October 2003). The higher dissolved zinc concentrations at BH-SF-E-0101 are potentially the result of higher concentration groundwater from the Milo Gulch groundwater system and/or increases in contamination in surface water lost from the SFCDR as it infiltrates through contaminated materials.

BH-SF-E-0104 is located in the southern levee of the SFCDR slightly downstream of BH-SF-LF-0002 (BH-SF-E-0104 was installed in September 2006). The dissolved zinc concentration at this location in October 2006 was 8.04 mg/L, higher than upgradient groundwater and SFCDR dissolved zinc concentrations. The elevated dissolved zinc concentration observed in BH-SF-E-0104 is likely the result of surface water infiltrating through contaminated materials.

When attempting to identify sources of contamination and eventual transport pathways, it is important to note that the flow path of the SFCDR within OU2 has been manipulated over time in response to needs for room to accommodate industrial activities, infrastructure, and community development. The evolution of the SFCDR channel over time is shown in Figure 3-3. Over the long period of mining activities, as the SFCDR channel was relocated the abandoned channel was filled with tailings and other mine wastes. In addition, tailings and mine wastes within OU2 and upstream were often disposed of directly in the SFCDR and its tributaries, resulting in widespread contamination of the floodplain throughout the Coeur d'Alene Basin. A significant amount of tailings and other mine wastes were used as fill material for the development of the populated areas within OU2. These materials represent a significant contaminant source throughout OU2 and the Coeur d'Alene Basin. Surface water lost from the SFCDR and other water sources (such as precipitation and snowmelt) infiltrating through these materials would be expected to release contaminants and result in their subsequent transport downgradient in groundwater. In addition, the historical SFCDR channel may act as a preferential flow pathway for shallow groundwater.

The increasing dissolved zinc concentrations in groundwater from upgradient to downgradient in this area suggest that surface water lost from the SFCDR to the underlying groundwater system is infiltrating through contaminated materials and picking up contamination. BH-SF-E-0104 is located near the historical SFCDR channel and elevated dissolved zinc concentrations in this location may be the result of the preferential flow of groundwater and infiltrating surface water through highly contaminated materials that may be present in the historical channel.

In October 2003, discharge remained constant and the dissolved zinc concentration decreased slightly between BH-SF-LF-0002 and BH-SF-LF-0003. In October 2006, discharge and dissolved zinc concentrations decreased between these locations. Dissolved zinc concentrations in groundwater monitoring wells located on the south side of the SFCDR between these locations exhibited decreases during both time periods. However, the dissolved zinc concentration at BH-SF-E-0201 was considerably higher in October 2003 (23.7 mg/L) than it was in October 2006 (5.46 mg/L). The reason for this concentration difference is unknown.

The head difference measured between the SFCDR and groundwater at BH-SF-LF-0003 was 2.8 feet downward in October 2003 and 1.42 feet downward in October 2006. This is a large difference and suggests that a large amount of surface water is being lost to groundwater in this area. Dissolved zinc concentrations in groundwater monitoring wells located to the south and west of BH-SF-LF-0003 are similar to dissolved zinc concentrations measured in the SFCDR. Dissolved zinc concentrations in groundwater increased with their distance downgradient in both October 2003 and October 2006, suggesting that surface water lost from the SFCDR to groundwater begins to pick up contamination from sources as it moves downgradient. In this area, the likely source of contamination is tailings and tailings mixed with alluvium located at depth throughout the floodplain.

At groundwater monitoring Transect 2 (see Figures 3-1) located near SF-269, dissolved zinc concentrations increased from north to south. As noted earlier, this suggests that surface water lost to the groundwater system in this area is picking up additional contamination as it moves downgradient. At the southern end of Transect 2, BH-SF-E-0301-U is located in the vicinity of the historical SFCDR channel. In October 2003, only two groundwater monitoring wells were located to the east of BH-SF-E-0301-U. In October 2006, additional monitoring wells had been installed on the south side of the SFCDR. However, none of the new monitoring wells were located in the west Kellogg area, which would have assisted in delineating upgradient groundwater conditions. Therefore, it is difficult to determine potential sources of contamination that would result in the elevated dissolved zinc concentrations observed at the southern end of Transect 2. Potential sources of contamination upgradient of BH-SF-E-0301-U include the infiltration of water lost from the SFCDR through contaminated materials, as well as the preferential flow of groundwater through contaminated materials used to fill the historical SFCDR channel.

SF-269 to SF-270

The SFCDR transitions from a losing to a gaining stream downstream of SF-269 where the main SFCDR valley begins to narrow. The exact location of the transition between gaining and losing in this area is unknown, but based on inferred groundwater elevation isopleths, the transition zone appears to occur in the vicinity of groundwater monitoring wells BH-SF-E-0317-U and BH-SF-E-0321-U. The SFCDR continues as a gaining stream until it is slightly upstream of SF-270 in the vicinity of BH-SF-LF-0006 where the main SFCDR valley begins to widen (see Figures 3-1).

In October 2006, gains in discharge and dissolved zinc concentration occurred in the SFCDR between SF-269 (80 cfs and 0.884 mg/L) and SF-270 (84 cfs and 1.12 mg/L). Based on these measurements, the input to the SFCDR between these locations was 4 cfs at a dissolved zinc concentration of 5.84 mg/L. Similarly, gains in discharge and dissolved zinc concentrations were measured in the SFCDR between SF-269 and SF-270 during August 2006. The input to the SFCDR between these locations was 5 cfs at a dissolved concentration of 7.47 mg/L.

Between SF-269 and SF-270, the predominant source of contaminant input to the SFCDR is believed to be from shallow aquifer groundwater discharging to the SFCDR. Figure 3-1 shows dissolved zinc concentrations in groundwater in this area during the October 2006 sampling event. An area of elevated dissolved zinc concentrations in groundwater is present in monitoring wells located upgradient of BH-SF-LF-0005 extending to the south and east toward Bunker Creek. Although not shown on this figure, dissolved zinc concentrations in the A-4 Gypsum Pond area located south of BH-SF-E-0410-U exceeded 100 mg/L in the most recent data collected in 2004.

Dissolved zinc AWQC ratios decreased between SF-269 and SF-270 during August 2006 (0.8) and October 2006 (1.1). The decrease in AWQC ratios is most likely the result of the input of high hardness water from Bunker Creek resulting from the discharge of CTP effluent.

Dissolved zinc concentration and discharge increases were measured during October 2003. Concentrations increased from 0.765 mg/L (BH-SF-LF003) to 1.23 mg/L (SF-270). The SFCDR discharge increased by 4 cfs between BH-SF-LF003 (74 cfs) and BH-SF-LF006 (78 cfs). The dissolved zinc AWQC ratio slightly decreased between BH-SF-LF003 (4.97) and SF-270 (4.81). A discussion of potential factors contributing to these differences is provided above.

The presence of elevated dissolved zinc concentrations in groundwater extending south and east of BH-SF-LF-0005 may be attributable to several sources, including the A-4 Gypsum Pond, the historical SFCDR channel, losses of water from Bunker Creek, and tailings located beneath the CIA.

The historical SFCDR channel between SF-269 and SF-270 roughly parallels the current alignment of Bunker Creek along the southern edge of the CIA. After passing the CIA, the historical channel moves north across the valley floor and intersects the current SFCDR channel roughly in the vicinity of BH-SF-LF-0005. The locations of groundwater monitoring wells with dissolved zinc concentrations greater than 20 mg/L in this area roughly follow the historical SFCDR channel pathway. Elevated dissolved zinc concentrations continue to the east of BH-SF-E-0410-U to monitoring well BH-SF-E-0301-U. The A-4 Gypsum Pond, where historically high dissolved zinc concentrations have been observed, is located to the south of BH-SF-E-0410-U.

Under low-flow conditions, the majority of discharge present in Bunker Creek is CTP effluent. Monitoring data collected in October 2006 show large losses of discharge in Bunker Creek as it flows along the southern margin of the CIA, roughly between BH-SF-E-0301-U and BH-SF-E-0427-U. Gains in discharge are measured in Bunker Creek from the southwestern corner of the CIA near BH-SF-E-0427-U to its confluence with the SFCDR.

Clean CTP effluent lost from Bunker Creek likely infiltrates through contaminated materials located below Bunker Creek resulting in the release and transport of contaminants that eventually migrate to the SFCDR. In addition, the losses of discharge from Bunker Creek likely impact the gradient of the underlying water table, creating a steeper gradient toward the SFCDR in this area.

From 2000 through 2006, the median and average dissolved zinc concentrations in CTP effluent have been 0.144 mg/L and 0.289 mg/L. Dissolved zinc concentrations in groundwater monitoring wells located adjacent to the losing portion of Bunker Creek in October 2006 ranged from 10.6 mg/L (BH-SF-E-0320-U) to 22.8 mg/L (BH-SF-E-0410-U). The October 2003 dissolved zinc concentrations were similar for the Bunker Creek wells, where concentrations ranged from 9.06 mg/L (BH-SF-0427-U) to 22.6 mg/L (BH-SF-0320-U).

This suggests that cleaner water lost from Bunker Creek becomes contaminated relatively quickly after coming into contact with source materials. The degree to which the entire increase in concentration is attributable to contaminated materials located beneath Bunker Creek or to upgradient sources of contamination and groundwater cannot be determined with the available data. Additional data regarding potential upgradient sources, groundwater and surface water geochemistry, and contaminant source geochemistry are needed to further evaluate the sources of elevated dissolved zinc concentrations in this vicinity.

Government Creek discharges to the SFCDR between SF-269 and SF-270 immediately downgradient of Bunker Creek. In October 2006, Government Creek discharged 0.7 cfs to the SFCDR at a concentration of 2.54 mg/L. Government Creek itself contributes to metals loading into the SFCDR; however, impacts to the SFCDR from the losing portion of Government Creek as it passes along the valley floor are unknown. In October 2006, Government Creek lost 0.5 cfs (that is, 40% of its total discharge) between stations BH-GG-0001 and BH-GG-0004. This losing discharge may contact contaminated materials and transport dissolved metals to shallow groundwater.

SF-270 to SF-271

The SFCDR between SF-270 and SF-271 contains both gaining and losing reaches. Based on the BEMP and OU2 EMP data, the SFCDR is a losing reach between SF-270 and BH-SF-LF-0007. The SFCDR is a gaining reach between BH-SF-LF-0007 and BH-SF-LF-0010 at Pinehurst Narrows. Between BH-SF-LF-0010 and SF-271/BH-SF-LF-0011, Pine Creek and groundwater from the Pine Creek drainage enter the main SFCDR valley and the SFCDR gains discharge.

In October 2006 a substantial amount of discharge (16 cfs) was lost from the SFCDR to groundwater between SF-270 and BH-SF-LF-0007. Both discharge and dissolved zinc concentrations decreased between these locations. In October 2003, the discharge was not measured at SF-270; however, the discharge decreased 5 cfs between station BH-SF-LF006 and BH-SF-LF007.

Groundwater monitoring data collected in October 2006 are shown on Figure 3-1. Dissolved zinc concentrations between SF-270 and BH-SF-LF-0007 tend to increase with distance downgradient from the SFCDR in the majority of monitoring wells located in this area. It appears that discharge lost from the SFCDR in this area is infiltrating through contaminated materials and picking up contamination. However, the spatial distribution of monitoring wells does not allow for the identification of contaminant source areas or transport pathways. Dissolved zinc concentrations appear to be greater in monitoring wells located near the center of the valley between SF-270 and BH-SF-E-0007 than in those located either near the SFCDR or along the southern margin of the main SFCDR valley in Smelterville. Fewer wells were sampled during the October 2003 groundwater monitoring. Dissolved zinc concentrations in October 2003 are similar to concentrations in the same wells sampled in October 2006. In general, dissolved zinc concentrations in groundwater between SF-270 and BH-SF-LF-0007 are lower than those observed in the eastern portion of OU2. A significant amount of contaminated materials were removed from this area during Phase I remedial action implementation and may account for the lower concentrations in this area.

Between BH-SF-LF-0007 and BH-SF-LF-0010 at Pinehurst Narrows, the SFCDR is gaining discharge from groundwater. The October 2006 dissolved zinc concentrations exhibited a steady increase between BH-SF-LF-0007 (1.03 mg/L) and BH-SF-LF-0010 (1.33 mg/L). Based on discharge and concentration data from these locations, groundwater discharge to the SFCDR in this area is approximately 11 cfs with an average dissolved zinc concentration of 3.18 mg/L.

In October 2003, the discharge and concentration increase was measured between stations BH-SF-LF008 and BH-SF-LF-0010. The dissolved zinc concentration increased from 1.18 mg/L (BH-SF-LF008) to 1.38 mg/L (BH-SF-LF010). Based on discharge and dissolved zinc concentration data from these locations, groundwater discharge to the SFCDR in this area was approximately 11 cfs with an average dissolved zinc concentration of 2.4 mg/L.

In August 2006, the discharge increased in the SFCDR between SF-270 and SF-271, while the dissolved zinc concentration and AWQC ratio decreased. These differences are likely a result of the clean water input from Pine Creek as discussed above. Tributary or OU2 EMP low-flow stations were not sampled during August 2006, resulting in difficult data evaluation and interpretation.

Groundwater monitoring wells are sparsely located in the area between BH-SF-LF-0007 and BH-SF-LF-0010. This prevents the identification of contaminant sources and potential transport pathways in this area. However, potential contaminant sources in this area may include remaining contaminants below the level of Phase I removals or under the existing structures (such as, the Shoshone County Airport and I-90), the Page Ponds area, and upgradient groundwater.

Between BH-SF-LF-0010 and BH-SF-LF-0011/SF-271, the SFCDR gains discharge and dissolved zinc concentrations decrease. Both the gain in discharge and the decrease in dissolved zinc concentration are likely the result of the input of relatively clean water from Pine Creek and groundwater from the Pine Creek drainage. The October 2006 dissolved zinc concentrations decreased from Transect 6 at Pinehurst Narrows (5.42 mg/L at BH-SF-W-0201-U) to Transect 7 at the western OU2 boundary near SF-271. At groundwater monitoring Transect 7, dissolved zinc concentrations are greater in monitoring wells completed on the northern side of the valley (BH-SF-W-0206-U = 1.19 mg/L) than in wells completed on the southern side of the valley (BH-SF-W-0204-U = 0.0283 mg/L). This suggests that cleaner groundwater from the Pine Creek drainage is mixing with more contaminated water from OU2, resulting in higher concentrations farther from the Pine Creek drainage source.

3.1.2 25th to 50th Percentile Flow Tier

For the 2006 to 2007 time period, three BEMP sampling events were conducted when discharge in the SFCDR measured at Pinehurst (SF-271) was between the 25th and 50th percentile. Monitoring data from BEMP and OU2 tributary monitoring locations are summarized in Tables 3-3 and 3-4, respectively. The sampling events occurred in February 2006, July 2006, and February 2007. No OU2 tributary surface water or groundwater data are available for these sampling events.

Both sampling events represent two significantly different times during the water year. August 2006 is during the late summer hydrograph recession when discharges are approaching low-flow conditions. February 2007 is representative of winter base-flow conditions, which are generally higher than the late summer/early fall base flow.

SF-268 to SF-269

In July and February 2007, gains in discharge of 3 cfs and 1 cfs were measured between SF-268 and SF-269, while a discharge loss of 11 cfs was measured in February 2006. These gains in discharge are less than the expected tributary discharge to the SFCDR in this reach from Milo Creek (3 cfs at the less than 25th percentile flow tier). Discharge from Montgomery Creek, Italian Gulch, and Jackass Creek at this time are unknown. Therefore, it is likely that the SFCDR remains a losing reach between SF-268 and SF-269 at the 25th to 50th percentile flow tier.

Dissolved zinc concentrations increased between SF-268 (0.629 mg/L) and SF-269 (0.86 mg/L) in July 2006. The source of the majority of the increase in dissolved zinc concentrations between these locations is likely attributable to discharge from Milo Creek. Also, additional potential sources of contamination similar to those identified for this reach in Section 3.1.1 may also have contributed to the dissolved zinc concentration increase.

In February 2006 and February 2007, dissolved zinc concentrations decreased by 0.13 mg/L and 0.28 mg/L, respectively. The decrease in dissolved zinc concentrations between these locations may be a result of weather conditions in the area. As a result of lower temperatures, it is likely that less infiltration of surface water to the mine workings in Milo Gulch was occurring. Typically, discharge measured in the Bunker Hill Mine workings during the winter are lower than during other times of the year (CH2M HILL, 2001). Therefore, discharge of acid mine drainage (AMD) from the Reed and Russell adits would be expected to be lower as well. A significant reduction in dissolved metal concentrations in Milo Creek discharge coupled with discharge from other clean tributaries (Italian Gulch and Jackass Creek) would be expected to result in a dilution of SFCDR dissolved zinc concentrations. Because discharge and dissolved zinc concentrations are not available for the tributaries during this time, this condition cannot be quantified.

SF-269 to SF-270

Gains in discharge were measured between SF-269 and SF-270 during the three monitoring events and ranged from 2 cfs (February 2007) to 29 cfs (February 2006). Under the less than 25th percentile flow tier, Bunker Creek and Government Creek combined to discharge approximately 4 cfs to the SFCDR in this reach. This indicates that the SFCDR is not gaining or losing a significant amount of discharge between SF-269 and SF-270 during July 2006 and February 2007. However, the SFCDR between SF-269 and SF-270 is known to transition between losing and gaining reaches. Therefore, the gains and losses in discharge measured at these locations are somewhat misleading.

Increases in dissolved zinc concentrations were measured between SF-269 and SF-270 during all three monitoring events. The increases in dissolved zinc concentration are most likely the result of groundwater discharge to the SFCDR between these locations.

Dissolved zinc AWQC ratios between SF-269 and SF-270 increased in February 2006 and February 2007, and did not change in July 2006. Varying AWQC ratios are likely the result of changes to the amount of high hardness discharge from Bunker Creek to the SFCDR. As noted in Section 3.1.1, under low-flow conditions, Bunker Creek discharge is largely the result of effluent discharge from the CTP. The CTP effluent is a high hardness source of water. Discharge from the CTP in the late winter would be expected to be lower than other times of the year because the majority of water sources to the mine workings are sequestered as snowpack in the higher elevations. Therefore, less high hardness water would be expected to reach the SFCDR from the CTP. This reduction in hardness in the SFCDR results in a decrease in the hardness-dependant dissolved zinc AWQC, resulting in higher AWQC ratios in the SFCDR at SF-270 in February 2006 and February 2007.

SF-270 to SF-271

Gains in discharge were measured during the three monitoring events and ranged from 54 cfs (July 2006) to 109 cfs (February 2007) between SF-270 and SF-271. The predominant source for the increases in discharge between these monitoring locations is likely from the relatively large Pine Creek drainage. This is further supported by the reductions in dissolved zinc concentrations between SF-270 and SF-271. Dissolved zinc concentrations in Pine Creek are substantially lower than those in the SFCDR and dissolved zinc concentrations in the SFCDR would be expected to decrease as a result of this input.

The large area between SF-270 and SF-271 coupled with the presence of the relatively large Pine Creek drainage makes the interpretation of dissolved zinc and discharge data for these two locations relatively difficult. In addition, the area between SF-270 and SF-271 includes both gaining and losing reaches of the SFCDR.

3.1.3 50th to 75th Percentile Flow Tier

For the 2006 to 2007 time period, two sampling events were conducted when discharge in the SFCDR measured at Pinehurst (SF-271) was between the 50th and 75th percentile. In January 2006, BEMP and OU2 groundwater and surface water monitoring was conducted. In June 2006 only BEMP monitoring locations were sampled. Monitoring data from BEMP and OU2 tributary monitoring locations are summarized in Tables 3-3 and 3-4, respectively.

It is important to note that during relatively higher discharge conditions (greater than 50th percentile), error associated with discharge measurements increases and therefore conclusions regarding gaining and losing conditions are more difficult to quantify. However, concentrations and AWQC ratio data still provide a method to evaluate changes and impacts to the SFCDR water quality.

SF-268 to SF-269

Between SF-268 and SF-269, discharge increased slightly during the June 2006 monitoring event. The increases in discharge are most likely a result of inputs from tributaries in this area (Montgomery Creek, Milo Creek, Italian Gulch and Jackass Creek). Discharge decreased during the January 2006 (3 cfs) and February 2006 (11 cfs) monitoring events at this location, suggesting the SFCDR at this flow tier is losing between SF-268 and SF-269. Measured tributaries in January 2006 contributed a combined 14.7 cfs into the SFCDR.

In January 2006 and June 2006, dissolved zinc concentrations increased between SF-268 and SF-269 from 0.794 mg/L to 0.839 mg/L and from 0.335 mg/L to 0.346, respectively. Because the SFCDR during this flow tier is losing between SF-268 and SF-269, the gains are likely dependent on tributary influences. Tributary data are only available from January 2006. AWQC ratios also increased and are likely a result of the increase in dissolved zinc concentrations.

During this flow tier, dissolved zinc was detected in shallow groundwater at a concentration of 3.08 mg/L (January 2006) from well BH-SF-E-0101. Potential sources of contamination contributing to dissolved zinc contamination in this well are discussed in Section 3.1.1.

BH-SF-E-0201 is located in the southern bank of the SFCDR near SF-269. The dissolved zinc concentration at this location in January 2006 was 4.5 mg/L. These concentrations are higher than upgradient groundwater and SFCDR dissolved zinc concentrations. The elevated dissolved zinc concentration observed in BH-SF-E-0201 is likely the result of surface water infiltrating through contaminated materials.

SF-269 to SF-270

Discharge increases were measured during the two monitoring events between station SF-269 and SF-270 and ranged from 10 cfs (June 2006) to 54 cfs (January 2006). Bunker Creek and Government Creek discharge to the SFCDR between these locations. During January 2006, these tributaries combined to discharge approximately 17 cfs into the SFCDR. As such, the SFCDR between SF-269 and SF-270 gained approximately 37 cfs from shallow groundwater or other unmeasured surface water sources during January 2006. No tributary data are available for June 2006.

Dissolved zinc concentrations increased during the two monitoring events, ranging from 0.144 mg/L (June 2006) to 0.156 mg/L (January 2006). These increases are most likely the result of groundwater discharge to the SFCDR between these locations.

Dissolved zinc AWQC ratios between SF-269 and SF-270 decreased in January 2006 and increased in June 2006. This is likely the result of changes in discharge input to the SFCDR from Bunker Creek. As noted in Section 3.1.1, under low-flow conditions, Bunker Creek discharge is largely the result of effluent discharge from the CTP, which is a high hardness source of water. The January 2006 AWQC ratio decrease is likely a result of the elevated Bunker Creek discharge (10.63 cfs) into the SFCDR.

January 2006 dissolved zinc concentrations in three wells (BH-SF-E-0315-U, BH-SF-E-0317-U, and BH-SF-E-0318-U) located at the northeast portion of the CIA were below the 5 mg/L MCL. The dissolved zinc concentrations in these wells are likely influenced by the losing discharge from the SFCDR and the relatively short time that infiltrating water is in contact with contaminated materials. Elevated dissolved zinc concentrations were observed in three wells (BH-SF-E-0301-U, BH-SF-E-0305-U, and BH-SF-E-0320-U) located at the southeast portion of the CIA (near Transect 2), and are likely influenced by groundwater in direct contact with contaminated materials. This is supported by the large fluctuations of dissolved zinc concentrations between the low (<25th percentile) and high (>90th percentile) groundwater events. The two wells located at Transect 2 (BH-SF-E-0301-U and BH-SF-E-0305-U) are also likely affected by upgradient factors, which are discussed in Section 3.1.1.

Elevated dissolved zinc concentrations were detected in numerous upper aquifer wells during January 2006 (see Figure 3-4). Concentrations in these wells were higher (near or above 20 mg/L) than concentrations in all other surrounding wells. These wells include BH-SF-E-0409-U, BH-SF-E-423-U, BH-SF-E-0425-U and BH-SF-E-0429-U. The locations of these wells with higher concentrations may be indicative of preferential groundwater flow pathways from one or more source areas and/or groundwater in direct contact with contaminated materials.

Above MCL dissolved zinc concentrations were also observed in numerous wells located in Government Gulch and in wells between Transect 3 and Transect 5 (Figure 3-4). Potential sources of shallow groundwater contamination at these locations are discussed in Section 3.1.1.

SF-270 to SF-271

Discharge gains were measured between monitoring stations SF-270 and SF-271 during the two monitoring events. Discharge gains ranged from 189 cfs (January 2006) to 234 cfs (June 2006). As noted in Section 3.1.1, Pine Creek is the only major surface water input to the SFCDR at this location. Pine Creek discharge was measured only during the January 2006 (PC-339) monitoring event. The discharge measured during this event was 298 cfs, suggesting the SFCDR is losing over 100 cfs between SF-270 and SF-271. PC-339 is located well upstream of the mouth of Pine Creek and above the input of water from West Page to Pine Creek and may not be representative of actual contributions to the SFCDR.

Dissolved zinc concentrations in the SFCDR decreased between SF-270 to SF-271 during January 2006 and June 2006, likely as a result of the input of relatively clean water from Pine Creek. The dissolved zinc AWQC ratio increased during the two events. Significant changes to the AWQC ratio would most likely occur from the gaining reach of the SFCDR in the western portion of Smelterville Flats and influences from Pine Creek. Any impact to the SFCDR in this location is unknown because of insufficient data from directly upgradient of the Pine Creek tributary.

Elevated dissolved zinc concentrations were present in several upper aquifer wells throughout Smelterville Flats during the January 2006 monitoring event. Dissolved zinc concentrations in wells located on Transect 5 (BH-SF-W-0001-U and BH-SF-W-0003-U) exceeded the 5 mg/L MCL, indicating upgradient sources may be causing these elevated concentrations. In the eastern portion of Smelterville Flats, the SFCDR is a losing reach. Dissolved zinc concentrations in monitoring wells in this area increase with increasing distance from the SFCDR. This suggests that water lost from the SFCDR continues to pick up contamination as it moves through the groundwater system. Contaminated groundwater upgradient of Transect 5 may also contribute to elevated dissolved zinc in these wells. In the western portion of Smelterville Flats and Page Ponds, above MCL dissolved zinc concentrations were observed in wells BH-SF-W-0104-U, BH-SF-W-0111-U, and BH-SF-W-0119-U. Dissolved zinc concentrations just below the MCL occurred in wells BH-SF-W-0118-U, BH-SF-W-0121-U, and BH-SF-W-201-U.

3.1.4 Greater than 75th Percentile Flow Tier

For the 2006 to 2007 time period, four sampling events were conducted when discharge in the SFCDR measured at Pinehurst (SF-271) was greater than the 75th percentile. Two of these sampling events were conducted when discharge was greater than the 90th percentile. For monitoring events conducted in May 2006 and November 2006, only BEMP monitoring locations were sampled. For the April 2006 and March 2007 sampling events, OU2 tributary surface water and groundwater monitoring were also conducted. Dissolved zinc monitoring data from the BEMP monitoring stations and the OU2 tributary monitoring locations are presented in Tables 3-2 and 3-3. Data from the April 2006 and March 2007 monitoring events are shown on Figures 3-5 and 3-6, respectively.

SF-268 to SF-269

Discharge gains were measured during three of four monitoring events at this flow tier between stations SF-268 and SF-269. These gains ranged from 30 cfs (May 2006) to 200 cfs (March 2007) and the discharge loss occurred during April 2006 (20 cfs). A large discharge gain was measured during the March 2007 monitoring event and considering the sum of discharge from Milo Creek, Jackass Creek, and Italian Gulch (about 25 cfs), unmeasured surface water sources such as storm water and potentially the release of bank storage likely contributed to the majority of the discharge gain in the SFCDR. Montgomery Creek discharges to the SFCDR near SF-268 and is not monitored. The quantity of water discharged to the SFCDR during the March 2007 monitoring is unknown. Tributary monitoring was not conducted during the May 2006 and November 2006 events. Tributaries likely contributed a large amount of discharge in this flow tier; however, these inputs to the SFCDR cannot be quantified.

The loss of discharge measured during the April 2006 monitoring event is greater than the loss for all other flow tiers in this reach of the SFCDR. Hydrologic factors resulting in this significant discharge loss are uncertain.

Dissolved zinc concentrations between SF-268 and SF-269 increased in three of four monitoring events during this flow tier and ranged from 0.008 mg/L (November 2006) to 0.064 mg/L (April 2006). The AWQC ratio also increased during three of five monitoring events. Dissolved zinc concentration and AWQC ratio increases during the April 2006 monitoring event are likely from Milo Creek or other contaminated water inputs. As mentioned above, this stretch of the SFCDR was losing discharge during April 2006; however, there may be lesser areas of groundwater/surface water interaction.

Tributary data are not available for three of these monitoring events. As such, sources causing these concentration increases cannot be evaluated.

The March 2007 monitoring event showed a dissolved zinc concentration and AWQC ratio loss between SF-268 and SF-269. This loss is likely the result of a large input of relatively clean water to the SFCDR in this reach. The concentration fluctuations at this flow tier are likely a result of the hydrologic characteristics between the SFCDR and the upper aquifer between SF-268 and SF-269, which are not well-understood under high-flow conditions. Many factors can influence the hydrologic characteristics of the SFCDR during high-flow events, including whether inputs are from storm water and overland flow or from the progression of snowmelt infiltration. To evaluate source areas in this flow tier, a broader understanding of these hydrologic factors is necessary. In contrast, under low or base-flow conditions, these hydrologic factors influencing high-flow conditions are typically not present.

Dissolved zinc concentrations in well BH-SF-E-0101, located between the SFCDR and the mouth of Milo Gulch, exhibit similar concentrations during all 2006 and 2007 monitoring events, suggesting a relatively stable source of contamination. During this flow tier, dissolved zinc was detected at concentrations of 2.62 mg/L (April 2006) and 2.69 mg/L (March 2007), similar to the October 2006 concentration of 2.58 mg/L. Potential sources of contamination in this well are discussed in Section 3.1.1.

BH-SF-E-0201 is located in the southern bank of the SFCDR near SF-269. The dissolved zinc concentration at this location in April 2006 was 6.11 mg/L, and 4.14 mg/L in March 2007. These concentrations are higher than upgradient groundwater and SFCDR dissolved zinc concentrations. The elevated dissolved zinc concentration observed in BH-SF-E-0201 is likely the result of surface water infiltrating through contaminated materials.

SF-269 to SF-270

Discharge gains were realized during three of four monitoring events between stations SF-269 and SF-270. These gains ranged from 70 cfs (April 2006) to 430 cfs (March 2007) and the one discharge loss occurred during November 2006 (50 cfs). Discharge gains are expected in this reach of the SFCDR at this flow tier, so the cause of the single discharge loss event for this flow tier is unclear but is most likely associated with measurement error. Surface water monitoring of Bunker Creek and Government Creek were not conducted during the November 2006 event.

Bunker Creek and Government Creek discharge to the SFCDR between SF-269 and SF-270. These tributaries contributed approximately 15.3 cfs and 45 cfs during the April 2006 and March 2007 monitoring events, respectively. Comparing these tributary inputs to the overall gains between SF-270 and SF-271 described above suggests the majority of SFCDR discharge gain is a result of groundwater discharging to the SFCDR. Estimated discharge gains from shallow groundwater were 55 cfs (April 2006) and 385 cfs (March 2007).

Dissolved zinc concentration increases were measured during all four monitoring events at this flow tier, ranging from 0.046 mg/L (May 2006) to 0.159 mg/L (April 2006). These concentration increases are expected between SF-269 and SF-270 as a result of dissolved zinc inputs from Bunker Creek, Government Creek, and shallow groundwater discharging to the SFCDR.

Dissolved zinc AWQC ratios between SF-269 and SF-270 increased during the April 2006, and May 2006 monitoring events, while decreasing during the November 2006 and March 2007 monitoring events. The four monitoring events likely occurred during different hydrologic conditions, so the amount of high hardness water reaching the SFCDR at this flow tier would vary. As noted in Section 3.1.1, Bunker Creek discharge is largely the result of effluent discharge from the CTP, which is a high hardness source of water. The AWQC ratio increase during the April 2006 event is likely a result of the low discharge of Bunker Creek (5.1 cfs), comprised of mostly CTP effluent, into the SFCDR. The AWQC decrease during the March 2007 event is likely a result of the high discharge of Bunker Creek (16.56 cfs), with dilute high hardness CTP effluent, into the SFCDR.

Bunker Creek gained approximately 8.38 cfs during the March 2007 monitoring event. Government Creek lost about 2.24 cfs during April 2006 and 4.25 cfs during March 2007 between the mouth of Government Gulch and its confluence with the SFCDR. Their impacts to the SFCDR are discussed in Section 3.1.1.

Dissolved zinc concentrations in groundwater in the vicinity of the CIA and Bunker Creek vary considerably and may conceptually indicate the area's hydrologic characteristics as well as potential source areas. Concentrations in five wells (E-0309-U, E-0315-U, E-0316-U, E-0317-U, and E-0318-U) located at the northeast portion of the CIA were below the 5 mg/L MCL. The dissolved zinc concentrations in these wells are likely influenced by the losing discharge from the SFCDR and the relatively short time that infiltrating water is in direct contact with contaminated materials. Elevated dissolved zinc concentrations were observed in three wells (E-0301-U, E-0305-U, and E-0320-U) located at the southeast portion of the CIA (near Transect 2) and are likely influenced by groundwater in direct contact with contaminated materials. This is supported by the significant fluctuations of dissolved zinc concentrations between the low (<25th percentile) and high (>90th percentile) groundwater events. The two wells located at Transect 2 (BH-SF-E-0301-U and BH-SF-E-0305-U) are also likely affected by upgradient factors, which are discussed in Section 3.1.1.

Elevated dissolved zinc concentrations were detected in numerous upper aquifer wells during April 2006 and March 2007 (see Figures 3-5 and 3-6). Concentrations in these wells were higher (near or above 20 mg/L) than concentrations in all other surrounding wells. These wells include BH-SF-E-0409-U, BH-SF-E-410-U, BH-SF-E-423-U, BH-SF-E-0425-U, and BH-SF-E-0429-U. The locations of these wells with higher concentrations may be indicative of the groundwater flow pathway from one or more source areas and/or groundwater in direct contact with contaminated materials. However, the contribution of dissolved zinc to shallow groundwater from specific source areas is unknown.

Above MCL dissolved zinc concentrations were also observed in numerous wells located in Government Gulch and in wells between Transect 3 and Transect 5 (Figures 3-5 and 3-6). Potential sources of shallow groundwater contamination at these locations are discussed in Section 3.1.1.

SF-270 to SF-271

Discharge gains were measured between SF-270 and SF-271 during the five monitoring events for this flow tier, and ranged from 520 cfs (November 2006) to 1,790 cfs (March 2007). As noted in Section 3.1.1, Pine Creek is the only major surface water input to the SFCDR at this location. Pine Creek discharge was measured only during the April 2006 (PC-339) and March 2007 (BH-PC-0001) monitoring events. The discharge for these events was 596 cfs and 1,794 cfs, respectively. As such, nearly half of the discharge gains realized during April 2006 were a result of shallow groundwater discharging to the SFCDR. However, during March 2007 the gain in discharge is equivalent to the Pine Creek discharge, suggesting no significant groundwater and surface water interaction.

Dissolved zinc concentrations in the SFCDR decreased between SF-270 to SF-271 during all four monitoring events. Concentrations decreased from 0.01 mg/L (May 2006) to 0.311 mg/L (November 2006). These concentration decreases are expected because Pine Creek discharges relatively clean water and dilutes the SFCDR.

The dissolved zinc AWQC ratio increased and decreased during the four events. Significant changes to the AWQC ratio would most likely occur from the gaining reach of the SFCDR in the western portion of Smelterville Flats and influences from Pine Creek. Any impact to the SFCDR in this location is unknown because of insufficient data directly upgradient of the

Pine Creek tributary. Additionally, these greater than 90th percentile flows occurred during different periods throughout 2006 and 2007, and hydrologic influences during these periods are likely different.

Elevated dissolved zinc concentrations were present in several upper aquifer wells throughout Smelterville Flats during the April 2006 and March 2007 monitoring events. Dissolved zinc concentrations in wells located on Transect 5 (BH-SF-W-0001-U and BH-SF-W-0003-U) exceeded the 5 mg/L MCL, indicating upgradient sources may be causing these elevated concentrations. In the eastern portion of Smelterville Flats, the SFCDR is a losing reach. Dissolved zinc concentrations in monitoring wells in this area increase with increasing distance from the SFCDR. This suggests that water lost from the SFCDR continues to pick up contamination as it moves through the groundwater system. Contaminated groundwater upgradient of Transect 5 may also contribute to elevated dissolved zinc in these wells. In the western portion of Smelterville Flats and Page Ponds, above MCL dissolved zinc concentrations were observed in wells BH-SF-0022-U, BH-SF-W-0104-U, BH-SF-W-0111-U, BH-SF-W-0119-U, and BH-SF-W-0201-U. Dissolved zinc concentrations just below the MCL occurred in wells BH-SF-W-0118-U and BH-SF-W-0121-U. Similar to the discussion in Section 3.1.1, dissolved zinc concentrations at Transect 7 are greater in monitoring wells completed on the northern side of the valley (BH-SF-W-0206-U) than in wells completed on the southern side of the valley (BH-SF-W-0204-U). Additional hydrologic characteristics between SF-270 and SF-271 are provided in Section 3.1.1.

3.1.5 Dissolved Zinc Source Areas

This section presents the potential sources of dissolved zinc contamination that result in negative impacts on SFCDR water quality. The source areas were identified during the evaluation of water quality data under different flow tiers presented in the previous sections. Additional source areas may be identified during subsequent data collection activities. Potential source areas and associated data gaps are summarized below.

- Contaminated materials present in the floodplain and beneath infrastructure throughout OU2 represent a widespread source of dissolved zinc contamination. The movement of surface water, groundwater, snowmelt, precipitation, and other water sources through these materials results in increased levels of dissolved zinc in groundwater and surface water throughout OU2.

- The discharge of AMD from the Reed and Russell adits in Milo Gulch to Milo Creek represents a source of dissolved zinc contamination to the SFCDR.

- In the eastern portion of OU2, surface water lost from the SFCDR infiltrates through contaminated materials and results in increased dissolved zinc concentrations. As groundwater moves further downgradient, dissolved zinc concentrations increase as it passes through additional contaminated materials. However, there is little groundwater monitoring data available for the Kellogg area to allow for the delineation of contaminant sources and transport pathways.

- The historical SFCDR channel (pre-mining activity) appears to be a preferential flow pathway for groundwater in the eastern portion of OU2. In addition, because the historical channel was filled with contaminated materials, it may represent a contaminant source. The lack of groundwater monitoring data in this area prevents this condition from being quantified. However, the presence of elevated dissolved zinc concentrations in available monitoring wells located near or within the historical channel supports this conclusion.

- Between SF-269 and BH-SF-LF-0006, a significant amount of groundwater with elevated dissolved zinc concentrations discharges to the SFCDR. Evaluation of groundwater monitoring data upgradient of this area shows that elevated dissolved zinc concentrations are present to the south and east of this area in the approximate location of the historical SFCDR channel. These elevated dissolved zinc concentrations may be the result of multiple sources, including losses of discharge from Bunker Creek through contaminated materials beneath the channel, the introduction of high dissolved zinc concentration groundwater from the A-4 Gypsum Pond Area, and contaminated materials located within and adjacent to the Bunker Creek channel that are in contact with groundwater.
- Although elevated dissolved zinc concentrations have been measured in Government Gulch and Government Creek, their impact on SFCDR water quality appears to be minimal in comparison to other contaminant sources in OU2.
- Government Creek loses discharge during low-flow conditions (less than 25th percentile) as it passes along the valley floor between monitoring stations BH-GG-0001 and BH-GG-0004. The losing Government Creek surface water has the potential to transport dissolved metals to shallow groundwater; however, the presence and spatial distribution of contaminated materials in the losing area beneath Government Creek is unknown.
- The monitoring network in the western portion of OU2 is relatively sparse and does not allow for the identification of dissolved zinc sources or transport pathways. Changes in water quality in the gaining reach of the SFCDR between BH-SF-LF-0007 and BH-SF-LF-0010 suggests there are dissolved zinc sources in this area, which may include the Page Ponds area, contaminated material located beneath infrastructure (such as the airport and I-90), and contaminated materials located beneath the level of Phase I removals or capped areas.

3.2 Total Lead

This section presents an analysis of potential sources of total lead contamination to the SFCDR within OU2 under different flow conditions. Lead primarily exists in the particulate phase in OU2. Most total lead transport and loading is expected during higher flows (greater than 75th percentile). The total lead data set used in this report is not as extensive as the dissolved zinc data set evaluated in Section 3.1. Total lead data collected at BEMP monitoring locations under different flow tiers are presented in Table 3-4. Available OU2 tributary surface water total lead data are presented in Table 3-5. Total lead was not detected at concentrations greater than 0.01 mg/L at any monitoring location on the SFCDR during the 2006 to 2007 time period when the discharge measured in the SFCDR at Pinehurst (SF-271) was below the 75th percentile, except for two detections: one in the 25th to 50th percentile flow tier, and one in the 50th to 75th percentile flow tier. Therefore, impacts to the SFCDR from total lead sources within OU2 appear to be limited to time periods when discharge conditions are greater than the 75th percentile flow tier.

In October 2006, when discharge was less than the 25th percentile, total lead concentrations exceeded 0.01 mg/L at Milo Creek and Pine Creek. The total lead concentrations measured in Milo Creek at its confluence with the SFCDR (BH-MC-0002) and at the old Milo Creek outfall (BH-MC-0001) were 0.198 mg/L and 0.149 mg/L, respectively. The high concentrations of total lead observed at these locations are likely the result of AMD from the Reed and Russell adits located upstream in Milo Gulch. At the confluence of Pine Creek with the SFCDR (BH-PC-0001), the total lead concentration was 0.022 mg/L. Upstream on Pine Creek at PC-339 the total lead concentration was 0.0002 mg/L. The reason for the increase in total lead concentrations between these points under high-flow conditions is unknown.

In January 2006 when discharge was between the 50th and 75th percentile, total lead concentrations exceeded 0.01 mg/L at a number of locations, including Milo Creek (BH-MC-0002 = 0.34 mg/L), Government Creek (BH-GG-0001 = 0.0277 mg/L), Grouse Creek (BH-GC-0001 = 0.0138 mg/L), Humboldt Creek (BH-HC-0001 = 0.0392 mg/L) and the outfall of the West Page Swamp (BH-WP-0001 = 0.0118 mg/L).

In the SFCDR under greater than 75th percentile discharge conditions, total lead concentrations were greater than 0.01 mg/L for all sampling events. Discharge in the SFCDR for the November 2006 sampling event was lower than for the other monitoring events. Total lead concentrations measured in the SFCDR for this event were also lower. This suggests that the majority of total lead transport in the SFCDR occurs under the highest discharge conditions.

Increases and decreases in total lead concentrations for SFCDR monitoring locations is highly variable for the remaining sampling events, with the exception of differences between SF-269 and SF-270 where increases occurred for each of the remaining sampling events.

With a few exceptions, total lead concentrations in the SFCDR at greater than 75th percentile discharge are greater at SF-268 than they are at SF-271. This suggests that the SFCDR channel and floodplain are acting as a sink for particulate lead from upstream sources.

The BEMP sediment data can also be used to supplement the discussion of total lead transport during higher SFCDR flow tiers. Three SFCDR floodplain depositional areas are sampled annually in OU2 (Elizabeth Park, Smelterville Flats, and Pinehurst). Total lead concentrations in the 2007 bulk sample from these locations ranged from 1,720 mg/kg to 3,390 mg/kg. A portion of the contaminated sediments identified during BEMP sampling are likely from upgradient OU3 sources and are continually re-suspended during higher flow events.

3.2.1 Total Lead Source Areas

Total lead concentrations are relatively low in the SFCDR within OU2 when discharge conditions are less than the 75th percentile and typically remain low, with the exception of very high discharge conditions, above the 90th percentile. The largest increases in total lead concentration in the SFCDR typically occur between SF-269 and SF-270. Bunker Creek and

Government Creek discharge to the SFCDR in this area. However, total lead concentrations measured in Bunker Creek and Government Creek under high-flow conditions in April 2006 and March 2007 are less than those observed in the SFCDR. This suggests that the source of total lead concentration increases in the SFCDR within OU2 is associated with unmeasured surface water runoff that is not conveyed to the SFCDR in a tributary; and the erosion and/or resuspension of particulate lead from channel banks, floodplains, and the channel bottom of the SFCDR.

3.3 Phosphorous

This section presents an analysis of potential sources of phosphorous to the SFCDR within OU2 under different flow conditions. Phosphorous data are only available for BEMP monitoring locations within OU2. Currently, phosphorous is not monitored as part of OU2 EMP monitoring efforts. Total and dissolved phosphorous data from BEMP monitoring locations within OU2 under different flow conditions are summarized in Table 3-6.

3.3.1 Less than 25th Percentile Flow Tier

For the 2006 to 2007 time period, two sampling events were conducted when discharge in the SFCDR measured at Pinehurst (SF-271) was less than the 25th percentile.

In August 2006, total phosphorous was detected at SF-268 and SF-269 at a concentration of 0.003 mg/L, suggesting an upgradient source. In October 2006, dissolved and total phosphorous were not detected at stations SF-268 and SF-269.

In August 2006 and October 2006, total and dissolved phosphorous were detected at concentrations of 0.026 mg/L and 0.015 mg/L at SF-270, respectively. At SF-271, total and dissolved phosphorous were detected at 0.052 mg/L and 0.033 mg/L in August 2006, and 0.044 mg/L and 0.034 mg/L in October 2006, respectively. Available data are insufficient to evaluate the locations of these sources. However, sources thought to contribute to phosphorous in the SFCDR include the A-4 Gypsum Pond area, the former phosphoric acid/fertilizer plant in Government Gulch, and the Page Ponds area.

3.3.2 Between 25th and 50th Percentile Flow Tier

For the 2006 to 2007 time period, three BEMP sampling events were conducted when discharge in the SFCDR measured at Pinehurst (SF-271) was between the 25th and 50th percentile. The sampling events occurred in February 2006, July 2006, and February 2007.

In February 2006, total and dissolved phosphorous was detected at SF-268, suggesting an upgradient source. The total phosphorous concentration decreased at stations SF-269 and SF-270, but increased at SF-271. The dissolved phosphorous concentration also decreased at SF-269, did not change at SF-270, and increased at SF-271.

In July 2006, total phosphorous was detected at a concentration of 0.004 mg/L at SF-268 and SF-269, suggesting an upgradient source. Dissolved phosphorous was not detected at SF-268 or SF-269. In February 2007, dissolved and total phosphorous was not detected at SF-268 and SF-269. Concentrations of dissolved and total phosphorous increased during both monitoring events in the SFCDR downstream at SF-270 and SF-271.

3.3.3 Between 50th and 75th Percentile Flow Tier

For the 2006 to 2007 time period, two sampling events were conducted when discharge in the SFCDR measured at Pinehurst (SF-271) was between the 50th and 75th percentile.

Total and dissolved phosphorous were detected for both sampling events at SF-268. This suggests that the release of phosphorous from upstream sources increases with increasing discharge in the SFCDR.

Total and dissolved phosphorous concentrations decreased between SF-268 and SF-269. In January 2006 and June 2006, total and dissolved phosphorous concentrations increased between SF-269 and SF-270. Between SF-270 and SF-271, total and dissolved phosphorous concentrations increased for both sampling events.

3.3.4 Greater than 75th Percentile Flow Tier

For the 2006 to 2007 time period, four sampling events were conducted when discharge in the SFCDR measured at Pinehurst (SF-271) was greater than the 75th percentile. Two of these sampling events were conducted when discharge was greater than the 90th percentile.

For all four sampling events, total and dissolved phosphorous concentrations measured at SF-268 were greater than for any other flow tiers.

Total and dissolved phosphorous concentrations decreased between SF-268 and SF-269 for all sampling events with the exception of May 2006 and March 2007, when concentrations increased. These two events also exhibit greater discharges than other sampling events.

Between SF-269 and SF-270, total and dissolved phosphorous concentrations increased for all monitoring events with the largest increases occurring during the May 2006 and March 2007 sampling events.

Between SF-270 and SF-271, total and dissolved phosphorous concentrations increased for all monitoring events with the exception of May 2006, when total phosphorous concentrations decreased and dissolved concentrations remained the same. The greatest total phosphorous concentration and highest discharge occurred during the March 2007 sampling event.

3.3.5 Phosphorous Source Areas

Review of available SFCDR total and dissolved phosphorous data for the 2006 to 2007 time period suggests that phosphorous concentrations are related to discharge, with greater concentrations occurring under greater discharge in most cases.

Within OU2, the greatest increases in phosphorous concentration occurred under high-flow conditions and occur between SF-269 and SF-271. There is insufficient data available to further evaluate sources of phosphorous and their relative impact on the SFCDR within OU2. However, areas within OU2 thought to contribute to phosphorous in the SFCDR include the A-4 Gypsum Pond area, the former phosphoric acid/fertilizer plant in Government Gulch, and the Page Ponds area.

TABLE 3-1

Summary of Dissolved Zinc During October 2003 and October 2006 Base Flow Conditions - South Fork Coeur d'Alene River

Source Areas of Concern Report
Bunker Hill Superfund Site OU2

	Discharge (cfs)		Concentration (mg/L)		Load (lb/day)		AWQC Ratio	
Location[1]	**Oct-03**	**Oct-06**	**Oct-03**	**Oct-06**	**Oct-03**	**Oct-06**	**Oct-03**	**Oct-06**
SF-268	62	77	0.936	0.924		383	6.0	6.3
BH-SF-LF001[1]	74	74	0.771	0.746	304	298	5.00	4.8
BH-SF-LF002[2]	74	81	0.769	0.783	303	342	5.04	5.1
BH-SF-LF003	74	76	0.765	0.763	304	313	4.97	5.0
SF-269	--	80	--	0.884	--	381	--	6.0
BH-SF-LF004	78	--	0.950	--	397	--	--	--
BH-SF-LF005	74	68	0.977	1.04	392	381	5.98	6.3
BH-SF-LF006	78	76	1.12	1.12	466	459	4.46	4.5
SF-270	--	84	1.23	1.12	--	507	--	4.9
BH-SF-LF007	73	68	1.18	1.03	461	378	5.08	4.5
BH-SF-LF008	68	68	1.18	1.12	435	411	5.08	4.8
BH-SF-LF009	79	76	1.26	1.23	534	504	5.37	5.2
BH-SF-LF010	81	79	1.38	1.33	602	567	5.84	5.6
SF-271	87	104	1.41	1.18		661	6.19	5.7
BH-SF-LF011[3]	113	99	1.26	1.14	772	609	5.90	5.3
Bunker Creek	1.3	3.2	0.72	0.304	5	5.2	1.47	0.6
Government Gulch	0.7	0.7	2.78	1.747	12	6.8	38.93	24.5
Milo Creek	2.3	3.0	1.05	1.271	13	20	9.54	11.6
Pine Creek	3.0	7.5	0.10	0.068	1.6	2.7	1.71	1.2

Notes

-- = Not sampled or measured.

[2] BH-SF-LF001 is located approximately 5,000 feet downstream of SF-268.

[3] BH-SF-LF002 2006 results are from 2 samples

[6] BH-SF-LF-011 is located approximately 250 feet downstream of SF-271

TABLE 3-2

Summary of Dissolved Zinc in OU2 Tributaries - 2006 to 2007

Source Areas of Concern Report

Bunker Hill Superfund Site OU2

	Jan-06 (50th to 75th Percentile)				Apr-06 (>75th Percentile)				Oct-06 (<25th Percentile)				Mar-07 (>75th Percentile)			
Monitoring Location	**Discharge (cfs)**	**Concentration (mg/L)**	**Load (lb/day)**	**AWQC Ratio**	**Discharge (cfs)**	**Concentration (mg/L)**	**Load (lb/day)**	**AWQC Ratio**	**Discharge (cfs)**	**Concentration (mg/L)**	**Load (lb/day)**	**AWQC Ratio**	**Discharge (cfs)**	**Concentration (mg/L)**	**Load (lb/day)**	**AWQC Ratio**
BH-IG-0001	--	0.0171	--	--	0.27	0.00048	0.0007	0.007	--	--	--	--	4.7	0.0091	0.23	0.2
BH-JC-0001	14.66	0.0084	0.7	--	18.38	0.00078	0.08	0.01	--	--	--	--	20.09	0.0044	0.048	0.09
Milo Creek																
BH-MC-0001	0.067	0.226	0.1	--	--	0.129	--	1.2	3.0	1.271	20	11.6	0.13	0.149	0.1	1.8
BH-MC-0002	5.35	3.39	97.7	--	6.23	6.63	--	86	--	1.9	--	27.7	24.17	0.923	--	11
Bunker Creek																
BH-BC-0001	10.63	3.12	179	--	5.1	2.06	57	4.2	3.2	0.304	5.2	0.6	16.56	2.14	191	5.0
BH-BC-0006	--	--	--	--	--	--	--	--	2.6	--	--	0.5	13.41	2.45	177	5.0
BH-MG-0001	3.88	2.98	62.3	--	--	2.22	--	14	0.0	1.13	0.04	5.7	1.27	1.79	12	14
BH-BC-0005	--	--	--	--	--	--	--	--	3.2	0.093	1.6	0.2	10.12	0.334	18	0.6
BH-DW-0001	1.75	--	--	--	1.67	--	--	--	0.0	0.303	0.07	2.3	5.61	0.379	11	5.3
BH-BC-0004	--	--	--	--	--	--	--	--	--	--	--	--	6.13	0.291	10	0.3
BH-PG-0001	--	--	--	--	--	0.114	--	2.2	--	--	--	--	1	0.123	0.66	1.8
BH-MY-0001	--	--	--	--	--	0.438	--	4.9	0.013	0.115	0.008	1.3	0.1	0.7	0.38	8.0
BH-BC-0003	--	--	--	--	--	--	--	--	--	--	--	--	0.23	0.557	0.69	7.0
Government Creek																
BH-GG-0004	--	--	--	--	10.17	1.25	69	21	0.7	2.54	10	119	28.38	1.78	272	25
BH-GG-0001	6.87	5.65	209	74	7.93	1.3	56	23	1.2	2.54	16	33	24.13	1.61	209	24
BH-GG-0008	--	--	--	--	--	--	--	--	1.1	2.40	15	32	30.53	1.69	278	25
BH-GG-0007	--	--	--	--	--	--	--	--	1.3	2.21	16	31	32.44	1.62	283	26
BH-GG-0006	--	--	--	--	--	--	--	--	1.2	2.09	13	30	32.87	1.53	271	25
BH-GG-0005	--	--	--	--	--	--	--	--	1.4	0.831	6.0	13	28.86	1.07	166	19
BH-GG-0002	--	--	--	--	--	--	--	--	1.2	0.133	0.9	2.6	41.56	0.0873	20	2.0
West Page																
BH-WP-0001	10.44	0.896	50	--	4.32	0.611	14	3.6	--	--	--	--	14.6	0.513	40	3.2
BH-HC-0001	3.9	0.928	19	--	2.8	0.772	12	8.2	0.006	--	--	--	13.7	0.693	51	7.7
BH-GC-0001	2.48	0.227	3	--	1.41	0.148	1.1	0.5	0.16	--	--	--	5.23	0.0765	2.2	0.6
Pine Creek																
BH-PC-0001	--	--	--	--	--	--	--	--	7.5	0.068	2.7	0.4	1794	0.0781	755	1.9
PC-339	298	--	--	--	596	0.0838	269	2.4	14.0	0.131	9.9	2.3	556	0.0936	280	2.7

Notes:

-- = Not sampled or measured.

[1] January and April 2006 data collected from PC-339.

TABLE 3-3

Summary of Dissolved Zinc Under All 2006 and 2007 Flow Conditions - South Fork Coeur d'Alene River

Source Areas of Concern Report
Bunker Hill Superfund Site OU2

	SFCDR Flow	SF-268				SF-269				SF-270				SF-271			
Measurement Date	**Tier (percentile)**	**Discharge (cfs)**	**Concentration (mg/L)**	**Load (lb/day)**	**AWQC Ratio**	**Discharge (cfs)**	**Concentration (mg/L)**	**Load (lb/day)**	**AWQC Ratio**	**Discharge (cfs)**	**Concentration (mg/L)**	**Load (lb/day)**	**AWQC Ratio**	**Discharge (cfs)**	**Concentration (mg/L)**	**Load (lb/day)**	**AWQC Ratio**
Oct-03	<25	62	0.936	313	6	--	--	--	--	--	10.6	--	4.81	87	1.41	661	6.19
Jan-06	50 to 75	393	0.794	1681	6.5	390	0.839	1763	6.9	444	0.995	2380	6.3	633	0.879	2998	7.3
Feb-06	25 to 50	249	0.845	1134	6.2	238	0.832	1067	6.1	267	1.26	1813	6.9	333	1.11	1991	7.7
Apr-06	>75	1010	0.461	2509	4.5	990	0.526	2806	5.0	1060	0.685	3912	5.9	2060	0.486	5394	5.6
May-06	>75*	1770	0.181	1726	2.7	1800	0.194	1881	2.9	1930	0.24	2496	3.2	3000	0.23	3718	3.6
Jun-06	50 to 75	647	0.335	1168	3.8	660	0.346	1230	4.0	670	0.49	1769	4.3	904	0.483	2352	4.7
Jul-06	25 to 50	217	0.573	670	4.7	220	0.584	692	5.0	228	0.846	1039	5.0	282	0.874	1328	5.8
Aug-06	<25	110	0.629	373	4.6	112	0.86	519	6.3	117	1.14	719	5.5	155	0.978	817	5.2
Oct-06	<25	77	0.924	383	6.3	80	0.884	381	6.0	84	1.12	507	4.9	104	1.18	661	5.6
Nov-06	>75	741	0.667	2663	7.1	800	0.675	2909	7.1	750	0.787	3180	7.0	1270	0.476	3257	5.5
Feb-07	25 to 50	147	0.831	658	6.2	148	0.803	640	6.0	150	1.13	913	6.2	259	0.988	1379	6.4
Mar-07	>75*	1220	0.401	2636	6.2	1420	0.349	2670	4.5	1850	0.431	4296	1.5	3640	0.244	4785	3.5

Notes:
-- = Not sampled or measured
>75* = Discharge greater than 90th percentile.

TABLE 3-4

Summary of Total Lead Under All 2006 and 2007 Flow Conditions - South Fork Coeur d'Alene River

Source Areas of Concern Report

Bunker Hill Superfund Site OU2

Measurement Date	Discharge Tier (percentile)	SF-268			SF-269			SF-270			SF-271		
		Discharge (cfs)	**Concentration (mg/L)**	**Load (lb/day)**	**Discharge (cfs)**	**Concentration (mg/L)**	**Load (lb/day)**	**Discharge (cfs)**	**Concentration (mg/L)**	**Load (lb/day)**	**Discharge (cfs)**	**Concentration (mg/L)**	**Load (lb/day)**
1/5/2006	50 to 75	393	0.00629	13	390	0.00929	20	444	0.00987	24	633	0.00754	26
2/15/2006	25 to 50	249	0.00418	6	238	0.0078	10	267	0.00772	11	333	0.00761	14
4/7/2006	>75	1010	0.118	642	990	0.0812	433	1060	0.107	611	2060	0.116	1287
5/18/2006	>75*	1770	0.246	2346	1800	0.231	2240	1930	0.279	2901	3000	0.223	3604
6/14/2006	50 to 75	647	0.00874	30	660	0.00781	28	670	0.00918	33	904	0.0143	70
7/12/2006	25 to 50	217	0.00618	7	220	0.00954	11	228	0.0102	13	282	0.00812	12
8/15/2006	<25	110	0.00486	3	112	0.00962	6	117	0.00797	5	155	0.00889	7
10/5/2006	<25	77	0.0037	2	80	0.00819	4	84	0.00895	4	104	0.00544	3
11/8/2006	>75	741	0.0247	99	800	0.0233	100	750	0.0236	95	1270	0.0242	166
2/8/2007	25 to 50	147	0.00436	3	148	0.0072	6	150	0.0075	6	259	0.00792	11
3/12/2007	>75*	1220	--	--	1420	0.236	1806	1850	0.282	2811	3640	0.304	5962

Notes:

-- = Not sampled

>75* = Discharge greater than 90th percentile.

TABLE 3-5

Summary of Total Lead in OU2 Tributaries

Source Areas of Concern Report

Bunker Hill Superfund Site OU2

	Jan-06 (50th to 75th Percentile)			Apr-06 (>75th Percentile)			Oct-06 (<25th Percentile)			Mar-07 (>75th Percentile)		
Monitoring Location	**Discharge (cfs)**	**Concentration (mg/L)**	**Load (lb/day)**	**Discharge (cfs)**	**Concentration (mg/L)**	**Load (lb/day)**	**Discharge (cfs)**	**Concentration (mg/L)**	**Load (lb/day)**	**Discharge (cfs)**	**Concentration (mg/L)**	**Load (lb/day)**
BH-IG-0001	--	0.00094	--	0.27	0.00056	0.001	--	--	--	4.7	0.00095	0.02
BH-JC-0001	14.66	0.00066	0.1	18.38	0.00045	0.04	--	--	--	20.09	0.0017	0.2
Milo Creek												
BH-MC-0001	0.067	0.003	0.001	--	0.0021	--	--	0.198	--	0.13	0.002	0.001
BH-MC-0002	5.35	0.34	9.8	6.23	0.166	5.6	3	0.149	2.4	24.17	0.115	15
Bunker Creek												
BH-BC-0001	10.63	0.0102	0.6	5.1	0.0044	0.1	3.2	0.0005	0.008	16.56	0.0085	0.8
BH-BC-0006	--	--	--	--	--	--	2.6	0.001	0.02	13.41	0.0101	0.7
BH-MG-0001	3.88	0.0106	0.2	--	0.0047	--	0.0	0.003	0.0001	1.27	0.0151	0.1
BH-BC-0005	--	--	--	--	--	--	3.2	0.001	0.02	10.12	0.0087	0.5
BH-DW-0001	1.75	0.0099	0.1	1.67	0.0372	0.3	0.0	0.007	0.002	5.61	0.0158	0.5
BH-BC-0004	--	--	--	--	--	--	--	--	--	6.13	0.0084	0.3
BH-PG-0001	--	--	--	--	--	--	--	0.0	--	1	0.037	0.2
BH-MY-0001	--	--	--	--	0.0039	--	0.013	0.0	0.001	0.1	0.0132	0.01
BH-BC-0003	--	--	--	--	--	--	--	--	--	0.23	0.011	0.01
Government Creek												
BH-GG-0004	--	--	--	10.17	0.0097	0.5	0.7	0.001	0.004	28.38	0.0144	2.2
BH-GG-0001	6.87	0.0277	1.0	7.93	0.0071	0.3	1.2	0.004	0.03	24.13	0.0307	4.0
BH-GG-0008	--	--	--	--	--	--	1.1	0.008	0.05	30.53	0.0073	1.2
BH-GG-0007	--	--	--	--	--	--	1.3	0.003	0.02	32.44	0.0044	0.8
BH-GG-0006	--	--	--	--	--	--	1.2	0.003	0.02	32.87	0.0042	0.7
BH-GG-0005	--	--	--	--	--	--	1.4	0.000	0.003	28.86	0.0018	0.3
BH-GG-0002	--	--	--	--	--	--	1.2	0.00064	0.004	41.56	0.00084	0.2
West Page												
BH-WP-0001	10.44	0.0118	0.7	4.32	0.0712	1.7	--	--	--	14.6	0.0103	0.8
BH-HC-0001	3.9	0.0392	0.8	2.8	ND	--	0.006	0.0018	0.0001	13.7	0.146	11
BH-GC-0001	2.48	0.0138	0.2	1.41	0.0112	0.1	0.16	0.0014	0.001	5.23	0.043	1.2
Pine Creek												
BH-PC-0001	--	--	--	--	--	--	7.5	0.022	0.9	1794	0.0269	260
PC-339	298	--	--	596	0.0004	1.3	14	0.0002	0.02	556	0.00042	1.3

Notes:

-- = Not sampled, not measured, or insufficient data.

ND = Not detected above the method detection limit.

TABLE 3-6

Phosphorous Concentrations Under All 2006 and 2007 Flow Conditions - South Fork Coeur d'Alene River

Source Areas of Concern Report

Bunker Hill Superfund Site OU2

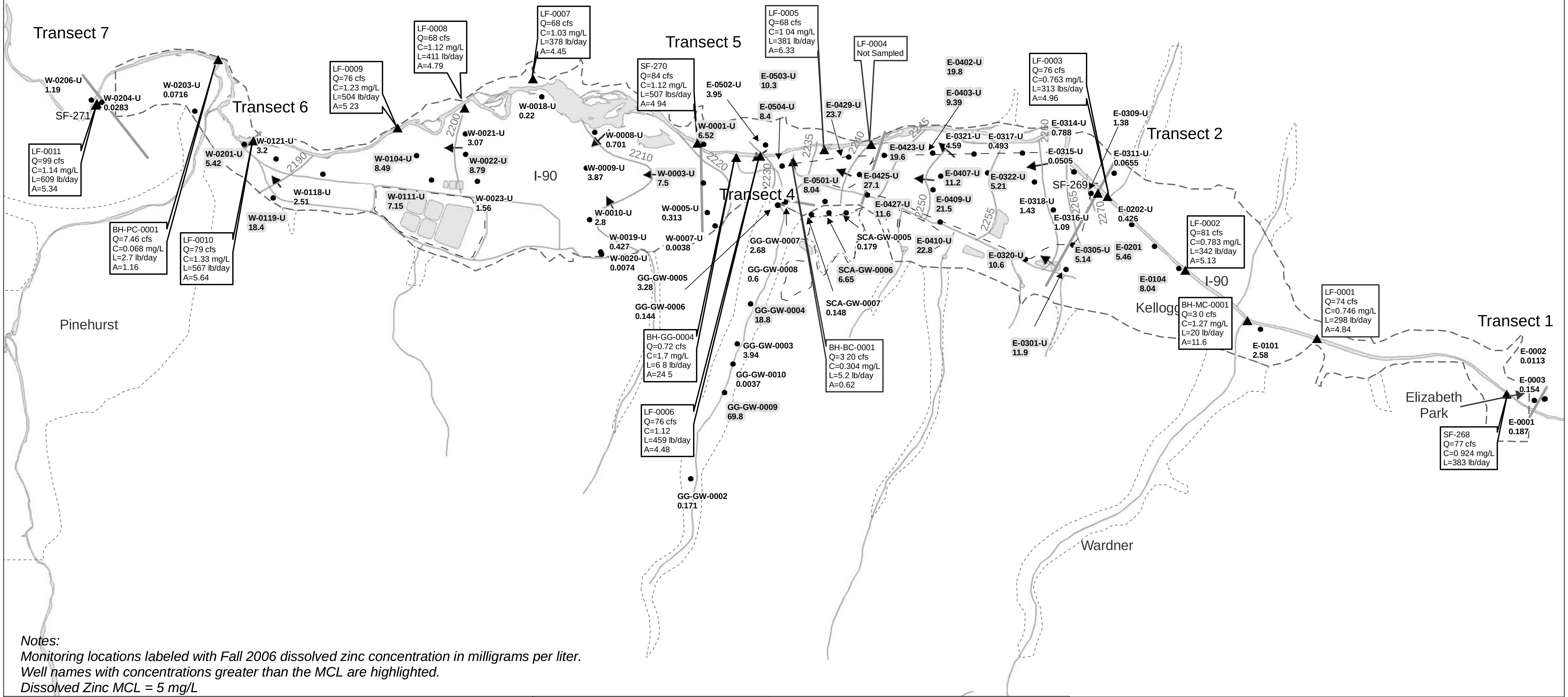
Measurement Date	SFCDR Flow Tier (percentile)	SF-268			SF-269			SF-270			SF-271		
		Discharge (cfs)	**Total (mg/L)**	**Dissolved (mg/L)**	**Discharge (cfs)**	**Total (mg/L)**	**Dissolved (mg/L)**	**Discharge (cfs)**	**Total (mg/L)**	**Dissolved (mg/L)**	**Discharge (cfs)**	**Total (mg/L)**	**Dissolved (mg/L)**
1/5/2006	50 to 75	393	0.007	0.004	390	0.005	0.003	444	0.013	0.009	633	0.025	0.016
2/15/2006	25 to 50	249	0.022	0.013	238	0.003	0.003	267	ND	0.003	333	0.004	0.004
4/7/2006	>75	1010	0.044	0.003	990	0.031	0.004	1060	0.055	0.006	2060	0.058	0.008
5/18/2006	>75*	1770	0.036	0.004	1800	0.041	0.004	1930	0.087	0.005	3000	0.044	0.005
6/14/2006	50 to 75	647	0.007	0.005	660	0.005	0.002	670	0.01	0.006	904	0.019	0.012
7/12/2006	25 to 50	217	0.004	ND	220	0.004	ND	228	0.018	0.01	282	0.027	0.019
8/15/2006	<25	110	0.003	ND	112	0.003	ND	117	0.026	0.015	155	0.052	0.033
10/5/2006	<25	77	ND	ND	80	ND	ND	84	0.026	0.015	104	0.044	0.034
11/8/2006	>75	741	0.014	ND	800	0.013	--	750	0.02	--	1270	0.037	0.015
2/8/2007	25 to 50	147	ND	ND	148	ND	ND	150	0.02	0.013	259	0.036	0.018
3/12/2007	>75*	1220	0.091	0.005	1420	0.111	0.007	1850	0.183	0.007	3640	0.228	0.009

Notes:

-- = Not sampled

>75* = Discharge greater than 90th percentile.

ND - Not detected above the method detection limit.



Notes:
Monitoring locations labeled with Fall 2006 dissolved zinc concentration in milligrams per liter.
Well names with concentrations greater than the MCL are highlighted.
Dissolved Zinc MCL = 5 mg/L

Legend

- ● Groundwater Monitoring Well
- ▲ Surface Water Monitoring Location
- — Inferred Upper Aquifer Equipotential Line
- → Inferred Direction of Groundwater Flow

Q=Discharge (cfs)
C=D. Zn Conc. (mg/L)
L=Zinc Load (lb/day)
A=AWQC Ratio

N

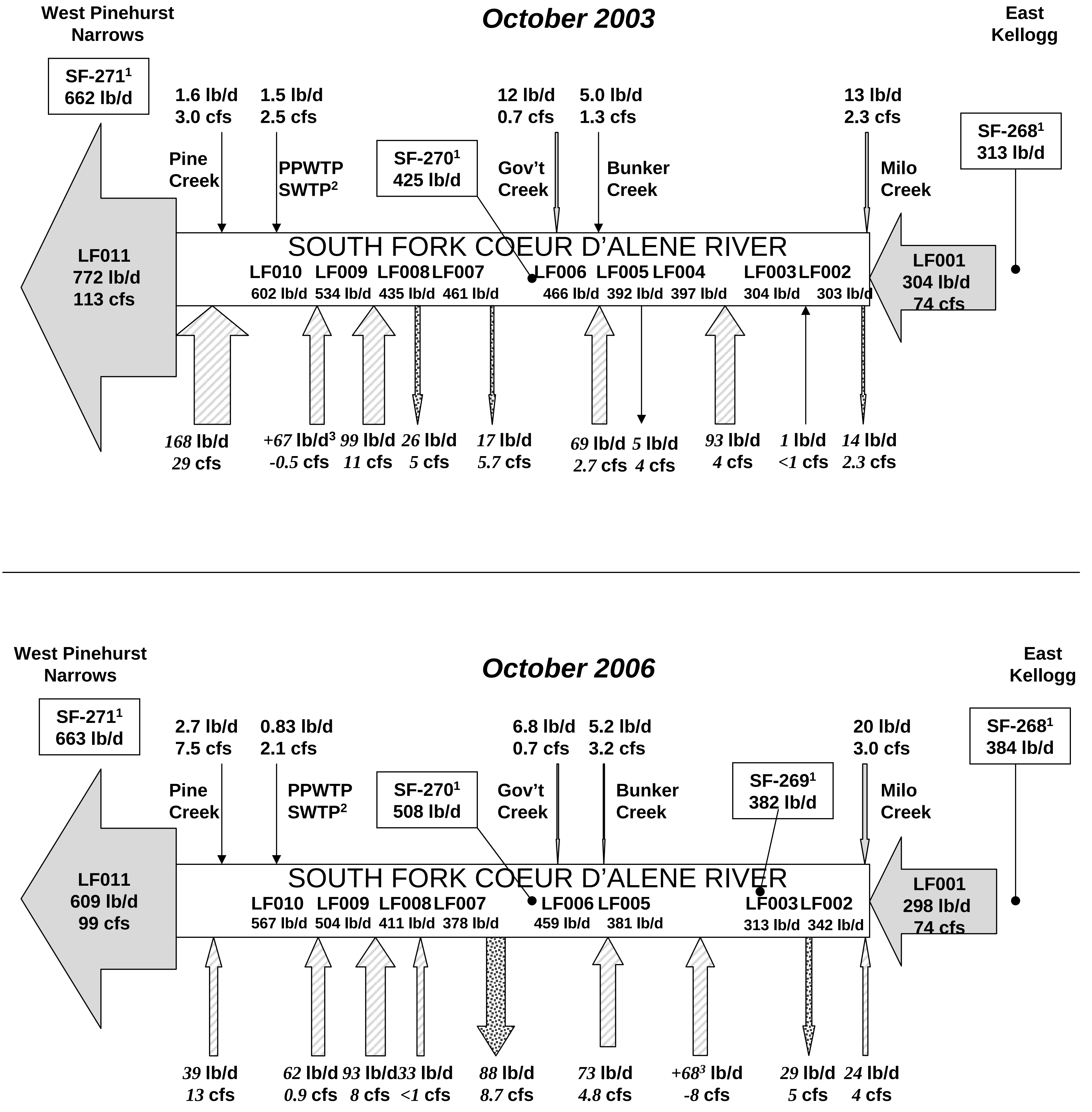
0 1,700 3,400 Feet

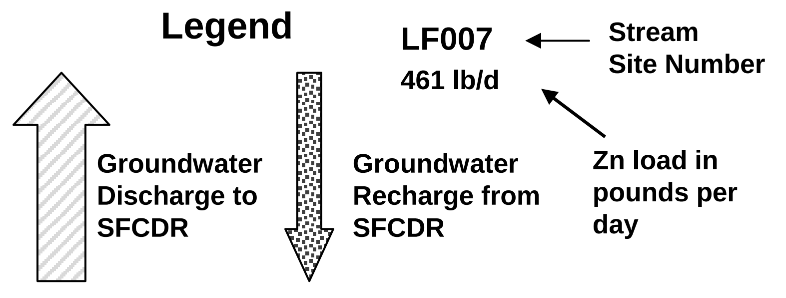
FIGURE 3-1

OCTOBER 2006 DATA SUMMARY DISSOLVED ZINC

SOURCE AREAS OF CONCERN REPORT
BUNKER HILL SUPERFUND SITE OU2

CH2MHILL





Arrow width reflects amount of zinc loading.

Values in italics have been calculated.

SF and LF site locations are approximate and relative to distance downstream from SF-268.

[1] Data for "SF" sites were collected by USGS as part of BEMP on different dates than the "LF" sites. In 2003, BEMP sites were sampled one week prior to the LF sites.

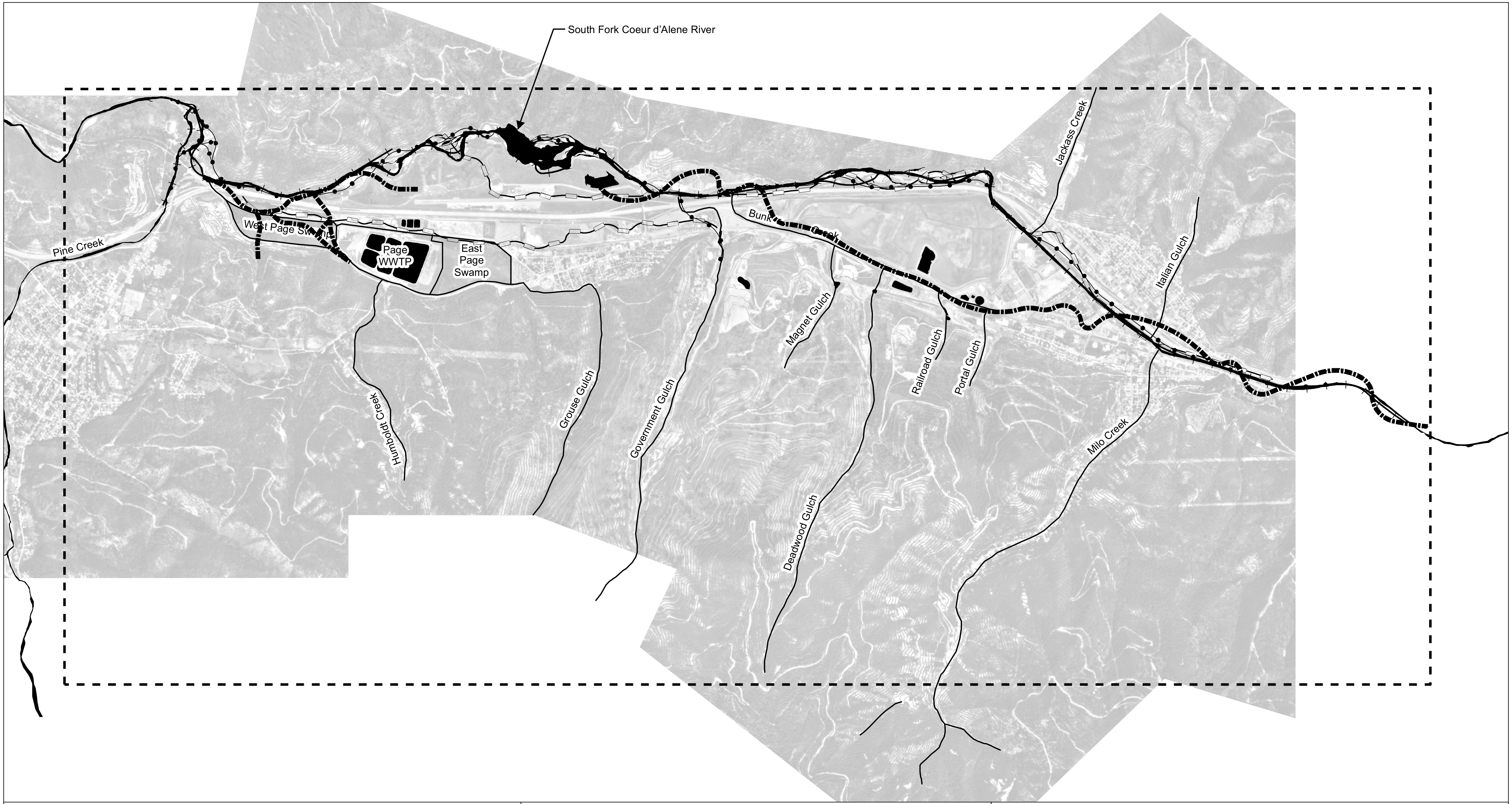
[2] Loading and flow data are a monthly average from October 2004 and 2006, data were not available for 2003. PPWTP and SWTP concentrations and loading calculations were based on total Zinc concentrations, dissolved Zinc concentrations were not available.

[3] Discharge measurement data error may account for positive loading paired with discharge loss.

Note: This figure represents the current refined conceptual model of loading to the South Fork of the Coeur d'Alene River and is subject to change based on available data and site knowledge.

FIGURE 3-2

SFCDR DISSOLVED ZINC LOADING CONCEPTUAL MODEL POST-REMEDIATION (2003 & 2006)



Legend

- River Channels in 1883
- River Channels in 1932-1942
- River Channels in 1957
- River Channels in 1985
- Water Features

N

0 2,500 5,000 Feet

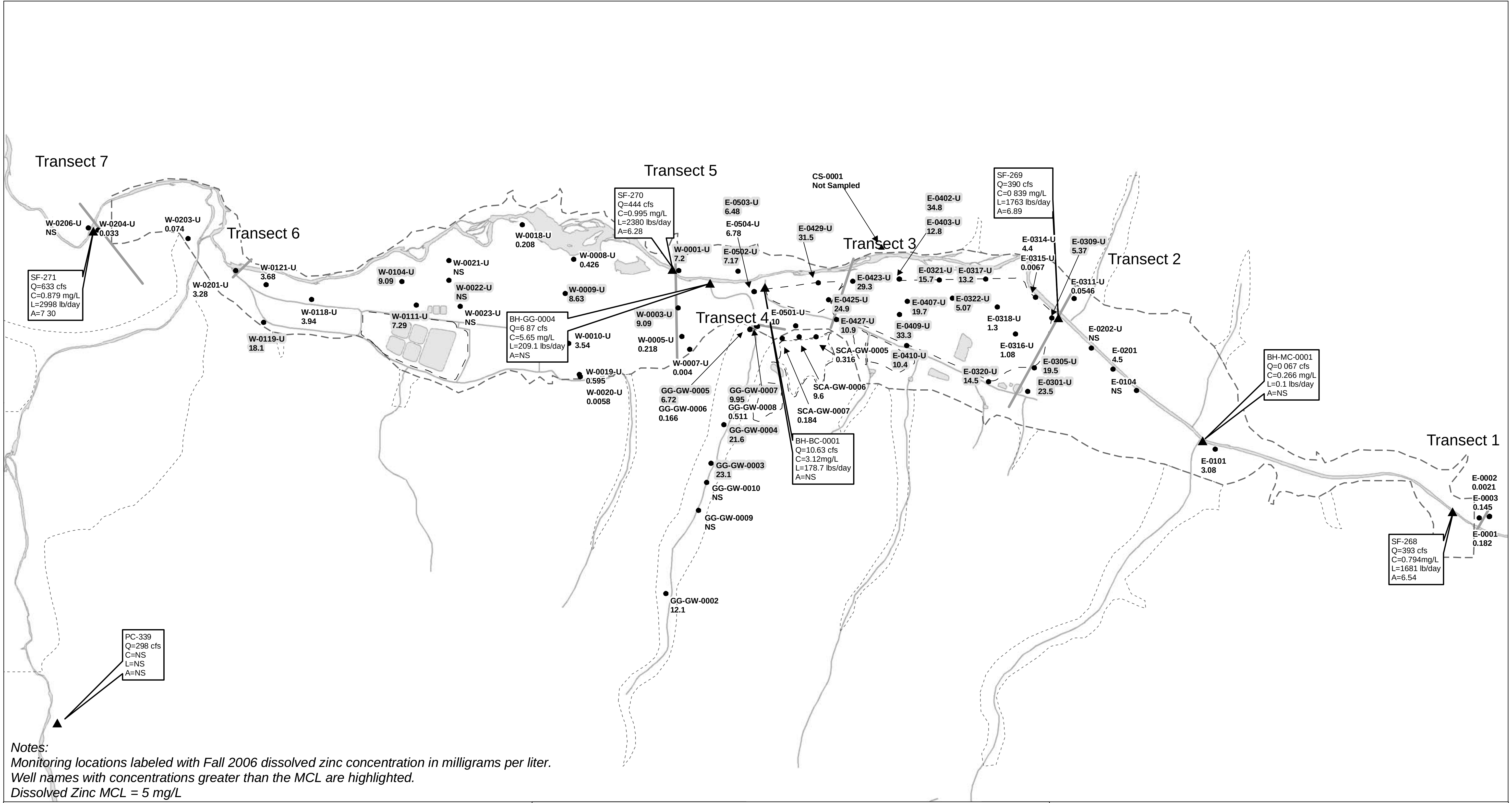
FIGURE 3-3

HISTORIC SFCDR CHANNEL LOCATIONS

SOURCE AREAS OF CONCERN REPORT

BUNKER HILL SUPERFUND SITE OU2

CH2MHILL



Notes:
Monitoring locations labeled with Fall 2006 dissolved zinc concentration in milligrams per liter.
Well names with concentrations greater than the MCL are highlighted.
Dissolved Zinc MCL = 5 mg/L

Legend

Q=Discharge
C=D. Zn Conc.
L=Zinc Load
A=AWQC Ratio

- ● Groundwater Monitoring Well
- ▲ Surface Water Monitoring Location

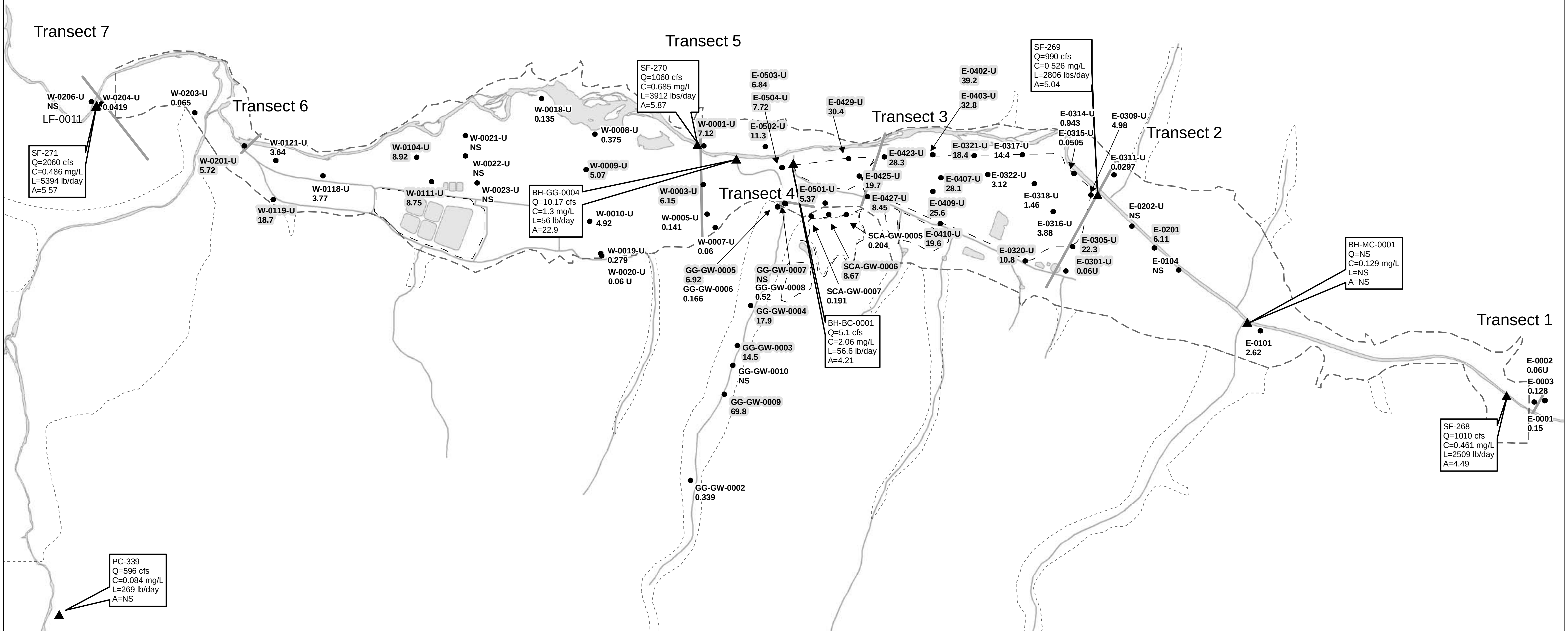
FIGURE 3-4

JANUARY 2006 DATA SUMMARY DISSOLVED ZINC

SOURCE AREAS OF CONCERN REPORT

BUNKER HILL SUPERFUND SITE OU2

CH2MHILL



Notes:
Monitoring locations labeled with Fall 2006 dissolved zinc concentration in milligrams per liter.
Well names with concentrations greater than the MCL are highlighted.
Dissolved Zinc MCL = 5 mg/L

Legend

Q=Discharge
C=D. Zn Conc.
L=Zinc Load
A=AWQC Ratio

● Groundwater Monitoring Well
▲ Surface Water Monitoring Location

N

0 1,700 3,400 Feet

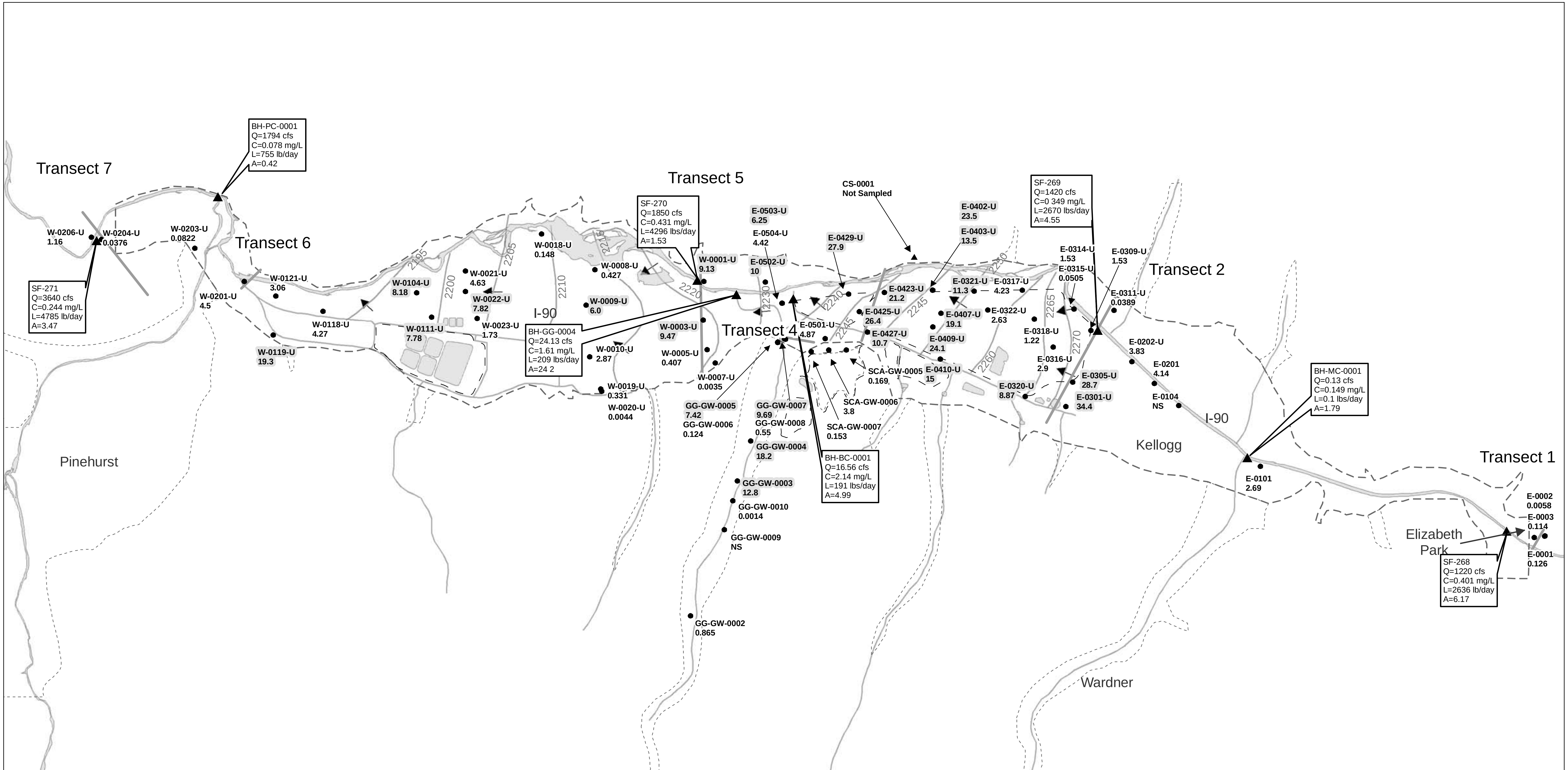
FIGURE 3-5

APRIL 2006 DATA SUMMARY DISSOLVED ZINC

SOURCE AREAS OF CONCERN REPORT

BUNKER HILL SUPERFUND SITE OU2

CH2MHILL



Notes:
Monitoring locations labeled with Fall 2006 dissolved zinc concentration in milligrams per liter.
Well names with concentrations greater than the MCL are highlighted.
Dissolved Zinc MCL = 5 mg/L

Legend

- ● Groundwater Monitoring Well
- ▲ Surface Water Monitoring Location
- — Inferred Upper Aquifer Equipotential Line
- → Inferred Direction of Groundwater Flow

Q=Discharge
C=D. Zn Conc.
L=Zinc Load
A=AWQC Ratio

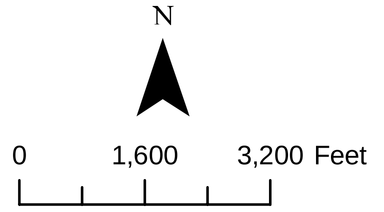


FIGURE 3-6

MARCH 2007 DATA SUMMARY DISSOLVED ZINC

SOURCE AREAS OF CONCERN REPORT

BUNKER HILL SUPERFUND SITE OU2

CH2MHILL

4.0 Summary and Next Steps

This section presents a summary of the findings of the source areas of concern analysis performed in Section 3.0 for dissolved zinc, total lead, and phosphorous. Section 4.4 presents a summary of next steps required to further delineate source areas and identify and design potential Phase II remedial actions to address these source areas.

4.1 Dissolved Zinc

The greatest increases in dissolved zinc concentrations in the SFCDR in OU2 occur between monitoring locations BH-SF-LF-0004 and BH-SF-LF-0006 in the eastern portion of OU2, and between BH-SF-LF-0007 and BH-SF-LF-0010 in the western portion of OU2 (see Figure 3-1). The sources of these dissolved zinc increases are summarized below to the extent practicable.

The analysis of OU2 water quality data allowed for the identification of both discrete and non-discrete potential sources of contamination. The discrete source areas include the historical (pre-mining) SFCDR channel, Bunker Creek, A-4 Gypsum Pond, Milo Creek, Government Creek, and the Page Ponds area. The non-discrete source areas include the widespread contaminated materials distributed across the valley floor within OU2 as a result of historical mine and process waste disposal practices, and contaminated materials used as fill in populated areas and beneath infrastructure. Source areas are summarized in Table 4-1 and data gaps associated with the identification and delineation of these source areas are presented in Table 4-2.

4.4.1 Contaminated Materials in the Floodplain and Beneath Populated Areas and Infrastructure

The largest source of dissolved zinc contamination to groundwater and surface water within OU2 is contaminated materials located in the floodplains and beneath the populated areas and infrastructure within OU2. These materials are widespread throughout the floodplain and are present to significant depth. The widespread nature of this source of contamination makes it difficult to identify discrete areas where contaminated floodplain materials are affecting water quality. Although these areas are known to contribute to shallow groundwater quality in OU2, the overall impact on the SFCDR is uncertain.

4.4.2 Historical SFCDR Channel

The approximate location of the historical (pre-mining) SFCDR channel is shown on Figure 3-3. This channel was filled with mine and process waste following relocation of the channel on the north side of the valley.

The historical SFCDR channel likely acts as a preferential flow pathway for groundwater. As a result of the filling of the SFCDR channel with contaminated materials, groundwater concentrations would be expected to increase as it moves through the channel. The location of the historical SFCDR channel coincides with the locations of groundwater monitoring wells exhibiting some of the highest dissolved zinc concentrations within OU2 (see Figure 3-1).

The groundwater monitoring network in the vicinity of the historical SFCDR channel in the eastern portion of OU2 is minimal. Additional monitoring wells will be required to more fully delineate the location of the historical channel and groundwater conditions in this area. Tracer testing and synoptic sampling in the vicinity of the historical SFCDR channel would provide valuable information regarding contaminant transport in this area. If additional monitoring wells are installed in this area, information regarding the metals concentrations and speciation of metals in the historical SFCDR channel materials would improve the level of understanding of contaminant release mechanisms and anticipated rates and concentrations of contaminant release.

4.4.3 Bunker Creek

Contaminated materials are known to be present beneath the Bunker Creek channel. The current Bunker Creek channel is aligned with the historical SFCDR channel for a large portion of its flow path. Significant losses of surface water from Bunker Creek to the underlying groundwater system have been measured in the portion of Bunker Creek located south of the CIA. As surface water lost from Bunker Creek infiltrates through contaminated materials, it is likely that contaminants are released and transported downgradient. In addition, the losses of discharge from Bunker Creek likely affect the gradient of the groundwater table in this area and skew it toward the SFCDR.

Groundwater monitoring data in the vicinity of Bunker Creek south of the CIA are limited to monitoring wells located on the north (downgradient) side of Bunker Creek. Additional monitoring wells on the southern side of the channel would provide information regarding the impact of losses of surface water on Bunker Creek on the south side of the channel, as well as information regarding potential upgradient sources of contamination (such as hillside gulches and the A-4 Gypsum Pond) and their relative impact on water quality. Although a large amount of information is available regarding contaminant metals concentrations in materials located beneath and adjacent to Bunker Creek, little information is available regarding the speciation of these metals, which is of particular importance in evaluating the potential for and rate of contaminant release. This information is critical to determine the impact of the losses from Bunker Creek on underlying groundwater, to separate out the impacts of other potential sources located upgradient, and to evaluate and design potential remedial technologies.

4.4.4 A-4 Gypsum Pond

Available monitoring data from the A-4 Gypsum Pond show extremely high concentrations of dissolved zinc in groundwater below the gypsum materials. Based on available depth to groundwater measurements from the A-4 monitoring network and the gypsum depths identified during placement of these wells, groundwater does not appear to be in contact with the gypsum but is likely in contact with tailings and other contaminated materials located beneath the gypsum. Because the A-4 gypsum pond cap was not constructed of low-permeability materials, infiltration from precipitation and snowmelt and downgradient movement of tributary and hillside groundwater are likely contaminant release and transport mechanisms. The impact of groundwater from the A-4 Gypsum Pond area on downgradient groundwater and eventually the SFCDR cannot be determined with the available data.

4.4.5 Page Ponds

Other than contaminated materials located in the floodplain and beneath infrastructure, the Page Ponds area represents the most likely potential source of contamination in the western portion of OU2. Contaminated materials are known to be present beneath the Page Wastewater Treatment Plant and the West Page Swamp, and in the repository. Several factors may lead to the transport of dissolved metals to the upper aquifer at this site and include the leaking wastewater ponds, the increased groundwater levels as a result of weir construction, and the repository materials exposed to precipitation.

The lack of a robust groundwater monitoring network in the western portion of OU2 and specifically in the vicinity of Page Ponds prevents the evaluation of this area. Additional groundwater and surface water monitoring coupled with evaluation of source material concentrations and metals speciation will be required to more fully understand contaminant conditions and the impact of the Page Ponds area on groundwater and SFCDR water quality.

4.4.6 Milo Creek

Milo Creek is a contributor of dissolved metals into the SFCDR between BH-SF-LF-0001 and BH-SF-LF-0002. Much of the contamination present in Milo Creek is the result of AMD discharging from the Reed and Russell adits to Milo Creek. Because the discharge and metal concentrations associated with the mine adits are not monitored, it is not possible to determine the impact of other potential contaminant sources on Milo Creek and SFCDR water quality.

The groundwater component of Milo Gulch is not well understood and may contribute to contamination of the upper aquifer. One well (BH-SF-E-0101) is located near the mouth of Milo Gulch. Water quality at BH-SF-E-0101 may be more representative of main SFCDR valley groundwater quality than Milo Gulch groundwater quality.

4.4.7 Government Gulch

A significant amount of contamination is present in the vicinity of the former Zinc Plant in areas where Phase I remedial actions did not result in their removal (near and under foundations and at significant depths). This represents a large source of contamination to groundwater and surface water in Government Gulch. About 40 percent of the Government Creek discharge was lost to the underlying upper aquifer between the mouth of Government Gulch and its confluence with the SFCDR under low-flow conditions. Surface water lost from Government Creek in this area would be expected to come into contact with contaminated materials while infiltrating to underlying groundwater. An evaluation of source material concentrations and metal speciation will be required to more fully understand potential sources of contamination and their impact on water quality.

4.2 Total Lead

Contributions of total lead to the SFCDR from OU2 sources do not appear to be significant, with the exception of slight increases in total lead concentrations under high-flow conditions between BEMP monitoring locations SF-269 and SF-270. Tributaries discharging to the SFCDR in this area typically have total lead concentrations less than those observed in the SFCDR. Therefore, the contribution of total lead to the SFCDR appears to be from unmonitored sources such as the resuspension of lead from the channel bed, banks, and floodplains from within OU2, and sources upgradient in OU3.

4.3 Phosphorous

Insufficient monitoring data have been collected within OU2 to identify potential source areas of phosphorous. However, areas believed to contribute phosphorous to the SFCDR include the A-4 Gypsum Pond, the former phosphoric acid/fertilizer plant in Government Gulch, and the Page Ponds area.

4.4 Next Steps

This section summarizes the next steps to be completed and provides a general path forward to implement Phase II remedial actions in OU2. These next steps include:

- Conduct remedial action screening for the source areas listed in Section 4.0.
- Prioritize source areas based on impacts to SFCDR and potential remedial actions identified during screening process.
- Construct a shell groundwater model of OU2 to evaluate groundwater conditions and the impact of potential remedial actions on the OU2 groundwater and surface water systems. The construction of the model will also assist in identifying critical data gaps that must be filled in order to design and implement potential Phase II remedial actions.
- Identify and implement investigation and data collection activities to address data gaps at priority source areas.
- Identify, design, and implement Phase II remedial actions.

TABLE 4-1
OU2 Source Areas
Source Areas of Concern Report
Bunker Hill Superfund Site OU2

Source Area	**Summary**
Contaminated Materials in the Floodplain and Beneath Populated Areas and Infrastructure	• The largest source of dissolved zinc contamination to groundwater and surface water within OU2. • Widespread and present at significant depths throughout OU2. • Difficult to identify discrete areas where the greatest impacts are occurring because of limited monitoring network and source material properties.
Historical SFCDR Channel	• The location of the historical SFCDR channel coincides with the locations of groundwater monitoring wells exhibiting the greatest dissolved zinc concentrations within OU2 (Figure 3-1). • The historical SFCDR channel likely acts as a preferential flow pathway for groundwater. • As a result of the filling of the SFCDR channel with contaminated materials, groundwater concentrations would be expected to increase as it moves through the channel.
Bunker Creek	• A large portion of the Bunker Creek channel is aligned with the historical SFCDR channel. • Significant losses of surface water from Bunker Creek to the underlying groundwater system are occurring in the portion of Bunker Creek located south of the CIA. • Relatively clean surface water lost from Bunker Creek infiltrates through contaminated materials, resulting in contaminant release and transport downgradient. • Losses of discharge from Bunker Creek likely affect the groundwater gradient in the area south of the CIA and skew the gradient toward the SFCDR.
A-4 Gypsum Pond	• Elevated dissolved zinc concentrations have been observed in the upper aquifer beneath the A-4 Gypsum Pond. • Insufficient groundwater elevation data are available to assess the direction of groundwater flow and gradients. • It is assumed that highly contaminated groundwater from the A-4 Gypsum Pond area migrates toward the Bunker Creek area and eventually to the SFCDR. There is insufficient data to evaluate the impact of this groundwater on downgradient water quality.
Page Ponds	• Other than contaminated materials located in the floodplain and beneath infrastructure, the Page Ponds area represents the most likely potential source of contamination in the western portion of OU2. • The limited groundwater monitoring network in the western portion of OU2 and specifically in the vicinity of Page Ponds prevents the evaluation of this area. • Additional groundwater and surface water monitoring coupled with evaluation of source material concentrations and metal speciation will be required to more fully understand contaminant conditions and the impact of the Page Ponds area on SFCDR water quality.
Milo Creek	• Milo Creek is a contributor of dissolved metals into the SFCDR between BH-SF-LF-0001 and BH-SF-LF-0002. • Much of the metals loading in Milo Creek is a result of acid mine drainage (AMD) discharging from the Reed and Russell adits to Milo Creek. Because the discharge and metal concentrations associated with the mine adits are not monitored, it is not possible to determine their exact impact on Milo Creek water quality. • Milo Gulch groundwater is not well understood and may contribute to contamination of the main SFCDR valley aquifer.
Government Gulch/ Government Creek	• A significant amount of contamination is present in the vicinity of the former Zinc Plant where Phase I remedial actions did not remove contaminants (under foundations and at depth). This represents a source area for groundwater and surface water in Government Gulch. • Under low-flow conditions, Government Creek loses approximately 40 percent of its discharge to the underlying upper aquifer between the mouth of Government Gulch and its confluence with the SFCDR. • Discharge lost from Government Creek likely infiltrates through contaminated materials. An evaluation of source material concentrations and metals speciation will be required to more fully understand contaminant conditions and the impact of the losing Government Creek discharge on the SFCDR.

Notes:
Rankings are listed based on assumed impact on SFCDR water quality.

TABLE 4-2
OU2 Source Area Data Gaps
Source Areas of Concern Report
Bunker Hill Superfund Site OU2

Location	**Data Gaps**
Contaminated Materials in the Floodplain and Beneath Populated Areas and Infrastructure	• The current groundwater monitoring network does not provide sufficient data to characterize and define groundwater flow and preferential pathways, including identifying contaminated groundwater inputs to the SFCDR from potential source areas (i.e., Smelterville Flats sediments and sediments beneath Kellogg) • A significant amount of infrastructure and populated areas is present throughout OU2. The contaminant mass and locations affecting groundwater quality in the vicinity of Kellogg, beneath I-90, and beneath other infrastructure is unknown.
Historical SFCDR Channel	• Insufficient data is available regarding groundwater conditions in the vicinity of the historical SFCDR channel. • Additional data collection, such as tracer testing coupled with synoptic sampling of groundwater and surface water in the vicinity of the historical SFCDR channel where the greatest concentrations of dissolved zinc are present, would provide information regarding the potential for the channel to act as a preferential flow pathway and its resultant impact on downgradient water quality. • No data are available regarding contaminant concentrations present in the historical SFCDR channel. Additional information regarding contaminant concentrations and metals speciation in these materials will be required to evaluate the contaminant fate and transport in this area.
Bunker Creek	• The current Bunker Creek monitoring network does not provide sufficient data to characterize and define groundwater flow and preferential pathways in the Bunker Creek corridor. • The overall impact of Bunker Creek discharge loss on the upper aquifer groundwater quality is uncertain. Gaining and losing reaches of Bunker Creek under different discharge conditions are not well understood. • Groundwater quality and elevations along the south side of Bunker Creek are uncertain. • The impact of losses of discharge from Bunker Creek to the gradient of the underlying groundwater table is not understood.
A-4 Gypsum Pond	• The current A-4 Gypsum Pond monitoring network does not provide sufficient data to characterize and define groundwater flow and preferential pathways. • The overall impact of contaminated groundwater on main SFCDR valley groundwater quality is unknown. • The impact of upgradient contaminant sources on A-4 Gypsum Pond area water quality is unknown.
Page Ponds	• The current Page Ponds groundwater monitoring network does not provide sufficient data to characterize and define groundwater flow and preferential pathways, including identifying contaminated groundwater inputs to the SFCDR. • Tailings are known to be present beneath the wastewater lagoons and in the West Page Swamp, and are impacted by several contaminant release mechanisms. The overall impact of these contaminant release mechanisms on groundwater quality is unknown. • The amount of metals loading to the upper aquifer from the leaking wastewater lagoons in contact with the underlying tailings, precipitation infiltration through the repository waste material, and from the construction of the weir to control water levels in the East Page Swamp are unknown. • The amount of recharge and water quality impacts to the upper aquifer from Humboldt Creek and Grouse Creek is unknown.
Government Gulch/ Government Creek	• The remaining contaminant mass within Government Gulch and the contaminant release mechanisms contributing to the propagation of dissolved metals in groundwater and surface water are not well understood. • Specific gaining and losing reaches of Government Creek under different discharge conditions are not refined. Groundwater/surface water interaction within Government Gulch and its impact on contaminant fate and transport is not known. • The presence and characteristics of source materials in the vicinity of Government Creek as it crosses the main SFCDR valley are not well known. • The groundwater monitoring network in the vicinity of Government Creek as it crosses the main SFCDR valley is insufficient to delineate the potential impact that losses of discharge from Government Creek have on underlying groundwater and eventually the SFCDR.
Milo Creek/Milo Gulch	• The quantity and quality of the acid mine drainage (AMD) discharged to Milo Creek from the Reed and Russell adits is unknown. • Spatially limiting groundwater quality and elevation data are available for Milo Gulch that prevent the delineation and identification of potential source areas and resultant impacts on SFCDR and main SFCDR valley groundwater.

Notes:
Rankings are prioritized based on the source area rankings listed in Table 4-1.

5.0 References

Buchannon and Somers. 1969. *Techniques of Water Resource Investigations of the United States Geologic Survey, Chapter A7, Stage Measurements at Gauging Stations.* 1969.

CH2M HILL. 2001. *Bunker Hill Mine Water Management Remedial Investigation/Feasibility Study*. Prepared for U.S. E.P.A., April 2001.

CH2M HILL. 2006a. *Current Status Conceptual Site Model, Operable Unit 2, Bunker Hill Mining and Metallurgical Complex Superfund Site*. Prepared for EPA. January.

CH2M HILL. 2006b. *Environmental Monitoring Plan, Operable Unit 2, Bunker Hill Mining and Metallurgical Complex Superfund Site*. Prepared for EPA. January.

CH2M HILL. 2007. *Phase I Remedial Action Assessment Report, Operable Unit 2, Bunker Hill Mining and Metallurgical Complex Superfund Site.* Prepared for EPA. October.

Idaho Department of Health and Welfare. 1995. *State Superfund Contract [SSC] and Corresponding Documents*. April.

Idaho National Laboratory. 2007. *Canyon Creek Groundwater Metal Source Characterization*. May 2007.

Johnson Environmental Concepts. 2008. *OU2 Water Quality – Source Areas of Concern*. February.

Nimick, et. al. 2003. *Diel Cycles in Dissolved Metal Concentrations in Streams: Occurrence and Possible Causes.*

Terragraphics Environmental Engineering, Inc. and Ralston Hydrologic Services. 2006. *Phase I Remedial Action Characterization Report for the Bunker Hill Mining and Metallurgical Complex, Operable Unit 2.* Prepared for IDEQ. January.

U.S. Environmental Protection Agency (EPA). 1991. *Record of Decision, Bunker Hill Mining and Metallurgical Complex Residential Soils Operable Unit.* Shoshone County, Idaho. August.

U.S. Environmental Protection Agency (EPA). 1992. *Record of Decision, Bunker Hill Mining and Metallurgical Complex [Non-Populated Area].* Shoshone County, Idaho. EPA ROD R10-92-028. September.

U.S. Environmental Protection Agency (EPA). 2002. *Interim Record of Decision Bunker Hill Mining and Metallurgical Complex OU3.*

U.S. Environmental Protection Agency (EPA). 2004. *Basin Environmental Monitoring Plan, Bunker Hill Mining and Metallurgical Complex OU3*. March.

U.S. Environmental Protection Agency (EPA), 2005. *Second Five-Year ROD Review for Bunker Hill Mining and Metallurgical Complex Superfund Site Operable Units 1, 2, and 3, Idaho and Washington. EPA 910-R-05-006.* October 2005.

U.S. Environmental Protection Agency and Idaho Department of Environmental Quality (EPA and IDEQ). 2007. *Bunker Hill Mining and Metallurgical Complex Superfund Site Operable Unit 2, Monitoring and Evaluation Work Plan*. March 13, 2007.

Appendix A
OU2 Water Quality – Source Areas of Concern
(Johnson, 2008)

Johnson Environmental Concepts
24054 Palmer Gulch Rd., Hill City, SD 57745
605 574 2024; Fax 60 /343 4131
kjohnson@johnsonenviro.com

TO: Nick Zilka, IDEQ
Anne Dailey, USEPA

FROM: Kathryn Johnson, Johnson Environmental Concepts
Subcontractor to TerraGraphics for IDEQ

DATE: February 26, 2008

SUBJECT OU2 Water Quality – Source Areas of Concern

In response to the assignment that came from the January 31, 2008 meeting of the OU2 Water Quality Team discussing Source Areas of Concern, this memo summarizes my thoughts on the relationship between groundwater pH and dissolved zinc and cadmium concentrations. The relationship between pH and metals, primarily zinc and cadmium is explored as it might relate to remedial actions conducted to reduce the metal loading to the SFCDR.

My understanding of the geochemistry of zinc and other metals in the OU2 SFCDR alluvium has been developed from the chemical groundwater data from monitoring wells in the area and the results of experimental work conducted on the Canyon Creek alluvium by Idaho National Laboratory (INL, 2007. Canyon Creek Groundwater Metal Characterization, prepared for US EPA). There may be other data relevant to this discussion of which I am not aware. I will incorporate additional data upon its receipt.

Relevant Experimental Results

Idaho National Laboratory (INL, 2007) conducted various leaching experiments on Canyon Creek alluvium samples to assess metal speciation in and metal release from the sediments to help understand the factors that affect metal mobility. The water quality of the groundwater in Canyon Creek alluvium and in OU2 SFCDR alluvium is similar. The pH of groundwater ranges primarily from 4 – 7 in both areas and zinc is mostly present in concentrations ranging from about 0.50 – 50 mg/l.

Sequential extractions by INL showed that about 40 percent of the zinc and cadmium were contained in the fraction easily leachable by water and a weak acid of pH 5. Another 40 percent of the zinc and cadmium was associated with Fe/Mn/Al hydrous oxide and organic matter leachable under more strongly acidic conditions. Difficult to leach sulfide or other residual mineral contained the remaining 20 percent of zinc and cadmium. Zinc and cadmium did not follow the pattern of iron. All but about 10 percent of the iron was associated with the residual/sulfide fraction. Manganese more closely aligned with the pattern of zinc and cadmium. The proportion of manganese outside the residual/sulfide ranged from about 60 – 90 percent.

INL also evaluated leaching of metals by groundwater at two different pH conditions. Simulated groundwater samples adjusted to pH 2 and pH 7 were put in contact with the sediment samples for 68 days and the concentration of leached metals was measured 10 times through the duration of the experiment. The leaching slurries were assembled in a nitrogen environmental and stored in gas-tight

Teflon jars to prevent atmospheric oxygen from affecting the leaching. In the pH 7 groundwater, concentrations of zinc and cadmium decreased initially and maintained relatively stable concentrations. Zinc started at 0.98 mg/l and declined to 0.33 mg/l. Under pH 2 conditions, concentrations of zinc and cadmium increased sharply within the first 3 days and continued to increase at a slower rate throughout the experiment. Zinc started at 40.2 mg/l and increased to 81.1 mg/l over 86 days. The initial increase is likely due to the desorption of the very easily leachable zinc followed by desorption of the zinc associated with Fe/Mn/Al hydrous oxide and organic matter that required more acidic conditions.

Although the effects of introducing oxygen into the system were not evaluated in the experiments by INL, the fact that up to 80 percent of the zinc and cadmium is associated with phases not sensitive to oxidation/reduction chemistry suggests that oxygen would not play a significant role in determining the parameters of mobility from the alluvial sediments into the groundwater.

A column experiment by INL in which 41 pore volumes of synthetic groundwater were passed through a composite sediment sample over 41 days showed that although the zinc concentration declined by about an order of magnitude over the duration of the experiment, the leaching removed a very small portion of the easily extractable mass of zinc in the sample. This suggests that the alluvium is a very large source of metals to the groundwater.

OU2 Empirical Data

The zinc concentrations and pH measurements in groundwater samples from the OU2 SFCDR alluvium were examined. The data do not show a proportional relationship as shown in the following figures that illustrate the relationship between zinc and pH from the various OU2 subareas. Generally all of the areas show a similar pattern. At lower concentrations the pH measurements range broadly from less than 5 to greater than 7. The pH values corresponding to increasing concentrations of zinc are skewed toward lower pH conditions. For example, in several of the subareas essentially all of the pH values corresponding to zinc concentrations greater than about 30 mg/l are less than 6.5.

The data suggest that the mass of zinc available for desorption into the groundwater is an important parameter controlling the soluble concentration. The zinc concentrations at acidic pH conditions may be limited by the mass of zinc available to desorp from the sediment in contact with the groundwater rather than any pH dependency.

The data also suggest that although pH is likely just one of several controlling factors at the higher zinc concentrations, i.e. in general, zinc concentrations greater than about 30 mg/l only occur when the pH is less than 6.5, the concentration of zinc does not appear to be sensitive to pH at conditions less than 6.5. Although additional experimental work would be needed to examine the effects of raising the pH to greater than 6.5 on zinc concentrations, the results by INL suggest an expected effect. Initially groundwater at pH 7 in contact with sediment contained about 1 mg/l compared to about 40 mg/l in the groundwater adjusted to pH 2.

Although the field measurements do not show sensitivity between zinc concentrations and pH at values less than about 6.5 and show an uncertain relationship at pH values greater than 6.5, an experiment to evaluate this further would provide important information. For example, adjusting the pH of slurries of sediment and groundwater collected from the field from areas representing a range of soluble zinc concentrations and a range of pH conditions would shed light on the question of pH sensitivity.

Adsorption Concepts

Considering that zinc is not expected to precipitate as a carbonate or hydroxide mineral until the pH reaches values greater than 8, adsorption is the most likely mechanism to influence the exchange between the sediment and groundwater at the pH conditions along the SFCDR and its tributaries. The charge on the mineral surface is a function of pH which in turn affects the potential for metal adsorption. In general, the adsorption potential is greater at higher pH values and declines as the pH becomes more acidic. Data reported in the literature suggests that adsorption of metals such as zinc and cadmium occurs only at pH conditions greater than 6.5 or 7 (Metals in Groundwater, 1993, edited by Allen, H.E., E.M. Perdue and D.S. Brown). Adsorption under pH conditions greater than about 6.5 may explain why the highest concentrations of zinc generally exist with pH values less than about 6.5. However, the pH sensitivity to adsorption varies for different minerals and the sequential extractions by INL suggest a variety of mineral phases and desorption mechanisms. Experimental work is the only way to really understand the relationship between pH and perhaps other parameters that control the adsorption/desorption of zinc and cadmium.

Once the relationship between pH and adsorption of metals are understood then the questions about how a contemplated remedial action may affect the pH of the groundwater could be evaluated in light of any effects that it could have on metal mobility. For example, decreasing the contact between groundwater and the sediments by hydrologic focused remedies would not likely affect the pH of the groundwater. And even if the pH of the groundwater did decrease within the range typical of the alluvium of the SFCDR it may not result in an increase in the soluble zinc and cadmium in the groundwater. Increasing the pH to 7 or greater would only increase the sorption thus decreasing the soluble concentrations of zinc and cadmium.

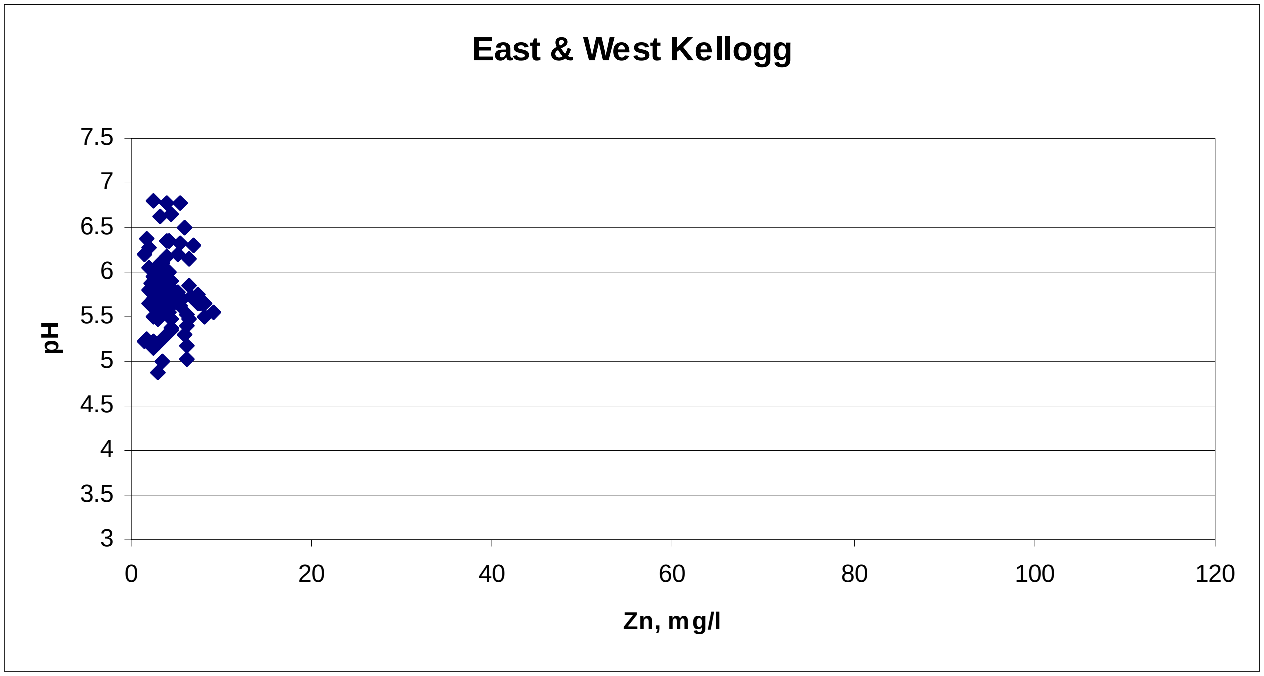


Figure 1. Zinc and pH in groundwater from the East and West Kellogg subareas of OU2 (data provided by CH2M Hill, Steve Hicks)

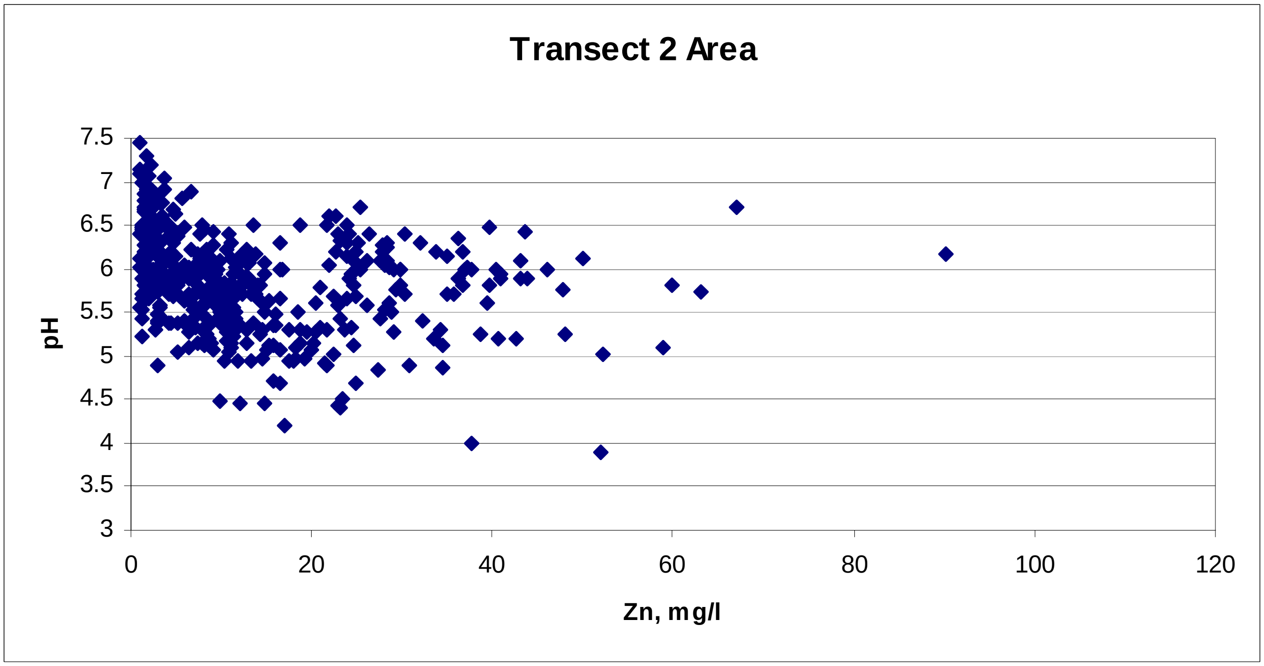


Figure 2. Zinc and pH in groundwater from the Transect 2 subarea of OU2 (data provided by CH2M Hill, Steve Hicks)

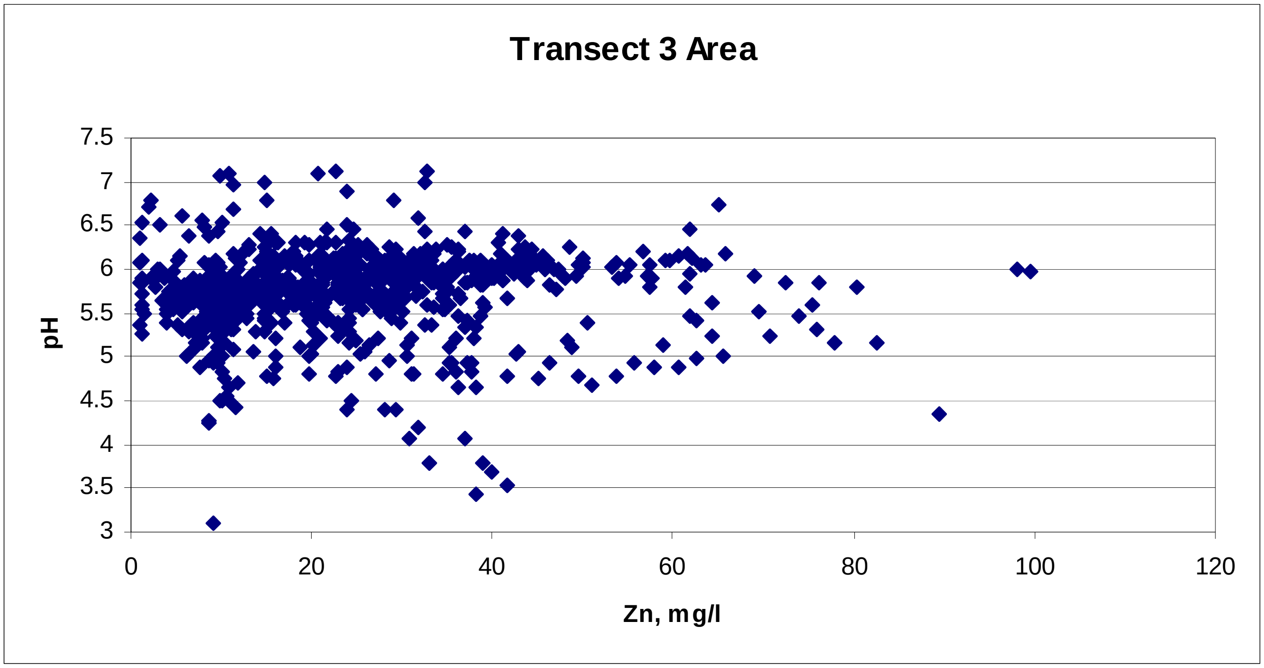


Figure 3. Zinc and pH in groundwater from the Transect 3 subarea of OU2
(data provided by CH2M Hill, Steve Hicks)

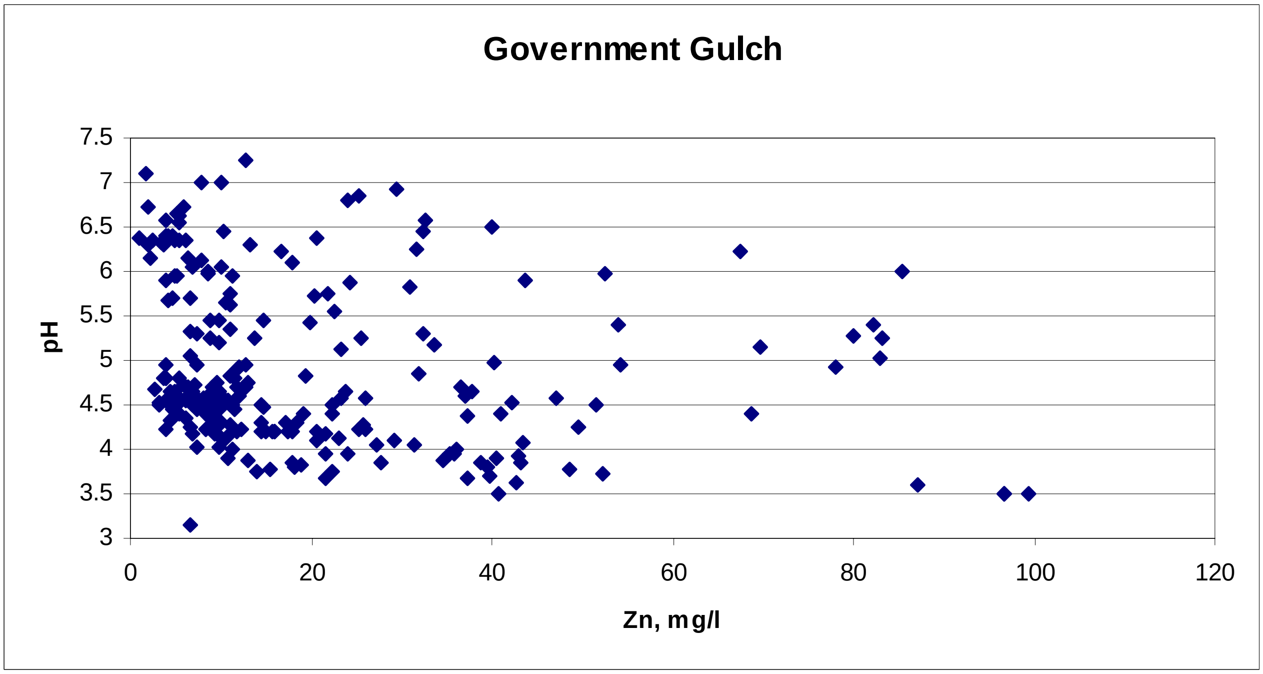


Figure 4. Zinc and pH in groundwater from the Government Gulch subarea of OU2
(data provided by CH2M Hill, Steve Hicks)

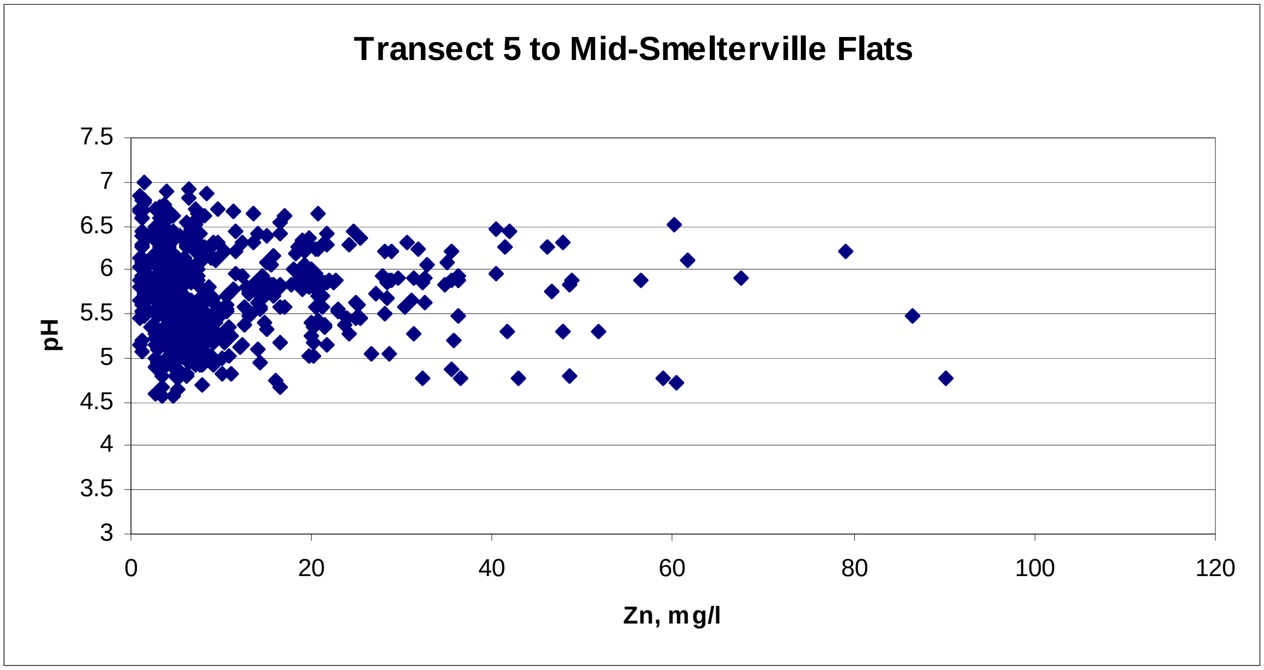


Figure 5. Zinc and pH in groundwater from the subarea Transect 5 to mid-Smelterville Flats of OU2 (data provided by CH2M Hill, Steve Hicks)

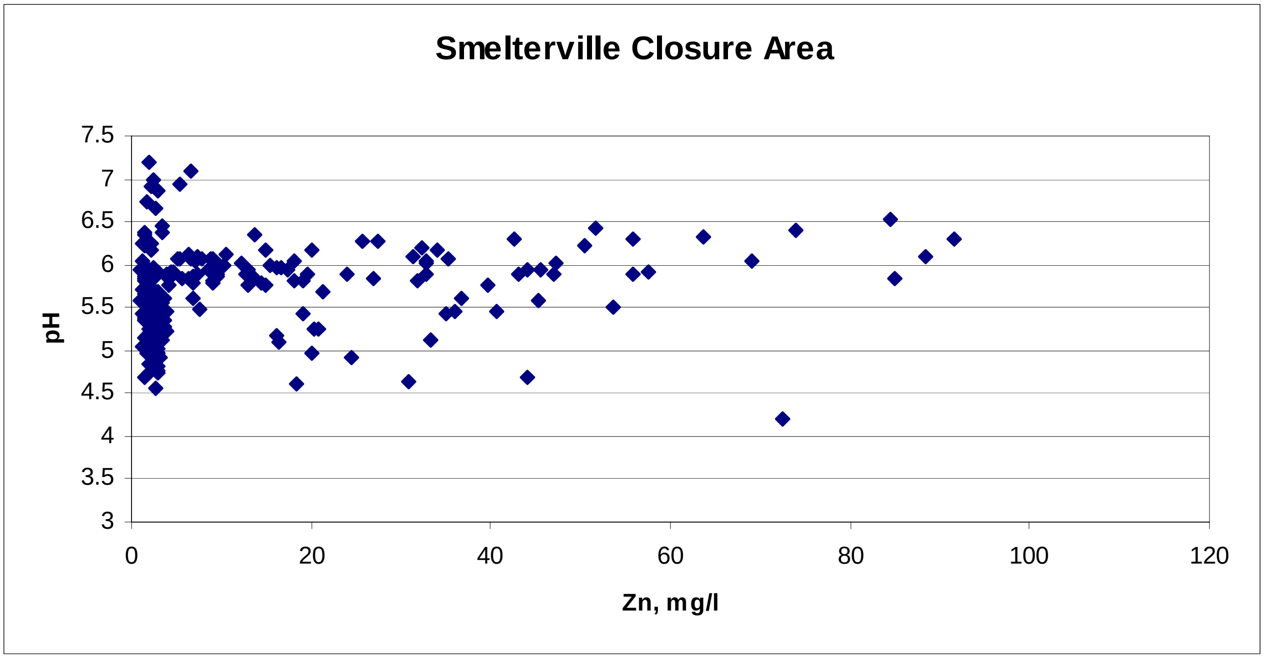


Figure 6. Zinc and pH in groundwater from the Smelterville Closure Area of OU2 (data provided by CH2M Hill, Steve Hicks)