Final

Statistical Analysis of Post-Phase I Remedial Action Water Quality Data 2000-2004 Operable Unit 2

Bunker Hill Mining and Metallurgical Complex Superfund Site

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Executive Summary

This document presents a statistical analysis and evaluation of water quality monitoring data collected within Operable Unit 2 (OU2) of the Bunker Hill Mining and Metallurgical Complex Superfund Site following the implementation of Phase I remedial actions. This document is a companion document to the Current Status Conceptual Site Model for OU2 (CSM) (CH2M HILL, 2006a) and the OU2 Environmental Monitoring Plan (OU2 EMP) (CH2M HILL, 2006b). This statistical analysis and evaluation provides an evaluation of water quality status and trends following the implementation of Phase I remedial actions and provides a framework for future analyses of water quality data collected within OU2.

Water quality monitoring has been conducted within OU2 from 1987 to the present. Three time periods representing different physical and contaminant conditions were evaluated, as follows:

- 1987 to 1994 – Remedial Investigation and Design (characterization monitoring)
- 1994 to 2000 – Phase I Remedial Action Implementation (detection monitoring)
- 2000 to 2004 – Post-Phase I Remedial Action Implementation (effectiveness monitoring)

The post-Phase I remedial action implementation time period best represents water quality and trends attributable to the implementation of Phase I remedial actions and evaluation of these actions toward meeting water quality objectives for OU2.

The statistical evaluation methodologies included comparing monitoring results to water quality criteria (exceedence), noting correlations between monitoring parameters, and performing an evaluation of trend using the Mann-Kendall test. The Mann-Kendall test is a non-parametric test for the detection of trends in time series data. The Mann-Kendall test is widely used in environmental science because it is simple, robust, and can cope with missing values and values below detection limits (Libiseller and Grimvall, 2002). Both groundwater and surface water monitoring data collected between April 2000 and October 2004 were evaluated. The focus of the evaluation was on groundwater, with surface water as an ancillary component of the groundwater evaluation. Both the full period of record monitoring results (1987 to 2004) and the post-Phase I remedial action implementation monitoring results were evaluated. Results and conclusions presented in this document are focused on the post-Phase I remedial action implementation period (2000 to 2004). Water quality results for exceedence and trends at each monitoring location were evaluated geospatially for the monitoring network and with respect to the hydrogeologic site conceptual model.

The results of the evaluation are summarized by the methodologies used, and are as follows:

- Dissolved metals in groundwater were evaluated against maximum contaminant levels (MCLs) to determine the frequency of MCL exceedence.
  - The MCL was exceeded most often by cadmium, followed by zinc, arsenic, lead and antimony (Table ES-1).

  - Dissolved cadmium (Figure ES-1) and dissolved zinc exceeded their respective MCLs at a relatively high frequency in the upper aquifer throughout OU2 with the exception of the eastern and western boundaries of the site.
  - Dissolved lead and dissolved arsenic (Figure ES-2) MCLs were most frequently exceeded in Government Gulch and in the upper aquifer near the Central Impoundment Area (CIA) and Page Ponds.
  - Dissolved antimony exceeded the MCL at relatively low frequencies throughout OU2.
  - The distribution of dissolved cadmium (Figure ES-1) and zinc MCL exceedence frequencies in the lower aquifer suggest that a preferential flow pathway may be present in the southern portion of the lower aquifer.
- Groundwater quality parameter correlations were observed and are summarized as follows:
  - A strong correlation between dissolved cadmium and dissolved zinc and to a lesser extent between dissolved arsenic and dissolved lead were observed.
  - A correlation was indicated between pH and dissolved arsenic and to a lesser degree dissolved cadmium and dissolved zinc.
  - A correlation between conductivity and the parameters dissolved cadmium and dissolved zinc was present.
- Groundwater quality trends associated with post-Phase I remedial actions are summarized as follows:
  - Decreasing or not significant (confidence interval less than 95 percent) trends were determined for dissolved metals in all except two wells; one with an increasing dissolved cadmium trend (Figure ES-3) and the other an increasing dissolved zinc trend (Figure ES-4).
  - The increasing dissolved cadmium trend occurred at monitoring well BH-SF-W-0113-U, completed in the tailings material of the Page Ponds tailings impoundment.
  - The increasing dissolved zinc trend occurred at monitoring well BH-SF-E-0321-U, located in the upper aquifer between the CIA and the South Fork Coeur d'Alene River (SFCDR).
- Surface water parameters were evaluated for frequency of ambient water quality criteria (AWQC) exceedence for the post-Phase I remedial actions time period, and are summarized as follows:
  - In general, dissolved metals exceed AWQC at relatively high frequencies throughout OU2 (Table ES-2).
  - Lack of sufficient monitoring data limited the applicability of determining correlations and trends; however, extensive work is being conducted to develop methods of analysis for surface water monitoring locations within the Coeur d'Alene

River Basin as part of the OU3 Basin Environmental Monitoring Plan (EPA, 2004) and will implemented within OU2.

Based on the results and lessons learned during the performance of this statistical analysis and evaluation, the following conclusions and recommendations have been developed regarding future monitoring data collection and statistical analysis:

- Post-Phase I remedial action groundwater monitoring results indicate that the OU2 Phase I source removal and containment actions have generally resulted in downward dissolved metal contaminant concentrations, but concentrations continue to frequently exceed the MCLs.
- Post-Phase I surface water monitoring results indicate that dissolved metal concentrations continue to frequently exceed AWQC throughout OU2.
- Monitoring well hydrographs indicate past inconsistent and noncoincident sampling of groundwater monitoring locations, which limits the utility of the data for statistical evaluation.
- Consistent and coincident surface water and groundwater monitoring and placement of groundwater monitoring locations adjacent to surface water monitoring locations would improve comparison and statistical evaluation for surface water and groundwater quality. Events should coincide with SFCDR base-flow and high-flow surface water events.
- Surface water method detection limits (MDLs) were found to be greater than AWQC for several monitoring parameters. This limited the ability to analyze surface water monitoring data with respect to AWQC. Revised MDLs for surface water monitoring parameters are needed to improve analysis of these parameters.
- Continued groundwater and surface water monitoring is recommended to refine the ability to track trends over time and to increase the post-Phase I remedial action data set to develop time-dependant estimates for achieving remedial action objectives through regression analyses.

Based on the results to date, the OU2 Environmental Monitoring Plan has been developed and includes streamlined monitoring activities to assess long-term status and trends of OU2 groundwater and surface water, and to provide data required for future Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) required five-year reviews.

TABLE ES-1
Groundwater Parameter MCL Exceedence
OU2 Statistical Analysis
Bunker Hill Superfund Site OU2

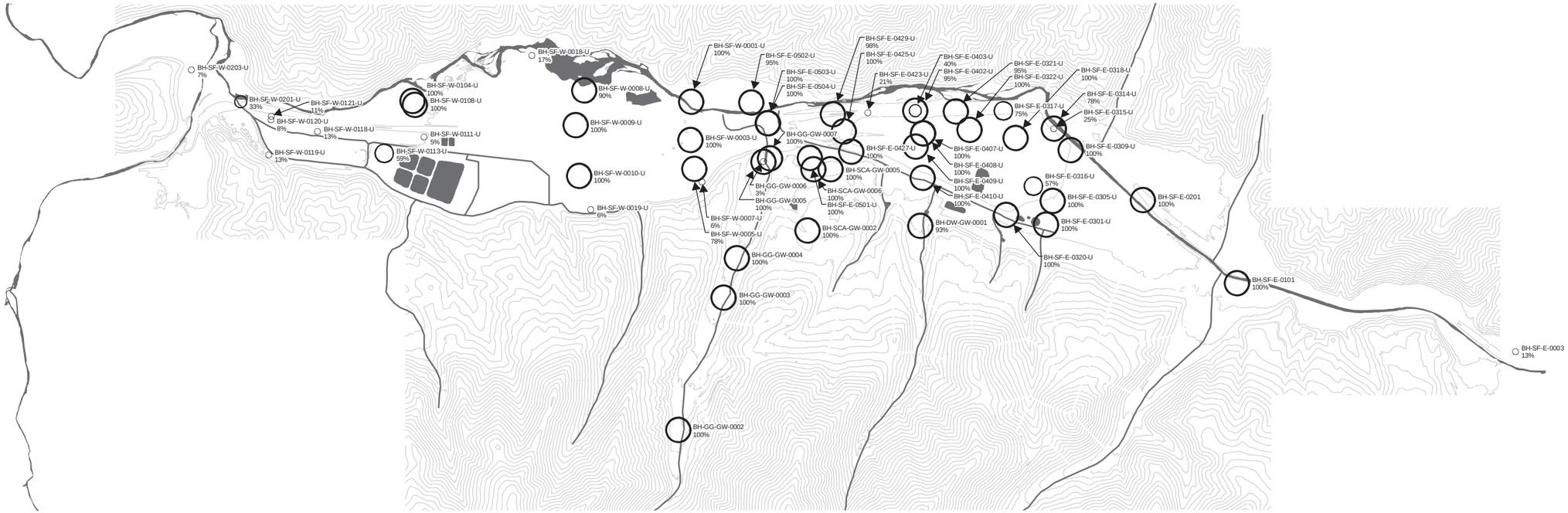
Parameter (dissolved)	Exceedence (# of wells [% of all wells])	Range of Exceedence Frequency within a Well			Range of Detected Concentrations			MCL (µg/L)
		Minimum (%)	Maximum (%)	Mean (%)	Minimum (µg/L)	Maximum (µg/L)	Mean (µg/L)	
Cadmium	68 [81%]	3	100	74	0.01	2,130	115	5
Zinc	47 [58%]	6	100	82	2	162,000	7,820	5,000[a]
Arsenic	47 [58%]	3	100	27	0.04	119	10	10
Lead	21 [26%]	3	100	35	0.01	540	11	15
Antimony	5 [6%]	5	25	11	0.04	518	25	6

[a] Secondary MCL

TABLE ES-2
Surface Water Parameter AWQC Exceedence
OU2 Statistical Analysis
Bunker Hill Superfund Site OU2

Parameter	Exceedence (# of stations [% of all stations])	Range of Exceedence Frequency at a Station			Range of Detected Concentrations	
		Minimum (%)	Maximum (%)	Mean (%)	Minimum (µg/L)	Maximum (µg/L)
Zinc (dissolved)	13 [100%]	46	100	90	14	34,500
Cadmium (dissolved)	13 [100%]	13	100	70	0.12	260
Lead (total)	13 [100%]	9	100	74	0.07	3,180
Arsenic (dissolved)	12 [100%]	17	100	50	0.12	61

UPPER AQUIFER



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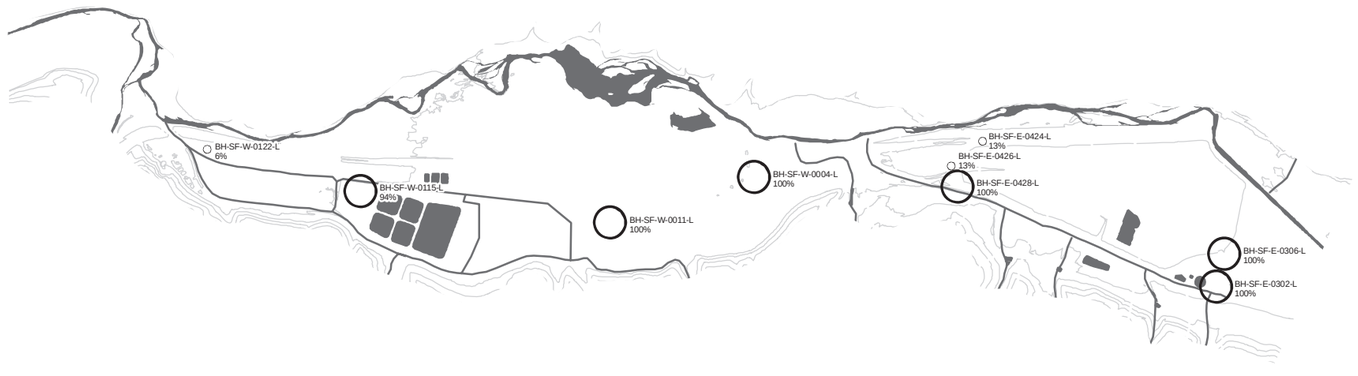

NOTE: Data gathered between April 2000 and May 2004.

Legend

- 1-25% Exceedence
- 26-50% Exceedence
- 51-75% Exceedence
- 76-100% Exceedence
- Water Features

N

0 3,000 6,000 Feet

FIGURE ES-1

DISSOLVED CADMIUM FREQUENCY OF MCL EXCEEDENCE IN GROUNDWATER OU2 STATISTICAL ANALYSIS

BUNKER HILL SUPERFUND SITE OU2

CH2MHILL

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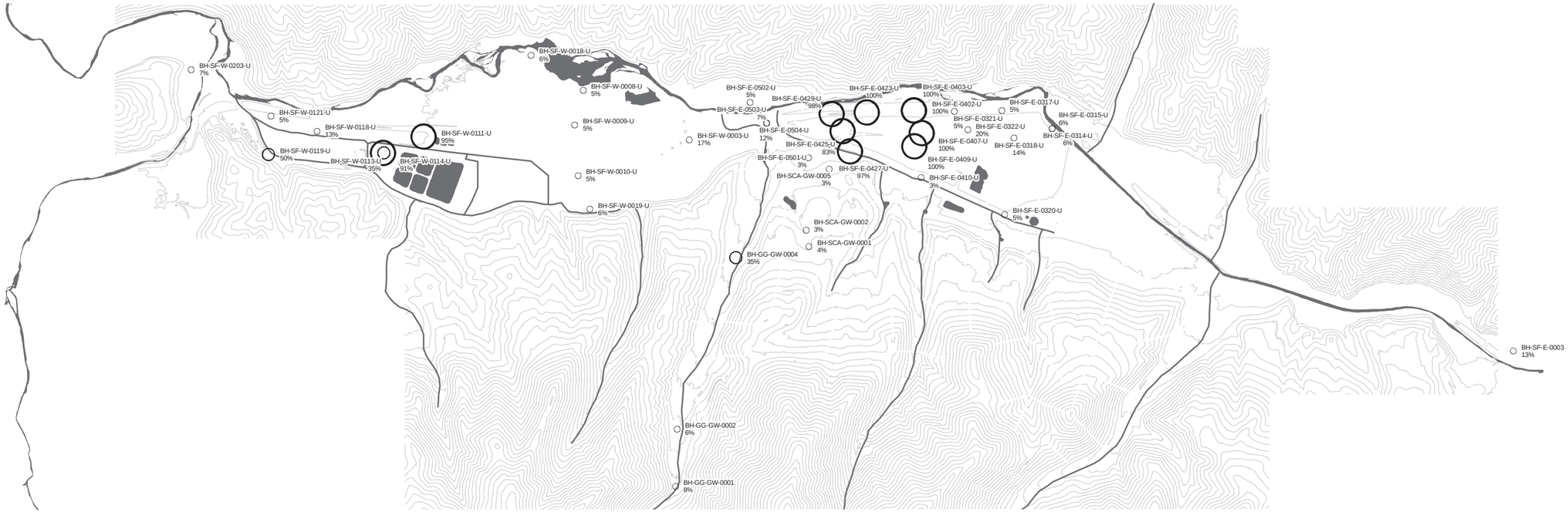

LOWER AQUIFER

NOTE: Data gathered between April 2000 and May 2004.

Legend

- 1-25% Exceedence
- 26-50% Exceedence
- 51-75% Exceedence
- 76-100% Exceedence
- Water Features

N

0 3,000 6,000 Feet

FIGURE ES-2

DISSOLVED ARSENIC FREQUENCY OF MCL EXCEEDENCE IN GROUNDWATER OU2 STATISTICAL ANALYSIS

BUNKER HILL SUPERFUND SITE OU2

CH2MHILL

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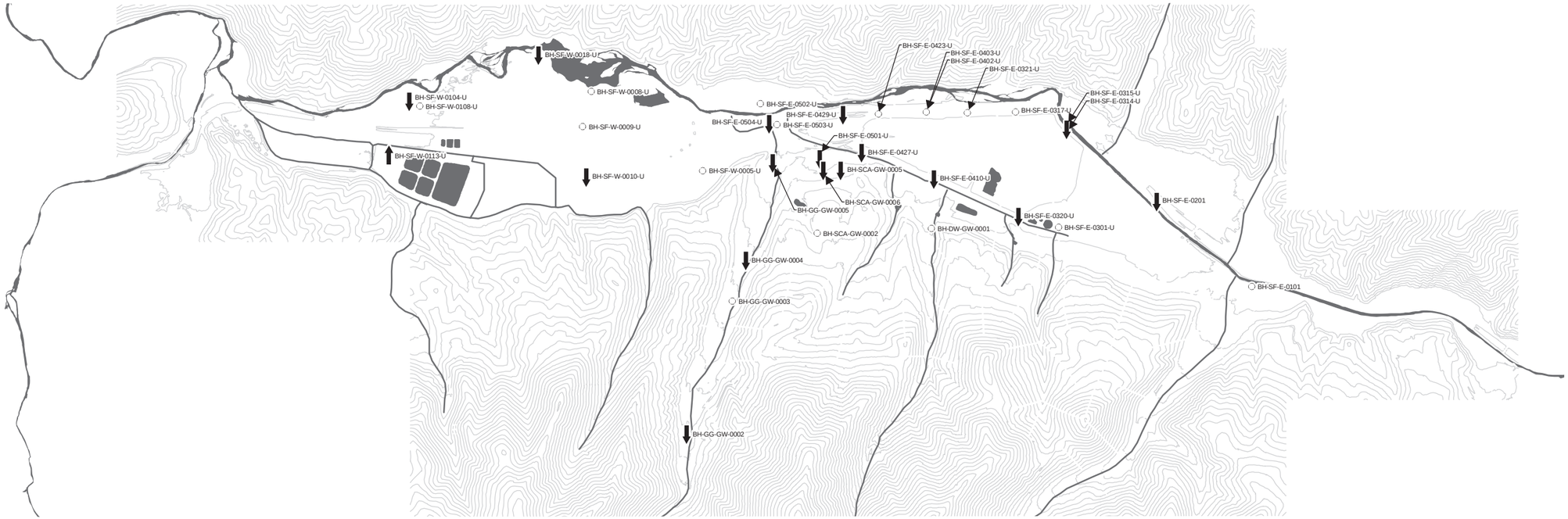

LOWER AQUIFER

NOTE: Data gathered between April 2000 and May 2004.

Legend

- Increasing Trend
- Decreasing Trend
- No Significant Trend
- Water Features

N

0 3,000 6,000 Feet

FIGURE ES-3

DISSOLVED CADMIUM TRENDS IN GROUNDWATER
OU2 STATISTICAL ANALYSIS

BUNKER HILL SUPERFUND SITE OU2

CH2MHILL

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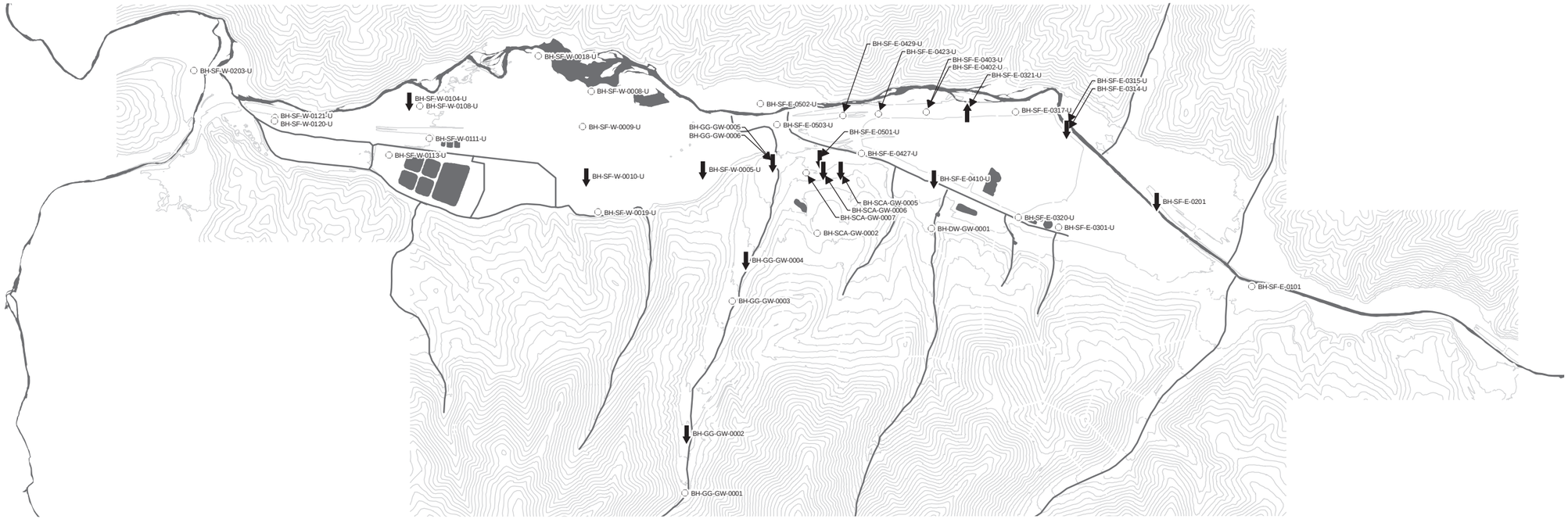

LOWER AQUIFER

NOTE: Data gathered between April 2000 and May 2004.

Legend

- Increasing Trend
- Decreasing Trend
- No Significant Trend
- Water Features

N

0 3,000 6,000 Feet

FIGURE ES-4

DISSOLVED ZINC TRENDS IN GROUNDWATER
OU2 STATISTICAL ANALYSIS

BUNKER HILL SUPERFUND SITE OU2

CH2MHILL

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