

**APPENDIX I**

**STATISTICAL AND GEOCHEMICAL EVALUATION OF  
SITE METALS DATA**

# Technical Memorandum

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To: Fort McClellan (FTMC) Risk Assessment File

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Subject: ***Selecting Site-Related Chemicals for Human Health and Ecological Risk Assessments for FTMC: Revision 2.***

*Note: Early Shaw E & I experience with the previously agreed-upon 28 April 2003 memo describing the protocol for background screening revealed considerable inefficiency arising from characteristics of the background data sets and occasionally the site data sets. Primary among these is a high percentage of non-detects, which renders the statistical tests described in Tier 2 invalid. Conversations between Shaw E & I and EPA Region IV led to revision of the Tier 2 statistical procedure whereby comparison with the 95<sup>th</sup> upper tolerance limit could be substituted for the previously designated tests under certain conditions.*

The purpose of this memo is to describe the protocol for background screening – comparing site data with background data – for the purpose of selecting site-related chemicals. This memo is intended to reflect agreement reached between the USACE (via Shaw E & I) and EPA Region IV during informal discussion on 24 to 26 March 2003, as amended by further conversations between Shaw E & I and EPA Region IV. Background screening is part of the chemical of potential concern (COPC) or chemical of potential ecological concern (COPEC) selection step of a risk assessment.

Background screening will be performed as a multi-tiered process as follows:

**Tier 1:** *(Tier 1 remains unchanged from the 28 April 2003 memo.)* The maximum detected concentration (MDC) of site data is compared with the background screening criterion (BSC). Chemicals for which the MDC of site data does not exceed the BSC are considered to be present at background concentrations, are not selected as site-related chemicals and are not considered further in the risk assessment. Chemicals for which the MDC of site data exceeds the BSC are carried forward to Tier 2.

**Tier 2:** Tier 2 is performed in two steps: (a) The Slippage test is performed as the preferred high value test. In those cases where the Slippage test is inappropriate, comparison of site data with the background 95 UTL (or 95th percentile for background data sets for which estimation of a UTL is inappropriate) is performed instead of the Slippage test. (b) The Wilcoxon Rank Sum test (WRST) is performed. In those cases where the WRST cannot be performed (generally due to a large number of non-detects in the background or site data set), comparison of site data with the

background UTL is performed as described above. Metals that "fail" any of the statistical tests that were performed are evaluated under Tier 3.

**Tier 3:** *(Tier 3 remains unchanged from the 28 April memo.)* Tier 3 consists of a geochemical evaluation to determine whether concentrations of site metals are naturally occurring or elevated due to contamination. Geochemical evaluations are based on the natural association between a trace element and one or more specific soil-forming minerals that concentrate that trace element. The correlation of the trace element of interest with a major element representing the abundance of the specific mineral that concentrates the trace element is evaluated. The selection of the major reference element is dependent on a number of general and site-specific factors as discussed below.

Some elements, under certain environmental conditions, display exclusive associations with specific reference elements. For instance, in oxic, neutral-pH soils, arsenic, selenium, and vanadium are almost exclusively associated with iron oxides, so iron is usually used as a reference element for these trace elements (Bowell, 1994; Schiff and Weisberg, 1997). The reason for this association is well understood, and is based on aqueous speciation and surface chemistry effects. These three elements are present in oxic soil pore fluid as negatively charged oxyanions ( $\text{HAsO}_4^{-2}$ ,  $\text{HSeO}_3^-$ ,  $\text{H}_2\text{VO}_4^-$ ) (Pourbaix, 1974; EPRI, 1986; Brookins, 1988). Iron oxides maintain a positive surface charge that strongly attracts these oxyanions, resulting in the observed linear correlations (Bowell, 1994).

Cadmium, nickel, lead, and zinc exist in the pore fluid of most soils as positively charged divalent cations ( $\text{Cd}^{+2}$ ,  $\text{Ni}^{+2}$ ,  $\text{Pb}^{+2}$ ,  $\text{Zn}^{+2}$ ) (Brookins, 1988; Pourbaix, 1974). These trace elements have a strong affinity to adsorb on clay minerals which maintain a negative surface charge (EPRI, 1984). These elements are usually evaluated against aluminum, which is a major component of all clay minerals.

Chromium can be present in soil pore fluid as a mixture of aqueous species with different charges such as  $\text{Cr}(\text{OH})_2^+$ ,  $\text{Cr}(\text{OH})_3^0$ , and  $\text{Cr}(\text{OH})_4^-$ , depending on the pH of the pore fluid (EPRI, 1984). The positive, neutral, and negative charges on these species result in the distribution of chromium on several different types of sorptive surfaces, including clay and iron oxide minerals. Higher soil pH conditions will favor the anionic Cr species which adsorb on iron oxides, and lower soil pH conditions will favor the cationic Cr species which preferentially adsorb on clay minerals.

Manganese oxides have a specific affinity to adsorb barium, cobalt, and lead (Kabata-Pendias, 2001). In most soils, the manganese concentrations are too low for it to form discrete manganese oxide minerals. However, in oxic, manganese-rich soils, minerals such as pyrolusite ( $\text{MnO}_2$ ) and nsutite ( $\text{MnO}_{1.9}$ ) will form that strongly adsorb Ba, Co, and Pb. Under reducing, low  $\text{CO}_2$  conditions, the minerals  $\text{MnO}\cdot\text{OH}$ ,  $\text{Mn}_2\text{O}_3$  and  $\text{Mn}_3\text{O}_4$  will form, which also concentrate these trace elements. Under reducing, high  $\text{CO}_2$  conditions however, Mn will be present as rhodochrosite ( $\text{MnCO}_3$ ) which does not have as strong adsorptive properties as the Mn-oxides (EPRI, 1984).

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Soils that contain fragments of limestone often show linear correlations between barium, cadmium, cobalt, nickel, strontium, lead, and zinc versus calcium. This is because these divalent metals readily substitute for calcium in calcite ( $\text{CaCO}_3$ ) and dolomite  $[(\text{Ca},\text{Mg})\text{CO}_3]$ , which are the major minerals present in limestone. This association is also common in arid regions where the divalent metals co-precipitate with calcite and gypsum ( $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ ) in caliche horizons.

Arkosic soils that contain unweathered fragments of feldspar have very different trace/major element associations, reflecting the mineralogy of the primary igneous or metamorphic source material. For instance, beryllium is associated with alkali feldspars which all contain sodium, potassium and aluminum, so the correlations of beryllium versus those major elements would be evaluated.

Total organic carbon is a good reference element for mercury, which has a strong affinity for adsorption on natural organic material. Mercury often shows better correlations with total organic carbon than with inorganic reference elements.

In reducing environments such as swamps, bogs, and wetlands where organic content is high, anaerobic sulfate-reducing conditions can become established. Under these conditions, trace elements such as arsenic, cadmium, nickel, lead, and zinc will co-precipitate with iron as sulfide minerals. These trace metals in this environment would be expected to be correlated with iron and sulfide in soil samples.

Care must be taken in the selection of reference elements to ensure that those elements are themselves not directly or indirectly impacted by contamination. Aluminum is usually a good reference element because it is not sensitive to redox conditions, and direct aluminum contamination is rare. A further advantage of aluminum is its low solubility over the neutral pH range, but it does become soluble at pH conditions below 4 and above 9. The release of strong acids or bases will leach aluminum from soil and solubilize aluminum in groundwater, so evaluation of the pH conditions is important.

Examining the correlation between iron versus aluminum in soil is an important tool in geochemical evaluations. Both elements tend to concentrate in the finer grain size fractions as oxide and clay minerals, respectively. Concentrations of iron and aluminum may vary from sample to sample by orders of magnitude reflecting differences in grain size, but they are usually present at a fixed ratio. Site samples that plot off of the trend established by the background samples and exhibit anomalously high Fe/Al ratios, may have some excess component of iron, suggesting contamination from rust, machine shop sweepings, ferric chloride sludge, etc. If iron contamination is identified in some samples, then those samples should be identified as such and removed from the evaluation, or an alternate reference element should be selected.

Iron and manganese in groundwater are subject to reductive dissolution effects which should be evaluated before they are used as reference elements. The release of organic contaminants such as hydrocarbon fuels or chlorinated solvents can establish local reducing environments caused by anaerobic microbial degradation of the organic compounds. The establishment of local reducing conditions can drive the dissolution of iron and manganese oxides, which become soluble as the redox potential drops below a threshold value. Dissolution of these oxide minerals can mobilize the trace elements that were adsorbed on the oxide surfaces, which is a process termed “reductive dissolution.” Several investigations have documented the mobilization of arsenic, selenium, and other trace elements under locally reducing redox conditions (Sullivan and Aller, 1996; Nickson, et al., 2000; Belzile, et al., 2000).

Evidence for reductive dissolution would be a correlation between elevated trace elements (arsenic, selenium, and vanadium in particular) versus lower redox conditions. Low redox conditions can be identified in groundwater by local depressions in oxidation-reduction potential or dissolved oxygen measurements, or the presence of reducing gases such as hydrogen, methane, ethane, or ethene. Anaerobic microbes can also reduce sulfate to sulfide and nitrate to ammonia, resulting in local depressions in sulfate and nitrate concentrations, and local detections of sulfide and ammonia. In areas impacted by chlorinated solvents, additional evidence for the establishment of anaerobic reducing conditions is the presence of dichloroethene and/or vinyl chloride, which are reductive dechlorination products resulting from the microbial degradation of trichloroethene or tetrachloroethene under anaerobic conditions.

An additional technique that is used to identify the presence of local reducing conditions in groundwater is a correlation plot of iron versus aluminum. These two elements are usually highly correlated in oxic groundwater because they are both insoluble and tend to be present as suspended particulates at a fairly constant ratio. If local reducing conditions are present, then samples from those areas will have a higher Fe/Al ratio than oxic areas because iron becomes soluble under reducing conditions but aluminum does not. Results can be independently confirmed by evaluating manganese versus aluminum because manganese and iron have similar redox behavior.

All available laboratory and field data are examined to determine if there is a local reducing environment that is driving the dissolution of iron and manganese oxides, as this effect may cause erroneous geochemical evaluation results if this process is not taken into account. Data are also evaluated for pH anomalies and the presence of organic contaminants that may alter the geochemical environment.

## References

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**STATISTICAL  
(TIERS 1 AND 2)**

# **Statistical Comparison of Site and Background Data Baby Bains Gap Road Ranges Fort McClellan, Alabama**

## **1.0 Introduction**

This report provides the Tier 1 and Tier 2 site-to-background comparison results for the Baby Bains Gap Road Ranges located at Fort McClellan in Calhoun County, Alabama. Tier 1 and Tier 2 evaluations have been performed for target analyte list (TAL) metals in the surface soil, groundwater, sediment, surface water, and subsurface soil data sets. In the first step of the comparison, the maximum detected concentration (MDC) of each element is compared to two times the arithmetic mean of the background data (SAIC, 1998). Any metal that has an MDC greater than the background screening value is carried forward for Tier 2 evaluation, which includes the Slippage Test and the Wilcoxon Rank Sum Test (WRS).

The methodology and results of the Tier 1 and Tier 2 comparisons are summarized in Tables 1 through 5, and described in more detail in the following sections. Site data used in the site-to-background comparison include 144 surface soil samples (0 to 1 foot below ground surface [bgs]), 19 groundwater samples, 10 sediment samples, 10 surface water samples, and 91 subsurface soil samples (1 to 12 feet bgs) that were collected at the site.

Background distributions and screening values have been established for TAL metals in surface soil (0 to 1 foot bgs), groundwater, sediment, surface water, and subsurface soil (1 to 12 feet bgs) for Fort McClellan (SAIC, 1998).

## **2.0 Comparison Methodology**

This section describes the statistical techniques that were employed in the Baby Bains Gap Road site-to-background comparisons.

### **2.1 Statistical Procedures**

Contamination can be caused by a variety of processes that yield different spatial distributions of elevated contaminant concentrations. Slight but pervasive contamination can occur from non-point-source releases, and can result in slight increases in contaminant concentrations in a large percentage of samples. Localized, or “hot-spot,” contamination can result in elevated concentrations in a small percentage of the total number of site samples. No single two-sample statistical comparison test is sensitive to both of these modes of contamination. For this reason,

Table 1

**Summary of Tier 1 and Tier 2 Site to Background Comparison for Surface Soil  
Baby Bains Gap Road Ranges  
Fort McClellan, Calhoun County, Alabama**

	Number of Detects	Number of Detects Exceeding 2 X bkgd mean <sup>a</sup>	Slippage Test <sup>b</sup>	Wilcoxon Rank Sum Test <sup>b</sup>	Site MDC > Background 95th UTL/Percentile <sup>c</sup>	Carried Forward for Tier 3 Geochemical Evaluation
<b>Metals</b>						
Aluminum	144	40	Passed	Failed	NA	Yes
Antimony	34	34	NA <sup>d</sup>	NA <sup>e</sup>	Yes	Yes
Arsenic	143	15	Passed	Failed	NA	Yes
Barium	144	46	Failed	Failed	NA	Yes
Beryllium	112	58	Failed	Failed	NA	Yes
Cadmium	0	0	NA	NA	NA	
Calcium	142	23	Passed	Failed	NA	Yes
Chromium	144	9	Passed	Failed	NA	Yes
Cobalt	142	28	Passed	Failed	NA	Yes
Copper	144	106	Failed	Failed	NA	Yes
Iron	144	23	Passed	Failed	NA	Yes
Lead	323	202	Failed	Failed	NA	Yes
Magnesium	144	43	Passed	Failed	NA	Yes
Manganese	144	20	Passed	Failed	NA	Yes
Mercury	69	3	Passed	NA <sup>e</sup>	Yes	Yes
Nickel	142	64	Failed	Failed	NA	Yes
Potassium	142	78	Passed	Failed	NA	Yes
Selenium	49	47	Passed	NA <sup>e</sup>	Yes	Yes
Silver	23	23	Failed	NA <sup>e</sup>	Yes	Yes
Sodium	103	0	NA	NA	NA	
Thallium	4	1	NA <sup>d</sup>	NA <sup>e</sup>	No	
Vanadium	144	5	Passed	Passed	NA	
Zinc	144	48	Passed	Failed	NA	Yes

NA = not applicable

a Tier 1 evaluation per **Selecting Site-Related Chemicals for Human Health and Ecological Risk Assessments for FTMC**, Technical Memorandum, 28 April 2003 by Paul Goetchius.

b Part of Tier 2 evaluation per the above referenced memo.

c Performed only when the Slippage test and/or WRS test cannot be performed.

d Slippage test is not performed on data sets for which the maximum background value is a nondetect.

e WRS test is not performed on data sets containing 50% or more nondetects.

**Table 2**

**Summary of Tier 1 and Tier 2 Site to Background Comparison for Subsurface Soil  
Baby Bains Gap Road Ranges  
Fort McClellan, Calhoun County, Alabama**

Metals	Number of Detects	Number of Detects Exceeding 2 X bkgd mean <sup>a</sup>	Slippage Test <sup>b</sup>	Wilcoxon Rank Sum Test <sup>b</sup>	Site MDC > Background 95th UTL/Percentile <sup>c</sup>	Carried Forward for Tier 3 Geochemical Evaluation
Aluminum	91	67	Failed	Failed	NA	Yes
Antimony	7	7	NA <sup>d</sup>	NA <sup>e</sup>	Yes	Yes
Arsenic	91	5	Passed	Failed	NA	Yes
Barium	91	7	Passed	Failed	NA	Yes
Beryllium	81	52	Failed	Failed	NA	Yes
Cadmium	0	0	NA	NA	NA	
Calcium	91	42	Passed	Failed	NA	Yes
Chromium	91	10	Passed	Failed	NA	Yes
Cobalt	89	14	Passed	Failed	NA	Yes
Copper	91	42	Passed	Failed	NA	Yes
Iron	91	12	Failed	Failed	NA	Yes
Lead	128	31	Passed	Failed	NA	Yes
Magnesium	91	54	Passed	Failed	NA	Yes
Manganese	91	9	Passed	Failed	NA	Yes
Mercury	49	15	Failed	NA <sup>e</sup>	Yes	Yes
Nickel	91	53	Failed	Failed	NA	Yes
Potassium	91	79	Passed	Failed	NA	Yes
Selenium	46	46	NA <sup>d</sup>	NA <sup>e</sup>	Yes	Yes
Silver	22	22	NA <sup>d</sup>	NA <sup>e</sup>	Yes	Yes
Sodium	78	0	NA	NA	NA	
Thallium	5	3	Passed	NA <sup>e</sup>	No	
Vanadium	91	7	Passed	Failed	NA	Yes
Zinc	91	59	Passed	Failed	NA	Yes

NA = not applicable

<sup>a</sup> Tier 1 evaluation per **Selecting Site-Related Chemicals for Human Health and Ecological Risk Assessments for FTMC**, Technical Memorandum, 28 April 2003 by Paul Goetchius.

<sup>b</sup> Part of Tier 2 evaluation per the above referenced memo.

<sup>c</sup> Performed only when the Slippage test and/or WRS test cannot be performed.

<sup>d</sup> Slippage test is not performed on data sets for which the maximum background value is a nondetect.

<sup>e</sup> WRS test is not performed on data sets containing 50% or more nondetects.

**Table 3**

**Summary of Tier 1 and Tier 2 Site to Background Comparison for Groundwater  
Baby Bains Gap Road Ranges  
Fort McClellan, Calhoun County, Alabama**

Metals	Number of Detects	Number of Detects Exceeding 2 X bkgd mean <sup>a</sup>	Slippage Test <sup>b</sup>	Wilcoxon Rank Sum Test <sup>b</sup>	Site MDC > Background 95th UTL/Percentile <sup>c</sup>	Carried Forward for Tier 3 Geochemical Evaluation
Aluminum	11	0	NA	NA	NA	
Antimony	0	0	NA	NA	NA	
Arsenic	1	0	NA	NA	NA	
Barium	19	4	Passed	Failed	NA	Yes
Beryllium	0	0	NA	NA	NA	
Cadmium	0	0	NA	NA	NA	
Calcium	19	13	Passed	Failed	NA	Yes
Chromium	0	0	NA	NA	NA	
Cobalt	0	0	NA	NA	NA	
Copper	0	0	NA	NA	NA	
Iron	16	0	NA	NA	NA	
Lead	1	0	NA	NA	NA	
Magnesium	16	0	NA	NA	NA	
Manganese	15	3	Passed	Passed	NA	
Mercury	0	0	NA	NA	NA	
Nickel	0	0	NA	NA	NA	
Potassium	5	0	NA	NA	NA	
Selenium	0	0	NA	NA	NA	
Silver	0	0	NA	NA	NA	
Sodium	16	0	NA	NA	NA	
Thallium	1	1	NA <sup>d</sup>	NA <sup>e</sup>	No	
Vanadium	0	0	NA	NA	NA	
Zinc	0	0	NA	NA	NA	

NA = not applicable

B&W = box and whisker

a Tier 1 evaluation per **Selecting Site-Related Chemicals for Human Health and Ecological Risk Assessments for FTMC**, Technical Memorandum, 28 April 2003 by Paul Goetchius.

b Part of Tier 2 evaluation per the above referenced memo.

c Performed only when the Slippage test and/or WRS test cannot be performed.

d Slippage test is not performed on data sets for which the maximum background value is a nondetect..

e WRS test is not performed on data sets containing 50% or more nondetects.

Table 4

**Summary of Tier 1 and Tier 2 Site to Background Comparison for Sediment  
Baby Bains Gap Road Ranges  
Fort McClellan, Calhoun County, Alabama**

Metals	Number of Detects	Number of Detects Exceeding 2 X bkgd mean <sup>a</sup>	Slippage Test <sup>b</sup>	Wilcoxon Rank Sum Test <sup>b</sup>	Site MDC > Background 95th UTL/Percentile <sup>c</sup>	Carried Forward for Tier 3 Geochemical Evaluation
Aluminum	10	4	Passed	Failed	NA	Yes
Antimony	1	1	Passed	NA <sup>d</sup>	Yes	Yes
Arsenic	10	0	NA	NA	NA	
Barium	10	5	Passed	Failed	NA	Yes
Beryllium	10	3	Passed	Failed	NA	Yes
Cadmium	0	0	NA	NA	NA	
Calcium	10	5	Failed	Failed	NA	Yes
Chromium	10	1	Passed	Failed	NA	Yes
Cobalt	10	2	Passed	Failed	NA	Yes
Copper	10	5	Passed	Failed	NA	Yes
Iron	10	2	Passed	Failed	NA	Yes
Lead	12	4	Passed	Failed	NA	Yes
Magnesium	10	4	Passed	Failed	NA	Yes
Manganese	10	3	Passed	Failed	NA	Yes
Mercury	2	0	NA	NA	NA	
Nickel	10	1	Passed	Failed	NA	Yes
Potassium	10	5	Passed	Failed	NA	Yes
Selenium	1	1	Passed	NA <sup>d</sup>	No	
Silver	1	1	Passed	NA <sup>d</sup>	Yes	Yes
Sodium	4	0	NA	NA	NA	
Thallium	1	1	Passed	NA <sup>d</sup>	Yes	Yes
Vanadium	10	0	NA	NA	NA	
Zinc	10	3	Passed	Failed	NA	Yes

NA = not applicable

B&W = box and whisker

a Tier 1 evaluation per **Selecting Site-Related Chemicals for Human Health and Ecological Risk Assessments for FTMC**, Technical Memorandum, 28 April 2003 by Paul Goetchius.

b Part of Tier 2 evaluation per the above referenced memo.

c Performed only when the Slippage test and/or WRS test cannot be performed.

**Table 5**

**Summary of Tier 1 and Tier 2 Site to Background Comparison for Surface Water  
Baby Bains Gap Road Ranges  
Fort McClellan, Calhoun County, Alabama**

Metals	Number of Detects	Number of Detects Exceeding 2 X bkgd mean <sup>a</sup>	Slippage Test <sup>b</sup>	Wilcoxon Rank Sum Test <sup>b</sup>	Site MDC > Background 95th UTL/Percentile <sup>c</sup>	Carried Forward for Tier 3 Geochemical Evaluation
Aluminum	6	0	NA	NA	NA	
Antimony	0	0	NA	NA	NA	
Arsenic	0	0	NA	NA	NA	
Barium	10	2	Pass	Fail	NA	Yes
Beryllium	0	0	NA	NA	NA	
Cadmium	0	0	NA	NA	NA	
Calcium	10	6	Fail	Fail	NA	Yes
Chromium	0	0	NA	NA	NA	
Cobalt	0	0	NA	NA	NA	
Copper	0	0	NA	NA	NA	
Iron	9	0	NA	NA	NA	
Lead	3	0	NA	NA	NA	
Magnesium	10	1	Pass	Pass	NA	
Manganese	8	0	NA	NA	NA	
Mercury	0	0	NA	NA	NA	
Nickel	0	0	NA	NA	NA	
Potassium	6	0	NA	NA	NA	
Selenium	0	0	NA	NA	NA	
Silver	0	0	NA	NA	NA	
Sodium	10	0	NA	NA	NA	
Thallium	0	0	NA	NA	NA	
Vanadium	0	0	NA	NA	NA	
Zinc	0	0	NA	NA	NA	

NA = not applicable

B&W = box and whisker

a Tier 1 evaluation per **Selecting Site-Related Chemicals for Human Health and Ecological Risk Assessments for FTMC**, Technical Memorandum, 28 April 2003 by Paul Goetchius.

b Part of Tier 2 evaluation per the above referenced memo.

c Performed only when the Slippage test and/or WRS test cannot be performed.

the use of several simultaneous tests is recommended for a valid and complete comparison of site versus background distributions (U.S. Environmental Protection Agency [EPA], 1989, 1992, and 1994; U.S. Navy, 2002).

Analytes that fail the Tier 1 and Tier 2 comparisons are subject to a geochemical evaluation to determine if the elevated concentrations are due to natural processes or if they represent potential contamination.

### **2.1.1 Tier 1**

In this step of the background screening process, the maximum detected concentration (MDC) of the site data set is compared to the background screening value of two times the background mean (SAIC, 1998). Elements for which the site MDC does not exceed the background screening value are considered to be present at background concentrations, and are not considered site-related chemicals. Elements for which the site MDC exceeds the background screening value undergo further evaluation (Tier 2).

### **2.1.2 Tier 2**

**Slippage Test.** The nonparametric Slippage test is designed to detect a difference between the upper tails of two distributions, and has been recommended for use in site-to-background comparisons to identify potential localized, or hot-spot, contamination (U.S. Navy, 2002). The test is performed by counting the number ( $K$ ) of detected concentrations in the site data set that exceed the maximum background measurement, and then comparing this number to a critical value ( $K_c$ ), which is a function of the number of background samples and the number of site samples. If  $K > K_c$ , then potential contamination is indicated and the analyte will be subjected to geochemical evaluation. If  $K \leq K_c$ , then localized contamination is not suspected.

Critical values tables for site and background data sets up to size  $n = 50$  are provided in U.S. Navy (2002). Critical values for larger data sets are calculated using the test statistic provided in Rosenbaum (1954). In this report, the Slippage test is performed at the 95 percent confidence level. The test cannot be performed if the maximum background value is a nondetect, because the actual concentration in that sample is unknown.

**Wilcoxon Rank Sum Test.** The nonparametric WRS test is designed to detect a difference between the medians of two data sets, and has been recommended for use in site-to-background comparisons to identify slight but pervasive contamination (EPA, 2000; U.S. Navy, 2002). In this report, the WRS test is performed when the site and background data sets each contain less

than 50 percent nondetects (i.e., measurements reported as not detected below the laboratory reporting limit). The WRS test will not be performed on data sets containing 50 percent or more nondetects. The medians of such data sets are unknown, and hence the test results would lack sufficient power to yield reliable results.

The WRS test compares two data sets of size  $n$  and  $m$  ( $n > m$ ), and tests the null hypothesis that the samples were drawn from populations with distributions having the same medians. To perform the test, the two sets of observations are pooled and arranged in order from smallest to largest. Each observation is assigned a rank; that is, the smallest is ranked 1, the next largest is ranked 2, and so on up to the largest observation, which is ranked  $(n + m)$ . If ties occur between or within samples, each one is assigned the mid-rank. Next, the sum of the ranks of smaller data set  $m$  is calculated. Then the test statistic  $Z$  is determined,

$$Z = \frac{W - m(m + n + 1)/2}{\sqrt{mn(m + n + 1)/12}}$$

Where:

- $W$  = Sum of the ranks of the smaller data set
- $m$  = Number of data points in smaller group
- $n$  = Number of data points in larger group.

This test statistic  $Z$  is used to find the two-sided significance. For instance, if the test statistic yields a probability of a Type I error (p-level) less than 0.2, then there is a statistically significant difference between the medians at the 80 percent confidence level. A Type I error involves rejecting the null hypothesis when it is true. If the p-level is greater than 0.2, then there is no reasonable justification to reject the null hypothesis at the 80 percent confidence level. It can therefore be concluded that the medians of the two data sets are similar, and it can be assumed to be drawn from the same population.

If the p-level is less than 0.2, then the medians of the two distributions are significantly different at the 80 percent confidence level. This can occur if the site data are shifted higher or lower than the background data. If the site data are shifted higher relative to background, then contamination may be indicated, and the analyte in question will be carried on for geochemical evaluation; however, if the site data are shifted lower relative to background, then contamination is not indicated. If the p-level is greater than 0.2, then pervasive site contamination is not suspected.

**Box Plots.** A quick, robust graphical method recommended by the EPA to visualize and compare two or more groups of data is the box plot comparison (EPA, 1989 and 1992). These plots provide a summary view of the entire data set, including the overall location and degree of symmetry. The box encloses the central 50 percent of the data points so that the top of the box represents the 75<sup>th</sup> percentile and the bottom of the box represents the 25<sup>th</sup> percentile. The small box within the larger box represents the median of the data set. The upper whisker extends outward from the box to the maximum point and the lower whisker extends to the minimum point. Nondetect results are set equal to one-half of the reporting limit for plotting purposes.

For each analyte, box plots of site and background data are placed side by side to visually compare the distributions and qualitatively determine whether the data sets are similar or distinct. Accordingly, the box plots are a necessary adjunct to the WRS test. As described previously, the WRS test may indicate that the medians of the site and background data sets are significantly different. Examination of the box plots will confirm whether that difference is caused by site data that are shifted higher or lower relative to background.

**Hot Measurement Test.** The hot measurement test is performed only when the Slippage test or WRS test cannot be performed (due to a high percentage of nondetects, etc.). The hot measurement test consists of comparing each site measurement with a concentration value that is representative of the upper limit of the background distribution (EPA, 1994). Ideally, a site sample with a concentration above the background screening value would have a low probability of being a member of the background distribution, and may be an indicator of contamination. It is important to select such a background screening value carefully so that the probability of falsely identifying site samples as contaminated or uncontaminated is minimized.

The 95<sup>th</sup> upper tolerance limit (95<sup>th</sup> UTL) is recommended as a screening value for normally or lognormally distributed analytes and the 95<sup>th</sup> percentile is recommended as a screening value for nonparametrically distributed analytes (EPA, 1989, 1992, and 1994). Site samples with concentrations above these values are not necessarily contaminated, but should be considered suspect. To perform the test, each analyte's site MDC is compared to the background 95<sup>th</sup> UTL or 95<sup>th</sup> percentile, in accordance with the type of background distribution. If the site MDC exceeds the background screening value, then that analyte will undergo a geochemical evaluation. If the MDC does not exceed the background threshold value, then hot-spot contamination is not indicated.

### **2.1.3 Geochemical Evaluation**

If an analyte fails either of the statistical tests described above then a geochemical evaluation is performed to determine if the elevated concentrations are caused by natural processes. The methodology and results of the geochemical evaluation are provided separately.

## **3.0 Results of the Site-to-Background Comparisons**

This section presents the results of the site-to-background comparisons for 23 TAL metals in the Baby Bains Gap Road surface soil, groundwater, sediment, surface water, and subsurface soil samples. The WRS test results with corresponding box plots are provided in Attachment 1. Tables 1 through 5 summarize the Tier 1 and Tier 2 test results for each media as discussed in the following sections.

### **3.1 Surface Soil**

Twenty-three TAL metals were evaluated in the Baby Bains Gap surface soil. Cadmium had no detects in surface soil in this area, so no further discussion of cadmium is included. Sodium was the only metal that screened out in the Tier 1 evaluation and will not be discussed any further. The WRS test results with corresponding box plots are provided in Attachment 1. Table 1 summarizes the surface soil results of each test discussed in detail below.

#### **Aluminum**

##### Tier 1 Evaluation

Forty of the site samples exceed the background screening value of 1.6E+4 milligrams per kilogram (mg/kg).

##### Slippage Test

The critical value,  $K_c$ , is eight. There were no site samples exceeding the maximum background measurement ( $K=0$ ). Because  $K < K_c$ , aluminum passes the Slippage Test.

##### WRS Test

The WRS test p-level of  $<0.001$  indicates significant difference between the site and background distributions.

##### Box Plot

Box plots for the site and background data sets are provided in Figure 1-1. The site minimum and maximum are below the corresponding background values; however, the median value of the site data is greater than that of background.

##### Conclusion

Because aluminum in surface soil failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

## **Antimony**

### Tier 1 Evaluation

Thirty-four site samples contain detected concentrations of antimony above the background screening value of 2.0E+0 mg/kg.

### Slippage Test

The maximum result for antimony in background sample data is a nondetect so this test cannot be performed for this element.

### WRS Test

The WRS test was not performed because the site set contains more than 50 percent nondetects.

### Box Plot

The site minimum, interquartile range, and maximum are higher than their respective background values (Figure 1-1).

### Hot Measurement Test

Fifteen samples exceed the background 95<sup>th</sup> percentile of 7.1 mg/kg.

### Conclusion

Because antimony in surface soil failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

## **Arsenic**

### Tier 1 Evaluation

Fifteen of the samples exceed the background screening value of 1.4E+1 mg/kg.

### Slippage Test

$K_c$  is 9, and no arsenic samples exceed the maximum background measurement. Because  $K < K_c$ , arsenic passes the Slippage Test.

### WRS Test

The WRS test has p-level of 0.025 indicating a difference between site and background data.

### Box Plot

The site 25<sup>th</sup> percentile, median, and 75<sup>th</sup> percentile are slightly higher than their respective background values (Figure 1-2). The maximum is below the corresponding background values, and the two minimums are similar.

### Conclusion

Because arsenic in surface soil failed statistical comparison to background it will be carried forward for Tier 3 geochemical evaluation.

## **Barium**

### Tier 1 Evaluation

Forty-six site samples exceed the background screening value of 1.2E+2 mg/kg.

### Slippage Test

$K_c$  for barium is eight, and nine site samples exceed the maximum background measurement. Because  $K > K_c$ , barium fails the Slippage Test.

### WRS Test

The p-level of <0.001 indicates significant difference between the site and background distributions.

### Box Plot

The site 25<sup>th</sup> percentile, median, 75<sup>th</sup> percentile, and maximum are all higher than the corresponding background values (Figure 1-2). The two minimums are similar.

### Conclusion

Because barium in surface soil failed statistical comparison to background it will be carried forward for Tier 3 geochemical evaluation.

## **Beryllium**

### Tier 1 Evaluation

Fifty-eight site samples of beryllium exceed the background screening value of 8.0E-1 mg/kg.

### Slippage Test

$K_c$  for beryllium is ten and fifty-one site samples exceed the maximum background measurement. Because  $K > K_c$  beryllium fails the Slippage Test.

### WRS Test

The p-level of <0.001 indicates significant difference between the site and background distributions.

### Box Plot

The site minimum and interquartile range are below the corresponding background values. The site maximum is significantly higher than the background maximum (Figure 1-3).

### Conclusion

Because beryllium in surface soil failed statistical comparison to background it will be carried forward for Tier 3 geochemical evaluation.

## **Calcium**

### Tier 1 Evaluation

Twenty-three samples exceed the background screening value of 1.7E+3 mg/kg.

### Slippage Test

$K_c$  for calcium is eight and one sample of calcium exceeds the maximum background measurement. Because  $K < K_c$  calcium passes the Slippage Test.

### WRS Test

The p-level of  $<0.001$  indicates significant difference between the site and background distributions.

### Box Plot

The site interquartile range appears slightly higher than the respective background values (Figure 1-3). The site minimum is similar to that of background, and the site maximum is significantly higher than that of background.

### Conclusion

Because calcium in surface soil failed statistical comparison to background it will be carried forward for Tier 3 geochemical evaluation.

## **Chromium**

### Tier 1 Evaluation

Nine samples exceed the background screening value of  $3.7E+1$  mg/kg.

### Slippage Test

$K_c$  for chromium is eight. There are no detects in the site samples of chromium that exceed the maximum background measurement. Because  $K < K_c$  chromium passes the Slippage Test.

### WRS Test

The p-level of  $3.8E-3$  indicates significant difference between the site and background distributions.

### Box Plot

The site minimum is slightly elevated as compared to that of background. The site interquartile range is higher than that of background (Figure 1-4) and the site maximum is lower than the background maximum.

### Conclusion

Because chromium in surface soil failed statistical comparison to background it will be carried forward for Tier 3 geochemical evaluation.

## **Cobalt**

### Tier 1 Evaluation

Twenty-eight of the detected concentrations in the site data set exceeded the background screening value of  $1.5E+1$  mg/kg.

### Slippage Test

$K_c$  for cobalt is eight and two detects in the site samples exceed the maximum background measurement. Because  $K < K_c$  cobalt passes the Slippage Test.

### WRS Test

The p-level of  $<0.001$  indicates a significant difference between the site and background distributions.

### Box Plot

The site minimum, 25<sup>th</sup> percentile, median, and 75<sup>th</sup> percentile are slightly higher than the corresponding background values (Figure 1-4). The site maximum is significantly higher than the background maximum.

### Conclusion

Because cobalt in surface soil failed statistical comparison to background it will be carried forward for Tier 3 geochemical evaluation.

## **Copper**

### Tier 1 Evaluation

One hundred and six site samples exceed the background screening value of  $1.3E+1$ .

### Slippage Test

$K_c$  of copper is eight. Sixty-seven detected site samples exceed the maximum background measurement. Because  $K > K_c$  copper fails the Slippage Test.

### WRS Test

The p-level of  $<0.001$  indicates a significant difference between the site and background distributions.

### Box Plot

The site minimum and interquartile range are slightly higher to the corresponding background values (Figure 1-5). The site maximum is significantly higher than that of background.

### Conclusion

Because copper in surface soil failed statistical comparison to background it will be carried forward for Tier 3 geochemical evaluation.

## **Iron**

### Tier 1 Evaluation

Twenty-three site samples had detects that exceed the background screening value of  $3.4E+4$  mg/kg.

### Slippage Test

$K_c$  for iron is eight and three site samples have detects exceeding the maximum background measurement. Because  $K < K_c$  iron passes the Slippage Test.

### WRS Test

The p-level of 0.001 indicates a significant difference between the site and background distributions.

### Box Plot

The site minimum and interquartile range are slightly elevated with respect to background (Figure 1-5). The site maximum is significantly higher than the background maximum.

### Conclusion

Because iron in surface soil failed statistical comparison to background it will be carried forward for Tier 3 geochemical evaluation.

## **Lead**

### Tier 1 Evaluation

Two hundred two site samples exceed the background screening value of 4.0E+1 mg/kg.

### Slippage Test

$K_c$  for lead is 16. One hundred sixty-four detects in site samples exceed the maximum background measurement. Because  $K > K_c$ , lead fails the Slippage Test.

### WRS Test

The p-level of <0.001 indicates a significant difference between the site and background distributions.

### Box Plot

The site minimum, 25<sup>th</sup> percentile, and median appear similar to that of background (Figure 1-6). The site 75<sup>th</sup> percentile is slightly elevated compared to that of background, and the site maximum is significantly higher the background maximum.

### Conclusion

Because lead in surface soil failed statistical comparison to background it will be carried forward for Tier 3 geochemical evaluation.

## **Magnesium**

### Tier 1 Evaluation

Forty-three site samples exceed the background screening value of 1.0E+3 mg/kg.

### Slippage Test

$K_c$  for magnesium is eight and no detects in the site samples exceed the maximum background measurement. Because  $K < K_c$ , magnesium passes the Slippage Test.

### WRS Test

The p-level of <0.001 indicates significant difference between the site and background distributions.

### Box Plot

The interquartile range of the site data set is elevated with respect to background (Figure 1-6). The site maximum is lower than the background maximum, and the minimums are similar.

### Conclusion

Because magnesium in surface soil failed statistical comparison to background it will be carried forward for Tier 3 geochemical evaluation.

## **Manganese**

### Tier 1 Evaluation

Twenty site samples had detects exceeding the background screening value of 1.6E+3 mg/kg.

### Slippage Test

$K_c$  for manganese is eight, and no detects in site samples exceed the maximum background measurement. Because  $K < K_c$ , manganese passes the Slippage Test.

### WRS Test

The p-level of 1.1E-2 indicates a difference between the site and background distributions.

### Box Plot

The site minimum and interquartile range are slightly higher than their respective background values (Figure 1-7). The site maximum is less than the background maximum.

### Conclusion

Because manganese in surface soil failed statistical comparison to background it will be carried forward for Tier 3 geochemical evaluation.

## **Mercury**

### Tier 1 Evaluation

Three of the detected concentrations exceed the background screening value of 8.0E-2 mg/kg.

### Slippage Test

The critical value for mercury,  $K_c$ , is eight. There are no detects in site samples that exceed the maximum background measurement. Since  $K < K_c$ , mercury passes the Slippage test.

### WRS Test

The WRS test was not performed because both the site and background data sets contain <50 percent detects.

### Box Plot

The site minimum and interquartile range are elevated relative to their corresponding background values (Figure 1-7). The site maximum is lower than the background maximum.

### Hot Measurement Test

One sample of mercury exceeds the background 95<sup>th</sup> percentile of 1.3E-1 mg/kg.

### Conclusion

Because mercury in surface soil failed statistical comparison to background it will be carried forward for Tier 3 geochemical evaluation.

## **Nickel**

### Tier 1 Evaluation

Sixty-four of the detected concentrations of nickel exceed the background screening value of  $1.0E+1$  mg/kg.

### Slippage Test

$K_c$  for nickel is eight, and twelve detects in site samples exceed the maximum background measurement. Because  $K > K_c$ , nickel fails the Slippage Test.

### WRS Test

The p-level of  $<0.001$  indicates a significant difference between the site and background distributions.

### Box Plot

The site interquartile range and maximum are higher compared with the corresponding background values (Figure 1-8). The site minimum appears similar to that of background.

### Conclusion

Because nickel in surface soil failed statistical comparison to background it will be carried forward for Tier 3 geochemical evaluation.

## **Potassium**

### Tier 1 Evaluation

Seventy-eight site samples exceed the background screening value of  $8.0E+2$  mg/kg.

### Slippage Test

$K_c$  for potassium is eight, and there are no detects in site samples that exceed the maximum background measurement. Because  $K < K_c$  potassium passes the Slippage Test.

### WRS Test

The p-level of  $<0.001$  indicates a significant difference between the site and background distributions.

### Box Plot

The site minimum and interquartile range are higher than the corresponding background values (Figure 1-8). The site maximum is significantly less than the background maximum.

### Conclusion

Because potassium in surface soil failed statistical comparison to background it will be carried forward for Tier 3 geochemical evaluation.

## **Selenium**

### Tier 1 Evaluation

Forty-seven detected concentrations in the site data set exceed the background screening value of  $4.8E-1$  mg/kg.

### Slippage Test

$K_c$  for selenium is eight, and eight site samples exceed the maximum background measurement. Because  $K \leq K_c$ , selenium passes the Slippage Test.

### WRS Test

No WRS test was performed because the site and background data sets each contain <50 percent detects.

### Box Plot

The site minimum, interquartile range, and the maximum are all above the corresponding background values (Figure 1-9).

### Hot Measurement Test

Forty-three samples exceed the background 95<sup>th</sup> percentile of 5.6E-1 mg/kg.

### Conclusion

Because selenium in surface soil failed statistical comparison to background it will be carried forward for Tier 3 geochemical evaluation.

## **Silver**

### Tier 1 Evaluation

Twenty-three of the detected concentrations exceed the background screening value of 3.6E-1 mg/kg.

### Slippage Test

$K_c$  for silver is eight, and 11 site samples exceed the maximum background measurement. Because  $K > K_c$ , silver fails the Slippage Test.

### WRS Test

The WRS test was not performed because the site data set contains more than 50 percent nondetects.

### Box Plot

The shape and location of the site box plot are defined by the high percentage of nondetects (16 percent) and the replacement values of one-half the reporting limit (Figure 1-9). The site minimum, interquartile range, and the maximum are higher than the corresponding background values.

### Hot Measurement Test

Twenty-three samples exceed the background 95<sup>th</sup> percentile of 7.7E-1 mg/kg.

### Conclusion

Because silver in surface soil failed statistical comparison to background it will be carried forward for Tier 3 geochemical evaluation.

## **Thallium**

### Tier 1 Evaluation

Only one detected concentration in site samples exceeded the background screening value of 3.4E+0 mg/kg. Thallium had just four detected concentrations in site samples.

### Slippage Test

The maximum result for background data is a nondetect, so the Slippage Test cannot be done.

### WRS Test

The WRS test was not performed because the site data set contains more than 50 percent nondetects.

### Box Plot

The shape and location of the site box plot reflects the high percentage of nondetects (97%) and the replacement values of one-half the reporting limit (Figure 1-10).

### Hot Measurement Test

No samples exceed the background 95<sup>th</sup> percentile of 6.6E+0 mg/kg.

### Conclusion

Thallium is considered within the range of background.

## **Vanadium**

### Tier 1 Evaluation

Five of the detected concentrations in site samples exceed the background screening value of 5.9E+1 mg/kg.

### Slippage Test

$K_c$  for vanadium is eight, and no site samples exceed the maximum background measurement. Because  $K < K_c$ , vanadium passes the Slippage Test.

### WRS Test

The p-level of 2.4E-1 indicates agreement between the site and background distributions.

### Box Plot

The site minimum, interquartile range, and maximum are within the corresponding background values (Figure 1-10).

### Conclusion

Vanadium in the site samples is within range of background.

## **Zinc**

### Tier 1 Evaluation

Forty-eight samples exceed the background screening value of 4.1E+1 mg/kg.

### Slippage Test

$K_c$  for zinc is eight. There are four detects in site samples exceeding the maximum background measurement. Because  $K < K_c$ , zinc passes the Slippage Test.

### WRS Test

The p-level of  $<0.001$  indicates significant difference between the site and background distributions.

### Box Plot

The site interquartile range is slightly higher than the respective background values (Figure 1-11). The two minimum values are similar, and the site maximum is significantly higher than that of background.

### Conclusion

Because zinc in surface soil failed statistical comparison to background it will be carried forward for Tier 3 geochemical evaluation.

## **3.2 Groundwater**

This section presents the results of the site-to-background comparisons for 23 metals unfiltered groundwater samples. Twelve of the metals (antimony, beryllium, cadmium, chromium, cobalt, copper, mercury, nickel, selenium, silver, vanadium, and zinc) had no detects in the site samples and are not considered any further. Another seven metals (aluminum, arsenic, iron, lead, magnesium, potassium, and sodium) had no detected concentrations that exceeded their respective background screening values. These metals are considered within the background range based on the Tier 1 evaluation, and will not be tested or discussed further. Table 2 summarizes these results.

For the remaining four metals with detected concentrations exceeding the background screening value, the Slippage test and WRS test were performed. The results of this Tier 2 evaluation are summarized in Table 2 and discussed in detail below. The WRS test results with corresponding box plots are provided in Attachment 1.

## **Barium**

### Tier 1 Evaluation

Four samples exceed the background screening value of  $1.3E-01$  mg/L.

### Slippage Test

$K_c$  for barium is three, and no detected concentrations in site samples exceed the maximum background measurement. Because  $K < K_c$ , barium passes the Slippage Test.

### WRS Test

The p-level of  $1.9E-2$  indicates a slight difference between the site and background distributions.

### Box Plot

The site minimum and interquartile range are all slightly higher than the corresponding background values (Figure 1-12). The site maximum is less than that of background.

### Conclusion

Because barium in surface soil failed statistical comparison to background it will be carried forward for Tier 3 geochemical evaluation.

## **Calcium**

### Tier 1 Evaluation

Thirteen detected concentrations in site samples exceed the background screening value of 5.6E+1 mg/L.

### Slippage Test

$K_c$  for calcium is three, and no site samples exceed the maximum background measurement. Because  $K < K_c$ , calcium passes the Slippage Test.

### WRS Test

The p-level of <0.001 indicates significant difference between the site and background distributions.

### Box Plot

The site interquartile range is higher than the corresponding background range (Figure 1-12). Both site and background minimums are similar, and the site maximum is lower than that of background.

### Conclusion

Because calcium in surface soil failed statistical comparison to background it will be carried forward for Tier 3 geochemical evaluation.

## **Manganese**

### Tier 1 Evaluation

Three samples exceed the background screening value of 5.8E-01 mg/L.

### Slippage Test

Critical value,  $K_c$ , three. Manganese has no samples that exceed the maximum background measurement. Because  $K < K_c$ , manganese passes the Slippage Test.

### WRS Test

The p-level of 6.9E-1 indicates a strong agreement between the site and background distributions.

### Box Plot

The site minimum and interquartile range are similar to the corresponding background values. The site maximum is lower than the background minimum values (Figure 1-13).

### Conclusion

Manganese is considered within the range of background.

### **Thallium**

#### Tier 1 Evaluation

Just one detect in the site samples exceeds the background screening value of 1.5E-3 mg/L.

#### Slippage Test

The slippage test was not performed because the maximum value in the background samples is a nondetect.

#### WRS Test

The WRS test was not performed because the site and background data sets have less than 50% detects.

#### Box Plot

The shapes and locations of the site and background box plots reflect the high percentage of nondetects (95% and 88% respectively) and the replacement values of one-half the reporting limit (Figure 1-13). There is little similarity between the two box plots as each reflects the reporting limits of the two data sets.

#### Hot Measurement Test

No samples exceed the background 95<sup>th</sup> percentile of 1.0E-2 mg/L.

### Conclusion

Thallium is considered within the range of background.

## **3.3 Sediment**

This section presents the results of the site-to-background comparisons for 23 TAL metals in the Baby Bains Gap Road sediment samples. Cadmium had no detects in sediment, so no further discussion of cadmium is included.

Arsenic, mercury, sodium, and vanadium had no detected concentrations in site samples exceeding the background screening value. These metals will not be tested or discussed further. The remaining 18 metals will be carried forward for Tier 2 evaluation. The WRS results with corresponding box plots are provided in Attachment 1.

The Tier 1 and Tier 2 results are summarized on Table 3, and discussed in detail below.

### **Aluminum**

#### Tier 1 Evaluation

Four site samples exceed the background screening value of 8.6E+3 mg/kg.

### Slippage Test

The critical value,  $K_c$ , for aluminum is two. Aluminum has no site samples that exceed the maximum background measurement. Because  $K < K_c$ , aluminum passes the Slippage Test.

### WRS Test

The WRS test p-level of  $7.4E-4$  fails to prove an agreement between the site and background distributions.

### Box Plot

Box plots for the site and background data sets are provided in Figure 1-14. The site minimum and maximum are within the range of the corresponding background values; however, the median value of the site data is greater than that of background.

### Conclusion

Because aluminum in sediment failed statistical comparison to background it will be carried forward for Tier 3 geochemical evaluation.

## **Antimony**

### Tier 1 Evaluation

One site sample exceeds the background screening value of  $7.3E-1$  mg/kg.

### Slippage Test

$K_c$  for antimony is two. Only one site sample exceeds the maximum background measurement. Because  $K < K_c$ , antimony passes the Slippage Test.

### WRS Test

The WRS test was not performed because the site data set contains only one detect (10%).

### Box Plot

The shapes and locations of the site box plot reflect the high percentage of nondetects (90 percent) and the replacement values of one-half the reporting limit (Figure 1-14). There is little similarity between the site box plot reflects the reporting limits of the data set.

### Hot Measurement Test

One sample exceeds the background 95<sup>th</sup> percentile of  $8.8E-1$  mg/kg.

### Conclusion

Because antimony in sediment failed statistical comparison to background it will be carried forward for Tier 3 geochemical evaluation.

## **Barium**

### Tier 1 Evaluation

Five site samples exceed the background screening value of  $9.9E+1$  mg/kg.

### Slippage Test

The critical value,  $K_c$ , of barium is two, and there are no site samples that exceed the maximum background measurement. Because  $K < K_c$ , barium passes the Slippage Test.

### WRS Test

The p-level of 7.4E-4 indicates significant difference between the site and background distributions.

### Box Plot

The site minimum and interquartile range are all higher than the corresponding background values (Figure 1-15). The site maximum is lower than the maximum of background.

### Conclusion

Because barium in sediment failed statistical comparison to background it will be carried forward for Tier 3 geochemical evaluation.

## **Beryllium**

### Tier 1 Evaluation

Three site samples exceed the background screening value of 9.7E-1 mg/kg.

### Slippage Test

$K_c$  of beryllium is two. There are two site samples that exceed the maximum background measurement. Because  $K < K_c$ , beryllium passes the Slippage Test.

### WRS Test

The p-level of 1.6E-3 indicates significant difference between the site and background distributions.

### Box Plot

The site minimum and maximum range exceeds that of background, and the site median and interquartile range are elevated with respect to their background counterparts (Figure 1-15).

### Conclusion

Because beryllium in sediment failed statistical comparison to background it will be carried forward for Tier 3 geochemical evaluation.

## **Calcium**

### Tier 1 Evaluation

Five site samples exceed the background screening value of 1.1E+3 mg/kg.

### Slippage Test

$K_c$  of calcium is two, and three samples exceed the maximum background measurement. Because  $K > K_c$ , calcium fails the Slippage Test.

### WRS Test

The p-level of 3.2E-3 indicates significant difference between the site and background distributions.

### Box Plot

The site minimum and maximum range exceeds that of background, and the site median is elevated with respect to background (Figure 1-16).

### Conclusion

Because calcium in sediment failed statistical comparison to background it will be carried forward for Tier 3 geochemical evaluation.

## **Chromium**

### Tier 1 Evaluation

One sample exceeds the background screening value of 3.1E+1 mg/kg.

### Slippage Test

$K_c$  of chromium is two, and just one site sample exceeds the maximum background measurement. Because  $K < K_c$ , chromium passes the Slippage Test.

### WRS Test

The p-level of 9.0E-2 indicates weak agreement between the site and background distributions.

### Box Plot

The site minimum and maximum are elevated with respect to background. The site interquartile range is higher than background (Figure 1-16).

### Conclusion

Because chromium in sediment failed statistical comparison to background it will be carried forward for Tier 3 geochemical evaluation.

## **Cobalt**

### Tier 1 Evaluation

Two of the detected concentrations in the site data set exceed the background screening value of 1.1E+1 mg/kg.

### Slippage Test

$K_c$  of cobalt is two, and no site samples exceed the maximum background measurement. Because  $K < K_c$ , cobalt passes the Slippage Test.

### WRS Test

The p-level of 6.7E-3 indicates a difference between the site and background distributions.

### Box Plot

The site minimum and interquartile range are above the corresponding background values. The site maximum is lower than the corresponding background value (Figure 1-17).

### Conclusion

Because cobalt in sediment failed statistical comparison to background it will be carried forward for Tier 3 evaluation.

## **Copper**

### Tier 1 Evaluation

Five site samples exceed the background screening value of 1.7E+1 mg/kg.

### Slippage Test

The critical value,  $K_c$ , of copper is two, and one site sample exceeds the maximum background measurement. Because  $K < K_c$ , copper passes the Slippage Test.

### WRS Test

The p-level of  $< 0.001$  indicates a significant difference between the site and background distributions.

### Box Plot

The site minimum, interquartile range, and maximum are all higher than the respective background values (Figure 1-17).

### Conclusion

Because copper in sediment failed statistical comparison to background it will be carried forward for Tier 3, geochemical evaluation.

## **Iron**

### Tier 1 Evaluation

Two site samples exceed the background screening value of 3.5E+4 mg/kg.

### Slippage Test

$K_c$  for iron is two, and just one site sample exceeds the maximum background measurement. Because  $K < K_c$ , iron passes the Slippage Test.

### WRS Test

The p-level of 3.6E-2 indicates a difference between the site and background distributions.

### Box Plot

The site minimum, interquartile range, and maximum are all elevated with respect to background (Figure 1-18).

### Conclusion

Because iron in sediment failed statistical comparison to background it will be carried forward for Tier 3 geochemical evaluation.

## **Lead**

### Tier 1 Evaluation

Four samples exceed the background screening value of 3.8E+1 mg/kg.

### Slippage Test

$K_c$  for lead is two, and two site samples exceed the maximum background measurement. Because  $K \leq K_c$ , lead passes the Slippage Test.

### WRS Test

The p-level of  $< 0.001$  indicates a significant difference between the site and background distributions.

### Box Plot

The site minimum, interquartile range, and maximum are all elevated with respect to background (1-18).

### Conclusion

Because lead in sediment failed statistical comparison to background it will be carried forward for Tier 3 geochemical evaluation.

## **Magnesium**

### Tier 1 Evaluation

Four site samples exceed the background screening value of 9.1E+2 mg/kg.

### Slippage Test

$K_c$  for magnesium is two, and just one site sample exceeds the maximum background measurement. Because  $K < K_c$ , magnesium passes the Slippage Test.

### WRS Test

The p-level of  $< 0.001$  indicates a difference between the site and background distributions.

### Box Plot

The site minimum, interquartile range, and maximum are all elevated with respect to background (Figure 1-19).

### Conclusion

Magnesium will be carried forward for Tier 3 geochemical evaluation.

## **Manganese**

### Tier 1 Evaluation

Three samples exceed the background screening value of 7.1E+2 mg/kg.

### Slippage Test

The critical value,  $K_c$ , for manganese is two, and no site samples exceed the maximum background measurement. Because  $K < K_c$ , manganese passes the Slippage Test.

### WRS Test

The p-level of 9.1E-2 indicates a slight difference between the site and background distributions.

### Box Plot

The site minimum and interquartile range are higher than their respective background values. The site maximum is actually lower than that of background (Figure 1-19).

### Conclusion

Because manganese in sediment failed statistical comparison to background it will be carried forward for Tier 3 geochemical evaluation.

## **Nickel**

### Tier 1 Evaluation

One sample exceeds the background screening value of 1.3E+1 mg/kg.

### Slippage Test

$K_c$  for nickel is two, and no site samples exceeded the maximum background measurement. Because  $K < K_c$ , nickel passes the Slippage Test.

### WRS Test

The p-level of 3.1E-2 indicates a slight difference between the site and background distributions.

### Box Plot

The site minimum and interquartile range are higher than the corresponding background values (Figure 1-20). The site maximum is considerably lower than the background maximum.

### Conclusion

Because nickel in sediment failed statistical comparison to background it is carried forward for Tier 3 geochemical evaluation.

## **Potassium**

### Tier 1 Evaluation

Five samples exceed the background screening value of 1.0E+3 mg/kg.

### Slippage Test

$K_c$  for potassium is two, and no site samples exceeded the maximum background measurement. Because  $K < K_c$ , potassium passes the Slippage Test.

### WRS Test

The p-level of <0.001 indicates a significant difference between the site and background distributions.

### Box Plot

The site minimum and interquartile range are higher than the corresponding background values (Figure 1-20). The site maximum is considerably less than the background maximum.

### Conclusion

Because potassium in sediment failed statistical comparison to background it will be carried forward for Tier 3 geochemical evaluation.

### **Selenium**

#### Tier 1 Evaluation

One detected concentration in the site data exceeds the background screening value of 7.2E-1 mg/kg.

#### Slippage Test

$K_c$  for selenium is two, and no site samples exceed the maximum background measurement. Because  $K < K_c$ , selenium passes the Slippage Test.

#### WRS Test

No WRS test was performed because the site data set contains 90 percent nondetects.

#### Box Plot

The shape and location of the site box plot are defined by the high percentage of nondetects (90 percent) and the replacement values of one-half the reporting limit. The site maximum is below the background minimum. The site minimum and interquartile range are above the corresponding background (Figure 1-21).

#### Hot Measurement Test

No samples exceed the background 95<sup>th</sup> percentile of 1.0E+0 mg/kg.

### Conclusion

Selenium is considered within the range of background.

### **Silver**

#### Tier 1 Evaluation

One detected concentration exceeds the background screening value of 3.2E-1 mg/kg.

#### Slippage Test

$K_c$  for silver is two, and one site sample exceeds the maximum background measurement. Because  $K < K_c$ , silver passes the Slippage Test.

#### WRS Test

The WRS test was not performed because the site data set contains 90 percent nondetects.

#### Box Plot

The shape and location of the site box plot are defined by the high percentage of nondetects (90 percent) and the replacement values of one-half the reporting limit (Figure 1-21). The site minimum, interquartile range, and maximum are higher than the corresponding background values.

Hot Measurement Test

One site sample of silver exceeds the background 95<sup>th</sup> percentile of 5.3E-1 mg/kg.

Conclusion

Because silver in sediment failed statistical comparison to background it will be carried forward for Tier 3 geochemical evaluation.

**Thallium**

Tier 1 Evaluation

One sample exceeds the background screening value of 1.3E-1 mg/kg.

Slippage Test

K<sub>c</sub> for thallium is two, and only one site sample exceeds the maximum background measurement. Because  $K < K_c$ , thallium passes the Slippage Test.

WRS Test

The WRS test was not performed because the site data set contains 90 percent nondetects.

Box Plot

The shapes and locations of the site box plots reflect the high percentage of nondetects (90 percent) and the replacement values of one-half the reporting limit (Figure 1-22). There is no similarity between the two box plots.

Hot Measurement Test

One sample exceeds the background 95<sup>th</sup> UTL of 2.1E-1 mg/kg.

Conclusion

Because thallium in sediment failed statistical comparison to background it will be carried forward for Tier 3 geochemical evaluation.

**Zinc**

Tier 1 Evaluation

Three samples exceed the background screening value of 5.3E+1 mg/kg.

Slippage Test

K<sub>c</sub> for zinc is two and no site samples exceed the maximum background measurement. Because  $K < K_c$ , zinc passes the Slippage Test.

WRS Test

The p-level of 8.67E-3 indicates significant difference between the site and background distributions.

Box Plot

The site minimum and interquartile range are higher than the corresponding background values (Figure 1-22). The site maximum is lower than the corresponding background values.

### Conclusion

Because zinc in sediment failed statistical comparison to background it will be carried forward for Tier 3 geochemical evaluation.

### **3.4 Surface Water**

This section presents the results of the site-to-background comparisons for the 23 metals tested in surface water samples. Fourteen of the metals (antimony, arsenic, beryllium, cadmium, chromium, cobalt, copper, mercury, nickel, selenium, silver, thallium, vanadium, and zinc) had no detects in the site samples and are not considered any further. Another six metals (aluminum, iron, lead, manganese, potassium, and sodium) had no detected concentrations that exceeded their respective background screening values. These metals are considered within the background range based on the Tier 1 evaluation, and will not be tested or discussed further.

The three remaining metals (barium, calcium, and magnesium) with detected concentrations exceeding the background screening value, are carried forward for Tier 2 evaluation.

Table 4 summarizes the test results for surface water. The WRS results with corresponding box plots are provided in Attachment 1.

### **Barium**

#### Tier 1 Evaluation

Two samples exceed the background screening value of  $7.5E-02$  mg/L.

#### Slippage Test

$K_c$  for barium is two, and no detected concentrations in site samples exceed the maximum background measurement. Because  $K < K_c$ , barium passes the Slippage Test.

#### WRS Test

The p-level of  $3.0E-3$  indicates a significant difference between the site and background distributions.

#### Box Plot

The site minimum and interquartile range are higher than the corresponding background values (Figure 1-23).

### Conclusion

Because barium in surface water failed statistical comparison to background it will be carried forward for Tier 3 geochemical evaluation.

## **Calcium**

### Tier 1 Evaluation

Six detected concentrations in site samples exceed the background screening value of 2.5E+1 mg/L.

### Slippage Test

$K_c$  for calcium is two, and three site samples exceed the maximum background measurement. Because  $K > K_c$ , calcium fails the Slippage Test.

### WRS Test

The p-level of 1.1E-2 indicates a difference between the site and background distributions.

### Box Plot

The site interquartile range and maximum are higher than their respective background values (Figure 1-23).

### Conclusion

Because calcium in surface water failed statistical comparison to background it will be carried forward for Tier 3 geochemical evaluation.

## **Magnesium**

### Tier 1 Evaluation

One sample exceeds the background screening value of 1.1E+1 mg/L.

### Slippage Test

$K_c$  for magnesium is two, and no site samples exceed the maximum background measurement. Because  $K < K_c$ , magnesium passes the Slippage Test.

### WRS Test

The p-level of 5.1E-1 indicates a strong agreement between the site and background distributions.

### Box Plot

The site minimum is similar to the background minimum value. The site 25<sup>th</sup> percentile and median are slightly higher than the corresponding background values. The maximum and the 75<sup>th</sup> percentile are much lower than the corresponding background values (Figure 1-24).

### Conclusion

Magnesium is considered within the range of background.

## **3.5 Subsurface Soil**

Twenty-three TAL metals were evaluated in the Baby Bains Gap Road subsurface soil data set. The site samples are 100 percent nondetect for cadmium. Sodium passed the Tier 1 evaluation, and it will not be discussed further. The remaining 21 metals are carried forward for Tier 2

evaluation. Table 5 summarizes the subsurface soil statistical site-to-background comparison results. Box plots are provided in Attachment 1.

## **Aluminum**

### Tier 1 Evaluation

Sixty-seven of the site samples exceed the background screening value of 13,591 mg/kg.

### Slippage Test

$K_c$  for aluminum is seven, and 31 site samples exceed the maximum background measurement ( $K=31$ ). Because  $K > K_c$ , aluminum fails the Slippage Test.

### WRS Test

The WRS test p-level of  $< 0.001$  indicates a significant difference between the site and background distributions.

### Box Plot

The site minimum, median, and maximum are higher than the corresponding background values (Figure 1-25).

### Conclusion

Because aluminum is subsurface soil failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

## **Antimony**

### Tier 1 Evaluation

Seven detected concentrations of antimony exceed the background screening value of 1.31 mg/kg.

### Slippage Test

The maximum background result for antimony is a nondetect, so the Slippage test could not be performed.

### WRS Test

The WRS test was not performed because the site data set contains 92 percent nondetects.

### Box Plot

The location and shape of the site box plot are largely defined by the high percentage of nondetects (92 percent) and the replacement values of one-half the reporting limit (Figure 1-26). The site minimum, median, and maximum are higher than the corresponding background values.

### Hot Measurement Test

The site MDC exceeds the background 95<sup>th</sup> percentile of 7.14 mg/kg.

### Conclusion

Because antimony in subsurface soil failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

## **Arsenic**

### Tier 1 Evaluation

Five site samples exceed the background screening value of 18.3 mg/kg.

### Slippage Test

$K_c$  for arsenic is 7, and no site samples exceed the maximum background measurement ( $K=0$ ). Because  $K < K_c$ , arsenic passes the Slippage Test.

### WRS Test

The p-level of 0.029 indicates weak agreement between site and background distributions.

### Box Plot

The site minimum and median are higher than the corresponding background values, and the site maximum is lower than the background maximum (Figure 1-27).

### Conclusion

Because arsenic in subsurface soil failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

## **Barium**

### Tier 1 Evaluation

Seven site samples exceed the background screening value of 233.62 mg/kg.

### Slippage Test

$K_c$  for barium is 7, and no site samples exceed the maximum background measurement ( $K=0$ ). Because  $K < K_c$ , barium passes the Slippage Test.

### WRS Test

The p-level of  $< 0.001$  indicates a significant difference between site and background distributions.

### Box Plot

The site minimum and median are higher than the corresponding background values, and the site maximum is lower than the background maximum (Figure 1-28).

### Conclusion

Because barium in subsurface soil failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

## **Beryllium**

### Tier 1 Evaluation

Fifty-two site samples exceed the background screening value of 0.86 mg/kg.

### Slippage Test

$K_c$  for beryllium is 7, and eleven site samples exceed the maximum background measurement ( $K=11$ ). Because  $K > K_c$ , beryllium fails the Slippage Test.

### WRS Test

The p-level of  $< 0.001$  indicates a significant difference between the site and background distributions.

### Box Plot

The site minimum, median, and maximum are higher than the corresponding background values (Figure 1-29).

### Conclusion

Because beryllium in subsurface soil failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

## **Calcium**

### Tier 1 Evaluation

Forty-two site samples exceed the background screening value of 637.17 mg/kg.

### Slippage Test

$K_c$  for calcium is 7, and one site sample exceeds the maximum background measurement ( $K=1$ ). Because  $K < K_c$ , calcium passes the Slippage Test.

### WRS Test

The p-level of  $< 0.001$  indicates a significant difference between the site and background distributions.

### Box Plot

The site minimum, median, and maximum are higher than the corresponding background values (Figure 1-30).

### Conclusion

Because calcium in subsurface soil failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

## **Chromium**

### Tier 1 Evaluation

Ten site samples exceed the background screening value of 38.25 mg/kg.

### Slippage Test

$K_c$  for chromium is 7, and 3 site samples exceed the maximum background measurement ( $K=3$ ). Because  $K < K_c$ , chromium passes the Slippage Test.

### WRS Test

The p-level of 0.004 indicates a significant difference between the site and background distributions.

### Box Plot

The site minimum, median, and maximum are higher than the corresponding background values (Figure 1-31).

### Conclusion

Because chromium in subsurface soil failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

## **Cobalt**

### Tier 1 Evaluation

Fourteen site samples exceed the background screening value of 17.54 mg/kg.

### Slippage Test

$K_c$  for cobalt is 7, and no site samples exceed the maximum background measurement ( $K=0$ ). Because  $K < K_c$ , cobalt passes the Slippage Test.

### WRS Test

The p-level of  $< 0.001$  indicates a significant difference between the site and background distributions.

### Box Plot

The site minimum and median are higher than the corresponding background values, and the site maximum is lower than the background maximum (Figure 1-32).

### Conclusion

Because cobalt in subsurface soil failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

## **Copper**

### Tier 1 Evaluation

Forty-two site samples exceed the background screening value of 19.43 mg/kg.

### Slippage Test

$K_c$  for copper is 7, and 5 site samples exceed the maximum background measurement ( $K=5$ ). Because  $K < K_c$ , copper passes the Slippage Test.

### WRS Test

The p-level of  $< 0.001$  indicates a significant difference between the site and background distributions.

### Box Plot

The site minimum, median, and maximum are higher than the corresponding background values (Figure 1-33).

### Conclusion

Because copper in subsurface soil failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

## **Iron**

### Tier 1 Evaluation

Twelve site samples exceed the background screening value of 44,817 mg/kg.

### Slippage Test

$K_c$  for iron is 7, and 9 site samples exceed the maximum background measurement ( $K=9$ ). Because  $K > K_c$ , iron fails the Slippage Test.

### WRS Test

The p-level of  $< 0.001$  indicates a significant difference between the site and background distributions.

### Box Plot

The site minimum, median, and maximum are higher than the corresponding background values (Figure 1-34).

### Conclusion

Because iron in subsurface soil failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

## **Lead**

### Tier 1 Evaluation

Thirty-one site samples exceed the background screening value of 38.53 mg/kg.

### Slippage Test

$K_c$  for lead is 7, and 6 site samples exceed the maximum background measurement ( $K=6$ ). Because  $K < K_c$ , lead passes the Slippage Test.

### WRS Test

The p-level of  $< 0.001$  indicates a significant difference between the site and background distributions.

### Box Plot

The site minimum, median, and maximum are higher than the corresponding background values (Figure 1-35).

### Conclusion

Because lead in subsurface soil failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

## **Magnesium**

### Tier 1 Evaluation

Fifty-four site samples exceed the background screening value of 766.24 mg/kg.

### Slippage Test

$K_c$  for magnesium is 7, and no site samples exceed the maximum background measurement ( $K=0$ ). Because  $K < K_c$ , magnesium passes the Slippage Test.

### WRS Test

The p-level of  $< 0.001$  indicates a significant difference between the site and background distributions.

### Box Plot

The site minimum and median are higher than the corresponding background values, and the site maximum is lower than the background maximum (Figure 1-36).

### Conclusion

Because magnesium in subsurface soil failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

## **Manganese**

### Tier 1 Evaluation

Nine site samples exceed the background screening value of 1,355 mg/kg.

### Slippage Test

$K_c$  for manganese is 7, and no site samples exceed the maximum background measurement ( $K=0$ ). Because  $K < K_c$ , manganese passes the Slippage Test.

### WRS Test

The p-level of  $< 0.001$  indicates a significant difference between the site and background distributions.

### Box Plot

The site minimum and median are higher than the corresponding background values, and the site maximum is lower than the background maximum (Figure 1-37).

### Conclusion

Because manganese in subsurface soil failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

## **Mercury**

### Tier 1 Evaluation

Fifteen of the detected concentrations exceed the background screening value of 0.07 mg/kg.

### Slippage Test

$K_c$  for mercury is 7, and 9 site samples exceed the maximum background measurement ( $K=9$ ). Because  $K > K_c$ , mercury fails the Slippage Test.

### WRS Test

The WRS test was not performed because the background data set contains 53 percent nondetects.

### Box Plot

The site minimum, median, and maximum are higher than the corresponding background values (Figure 1-38).

### Hot Measurement Test

The site MDC exceeds the background 95<sup>th</sup> percentile of 0.094 mg/kg.

### Conclusion

Because mercury in subsurface soil failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

## **Nickel**

### Tier 1 Evaluation

Fifty-three site samples exceed the background screening value of 12.89 mg/kg.

### Slippage Test

$K_c$  for nickel is 7, and 8 site samples exceed the maximum background measurement ( $K=8$ ). Because  $K > K_c$ , nickel fails the Slippage Test.

### WRS Test

The p-level of  $< 0.001$  indicates a significant difference between the site and background distributions.

### Box Plot

The site minimum, median, and maximum are higher than the corresponding background values (Figure 1-39).

### Conclusion

Because nickel in subsurface soil failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

## **Potassium**

### Tier 1 Evaluation

Seventy-nine site samples exceed the background screening value of 710.74 mg/kg.

### Slippage Test

$K_c$  for potassium is 7, and one site sample exceeds the maximum background measurement ( $K=1$ ). Because  $K < K_c$ , potassium passes the Slippage Test.

### WRS Test

The p-level of  $< 0.001$  indicates a significant difference between the site and background distributions.

### Box Plot

The site minimum, median, and maximum are higher than the corresponding background values (Figure 1-40).

### Conclusion

Because potassium in subsurface soil failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

## **Selenium**

### Tier 1 Evaluation

Forty-six of the detected concentrations exceed the background screening value of 0.47 mg/kg.

### Slippage Test

The maximum background result for selenium is a nondetect, so the Slippage test could not be performed.

### WRS Test

The WRS test was not performed because the background data set contains 98 percent nondetects.

### Box Plot

The location and shape of the background box plot are largely defined by the high percentage of nondetects (98 percent) and the replacement values of one-half the reporting limit (Figure 1-41). The site minimum, median, and maximum are higher than the corresponding background values.

### Hot Measurement Test

The site MDC exceeds the background 95<sup>th</sup> percentile of 0.574 mg/kg.

### Conclusion

Because selenium in subsurface soil failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

## **Silver**

### Tier 1 Evaluation

Twenty-two of the detected concentrations exceed the background screening value of 0.24 mg/kg.

### Slippage Test

The maximum background result for silver is a nondetect, so the Slippage test could not be performed.

### WRS Test

The WRS test was not performed because the site data set contains 76 percent nondetects.

### Box Plot

The location and shape of the site box plot are largely defined by the high percentage of nondetects (76 percent) and the replacement values of one-half the reporting limit (Figure 1-42). The site minimum, median, and maximum are higher than the corresponding background values.

### Hot Measurement Test

The site MDC exceeds the background 95<sup>th</sup> percentile of 0.88 mg/kg.

### Conclusion

Because silver in subsurface soil failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

## **Thallium**

### Tier 1 Evaluation

Three concentrations exceed the background screening value of 1.4 mg/kg.

### Slippage Test

$K_c$  for thallium is 7, and no site samples exceed the maximum background measurement ( $K=0$ ). Because  $K < K_c$ , thallium passes the Slippage Test.

### WRS Test

The WRS test was not performed because the site data set contains 95 percent nondetects.

### Box Plot

The location and shape of the site box plot are largely defined by the high percentage of nondetects (95 percent) and the replacement values of one-half the reporting limit (Figure 1-43). The site minimum and median are higher than the corresponding background values.

### Hot Measurement Test

The site MDC is below the background 95<sup>th</sup> percentile of 6.62 mg/kg.

### Conclusion

Because thallium in subsurface soil is within the range of background, it will not be carried forward for Tier 3 geochemical evaluation.

## **Vanadium**

### Tier 1 Evaluation

Seven site samples exceed the background screening value of 64.89 mg/kg.

### Slippage Test

$K_c$  for vanadium is 7, and one site sample exceeds the maximum background measurement ( $K=1$ ). Because  $K < K_c$ , vanadium passes the Slippage Test.

### WRS Test

The p-level of 0.039 indicates weak agreement between the site and background distributions.

### Box Plot

The site minimum is lower than the background minimum, and the site median and maximum are higher than the corresponding background values (Figure 1-44).

### Conclusion

Because vanadium in subsurface soil failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

## **Zinc**

### Tier 1 Evaluation

Fifty-nine site samples exceed the background screening value of 34.86 mg/kg.

### Slippage Test

$K_c$  for zinc is 7, and five site samples exceed the maximum background measurement ( $K=5$ ). Because  $K < K_c$ , zinc passes the Slippage Test.

### WRS Test

The p-level of  $< 0.001$  indicates a significant difference between the site and background distributions.

### Box Plot

The site minimum, median, and maximum are higher than the corresponding background values (Figure 1-45).

### Conclusion

Because zinc in subsurface soil failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

## **4.0 Summary and Conclusions**

The statistical methodology used to compare the Baby Bains Gap Road and background data sets for 23 elements in surface soil, groundwater, sediment, surface water, and subsurface soil includes a comparison of the site MDC to the background screening value (Tier 1 evaluation). Analytes that failed this comparison were subjected to the Slippage test and WRS test. Box-and-whisker plots were prepared to visually compare the two data sets and properly interpret the WRS test results. The hot measurement test was performed for elements with data sets that precluded either the Slippage test or WRS test. Analytes that failed any of the statistical tests in

the Tier 2 evaluation are carried forward for geochemical evaluation to determine if the elevated concentrations can be explained as a result of natural processes. Tables 1 through 5 summarize the comparison test results and show the metals carried forward for geochemical evaluation.

## **5.0 References**

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## **ATTACHMENT 1**

## Box Plots Baby Bains Gap Road Ranges

Figure 1-25. Box Plot Comparison for Aluminum in Subsurface Soil  
Baby Bains Gap Road, Ft. McClellan  
(WRS Test p-level < 0.001)

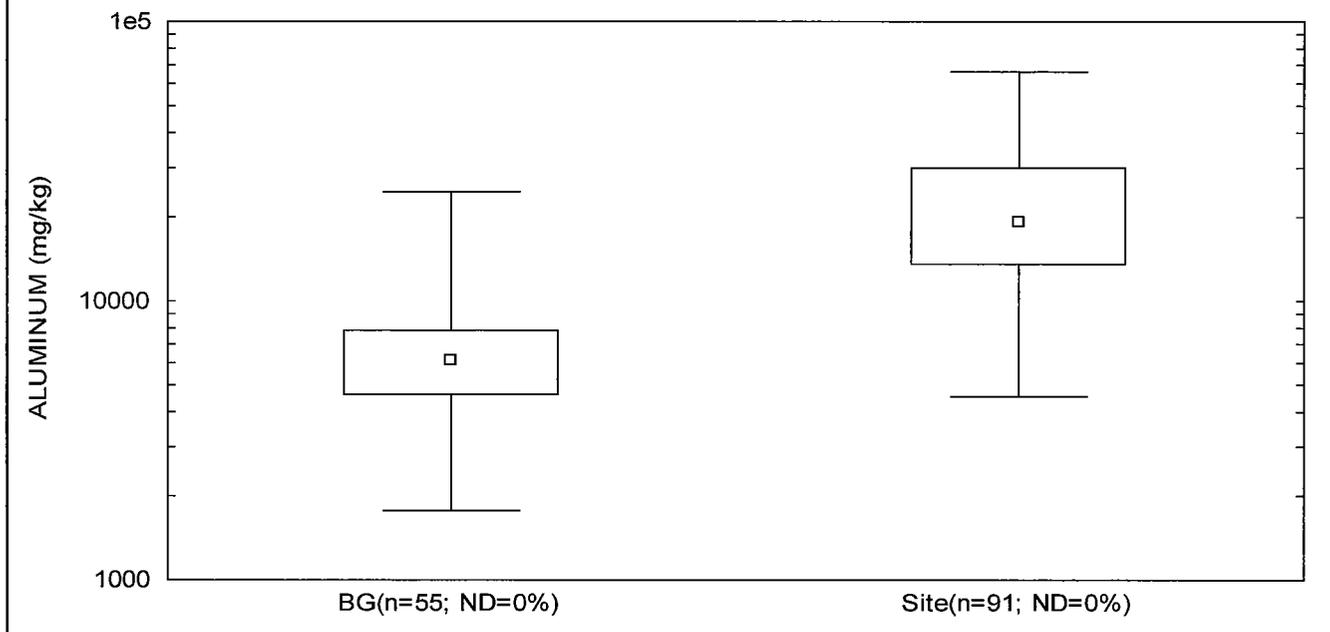
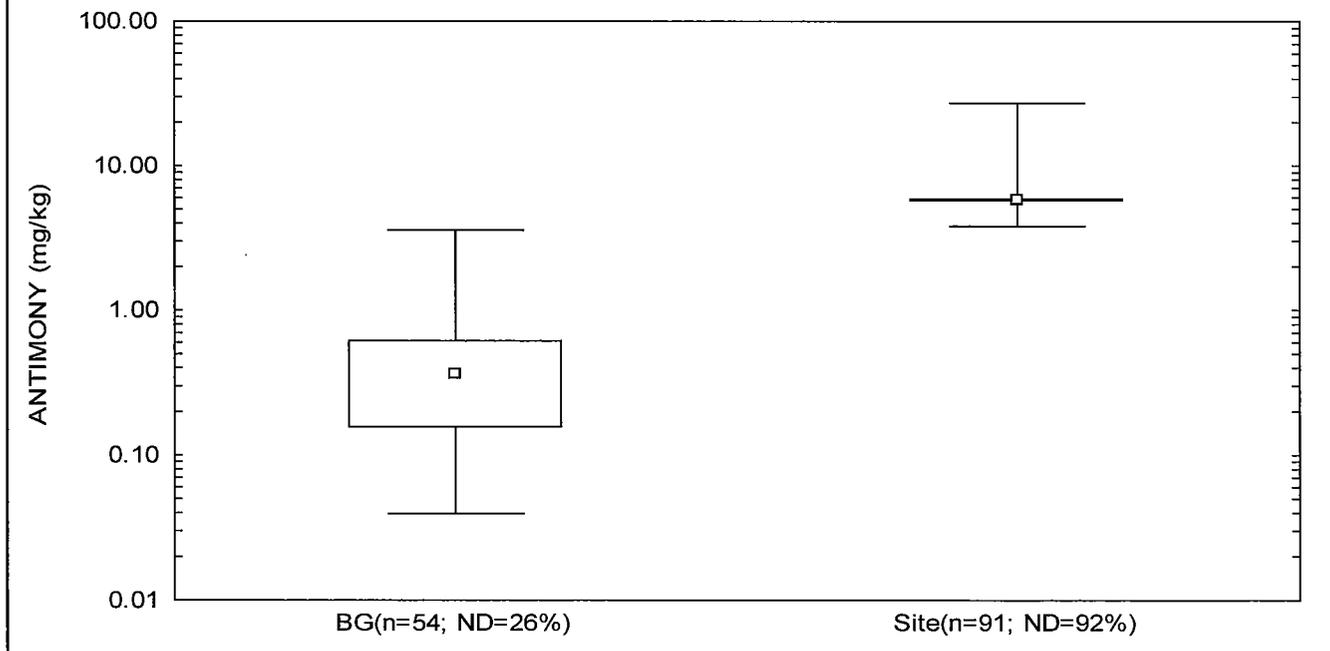


Figure 1-26. Box Plot Comparison for Antimony in Subsurface Soil  
Baby Bains Gap Road, Ft. McClellan



## Box Plots Baby Bains Gap Road Ranges

Figure 1-27. Box Plot Comparison for Arsenic in Subsurface Soil  
Baby Bains Gap Road, Ft. McClellan  
(WRS Test p-level = 0.029)

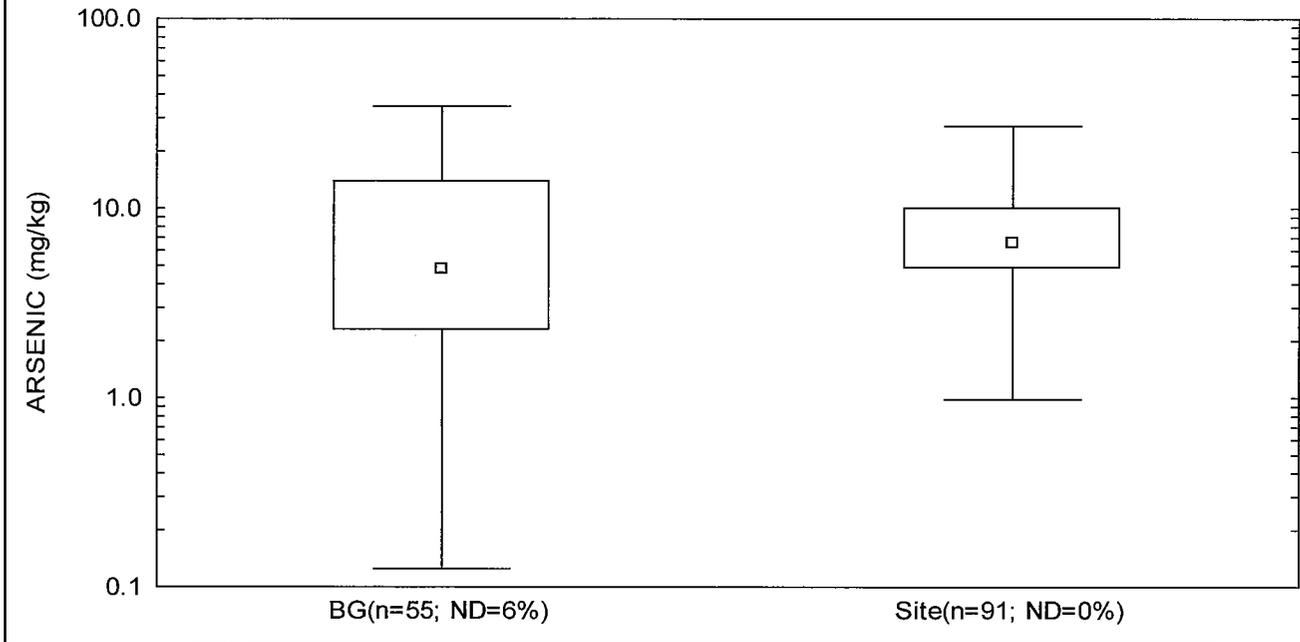
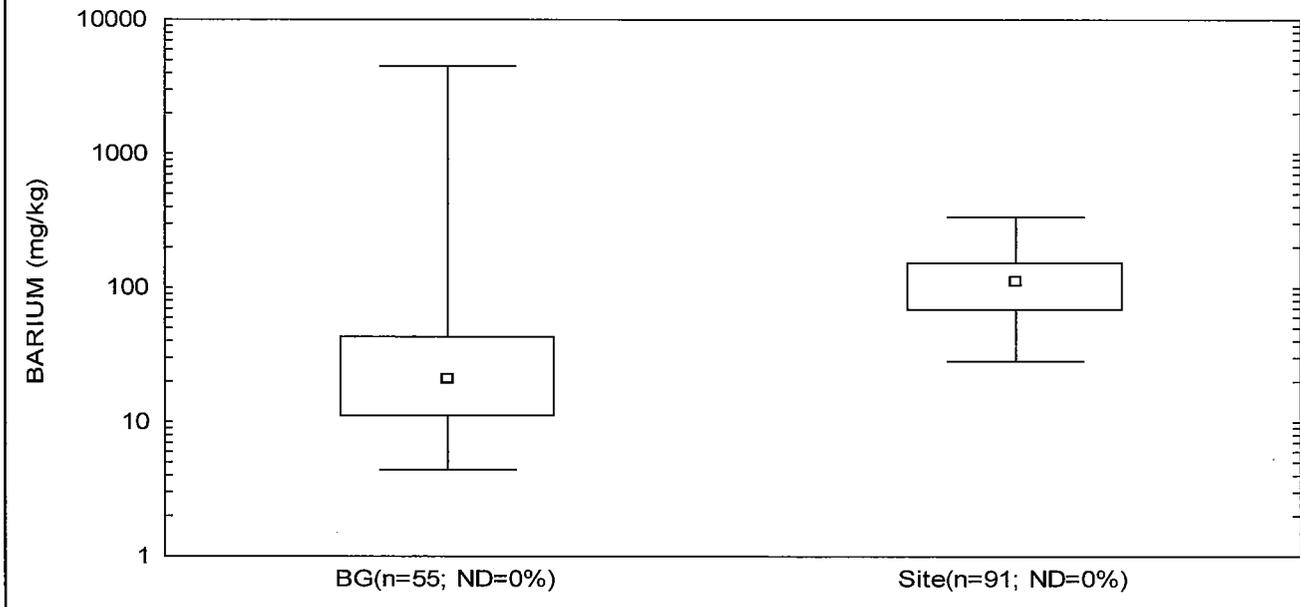


Figure 1-28. Box Plot Comparison for Barium in Subsurface Soil  
Baby Bains Gap Road, Ft. McClellan  
(WRS Test p-level < 0.001)



## Box Plots Baby Bains Gap Road Ranges

Figure 1-29. Box Plot Comparison for Beryllium in Subsurface Soil  
Baby Bains Gap Road, Ft. McClellan  
(WRS Test p-level < 0.001)

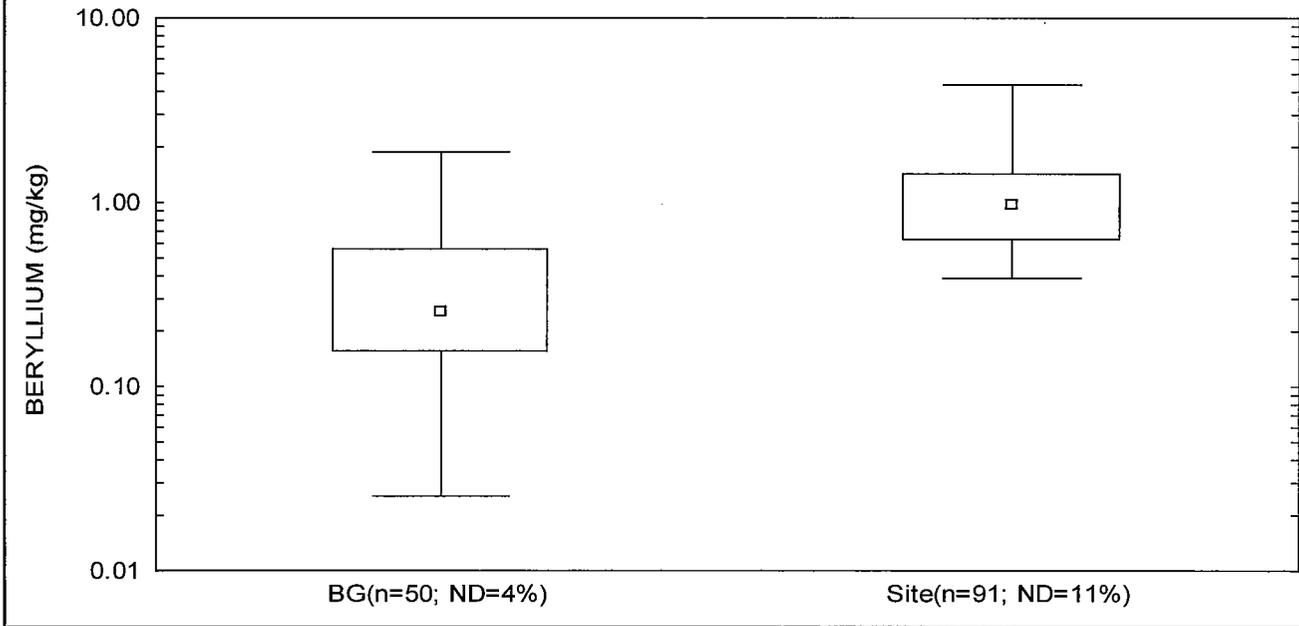
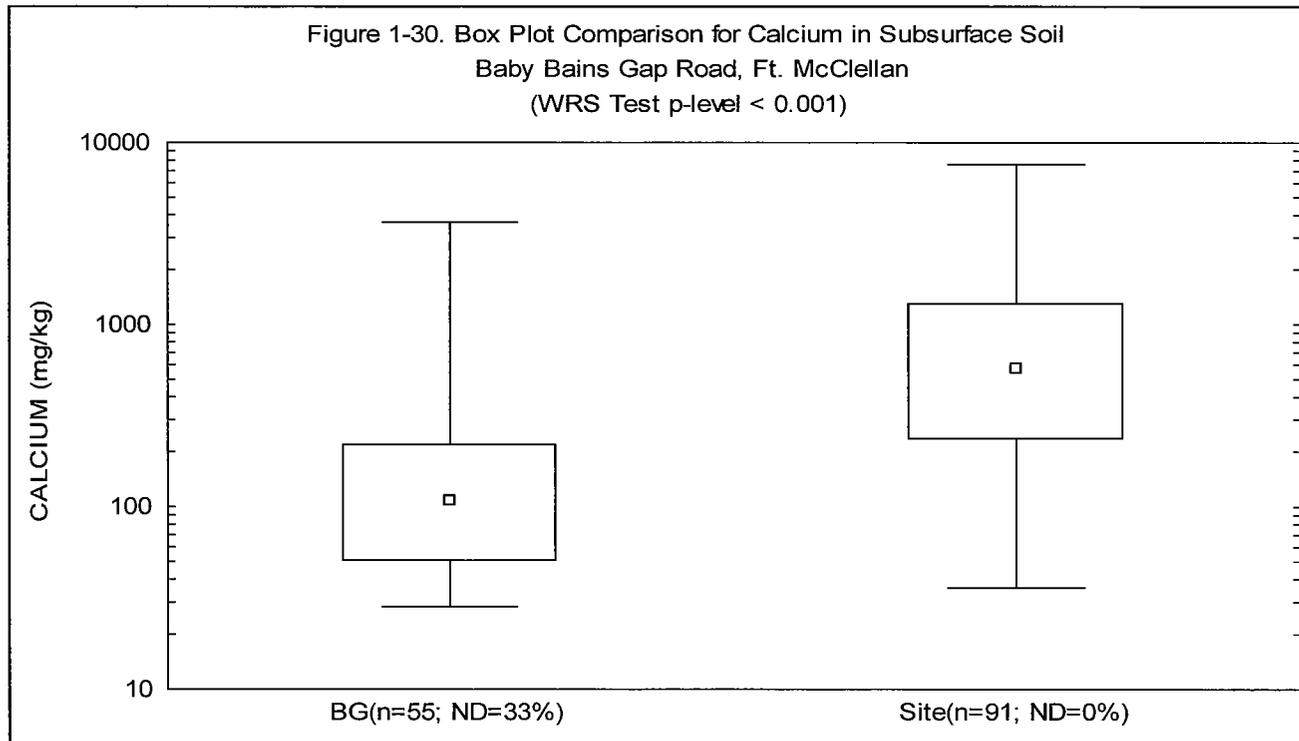


Figure 1-30. Box Plot Comparison for Calcium in Subsurface Soil  
Baby Bains Gap Road, Ft. McClellan  
(WRS Test p-level < 0.001)



## Box Plots Baby Bains Gap Road Ranges

Figure 1-31. Box Plot Comparison for Chromium in Subsurface Soil  
Baby Bains Gap Road, Ft. McClellan  
(WRS Test p-level = 0.004)

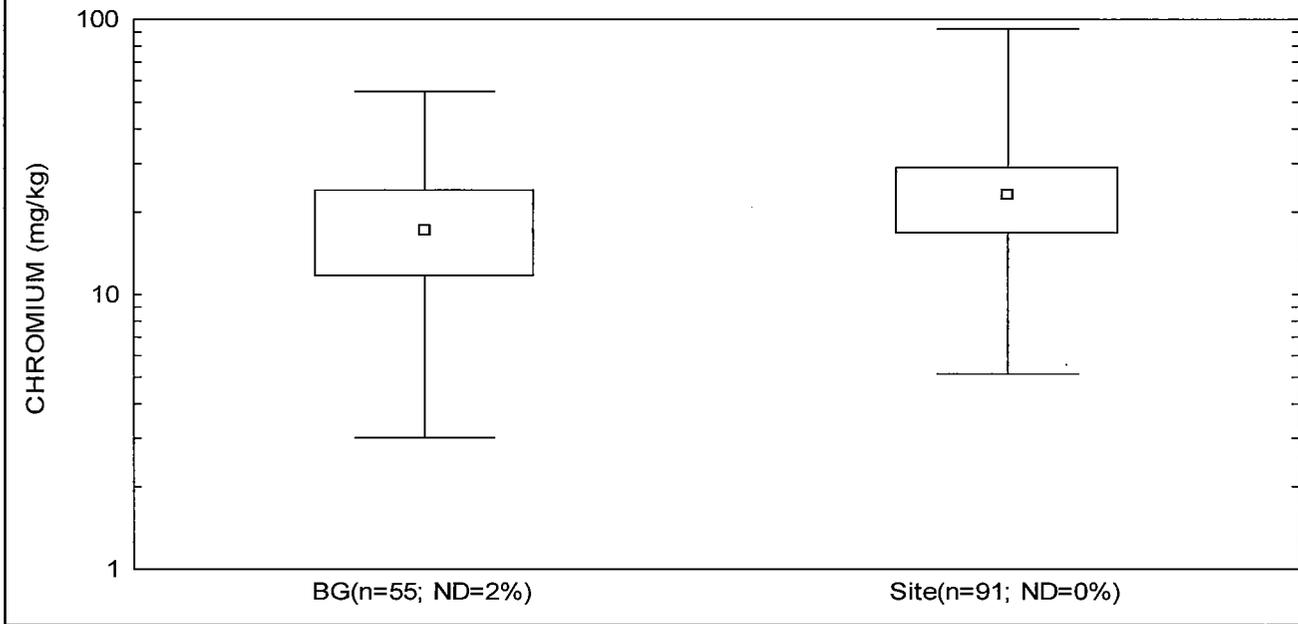
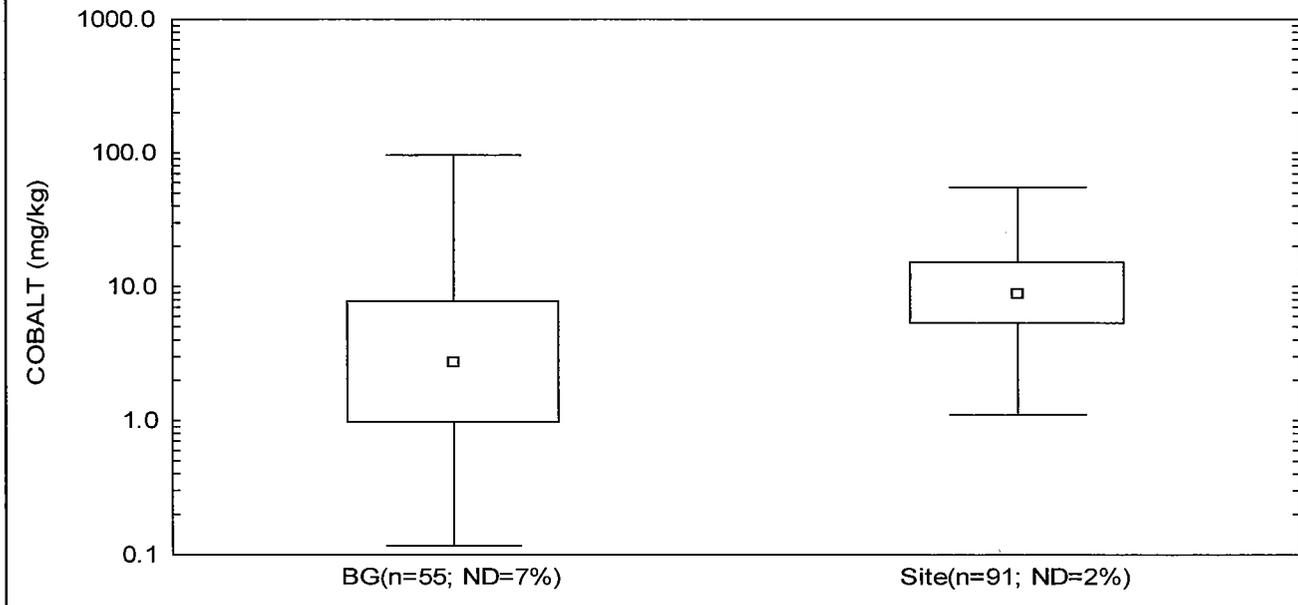


Figure 1-32. Box Plot Comparison for Cobalt in Subsurface Soil  
Baby Bains Gap Road, Ft. McClellan  
(WRS Test p-level < 0.001)



# Box Plots

## Baby Bains Gap Road Ranges

Figure 1-33. Box Plot Comparison for Copper in Subsurface Soil  
Baby Bains Gap Road, Ft. McClellan  
(WRS Test p-level < 0.001)

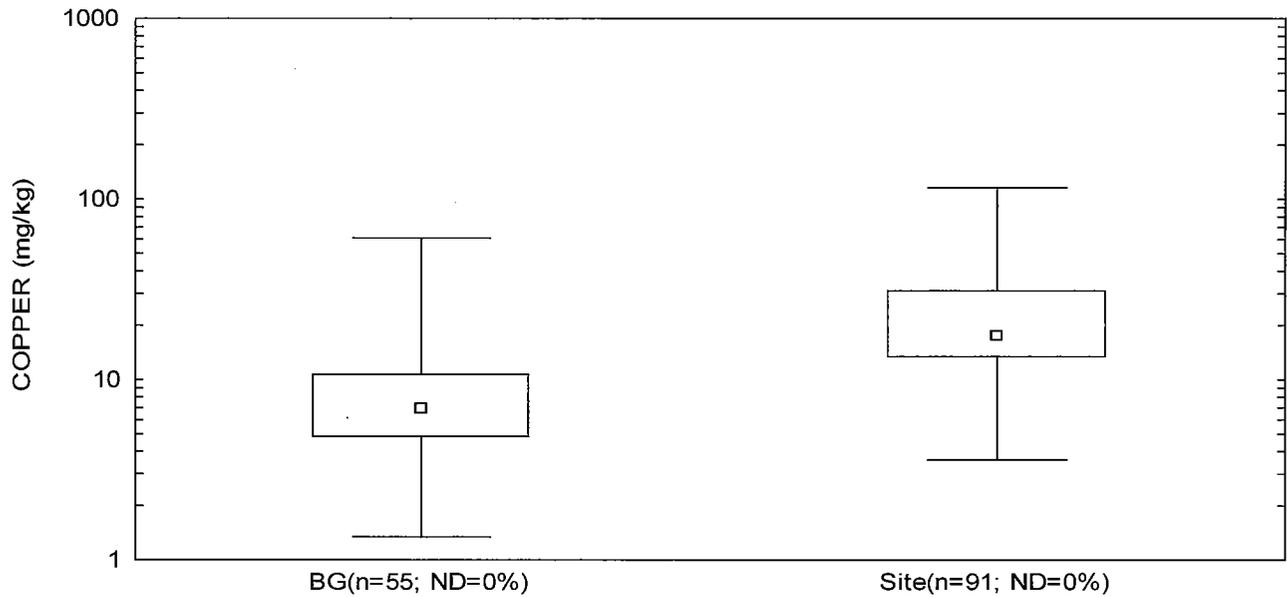
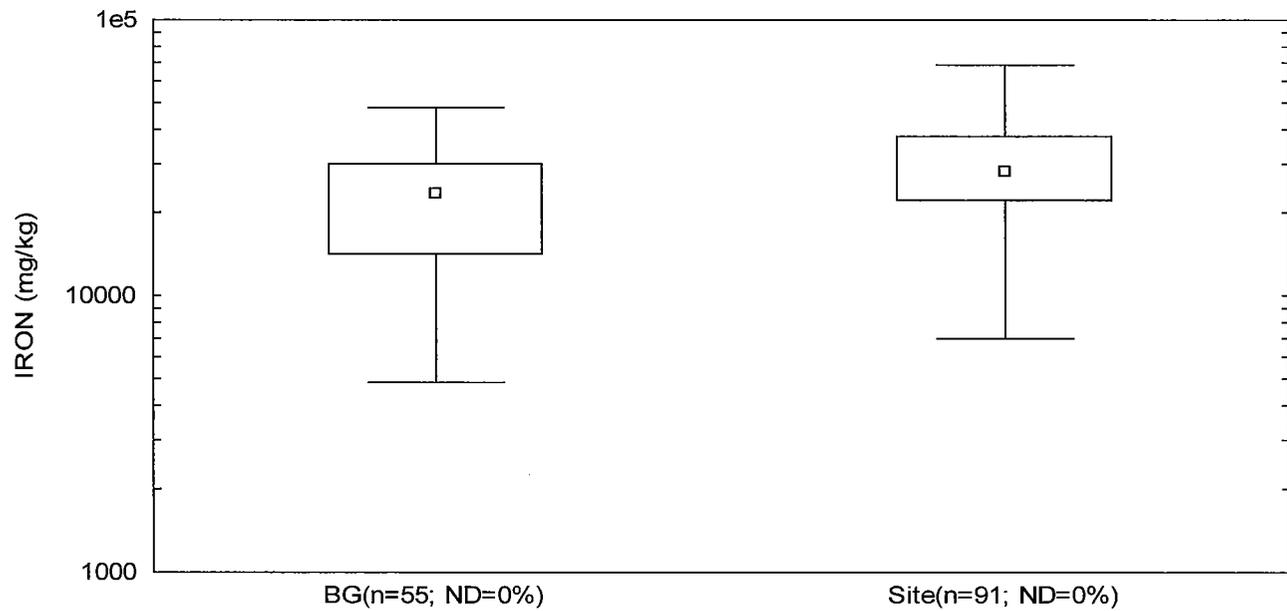
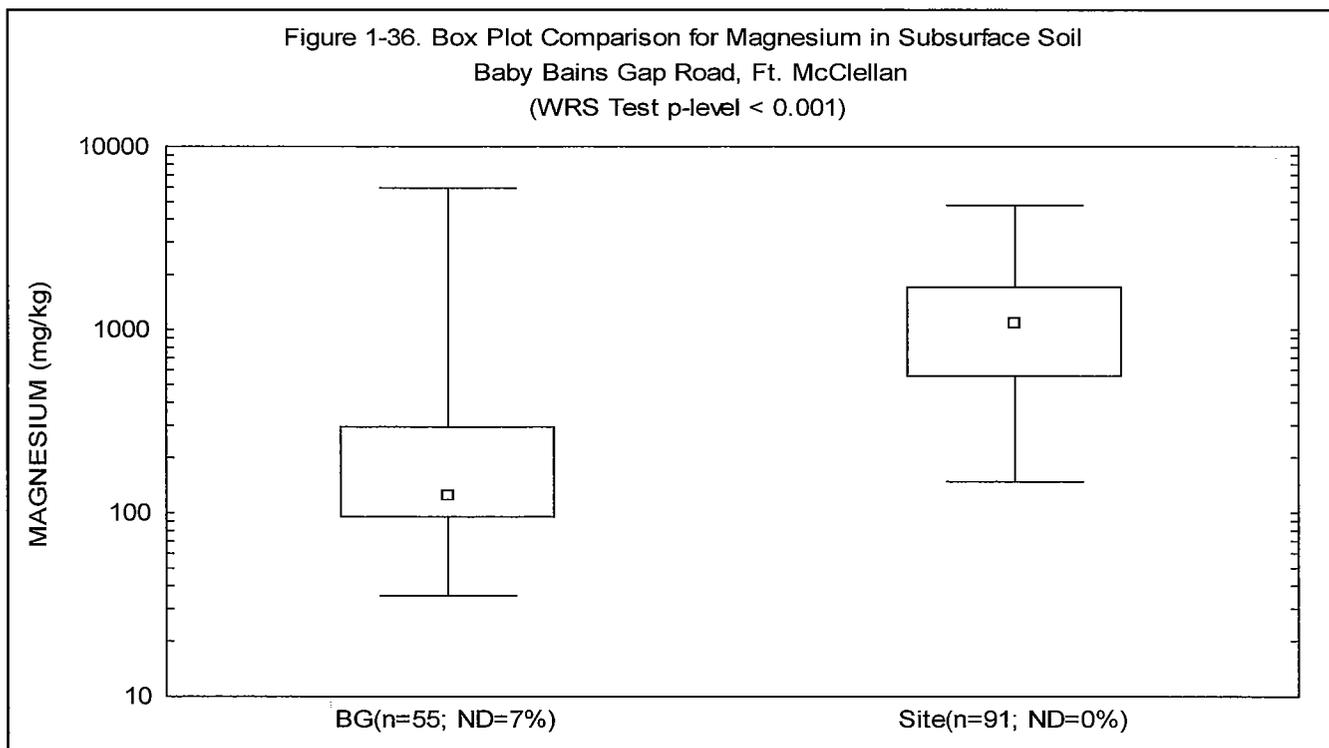
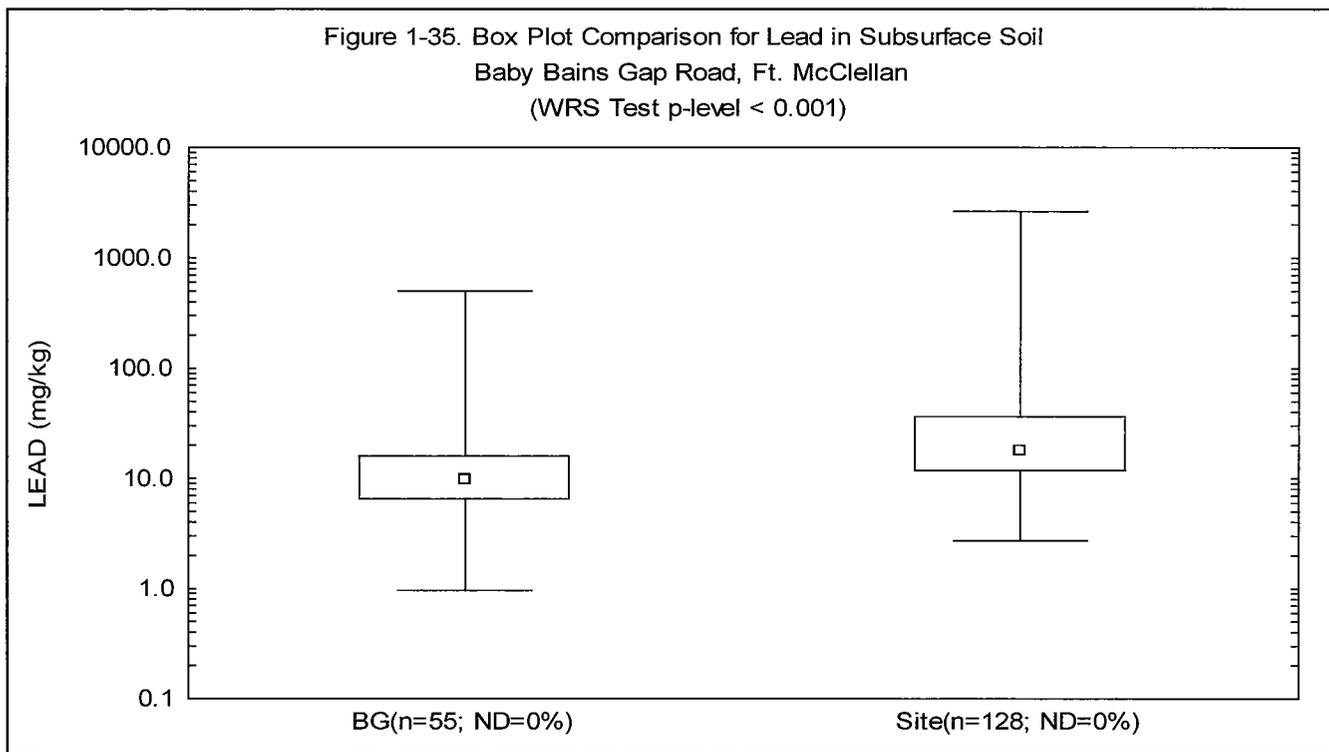


Figure 1-34. Box Plot Comparison for Iron in Subsurface Soil  
Baby Bains Gap Road, Ft. McClellan  
(WRS Test p-level < 0.001)



## Box Plots Baby Bains Gap Road Ranges



## Box Plots Baby Bains Gap Road Ranges

Figure 1-37. Box Plot Comparison for Manganese in Subsurface Soil  
Baby Bains Gap Road, Ft. McClellan  
(WRS Test p-level < 0.001)

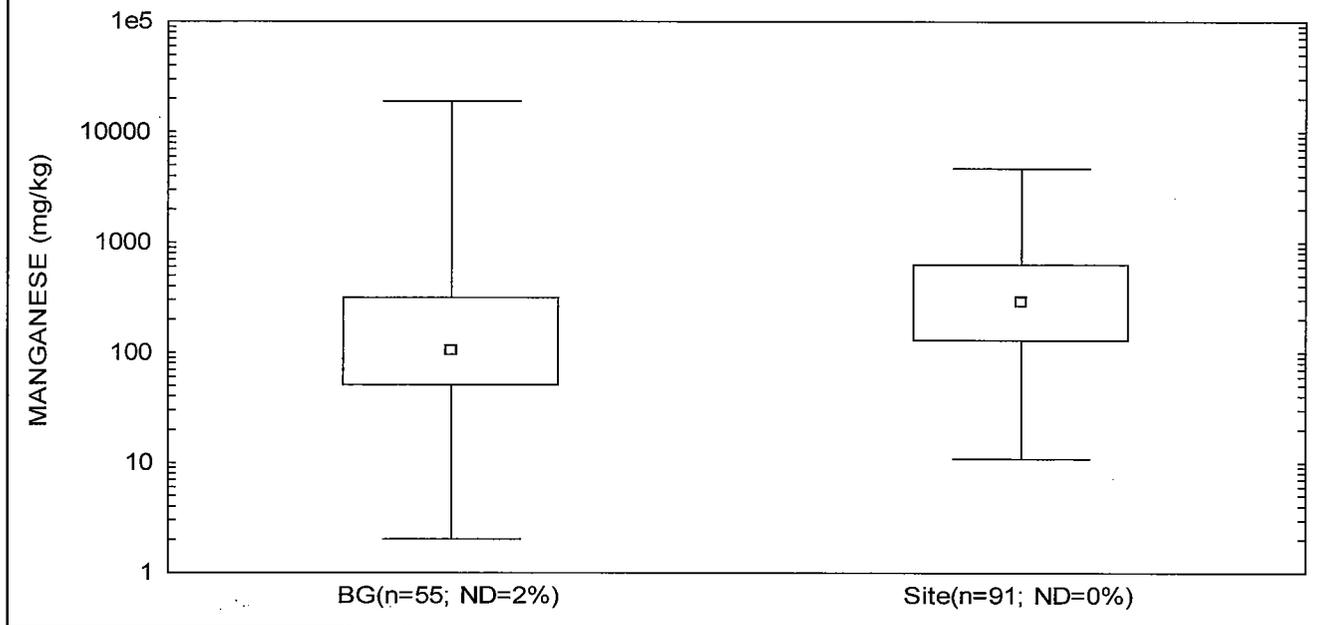
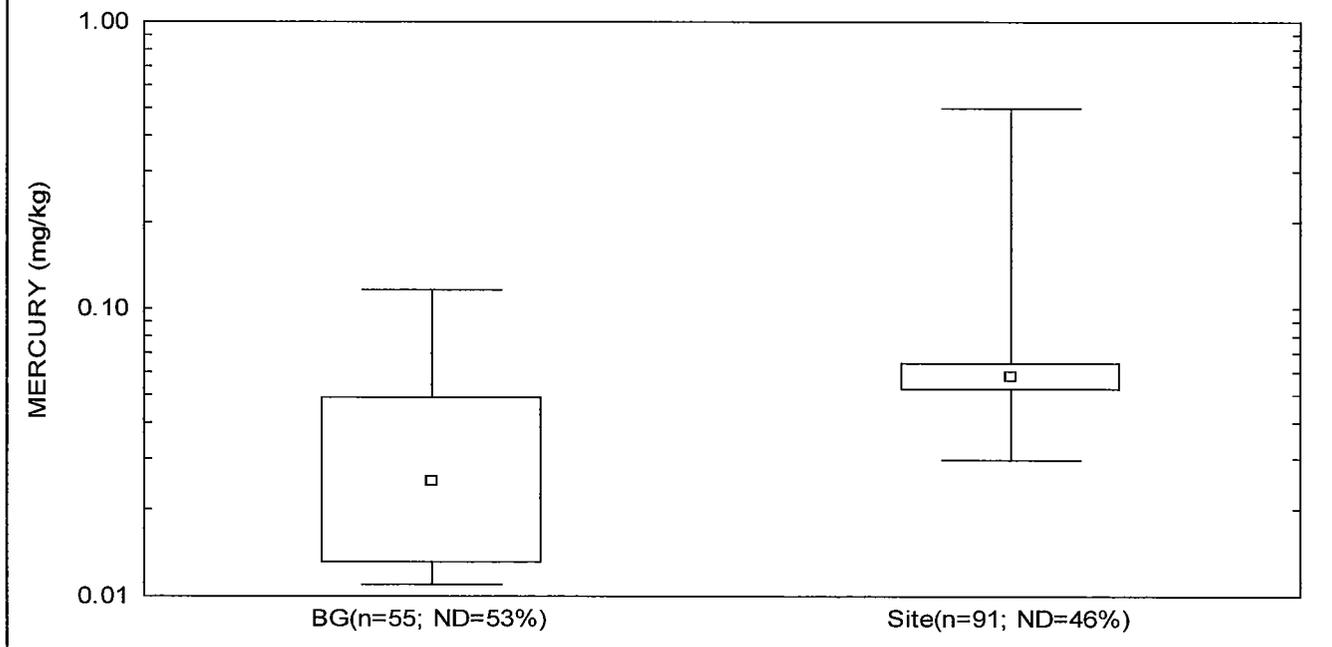


Figure 1-38. Box Plot Comparison for Mercury in Subsurface Soil  
Baby Bains Gap Road, Ft. McClellan



## Box Plots Baby Bains Gap Road Ranges

Figure 1-39. Box Plot Comparison for Nickel in Subsurface Soil  
Baby Bains Gap Road, Ft. McClellan  
(WRS Test p-level < 0.001)

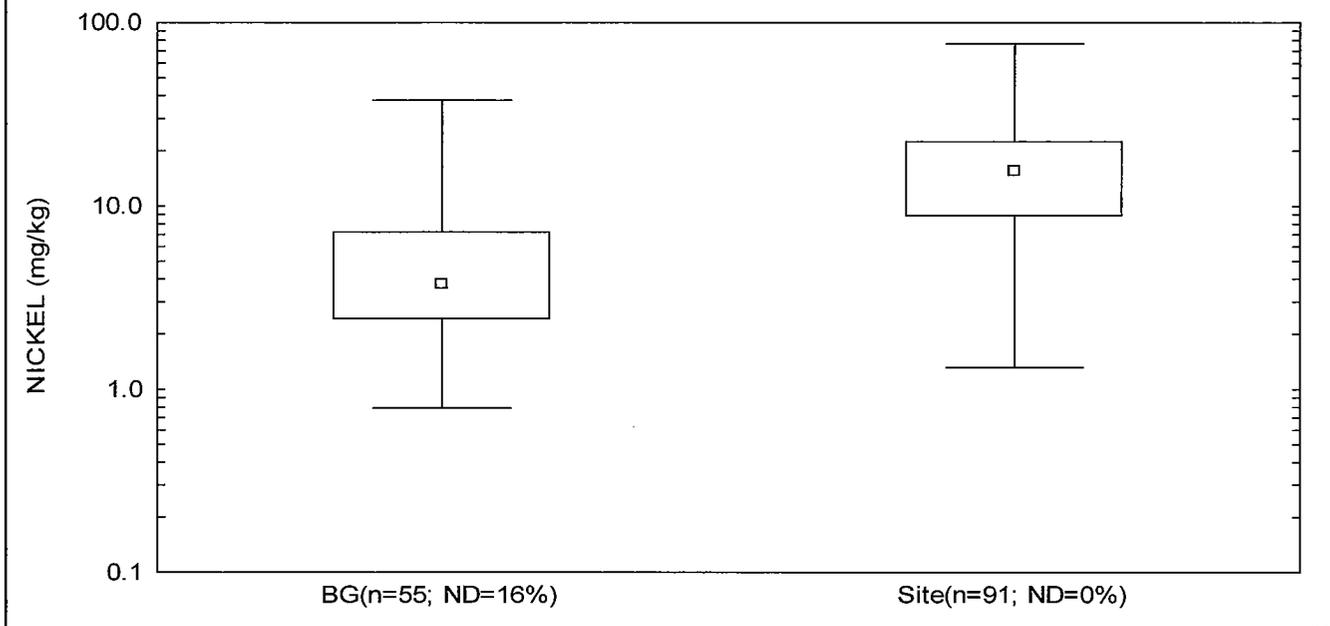
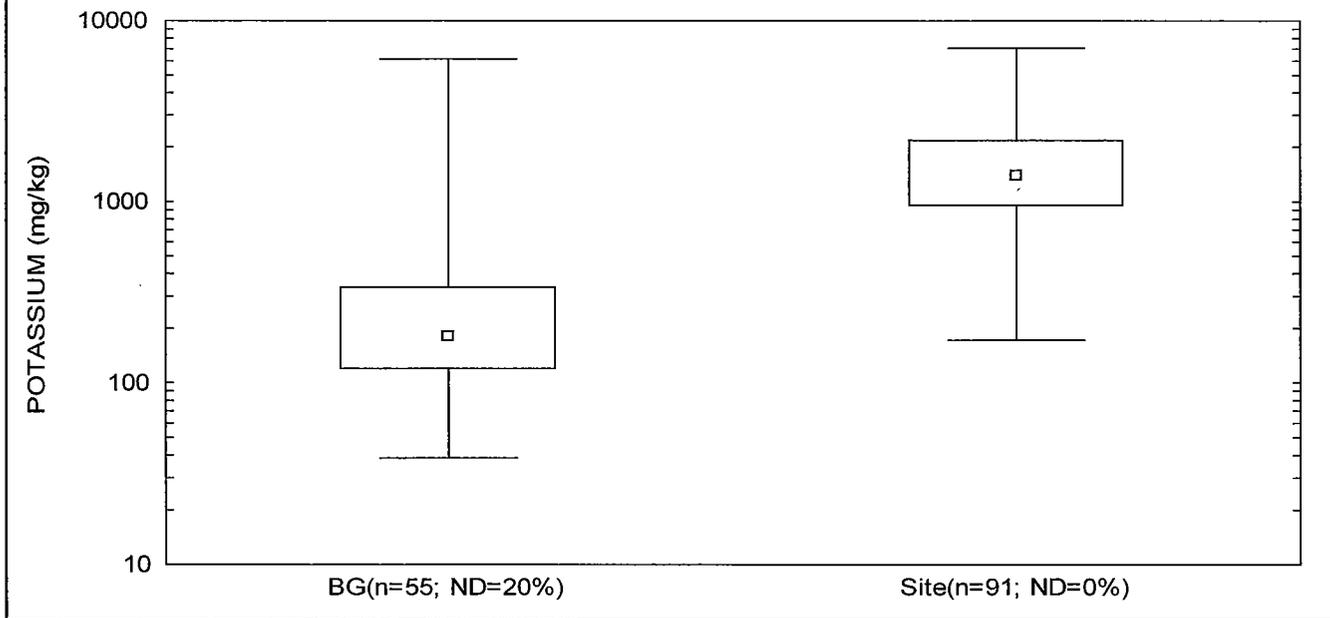


Figure 1-40. Box Plot Comparison for Potassium in Subsurface Soil  
Baby Bains Gap Road, Ft. McClellan  
(WRS Test p-level < 0.001)



## Box Plots Baby Bains Gap Road Ranges

Figure 1-41. Box Plot Comparison for Selenium in Subsurface Soil  
Baby Bains Gap Road, Ft. McClellan

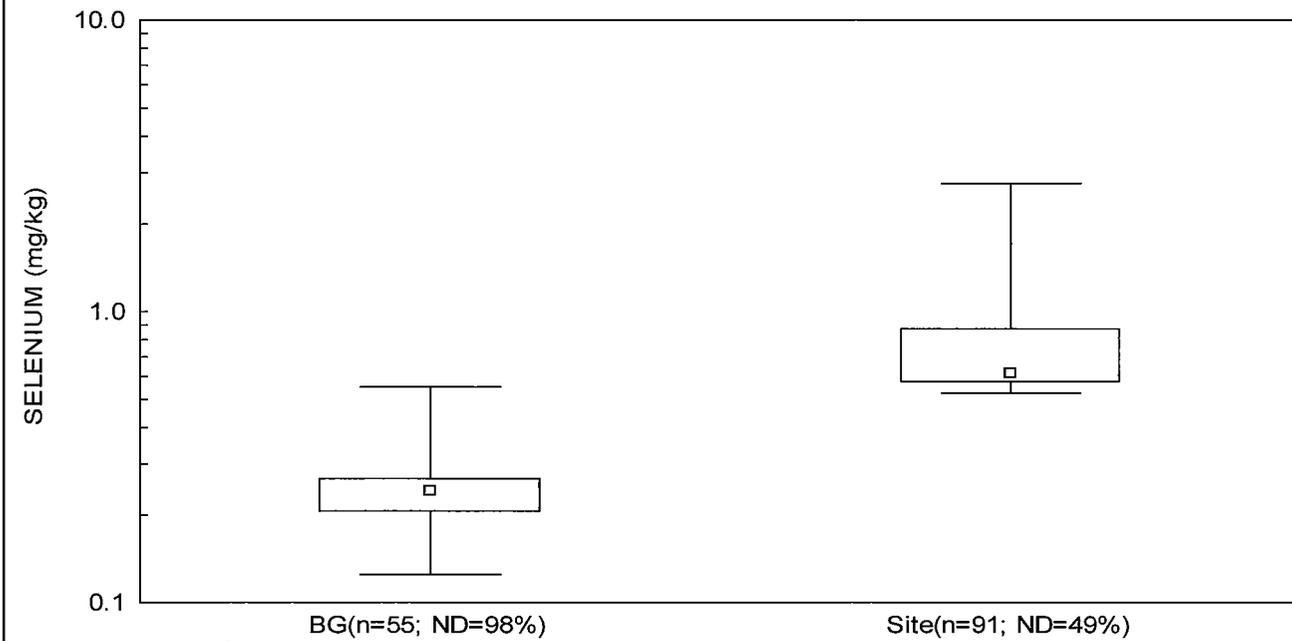
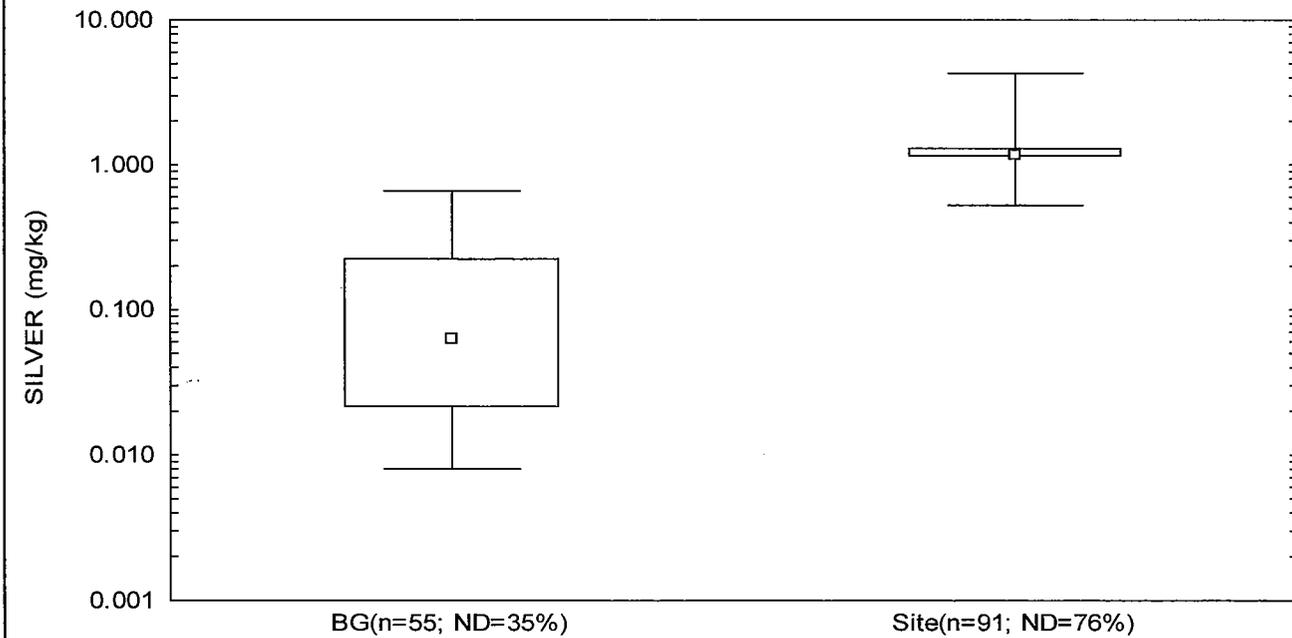


Figure 1-42. Box Plot Comparison for Silver in Subsurface Soil  
Baby Bains Gap Road, Ft. McClellan



## Box Plots Baby Bains Gap Road Ranges

Figure 1-43. Box Plot Comparison for Thallium in Subsurface Soil  
Baby Bains Gap Road, Ft. McClellan

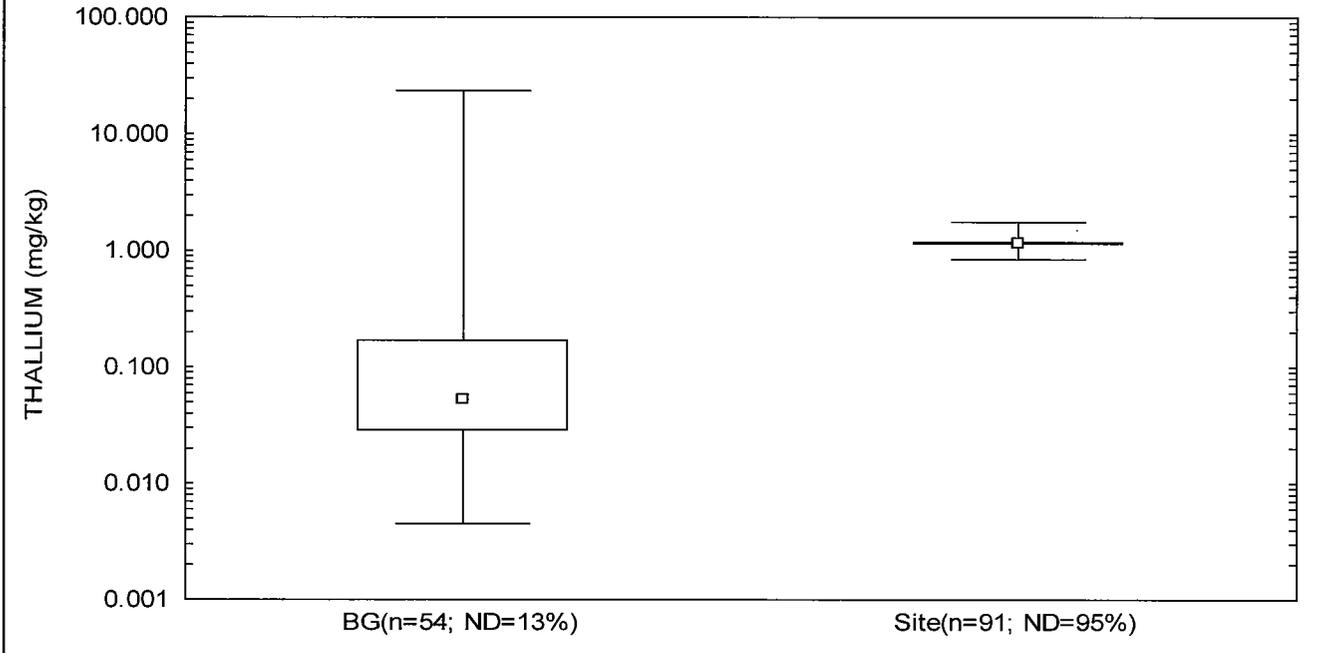
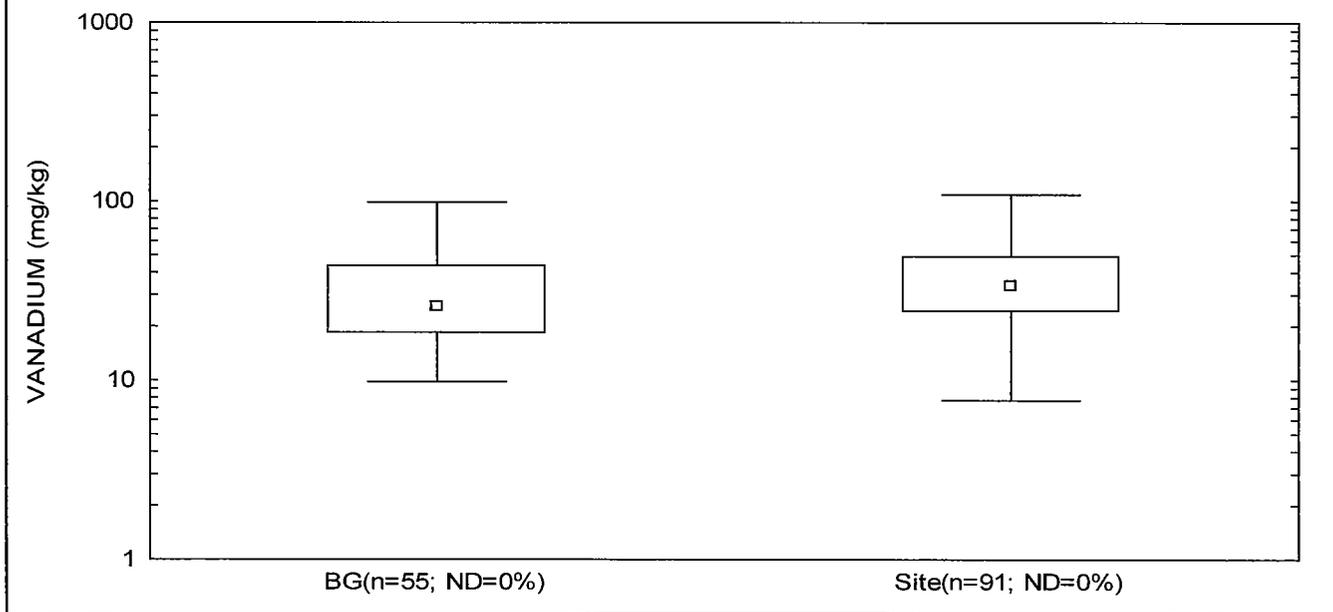


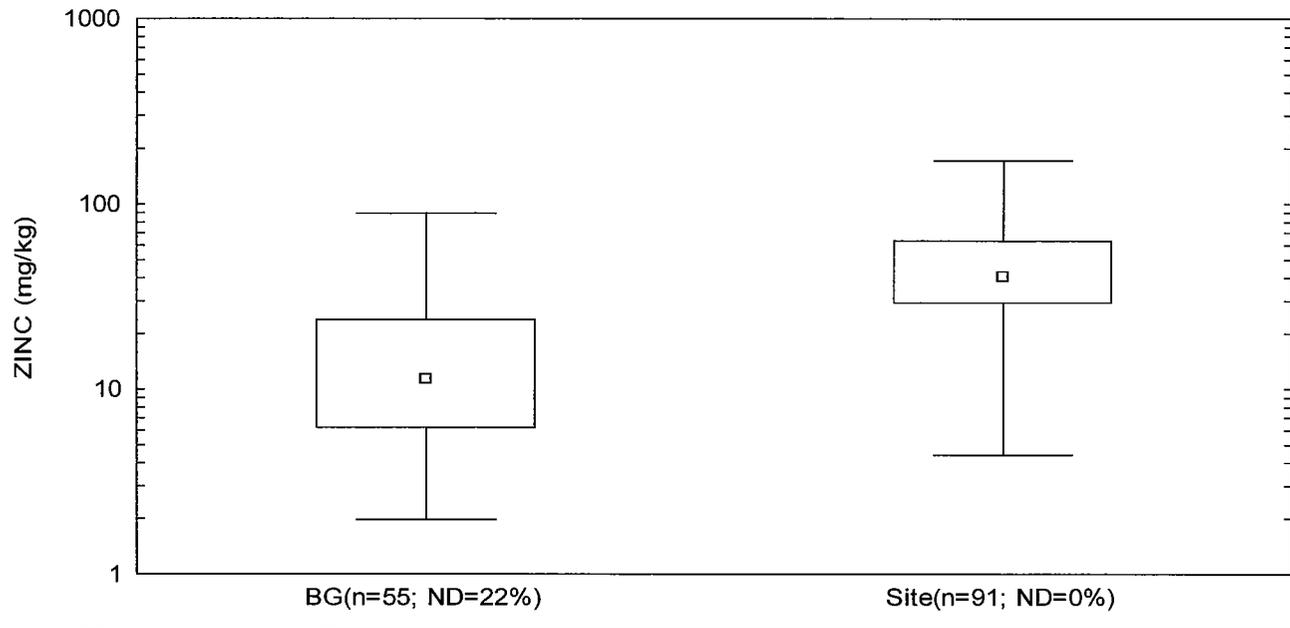
Figure 1-44. Box Plot Comparison for Vanadium in Subsurface Soil  
Baby Bains Gap Road, Ft. McClellan  
(WRS Test p-level = 0.039)



# Box Plots

## Baby Bains Gap Road Ranges

Figure 1-45. Box Plot Comparison for Zinc in Subsurface Soil  
Baby Bains Gap Road, Ft. McClellan  
(WRS Test p-level < 0.001)



**GEOCHEMICAL  
(TIER 3)**

# **Geochemical Evaluation of Metals in Site Media Baby Bains Gap Road Ranges Fort McClellan, Alabama**

## ***1.0 Introduction***

This report provides the results of a geochemical evaluation of surface soil, sediment, groundwater, and surface water samples from the Baby Bains Gap Road Ranges at Fort McClellan in Calhoun County, Alabama. Nineteen elements in surface soil, twenty elements in subsurface soil, seventeen elements in sediment, two elements in groundwater, and two elements in surface water failed statistical comparison to background. A geochemical evaluation was performed to determine if the elevated concentrations are naturally occurring or if they contain a component of contamination.

Site samples included in the evaluations consist of 323 surface soil samples (0 to 0.5 foot below ground surface [bgs] or 0 to 1 foot bgs) and 128 subsurface soil (various depths ranging from 1 to 12 bgs) collected from July 2001 to June 2002; 12 sediment samples collected from November 2001 to May 2002; 19 unfiltered groundwater samples collected from August 2001 to June 2002; and 10 unfiltered surface water samples collected from November 2001 to May 2002. It should be noted that only 144 surface soil and 91 subsurface soil samples were analyzed for the full list of twenty-three target analyte list (TAL) metals; and 179 surface soil and 37 subsurface soil samples were analyzed only for lead. In addition, 10 of the 12 sediment samples were analyzed for the full TAL suite, and 2 sediment samples were analyzed only for lead. Installation-wide background data for TAL metals in soil, sediment, groundwater, and surface water are provided in the background study report (Science Applications International Corporation, 1998) and are used in the following evaluations.

## ***2.0 Geochemical Evaluation Methodology***

Statistical site-to-background comparisons for trace elements in soil commonly have high false-positive error rates. A large number of background samples is required to adequately characterize the upper tails of most trace element distributions, which are typically right skewed and span a wide range of concentrations, but such a large background data set is not always feasible. Higher false positive error rates are expected if the site sample size is greater than the background sample size. The presence of estimated concentrations and nondetects with differing reporting limits can also cause statistical comparison tests to fail.

Statistical tests consider only the absolute concentrations of individual elements, and they disregard the interdependence of element concentrations and the geochemical mechanisms controlling element behavior. However, it is well established that trace elements are naturally associated with specific soil-forming minerals, and the preferential enrichment of a sample with these minerals will result in elevated trace element concentrations. It is thus important to be able to identify these naturally high concentrations and distinguish them from potential contamination.

If an analyte fails statistical comparison to background as described in the “Statistical Comparison of Site and Background Data, Baby Bains Gap Road Ranges,” then a geochemical evaluation is performed to determine if the elevated concentrations are caused by natural processes. Recent publications indicate that geochemical evaluations are assuming a larger role in environmental investigations (e.g., U.S. Environmental Protection Agency, 1995; Barclift, *et al.*, 2000; U.S. Navy, 2002; Myers and Thorbjornsen, 2004). A properly executed geochemical evaluation can reveal the mechanisms responsible for naturally high element concentrations, and can identify the samples with anomalously high concentrations that may reflect site-related contamination. This section describes the geochemical evaluation techniques that were employed in the site-to-background comparison for the Baby Bains Gap Road site. Additional supporting information on these techniques are provided in the installation-wide work plan (IT Corporation, 2002) and Shaw Environmental’s technical memorandum dated June 24, 2003.

It should be noted that the geochemical evaluations rely in part on professional judgment and qualitative assessment is a necessary part of the process. Samples that plot off the linear trend on a correlation plot are certainly suspect, but because all uncertainty cannot be eliminated from the evaluation, such plots cannot be construed as definitive proof of contamination. However, anomalous samples should be flagged as suspect and their results used as a basis for further investigation, risk assessment, or remediation, as appropriate. The combination of statistical evaluations (Tiers 1 and 2) and geochemical evaluation (Tier 3) as presented in this appendix is effective in reducing the occurrences of decision errors relative to consideration of statistics or geochemistry alone.

## **2.1 Soil and Sediment**

Trace elements naturally associate with specific soil-forming minerals, and geochemical evaluations are predicated on these known associations. For example, in most uncontaminated oxic soils, arsenic exhibits an almost exclusive association with iron oxide minerals (Bowell, 1994; Schiff and Weisberg, 1997). Arsenic exists in oxic soil pore fluid as oxyanions such as

$\text{HAsO}_4^{-2}$  and  $\text{H}_2\text{AsO}_4^-$  (Brookins, 1988), and these negatively charged species have a strong affinity to adsorb on iron oxides, which tend to maintain a net positive surface charge (Electric Power Research Institute [EPRI], 1986). (In this report the term “iron oxide” encompasses oxides, hydroxides, oxyhydroxides, and hydrous oxides of iron.) This association is expressed as a positive correlation between arsenic concentrations and iron concentrations for uncontaminated samples: soil samples with a low percentage of iron oxides will contain proportionally lower arsenic concentrations, and soil samples that are enriched in iron oxides will contain proportionally higher arsenic concentrations. Although there is variability in the absolute concentrations of arsenic and iron in soil at a site, the As/Fe ratios of the samples will be relatively constant if no contamination is present (Daskalakis and O’Connor, 1995). Samples that contain excess arsenic from an contaminant source (e.g., arsenic-bearing compounds such as the chemical warfare agent lewisite or certain herbicides) will exhibit anomalously high As/Fe ratios compared to the uncontaminated samples.

To perform the geochemical evaluation, correlation plots are constructed to explore the elemental associations and identify potentially contaminated samples. The detected concentrations of the trace element of interest (dependent variable) are plotted against the detected concentrations of the reference element (independent variable), which represents the mineral to which the trace element may be adsorbed. In the case of arsenic, the arsenic concentrations for a given set of samples would be plotted on the y-axis and the corresponding iron concentrations would be plotted on the x-axis. If no contamination is present, then the samples will exhibit a generally linear trend and the samples with the highest arsenic concentrations will lie on this trend. This indicates that the elevated arsenic is due to the preferential enrichment of iron oxides in those samples, and that the arsenic has a natural source. If, however, the samples with high arsenic concentrations have low or moderate iron concentrations (anomalously high As/Fe ratios), then they will lie above the linear trend established by the other samples. This would indicate that the anomalous samples contain excess arsenic beyond that which can be explained by the natural iron oxide content, and such samples may contain a component of contamination.

The reference elements against which trace elements are evaluated reflect the affinity that the trace elements have for specific minerals. The concentrations of iron, aluminum, and manganese serve as qualitative indicators of the amounts of iron oxide, clay, and manganese oxide minerals in the soil samples. Along with arsenic, selenium and vanadium are present in oxic soil pore fluid as anions, and have an affinity to adsorb on iron oxides, which tend to maintain a net positive surface charge. Concentrations of arsenic, selenium, or vanadium in a set of samples

can be evaluated through comparison to the corresponding iron concentrations. Barium, cadmium, lead, and zinc are typically present in soil as divalent cations and have an affinity to adsorb on clay minerals, which tend to maintain a net negative surface charge. Concentrations of barium, cadmium, lead, or zinc can be evaluated through comparison to the corresponding aluminum concentrations. Manganese oxides have a strong affinity to adsorb barium, cobalt, and lead (Kabata-Pendias, 2001), so concentrations of these elements can be compared to the corresponding manganese concentrations, as long as there is enough manganese present in the soil to form discrete manganese oxides.

The trends in the correlation plots may be linear or may have some curvature to them. The adsorption of a trace element on a mineral surface can usually be described by a linear isotherm over a limited range of concentrations, but a two-parameter curved fit (such as a Freundlich or Langmuir isotherm) can be more appropriate for some trace elements over a broader range of concentrations. The trace-versus-major element correlations are referred to as “linear trends” for convenience in this report, although there may be some degree of curvature to the natural relationship.

It is important to note that some trace elements have very strong affinities for a particular type of mineral, whereas other elements will partition themselves between several minerals. For instance, vanadium has a particularly strong affinity for iron oxides, so correlation coefficients for vanadium versus iron in uncontaminated samples are usually very high, and this is expressed on a correlation plot as a highly linear trend. In contrast, chromium will form several co-existing aqueous species with different charges [ $\text{Cr}(\text{OH})_2^+$ ,  $\text{Cr}(\text{OH})_3^0$ , and  $\text{Cr}(\text{OH})_4^-$ ] that will adsorb on several different types of minerals including clays and iron oxides. This behavior will yield lower correlation coefficients for chromium versus iron or chromium versus aluminum relative to the coefficients observed for vanadium versus iron, and more scatter may be observed on the correlation plots. Some elements are more selective than others with respect to adsorption on specific mineral surfaces, and this selectivity is dependent on site-specific conditions, including soil pH, redox conditions, and concentrations of competing elements.

## **2.2 Groundwater and Surface Water**

Elevated concentrations of inorganic constituents in groundwater and surface water samples may be due to naturally high dissolved concentrations, the presence of suspended particulates in the samples, reductive dissolution, or contamination resulting from site activities. This section discusses the major geochemical processes considered during the evaluation of groundwater and surface water analytical data.

**Effects of Suspended Particulates.** The presence of trace elements adsorbed on suspended particulates can greatly increase trace element concentrations as reported by an analytical laboratory. These adsorbed trace elements are not in true solution, and can be removed by settling or filtration. The same concepts involved in the evaluation of soil and sediment data also apply to groundwater and surface water data: uncontaminated samples containing trace elements adsorbed on suspended clay particulates should show a positive correlation with aluminum concentrations, and uncontaminated samples containing trace elements adsorbed on suspended iron oxides should show a positive correlation with iron concentrations. These correlations are evaluated by generating x-y plots of the concentrations of an elevated trace metal versus aluminum or iron (depending on the trace element).

The most common suspended particulates in groundwater samples are clay minerals; hydrous aluminum oxides ( $\text{Al}_2\text{O}_3 \cdot n\text{H}_2\text{O}$ ) and hydroxides [ $\text{Al}(\text{OH})_3$ ]; and iron oxide ( $\text{Fe}_2\text{O}_3$ ), hydrous iron oxide, iron hydroxide [ $\text{Fe}(\text{OH})_3$ ], and iron oxyhydroxide ( $\text{FeO} \cdot \text{OH}$ ) minerals, collectively referred to as “iron oxides.” All clay minerals contain aluminum and have low solubilities over a neutral pH range of 6 to 8. Measured concentrations of aluminum in excess of ~1 milligram per liter (mg/L) indicate the presence of suspended clay minerals (Hem, 1985; Stumm and Morgan, 1996), with higher aluminum concentrations being a qualitative indicator of the mass of suspended clay minerals. Iron also has a very low solubility under neutral pH and moderate to oxidizing redox conditions, so that measured iron concentrations in excess of ~1 mg/L under these conditions indicate the presence of suspended iron oxides (Hem, 1985).

The presence of suspended clay or iron oxides in groundwater samples has particular importance in the interpretation of trace element concentrations. Most clay particles maintain a negative surface charge under neutral pH conditions, and have a strong tendency to adsorb positively charged (cationic) aqueous species. Iron oxides display the opposite behavior; they maintain a positive surface charge under neutral pH conditions, and have a strong tendency to adsorb negatively charged (anionic) aqueous species.

Barium, lead, and zinc are usually present in groundwater as divalent cations and thus tend to concentrate on clay surfaces (EPRI, 1984; Brookins, 1988). Arsenic, selenium, and vanadium are usually present under oxidizing conditions as oxyanions, and thus tend to concentrate on iron oxide surfaces (Bowell, 1994; Hem, 1985; Pourbaix, 1974; Brookins, 1988).

Chromium can be present in groundwater as a mixture of aqueous species with different charges, depending on pH (EPRI, 1984). The positive, neutral, and negative charges on these species result in the distribution of chromium on several different types of sorptive surfaces, including clay and iron oxide minerals.

As an example, the concentrations of zinc (y-axis) would be plotted against aluminum (x-axis). If all of the samples display a common linear trend, then it is most likely that the zinc concentrations are due to the presence of suspended clay minerals in the samples. The slope of a best-fit line through the points is equal to the average Zn/Al ratio. If some samples plot above the linear trend established by the other samples, then those samples have an anomalously high Zn/Al ratio, and most likely contain excess zinc that cannot be explained by these natural processes.

Alternative techniques for assessing the effects of suspended particulates on trace element concentrations are the evaluation of correlations of trace element concentrations versus turbidity, and comparison of analyses of filtered versus unfiltered splits of samples. Turbidity measurements are qualitative, and do not distinguish between suspended clay minerals, iron oxides, and natural organic material, so this approach lacks the resolution provided by trace element versus aluminum or trace element versus iron correlations.

If the concentrations of trace elements in unfiltered samples are correlated with aluminum or iron, then they are most likely adsorbed to the surfaces of suspended particulates. If these correlations are linear, then the elevated concentrations are most likely natural.

***Effects of Reductive Dissolution.*** Iron and manganese oxides concentrate several trace elements such as arsenic, selenium, and vanadium on mineral surfaces, as discussed above. In soils and sedimentary aquifers, these elements are almost exclusively associated with iron and manganese oxide minerals and grain coatings, as long as the redox conditions are moderate to oxidizing.

The release of organic contaminants such as fuels or chlorinated solvents can establish local reducing environments caused by anaerobic microbial degradation of the organic compounds. The establishment of local reducing conditions can drive the dissolution of iron and manganese oxides, which become soluble as the redox potential drops below a threshold value. Dissolution of these oxide minerals can mobilize the trace elements that were adsorbed on the oxide surfaces, which is a process termed “reductive dissolution.” Several investigations have documented the

mobilization of arsenic, selenium, and other trace elements under locally reducing redox conditions (Sullivan and Aller, 1996; Nickson, *et al.*, 2000; Belzile, *et al.*, 2000).

Evidence for reductive dissolution would be a correlation between elevated trace elements (arsenic, selenium, and vanadium in particular) versus lower redox conditions. Low redox conditions can be identified by local depressions in oxidation-reduction potential (ORP) or dissolved oxygen (DO) measurements, or the presence of reducing gases such as hydrogen, methane, ethane, or ethene. Anaerobic microbes can also reduce sulfate to sulfide and nitrate to ammonia, resulting in local depressions in sulfate and nitrate concentrations, and local detections of sulfide and ammonia. In areas impacted by chlorinated solvents, additional evidence for the establishment of anaerobic reducing conditions is the presence of *cis*-1,2-dichloroethene and/or vinyl chloride, which are reductive dechlorination products resulting from the microbial degradation of trichloroethene or tetrachloroethene under anaerobic conditions.

### **3.0 Results of the Geochemical Evaluation for Multiple Metals in Soil**

This section presents the results of the geochemical evaluation of aluminum, antimony, arsenic, barium, beryllium, calcium, chromium, cobalt, copper, iron, lead, magnesium, manganese, mercury, nickel, potassium, selenium, silver, vanadium, and zinc in soil samples from the Baby Bains Gap Road site. Correlation plots are provided in Attachment 1.

#### **Aluminum**

Aluminum is the second most abundant element analyzed in the site soil samples, with a mean concentration of 16,965 milligrams per kilogram (mg/kg) (1.7 weight percent). Aluminum is a primary component of common soil-forming minerals such as clays, feldspars, and micas. Aluminum also substitutes for ferric iron in iron oxide minerals, and can adsorb on iron oxide surfaces (Cornell and Schwertmann, 2003). Iron is the most abundant element analyzed in the site soil samples (mean concentration of 25,099 mg/kg; 2.5 weight percent). The iron in the site samples is mostly present as iron oxides, which are common soil-forming minerals and which occur as discrete mineral grains or as coatings on silicate minerals (Cornell and Schwertmann, 2003). Clays and iron oxides tend to exist as very fine particles, so both aluminum and iron are enriched in samples with finer grain sizes. The Baby Bains Gap Road soil boring logs note the presence of clays in many of the sampled intervals.

A plot of aluminum versus iron concentrations can be used as a qualitative indicator of the relative abundance of clays and iron oxides in site soil (Figure 1). Site surface soil samples are represented by open triangles (“Site SS”), site subsurface soil samples by filled triangles (“Site DS”), and background soil samples by filled circles (“BG”). For both soil intervals, most of the site samples contain a similar range of aluminum concentrations as the background samples, and they all lie on or near the general background trend (Figure 1). The site samples with high aluminum concentrations also contain proportionally higher iron. The similarity in Al/Fe ratios

between the site and background samples indicates a natural source for the aluminum in the site samples. It is important to note that clays and iron oxides adsorb specific trace elements (as discussed in Section 2.1), so the samples that plot on the upper end of the trend in Figure 1 are expected to contain proportionally higher concentrations of trace elements.

### Conclusion

Aluminum detected in the site soil samples is naturally occurring.

### **Antimony**

Antimony is geochemically similar to arsenic, and like arsenic it has an affinity to adsorb on the surfaces of iron oxides. The background samples exhibit a positive correlation for antimony versus iron; the background samples with high antimony contain proportionally higher iron and lie on the linear trend formed by the other samples (Figure 2). This indicates that antimony in the background soil samples is associated with iron oxides at a relatively constant ratio, and is natural.

Antimony in the site samples does not correlate with iron, and all of the site samples lie above the linear background trend in Figure 2. The Baby Bains Gap Road site encompasses several firing ranges, and lead is a known contaminant due to its presence in bullets and bullet fragments. Antimony is used as a hardening agent in bullets (Interstate Technology and Regulatory Council [ITRC], 2003), and is present in lead bullets at concentrations of 3 to 8 percent; thus, elevated antimony concentrations would be expected in soil samples from firing ranges. The positive correlation between antimony and lead in the site samples ( $R^2 = 0.49$  and  $0.46$  for the surface and subsurface intervals) and the presence of elevated antimony concentrations in samples with high lead indicates that lead and antimony are co-contaminants at the site. Table 1 lists the site samples with anomalous element concentrations, and provides both the sample identification numbers and corresponding sample location codes.

### Conclusion

Antimony concentrations detected in the site soil samples most likely reflect site-related contamination (Table 1).

### **Arsenic**

As discussed in Section 2.1, arsenic has an affinity to adsorb on the surfaces of iron oxides in soil, so a positive correlation is expected between arsenic and iron in uncontaminated samples. A plot of arsenic versus iron reveals a common linear trend for the background samples and most of the site samples (Figure 3). Most of the site samples with elevated arsenic also exhibit proportionally higher iron, and lie on the linear trend. Arsenic in these samples is associated with iron oxides at a ratios consistent with those of the background samples, and is natural. The exception is surface soil sample PJ0031 (from sample location HR-74Q-GP21), which contains elevated arsenic (24.3 mg/kg) but only moderate iron, and which lies slightly above the linear trend established by the other site samples. Elevated arsenic in this sample should be considered suspect.

**Table 1**

**Samples With Anomalous Element Concentrations  
Baby Bains Gap Road  
Fort McClellan, Alabama**

(Page 1 of 4)

<b>Medium</b>	<b>Sample Location</b>	<b>Sample Number</b>	<b>Element(s)</b>
Surface Soil	HR-226Q-GP05	MR0009	Copper, Lead
Surface Soil	HR-226Q-GP07	MR0014	Lead
Surface Soil	HR-226Q-GP08	MR0016	Antimony, Copper, Lead
Surface Soil	HR-226Q-GP09	MR0018	Antimony, Copper, Lead
Surface Soil	HR-226Q-GP10	MR0020	Antimony, Copper, Lead
Surface Soil	HR-226Q-GP11	MR0022	Lead
Surface Soil	HR-226Q-GP12	MR0023	Antimony
Surface Soil	HR-226Q-GP13	MR0024	Antimony, Copper, Lead
Surface Soil	HR-226Q-MW02	MR0027	Antimony, Copper, Lead
Surface Soil	HR-226Q-MW03	MR0029	Antimony, Copper, Lead
Surface Soil	HR-226Q-DEP03	MR0039	Antimony, Lead
Surface Soil	HR-226Q-DEP04	MR0041	Antimony, Copper, Lead
Surface Soil	HR-83Q-GP10	NN0021	Lead
Surface Soil	HR-83Q-GP14	NN0029	Antimony
Surface Soil	HR-83Q-GP15	NN0031	Antimony
Surface Soil	HR-83Q-GP16	NN0033	Copper, Lead
Surface Soil	HR-83Q-GP21	NN0044	Antimony
Surface Soil	HR-83Q-GP31	NN0066	Lead
Surface Soil	HR-83Q-GP33	NN0070	Antimony, Copper, Lead
Surface Soil	HR-83Q-GP34	NN0073	Lead
Surface Soil	HR-83Q-GP35	NN0075	Lead
Surface Soil	HR-83Q-GP36	NN0078	Lead
Surface Soil	HR-83Q-DEP05	NN0095	Antimony
Surface Soil	HR-118Q-GP01	NP0001	Antimony, Copper, Lead
Surface Soil	HR-118Q-GP03	NP0005	Copper, Lead
Surface Soil	HR-118Q-GP05	NP0009	Copper, Lead
Surface Soil	HR-118Q-GP06	NP0012	Antimony, Copper, Lead
Surface Soil	HR-118Q-GP07	NP0014	Copper, Lead
Surface Soil	HR-118Q-GP08	NP0016	Copper, Lead
Surface Soil	HR-118Q-GP09	NP0018	Lead
Surface Soil	HR-118Q-GP10	NP0021	Antimony, Copper, Lead
Surface Soil	HR-118Q-GP11	NP0023	Copper, Lead
Surface Soil	HR-118Q-MW01	NP0026	Copper, Lead
Surface Soil	HR-118Q-DEP01	NP0028	Antimony, Copper, Lead, Zinc
Surface Soil	HR-74Q-GP07	PJ0012	Lead
Surface Soil	HR-74Q-GP08	PJ0013	Lead
Surface Soil	HR-74Q-GP09	PJ0014	Lead
Surface Soil	HR-74Q-GP10	PJ0015	Antimony, Copper, Lead
Surface Soil	HR-74Q-GP11	PJ0017	Lead
Surface Soil	HR-74Q-GP14	PJ0020	Lead
Surface Soil	HR-74Q-GP15	PJ0021	Lead
Surface Soil	HR-74Q-GP16	PJ0023	Lead
Surface Soil	HR-74Q-GP17	PJ0024	Lead
Surface Soil	HR-74Q-GP19	PJ0027	Copper
Surface Soil	HR-74Q-GP20	PJ0029	Lead
Surface Soil	HR-74Q-GP21	PJ0031	Antimony, Arsenic, Copper, Lead
Surface Soil	HR-74Q-GP22	PJ0032	Antimony, Copper, Lead
Surface Soil	HR-74Q-GP26	PJ0037	Lead
Surface Soil	HR-74Q-GP27	PJ0038	Beryllium, Lead, Nickel

**Table 1**

**Samples With Anomalous Element Concentrations  
Baby Bains Gap Road  
Fort McClellan, Alabama**

(Page 2 of 4)

<b>Medium</b>	<b>Sample Location</b>	<b>Sample Number</b>	<b>Element(s)</b>
Surface Soil	HR-74Q-GP29	PJ0040	Lead
Surface Soil	HR-74Q-GP30	PJ0042	Antimony, Copper, Lead, Zinc
Surface Soil	HR-74Q-GP31	PJ0044	Lead
Surface Soil	HR-74Q-GP34	PJ0048	Lead
Surface Soil	HR-74Q-GP39	PJ0055	Lead
Surface Soil	HR-74Q-GP40	PJ0056	Lead
Surface Soil	HR-74Q-GP42	PJ0058	Antimony, Copper, Lead
Surface Soil	HR-74Q-GP45	PJ0061	Lead
Surface Soil	HR-74Q-MW01	PJ0064	Lead
Surface Soil	HR-74Q-MW03	PJ0068	Antimony, Copper, Lead
Surface Soil	HR-74Q-MW04	PJ0071	Lead
Surface Soil	HR-74Q-DEP01	PJ0073	Copper, Lead, Zinc
Surface Soil	HR-74Q-DEP04	PJ0077	Antimony, Copper, Lead
Surface Soil	HR-76Q-GP01	PK0001	Lead
Surface Soil	HR-76Q-GP02	PK0002	Lead
Surface Soil	HR-76Q-GP03	PK0004	Lead
Surface Soil	HR-76Q-GP04	PK0005	Antimony, Copper, Lead
Surface Soil	HR-76Q-GP06	PK0007	Antimony, Copper, Lead
Surface Soil	HR-76Q-GP07	PK0010	Lead
Surface Soil	HR-76Q-GP08	PK0011	Lead
Surface Soil	HR-76Q-GP09	PK0013	Lead
Surface Soil	HR-76Q-GP10	PK0014	Lead
Surface Soil	HR-76Q-GP11	PK0015	Lead
Surface Soil	HR-76Q-GP13	PK0017	Lead
Surface Soil	HR-79Q-SB01	PL0001	Copper, Lead
Surface Soil	HR-79Q-SS01	PL0003	Lead
Surface Soil	HR-79Q-SS02	PL0004	Lead
Surface Soil	HR-79Q-SS03	PL0005	Lead
Surface Soil	HR-79Q-SS04	PL0006	Lead
Surface Soil	HR-79Q-SB02	PL0007	Copper, Lead
Surface Soil	HR-79Q-SS05	PL0010	Lead
Surface Soil	HR-79Q-SS06	PL0011	Lead
Surface Soil	HR-79Q-SS07	PL0012	Lead
Surface Soil	HR-79Q-SS08	PL0013	Lead
Surface Soil	HR-79Q-SB03	PL0014	Copper, Lead
Surface Soil	HR-79Q-SS09	PL0017	Lead
Surface Soil	HR-79Q-SS10	PL0018	Lead
Surface Soil	HR-79Q-SS11	PL0019	Lead
Surface Soil	HR-79Q-SS12	PL0020	Lead
Surface Soil	HR-79Q-SB04	PL0021	Lead
Surface Soil	HR-79Q-SS14	PL0024	Lead
Surface Soil	HR-79Q-SS15	PL0025	Lead
Surface Soil	HR-79Q-SS16	PL0026	Lead
Surface Soil	HR-79Q-SB05	PL0027	Antimony, Copper, Lead
Surface Soil	HR-79Q-SS17	PL0030	Lead
Surface Soil	HR-79Q-SS18	PL0031	Lead
Surface Soil	HR-79Q-SS19	PL0032	Lead
Surface Soil	HR-79Q-SS20	PL0033	Lead
Surface Soil	HR-79Q-SB06	PL0034	Antimony, Copper, Lead

**Table 1**

**Samples With Anomalous Element Concentrations  
Baby Bains Gap Road  
Fort McClellan, Alabama**

(Page 3 of 4)

<b>Medium</b>	<b>Sample Location</b>	<b>Sample Number</b>	<b>Element(s)</b>
Surface Soil	HR-79Q-SS21	PL0036	Lead
Surface Soil	HR-79Q-SS22	PL0037	Lead
Surface Soil	HR-79Q-SS23	PL0038	Lead
Surface Soil	HR-79Q-SS24	PL0039	Lead
Surface Soil	HR-79Q-SS25	PL0042	Lead
Surface Soil	HR-79Q-SS26	PL0044	Lead
Surface Soil	HR-79Q-SS28	PL0046	Lead
Surface Soil	HR-79Q-SB08	PL0047	Copper, Lead
Surface Soil	HR-79Q-SS29	PL0049	Lead
Surface Soil	HR-79Q-SS32	PL0052	Lead
Surface Soil	HR-79Q-SB09	PL0053	Copper, Lead
Surface Soil	HR-79Q-SS33	PL0055	Lead
Surface Soil	HR-79Q-SS34	PL0056	Lead
Surface Soil	HR-79Q-SS35	PL0058	Lead
Surface Soil	HR-79Q-SS38	PL0063	Lead
Surface Soil	HR-79Q-GP04	PL0071	Copper
Surface Soil	HR-79Q-GP09	PL0077	Lead
Surface Soil	HR-79Q-GP13	PL0082	Lead
Surface Soil	HR-79Q-GP20	PL0091	Lead
Surface Soil	HR-79Q-GP31	PL0105	Lead
Surface Soil	HR-79Q-GP32	PL0106	Lead
Surface Soil	HR-79Q-MW01	PL0109	Antimony, Copper, Lead
Surface Soil	HR-79Q-MW04	PL0116	Copper, Lead
Surface Soil	HR-79Q-DEP04	PL0123	Copper, Lead
Surface Soil	HR-84Q-SB01	PM0001	Antimony, Lead
Surface Soil	HR-84Q-SS01	PM0003	Lead
Surface Soil	HR-84Q-SS02	PM0004	Lead
Surface Soil	HR-84Q-SS03	PM0005	Lead
Surface Soil	HR-84Q-SS04	PM0006	Lead
Surface Soil	HR-84Q-SB02	PM0007	Lead
Surface Soil	HR-84Q-SS05	PM0010	Lead
Surface Soil	HR-84Q-SS06	PM0011	Lead
Surface Soil	HR-84Q-SS07	PM0012	Lead
Surface Soil	HR-84Q-SS08	PM0013	Lead
Surface Soil	HR-84Q-SB03	PM0014	Lead
Surface Soil	HR-84Q-SS10	PM0018	Lead
Surface Soil	HR-84Q-SS11	PM0019	Lead
Surface Soil	HR-84Q-SS12	PM0020	Lead
Surface Soil	HR-84Q-SB04	PM0021	Copper, Lead
Surface Soil	HR-84Q-SS16	PM0026	Lead
Surface Soil	HR-84Q-SS17	PM0029	Copper, Lead
Surface Soil	HR-84Q-SS18	PM0030	Lead
Surface Soil	HR-84Q-SS19	PM0032	Lead
Surface Soil	HR-84Q-SS20	PM0033	Lead
Surface Soil	HR-84Q-GP06	PM0040	Antimony, Copper, Lead
Surface Soil	HR-84Q-GP07	PM0041	Copper, Lead
Surface Soil	HR-84Q-GP09	PM0045	Lead
Surface Soil	HR-84Q-GP15	PM0052	Antimony, Copper, Lead
Surface Soil	HR-84Q-GP16	PM0055	Lead

**Table 1**

**Samples With Anomalous Element Concentrations  
Baby Bains Gap Road  
Fort McClellan, Alabama**

(Page 4 of 4)

<b>Medium</b>	<b>Sample Location</b>	<b>Sample Number</b>	<b>Element(s)</b>
Surface Soil	HR-84Q-GP17	PM0056	Lead
Surface Soil	HR-84Q-GP18	PM0057	Lead
Surface Soil	HR-84Q-GP19	PM0058	Lead
Surface Soil	HR-84Q-GP22	PM0061	Lead
Surface Soil	HR-84Q-GP29	PM0069	Lead
Surface Soil	HR-84Q-GP30	PM0070	Antimony, Lead
Surface Soil	HR-84Q-GP33	PM0074	Lead
Surface Soil	HR-84Q-DEP03	PM0087	Lead
Surface Soil	HR-224Q-MW03	QE0018	Copper, Lead
Subsurface Soil	HR-226Q-GP09	MR0019	Antimony
Subsurface Soil	HR-226Q-MW02	MR0028	Beryllium
Subsurface Soil	HR-226Q-MW03	MR0031	Antimony
Subsurface Soil	HR-83Q-GP15	NN0032	Antimony
Subsurface Soil	HR-83Q-GP16	NN0034	Copper
Subsurface Soil	HR-83Q-GP32	NN0069	Copper, Mercury
Subsurface Soil	HR-83Q-GP33	NN0071	Lead
Subsurface Soil	HR-83Q-GP34	NN0074	Lead
Subsurface Soil	HR-83Q-MW01	NN0083	Antimony, Copper
Subsurface Soil	HR-118Q-GP01	NP0002	Copper
Subsurface Soil	HR-118Q-GP03	NP0006	Copper, Lead
Subsurface Soil	HR-118Q-GP04	NP0008	Copper
Subsurface Soil	HR-118Q-GP07	NP0015	Copper
Subsurface Soil	HR-118Q-GP10	NP0022	Copper
Subsurface Soil	HR-118Q-GP11	NP0024	Copper, Lead
Subsurface Soil	HR-74Q-GP30	PJ0043	Copper, Zinc
Subsurface Soil	HR-74Q-GP31	PJ0045	Lead
Subsurface Soil	HR-76Q-GP02	PK0003	Lead
Subsurface Soil	HR-76Q-GP06	PK0009	Antimony, Copper, Lead
Subsurface Soil	HR-79Q-SB01	PL0002	Lead
Subsurface Soil	HR-79Q-SB02	PL0009	Lead
Subsurface Soil	HR-79Q-SB04	PL0022	Lead
Subsurface Soil	HR-79Q-SB05	PL0028	Lead
Subsurface Soil	HR-79Q-SB07	PL0041	Lead
Subsurface Soil	HR-79Q-GP18	PL0089	Copper
Subsurface Soil	HR-79Q-MW01	PL0110	Antimony, Copper, Lead
Subsurface Soil	HR-84Q-SB05	PM0028	Lead
Subsurface Soil	HR-84Q-GP14	PM0051	Antimony
Subsurface Soil	HR-84Q-GP15	PM0053	Copper
Subsurface Soil	HR-224Q-MW03	QE0019	Mercury
Sediment	HR-79Q-SW/SD02	PL1002	Lead
Sediment	HR-79Q-SW/SD03	PL1003	Copper

### Conclusion

The arsenic concentration in surface soil sample PJ0031 is anomalously high relative to iron and may contain a component of contamination. Anomalous concentrations of antimony, copper, and lead have also been identified in this sample (Table 1). Arsenic detected in the other site soil samples is naturally occurring.

### **Barium**

Manganese oxides have an affinity to adsorb divalent cations such as barium and cobalt (Kabata-Pendias, 2001). If a soil sample contains a high proportion of manganese oxides, then it is expected to contain high concentrations of manganese and associated trace elements. The site and background samples form a collinear trend in a plot of barium versus manganese (Figure 4). The site samples with the highest barium concentrations also contain the highest manganese concentrations, and lie on the trend established by the other samples. These observations indicate that barium in the site samples is associated with manganese oxides at ratios consistent with those of the background samples, and is natural. Two subsurface soil samples and one surface soil sample have moderately high barium concentrations (141 to 167 mg/kg) and lie slightly above the linear background trend in Figure 4. As noted in Section 2.1, barium has an affinity to adsorb on clay minerals. These three samples exhibit Ba/Al ratios that are consistent with the background Ba/Al ratios, indicating a natural source for the barium in these samples.

### Conclusion

Barium detected in the site soil samples is naturally occurring.

### **Beryllium**

Beryllium can substitute for aluminum in soil-forming minerals (Kabata-Pendias, 2001), so a positive correlation between beryllium and aluminum would be expected for uncontaminated samples. A plot of beryllium versus aluminum is provided in Figure 5. Most of the site samples form a common linear trend with the background samples. There are three samples with anomalously high Be/Al ratios relative to background and which lie above the linear trend. Surface soil sample PJ0058 (3.03 mg/kg Be) contains the highest calcium concentration of the site and background data sets (67,300 mg/kg). Trace elements commonly substitute for calcium in carbonate minerals; it is likely that this sample is preferentially enriched in carbonates and that the beryllium is natural. Surface soil sample PJ0038 (sample location HR-74Q-GP27; 5.95 mg/kg Be) and subsurface soil sample MR0028 (HR-226Q-MW02; 4.35 mg/kg), however, have beryllium concentrations that are anomalously high with respect to aluminum, calcium, and the other reference elements. Elevated beryllium in these two samples should be considered suspect.

### Conclusion

Beryllium concentrations in surface soil sample PJ0038 and subsurface soil sample MR0028 are anomalously high relative to the reference elements and may contain a component of contamination (Table 1). Beryllium detected in the other site soil samples is naturally occurring.

### **Calcium**

Calcium and magnesium have similar chemical properties, and magnesium often substitutes for calcium in minerals. A plot of magnesium versus calcium is provided in Figure 6. The background samples exhibit a generally linear trend with a positive slope. Most of the site

samples lie on this trend, and most of the site samples with high calcium concentrations also have high magnesium. These observations indicate that calcium in the site samples has a natural source. There are two surface soil samples with elevated calcium and only moderate magnesium content, and which lie below the linear trend. It is likely that these two samples are preferentially enriched in calcium carbonate or other calcium-bearing minerals, and that the calcium is natural.

#### Conclusion

Calcium detected in the site soil samples is naturally occurring.

### **Chromium**

As discussed in Section 2.1, chromium can be present in soil pore fluid as various species with different charges, and thus it can adsorb on several different types of minerals including iron oxides and clays. A plot of chromium versus iron reveals a collinear trend with a positive slope for the site and background samples (Figure 7). The site samples with high chromium concentrations also contain proportionally higher iron and lie on the background trend. These observations indicate that chromium in the site samples is associated with iron oxides at a relatively constant ratio, and is natural.

#### Conclusion

Chromium detected in the site soil samples is naturally occurring.

### **Cobalt**

Manganese oxides have an affinity to adsorb divalent cations such as barium and cobalt (Kabata-Pendias, 2001). If a soil sample contains a high proportion of manganese oxides, then it is expected to contain naturally high concentrations of manganese and associated trace elements such as cobalt. A plot of cobalt versus manganese reveals a common linear trend with a positive slope for the site and background samples (Figure 8). The site samples with elevated cobalt concentrations also contain elevated manganese, and lie on the trend established by the other samples. Cobalt in the site samples is associated with manganese oxides at ratios consistent with those of the background samples, and is natural.

#### Conclusion

Cobalt detected in the site soil samples is naturally occurring.

### **Copper**

Copper in soil has an affinity to adsorb on the surfaces of minerals such as clays and iron oxides (Kabata-Pendias, 2001). Positive correlations for copper versus aluminum or copper versus iron are thus commonly observed for uncontaminated samples. The background samples form a linear trend in a plot of copper versus aluminum (Figure 9). Many of the site samples lie on the background trend, but many other site samples exhibit anomalously high Cu/Al ratios and lie above the linear trend. Copper, along with zinc, is a primary component of shell casings and jackets (ITRC, 2003), so copper contamination would be expected at firing range sites such as the Baby Bains Gap Road site. Lead is a known contaminant at firing ranges; a plot of copper versus lead reveals that the samples with elevated copper also have high lead content (Figure 10). This indicates that copper and lead are co-contaminants in site soil.

Based on the comparison to background samples in Figure 9, most of the site samples with copper concentrations of approximately 40 mg/kg and higher exhibit anomalously high Cu/Al ratios and most likely contain a component of contamination. The two exceptions are subsurface soil sample NN0058 and NN0079, which contain elevated copper (48.2 and 52 mg/kg, respectively) but proportionally higher aluminum (57,700 and 66,200 mg/kg), and which lie on the background trend. The list of anomalous samples also includes surface soil sample PM0021 (from sample location HR-84Q-SB04), which has moderately high copper (21.7 mg/kg) but the lowest aluminum concentration of the site and background samples (1,990 mg/kg), and lies above the linear trend. Copper in this sample should be considered suspect. Table 1 lists the site samples with anomalous element concentrations, and provides both the sample identification numbers and corresponding sample location codes.

### Conclusion

Copper concentrations detected in many of the site soil samples contain a component of contamination (Table 1).

### **Iron**

Iron is the most abundant element analyzed in the site soil samples, with a mean concentration of 25,099 mg/kg (2.5 weight percent). The iron in the samples is dominantly present as iron oxides, which are common soil-forming minerals and occur as discrete mineral grains or as coatings on silicate minerals (Cornell and Schwertmann, 2003). Aluminum is the second most abundant element analyzed in the site soil samples (mean concentration of 16,965 mg/kg; 1.7 weight percent), and is a primary component of minerals such as clays, feldspars, and micas. Aluminum also substitutes for ferric iron in iron oxide minerals, and can adsorb on iron oxide surfaces (Cornell and Schwertmann, 2003). Clays and iron oxides tend to exist as very fine particles, so both aluminum and iron are enriched in samples with finer grain sizes.

As discussed in the Aluminum evaluation, a plot of aluminum versus iron concentrations can be used as a qualitative indicator of the relative abundance of clay and iron oxide minerals in site soil (Figure 1). For both soil intervals, most of the site samples contain a similar range of iron concentrations as the background samples, and they all lie on or near the general background trend (Figure 1). The similarity in Al/Fe ratios between the site and background samples indicates a natural source for the aluminum in the site samples. It is important to note that clays and iron oxides adsorb specific trace elements (as discussed in Section 2.1), so samples that plot on the upper end of the trend in Figure 1 are expected to contain proportionally higher concentrations of trace elements. For example, the positive correlation between chromium and iron, and the absence of outliers plotting off the linear trend on the correlation plot, indicate a natural source for these elements (Figure 7).

### Conclusion

Iron detected in the site soil samples is naturally occurring.

### **Lead**

As discussed in Section 2.1, divalent metals such as lead tend to form cationic species in solution and are attracted to clay mineral surfaces, which maintain a negative surface charge. The

background samples form a weak linear trend in a plot of lead versus aluminum (Figure 11). Some of the site samples lie on the background trend, but many other sites samples exhibit anomalously high Pb/Al ratios and lie above the linear trend. Elevated lead in these samples should be considered suspect. The Baby Bains Gap Road site encompasses several firing ranges, and thus lead is an expected contaminant due to its presence in bullets and bullet fragments.

Based on the comparison to background samples in Figure 11, the site samples with lead concentrations of approximately 113 mg/kg and higher exhibit anomalously high Pb/Al ratios and most likely contain a component of contamination (Table 1). In addition, surface soil sample PM0021 (from sample location HR-84Q-SB04) has relatively high lead (81.6 mg/kg) but the lowest aluminum concentration of the site and background samples (1,990 mg/kg), and lies above the linear trend. Lead in this sample should also be considered suspect (Table 1).

It is important to note that the site data set contains 323 surface soil and 128 subsurface soil samples that were analyzed for lead, but of these only 144 surface soil and 91 subsurface soil samples were analyzed for the other TAL metals. Only those samples analyzed for the complete suite of 23 TAL metals are depicted on Figure 11. The 179 non-TAL surface soil samples and 37 non-TAL subsurface soil samples cannot be subjected to geochemical evaluation, but given their elevated concentrations (ranging from 2.72 to 10,100 mg/kg, with a mean of 507 mg/kg) it is likely that many of them also contain contamination. Table 1 lists all of the anomalous samples identified in Figure 11, as well as the non-TAL samples containing lead concentrations above 113 mg/kg.

### Conclusion

Lead concentrations in many of the site soil samples contain a component of contamination (Table 1).

### **Magnesium**

As discussed in the Calcium evaluation, calcium and magnesium have similar chemical properties, and magnesium often substitutes for calcium in minerals. A plot of magnesium versus calcium reveals a generally linear trend with a positive slope for the background samples (Figure 6). The site samples all lie on this trend, and the site samples with the highest magnesium concentrations also contain proportionally higher calcium. Magnesium in the site samples is naturally occurring.

### Conclusion

Magnesium detected in the site soil samples is naturally occurring.

### **Manganese**

Manganese in the site soil samples is dominantly present as manganese oxide minerals, which have an affinity to adsorb specific trace elements such as cobalt. If a sample contains a high percentage of manganese oxides, then it will have naturally high concentrations of manganese and associated trace elements. For example, the positive correlation observed for cobalt versus manganese in the site samples, and the absence of outliers plotting off the linear trend on the correlation plot, indicate a natural source for these two elements (Figure 8).

### Conclusion

Manganese in the site soil samples is naturally occurring.

### **Mercury**

Mercury concentrations in soil are commonly controlled through organic complex formation (Kabata-Pendias, 2001), so poor correlations between mercury and iron or mercury and aluminum are often observed, even in uncontaminated samples. A plot of mercury versus aluminum is provided in Figure 12. The background samples form a generally linear trend with a positive slope. A few of the site samples, including the sample with the site maximum concentration (0.138 mg/kg), exhibit Hg/Al ratios similar to those of the background samples and lie on the background trend. Mercury concentrations in the other site samples are estimated ("J"-qualified) values below the reporting limit, and these samples lie below the background trend. There is a high degree of uncertainty associated with such estimated values, which may explain the poor correlation between mercury and aluminum in these samples. However, these concentrations are well below the background maximum detected concentration of 0.322 mg/kg and thus are within the background range. Subsurface soil samples NN0069 (sample location HR-83Q-GP32; 0.499 J mg/kg Hg) and QE0019 (HR-224Q-MW03; 0.339 mg/kg Hg) exhibit anomalously high Hg/Al ratios relative to background and lie above the general background trend in Figure 12. There may be a component of contamination in these two samples.

### Conclusion

The mercury concentrations in subsurface soil samples NN0069 and QE0019 are anomalously high and may contain a component of contamination (Table 1). Mercury detected in the other samples is most likely naturally occurring.

### **Nickel**

Nickel concentrations in soil are commonly controlled through adsorption on iron oxides (Kabata-Pendias, 2001), so positive correlations between nickel and iron concentrations are commonly observed for uncontaminated samples. A plot of nickel versus iron reveals a generally linear trend with a positive slope for most of the background samples, and most of the site samples lie on this background trend (Figure 13). Nickel in these site samples is associated with iron oxides at ratios consistent with those of the background samples, and is natural. The exception is site sample PJ0038 (HR-74Q-GP72), which contains a high nickel concentration (65.9 mg/kg) but only moderate iron (as well as only moderate aluminum), and lies above the trend formed by the other samples. Elevated nickel in this sample should be considered suspect.

### Conclusion

The nickel concentration in surface soil sample PJ0038 is anomalously high and may contain a component of contamination (Table 1). Nickel detected in the other soil samples is naturally occurring.

### **Potassium**

Potassium is a major element that is a common constituent of minerals such as clays, which also contain aluminum as a primary component. The site samples form a linear trend with a positive slope in a plot of potassium versus aluminum, and lie on the background trend (Figure 14). The site samples with higher potassium generally have higher aluminum, indicating that these

samples are preferentially enriched in clays (and other aluminum-bearing minerals) and that the potassium is natural.

#### Conclusion

Potassium detected in the site soil samples is naturally occurring.

#### **Selenium**

As explained in Section 2.1, selenium has an affinity to adsorb on iron oxides in oxic soils. A positive correlation between selenium and iron is thus expected for uncontaminated soil samples. Comparison to background is hindered because of the high percentage of nondetects in the background data set. However, a plot of selenium versus iron reveals a linear trend with a positive slope for the site samples (Figure 15). The samples with high selenium also exhibit high iron, and lie on the linear trend. These observations indicate that the elevated selenium is due to the preferential enrichment of iron oxides in those samples, and is natural.

#### Conclusion

Selenium detected in the site soil samples is naturally occurring.

#### **Silver**

A plot of silver versus iron is provided in Figure 16. Site silver concentrations are higher than most of the background silver concentrations, but the site samples form a linear trend with a positive slope. The site samples with the highest silver concentrations also have proportionally higher iron, and lie on the trend formed by the other site samples. This suggests that silver in the site samples is associated with iron oxides at a relatively constant ratio, and is natural. The site detections range from 1.25 J to 4.72 mg/kg, with a mean of 2.04 mg/kg. It is important to note that most of these detections (35 of 45 samples) are estimated (“J”-qualified) concentrations below the reporting limit, and such values are highly uncertain. In comparison, the background detections are mostly unestimated concentrations ranging from 0.019 to 1.87 mg/kg, with a mean of 0.15 mg/kg (only 14 of the 82 background detections are estimated values). Additionally, the site samples are characterized by higher reporting limits relative to the background samples: the site reporting limits range from 1.05 to 2.69 mg/kg, with a mean of 2.19 mg/kg, whereas the reporting limits for the background nondetects range from 0.016 to 1.2 mg/kg, with a mean of 0.293 mg/kg [reporting limit data are unavailable for the background detected concentrations]. The uncertainty associated with the estimated site concentrations, combined with the difference in reporting limits between the site and background data sets, most likely explains why the site samples do not exhibit the same Ag/Fe ratios exhibited by the background samples.

#### Conclusion

Silver detected in the site soil samples is naturally occurring.

#### **Vanadium**

As discussed in Section 2.2, vanadium is present in oxic soil pore fluid as oxyanions and has a strong affinity to adsorb on iron oxides, which tend to maintain a positive surface charge. A positive correlation between vanadium and iron concentrations is expected for uncontaminated samples under those conditions. A plot of vanadium versus iron reveals a common linear trend with a positive slope for the site and background samples (Figure 17). The site samples with the

highest vanadium concentrations also contain the highest iron concentrations and lie on the trend established by the other samples. These observations indicate that vanadium in the site samples is associated with iron oxides at ratios consistent with those of the background samples, and is natural.

#### Conclusion

Vanadium detected in the site soil samples is naturally occurring.

#### **Zinc**

As discussed in Section 2.1, divalent metals such as zinc tend to form cationic species in solution and are attracted to clay mineral surfaces, which maintain a negative surface charge. A positive correlation between zinc and aluminum is thus expected for uncontaminated samples. Most of the site samples lie on the linear background trend in a plot of zinc versus aluminum, indicating the zinc in these samples is associated with clays at a relatively constant ratio (Figure 18). There are five samples with anomalously high Zn/Al ratios relative to background and which lie above the linear trend. Surface soil sample PJ0058 (348 mg/kg Zn) contains the highest calcium concentration of the site and background data sets (67,300 mg/kg). Zinc commonly substitutes for calcium in minerals such as carbonates; it is likely that this sample is preferentially enriched in calcium-bearing minerals and that the zinc is natural. Surface soil samples PJ0073 (sample location HR-74Q-DEP01; 1,250 mg/kg Zn), PJ0042 (HR-74Q-GP30; 399 mg/kg), and NP0028 (HR-118Q-DEP01; 221 mg/kg); and subsurface soil sample PJ0043 (HR-74Q-GP30; 163 mg/kg) have zinc concentrations that are anomalously high with respect to aluminum, calcium, and the other reference elements. Elevated zinc in these three samples cannot be explained as the result of natural processes and should be considered suspect. It is important to note that copper and zinc are primary components of shell casings and jackets (ITRC, 2003), so zinc contamination would be expected at firing range sites.

#### Conclusion

Zinc concentrations in surface soil samples NP0028, PJ0042, and PJ0073; and subsurface soil sample PJ0043 are anomalously high relative to the major elements and may contain a component of contamination (Table 1). Zinc detected in the other site soil samples is naturally occurring.

### **4.0 Results of the Geochemical Evaluation for Multiple Metals in Sediment**

This section presents the results of the geochemical evaluation of aluminum, antimony, barium, beryllium, calcium, chromium, cobalt, copper, iron, lead, magnesium, manganese, nickel, potassium, silver, thallium, and zinc in sediment samples from the Baby Bains Gap Road site. Correlation plots are provided in Attachment 1.

#### **Aluminum**

Aluminum is a primary component of common minerals such as clays, feldspars, and micas. Iron oxides are minerals that are also common in sediment. Clays and iron oxides tend to exist

as very fine particles, so both aluminum and iron are enriched in samples with finer grain sizes. A plot of aluminum versus iron concentrations can be used to qualitatively assess the relative abundance of these minerals in site sediment (Figure 19). The site samples exhibit higher aluminum concentrations than many of the background samples, but they also contain proportionally higher iron and lie on the background trend. This suggests that the site samples are naturally enriched in clays and iron oxides relative to the background samples, and that the aluminum is natural. It is worth noting that iron oxide and clay minerals adsorb specific trace elements (as discussed in Section H.2.2), so samples that plot on the upper end of the trend in Figure 19 are expected to contain proportionally higher concentrations of trace elements.

#### Conclusion

Aluminum detected in the site sediment samples is naturally occurring.

#### **Antimony**

Only one site sample contains detectable antimony (an estimated concentration of 5.98 J mg/kg). The background samples form a generally linear trend with a positive slope in a plot of antimony versus iron (Figure 20). The site sample with detectable antimony has the highest antimony concentration of all of the samples, but it also contains high iron. It is likely that this sample is preferentially enriched in iron oxides and thus contains naturally high concentrations of iron and associated trace elements. Antimony detected in this sample is naturally occurring.

#### Conclusion

The single detected concentration of antimony in the site sediment data set is naturally occurring.

#### **Barium**

As discussed in Section 2.1, divalent metals such as barium tend to form cationic species in solution and are attracted to clay mineral surfaces, which maintain a negative surface charge. If a sediment sample contains a high proportion of clay minerals, then it is expected to contain high concentrations of aluminum and associated trace elements. The site and background samples form a collinear trend in a plot of barium versus aluminum (Figure 21). The site samples with the highest barium concentrations also contain the highest aluminum concentrations, and lie on the trend established by the other samples. These observations indicate that barium in the site samples is associated with clays at a relatively constant ratio, and is natural.

#### Conclusion

Barium detected in the site sediment samples is naturally occurring.

#### **Beryllium**

A plot of beryllium versus manganese reveals a common linear trend for the site and background samples (Figure 22). The site samples with high beryllium concentrations contain proportionally higher manganese, and lie on the background trend. Beryllium in the site samples is associated with manganese oxides at a relatively constant ratio, and is natural.

#### Conclusion

Beryllium in the site sediment samples is naturally occurring.

## **Calcium**

Calcium and magnesium have similar chemical properties, and magnesium often substitutes for calcium in minerals. A plot of magnesium versus calcium is provided in Figure 23. The background samples exhibit a generally linear trend with a positive slope. The site samples all lie on this trend, and the site sample with the highest calcium also has the highest magnesium concentration. Calcium in the site samples is naturally occurring.

### Conclusion

Calcium detected in the site sediment samples is naturally occurring.

## **Chromium**

As discussed in Section 2.1, chromium can be present as various species with different charges, and thus it can adsorb on several different types of minerals including iron oxides and clays. A plot of chromium versus iron reveals a strong collinear trend for the site and background samples ( $R^2 = 0.70$  and  $0.50$  for the site and background samples, respectively) (Figure 24). The site sample with the highest chromium concentration also contains proportionally higher iron and lies on the background trend. These observations indicate that chromium in the site samples is associated with iron oxides at a relatively constant ratio, and is natural.

### Conclusion

Chromium detected in the site sediment samples is naturally occurring.

## **Cobalt**

Manganese oxides have an affinity to adsorb divalent cations such as cobalt (Kabata-Pendias, 2001). If a soil sample contains a high proportion of manganese oxides, then it is expected to contain high concentrations of manganese and associated trace elements. A plot of cobalt versus manganese reveals a common linear trend with a positive slope for the site and background samples (Figure 25). The site samples with high cobalt concentrations also contain high manganese concentrations, and lie on the trend established by the other samples. This indicates that cobalt in the sediment samples is associated with manganese oxides at a relatively constant ratio, and is natural.

### Conclusion

Cobalt detected in the site sediment samples is naturally occurring.

## **Copper**

Most samples form a linear trend in a plot of copper versus aluminum (Figure 26). Several of the site samples have higher copper concentrations relative to background, but they also contain proportionally higher aluminum and lie on the background trend. Copper in these samples is associated with clay minerals at a relatively constant ratio, and is natural. The exception is site sample PL1003 (from sample location HR-79Q-SW/SD03), which exhibits high copper but only moderate aluminum (and only moderate iron and manganese), and lies off the trend formed by the other samples. This sample contains an excess component of copper, and should be considered suspect.

### Conclusion

The copper concentration in sample PL1003 is anomalously high relative to the major elements and may contain a component of contamination. Copper detected in the other site sediment samples is naturally occurring.

### **Iron**

As discussed in the Aluminum evaluation, iron oxide minerals are common in sediments and tend to concentrate specific trace elements. The strong correlation between chromium and iron, and the absence of outliers plotting off the linear trend on the correlation plot, indicate a natural source for these elements (Figure 24). Iron in the site samples is naturally occurring.

### Conclusion

Iron detected in the site sediment samples is naturally occurring.

### **Lead**

As discussed in Section 2.1, divalent metals such as lead tend to form cationic species in solution and are attracted to clay mineral surfaces, which maintain a negative surface charge. A plot of lead versus aluminum is provided in Figure 27. Most of the site samples with high lead concentrations also contain proportionally higher aluminum, and lie on the trend established by the background samples. Lead in these samples is associated with clay minerals at a relatively constant ratio, and is natural. One exception is site sample PL1002 (sample location HR-79Q-SW/SD02), which contains the highest lead concentration of the site and background samples (533 J mg/kg) but only moderate aluminum (and only moderate iron and manganese), and lies off the background trend. This sample contains an excess amount of lead that, given the available data, cannot be explained as the result of natural processes. The lead concentration in this sample should be considered suspect.

### Conclusion

The lead concentration in sample PL1003 is anomalously high relative to the major elements and may contain a component of contamination. Lead detected in the other site sediment samples is naturally occurring.

### **Magnesium**

As discussed in the Calcium evaluation, calcium and magnesium have similar chemical properties, and magnesium often substitutes for calcium in minerals. A plot of magnesium versus calcium reveals a generally linear trend with a positive slope for the background samples (Figure 23). The site samples all lie on this trend, and the site sample with the highest magnesium concentration also contains the highest calcium. Magnesium in the site samples is naturally occurring.

### Conclusion

Magnesium detected in the site sediment samples is naturally occurring.

### **Manganese**

As discussed previously, manganese oxides are common in sediments and tend to concentrate specific trace elements. The strong correlation between cobalt and manganese, and the absence

of outliers plotting off the linear trend on the correlation plot, indicate a natural source for these elements (Figure 25).

#### Conclusion

Manganese in the site sediment samples is naturally occurring.

#### **Nickel**

Nickel has an affinity to adsorb on iron oxides (Kabata-Pendias, 2001), so positive correlations between nickel and iron concentrations are commonly observed for uncontaminated sediment samples. A plot of nickel versus iron reveals a generally linear trend with a positive slope for most of the background samples (Figure 28). The site samples with high nickel concentrations have proportionally higher iron, and lie on the general background trend. Nickel in the site samples is natural.

#### Conclusion

Nickel detected in the site sediment samples is naturally occurring.

#### **Potassium**

Potassium is a major element that is a common constituent of minerals such as clays, which also contain aluminum. The site samples form a linear trend in a plot of potassium versus aluminum, and lie on the general background trend (Figure 29). The site samples with higher potassium also have higher aluminum, indicating that these samples are preferentially enriched in clays (and other aluminum-bearing minerals). Potassium in the site samples is natural.

#### Conclusion

Potassium detected in the site sediment samples is naturally occurring.

#### **Silver**

Silver commonly substitutes for calcium in minerals such as carbonates. A plot of silver versus calcium for the site and background samples is provided in Figure 30. The single detected concentration in the site data set (sample NN1001, 4.69 mg/kg Ag) is observed in the sample with the highest calcium concentration of the site and background data sets (13,100 mg/kg). This indicates that the sample is preferentially enriched in calcium-bearing minerals and associated trace elements, including silver. Silver detected in this site sample is naturally occurring.

#### Conclusion

The single detected concentration of silver in the site sediment data set is observed in the sample with the highest calcium, and is natural.

#### **Thallium**

A plot of thallium versus iron is provided in Figure 31. The single detected concentration in the site data set (sample PK1001, 1.32 J mg/kg Tl) is observed in the sample with the second-highest iron concentration of the site data set. This suggests that the sample is relatively enriched in iron oxides and associated trace elements, including thallium. It is important to note that the site detection is an estimated (J-qualified) concentration below the reporting limit, and such values

are highly uncertain. Additionally, the site samples are most likely characterized by higher reporting limits relative to the background samples: the site reporting limits range from 2.42 to 3.29 mg/kg, whereas the background samples are all unestimated detected concentrations ranging from 0.012 to 0.221 mg/kg. The uncertainty associated with the estimated site concentration, combined with the difference in reporting limits between the data sets, may explain why the site sample does not exhibit the same Tl/Fe ratio exhibited by the background samples.

#### Conclusion

The single detected concentration of thallium in the site sediment data set is observed in a sample with high iron content, and is most likely natural.

#### **Zinc**

As discussed in Section 2.1, divalent metals such as zinc tend to form cationic species in solution and are attracted to clay mineral surfaces, which maintain a negative surface charge. A positive correlation between zinc and aluminum is thus expected for uncontaminated samples. All of the site samples lie on the general background trend in a plot of zinc versus aluminum (Figure 32). The site samples form a linear trend with a positive slope ( $R^2 = 0.71$ ), and the samples with the highest zinc also contain proportionally higher aluminum. This suggests that zinc in the site samples is associated with clay minerals at a relatively constant ratio, and that the zinc is natural.

#### Conclusion

Zinc detected in the site sediment samples is naturally occurring.

### ***5.0 Results of the Geochemical Evaluation for Barium and Calcium in Groundwater***

This section presents the results of the geochemical evaluation of barium and calcium in unfiltered groundwater samples from the Baby Bains Gap Road site. Correlation plots are provided in Attachment 1.

Field-measured pH readings for the site groundwater samples range from 6.4 to 11.43 standard units, with a mean of 7.48 (omitting the anomalously high pH reading of 11.43 gives a range of values from 6.4 to 7.89, with a mean of 7.26). These observations indicate neutral-pH groundwater conditions at most of the sample locations. Field-measured DO readings range from 0.41 to 8.03 mg/L, with a mean of 3.87 mg/L, and ORP readings range from -143 to +378 millivolts (mV), with a mean of +73 mV. These readings suggest oxidizing conditions at most of the sample locations, and mildly to moderately reducing conditions at some locations. Turbidity measurements range from 0 to 1,000 nephelometric turbidity units (NTU), with a mean of 57 mg/kg. Although one site sample (PL3003, from well HR-79Q-MW02) contained a significant mass of suspended particulates (1,000 NTU), the other samples had low turbidity (10 NTU or less).

## **Barium**

As discussed in Section 2.2, barium is usually present in groundwater as a divalent cation and tends to concentrate on clay surfaces, which maintain a negative surface charge. A plot of barium versus aluminum reveals a weak linear trend for the background samples (Figure 33). The site samples all lie on the background trend, and the two site samples with the highest barium concentrations also have high aluminum. These observations suggest that barium in the site samples is associated with suspended clays at ratios consistent with those of the background samples, and is natural.

### Conclusion

Barium concentrations detected in the site groundwater samples are naturally occurring.

## **Calcium**

Calcium and magnesium are both major dissolved constituents in groundwater, and are derived from the weathering of silicate and carbonate minerals. A plot of calcium versus magnesium reveals a linear trend with a positive slope for the background samples, and most of the site samples lie on this trend (Figure 34). Calcium in these samples is natural. Calcium in sample NP3001 (from monitoring well HR-118Q-MW01; 61.9 mg/L) is anomalously high relative to magnesium, and this sample has unusually high pH (11.43). This well was installed in December 2001 and the sample was collected in February 2002. It is likely that the calcium in the sample is elevated due to grout contamination. This concentration, however, is well below the background maximum of 452 mg/L.

### Conclusion

Most of the calcium concentrations in the site groundwater samples are naturally occurring. Calcium in sample NP3001 is anomalously high, most likely due to grout contamination from well construction, but is well below the maximum concentration in the background data set.

## **6.0 Results of the Geochemical Evaluation for Barium and Calcium in Surface Water**

This section presents the results of the geochemical evaluation of barium and calcium in unfiltered surface water samples from the Baby Bains Gap Road site. Correlation plots are provided in Attachment 1.

Field-measured pH readings for the site samples range from 5.21 to 7.14 standard units, with a mean of 6.35. These observations indicate near-neutral pH conditions at most of the sample locations. Field-measured DO readings range from 3.79 to 11.58 mg/L, with a mean of 7.99 mg/L, and ORP readings range from +118 to +360 mV, with a mean of +271 mV. These readings suggest oxidizing conditions at all of the sample locations. Turbidity measurements range from 0.6 to 37 NTU, with a mean of 11 mg/kg. These values indicate that the samples did not contain a significant mass of suspended particulates.

## **Barium**

As discussed in Section 2.2, barium is usually present in groundwater as a divalent cation and tends to concentrate on clay surfaces, which maintain a negative surface charge. A plot of barium versus aluminum reveals a linear trend with a positive slope for the background samples, and the site samples lie on this background trend (Figure 35). These observations suggest that barium in the site samples is associated with suspended clays at ratios consistent with those of the background samples, and is natural.

### Conclusion

Barium concentrations detected in the site surface water samples are naturally occurring.

## **Calcium**

Calcium and magnesium are both major dissolved constituents in natural waters, and their concentrations typically covary, with samples exhibiting high calcium also exhibiting proportionally higher magnesium. A plot of calcium versus magnesium reveals a strong linear trend with a positive slope for most of the background samples (Figure 36). All of the site samples lie on this linear background trend, and the site samples with the highest calcium also have proportionally higher magnesium. Calcium in these samples is natural.

### Conclusion

Calcium in the site surface water samples is naturally occurring.

## **7.0 Summary**

This section summarizes the results of the geochemical evaluations of selected inorganics in soil, sediment, groundwater, and surface water samples from the Baby Bains Gap Road site.

**Soil.** Geochemical evaluation indicates that all detected concentrations of aluminum, barium, calcium, chromium, cobalt, iron, magnesium, manganese, potassium, selenium, silver and vanadium in the surface and subsurface soil samples are naturally occurring. In addition, the detected concentrations of arsenic and nickel in the subsurface soil samples are naturally occurring; and the detected concentrations of mercury in the surface soil samples are naturally occurring. Antimony, arsenic, beryllium, copper, lead, nickel, and zinc each have anomalously high concentrations in one or more surface soil samples, indicating potential contamination. Antimony, beryllium, copper, lead, and zinc each have anomalously high concentrations in one or more subsurface soil samples, indicating potential contamination. A list of the samples that contain anomalous element concentrations is provided in Table 1.

**Sediment.** Geochemical evaluation indicate that detected concentrations of aluminum, antimony, barium, beryllium, calcium, chromium, cobalt, iron, magnesium, manganese, nickel, potassium, silver, thallium, and zinc in the sediment samples are naturally occurring. The copper

concentration in sample PL1003 (sample location HR-79Q-SW/SD03) and the lead concentration in sample PL1002 (HR-79Q-SW/SD02) are anomalously high relative to the major elements, indicating potential contamination (Table 1).

**Groundwater.** Geochemical evaluation indicates that the barium concentrations and most of the calcium concentrations are naturally occurring. The calcium concentration in sample NP3001 (well HR-118Q-MW01) is anomalously high relative to magnesium, and exhibits high pH. This groundwater sample was collected in February 2002, shortly after construction of the well in December 2001, and it is likely that the calcium is elevated due to grout contamination. However, this concentration is well below the maximum background concentration.

**Surface Water.** Geochemical evaluation indicates that the barium and calcium concentrations detected in the site samples are naturally occurring.

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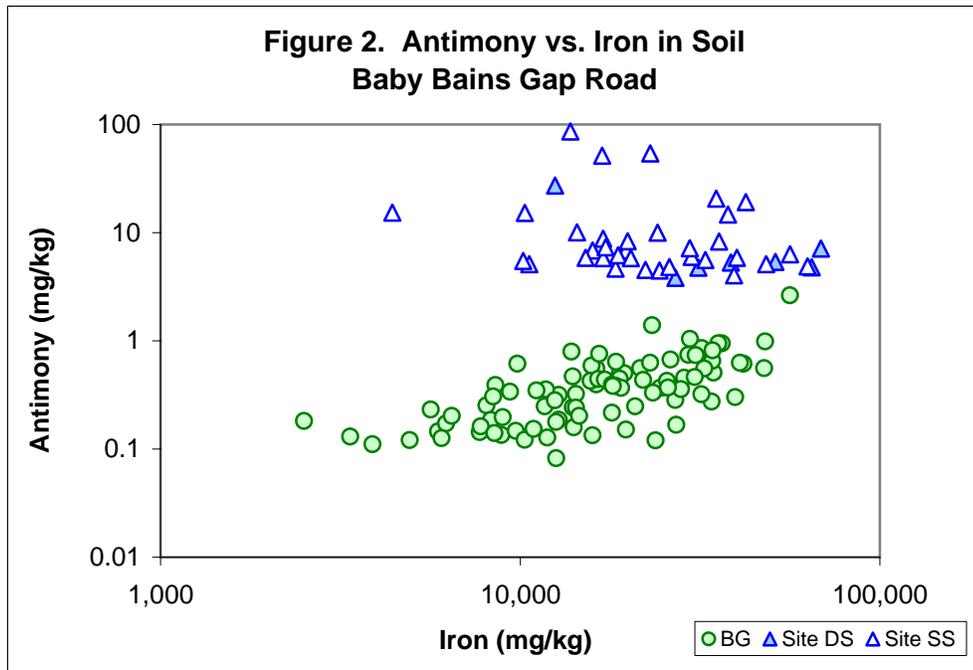
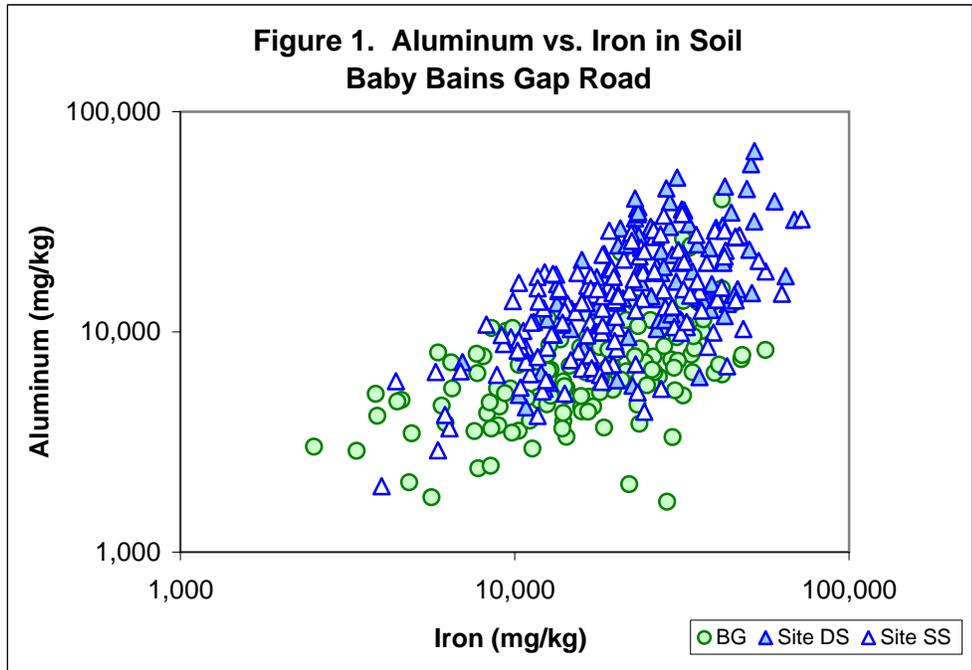
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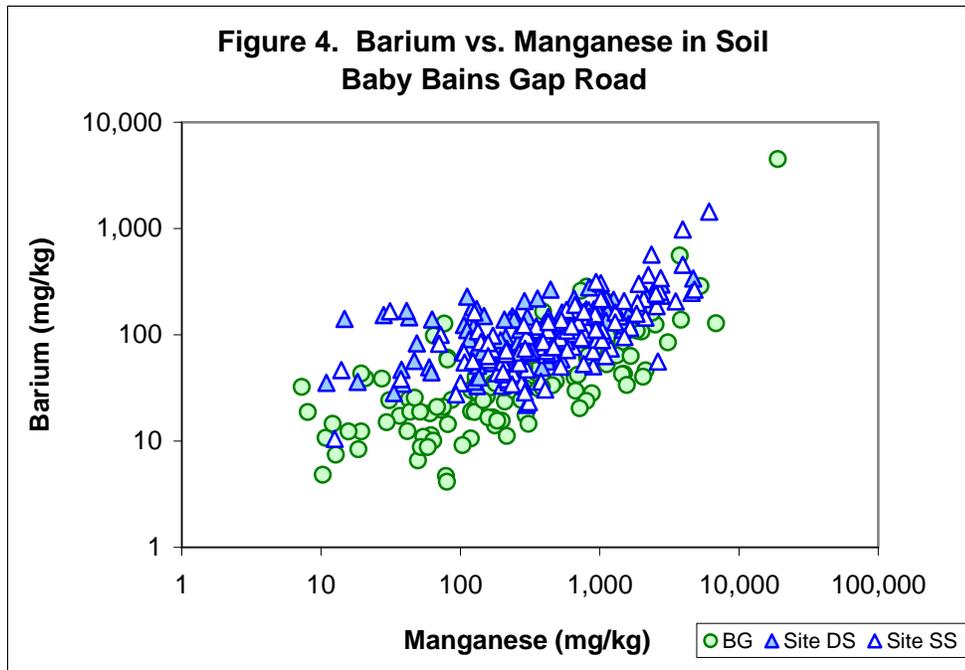
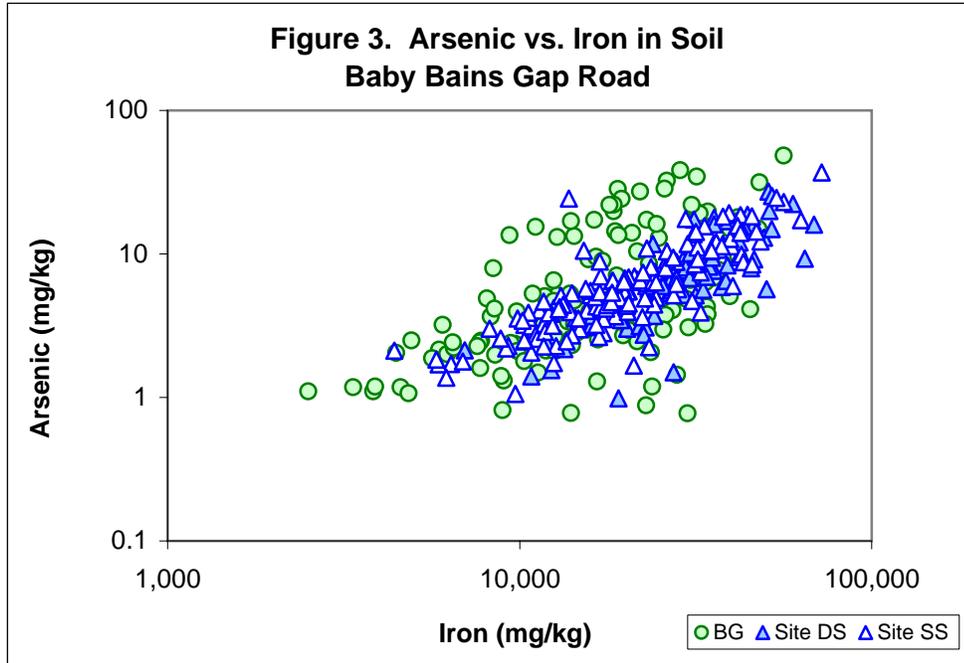
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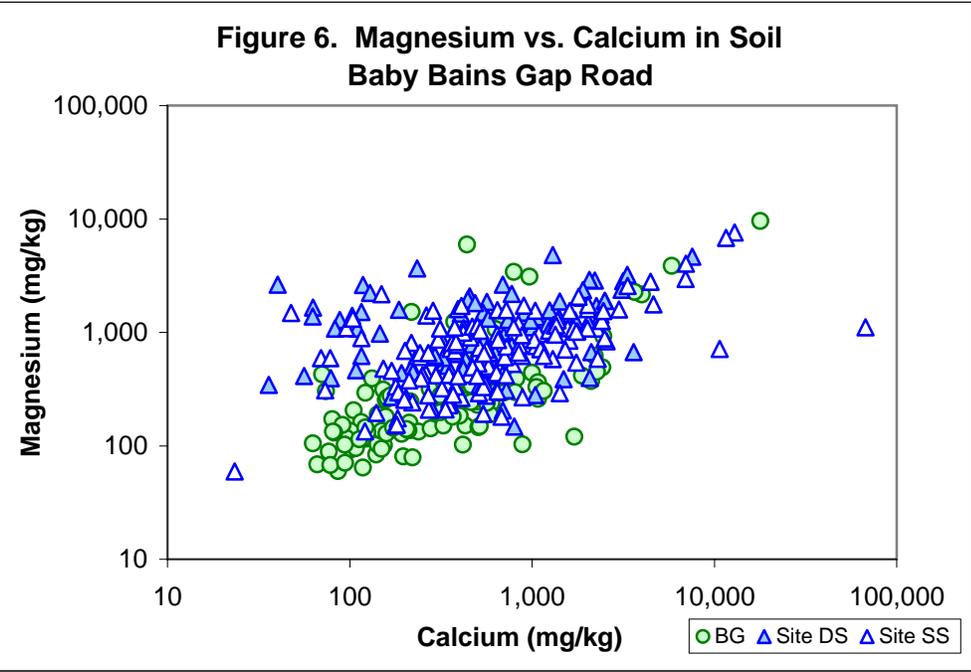
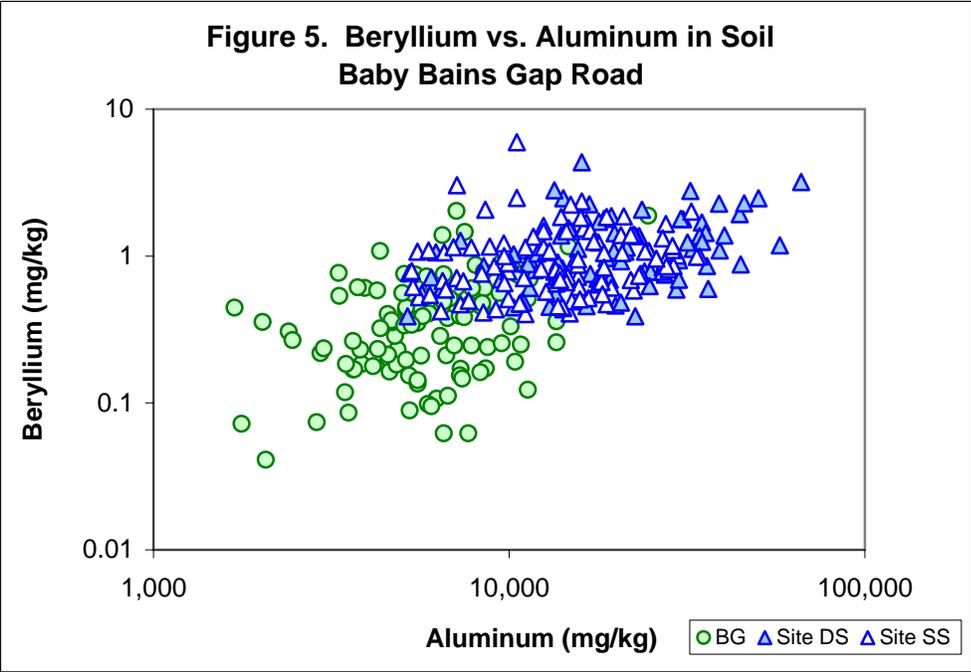
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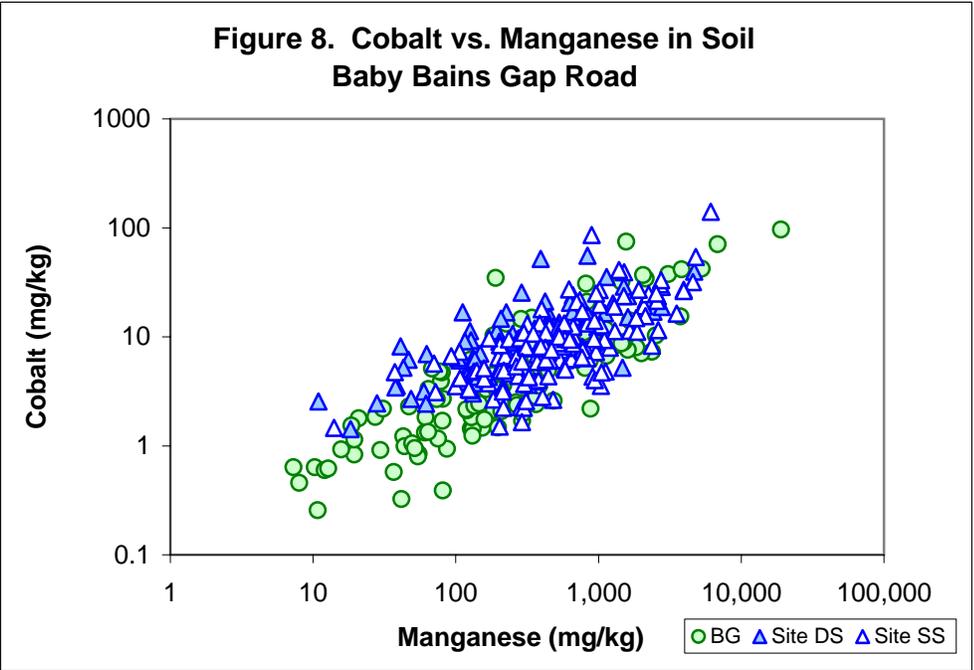
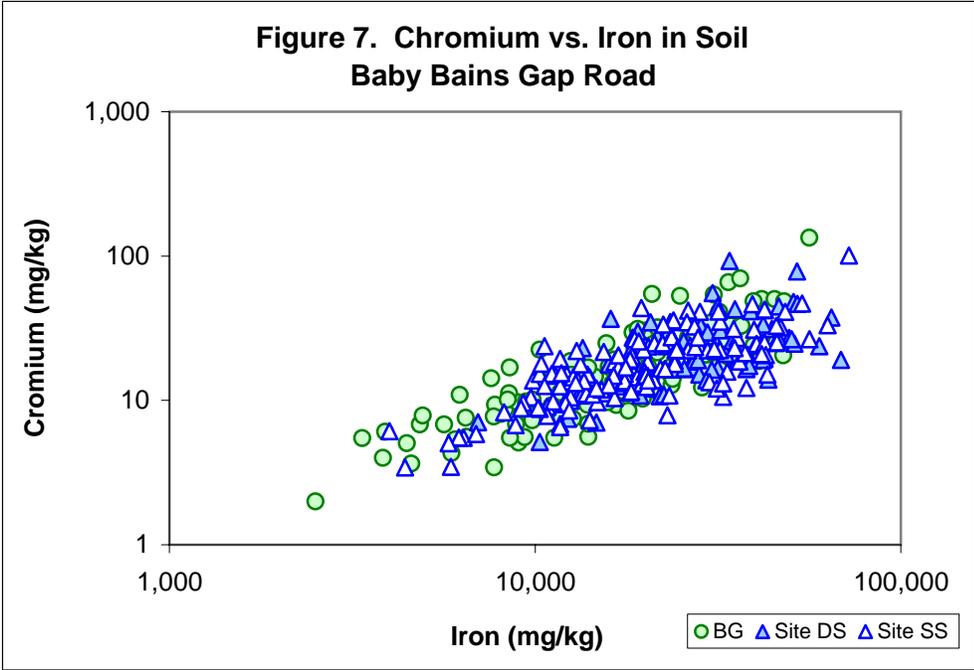
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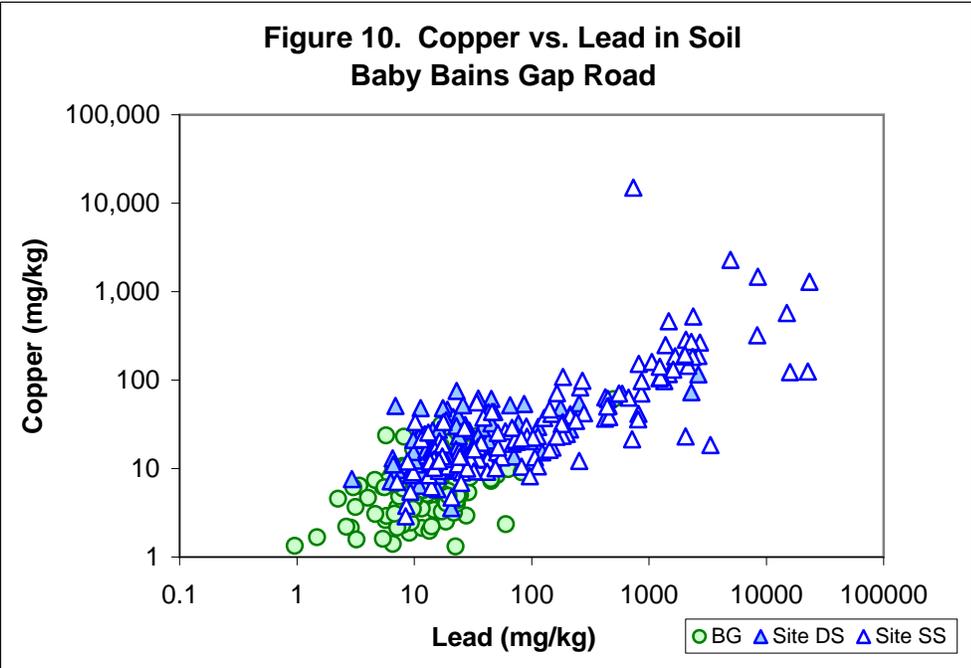
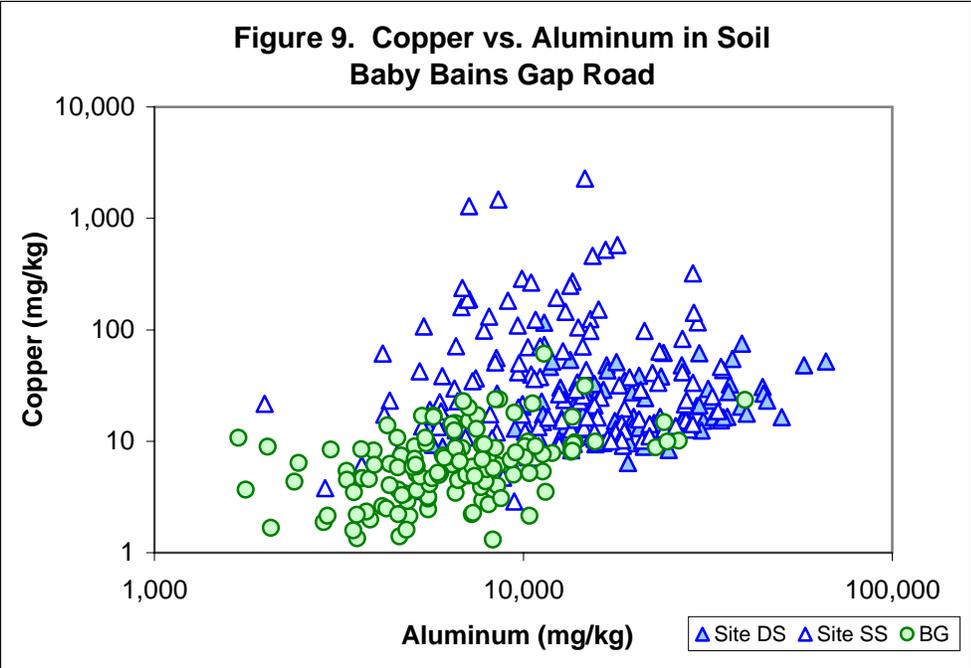
**ATTACHMENT 1**

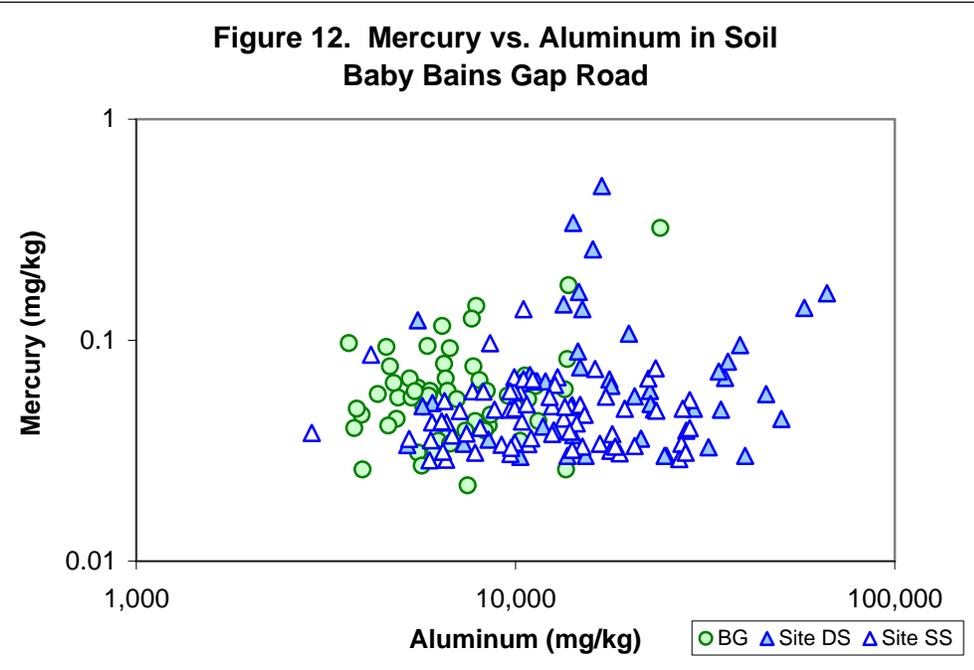
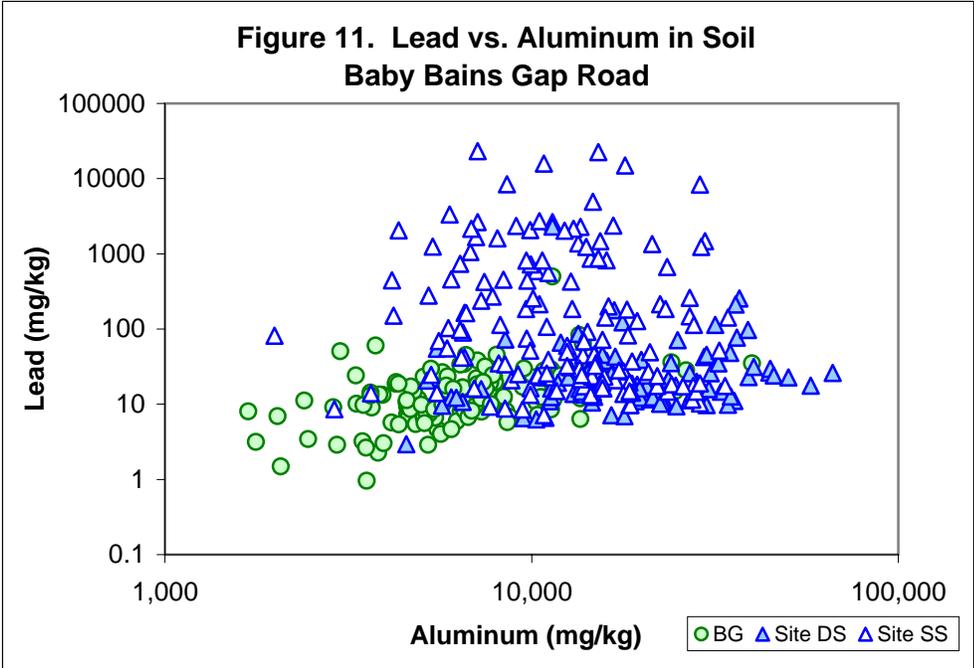


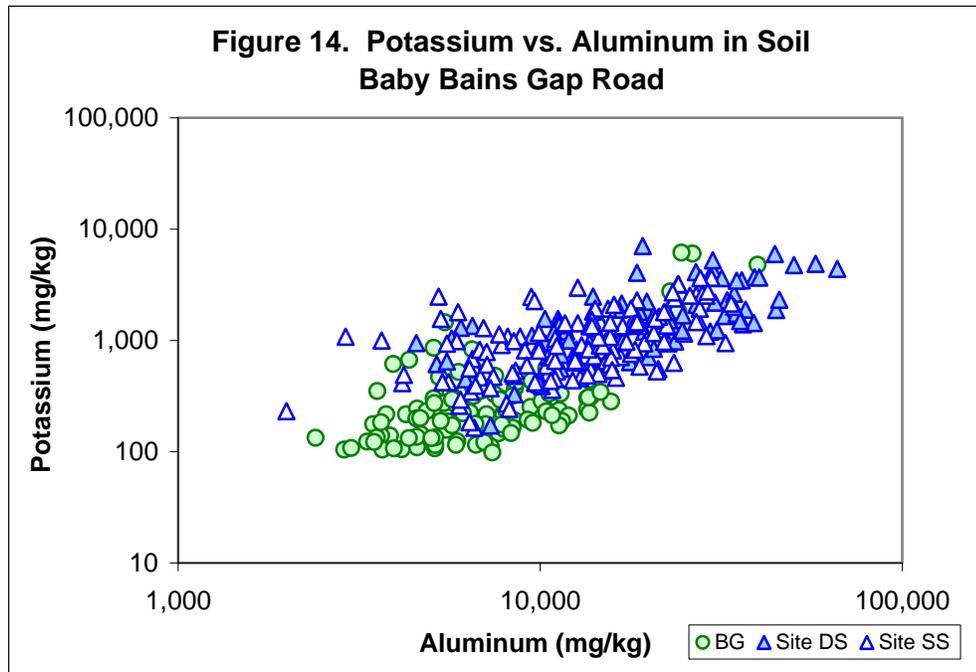
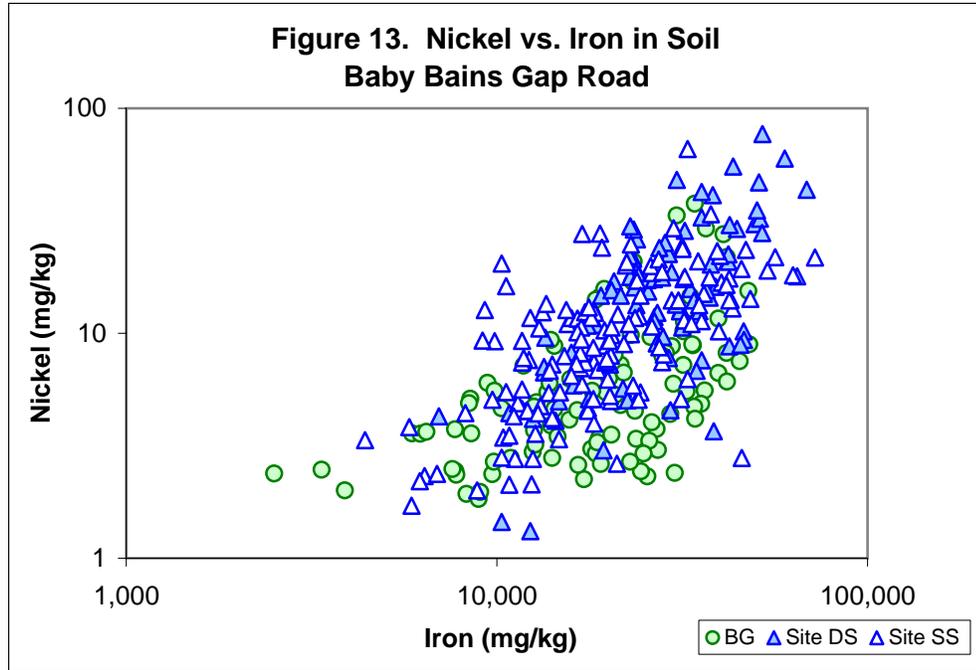


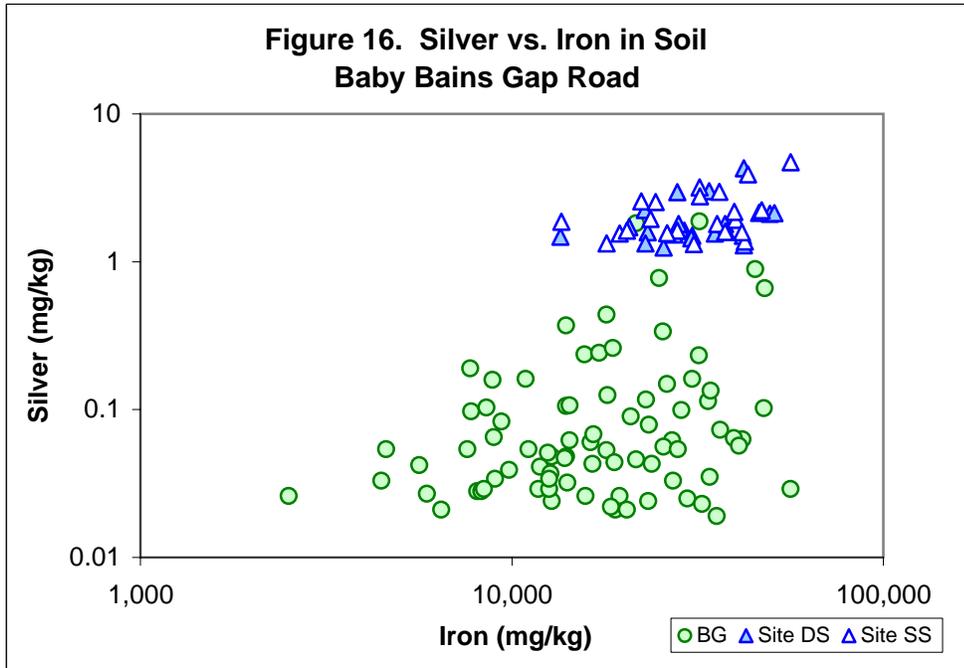
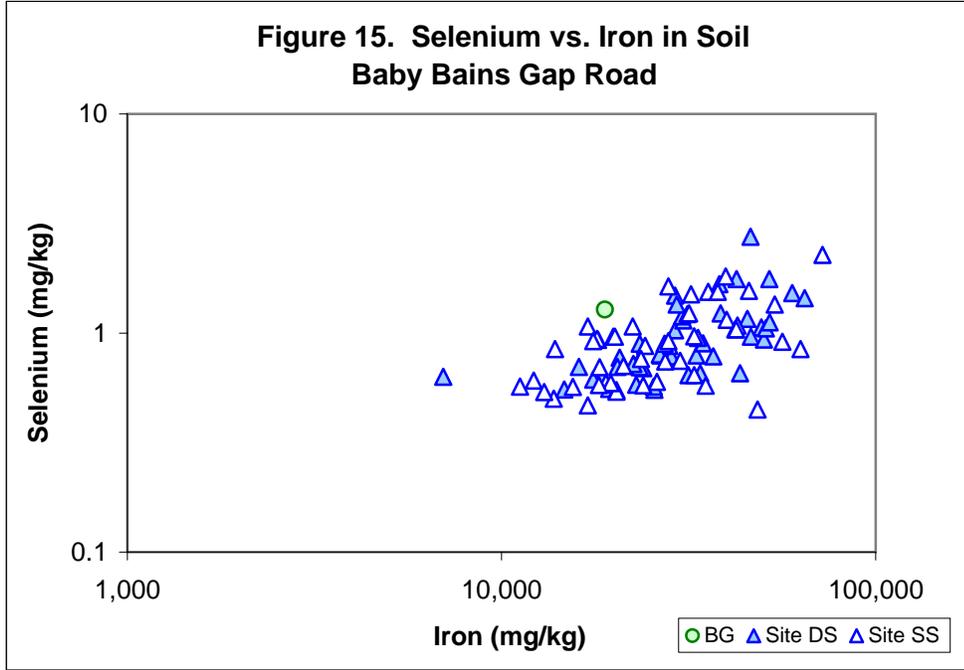


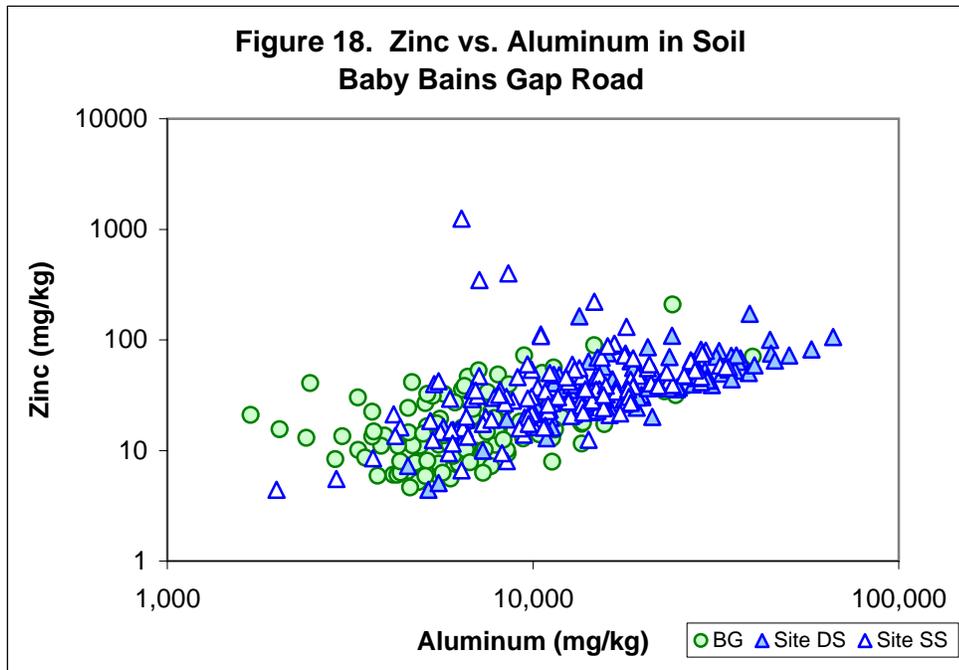
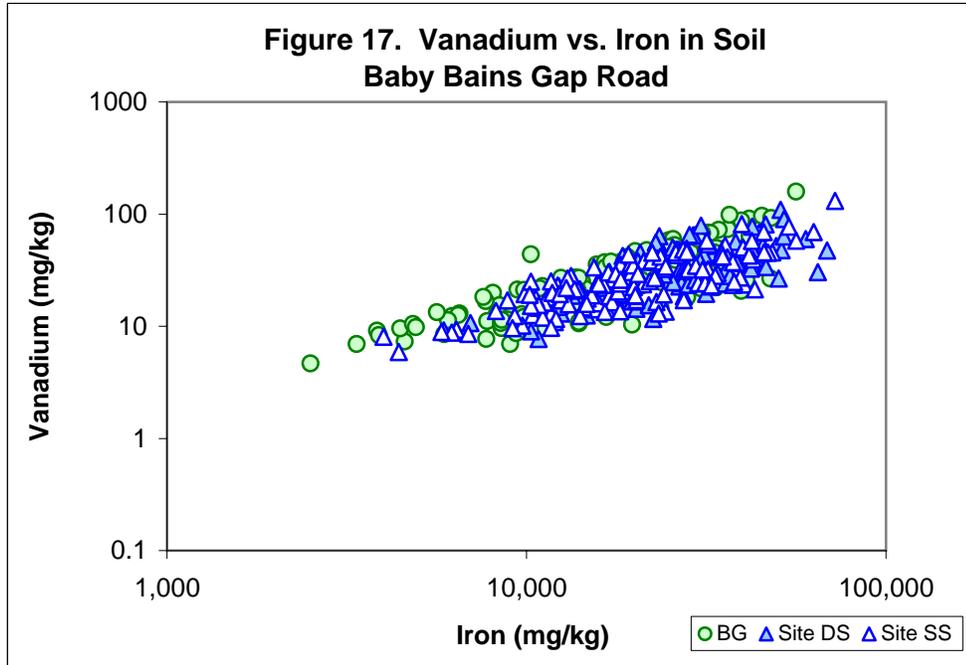


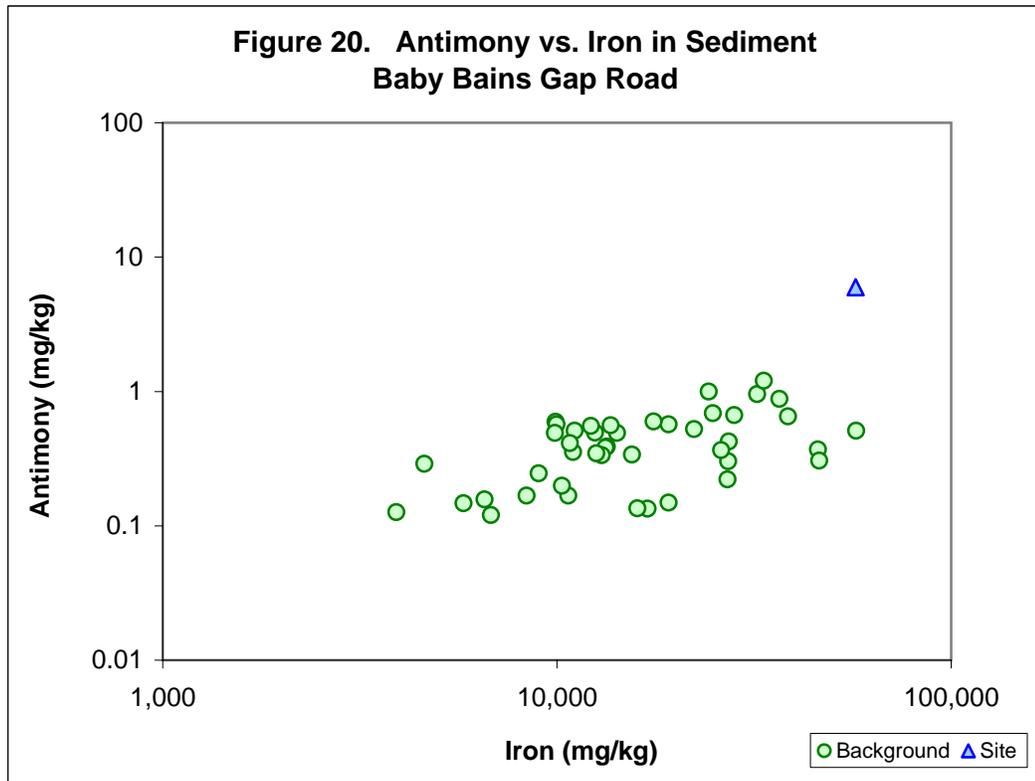
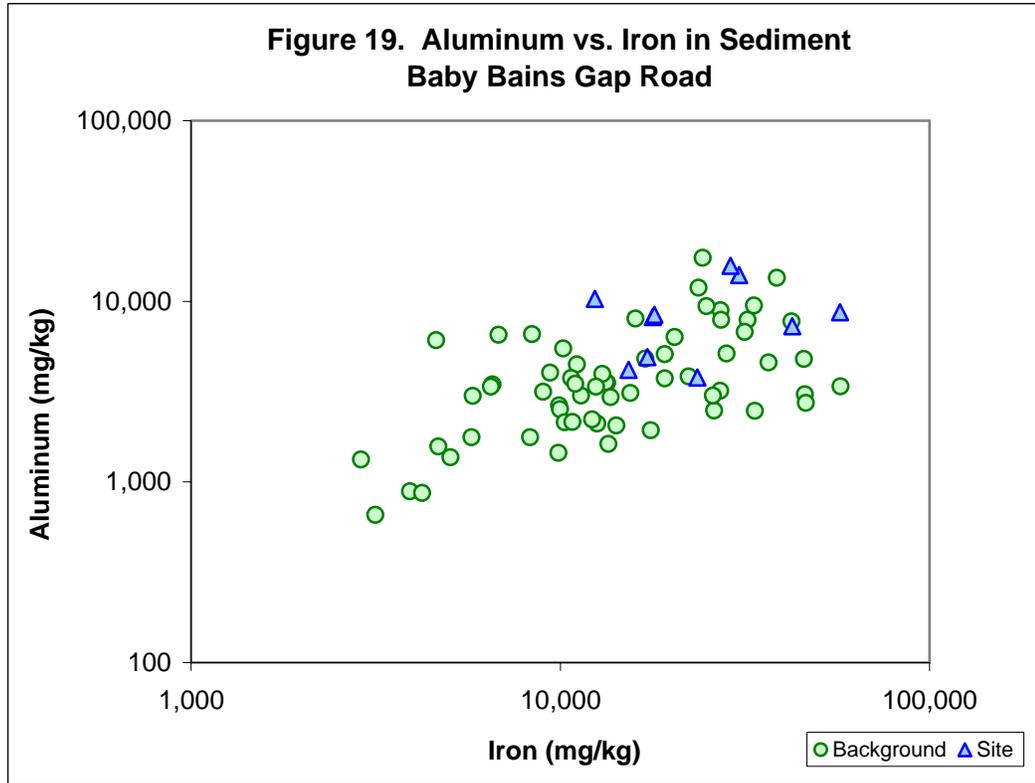


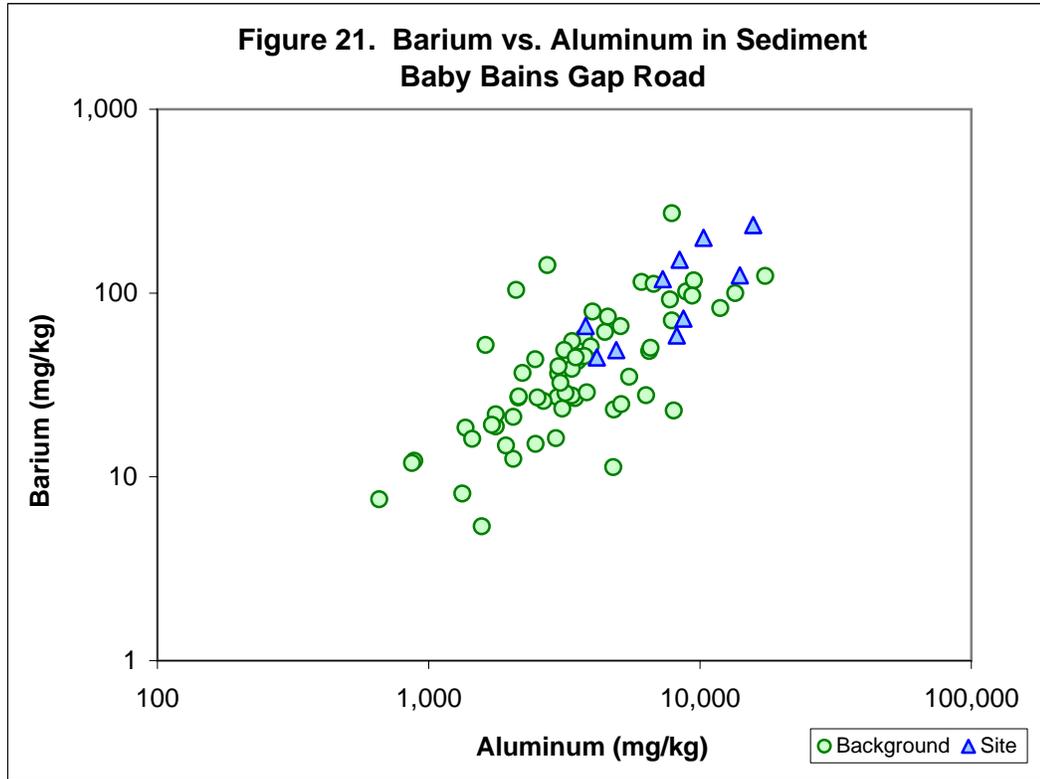




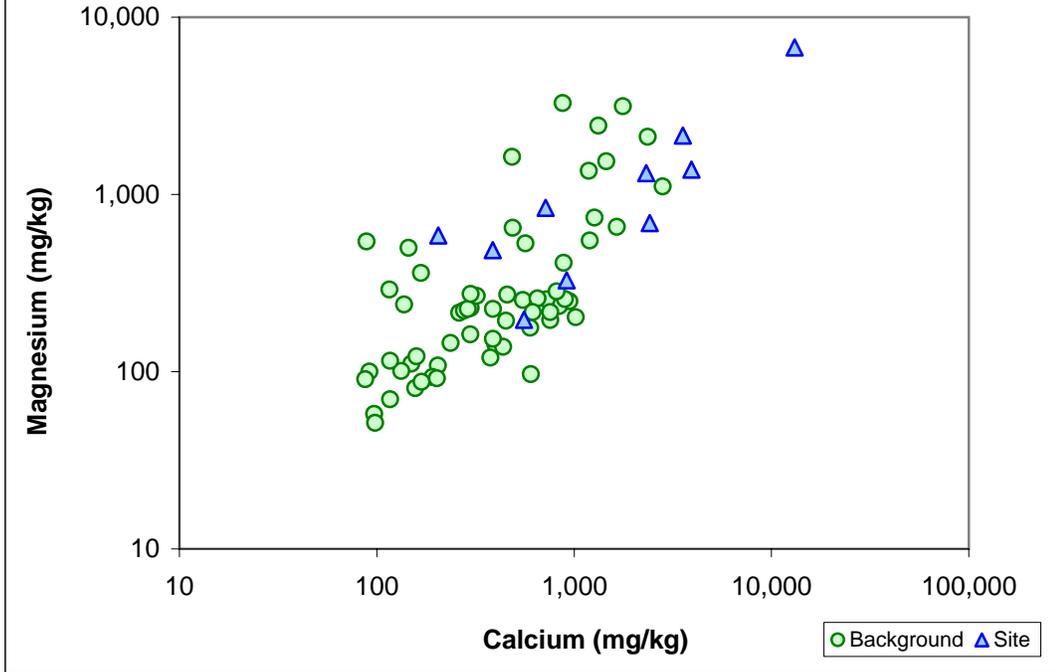




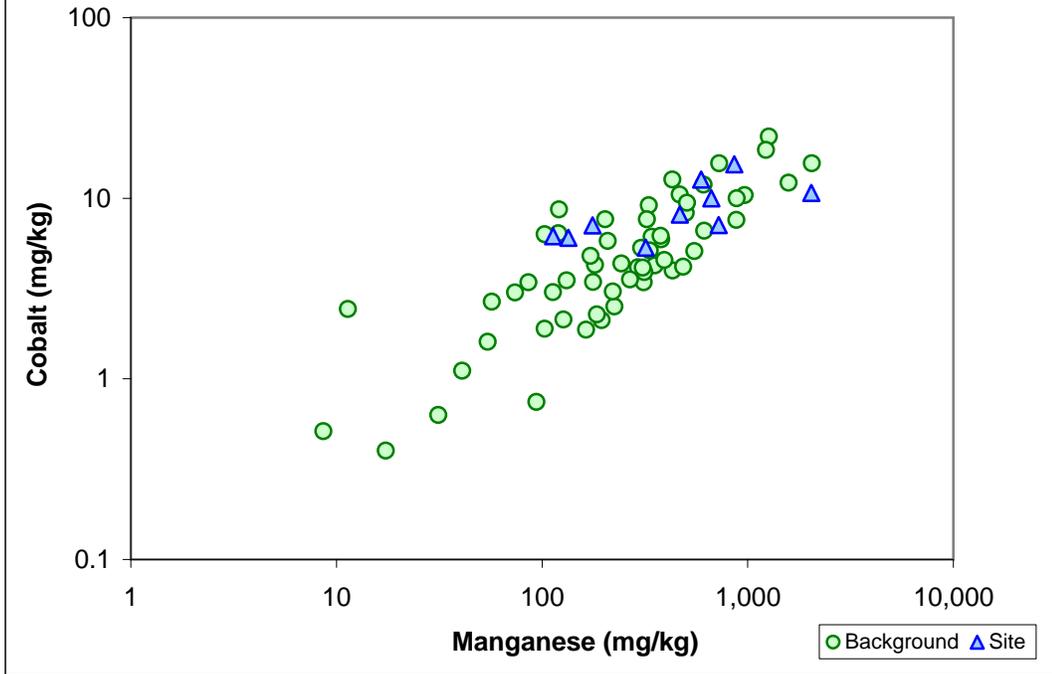


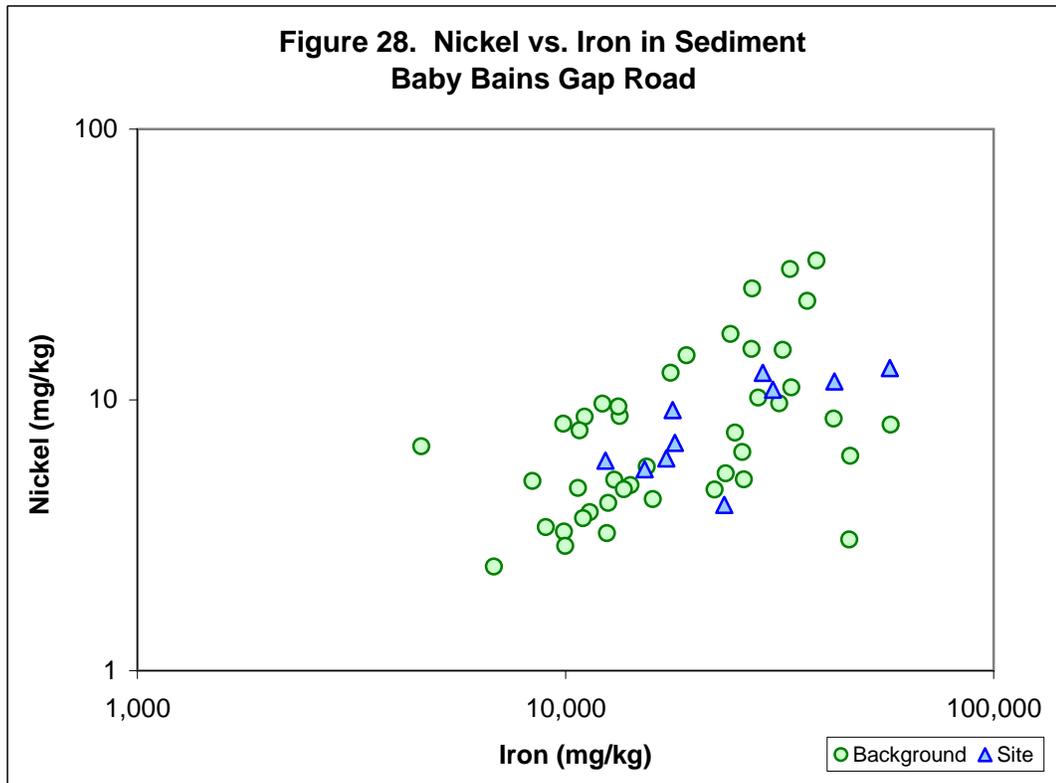
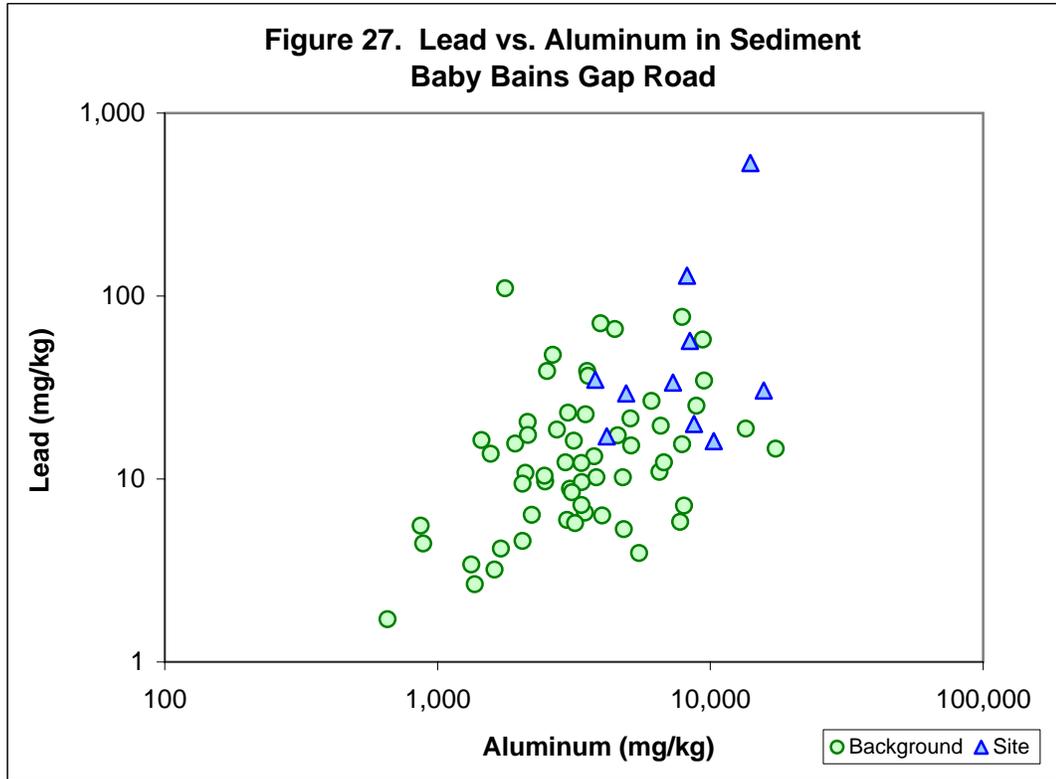


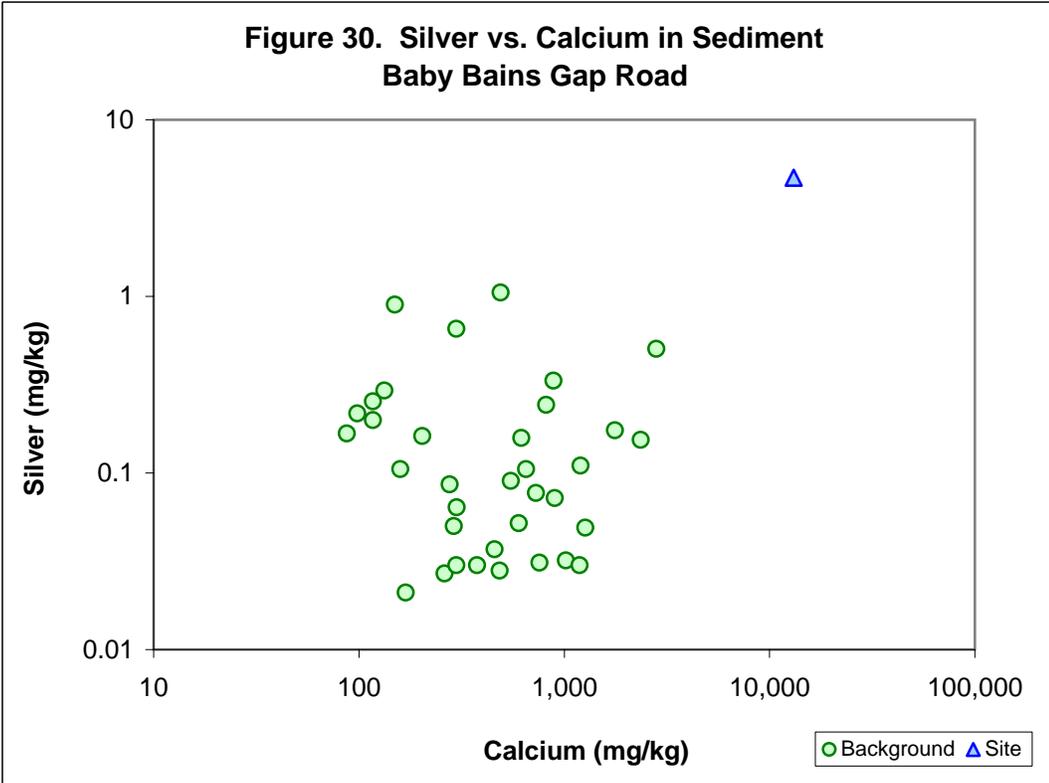
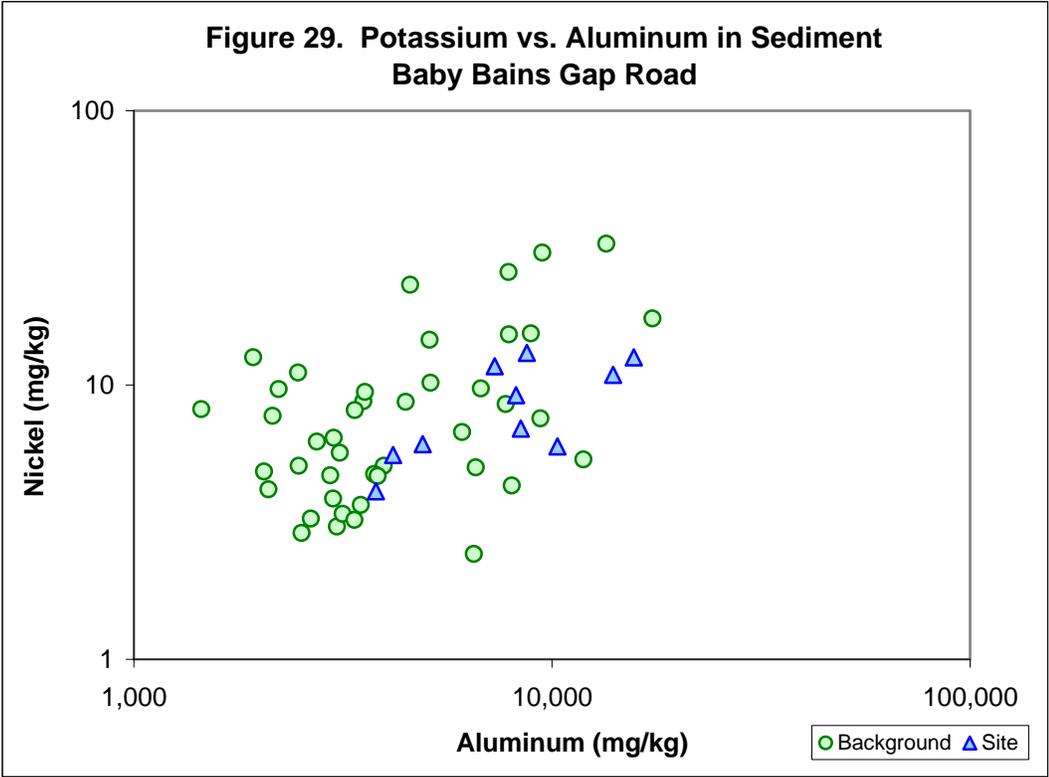
**Figure 23. Magnesium vs. Calcium in Sediment  
Baby Bains Gap Road**

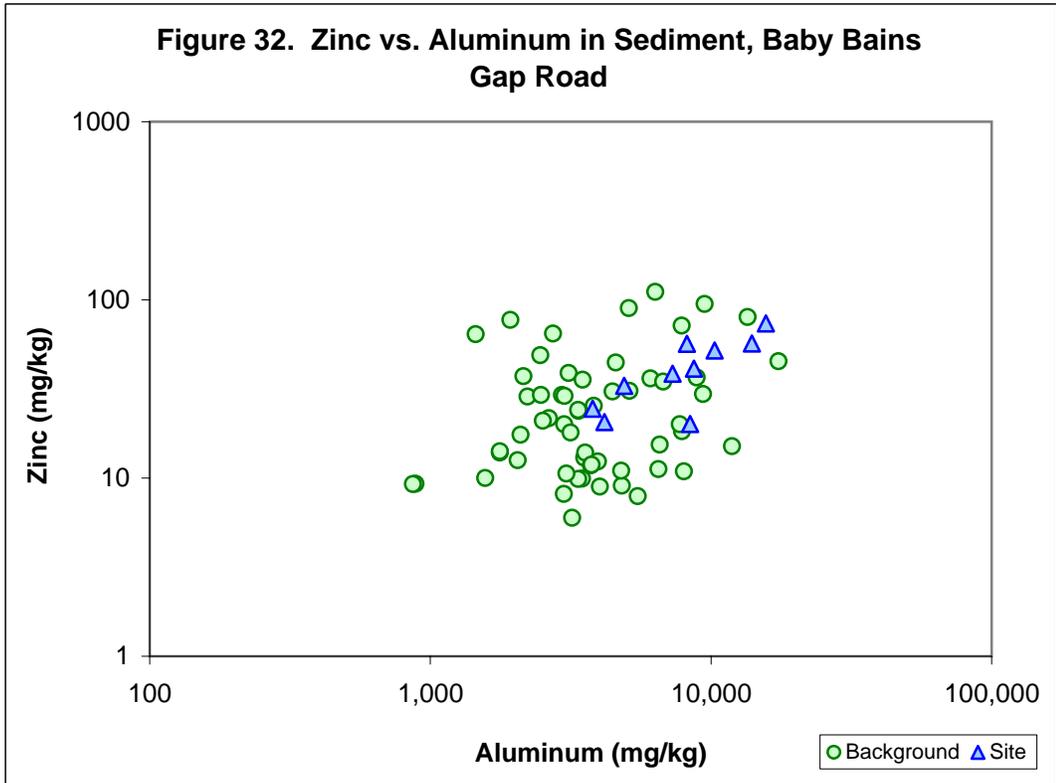
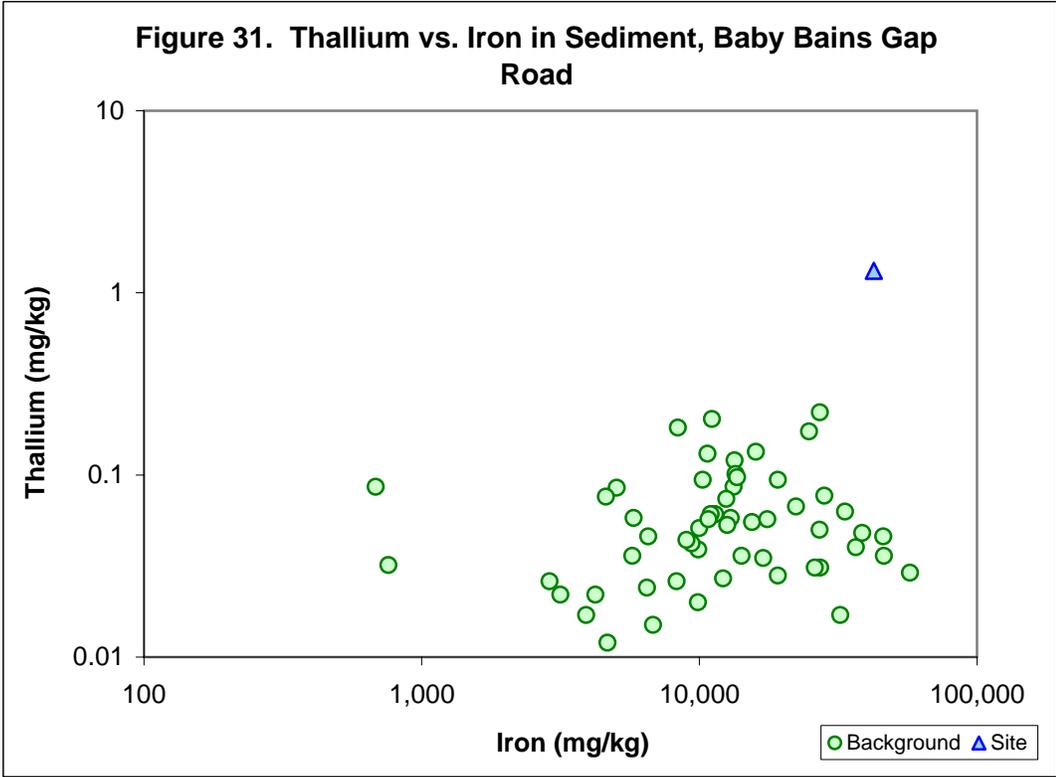


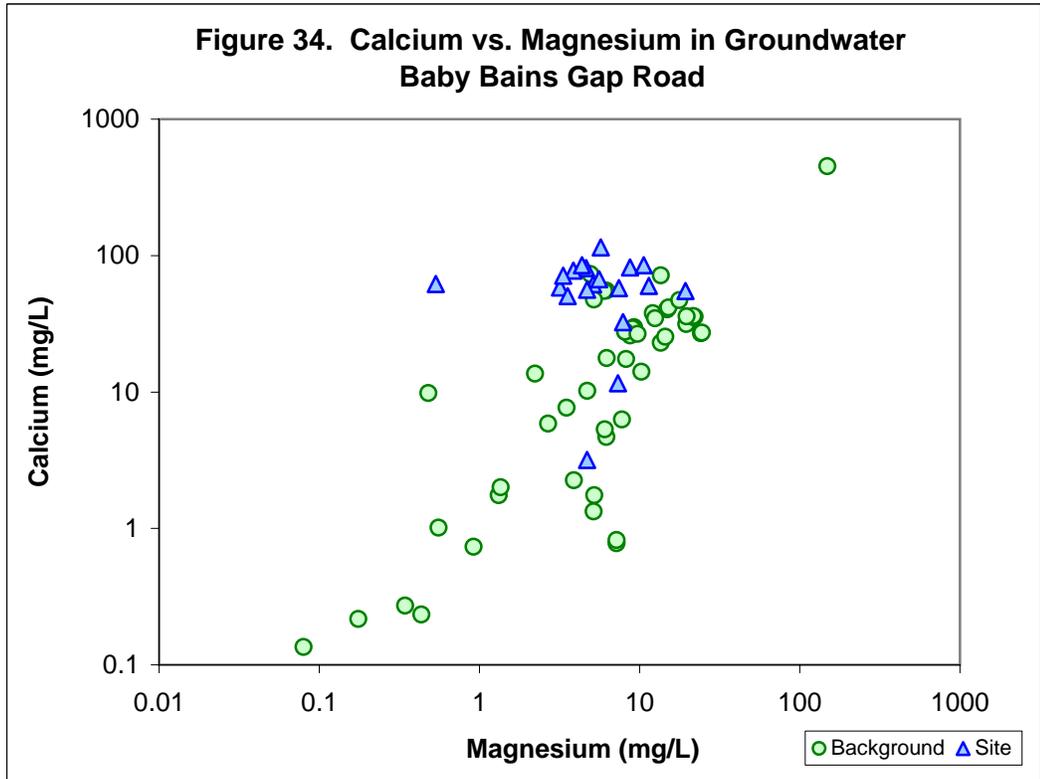
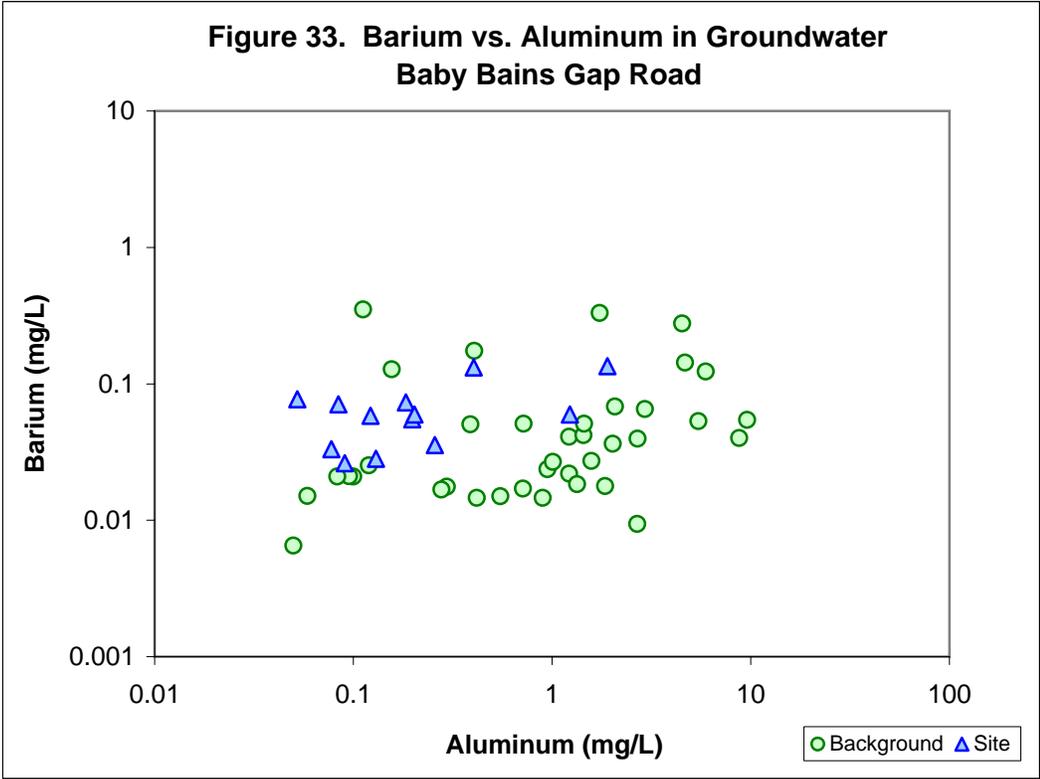
**Figure 25. Cobalt vs. Manganese in Sediment  
Baby Bains Gap Road**













**APPENDIX J**

**DEVELOPMENT OF LEAD CLEANUP LEVELS**

# Technical Memorandum

From: Paul F. Goetchius, DVM, DABT

To: FTMC IRON MOUNTAIN ROAD RANGES EE/CA FILE

Date: 12 February 2001

Subject: **DEVELOPMENT OF LEAD CLEANUP LEVELS FOR THE "OPEN SPACE" SCENARIO FOR THE IRON MOUNTAIN ROAD FIRING RANGES: REVISION 1.**

## 1.0 Introduction

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The purpose of this task is to develop cleanup levels for lead at some former shooting ranges on Fort McClellan (FTMC). Lead was released as a result of handling and discharge of lead-based ammunition in firearms. It is the intent of FTMC and the Mobile Office of the U.S. Army Corps of Engineers (USACE) to comply with the site-use scenarios proposed in the *Comprehensive Reuse Plan* (FTMC, 1997), which identifies "residential use" and "open space" as the two future reuse options for the sites in question.

Potentially contaminated media of interest at the shooting ranges include soil, sediment and surface water. However, surface water bodies on the Iron Mountain Road ranges are ephemeral in nature, so that exposure is likely to be infrequent and too uncertain to be predictable or quantifiable. Therefore, exposure to surface water is not included, and sediment is evaluated as soil for the purpose of estimating exposure. This memorandum develops cleanup levels for lead in soil for the most highly exposed receptor under the "open space" reuse scenario.

A cleanup level for lead of 400 mg/kg in soil for residential exposure was developed in the subject EE/CA and defended in the response to the January 2001 Independent Technical Review (ITR) report (ITR, 2001). The 400 mg/kg value was developed by applying site-specific data, to the extent that they were available, to the EPA (1994a) Integrated Exposure Uptake Biokinetic (IEUBK) model for predicting blood lead levels in young children.

## 2.0 Toxicity Assessment

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Lead is classified as a cancer weight-of-evidence Group B2 chemical – probable human carcinogen – on the basis of sufficient evidence in animals and inadequate evidence in humans (EPA, 2001). The human data consist of four occupational exposure studies of lead smelter and/or lead battery workers. All of the occupational studies lack quantitative exposure information, as well as information on the possible contribution from smoking. All studies also include exposures to other metals such as arsenic and cadmium, both of which are associated with carcinogenicity, for which no adjustment was done. The animal data include ten rat bioassays and one mouse assay that have shown statistically significant increases in renal tumors with dietary and subcutaneous exposure to several soluble lead salts. Animal assays provide reproducible results in several laboratories, in multiple rat strains, and with some evidence of multiple tumor sites. Short term studies show that lead affects gene expression, which contributes to the weight of evidence for a carcinogenic role. The data are inadequate for development of a cancer slope factor from which a cleanup level for lead could be estimated.

The regulation of lead in environmental media is generally based on its potential to induce noncancer effects. A plethora of information on the health effects of lead has been obtained through decades of medical observation and scientific research (EPA, 2001). By comparison to most other environmental contaminants, the degree of uncertainty about the health effects of lead is quite low. It appears that some of these effects, particularly changes in the levels of certain blood enzymes and in aspects of children's neurological and neurobehavioral development, may occur at blood lead levels so low as to be essentially without a threshold. The EPA RfD Work Group discussed inorganic lead (and lead compounds) at two meetings and considered the development of an RfD for inorganic lead to be inappropriate.

In the absence of an RfD for lead, other methods have arisen to estimate safe levels in environmental media. The 400 mg/kg residential soil cleanup level, for example, is based on estimations of blood lead levels in very young children, the most highly exposed and physiologically the most sensitive receptor in a residential setting (EPA, 1994b). Blood lead levels in children are estimated with the EPA (1994a) IEUBK model that calculates the geometric mean blood lead concentration, generates a probability density plot, and estimates the percent of a hypothetical population that may have blood lead levels exceeding a cutoff level, generally accepted to be 10 micrograms per deciliter ( $\mu\text{g}/\text{dL}$ ). A pregnant women represents the most sensitive adult receptor because of potential neurological damage to the fetus.

The EPA Technical Review Workgroup for lead examined several adult blood lead models, but currently recommends only one for developing cleanup levels in environmental media (EPA, 1996). They acknowledge, however, that other models provide useful information, particularly regarding the time-course of blood lead concentrations during brief or acute exposures, and that the recommended model is intended for adults who have relatively steady exposure patterns; i.e., at least one day per week over at least a 90-day period (13 days in a 90-day period). The model tends to overestimate blood lead levels for less frequent exposure scenarios because it is not designed to account for the time required to attain steady state (Maddaloni, 2000).

### **3.0 Exposure Assessment**

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The recreational site user was selected as the most intensely exposed receptor for land designated as open space (IT, 1998). The recreational site user scenario developed for the purpose of estimating SSSLs is a 7- to 16-year-old youth who visits the site on 2 days per week for 4 hours per day for purposes of hiking, playing, nature walks, hunting, or other recreational activities. The youth, rather than an adult or child, was selected for SSSL development to be consistent with EPA (1995) Region IV guidance for a trespasser scenario, and to capture the greater conservatism of the lesser average body weight of the youth compared with an adult. However, a pregnant woman is probably the receptor most sensitive to lead that might regularly visit a site for recreational purposes, and is chosen for development of cleanup levels for lead in media for open space.

The receptor scenarios developed for SSSL estimation are based on the EPA (1989, 1991) reasonable maximum exposure (RME) paradigm to ensure adequate protectiveness. An RME evaluation usually selects upper bound estimates for ingestion rate and exposure frequency, and central tendency (CT) estimates for some other variable values such as body weight. The relevant exposure assumptions for the recreational site user from IT (1998) are summarized in Table 1.

It is inappropriate, however, to use RME values in either the IEUBK model or the adult blood lead model because both models have a statistical module that addresses the variability about exposure (e.g., ingestion rate) and physiological parameters (e.g., bioavailability) to estimate blood lead level. Therefore, CT estimates of the exposure variables should be used, and are derived and presented in Table 1. Justification for the CT variable values is presented in the

footnotes in Table 1. However, further clarification may be helpful. For example, it is assumed that the soil incidental ingestion rate for a recreational site user is similar to that for a resident, but the rate is factored downward to reflect the fraction of a waking day spent on site (IT, 1998).

The exposure pathways and variables discussed above are relevant to ingestion. Dermal contact with soil, sediment and surface water was also evaluated for SSSL development because many chemicals, such as some semivolatile organic compounds, are readily absorbed by the skin. Dermal uptake of lead, however, is not expected to be significant (EPA, 1990, 1994a) and is not considered further.

The CT exposure variables in Table 1 can be applied to the EPA (1996) adult blood lead model to estimate a cleanup level for lead in soil for the recreational site user. The cleanup level is understood to be the lead concentration averaged over an exposure unit, defined as the entire area over which the receptor is expected to be randomly and uniformly exposed. There is no basis to predict what physical site features would be most attractive for a recreational site user, given the myriad of recreational purposes for which a visit might occur. Therefore, it is assumed that the largest contiguous open space area, whether within a single range or across multiple ranges, constitutes an exposure unit for soil.

#### **4.0 Estimating Cleanup Levels for Lead in Soil for the Recreational Site User**

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The EPA (1996) model was first used to develop cleanup levels for lead in soil in an occupational exposure scenario. The model consists of the following algorithm and default assumptions:

$$PbB_{\text{adult,central}} = PbB_{\text{adult,0}} + \frac{PbS \cdot BKSf \cdot IR_s \cdot AF_s \cdot EF_s}{AT} \quad (1)$$

where the variable definitions and their default values are:

- $PbB_{\text{adult, central}}$  = CT estimate of blood lead concentration ( $\mu\text{g/dL}$ ) in women of child-bearing age, calculated.
- $PbB_{\text{adult,0}}$  = typical background blood lead concentration (1.7 to 2.2  $\mu\text{g/dL}$ ) in women of child-bearing age

PbS	=	soil lead concentration (microgram/gram [ $\mu\text{g/g}$ ], which is equivalent to milligram per kilogram [ $\text{mg/kg}$ ])
BKSF	=	biokinetic slope factor relating increase in typical adult blood lead concentration to average daily lead uptake (0.4 $\mu\text{g/dL}$ blood lead increase per microgram per day [ $\mu\text{g/day}$ ] lead uptake)
IR <sub>S</sub>	=	soil intake rate (0.05 grams per day [ $\text{g/day}$ ])
AF <sub>S</sub>	=	gastrointestinal absorption factor for lead in soil (0.12 unitless fraction)
EF <sub>S</sub>	=	exposure frequency (219 total days of exposure [employment] during the averaging period [one year])
AT	=	averaging time (1 year [365days]).

EPA (1996) rearranged and modified Equation 1 to derive an equation by which a risk-based remedial goal (RBRG), analogous to a cleanup level, for lead in soil can be estimated:

$$RBRG = \frac{(PbB_{adult,central,goal} - PbB_{adult,0}) \cdot AT}{BKSF \cdot IR_S \cdot AF_S \cdot EF_S} \quad (2)$$

where the variable definitions and their default values are:

RBRG	=	risk-based remedial goal (analogous to cleanup level) for lead in soil ( $\mu\text{g/g}$ , equivalent to $\text{mg/kg}$ ), calculated
PbB <sub>adult,central,goal</sub>	=	goal for CT estimate of blood lead concentration ( $\mu\text{g/dL}$ ) in women to ensure that fetal blood levels (in 95 percent of population) do not exceed 10 $\mu\text{g/dL}$
PbB <sub>adult,0</sub>	=	typical background blood lead concentration (1.7 to 2.2 $\mu\text{g/dL}$ ) in women of child-bearing age (average of 2.0 $\mu\text{g/dL}$ used in this evaluation)
AT	=	averaging time (365 days).
BKSF	=	biokinetic slope factor relating increase in typical adult blood lead concentration to average daily lead uptake (0.4 $\mu\text{g/dL}$ blood lead increase per $\mu\text{g/day}$ lead uptake)
IR <sub>S</sub>	=	soil intake rate (0.05 grams per day [ $\text{g/day}$ ])
AF <sub>S</sub>	=	gastrointestinal absorption factor for lead in soil (0.12 unitless fraction)
EF <sub>S</sub>	=	exposure frequency (219 total days of exposure [employment] during the averaging period [one year]).

PbB<sub>adult,central,goal</sub> is estimated as (EPA, 1996):

$$PbB_{adult,central,goal} = \frac{PbB_{fetal,0.95,goal}}{GSD_{i,adult}^{1.645} \cdot R_{fetal/maternal}} \quad (3)$$

where the variable definitions and their default values are:

$PbB_{adult,central,goal}$	=	goal for CT estimate of blood lead concentration ( $\mu\text{g}/\text{dL}$ ) in women to ensure that fetal blood levels (in 95 percent of population) do not exceed 10 $\mu\text{g}/\text{dL}$ , calculated
$PbB_{fetal,0.95,goal}$	=	goal for the 95 <sup>th</sup> percentile blood lead concentration (generally accepted to be 10 $\mu\text{g}/\text{dL}$ )
$GSD_{i,adult}$	=	individual geometric standard deviation among adults that have similar site-related exposures, but dissimilar responses to site-related exposures and dissimilar background exposures (value of 2.1 selected for a heterogeneous population)
$R_{fetal/maternal}$	=	proportionality constant between fetal blood lead level and maternal blood lead level at birth (0.9).

From Equation 3 and the variable values provided by EPA (1996)  $PbB_{adult,central,goal}$  is estimated as follows:

$$PbB_{adult,central,goal} = \frac{10}{2.1^{1.645} \cdot 0.9} = 3.3 \mu\text{g} / \text{dL} \quad (4)$$

The  $PbB_{adult,central,goal} - PbB_{adult,0}$  term in Equation 2 can be replaced with:

$$3.3 - 2.0 = 1.3 \mu\text{g} / \text{dL} \quad (5)$$

Preliminary cleanup goals for lead in soil can be estimated for the recreational site user by substituting actual default and site-specific values in Equation 2:

$$RBRG = \frac{1.3 \cdot 365}{0.4 \cdot 0.0125 \cdot 0.12 \cdot 104} = 7604 \text{ mg} / \text{kg} \quad (6)$$

Site-specific variable values in Equation 6 include the  $IR_s$  of 0.0125 g/day, and the CT  $EF_s$  of 104 days/year and the FI of 0.25 from Table 1. The  $IR_s$  is the product of the CT soil incidental ingestion rate of 0.05 g/day and the FI of 0.25. The preliminary cleanup level for lead in soil for the recreational site user is 7604 mg/kg, which, rounded to two significant figures to reflect the uncertainty associated with the model, is 7600 mg/kg.

## 5.0 Uncertainties

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The EPA (1994a) IEUBK model and the EPA (1996) adult blood lead model are among the most rigorously validated of the models generally used in risk assessment. Their use introduces little uncertainty into the evaluation.

The EPA (1996) adult blood lead model addresses incidental ingestion but does not include the potential contribution from dermal exposure. Dermal uptake, however, is not considered a significant route of absorption for inorganic lead (EPA, 1990, 1994a). The fact that dermal exposure is not included in the adult blood lead model is judged not to be a significant source of uncertainty in estimation of the RBRG.

Probably the greatest uncertainty arises from the hypothetical exposure assumptions applied to the recreational site user. This receptor scenario, however, was selected to represent the most intense exposure plausible, and the exposure variable values were chosen to bias the evaluation toward increased conservatism (IT, 1998). Although the uncertainty is great, it is unlikely that risks would be underestimated or cleanup levels would be overestimated.

## 6.0 References

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**Table 1**

Pathway Variable <sup>a</sup>	Units	Recreational Site User	
		RME <sup>a</sup>	CT
Soil Exposure Pathways			
Soil incidental ingestion rate (IR)	g/day	0.1	0.05 <sup>b</sup>
Fraction of exposure to site soil (FI)	unitless	0.25	0.25 <sup>c</sup>
Exposure frequency (EF)	days/year	104 <sup>d</sup>	104 <sup>c</sup>
<p>RME = reasonable maximum exposure; CT = central tendency</p> <p><sup>a</sup>Please see IT Corporation (IT), 1998, Final <i>Installation-Wide Work Plan, Fort McClellan, Alabama</i>, Prepared for the U.S. Department of the Army, Mobile District, Corps of Engineers, August, unless otherwise specified, for development and defense of relevant exposure pathways and RME variable values.</p> <p><sup>b</sup>U.S. Environmental Protection Agency (EPA), 1997, <i>Exposure Factors Handbook</i>, Office of Research and Development, National Center for Environmental Assessment, Washington, DC, August, EPA/600/P-95/002Fa.</p> <p><sup>c</sup>RME values are used where CT values cannot be estimated.</p> <p><sup>d</sup>Based on the assumption that exposure would occur on 2 days per week, 52 weeks per year.</p>			