APPENDIX H

STATISTICAL AND GEOCHEMICAL EVALUATION OF SITE METALS DATA

Technical Memorandum

From: Paul F. Goetchius, DVM
Senior Toxicologist
Risk Management Services

To: Fort McClellan (FTMC) Risk Assessment File

Date: 24 June 2003

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 95th 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 ($HAsO_4^{-2}$, $HSeO_3^-$, $H_2VO_4^-$) (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 (Cd^{+2}, Ni^{+2}, Pb^{+2}, 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 $Cr(OH)_2^+$, $Cr(OH)_3^o$, and $Cr(OH)_4^-$, 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 (MnO_2) and nsutite ($MnO_{1.9}$) will form that strongly adsorb Ba, Co, and Pb. Under reducing, low CO_2 conditions, the minerals MnO•OH, Mn_2O_3 and Mn_3O_4 will form, which also concentrate these trace elements. Under reducing, high CO_2 conditions however, Mn will be present as rhodochrosite ($MnCO_3$) which does not have as strong adsorptive properties as the Mn-oxides (EPRI, 1984).

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 ($CaCO_3$) and dolomite [$(Ca,Mg)CO_3$], 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 ($CaSO_4 \cdot 2H_2O$) 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

Belzile, N., Y. W. Chen, and R. Xu, 2000, "Early Diagenetic Behavior of Selenium in Freshwater Sediments," ***Applied Geochemistry***, Vol. 15, pp. 1439-1454.

Bowell, R. J., 1994, "Sorption of Arsenic by Iron Oxides and Oxyhydroxides in Soils," ***Applied Geochemistry***, Vol. 9, pp. 279-286.

Brookins, D. G., 1988, ***Eh-pH Diagrams for Geochemistry***, Springer-Verlag.

EPRI, 1984, ***Chemical Attenuation Rates, Coefficients, and Constants in Leachate Migration, Volume 1: A Critical Review***, Electric Power Research Institute, EPRI EA-3356, Palo Alto, California.

EPRI, 1986, ***Speciation of Selenium and Arsenic in Natural Waters and Sediments, Volume 2: Arsenic Speciation***, Electric Power Research Institute, EPRI EA-4641, Palo Alto, California.

Kabata-Pendias, A., 2001, ***Trace Elements in Soils and Plants***, Third Edition, CRC Press.

Nickson, R. T., J. M. McArthur, P. Ravenscroft, W. G. Burgess, and K. M. Ahmed, 2000, "Mechanism of Arsenic Release to Groundwater, Bangladesh and West Bengal," ***Applied Geochemistry***, Vol. 15, pp. 403-413.

Pourbaix, 1974, ***Atlas of Electrochemical Equilibria in Solutions***, National Association of Corrosion Engineers, Houston, Texas.

Science Applications International Corporation (SAIC), 1998, ***Final Background Metals Survey Report***, prepared for U.S. Army Corps of Engineers, Mobile District, July.

Schiff, K. and S. B. Weisberg, 1997, "Iron as a Reference Element for Determining Trace Metal Enrichment in California Coastal Shelf Sediments," *in*: S. Weisberg, C. Francisco, and D. Hallock, (eds.), ***Southern California Coastal Water Research Project Annual Report 1995-96***, pp. 68-78.

Sullivan, K. A. and R. C. Aller, 1996, "Diagenetic Cycling of Arsenic in Amazon Shelf Sediments," ***Geochimica et Cosmochimica Acta***, Vol. 60, No. 9, pp. 1465-1477.

STATISTICAL
(TIERS 1 AND 2)

Statistical Comparison of Site and Background Data
Former 81mm Mortar Range, Parcel 137Q-X
Fort McClellan, Alabama

1.0 Introduction

This report provides the Tier 1 and Tier 2 site-to-background comparison results for the Former 81mm Mortar Range, Parcel 137Q-X, located at Fort McClellan in Calhoun County, Alabama. Tier 1 and Tier 2 evaluations (Shaw Environmental, Inc., 2003) have been performed for target analyte list (TAL) metals in the surface soil, subsurface soil, groundwater, sediment, and surface water 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, the Wilcoxon Rank Sum Test (WRS), and Hot Measurement Test.

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 samples used in the site-to-background comparison include 55 surface soil samples (0 to 1 foot below ground surface [bgs]), 40 subsurface soil samples (1 to 12 feet bgs), seven groundwater samples, four sediment samples, and four surface water samples. Eleven surface soil samples were analyzed only for lead while the remainder of the site samples were analyzed for 23 TAL metals.

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

2.0 Comparison Methodology

This section describes the statistical techniques that were employed in the Parcel 137Q-X site-to-background comparison.

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

Table 1

Summary of Site to Background Comparison for Surface Soil
Former 81mm Mortar Range, Parcel 137Q-X
Fort McClellan, Calhoun County, Alabama

Metals	Frequency of Detection	Tier 1 Evaluation	Slippage Test[b]	Wilcoxon Rank Sum Test[b]	Hot Measurement Test[b,c]	Carried Forward for Tier 3 Geochemical Evaluation
Aluminum	44 / 44	Failed	Passed	Failed	NA	Yes
Antimony	6 / 44	Failed	NA[d]	NA[e]	Failed	Yes
Arsenic	43 / 44	Passed	NA	NA	NA	
Barium	44 / 44	Failed	Passed	Passed	NA	
Beryllium	10 / 44	Failed	Passed	NA[e]	Passed	
Cadmium	0 / 44	NA	NA	NA	NA	
Calcium	44 / 44	Passed	NA	NA	NA	
Chromium	44 / 44	Passed	NA	NA	NA	
Cobalt	30 / 44	Failed	Passed	Passed	NA	
Copper	44 / 44	Failed	Failed	Failed	NA	Yes
Iron	44 / 44	Passed	NA	NA	NA	
Lead	55 / 55	Failed	Failed	Failed	NA	Yes
Magnesium	44 / 44	Passed	NA	NA	NA	
Manganese	44 / 44	Passed	NA	NA	NA	
Mercury	26 / 44	Failed	Passed	NA[e]	Passed	
Nickel	36 / 44	Passed	NA	NA	NA	
Potassium	24 / 44	Failed	Passed	Failed	NA	Yes
Selenium	17 / 44	Failed	Passed	NA[e]	Failed	Yes
Silver	0 / 44	NA	NA	NA	NA	
Sodium	32 / 44	Passed	NA	NA	NA	
Thallium	1 / 44	Passed	NA	NA	NA	
Vanadium	44 / 44	Passed	NA	NA	NA	
Zinc	44 / 44	Failed	Passed	Failed	NA	Yes

NA = not applicable; MDC = maximum detected concentration

[a] Tier 1 evaluation (site MDC compared to 2 x the background mean) per *Selecting Site-Related Chemicals for Human Health and Ecological Risk Assessments for FTMC, Revision 2,* Technical Memorandum, 24 June 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 Site to Background Comparison for Subsurface Soil
Former 81mm Mortar Range, Parcel 137Q-X
Fort McClellan, Calhoun County, Alabama

Metals	Frequency of Detection	Tier 1 Evaluation[a]	Slippage Test[b]	Wilcoxon Rank Sum Test[b]	Hot Measurement Test[b,c]	Carried Forward for Tier 3 Geochemical Evaluation
Aluminum	40 / 40	Failed	Passed	Failed	NA	Yes
Antimony	1 / 40	Failed	NA[d]	NA[e]	Failed	Yes
Arsenic	40 / 40	Passed	NA	NA	NA	
Barium	40 / 40	Passed	NA	NA	NA	
Beryllium	10 / 40	Failed	Passed	NA[e]	Passed	
Cadmium	2 / 40	Failed	NA[d]	NA[e]	Failed	Yes
Calcium	39 / 40	Passed	NA	NA	NA	
Chromium	40 / 40	Failed	Passed	Passed	NA	
Cobalt	23 / 40	Passed	NA	NA	NA	
Copper	40 / 40	Failed	Passed	Failed	NA	Yes
Iron	40 / 40	Passed	NA	NA	NA	
Lead	40 / 40	Failed	Passed	Failed	NA	Yes
Magnesium	40 / 40	Failed	Passed	Failed	NA	Yes
Manganese	40 / 40	Passed	NA	NA	NA	
Mercury	14 / 40	Failed	Passed	NA[e]	Failed	Yes
Nickel	30 / 40	Passed	NA	NA	NA	
Potassium	30 / 40	Failed	Passed	Failed	NA	Yes
Selenium	17 / 40	Failed	NA[d]	NA[e]	Failed	Yes
Silver	0 / 40	NA	NA	NA	NA	
Sodium	25 / 40	Passed	NA	NA	NA	
Thallium	1 / 40	Passed	NA	NA	NA	
Vanadium	40 / 40	Failed	Passed	Passed	NA	
Zinc	38 / 40	Failed	Passed	Passed	NA	

NA = not applicable; MDC = maximum detected concentration

[a] Tier 1 evaluation (site MDC compared to 2 x the background mean) per *Selecting Site-Related Chemicals for Human Health and Ecological Risk Assessments for FTMC, Revision 2,* Technical Memorandum, 24 June 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 3

Summary of Site to Background Comparison for Groundwater
Former 81mm Mortar Range, Parcel 137Q-X
Fort McClellan, Calhoun County, Alabama

Metals	Frequency of Detection	Tier 1 Evaluation	Slippage Test[b]	Wilcoxon Rank Sum Test[b]	Hot Measurement Test[b,c]	Carried Forward for Tier 3 Geochemical Evaluation
Aluminum	7 / 7	Failed	Passed	Failed	NA	Yes
Antimony	0 / 7	NA	NA	NA	NA	
Arsenic	2 / 7	Passed	NA	NA	NA	
Barium	7 / 7	Passed	NA	NA	NA	
Beryllium	0 / 7	NA	NA	NA	NA	
Cadmium	0 / 7	NA	NA	NA	NA	
Calcium	6 / 7	Passed	NA	NA	NA	
Chromium	1 / 7	Failed	NA	NA	Passed	
Cobalt	0 / 7	NA	NA	NA	NA	
Copper	1 / 7	Passed	NA	NA	NA	
Iron	7 / 7	Failed	Passed	Passed	NA	
Lead	1 / 7	Passed	NA	NA	NA	
Magnesium	6 / 7	Passed	NA	NA	NA	
Manganese	7 / 7	Passed	NA	NA	NA	
Mercury	0 / 7	NA	NA	NA	NA	
Nickel	0 / 7	NA	NA	NA	NA	
Potassium	4 / 7	Failed	Passed	Failed	NA	Yes
Selenium	0 / 7	NA	NA	NA	NA	
Silver	0 / 7	NA	NA	NA	NA	
Sodium	5 / 7	Passed	NA	NA	NA	
Thallium	0 / 7	NA	NA	NA	NA	
Vanadium	1 / 7	Passed	NA	NA	NA	
Zinc	1 / 7	Passed	NA	NA	NA	

NA = not applicable; MDC = maximum detected concentration

[a] Tier 1 evaluation (site MDC compared to 2 x the background mean) per *Selecting Site-Related Chemicals for Human Health and Ecological Risk Assessments for FTMC, Revision 2,* Technical Memorandum, 24 June 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 Site to Background Comparison for Sediment
Former 81mm Mortar Range, Parcel 137Q-X
Fort McClellan, Calhoun County, Alabama

Metals	Frequency of Detection	Tier 1 Evaluation	Slippage Test[b]	Wilcoxon Rank Sum Test[b]	Hot Measurement Test[b,c]	Carried Forward for Tier 3 Geochemical Evaluation
Aluminum	4 / 4	Passed	NA	NA	NA	
Antimony	0 / 4	NA	NA	NA	NA	
Arsenic	4 / 4	Passed	NA	NA	NA	
Barium	4 / 4	Passed	NA	NA	NA	
Beryllium	2 / 4	Passed	NA	NA	NA	
Cadmium	0 / 4	NA	NA	NA	NA	
Calcium	4 / 4	Failed	Passed	Passed	NA	
Chromium	4 / 4	Passed	NA	NA	NA	
Cobalt	4 / 4	Passed	NA	NA	NA	
Copper	4 / 4	Passed	NA	NA	NA	
Iron	4 / 4	Passed	NA	NA	NA	
Lead	4 / 4	Failed	Passed	Failed	NA	Yes
Magnesium	4 / 4	Failed	Passed	Passed	NA	
Manganese	4 / 4	Passed	NA	NA	NA	
Mercury	0 / 4	NA	NA	NA	NA	
Nickel	4 / 4	Passed	NA	NA	NA	
Potassium	2 / 4	Passed	NA	NA	NA	
Selenium	0 / 4	NA	NA	NA	NA	
Silver	0 / 4	NA	NA	NA	NA	
Sodium	2 / 4	Passed	NA	NA	NA	
Thallium	0 / 4	NA	NA	NA	NA	
Vanadium	4 / 4	Passed	NA	NA	NA	
Zinc	4 / 4	Passed	NA	NA	NA	

NA = not applicable; MDC = maximum detected concentration

[a] Tier 1 evaluation (site MDC compared to 2 x the background mean) per *Selecting Site-Related Chemicals for Human Health and Ecological Risk Assessments for FTMC, Revision 2,* Technical Memorandum, 24 June 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 5

Summary of Site to Background Comparison for Surface Water
Former 81mm Mortar Range, Parcel 137Q-X
Fort McClellan, Calhoun County, Alabama

Metals	Frequency of Detection	Tier 1 Evaluation	Slippage Test[b]	Wilcoxon Rank Sum Test[b]	Hot Measurement Test[b,c]	Carried Forward for Tier 3 Geochemical Evaluation
Aluminum	0 / 4	NA	NA	NA		
Antimony	0 / 4	NA	NA	NA		
Arsenic	0 / 4	NA	NA	NA		
Barium	4 / 4	Passed	NA	NA		
Beryllium	0 / 4	NA	NA	NA		
Cadmium	0 / 4	NA	NA	NA		
Calcium	4 / 4	Passed	NA	NA		
Chromium	0 / 4	NA	NA	NA		
Cobalt	0 / 4	NA	NA	NA		
Copper	0 / 4	NA	NA	NA		
Iron	3 / 4	Passed	NA	NA		
Lead	0 / 4	NA	NA	NA		
Magnesium	4 / 4	Passed	NA	NA		
Manganese	4 / 4	Passed	NA	NA		
Mercury	0 / 4	NA	NA	NA		
Nickel	0 / 4	NA	NA	NA		
Potassium	0 / 4	NA	NA	NA		
Selenium	0 / 4	NA	NA	NA		
Silver	0 / 4	NA	NA	NA		
Sodium	4 / 4	Passed	NA	NA		
Thallium	0 / 4	NA	NA	NA		
Vanadium	0 / 4	NA	NA	NA		
Zinc	0 / 4	NA	NA	NA		

NA = not applicable; MDC = maximum detected concentration

[a] Tier 1 evaluation (site MDC compared to 2 x the background mean) per *Selecting Site-Related Chemicals for Human Health and Ecological Risk Assessments for FTMC, Revision 2,* Technical Memorandum, 24 June 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.

statistical comparison test is sensitive to both of these modes of contamination. For this reason, 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 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 75th percentile and the bottom of the box represents the 25th 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 95th upper tolerance limit (95th UTL) is recommended as a screening value for normally or lognormally distributed analytes and the 95th 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 95th UTL or 95th 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 Comparison

This section presents the results of the site-to-background comparison for 23 TAL metals in the surface soil, subsurface soil, groundwater, sediment, and surface water samples from Parcel 137Q-X. 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 Parcel 137Q-X surface soil data set. Two metals (cadmium and silver) have no detected concentrations in the surface soil site samples and are not considered any further. Ten metals (arsenic, calcium, chromium, iron, magnesium, manganese, nickel, sodium, thallium, and vanadium) have no detected concentrations above their respective background screening values, and thus they pass the Tier 1 evaluation. These metals are not discussed further. The remaining eleven metals are carried forward for Tier 2 evaluation.

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

Aluminum

Tier 1 Evaluation

One site sample exceeds the background screening value of 16,306 mg/kg.

Slippage Test

K_c for aluminum is 4, and no site samples exceed the maximum background measurement (K=0). Because $K < K_c$, aluminum passes the Slippage test.

WRS Test

The p-level of 0.028 indicates weak agreement between the site and background distributions.

Box Plot

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

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
Six site samples exceed the background screening value of 1.99 mg/kg.

Slippage Test
The maximum background value 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 86 percent nondetects.

Box Plot
The site minimum, median, and maximum are higher than the corresponding background values (Figure 1-2).

Hot Measurement Test
The site MDC of antimony exceeds the background 95th percentile of 7.14 mg/kg.

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

Barium

Tier 1 Evaluation
One site sample exceeds the background screening value of 123.94 mg/kg.

Slippage Test
K_c for barium is 4, 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 0.645 indicates strong agreement between the site and background distributions.

Box Plots
The site minimum and median are higher than the corresponding background values, and the site maximum is lower than the background maximum (Figure 1-3).

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

Beryllium

Tier 1 Evaluation

Three site samples exceed the background screening value of 0.8 mg/kg.

Slippage Test

K_c for beryllium is 4, and no site samples exceed the maximum background measurement (K=0). Because $K < K_c$, beryllium passes the Slippage test.

WRS Test

The WRS test was not performed because the site data set contains 77 percent nondetects.

Box Plots

The location and shape of the site box plot is largely defined by the high percentage of nondetects (77 percent) and the replacement values of one-half the reporting limit (Figure 1-4). The site minimum, median, and maximum are higher than the corresponding background values.

Hot Measurement Test

The site MDC of beryllium does not exceed the background 95th UTL of 1.189 mg/kg.

Conclusion

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

Cobalt

Tier 1 Evaluation

One site sample exceeds the background screening value of 15.15 mg/kg.

Slippage Test

K_c for cobalt is 4, 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 0.004 indicates a significant difference between the site and background distributions. The reason for the low p-level is that the site data are shifted lower relative to background.

Box Plot

The site minimum is higher than the background minimum, and the site median and maximum are lower than the corresponding background values (Figure 1-5).

Conclusion

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

Copper

Tier 1 Evaluation

Twenty-six site samples exceed the background screening value of 12.71 mg/kg.

Slippage Test

K_c for copper is 4, and 19 site samples exceed the maximum background measurement (K=19). 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, median, and maximum are higher than the corresponding background values (Figure 1-6).

Conclusion

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

Lead

Tier 1 Evaluation

Forty site samples exceed the background screening value of 40.05 mg/kg.

Slippage Test

K_c for lead is 5, and 32 site samples exceed the maximum background measurement (K=32). 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, median, and maximum are higher than the corresponding background values (Figure 1-7).

Conclusion

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

Mercury

Tier 1 Evaluation

Three site samples exceed the background screening value of 0.08 mg/kg.

Slippage Test
K_c for mercury is 4, and no site samples exceed the maximum background measurement (K=0). Since $K < K_c$, mercury passes the Slippage test.

WRS Test
The WRS test was not performed because the background data set contains 66 percent nondetects.

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 1-8).

Hot Measurement Test
The site MDC of mercury does not exceed the background 95th percentile of 0.125 mg/kg.

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

Potassium

Tier 1 Evaluation
Two site samples exceed the background screening value of 799.76 mg/kg.

Slippage Test
K_c for potassium is 4, and no site samples exceed maximum background measurement (K=0). 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 median are higher than the corresponding background values, and the site maximum is lower than the background maximum (Figure 1-9).

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

Selenium

Tier 1 Evaluation
Seventeen site samples exceed the background screening value of 0.48 mg/kg.

Slippage Test
K_c for selenium is 4, and no site samples exceed the maximum background measurement (K=0). Because $K < K_c$, selenium passes the Slippage test.

WRS Test
The WRS test was not performed because the background and site data sets contain 99 and 61 percent nondetects, respectively.

Box Plots
The background data set is characterized by a high percentage of nondetects (99 percent), so the background box plot reflects the replacement values of one-half the reporting limit (Figure 1-10). The site minimum and median are higher than the corresponding background values, and the site maximum is lower than the background maximum.

Hot Measurement Test
The site MDC of selenium exceeds the background 95 percentile of 0.563 mg/kg.

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

Zinc

Tier 1 Evaluation
Two site samples exceed the background screening value of 40.64 mg/kg.

Slippage Test
K_c for zinc is 4, and no site samples exceed the maximum background measurement (K=0). Because $K < K_c$, zinc passes the Slippage test.

WRS Test
The p-level of 0.121 indicates weak agreement 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 1-11).

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

3.2 Subsurface Soil

Twenty-three TAL metals were evaluated in the Parcel 137Q-X subsurface soil data set. Silver had no detected concentrations in the subsurface soil and is not considered any further. Nine metals (arsenic, barium, calcium, cobalt, iron, manganese, nickel, sodium, and thallium) have no detected concentrations above their respective background screening values, and thus they pass the Tier 1 evaluation. Because these metals passed the Tier 1 evaluation, they will not be discussed further.

Table 2 summarizes the subsurface soil statistical site to background comparison results. The remaining thirteen metals are carried forward for Tier 2 evaluation, and the test results are discussed below in detail. Box plots are provided in Attachment 1.

Aluminum

Tier 1 Evaluation

Seventeen site samples exceed the background screening value of 13,591 mg/kg.

Slippage Test

K_c for aluminum is 4, and three site samples exceed the maximum background measurement (K=3). Because $K < K_c$, aluminum 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 1-12).

Conclusion

Because aluminum in subsurface soil 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 1.31 mg/kg.

Slippage Test

The maximum background value 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 98 percent nondetects.

Box Plot

The location and shape of the site box plot are largely defined by the high percentage of nondetects (98 percent) and the replacement values of one-half the reporting limit (Figure 1-13). The site minimum, median, and maximum are higher than the corresponding background values.

Hot Measurement Test

The site MDC of antimony exceeds the background 95th 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.

Beryllium

Tier 1 Evaluation
One site sample exceeds the background screening value of 0.86 mg/kg.

Slippage Test
K_c for beryllium is 4, and one site sample exceeds the maximum background measurement (K=1). Because $K < K_c$, beryllium passes the Slippage test.

WRS Test
The WRS test was not performed because the site data set contains 75 percent nondetects.

Box Plot
The location and shape of the site box plot are largely defined by the high percentage of nondetects (75 percent) and the replacement values of one-half the reporting limit (Figure 1-14). The site minimum and median are higher than the corresponding background values, and the site maximum is slightly higher than the background maximum.

Hot Measurement
The site MDC of beryllium does not exceed the background 95th UTL of 2.19 mg/kg.

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

Cadmium

Tier 1 Evaluation
Two site samples exceed the background screening value of 0.22 mg/kg.

Slippage Test
K_c for cadmium is 4, and no site samples exceed the maximum background measurement (K=3). Because $K < K_c$, cadmium 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 1-15). The site minimum and median are higher than the corresponding background values, and the site maximum is lower than the background maximum.

Hot Measurement
The site MDC exceeds the background 95th percentile of 0.62 mg/kg.

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

Chromium

Tier 1 Evaluation
One site sample exceeds the background screening value of 38.25 mg/kg.

Slippage Test
K_c for chromium is 4, and no site sample exceeds the maximum background measurement (K=0). Because $K < K_c$, chromium passes the Slippage test.

WRS Test
The p-level of 0.016 indicates weak agreement between the site and background distributions. The reason for the low p-level is that the site data are shifted lower relative to background.

Box Plot
The site minimum is higher than the background minimum, and the site median and maximum are lower than the respective background values (Figure 1-16).

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

Copper

Tier 1 Evaluation
Four site samples exceed the background screening value of 19.43 mg/kg.

Slippage Test
K_c for copper is 4, and one site sample exceeds the maximum background measurement (K=1). Because $K < K_c$, copper passes the Slippage test.

WRS Test
The p-level of 0.148 indicates acceptable agreement between the site and background distributions.

Box Plot
The site minimum, median, and maximum are higher than the corresponding background values (Figure 1-17).

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

Lead

Tier 1 Evaluation
Twenty-four site samples exceed the background screening value of 38.53 mg/kg.

Slippage Test
K_c for lead is 4, and one site sample exceeds the maximum background measurement (K=1). 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 1-18).

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
Six site samples exceed the background screening value of 766.24 mg/kg.

Slippage Test
K_c for magnesium is 4, and no site sample exceeds 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 1-19).

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

Mercury

Tier 1 Evaluation

Two site samples exceed the background screening value of 0.07 mg/kg.

Slippage Test

K_c for mercury is 4, and no site sample exceeds the maximum background measurement (K=0). Since $K < K_c$, mercury passes the Slippage test.

WRS Test

The WRS test was not performed because the background and site data sets contain 53 and 65 percent nondetects, respectively.

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 1-20).

Hot Measurement Test

The site MDC of mercury exceeds the background 95th 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.

Potassium

Tier 1 Evaluation

Twelve site samples exceed the background screening value of 710.74 mg/kg.

Slippage Test

K_c for potassium is 4, 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 1-21).

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

Seventeen site samples exceed the background screening value of 0.47 mg/kg.

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

WRS Test
The WRS test was not performed because the background and site data sets contain 98 and 58 percent nondetects, respectively.

Box Plot
The background data set is characterized by a high percentage of nondetects (98 percent), so the background box plot reflects the replacement values of one-half the reporting limit (Figure 1-22). The site minimum, median, and maximum are higher than the respective background values.

Hot Measurement Test
The site MDC of selenium exceeds the background 95th 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.

Vanadium

Tier 1 Evaluation
One site sample exceeds the background screening value of 64.89 mg/kg.

Slippage Test
K_c for vanadium is 4, and no site sample exceeds the maximum background measurement (K=0). Because $K < K_c$, vanadium passes the Slippage test.

WRS Test
The p-level of 0.003 indicates poor agreement between the site and background distributions. The reason for the low p-level is that the site data are shifted lower relative to background.

Box Plot
The site minimum, median, and maximum are lower than the corresponding background values (Figure 1-23).

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

Zinc

Tier 1 Evaluation
One site sample exceeds the background screening value of 34.86 mg/kg.

Slippage Test
K_c for zinc is 4, and no site sample exceeds the maximum background measurement (K=0). Because $K < K_c$, zinc passes the Slippage test.

WRS Test
The p-level of 0.396 indicates good agreement between the site and background distributions.

Box Plot
The site minimum and maximum are lower than the respective background values, and the site median is higher than background median (Figure 1-24).

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

3.3 Groundwater

This section presents the results of the site-to-background comparisons for 23 metals unfiltered groundwater samples. Nine metals (antimony, beryllium, cadmium, cobalt, mercury, nickel, selenium, silver, and thallium) had no detects in the groundwater site samples and are not considered any further. Ten metals (arsenic, barium, calcium, copper, lead, magnesium, manganese, sodium, vanadium, and zinc) 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 3 summarizes these results.

The remaining four metals (aluminum, chromium, iron, and potassium) are carried forward for Tier 2 evaluation. The results of this evaluation are summarized in Table 3 and discussed in detail below. Box plots are provided in Attachment 1.

Aluminum

Tier 1 Evaluation
Two site samples exceed the background screening value of 2.335 mg/L.

Slippage Test
K_c for aluminum is 2, and one site sample exceeds the maximum background measurement (K=1). Because $K < K_c$, aluminum passes the Slippage test.

WRS Test
The p-level of 0.074 indicates weak agreement 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 in groundwater failed the statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

Chromium

Tier 1 Evaluation
There is no background screening value for chromium. One site sample has a detected concentration.

Slippage Test
The maximum value for chromium is a nondetect, so the Slippage test could not be performed.

WRS Test
The WRS test was not performed because the background and site data sets contain 100 and 86 percent nondetects, respectively.

Box Plots
The background and site data sets are characterized by high percentages of nondetects (100 and 86 percent, respectively), so the background and site box plots reflect 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 of chromium does not exceed the background 95th UTL of 0.0168 mg/L.

Conclusion
Because chromium in groundwater is within the range of background, it will not be carried forward for Tier 3 geochemical evaluation.

Iron

Tier 1 Evaluation
One site sample exceeds the background screening value of 7.04 mg/L.

Slippage Test
K_c for iron is 2, and one site sample exceeds the maximum background measurement (K=1). Because $K < K_c$, iron passes the Slippage test.

WRS Test
The p-level of 0.619 indicates strong agreement between the background and site distributions.

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

Conclusion
Because iron in groundwater is within the range of background, it will not be carried forward for Tier 3 geochemical evaluations.

Potassium

Tier 1 Evaluation
One site sample exceeds the background screening value of 7.195 mg/L.

Slippage Test
K_c for potassium is 2, and no site samples exceed the maximum background measurement (K=0). Because $K < K_c$, potassium passes the Slippage test.

WRS Test
The p-level of 0.009 indicates a significant difference between the background and site 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 potassium in groundwater failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

3.4 Sediment

This section presents results of the site-to-background comparison for TAL metals in the Parcel 137Q-X sediment samples. Six metals (antimony, cadmium, mercury, selenium, silver, and thallium) had no detected concentrations in the sediment site samples and are not considered further. Fourteen metals (aluminum, arsenic, barium, beryllium, chromium, cobalt, copper, iron, manganese, nickel, potassium, sodium, vanadium, and zinc) have 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 remaining metals (calcium, lead, and magnesium) are carried forward for Tier 2 evaluation. The results of these evaluations are summarized in Table 4 and discussed in detail below. Box plots are provided in Attachment 1.

Calcium

Tier 1 Evaluation

One site sample exceeds the background screening value of 1111.51 mg/kg.

Slippage Test

K_c for calcium is 2, 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 0.176 indicates weak agreement between background and site distributions. The reason for the low p-level is that the site median is shifted lower relative to the background median.

Box Plots

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

Conclusion

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

Lead

Tier 1 Evaluation

One site sample exceeds the background screening value of 37.82 mg/kg.

Slippage Test

K_c for lead is 2, and no site samples exceed the maximum background measurement (K=0). Because $K < K_c$, lead passes the Slippage test.

WRS Test

The p-level of 0.116 indicates weak agreement between the background and site distributions.

Box Plots

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

Conclusion

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

Magnesium

Tier 1 Evaluation

One site sample exceeds the background screening value of 905.94 mg/kg.

Slippage Test
K_c for magnesium is 2, 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 0.632 indicates strong agreement between the background and site distributions.

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

Conclusion
Because magnesium in sediment is within the range of background, it will not be carried forward for Tier 3 geochemical evaluation.

3.5 Surface Water

This section presents the results of the site-to-background comparisons for TAL metals in the Parcel 137Q-X surface water samples. Seventeen metals (aluminum, antimony, arsenic, beryllium, cadmium, chromium, cobalt, copper, lead, mercury, nickel, potassium, selenium, silver, thallium, vanadium, and zinc) had no detected concentrations in the surface water samples and are not considered further. The remaining metals (barium, calcium, iron, magnesium, manganese, 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 3 summarizes these results. Therefore, no metals will be carried forward for Tier 3 geochemical evaluation.

4.0 Summary and Conclusions

The statistical methodology used to compare the Parcel 137Q-X and background data sets for 23 elements in surface soil, subsurface soil, groundwater, sediment, and surface water include 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 (Tier 2 evaluation). 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 natural processes can explain the elevated concentrations. Tables 1 through 5 summarize the comparison test results and show the metals carried forward for geochemical evaluation.

5.0 References

Rosenbaum, S., 1954, "Tables for a Nonparametric Test of Location," ***Annals of Mathematical Statistics***, Vol. 24, pp. 146-150.

Science Application International Corporation (SAIC), 1998, ***Final Background Metals Survey Report, Fort McClellan, Anniston, Alabama***, prepared for U.S. Army Corps of Engineers, Mobile, Alabama, July.

Shaw Environmental, Inc., 2003, ***Selecting Site-Related Chemicals for Human Health and Ecological Risk Assessments for FTMC, Revision 2,*** Technical Memorandum, 24 June 2003 by Paul Goetchius.

U.S. Environmental Protection Agency (EPA), 1989, ***Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Final Guidance***, Office of Solid Waste, Waste Management Division, EPA/530/SW-89/026, July.

U.S. Environmental Protection Agency (EPA), 1992, ***Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Addendum to Interim Final Guidance***, Environmental Statistics and Information Division, Office of Policy, Planning, and Evaluation, EPA/530/R-93/003, July.

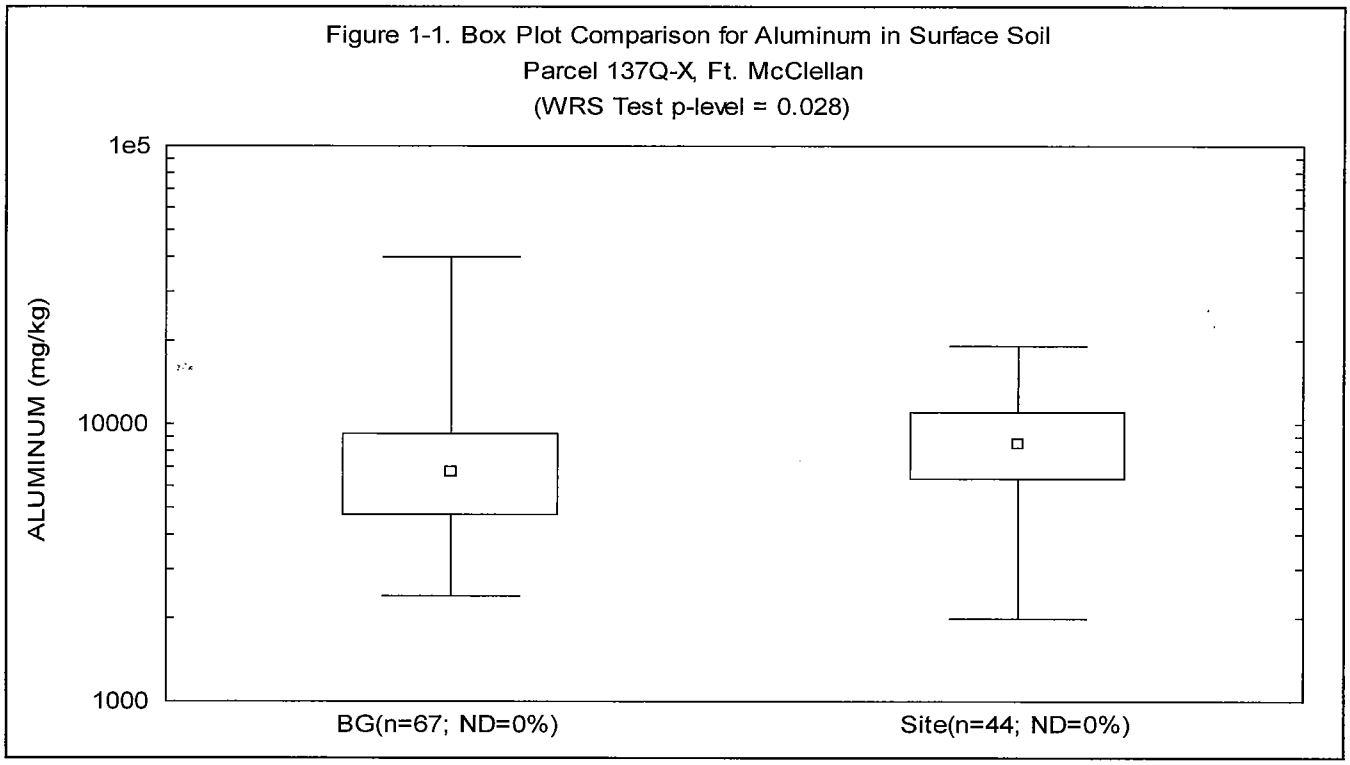
U.S. Environmental Protection Agency (EPA), 1994, ***Statistical Methods For Evaluating The Attainment Of Cleanup Standards***, Environmental Statistics and Information Division, Office of Policy, Planning, and Evaluation, EPA/230/R-94/004, June.

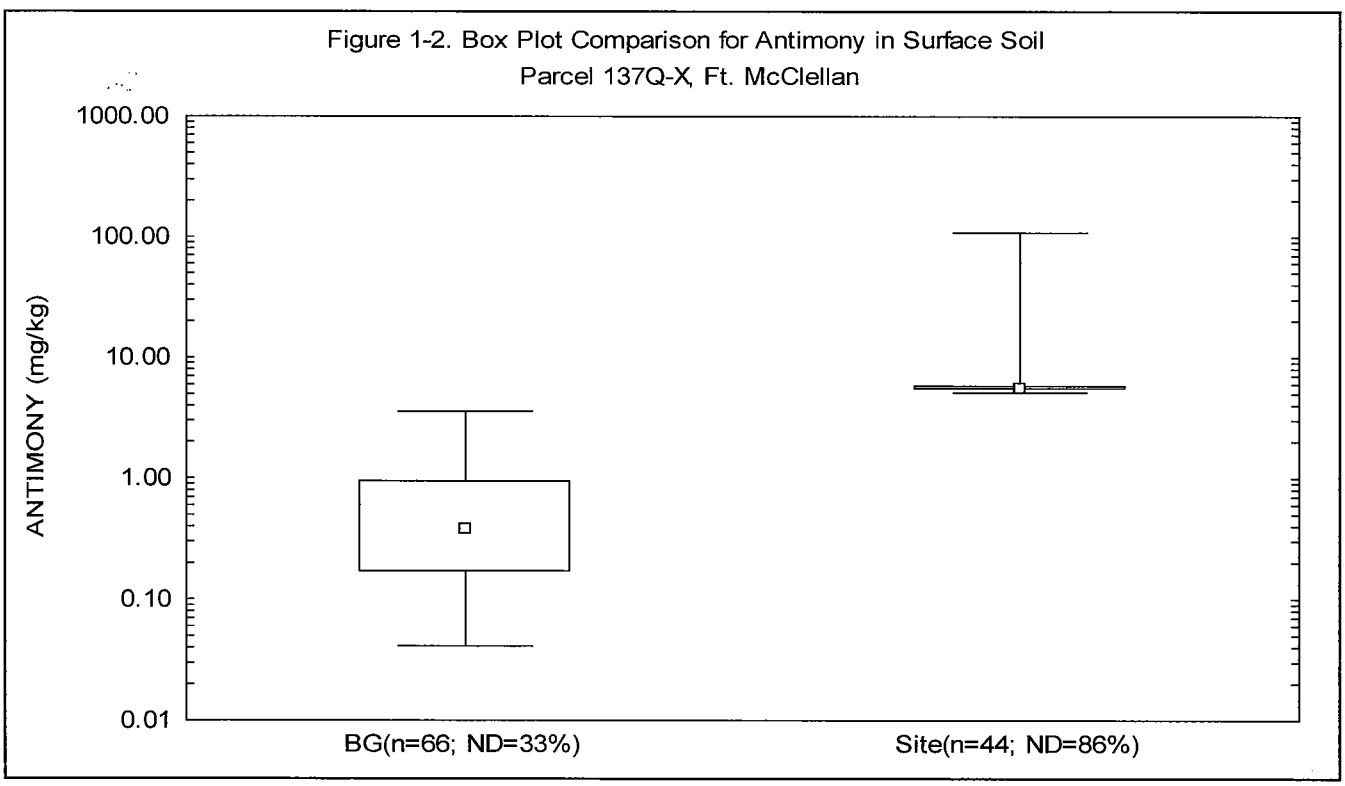
U.S. Environmental Protection Agency (EPA), 2000, ***Guidance for Data Quality Assessment: Practical Methods for Data Analysis, EPA QA/G-9, QA00 Update***, Office of Environmental Information, EPA/600/R-96/084, July.

U.S. Navy, 2002, ***Guidance for Environmental Background Analysis, Volume 1: Soil***, NFESC User's Guide UG-2049-ENV, Naval Facilities Engineering Command, Washington, D.C., April.

ATTACHMENT 1

Box Plots for Parcel 137Q-X
Ft. McClellan





Box Plots for Parcel 137Q-X
Ft. McClellan

Figure 1-3. Box Plot Comparison for Barium in Surface Soil
Parcel 137Q-X, Ft. McClellan
(WRS Test p-level = 0.645)

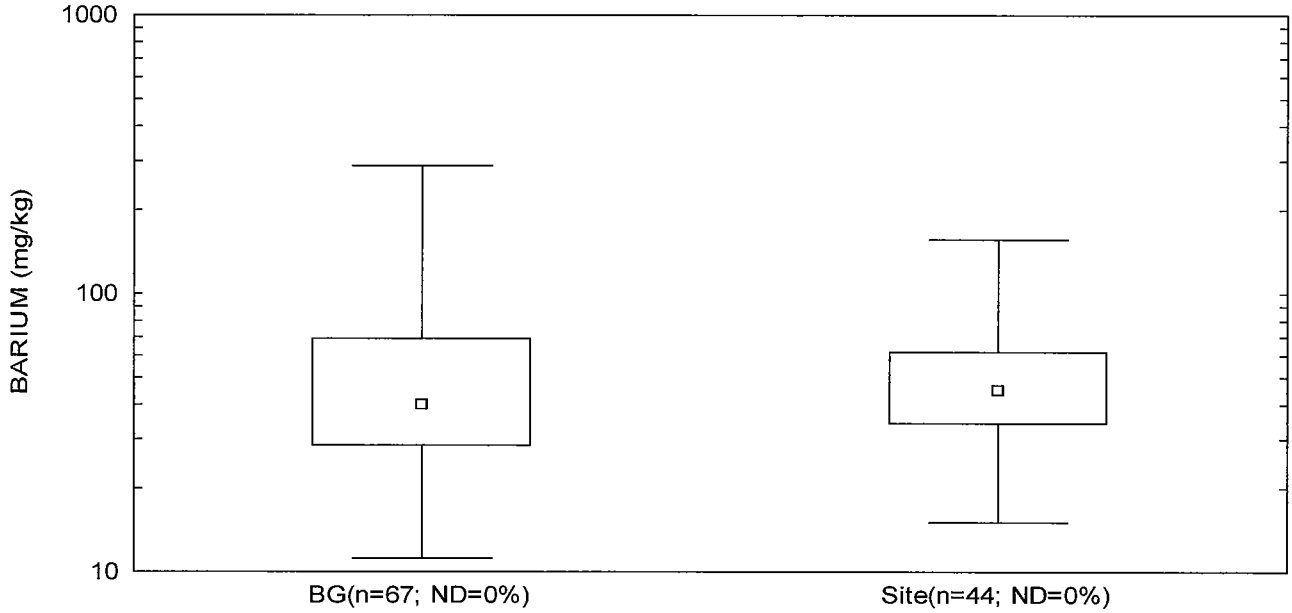
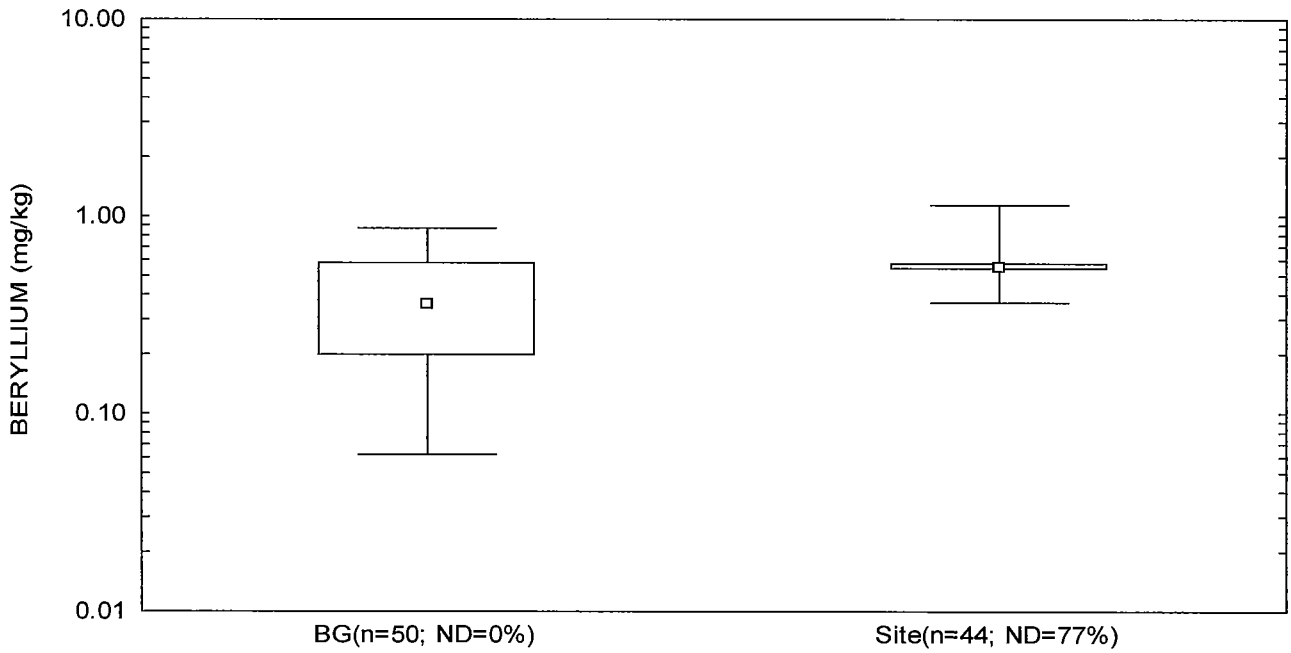


Figure 1-4. Box Plot Comparison for Beryllium in Surface Soil
Parcel 137Q-X, Ft. McClellan



Box Plots for Parcel 137Q-X
Ft. McClellan

Figure 1-5. Box Plot Comparison for Cobalt in Surface Soil
Parcel 137Q-X, Ft. McClellan
(WRS Test p-level = 0.004)

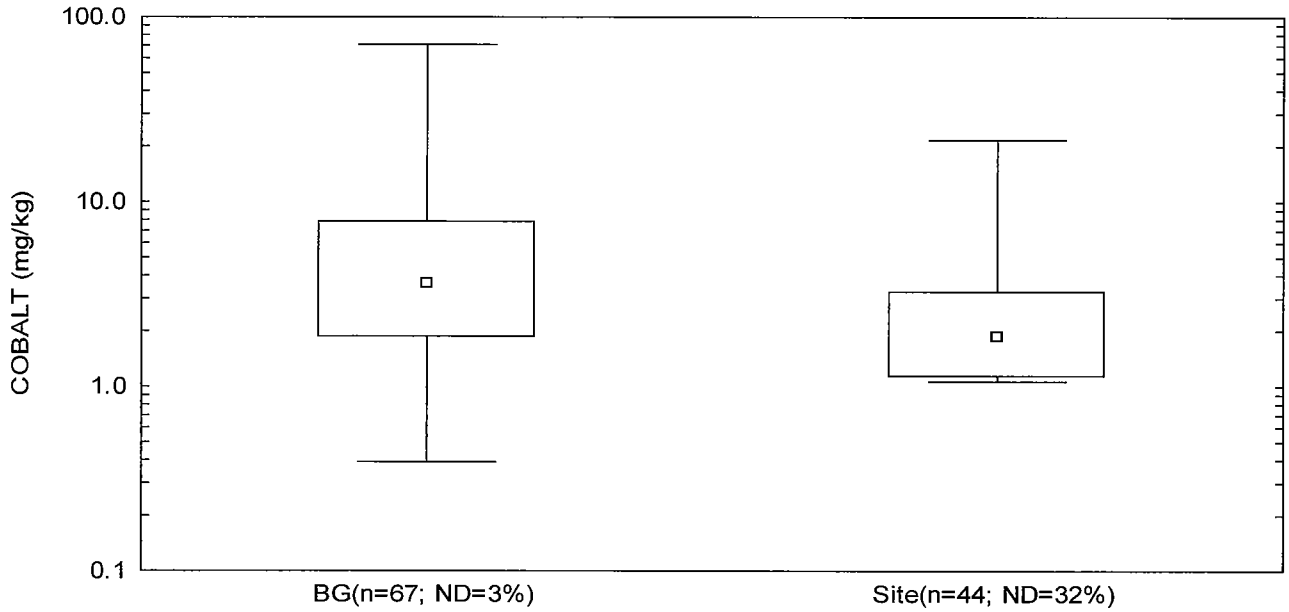
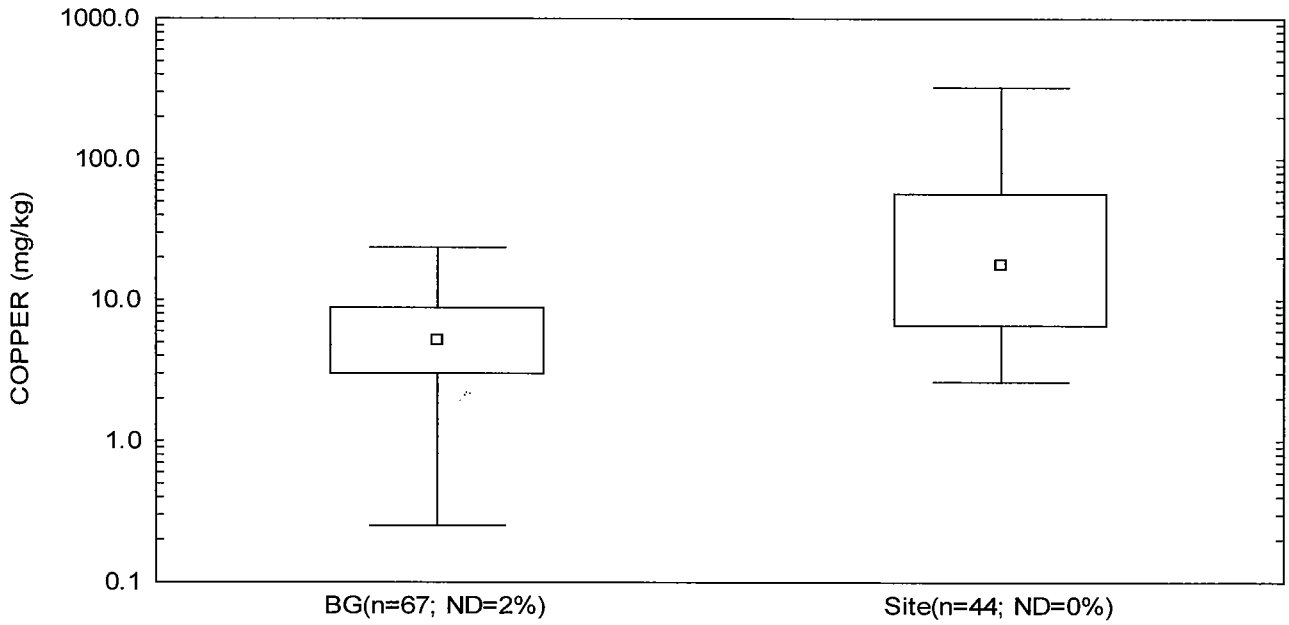


Figure 1-6. Box Plot Comparison for Copper in Surface Soil
Parcel 137Q-X, Ft. McClellan
(WRS Test p-level < 0.001)



Box Plots for Parcel 137Q-X
Ft. McClellan

Figure 1-9. Box Plot Comparison for Potassium in Surface Soil
Parcel 137Q-X, Ft. McClellan
(WRS Test p-level < 0.001)

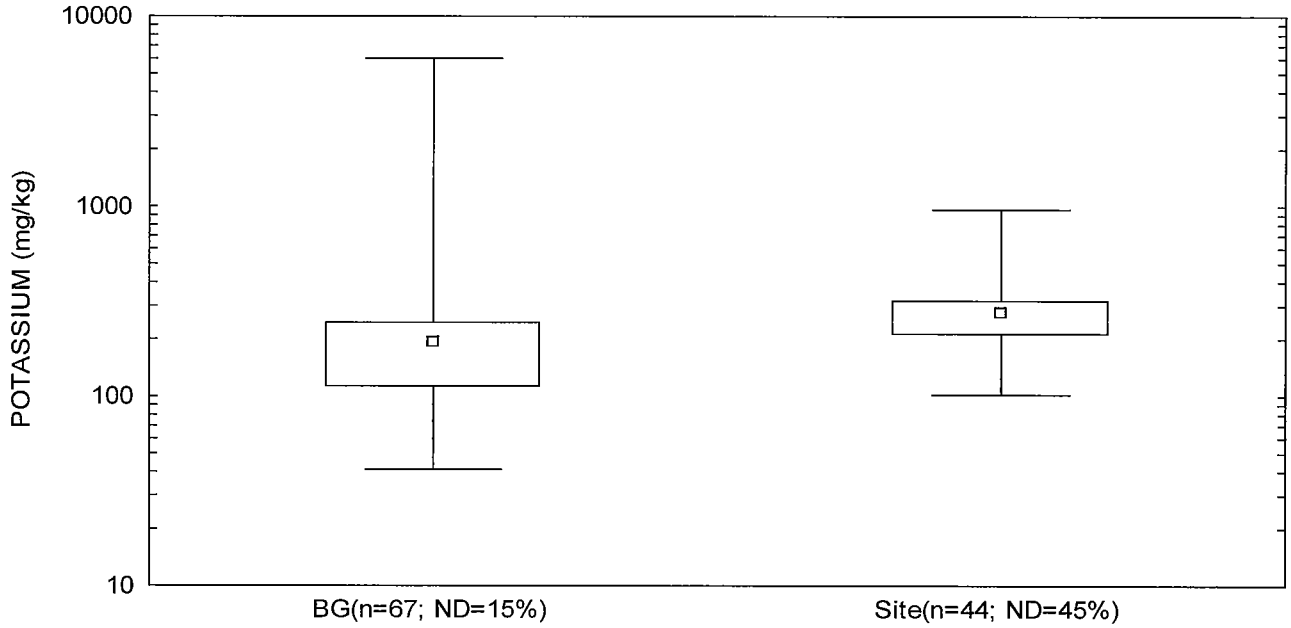
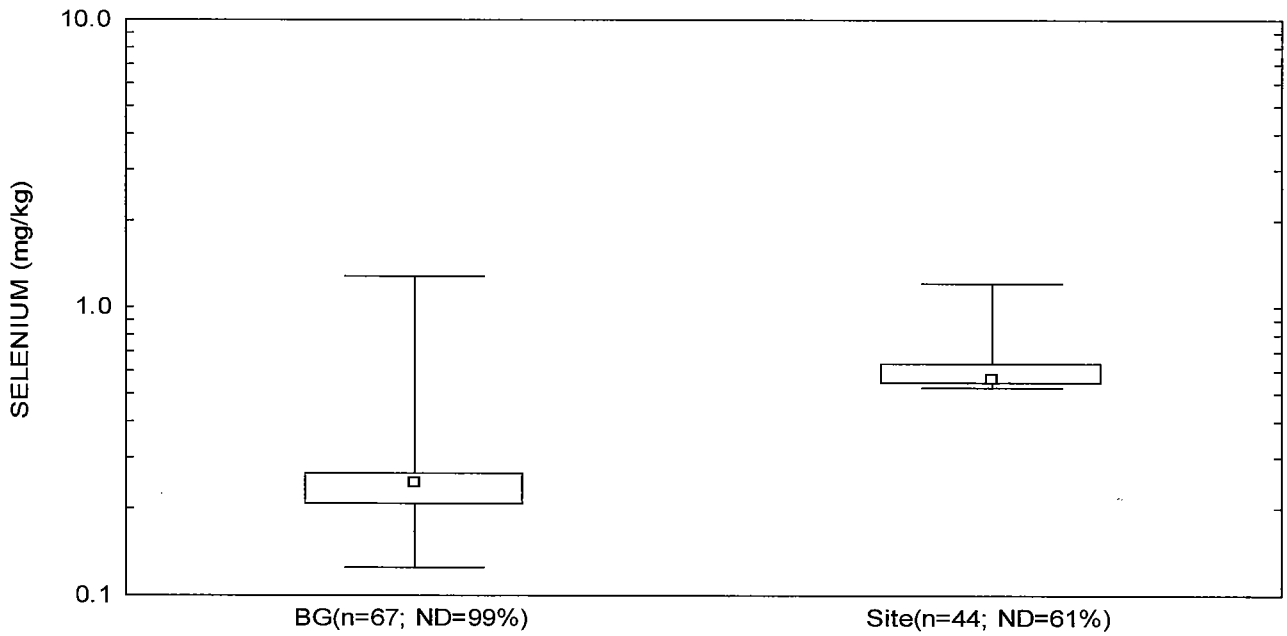


Figure 1-10. Box Plot Comparison for Selenium in Surface Soil
Parcel 137Q-X, Ft. McClellan



Box Plots for Parcel 137Q-X
Ft. McClellan

Figure 1-11. Box Plot Comparison for Zinc in Surface Soil
Parcel 137Q-X, Ft. McClellan
(WRS Test p-level = 0.121)

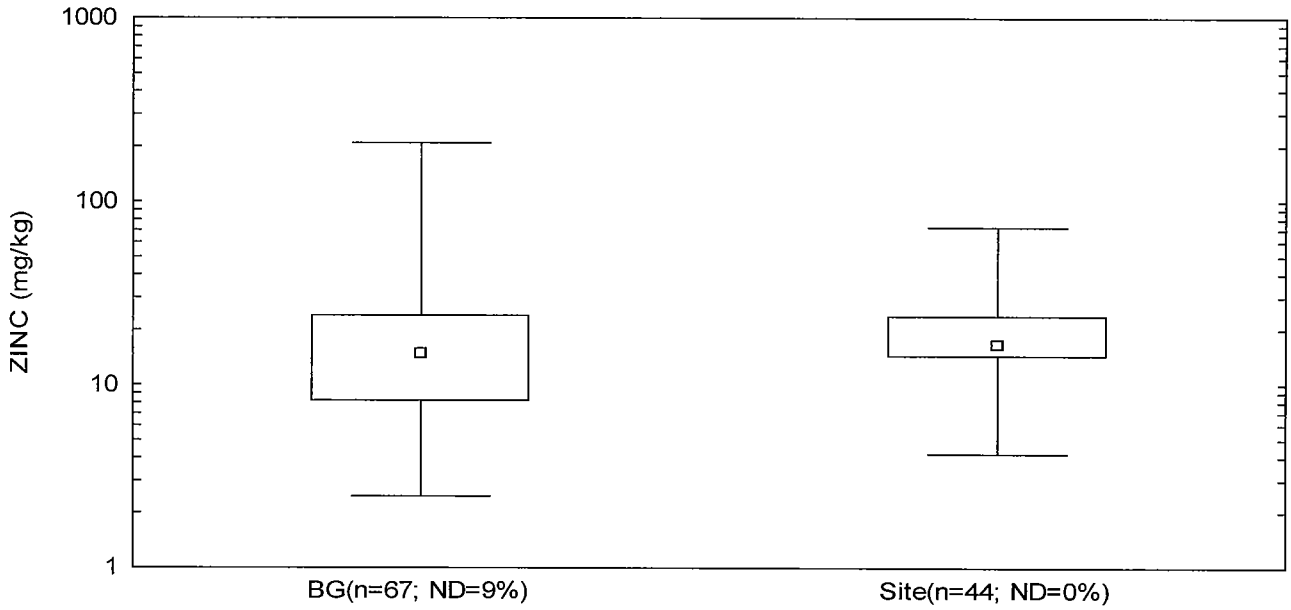
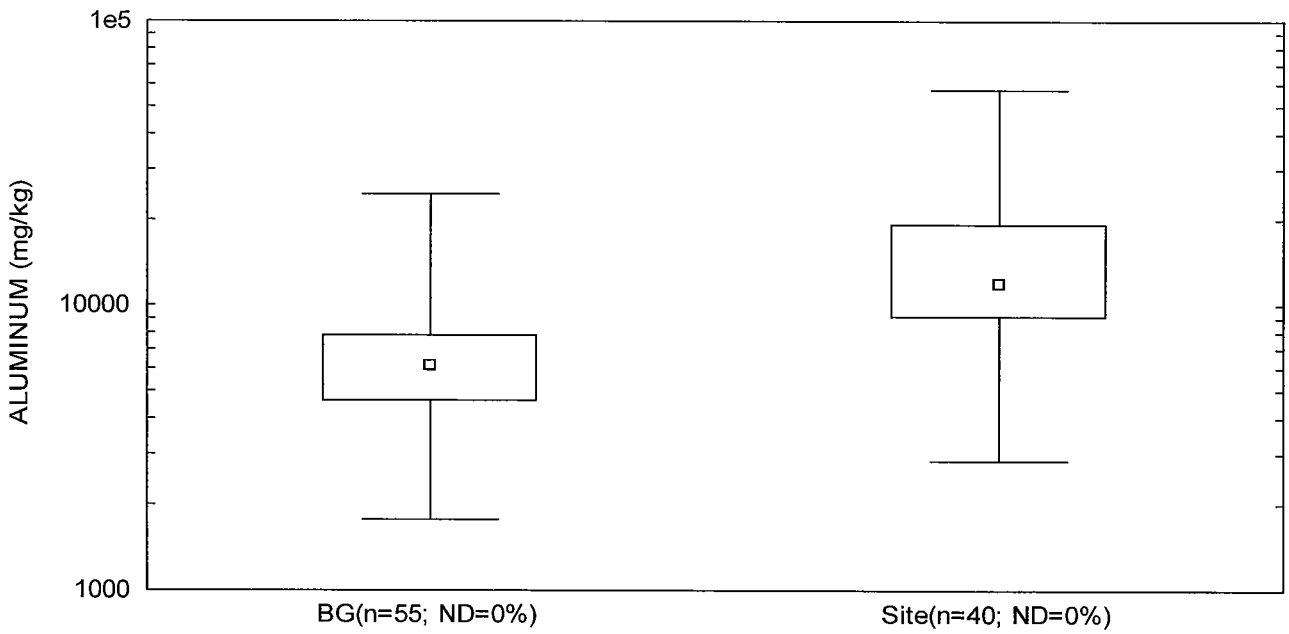
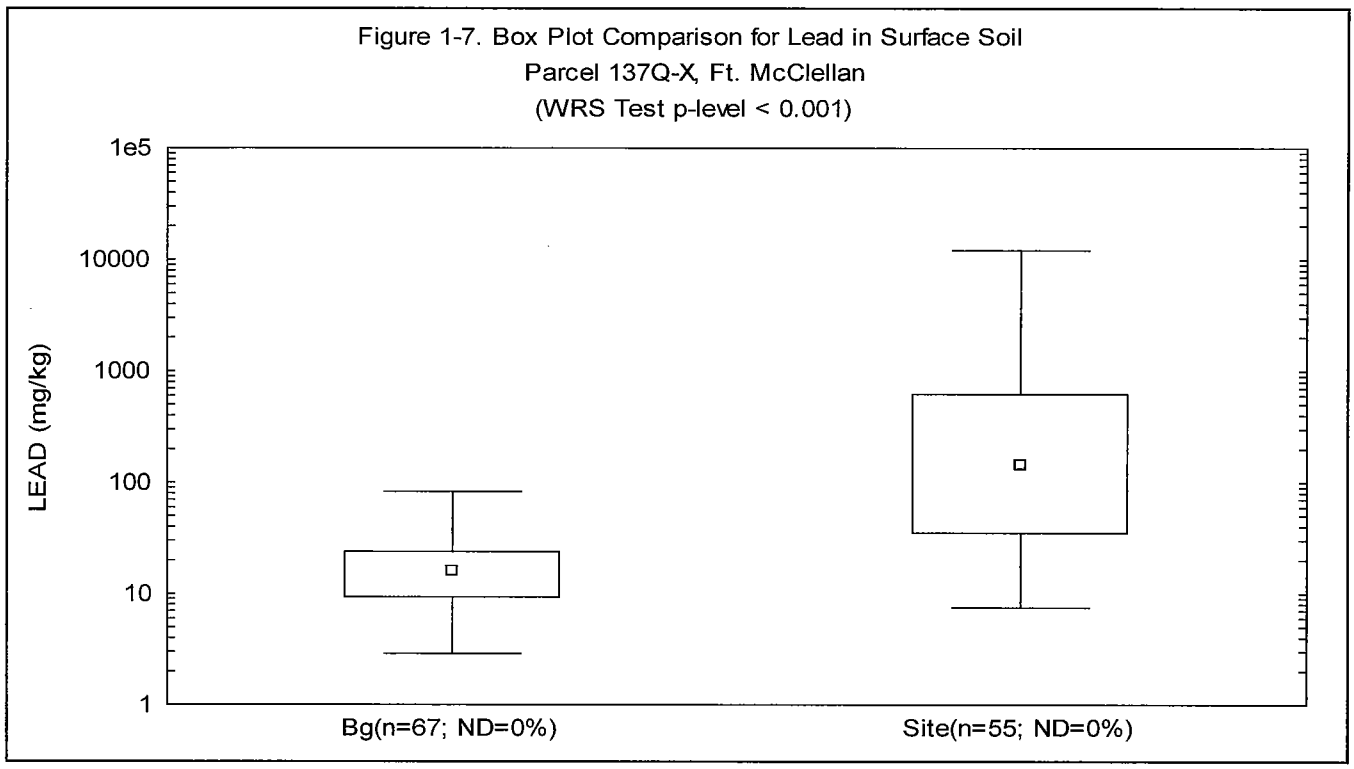
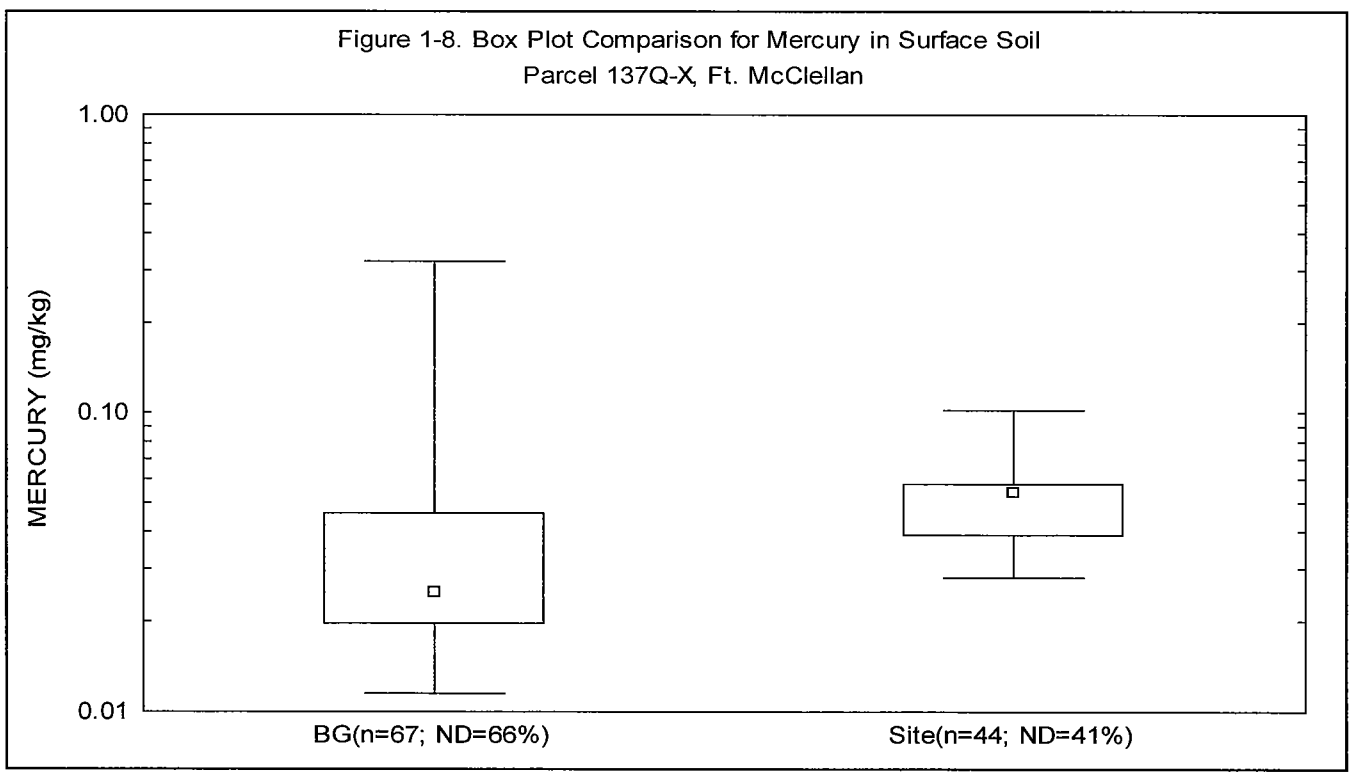


Figure 1-12. Box Plot Comparison for Aluminum in Subsurface Soil
Parcel 137Q-X, Ft. McClellan
(WRS Test p-level < 0.001)



Box Plots for Parcel 137Q-X
Ft. McClellan





Box Plots for Parcel 137Q-X
Ft. McClellan

Figure 1-13. Box Plot Comparison for Antimony in Subsurface Soil
Parcel 137Q-X, Ft. McClellan

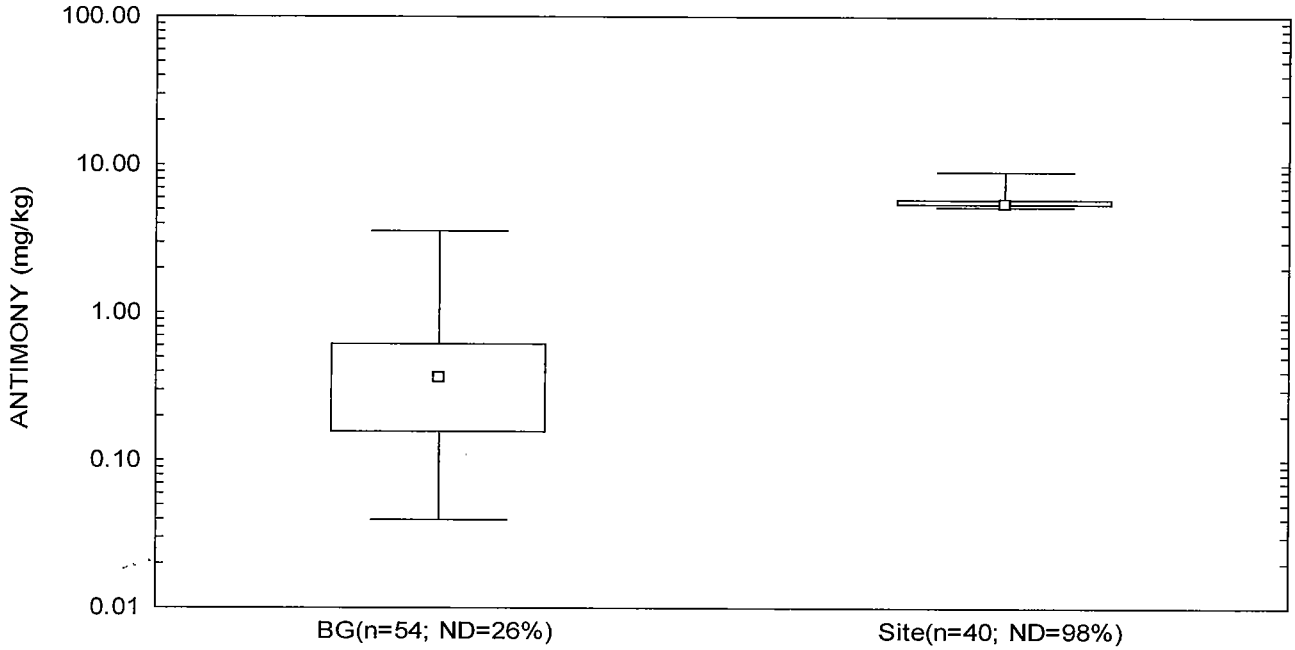
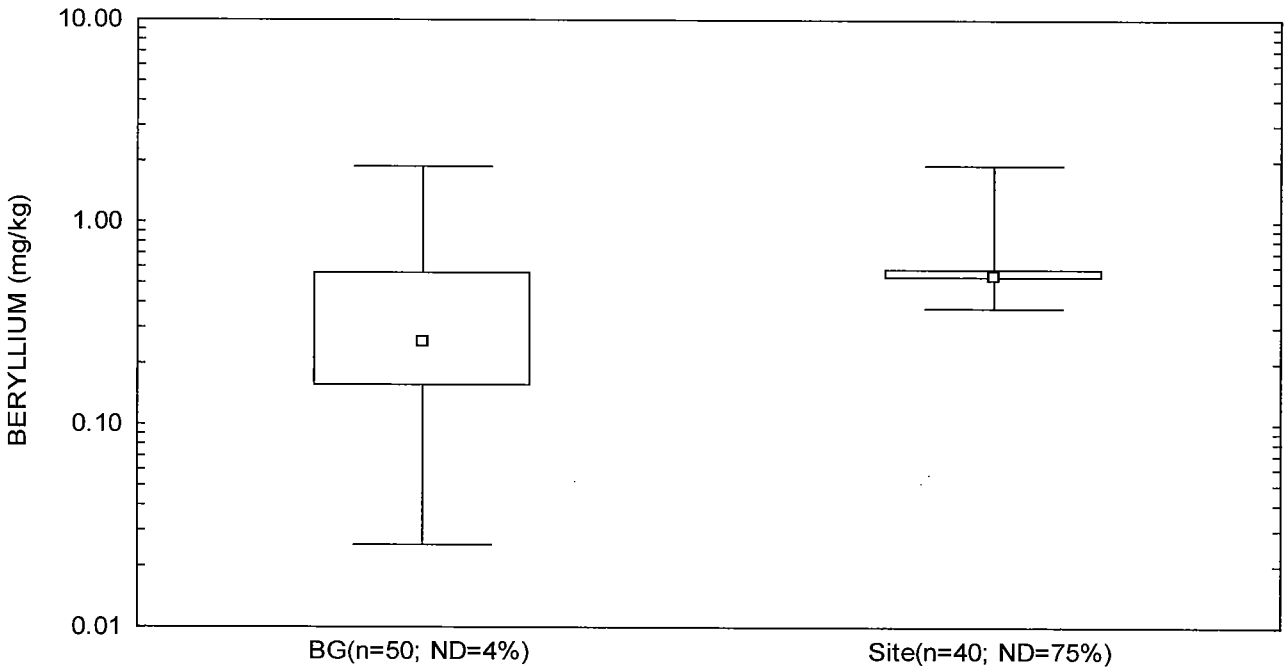


Figure 1-14. Box Plot Comparison for Beryllium in Subsurface Soil
Parcel 137Q-X, Ft. McClellan



Box Plots for Parcel 137Q-X
Ft. McClellan

Figure 1-15. Box Plot Comparison for Cadmium in Subsurface Soil
Parcel 137Q-X, Ft. McClellan

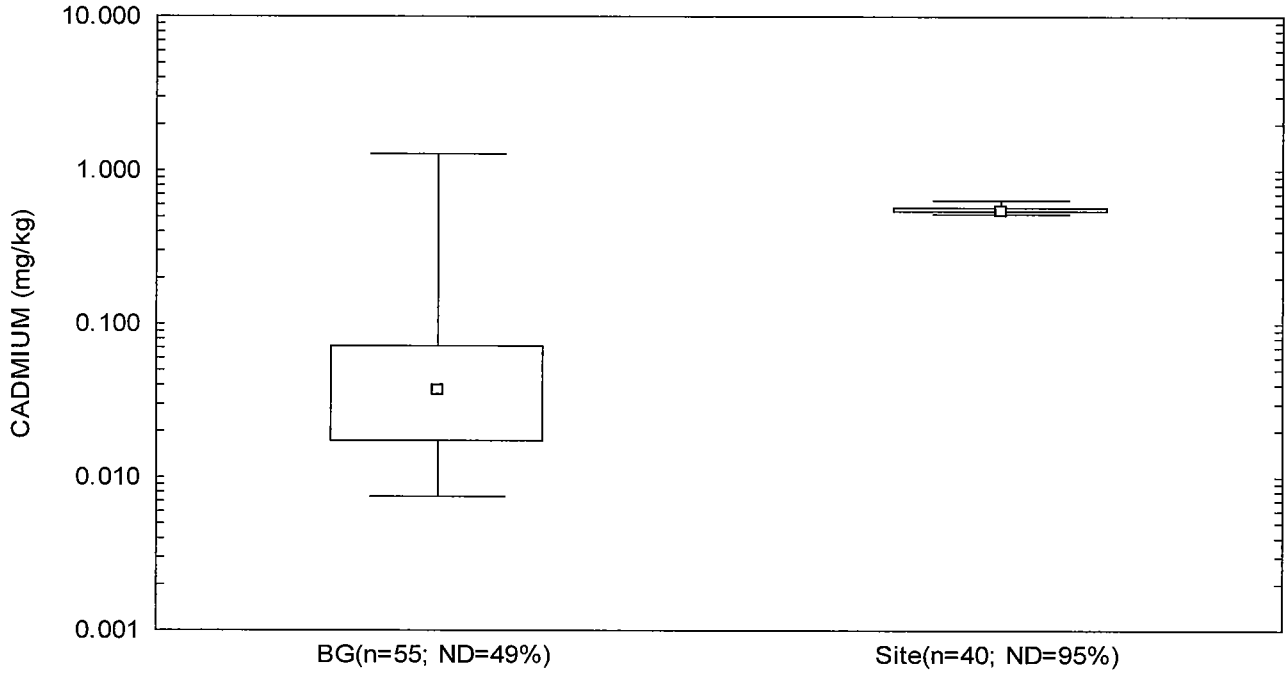
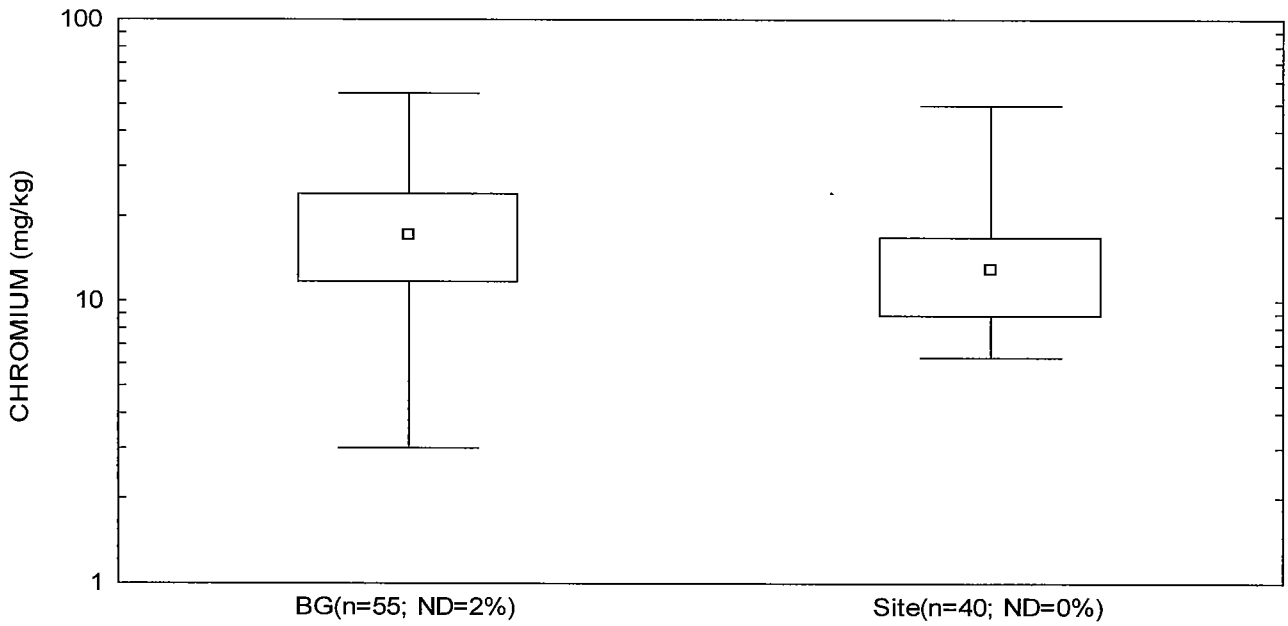


Figure 1-16. Box Plot Comparison for Chromium in Subsurface Soil
Parcel 137Q-X, Ft. McClellan
(WRS Test p-level = 0.016)



Box Plots for Parcel 137Q-X
Ft. McClellan

Figure 1-17. Box Plot Comparison for Copper in Subsurface Soil
Parcel 137Q-X, Ft. McClellan
(WRS Test p-level = 0.148)

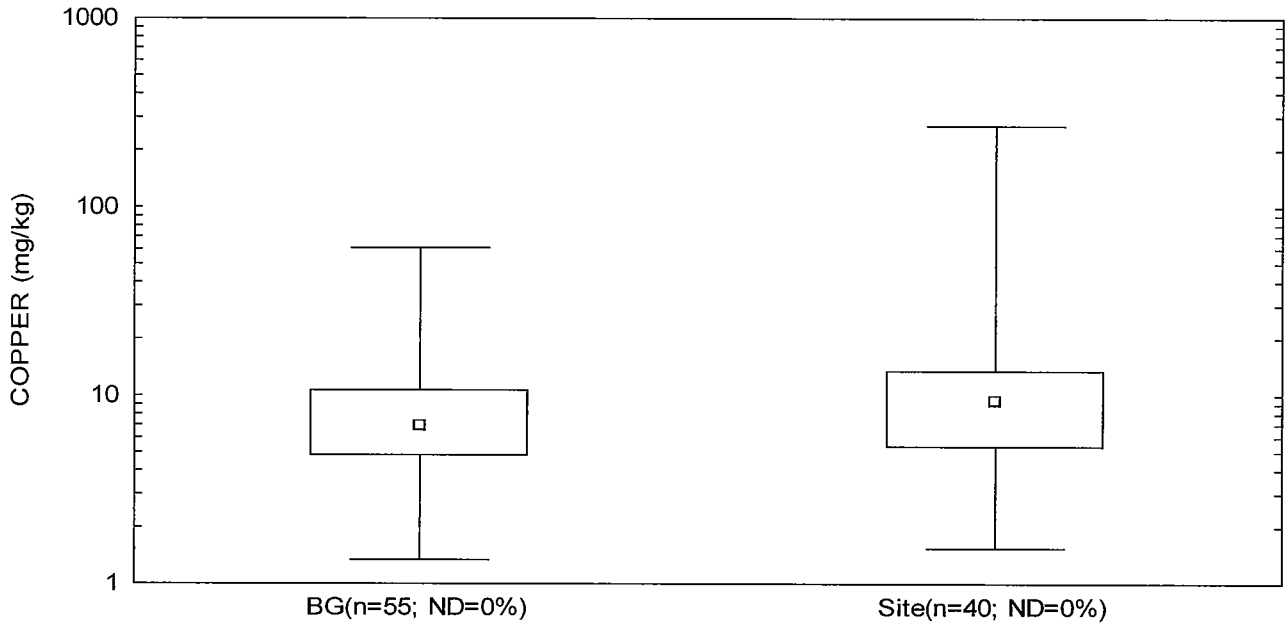
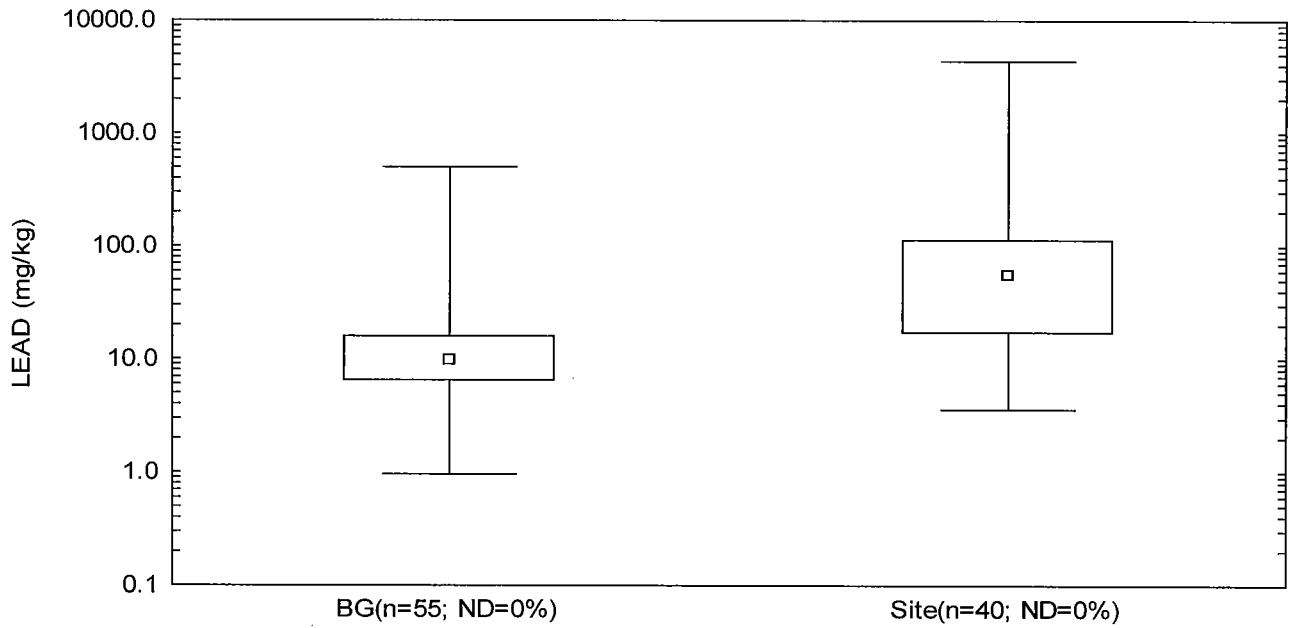


Figure 1-18. Box Plot Comparison for Lead in Subsurface Soil
Parcel 137Q-X, Ft. McClellan
(WRS Test p-level < 0.001)



Box Plots for Parcel 137Q-X
Ft. McClellan

Figure 1-19. Box Plot Comparison for Magnesium in Subsurface Soil
Parcel 137Q-X, Ft. McClellan
(WRS Test p-level < 0.001)

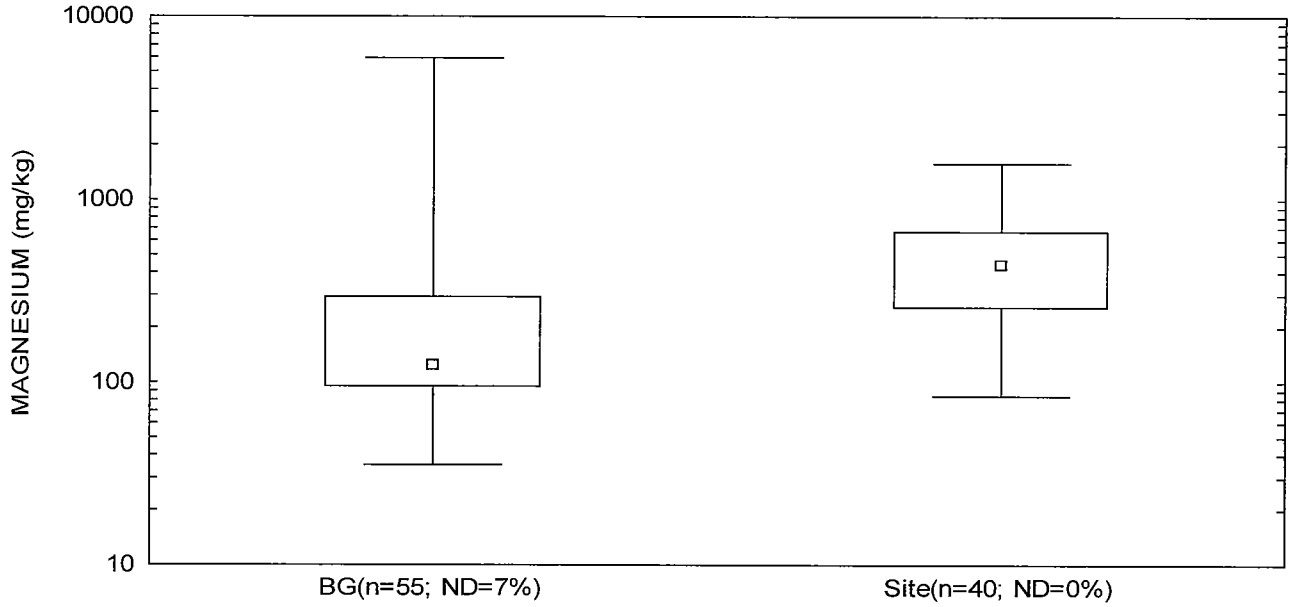
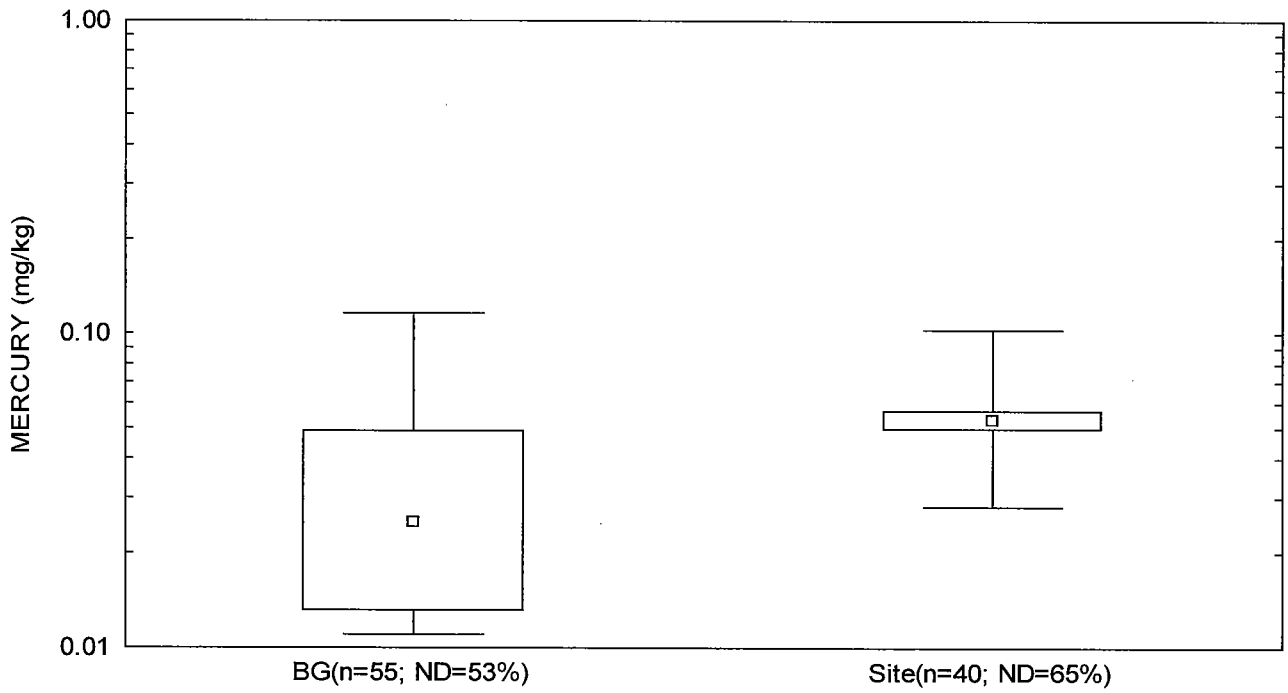


Figure 1-20. Box Plot Comparison for Mercury in Subsurface Soil
Parcel 137Q-X, Ft. McClellan



Box Plots for Parcel 137Q-X
Ft. McClellan

Figure 1-21. Box Plot Comparison for Potassium in Subsurface Soil
Parcel 137Q-X, Ft. McClellan
(WRS Test p-level < 0.001)

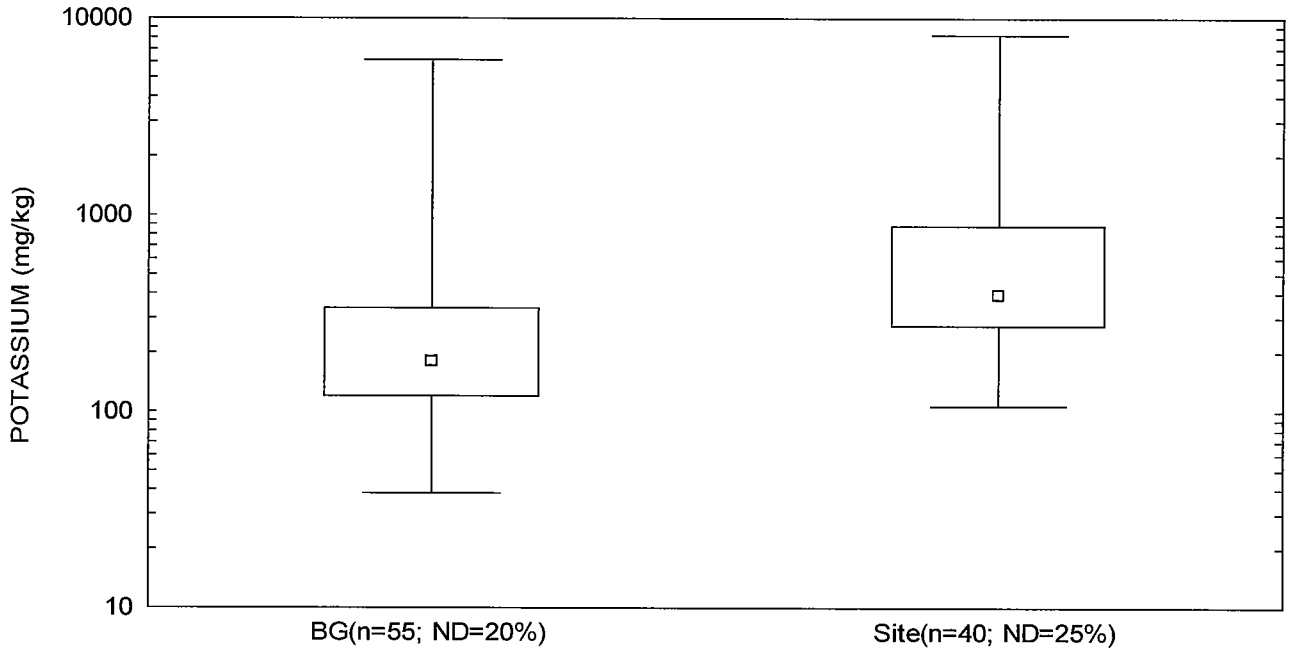
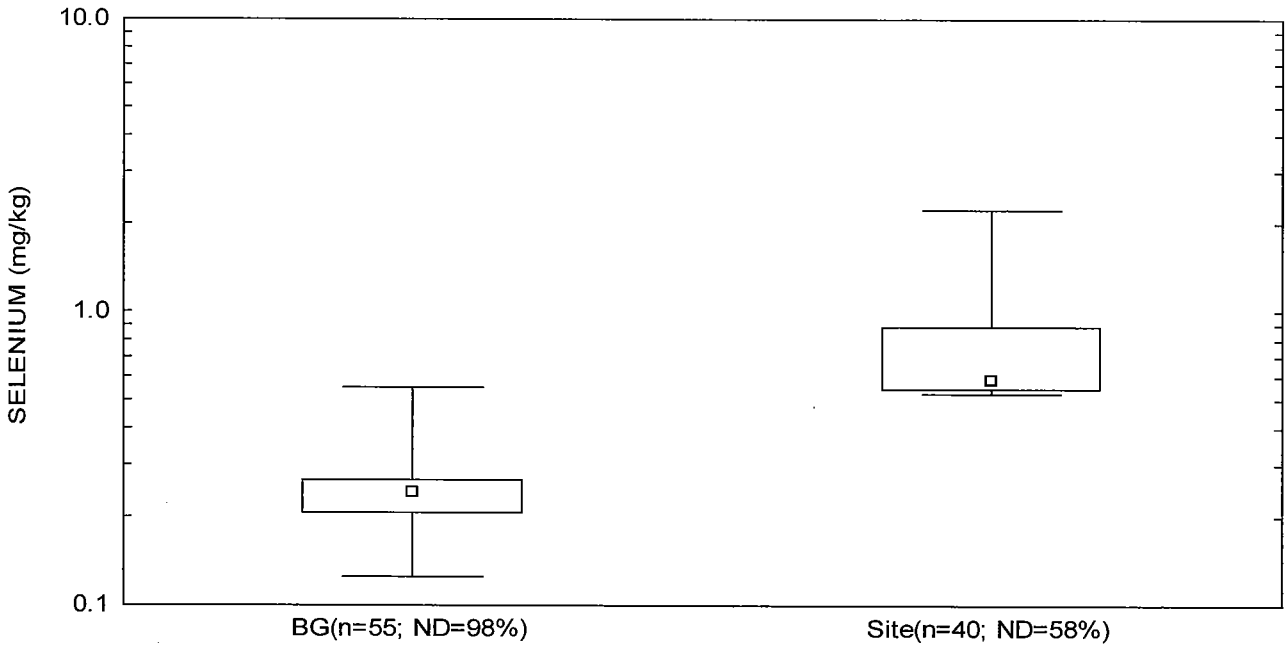


Figure 1-22. Box Plot Comparison for Selenium in Subsurface Soil
Parcel 137Q-X, Ft. McClellan



Box Plots for Parcel 137Q-X
Ft. McClellan

Figure 1-23. Box Plot Comparison for Vanadium in Subsurface Soil
Parcel 137Q-X, Ft. McClellan
(WRS Test p-level = 0.003)

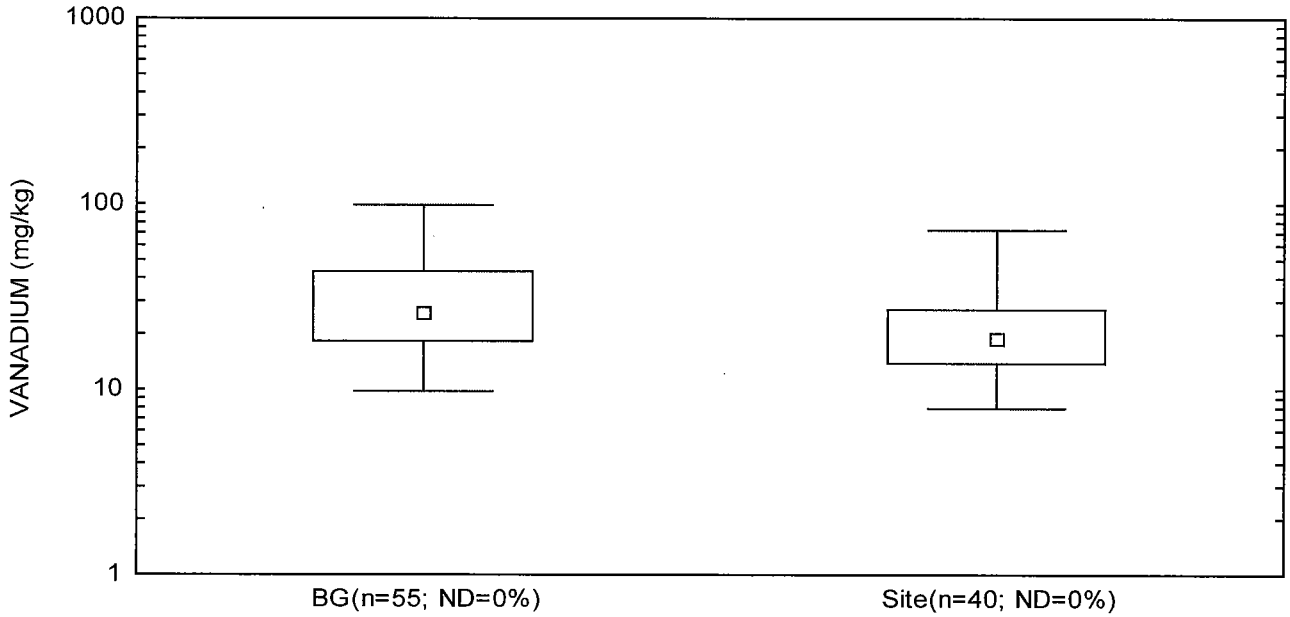
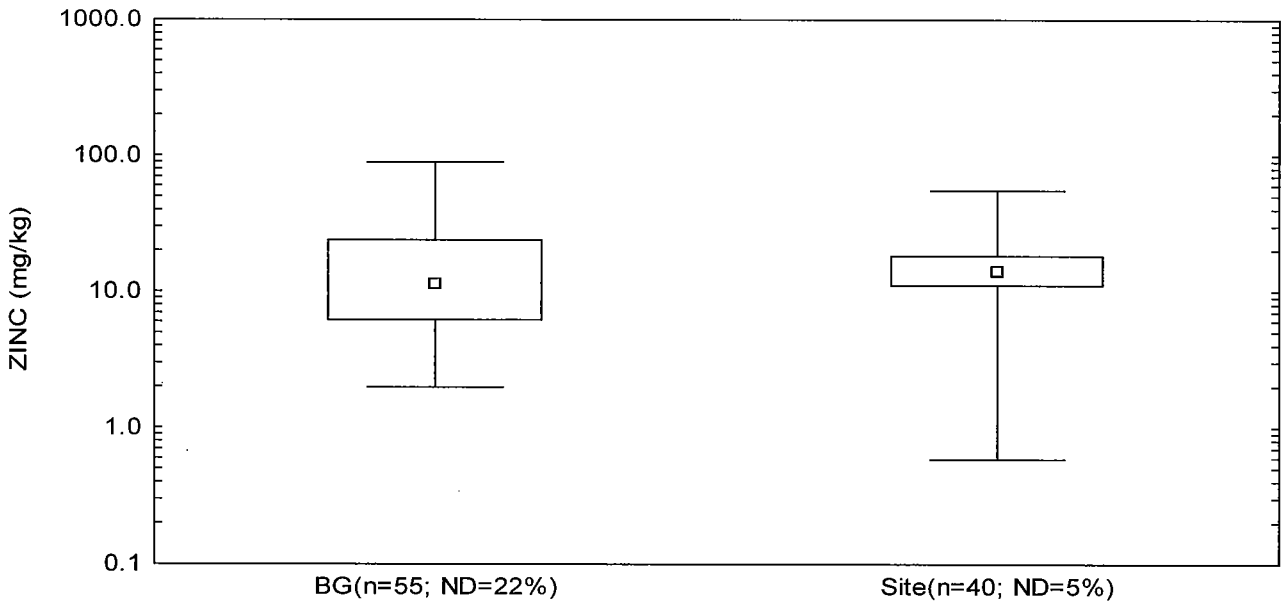


Figure 1-24. Box Plot Comparison for Zinc in Subsurface Soil
Parcel 137Q-X, Ft. McClellan
(WRS Test p-level = 0.396)



Box Plots for Parcel 137Q-X
Ft. McClellan

Figure 1-25. Box Plot Comparison for Aluminum in Groundwater
Parcel 137Q-X, Ft. McClellan
(WRS Test p-level = 0.074)

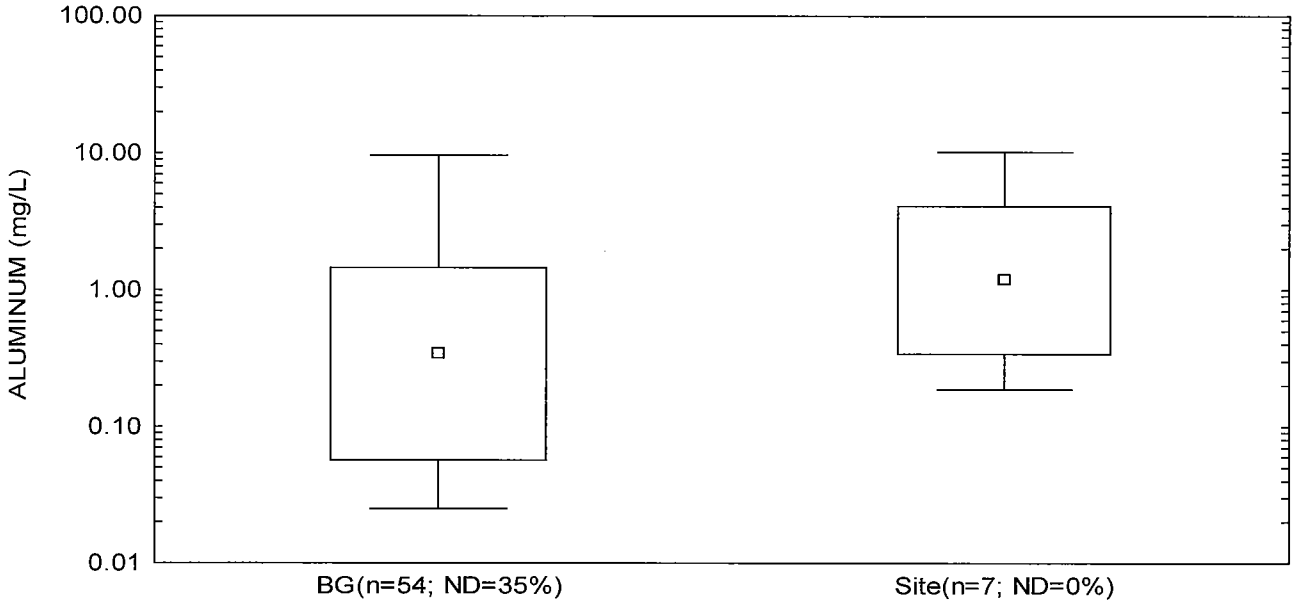
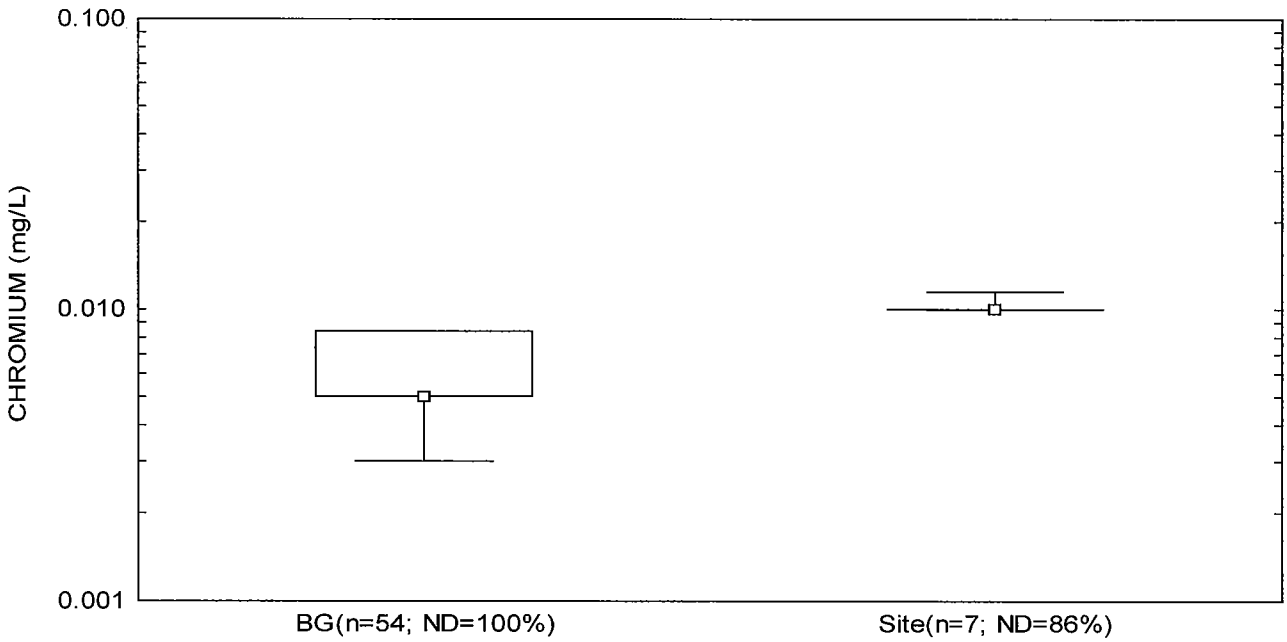


Figure 1-26. Box Plot Comparison for Chromium in Groundwater
Parcel 137Q-X, Ft. McClellan



Box Plots for Parcel 137Q-X
Ft. McClellan

Figure 1-27. Box Plot Comparison for Iron in Groundwater
Parcel 137Q-X, Ft. McClellan
(WRS Test p-level = 0.619)

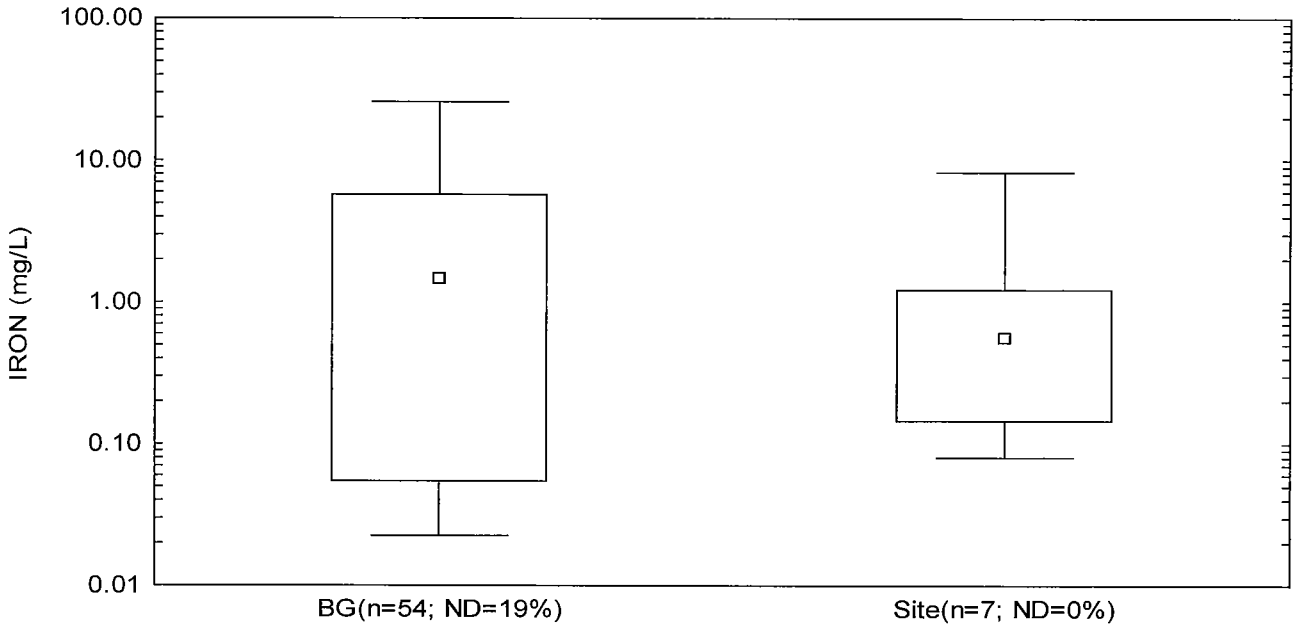
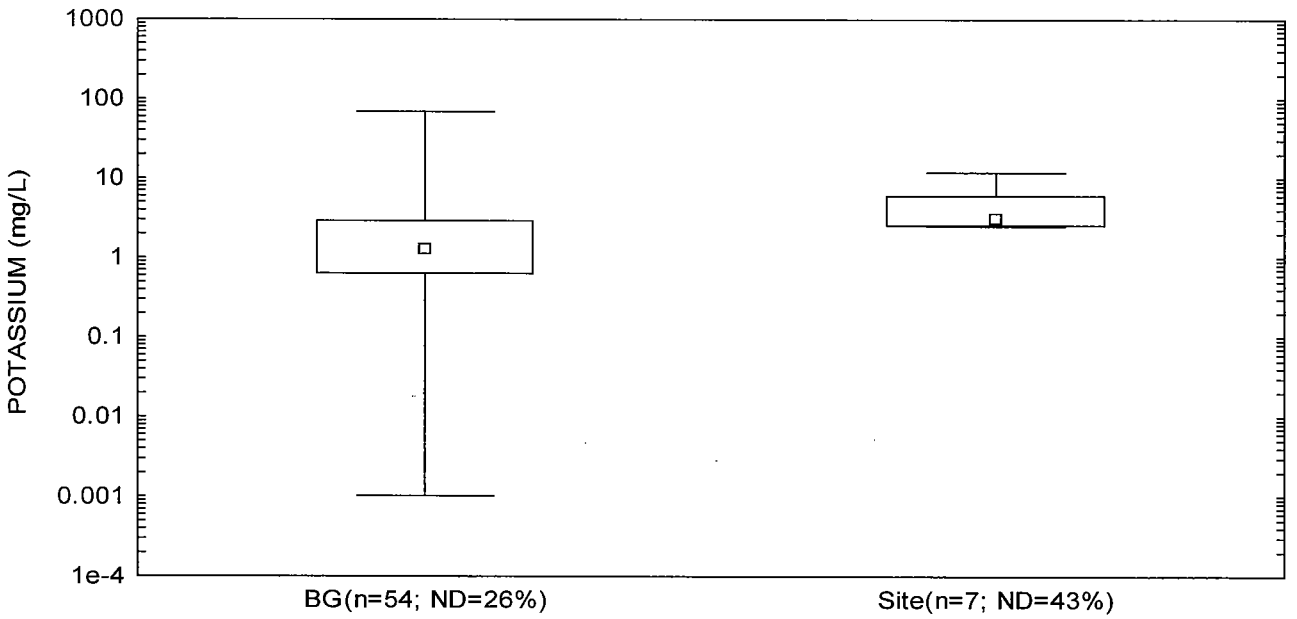


Figure 1-28. Box Plot Comparison for Potassium in Groundwater
Parcel 137Q-X, Ft. McClellan
(WRS Test p-level = 0.009)



Box Plots for Parcel 137Q-X
Ft. McClellan

Figure 1-29. Box Plot Comparison for Calcium in Sediment
Parcel 137Q-X, Ft. McClellan
(WRS Test p-level = 0.176)

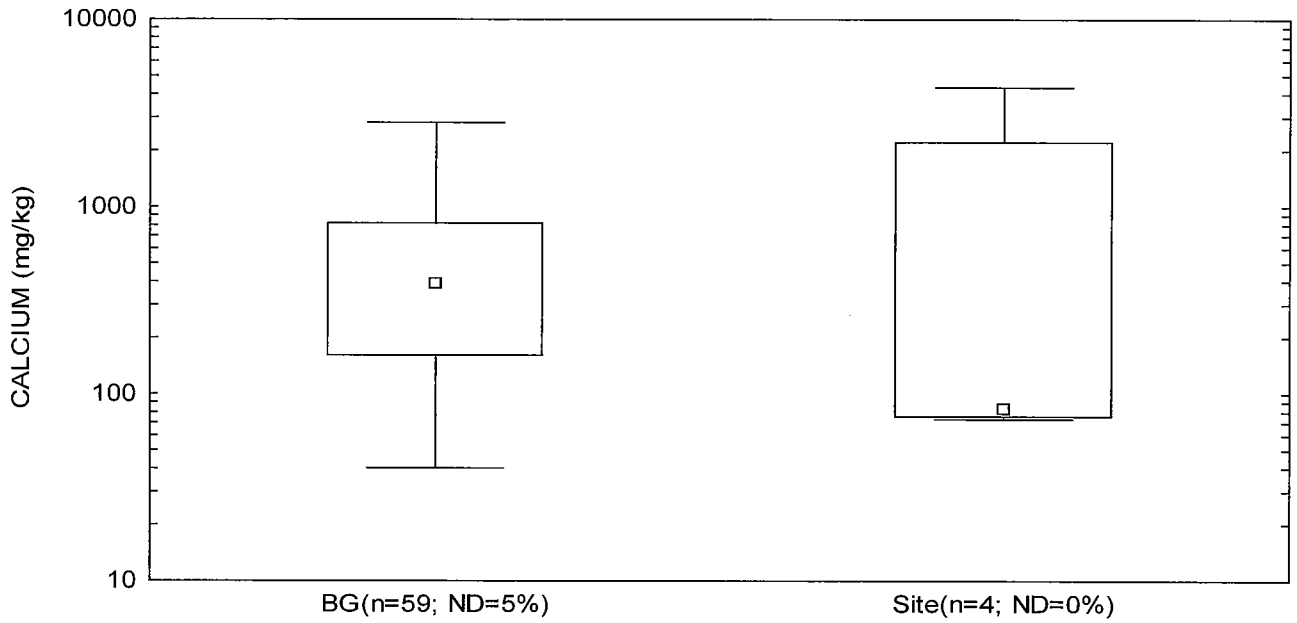
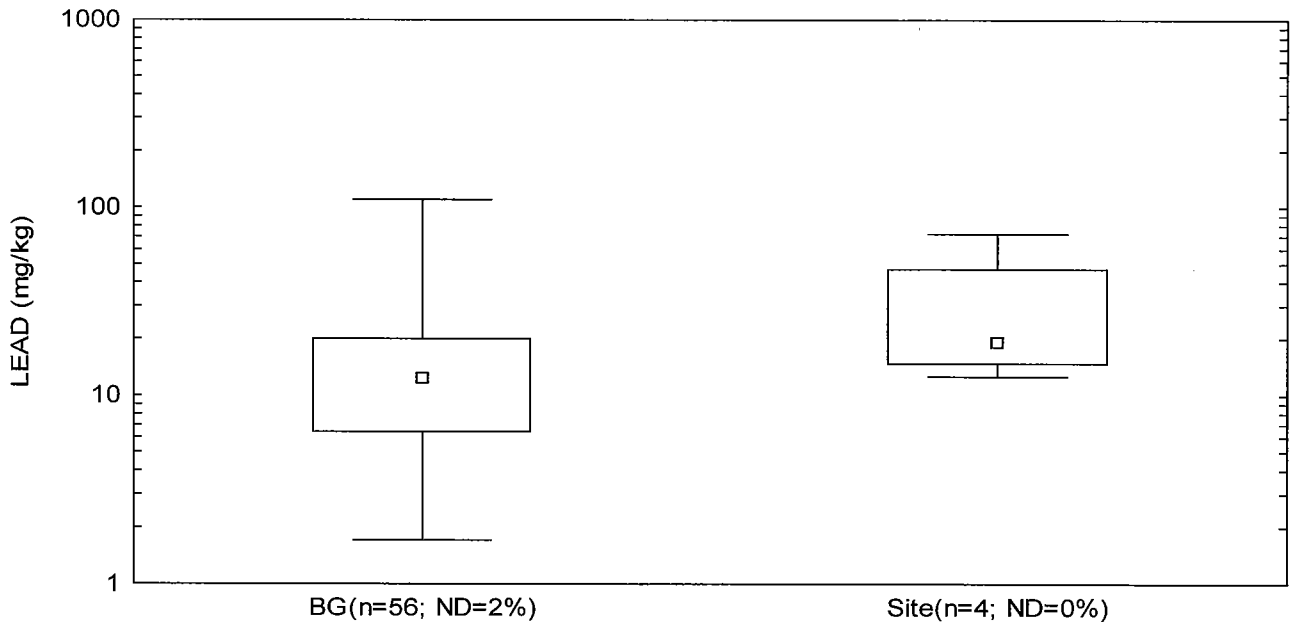
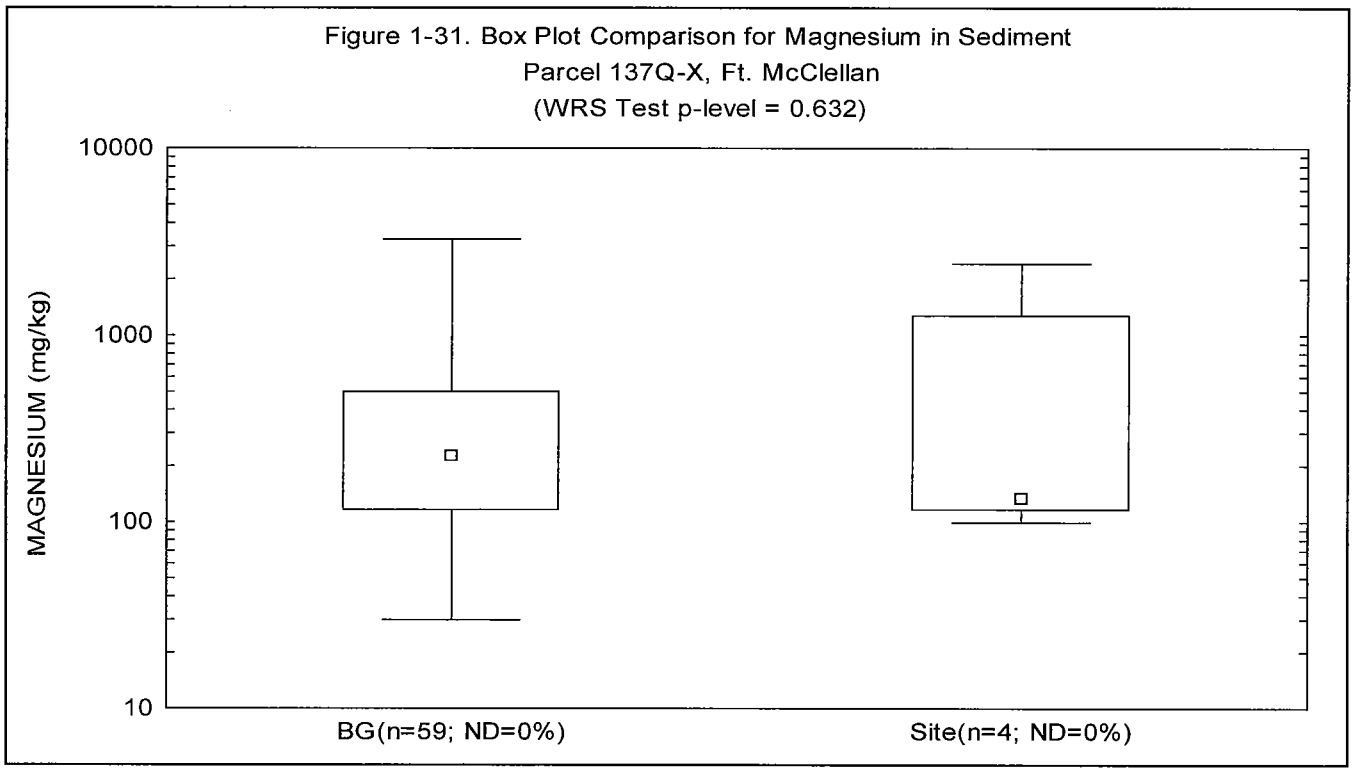


Figure 1-30. Box Plot Comparison for Lead in Sediment
Parcel 137Q-X, Ft. McClellan
(WRS Test p-level = 0.116)



Box Plots for Parcel 137Q-X
Ft. McClellan



GEOCHEMICAL
(TIER 3)

Geochemical Evaluation of Metals in Site Media
Former 81mm Mortar Range, Parcel 137Q-X
Fort McClellan, Alabama

1.0 Introduction

This report provides the results of a geochemical evaluation of inorganic constituents in soil, sediment, and groundwater samples from the Former 81mm Mortar Range, Parcel 137Q-X, at Fort McClellan in Calhoun County, Alabama. Ten elements in soil, one element in sediment, and two elements in groundwater 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 evaluation consist of 55 surface soil samples (obtained from depths of 0 to 0.5 or 0 to 1 foot below ground surface [bgs]) and 40 subsurface soil samples (obtained from various depths ranging from 1 to 12 feet bgs) collected from June 2002 through March 2004; four sediment samples collected in March 2004; and seven unfiltered groundwater samples collected in July 2002 and July 2003. Most of the site samples were analyzed for the full suite of 23 target analyte list (TAL) metals. However, 11 of the 55 surface soil samples were analyzed only for lead. Installation-wide background data for TAL metals in soil and groundwater are provided in the background study report (Science Applications International Corporation, 1998) and are used in the following evaluation.

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, Former 81mm Mortar Range, Parcel 137Q-X," 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 Parcel 137Q-X. 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 $HAsO_4^{-2}$ and $H_2AsO_4^-$ (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 a 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.

Over a limited range of concentrations, the adsorption of a trace element on a mineral surface can usually be described by a linear isotherm. Over a wider range of concentrations, a two-parameter curved fit (such as a Freundlich or Langmuir isotherm) may be more appropriate for some trace elements. In this report the elemental correlations are referred to as "linear trends," although though 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 [$Cr(OH)_2^+$, $Cr(OH)_3^0$, and $Cr(OH)_4^-$] 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. The effects of suspended particulates are discussed below.

Effects of Suspended Particulates. Under natural conditions, metal concentrations are commonly controlled through adsorption on suspended particulates. The most common suspended particulates in groundwater samples are clay minerals, hydrous aluminum oxides ($Al_2O_3 \bullet nH_2O$), and aluminum hydroxides [$Al(OH)_3$], hereafter referred to as "clays"; and iron oxide (Fe_2O_3), hydrous iron oxide, iron hydroxide [$Fe(OH)_3$], and iron oxyhydroxide ($FeO \bullet OH$) minerals, hereafter referred to as "iron oxides." Aluminum is a primary component of all clay

minerals, which have low solubilities over the neutral pH range (6 to 8). Measured concentrations of aluminum greater than approximately 1 milligram per liter (mg/L) indicate the presence of suspended clay minerals (Hem, 1985; Stumm and Morgan, 1996); the higher the aluminum concentration, the greater the mass of suspended clay minerals in the sample. Iron oxides also have very low solubilities under neutral pH conditions, but they are redox-sensitive. Measured iron concentrations above approximately 1 mg/L under neutral-pH, moderate to oxidizing redox conditions indicate the presence of suspended iron oxides (Hem, 1985).

The same concepts involved in the evaluation of soil and sediment data also apply to groundwater and surface water data: samples containing trace elements adsorbed on suspended clay particulates should show a positive correlation with aluminum concentrations, and 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). Divalent cations such as barium, lead, and zinc have an affinity to adsorb on clay surfaces, which tend to maintain a net negative charge (EPRI, 1984; Brookins, 1988). Concentrations of barium, lead, or zinc in a set of samples can be evaluated through comparison to the corresponding aluminum concentrations. Under oxidizing conditions, elements such as arsenic, selenium, and vanadium are usually present as oxyanions and have a strong affinity to adsorb on iron oxide surfaces, which tend to maintain a net positive charge (Pourbaix, 1974; Hem, 1985; Brookins, 1988; Bowell, 1994). Concentrations of arsenic, selenium, or vanadium can be evaluated through comparison to the corresponding iron concentrations. Chromium can exist as a mixture of aqueous species with different charges [$Cr(OH)_2^+$, $Cr(OH)_3^o$, and $Cr(OH)_4^-$], depending on pH (EPRI, 1984), so it can be distributed on several different types of sorptive surfaces, including clay and iron oxide minerals.

As an example geochemical evaluation for groundwater or surface water, the detected concentrations of zinc would be plotted on the y-axis and the corresponding detected concentrations of aluminum would be plotted on the x-axis. A linear trend with a positive slope (positive correlation) indicates that the zinc in those samples is associated with suspended clay minerals at a relatively constant ratio, and that the zinc is natural. A sample that plots above the linear trend contains excess zinc beyond that which can be explained by the suspended clay content and may contain a component of contamination.

Over a limited range of concentrations, the adsorption of a trace element on a mineral surface can usually be described by a linear isotherm. Over a wider range of concentrations, a two-

parameter curved fit (such as a Freundlich or Langmuir isotherm) may be more appropriate for some trace elements. In this report the elemental correlations are referred to as "linear trends," although though there may be some degree of curvature to the natural relationship.

In addition to the evaluation of trace-versus-major element correlations, the effects of suspended particulates can be assessed via the evaluation of element-versus-turbidity correlations, element-versus-total suspended solids (TSS) correlations, and the comparison of filtered versus unfiltered splits. Evaluations of turbidity and TSS measurements provide additional lines of evidence that support the conclusions drawn from the evaluation of trace-versus-major element correlations. However, turbidity and TSS measurements are qualitative and cannot distinguish between suspended iron oxides, clay minerals, and natural organic material. Consequently, they do not provide the mechanistic information afforded by the correlations of trace elements versus aluminum or trace elements versus iron. Comparisons of filtered versus unfiltered splits of samples are highly informative and permit the identification of elements that are present as suspended particulates versus those that are in true solution. However, filtered-versus-unfiltered comparisons cannot be performed for the majority of Parcel 137Q-X samples because only one sample (RH3001) has both filtered and unfiltered splits.

3.0 Results of the Geochemical Evaluation of Multiple Metals in Soil

This section presents the results of the geochemical evaluation of aluminum, antimony, cadmium, copper, lead, magnesium, mercury, potassium, selenium, and zinc in soil samples from Parcel 137Q-X. Correlation plots are provided in Attachment 1. Table 1 lists the samples identified as containing anomalously high element concentrations, and provides their location codes and depth intervals.

As previously noted, 44 of the 55 surface soil samples and all 40 subsurface soil samples collected at Parcel 137Q-X were analyzed for the full list of 23 TAL metals (which includes the primary reference elements aluminum, iron, and manganese). Accordingly, these are the only samples that can be examined during the geochemical evaluation. For ease of description in this report, these samples are referred to as the "TAL samples." Eleven surface soil samples were analyzed only for lead. These samples lack data for the primary reference elements and thus cannot be included in the correlation plots. These samples are referred to hereafter as the "non-TAL samples."

Table 1

Soil Samples Containing Anomalously High Element Concentrations
Former 81mm Mortar Range, Parcel 137Q-X
Fort McClellan, Calhoun County, Alabama

Medium	Sample Location	Sample No.	Date	Depth Interval [a]	TAL or Non-TAL	Element(s) [b]
Surface Soil	HR-137Q-DEP05	RH0039	22-Jul-02	0 - 0.5		Copper
Surface Soil	HR-137Q-DEP07	RH0115	10-Mar-04	0 - 0.5		Copper
Surface Soil	HR-137Q-GP03	RH0005	12-Jun-02	0 - 1		Copper, Lead
Surface Soil	HR-137Q-GP04	RH0007	18-Jun-02	0 - 1		Antimony, Copper, Lead
Surface Soil	HR-137Q-GP06	RH0011	18-Jun-02	0 - 1		Copper, Lead
Surface Soil	HR-137Q-GP07	RH0013	13-Jun-02	0 - 1		Copper, Lead
Surface Soil	HR-137Q-GP08	RH0015	12-Jun-02	0 - 1		Copper, Lead
Surface Soil	HR-137Q-GP09	RH0017	13-Jun-02	0 - 1		Copper, Lead
Surface Soil	HR-137Q-GP10	RH0019	13-Jun-02	0 - 1		Lead
Surface Soil	HR-137Q-GP11	RH0021	12-Jun-02	0 - 1		Copper, Lead
Surface Soil	HR-137Q-GP12	RH0041	30-Sep-03	0 - 1		Lead
Surface Soil	HR-137Q-GP13	RH0044	14-Oct-03	0 - 1		Copper, Lead
Surface Soil	HR-137Q-GP14	RH0048	1-Oct-03	0 - 1		Lead
Surface Soil	HR-137Q-GP15	RH0051	14-Oct-03	0 - 1		Antimony, Copper, Lead
Surface Soil	HR-137Q-GP17	RH0057	15-Oct-03	0 - 1		Antimony, Copper, Lead
Surface Soil	HR-137Q-GP18	RH0060	14-Oct-03	0 - 1		Copper, Lead
Surface Soil	HR-137Q-GP19	RH0063	1-Oct-03	0 - 1		Copper, Lead
Surface Soil	HR-137Q-GP20	RH0067	1-Oct-03	0 - 1		Antimony, Copper, Lead
Surface Soil	HR-137Q-GP22	RH0074	15-Oct-03	0 - 1		Copper, Lead
Surface Soil	HR-137Q-GP24	RH0080	6-Oct-03	0 - 1		Antimony, Copper, Lead
Surface Soil	HR-137Q-GP25	RH0083	16-Oct-03	0 - 1		Copper, Lead
Surface Soil	HR-137Q-GP26	RH0086	6-Oct-03	0 - 1		Copper, Lead
Surface Soil	HR-137Q-GP30	RH0093	30-Sep-03	0 - 1		Lead
Surface Soil	HR-137Q-GP33	RH0109	16-Oct-03	0 - 1	Non-TAL	Lead
Surface Soil	HR-137Q-GP34	RH0110	6-Oct-03	0 - 1	Non-TAL	Lead
Surface Soil	HR-137Q-MW01	RH0023	11-Jun-02	0 - 1		Antimony, Copper, Lead
Surface Soil	HR-137Q-MW02	RH0026	11-Jun-02	0 - 1		Lead
Surface Soil	HR-137Q-MW03	RH0029	12-Jun-02	0 - 1		Copper, Lead
Surface Soil	HR-137Q-MW04	RH0031	10-Jun-02	0 - 1		Copper, Lead
Subsurface Soil	HR-137Q-GP04	RH0008	18-Jun-02	1 - 2		Antimony, Copper, Lead
Subsurface Soil	HR-137Q-GP06	RH0012	18-Jun-02	1 - 2		Lead
Subsurface Soil	HR-137Q-GP10	RH0020	13-Jun-02	2 - 4		Lead
Subsurface Soil	HR-137Q-GP11	RH0022	12-Jun-02	4 - 6		Lead
Subsurface Soil	HR-137Q-GP13	RH0045	14-Oct-03	1 - 2		Lead
Subsurface Soil	HR-137Q-GP14	RH0049	1-Oct-03	1 - 2		Lead
Subsurface Soil	HR-137Q-GP14	RH0050	1-Oct-03	8 - 9		Lead
Subsurface Soil	HR-137Q-GP17	RH0058	15-Oct-03	1 - 2		Lead
Subsurface Soil	HR-137Q-GP18	RH0061	14-Oct-03	1 - 2		Lead
Subsurface Soil	HR-137Q-GP19	RH0064	1-Oct-03	1 - 2		Lead
Subsurface Soil	HR-137Q-GP20	RH0068	1-Oct-03	1 - 1.5		Lead
Subsurface Soil	HR-137Q-GP22	RH0075	15-Oct-03	1 - 2		Lead
Subsurface Soil	HR-137Q-GP22	RH0076	15-Oct-03	2 - 3		Lead
Subsurface Soil	HR-137Q-GP24	RH0082	6-Oct-03	2 - 3		Copper, Lead
Subsurface Soil	HR-137Q-GP24	RH0081	6-Oct-03	1 - 2		Lead
Subsurface Soil	HR-137Q-GP25	RH0084	16-Oct-03	1 - 2		Lead
Subsurface Soil	HR-137Q-GP26	RH0088	6-Oct-03	1 - 2		Lead
Subsurface Soil	HR-137Q-MW03	RH0030	12-Jun-02	6 - 8		Lead
Subsurface Soil	HR-137Q-MW04	RH0032	11-Jun-02	6 - 8		Lead

[a] Feet below ground surface.

[b] Non-TAL samples could not be subjected to geochemical evaluation due to a lack of reference element data. The non-TAL samples listed above contain lead concentrations above the corresponding background 95th upper tolerance limit of 63.8 mg/kg.

TAL - Target analyte list.

Aluminum

Aluminum is the most abundant element analyzed in the site soil samples, with a mean concentration of 11,710 milligrams per kilogram (mg/kg) (1.2 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 second most abundant element analyzed in the site soil samples (mean concentration of 10,206 mg/kg; 1.0 weight percent). The iron in the site samples is dominantly 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). The Parcel 137Q-X soil boring logs note that yellowish brown, brown, or gray silt or silt with clay and sand; and brown to reddish brown clay with some silt and sand are the predominant soil types in the sampled intervals. Many intervals contain sandstone gravel.

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 provides a qualitative indicator of the relative abundance of clay and iron oxide minerals in site soil (Figure 1). Installation-wide background soil samples are represented by circles ("BG"), site subsurface (deep) soil samples are represented by filled triangles ("Site DS"), and site surface soil samples are represented by open triangles ("Site SS"). For both surface and subsurface intervals, 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. A few site samples have slightly elevated Al/Fe ratios, and lie slightly above the linear trend. These observations suggest that the site samples are naturally enriched in clays and other aluminum-bearing minerals relative to the background samples.

The positive correlation between aluminum and iron concentrations in the site samples indicates a natural source for the elevated aluminum. 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 – including some of the site samples – are expected to contain proportionally higher concentrations of trace elements.

<u>Conclusion</u>

Aluminum detected in the site soil samples is naturally occurring.

Antimony

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

All of the site samples with detectable antimony lie above the linear background trend in Figure 2. Lead is a suspected contaminant at Parcel 137Q-X due to its presence in bullets and munitions. Antimony is used as a hardening agent in bullets (Interstate Technology and

Regulatory Council [ITRC], 2003) and is a component of mortar-round primers; elevated antimony concentrations, therefore, would be expected in soil samples from firing ranges. The correlation between antimony and lead in the site samples ($R^2 = 0.83$ for the surface interval) (Figure 3) and the presence of elevated antimony concentrations in samples with high lead indicate that lead and antimony are co-contaminants at the site.

The single subsurface soil sample with detectable antimony and all six surface soil samples with detectable antimony contain anomalously high concentrations. These samples exhibit low to moderate iron content (as well as low to moderate aluminum and manganese), elevated lead, and lie above the linear trend established by the background samples in Figure 2. They contain an excess amount of antimony that cannot be explained by natural processes, and are most likely contaminated (Table 1).

Conclusion

Antimony concentrations in six surface soil samples and one subsurface soil sample are anomalously high and reflect site-related contamination (Table 1).

Cadmium

Cadmium is commonly present in soil as a divalent cation and has an affinity to adsorb on clay minerals (Kabata-Pendias, 2001), which tend to maintain a net negative surface charge. If a soil sample contains a high proportion of clay minerals, then it will have naturally high concentrations of aluminum and associated trace elements, such as cadmium. The background samples form a weak trend with a positive slope in a plot of beryllium versus aluminum (Figure 4). Only two site samples have detectable cadmium (RH0065, 0.557 J mg/kg; RH0050, 0.635 J mg/kg); these are the same samples with the two highest aluminum concentrations of the site data set (57,300 mg/kg and 37,400 mg/kg, respectively), and they lie on the general background trend in the plot. This indicates that samples RH0050 and RH0065 have Cd/Al ratios that are consistent with those of the background samples. The elevated cadmium in these samples is due to the preferential enrichment of clay minerals, and is natural.

Conclusion

Cadmium detected in the site soil samples is naturally occurring.

Copper

Copper in soil has an affinity for different sorptive surfaces including aluminum hydroxides, clays, iron oxides, and manganese oxides (Kabata-Pendias, 2001); as a result, correlations of copper concentrations versus aluminum, iron, or manganese concentrations are not always strong, even in uncontaminated samples. A plot of copper versus iron for the site and background samples is provided in Figure 5. Most of the background samples form a generally linear trend with a positive slope, and many of the site samples lie on this trend. Copper in these samples is associated with iron oxides at ratios consistent with those of the background samples, and is natural. There are many site samples, however, with anomalously high Cu/Fe ratios relative to background, and these samples may contain a component of contamination.

This conclusion is supported by a comparison of the site and background Cu/Fe ratios. Figure 6 displays the copper concentrations of the site and background samples (y-axis) versus their

corresponding Cu/Fe ratios (x-axis). If a site sample contains excess copper from a contaminant source, then it will exhibit an anomalously high Cu/Fe ratio relative to background and will plot to the right of the background samples in Figure 6. Although many of the site samples exhibit Cu/Fe ratios that are within the background range, there are 22 surface soil samples and 2 subsurface soil samples with Cu/Fe ratios that exceed the maximum background Cu/Fe ratio of 0.00335. Elevated copper in these samples should be considered suspect (Table 1).

Copper is a primary component of shell casings and jackets (ITRC, 2003), so copper contamination would be expected at firing-range sites such as Parcel 137Q-X. 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 7). This indicates that copper and lead are co-contaminants in site soil.

Conclusion

Copper concentrations in 22 surface soil samples and 2 subsurface soil samples are anomalously high and reflect site-related contamination (Table 1). Copper detected in the other TAL samples is naturally occurring.

Lead

Manganese oxides are naturally occurring minerals in soil, and are present as discrete mineral grains or as coatings on other minerals. Manganese oxides have a strong affinity to adsorb divalent cations (such as Ba^{2+}, Co^{2+}, and Pb^{2+}), due to the large surface area and high negative surface charges of these minerals. 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 such as lead. A plot of lead versus manganese reveals a linear trend with a positive slope for the background samples and some of the site samples (Figure 8). Lead in these samples is associated with manganese oxides at ratios consistent with those of the background samples, and is natural. There are many site samples, however, with anomalously high Pb/Mn ratios relative to background, and these samples may contain a component of contamination. Lead is an expected contaminant at Parcel 137Q-X, due to its presence in bullets, mortar rounds, and other munitions.

Another perspective of the data sets is provided in Figure 9, which displays the lead concentrations of the site and background samples (y-axis) versus their corresponding Pb/Mn ratios (x-axis). If a site sample contains excess lead from a contaminant source, then it will exhibit an anomalously high Pb/Mn ratio relative to background and will plot to the right of the background samples in Figure 9. Although many of the site samples exhibit Pb/Mn ratios that are within the background range, there are 25 surface soil samples and 19 subsurface soil samples with Pb/Mn ratios that exceed the maximum background Pb/Mn ratio of 1.715. Elevated lead in these samples should be considered suspect (Table 1).

The surface soil data set includes eleven non-TAL samples that could not be included in the geochemical evaluation. Two of these non-TAL samples contain lead concentrations above the background 95th UTL of 63.8 mg/kg, and should be considered suspect (Table 1).

Conclusion
Lead concentrations in 25 TAL surface soil samples and 19 subsurface soil samples are anomalously high and reflect site-related contamination (Table 1). Lead detected in the other TAL samples is naturally occurring. Two non-TAL surface soil samples contain lead concentrations that exceed the background 95th UTL, and these concentrations should be considered suspect (Table 1).

Magnesium

Magnesium (Mg^{2+}) is a common component of soil-forming minerals such as clays, often occurring as part of the mineral structure and as loosely adsorbed cations. Clays are characterized by large surface-area-to-volume ratios and strong negative surface charges. As a result, the major cations, such as magnesium, are attracted to these mineral surfaces and take part in cation exchange reactions. Positive correlations between magnesium and aluminum concentrations are thus typically observed for uncontaminated soil samples. A plot of magnesium versus aluminum reveals a linear trend for the site samples and most of the background samples (Figure 10). The site samples with high magnesium concentrations also have proportionally higher aluminum concentrations, and lie on the trend established by the other samples. These observations indicate a natural source for the elevated magnesium in the site samples.

Conclusion
Magnesium detected in the site soil samples is naturally occurring.

Mercury

Mercury in soil can adsorb on the surfaces of iron oxide and clay minerals, but its concentrations are commonly controlled through organic complex formation (Kabata-Pendias, 2001). As a result, weak correlations for mercury versus iron or mercury versus aluminum are often observed, even in uncontaminated soil samples. Most of the background samples form a weak linear trend with a positive slope in a plot of mercury versus aluminum (Figure 11). The site samples lie on or slightly below the background trend. None of the site samples exhibits elevated Hg/Al ratios relative to background, which suggests that the site samples do not contain excess mercury from a contaminant source. These observations indicate a natural source for the mercury detected in the site samples.

Conclusion
Mercury detected in the site soil samples is naturally occurring.

Potassium

Potassium (K^{+}) is a common component of soil-forming minerals such as clays, often occurring as part of the mineral structure and as loosely adsorbed cations. Clays are characterized by large surface-area-to-volume ratios and strong negative surface charges. As a result, the major cations, such as potassium, are attracted to these mineral surfaces and take part in cation exchange reactions. Positive correlations between potassium and aluminum concentrations are thus typically observed for uncontaminated soil samples. A plot of potassium versus aluminum reveals a common, generally linear trend with a positive slope for the site and background samples (Figure 12). The site samples with high potassium concentrations also have high

aluminum content, and lie on the trend established by the other samples. These observations indicate a natural source for the potassium in the site samples.

Conclusion
Potassium detected in the site soil samples is naturally occurring.

Selenium

As noted in Section 2.1, selenium is present in oxic soil pore fluid as oxyanions and has an affinity to adsorb on iron oxides, which tend to maintain a net positive surface charge. Positive correlations between selenium and iron concentrations are thus commonly observed for uncontaminated soil samples. A plot of selenium versus iron is provided in Figure 13. The site samples form a generally linear trend with a positive slope, and the two background samples with detectable selenium lie on this trend. The site samples with high selenium concentrations also exhibit high iron content, which indicates that these samples are preferentially enriched in iron oxides and associated trace elements. Selenium in these samples is natural. It is important to note that 27 of the 34 selenium detections in the site data set are estimated ("J"-qualified) concentrations below the reporting limit. The uncertainty associated with estimated values most likely explains why a stronger correlation is not observed for the site samples.

Conclusion
Selenium detected in the site soil samples is naturally occurring.

Zinc

Zinc in soils is commonly associated with clay minerals and hydrous iron and aluminum oxides (Kabata-Pendias, 2001), so positive correlations for zinc versus aluminum and zinc versus iron are expected for uncontaminated samples. The site samples and most of the background samples form a common, generally linear trend with a positive slope in a plot of zinc versus aluminum (Figure 14). The site samples with high zinc concentrations also contain high aluminum concentrations, and lie on the linear background trend. None of the site samples exhibits elevated Zn/Al ratios relative to background, which suggests that the site samples do not contain excess zinc from a contaminant source. These observations indicate that zinc in the site samples is associated with clays (and other aluminum-bearing minerals) at ratios consistent with those of the background samples, and is natural.

Conclusion
Zinc detected in the site soil samples is naturally occurring.

4.0 Results of the Geochemical Evaluation of Lead in Sediment

This section presents the results of the geochemical evaluation of lead in sediment samples from Parcel 137Q-X. Correlation plots are provided in Attachment 1.

Lead

As discussed in Section 2.1, divalent cations such as lead have an affinity to adsorb on the surfaces of clay minerals, which tend to maintain a net negative surface charge. Positive correlations between lead and aluminum concentrations are thus commonly observed for

uncontaminated samples. Lead can also replace calcium in carbonate minerals and in sorption sites (Kabata-Pendias, 2001). If a sample contains a high proportion of carbonate minerals it may contain naturally high lead.

Plots of lead versus aluminum and lead versus calcium are provided in Figures 15 and 16. In Figure 15, the background samples form a weak linear trend with a positive slope, and the site samples all lie on this trend. This suggests that the lead in the site samples is associated with clay minerals at ratios consistent with those of the background samples, and is natural. Site sample RH1002 contains the highest lead concentration of the site samples (72.3 mg/kg), but it also contains the highest calcium concentration of the both data sets (4,340 mg/kg) (Figure 16). This suggests that the elevated lead is due to the preferential enrichment of carbonate minerals in the sample, and is natural.

Conclusion
Lead detected in the site sediment samples is naturally occurring.

5.0 Results of the Geochemical Evaluation of Aluminum and Potassium in Groundwater

This section presents the results of the geochemical evaluation of aluminum and potassium in the seven unfiltered groundwater samples from Parcel 137Q-X. Correlation plots are provided in Attachment 1.

Field-measured pH readings for the groundwater samples range from 4.63 to 6.44 standard units, with a median of 5.19 and mean of 5.36. These values indicate near-neutral to slightly acidic pH conditions at the sample locations. Field-measured DO readings range from 0.99 to 8.97 mg/L, with a median of 7.03 mg/L and mean of 5.87 mg/L, and ORP readings range from -37 to +265 millivolts (mV), with a median of +155 mV and mean of +161 mV. These values suggest moderate to oxidizing redox conditions at the sample locations. Turbidity measurements range from 6 to 1,000 nephelometric turbidity units (NTU), with a median of 31 NTU and mean of 188 NTU. Two of the samples contained a high mass of suspended particulates (223 and 1,000 NTU for samples RH3005 and RH3001), but the remaining samples did not (34 NTU and lower). It should be noted that field readings are not available for the background groundwater samples.

Aluminum

Aluminum was detected in all seven unfiltered groundwater samples, at concentrations ranging from an estimated 0.187 mg/L to an estimated 10.2 mg/L. As discussed previously, aluminum concentrations in excess of approximately 1 mg/L in neutral-pH groundwater indicate the presence of suspended clays. Aluminum will be present in solution at a pH below about 4.0, but all of the Parcel 137Q-X pH readings are higher than this (see the discussion of field readings, above).

Iron concentrations in excess of approximately 1 mg/L in neutral-pH, moderate to oxidizing groundwater conditions indicate the presence of suspended iron oxides. A plot of aluminum versus iron can be used as a qualitative indicator of the amount of suspended particulates in the groundwater samples (Figure 17). A strong linear trend with a positive slope is typically observed when the aluminum and iron concentrations are present in particulate form, and just such a trend is observed in Figure 17 for all of the site samples ($R^2 = 0.94$) and most of the background samples. The site samples with high aluminum concentrations exhibit proportionally higher iron, and lie on the linear trend formed by the other samples. This indicates that the elevated aluminum is due to the presence of suspended clay particulates, and is natural.

This conclusion is corroborated by the field-measured turbidity readings and by comparison of filtered versus unfiltered splits. A linear trend with a positive slope is apparent in a plot of unfiltered aluminum concentrations versus turbidity (Figure 18), and the samples with the highest aluminum exhibit proportionally higher turbidity. Sample RH3001, which has the highest aluminum and turbidity readings (10.2 J mg/L and 1,000 NTU) of the site data set, is the only sample with a filtered split. Its filtered/unfiltered ratio of 0.006 reflects a significant decrease in aluminum concentration after filtration. The positive correlation between unfiltered aluminum concentrations versus turbidity, and the decrease in aluminum concentration upon filtration for sample RH3001, support the contention that the elevated aluminum in the site samples is associated with filterable, suspended clay particulates, and is natural.

Conclusion
Aluminum detected in the site groundwater samples is naturally occurring.

Potassium

Potassium (K^+) is a major dissolved constituent in groundwater and is derived from the weathering of silicate minerals. Magnesium is also a primary dissolved constituent in groundwater, and potassium and magnesium concentrations often covary in uncontaminated samples. A plot of potassium versus magnesium reveals a linear trend with a positive slope for the site samples ($R^2 = 0.95$) (Figure 19). The site samples have moderately high potassium concentrations, but they also have proportionally higher magnesium content. This indicates a natural source for potassium in these samples. The background samples exhibit no correlation for potassium versus magnesium, but do exhibit a positive correlation for potassium versus aluminum (Figure 20). This correlation most likely reflects the affinity of potassium to adsorb on suspended clay particulates and participate in cation exchange reactions.

Conclusion
Potassium detected in the site groundwater samples is naturally occurring.

6.0 Summary

This section summarizes the results of the geochemical evaluations of selected elements in soil, sediment, and groundwater samples from Parcel 137Q-X.

Soil. Geochemical evaluation indicates that all detected concentrations of aluminum, cadmium, magnesium, mercury, potassium, selenium, and zinc in the surface and subsurface soil samples are naturally occurring. Anomalously high concentrations of antimony, copper, and lead are present in at least one sample each, for both the surface soil and subsurface soil intervals. These anomalous concentrations are elevated with respect to the corresponding reference element concentrations, and may contain a component of contamination. Table 1 lists the samples that contain anomalously high element concentrations, and provides the corresponding location codes and depth intervals.

Sediment. Geochemical evaluation indicates that the detected concentrations of lead in the site sediment samples are naturally occurring.

Groundwater. Geochemical evaluation indicates that the detected concentrations of aluminum and potassium in the site groundwater samples are naturally occurring.

7.0 References

Barclift, D., J. Heath, and A. Drucker, 2000, "Focus on Environmental Background Data Analysis," ***Soil Sediment & Groundwater***, August/September, pp. 10-17.

Bowell, R. J., 1994, "Sorption of arsenic by iron oxides and oxyhydroxides in soils," ***Applied Geochemistry***, Vol. 9, No. 3, pp. 279-286.

Brookins, D. G., 1988, ***Eh-pH Diagrams for Geochemistry***, Springer-Verlag.

Cornell, R. M. and U. Schwertmann, 2003, ***The Iron Oxides: Structure, Properties, Reactions, Occurrences and Uses***, Second Edition, Wiley-VCH, Weinheim.

Daskalakis, K. D. and T. P. O'Connor, 1995, "Normalization and Elemental Sediment Contamination in the Coastal United States," ***Environmental Science & Technology***, Vol. 29, No. 2, pp. 470-477.

Electric Power Research Institute (EPRI), 1984, ***Chemical Attenuation Rates, Coefficients, and Constants in Leachate Migration, Volume 1: A Critical Review***, EPRI EA-3356, Palo Alto, California.

Electric Power Research Institute (EPRI), 1986, ***Speciation of Selenium and Arsenic in Natural Waters and Sediments, Volume 2: Arsenic Speciation***, EPRI EA-4641, Palo Alto, California.

Hem, J. D., 1985, ***Study and Interpretation of the Chemical Characteristics of Natural Water***, U. S. Geological Survey, Water Supply Paper 2254, 3rd Edition.

Interstate Technology and Regulatory Council (ITRC), 2003, ***Characterization and Remediation of Soils at Closed Small Arms Firing Ranges***, Prepared by the Interstate Technology and Regulatory Council Small Arms Firing Range Team, January.

IT Corporation, 2002, ***Draft Installation-Wide Work Plan, Fort McClellan, Calhoun County, Alabama, Revision 2***, Prepared for the U.S. Army Corps of Engineers, Mobile District, February.

Kabata-Pendias, A., 2001, ***Trace Elements in Soils and Plants,*** Third Edition, CRC Press.

Myers, J. and K. Thorbjornsen, 2004, "Identifying Metals Contamination in Soil: A Geochemical Approach," ***Soil & Sediment Contamination: An International Journal***, Vol. 13, No. 1, pp. 1-16.

Pourbaix, M., 1974, ***Atlas of Electrochemical Equilibria in Solutions***, National Association of Corrosion Engineers, Houston, Texas.

Science Applications International Corporation, 1998, ***Final Background Metals Survey Report, Fort McClellan, Anniston, Alabama***, July.

Schiff, K. and S. B. Weisberg, 1997, "Iron as a Reference Element for Determining Trace Metal Enrichment in California Coastal Shelf Sediments," *in*: S. Weisberg, C. Francisco, and D. Hallock (editors), ***Southern California Coastal Water Research Project Annual Report 1995-96***, pp. 68-78.

Stumm, W. and J. Morgan, 1996, ***Aquatic Chemistry***, Third Edition, Wiley-Interscience, New York.

U.S. Environmental Protection Agency, 1995, ***Determination of Background Concentrations of Inorganics in Soils and Sediments at Hazardous Waste Sites***, Office of Research and Development, EPA/540/S-96/500, December.

U.S. Navy, 2002, ***Guidance for Environmental Background Analysis, Volume 1: Soil***, NFESC User's Guide UG-2049-ENV, Naval Facilities Engineering Command, Washington, D.C., April.

ATTACHMENT 1

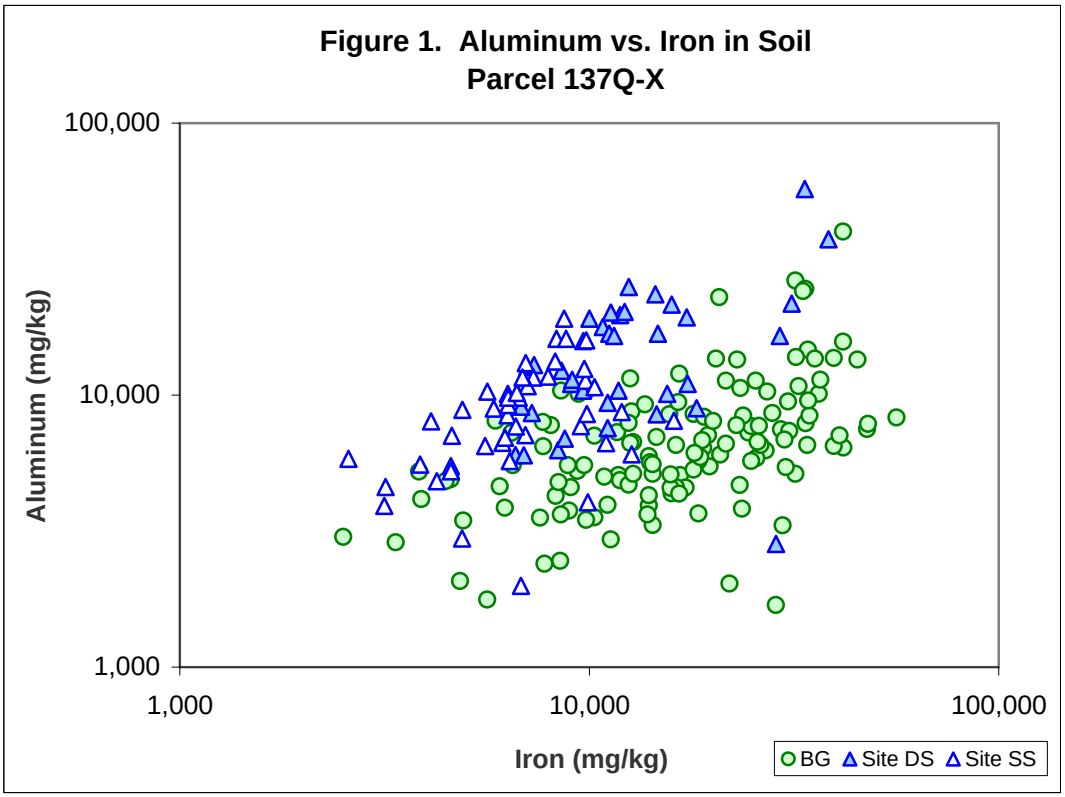


Figure 1. Aluminum vs. Iron in Soil
Parcel 137Q-X
100,000
10,000
1,000
Aluminum (mg/kg)
1,000
10,000
100,000
Iron (mg/kg)
BG
Site DS
Site SS

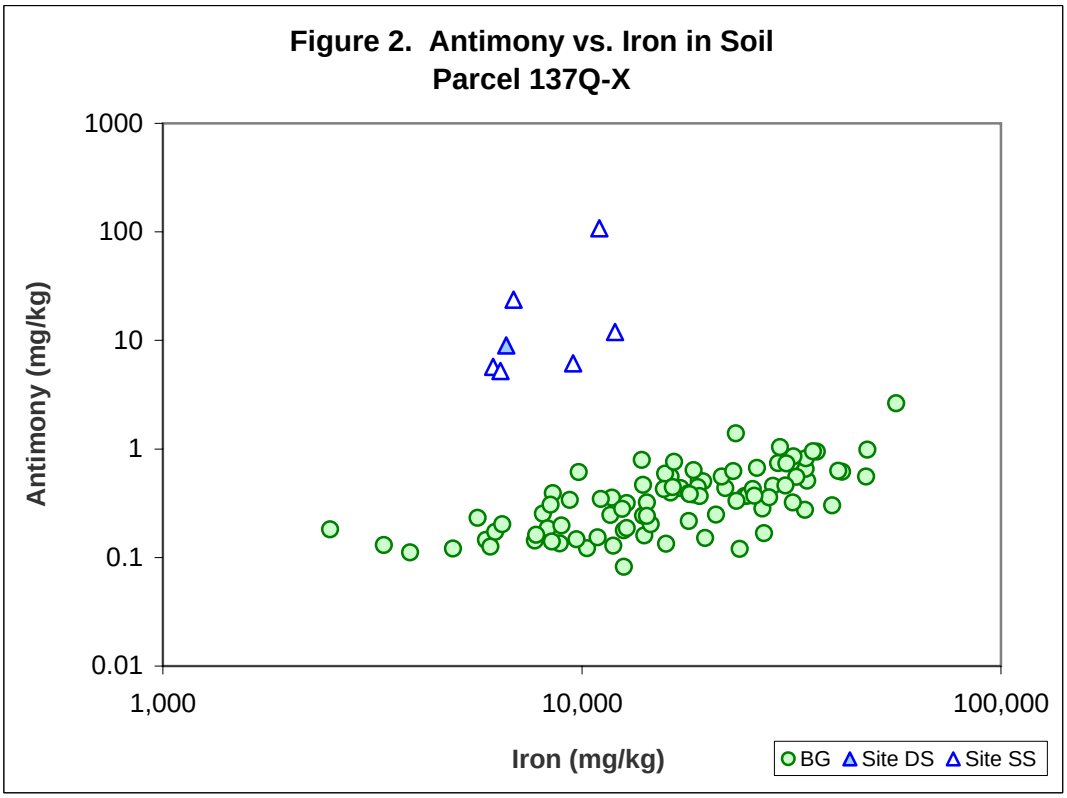


Figure 2. Antimony vs. Iron in Soil
Parcel 137Q-X
1000
100
10
1
0.1
0.01
Antimony (mg/kg)
1,000
10,000
100,000
Iron (mg/kg)
BG
Site DS
Site SS

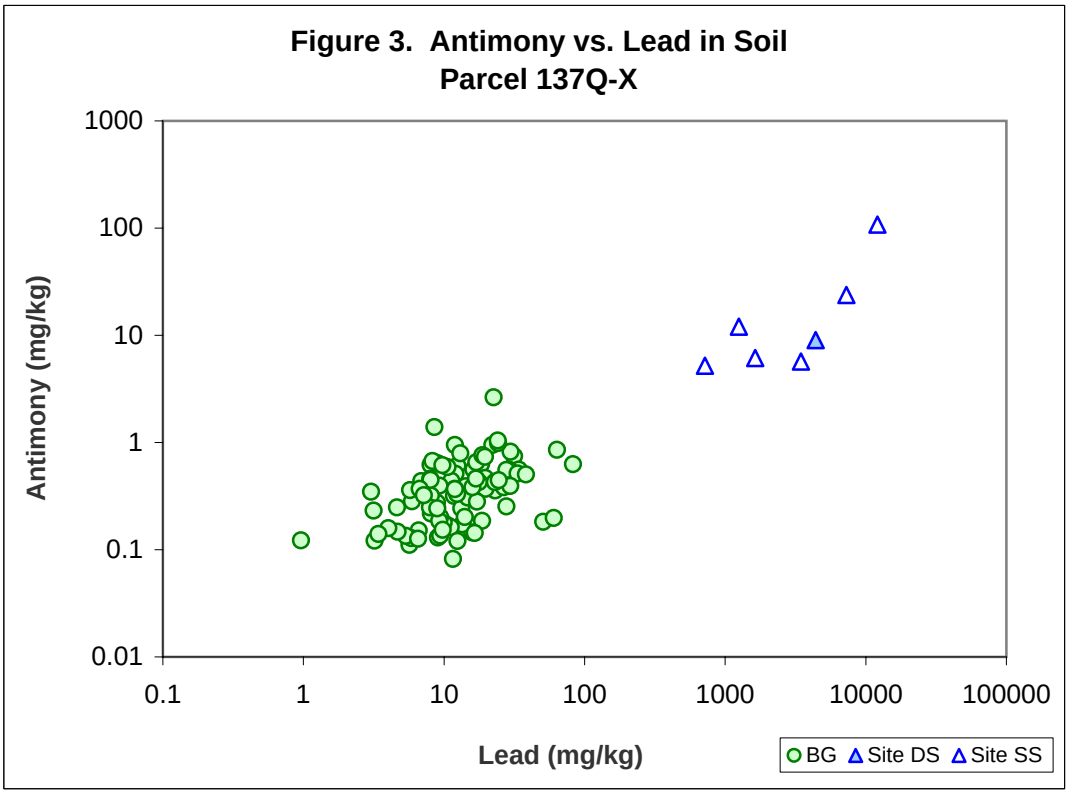


Figure 3. Antimony vs. Lead in Soil
Parcel 137Q-X
Antimony (mg/kg)
1000
100
10
1
0.1
0.01
0.1
1
10
100
1000
10000
100000
Lead (mg/kg)
BG
Site DS
Site SS

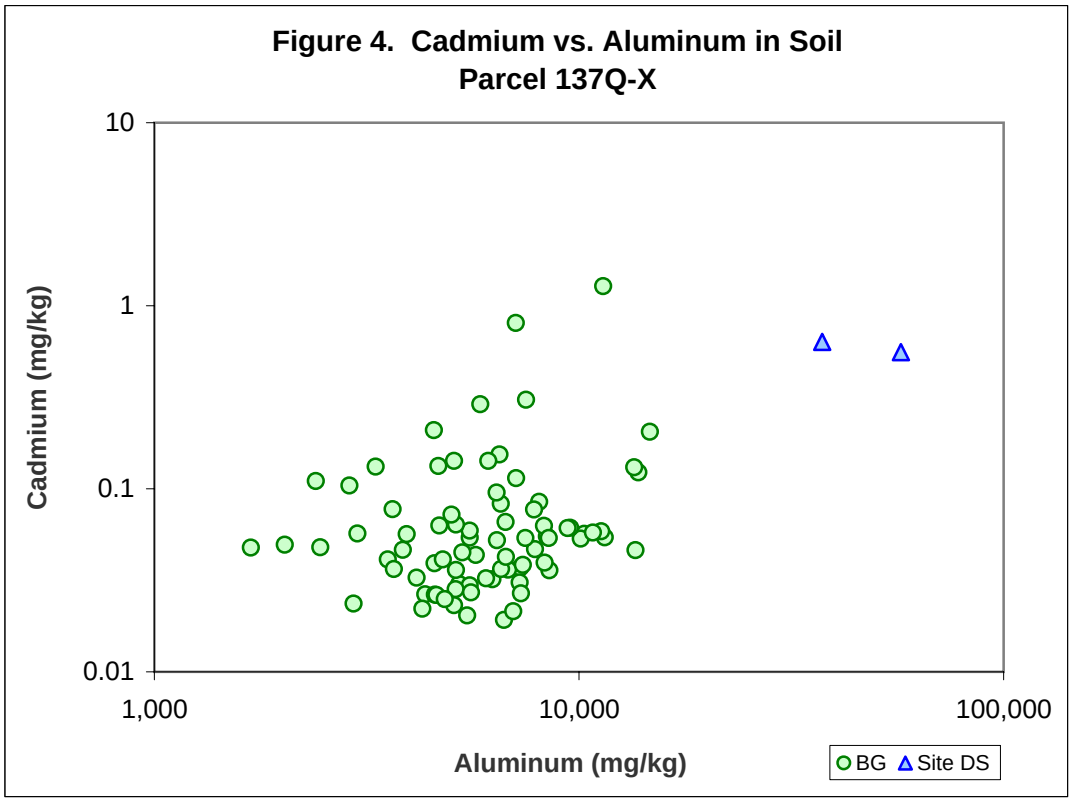


Figure 4. Cadmium vs. Aluminum in Soil
Parcel 137Q-X
Cadmium (mg/kg)
10
1
0.1
0.01
1,000
10,000
100,000
Aluminum (mg/kg)
BG
Site DS

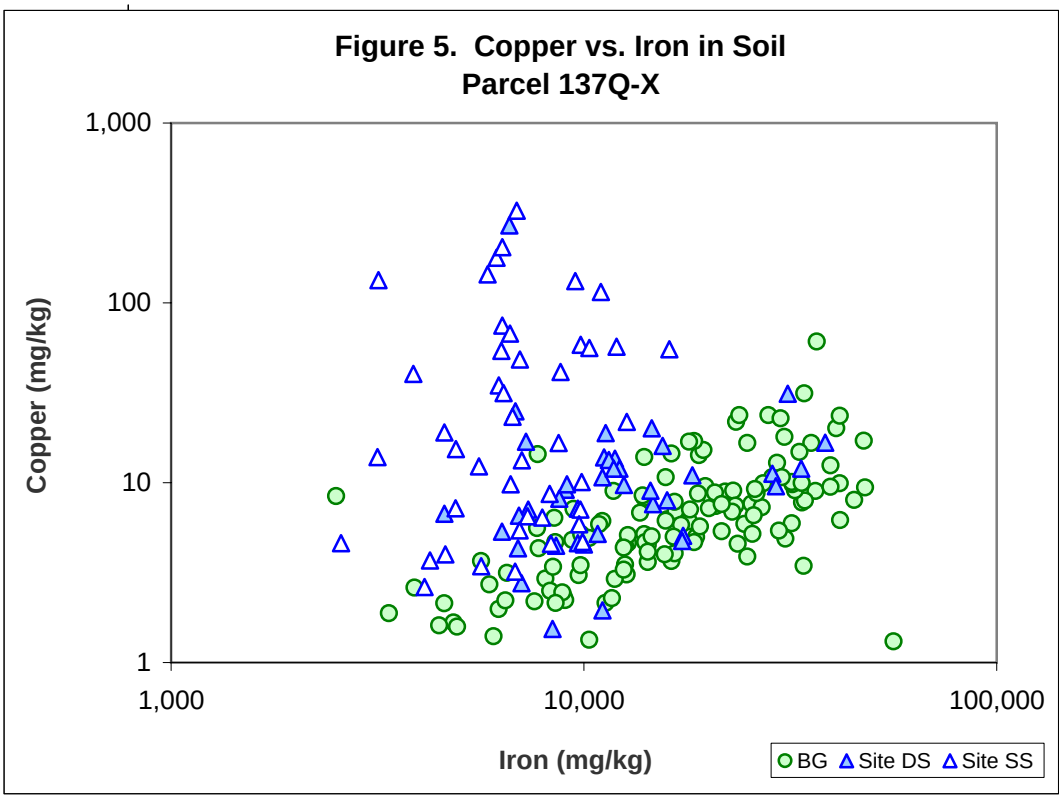


Figure 5. Copper vs. Iron in Soil
Parcel 137Q-X
1,000
100
10
1
Copper (mg/kg)
1,000
10,000
100,000
Iron (mg/kg)
BG
Site DS
Site SS

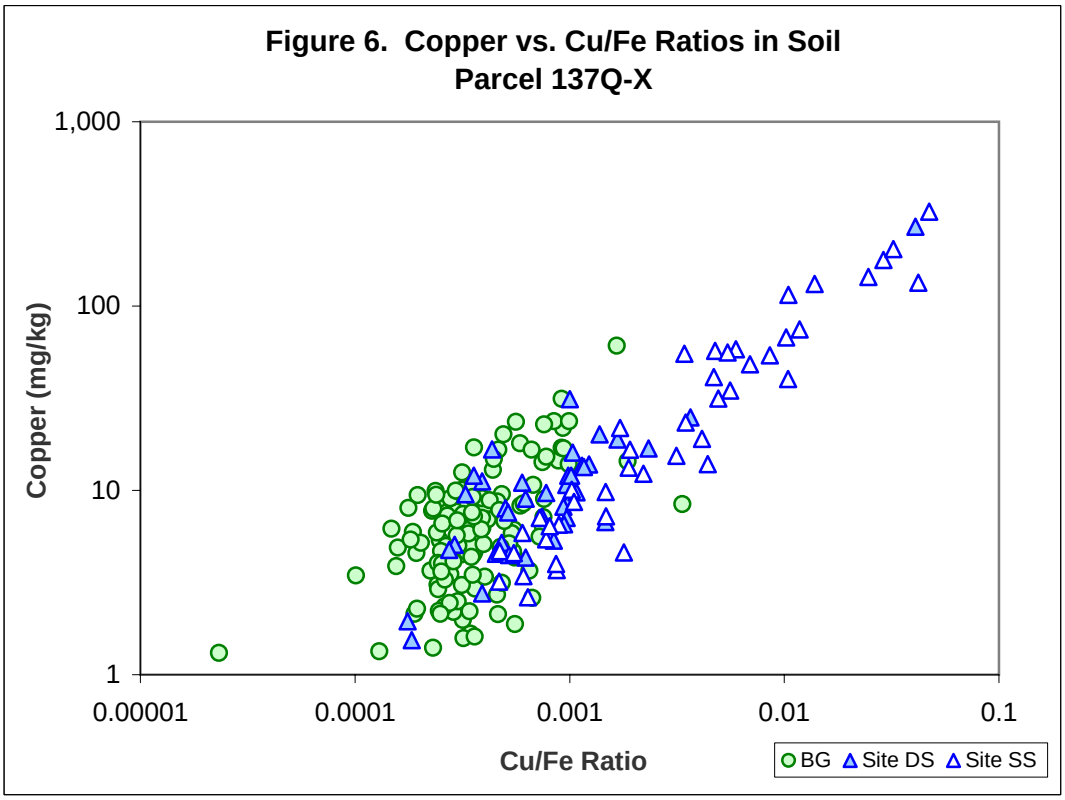


Figure 6. Copper vs. Cu/Fe Ratios in Soil
Parcel 137Q-X
1,000
100
10
1
Copper (mg/kg)
0.00001
0.0001
0.001
0.01
0.1
Cu/Fe Ratio
BG
Site DS
Site SS

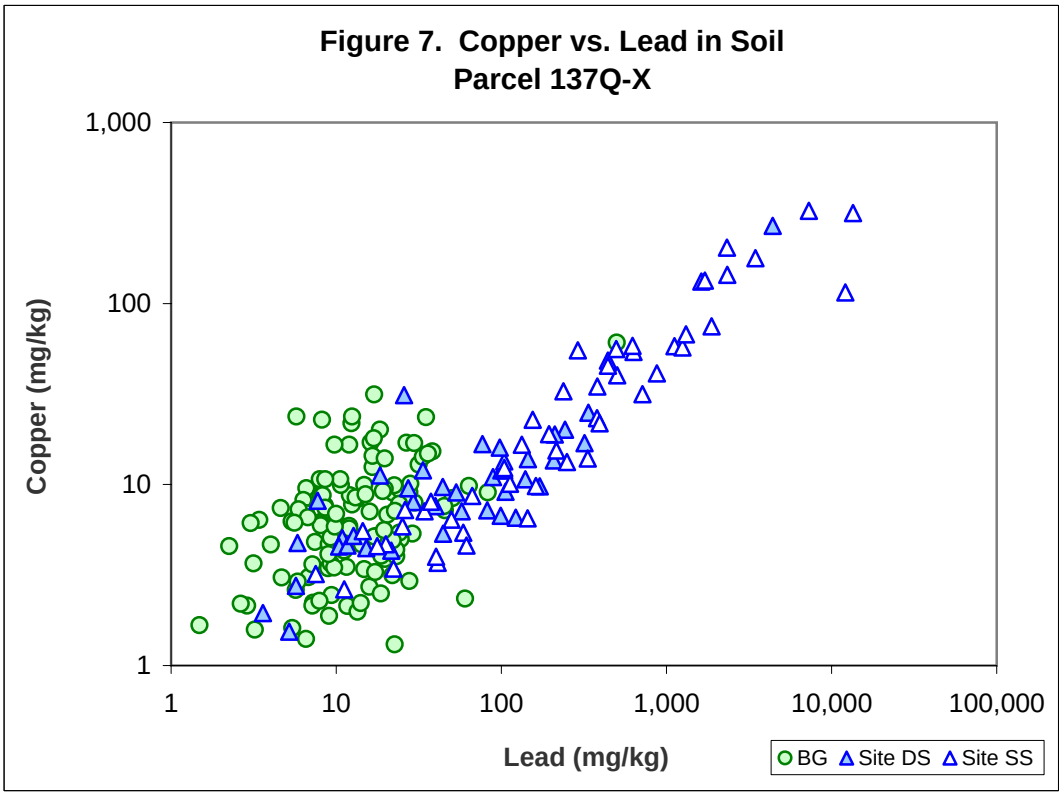


Figure 7. Copper vs. Lead in Soil
Parcel 137Q-X
Copper (mg/kg)
1,000
100
10
1
1
10
100
1,000
10,000
100,000
Lead (mg/kg)
BG
Site DS
Site SS

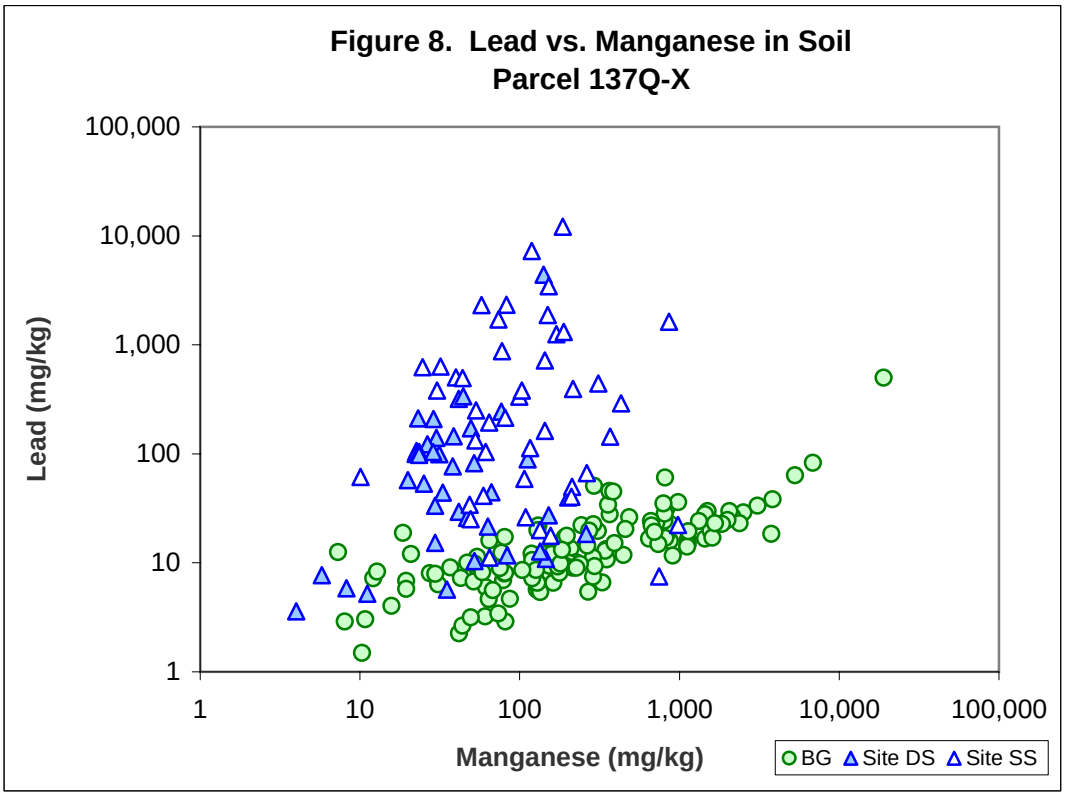


Figure 8. Lead vs. Manganese in Soil
Parcel 137Q-X
Lead (mg/kg)
100,000
10,000
1,000
100
10
1
1
10
100
1,000
10,000
100,000
Manganese (mg/kg)
BG
Site DS
Site SS

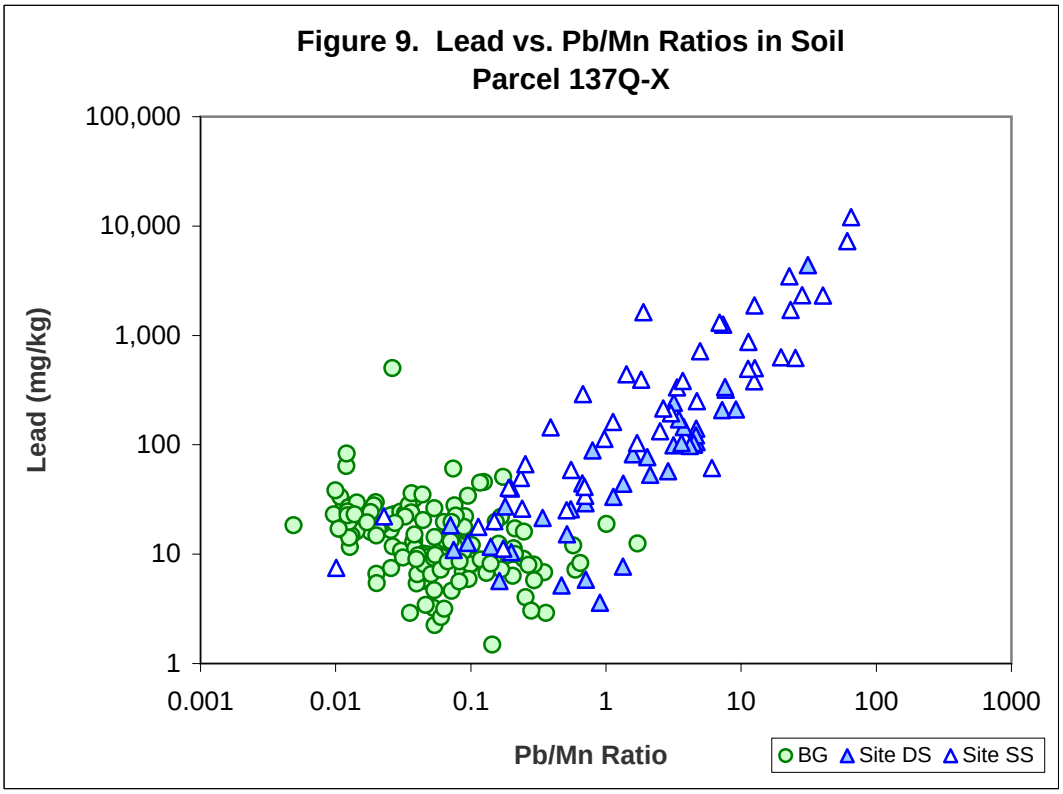


Figure 9. Lead vs. Pb/Mn Ratios in Soil
Parcel 137Q-X
100,000
10,000
1,000
100
10
1
Lead (mg/kg)
0.001
0.01
0.1
1
10
100
1000
Pb/Mn Ratio
BG
Site DS
Site SS

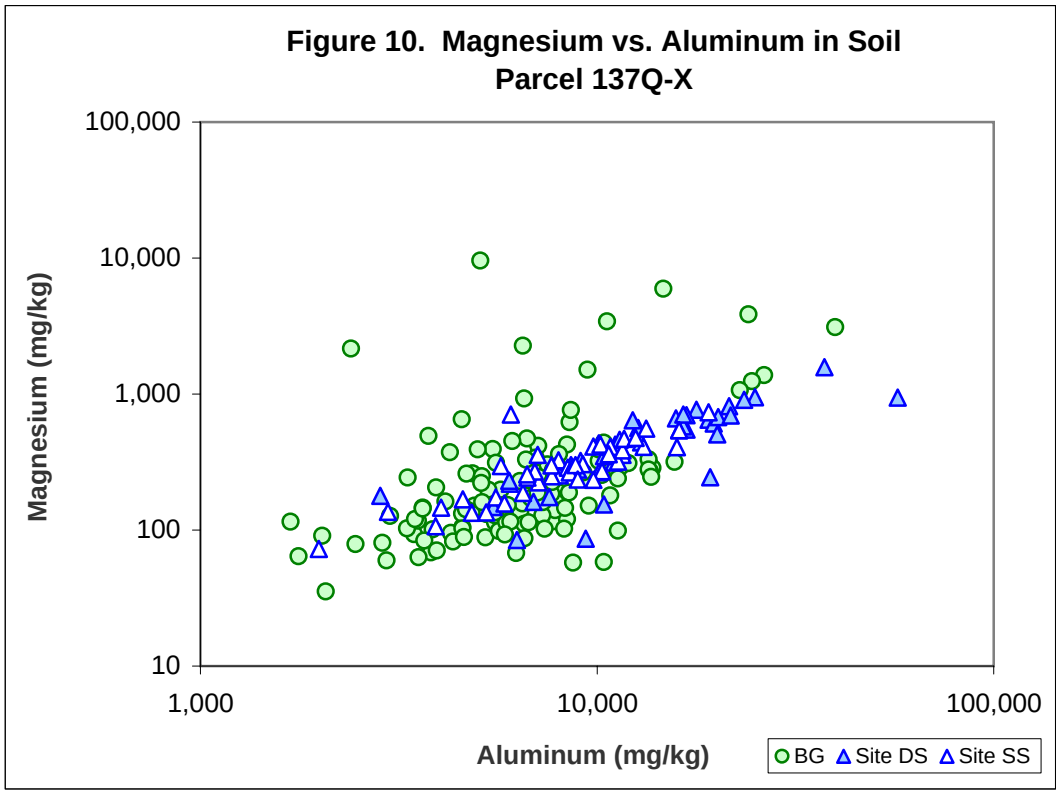


Figure 10. Magnesium vs. Aluminum in Soil
Parcel 137Q-X
100,000
10,000
1,000
100
10
Magnesium (mg/kg)
1,000
10,000
100,000
Aluminum (mg/kg)
BG
Site DS
Site SS

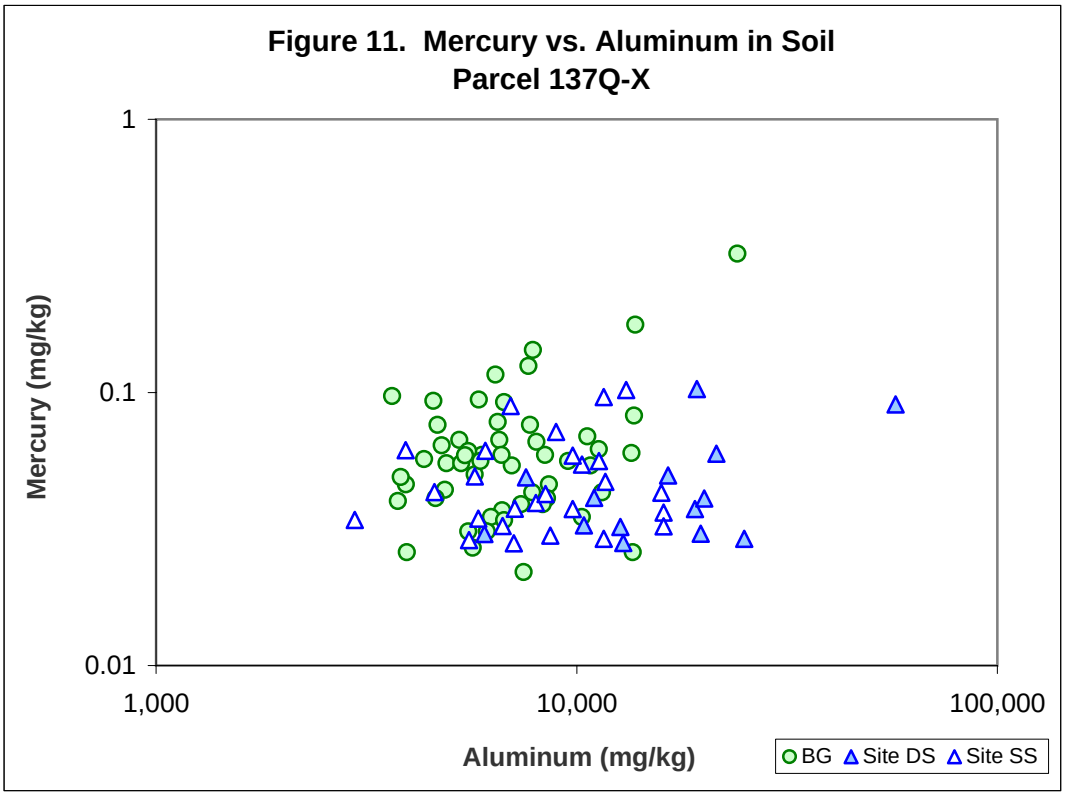


Figure 11. Mercury vs. Aluminum in Soil
Parcel 137Q-X
Mercury (mg/kg)
1
0.1
0.01
1,000
10,000
100,000
Aluminum (mg/kg)
BG
Site DS
Site SS

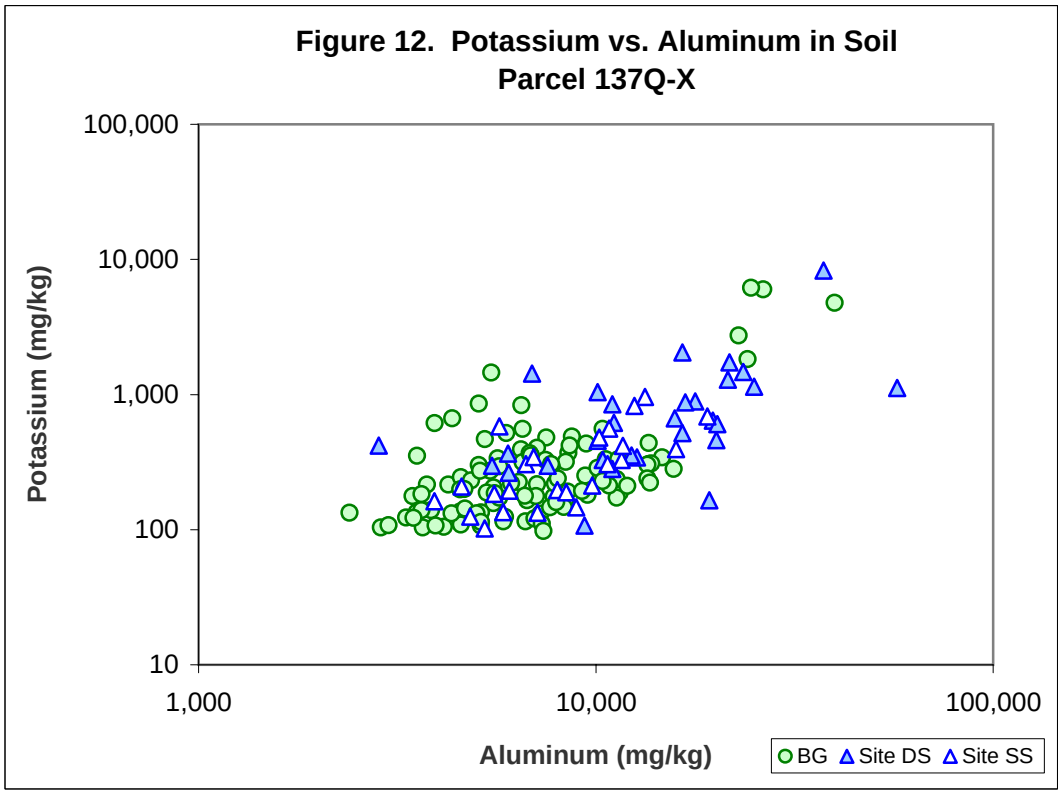


Figure 12. Potassium vs. Aluminum in Soil
Parcel 137Q-X
Potassium (mg/kg)
100,000
10,000
1,000
100
10
1,000
10,000
100,000
Aluminum (mg/kg)
BG
Site DS
Site SS

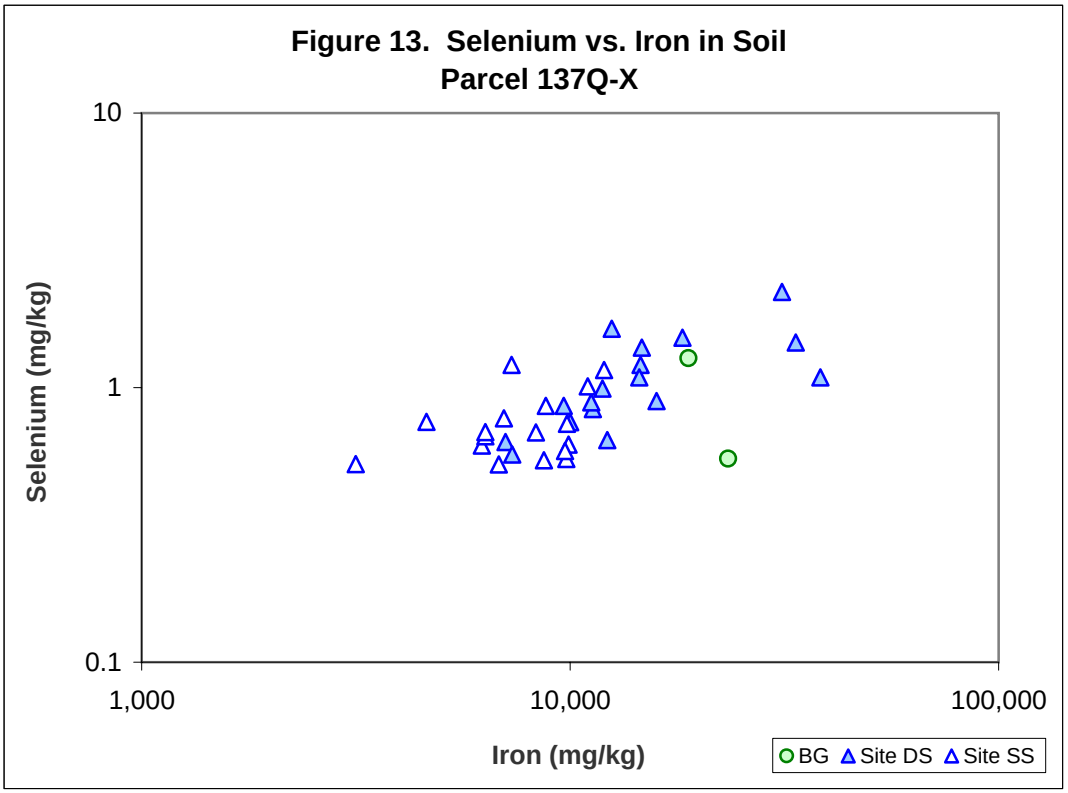


Figure 13. Selenium vs. Iron in Soil
Parcel 137Q-X
10
1
0.1
Selenium (mg/kg)
1,000
10,000
100,000
Iron (mg/kg)
BG
Site DS
Site SS

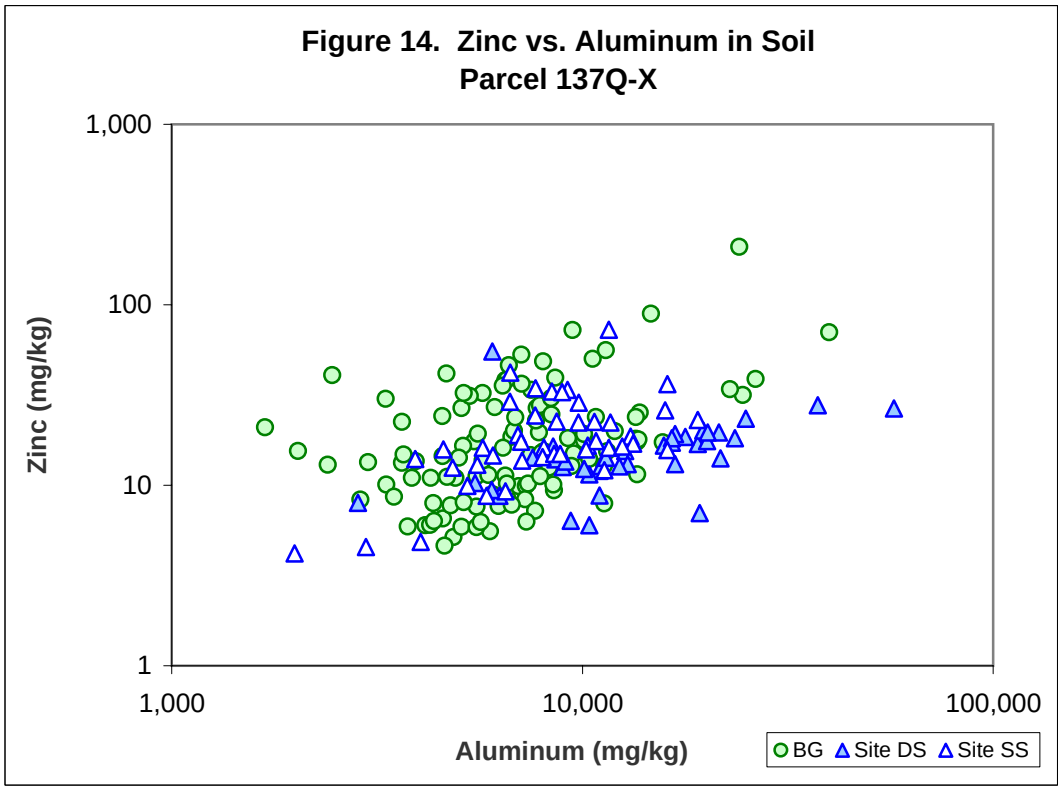


Figure 14. Zinc vs. Aluminum in Soil
Parcel 137Q-X
1,000
100
10
1
Zinc (mg/kg)
1,000
10,000
100,000
Aluminum (mg/kg)
BG
Site DS
Site SS

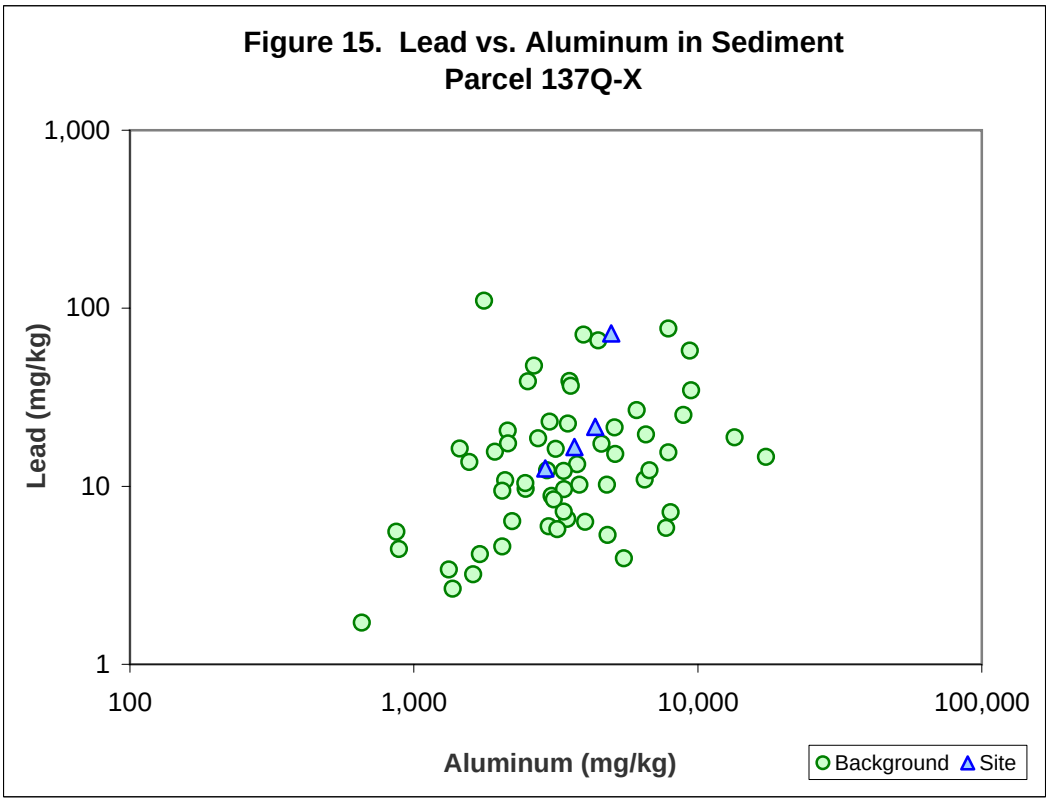


Figure 15. Lead vs. Aluminum in Sediment
Parcel 137Q-X
1,000
100
10
1
Lead (mg/kg)
100
1,000
10,000
100,000
Aluminum (mg/kg)
Background
Site

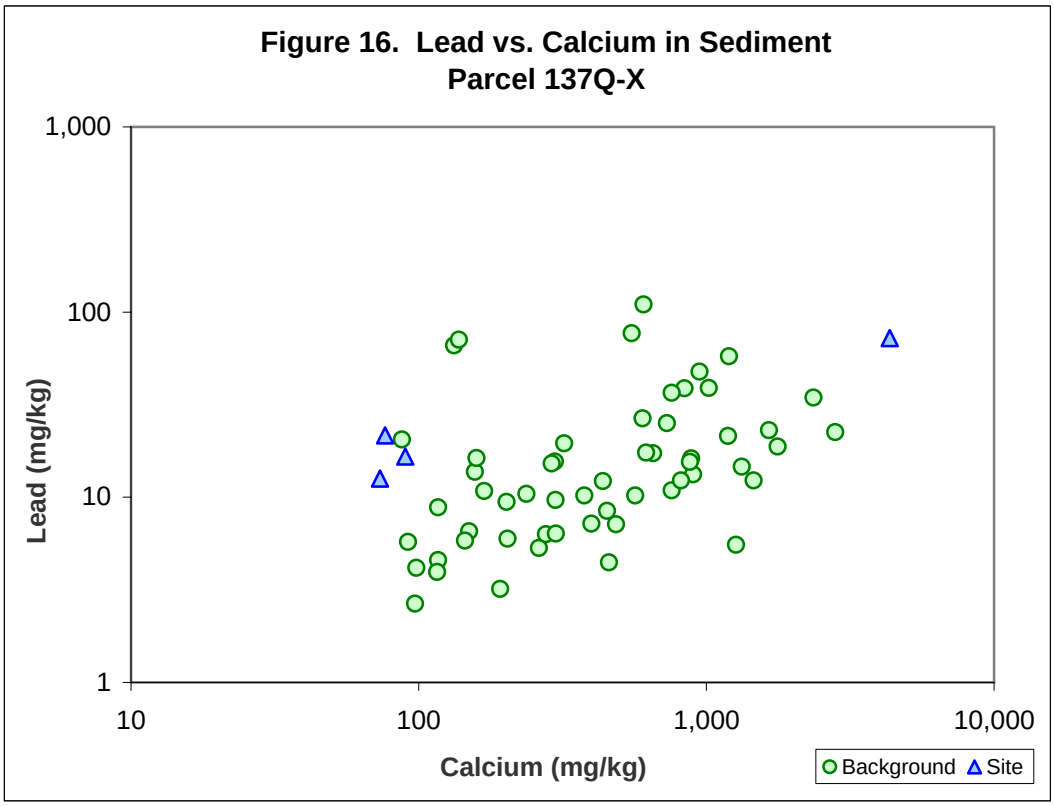


Figure 16. Lead vs. Calcium in Sediment
Parcel 137Q-X
1,000
100
10
1
Lead (mg/kg)
10
100
1,000
10,000
Calcium (mg/kg)
Background
Site

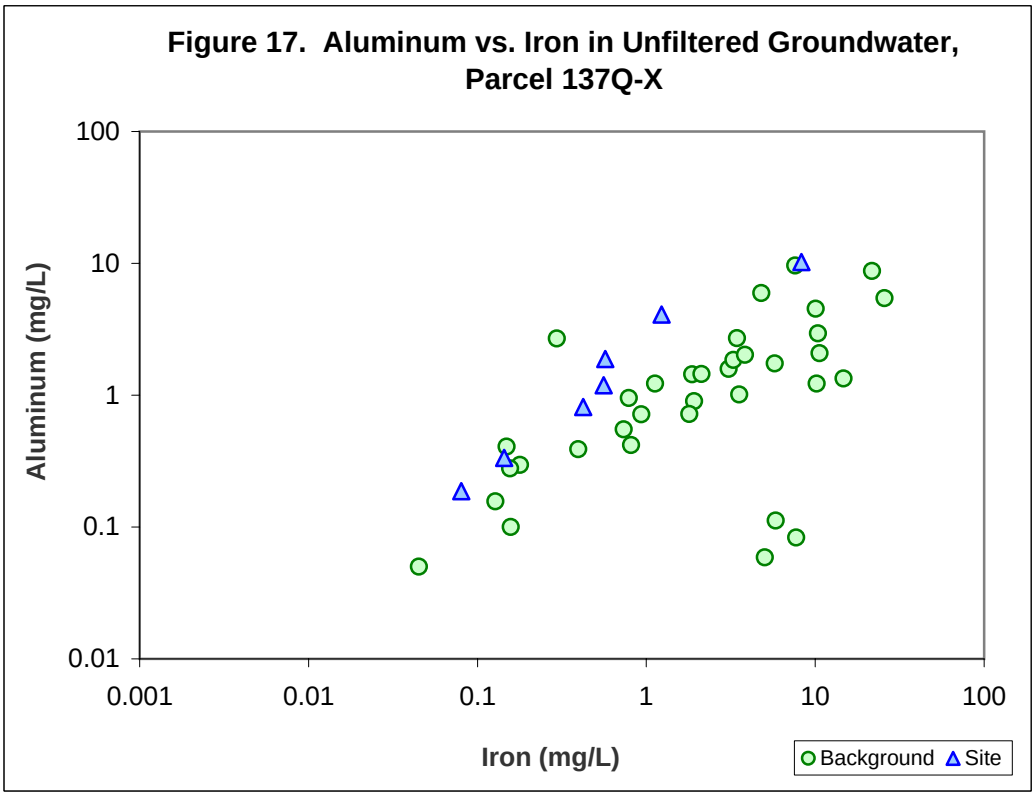


Figure 17. Aluminum vs. Iron in Unfiltered Groundwater, Parcel 137Q-X
Aluminum (mg/L)
100
10
1
0.1
0.01
0.001
0.01
0.1
1
10
100
Iron (mg/L)
Background
Site

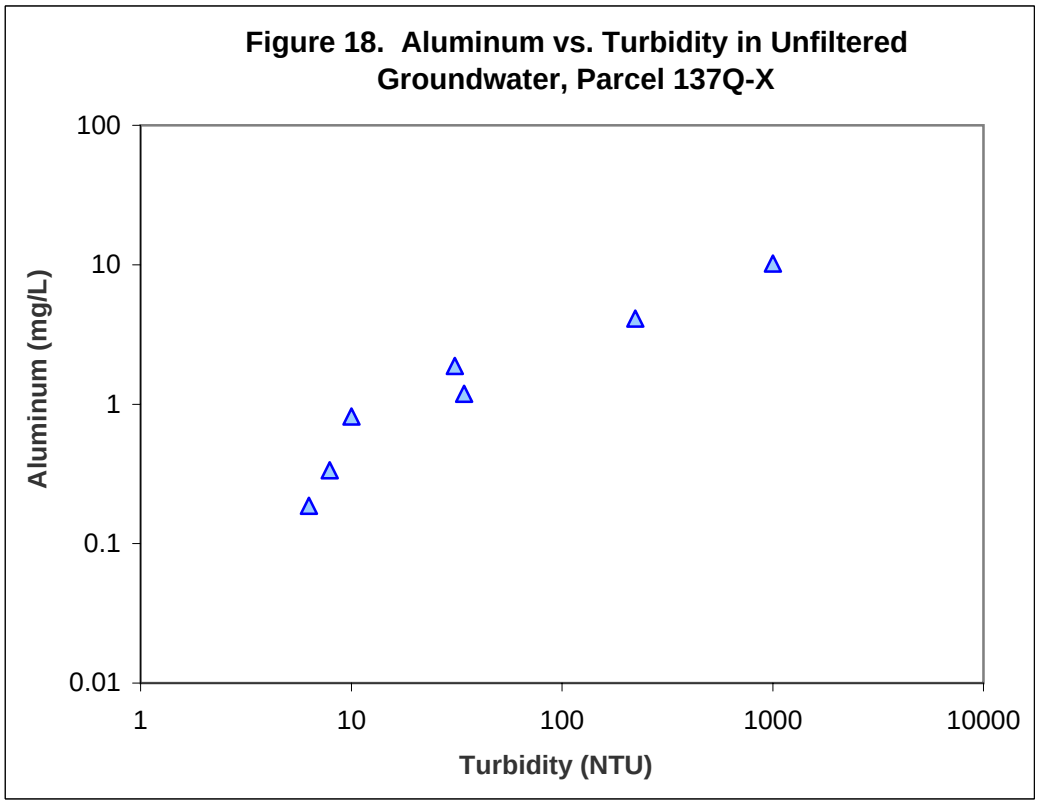


Figure 18. Aluminum vs. Turbidity in Unfiltered Groundwater, Parcel 137Q-X
Aluminum (mg/L)
100
10
1
0.1
0.01
1
10
100
1000
10000
Turbidity (NTU)

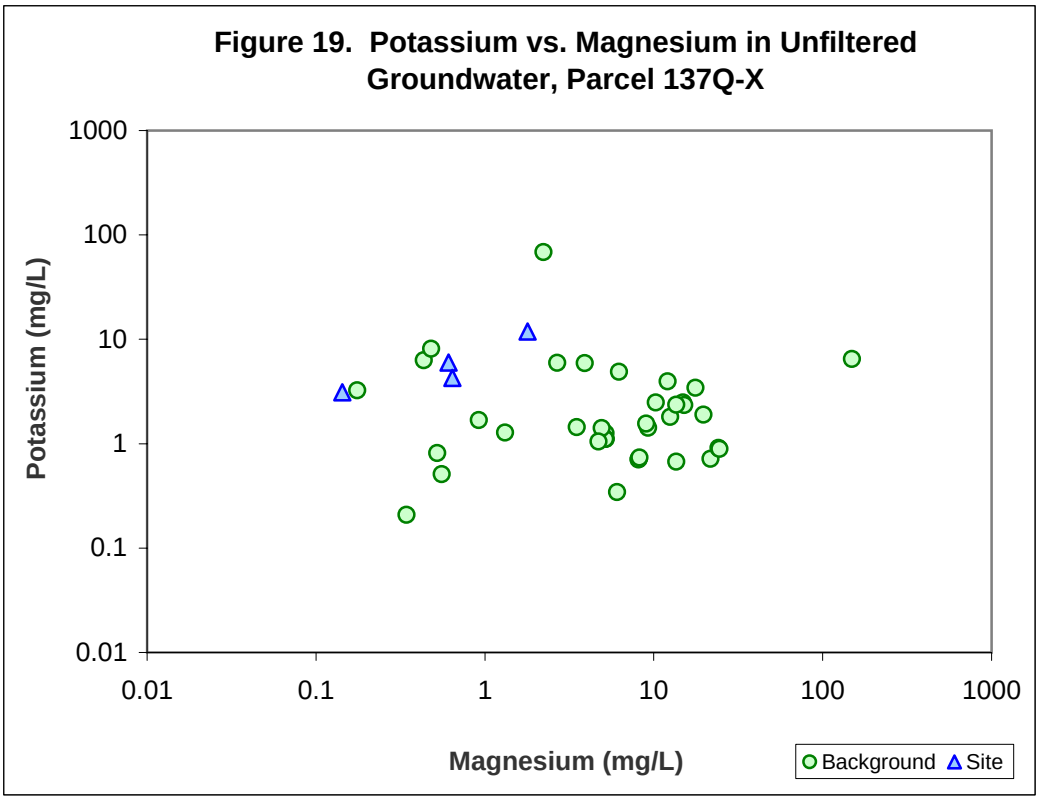


Figure 19. Potassium vs. Magnesium in Unfiltered Groundwater, Parcel 137Q-X
Potassium (mg/L)
1000
100
10
1
0.1
0.01
0.01
0.1
1
10
100
1000
Magnesium (mg/L)
Background
Site

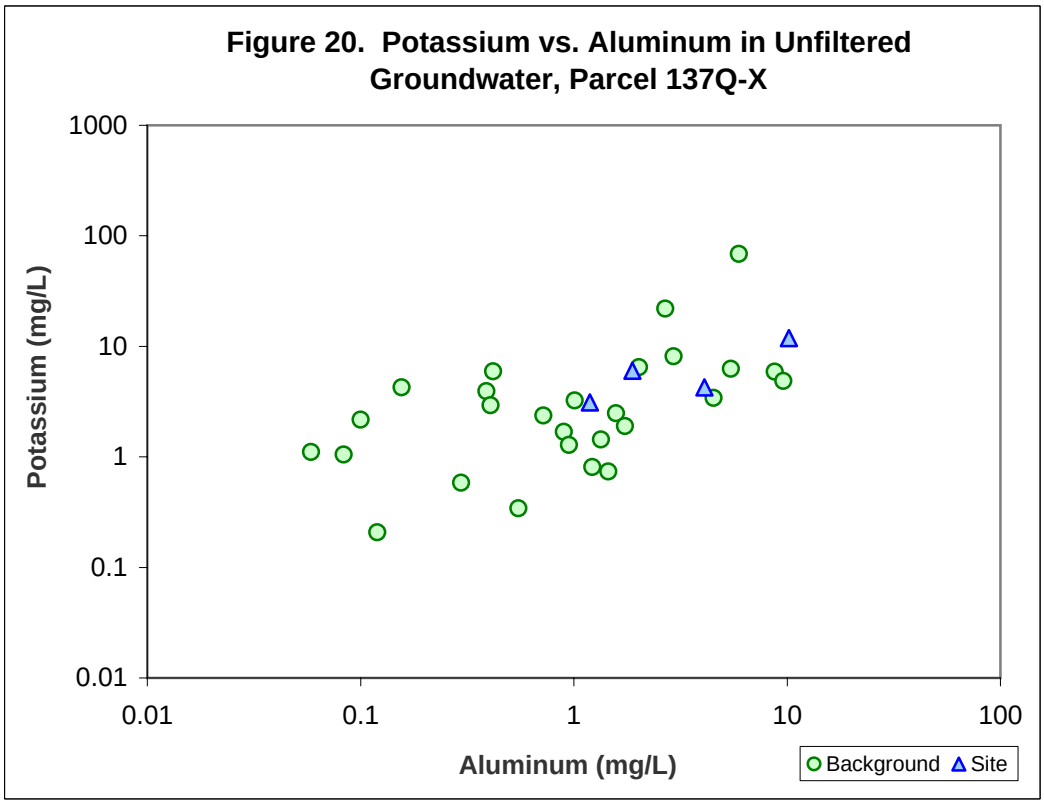


Figure 20. Potassium vs. Aluminum in Unfiltered Groundwater, Parcel 137Q-X
Potassium (mg/L)
1000
100
10
1
0.1
0.01
0.01
0.1
1
10
100
Aluminum (mg/L)
Background
Site

APPENDIX I

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

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

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 (μg/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

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

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:

$$PbB_{adult,central} = PbB_{adult,0} + \frac{PbS \cdot BKSF \cdot IR_S \cdot AF_S \cdot EF_S}{AT} \qquad (1)$$

where the variable definitions and their default values are:

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

PbS	=	soil lead concentration (microgram/gram [μg/g], which is equivalent to milligram per kilogram [mg/kg])
BKSF	=	biokinetic slope factor relating increase in typical adult blood lead concentration to average daily lead uptake (0.4 μg/dL blood lead increase per microgram per day [μg/day] lead uptake)
IR_S	=	soil intake rate (0.05 grams per day [g/day])
AF_S	=	gastrointestinal absorption factor for lead in soil (0.12 unitless fraction)
EF_S	=	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:

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

where the variable definitions and their default values are:

RBRG	=	risk-based remedial goal (analogous to cleanup level) for lead in soil (μg/g, equivalent to mg/kg), calculated
$PbB_{adult,central,goal}$	=	goal for CT estimate of blood lead concentration (μg/dL) in women to ensure that fetal blood levels (in 95 percent of population) do not exceed 10 μg/dL
$PbB_{adult,0}$	=	typical background blood lead concentration (1.7 to 2.2 μg/dL) in women of child-bearing age (average of 2.0 μg/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 μg/dL blood lead increase per μg/day lead uptake)
IR_S	=	soil intake rate (0.05 grams per day [g/day])
AF_S	=	gastrointestinal absorption factor for lead in soil (0.12 unitless fraction)
EF_S	=	exposure frequency (219 total days of exposure [employment] during the averaging period [one year]).

$PbB_{adult,central,goal}$, is estimated as (EPA, 1996):

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

where the variable definitions and their default values are:

$PbB_{adult,central,goal}$	=	goal for CT estimate of blood lead concentration (µg/dL) in women to ensure that fetal blood levels (in 95 percent of population) do not exceed 10 µg/dL, calculated
$PbB_{fetal,0.95,goal}$	=	goal for the 95th percentile blood lead concentration (generally accepted to be 10 µg/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:

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

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

$$3.3 - 2.0 = 1.3 \mu g / dL \tag{5}$$

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:

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

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

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

Fort McClellan (FTMC), 1997, ***Fort McClellan Comprehensive Reuse Plan***, Prepared under contract to the Calhoun County Commission, November.

Independent Technical Review (ITR), 2001, ***Fort McClellan, Alabama Independent Technical Review Draft Recommendations Report***, January.

IT Corporation (IT), 1998, Final ***Installation-Wide Work Plan, Fort McClellan, Alabama***, Prepared for the U.S. Department of the Army, Mobile District, Corps of Engineers, August.

Maddaloni, M., 2000, Personal communication: Telephone call between M. Maddaloni, EPA Region II, Chairperson, Technical Review Workgroup for Lead, and P. Goetchius, IT Corp., 13 December.

U.S. Environmental Protection Agency (EPA), 1989, ***Risk Assessment Guidance for Superfund Volume I Human Health Evaluation Manual (Part A)***, Interim Final, Office of Emergency and Remedial Response, Washington, DC, EPA/540/1-89/002, December.

U.S. Environmental Protection Agency (EPA), 1990, ***Technical Support Document for Lead***, Prepared by Syracuse Research Corporation for the Environmental Criteria and Assessment

Office, Cincinnati, OH, under Contract No. 68-C8-0004, 28 August.

U.S. Environmental Protection Agency (EPA), 1991, ***Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual Supplemental Guidance, Standard Default Exposure Factors, Interim Final***, Office of Solid Waste and Emergency Response, Washington, DC, OSWER Directive 9285.6-03, 25 March.

U.S. Environmental Protection Agency (EPA), 1994a, ***Guidance Manual for the Integrated Exposure Uptake Biokinetic Model for Lead in Children***, Office of Emergency and Remedial Response, Washington, DC, February, EPA/540/R-93/081, PB93-963510.

U.S. Environmental Protection Agency (EPA), 1994b, AGuidance on Residential Lead-Based Paint, Lead-Contaminated Dust, and Lead-Contaminated Soil,@ Memorandum from L.R. Goldman to regional directors, 14 July.

U.S. Environmental Protection Agency (EPA), 1995, ***Supplemental Guidance to RAGS: Region 4 Bulletins, Human Health Risk Assessment (Interim)***, Waste Management Division, Office of Health Assessment, EPA Region 4, Atlanta, GA, November.

U.S. Environmental Protection Agency (EPA), 1996, ***Recommendations of the Technical Review Workgroup for Lead for an Interim Approach to Assessing Risks Associated with Adult Exposures to Lead in Soil***, Technical Review Workgroup for Lead, December.

U.S. Environmental Protection Agency (EPA), 1997, ***Exposure Factors Handbook***, Office of Research and Development, National Center for Environmental Assessment, Washington, DC, August, EPA/600/P-95/002Fa.

U.S. Environmental Protection Agency (EPA), 2001, ***Integrated Risk Information System (IRIS)***, National Center for Environmental Assessment, Cincinnati, OH, on line.

Table 1

Pathway Variable[a]	Units	Recreational Site User	
		RME[a]	CT
Soil Exposure Pathways			
Soil incidental ingestion rate (IR)	g/day	0.1	0.05[b]
Fraction of exposure to site soil (FI)	unitless	0.25	0.25[c]
Exposure frequency (EF)	days/year	104[d]	104[c]

RME = reasonable maximum exposure; CT = central tendency
[a]Please see IT Corporation (IT), 1998, Final ***Installation-Wide Work Plan, Fort McClellan, Alabama***, 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.
[b]U.S. Environmental Protection Agency (EPA), 1997, ***Exposure Factors Handbook***, Office of Research and Development, National Center for Environmental Assessment, Washington, DC, August, EPA/600/P-95/002Fa.
[c]RME values are used where CT values cannot be estimated.
[d]Based on the assumption that exposure would occur on 2 days per week, 52 weeks per year.