APPENDIX L

STATISTICAL AND GEOCHEMICAL EVALUATION OF METALS DATA

SOILS

Comparison of Site and Background Soil Data for the Former Chemical Laundry and Motor Pool Area 1500, Parcel 94(7), at Fort McClellan, Calhoun County, Alabama

Summary

An integrated statistical and geochemical evaluation of 23 elements in soil was performed for the Former Chemical Laundry and Motor Pool Area 1500, Parcel 94(7), at Fort McClellan. Elevated concentrations of aluminum, arsenic, beryllium, calcium, chromium, cobalt, copper, iron, magnesium, mercury, nickel, potassium, selenium, and zinc were shown to be naturally occurring. Subsurface soil sample EM0018 (from sample location FTA-94-GP11) contains an anomalous concentration of lead that could not be explained as the result of natural processes.

1.0 Introduction

This report provides the methodology and results of the comparisons of concentrations of inorganic constituents in soil samples from background areas versus samples from the Former Chemical Laundry and Motor Pool Area 1500, Parcel 94(7), at Fort McClellan in Calhoun County, Alabama. Site samples used in the site-to-background comparison include the thirteen surface soil samples (0 to 1 foot below ground surface [bgs]) and fifteen subsurface soil samples (varying depths from 1 to 28 feet bgs) that were collected during the 1998 and 2001 site investigations.

Background distributions and screening values have been established for target analyte list metals in surface soil (0 to 1 foot bgs), subsurface soil (1 to 10 feet bgs), and combined (surface and subsurface) soil for Fort McClellan (IT Corporation, 2002). Because there are no significant differences between the background distributions of inorganic constituents in surface and subsurface soil, the combined (surface and subsurface) soil data set is considered the primary reference for background. Greater confidence can be placed in the combined background summary statistics because they are based on a larger data set (122 samples, for most analytes) than the individual surface and subsurface soil intervals (67 and 55 samples each, for most analytes). Accordingly, the background screening values used in the following site-to-background comparisons are based on the combined soil data set.

2.0 Comparison Methodology

This section describes the statistical and geochemical evaluation techniques that were employed in the Parcel 94(7) site-to-background comparisons.

2.1 Statistical Procedures

Contamination can be caused by a variety of processes that yield different spatial distributions of elevated contaminant concentrations. Slight but pervasive contamination can occur from non-point-source releases, and can result in slight increases in contaminant concentrations in a large percentage of samples. Localized, or "hot-spot," contamination can result in elevated concentrations in a small percentage of the total number of site samples. No single two-sample statistical comparison test is sensitive to both of these modes of contamination. For this reason, the use of multiple simultaneous tests is recommended for comparison of site and background distributions (U.S. Environmental Protection Agency [EPA], 1989, 1992, and 1994; U.S. Navy, 1998 and 1999).

The Wilcoxon rank sum (WRS) test is sensitive to slight but pervasive contamination, but is not sensitive to localized or more extreme hot-spot situations. The background threshold comparison, or "hot measurement test," is effective in identifying localized contamination, but is not sensitive to slight but pervasive contamination. The WRS test and hot measurement test are thus complementary. In addition to these tests, box-and-whisker plots are useful for visually comparing the site and background distributions and for properly interpreting the results of the WRS test.

Hot Measurement Test. 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 (UTL_{95}) 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.

The UTL_{95} or 95th percentile of the background distributions for 23 elements in Fort McClellan soil are provided in Table 1. To perform the test, each analyte's site maximum detected concentration (MDC) is compared to the background UTL_{95} 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.

Wilcoxon Rank Sum Test. The WRS test has been recommended for use in site-to-background comparisons (U.S. Navy, 1998 and 1999; EPA, 2000). 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 midrank. 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 0.05, then there is a statistically significant difference between the medians at the 95 percent confidence level. A Type I error involves rejecting the null hypothesis when it is true. If the p-level is greater than 0.05, then there is no reasonable justification to reject the null hypothesis at the 95 percent confidence level. It can therefore be concluded that the medians of the two data sets are similar, and can be assumed to be drawn from the same population.

If the p-level is less than 0.05, then the medians of the two distributions are significantly different at the 95 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. If the p-level is greater than 0.05, 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 (EPA, 1989 and 1992). An example box plot is provided in Figure 1. These plots provide a summary view of the entire data set, including the overall location and degree of symmetry. The box encloses the central 50 percent of the data points so that the top of the box represents the 75^{th} percentile and the bottom of the box represents the 25^{th} percentile. The small box within the larger box represents the median of the data set. The upper whisker extends outward from the box to either 1.5 times the interquartile distance (i.e., range between 25^{th} and 75^{th} percentiles) or to the maximum point, whichever is larger. The lower whisker extends either 1.5 times the interquartile distance or to the minimum point, whichever is smaller. Values outside the whiskers are shown as circles representing distinct points. 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. 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.

2.2 Geochemical Evaluation

If an analyte fails either of the statistical tests described in Section 2.1, then a geochemical evaluation is performed to determine if the elevated concentrations are caused by natural processes. The importance of geochemical evaluations in distinguishing between site and background data sets has been recognized in the industry (EPA, 1995; U.S. Navy, 1998 and 1999; Barclift, *et al.*, 2000). When properly evaluated, geochemistry can provide mechanistic explanations for apparently high, yet naturally occurring, constituents. Anomalous samples that may represent contamination can also be readily distinguished from uncontaminated samples.

The geochemical evaluation is based on the natural associations of trace elements with specific minerals in the soil matrix. For instance, arsenic, vanadium, nickel, and selenium are usually associated with iron oxide minerals. If a soil sample has a high percentage of iron oxide minerals, then it is expected to have proportionally higher concentrations of associated trace elements.

As an example, the absolute concentrations of arsenic and iron can vary by several orders of magnitude at a site, but the arsenic/iron ratios in each sample are usually quite constant at a given site as long as no contamination is present (Daskalakis and O'Connor, 1995). If a sample has some naturally occurring arsenic plus additional arsenic from an herbicide or some other source, then it will have an anomalously high ratio relative to the other uncontaminated samples. These ratios thus serve as a powerful technique for identifying contaminated samples.

The evaluation includes the generation of plots in which arsenic concentrations in a set of samples are plotted on the y-axis, and the corresponding iron concentrations are plotted on the x-axis. The slope of a best-fit line through the samples is equal to the average arsenic-to-iron background ratio. If the samples with the highest arsenic concentrations plot on the same linear trend as the other samples, then it is most probable that the elevated concentrations are natural, and are caused by the preferential enrichment of iron oxides in those samples. If the site samples with elevated arsenic concentrations plot above the trend displayed by the uncontaminated samples, then there is evidence that those samples have an excess contribution of arsenic, and contamination may be indicated.

Each trace element is associated with one or more minerals in the soil matrix. Arsenic, vanadium, and selenium form anionic species in solution and are associated with iron oxides, which maintain a positive surface charge. Divalent metals such as barium, cadmium, lead, and zinc tend to form cationic species in solution and are attracted to clay mineral surfaces, which maintain a negative surface charge. These trace elements would be evaluated against aluminum, which is a major component of clay minerals.

3.0 Results of the Site-to-Background Comparisons

Aluminum

Hot Measurement Test: One of the site samples exceeds the background screening value of 17,981 milligrams per kilogram (mg/kg).

WRS Test: The p-level of <0.0001 indicates a significant difference between the site and background distributions.

Box Plot: A box plot comparing the data sets is shown in Figure 2. The minimum, 25th percentile, median, and 75th percentile of the site data are higher than the respective background values. The site maximum is below the background maximum.

Geochemical Evaluation: Aluminum is the second most abundant of the 23 elements analyzed in the site soil samples, with a mean concentration of 10,148 mg/kg (1.0 weight percent). Aluminum is a primary component of common soil-forming minerals such as clays, feldspars, and micas. The Parcel 94(7) soil boring logs note that clay is the predominant soil type in the sampled intervals. If a soil sample is enriched in clays or other aluminum-bearing minerals, then that sample is expected to contain high concentrations of aluminum and associated trace elements. The site samples with high aluminum concentrations contain high concentrations of trace elements such as barium, cobalt, and zinc. For example, a plot of cobalt versus aluminum reveals a linear trend (see the Cobalt evaluation, below). The site samples with high cobalt concentrations also contain high aluminum concentrations, and lie on the trend formed by the background samples. These observations support the contention of a natural origin for aluminum in the site samples.

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

Antimony

Hot Measurement Test: One hundred percent of the site samples are nondetect for antimony. Site reporting limits range from 6.5 to 12.7 mg/kg, so it is not possible to determine if all of the site antimony concentrations are below the background screening value of 7.14 mg/kg.

WRS Test: The WRS test was not performed because the site data set contains 100 percent nondetects.

Box Plot: The site data set is characterized by 100 percent nondetects, so the site box plot reflects the replacement values of one-half the reporting limit (Figure 3). The site plot is elevated with respect to background because the site samples have significantly higher reporting limits (one to two orders of magnitude higher, in many cases).

Geochemical Evaluation: Lower reporting limits would be required to perform a geochemical evaluation.

Conclusion: Lower reporting limits would be required to adequately compare the site and background data sets.

Arsenic

Hot Measurement Test: None of the site samples have arsenic concentrations that exceed the background screening value of 32.42 mg/kg.

WRS Test: The p-level of 0.018 indicates weak agreement between the site and background distributions.

Box Plot: The minimum, 25th percentile, and median of the site data are higher than their respective background values (Figure 4). The 75th percentiles are similar, and the site maximum is below the background maximum.

Geochemical Evaluation: As discussed in Section 2.2, arsenic is typically associated with iron oxide minerals in soil. A plot of arsenic concentrations versus iron concentrations reveals a linear trend (Figure 5). The site samples with the highest arsenic concentrations also contain the highest iron and plot on the trend formed by the other samples, indicating that the arsenic in the soil samples is associated with iron oxides at a relatively constant ratio.

Conclusion: The elevated arsenic concentrations are observed in samples with elevated iron concentrations. Arsenic in the site samples is naturally occurring.

Barium

Hot Measurement Test: None of the site samples exceeds the background screening value of 242 mg/kg.

WRS Test: The p-level of 0.072 indicates acceptable agreement between the site and background distributions.

Box Plot: The minimum, 25th percentile, and median of the site data are higher than the corresponding background values (Figure 6). The 75th percentiles are similar, and the site maximum is below the background maximum.

Geochemical Evaluation: A geochemical evaluation is not required because the site data are within range of background.

Conclusion: Barium in the site samples is probably naturally occurring.

Beryllium

Hot Measurement Test: One of the site samples exceeds the background screening value of 1.502 mg/kg.

WRS Test: The p-level of 0.0001 indicates a significant difference between the site and background distributions.

Box Plot: The minimum, 25th percentile, median, and 75th percentile of the site data are higher than the respective background values (Figure 7). The site maximum is slightly lower than the background maximum.

Geochemical Evaluation: A plot of beryllium versus iron reveals a weak linear trend (Figure 8). The site samples with high beryllium concentrations generally have high iron, and all of the site samples lie on the trend defined by the background samples.

Conclusion: The elevated beryllium concentrations are observed in samples with high iron content. Beryllium in the site samples is naturally occurring.

Cadmium

Hot Measurement Test: One hundred percent of the site samples are nondetect for cadmium. The site reporting limits range from 0.54 to 0.88 mg/kg, so cadmium concentrations in the site samples are below the background screening value of 1.2 mg/kg.

WRS Test: No WRS test was performed because the site data set contains 100 percent nondetects.

Box Plot: The location and shape of the site box plot reflects the high percentage of nondetects (100 percent), the narrow range of reporting limits (0.54 to 0.88 mg/kg), and the higher reporting limits relative to the background data (Figure 9).

Geochemical Evaluation: Lower reporting limits for the site data would be required to perform a geochemical evaluation.

Conclusion: Lower reporting limits would be required to adequately compare the site and background data.

Calcium

Hot Measurement Test: Three of the site samples exceed the background screening value of 5,490 mg/kg.

WRS Test: The p-level of <0.0001 indicates a significant difference between the site and background distributions.

Box Plot: The site minimum, 25th percentile, median, and 75th percentile are higher than their respective background values (Figure 10). The site maximum is slightly lower than the background maximum.

Geochemical Evaluation: Calcium occurs in common soil minerals such as carbonates, clays, and feldspars. Calcium and magnesium have similar chemical properties, and magnesium often substitutes for calcium in minerals. Figure 11 contains a plot of magnesium versus calcium. The site samples with high calcium concentrations generally contain high magnesium, and lie on the trend established by the background samples. This indicates that the calcium is most likely natural.

Conclusion: Calcium concentrations detected in the site samples are naturally occurring.

Chromium

Hot Measurement Test: None of the site samples exceeds the background screening value of 56.3 mg/kg.

WRS Test: A WRS test p-level of 0.0003 indicates a significant difference between the site and background distributions.

Box Plot: The minimum, 25th percentile, median, and 75th percentile of the site data set are elevated with respect to background (Figure 12). The site maximum is below the background maximum.

Geochemical Evaluation: A plot of chromium versus iron reveals a strong linear trend (Figure 13). The site samples with high chromium concentrations also have high iron concentrations, and lie on the trend formed by the other samples. This indicates that chromium in the site samples is associated with iron oxides at a relatively constant ratio.

Conclusion: The elevated chromium concentrations are observed in samples with elevated iron content. Chromium in the site samples is naturally occurring.

Cobalt

Hot Measurement Test: None of the site samples exceeds the background screening value of 36.3 mg/kg.

WRS Test: The p-level of <0.0001 indicates a significant difference between the site and background distributions.

Box Plot: The minimum, 25th percentile, median, and 75th percentile of the site data set are higher than the respective background values (Figure 14). The site maximum is below the background maximum.

Geochemical Evaluation: A plot of cobalt versus manganese reveals a strong linear trend for the background samples (Figure 15a). The site samples with high cobalt concentrations generally contain high magnesium and lie on the trend established by the background samples. Exceptions include site samples EM0007, EM0018, and EM0020, which have moderate cobalt concentrations but low manganese concentrations, and plot slightly above the background trend. However, a plot of cobalt versus aluminum reveals that the site samples with high cobalt also have high aluminum (Figure 15b) and that all of the site samples (including EM0007, EM0018, and EM0020) lie on the trend formed by the background samples. These observations suggest that cobalt in the site samples is associated with manganese oxides and clay minerals.

Conclusion: The elevated cobalt concentrations are observed in samples with elevated manganese and aluminum content. Cobalt in the site samples is naturally occurring.

Copper

Hot Measurement Test: Ten site samples exceed the background screening value of 25.9 mg/kg.

WRS Test: The p-level of <0.0001 indicates a significant difference between the site and background distributions.

Box Plot: The site minimum, 25th percentile, median, and 75th percentile are higher than their respective background values (Figure 16). The site and background maxima are similar.

Geochemical Evaluation: A plot of copper versus iron exhibits a linear trend (Figure 17). The site samples with the highest copper concentrations also contain the highest iron concentrations, and lie on the trend defined by the other samples. These concentrations are most likely natural.

Conclusion: The elevated copper concentrations are observed in samples with high iron content. Copper in the site samples is naturally occurring.

Iron

Hot Measurement Test: None of the site samples exceeds the background screening value of 56,312 mg/kg.

WRS Test: The p-level of <0.0001 indicates poor agreement between the site and background distributions.

Box Plot: The site minimum, 25th percentile, median, and 75th percentile are higher than the corresponding background values (Figure 18). The site and background maxima are similar.

Geochemical Evaluation: Iron is the most abundant element of the 23 elements analyzed in the site soil samples, with a mean concentration of 31,498 mg/kg (3.1 weight percent). It is probably present in site soil in the form of iron oxide minerals, which have an affinity for trace elements such as arsenic, nickel, selenium, and vanadium. If a soil sample contains a high proportion of iron oxides, then it is expected to contain high concentrations of iron and associated trace elements. As discussed in the Arsenic, Beryllium, Chromium, Copper, and Nickel evaluations, plots of arsenic, beryllium, chromium, copper, and nickel versus iron reveal linear trends. The site samples with high iron concentrations contain high concentrations of these trace elements, and lie on the trends formed by the background samples. These observations support the contention of a natural origin for arsenic, beryllium, chromium, copper, iron, and nickel in the site samples.

Conclusion: Iron concentrations in the site samples are naturally occurring.

Lead

Hot Measurement Test: One of the site samples exceeds the background screening value of 60.5 mg/kg.

WRS Test: The p-level of 0.013 indicates weak agreement between the site and background distributions.

Box Plot: The minimum, 25th percentile, and median of the site data are elevated with respect to background (Figure 19). The 75th percentiles are similar, and the site maximum is below the background maximum.

Geochemical Evaluation: A plot of lead versus manganese reveals a strong linear trend for most of the samples (Figure 20). Most of the site samples with high lead concentrations also contain high manganese and lie on the trend formed by the background samples. This suggests that lead is associated with manganese oxides in soil at a relatively constant ratio. An exception is subsurface soil sample EM0018 (from sample location FTA-94-GP11), which contains high lead (40.7 mg/kg) but low manganese (6.9 mg/kg). Elevated lead in this sample is unexpected.

Conclusion: Subsurface soil sample EM0018 contains an anomalously high concentration of lead.

Magnesium

Hot Measurement Test: Two of the site samples exceed the background screening value of 5,545 mg/kg.

WRS Test: The WRS test was not performed because the site data set contains 54 percent nondetects.

Box Plot: The site minimum, 25th percentile, median, and 75th percentile are higher than the corresponding background values (Figure 21). The site maximum is below the background maximum.

Geochemical Evaluation: Magnesium is probably present in site soil in the form of mica, clay, and carbonate minerals. As discussed in the Calcium evaluation, calcium and magnesium have similar chemical properties, and magnesium often substitutes for calcium in minerals. A plot of magnesium versus calcium shows a linear trend (Figure 11); the site samples with high magnesium concentrations generally contain high calcium, and lie on the trend established by the background samples. This indicates that the magnesium is most likely natural.

Conclusion: Magnesium in the site samples is naturally occurring.

Manganese

Hot Measurement Test: None of the site samples exceeds the background screening value of 4,120 mg/kg.

WRS Test: The p-level of 0.881 indicates excellent agreement between the site and background distributions.

Box Plot: The minimum and 25th percentile of the site data are higher than the corresponding background values (Figure 22). The medians of the two data sets are similar, and the site 75th percentile and maximum are lower than the respective background values.

Geochemical Evaluation: A geochemical evaluation is not required because the site data are within range of background.

Conclusion: Manganese in the site samples is probably naturally occurring.

Mercury

Hot Measurement Test: Seven of the site samples exceeds the background screening value of 0.094 mg/kg.

WRS Test: No WRS test was performed because the background data set contains 59.8 percent nondetects.

Box Plot: The site minimum, 25th percentile, median, and 75th percentile are higher than their respective background values (Figure 23). The site maximum is lower than the background maximum.

Geochemical Evaluation: A plot of mercury versus aluminum reveals a weak linear trend (Figure 24). The site samples with high mercury concentrations generally contain high aluminum, and all of the site samples lie on the trend formed by the background samples. These concentrations are most likely natural.

Conclusion: The elevated mercury concentrations are generally observed in samples with elevated aluminum content. Mercury in the site samples is probably naturally occurring.

Nickel

Hot Measurement Test: Two of the site samples exceed the background screening value of 16.9 mg/kg.

WRS Test: The p-level of <0.0001 indicates a significant difference between the site and background distributions.

Box Plot: The minimum, 25^{th} percentile, median, 75^{th} percentile, and maximum of the site data are elevated with respect to background (Figure 25).

Geochemical Evaluation: A plot of nickel versus iron reveals a weak linear trend (Figure 26). The site samples with high nickel generally contain high iron, and plot on the trend formed by the background samples. The nickel concentrations are most likely natural.

Conclusion: The elevated nickel concentrations are observed in samples with elevated iron content. Nickel in the site samples is probably naturally occurring.

Potassium

Hot Measurement Test: Four of the site samples exceed the background screening value of 831 mg/kg.

WRS Test: No WRS test was performed because the site data set contains 54 percent nondetects.

Box Plot: The minimum, 25^{th} percentile, median, and 75^{th} percentile of the site data set are higher than the corresponding background values (Figure 27). The site maximum is below the background maximum.

Geochemical Evaluation: Potassium is present in minerals that also contain aluminum, such as feldspars, micas, and clays. Figure 28 reveals a linear relationship between potassium and aluminum. Site samples with high potassium concentrations also contain high aluminum, and plot on the trend formed by the other samples. Elevated potassium in these samples is most likely natural.

Conclusion: Elevated potassium concentrations are observed in samples with high aluminum content. Potassium in the site samples is naturally occurring.

Selenium

Hot Measurement Test: All eighteen detected concentrations exceed the background screening value of 0.571 mg/kg. The ten nondetect samples have reporting limits ranging from 0.54 to 1.27 mg/kg, so it is not possible to determine if all of the selenium concentrations in the nondetect samples are below the background screening value.

WRS Test: No WRS test was performed because the background data set contains 98.4 percent nondetects.

Box Plot: The site minimum, 25th percentile, median, 75th percentile, and maximum are all higher than the respective background values (Figure 29). The background data set is characterized by a high percentage of nondetects (98.4 percent), so the background box plot reflects the replacement values of one-half the reporting limit.

Geochemical Evaluation: As discussed in Section 2.2, selenium is typically associated with iron oxide minerals in soil. A plot of selenium versus iron reveals a linear trend (Figure 30). The samples with the highest selenium concentrations also have the highest iron concentrations, indicating that the selenium in the site samples is probably associated with iron oxides. Comparison to the background samples is hindered by the high percentage of nondetects (98.4 percent) in the background data set, but the two detected background concentrations lie on the same trend as the site samples.

Conclusion: The elevated selenium concentrations are observed in samples with elevated iron concentrations. Selenium detected in the site samples is probably naturally occurring.

Silver

Hot Measurement Test: One-hundred percent of the site samples are nondetect for silver. The site reporting limits range from 1.1 mg/kg to 1.8 mg/kg, so it cannot be determined if silver concentrations in the site samples exceed the background screening value of 0.803 mg/kg.

WRS Test: No WRS test was performed because the site data set contains 100 percent nondetects.

Box Plot: The site data set is characterized by a high percentage of nondetects (100 percent), so the shape and location of the box plot are defined by the replacement values of one-half the reporting limit (Figure 31). The site box plot is higher than the background box plot because the site samples have significantly higher reporting limits.

Geochemical Evaluation: Lower reporting limits would be required to perform a geochemical evaluation.

Conclusion: Lower reporting limits would be required to adequately compare the site and background data sets.

Sodium

Hot Measurement Test: None of the detected site concentrations exceeds the background screening value of 560 mg/kg. The nondetect samples have reporting limits ranging from 545 to 879 mg/kg, so it is not possible to determine if all of the sodium concentrations in the nondetect samples are below the background screening value.

WRS Test: The WRS test was not performed because the site data set contains 79 percent nondetects.

Box Plot: The site box plot reflects the high percentages of nondetects (79 percent), and thus the shape and location of the box plot reflect the replacement values of one-half the reporting limit (Figure 32).

Geochemical Evaluation: Lower reporting limits would be required to perform a geochemical evaluation.

Conclusion: The observed concentrations of sodium are probably naturally occurring.

Thallium

Hot Measurement Test: One hundred percent of the site samples are nondetect for thallium. Site reporting limits range from 1.1 to 2.55 mg/kg, so thallium concentrations in the site samples are below the background screening value of 6.62 mg/kg.

WRS Test: No WRS test was performed because the site data set contains 100 percent nondetects.

Box Plot: The site data set contains 100 percent nondetects, so the shape and location of the site box plot reflect the narrow range of reporting limits (1.1 to 2.55 mg/kg) (Figure 33). The site plot is higher than the background plot because the site reporting limits are significantly higher than the background detected concentrations.

Geochemical Evaluation: Lower reporting limits would be required to perform a geochemical evaluation.

Conclusion: Lower reporting limits would be required to adequately compare the site data to background.

Vanadium

Hot Measurement Test: None of the site samples exceeds the background screening value of 90.5 mg/kg.

WRS Test: A WRS test p-level of <0.0001 indicates a significant difference between the site and background distributions. The reason for the difference is that the site data are lower than the background data.

Box Plot: The minimum, 25th percentile, median, 75th percentile, and maximum of the site data set are lower than the respective background values (Figure 34).

Geochemical Evaluation: A geochemical evaluation is not required because the site data are within range of background.

Conclusion: Vanadium in the site samples is probably naturally occurring.

Zinc

Hot Measurement Test: Five of the site samples exceed the background screening value of 71.3 mg/kg.

WRS Test: A WRS test p-level of <0.0001 indicates a significant difference between the site and background distributions.

Box Plot: The site minimum, 25th percentile, median, and 75th percentile are elevated with respect to background (Figure 35). The site maximum is below the background maximum.

Geochemical Evaluation: A plot of zinc versus aluminum reveals a linear trend (Figure 36). Most of the site samples with high zinc concentrations also contain high aluminum, and lie on the trend defined by the background samples. Exceptions include samples EM0021, -23, and -24, which are depositional soil samples from locations FTA-94-DEP01, -03, and -04, respectively. These three samples contain high zinc concentrations but only moderate aluminum, and plot slightly above the trend formed by the other samples. Soils in depositional environments are expected to have higher metals concentrations than vadose-zone soils because they are in regular contact with surface water, which results in greater adsorption of metals to the mineral surfaces. Zinc in these samples is most likely natural.

Conclusion: The elevated zinc concentrations are observed in samples with elevated aluminum concentrations. Zinc detected in the site samples is probably naturally occurring.

4.0 Summary and Conclusions

The methodology used to compare the site and background data sets for 23 elements in soil consists of a combination of a hot measurement test, the nonparametric two-sample Wilcoxon rank sum test, and box-and-whisker plots. Analytes that failed either of the statistical tests were subjected to a geochemical evaluation to determine if the elevated concentrations could be explained by natural processes.

Aluminum, arsenic, beryllium, calcium, chromium, cobalt, copper, iron, lead, magnesium, mercury, nickel, potassium, selenium, and zinc were subjected to geochemical evaluation. For most of these elements, the elevated concentrations could be explained as most likely resulting from the preferential enrichment of samples with minerals such as clays, iron oxides, or manganese oxides, which naturally concentrate specific trace elements. Subsurface soil sample EM0018 (from sample location FTA-94-GP11) contains an anomalously high concentration of lead that cannot be explained as a result of natural processes.

5.0 References

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

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.

IT Corporation, 2002, "Background Screening Values for Groundwater, Surface Water, Sediment, and Soil at Fort McClellan," memo from J. Myers to K. Thorbjornsen, January 24.

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

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), 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. 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, 1998, ***Procedural Guidance for Statistically Analyzing Environmental Background Data***, Naval Facilities Engineering Command, Southwest Division and Engineering Field Activity, West, September.

U.S. Navy, 1999, ***Handbook for Statistical Analysis of Environmental Background Data***, Naval Facilities Engineering Command, Southwest Division and Engineering Field Activity, West, July.

ATTACHMENT 1

TABLES

Table 1

Background Screening Values (H_m) for Combined (Surface and Subsurface) Soils
Fort McClellan
Calhoun County, Alabama

Analyte	H_m (mg/kg)
Aluminum	17,981
Antimony	<7.14
Arsenic	32.42
Barium	242.0
Beryllium	1.502
Cadmium	<1.2
Calcium	5,490
Chromium	56.3
Cobalt	36.3
Copper	25.9
Iron	56,312
Lead	60.5
Magnesium	5,545
Manganese	4,120
Mercury	0.094
Nickel	16.9
Potassium	831
Selenium	<0.571
Silver	<0.803
Sodium	560.0
Thallium	<6.62
Vanadium	90.5
Zinc	71.3

mg/kg - Milligram(s) per kilogram.

ATTACHMENT 2

FIGURES

Figure 1
Example Box Plot

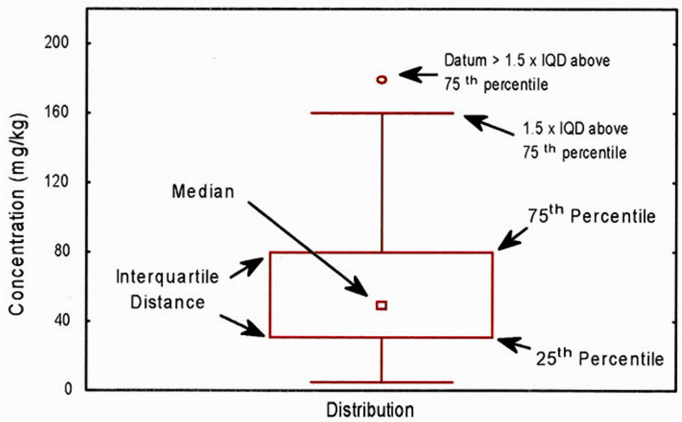
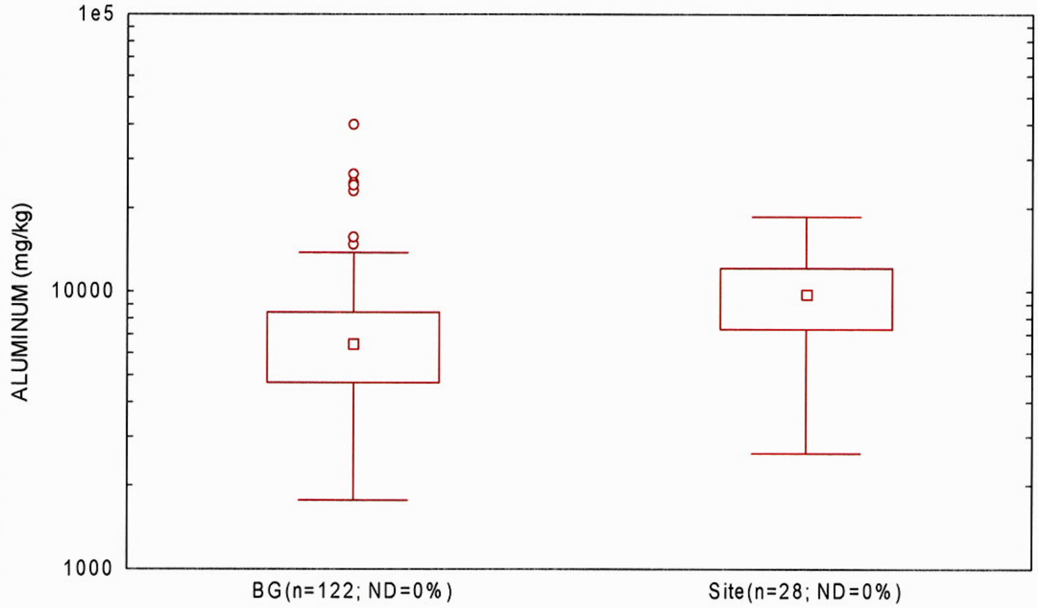


Figure 2. Box Plot Comparison for Aluminum in Soil
Parcel 94(7), Ft. McClellan
(WRS Test p-level = <0.0001)



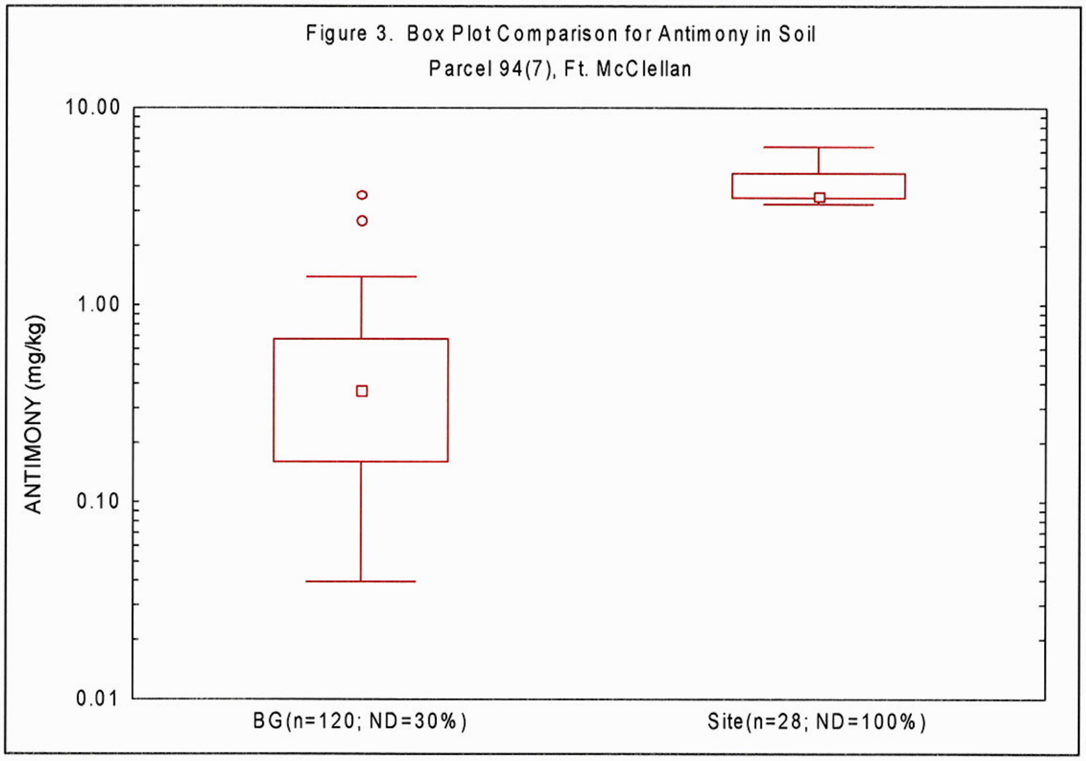


Figure 3. Box Plot Comparison for Antimony in Soil
Parcel 94(7), Ft. McClellan
ANTIMONY (mg/kg)
10.00
1.00
0.10
0.01
BG(n=120; ND=30%)
Site(n=28; ND=100%)

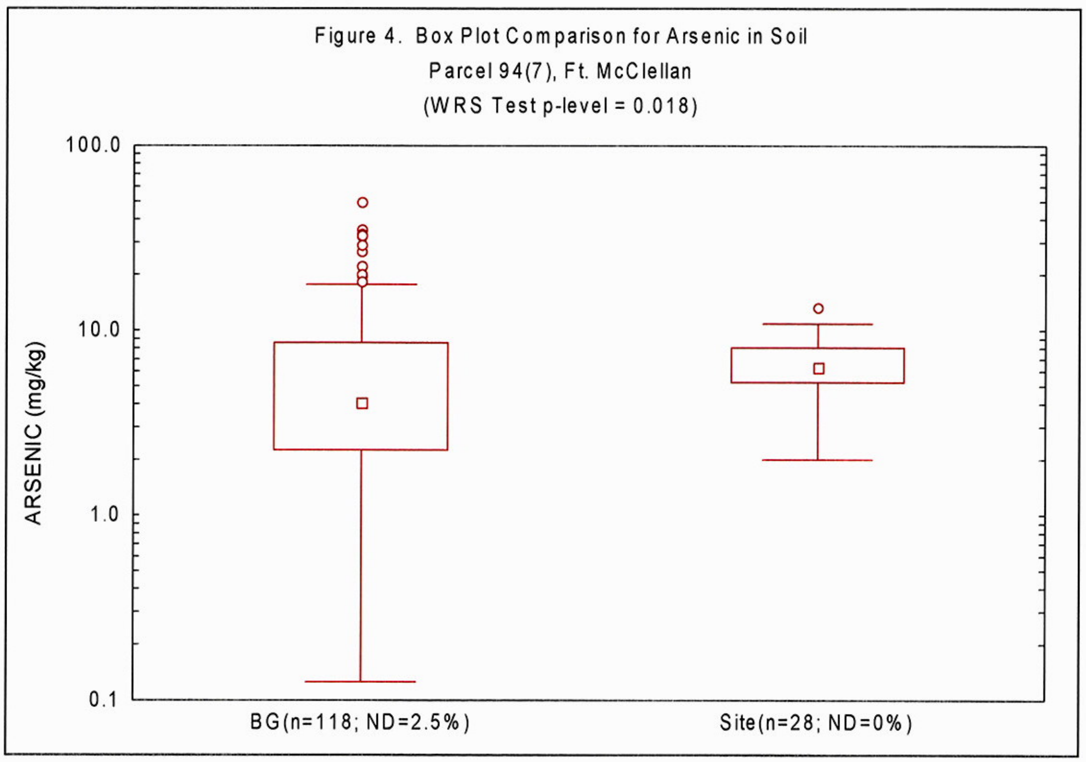


Figure 4. Box Plot Comparison for Arsenic in Soil
Parcel 94(7), Ft. McClellan
(WRS Test p-level = 0.018)
ARSENIC (mg/kg)
100.0
10.0
1.0
0.1
BG(n=118; ND=2.5%)
Site(n=28; ND=0%)

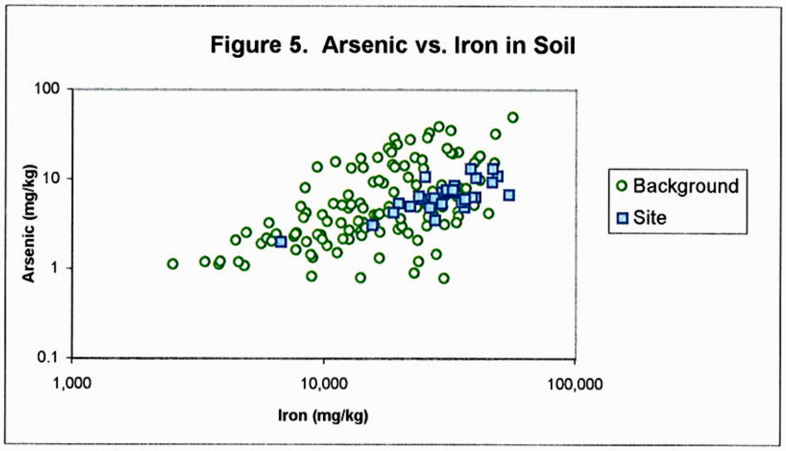


Figure 5. Arsenic vs. Iron in Soil
100
10
1
0.1
Arsenic (mg/kg)
1,000
10,000
100,000
Iron (mg/kg)
Background
Site

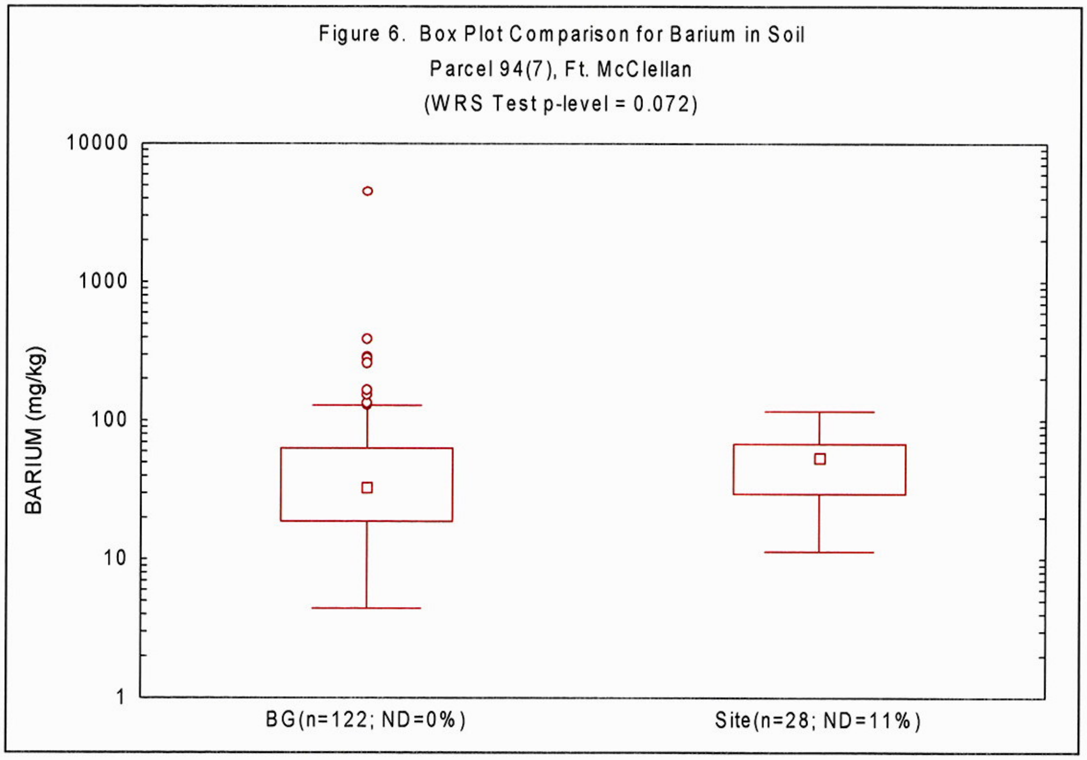


Figure 6. Box Plot Comparison for Barium in Soil
Parcel 94(7), Ft. McClellan
(WRS Test p-level = 0.072)
10000
1000
100
10
1
BARIUM (mg/kg)
BG(n=122; ND=0%)
Site(n=28; ND=11%)

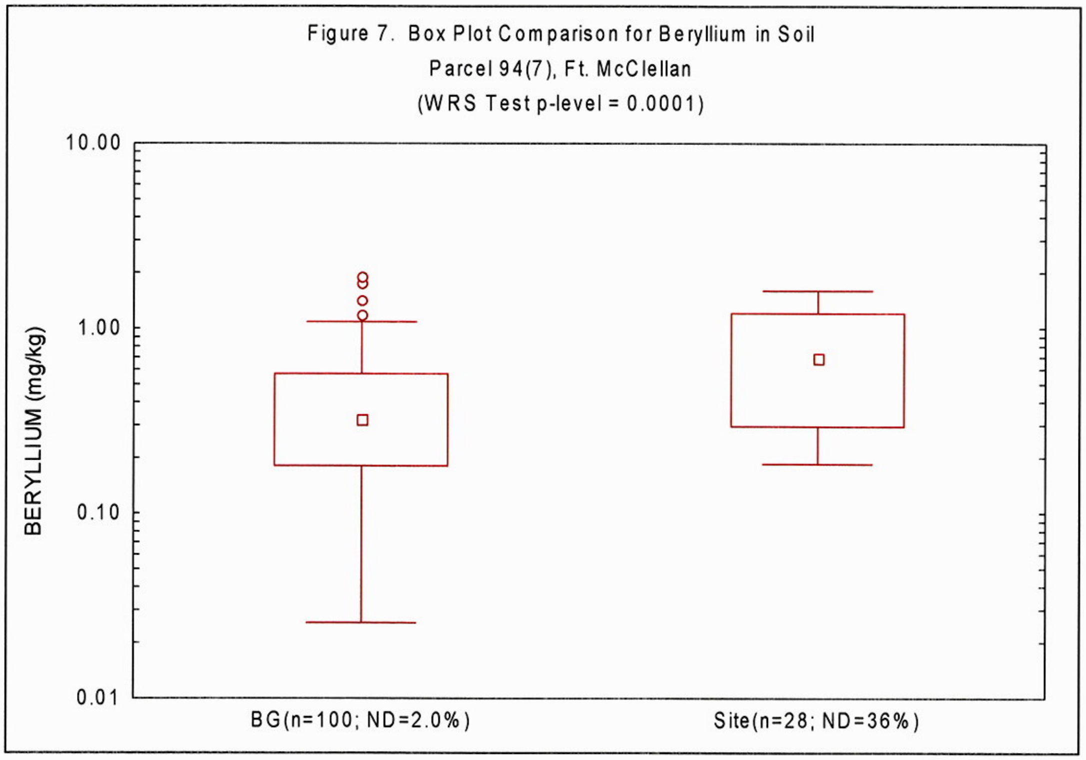


Figure 7. Box Plot Comparison for Beryllium in Soil
Parcel 94(7), Ft. McClellan
(WRS Test p-level = 0.0001)
10.00
1.00
0.10
0.01
BERYLLIUM (mg/kg)
BG(n=100; ND=2.0%)
Site(n=28; ND=36%)

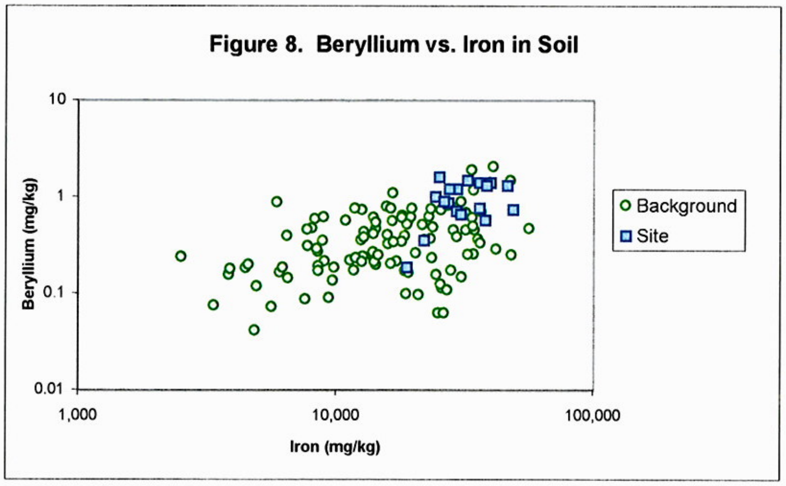


Figure 8. Beryllium vs. Iron in Soil
10
1
0.1
0.01
Beryllium (mg/kg)
1,000
10,000
100,000
Iron (mg/kg)
Background
Site

Figure 9. Box Plot Comparison for Cadmium in Soil
Parcel 94(7), Ft. McClellan

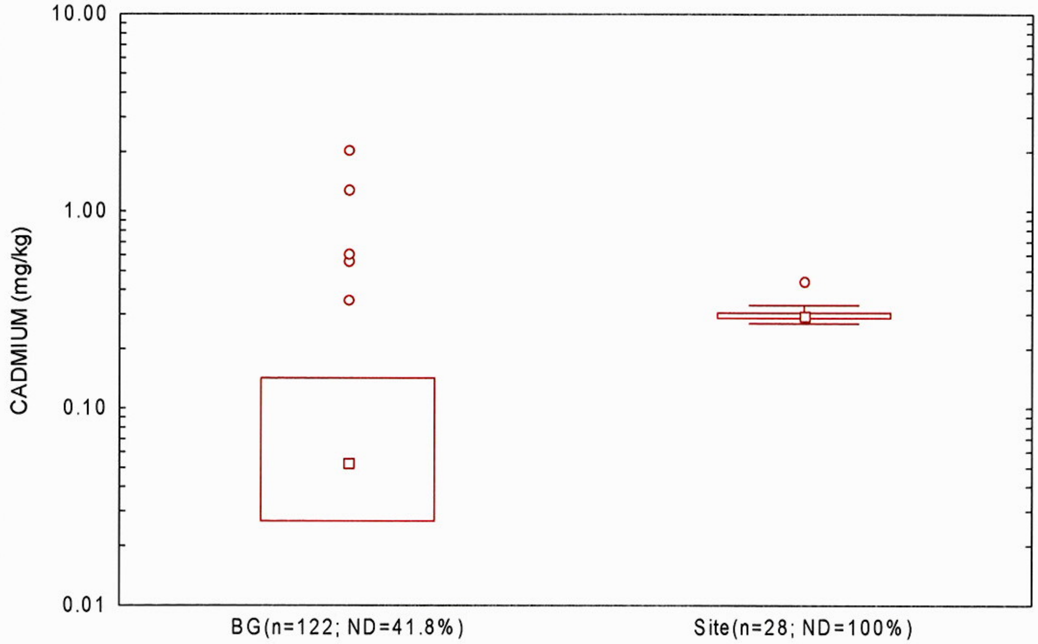


Figure 10. Box Plot Comparison for Calcium in Soil
Parcel 94(7), Ft. McClellan
(WRS Test p-level = <0.0001)

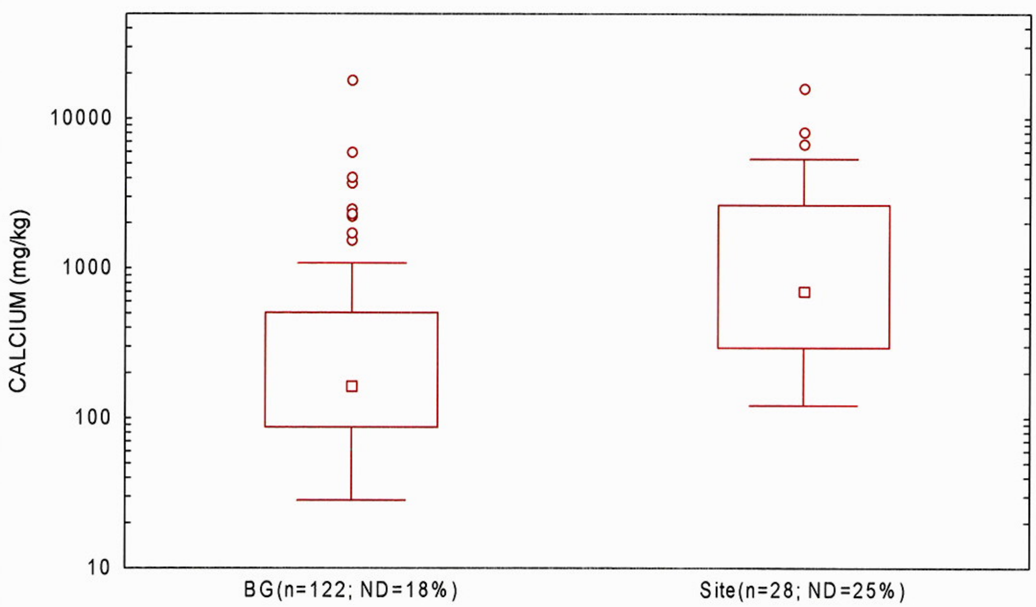


Figure 11. Magnesium vs. Calcium in Soil

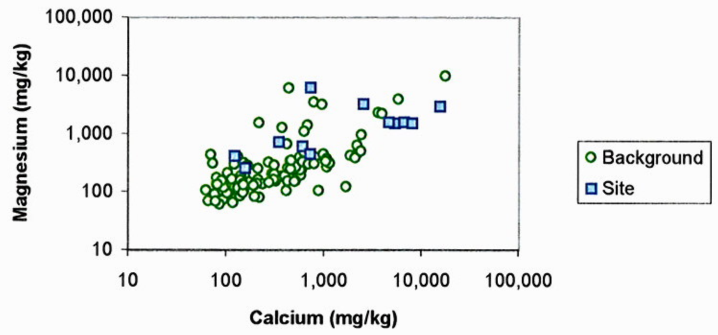
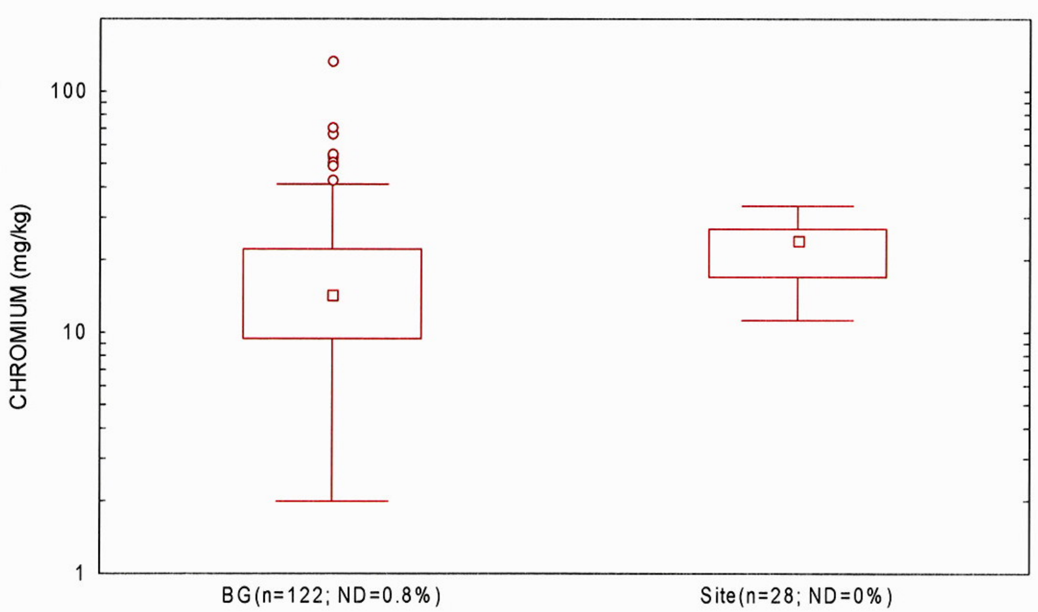


Figure 12. Box Plot Comparison for Chromium in Soil
Parcel 94(7), Ft. McClellan
(WRS Test p-level = 0.0003)



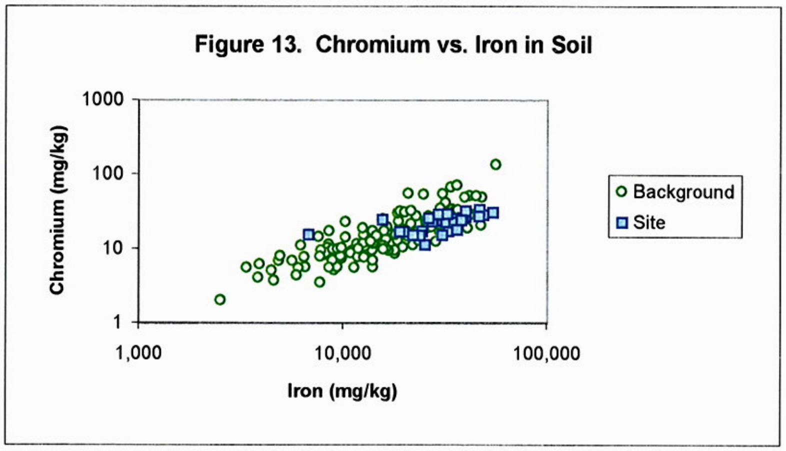


Figure 13. Chromium vs. Iron in Soil
Chromium (mg/kg)
1000
100
10
1
1,000
10,000
100,000
Iron (mg/kg)
Background
Site

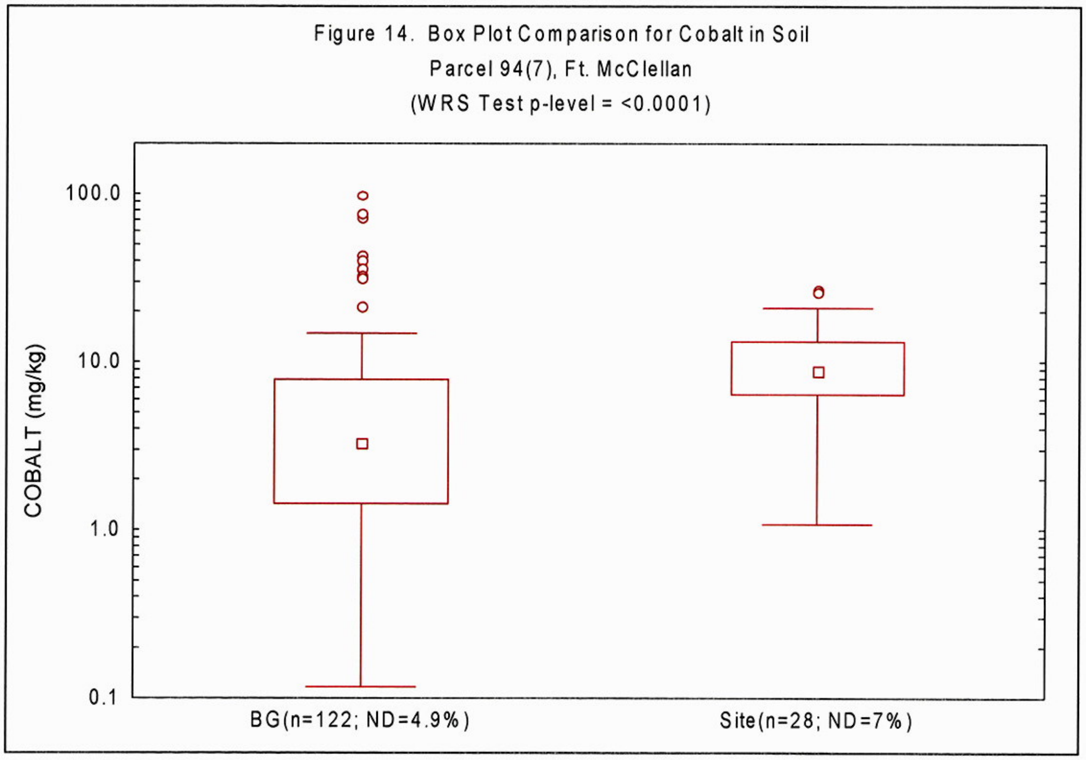


Figure 14. Box Plot Comparison for Cobalt in Soil
Parcel 94(7), Ft. McClellan
(WRS Test p-level = <0.0001)
COBALT (mg/kg)
100.0
10.0
1.0
0.1
BG(n=122; ND=4.9%)
Site(n=28; ND=7%)

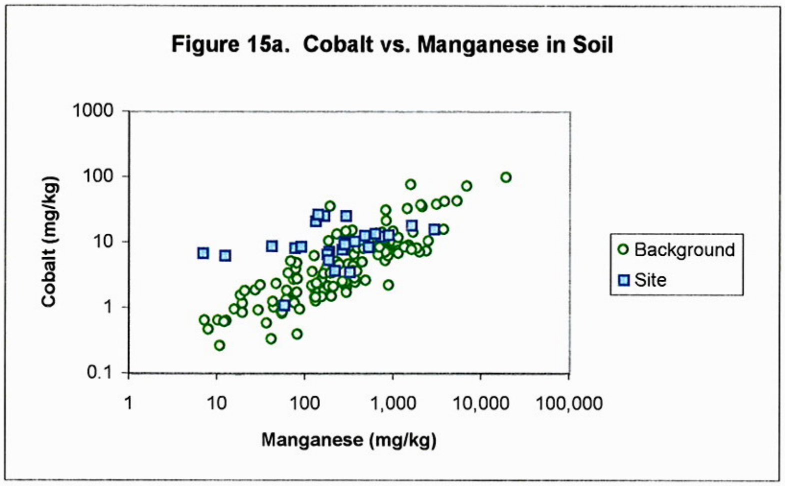


Figure 15a. Cobalt vs. Manganese in Soil
1000
100
10
1
0.1
Cobalt (mg/kg)
1
10
100
1,000
10,000
100,000
Manganese (mg/kg)
Background
Site

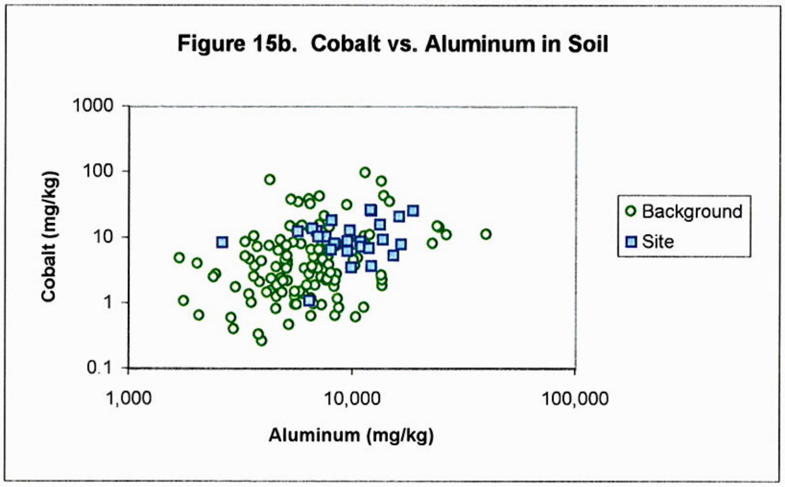


Figure 15b. Cobalt vs. Aluminum in Soil
1000
100
10
1
0.1
Cobalt (mg/kg)
1,000
10,000
100,000
Aluminum (mg/kg)
Background
Site

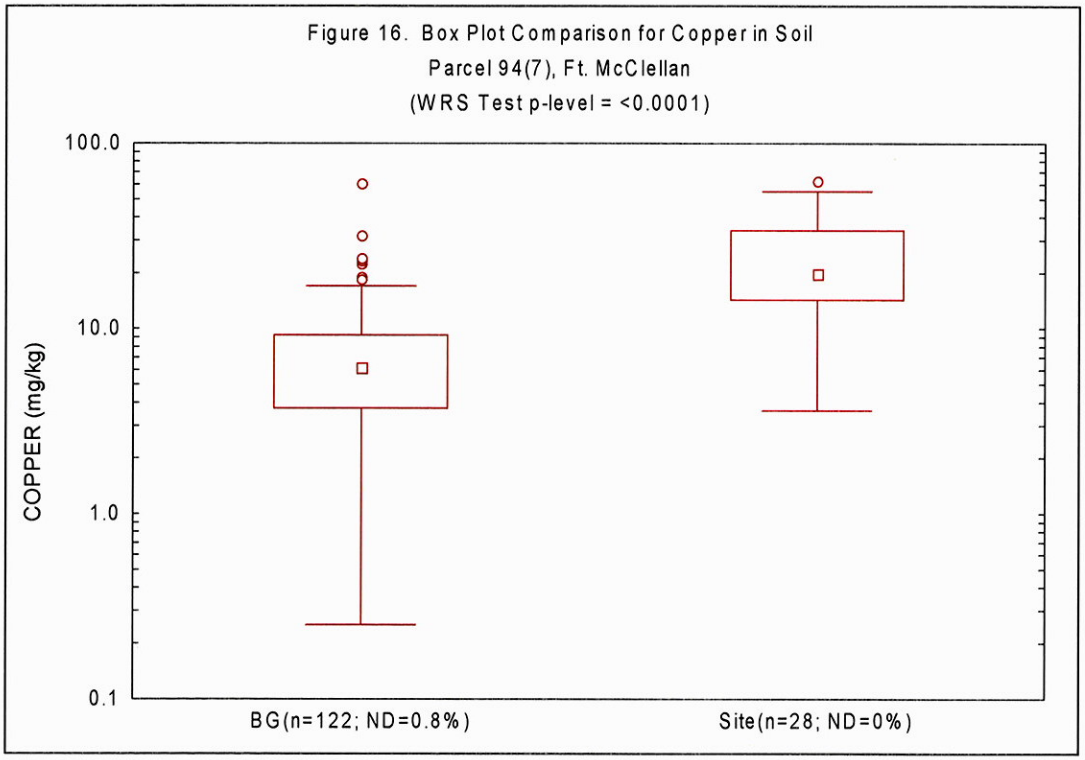


Figure 16. Box Plot Comparison for Copper in Soil
Parcel 94(7), Ft. McClellan
(WRS Test p-level = <0.0001)
COPPER (mg/kg)
100.0
10.0
1.0
0.1
BG(n=122; ND=0.8%)
Site(n=28; ND=0%)

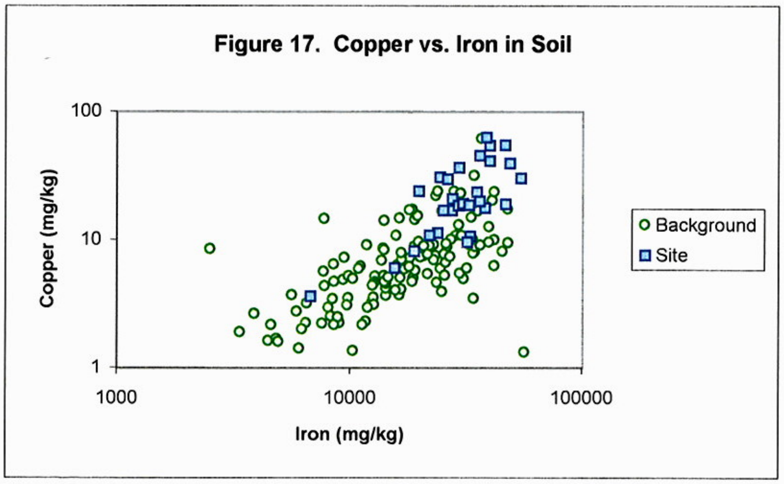


Figure 17. Copper vs. Iron in Soil
Copper (mg/kg)
100
10
1
1000
10000
100000
Iron (mg/kg)
Background
Site

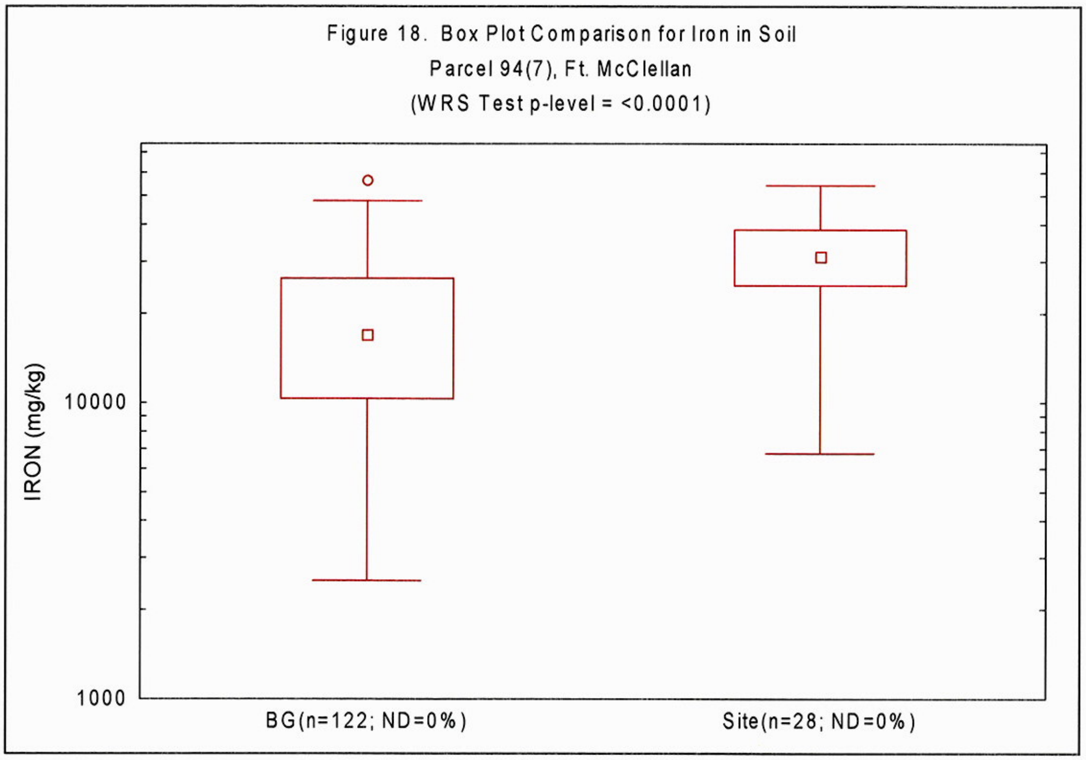


Figure 18. Box Plot Comparison for Iron in Soil
Parcel 94(7), Ft. McClellan
(WRS Test p-level = <0.0001)
IRON (mg/kg)
10000
1000
BG(n=122; ND=0%)
Site(n=28; ND=0%)

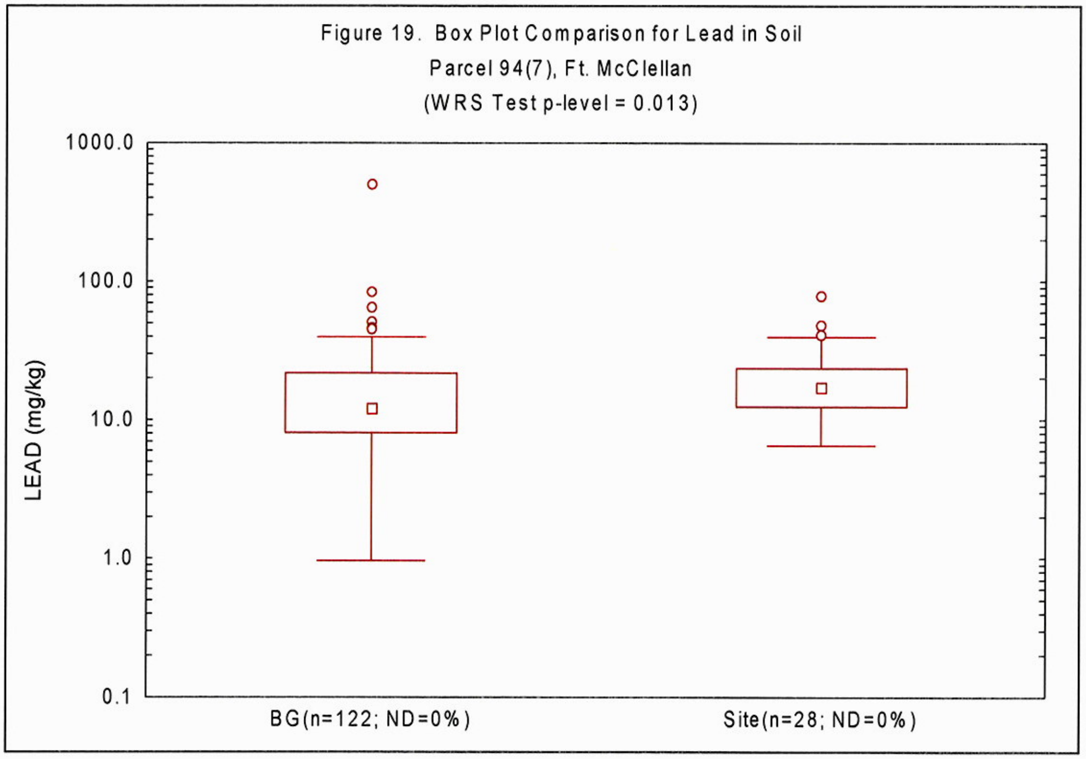


Figure 19. Box Plot Comparison for Lead in Soil
Parcel 94(7), Ft. McClellan
(WRS Test p-level = 0.013)
LEAD (mg/kg)
1000.0
100.0
10.0
1.0
0.1
BG(n=122; ND=0%)
Site(n=28; ND=0%)

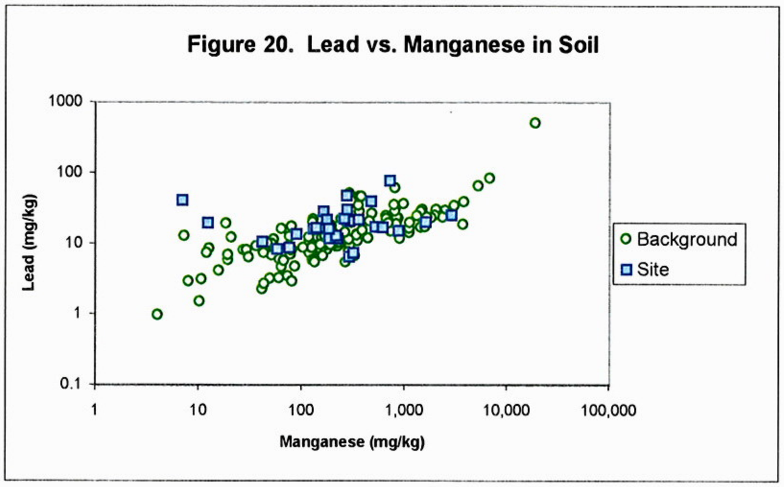


Figure 20. Lead vs. Manganese in Soil
1000
100
10
1
0.1
Lead (mg/kg)
1
10
100
1,000
10,000
100,000
Manganese (mg/kg)
Background
Site

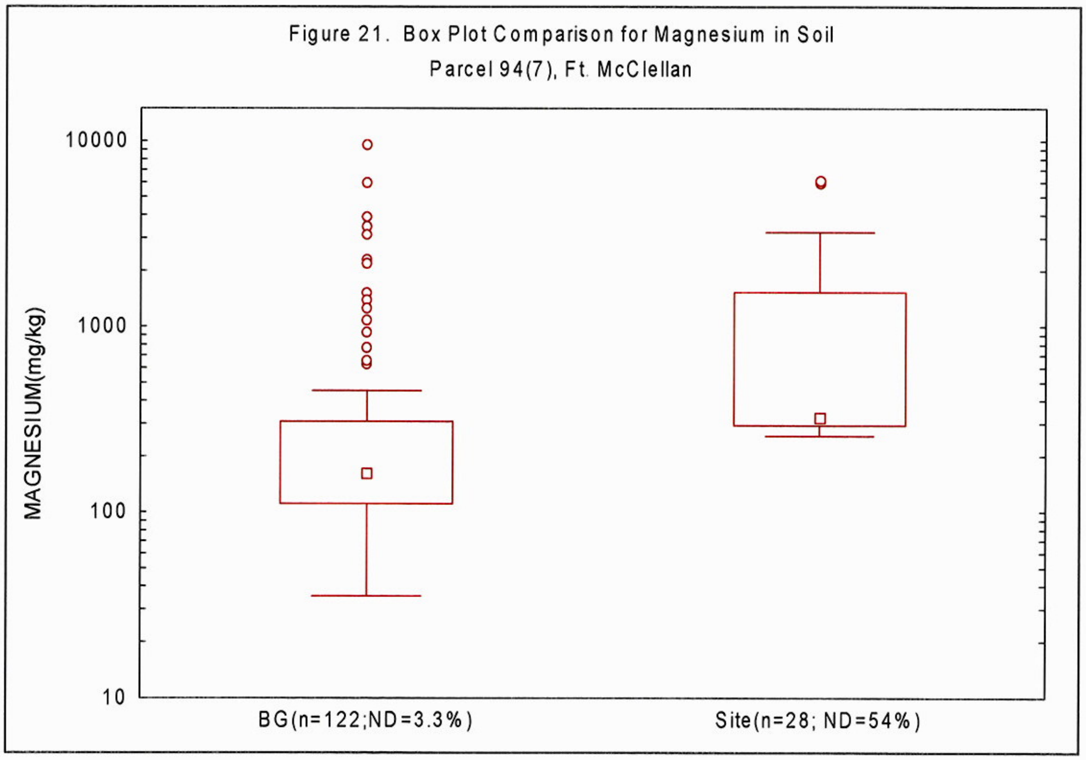


Figure 21. Box Plot Comparison for Magnesium in Soil
Parcel 94(7), Ft. McClellan
10000
1000
100
10
MAGNESIUM(mg/kg)
BG(n=122;ND=3.3%)
Site(n=28; ND=54%)

Figure 22. Box Plot Comparison for Manganese in Soil
Parcel 94(7), Ft. McClellan
(WRS Test p-level = 0.881)

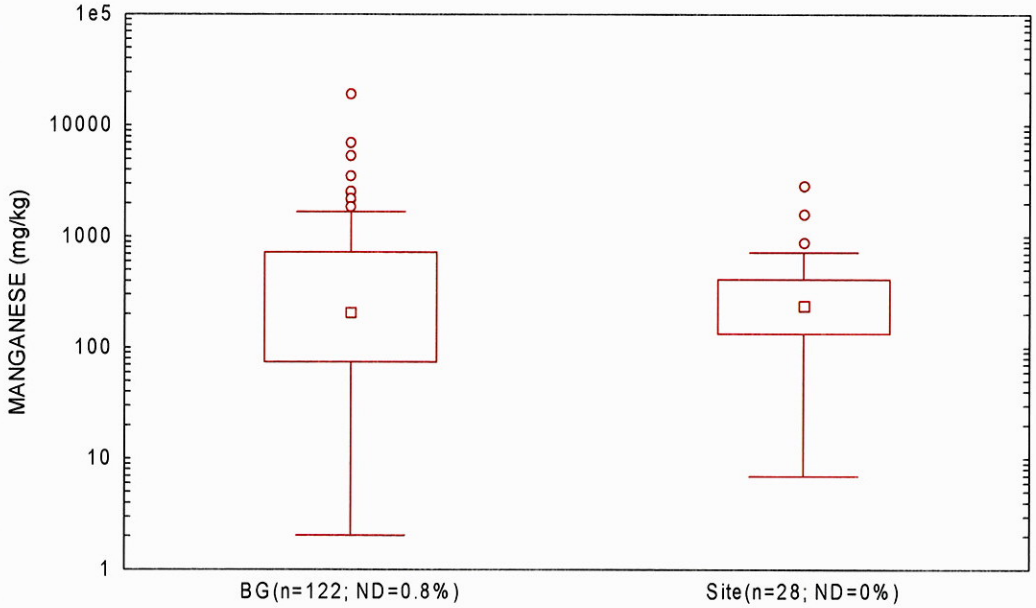
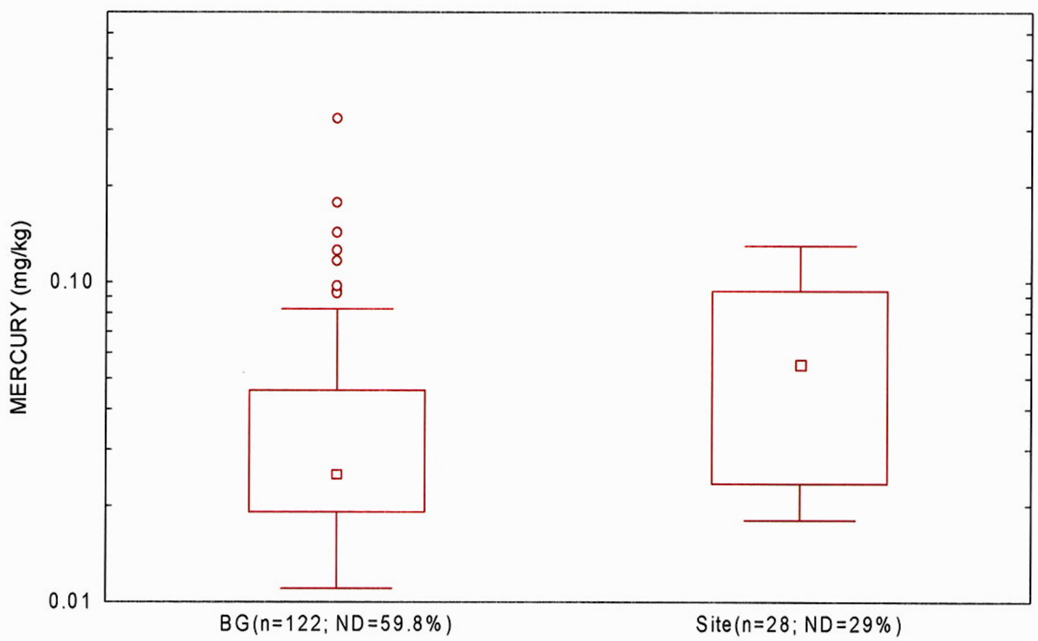


Figure 23. Box Plot Comparison for Mercury in Soil
Parcel 94(7), Ft. McClellan



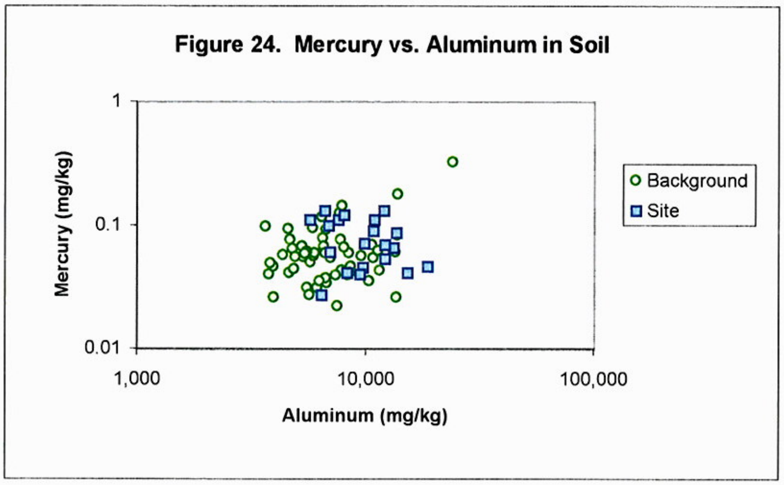


Figure 24. Mercury vs. Aluminum in Soil
Mercury (mg/kg)
1
0.1
0.01
1,000
10,000
100,000
Aluminum (mg/kg)
Background
Site

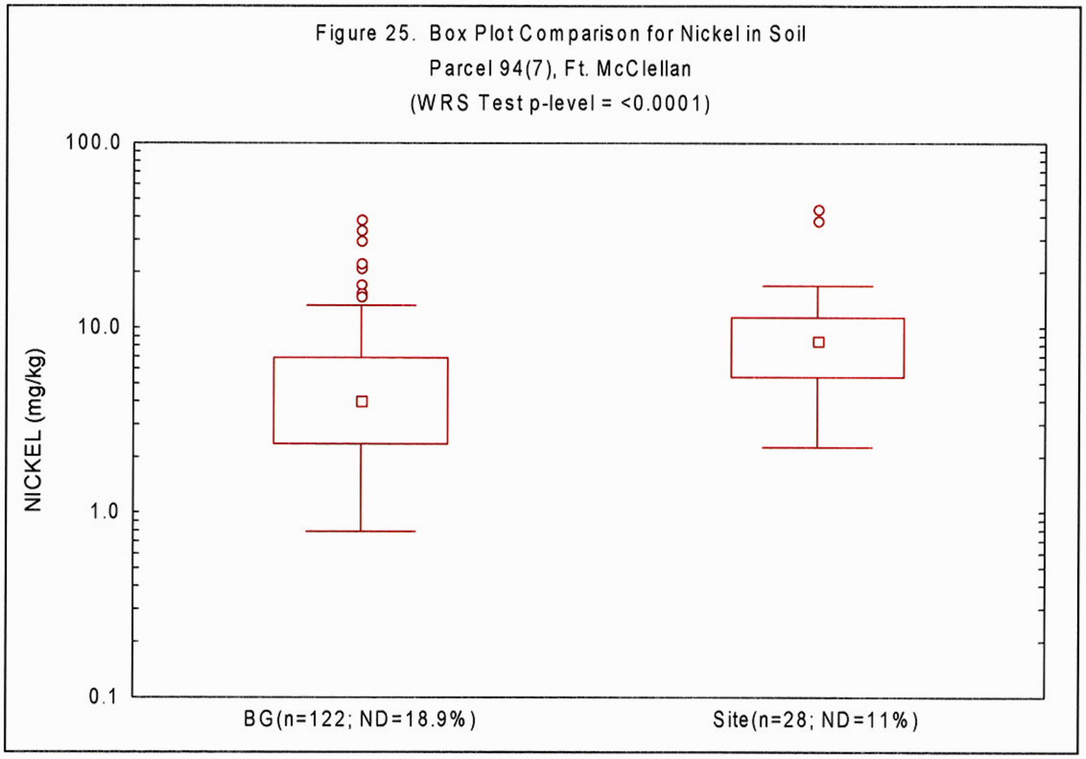


Figure 25. Box Plot Comparison for Nickel in Soil
Parcel 94(7), Ft. McClellan
(WRS Test p-level = <0.0001)
NICKEL (mg/kg)
100.0
10.0
1.0
0.1
BG(n=122; ND=18.9%)
Site(n=28; ND=11%)

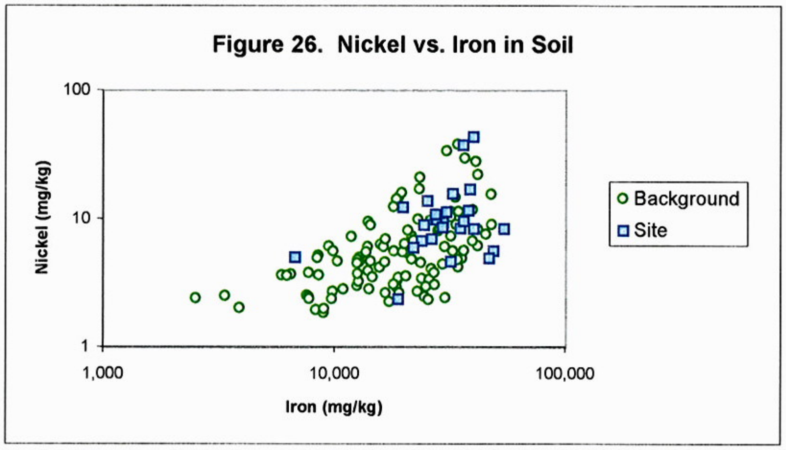


Figure 26. Nickel vs. Iron in Soil
100
10
1
Nickel (mg/kg)
1,000
10,000
100,000
Iron (mg/kg)
Background
Site

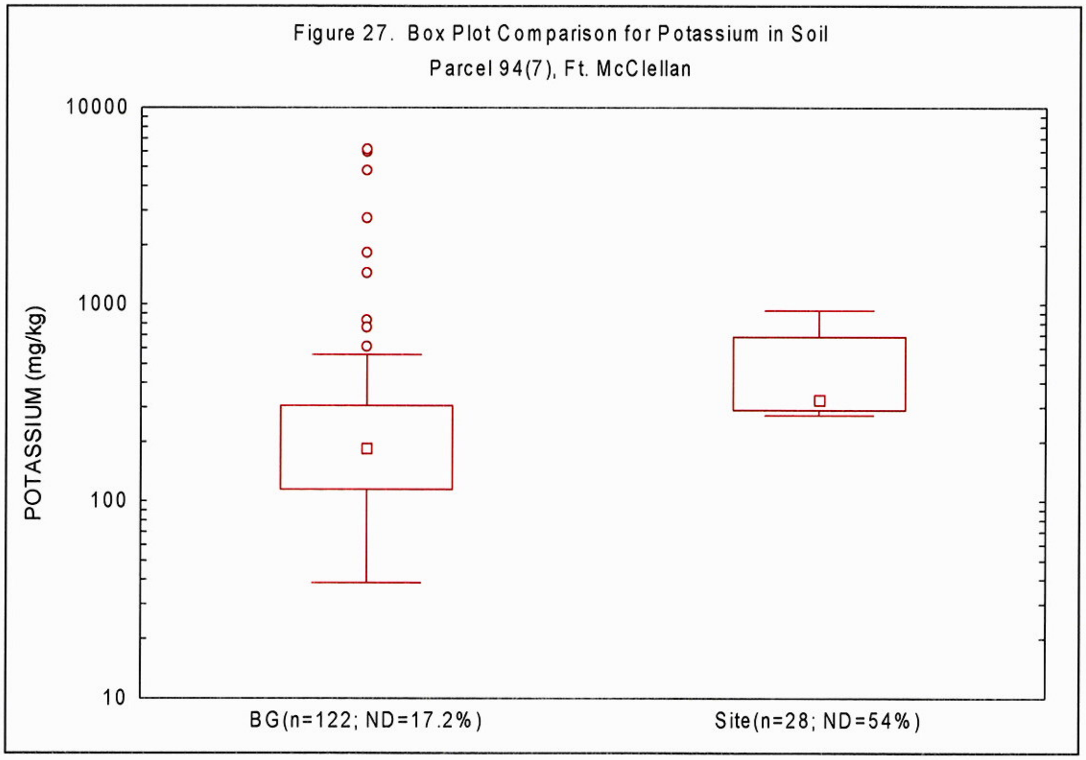


Figure 27. Box Plot Comparison for Potassium in Soil
Parcel 94(7), Ft. McClellan
10000
1000
100
10
POTASSIUM (mg/kg)
BG(n=122; ND=17.2%)
Site(n=28; ND=54%)

Figure 28. Potassium vs. Aluminum in Soil

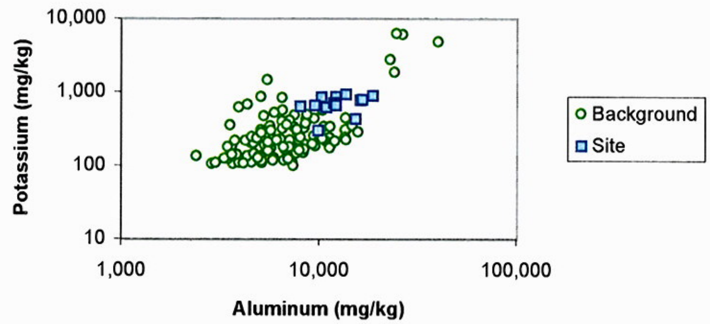
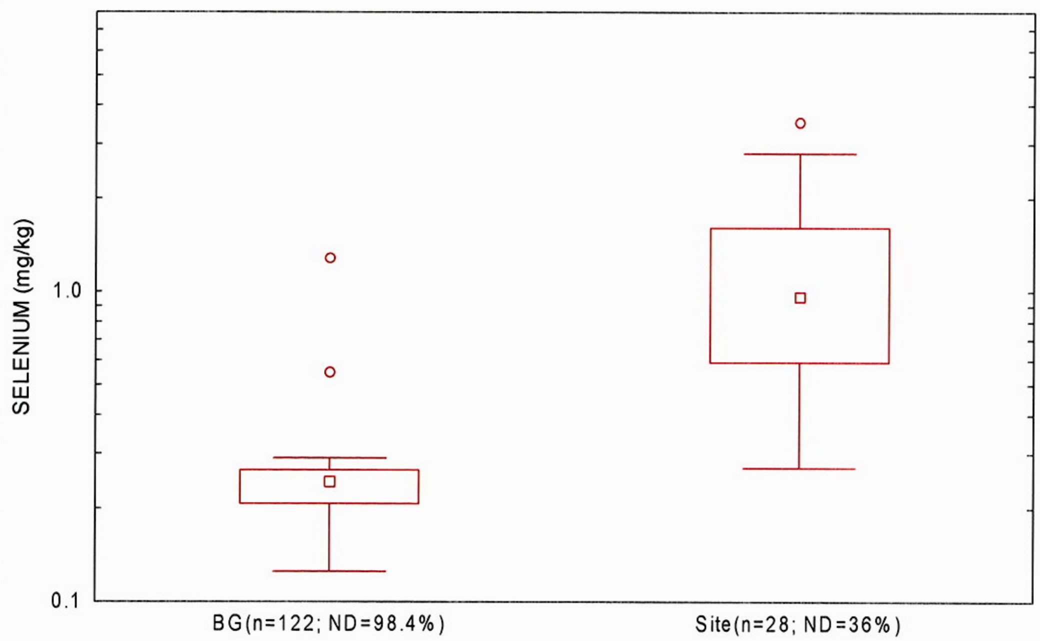


Figure 29. Box Plot Comparison for Selenium in Soil
Parcel 94(7), Ft. McClellan



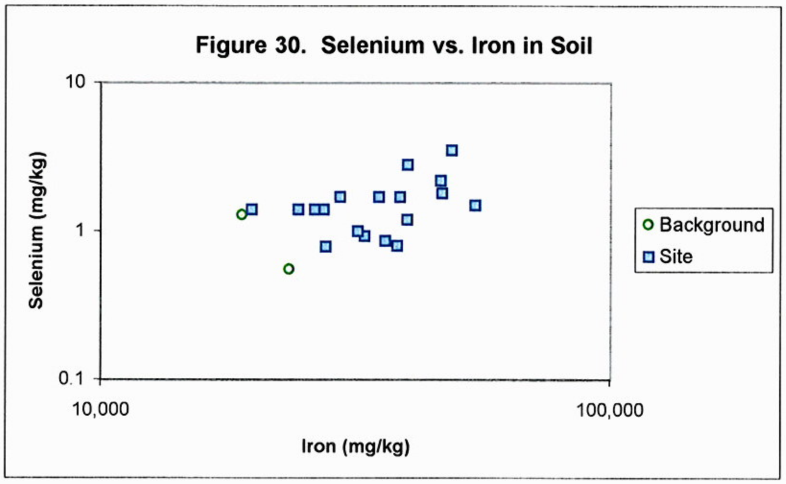


Figure 30. Selenium vs. Iron in Soil
10
1
0.1
Selenium (mg/kg)
10,000
100,000
Iron (mg/kg)
Background
Site

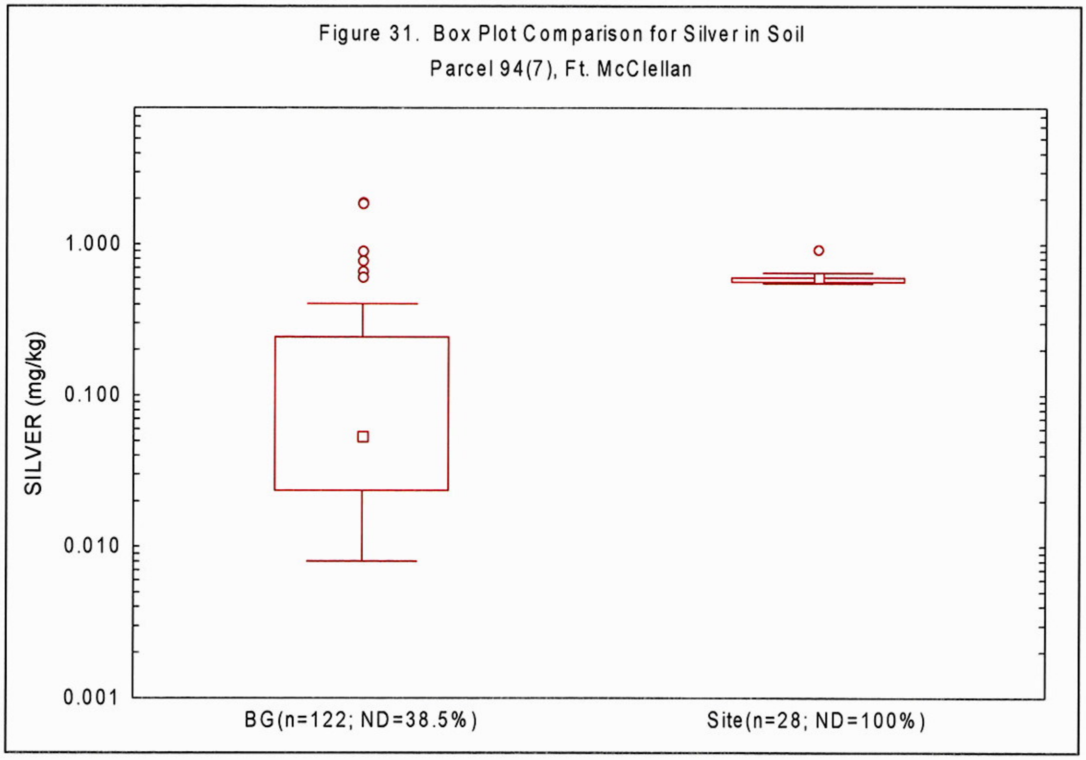


Figure 31. Box Plot Comparison for Silver in Soil
Parcel 94(7), Ft. McClellan
1.000
0.100
0.010
0.001
SILVER (mg/kg)
BG(n=122; ND=38.5%)
Site(n=28; ND=100%)

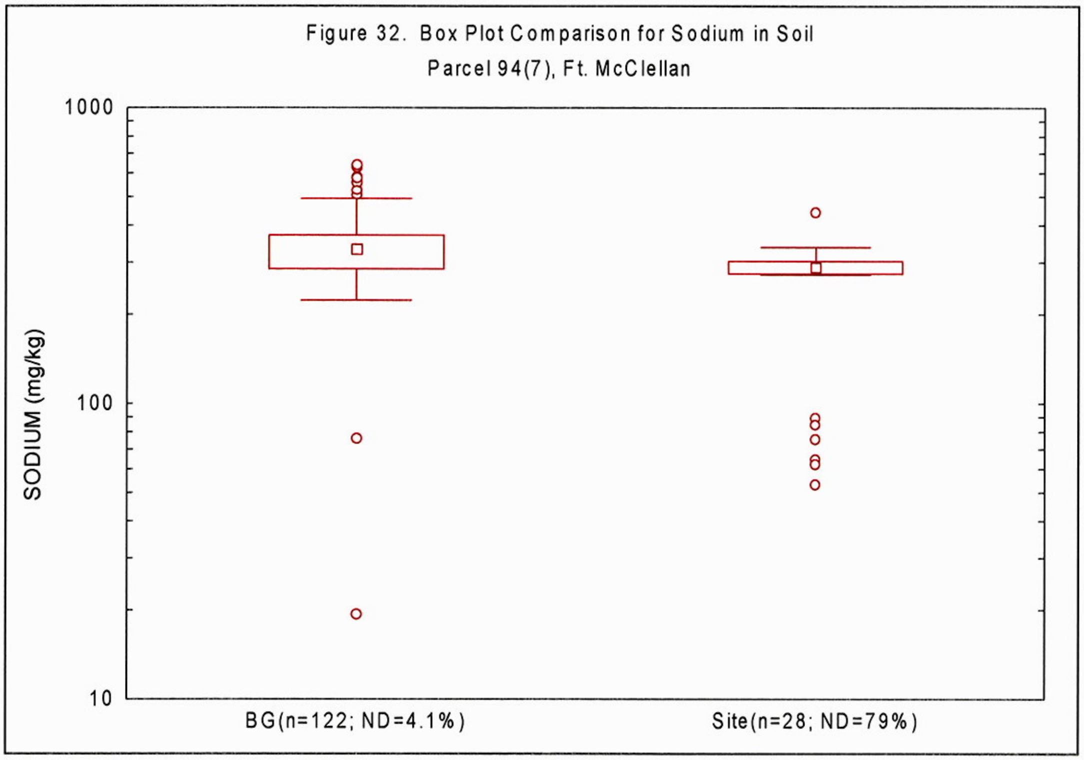


Figure 32. Box Plot Comparison for Sodium in Soil
Parcel 94(7), Ft. McClellan
1000
100
10
SODIUM (mg/kg)
BG(n=122; ND=4.1%)
Site(n=28; ND=79%)

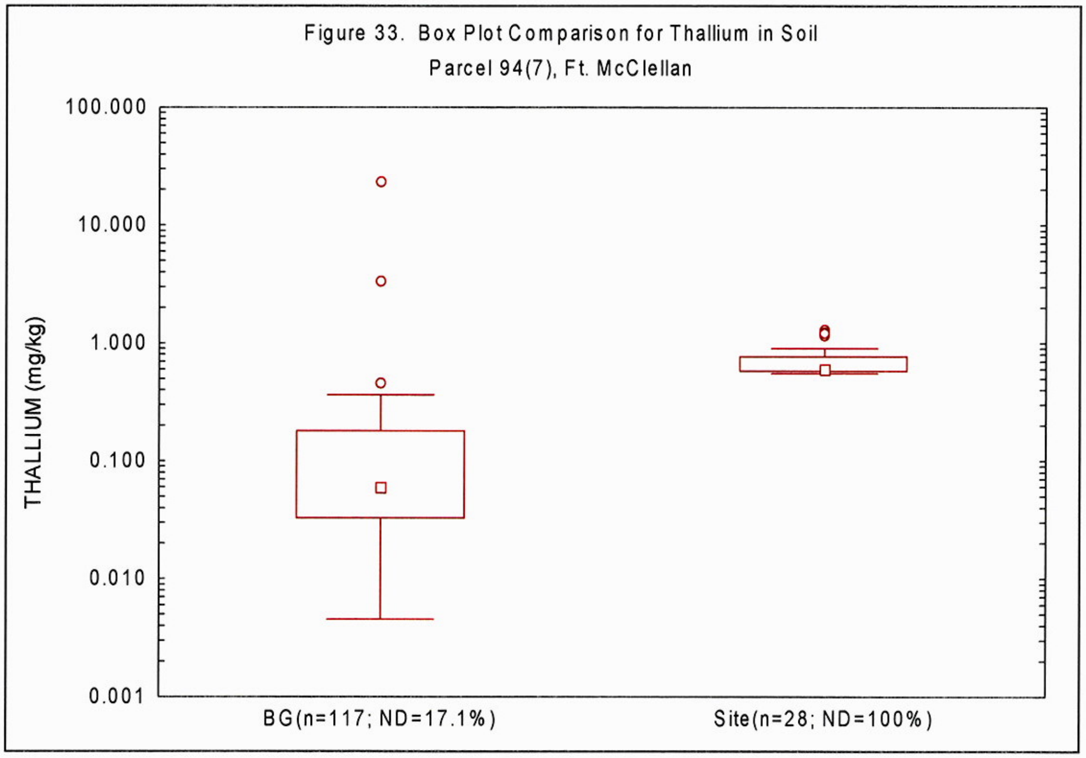


Figure 33. Box Plot Comparison for Thallium in Soil
Parcel 94(7), Ft. McClellan
100.000
10.000
1.000
0.100
0.010
0.001
THALLIUM (mg/kg)
BG(n=117; ND=17.1%)
Site(n=28; ND=100%)

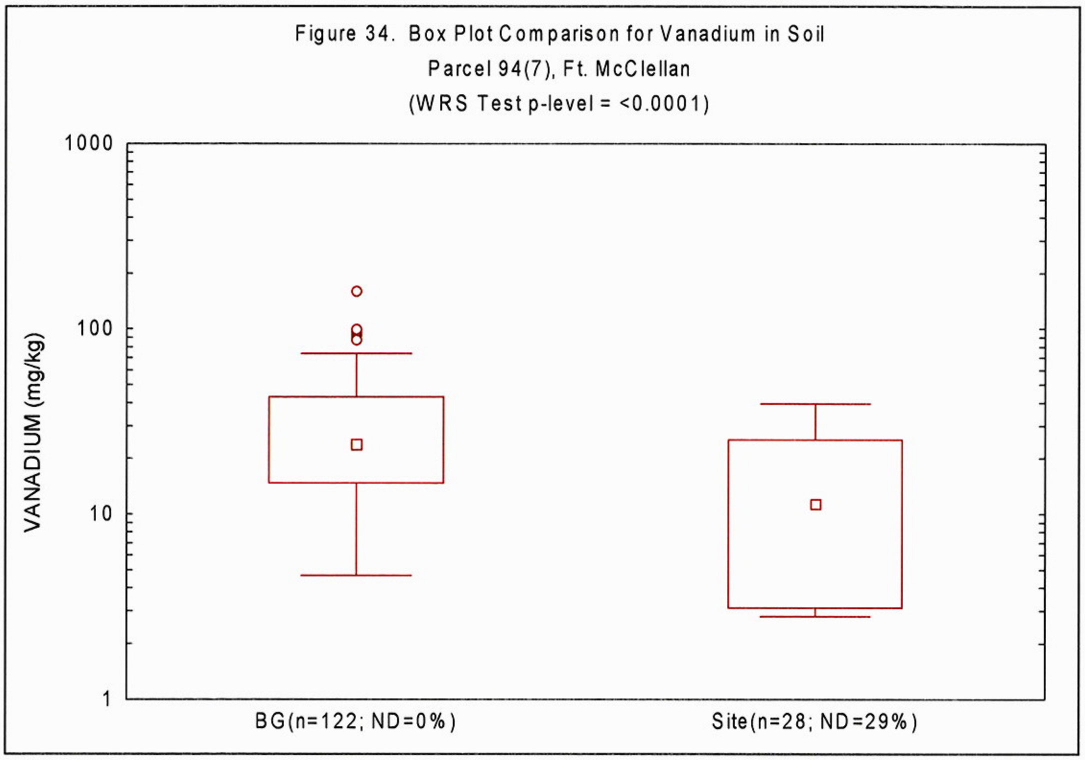


Figure 34. Box Plot Comparison for Vanadium in Soil
Parcel 94(7), Ft. McClellan
(WRS Test p-level = <0.0001)
VANADIUM (mg/kg)
1000
100
10
1
BG(n=122; ND=0%)
Site(n=28; ND=29%)

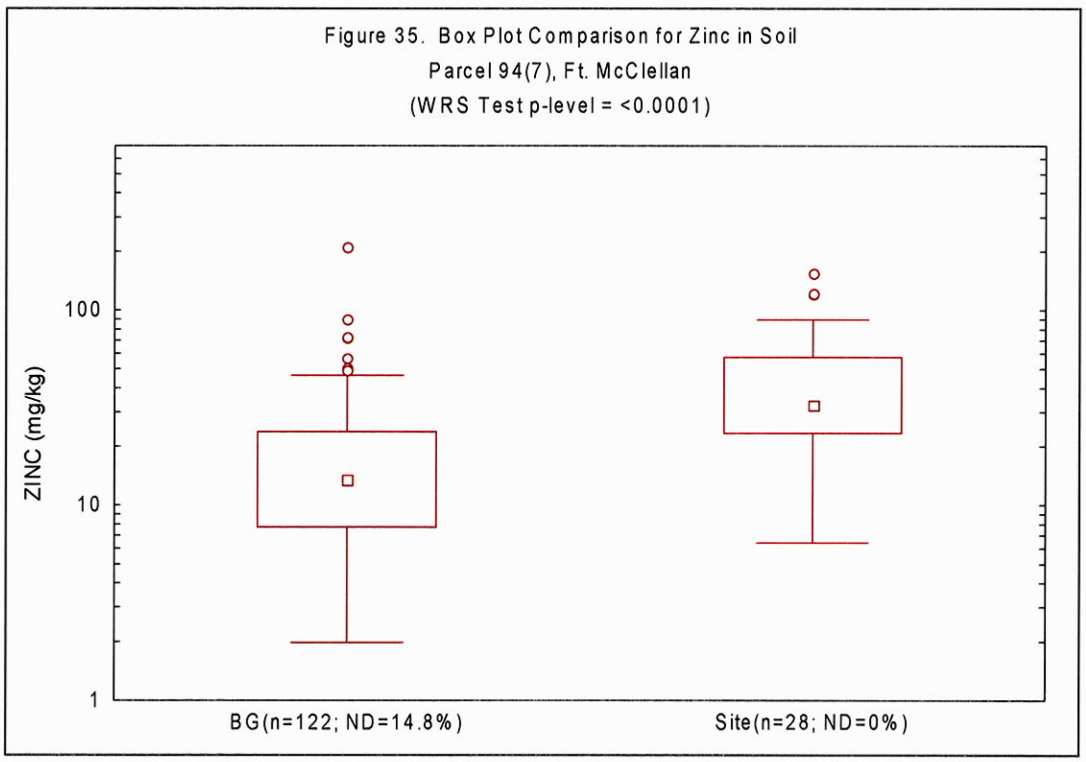
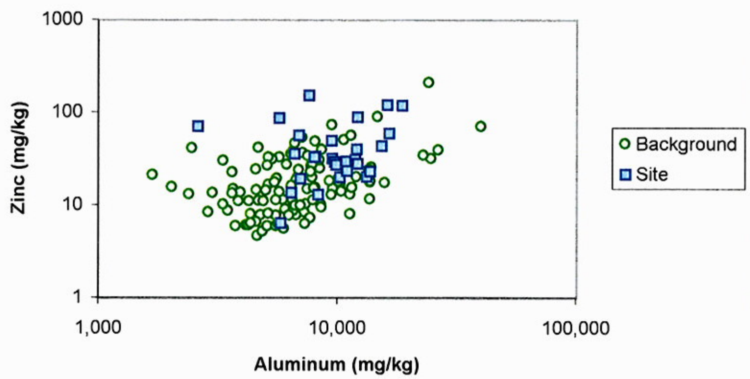


Figure 35. Box Plot Comparison for Zinc in Soil
Parcel 94(7), Ft. McClellan
(WRS Test p-level = <0.0001)
ZINC (mg/kg)
100
10
1
BG(n=122; ND=14.8%)
Site(n=28; ND=0%)

Figure 36. Zinc vs. Aluminum in Soil



GROUNDWATER

Comparison of Site and Background Groundwater Data for Former Chemical Laundry and Motor Pool Area 1500, Parcel 94(7), at Fort McClellan, Calhoun County, Alabama

Summary

An integrated statistical and geochemical evaluation of 23 elements in groundwater was performed for the Former Chemical Laundry and Motor Pool Area 1500, Parcel 94(7) at Fort McClellan. Elevated concentrations of aluminum, barium, calcium, chromium, iron, magnesium, nickel, and vanadium were determined to be naturally occurring. The available data do not indicate inorganics contamination in the four Parcel 94(7) groundwater samples that were analyzed for target analyte list metals.

1.0 Introduction

This report provides the methodology and results of the comparisons of the concentrations of inorganic constituents in unfiltered groundwater samples from background areas versus samples from the Former Chemical Laundry and Motor Pool Area 1500, Parcel 94(7) at Fort McClellan in Calhoun County, Alabama. Site samples used in the site-to-background comparison include the four unfiltered groundwater samples that were collected during the 2001 site investigation. Background distributions and screening values have been established for target analyte list (TAL) metals in unfiltered groundwater at Fort McClellan (IT Corporation, 2002), and are used in the following comparisons.

2.0 Comparison Methodology

This section describes the statistical and geochemical evaluation techniques that were employed in the Parcel 94(7) site-to-background comparisons.

2.1 Statistical Procedures

Contamination can be caused by a variety of processes that yield different spatial distributions of elevated contaminant concentrations. Slight but pervasive contamination can occur from non-point-source releases, and can result in slight increases in contaminant concentrations in a large percentage of samples. Localized, or "hot-spot," contamination can result in elevated concentrations in a small percentage of the total number of site samples. No single two-sample statistical comparison test is sensitive to both of these modes of contamination. For this reason, the use of multiple simultaneous tests is recommended for comparison of site and background distributions (U.S. Environmental Protection Agency [EPA], 1989, 1992, and 1994; U.S. Navy, 1998 and 1999).

The Wilcoxon rank sum (WRS) test is sensitive to slight but pervasive contamination, but is not sensitive to localized or more extreme hot-spot situations. The background threshold comparison, or "hot measurement test," is effective in identifying localized contamination, but is not sensitive to slight but pervasive contamination. The WRS test and hot measurement test are thus complementary. In addition to these tests, box-and-whisker plots are useful for visually comparing the site and background distributions and for properly interpreting the results of the WRS test.

Hot Measurement Test. The hot measurement test consists of comparing each site measurement with a concentration value that is representative of the upper limit of the background distribution (EPA, 1994). Ideally, a site sample with a concentration above the background screening value would have a low probability of being a member of the background distribution, and may be an indicator of contamination. It is important to select such a background screening value carefully so that the probability of falsely identifying site samples as contaminated or uncontaminated is minimized.

The 95^{th} upper tolerance limit (UTL_{95}) is recommended as a screening value for normally or lognormally distributed analytes and the 95^{th} 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.

The UTL_{95} or 95^{th} percentile of the background distributions for 23 elements in unfiltered groundwater are provided in Table 1. To perform the test, each analyte's site maximum detected concentration (MDC) is compared to the background UTL_{95} or 95^{th} 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 screening value, then hot-spot contamination is not indicated.

Wilcoxon Rank Sum Test. The WRS test has been recommended for use in site-to-background comparisons (U.S. Navy, 1998 and 1999; EPA, 2000). 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 midrank. 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 the smaller group
n = Number of data points in the 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 0.05, then there is a statistically significant difference between the medians at the 95 percent confidence level. A Type I error involves rejecting the null hypothesis when it is true. If the p-level is greater than 0.05, then there is no reasonable justification to reject the null hypothesis at the 95 percent confidence level. It can therefore be concluded that the medians of the two data sets are similar, and can be assumed to be drawn from the same population.

If the p-level is less than 0.05, then the medians of the two distributions are significantly different at the 95 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. If the p-level is greater than 0.05, 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 (EPA, 1989 and 1992). An example box plot is provided in Figure 1. 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 either 1.5 times the interquartile distance (i.e., range between 25th and 75th percentiles) or to the maximum point, whichever is larger. The lower whisker extends either 1.5 times the interquartile distance or to the minimum point, whichever is smaller. Values outside the whiskers are shown as circles representing distinct points. 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. 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.

2.2 Geochemical Evaluation

If an analyte fails either of the statistical tests described in Section 2.1, then a geochemical evaluation is performed to determine if the elevated concentrations are caused by natural processes. The importance of geochemical evaluations in distinguishing between site and background data sets has been recognized in the industry (EPA, 1995; U.S. Navy, 1998 and 1999; Barclift, *et al.*, 2000). When properly evaluated, geochemistry can provide mechanistic explanations for apparently high, yet naturally occurring, constituents. Anomalous samples that may represent contamination can also be readily distinguished from uncontaminated samples.

Groundwater samples often contain elevated concentrations of inorganic constituents. Common reasons for these elevated concentrations include naturally high dissolved concentrations, the presence of suspended particulates in the samples, or contamination resulting from site activities. One primary mechanism that is examined in this Parcel 94(7) groundwater site-to-background comparison is the presence of suspended particulates, as discussed in the following section.

Effects of Suspended Particulates. The presence of trace elements adsorbed on suspended particulates can greatly increase trace element concentrations as reported by an analytical laboratory. These adsorbed trace elements are not in true solution, and can be removed by settling or filtration. 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).

The most common suspended particulates in groundwater samples are clay minerals, hydrous aluminum oxides ($Al_2O_3 \bullet nH_2O$), and hydroxides [$Al(OH)_3$]; and iron oxide (Fe_2O_3), iron hydroxide [$Fe(OH)_3$], and iron oxyhydroxide ($FeO \bullet OH$) minerals, collectively referred to as "iron oxides." All clay minerals contain aluminum and have low solubilities over a neutral pH range of 6 to 8. Measured concentrations of aluminum in excess of ~1 milligram per liter (mg/L) indicate the presence of suspended clay minerals, with higher aluminum concentrations being a qualitative indicator of the mass of suspended clay minerals. Iron also has a very low solubility under neutral pH and moderate to oxidizing redox conditions, so that measured iron concentrations in excess of ~1 mg/L under these conditions indicate the presence of suspended iron oxides.

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

Barium, lead, and zinc are usually present in groundwater as divalent cations (Ba^{+2}, Pb^{+2}, Zn^{+2}) and thus tend to concentrate on clay surfaces (Electric Power Research Institute [EPRI], 1984; Brookins, 1988). Arsenic, selenium, and vanadium are usually present under oxidizing conditions as oxyanions ($HAsO_4^{-2}$, $HSeO_3^{-}$, $H_2VO_4^{-}$), and thus tend to concentrate on iron oxide surfaces (Bowell, 1994; Hem, 1985; Pourbaix, 1974; Brookins, 1988).

Chromium can be present in groundwater as a mixture of aqueous species with different charges such as $Cr(OH)_2^{+}$, $Cr(OH)_3^{0}$, and $Cr(OH)_4^{-}$ (EPRI, 1984). The positive, neutral, and negative charges on these species result in the distribution of chromium on several different types of sorptive surfaces, including clay and iron oxide minerals.

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

An alternative technique for assessing the effects of suspended particulates on trace element concentrations is the evaluation of correlations of trace element concentrations versus turbidity. Turbidity measurements are qualitative, and do not distinguish between suspended clay minerals, iron oxides, and natural organic material, so this approach lacks the resolution provided by trace element versus aluminum or trace element versus iron correlations. Despite these limitations, correlations of trace elements versus turbidity are still useful for providing independent confirmation of the conclusions reached by evaluation of the aluminum and iron ratios.

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

3.0 Results of the Site-to-Background Comparisons

Aluminum

Hot Measurement Test: One of the site samples exceeds the background screening value of 5.95 milligrams per liter (mg/L).

WRS Test: A p-level of 0.231 indicates good agreement between the site and background distributions.

Box Plot: A box plot comparing the data sets is shown in Figure 2. The minimum, 25th percentile, median, 75th percentile, and maximum of the site data are all higher than the respective background values.

Geochemical Evaluation: Aluminum has very low solubilities, on the order of a few tens of micrograms per liter, under neutral pH conditions (Hem, 1985). Detectable concentrations of aluminum in neutral pH groundwater therefore indicate the presence of suspended particulates, such as clay minerals, hydrous aluminum oxides, and aluminum hydroxides. Likewise, iron concentrations of approximately 1 mg/L or greater under neutral pH and moderate to oxidizing redox conditions indicate the presence of suspended iron oxides.

The sample (EM3006) that exceeds the background screening value has a neutral pH (7.31), the highest turbidity reading of the site samples (171 nephelometric turbidity units [NTU] versus 0.0 to 28.1 NTU for the other three samples), and the highest iron concentration of the site samples (43.2 mg/L versus 1.02 to 2.9 mg/L for the other three samples). A correlation plot of aluminum versus iron in unfiltered groundwater samples shows a linear trend (Figure 3a), and sample EM3006 lies on the trend formed by the other samples. A plot of aluminum and iron concentrations versus turbidity for the site samples also shows a linear trend (Figure 3b). These plots indicate that most of the aluminum is present in the samples as suspended particulates, most likely as natural turbidity.

Conclusion: Aluminum detected in groundwater is present in the form of suspended particulates, and is naturally occurring.

Antimony

Hot Measurement Test: All four of the site samples are nondetect for antimony. The site reporting limit is 0.06 mg/L, so it cannot be determined if of the site antimony concentrations are above the background screening value of 0.01 mg/L.

WRS Test: The WRS test was not performed because the site and background data sets contain 100 and 96.2 percent nondetects, respectively.

Box Plot: The site and background data sets are characterized by high percentages of nondetects (greater than 96 percent), so the box plots are defined by the replacement values of one-half the reporting limit (Figure 4). The site data are higher than background because the site data set has a higher reporting limit (0.06 mg/L) than most of the background samples. The background maximum is visible as a distinct point above the background box plot and represents a nondetect result with a reporting limit of 0.06 mg/L.

Geochemical Evaluation: Lower reporting limits would be required to perform a geochemical evaluation.

Conclusion: Lower reporting limits are required to adequately compare the site and background data sets.

Arsenic

Hot Measurement Test: None of the site samples have arsenic concentrations that exceed the background screening value of 0.117 mg/L.

WRS Test: The WRS test was not performed because the site and background data sets contain 50 and 83.9 percent nondetects, respectively.

Box Plot: The shapes and locations of the box plots are defined by the high percentages of nondetects (50 percent or greater) and the replacement values of one-half the reporting limit (Figure 5). The site median is higher than the background median because of the higher reporting limits in the site data set.

Geochemical Evaluation: A geochemical evaluation is not required because the detected site concentrations are within range of background.

Conclusion: Arsenic in the site samples is probably naturally occurring.

Barium

Hot Measurement Test: One of the site samples exceeds the background screening value of 0.472 mg/L.

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

Box Plot: The shape and location of the site box plot are affected by the two nondetects and their replacement value of one-half the reporting limit (Figure 6). The site plot is higher than the background plot because the site data set has higher reporting limits. The site maximum, which is an estimated concentration of 1.28 mg/L, is higher than the background maximum.

Geochemical Evaluation: A plot of barium versus iron reveals a linear trend with a positive slope (Figure 7). The site sample (EM3006) with the highest barium concentration also contains the highest iron concentration, and lies on the trend defined by the other samples. This correlation, coupled with the high turbidity reading (171

NTU) for the sample, indicates that most of the barium in this sample is adsorbed onto suspended particulates, such as iron oxides.

Conclusion: Elevated barium concentrations in the site samples are associated with suspended particulates, and are naturally occurring.

Beryllium

Hot Measurement Test: None of the site samples exceed the background screening value of 0.005 mg/L. The single site detection of 0.0018 mg/L is an estimated quantitation below the reporting limit of 0.005 mg/L; the "B" validation qualifier indicates that the result may be biased high due to blank contamination.

WRS Test: The WRS test was not performed because the site and background data sets contain 75 and 72.2 percent nondetects, respectively.

Box Plot: The shape and location of the site box plot are defined by the high percentages of nondetects (greater than 72 percent) and the replacement values of one-half the reporting limit (Figure 8). The site plot is higher than the background plot because the site data set contains higher reporting limits.

Geochemical Evaluation: A geochemical evaluation is not required because the site data are within range of background.

Conclusion: Lower reporting limits are required to adequately compare the site and background data sets. The single observed concentration of beryllium is an estimated quantitation below the reporting limit, and it may be biased high due to blank contamination.

Cadmium

Hot Measurement Test: All four of the site samples are nondetect for cadmium. The reporting limit of 0.005 mg/L is below the background screening value of 0.00678 mg/L.

WRS Test: No WRS test was performed because the site and background data sets contain 100 and 64.3 percent nondetects, respectively.

Box Plot: The location and shape of the site box plot reflect the high percentage of nondetects (100 percent) and replacement values of one-half the reporting limit (Figure 9). The site plot is elevated with respect to background because the site data set is characterized by a higher reporting limit.

Geochemical Evaluation: Lower reporting limits would be required to perform a geochemical evaluation.

Conclusion: Lower reporting limits would be required to adequately compare the site and background data sets.

Calcium

Hot Measurement Test: Three of the site samples exceed the background screening value of 71.4 mg/L.

WRS Test: The WRS test p-level of 0.002 indicates poor agreement between the site and background distributions.

Box Plot: The site median is higher than the background median (Figure 10). The site maximum is below the background maximum.

Geochemical Evaluation: Magnesium and calcium are major cations in groundwater, and are derived from the weathering of minerals from the carbonate rocks that characterize the Pelham Range region. For example, limestone consists primarily of the mineral calcite (calcium carbonate, $CaCO_3$), often with minor magnesium carbonate, and dolomite rock consists of primarily of the mineral dolomite ($CaMg[CO_3]_2$), with minor calcite. A plot of magnesium versus calcium reveals a linear trend, and the samples with high calcium also contain high magnesium (Figure 11). The site samples lie on the trend formed by the other samples. Calcium in the site samples is naturally occurring.

Conclusion: Calcium concentrations detected in the site samples are naturally occurring.

Chromium

Hot Measurement Test: The single detected concentration is an estimated concentration that exceeds the background screening value of 0.0168 mg/L.

WRS Test: No WRS test was performed because the site and background data sets contain 75 and 100 percent nondetects, respectively.

Box Plot: The site and background data sets are characterized by high percentages of nondetects (75 percent or greater), so the box plots reflect the replacement values of one-half the reporting limit (Figure 12).

Geochemical Evaluation: Correlation plots cannot be constructed because the background data set contains 100 percent nondetects and there is only one detected concentration in the site data set. The site sample (EM3006) that exceeds the background screening value also contains the highest turbidity (171 NTU), aluminum concentration (29 mg/L), and iron concentration (43.2 mg/L) of the site data set. Most of the chromium in sample EM3006 is probably adsorbed on the surfaces of suspended particulates such as clays and iron oxides, and is naturally occurring.

Conclusion: The observed chromium concentration in the site data is probably naturally occurring.

Cobalt

Hot Measurement Test: The two detected site concentrations are estimated values that do not exceed the background screening value of 0.0202 mg/L. The site reporting limit is

0.05 mg/L, so it is not possible to determine if cobalt concentrations in the two nondetect samples exceed the background screening value.

WRS Test: The WRS test was not performed because the site and background data sets contain 50 and 94.4 percent nondetects, respectively.

Box Plot: The site and background box plots reflect the high percentages of nondetects (50 percent or greater) and the replacement values of one-half the reporting limit (Figure 13). The site plot is elevated with respect to the background plot because the site data set has a higher reporting limit. The three background detected concentrations are visible as distinct points above the background box plot.

Geochemical Evaluation: Lower reporting limits would be required to perform a geochemical evaluation.

Conclusion: Lower reporting limits would be required to adequately compare the site and background data sets.

Copper

Hot Measurement Test: The single detected concentration is an estimated quantitation that does not exceed the background screening value of 0.207 mg/L. The site reporting limit is 0.025 mg/L, so no other site concentrations exceed the background screening value.

WRS Test: The WRS test was not performed because the site and background data sets contain 75 and 81.5 percent nondetects, respectively.

Box Plot: The site and background box plots reflect the high percentages of nondetects (75 percent or greater) and replacement value of one-half the reporting limit (Figure 14). The site plot is higher than the background plot because the site data set has higher reporting limits.

Geochemical Evaluation: A geochemical evaluation is not required because the site data are within range of background.

Conclusion: The observed concentration of copper is probably naturally occurring.

Iron

Hot Measurement Test: One of the site samples exceeds the background screening value of 22 mg/L.

WRS Test: A p-level of 0.341 indicates good agreement between the site and background distributions.

Box Plot: The medians of the two data sets are similar (Figure 15). The site maximum is higher than the background maximum.

Geochemical Evaluation: Iron has a very low solubility under neutral pH and moderate to oxidizing redox conditions, such that measured iron concentrations in excess of ~1 mg/L under these conditions indicate the presence of suspended iron oxides. Likewise, aluminum concentrations in excess of a few tens of micrograms per liter under neutral pH conditions indicate the presence of suspended clays, hydrous aluminum oxides, and hydroxides.

The sample (EM3006) that exceeds the background screening value has a neutral pH (7.31), the highest turbidity reading of the site samples (171 NTU versus 0.0 to 28.1 NTU for the other three samples), and the highest aluminum concentration of the site samples (29 mg/L versus 0.359 to 0.972 mg/L for the other three samples). A correlation plot of aluminum versus iron in unfiltered groundwater samples shows a linear trend (Figure 3a), and sample EM3006 lies on the trend formed by the other samples. A plot of aluminum and iron concentrations versus turbidity for the site samples also shows a linear trend (Figure 3b). These plots suggest that most of the iron is present in the samples as suspended particulates, most likely as natural turbidity.

Conclusion: Iron concentrations observed in the site samples are naturally occurring.

Lead

Hot Measurement Test: None of the site samples exceeds the background screening value of 0.0434 mg/L.

WRS Test: The WRS test was not performed because the site and background data sets contain 50 and 60 percent nondetects, respectively.

Box Plot: The site box plot represents a high percentage of nondetects (50 percent) and the replacement value of one-half the reporting limit (Figure 16). The site plot is elevated with respect to background, reflecting the fact that the site reporting limit of 0.003 mg/L is higher than many of the background reporting limits.

Geochemical Evaluation: A geochemical evaluation is not required because the site data are within range of background.

Conclusion: The observed concentrations of lead are probably naturally occurring.

Magnesium

Hot Measurement Test: Two of the site samples exceed the background screening value of 22 mg/L.

WRS Test: A p-level of 0.220 indicates good agreement between the site and background distributions.

Box Plot: The site median is higher than the background median (Figure 17). The site maximum is below the background maximum.

Geochemical Evaluation: As discussed in the Calcium evaluation, magnesium and calcium are major cations in groundwater, and are derived from the weathering of minerals from the carbonate rocks that characterize the Pelham Range region. Groundwater in such regions often contains calcium and magnesium concentrations at a relatively constant ratio. A plot of magnesium versus calcium reveals a linear trend, and the samples with high magnesium concentrations also have high calcium concentrations (Figure 11). The site samples lie on the trend formed by the other samples. Magnesium in the site samples is naturally occurring.

Conclusion: Magnesium concentrations detected in the site samples are naturally occurring.

Manganese

Hot Measurement Test: None of the site samples exceed the background screening value of 4.134 mg/L.

WRS Test: The WRS test p-level of 0.602 indicates strong agreement between the site and background distributions.

Box Plot: The site and background medians are similar (Figure 18). The site maximum is lower than the background maximum.

Geochemical Evaluation: A geochemical evaluation is not required because the site data are within range of background.

Conclusion: Manganese in the site samples is probably naturally occurring.

Mercury

Hot Measurement Test: The two detected concentrations in the site samples are estimated quantitations that do not exceed the background screening value of 0.000243 mg/L. The site reporting limit is 0.0002 mg/L, so it is not possible to determine if mercury concentrations in the nondetect samples exceed the background screening value.

WRS Test: No WRS test was performed because the site and background data sets contain 50 and 100 percent nondetects, respectively.

Box Plot: The site and background box plots reflect the high percentages of nondetects (50 percent or greater) and similarity in reporting limits between the two data sets (Figure 19).

Geochemical Evaluation: A geochemical evaluation is not required because the site data are within range of background.

Conclusion: The observed concentrations of mercury are probably naturally occurring.

Nickel

Hot Measurement Test: The single detected concentration is an estimated quantitation that does exceeds the background screening value of 0.0343 mg/L. The site reporting limit is 0.04 mg/L, so it is not possible to determine if nickel concentrations in the nondetect samples are below the background screening value.

WRS Test: The WRS test was not performed because the site and background data sets contain 75 and 100 percent nondetects, respectively.

Box Plot: The locations and shapes of the box plots reflect the high percentages of nondetects (75 percent or greater) and difference in reporting limits between the two data sets (Figure 20).

Geochemical Evaluation: Correlation plots cannot be constructed because the background data set contains 100 percent nondetects and there is only one detected concentration in the site data set. The site sample (EM3006) that exceeds the background screening value also contains the highest turbidity (171 NTU), aluminum concentration (29 mg/L), and iron concentration (43.2 mg/L) of the site data set. Most of the nickel in sample EM3006 is probably adsorbed on the surfaces of suspended particulates such as clays and iron oxides, and is naturally occurring.

Conclusion: The observed concentration of nickel is probably naturally occurring.

Potassium

Hot Measurement Test: None of the site samples exceeds the background screening value of 16 mg/L.

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

Box Plot: The site median is higher than the background median (Figure 21). The site maximum is lower than the background maximum.

Geochemical Evaluation: A geochemical evaluation is not required because the site data are within range of background.

Conclusion: Potassium in the site samples is probably naturally occurring.

Selenium

Hot Measurement Test: All four of the site samples are nondetect with a reporting limit of 0.005 mg/L, which is below the background screening value of 0.0971 mg/L.

WRS Test: No WRS test was performed because the site and background data sets both contain 100 percent nondetects.

Box Plot: The locations and shapes of the site and background box plots reflect the high percentages of nondetects and replacement values of one-half the reporting limit (Figure 22). The site plot is higher than the background plot because the site data set has higher reporting limits than most of the background samples.

Geochemical Evaluation: Lower reporting limits would be required to perform a geochemical evaluation.

Conclusion: Lower reporting limits would be required to adequately compare the site and background data sets.

Silver

Hot Measurement Test: All four site samples are nondetect for silver with a reporting limit of 0.01 mg/L. None of the samples exceeds the background screening value of 0.01 mg/L.

WRS Test: No WRS test was performed because the site and background data sets contain 100 and 98.2 percent nondetects, respectively.

Box Plot: The locations and shapes of the site and background box plots reflect the high percentages of nondetects (greater than 98 percent) and replacement values of one-half the reporting limit (Figure 23). The site plot is higher than the background plot because the site data set has higher reporting limits.

Geochemical Evaluation: Lower reporting limits would be required to perform a geochemical evaluation.

Conclusion: Lower reporting limits would be required to adequately compare the site and background data sets.

Sodium

Hot Measurement Test: None of the site samples exceeds the background screening value of 49.028 mg/L.

WRS Test: No WRS test was performed because the site data set contains 50 percent nondetects.

Box Plot: The site median is higher than the background median (Figure 24). The site maximum is below the background maximum.

Geochemical Evaluation: A geochemical evaluation is not required because the site data are within range of background.

Conclusion: Sodium in the site samples is probably naturally occurring.

Thallium

Hot Measurement Test: The single detected concentration is an estimated value that does not exceed the background screening value of 0.01 mg/L. The "B" validation qualifier indicates that this result may be biased high due to blank contamination. The site reporting limit is 0.01 mg/L, so none of the nondetect samples contain thallium concentrations above the background screening value.

WRS Test: No WRS test was performed because the site and background data sets contain 75 and 88 percent nondetects, respectively.

Box Plot: Both data sets are characterized by a high percentage of nondetects (75 percent or greater), so the locations and shapes of the box plots reflect the replacement value of one-half the reporting limit (Figure 25). The site plot is higher than the background plot because the site data set is characterized by a higher reporting limit.

Geochemical Evaluation: A geochemical evaluation is not required because the site data are within range of background.

Conclusion: The observed thallium concentration may be naturally occurring. However, it is an estimated quantitation with a "B" validation qualifier, which indicates that the result may be biased high due to blank contamination.

Vanadium

Hot Measurement Test: The single detected concentration of vanadium is an estimated quantitation that exceeds the background screening value of 0.0276 mg/L. The site reporting limit is 0.05 mg/L, so it is not possible to determine if any of the nondetect samples contain vanadium at concentrations above the background screening value.

WRS Test: No WRS test was performed because the site and background data sets contain 75 and 96.3 percent nondetects, respectively.

Box Plot: Both data sets are characterized by a high percentage of nondetects (75 percent or greater), so the locations and shapes of the box plots reflect the replacement value of one-half the reporting limit (Figure 26). The site plot is higher than the background plot because the site data set is characterized by a higher reporting limit.

Geochemical Evaluation: A plot of vanadium versus iron is provided in Figure 27. Comparison is hindered by the lack of detectable vanadium in the site and background data sets. Furthermore, the two background detections are estimated concentrations below the reporting limit, and such values are highly uncertain. Of the four site samples, sample EM3006 contains the only detectable vanadium, the highest turbidity, and the highest concentrations of iron and several trace elements. The relationship between the field turbidity readings and the presence of suspended clay and iron oxide particulates was previously established (see the Aluminum and Iron evaluations, above). As discussed in Section 2.3, vanadium tends to concentrate on iron oxide surfaces under neutral pH, oxidizing conditions. Most of the vanadium in sample EM3006 is probably adsorbed on the surfaces of suspended iron oxides, and is naturally occurring.

Conclusion: The observed concentration concentration of vanadium is probably naturally occurring.

Zinc

Hot Measurement Test: None of the site samples exceeds the background screening value of 1.155 mg/L.

WRS Test: No WRS test was performed because the site and background data sets contain 75 and 55.6 percent nondetects, respectively.

Box Plot: Both data sets are characterized by a high percentage of nondetects (greater than 55 percent), so the locations and shapes of the box plots are largely determined by the replacement value of one-half the reporting limit (Figure 28).

Geochemical Evaluation: A geochemical evaluation is not required because the site data are within range of background.

Conclusion: The observed concentration of zinc is probably naturally occurring.

4.0 Summary and Conclusions

The methodology used to compare the site and background data sets for 23 elements in unfiltered groundwater consists of a combination of a hot measurement test, the nonparametric two-sample Wilcoxon rank sum test, and box-and-whisker plots. Analytes that failed either of the statistical tests were subjected to a geochemical evaluation to determine if the elevated concentrations could be explained by natural processes.

Aluminum, barium, calcium, chromium, iron, magnesium, nickel, and vanadium were subjected to geochemical evaluation. The elevated concentrations of these elements could be explained as the result of suspended particulates (such as clays or iron oxides) or the presence of naturally occurring major cations. The available data do not indicate inorganics contamination in the four Parcel 94(7) groundwater samples analyzed for TAL metals.

5.0 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, pp. 279-286.

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

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

IT Corporation, 2002, "Background Screening Values for Groundwater, Surface Water, Sediment, and Soil at Fort McClellan," memo from J. Myers to K. Thorbjornsen, dated 24 January.

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

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), 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. 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, 1998, ***Procedural Guidance for Statistically Analyzing Environmental Background Data***, Naval Facilities Engineering Command, Southwest Division and Engineering Field Activity, West, September.

U.S. Navy, 1999, ***Handbook for Statistical Analysis of Environmental Background Data***, Naval Facilities Engineering Command, Southwest Division and Engineering Field Activity, West, July.

ATTACHMENT 1

TABLES

Table 1

Background Screening Values (H_m) for Groundwater
Fort McClellan
Calhoun County, Alabama

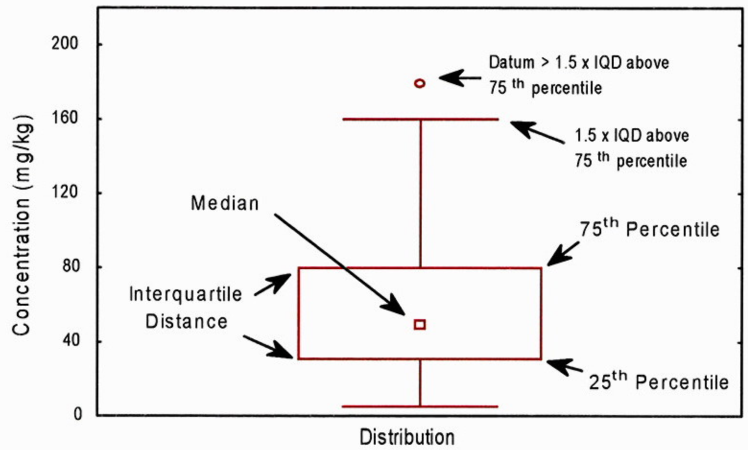
Analyte	H_m (mg/L)
Aluminum	5.95
Antimony	<0.01
Arsenic	<0.117
Barium	0.472
Beryllium	<0.005
Cadmium	<0.00678
Calcium	71.4
Chromium	<0.0168
Cobalt	0.0202
Copper	0.207
Iron	22
Lead	<0.0434
Magnesium	22
Manganese	4.134
Mercury	<0.000243
Nickel	<0.0343
Potassium	16
Selenium	<0.0971
Silver	<0.01
Sodium	49.028
Thallium	<0.01
Vanadium	<0.0276
Zinc	1.155

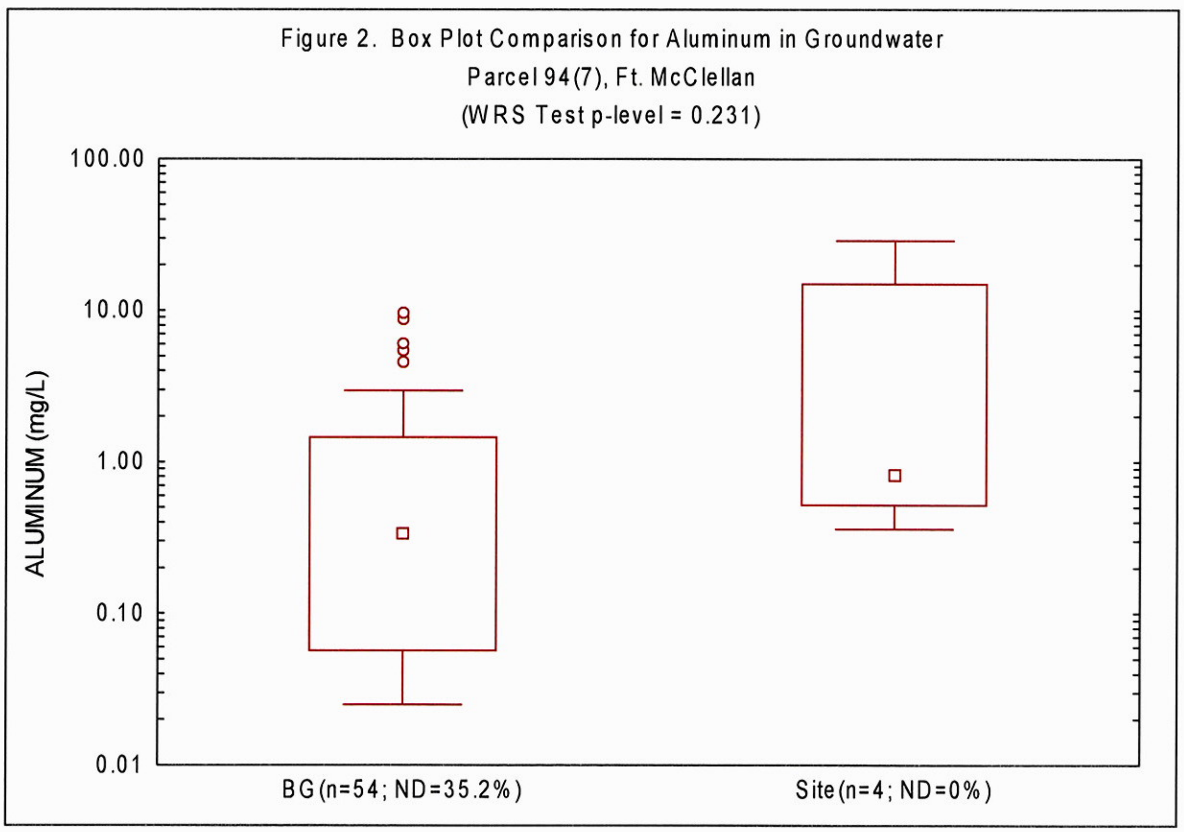
mg/kg - Milligram(s) per liter.

ATTACHMENT 2

FIGURES

Figure 1
Example Box Plot





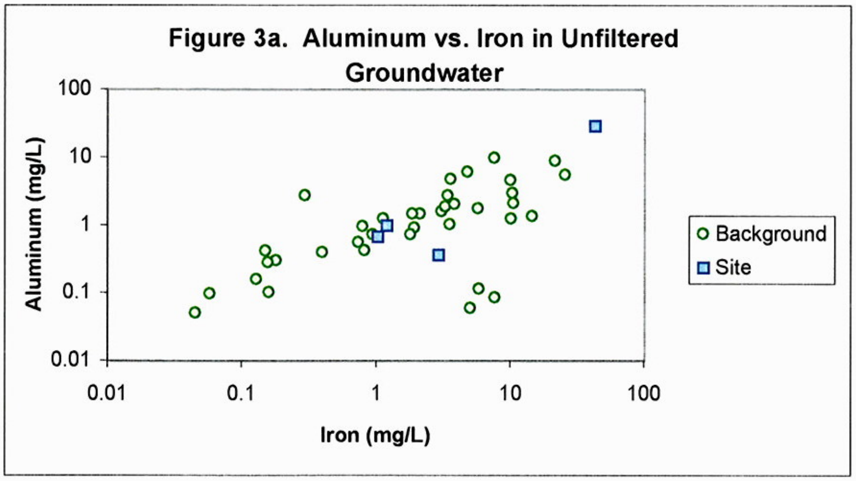


Figure 3a. Aluminum vs. Iron in Unfiltered Groundwater

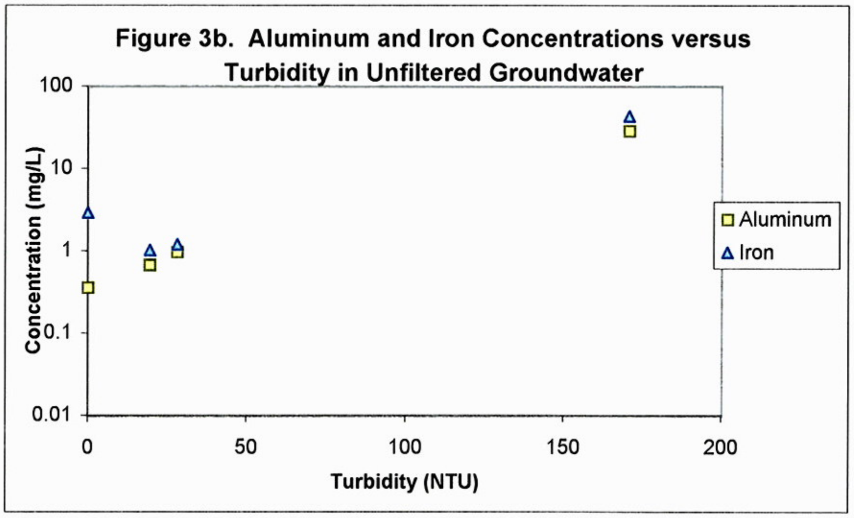


Figure 3b. Aluminum and Iron Concentrations versus Turbidity in Unfiltered Groundwater

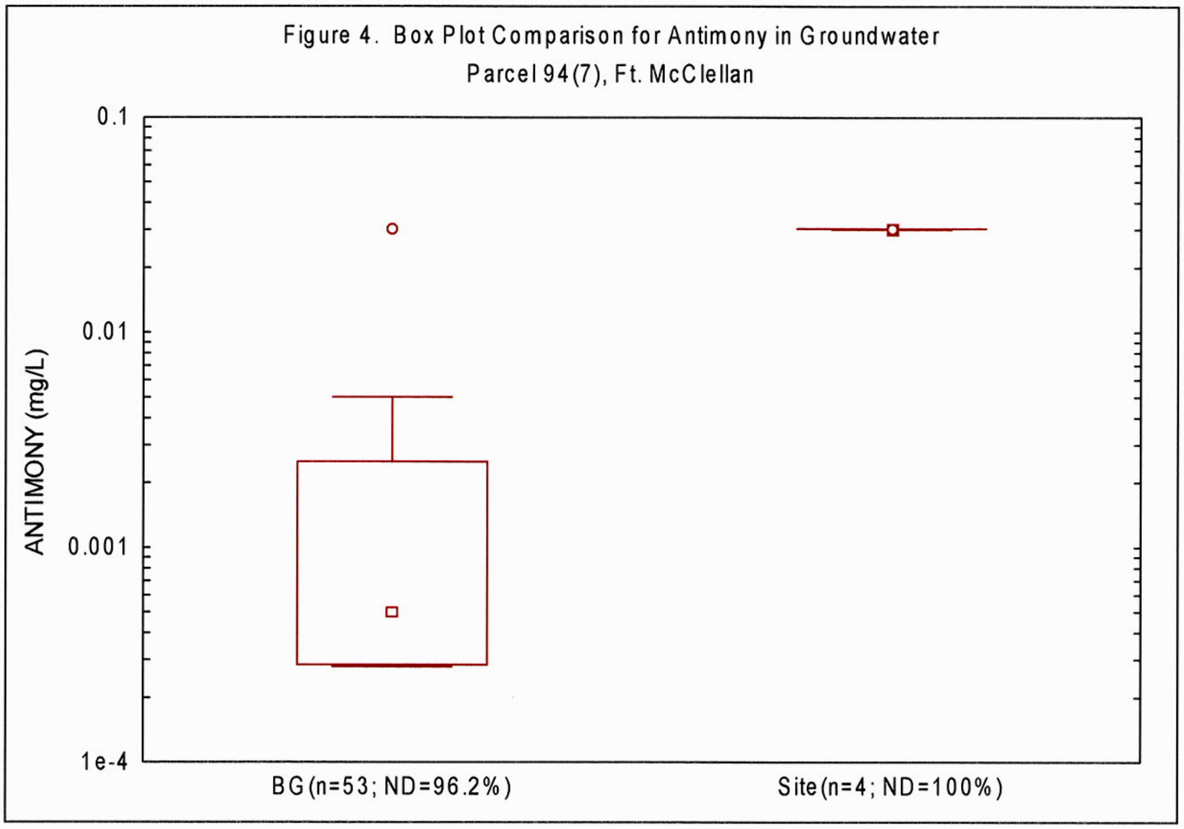


Figure 4. Box Plot Comparison for Antimony in Groundwater
Parcel 94(7), Ft. McClellan
0.1
0.01
0.001
1e-4
ANTIMONY (mg/L)
BG(n=53; ND=96.2%)
Site(n=4; ND=100%)

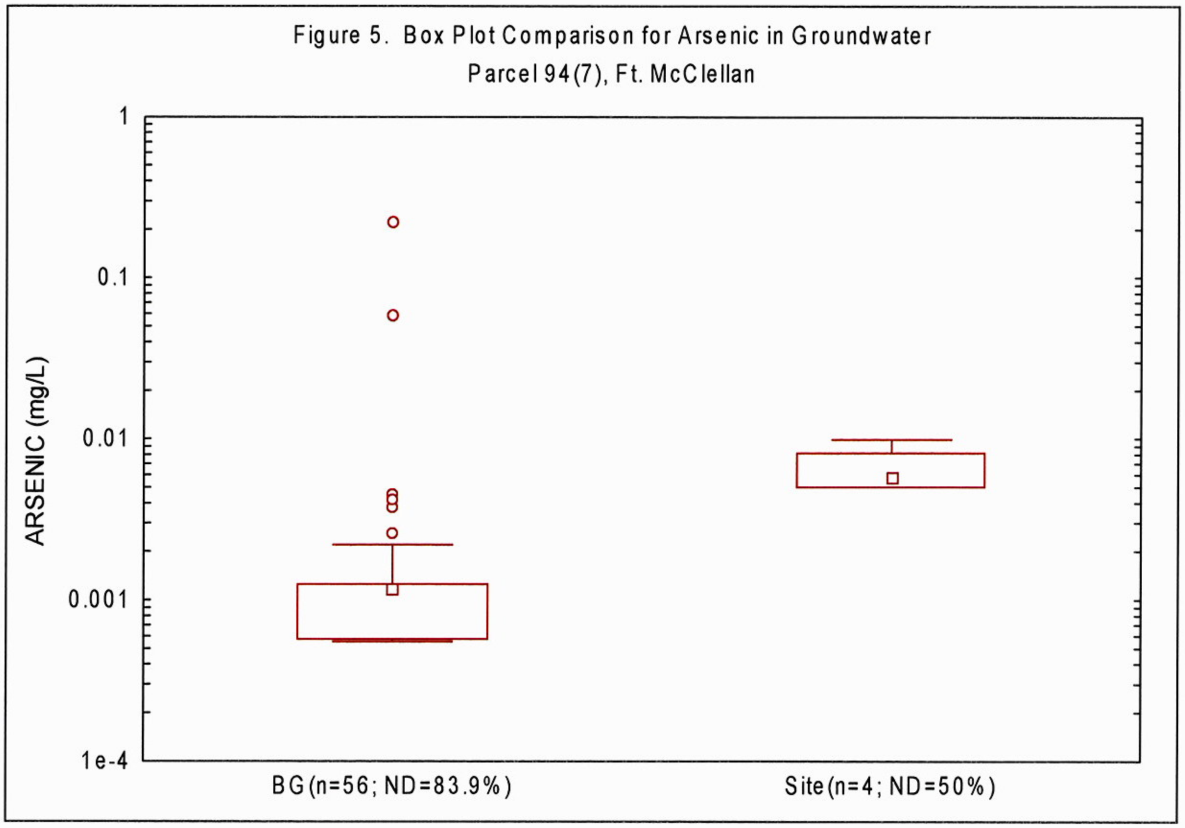


Figure 5. Box Plot Comparison for Arsenic in Groundwater
Parcel 94(7), Ft. McClellan
1
0.1
0.01
0.001
1e-4
ARSENIC (mg/L)
BG(n=56; ND=83.9%)
Site(n=4; ND=50%)

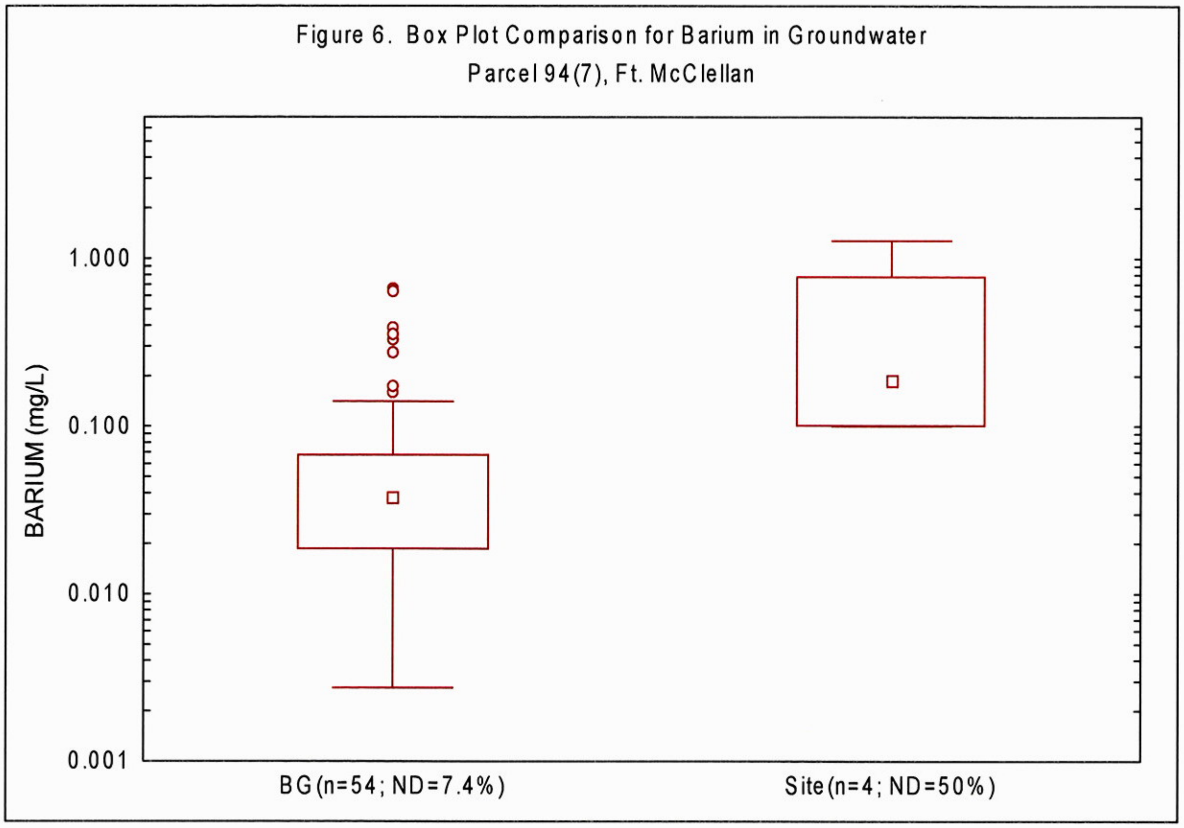


Figure 6. Box Plot Comparison for Barium in Groundwater
Parcel 94(7), Ft. McClellan
BARIUM (mg/L)
1.000
0.100
0.010
0.001
BG(n=54; ND=7.4%)
Site(n=4; ND=50%)

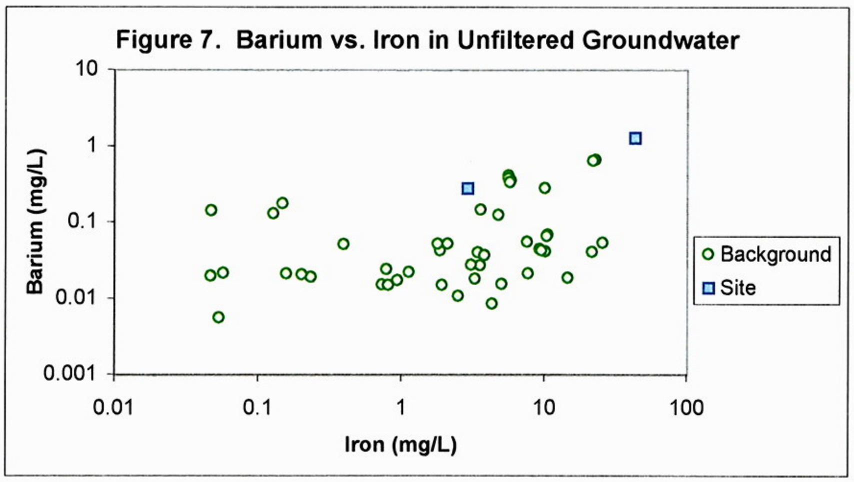


Figure 7. Barium vs. Iron in Unfiltered Groundwater
Barium (mg/L)
10
1
0.1
0.01
0.001
0.01
0.1
1
10
100
Iron (mg/L)
Background
Site

Figure 8. Box Plot Comparison for Beryllium in Groundwater
Parcel 94(7), Ft. McClellan

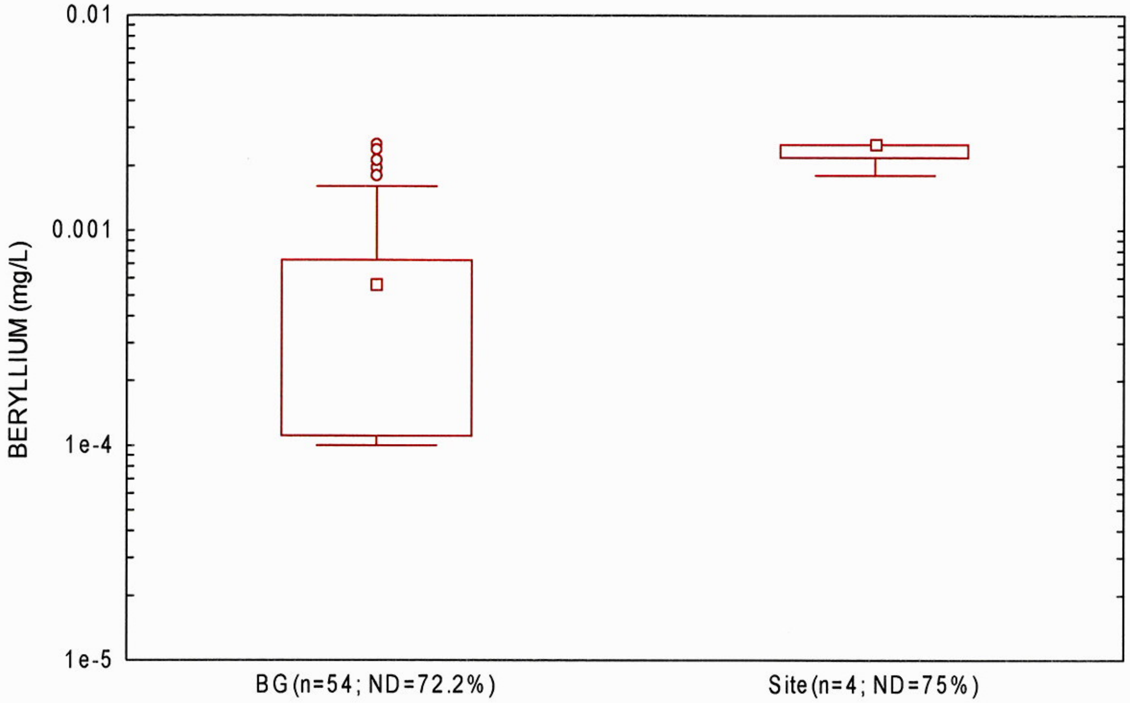
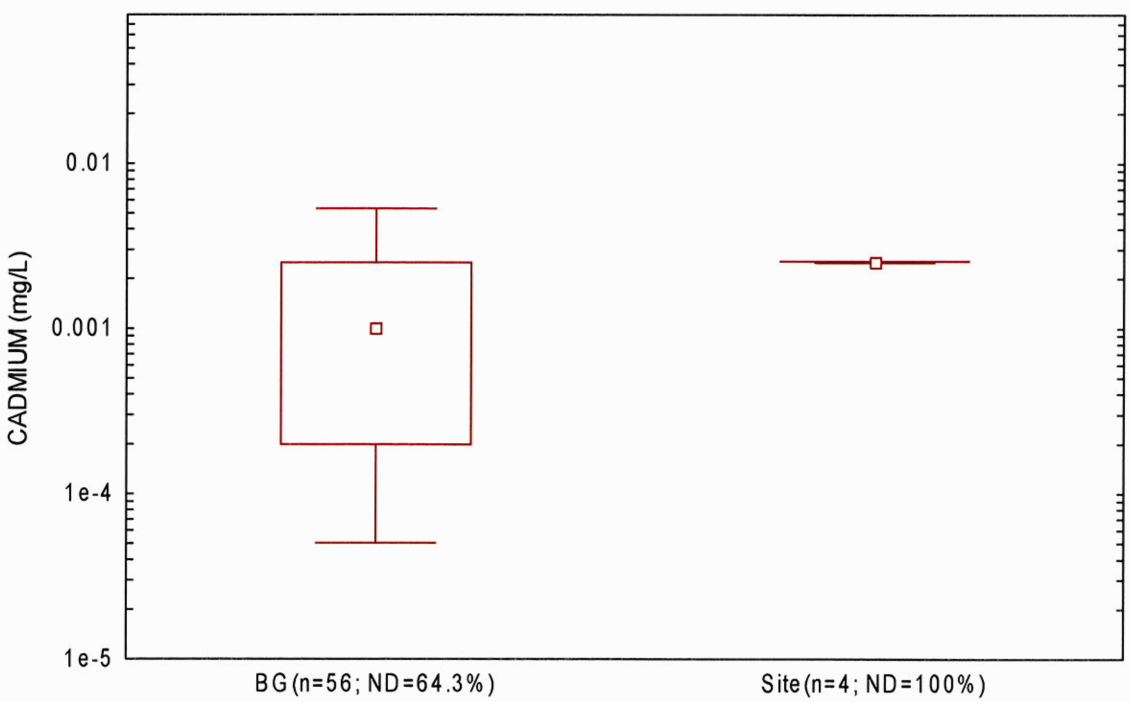


Figure 9. Box Plot Comparison for Cadmium in Groundwater
Parcel 94(7), Ft. McClellan



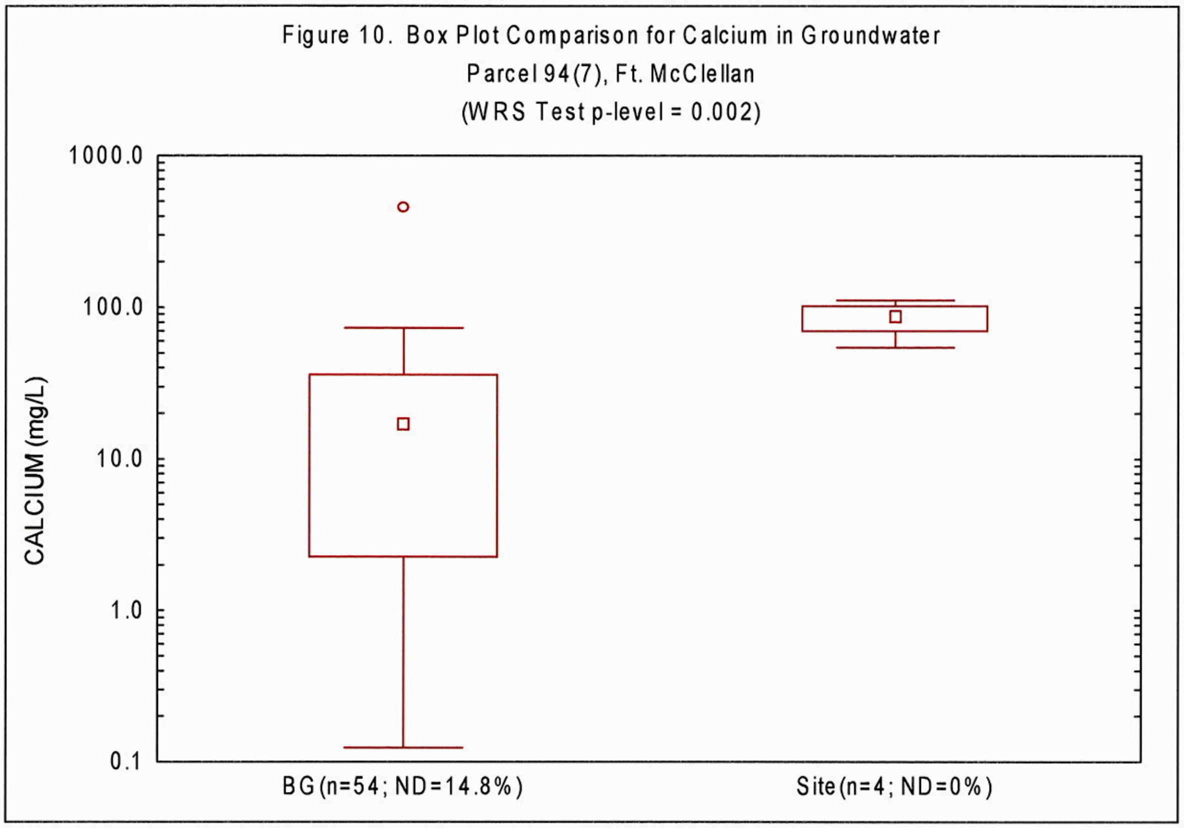


Figure 10. Box Plot Comparison for Calcium in Groundwater
Parcel 94(7), Ft. McClellan
(WRS Test p-level = 0.002)

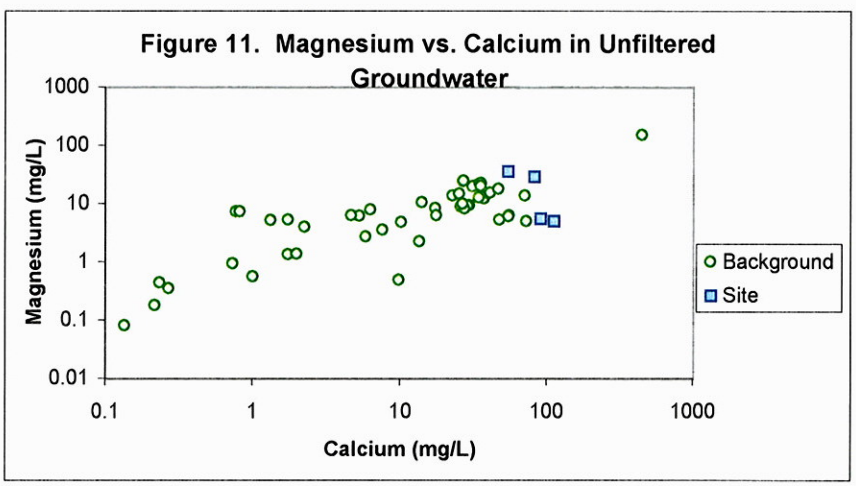


Figure 11. Magnesium vs. Calcium in Unfiltered Groundwater

Figure 12. Box Plot Comparison for Chromium in Groundwater
Parcel 94(7), Ft. McClellan

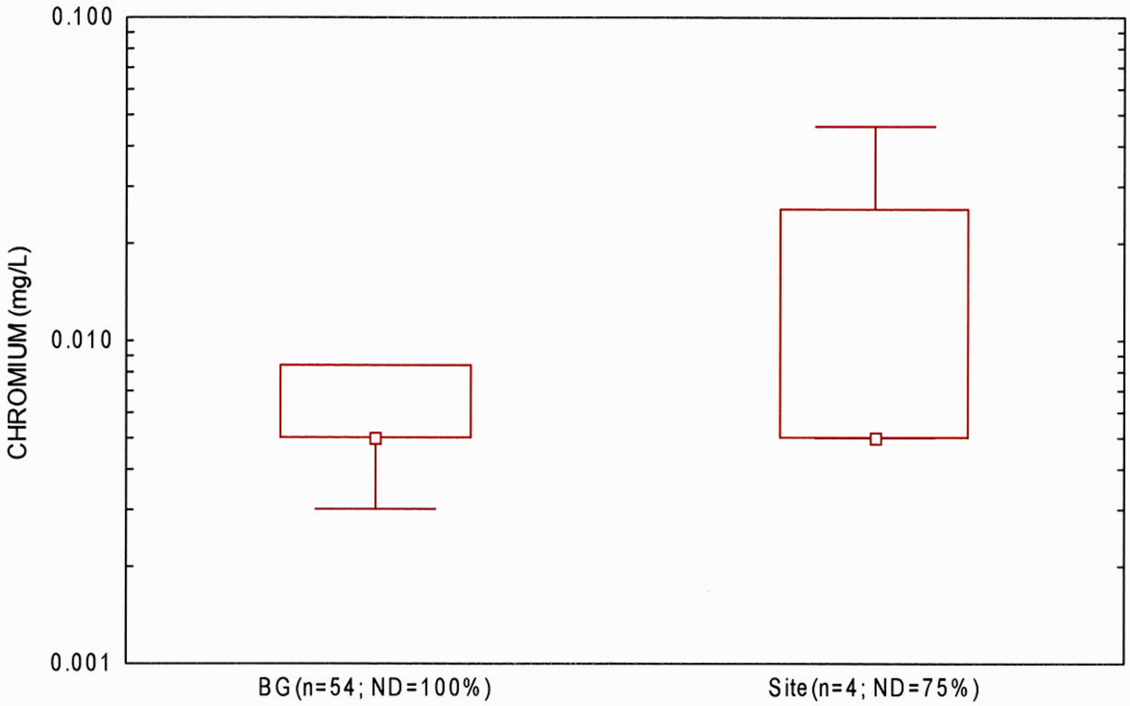
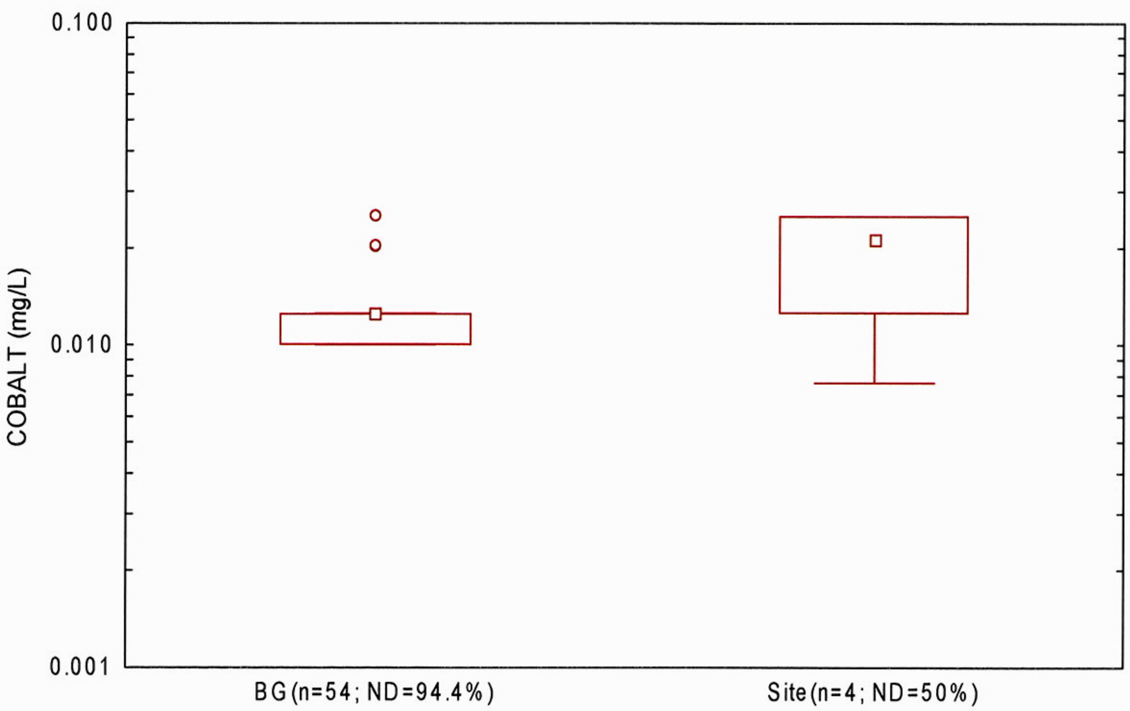


Figure 13. Box Plot Comparison for Cobalt in Groundwater
Parcel 94(7), Ft. McClellan



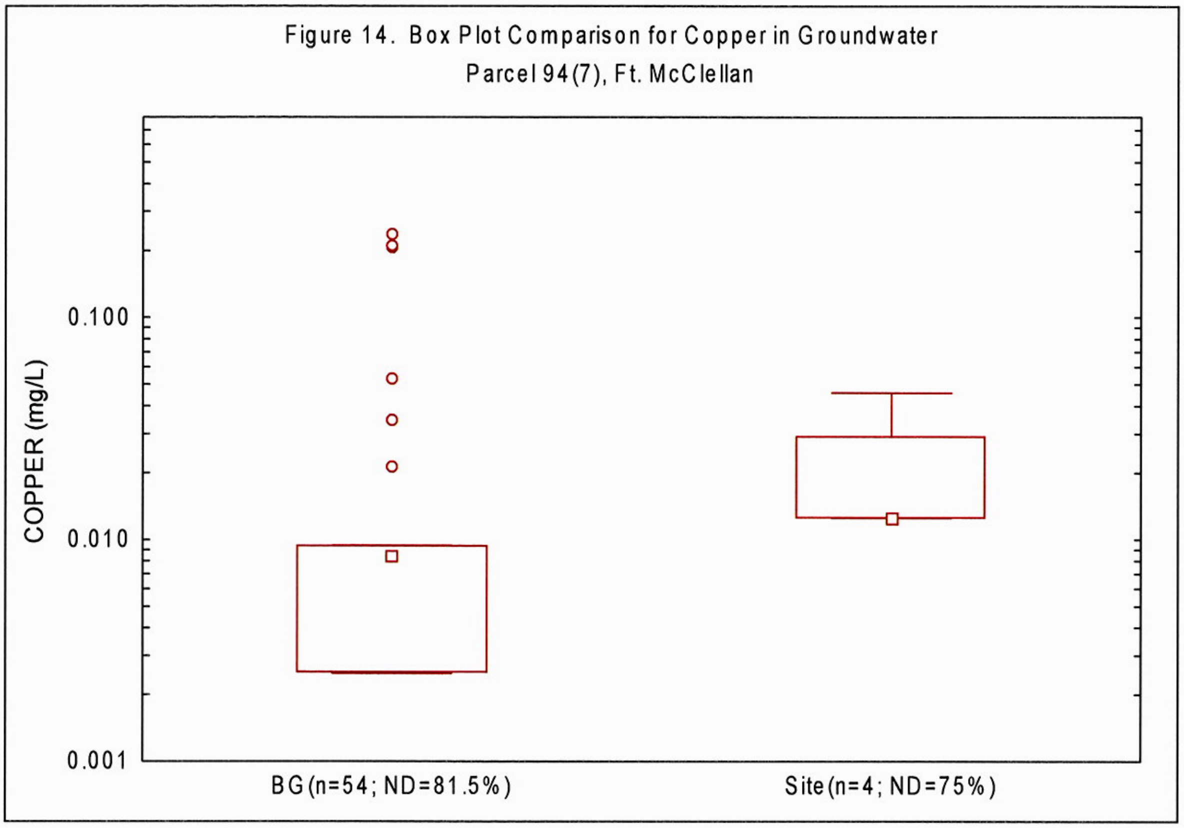


Figure 14. Box Plot Comparison for Copper in Groundwater
Parcel 94(7), Ft. McClellan
COPPER (mg/L)
0.100
0.010
0.001
BG(n=54; ND=81.5%)
Site(n=4; ND=75%)

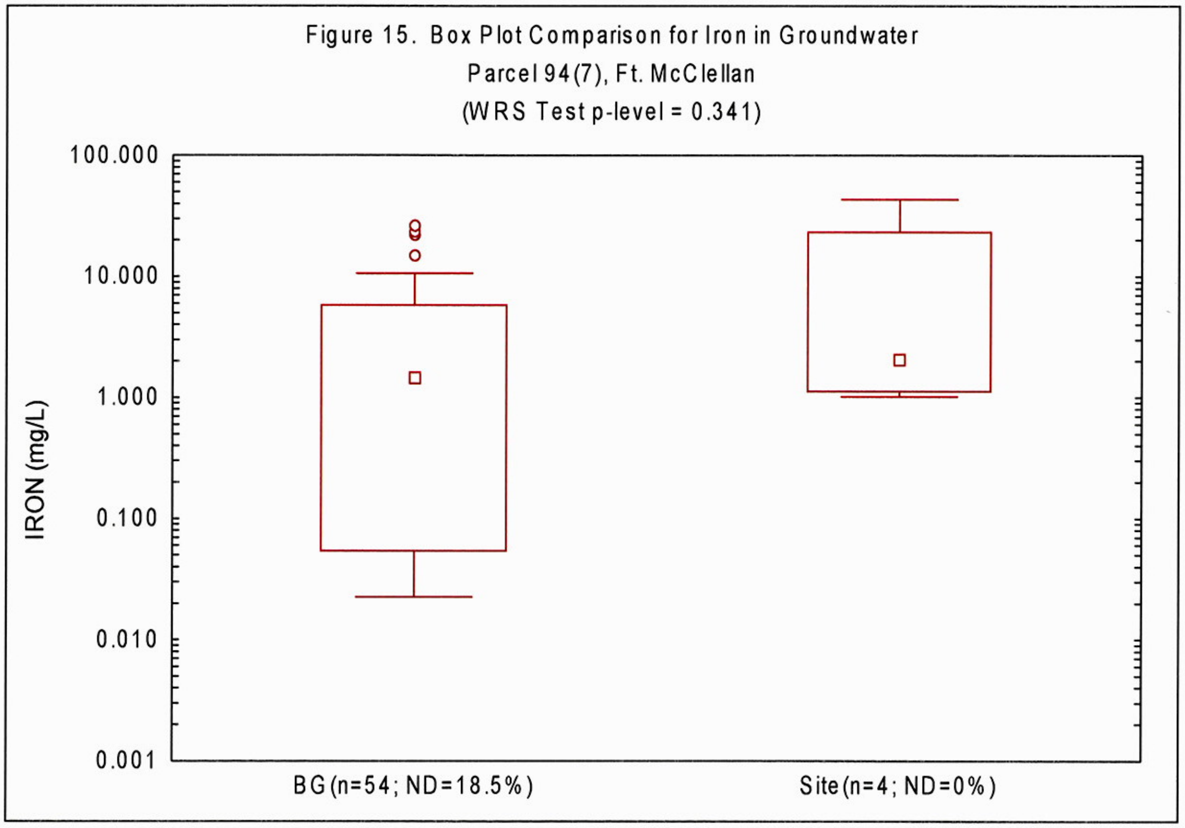


Figure 15. Box Plot Comparison for Iron in Groundwater
Parcel 94(7), Ft. McClellan
(WRS Test p-level = 0.341)
IRON (mg/L)
100.000
10.000
1.000
0.100
0.010
0.001
BG(n=54; ND=18.5%)
Site(n=4; ND=0%)

Figure 16. Box Plot Comparison for Lead in Groundwater
Parcel 94(7), Ft. McClellan

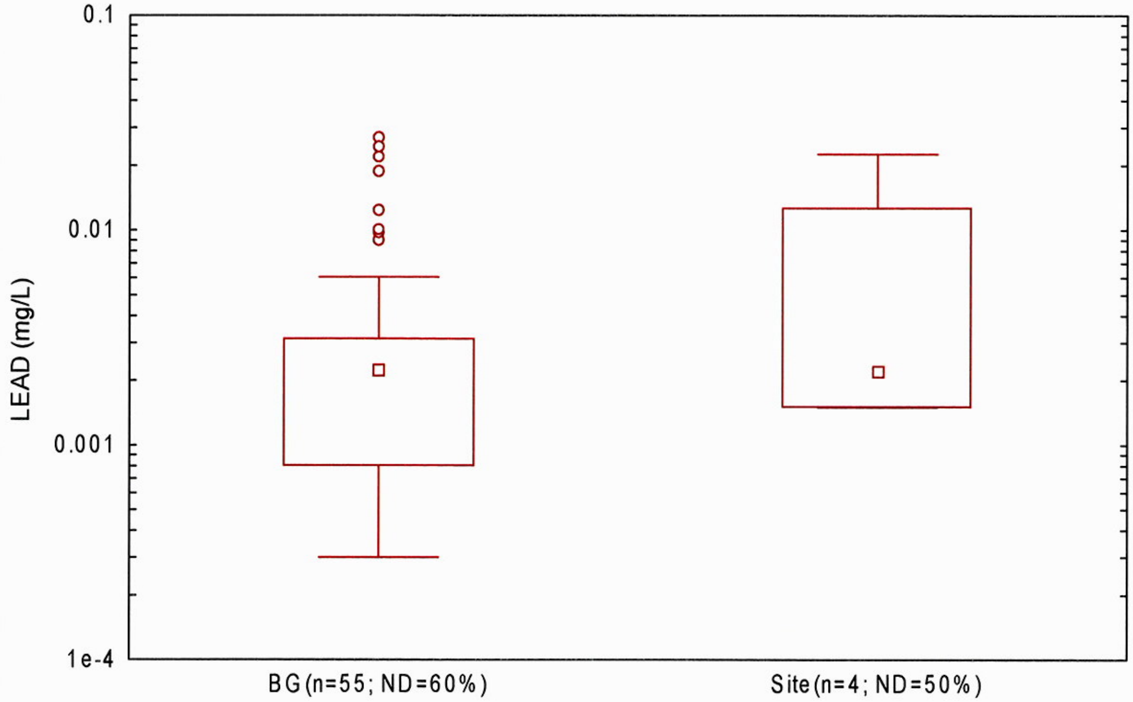
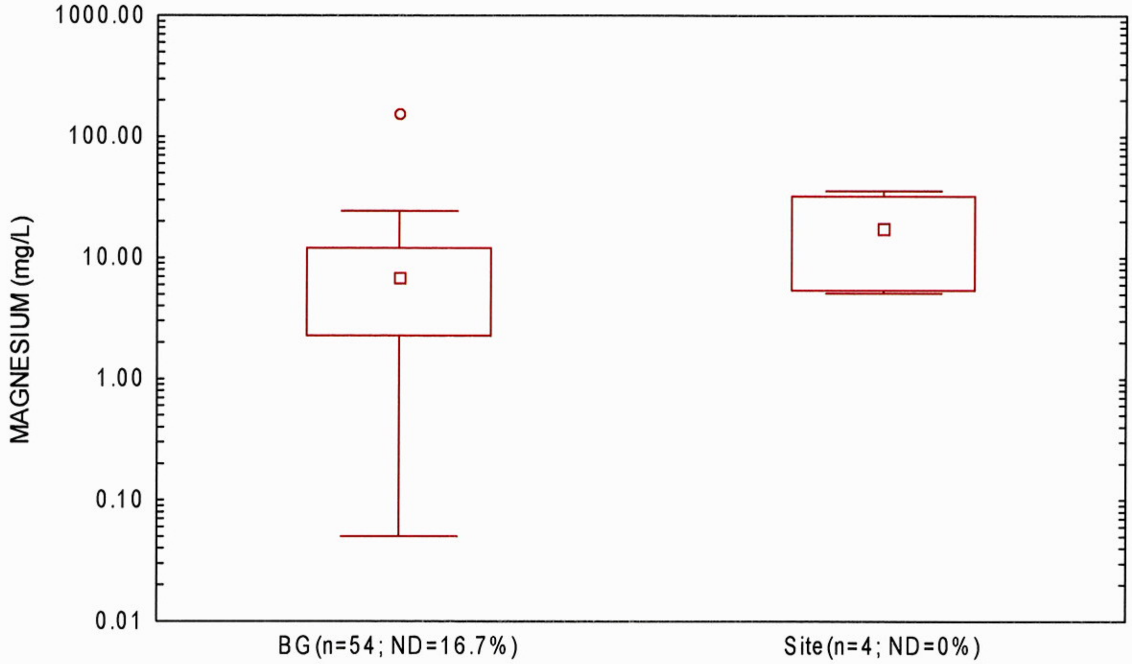


Figure 17. Box Plot Comparison for Magnesium in Groundwater
Parcel 94(7), Ft. McClellan
(WRS Test p-level = 0.220)



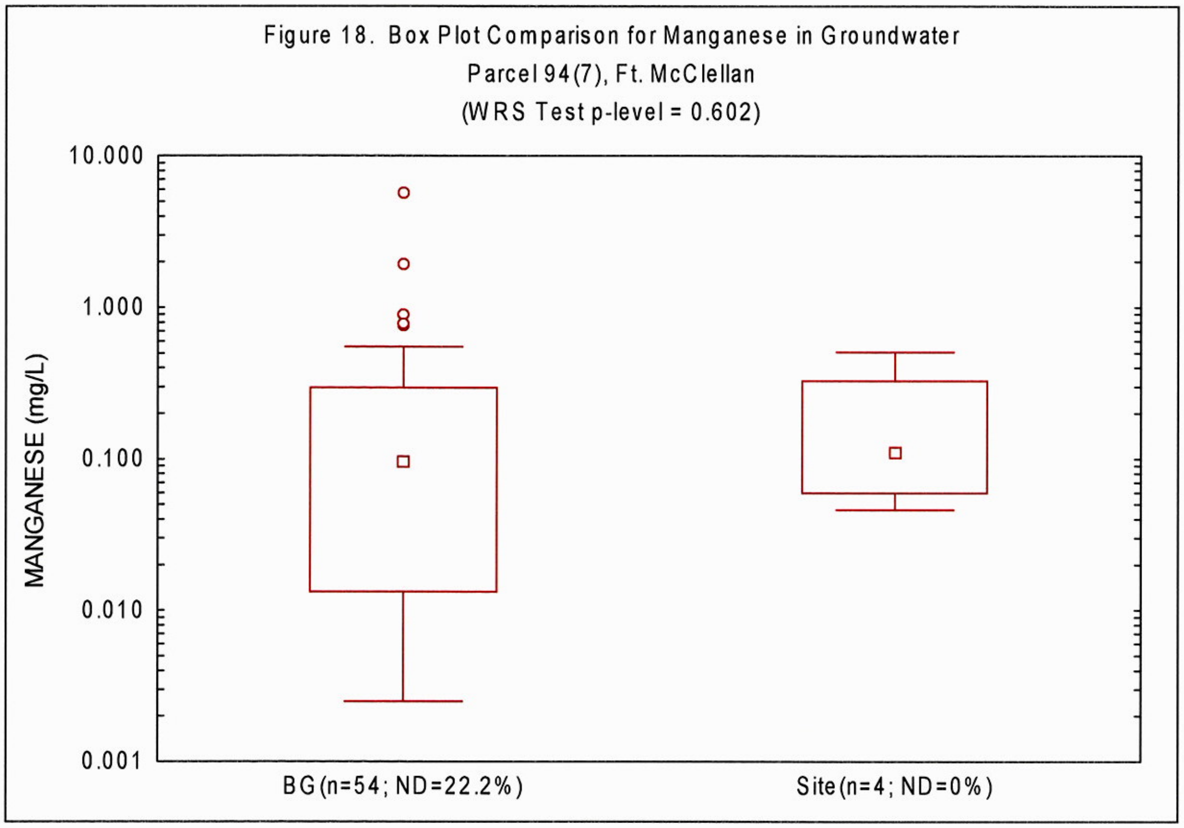


Figure 18. Box Plot Comparison for Manganese in Groundwater
Parcel 94(7), Ft. McClellan
(WRS Test p-level = 0.602)
10.000
1.000
0.100
0.010
0.001
MANGANESE (mg/L)
BG(n=54; ND=22.2%)
Site(n=4; ND=0%)

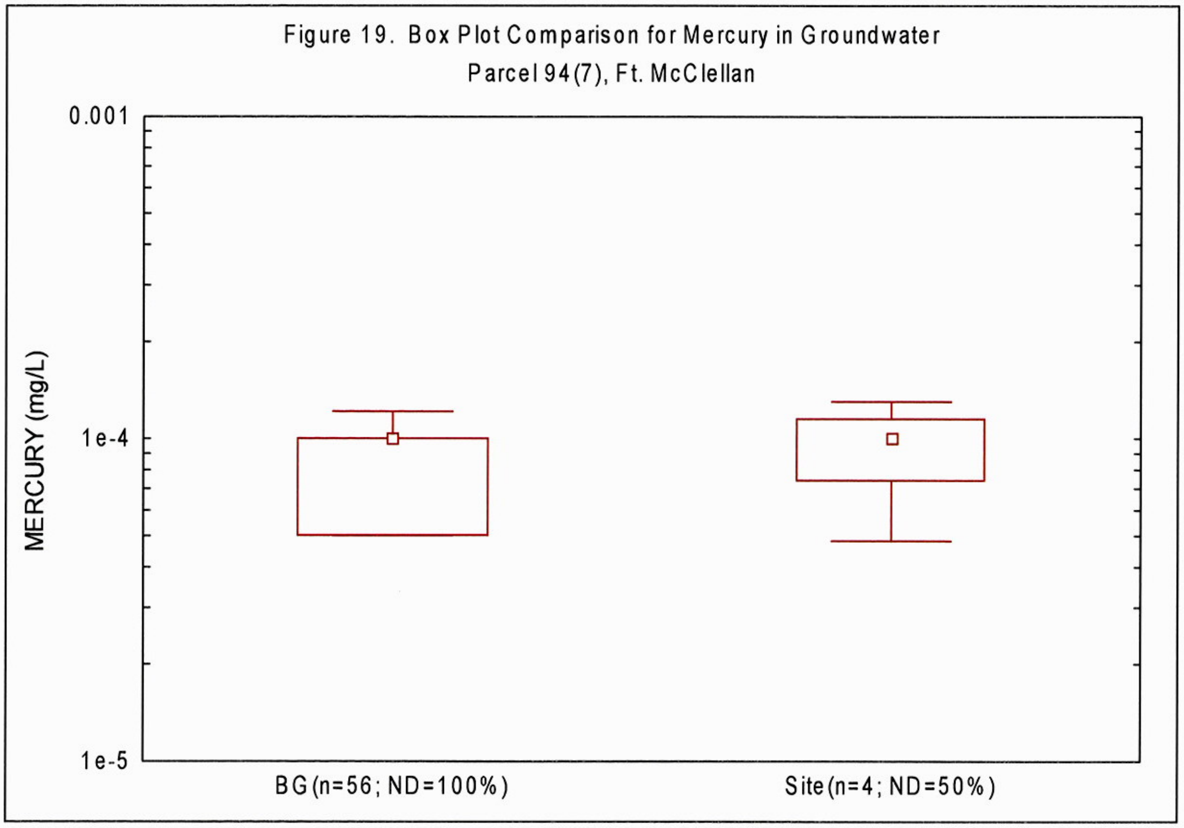


Figure 19. Box Plot Comparison for Mercury in Groundwater
Parcel 94(7), Ft. McClellan
0.001
1e-4
1e-5
MERCURY (mg/L)
BG(n=56; ND=100%)
Site(n=4; ND=50%)

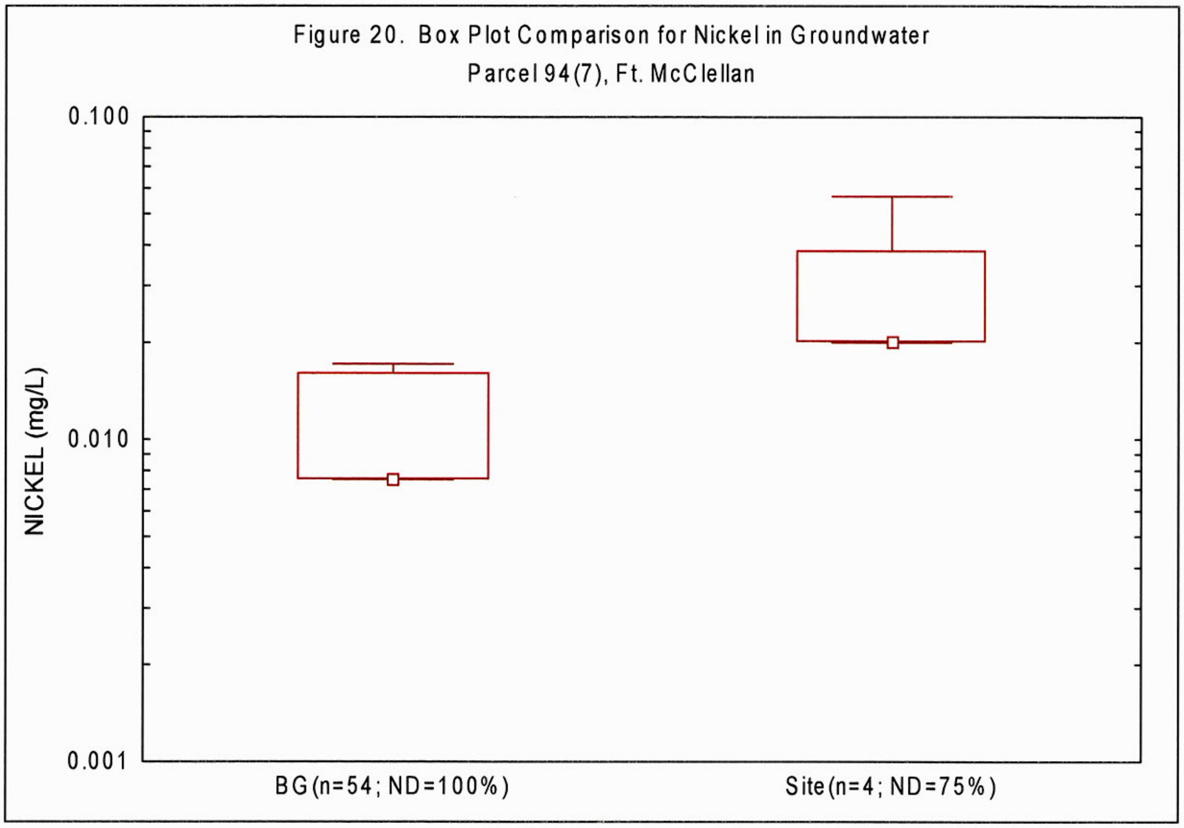


Figure 20. Box Plot Comparison for Nickel in Groundwater
Parcel 94(7), Ft. McClellan
NICKEL (mg/L)
0.100
0.010
0.001
BG(n=54; ND=100%)
Site(n=4; ND=75%)

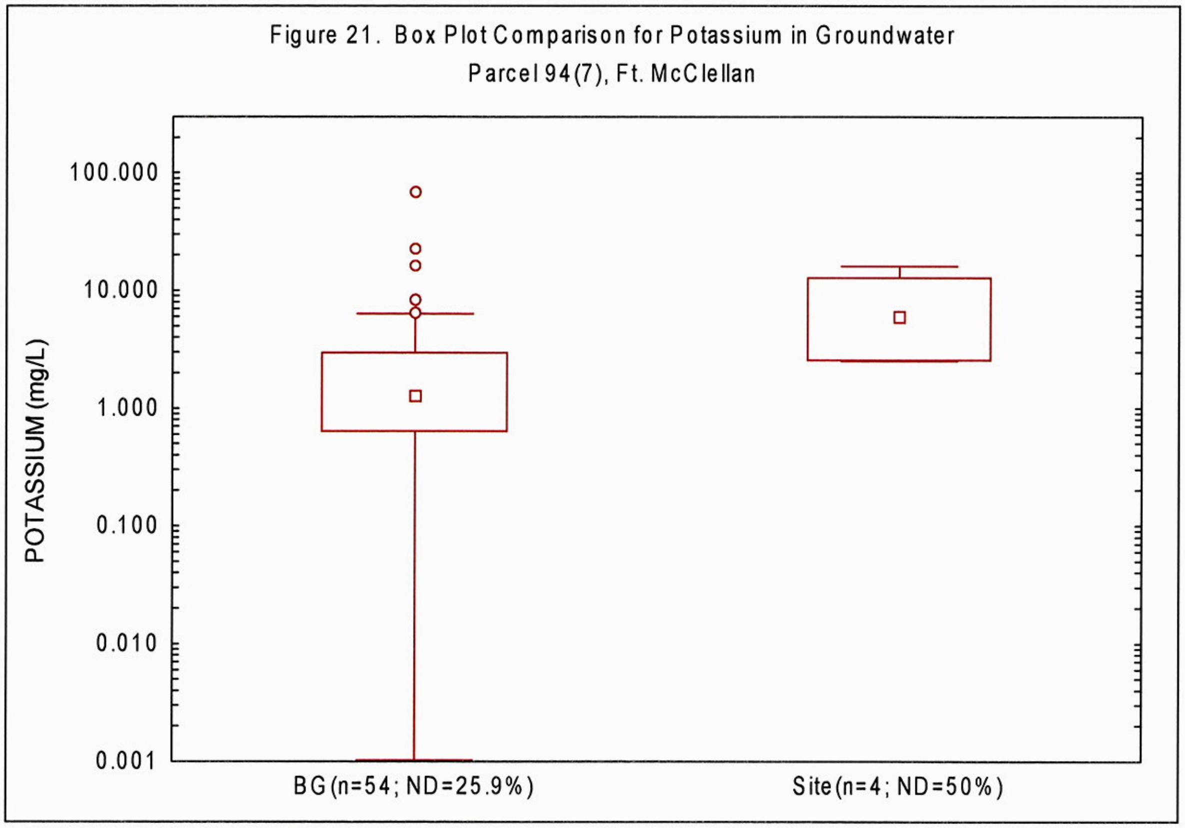


Figure 21. Box Plot Comparison for Potassium in Groundwater
Parcel 94(7), Ft. McClellan
POTASSIUM (mg/L)
100.000
10.000
1.000
0.100
0.010
0.001
BG(n=54; ND=25.9%)
Site(n=4; ND=50%)

Figure 22. Box Plot Comparison for Selenium in Groundwater
Parcel 94(7), Ft. McClellan

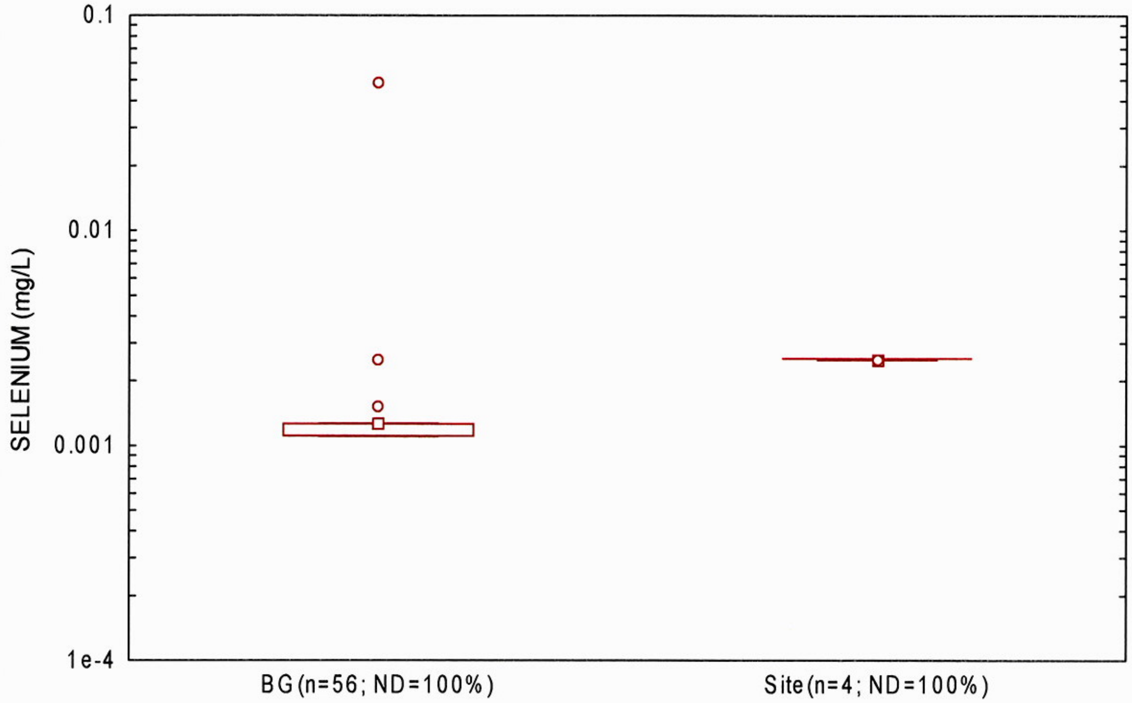
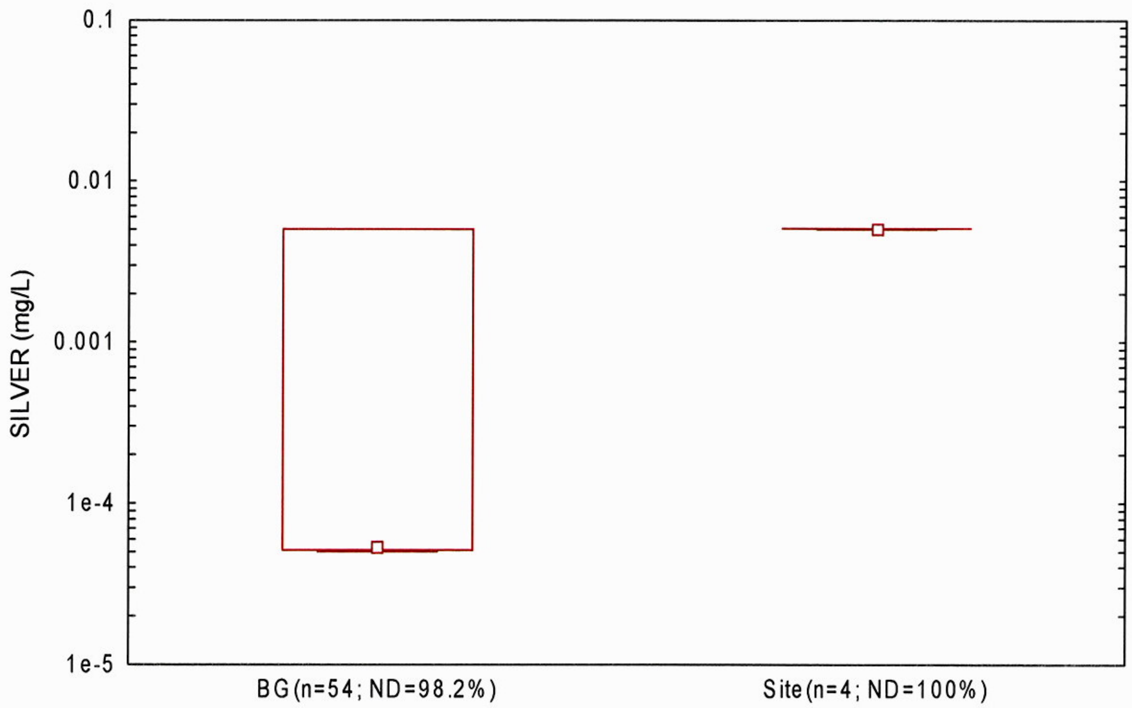


Figure 23. Box Plot Comparison for Silver in Groundwater
Parcel 94(7), Ft. McClellan



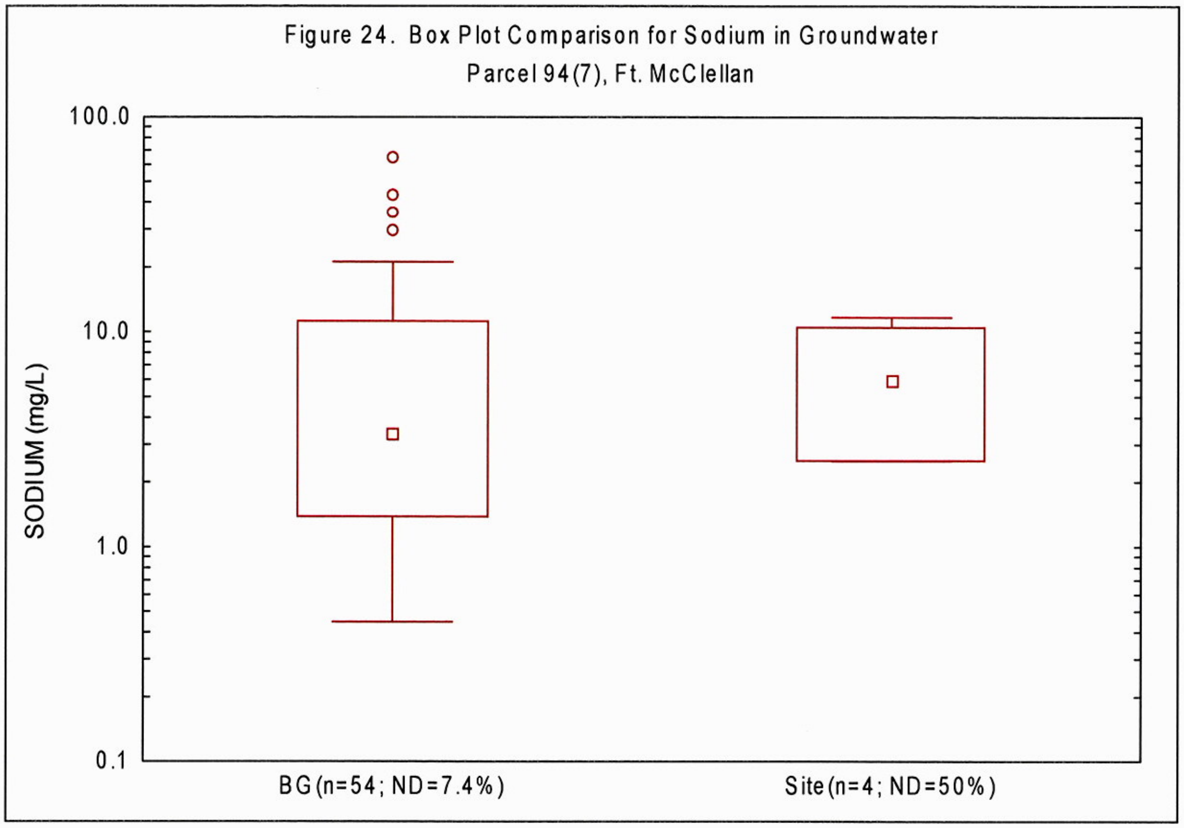


Figure 24. Box Plot Comparison for Sodium in Groundwater
Parcel 94(7), Ft. McClellan
100.0
10.0
1.0
0.1
SODIUM (mg/L)
BG(n=54; ND=7.4%)
Site(n=4; ND=50%)

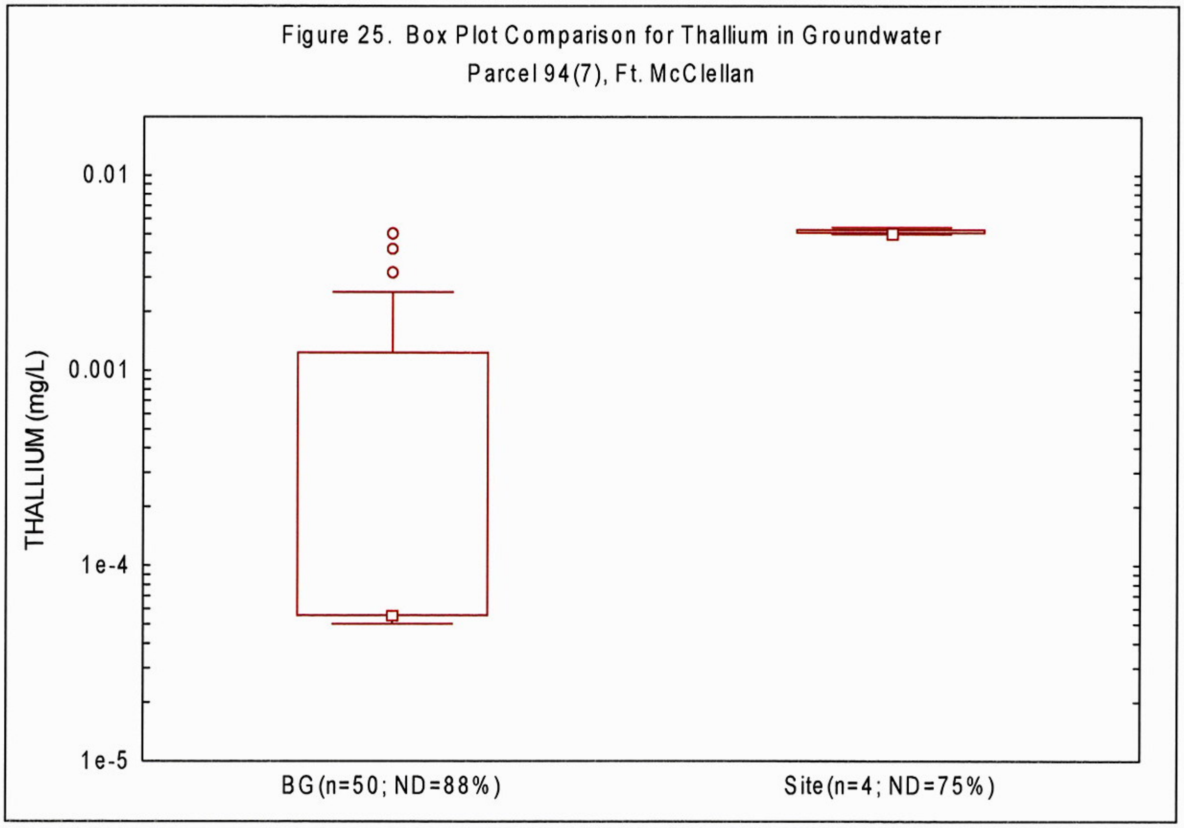


Figure 25. Box Plot Comparison for Thallium in Groundwater
Parcel 94(7), Ft. McClellan
0.01
0.001
1e-4
1e-5
THALLIUM (mg/L)
BG(n=50; ND=88%)
Site(n=4; ND=75%)

Figure 26. Box Plot Comparison for Vanadium in Groundwater
Parcel 94(7), Ft. McClellan

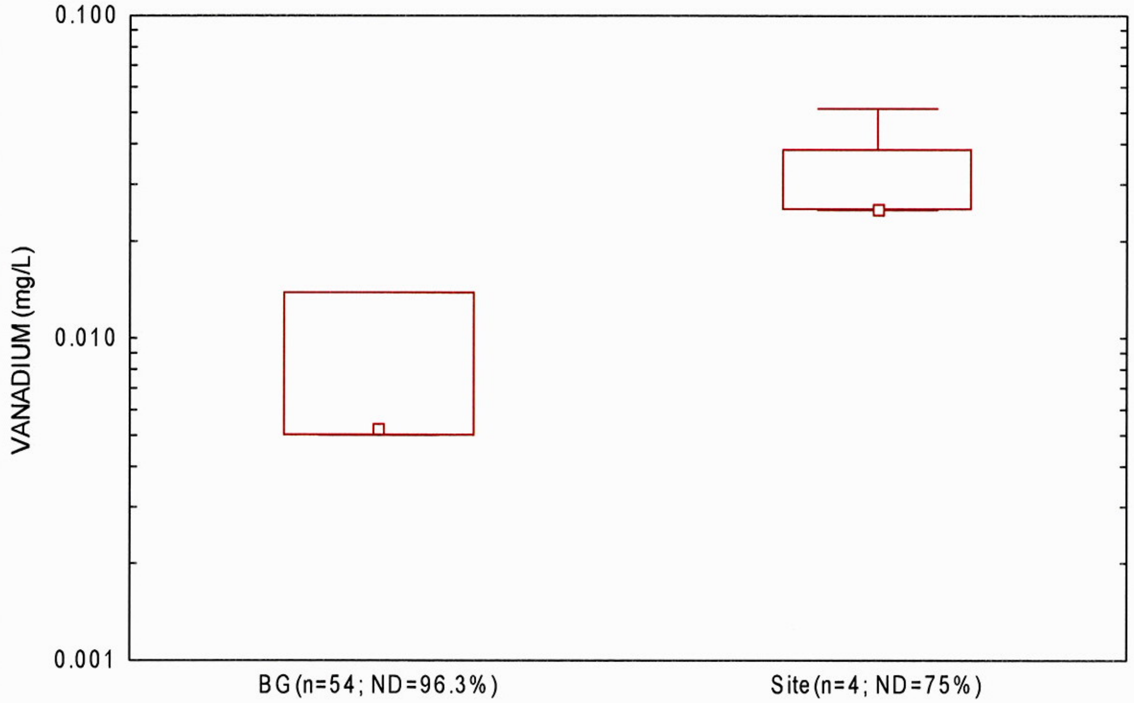


Figure 27. Vanadium vs. Iron in Unfiltered Groundwater

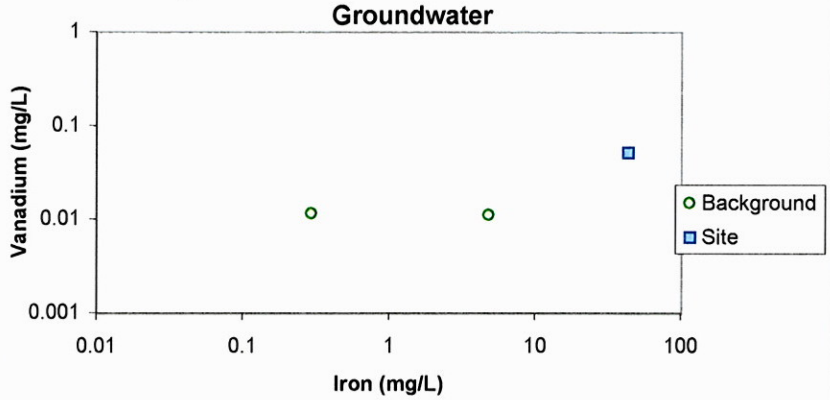


Figure 28. Box Plot Comparison for Zinc in Groundwater
Parcel 94(7), Ft. McClellan