FINAL

Ambient Metals Evaluation
Aluminum, Cobalt, Manganese, and Nickel

Technical Memorandum

Richmond Field Station Site
Berkeley Global Campus at Richmond Bay
University of California, Berkeley

Prepared for

Office of Environment, Health and Safety
University of California, Berkeley
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December 11, 2015

Lynn Nakashima
Project Manager
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700 Heinz Avenue
Berkeley, CA 94710

Subject: **Final Ambient Metals Evaluation**
Aluminum, Cobalt, Manganese, and Nickel
Berkeley Global Campus, Richmond Field Station Site
University of California, Berkeley
Site Investigation and Remediation Order I/SE-RAO 07/07-004

Dear Ms. Nakashima:

Please find enclosed the *Final Ambient Metals Evaluation Aluminum, Cobalt, Manganese, and Nickel*, dated December 11, 2015. The final version replaces the draft memorandum dated August 13, 2015 and incorporates input provided by the Department of Toxic Substances Control.

This technical memorandum presents site-specific data and existing literature references for the four metals listed. This technical memorandum will serve as a reference for future documents prepared for the Richmond Field Station Site in regard to screening criteria for aluminum, cobalt, manganese, and nickel.

This submittal includes two hard copies and two electronic copies on disc. A hard copy with disc has been delivered to the City of Richmond Public Library and the document is also available for public review at Building 478, Berkeley Global Campus.

If you have any questions or need further information regarding this submittal, please call me at (ghaet@berkeley.edu, 510-642-4848) or Karl Hans (khans@berkeley.edu, 510-643-9574).

Sincerely,

Greg Haet, P.E.
EH&S Associated Director
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Enclosures

cc: Bill Marsh, Edgcomb Law Group

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Appendices

1.0 INTRODUCTION

This technical memorandum was prepared on behalf of The Regents of the University of California (UC) in accordance with California Environmental Protection Agency, Department of Toxic Substances Control, Site Investigation and Remediation Order, Docket No. IS/E-RAO 06/07-004, dated September 15, 2006. The order provides for investigation and cleanup of 96 acres of upland and 13 acres of tidal marsh and transition habitat within the Richmond Field Station (RFS) Site, located at the Berkeley Global Campus at Richmond Bay.

UC Berkeley has conducted site investigation and cleanup activities at the RFS Site since the 1980s. Generally, analytical soil sampling results have been compared to (1) published regulatory criteria, such as California Human Health Screening Levels (California Environmental Protection Agency 2005), (2) published background documents, such as *"Use of the Northern and Southern California Polynuclear Aromatic Hydrocarbon (PAH) Studies in the Manufactured Gas Plant Site Cleanup Process"* (Department of Toxic Substances Control 2009), and RFS site-specific criteria, such as Remedial Goals for Soil (Tetra Tech 2014). These criteria are used to evaluate volatile organic compounds, semi-volatile compounds, pesticides, polychlorinated biphenyls, total petroleum hydrocarbons, and metals.

For metals which occur naturally in the soil, the application of regulatory screening levels or site-specific risk-based criteria can be ineffective if those levels are lower than the naturally-occurring or ambient concentrations in soil. For these metals, background studies or weight-of-evidence evaluations may be conducted to establish ambient or background concentrations. Establishing background or ambient concentrations helps ensure that investigation or cleanup efforts are not expended towards metals concentrations which are not associated with suspected contamination. "Ambient" concentrations represent metals in soils in the vicinity of a site but which are unaffected by site-related activities. Ambient conditions are some-times referred to as "local background" (Department of Toxic Substances Control 1997).

There are five metals in soil at the RFS Site which may be present in the absence of suspected contamination at concentrations higher than the human health screening criteria: aluminum, arsenic, cobalt, manganese, and nickel. A detailed background study was previously conducted to establish a background concentration for arsenic at the adjacent Campus Bay site (Erler & Kalinowski, Inc. 2007) and the findings have been applied to the RFS Site (Tetra Tech 2014) since the time critical removal action was conducted in 2007 at the former Forest Products Laboratory Wood Treatment Lab. Background studies have not been conducted for aluminum, cobalt, manganese, and nickel.

This technical memorandum presents a weight-of-evidence evaluation for aluminum, cobalt, manganese, and nickel. Section 2 presents a summary of each metal, including properties, chemical use, range of concentrations detected at RFS, and existing remedial goals for RFS, consisting of site-specific risk-based screening criteria. Section 3 presents statistical evaluations of site-specific soil chemical data. Section 4 presents a summary of the four metals from applicable literature reviews. Section 5 summarizes the findings from the statistical analyses and literature reviews, and identifies a range of natural or ambient soil concentrations for each metal.

2.0 METALS BACKGROUND INFORMATION

Section 2 presents a brief description of each metal and established regulatory and site-specific criteria. General descriptions, industrial uses, and information on potential chemical sources to the environment are based on toxicological profiles prepared by the Agency for Toxic Substances and Disease Registry (ATSDR). The summary of detected concentrations at the RFS Site are based on data presented in the Final Current Conditions Report (Tetra Tech 2008), Final Site Characterization Report (Tetra Tech 2013), and Draft Phase IV Sampling Results Technical Memorandum (Tetra Tech 2015). The soil remedial goals for the RFS Site are based on the Final Removal Action Workplan (Tetra Tech 2014). The regulatory criteria are based on the California Human Health Screening Levels (California Environmental Protection Agency 2005).

2.1 ALUMINUM

Aluminum is the most abundant metal in the earth's crust and is always found combined with other elements such as oxygen, silicon, and fluorine; aluminum as the metal is obtained from aluminum-containing minerals.

Aluminum is often mixed with small amounts of other metals to form aluminum alloys, which are stronger and harder. Aluminum compounds are used in many diverse and important industrial applications such as alums (aluminum sulfate) in water-treatment and alumina in abrasives and furnace linings. They are also found in consumer products such as antacids, astringents, buffered aspirin, food additives, and antiperspirants. Aluminum is used to make beverage cans, pots and pans, airplanes, siding, roofing, and foil (ATSDR 2008).

Elevated levels of aluminum in the environment can be caused by the mining and processing of aluminum ores or the production of aluminum metal, alloys, and compounds. Small amounts of aluminum are released into the environment from coal-fired power plants and incinerators (ATSDR 2008). Aluminum is common and widespread in the environment and exposure to the levels of aluminum that are naturally present in food and water and the forms that are present in soil and aluminum pots and pans are not considered to be harmful. Exposure to higher levels of aluminum through industrial exposure or through consumption of process food containing aluminum additives and other sources are known or suspected to cause health effects (ATSDR 2008). As a result of potential exposure to the higher levels of aluminum, RFS Site-Specific Remedial Goals were established in the Final Removal Action Workplan (Tetra Tech 2014).

Aluminum has been detected in all soil samples analyzed for metals at the RFS Site. Aluminum concentrations in soil at RFS Site have ranged from 8,500 to 28,000 mg/kg.

The RFS Site-Specific Remedial Goals for aluminum are:

Receptor	Concentration
Commercial Worker	100,000 mg/kg
Construction Worker	20,300 mg/kg
Maintenance Worker	100,000 mg/kg
Off-Site Residents	100,000 mg/kg

There are no California Human Health Screening Levels for aluminum.

There are no known or documented releases or spills of materials containing aluminum or aluminum compounds at the RFS Site.

2.2 COBALT

Cobalt is a naturally occurring element found in rocks, soil, water, plants, and animals with properties similar to iron and nickel. Elemental cobalt is a hard, silvery-grey metal, but cobalt is usually found in the environment combined with other elements such as oxygen, sulfur, and arsenic. Cobalt occurs as the biochemically important vitamin B12 and is essential for good health in animals and humans (ATSDR 2004).

Cobalt is an important industrial metal used in manufacturing mixed with other metals to form alloys which are harder or more resistant to corrosion, including use in artificial hip and knee joints. Cobalt compounds are used as colorants in glass, ceramics, and paints; as catalysts in the petroleum industry; as paint driers; and as trace element additives in agriculture and medicine. Radioactive cobalt is used for commercial and medical purposes (ATSDR 2004).

Cobalt is dispersed in the environment in low concentrations. The primary anthropogenic sources of cobalt in the environment are from the burning of fossil fuels, application of cobalt-containing phosphate fertilizers, mining and smelting of cobalt-containing ores, processing of cobalt-containing alloys, and industries that use or process cobalt compounds (ATSDR 2004).

Cobalt has been associated with elevated elevations of manganese present in chert rocks, which may be present at the RFS Site; a more complete discussion of elevated concentrations of manganese in chert is presented in Section 2.3 below. Cobalt-bearing manganese oxide is commonly associated with sandstone, chert, and other siliceous rocks (U.S. Department of the Interior 1944), which are present in the Franciscan Complex local to the RFS Site.

Cobalt has both beneficial and harmful effect on human health. It is present in vitamin B12 which is essential to maintain human health and has been used as a treatment of anemia. Excessive exposure and uptake of cobalt in industrial exposure is known to cause health effects, although it is not known to cause cancer. As a result of potential exposure to the higher levels of cobalt, RFS Site-Specific Remedial Goals were established in the Final Removal Action Workplan (Tetra Tech 2014).

Cobalt has been detected in all soil samples analyzed for metals at the RFS Site. Cobalt concentrations in soil at RFS Site have ranged from 3.1 to 73 mg/kg.

The RFS Site-Specific Remedial Goals for cobalt are:

Receptor	Concentration
Commercial Worker	273 mg/kg
Construction Worker	19.9 mg/kg
Maintenance Worker	34.1 mg/kg
Off-Site Residents	356 mg/kg

The California Human Health Screening Levels for cobalt are:

Receptor	Concentration
Residential	660 mg/kg
Commercial Worker	3,200 mg/kg

The calculation of RFS Site-specific Remedial Goals for cobalt are based on estimated exposures specific to workers at RBC. The RFS Site exposure estimates are higher (for example more days per year working in contact with soil) than the default exposures included in the California Human Health Screening Level calculations, and therefore result in remedial goals which are more stringent than the California Human Health Screening Levels.

There are no known or documented releases or spills of materials containing cobalt or cobalt compounds at the RFS Site.

2.3 MANGANESE

Manganese is a naturally-occurring metal found in many types of rocks and is a normal constituent of air, soil, water, and food. Pure manganese is silver-colored, but does not occur naturally. It combines with other substances such as oxygen, sulfur, or chlorine. Manganese can also be combined with carbon to make organic manganese compounds. Manganese occurs naturally in most foods and may be added to food or made available in nutritional substances. Manganese is a trace element and is necessary for good health (ATSDR 2012).

In addition to being used as a nutritional substance, manganese occurs in a wide variety of commercial products, including fireworks, dry-cell batteries, fertilizer, paints, and cosmetics. In manufacturing, it is used principally in steel production to improve hardness, stiffness, and strength. It is also used as a gasoline additive and in some pharmaceuticals and pesticides (ATSDR 2012).

Manganese is present at elevated concentrations and mined from many geologic formations throughout the U.S. Specifically, elevated concentrations of manganese are associated with the Franciscan Complex, specifically within chert rocks (National Park Service 2001).

The U.S. Geological Survey has mapped Franciscan Complex at Brooks Island, Point Molate, the East Shore Park and Albany Hill, indicating a high likelihood of manganese-rich chert source rocks may be present at the RFS Site (U.S. Geological Survey 2006). The presence of manganese is so prevalent that manganese ore was mined in the late 1860s from Red Rock Island, part of the Franciscan Complex located west of the RFS Site at the Richmond Bridge (U.S. Geological Survey 1910).

People are exposed to manganese primarily by eating food or manganese-containing nutritional supplements. Vegetarians may have a higher intake of manganese than the average person. Certain occupations like welding increase chances of exposure. Air emissions from industry, mining, automobile exhaust, and tobacco smoke may also increase chances of exposure (ATSDR 2012).

While manganese is an essential nutrient, uptake of excessive manganese is known to cause adverse health effects, although it is not known to cause cancer or birth defects. As a result of potential exposure to the higher levels of manganese, RFS Site-Specific Remedial Goals were established in the Final Removal Action Workplan (Tetra Tech 2014).

Manganese has been detected in all soil samples analyzed for metals at the RFS Site. Manganese concentrations in soil at RFS Site have ranged from 120 to 5,900 mg/kg.

The RFS Site-Specific Remedial Goals for manganese are:

Receptor	Concentration
Commercial Worker	20,500 mg/kg
Construction Worker	212 mg/kg
Maintenance Worker	5,300 mg/kg
Off-Site Residents	68,600 mg/kg

There are no California Human Health Screening Levels for manganese.

There are no known or documented releases or spills of materials containing manganese or manganese compounds at the RFS Site.

2.4 NICKEL

Nickel is present in all soil and is a very abundant natural element which can be combined with other metals, such as iron, copper, chromium, and zinc, to form alloys. These alloys are used to make coins, jewelry, and items such as valves and heat exchangers. Nickel compounds are used for nickel plating, to color ceramics, to make some batteries, and as substances known as catalysts that increase the rate of chemical reactions. Most nickel is used to make stainless steel (ATSDR 2005).

The major source of nickel exposure to the general population is food. Some foods are naturally high in nickel including chocolate, soybeans, nuts, and oatmeal. Higher levels of exposure can occur in industries that use nickel. The most common harmful health effect of nickel in humans is an allergic reaction. Approximately 10 to 20% of the population is sensitive to nickel, which can cause skin rashes on contact (with jewelry). Industrial exposures to higher concentrations in air are known to cause serious health effects. As a result of potential exposure to industrial concentrations of nickel, RFS Site-Specific Remedial Goals were established in the Final Removal Action Workplan (Tetra Tech 2014).Nickel has been detected in all soil samples analyzed for all metals at the RFS Site. Nickel concentrations in soil at RFS Site have ranged from 20 to 280 mg/kg.

The RFS Site-Specific Remedial Goals for Nickel are:

Receptor	Concentration
Commercial Worker	14,900 mg/kg
Construction Worker	60.6 mg/kg
Maintenance Worker	1,180 mg/kg
Off-Site Residents	12,300 mg/kg

The California Human Health Screening Levels for Nickel are:

Receptor	Concentration
Residential	1,600 mg/kg
Commercial Worker	16,000 mg/kg

The calculation of RFS Site-specific Remedial Goals for nickel are based on estimated exposures specific to workers at RBC. The RFS Site exposure estimates are higher (for example more days per year working in contact with soil) than the default exposures included in the California Human Health Screening Level calculations, and therefore result in remedial goals which are more stringent than the California Human Health Screening Levels.

There are no known or documented releases or spills of materials containing nickel or nickel compounds at the RFS Site.

3.0 RFS STATISTICAL EVALUATION

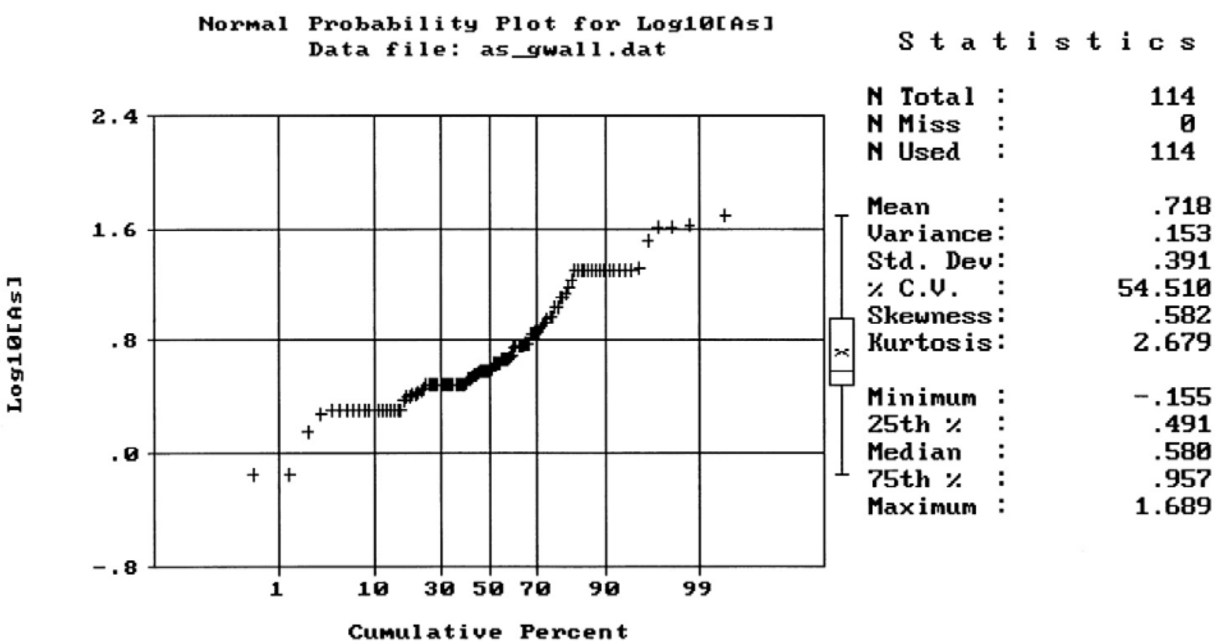
This section presents the two statistical evaluations for each of the four metals conducted with data collected from the RFS Site: (1) a comprehensive analysis of soil data collected to date; and (2) an analysis of data from contaminated soil samples compared with data from presumed uncontaminated soil samples. A summary of each evaluation is presented below, followed by the results for each metal.

3.1 INTRODUCTION

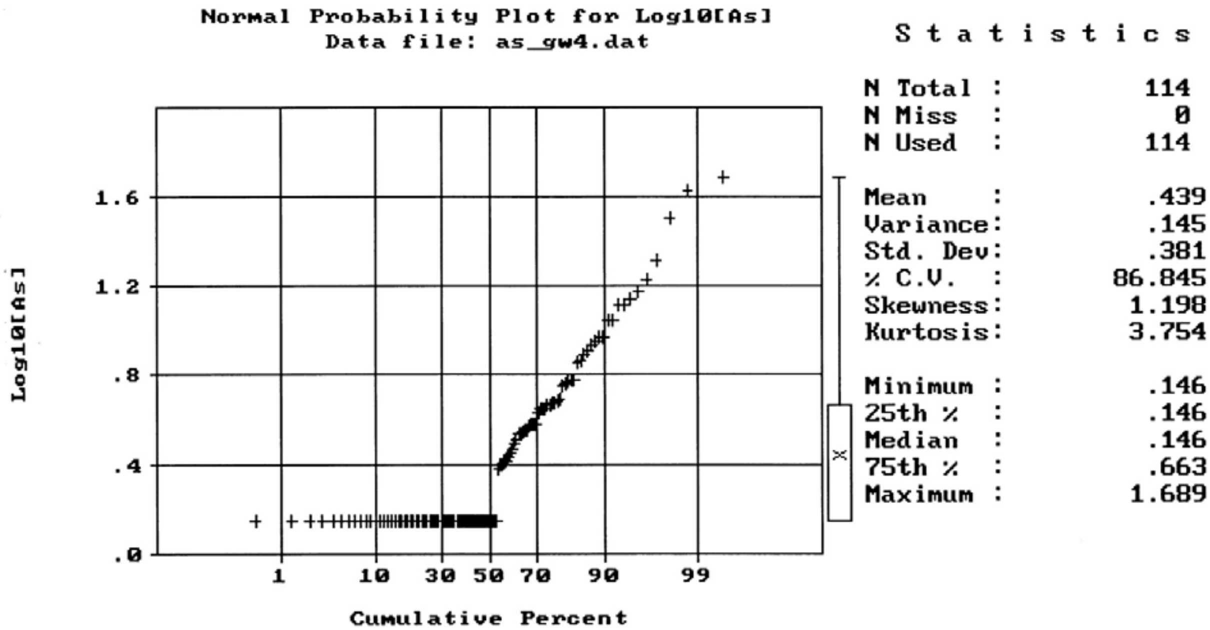
Statistical populations were examined for two different cases using graphical and mathematical techniques. First, the comprehensive data set from the RFS site was examined as a single data set in an attempt to identify multiple data populations. Second, the comprehensive data set was split into two subsets (contaminated and presumed uncontaminated) for comparison of these two subsets. Presumably if multiple populations are not observed and the contaminated subset is statistically equivalent to or less than the presumed uncontaminated subset, then the metal evaluated is not associated with known or suspected contaminant sources at the RFS Site, as defined in the Final Removal Action Workplan (Tetra Tech 2014).

Two graphical methods were used in the analysis: quantile-quantile (Q-Q) plots and cumulative probability plots were generated to enable visual analysis. Both types of plots provide visual indications of whether multiple populations are present in a data set. As examples, the two plots presented below demonstrate normal probability plots (similar to Q-Q plots and cumulative probability plots). The first example identifies a data set which appears to represent multiple populations, as evidenced by the multiple inflection points; the second example appears to represent a single population (DTSC 1997). The examples illustrate the general appearance of Q-Q plots with single and multiple populations.

Example 1. Normal probability plot for log-transformed data with multiple apparent populations.



Example 2. Normal probability plot for log-transformed data with a single population of detected data on the right side of plot, and a series of non-detect results on the left side of the plot.



A spreadsheet program was used to prepare Q-Q plots and cumulative probability plots for the four metals being studied, as summarized below.

- Q-Q plots show the concentration (or the log of the concentration) plotted against the theoretical quantile for a standard normal distribution based on the number of points in the data set. In this case, the distributions were expected to be lognormal, which is common for environmental data sets, so the log of the concentration was plotted initially. When the data points follow a straight line, it is likely that there is a single population.

- Cumulative probability plots show the concentration plotted against the cumulative percentage of the distribution. In the cumulative probability plots, the ends of the plot are compacted relative to the Q-Q plot. As such, it is easier to view the center of the plot on the cumulative probability plots, even though the ends are skewed away from the normal line. For a normal distribution, the cumulative probability plot will naturally show a linear response in the center, but resemble an s-shaped curve at the ends.

In addition, mathematical methods were used to determine whether the data sets appeared normal, lognormal, or nonparametric. ProUCL 5.0 was used to perform these tests (EPA 2013). Shapiro-Wilk tests of normality were used on the log-transformed data to test whether the data sets appeared lognormal. In some cases, Shapiro-Wilk tests were also used on the untransformed data to test whether the data sets appeared normal.

For the comparison of the contaminated and presumed uncontaminated data sets, Student's t-tests or Wilcoxon-Mann-Whitney (WMW) tests were conducted in ProUCL to compare the data sets (EPA 2013). Both tests are used to test for statistical differences between data sets that may or may not be from the same population. The t-test is appropriate when both data sets appear to be normal. The WMW test (equivalent to a Wilcoxon Rank-Sum test) is appropriate when the data sets do not appear to be normal. One-sided tests are used to assess whether the one data set appears to be below the other. Two-sided tests are conducted to assess whether the data sets do or do not appear statistically different.

3.2 COMPREHENSIVE ANALYSIS METHODOLOGY

The purpose of the comprehensive analysis was to identify disparate statistical populations, if present, for consideration as possible background or ambient populations. Soil data were reviewed for quality and appropriateness for acceptance into the data query for a comprehensive analysis. The data is comprehensive of all discrete soil sampling results from investigations conducted from 1990 through present. The data query includes field duplicates and sample results from soil which has been removed from the RFS Site, including sample results from soil disposed off-site with mercury-, PCB-, and cinder-impacted soils. The data query does not include waste characterization samples, sediment samples, composite samples, laboratory duplicates, and incremental sampling method samples.

A statistical evaluation was conducted for each metal. Statistical analyses consisted of standard data normality testing, data transformation (if necessary) and the creation of Q-Q and cumulative probability plots for each metal. For the plotting, nondetected results were plotted at the reporting limit.

3.3 COMPREHENSIVE ANALYSIS METHODOLOGY RESULTS

Each plot was reviewed for correlation, breaks, and possible inflection points. The analysis did not result in any significant conclusions; each plot appears to be generally consistent with standard scatter plots. Results from the statistical evaluation are presented in Appendix A. The visual analysis indicated a few minor findings for aluminum, cobalt, manganese, and nickel:

- Aluminum appears to be a normal or lognormal distribution, although there is a slight downward deflection at the top of the Q-Q plot for the normal plot, and a slight upward deflection at the bottom of the Q-Q plot for the lognormal plot. These minor deflections do not impact the finding of normal or lognormal distribution for aluminum. The statistical evaluation of aluminum strongly supports one data population.
- Cobalt appears close to lognormally distributed, although there is a limited number of concentrations above 26 mg/kg that appear to deviate from a lognormal distribution. These data do not indicate a separate population as traditionally observed in contaminant data sets; however, the evaluation of normality is not entirely conclusive for cobalt.
- Manganese appears close to lognormally although there are concentrations above 2,000 mg/kg that deviate from a lognormal distribution. There may also be a minor statistical break at 1,000 mg/kg. These data do not indicate separate populations as traditionally observed in contaminant data sets; however, the evaluation of normality is not entirely conclusive for manganese.
- Nickel appears close to lognormally distributed, although there are concentrations above 120 mg/kg that appear to deviate from a lognormal distribution. These data do not indicate a separate population as traditionally observed in contaminant data sets; however, the evaluation of normality is not entirely conclusive for nickel.

Shapiro-Wilk tests for normality were also performed on the untransformed or log-transformed data using ProUCL 5.0. The population for aluminum was found to be normally distributed by Shapiro-Wilk tests, consistent with the findings presented above. Cobalt, manganese, and nickel were not found to have definitive normal or lognormal distributions, indicating the possibility of multiple populations, although visual indications do not provide strong indications that multiple populations are present.

Sample locations of the cobalt, manganese, and nickel concentrations potentially outside of the normal or lognormal distributions are plotted in Appendix A on Figures A-1, A-2, and A-3, The spatial distribution of the samples with concentrations greater than the possible normal or lognormal distributions indicates that the sample locations are random and do not support location-specific or systematic contamination of cobalt, manganese, or nickel beyond the comprehensive data set.

3.4 CONTAMINATED AND PRESUMED UNCONTAMINATED ANALYSIS METHODOLOGY

Because the comprehensive analysis did not provide a clear indication that single populations are present for cobalt, manganese, and nickel, an analysis of contaminated and presumed uncontaminated sample results was conducted. While the aluminum distribution appears to represent one population, it was also included in this evaluation. The purpose of this analysis is to identify if any of the four metals are associated with known contamination. If elevated concentrations of aluminum, cobalt, manganese, or nickel are correlated with known RFS-contamination, such as cinder-related metals, PCBs, PAH, or mercury, then elevated levels may not represent background or ambient conditions. If there is no correlation between elevated concentrations of the four metals with known contamination, then there is a higher confidence that the concentrations are representative of background or ambient conditions.

The data query for this analysis is a subset of the comprehensive data query discussed in the previous subsection. The contaminated data set is composed of sample data with exceedences of RFS Site Remedial Goals (Tetra Tech 2014). If a sample did not include analysis for the four metals, then it was not included in the contaminated data set. The list of contaminated samples and locations are presented on Figure B-1 and Table B-1 of Appendix B.

The presumed uncontaminated data set is composed of samples not associated with any exceedences or even proximity to areas suspected of contamination. For example, no samples from the Mercury Fulminate Area, the RFS Corporation Yard, or historic areas of known California Cap Company industrial operations are included. Confirmation samples associated with previous cleanup or removal actions are not included. No sample results from boreholes with known contamination are included. If data results did not include analysis for the four metals, then it was not included in the presumed uncontaminated data set. The list of presumed uncontaminated samples and locations are presented on Figure B-1 and Table B-2 of Appendix B.

Each data set was evaluated for goodness of fit test for normality, and then evaluated against each other (metal by metal) with one- and two-sided tests statistical tests in EPA ProUCL 5.0 software (EPA 2013). For metals with normal distributions, t-tests were used to test for differences of central tendency. For metals that were not consistent with normal distributions, a nonparametric Wilcoxon-Mann-Whitney (WMW) test was used to test for differences. One-sided tests were used to test whether the contaminated samples were statistically lower than or equal to the presumed contaminated samples. Two-sided tests were used to test whether the contaminated samples were statistically equivalent to or not equivalent to the presumed contaminated samples. This information together was used to conclude whether the contaminated samples were statistically less than, equivalent to, or greater than the presumed contaminated samples.

In addition to tests for central tendency, a test of differences in upper quantiles was performed. The Quantile Test was used to perform these tests in EPA ProUCL 4.1 software (EPA 2010).

3.5 CONTAMINATED AND PRESUMED UNCONTAMINATED ANALYSIS RESULTS

Both data sets from the aluminum results are consistent with normal distributions; cobalt, manganese, and nickel results are not consistent with normal distributions. The evaluation of one-sided and two-sided test for each metal (contaminated and presumed uncontaminated) support that none of the metals concentrations within the contaminated data sets appear higher than the metals detected in the presumed uncontaminated data sets. The results support that single, elevated concentrations in the presumed uncontaminated data sets are not associated with known contaminant sources at RFS. The table below summarizes the results of the tests of central tendency:

Metal	Type of Test	One-Sided Test Result	Two-sided Test Result	Overall Conclusion
Aluminum	t-test	Contaminated less than or equal to Presumed Uncontaminated	Contaminated not equivalent to Presumed Uncontaminated	Contaminated less than Presumed Uncontaminated
Cobalt	Wilcoxon-Mann-Whitney	Contaminated less than or equal to Presumed Uncontaminated	Contaminated equivalent to Presumed Uncontaminated	Contaminated equivalent to Presumed Uncontaminated
Manganese	Wilcoxon-Mann-Whitney	Contaminated less than or equal to Presumed Uncontaminated	Contaminated not equivalent to Presumed Uncontaminated	Contaminated less than Presumed Uncontaminated
Nickel	Wilcoxon-Mann-Whitney	Contaminated less than or equal to Presumed Uncontaminated	Contaminated not equivalent to Presumed Uncontaminated	Contaminated less than Presumed Uncontaminated

The results of the Quantile test for all four metals indicated that the contaminated samples were lower than or equal to the presumed uncontaminated samples. Results from the statistical evaluation are presented in Appendix C.

A summary of chemical concentrations identified within the contaminated data set, presumed uncontaminated data set, and comprehensive data set is provided on the following page.

RFS Statistical Evaluation Summary

Metal	Number of Samples	Minimum (mg/kg)	Maximum (mg/kg)	Average (mg/kg)	Median (mg/kg)	Geometric Mean (mg/kg)	95th Upper Confidence Limit of the Mean [1] (mg/kg)	99th Upper Tolerance Limit [2] (mg/kg)
Aluminum								
Contaminated	18	10,000	20,300	15,200	15,700	15,000	16,400	23,654
Uncontaminated	71	8,500	28,000	18,600	18,600	18,100	19,500	28,220
Comprehensive	164	7,800	29,000	17,700	18,000	17,100	18,300	27,000
Cobalt								
Contaminated	24	2.82	32	12.2	11	11.0	14.6	32
Uncontaminated	82	3.1	73	14.6	12	12.8	16.5	63
Comprehensive	208	2.82	73	13.7	11.7	12.0	14.8	40
Manganese								
Contaminated	24	130	1,700	575	513	482	728	1,700
Uncontaminated	82	120	5,900	765	630	645	1,100	2,900
Comprehensive	195	89	5,900	742	620	591	956	2,600
Nickel								
Contaminated	85	8.3	260	40.3	34	35.6	52.8	85
Uncontaminated	90	20	280	47.3	42	42.6	45.4	170
Comprehensive	660	5.9	280	45.9	39	40.4	47.7	110

Notes:

All reported values rounded to three significant figures. See Appendices B and C for ProUCL output.

1 95th Upper Confidence Limit is the recommended value from ProUCL 5.0 (EPA 2013).

2 99th Upper Tolerance Limit was calculated using 95% coverage (EPA 2013). Aluminum was based on a normal distribution, other metals on a nonparametric distribution.

4.0 LITERATURE REVIEW

Many studies have been conducted both nation-wide and regionally regarding naturally-occurring metals concentrations. This section presents the results of three metals background studies.

4.1 ANALYSIS OF BACKGROUND DISTRIBUTIONS OF METALS IN THE SOIL AT LBNL, JUNE 2002, REVISED APRIL 2009

The Lawrence Berkeley National Laboratory (LBNL) Environmental Restoration Program conducted an evaluation of naturally occurring metals to determine if soils at specific locations contained elevated concentrations of metals relative to ambient conditions. The study was conducted at the LBNL facility, located adjacent to the UC Berkeley Campus in the Berkeley, CA. The study was first published in 2002 and updated in 2009 (LBNL 2009). The study defines “Ambient conditions” as concentrations of metals in the vicinity of a site, but which are unaffected by site-related activities (Cal-EPA 1997). The study is relevant to the RFS Site since there is overlap in the geologic classifications among the two properties.

The study evaluated 17 metals through the analyses of more than 1,600 soil samples collected from boreholes ranging in depth from the surface to a maximum depth of 180.5 feet throughout the LBNL facility. Cobalt and nickel were evaluated; aluminum and manganese were not included in the chemical analyses. A complete discussion of sampling protocols, statistical methods, and detailed results is presented in the LBNL study.

Data Evaluation

A maximum background level was selected for each metal based on the results of the statistical analyses. Due to the very large size of the data sets, calculated estimates of the 99th percentile of the data sets were used to identify background levels for metals with low numbers of non-detects and well-defined distributions, including cobalt and nickel. In total, 1,397 samples were analyzed for cobalt; 1,392 were analyzed for nickel.

Cobalt Results

The plots of the cobalt data indicated a normal distribution and passed the Jarque-Bera test for normality. Because the data fit a normal distribution, the maximum likelihood estimation method was used to calculate the 95th and 99th percentiles. Note that minimum and maximum outliners are not included in the summary statistics, per discussion rationale presented in the study.

Metal	Minimum (mg/kg)	Maximum (mg/kg)	Mean (mg/kg)	Median (mg/kg)	95^{th} Percentile (mg/kg)	99^{th} Percentile (mg/kg)
Cobalt	0.092	29	14	14	22	25

The 99^{th} percentile of 25 mg/kg was selected as the background concentration for cobalt.

Nickel Results

The plots of the nickel data indicated lognormal distribution; however, the log-transformed data failed the Jarque-Bera test for normality. The non-parametric bootstrap method was used to estimate the 95th and 99th percentiles. Note that minimum and maximum outliners are not included in the summary statistics, per discussion rationale presented in the study.

Metal	Minimum (mg/kg)	Maximum (mg/kg)	Mean (mg/kg)	Median (mg/kg)	95th Percentile (mg/kg)	99th Percentile (mg/kg)
Nickel	6	380	68	57	164	272

The 99th percentile of 272 mg/kg was selected as the background concentration for nickel.

4.2 BACKGROUND CONCENTRATIONS OF TRACE AND MAJOR ELEMENTS IN CALIFORNIA SOILS, KEARNEY FOUNDATION, MARCH 1996

The Kearney Foundation of Soil Science, Division of Agricultural and Natural Resources, University of California, published a background study of 46 elements in 50 benchmark soil samples from 22 soil series throughout California (Kearney 1996). The study did not include soil types specific to the RFS Site; however, the evaluation is relevant given the complex geology and variety of mixed soil types within California. The study helps identify a range of possible background or ambient concentrations for the four metals at the RFS Site. The 50 benchmark soil types were selected to best represent California soils (Kearney 1996.) The study included evaluation of aluminum, cobalt, manganese, and nickel.

20-gallons of soil were collected from the surface to 50 centimeters at 50 locations, primarily in agricultural fields distant from any known point sources of contamination. Each soil sample was processed through 60-mesh plastic screen and 1 gram of soil was submitted for analysis. Sample results were evaluated with routine statistics and are presented in the report.

Results

Data tables and graphs are presented for each metal, however, metal-specific narratives are not included. A summary section presents general observations, including that nickel concentrations vary by a factor of 60 times and cobalt varies by a factor of 15 times. The coefficients of variation are greatest in nickel (among five other metals), and least in aluminum (among two other metals). A summary of the results for aluminum, cobalt, manganese, and nickel is provided below.

Metal	Minimum (mg/kg)	Maximum (mg/kg)	Average (mg/kg)	Geometric Mean (mg/kg)	Coefficient of Variation (%)	Upper Quartile (mg/kg)
Aluminum	30,000	100,600	73,000	71,000	24	83,000
Cobalt	2.7	46.9	14.9	12.6	62	18.3

Metal	Minimum (mg/kg)	Maximum (mg/kg)	Average (mg/kg)	Geometric Mean (mg/kg)	Coefficient of Variation (%)	Upper Quartile (mg/kg)
Manganese	253	1,687	646	592	44	809
Nickel	9	509	412	290	141	56

4.3 ELEMENT CONCENTRATIONS IN SOILS AND OTHER SURFICIAL MATERIALS OF THE CONTERMINOUS UNITED STATES, USGS 1984

The U.S. Geological Survey conducted a background analysis of 50 elements collected from approximately 20 centimeters below ground surface from locations approximately 80 kilometers apart throughout the conterminous United States (USGS 1984). 1,318 sampling points were selected for analyses. The study included aluminum, cobalt, manganese, and nickel. The report also includes a summary of sampling results from five previous soil sampling studies from a variety of locations throughout the world.

Results

The study presents the range, average and geometric means, the geometric deviation, and histograms showing frequency distributions for each element across the entire study area; metal-specific narratives are not provided. The summary tables present the conterminous Unites States, Western United States (west of the 96th meridian), and Eastern United States. A summary of the Western United States results for aluminum, cobalt, manganese, and nickel is provided below.

Metal	Minimum (mg/kg)	Maximum (mg/kg)	Arithmetic Mean (mg/kg)	Geometric Mean (mg/kg)	Relative Standard Deviation
Aluminum	5,000	>100,000	74,000	58,000	2.00
Cobalt	<3	50	9	7.1	1.97
Manganese	30	5,000	480	380	1.98
Nickel	<5	700	19	15	2.10

5.0 SUMMARY AND RECOMMENDATIONS

This section provides a summary of the statistical evaluation and literature reviews for each metal. Recommendations regarding background or ambient concentrations to be considered at the RFS Site are presented in the summary table on the following page.

Aluminum

The results presented in Section 3 support that the population of aluminum concentrations detected in contaminated samples is not statistically different than the population of presumed clean samples, which demonstrates a strong weight of evidence that elevated aluminum detections are not likely related to known contamination. The mean, median, and maximum aluminum concentrations detected in the comprehensive RFS Site data are below the respective values within the Kearny and USGS studies presented in Section 4; aluminum was not evaluated in the LBNL study. The weight of evidence strongly suggests that all detected concentrations of aluminum at RFS are related to ambient or background concentrations.

Aluminum is recommended to be eliminated from further consideration as a chemical of concern at the RFS Site.

Cobalt

The results presented in Section 3 support that the population of cobalt concentrations detected in contaminated samples is not statistically different than the population of presumed clean samples, which demonstrates a strong weight of evidence that elevated cobalt detections are not likely related to known contamination. The maximum cobalt concentrations detected in the comprehensive RFS data are above the maximum values within the LBNL, Kearny, and USGS studies presented in Section 4. The RFS comprehensive data set mean and median concentrations are below the LBNL and Kearney studies; which are the studies most relevant to RFS soils. Cobalt has been identified as existing at elevated concentrations associated with manganese present in chert rocks, which are likely present at the RFS Site. While the maximum concentrations are above the reference study maximum concentrations, the weight of evidence suggests that all detected concentrations of cobalt at RFS are related to ambient or background concentrations.

Cobalt concentrations identified within the uncontaminated data set are recommended to represent ambient conditions at the RFS Site, and sample results up to 73 mg/kg should not be considered for further evaluation.

Manganese

The results presented in Section 3 support that the population of manganese concentrations detected in contaminated samples is not statistically different than the population of presumed clean samples, which demonstrates a strong weight of evidence that elevated manganese detections are not likely related to known contamination. The maximum manganese concentrations detected in the comprehensive RFS data are above the maximum values within the Kearny and USGS studies presented in Section 4; manganese was not evaluated in the LBNL study. The RFS comprehensive data set mean and median concentrations are slightly above the

Kearney study; which is the study most relevant to RFS soils. While the manganese concentrations appear above the reference study concentrations, the weight of evidence suggests that all detected concentrations of manganese at RFS are related to ambient or background concentrations. Manganese has been identified at elevated concentrations in the Franciscan Complex, specifically within chert rocks, which are likely present at the RFS Site.

Manganese concentrations identified within the uncontaminated data set are recommended to represent ambient conditions at the RFS Site, and sample results up to 5,900 mg/kg should not be considered for further evaluation.

Nickel

The results presented in Section 3 support that the population of nickel concentrations detected in contaminated samples is not statistically different than the population of presumed clean samples, which demonstrates a strong weight of evidence that elevated nickel detections are not likely related to known contamination. The mean, median, and maximum nickel concentrations detected in the comprehensive RFS data are below the respective values within the LBNL, Kearny, and USGS studies presented in Section 4. The weight of evidence strongly suggests that all detected concentrations of nickel at RFS are related to ambient or background concentrations.

Nickel concentrations identified within the uncontaminated data set are recommended to represent ambient conditions at the RFS Site, and sample results up to 280 mg/kg should not be considered for further evaluation.

Statistical and Literature Summary and Recommendations

Metal	Minimum (mg/kg)	Median (mg/kg)	Mean (mg/kg)	Maximum (mg/kg)
Aluminum				
LBNL Study	--	--	--	--
Kearney Study	30,000	71,000	73,000	100,600
USGS Study	5,000	58,000	74,000	>100,000
RFS Data				
Contaminated	10,000	15,000	15,200	20,300
Uncontaminated	8,500	18,100	18,600	28,000
Comprehensive	7,800	18,000	17,700	29,000
RFS Aluminum Background or Ambient: Up to 29,000 mg/kg				
Cobalt				
LBNL Study	0.92	14	14	29
Kearney Study	2.7	12.6	14.9	46.9
USGS Study	<3	7.1	9	50
RFS Data				
Contaminated	2.82	11	12.2	32
Uncontaminated	3.1	12	14.6	73
Comprehensive	2.82	11.7	13.7	73
RFS Cobalt Background or Ambient: Up to 73 mg/kg				
Manganese				
LBNL Study	--	--	--	--
Kearney Study	253	592	646	1,687
USGS Study	30	380	480	5,000
RFS Data				
Contaminated	130	513	575	1,700
Uncontaminated	120	630	765	5,900
Comprehensive	89	620	742	5,900
RFS Manganese Background or Ambien: Up to 5,900 mg/kg				
Nickel				
LBNL Study	6	57	68	380
Kearney Study	9	290	412	509
USGS Study	<5	15	19	700
RFS Data				
Contaminated	8.3	34	40.3	260
Uncontaminated	20	42	47.3	280
Comprehensive	5.9	39	45.9	280
RFS Nickel Background or Ambient: Up to 280 mg/kg				

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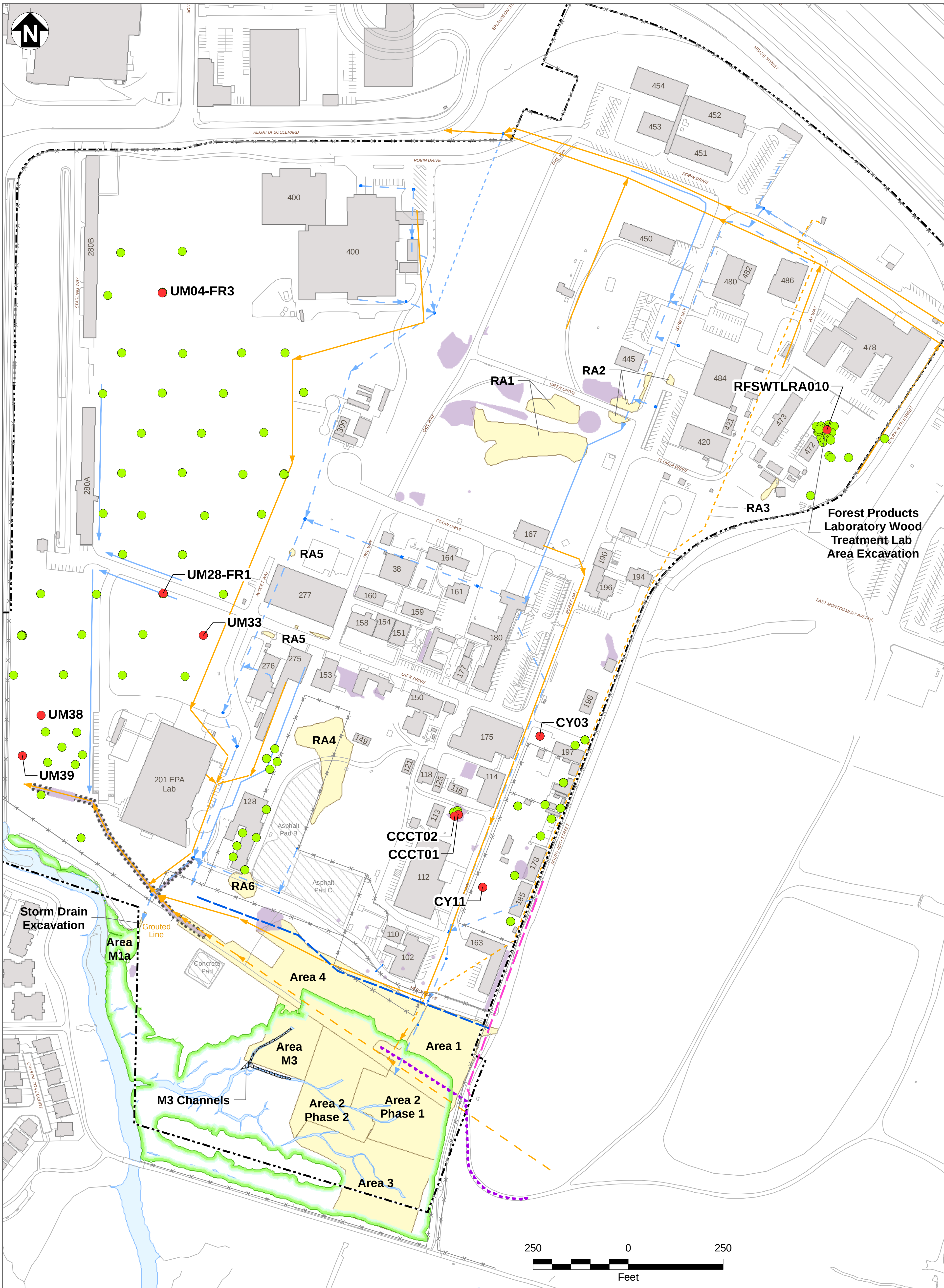
Appendix A
Comprehensive Data Analysis Results



Cobalt in Soil

- Greater than 26 mg/kg
- Less than 26 mg/kg
- Known Pyrite Cinders Area
- Suspect Pyrite Cinders (Presence Not Verified)
- Phase 3 Marsh Channel Widening
- Remediated Area (RA)

Note:
mg/kg Milligrams per kilogram

- Approximate Site Boundary
- Roads and Other Landscape Features
- Former Seawall (Approximate)
- Slurry Wall
- Biologically Active Permeable Barrier Wall
- Marsh Boundary
- Surface Water

Storm Drain Lines:

- Open Swale
- Underground Culvert
- Underground Culvert, Abandoned (Grouted at Manholes)

Sanitary Sewer Lines:

- Existing Sewer Line
- Removed Sewer Line
- Abandoned Sewer Line

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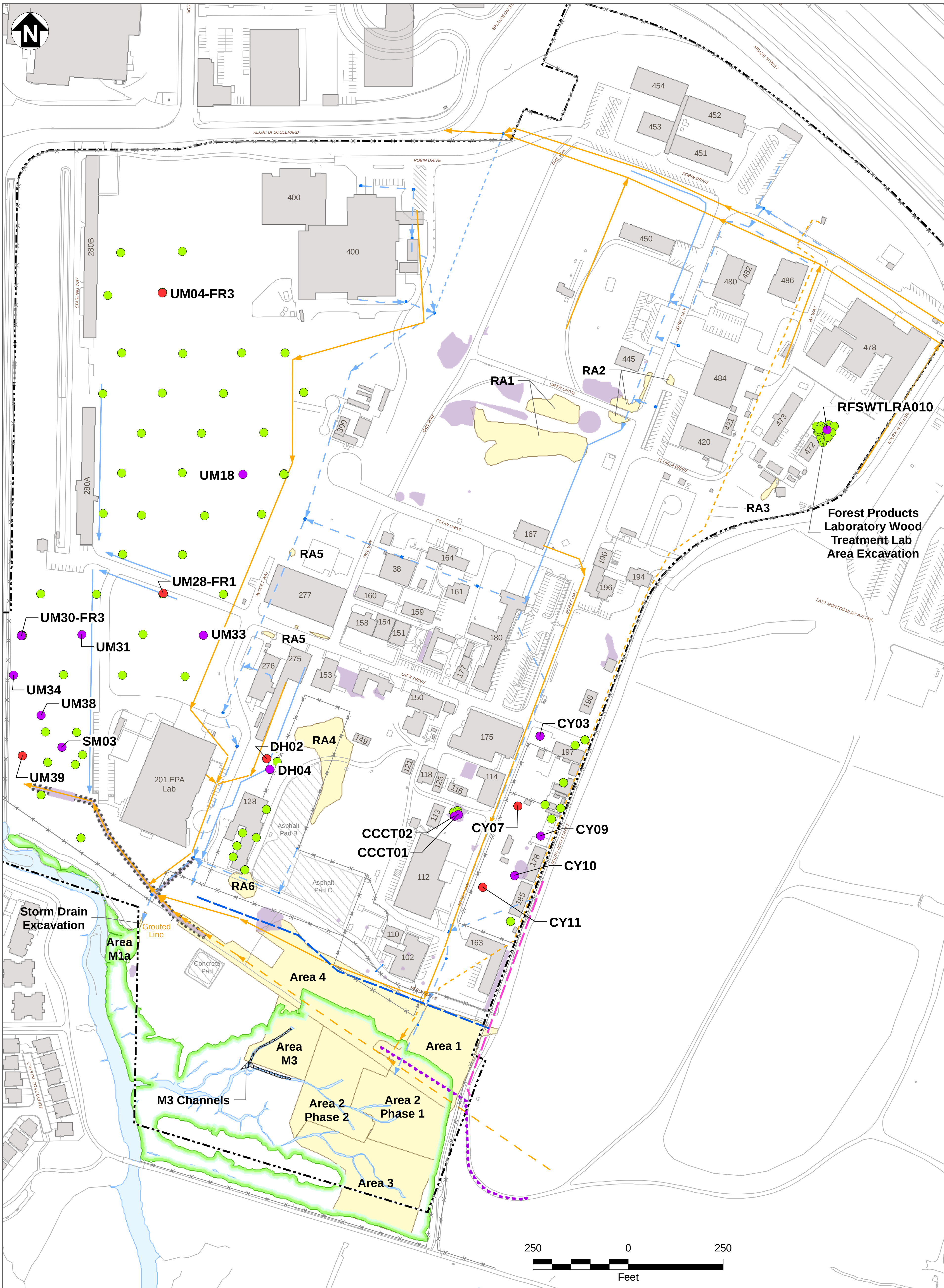
Richmond Field Station Site
Berkeley Global Campus at Richmond Bay

FIGURE A-1
COBALT DATA SET EVALUATION

Ambient Metals Evaluation Technical Memorandum



Manganese in Soil
- Greater than 2,000 mg/kg
- Greater than 1,000 mg/kg
- Less than 1,000 mg/kg
- Known Pyrite Cinders Area
- Suspect Pyrite Cinders (Presence Not Verified)
- Phase 3 Marsh Channel Widening
- Remediated Area (RA)

- Approximate Site Boundary
- Roads and Other Landscape Features
- Former Seawall (Approximate)
- Slurry Wall
- Biologically Active Permeable Barrier Wall
- Marsh Boundary
- Surface Water

Storm Drain Lines:
- Open Swale
- Underground Culvert
- Underground Culvert, Abandoned (Grouted at Manholes)

Sanitary Sewer Lines:
- Existing Sewer Line
- Removed Sewer Line
- Abandoned Sewer Line

Note:
mg/kg Milligrams per kilogram

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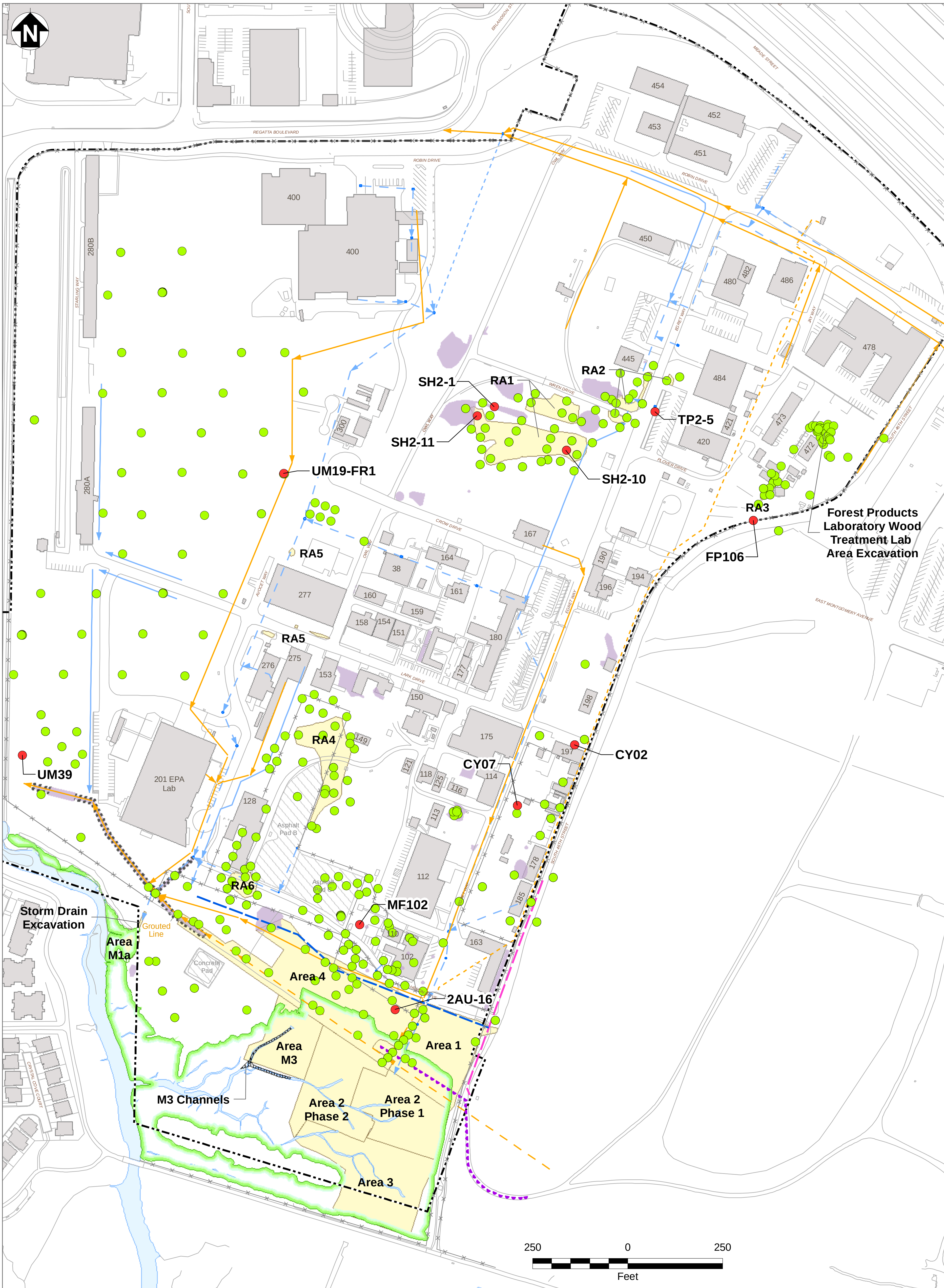
FIGURE A-2
MANGANESE DATA SET EVALUATION

Ambient Metals Evaluation Technical Memorandum

2015-11-12 V:\Misc_GIS\Richmond_Field_Station\Projects\008_Metals_Evaluation\Manganese.mxd TtEMI-AL simon.cardinale



Nickel in Soil
- Greater than 120 mg/kg
- Less than 120 mg/kg
- Known Pyrite Cinders Area
- Suspect Pyrite Cinders (Presence Not Verified)
- Phase 3 Marsh Channel Widening
- Remediated Area (RA)

- Approximate Site Boundary
- Roads and Other Landscape Features
- Former Seawall (Approximate)
- Slurry Wall
- Biologically Active Permeable Barrier Wall
- Marsh Boundary
- Surface Water

Storm Drain Lines:
- Open Swale
- Underground Culvert
- Underground Culvert, Abandoned (Grouted at Manholes)

Sanitary Sewer Lines:
- Existing Sewer Line
- Removed Sewer Line
- Abandoned Sewer Line

Note:
mg/kg Milligrams per kilogram

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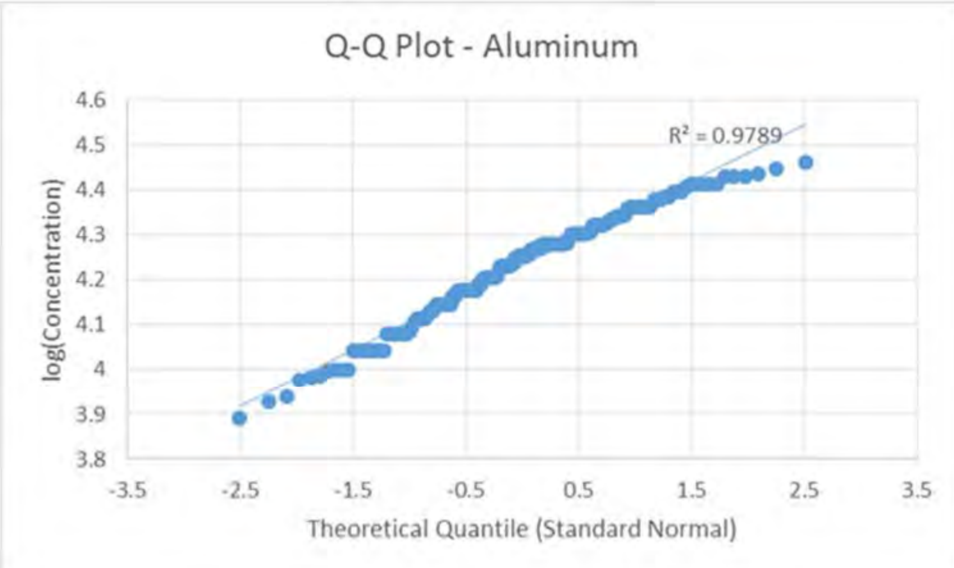
FIGURE A-3
NICKEL DATA SET EVALUATION

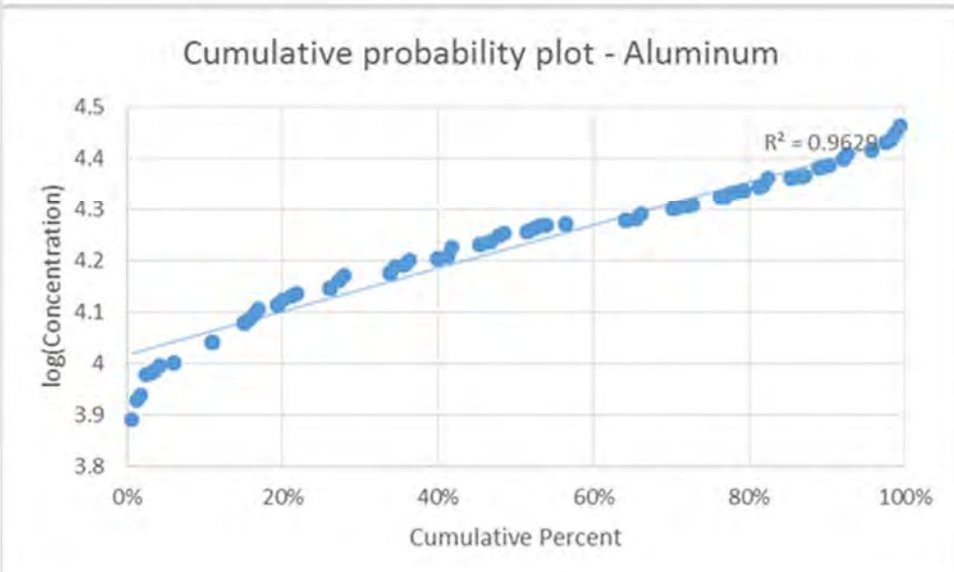
Ambient Metals Evaluation Technical Memorandum

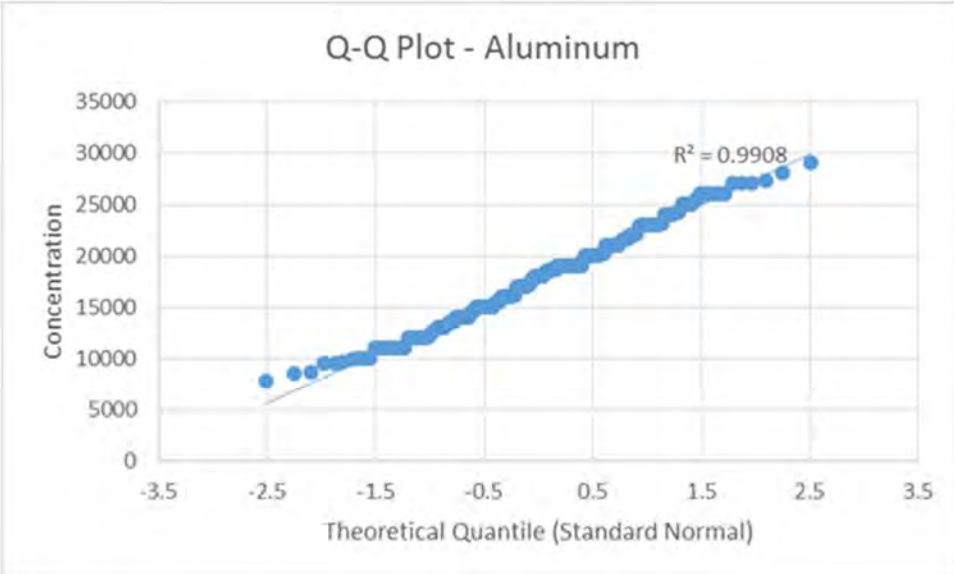
2015-11-03 V:\Misc_GIS\Richmond_Field_Station\Projects\008_Metals_Evaluation\Nickel.mxd TtEMI-AL simon.cardinale

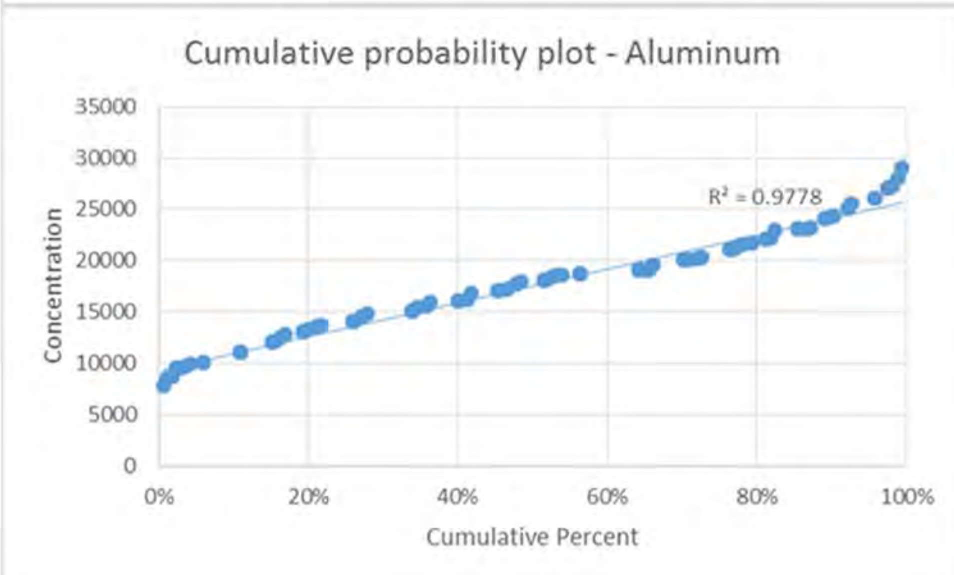
Aluminum

The lognormal Q-Q plot generally appear consistent a lognormal distribution. The Q-Q plot data at the top deflect downward instead of upward, as compared to the cumulative probability plot. This likely indicates that the distribution is closer to a normal distribution than a lognormal one, so the non-transformed concentrations were also plotted.



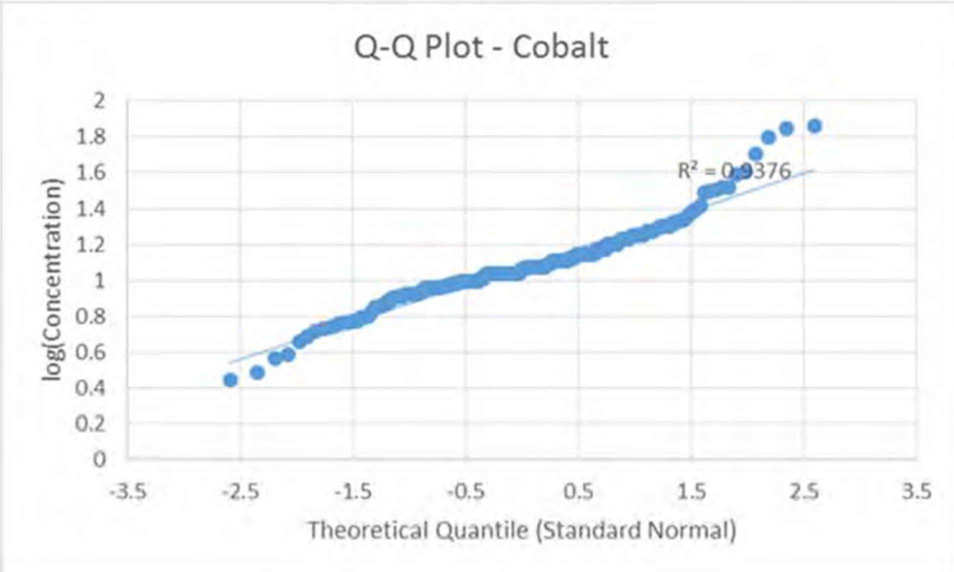


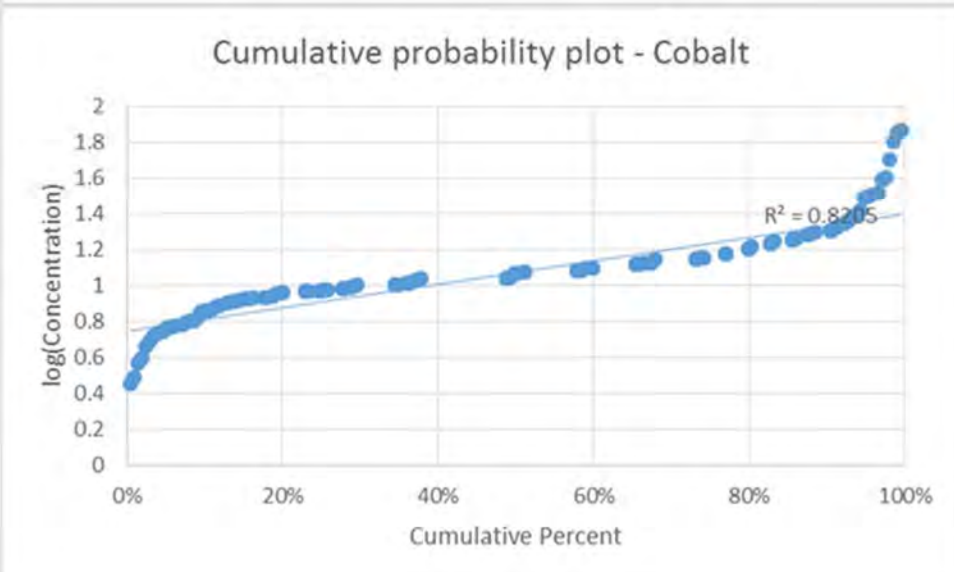

Q-Q Plot - Aluminum
$R^2 = 0.9908$
35000
30000
25000
20000
15000
10000
5000
0
Concentration
-3.5
-2.5
-1.5
-0.5
0.5
1.5
2.5
3.5
Theoretical Quantile (Standard Normal)


Cumulative probability plot - Aluminum
$R^2 = 0.9778$
35000
30000
25000
20000
15000
10000
5000
0
Concentration
0%
20%
40%
60%
80%
100%
Cumulative Percent

Cobalt

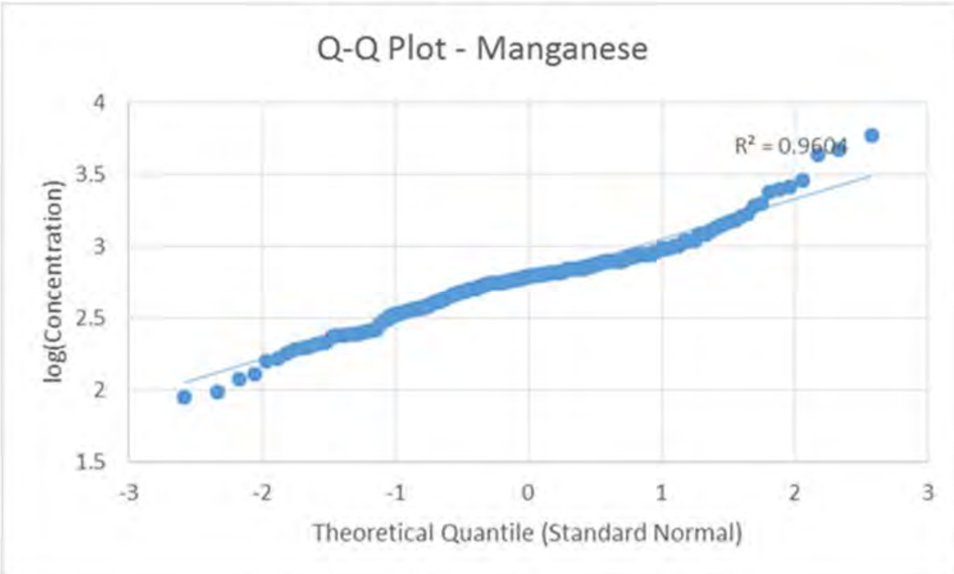
The distribution appears consistent with a lognormal distribution over most of the range, with an apparent break above 26 mg/kg.

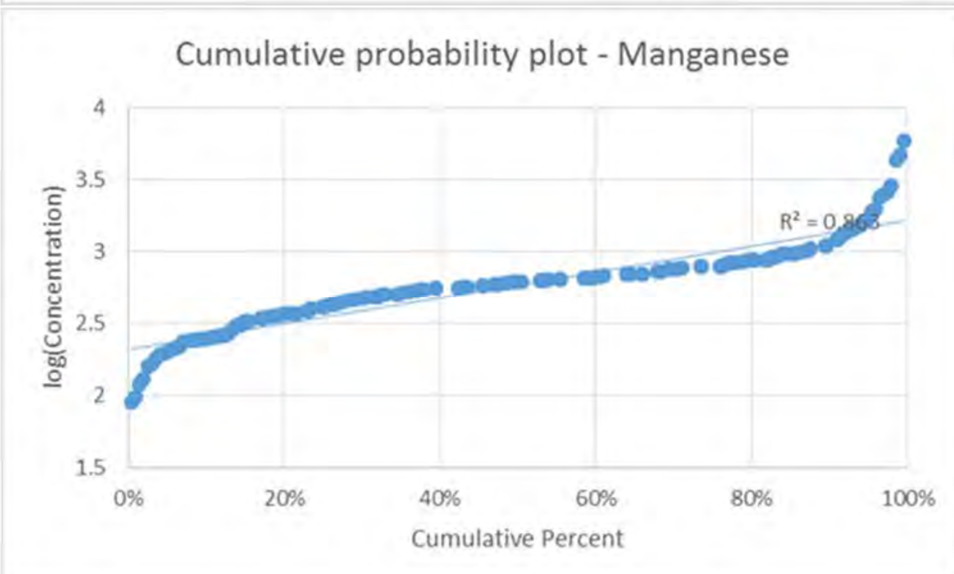




Manganese

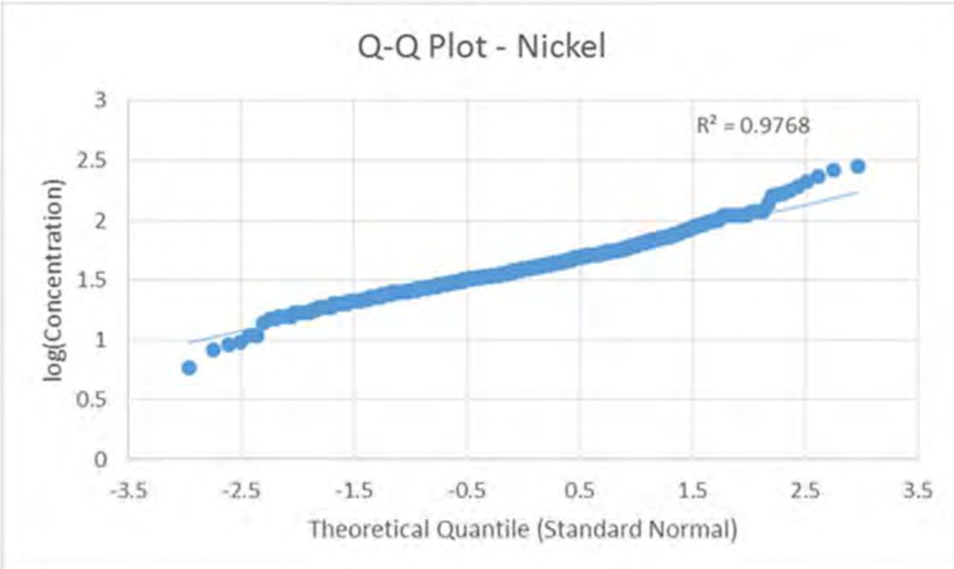
The distribution appears consistent with a lognormal distribution, with a slight break at about 2,000 mg/kg. There may also be a very slight break at around 1,000 mg/kg.

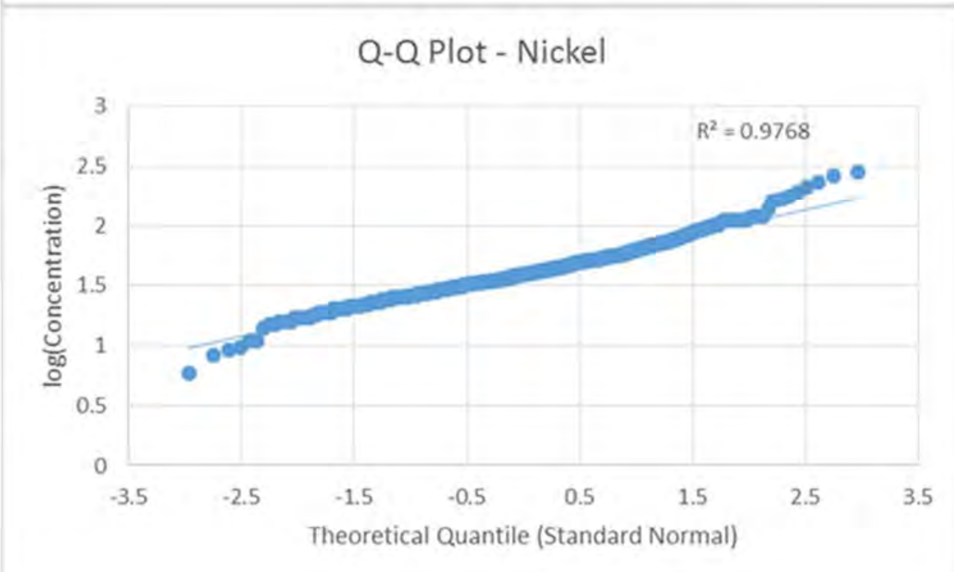




Nickel

The distribution looks similar to cobalt and consistent with a lognormal distribution, with a break at about 120 mg/kg.





UCL Statistics for Uncensored Full Data Sets

User Selected Options	
Date/Time of Computation	7/30/2015 2:47:28 PM
From File	WorkSheet.xls
Full Precision	OFF
Confidence Coefficient	95%
mber of Bootstrap Operations	2000

Al

General Statistics

Total Number of Observations	164	Number of Distinct Observations	65
		Number of Missing Observations	0
Minimum	7800	Mean	17729
Maximum	29000	Median	18000
SD	4759	Std. Error of Mean	371.6
Coefficient of Variation	0.268	Skewness	0.13

Normal GOF Test

Shapiro Wilk Test Statistic	0.968	**Shapiro Wilk GOF Test**
5% Shapiro Wilk P Value	0.0195	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.0583	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.0692	Data appear Normal at 5% Significance Level

Data appear Approximate Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	18343	95% Adjusted-CLT UCL (Chen-1995)	18344
		95% Modified-t UCL (Johnson-1978)	18344

Gamma GOF Test

A-D Test Statistic	0.72	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.751	etected data appear Gamma Distributed at 5% Significance Lev
K-S Test Statistic	0.0707	**Kolmogrov-Smirnoff Gamma GOF Test**
5% K-S Critical Value	0.0728	etected data appear Gamma Distributed at 5% Significance Lev

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	13.24	k star (bias corrected MLE)	13
Theta hat (MLE)	1339	Theta star (bias corrected MLE)	1364
nu hat (MLE)	4342	nu star (bias corrected)	4264
MLE Mean (bias corrected)	17729	MLE Sd (bias corrected)	4917
		Approximate Chi Square Value (0.05)	4114
Adjusted Level of Significance	0.0485	Adjusted Chi Square Value	4112

UCL Statistics for Uncensored Full Data Sets

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	18378	95% Adjusted Gamma UCL (use when n<50)	18384

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.959	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk P Value	9.5302E-4	Data Not Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.0869	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.0692	Data Not Lognormal at 5% Significance Level

Data Not Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	8.962	Mean of logged Data	9.745
Maximum of Logged Data	10.28	SD of logged Data	0.284

Assuming Lognormal Distribution

95% H-UCL	18454	90% Chebyshev (MVUE) UCL	18962
95% Chebyshev (MVUE) UCL	19507	97.5% Chebyshev (MVUE) UCL	20263
99% Chebyshev (MVUE) UCL	21748		

Nonparametric Distribution Free UCL Statistics

Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Distribution Free UCLs

95% CLT UCL	18340	95% Jackknife UCL	18343
95% Standard Bootstrap UCL	18331	95% Bootstrap-t UCL	18361
95% Hall's Bootstrap UCL	18312	95% Percentile Bootstrap UCL	18314
95% BCA Bootstrap UCL	18374		
90% Chebyshev(Mean, Sd) UCL	18843	95% Chebyshev(Mean, Sd) UCL	19348
97.5% Chebyshev(Mean, Sd) UCL	20049	99% Chebyshev(Mean, Sd) UCL	21426

Suggested UCL to Use

95% Student's-t UCL 18343

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). However, simulations results will not cover all Real World data sets.
For additional insight the user may want to consult a statistician.

Co

General Statistics

Total Number of Observations	208	Number of Distinct Observations	96
		Number of Missing Observations	0

UCL Statistics for Uncensored Full Data Sets

Minimum	2.82	Mean	13.72
Maximum	73	Median	11.65
SD	9.247	Std. Error of Mean	0.641
Coefficient of Variation	0.674	Skewness	3.805

Normal GOF Test

Shapiro Wilk Test Statistic	0.647	**Shapiro Wilk GOF Test**
5% Shapiro Wilk P Value	0	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.224	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.0614	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		95% UCLs (Adjusted for Skewness)	
95% Student's-t UCL	14.78	95% Adjusted-CLT UCL (Chen-1995)	14.96
		95% Modified-t UCL (Johnson-1978)	14.81

Gamma GOF Test

A-D Test Statistic	6.551	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.757	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.153	**Kolmogrov-Smirnoff Gamma GOF Test**
5% K-S Critical Value	0.063	Data Not Gamma Distributed at 5% Significance Level

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	3.945	k star (bias corrected MLE)	3.891
Theta hat (MLE)	3.479	Theta star (bias corrected MLE)	3.527
nu hat (MLE)	1641	nu star (bias corrected)	1619
MLE Mean (bias corrected)	13.72	MLE Sd (bias corrected)	6.956
		Approximate Chi Square Value (0.05)	1526
Adjusted Level of Significance	0.0488	Adjusted Chi Square Value	1526

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	14.55	95% Adjusted Gamma UCL (use when n<50)	14.56

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.946	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk P Value	5.1546E-8	Data Not Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.111	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.0614	Data Not Lognormal at 5% Significance Level

Data Not Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	1.037	Mean of logged Data	2.487
Maximum of Logged Data	4.29	SD of logged Data	0.48

UCL Statistics for Uncensored Full Data Sets

Assuming Lognormal Distribution

95% H-UCL	14.33	90% Chebyshev (MVUE) UCL	14.9
95% Chebyshev (MVUE) UCL	15.55	97.5% Chebyshev (MVUE) UCL	16.44
99% Chebyshev (MVUE) UCL	18.19		

Nonparametric Distribution Free UCL Statistics

Data do not follow a Discernible Distribution (0.05)

Nonparametric Distribution Free UCLs

95% CLT UCL	14.78	95% Jackknife UCL	14.78
95% Standard Bootstrap UCL	14.74	95% Bootstrap-t UCL	15.06
95% Hall's Bootstrap UCL	15.03	95% Percentile Bootstrap UCL	14.85
95% BCA Bootstrap UCL	15.03		
90% Chebyshev(Mean, Sd) UCL	15.64	95% Chebyshev(Mean, Sd) UCL	16.52
97.5% Chebyshev(Mean, Sd) UCL	17.73	99% Chebyshev(Mean, Sd) UCL	20.1

Suggested UCL to Use

95% Student's-t UCL	14.78	or 95% Modified-t UCL	14.81

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). However, simulations results will not cover all Real World data sets.
For additional insight the user may want to consult a statistician.

Mn

General Statistics

Total Number of Observations	195	Number of Distinct Observations	124
		Number of Missing Observations	0
Minimum	89	Mean	742
Maximum	5900	Median	620
SD	686.9	Std. Error of Mean	49.19
Coefficient of Variation	0.926	Skewness	4.387

Normal GOF Test

Shapiro Wilk Test Statistic	0.605	**Shapiro Wilk GOF Test**
5% Shapiro Wilk P Value	0	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.241	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.0634	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL **95% UCLs (Adjusted for Skewness)**

UCL Statistics for Uncensored Full Data Sets

95% Student's-t UCL	823.3	95% Adjusted-CLT UCL (Chen-1995)	839.4
		95% Modified-t UCL (Johnson-1978)	825.9

Gamma GOF Test

A-D Test Statistic	4.585	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.764	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.135	**Kolmogrov-Smirnoff Gamma GOF Test**
5% K-S Critical Value	0.0656	Data Not Gamma Distributed at 5% Significance Level

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	2.342	k star (bias corrected MLE)	2.31
Theta hat (MLE)	316.8	Theta star (bias corrected MLE)	321.2
nu hat (MLE)	913.6	nu star (bias corrected)	900.8
MLE Mean (bias corrected)	742	MLE Sd (bias corrected)	488.2
		Approximate Chi Square Value (0.05)	832.2
Adjusted Level of Significance	0.0488	Adjusted Chi Square Value	831.7

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	803.2	95% Adjusted Gamma UCL (use when n<50)	803.7

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.966	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk P Value	0.00411	Data Not Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.0882	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.0634	Data Not Lognormal at 5% Significance Level

Data Not Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	4.489	Mean of logged Data	6.381
Maximum of Logged Data	8.683	SD of logged Data	0.644

Assuming Lognormal Distribution

95% H-UCL	793.1	90% Chebyshev (MVUE) UCL	835.2
95% Chebyshev (MVUE) UCL	884.9	97.5% Chebyshev (MVUE) UCL	953.9
99% Chebyshev (MVUE) UCL	1089		

Nonparametric Distribution Free UCL Statistics

Data do not follow a Discernible Distribution (0.05)

Nonparametric Distribution Free UCLs

95% CLT UCL	822.9	95% Jackknife UCL	823.3
95% Standard Bootstrap UCL	823	95% Bootstrap-t UCL	847.8
95% Hall's Bootstrap UCL	863.8	95% Percentile Bootstrap UCL	828
95% BCA Bootstrap UCL	850.5		

UCL Statistics for Uncensored Full Data Sets

90% Chebyshev(Mean, Sd) UCL	889.6	95% Chebyshev(Mean, Sd) UCL	956.4
97.5% Chebyshev(Mean, Sd) UCL	1049	99% Chebyshev(Mean, Sd) UCL	1231

Suggested UCL to Use

95% Chebyshev (Mean, Sd) UCL	956.4

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). However, simulations results will not cover all Real World data sets.
For additional insight the user may want to consult a statistician.

Ni

General Statistics

Total Number of Observations	660	Number of Distinct Observations	145
		Number of Missing Observations	0
Minimum	5.9	Mean	45.94
Maximum	280	Median	39
SD	28.43	Std. Error of Mean	1.107
Coefficient of Variation	0.619	Skewness	3.347

Normal GOF Test

Shapiro Wilk Test Statistic	0.736	**Shapiro Wilk GOF Test**
5% Shapiro Wilk P Value	0	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.164	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.0345	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	47.77	95% Adjusted-CLT UCL (Chen-1995)	47.92
		95% Modified-t UCL (Johnson-1978)	47.79

Gamma GOF Test

A-D Test Statistic	9.887	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.759	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.0934	**Kolmogrov-Smirnoff Gamma GOF Test**
5% K-S Critical Value	0.0369	Data Not Gamma Distributed at 5% Significance Level

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	4.043	k star (bias corrected MLE)	4.026
Theta hat (MLE)	11.36	Theta star (bias corrected MLE)	11.41
nu hat (MLE)	5337	nu star (bias corrected)	5314

UCL Statistics for Uncensored Full Data Sets

MLE Mean (bias corrected)	45.94	MLE Sd (bias corrected)	22.9
		Approximate Chi Square Value (0.05)	5146
Adjusted Level of Significance	0.0496	Adjusted Chi Square Value	5145

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	47.45	95% Adjusted Gamma UCL (use when n<50)	47.45

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.977	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk P Value	0.0019	Data Not Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.0574	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.0345	Data Not Lognormal at 5% Significance Level

Data Not Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	1.775	Mean of logged Data	3.699
Maximum of Logged Data	5.635	SD of logged Data	0.486

Assuming Lognormal Distribution

95% H-UCL	47	90% Chebyshev (MVUE) UCL	48.17
95% Chebyshev (MVUE) UCL	49.4	97.5% Chebyshev (MVUE) UCL	51.11
99% Chebyshev (MVUE) UCL	54.48		

Nonparametric Distribution Free UCL Statistics

Data do not follow a Discernible Distribution (0.05)

Nonparametric Distribution Free UCLs

95% CLT UCL	47.76	95% Jackknife UCL	47.77
95% Standard Bootstrap UCL	47.71	95% Bootstrap-t UCL	47.9
95% Hall's Bootstrap UCL	47.94	95% Percentile Bootstrap UCL	47.72
95% BCA Bootstrap UCL	47.95		
90% Chebyshev(Mean, Sd) UCL	49.26	95% Chebyshev(Mean, Sd) UCL	50.77
97.5% Chebyshev(Mean, Sd) UCL	52.85	99% Chebyshev(Mean, Sd) UCL	56.96

Suggested UCL to Use

95% Student's-t UCL	47.77	or 95% Modified-t UCL	47.79

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). However, simulations results will not cover all Real World data sets.
For additional insight the user may want to consult a statistician.

Background Statistics for Uncensored Full Data Sets

User Selected Options

Date/Time of Computation	7/30/2015 3:03:03 PM
From File	WorkSheet.xls
Full Precision	OFF
Confidence Coefficient	99%
Coverage	95%
\New or Future K Observations	1
mber of Bootstrap Operations	2000

Al

General Statistics

Total Number of Observations	164	Number of Distinct Observations	65
Minimum	7800	First Quartile	14000
Second Largest	28000	Median	18000
Maximum	29000	Third Quartile	21000
Mean	17729	SD	4759
Coefficient of Variation	0.268	Skewness	0.13
Mean of logged Data	9.745	SD of logged Data	0.284

Critical Values for Background Threshold Values (BTVs)

Tolerance Factor K (For UTL)	1.955	d2max (for USL)	3.762

Normal GOF Test

Shapiro Wilk Test Statistic	0.968	**Normal GOF Test**
5% Shapiro Wilk P Value	0.0195	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.0583	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.0692	Data appear Normal at 5% Significance Level

Data appear Approximate Normal at 5% Significance Level

Background Statistics Assuming Normal Distribution

99% UTL with 95% Coverage	27035	90% Percentile (z)	23827
99% UPL (t)	28944	95% Percentile (z)	25556
99% USL	35631	99% Percentile (z)	28800

Gamma GOF Test

A-D Test Statistic	0.72	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.751	etected data appear Gamma Distributed at 5% Significance Lev
K-S Test Statistic	0.0707	**Kolmogrov-Smirnoff Gamma GOF Test**
5% K-S Critical Value	0.0728	etected data appear Gamma Distributed at 5% Significance Lev

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	13.24	k star (bias corrected MLE)	13

Background Statistics for Uncensored Full Data Sets

Theta hat (MLE)	1339	Theta star (bias corrected MLE)	1364
nu hat (MLE)	4342	nu star (bias corrected)	4264
MLE Mean (bias corrected)	17729	MLE Sd (bias corrected)	4917

Background Statistics Assuming Gamma Distribution

99% Wilson Hilferty (WH) Approx. Gamma UPL	31272	90% Percentile	24249
99% Hawkins Wixley (HW) Approx. Gamma UPL	31701	95% Percentile	26514
99% WH Approx. Gamma UTL with 95% Coverage	28496	99% Percentile	31121
99% HW Approx. Gamma UTL with 95% Coverage	28759		
99% WH USL	42411	99% HW USL	43818

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.959	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk P Value	9.5302E-4	Data Not Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.0869	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.0692	Data Not Lognormal at 5% Significance Level

Data Not Lognormal at 5% Significance Level

Background Statistics assuming Lognormal Distribution

99% UTL with 95% Coverage	29714	90% Percentile (z)	24544
99% UPL (t)	33295	95% Percentile (z)	27208
99% USL	49602	99% Percentile (z)	33011

Nonparametric Distribution Free Background Statistics

Data appear Approximate Normal at 5% Significance Level

Nonparametric Upper Limits for Background Threshold Values

Order of Statistic, r	161	99% UTL with 95% Coverage	27000
Approximate f	2.118	Confidence Coefficient (CC) achieved by UTL	0.966
99% Percentile Bootstrap UTL with 95% Coverage	27000	99% BCA Bootstrap UTL with 95% Coverage	27000
99% UPL	28350	90% Percentile	24140
90% Chebyshev UPL	32049	95% Percentile	26000
95% Chebyshev UPL	38536	99% Percentile	27559
99% USL	29000		

Note: The use of USL to estimate a BTV is recommended only when the data set represents a background data set free of outliers and consists of observations collected from clean unimpacted locations.
The use of USL tends to provide a balance between false positives and false negatives provided the data represents a background data set and when many onsite observations need to be compared with the BTV.

Background Statistics for Uncensored Full Data Sets

Co

General Statistics

Total Number of Observations	208	Number of Distinct Observations	96
Minimum	2.82	First Quartile	9.368
Second Largest	70.6	Median	11.65
Maximum	73	Third Quartile	15
Mean	13.72	SD	9.247
Coefficient of Variation	0.674	Skewness	3.805
Mean of logged Data	2.487	SD of logged Data	0.48

Critical Values for Background Threshold Values (BTVs)

Tolerance Factor K (For UTL)	1.917	d2max (for USL)	3.834

Normal GOF Test

Shapiro Wilk Test Statistic	0.647	**Normal GOF Test**
5% Shapiro Wilk P Value	0	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.224	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.0614	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Background Statistics Assuming Normal Distribution

99% UTL with 95% Coverage	31.45	90% Percentile (z)	25.57
99% UPL (t)	35.45	95% Percentile (z)	28.93
99% USL	49.17	99% Percentile (z)	35.23

Gamma GOF Test

A-D Test Statistic	6.551	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.757	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.153	**Kolmogrov-Smirnoff Gamma GOF Test**
5% K-S Critical Value	0.063	Data Not Gamma Distributed at 5% Significance Level

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	3.945	k star (bias corrected MLE)	3.891
Theta hat (MLE)	3.479	Theta star (bias corrected MLE)	3.527
nu hat (MLE)	1641	nu star (bias corrected)	1619
MLE Mean (bias corrected)	13.72	MLE Sd (bias corrected)	6.956

Background Statistics Assuming Gamma Distribution

99% Wilson Hilferty (WH) Approx. Gamma UPL	34.66	90% Percentile	23.05
99% Hawkins Wixley (HW) Approx. Gamma UPL	35.01	95% Percentile	26.79
99% WH Approx. Gamma UTL with 95% Coverage	29.43	99% Percentile	34.81
99% HW Approx. Gamma UTL with 95% Coverage	29.47		
99% WH USL	57.21	99% HW USL	60.05

Background Statistics for Uncensored Full Data Sets

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.946	**Shapiro Wilk Lognormal GOF Test**	
5% Shapiro Wilk P Value	5.1546E-8	Data Not Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.111	**Lilliefors Lognormal GOF Test**	
5% Lilliefors Critical Value	0.0614	Data Not Lognormal at 5% Significance Level	

Data Not Lognormal at 5% Significance Level

Background Statistics assuming Lognormal Distribution

99% UTL with 95% Coverage	30.19	90% Percentile (z)	22.25
99% UPL (t)	37.17	95% Percentile (z)	26.49
99% USL	75.78	99% Percentile (z)	36.74

Nonparametric Distribution Free Background Statistics

Data do not follow a Discernible Distribution (0.05)

Nonparametric Upper Limits for Background Threshold Values

Order of Statistic, r	204	99% UTL with 95% Coverage	40
Approximate f	2.147	Confidence Coefficient (CC) achieved by UTL	0.98
99% Percentile Bootstrap UTL with 95% Coverage	38.7	99% BCA Bootstrap UTL with 95% Coverage	39.55
99% UPL	69.92	90% Percentile	20
90% Chebyshev UPL	41.53	95% Percentile	29.25
95% Chebyshev UPL	54.13	99% Percentile	62.12
99% USL	73		

Note: The use of USL to estimate a BTV is recommended only when the data set represents a background data set free of outliers and consists of observations collected from clean unimpacted locations.
The use of USL tends to provide a balance between false positives and false negatives provided the data represents a background data set and when many onsite observations need to be compared with the BTV.

Background Statistics for Uncensored Full Data Sets

Mn

General Statistics

Total Number of Observations	195	Number of Distinct Observations	124
Minimum	89	First Quartile	412.5
Second Largest	4690	Median	620
Maximum	5900	Third Quartile	790
Mean	742	SD	686.9
Coefficient of Variation	0.926	Skewness	4.387
Mean of logged Data	6.381	SD of logged Data	0.644

Critical Values for Background Threshold Values (BTVs)

Tolerance Factor K (For UTL)	1.927	d2max (for USL)	3.815

Normal GOF Test

Shapiro Wilk Test Statistic	0.605	**Normal GOF Test**
5% Shapiro Wilk P Value	0	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.241	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.0634	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Background Statistics Assuming Normal Distribution

99% UTL with 95% Coverage	2066	90% Percentile (z)	1622
99% UPL (t)	2357	95% Percentile (z)	1872
99% USL	3362	99% Percentile (z)	2340

Gamma GOF Test

A-D Test Statistic	4.585	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.764	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.135	**Kolmogrov-Smirnoff Gamma GOF Test**
5% K-S Critical Value	0.0656	Data Not Gamma Distributed at 5% Significance Level

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	2.342	k star (bias corrected MLE)	2.31
Theta hat (MLE)	316.8	Theta star (bias corrected MLE)	321.2
nu hat (MLE)	913.6	nu star (bias corrected)	900.8
MLE Mean (bias corrected)	742	MLE Sd (bias corrected)	488.2

Background Statistics Assuming Gamma Distribution

99% Wilson Hilferty (WH) Approx. Gamma UPL	2289	90% Percentile	1396
99% Hawkins Wixley (HW) Approx. Gamma UPL	2340	95% Percentile	1683
99% WH Approx. Gamma UTL with 95% Coverage	1884	99% Percentile	2314
99% HW Approx. Gamma UTL with 95% Coverage	1899		
99% WH USL	4123	99% HW USL	4466

Background Statistics for Uncensored Full Data Sets

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.966	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk P Value	0.00411	Data Not Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.0882	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.0634	Data Not Lognormal at 5% Significance Level

Data Not Lognormal at 5% Significance Level

Background Statistics assuming Lognormal Distribution

99% UTL with 95% Coverage	2041	90% Percentile (z)	1347
99% UPL (t)	2683	95% Percentile (z)	1702
99% USL	6878	99% Percentile (z)	2639

Nonparametric Distribution Free Background Statistics

Data do not follow a Discernible Distribution (0.05)

Nonparametric Upper Limits for Background Threshold Values

Order of Statistic, r	191	99% UTL with 95% Coverage	2600
Approximate f	2.011	Confidence Coefficient (CC) achieved by UTL	0.969
99% Percentile Bootstrap UTL with 95% Coverage	2600	99% BCA Bootstrap UTL with 95% Coverage	2620
99% UPL	4738	90% Percentile	1160
90% Chebyshev UPL	2808	95% Percentile	1630
95% Chebyshev UPL	3744	99% Percentile	4352
99% USL	5900		

Note: The use of USL to estimate a BTV is recommended only when the data set represents a background data set free of outliers and consists of observations collected from clean unimpacted locations.
The use of USL tends to provide a balance between false positives and false negatives provided the data represents a background data set and when many onsite observations need to be compared with the BTV.

Background Statistics for Uncensored Full Data Sets

Ni

General Statistics

Total Number of Observations	660	Number of Distinct Observations	145
Minimum	5.9	First Quartile	30
Second Largest	260	Median	39
Maximum	280	Third Quartile	52.7
Mean	45.94	SD	28.43
Coefficient of Variation	0.619	Skewness	3.347
Mean of logged Data	3.699	SD of logged Data	0.486

Critical Values for Background Threshold Values (BTVs)

Tolerance Factor K (For UTL)	1.791	d2max (for USL)	4.145

Normal GOF Test

Shapiro Wilk Test Statistic	0.736	**Normal GOF Test**
5% Shapiro Wilk P Value	0	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.164	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.0345	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Background Statistics Assuming Normal Distribution

99% UTL with 95% Coverage	96.87	90% Percentile (z)	82.38
99% UPL (t)	112.3	95% Percentile (z)	92.71
99% USL	163.8	99% Percentile (z)	112.1

Gamma GOF Test

A-D Test Statistic	9.887	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.759	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.0934	**Kolmogrov-Smirnoff Gamma GOF Test**
5% K-S Critical Value	0.0369	Data Not Gamma Distributed at 5% Significance Level

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	4.043	k star (bias corrected MLE)	4.026
Theta hat (MLE)	11.36	Theta star (bias corrected MLE)	11.41
nu hat (MLE)	5337	nu star (bias corrected)	5314
MLE Mean (bias corrected)	45.94	MLE Sd (bias corrected)	22.9

Background Statistics Assuming Gamma Distribution

99% Wilson Hilferty (WH) Approx. Gamma UPL	114.6	90% Percentile	76.63
99% Hawkins Wixley (HW) Approx. Gamma UPL	116.4	95% Percentile	88.91
99% WH Approx. Gamma UTL with 95% Coverage	93.35	99% Percentile	115.1
99% HW Approx. Gamma UTL with 95% Coverage	93.71		
99% WH USL	208.3	99% HW USL	222.5

Background Statistics for Uncensored Full Data Sets

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.977	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk P Value	0.0019	Data Not Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.0574	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.0345	Data Not Lognormal at 5% Significance Level

Data Not Lognormal at 5% Significance Level

Background Statistics assuming Lognormal Distribution

99% UTL with 95% Coverage	96.42	90% Percentile (z)	75.28
99% UPL (t)	125.5	95% Percentile (z)	89.81
99% USL	302.6	99% Percentile (z)	125.1

Nonparametric Distribution Free Background Statistics

Data do not follow a Discernible Distribution (0.05)

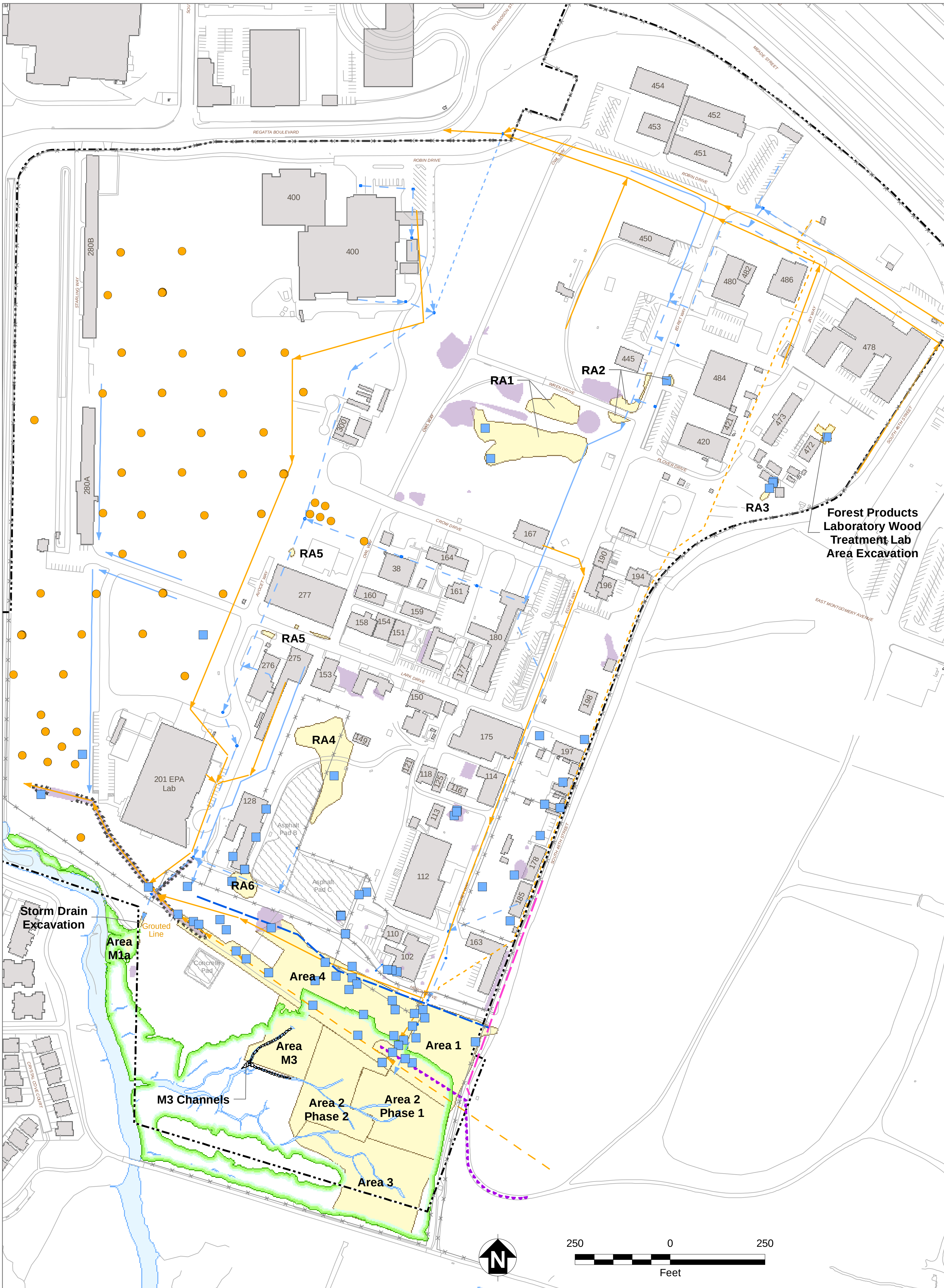
Nonparametric Upper Limits for Background Threshold Values

Order of Statistic, r	639	99% UTL with 95% Coverage	110
Approximate f	1.529	Confidence Coefficient (CC) achieved by UTL	0.985
99% Percentile Bootstrap UTL with 95% Coverage	110	99% BCA Bootstrap UTL with 95% Coverage	110
99% UPL	173.5	90% Percentile	73
90% Chebyshev UPL	131.3	95% Percentile	98
95% Chebyshev UPL	170	99% Percentile	165.9
99% USL	280		

Note: The use of USL to estimate a BTV is recommended only when the data set represents a background data set free of outliers and consists of observations collected from clean unimpacted locations.
The use of USL tends to provide a balance between false positives and false negatives provided the data represents a background data set and when many onsite observations need to be compared with the BTV.

Appendix B

Identification and Location of Contaminated and Presumed Uncontaminated Samples



■	Set A: Known contamination
●	Set B: Native or ambient soils, contamination not suspected
	Known Pyrite Cinders Area
	Suspect Pyrite Cinders (Presence Not Verified)
	Phase 3 Marsh Channel Widening
	Remediated Area (RA)
	Approximate Site Boundary
	Roads and Other Landscape Features
	Former Seawall (Approximate)
	Slurry Wall
	Biologically Active Permeable Barrier Wall
	Marsh Boundary
	Surface Water

Storm Drain Lines:
- Open Swale
- Underground Culvert
- Underground Culvert, Abandoned (Grouted at Manholes)

Sanitary Sewer Lines:
- Existing Sewer Line
- Removed Sewer Line
- Abandoned Sewer Line

TETRA TECH

Richmond Field Station Site
Berkeley Global Campus at Richmond Bay

FIGURE B-1
METALS EVALUATION
SAMPLING LOCATIONS

Ambient Metals Technical Memorandum

Table B-1: List of Contaminated Samples
Ambient Metals Technical Memorandum
UC Berkeley, Richmond Field Station Site

						Sample Results				Contaminant of Concern					
Point ID	Sample ID	Sample Date	Sample Type	Top Depth (ft bgs)	Bottom Depth (ft bgs)	Aluminum (mg/kg)	Cobalt (mg/kg)	Manganese (mg/kg)	Nickel (mg/kg)	Arsenic (mg/kg)	BAP(EQ) (mg/kg)	Diesel Range Organics (mg/kg)	Mercury (mg/kg)	Motor Oil Range Organics (mg/kg)	Total Aroclor (mg/kg)
2AU-1	2AU-1-4	18-APR-02	ORIG	4	4				62	210			41		
2AU-13	2AU-13-3.5	17-APR-02	ORIG	3.5	3.5				40	170			60		
2AU-16	2AU-16-7	16-APR-02	ORIG	7	7				260	100					
2AU-18	2AU-18-9	16-APR-02	ORIG	9	9				83	94					
2AU-23	2AU-23-4.8	09-JUL-02	ORIG	4.8	4.8				34	110			25		
2AU-24	2AU-24-4.5	09-JUL-02	ORIG	4.5	4.5				19	38			35		
2AU-25	2AU-25-4	09-JUL-02	ORIG	4	4				42	110			88		
2AU-3	2AU-3-4	18-APR-02	ORIG	4	4				41	66					
2AU-6	2AU-6-2.5	17-APR-02	ORIG	2.5	2.5				49	260			85		
A4-10	A4-10Z1	10-OCT-01	ORIG	4.5	4.5				36	67					
A4-12	A4-12Z1	10-OCT-01	ORIG	7.5	7.5				59	130			62		
A4-13	A4-13Z1	10-OCT-01	ORIG	7	7				65	150			27		
A4-14	A4-14Z1	12-OCT-01	ORIG	4.5	4.5				29	49					
A4-15	A4-15Z1	12-OCT-01	ORIG	4	4				56	57					
A4-16	A4-16Z1	12-OCT-01	ORIG	5.5	5.5				36	100			1000		
A4-17	A4-17Z1	10-OCT-01	ORIG	7	7				62	74					
A4-2	A4-2	21-SEP-01	ORIG	4	4				47	150			85		
A4-6	A4-6Z1	12-OCT-01	ORIG	5.5	5.5				34	64			57		
A4-7	A4-7Z1	12-OCT-01	ORIG	5.5	5.5				18	57			62		
A4-9	A4-9Z1	10-OCT-01	ORIG	4.5	4.5				27	140					
B-1	B-1 (ECI)Z1	01-AUG-98	ORIG	4.5	5				0	62					
B-1	B-1 (ECI)Z2	01-AUG-98	ORIG	8.5	9				11	160					
B12803	B1280301	14-AUG-12	ORIG	0	0.5		13	720	29				77		
B12804	B1280401	14-AUG-12	ORIG	0	0.5		9.2	380	27	17			130		
B12804	B1280402	14-AUG-12	ORIG	1.5	2		8.5	480	25	48			85	1400	
B12805	B1280501	14-AUG-12	ORIG	0	0.5		12	580	27	26			110		
B12806	B1280601	14-AUG-12	ORIG	0	0.5		10	550	26				190		
B12806	B1280601-DUP	14-AUG-12	FIELDDUP	0	0.5		12	500	27				180		
B12806	B1280601-DUP2	14-AUG-12	FIELDDUP	0	0.5		12	520	31				220		
B12806	B1280602	14-AUG-12	ORIG	1.5	2		19	410	26				45		
B-2	B-2 (ECI)	01-AUG-98	ORIG	0.5	1				20	35					
B-2	B-2 (ECI)Z2	01-AUG-98	ORIG	8	8.5				0	54					
B-4	B-4 (ECI)Z2	01-AUG-98	ORIG	8	8.5				0	110					
B-5	B-5 (ECI)Z1	01-AUG-98	ORIG	4	4.5				8.3	140					
B-5	B-5 (ECI)Z2	01-AUG-98	ORIG	8	8.5				23	120			32		
B-6	B-6 (ECI)Z2	01-AUG-98	ORIG	8.5	9				0	160			32		
B-8	B-8 (ECI)Z1	01-AUG-98	ORIG	4.5	5				25	160					
B-8	B-8 (ECI)Z2	01-AUG-98	ORIG	8.5	9				0	210					
BLDG 102-3	BLDG 102-3	18-MAR-05	ORIG	0	0.5				44				280		
BLDG 102-3	BLDG 102-3-2	14-APR-05	ORIG	2	2.5				22				51		
BLDG 102-4	BLDG 102-4	18-MAR-05	ORIG	0	0.5				28				330		
BLDG 102-4	BLDG 102-4-4	14-APR-05	ORIG	4	4.5				21				81		
CCCT02	PCB43	26-OCT-11	ORIG	0	0.5	12500	8	327	22.4	22	2.9088				

Table B-1: List of Contaminated Samples
Ambient Metals Technical Memorandum
UC Berkeley, Richmond Field Station Site

						Sample Results				Contaminant of Concern					
Point ID	Sample ID	Sample Date	Sample Type	Top Depth (ft bgs)	Bottom Depth (ft bgs)	Aluminum (mg/kg)	Cobalt (mg/kg)	Manganese (mg/kg)	Nickel (mg/kg)	Arsenic (mg/kg)	BAP(EQ) (mg/kg)	Diesel Range Organics (mg/kg)	Mercury (mg/kg)	Motor Oil Range Organics (mg/kg)	Total Aroclor (mg/kg)
CCCT05	PCB49	26-OCT-11	ORIG	0	0.5	10000	9.6	245	26.5	33.3		180			
CCCT05	PCB50	26-OCT-11	ORIG	1.5	2	12000	13.2	179	33.9	27					
CCCT06	PCB51	26-OCT-11	ORIG	0	0.5	16000	19.7	612	49.1	16.9					
CD18	CD-18-7	26-MAY-04	ORIG	7	7.5				20	100			50		
CD20	CD-20-7	18-MAR-05	ORIG	7	7				41	34			250		
CD25	CD-25-7.8	18-MAR-05	ORIG	7.8	7.8				29	37			120		
CY01	CY0101	27-OCT-11	ORIG	0	0.5	13700	10.9	477	29.6		0.79305	130			
CY03	CY0301	27-OCT-11	ORIG	0	0.5	12000	10.3	663	34.9		15.479	1100		1400	2.3
CY04	CY0401	27-OCT-11	ORIG	0	0.5	15900	13.9	546	33.9		0.51159	250			
CY05	CY0501	27-OCT-11	ORIG	0	0.5	16200	3.92	194	22.9	40.1					3.3
CY05	CY0502	27-OCT-11	ORIG	2	2.5	18500	2.82	130	24.6	81					
CY06	CY0601	27-OCT-11	ORIG	0	0.5	18700	17.7	836	38.9			190			5.5
CY06	CY0601D	27-OCT-11	FIELDDUP	0	0.5	15500	10.8	593	33.6		0.54609	330		1200	5.4
CY09	CY0901	28-OCT-11	ORIG	0	0.5	19100	12.1	1520	47.7	31.7	1.00464				
CY10	CY1001	28-OCT-11	ORIG	0	0.5	20300	8.12	323	33.8	27.8					
CY11	CY1101	28-OCT-11	ORIG	0	0.5	16200	11.6	867	31.2			700		900	
CY12	CY1201	28-OCT-11	ORIG	0	0.5	15500	11	424	33.3	29.9					
ES3-1	ES3-1-0	22-APR-04	ORIG	0	0.5				42	67					
FP104	FP-104-B-0	24-FEB-00	ORIG	0	0				54	66					
FP2-1	FP2-1-0	09-SEP-02	ORIG	0	0				34	55					
FP2-5	FP2-5-0	07-JAN-02	ORIG	0	0				32	150					
HD2-1	HD2-1-0	09-SEP-02	ORIG	-0.37	-0.37				43				24		8.2
MF101	MF-101-B-0	25-FEB-00	ORIG	4.59	4.59				37				45		
MF101	MF-101-B-2	25-FEB-00	ORIG	6.59	6.59				52				54		
MF101	MF-101-B-5	25-FEB-00	ORIG	9.59	9.59				85				67		
MF104	MF-104-B-3	17-MAR-00	ORIG	1.23	1.23				30	95			5300		
MF2-13	MF2-13-0	12-DEC-02	ORIG	0	0				36				73		
MF2-18	MF2-18-0.5	31-JAN-03	ORIG	0.5	0.5				46	19			370		
MF2-18	MF2-18-4	31-JAN-03	ORIG	4	4				24				180		
MF2-20	MF2-20-0.5	31-JAN-03	ORIG	0.27	0.27				45				470		
MF2-20	MF2-20-2	31-JAN-03	ORIG	1.77	1.77				35				380		
MF2-20	MF2-20-3.5	31-JAN-03	ORIG	3.27	3.27				49				82		
MF2-6	MF2-6-0	09-SEP-02	ORIG	3.29	3.29				26				200		
MF2-8	MF2-8-6	09-SEP-02	ORIG	10.77	10.77				53				370		
MF2-8	MF2-8-8	09-SEP-02	ORIG	12.77	12.77				65				810		
MF2-8	MF2-8-9.5	09-SEP-02	ORIG	14.27	14.27				55				360		
MF3-1	MF3-1-0	23-MAY-03	ORIG	-1.87	-1.87				34				62		
PB12	PB12Z1	10-OCT-01	ORIG	0	0				42	220					
PB12	PB12Z2	10-OCT-01	ORIG	4	4				29	89					
PH1	PH1-CINDER	31-MAY-01	ORIG	-3.09	-3.09				37	53					
PH4	PH4-CINDER	31-MAY-01	ORIG	-3.61	-3.61				33	210					
PH7	PH7-CINDER	31-MAY-01	ORIG	-4.04	-4.04				38	210					
RFSWTLRA019	RFSWTLRA019	05-OCT-07	ORIG	0	0	11000	11	690	30	170					

Table B-1: List of Contaminated Samples
Ambient Metals Technical Memorandum
UC Berkeley, Richmond Field Station Site

						Sample Results				Contaminant of Concern					
Point ID	Sample ID	Sample Date	Sample Type	Top Depth (ft bgs)	Bottom Depth (ft bgs)	Aluminum (mg/kg)	Cobalt (mg/kg)	Manganese (mg/kg)	Nickel (mg/kg)	Arsenic (mg/kg)	BAP(EQ) (mg/kg)	Diesel Range Organics (mg/kg)	Mercury (mg/kg)	Motor Oil Range Organics (mg/kg)	Total Aroclor (mg/kg)
SH2-3	SH2-3-0	12-DEC-02	ORIG	0	0				38	64					
SL101	SL-101-B-6	25-FEB-00	ORIG	4.71	4.71				85	160			77		
SM3-4	SM3-4-0	26-APR-04	ORIG	0	0.5				17	35					
TP2-7	TP2-7-0	17-JAN-03	ORIG	0	0				31	56					
UM33	UM3301	22-OCT-14	ORIG	0	0.5	16000	32	1700	62						4.76
UM41	UM4101	22-OCT-14	ORIG	0	0.5	15000	14	350	57	51					

Notes:

FIELDDUP	Field duplicate
ft bgs	Feet below ground surface
mg/kg	Milligrams per kilogram
ORIG	Original

Table B-2: List of Presumed Uncontaminated Samples
Ambient Metals Technical Memorandum
UC Berkeley, Richmond Field Station Site

Point ID	Sample ID	Sample Date	Sample Type	Top Depth (ft bgs)	Bottom Depth (ft bgs)	Sample Results Aluminum (mg/kg)	Cobalt (mg/kg)	Manganese (mg/kg)	Nickel (mg/kg)
EMI-1	EMI-1	30-MAR-05	ORIG	0	0.5				29
EMI-2	EMI-2	30-MAR-05	ORIG	0	0.5				25
EMI-4	EMI-4	30-MAR-05	ORIG	0	0.5				45
EMI-5	EMI-5	30-MAR-05	ORIG	0	0.5				44
EMI-6	EMI-6	30-MAR-05	ORIG	0	0.5				51
NP-1	NP1-0.5	10-SEP-02	ORIG	0.5	0.5				20
OW2-1	OW2-1-0	09-SEP-02	ORIG	1.02	1.02				29
OW2-1	OW2-1-8	09-SEP-02	ORIG	9.02	9.02				50
SM01	SM0101	15-AUG-12	ORIG	0	0.5		11	580	62
SM01	SM0101D	15-AUG-12	ORIG	0	0.5		10	480	53
SM01	SM0101-DUP	15-AUG-12	FIELDDUP	0	0.5		11	190	58
SM01	SM0101-DUP2	15-AUG-12	FIELDDUP	0	0.5		11	780	67
SM01	SM0102	15-AUG-12	ORIG	2	2.5		14	1000	72
SM02	SM0201	15-AUG-12	ORIG	0	0.5		8.4	630	26
SM02	SM0202	15-AUG-12	ORIG	2	2.5		9.2	340	26
SM03	SM0301	15-AUG-12	ORIG	0	0.5		9.1	560	24
SM03	SM0302	15-AUG-12	ORIG	1.5	2		9.1	1200	27
SM04	SM0401	15-AUG-12	ORIG	0	0.5		11	470	24
SM04	SM0402	15-AUG-12	ORIG	1.5	2		9.6	560	21
SM05	SM0501	15-AUG-12	ORIG	0	0.5		17	700	32
SM05	SM0502	15-AUG-12	ORIG	1.5	2		16	930	28
UM01	UM0101	20-OCT-14	ORIG	0	0.5	24000	9.6	470	51
UM01	UM0102	20-OCT-14	ORIG	1.5	2	26000	12	520	56
UM02	UM0201	20-OCT-14	ORIG	0	0.5	19000	14	650	61
UM03	UM0301	20-OCT-14	ORIG	0	0.5	24000	20	790	48
UM04-FR1	UM0401-R1	20-OCT-14	ORIG	0	0.5	26000	18	830	50
UM04-FR1	UM0402-R1	20-OCT-14	ORIG	1.5	2	26000	5.9	260	49
UM04-FR2	UM0401-R2	20-OCT-14	ORIG	0	0.5	20000	17	840	46
UM04-FR2	UM0402-R2	20-OCT-14	ORIG	1.5	2	26000	7.1	270	55

Table B-2: List of Presumed Uncontaminated Samples
Ambient Metals Technical Memorandum
UC Berkeley, Richmond Field Station Site

						Sample Results			
Point ID	Sample ID	Sample Date	Sample Type	Top Depth (ft bgs)	Bottom Depth (ft bgs)	Aluminum (mg/kg)	Cobalt (mg/kg)	Manganese (mg/kg)	Nickel (mg/kg)
UM04-FR3	UM0401-R3	20-OCT-14	ORIG	0	0.5	25000	9.8	380	45
UM04-FR3	UM0402-R3	20-OCT-14	ORIG	1.5	2	27000	63	2900	77
UM05	UM0501	20-OCT-14	ORIG	0	0.5	16000	12	610	29
UM05	UM0502	20-OCT-14	ORIG	1.5	2	22000	8.1	410	28
UM06	UM0601	20-OCT-14	ORIG	0	0.5	16000	18	650	83
UM07	UM0701	20-OCT-14	ORIG	0	0.5	13000	9.2	590	28
UM07	UM0702	20-OCT-14	ORIG	1.5	2	28000	8.9	250	43
UM08	UM0801	20-OCT-14	ORIG	0	0.5	21000	11	530	33
UM09	UM0901	20-OCT-14	ORIG	0	0.5	14000	10	630	26
UM10	UM1001	20-OCT-14	ORIG	0	0.5	12000	7.7	500	28
UM10	UM1002	20-OCT-14	ORIG	1.5	2	17000	7.2	290	30
UM11	UM1101	20-OCT-14	ORIG	0	0.5	16000	12	650	39
UM12	UM1201	20-OCT-14	ORIG	0	0.5	24000	10	460	51
UM12	UM1202	20-OCT-14	ORIG	1.5	2	23000	16	650	53
UM13	UM1301	20-OCT-14	ORIG	0	0.5	11000	8.2	540	20
UM14	UM1401	20-OCT-14	ORIG	0	0.5	13000	11	700	34
UM14	UM1402	20-OCT-14	ORIG	1.5	2	14000	16	1000	39
UM15	UM1501	20-OCT-14	ORIG	0	0.5	23000	15	720	39
UM16	UM1601	20-OCT-14	ORIG	0	0.5	23000	18	640	50
UM16	UM1602	20-OCT-14	ORIG	1.5	2	19000	15	620	38
UM17	UM1701	20-OCT-14	ORIG	0	0.5	15000	15	630	52
UM18	UM1801	20-OCT-14	ORIG	0	0.5	14000	8.7	600	25
UM18	UM1802	20-OCT-14	ORIG	1.5	2	19000	26	1300	35
UM19-FR1	UM1901-R1	20-OCT-14	ORIG	0	0.5	15000	23	760	280
UM19-FR2	UM1901-R2	20-OCT-14	ORIG	0	0.5	17000	14	550	55
UM19-FR3	UM1901-R3	20-OCT-14	ORIG	0	0.5	20000	13	640	52
UM20	UM2001	20-OCT-14	ORIG	0	0.5	22000	22	860	36
UM21	UM2101	20-OCT-14	ORIG	0	0.5	18000	6	340	35
UM21	UM2102	20-OCT-14	ORIG	1.5	2	25000	3.1	120	48

Table B-2: List of Presumed Uncontaminated Samples
Ambient Metals Technical Memorandum
UC Berkeley, Richmond Field Station Site

						Sample Results			
Point ID	Sample ID	Sample Date	Sample Type	Top Depth (ft bgs)	Bottom Depth (ft bgs)	Aluminum (mg/kg)	Cobalt (mg/kg)	Manganese (mg/kg)	Nickel (mg/kg)
UM22	UM2201	20-OCT-14	ORIG	0	0.5	11000	11	560	40
UM23	UM2301	20-OCT-14	ORIG	0	0.5	21000	13	610	41
UM23	UM2302	20-OCT-14	ORIG	1.5	2	25000	8.5	370	39
UM24	UM2401	20-OCT-14	ORIG	0	0.5	13000	10	450	51
UM25	UM2501	20-OCT-14	ORIG	0	0.5	14000	12	790	79
UM25	UM2502	20-OCT-14	ORIG	1.5	2	8500	9.8	630	37
UM26	UM2601	22-OCT-14	ORIG	0	0.5	21000	13	680	56
UM27	UM2701	22-OCT-14	ORIG	0	0.5	15000	17	790	40
UM27	UM2702	22-OCT-14	ORIG	1.5	2	19000	15	960	37
UM28-FR1	UM2801-R1	22-OCT-14	ORIG	0	0.5	12000	40	2500	41
UM28-FR2	UM2801-R2	22-OCT-14	ORIG	0	0.5	15000	14	810	37
UM28-FR3	UM2801-R3	22-OCT-14	ORIG	0	0.5	15000	11	780	32
UM29	UM2901	20-OCT-14	ORIG	0	0.5	19000	9.3	660	46
UM29	UM2902	20-OCT-14	ORIG	1.5	2	23000	8.4	410	47
UM30-FR1	UM3001-R1	22-OCT-14	ORIG	0	0.5	19000	12	690	57
UM30-FR1	UM3002-R1	22-OCT-14	ORIG	1.5	2	20000	11	580	39
UM30-FR2	UM3001-R2	22-OCT-14	ORIG	0	0.5	20000	12	570	52
UM30-FR2	UM3002-R2	22-OCT-14	ORIG	1.5	2	20000	10	550	38
UM30-FR3	UM3001-R3	22-OCT-14	ORIG	0	0.5	19000	18	1200	69
UM30-FR3	UM3002-R3	22-OCT-14	ORIG	1.5	2	19000	12	560	33
UM31	UM3101	22-OCT-14	ORIG	0	0.5	19000	25	1400	54
UM32	UM3201	22-OCT-14	ORIG	0	0.5	13000	12	720	42
UM32	UM3202	22-OCT-14	ORIG	1.5	2	14000	9.3	600	43
UM34	UM3401	22-OCT-14	ORIG	0	0.5	18000	17	1100	70
UM35	UM3501	22-OCT-14	ORIG	0	0.5	17000	9.2	460	35
UM35	UM3502	22-OCT-14	ORIG	1.5	2	20000	12	560	45
UM37	UM3701	22-OCT-14	ORIG	0	0.5	15000	11	530	37
UM37	UM3702	22-OCT-14	ORIG	1.5	2	19000	22	790	42
UM38	UM3801	22-OCT-14	ORIG	0	0.5	16000	14	690	35

Table B-2: List of Presumed Uncontaminated Samples

Ambient Metals Technical Memorandum

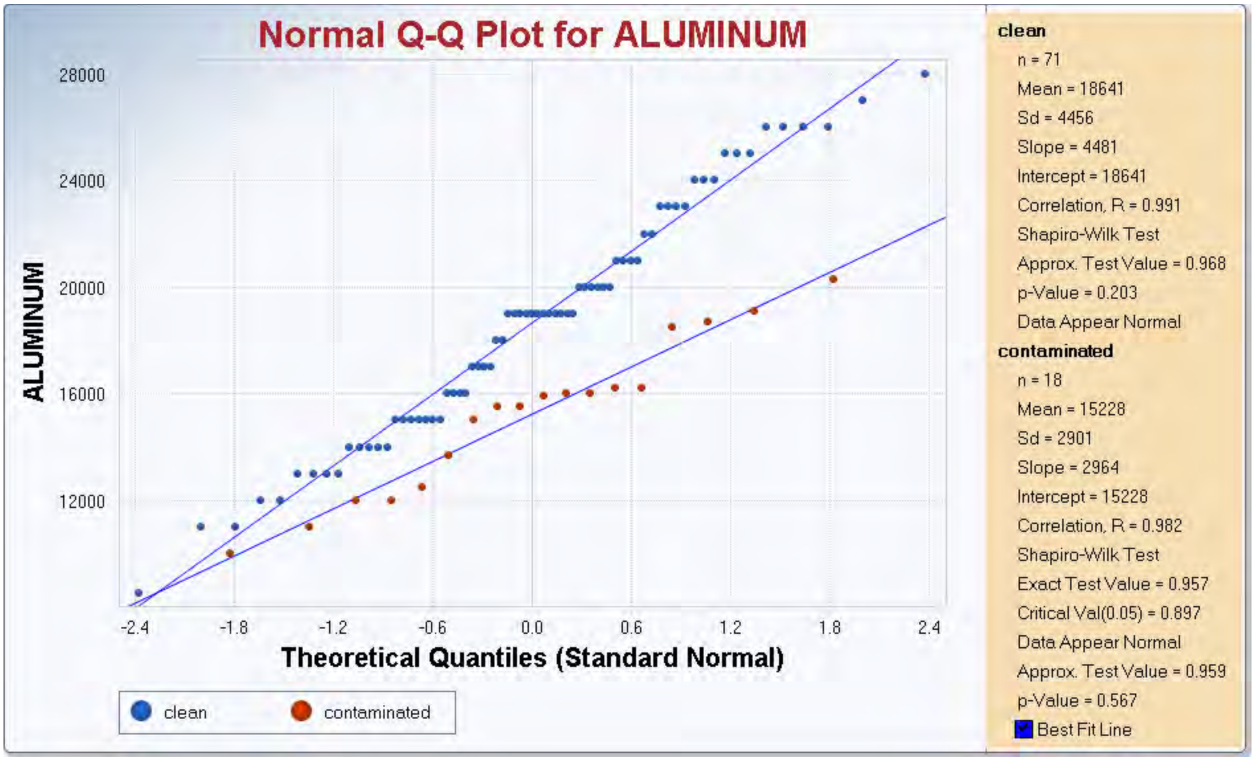
UC Berkeley, Richmond Field Station Site

						Sample Results			
Point ID	Sample ID	Sample Date	Sample Type	Top Depth (ft bgs)	Bottom Depth (ft bgs)	Aluminum (mg/kg)	Cobalt (mg/kg)	Manganese (mg/kg)	Nickel (mg/kg)
UM38	UM3802	22-OCT-14	ORIG	1.5	2	21000	31	1100	54
UM39	UM3901	22-OCT-14	ORIG	0	0.5	19000	21	1100	65
UM39	UM3902	22-OCT-14	ORIG	1.5	2	19000	73	5900	170
UM42	UM4202	22-OCT-14	ORIG	0	0.5	15000	14	650	54
UM42	UM4202	22-OCT-14	ORIG	1.5	2	17000	13	380	61

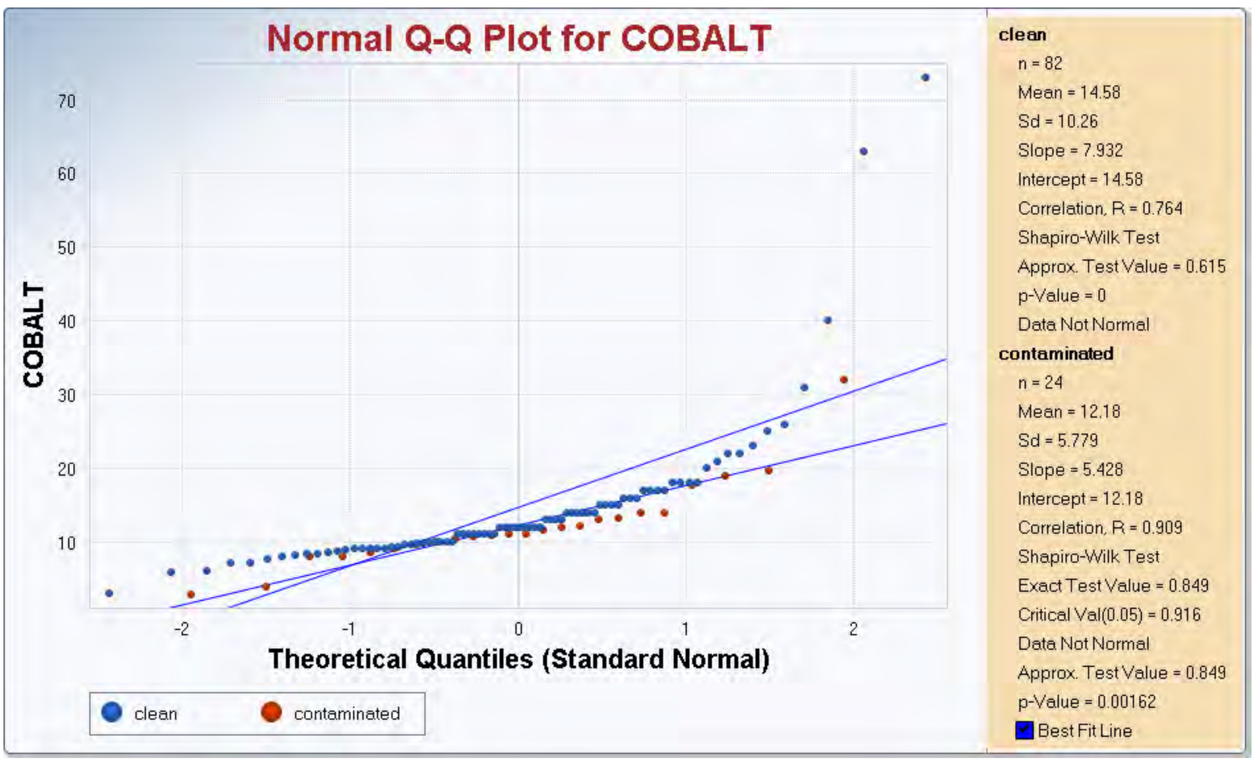
Notes:

FIELDDUP	Field duplicate
ft bgs	Feet below ground surface
mg/kg	Milligrams per kilogram
ORIG	Original

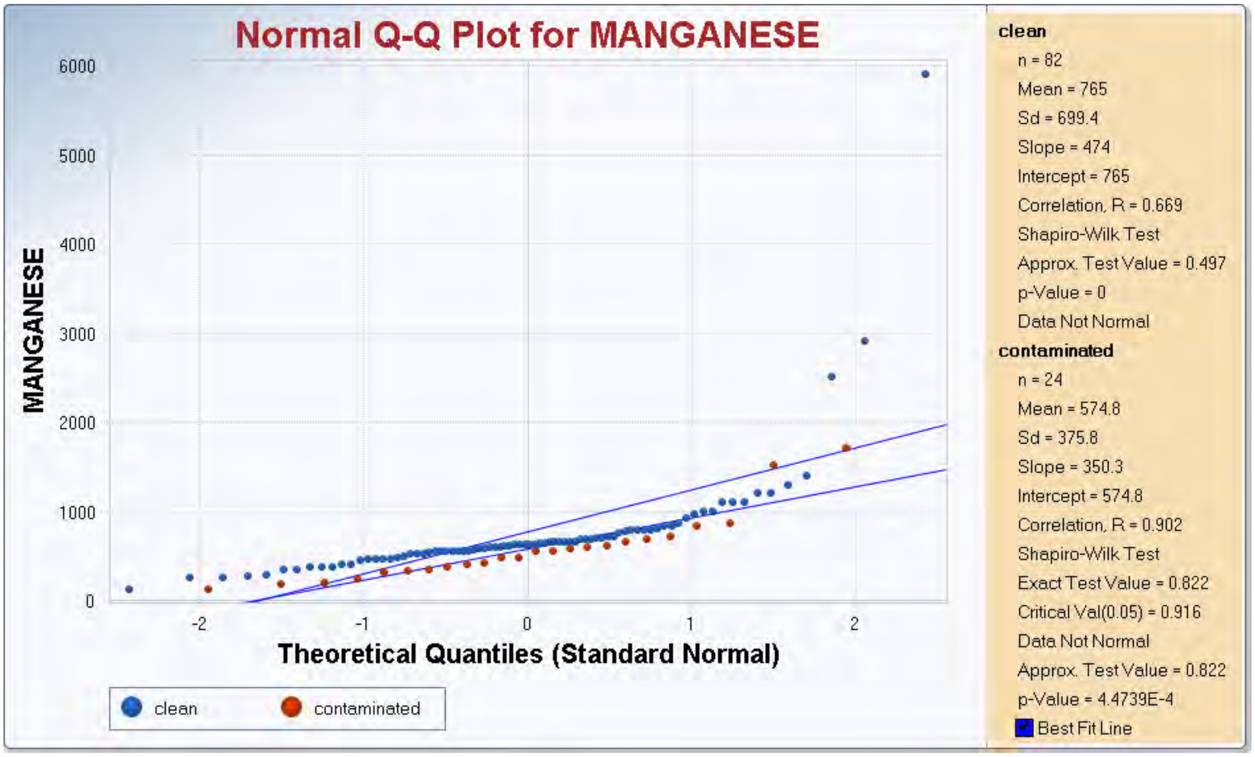
Appendix C
Contaminated and Presumed Uncontaminated Data Analysis Results

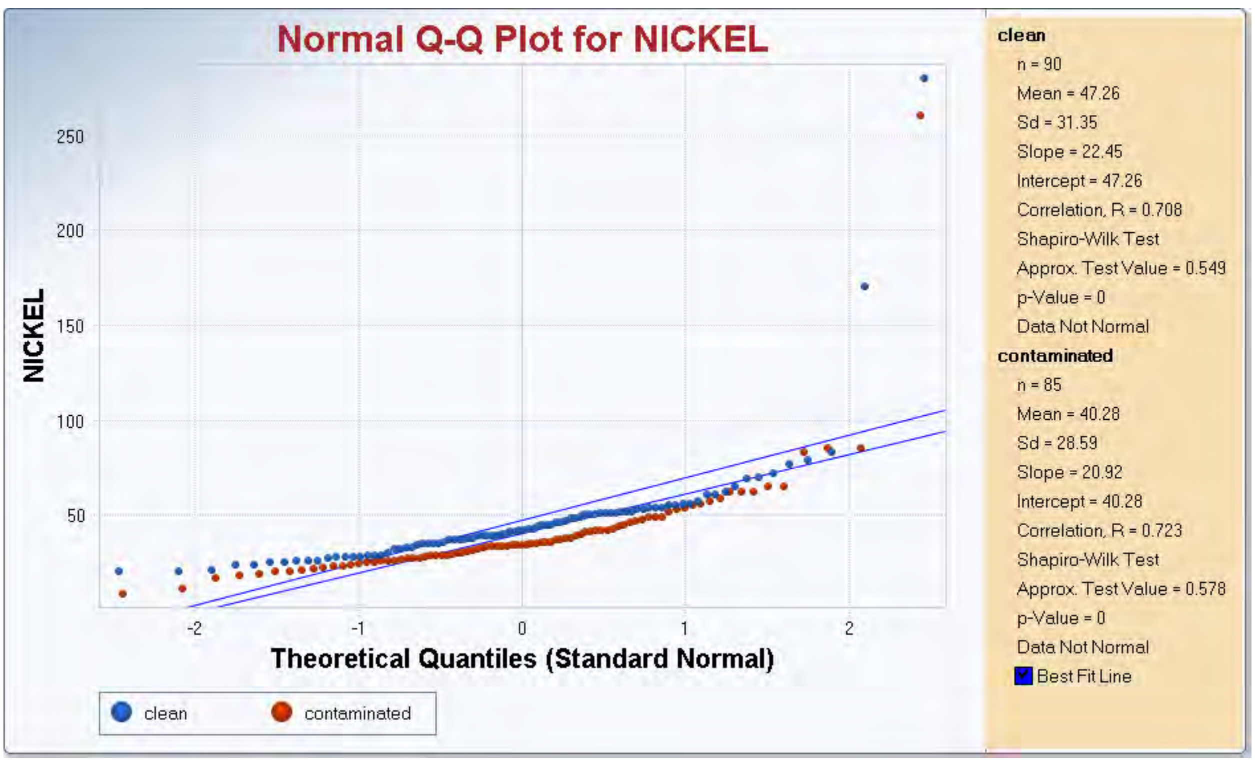


Normal Q-Q Plot for ALUMINUM
ALUMINUM
28000
24000
20000
16000
12000
-2.4
-1.8
-1.2
-0.6
0.0
0.6
1.2
1.8
2.4
Theoretical Quantiles (Standard Normal)
clean
contaminated
clean
n = 71
Mean = 18641
Sd = 4456
Slope = 4481
Intercept = 18641
Correlation, R = 0.991
Shapiro-Wilk Test
Approx. Test Value = 0.968
p-Value = 0.203
Data Appear Normal
contaminated
n = 18
Mean = 15228
Sd = 2901
Slope = 2964
Intercept = 15228
Correlation, R = 0.982
Shapiro-Wilk Test
Exact Test Value = 0.957
Critical Val(0.05) = 0.897
Data Appear Normal
Approx. Test Value = 0.959
p-Value = 0.567
Best Fit Line



Normal Q-Q Plot for COBALT
COBALT
70
60
50
40
30
20
10
-2
-1
0
1
2
Theoretical Quantiles (Standard Normal)
clean
contaminated
clean
n = 82
Mean = 14.58
Sd = 10.26
Slope = 7.932
Intercept = 14.58
Correlation, R = 0.764
Shapiro-Wilk Test
Approx. Test Value = 0.615
p-Value = 0
Data Not Normal
contaminated
n = 24
Mean = 12.18
Sd = 5.779
Slope = 5.428
Intercept = 12.18
Correlation, R = 0.909
Shapiro-Wilk Test
Exact Test Value = 0.849
Critical Val(0.05) = 0.916
Data Not Normal
Approx. Test Value = 0.849
p-Value = 0.00162
Best Fit Line


Normal Q-Q Plot for MANGANESE
6000
5000
4000
3000
2000
1000
0
MANGANESE
-2
-1
0
1
2
Theoretical Quantiles (Standard Normal)
clean
contaminated
clean
n = 82
Mean = 765
Sd = 699.4
Slope = 474
Intercept = 765
Correlation, R = 0.669
Shapiro-Wilk Test
Approx. Test Value = 0.497
p-Value = 0
Data Not Normal
contaminated
n = 24
Mean = 574.8
Sd = 375.8
Slope = 350.3
Intercept = 574.8
Correlation, R = 0.902
Shapiro-Wilk Test
Exact Test Value = 0.822
Critical Val(0.05) = 0.916
Data Not Normal
Approx. Test Value = 0.822
p-Value = 4.4739E-4
Best Fit Line


Normal Q-Q Plot for NICKEL
250
200
150
100
50
NICKEL
-2
-1
0
1
2
Theoretical Quantiles (Standard Normal)
clean
contaminated
clean
n = 90
Mean = 47.26
Sd = 31.35
Slope = 22.45
Intercept = 47.26
Correlation, R = 0.708
Shapiro-Wilk Test
Approx. Test Value = 0.549
p-Value = 0
Data Not Normal
contaminated
n = 85
Mean = 40.28
Sd = 28.59
Slope = 20.92
Intercept = 40.28
Correlation, R = 0.723
Shapiro-Wilk Test
Approx. Test Value = 0.578
p-Value = 0
Data Not Normal
Best Fit Line

UCL Statistics for Uncensored Full Data Sets

User Selected Options	
Date/Time of Computation	7/30/2015 3:50:30 PM
From File	WorkSheet_a.xls
Full Precision	OFF
Confidence Coefficient	95%
mber of Bootstrap Operations	2000

Al (contaminated)

General Statistics

Total Number of Observations	18	Number of Distinct Observations	14
		Number of Missing Observations	67
Minimum	10000	Mean	15228
Maximum	20300	Median	15700
SD	2901	Std. Error of Mean	683.7
Coefficient of Variation	0.19	Skewness	-0.111

Normal GOF Test

Shapiro Wilk Test Statistic	0.957	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.897	Data appear Normal at 5% Significance Level
Lilliefors Test Statistic	0.148	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.209	Data appear Normal at 5% Significance Level

Data appear Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	16417	95% Adjusted-CLT UCL (Chen-1995)	16333
		95% Modified-t UCL (Johnson-1978)	16414

Gamma GOF Test

A-D Test Statistic	0.467	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.739	)etected data appear Gamma Distributed at 5% Significance Lev
K-S Test Statistic	0.173	**Kolmogrov-Smirnoff Gamma GOF Test**
5% K-S Critical Value	0.203	)etected data appear Gamma Distributed at 5% Significance Lev

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	27.87	k star (bias corrected MLE)	23.26
Theta hat (MLE)	546.5	Theta star (bias corrected MLE)	654.7
nu hat (MLE)	1003	nu star (bias corrected)	837.3
MLE Mean (bias corrected)	15228	MLE Sd (bias corrected)	3158
		Approximate Chi Square Value (0.05)	771.1
Adjusted Level of Significance	0.0357	Adjusted Chi Square Value	765.1

UCL Statistics for Uncensored Full Data Sets

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	16534	95% Adjusted Gamma UCL (use when n<50)	16666

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.944	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk Critical Value	0.897	Data appear Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.183	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.209	Data appear Lognormal at 5% Significance Level

Data appear Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	9.21	Mean of logged Data	9.613
Maximum of Logged Data	9.918	SD of logged Data	0.198

Assuming Lognormal Distribution

95% H-UCL	16622	90% Chebyshev (MVUE) UCL	17387
95% Chebyshev (MVUE) UCL	18361	97.5% Chebyshev (MVUE) UCL	19713
99% Chebyshev (MVUE) UCL	22369		

Nonparametric Distribution Free UCL Statistics

Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Distribution Free UCLs

95% CLT UCL	16352	95% Jackknife UCL	16417
95% Standard Bootstrap UCL	16312	95% Bootstrap-t UCL	16446
95% Hall's Bootstrap UCL	16360	95% Percentile Bootstrap UCL	16333
95% BCA Bootstrap UCL	16222		
90% Chebyshev(Mean, Sd) UCL	17279	95% Chebyshev(Mean, Sd) UCL	18208
97.5% Chebyshev(Mean, Sd) UCL	19497	99% Chebyshev(Mean, Sd) UCL	22030

Suggested UCL to Use

95% Student's-t UCL	16417

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). However, simulations results will not cover all Real World data sets.
For additional insight the user may want to consult a statistician.

Note: For highly negatively-skewed data, confidence limits (e.g., Chen, Johnson, Lognormal, and Gamma) may not be reliable. Chen's and Johnson's methods provide adjustments for positvely skewed data sets.

UCL Statistics for Uncensored Full Data Sets

Al (uncontaminated)

General Statistics

Total Number of Observations	71	Number of Distinct Observations	19
		Number of Missing Observations	19
Minimum	8500	Mean	18641
Maximum	28000	Median	19000
SD	4456	Std. Error of Mean	528.9
Coefficient of Variation	0.239	Skewness	0.0894

Normal GOF Test

Shapiro Wilk Test Statistic	0.968	**Shapiro Wilk GOF Test**
5% Shapiro Wilk P Value	0.203	Data appear Normal at 5% Significance Level
Lilliefors Test Statistic	0.0955	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.105	Data appear Normal at 5% Significance Level

Data appear Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	19522	95% Adjusted-CLT UCL (Chen-1995)	19517
		95% Modified-t UCL (Johnson-1978)	19523

Gamma GOF Test

A-D Test Statistic	0.53	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.75	›etected data appear Gamma Distributed at 5% Significance Lev
K-S Test Statistic	0.127	**Kolmogrov-Smirnoff Gamma GOF Test**
5% K-S Critical Value	0.106	Data Not Gamma Distributed at 5% Significance Level

Detected data follow Appr. Gamma Distribution at 5% Significance Level

Gamma Statistics

k hat (MLE)	16.93	k star (bias corrected MLE)	16.22
Theta hat (MLE)	1101	Theta star (bias corrected MLE)	1149
nu hat (MLE)	2403	nu star (bias corrected)	2303
MLE Mean (bias corrected)	18641	MLE Sd (bias corrected)	4629
		Approximate Chi Square Value (0.05)	2193
Adjusted Level of Significance	0.0466	Adjusted Chi Square Value	2190

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	19580	95% Adjusted Gamma UCL (use when n<50)	19600

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.964	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk P Value	0.113	Data appear Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.141	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.105	Data Not Lognormal at 5% Significance Level

UCL Statistics for Uncensored Full Data Sets

Data appear Approximate Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	9.048	Mean of logged Data	9.803
Maximum of Logged Data	10.24	SD of logged Data	0.251

Assuming Lognormal Distribution

95% H-UCL	19662	90% Chebyshev (MVUE) UCL	20353
95% Chebyshev (MVUE) UCL	21118	97.5% Chebyshev (MVUE) UCL	22181
99% Chebyshev (MVUE) UCL	24268		

Nonparametric Distribution Free UCL Statistics

Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Distribution Free UCLs

95% CLT UCL	19511	95% Jackknife UCL	19522
95% Standard Bootstrap UCL	19516	95% Bootstrap-t UCL	19561
95% Hall's Bootstrap UCL	19487	95% Percentile Bootstrap UCL	19521
95% BCA Bootstrap UCL	19535		
90% Chebyshev(Mean, Sd) UCL	20227	95% Chebyshev(Mean, Sd) UCL	20946
97.5% Chebyshev(Mean, Sd) UCL	21944	99% Chebyshev(Mean, Sd) UCL	23903

Suggested UCL to Use

95% Student's-t UCL	19522

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). However, simulations results will not cover all Real World data sets.
For additional insight the user may want to consult a statistician.

UCL Statistics for Uncensored Full Data Sets

Co (contaminated)

General Statistics

Total Number of Observations	24	Number of Distinct Observations	23
		Number of Missing Observations	61
Minimum	2.82	Mean	12.18
Maximum	32	Median	11
SD	5.779	Std. Error of Mean	1.18
Coefficient of Variation	0.474	Skewness	1.736

Normal GOF Test

Shapiro Wilk Test Statistic	0.849	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.916	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.21	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.181	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	14.2	95% Adjusted-CLT UCL (Chen-1995)	14.57
		95% Modified-t UCL (Johnson-1978)	14.27

Gamma GOF Test

A-D Test Statistic	0.78	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.746	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.154	**Kolmogrov-Smirnoff Gamma GOF Test**
5% K-S Critical Value	0.178	etected data appear Gamma Distributed at 5% Significance Lev

Detected data follow Appr. Gamma Distribution at 5% Significance Level

Gamma Statistics

k hat (MLE)	4.975	k star (bias corrected MLE)	4.381
Theta hat (MLE)	2.448	Theta star (bias corrected MLE)	2.78
nu hat (MLE)	238.8	nu star (bias corrected)	210.3
MLE Mean (bias corrected)	12.18	MLE Sd (bias corrected)	5.82
		Approximate Chi Square Value (0.05)	177.7
Adjusted Level of Significance	0.0392	Adjusted Chi Square Value	175.6

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50)	14.41	95% Adjusted Gamma UCL (use when n<50)	14.59

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.904	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk Critical Value	0.916	Data Not Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.174	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.181	Data appear Lognormal at 5% Significance Level

UCL Statistics for Uncensored Full Data Sets

Data appear Approximate Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	1.037	Mean of logged Data	2.396
Maximum of Logged Data	3.466	SD of logged Data	0.486

Assuming Lognormal Distribution

95% H-UCL	15.09	90% Chebyshev (MVUE) UCL	16.09
95% Chebyshev (MVUE) UCL	17.81	97.5% Chebyshev (MVUE) UCL	20.2
99% Chebyshev (MVUE) UCL	24.9		

Nonparametric Distribution Free UCL Statistics

Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Distribution Free UCLs

95% CLT UCL	14.12	95% Jackknife UCL	14.2
95% Standard Bootstrap UCL	14.05	95% Bootstrap-t UCL	14.9
95% Hall's Bootstrap UCL	16.53	95% Percentile Bootstrap UCL	14.15
95% BCA Bootstrap UCL	14.64		
90% Chebyshev(Mean, Sd) UCL	15.72	95% Chebyshev(Mean, Sd) UCL	17.32
97.5% Chebyshev(Mean, Sd) UCL	19.55	99% Chebyshev(Mean, Sd) UCL	23.92

Suggested UCL to Use

95% Adjusted Gamma UCL	14.59

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). However, simulations results will not cover all Real World data sets.
For additional insight the user may want to consult a statistician.

UCL Statistics for Uncensored Full Data Sets

Co (uncontaminated)

General Statistics			
Total Number of Observations	82	Number of Distinct Observations	36
		Number of Missing Observations	8
Minimum	3.1	Mean	14.58
Maximum	73	Median	12
SD	10.26	Std. Error of Mean	1.133
Coefficient of Variation	0.703	Skewness	3.876

Normal GOF Test		
Shapiro Wilk Test Statistic	0.615	**Shapiro Wilk GOF Test**
5% Shapiro Wilk P Value	0	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.235	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.0978	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Assuming Normal Distribution			
95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	16.46	95% Adjusted-CLT UCL (Chen-1995)	16.96
		95% Modified-t UCL (Johnson-1978)	16.54

Gamma GOF Test		
A-D Test Statistic	3.326	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.756	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.147	**Kolmogrov-Smirnoff Gamma GOF Test**
5% K-S Critical Value	0.0991	Data Not Gamma Distributed at 5% Significance Level

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics			
k hat (MLE)	3.923	k star (bias corrected MLE)	3.788
Theta hat (MLE)	3.716	Theta star (bias corrected MLE)	3.849
nu hat (MLE)	643.4	nu star (bias corrected)	621.2
MLE Mean (bias corrected)	14.58	MLE Sd (bias corrected)	7.491
		Approximate Chi Square Value (0.05)	564.3
Adjusted Level of Significance	0.0471	Adjusted Chi Square Value	563.4

Assuming Gamma Distribution			
95% Approximate Gamma UCL (use when n>=50))	16.05	95% Adjusted Gamma UCL (use when n<50)	16.07

Lognormal GOF Test		
Shapiro Wilk Test Statistic	0.933	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk P Value	3.1077E-4	Data Not Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.113	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.0978	Data Not Lognormal at 5% Significance Level

UCL Statistics for Uncensored Full Data Sets

Data Not Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	1.131	Mean of logged Data	2.547
Maximum of Logged Data	4.29	SD of logged Data	0.471

Assuming Lognormal Distribution

95% H-UCL	15.7	90% Chebyshev (MVUE) UCL	16.57
95% Chebyshev (MVUE) UCL	17.63	97.5% Chebyshev (MVUE) UCL	19.1
99% Chebyshev (MVUE) UCL	21.98		

Nonparametric Distribution Free UCL Statistics

Data do not follow a Discernible Distribution (0.05)

Nonparametric Distribution Free UCLs

95% CLT UCL	16.44	95% Jackknife UCL	16.46
95% Standard Bootstrap UCL	16.43	95% Bootstrap-t UCL	17.56
95% Hall's Bootstrap UCL	18.26	95% Percentile Bootstrap UCL	16.53
95% BCA Bootstrap UCL	17.01		
90% Chebyshev(Mean, Sd) UCL	17.98	95% Chebyshev(Mean, Sd) UCL	19.51
97.5% Chebyshev(Mean, Sd) UCL	21.65	99% Chebyshev(Mean, Sd) UCL	25.85

Suggested UCL to Use

95% Student's-t UCL	16.46	or 95% Modified-t UCL	16.54

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). However, simulations results will not cover all Real World data sets.
For additional insight the user may want to consult a statistician.

UCL Statistics for Uncensored Full Data Sets

Mn (contaminated)

General Statistics

Total Number of Observations	24	Number of Distinct Observations	24
		Number of Missing Observations	61
Minimum	130	Mean	574.8
Maximum	1700	Median	513
SD	375.8	Std. Error of Mean	76.71
Coefficient of Variation	0.654	Skewness	1.802

Normal GOF Test

Shapiro Wilk Test Statistic	0.822	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.916	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.183	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.181	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	706.3	95% Adjusted-CLT UCL (Chen-1995)	731.2
		95% Modified-t UCL (Johnson-1978)	711

Gamma GOF Test

A-D Test Statistic	0.346	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.751	etected data appear Gamma Distributed at 5% Significance Lev
K-S Test Statistic	0.109	**Kolmogrov-Smirnoff Gamma GOF Test**
5% K-S Critical Value	0.179	etected data appear Gamma Distributed at 5% Significance Lev

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	2.978	k star (bias corrected MLE)	2.634
Theta hat (MLE)	193	Theta star (bias corrected MLE)	218.3
nu hat (MLE)	143	nu star (bias corrected)	126.4
MLE Mean (bias corrected)	574.8	MLE Sd (bias corrected)	354.2
		Approximate Chi Square Value (0.05)	101.5
Adjusted Level of Significance	0.0392	Adjusted Chi Square Value	99.88

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50)	716.3	95% Adjusted Gamma UCL (use when n<50)	727.6

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.976	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk Critical Value	0.916	Data appear Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.0904	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.181	Data appear Lognormal at 5% Significance Level

UCL Statistics for Uncensored Full Data Sets

Data appear Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	4.868	Mean of logged Data	6.177
Maximum of Logged Data	7.438	SD of logged Data	0.612

Assuming Lognormal Distribution

95% H-UCL	757.6	90% Chebyshev (MVUE) UCL	803.6
95% Chebyshev (MVUE) UCL	906.9	97.5% Chebyshev (MVUE) UCL	1050
99% Chebyshev (MVUE) UCL	1332		

Nonparametric Distribution Free UCL Statistics

Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Distribution Free UCLs

95% CLT UCL	701	95% Jackknife UCL	706.3
95% Standard Bootstrap UCL	704.2	95% Bootstrap-t UCL	785.3
95% Hall's Bootstrap UCL	898	95% Percentile Bootstrap UCL	703.5
95% BCA Bootstrap UCL	729.6		
90% Chebyshev(Mean, Sd) UCL	805	95% Chebyshev(Mean, Sd) UCL	909.2
97.5% Chebyshev(Mean, Sd) UCL	1054	99% Chebyshev(Mean, Sd) UCL	1338

Suggested UCL to Use

95% Adjusted Gamma UCL	727.6

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). However, simulations results will not cover all Real World data sets.
For additional insight the user may want to consult a statistician.

UCL Statistics for Uncensored Full Data Sets

Mn (uncontaminated)

General Statistics

Total Number of Observations	82	Number of Distinct Observations	50
		Number of Missing Observations	8
Minimum	120	Mean	765
Maximum	5900	Median	630
SD	699.4	Std. Error of Mean	77.23
Coefficient of Variation	0.914	Skewness	5.531

Normal GOF Test

Shapiro Wilk Test Statistic	0.497	**Shapiro Wilk GOF Test**
5% Shapiro Wilk P Value	0	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.275	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.0978	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	893.5	95% Adjusted-CLT UCL (Chen-1995)	942.4
		95% Modified-t UCL (Johnson-1978)	901.4

Gamma GOF Test

A-D Test Statistic	4.3	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.759	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.183	**Kolmogrov-Smirnoff Gamma GOF Test**
5% K-S Critical Value	0.0994	Data Not Gamma Distributed at 5% Significance Level

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	3.085	k star (bias corrected MLE)	2.98
Theta hat (MLE)	248	Theta star (bias corrected MLE)	256.7
nu hat (MLE)	506	nu star (bias corrected)	488.8
MLE Mean (bias corrected)	765	MLE Sd (bias corrected)	443.1
		Approximate Chi Square Value (0.05)	438.5
Adjusted Level of Significance	0.0471	Adjusted Chi Square Value	437.7

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	852.7	95% Adjusted Gamma UCL (use when n<50)	854.3

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.923	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk P Value	4.5594E-5	Data Not Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.129	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.0978	Data Not Lognormal at 5% Significance Level

UCL Statistics for Uncensored Full Data Sets

Data Not Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	4.787	Mean of logged Data	6.469
Maximum of Logged Data	8.683	SD of logged Data	0.522

Assuming Lognormal Distribution

95% H-UCL	823	90% Chebyshev (MVUE) UCL	872.7
95% Chebyshev (MVUE) UCL	933.9	97.5% Chebyshev (MVUE) UCL	1019
99% Chebyshev (MVUE) UCL	1186		

Nonparametric Distribution Free UCL Statistics

Data do not follow a Discernible Distribution (0.05)

Nonparametric Distribution Free UCLs

95% CLT UCL	892	95% Jackknife UCL	893.5
95% Standard Bootstrap UCL	889.1	95% Bootstrap-t UCL	1017
95% Hall's Bootstrap UCL	1436	95% Percentile Bootstrap UCL	894.9
95% BCA Bootstrap UCL	955.1		
90% Chebyshev(Mean, Sd) UCL	996.7	95% Chebyshev(Mean, Sd) UCL	1102
97.5% Chebyshev(Mean, Sd) UCL	1247	99% Chebyshev(Mean, Sd) UCL	1533

Suggested UCL to Use

95% Chebyshev (Mean, Sd) UCL	1102

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). However, simulations results will not cover all Real World data sets.
For additional insight the user may want to consult a statistician.

UCL Statistics for Uncensored Full Data Sets

Ni (contaminated)

General Statistics

Total Number of Observations	85	Number of Distinct Observations	59
		Number of Missing Observations	0
Minimum	8.3	Mean	40.28
Maximum	260	Median	34
SD	28.59	Std. Error of Mean	3.101
Coefficient of Variation	0.71	Skewness	5.617

Normal GOF Test

Shapiro Wilk Test Statistic	0.578	**Shapiro Wilk GOF Test**
5% Shapiro Wilk P Value	0	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.191	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.0961	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		95% UCLs (Adjusted for Skewness)	
95% Student's-t UCL	45.44	95% Adjusted-CLT UCL (Chen-1995)	47.4
		95% Modified-t UCL (Johnson-1978)	45.75

Gamma GOF Test

A-D Test Statistic	1.836	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.756	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.107	**Kolmogrov-Smirnoff Gamma GOF Test**
5% K-S Critical Value	0.0973	Data Not Gamma Distributed at 5% Significance Level

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	4.168	k star (bias corrected MLE)	4.029
Theta hat (MLE)	9.663	Theta star (bias corrected MLE)	9.997
nu hat (MLE)	708.6	nu star (bias corrected)	684.9
MLE Mean (bias corrected)	40.28	MLE Sd (bias corrected)	20.07
		Approximate Chi Square Value (0.05)	625.2
Adjusted Level of Significance	0.0472	Adjusted Chi Square Value	624.2

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	44.13	95% Adjusted Gamma UCL (use when n<50)	44.19

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.965	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk P Value	0.085	Data appear Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.0668	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.0961	Data appear Lognormal at 5% Significance Level

UCL Statistics for Uncensored Full Data Sets

Data appear Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	2.116	Mean of logged Data	3.571
Maximum of Logged Data	5.561	SD of logged Data	0.466

Assuming Lognormal Distribution

95% H-UCL	43.48	90% Chebyshev (MVUE) UCL	45.86
95% Chebyshev (MVUE) UCL	48.71	97.5% Chebyshev (MVUE) UCL	52.66
99% Chebyshev (MVUE) UCL	60.42		

Nonparametric Distribution Free UCL Statistics

Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Distribution Free UCLs

95% CLT UCL	45.38	95% Jackknife UCL	45.44
95% Standard Bootstrap UCL	45.26	95% Bootstrap-t UCL	49.4
95% Hall's Bootstrap UCL	68.19	95% Percentile Bootstrap UCL	46.07
95% BCA Bootstrap UCL	48.47		
90% Chebyshev(Mean, Sd) UCL	49.58	95% Chebyshev(Mean, Sd) UCL	53.79
97.5% Chebyshev(Mean, Sd) UCL	59.64	99% Chebyshev(Mean, Sd) UCL	71.13

Suggested UCL to Use

95% Student's-t UCL	45.44	or 95% Modified-t UCL	45.75
or 95% H-UCL	43.48		

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). However, simulations results will not cover all Real World data sets.
For additional insight the user may want to consult a statistician.

ProUCL computes and outputs H-statistic based UCLs for historical reasons only.
H-statistic often results in unstable (both high and low) values of UCL95 as shown in examples in the Technical Guide.
It is therefore recommended to avoid the use of H-statistic based 95% UCLs.
se of nonparametric methods are preferred to compute UCL95 for skewed data sets which do not follow a gamma distribution.

UCL Statistics for Uncensored Full Data Sets

Ni (uncontaminated)

General Statistics

Total Number of Observations	90	Number of Distinct Observations	46
		Number of Missing Observations	0
Minimum	20	Mean	47.26
Maximum	280	Median	42
SD	31.35	Std. Error of Mean	3.304
Coefficient of Variation	0.663	Skewness	5.368

Normal GOF Test

Shapiro Wilk Test Statistic	0.549	**Shapiro Wilk GOF Test**
5% Shapiro Wilk P Value	0	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.246	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.0934	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	52.75	95% Adjusted-CLT UCL (Chen-1995)	54.69
		95% Modified-t UCL (Johnson-1978)	53.06

Gamma GOF Test

A-D Test Statistic	2.637	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.755	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.151	**Kolmogrov-Smirnoff Gamma GOF Test**
5% K-S Critical Value	0.0944	Data Not Gamma Distributed at 5% Significance Level

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	4.994	k star (bias corrected MLE)	4.835
Theta hat (MLE)	9.462	Theta star (bias corrected MLE)	9.774
nu hat (MLE)	898.9	nu star (bias corrected)	870.3
MLE Mean (bias corrected)	47.26	MLE Sd (bias corrected)	21.49
		Approximate Chi Square Value (0.05)	802.8
Adjusted Level of Significance	0.0473	Adjusted Chi Square Value	801.8

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	51.23	95% Adjusted Gamma UCL (use when n<50)	51.29

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.92	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk P Value	8.5013E-6	Data Not Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.107	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.0934	Data Not Lognormal at 5% Significance Level

UCL Statistics for Uncensored Full Data Sets

Data Not Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	2.996	Mean of logged Data	3.752
Maximum of Logged Data	5.635	SD of logged Data	0.407

Assuming Lognormal Distribution

95% H-UCL	50.03	90% Chebyshev (MVUE) UCL	52.43
95% Chebyshev (MVUE) UCL	55.23	97.5% Chebyshev (MVUE) UCL	59.11
99% Chebyshev (MVUE) UCL	66.74		

Nonparametric Distribution Free UCL Statistics

Data do not follow a Discernible Distribution (0.05)

Nonparametric Distribution Free UCLs

95% CLT UCL	52.69	95% Jackknife UCL	52.75
95% Standard Bootstrap UCL	52.74	95% Bootstrap-t UCL	57.13
95% Hall's Bootstrap UCL	80.44	95% Percentile Bootstrap UCL	53.31
95% BCA Bootstrap UCL	55.2		
90% Chebyshev(Mean, Sd) UCL	57.17	95% Chebyshev(Mean, Sd) UCL	61.66
97.5% Chebyshev(Mean, Sd) UCL	67.89	99% Chebyshev(Mean, Sd) UCL	80.13

Suggested UCL to Use

95% Student's-t UCL	52.75	or 95% Modified-t UCL	53.06

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). However, simulations results will not cover all Real World data sets.
For additional insight the user may want to consult a statistician.

Background Statistics for Uncensored Full Data Sets

User Selected Options

Date/Time of Computation	7/30/2015 3:51:18 PM
From File	WorkSheet.xls
Full Precision	OFF
Confidence Coefficient	99%
Coverage	95%
lew or Future K Observations	1
mber of Bootstrap Operations	2000

Al (contaminated)

General Statistics

Total Number of Observations	18	Number of Distinct Observations	14
		Number of Missing Observations	67
Minimum	10000	First Quartile	12800
Second Largest	19100	Median	15700
Maximum	20300	Third Quartile	16200
Mean	15228	SD	2901
Coefficient of Variation	0.19	Skewness	-0.111
Mean of logged Data	9.613	SD of logged Data	0.198

Critical Values for Background Threshold Values (BTVs)

Tolerance Factor K (For UTL)	2.905	d2max (for USL)	2.821

Normal GOF Test

Shapiro Wilk Test Statistic	0.957	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.897	Data appear Normal at 5% Significance Level
Lilliefors Test Statistic	0.148	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.209	Data appear Normal at 5% Significance Level

Data appear Normal at 5% Significance Level

Background Statistics Assuming Normal Distribution

99% UTL with 95% Coverage	23654	90% Percentile (z)	18945
99% UPL (t)	22878	95% Percentile (z)	19999
99% USL	23410	99% Percentile (z)	21976

Gamma GOF Test

A-D Test Statistic	0.467	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.739	›etected data appear Gamma Distributed at 5% Significance Levi
K-S Test Statistic	0.173	**Kolmogrov-Smirnoff Gamma GOF Test**
5% K-S Critical Value	0.203	›etected data appear Gamma Distributed at 5% Significance Levi

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics

Background Statistics for Uncensored Full Data Sets

k hat (MLE)	27.87	k star (bias corrected MLE)	23.26
Theta hat (MLE)	546.5	Theta star (bias corrected MLE)	654.7
nu hat (MLE)	1003	nu star (bias corrected)	837.3
MLE Mean (bias corrected)	15228	MLE Sd (bias corrected)	3158

Background Statistics Assuming Gamma Distribution

99% Wilson Hilferty (WH) Approx. Gamma UPL	24229	90% Percentile	19388
99% Hawkins Wixley (HW) Approx. Gamma UPL	24454	95% Percentile	20766
99% WH Approx. Gamma UTL with 95% Coverage	25328	99% Percentile	23519
99% HW Approx. Gamma UTL with 95% Coverage	25613		
99% WH USL	24979	99% HW USL	25244

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.944	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk Critical Value	0.897	Data appear Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.183	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.209	Data appear Lognormal at 5% Significance Level

Data appear Lognormal at 5% Significance Level

Background Statistics assuming Lognormal Distribution

99% UTL with 95% Coverage	26620	90% Percentile (z)	19287
99% UPL (t)	25243	95% Percentile (z)	20729
99% USL	26179	99% Percentile (z)	23732

Nonparametric Distribution Free Background Statistics

Data appear Normal at 5% Significance Level

Nonparametric Upper Limits for Background Threshold Values

Order of Statistic, r	18	99% UTL with 95% Coverage	20300
Approximate f	0.947	Confidence Coefficient (CC) achieved by UTL	0.603
99% Percentile Bootstrap UTL with 95% Coverage	20300	99% BCA Bootstrap UTL with 95% Coverage	20300
99% UPL	20300	90% Percentile	18820
90% Chebyshev UPL	24168	95% Percentile	19280
95% Chebyshev UPL	28218	99% Percentile	20096
99% USL	20300		

Note: The use of USL to estimate a BTV is recommended only when the data set represents a background data set free of outliers and consists of observations collected from clean unimpacted locations.
The use of USL tends to provide a balance between false positives and false negatives provided the data represents a background data set and when many onsite observations need to be compared with the BTV.

Background Statistics for Uncensored Full Data Sets

Al (uncontaminated)

General Statistics

Total Number of Observations	71	Number of Distinct Observations	19
		Number of Missing Observations	19
Minimum	8500	First Quartile	15000
Second Largest	27000	Median	19000
Maximum	28000	Third Quartile	21500
Mean	18641	SD	4456
Coefficient of Variation	0.239	Skewness	0.0894
Mean of logged Data	9.803	SD of logged Data	0.251

Critical Values for Background Threshold Values (BTVs)

Tolerance Factor K (For UTL)	2.15	d2max (for USL)	3.476

Normal GOF Test

Shapiro Wilk Test Statistic	0.968	**Normal GOF Test**
5% Shapiro Wilk P Value	0.203	Data appear Normal at 5% Significance Level
Lilliefors Test Statistic	0.0955	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.105	Data appear Normal at 5% Significance Level

Data appear Normal at 5% Significance Level

Background Statistics Assuming Normal Distribution

99% UTL with 95% Coverage	28220	90% Percentile (z)	24352
99% UPL (t)	29325	95% Percentile (z)	25971
99% USL	34132	99% Percentile (z)	29008

Gamma GOF Test

A-D Test Statistic	0.53	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.75	etected data appear Gamma Distributed at 5% Significance Lev
K-S Test Statistic	0.127	**Kolmogrov-Smirnoff Gamma GOF Test**
5% K-S Critical Value	0.106	Data Not Gamma Distributed at 5% Significance Level

Detected data follow Appr. Gamma Distribution at 5% Significance Level

Gamma Statistics

k hat (MLE)	16.93	k star (bias corrected MLE)	16.22
Theta hat (MLE)	1101	Theta star (bias corrected MLE)	1149
nu hat (MLE)	2403	nu star (bias corrected)	2303
MLE Mean (bias corrected)	18641	MLE Sd (bias corrected)	4629

Background Statistics Assuming Gamma Distribution

99% Wilson Hilferty (WH) Approx. Gamma UPL	31344	90% Percentile	24764
99% Hawkins Wixley (HW) Approx. Gamma UPL	31705	95% Percentile	26850
99% WH Approx. Gamma UTL with 95% Coverage	29772	99% Percentile	31061
99% HW Approx. Gamma UTL with 95% Coverage	30045		

Background Statistics for Uncensored Full Data Sets

99% WH USL	38834	99% HW USL	39744

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.964	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk P Value	0.113	Data appear Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.141	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.105	Data Not Lognormal at 5% Significance Level

Data appear Approximate Lognormal at 5% Significance Level

Background Statistics assuming Lognormal Distribution

99% UTL with 95% Coverage	31026	90% Percentile (z)	24954
99% UPL (t)	33016	95% Percentile (z)	27335
99% USL	43278	99% Percentile (z)	32432

Nonparametric Distribution Free Background Statistics

Data appear Normal at 5% Significance Level

Nonparametric Upper Limits for Background Threshold Values

Order of Statistic, r	71	99% UTL with 95% Coverage	28000
Approximate f	3.737	Confidence Coefficient (CC) achieved by UTL	0.974
99% Percentile Bootstrap UTL with 95% Coverage	27500	99% BCA Bootstrap UTL with 95% Coverage	26500
99% UPL	28000	90% Percentile	25000
90% Chebyshev UPL	32104	95% Percentile	26000
95% Chebyshev UPL	38202	99% Percentile	27300
99% USL	28000		

Note: The use of USL to estimate a BTV is recommended only when the data set represents a background data set free of outliers and consists of observations collected from clean unimpacted locations.
The use of USL tends to provide a balance between false positives and false negatives provided the data represents a background data set and when many onsite observations need to be compared with the BTV.

Background Statistics for Uncensored Full Data Sets

Co (contaminated)

General Statistics

Total Number of Observations	24	Number of Distinct Observations	23
		Number of Missing Observations	61
Minimum	2.82	First Quartile	9.5
Second Largest	19.7	Median	11
Maximum	32	Third Quartile	13.38
Mean	12.18	SD	5.779
Coefficient of Variation	0.474	Skewness	1.736
Mean of logged Data	2.396	SD of logged Data	0.486

Critical Values for Background Threshold Values (BTVs)

Tolerance Factor K (For UTL)	2.662	d2max (for USL)	2.987

Normal GOF Test

Shapiro Wilk Test Statistic	0.849	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.916	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.21	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.181	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Background Statistics Assuming Normal Distribution

99% UTL with 95% Coverage	27.57	90% Percentile (z)	19.59
99% UPL (t)	26.93	95% Percentile (z)	21.69
99% USL	29.44	99% Percentile (z)	25.63

Gamma GOF Test

A-D Test Statistic	0.78	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.746	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.154	**Kolmogrov-Smirnoff Gamma GOF Test**
5% K-S Critical Value	0.178	etected data appear Gamma Distributed at 5% Significance Lev

Detected data follow Appr. Gamma Distribution at 5% Significance Level

Gamma Statistics

k hat (MLE)	4.975	k star (bias corrected MLE)	4.381
Theta hat (MLE)	2.448	Theta star (bias corrected MLE)	2.78
nu hat (MLE)	238.8	nu star (bias corrected)	210.3
MLE Mean (bias corrected)	12.18	MLE Sd (bias corrected)	5.82

Background Statistics Assuming Gamma Distribution

99% Wilson Hilferty (WH) Approx. Gamma UPL	31.02	90% Percentile	19.98
99% Hawkins Wixley (HW) Approx. Gamma UPL	32.19	95% Percentile	23.06
99% WH Approx. Gamma UTL with 95% Coverage	32.18	99% Percentile	29.6
99% HW Approx. Gamma UTL with 95% Coverage	33.5		

Background Statistics for Uncensored Full Data Sets

99% WH USL	35.75	99% HW USL	37.56

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.904	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk Critical Value	0.916	Data Not Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.174	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.181	Data appear Lognormal at 5% Significance Level

Data appear Approximate Lognormal at 5% Significance Level

Background Statistics assuming Lognormal Distribution

99% UTL with 95% Coverage	40.07	90% Percentile (z)	20.48
99% UPL (t)	37.97	95% Percentile (z)	24.44
99% USL	46.93	99% Percentile (z)	34.04

Nonparametric Distribution Free Background Statistics

Data appear Approximate Gamma Distribution at 5% Significance Level

Nonparametric Upper Limits for Background Threshold Values

Order of Statistic, r	24	99% UTL with 95% Coverage	32
Approximate f	1.263	Confidence Coefficient (CC) achieved by UTL	0.708
99% Percentile Bootstrap UTL with 95% Coverage	32	99% BCA Bootstrap UTL with 95% Coverage	32
99% UPL	32	90% Percentile	18.61
90% Chebyshev UPL	29.88	95% Percentile	19.6
95% Chebyshev UPL	37.89	99% Percentile	29.17
99% USL	32		

Note: The use of USL to estimate a BTV is recommended only when the data set represents a background data set free of outliers and consists of observations collected from clean unimpacted locations.
The use of USL tends to provide a balance between false positives and false negatives provided the data represents a background data set and when many onsite observations need to be compared with the BTV.

Background Statistics for Uncensored Full Data Sets

Co (uncontaminated)

General Statistics

Total Number of Observations	82	Number of Distinct Observations	36
		Number of Missing Observations	8
Minimum	3.1	First Quartile	9.6
Second Largest	63	Median	12
Maximum	73	Third Quartile	16
Mean	14.58	SD	10.26
Coefficient of Variation	0.703	Skewness	3.876
Mean of logged Data	2.547	SD of logged Data	0.471

Critical Values for Background Threshold Values (BTVs)

Tolerance Factor K (For UTL)	2.108	d2max (for USL)	3.53

Normal GOF Test

Shapiro Wilk Test Statistic	0.615	**Normal GOF Test**
5% Shapiro Wilk P Value	0	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.235	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.0978	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Background Statistics Assuming Normal Distribution

99% UTL with 95% Coverage	36.2	90% Percentile (z)	27.72
99% UPL (t)	39.07	95% Percentile (z)	31.45
99% USL	50.78	99% Percentile (z)	38.44

Gamma GOF Test

A-D Test Statistic	3.326	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.756	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.147	**Kolmogrov-Smirnoff Gamma GOF Test**
5% K-S Critical Value	0.0991	Data Not Gamma Distributed at 5% Significance Level

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	3.923	k star (bias corrected MLE)	3.788
Theta hat (MLE)	3.716	Theta star (bias corrected MLE)	3.849
nu hat (MLE)	643.4	nu star (bias corrected)	621.2
MLE Mean (bias corrected)	14.58	MLE Sd (bias corrected)	7.491

Background Statistics Assuming Gamma Distribution

99% Wilson Hilferty (WH) Approx. Gamma UPL	37.47	90% Percentile	24.62
99% Hawkins Wixley (HW) Approx. Gamma UPL	37.68	95% Percentile	28.67
99% WH Approx. Gamma UTL with 95% Coverage	33.74	99% Percentile	37.35
99% HW Approx. Gamma UTL with 95% Coverage	33.75		

Background Statistics for Uncensored Full Data Sets

99% WH USL	55.5	99% HW USL	57.36

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.933	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk P Value	3.1077E-4	Data Not Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.113	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.0978	Data Not Lognormal at 5% Significance Level

Data Not Lognormal at 5% Significance Level

Background Statistics assuming Lognormal Distribution

99% UTL with 95% Coverage	34.47	90% Percentile (z)	23.35
99% UPL (t)	39.33	95% Percentile (z)	27.71
99% USL	67.38	99% Percentile (z)	38.21

Nonparametric Distribution Free Background Statistics

Data do not follow a Discernible Distribution (0.05)

Nonparametric Upper Limits for Background Threshold Values

Order of Statistic, r	81	99% UTL with 95% Coverage	63
Approximate f	2.132	Confidence Coefficient (CC) achieved by UTL	0.921
99% Percentile Bootstrap UTL with 95% Coverage	63	99% BCA Bootstrap UTL with 95% Coverage	63
99% UPL	73	90% Percentile	21.9
90% Chebyshev UPL	45.53	95% Percentile	25.95
95% Chebyshev UPL	59.55	99% Percentile	64.9
99% USL	73		

Note: The use of USL to estimate a BTV is recommended only when the data set represents a background data set free of outliers and consists of observations collected from clean unimpacted locations.
The use of USL tends to provide a balance between false positives and false negatives provided the data represents a background data set and when many onsite observations need to be compared with the BTV.

Background Statistics for Uncensored Full Data Sets

Mn (contaminated)

General Statistics

Total Number of Observations	24	Number of Distinct Observations	24
		Number of Missing Observations	61
Minimum	130	First Quartile	344.3
Second Largest	1520	Median	513
Maximum	1700	Third Quartile	669.8
Mean	574.8	SD	375.8
Coefficient of Variation	0.654	Skewness	1.802
Mean of logged Data	6.177	SD of logged Data	0.612

Critical Values for Background Threshold Values (BTVs)

Tolerance Factor K (For UTL)	2.662	d2max (for USL)	2.987

Normal GOF Test

Shapiro Wilk Test Statistic	0.822	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.916	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.183	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.181	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Background Statistics Assuming Normal Distribution

99% UTL with 95% Coverage	1575	90% Percentile (z)	1056
99% UPL (t)	1534	95% Percentile (z)	1193
99% USL	1697	99% Percentile (z)	1449

Gamma GOF Test

A-D Test Statistic	0.346	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.751	)etected data appear Gamma Distributed at 5% Significance Lev
K-S Test Statistic	0.109	**Kolmogrov-Smirnoff Gamma GOF Test**
5% K-S Critical Value	0.179	)etected data appear Gamma Distributed at 5% Significance Lev

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	2.978	k star (bias corrected MLE)	2.634
Theta hat (MLE)	193	Theta star (bias corrected MLE)	218.3
nu hat (MLE)	143	nu star (bias corrected)	126.4
MLE Mean (bias corrected)	574.8	MLE Sd (bias corrected)	354.2

Background Statistics Assuming Gamma Distribution

99% Wilson Hilferty (WH) Approx. Gamma UPL	1802	90% Percentile	1050
99% Hawkins Wixley (HW) Approx. Gamma UPL	1882	95% Percentile	1253
99% WH Approx. Gamma UTL with 95% Coverage	1884	99% Percentile	1697
99% HW Approx. Gamma UTL with 95% Coverage	1976		

Background Statistics for Uncensored Full Data Sets

99% WH USL	2138	99% HW USL	2270

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.976	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk Critical Value	0.916	Data appear Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.0904	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.181	Data appear Lognormal at 5% Significance Level

Data appear Lognormal at 5% Significance Level

Background Statistics assuming Lognormal Distribution

99% UTL with 95% Coverage	2455	90% Percentile (z)	1055
99% UPL (t)	2294	95% Percentile (z)	1317
99% USL	2994	99% Percentile (z)	1999

Nonparametric Distribution Free Background Statistics

Data appear Gamma Distributed at 5% Significance Level

Nonparametric Upper Limits for Background Threshold Values

Order of Statistic, r	24	99% UTL with 95% Coverage	1700
Approximate f	1.263	Confidence Coefficient (CC) achieved by UTL	0.708
99% Percentile Bootstrap UTL with 95% Coverage	1700	99% BCA Bootstrap UTL with 95% Coverage	1700
99% UPL	1700	90% Percentile	857.7
90% Chebyshev UPL	1726	95% Percentile	1422
95% Chebyshev UPL	2247	99% Percentile	1659
99% USL	1700		

Note: The use of USL to estimate a BTV is recommended only when the data set represents a background data set free of outliers and consists of observations collected from clean unimpacted locations.
The use of USL tends to provide a balance between false positives and false negatives provided the data represents a background data set and when many onsite observations need to be compared with the BTV.

Background Statistics for Uncensored Full Data Sets

Mn (uncontaminated)

General Statistics

Total Number of Observations	82	Number of Distinct Observations	50
		Number of Missing Observations	8
Minimum	120	First Quartile	530
Second Largest	2900	Median	630
Maximum	5900	Third Quartile	790
Mean	765	SD	699.4
Coefficient of Variation	0.914	Skewness	5.531
Mean of logged Data	6.469	SD of logged Data	0.522

Critical Values for Background Threshold Values (BTVs)

Tolerance Factor K (For UTL)	2.108	d2max (for USL)	3.53

Normal GOF Test

Shapiro Wilk Test Statistic	0.497	**Normal GOF Test**
5% Shapiro Wilk P Value	0	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.275	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.0978	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Background Statistics Assuming Normal Distribution

99% UTL with 95% Coverage	2239	90% Percentile (z)	1661
99% UPL (t)	2435	95% Percentile (z)	1915
99% USL	3234	99% Percentile (z)	2392

Gamma GOF Test

A-D Test Statistic	4.3	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.759	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.183	**Kolmogrov-Smirnoff Gamma GOF Test**
5% K-S Critical Value	0.0994	Data Not Gamma Distributed at 5% Significance Level

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	3.085	k star (bias corrected MLE)	2.98
Theta hat (MLE)	248	Theta star (bias corrected MLE)	256.7
nu hat (MLE)	506	nu star (bias corrected)	488.8
MLE Mean (bias corrected)	765	MLE Sd (bias corrected)	443.1

Background Statistics Assuming Gamma Distribution

99% Wilson Hilferty (WH) Approx. Gamma UPL	2134	90% Percentile	1359
99% Hawkins Wixley (HW) Approx. Gamma UPL	2137	95% Percentile	1608
99% WH Approx. Gamma UTL with 95% Coverage	1904	99% Percentile	2149
99% HW Approx. Gamma UTL with 95% Coverage	1895		

Background Statistics for Uncensored Full Data Sets

99% WH USL	3265	99% HW USL	3370

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.923	**Shapiro Wilk Lognormal GOF Test**	
5% Shapiro Wilk P Value	4.5594E-5	Data Not Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.129	**Lilliefors Lognormal GOF Test**	
5% Lilliefors Critical Value	0.0978	Data Not Lognormal at 5% Significance Level	

Data Not Lognormal at 5% Significance Level

Background Statistics assuming Lognormal Distribution

99% UTL with 95% Coverage	1938	90% Percentile (z)	1259
99% UPL (t)	2243	95% Percentile (z)	1522
99% USL	4070	99% Percentile (z)	2172

Nonparametric Distribution Free Background Statistics

Data do not follow a Discernible Distribution (0.05)

Nonparametric Upper Limits for Background Threshold Values

Order of Statistic, r	81	99% UTL with 95% Coverage	2900
Approximate f	2.132	Confidence Coefficient (CC) achieved by UTL	0.921
99% Percentile Bootstrap UTL with 95% Coverage	2900	99% BCA Bootstrap UTL with 95% Coverage	2880
99% UPL	5900	90% Percentile	1100
90% Chebyshev UPL	2876	95% Percentile	1295
95% Chebyshev UPL	3832	99% Percentile	3470
99% USL	5900		

Note: The use of USL to estimate a BTV is recommended only when the data set represents a background data set free of outliers and consists of observations collected from clean unimpacted locations.
The use of USL tends to provide a balance between false positives and false negatives provided the data represents a background data set and when many onsite observations need to be compared with the BTV.

Background Statistics for Uncensored Full Data Sets

Ni (contaminated)

General Statistics

Total Number of Observations	85	Number of Distinct Observations	59
Minimum	8.3	First Quartile	27
Second Largest	85	Median	34
Maximum	260	Third Quartile	46
Mean	40.28	SD	28.59
Coefficient of Variation	0.71	Skewness	5.617
Mean of logged Data	3.571	SD of logged Data	0.466

Critical Values for Background Threshold Values (BTVs)

Tolerance Factor K (For UTL)	2.098	d2max (for USL)	3.543

Normal GOF Test

Shapiro Wilk Test Statistic	0.578	Normal GOF Test
5% Shapiro Wilk P Value	0	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.191	Lilliefors GOF Test
5% Lilliefors Critical Value	0.0961	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Background Statistics Assuming Normal Distribution

99% UTL with 95% Coverage	100.3	90% Percentile (z)	76.92
99% UPL (t)	108.5	95% Percentile (z)	87.3
99% USL	141.6	99% Percentile (z)	106.8

Gamma GOF Test

A-D Test Statistic	1.836	Anderson-Darling Gamma GOF Test
5% A-D Critical Value	0.756	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.107	Kolmogrov-Smirnoff Gamma GOF Test
5% K-S Critical Value	0.0973	Data Not Gamma Distributed at 5% Significance Level

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	4.168	k star (bias corrected MLE)	4.029
Theta hat (MLE)	9.663	Theta star (bias corrected MLE)	9.997
nu hat (MLE)	708.6	nu star (bias corrected)	684.9
MLE Mean (bias corrected)	40.28	MLE Sd (bias corrected)	20.07

Background Statistics Assuming Gamma Distribution

99% Wilson Hilferty (WH) Approx. Gamma UPL	100.9	90% Percentile	67.17
99% Hawkins Wixley (HW) Approx. Gamma UPL	101.8	95% Percentile	77.93
99% WH Approx. Gamma UTL with 95% Coverage	90.9	99% Percentile	100.9
99% HW Approx. Gamma UTL with 95% Coverage	91.12		
99% WH USL	148.9	99% HW USL	154.2

Background Statistics for Uncensored Full Data Sets

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.965	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk P Value	0.085	Data appear Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.0668	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.0961	Data appear Lognormal at 5% Significance Level

Data appear Lognormal at 5% Significance Level

Background Statistics assuming Lognormal Distribution

99% UTL with 95% Coverage	94.51	90% Percentile (z)	64.6
99% UPL (t)	108.1	95% Percentile (z)	76.52
99% USL	185.3	99% Percentile (z)	105.1

Nonparametric Distribution Free Background Statistics

Data appear Lognormal at 5% Significance Level

Nonparametric Upper Limits for Background Threshold Values

Order of Statistic, r	84	99% UTL with 95% Coverage	85
Approximate f	2.211	Confidence Coefficient (CC) achieved by UTL	0.93
99% Percentile Bootstrap UTL with 95% Coverage	85	99% BCA Bootstrap UTL with 95% Coverage	85
99% UPL	260	90% Percentile	60.8
90% Chebyshev UPL	126.6	95% Percentile	65
95% Chebyshev UPL	165.6	99% Percentile	113
99% USL	260		

Note: The use of USL to estimate a BTV is recommended only when the data set represents a background data set free of outliers and consists of observations collected from clean unimpacted locations.
The use of USL tends to provide a balance between false positives and false negatives provided the data represents a background data set and when many onsite observations need to be compared with the BTV.

Background Statistics for Uncensored Full Data Sets

Ni (uncontaminated)

General Statistics

Total Number of Observations	90	Number of Distinct Observations	46
Minimum	20	First Quartile	33.25
Second Largest	170	Median	42
Maximum	280	Third Quartile	52
Mean	47.26	SD	31.35
Coefficient of Variation	0.663	Skewness	5.368
Mean of logged Data	3.752	SD of logged Data	0.407

Critical Values for Background Threshold Values (BTVs)

Tolerance Factor K (For UTL)	2.083	d2max (for USL)	3.563

Normal GOF Test

Shapiro Wilk Test Statistic	0.549	**Normal GOF Test**
5% Shapiro Wilk P Value	0	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.246	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.0934	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Background Statistics Assuming Normal Distribution

99% UTL with 95% Coverage	112.6	90% Percentile (z)	87.43
99% UPL (t)	121.9	95% Percentile (z)	98.81
99% USL	158.9	99% Percentile (z)	120.2

Gamma GOF Test

A-D Test Statistic	2.637	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.755	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.151	**Kolmogrov-Smirnoff Gamma GOF Test**
5% K-S Critical Value	0.0944	Data Not Gamma Distributed at 5% Significance Level

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	4.994	k star (bias corrected MLE)	4.835
Theta hat (MLE)	9.462	Theta star (bias corrected MLE)	9.774
nu hat (MLE)	898.9	nu star (bias corrected)	870.3
MLE Mean (bias corrected)	47.26	MLE Sd (bias corrected)	21.49

Background Statistics Assuming Gamma Distribution

99% Wilson Hilferty (WH) Approx. Gamma UPL	110.8	90% Percentile	76.03
99% Hawkins Wixley (HW) Approx. Gamma UPL	110.7	95% Percentile	87.24
99% WH Approx. Gamma UTL with 95% Coverage	100.1	99% Percentile	110.9
99% HW Approx. Gamma UTL with 95% Coverage	99.57		
99% WH USL	160.7	99% HW USL	163.9

Background Statistics for Uncensored Full Data Sets

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.92	**Shapiro Wilk Lognormal GOF Test**	
5% Shapiro Wilk P Value	8.5013E-6	Data Not Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.107	**Lilliefors Lognormal GOF Test**	
5% Lilliefors Critical Value	0.0934	Data Not Lognormal at 5% Significance Level	

Data Not Lognormal at 5% Significance Level

Background Statistics assuming Lognormal Distribution

99% UTL with 95% Coverage	99.55	90% Percentile (z)	71.82
99% UPL (t)	112.4	95% Percentile (z)	83.28
99% USL	181.9	99% Percentile (z)	109.9

Nonparametric Distribution Free Background Statistics

Data do not follow a Discernible Distribution (0.05)

Nonparametric Upper Limits for Background Threshold Values

Order of Statistic, r	89	99% UTL with 95% Coverage	170
Approximate f	2.342	Confidence Coefficient (CC) achieved by UTL	0.943
99% Percentile Bootstrap UTL with 95% Coverage	170	99% BCA Bootstrap UTL with 95% Coverage	170
99% UPL	280	90% Percentile	62.3
90% Chebyshev UPL	141.8	95% Percentile	74.75
95% Chebyshev UPL	184.6	99% Percentile	182.1
99% USL	280		

Note: The use of USL to estimate a BTV is recommended only when the data set represents a background data set free of outliers and consists of observations collected from clean unimpacted locations.
The use of USL tends to provide a balance between false positives and false negatives provided the data represents a background data set and when many onsite observations need to be compared with the BTV.

t-Test Sample 1 vs Sample 2 Comparison for Uncensored Full Data Sets without NDs

User Selected Options	
Date/Time of Computation	7/30/2015 4:19:35 PM
From File	WorkSheet_a.xls
Full Precision	OFF
Confidence Coefficient	95%
Substantial Difference (S)	0.000
Selected Null Hypothesis	Sample 1 Mean <= Sample 2 Mean (Form 1)
Alternative Hypothesis	Sample 1 Mean > the Sample 2 Mean

Sample 1 Data: Al(contaminated)

Sample 2 Data: Al(uncontaminated)

Raw Statistics

	Sample 1	Sample 2
Number of Valid Observations	18	71
Number of Missing Observations	67	19
Number of Distinct Observations	14	19
Minimum	10000	8500
Maximum	20300	28000
Mean	15228	18641
Median	15700	19000
SD	2901	4456
SE of Mean	683.7	528.9

Sample 1 vs Sample 2 Two-Sample t-Test

H0: Mean of Sample 1 - Mean of Sample 2 <= 0

Method	DF	t-Test Value	Critical t (0.05)	P-Value
Pooled (Equal Variance)	87	-3.081	1.663	0.999
Welch-Satterthwaite (Unequal \	40.0	-3.949	1.684	1.000

Pooled SD 4197.875

Conclusion with Alpha = 0.050

Student t (Pooled) Test: Do Not Reject H0, Conclude Sample 1 <= Sample 2

Welch-Satterthwaite Test: Do Not Reject H0, Conclude Sample 1 <= Sample 2

Test of Equality of Variances

Variance of Sample 1	8413889
Variance of Sample 2	19858451

Numerator DF	Denominator DF	F-Test Value	P-Value
70	17	2.360	0.050

Conclusion with Alpha = 0.05

Two variances appear to be equal

t-Test Sample 1 vs Sample 2 Comparison for Uncensored Full Data Sets without NDs

User Selected Options	
Date/Time of Computation	7/30/2015 4:25:58 PM
From File	WorkSheet_a.xls
Full Precision	OFF
Confidence Coefficient	95%
Substantial Difference (S)	0.000
Selected Null Hypothesis	Sample 1 Mean = Sample 2 Mean (Two Sided Alternative)
Alternative Hypothesis	Sample 1 Mean <> Sample 2 Mean

Sample 1 Data: Al(contaminated)

Sample 2 Data: Al(uncontaminated)

Raw Statistics

	Sample 1	Sample 2
Number of Valid Observations	18	71
Number of Missing Observations	67	19
Number of Distinct Observations	14	19
Minimum	10000	8500
Maximum	20300	28000
Mean	15228	18641
Median	15700	19000
SD	2901	4456
SE of Mean	683.7	528.9

Sample 1 vs Sample 2 Two-Sample t-Test

H0: Mean of Sample 1 = Mean of Sample 2

Method	DF	t-Test Value	Lower C.Val t (0.025)	Upper C.Val t (0.975)	P-Value
Pooled (Equal Variance)	87	-3.081	-1.988	1.988	0.003
Welch-Satterthwaite (Unequal Varian	40.0	-3.949	-2.021	2.021	0.000

Pooled SD: 4197.875

Conclusion with Alpha = 0.050

Student t (Pooled): Reject H0, Conclude Sample 1 <> Sample 2

Welch-Satterthwaite: Reject H0, Conclude Sample 1 <> Sample 2

Test of Equality of Variances

Variance of Sample 1	8413889
Variance of Sample 2	19858451

Numerator DF	Denominator DF	F-Test Value	P-Value
70	17	2.360	0.050

Conclusion with Alpha = 0.05

Two variances appear to be equal

Wilcoxon-Mann-Whitney Sample 1 vs Sample 2 Comparison Test for Uncensored Full Data Sets without NDs

User Selected Options	
Date/Time of Computation	7/30/2015 4:30:06 PM
From File	WorkSheet_a.xls
Full Precision	OFF
Confidence Coefficient	95%
Substantial Difference	0.000
Selected Null Hypothesis	Sample 1 Mean/Median <= Sample 2 Mean/Median (Form 1)
Alternative Hypothesis	Sample 1 Mean/Median > Sample 2 Mean/Median

Sample 1 Data: Co(contaminated)

Sample 2 Data: Co(uncontaminated)

Raw Statistics

	Sample 1	Sample 2
Number of Valid Observations	24	82
Number of Missing Observations	61	8
Number of Distinct Observations	23	36
Minimum	2.82	3.1
Maximum	32	73
Mean	12.18	14.58
Median	11	12
SD	5.779	10.26
SE of Mean	1.18	1.133

Wilcoxon-Mann-Whitney (WMW) Test

H0: Mean/Median of Sample 1 <= Mean/Median of Sample 2

Sample 1 Rank Sum W-Stat	1155
Standardized WMW U-Stat	-0.979
Mean (U)	984
SD(U) - Adj ties	132.3
Approximate U-Stat Critical Value (0.05)	1.645
P-Value (Adjusted for Ties)	0.836

Conclusion with Alpha = 0.05

Do Not Reject H0, Conclude Sample 1 <= Sample 2

P-Value >= alpha (0.05)

Wilcoxon-Mann-Whitney Sample 1 vs Sample 2 Comparison Test for Uncensored Full Data Sets without NDs

User Selected Options	
Date/Time of Computation	7/30/2015 4:32:22 PM
From File	WorkSheet_a.xls
Full Precision	OFF
Confidence Coefficient	95%
Substantial Difference	0.000
Selected Null Hypothesis	Sample 1 Mean/Median = Sample 2 Mean/Median (Two Sided Alternative
Alternative Hypothesis	Sample 1 Mean/Median <> Sample 2 Mean/Median

Sample 1 Data: Co(contaminated)

Sample 2 Data: Co(uncontaminated)

Raw Statistics

	Sample 1	Sample 2
Number of Valid Observations	24	82
Number of Missing Observations	61	8
Number of Distinct Observations	23	36
Minimum	2.82	3.1
Maximum	32	73
Mean	12.18	14.58
Median	11	12
SD	5.779	10.26
SE of Mean	1.18	1.133

Wilcoxon-Mann-Whitney (WMW) Test

H0: Mean/Median of Sample 1 = Mean/Median of Sample 2

Sample 1 Rank Sum W-Stat	1155
WMW U-Stat	855
Standardized WMW U-Stat	-0.975
Mean (U)	984
SD(U) - Adj ties	132.3
Lower Approximate U-Stat Critical Value (0.025)	-1.96
Upper Approximate U-Stat Critical Value (0.975)	1.96
P-Value (Adjusted for Ties)	0.33

Conclusion with Alpha = 0.05

Do Not Reject H0, Conclude Sample 1 = Sample 2

P-Value >= alpha (0.05)

Wilcoxon-Mann-Whitney Sample 1 vs Sample 2 Comparison Test for Uncensored Full Data Sets without NDs

User Selected Options	
Date/Time of Computation	7/30/2015 4:31:11 PM
From File	WorkSheet_a.xls
Full Precision	OFF
Confidence Coefficient	95%
Substantial Difference	0.000
Selected Null Hypothesis	Sample 1 Mean/Median <= Sample 2 Mean/Median (Form 1)
Alternative Hypothesis	Sample 1 Mean/Median > Sample 2 Mean/Median

Sample 1 Data: Mn(contaminated)

Sample 2 Data: Mn(uncontaminated)

Raw Statistics

	Sample 1	Sample 2
Number of Valid Observations	24	82
Number of Missing Observations	61	8
Number of Distinct Observations	24	50
Minimum	130	120
Maximum	1700	5900
Mean	574.8	765
Median	513	630
SD	375.8	699.4
SE of Mean	76.71	77.23

Wilcoxon-Mann-Whitney (WMW) Test

H0: Mean/Median of Sample 1 <= Mean/Median of Sample 2

Sample 1 Rank Sum W-Stat	991.5
Standardized WMW U-Stat	-2.212
Mean (U)	984
SD(U) - Adj ties	132.4
Approximate U-Stat Critical Value (0.05)	1.645
P-Value (Adjusted for Ties)	0.987

Conclusion with Alpha = 0.05

Do Not Reject H0, Conclude Sample 1 <= Sample 2

P-Value >= alpha (0.05)

Wilcoxon-Mann-Whitney Sample 1 vs Sample 2 Comparison Test for Uncensored Full Data Sets without NDs

User Selected Options	
Date/Time of Computation	7/30/2015 4:35:34 PM
From File	WorkSheet_a.xls
Full Precision	OFF
Confidence Coefficient	95%
Substantial Difference	0.000
Selected Null Hypothesis	Sample 1 Mean/Median = Sample 2 Mean/Median (Two Sided Alternative)
Alternative Hypothesis	Sample 1 Mean/Median <> Sample 2 Mean/Median

Sample 1 Data: Mn(contaminated)

Sample 2 Data: Mn(uncontaminated)

Raw Statistics

	Sample 1	Sample 2
Number of Valid Observations	24	82
Number of Missing Observations	61	8
Number of Distinct Observations	24	50
Minimum	130	120
Maximum	1700	5900
Mean	574.8	765
Median	513	630
SD	375.8	699.4
SE of Mean	76.71	77.23

Wilcoxon-Mann-Whitney (WMW) Test

H0: Mean/Median of Sample 1 = Mean/Median of Sample 2

Sample 1 Rank Sum W-Stat	991.5
WMW U-Stat	691.5
Standardized WMW U-Stat	-2.209
Mean (U)	984
SD(U) - Adj ties	132.4
ower Approximate U-Stat Critical Value (0.025)	-1.96
pper Approximate U-Stat Critical Value (0.975)	1.96
P-Value (Adjusted for Ties)	0.0272

Conclusion with Alpha = 0.05

Reject H0, Conclude Sample 1 <> Sample 2

P-Value < alpha (0.05)

Wilcoxon-Mann-Whitney Sample 1 vs Sample 2 Comparison Test for Uncensored Full Data Sets without NDs

User Selected Options	
Date/Time of Computation	7/30/2015 4:31:40 PM
From File	WorkSheet_a.xls
Full Precision	OFF
Confidence Coefficient	95%
Substantial Difference	0.000
Selected Null Hypothesis	Sample 1 Mean/Median <= Sample 2 Mean/Median (Form 1)
Alternative Hypothesis	Sample 1 Mean/Median > Sample 2 Mean/Median

Sample 1 Data: Ni(contaminated)

Sample 2 Data: Ni(uncontaminated)

Raw Statistics

	Sample 1	Sample 2
Number of Valid Observations	85	90
Number of Distinct Observations	59	46
Minimum	8.3	20
Maximum	260	280
Mean	40.28	47.26
Median	34	42
SD	28.59	31.35
SE of Mean	3.101	3.304

Wilcoxon-Mann-Whitney (WMW) Test

H0: Mean/Median of Sample 1 <= Mean/Median of Sample 2

Sample 1 Rank Sum W-Stat	6496
Standardized WMW U-Stat	-2.94
Mean (U)	3825
SD(U) - Adj ties	334.9
Approximate U-Stat Critical Value (0.05)	1.645
P-Value (Adjusted for Ties)	0.998

Conclusion with Alpha = 0.05

Do Not Reject H0, Conclude Sample 1 <= Sample 2

P-Value >= alpha (0.05)

Wilcoxon-Mann-Whitney Sample 1 vs Sample 2 Comparison Test for Uncensored Full Data Sets without NDs

User Selected Options	
Date/Time of Computation	7/30/2015 4:36:07 PM
From File	WorkSheet_a.xls
Full Precision	OFF
Confidence Coefficient	95%
Substantial Difference	0.000
Selected Null Hypothesis	Sample 1 Mean/Median = Sample 2 Mean/Median (Two Sided Alternative)
Alternative Hypothesis	Sample 1 Mean/Median <> Sample 2 Mean/Median

Sample 1 Data: Ni(contaminated)

Sample 2 Data: Ni(uncontaminated)

Raw Statistics

	Sample 1	Sample 2
Number of Valid Observations	85	90
Number of Distinct Observations	59	46
Minimum	8.3	20
Maximum	260	280
Mean	40.28	47.26
Median	34	42
SD	28.59	31.35
SE of Mean	3.101	3.304

Wilcoxon-Mann-Whitney (WMW) Test

H0: Mean/Median of Sample 1 = Mean/Median of Sample 2

Sample 1 Rank Sum W-Stat	6496
WMW U-Stat	2841
Standardized WMW U-Stat	-2.938
Mean (U)	3825
SD(U) - Adj ties	334.9
Lower Approximate U-Stat Critical Value (0.025)	-1.96
Upper Approximate U-Stat Critical Value (0.975)	1.96
P-Value (Adjusted for Ties)	0.0033

Conclusion with Alpha = 0.05

Reject H0, Conclude Sample 1 <> Sample 2

P-Value < alpha (0.05)