Attachment 1-4

Guidance for Developing Ecological Soil Screening Levels (Eco-SSLs)

Review of Background Concentrations for Metals

OSWER Directive 92857-55

November 2003

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1.0 INTRODUCTION

Many metals of concern commonly found at Superfund sites are also found in non-impacted areas. Background refers to constituents or locations that are not influenced by the releases from a site, and is usually described as naturally occurring or anthropogenic (US EPA, 2002). Naturally occurring metals are present in the environment in forms that are not influenced by human activity while anthropogenic refers to natural and human-made substances present as a result of human activities (not specifically related to a Superfund release) (US EPA, 2002). Understanding typical background concentrations of metals in soil is important to interpreting the toxicity-derived ecological soil screening levels (Eco-SSLs).

Ideally, this document would provide discrete contaminant concentrations that define the background concentrations for each metal applicable to soils across the United States. Unfortunately, this cannot be accomplished since soil characteristics are highly variable from state to state and from region to region (Connor and Shacklette, 1975; Shacklette and Boerngen, 1984). This document instead provides a summary of the data available on background concentrations in soil for the metals for which ecological soil screening levels (Eco-SSLs) were developed. The purpose is to provide a range of background concentrations that are expected in soils across the United States that can be used to:

- Identify if the Eco-SSLs are near or below typical background soil concentrations; and
- Illustrate the importance of performing investigations to quantify site-specific background concentrations.

Definition of Background

Background refers to constituents or locations that are not influenced by the releases from a site, and is usually described as naturally occurring or anthropogenic (US EPA, 2002)

1) **Anthropogenic** -natural and human-made substances present in the environment as a result of human activities (not specifically related to the CERCLA release in question); and,

2) **Naturally occurring** - substances present in the environment in forms that have not been influenced by human activity.

Little adequate and reliable data were found concerning background concentrations of organics in soils therefore the scope has been limited to inorganics. Metals and metalloids are consistently found as components of soil in uncontaminated areas. Over 50 inorganic elements can be found in native soils; however, only 17 of these are considered for the development of Eco-SSLs. (Table 1.1). The subsequent sections summarize the methods used to obtain appropriate data and the compile that data into a database of background concentrations. The data is then subsequently used to describe typical background concentrations of metals found in soils across the United States.

Table 1.1 Metals Considered in Developing Ecological Soil Screening Levels		
Aluminum	Chromium	Nickel
Antimony	Cobalt	Selenium
Arsenic	Copper	Silver
Barium	Iron	Vanadium
Beryllium	Lead	Zinc
Cadmium	Manganese	

2.0 DATA REQUIREMENTS AND RETRIEVAL

When compiling information from a variety of data sets, it is important to realize that no single data set will contain all the information that is desired. Therefore, it is important to describe the scope of desirable data from which all potential data sources may be measured. This section summarizes both the list of identified data requirements and data retrieval processes.

2.1 Data Requirements

Ideally, each data source contains the same information and meets all of the requirements for inclusion in the background database. However, this is not a realistic expectation given the fact that studies are performed across different soil types, sampling conditions and for a variety of study objectives. Therefore, a list of data characteristics to be reviewed for each data source was compiled (Table 2.1) and segregated into two classifications: 1) mandatory; and 2) optional. Data characteristics that must be included in the data source are classified as mandatory, whereas data characteristics that are useful but not essential are classified as optional.

Table 2.1 Data Characteristics for the Review of Data Sources Reporting Metal Background Concentrations in Soil

Classification	Data Characteristic
Mandatory	Contains data on soils for an Eco-SSL metal of concern
	The data is representative of natural conditions (e.g., not impacted by site releases)
	Statistics (arithmetic or geometric mean) clearly differentiated or raw data available to calculate statistics
Optional	Soil type or classification
	Wet-weight or dry-weight concentration
	Soil depth
	Geographic or regional location of soil
	Sample preparation and analysis methods
	Raw data reported

2.2 Data Retrieval

A literature review was performed to identify sources of information on background concentrations in soil for metals. The data retrieval consisted of a review of published data, a review of references from published literature, and an on-line (Internet) search to find additional state or federal publications. Data were retrieved from the following sources:

- United States Geological Survey (USGS) reports;
- Reports from State and other agencies; and
- Published literature.
- CERCLIS-3 records associated with Superfund sites;

The review of each study and its respective data characteristics are recorded in Table 2.1. As was anticipated, the number of data characteristics reported varied significantly among the data sources. The studies that contained the mandatory data characteristics were included in the database and are listed in Table 2.2.

2.3 Source Documents

The source documents obtained could be divided into three general categories: CERCLIS-3 database, USGS nationwide studies, and state and other independent surveys. Each of the source documents for which data were included in the background soil concentration database are discussed in the following subsections.

2.3.1 Data from USGS Nationwide Soil Studies

Two large data sets were obtained from the USGS. The findings in these two publications were considered natural background concentrations because environmental samples were intentionally excluded in locations where metals concentrations were expected to be affected due to anthropogenic activities. Connor and Shacklette (1975) compiled the results of 25 different studies carried out to collect background samples of rock, soil, and plant material through out the United States. Of the 25 studies identified, ten provided information on background levels of metals in soil by state or by region. Connor and Shacklette (1975) provided geometric mean, minimum and maximum values for both cultivated and uncultivated lands. Only data for uncultivated soils were included in the Background Soil Concentration Database.

Shacklette and Boerngen (1984) summarized background concentrations of metals present in surficial soil samples collected at a depth of 20 cm across the United States. Raw analytical data were downloaded electronically in a spreadsheet format provided by the USGS website (*http://minerals.usgs.gov/sddp/mrdata/sddpftp.shtml* - "Soil Chemistry" category) and summary statistics for each analyte were calculated for each state. Calculated arithmetic means and standard deviations for each analyte grouped by state were incorporated into the Background Soil Concentration Database from Shacklette and Boerngen (1984). A more recent publication reprocessed this same dataset to provide full-color maps for seven major elements (Al, Ca, Fe, K, Mg, Na and Ti) and 15 trace elements (As, Ba, Cr, Cu, Hg, Li, Mn, Ni, Pb, Se, Sr, V, Y, Zn and Zr) (USGS, 2001).

Table 2.2 Summary of Documents Reviewed for the Background Soil Database

	Geographic								Data and Statistics Provided by Study			
Citation	Region	State (s)	Depth	Soil Type	Basis (ww or dw)*	Date	Description	Description of Data Used for Database	Raw Data	Minimum/ Maximum	Mean	Std Dev
Ames and Hawkins, 1997	West	WA	soil horizons (A=2-6 in.; B=24-30 in)	primarily alluvium	dry weight	1991	Sampling was conducted in Clark County, WA in April and May 1991. Four methods were used to analyze metals including : total, total recoverable, TCLP and ASTM. 55 soil samples were collected from 26 sites and analyzed using the total method.	Table 3 data for total method analyses added to database.	Yes - (appendix A)	Yes (table 3)	Yes (table 3)	Yes (table 3)
Arizona Department of Environmental Quality (ADEQ), 1991	West	AZ	0.25 to 9 ft	NR	NR	NR	62 samples collected from 10 sites from areas without known site contamination (Tuscon and Phoenix areas only) Study also presents Arixona data from USGS (Borengen and Shacklette 1981)	ADEQ samples included in the database but not the USGS data as it was incorporated from the primary source.	Yes - (appendix B)	Yes (table 3-1)	Yes (table 3-1)	Yes (table 3-1)
Barringer, et. al 1998	East	NJ	soil horizon (O,E,A,B,C)	sand and clay	NR	1995	Uncultivated, cultivated and residential sites.	Statistics calculated from undeveloped forest areas and entered in database. Mean for each soil horizon included.	Yes - (appendix 1)	No (calculated)	No (calculated)	No (caclulated)
Bradford, et. al 1996	West	CA	Approx 50cm	22 different soil types	NR	1967	Sampling was conducted across 22 soil types and were collected in 1967. Sampling was conducted across 22 soil types (50 samples) across California.	Table 3 data added to database	Yes (table 2)	Yes (table 3)	Yes arithmetic & geometric (table 3)	Yes (table 3)
Breckenridge and Crockett 1995	US	NR	NR	15 different soil types	dry weight	NR	Guidance document for determining background soil concentrations at hazardous waste sites. Presents data from Kabata-Pendias & Pendias (1984).	Table 3 data added to database	No	Yes (table 1)	Yes (table 1)	No
Chen et al., 1999	East	FL	NR	sandy soils from uncultivated or minimally cultivated sites	dry weight	NR	448 soil samples collected by the Florida Cooperative Soil Survey Program (FCSSP) selected as representative of Florida soils.	Table 3 data added to database	No	Yes (table 2)	Yes (table 2)	Yes (table 2)
Conner and Shacklette 1975	West and East	MO, CO, CA, NV, ID, MT, WY, SD, NE, NM, GA, KY, AR, KA, OK, WI	A, B, C soil horizons	cultivated and uncultivated soils	NR	see text	25 different field studies across the US. Soil data from 10 different primary sources		No	Yes (as a %)	Yes geometric unless noted	Yes geometric unless noted
Holmgren et al., 1993	US	multiple	surface to 50 cm	major agricultural production areas	dry weight	1978	Study conducted by USDA, FDA, and USEPA at 3,045 agricultural sites across the US.	Table 4 data added to database.	No	Yes (table 4)	Yes- geometric & arithmetic (table 4)	Yes geometric & arithmetic (table 4)
McGovern, 1998	East	NY, MA, NJ	NR	See text	dry weight	see text	Literature values of elements from uncontaminated/unidsturbed areas or areas far from pollution sources.		No	Yes	Yes geometric for regional, arithmetic for others	No
Michigan Dept of Environmental Quality (MDEQ) 1991	East	MI	NR	topsoil/ clay/ silt/ sand/ swamp-peat (swamp-peat excluded b/c sediment)	NR	1987 to 1991	Local unimpacted background conditions data from hazardous waste sites. 348 samples. State background sampling continuous since 1987 (176 samples) and data from closure documents reviewed by MI WMD.	Means and standard deviations are reported for soil type and then sub-divided geographically to account for different glacial sheet areas in the state.	Yes as attachment	Yes as attachment	Yes as attachment	Yes as attachment

Table 2.2 Summary of Documents Reviewed for the Background Soil Database

Citation	Geographic		Depth	Soil Type	Basis (ww or dw)*	Date	Description	Description of Data Used for Database	Data and Statistics Provided by Study			
	Region	State (s)							Raw Data	Minimum/ Maximum	Mean	Std Dev
New Hampshire Division of Public Health Services 1991	East	NH	0 to 6 inches	NR	NR	1989	Sampling was conducted at public schools in New Hampshire. Four composite soils were collected at each school.		Yes - (appendix A)	Yes (table 2)	Yes (table 2)	Yes (table 2)
Pierce et al., 1982	West	MN	Surface,subsurface, till	representative of 7 major parent materials with a range of soil properties. Surface (0-15 cm) Subsoil (15cm-top of C), Parent Material (top of C to depth)	dry weight	NR	Seven "parent soil materials" were sampled at locations determined by the USDA Soil Conservation Service and area soil scientists. Weighted mean total metals and total extractable metals (weighted by metal concentration, depth, and bulk density of each horizon within each layer) for 16 surface, subsurface and till samples representative of 7 parent materials.	The weighted mean HNO_3 extractable metals summary statistics for all surface and subsurface soils were incorporated into the Background Soil Concentration database.	No	Yes total metals (Table 2)	Yes weighted mean for total metals (Table 2)	Yes weighted stedev for total metals (Table 2)
Shacklette and Boerngen 1984	East and West	multiple	Approx 20 cm (8 in)	NR	NR	1961-1975	In 1961 sampling program started to estimate ranges of element abundances in unaltered/minimally altered surficial materials. 1318 sampling sites--samples taken at depths of 20cm approximately .8km apart throughout the US	1,318 sampling stations across the US and analyzed for 50 analytes. Raw data obtained electronically in spreadsheet format from website.	Yes electronic from website	Yes (table 1) calculated from raw data	Yes (table 1) calculated from raw data	No calculated
Washington State Department of Ecology 1994	West	WA	Mostly from B & C soil horizons (2 to 5 ft)	NR	NR	1987-1993	USGS and Washington Dept. of Ecology 7 year study--on natural background concentrations of metals in surficial soils. Six different study results used to determine background concentrations. 490 smaples from 166 sites.	Total recoverable metals; 90th percentile value is used to calculate natural background levels.	Yes (section 11)	Yes (section 11)	Yes arithmetic & geometric (section 11)	Yes (section 11)
Watkins, et. al 1993	East	TN-Oak Ridge Reservation	Stratified by soil horizons A, B, C	Soil types are described by the site locations, not for the individual samples taken	NR	1992	Sampling conducted at various sites on ORNL Reservation lands.	Composited samples for inorganics from sites within 5 different geologic groups. Field operations and sampling conducted by: BSCP-SOP-01 (May 1992) and BSCP-SOP-02 (Aug 1992)	Yes (appendix D)	Yes	No calculated	No calculated

NR= not reported
ASTM = American Society for Testing and Materials
TCLP = Toxic Characteristic Leaching Procedure

2.3.2 Data from State, Federal or Other Independent Surveys

Additional background information was obtained from the following state or federal agencies and from literature searches:

- Ames and Hawkins (1997)
- Arizona Department of Environmental Quality (ADEQ 1991)
- USGS Water Resources - New Jersey (Barringer et al., 1998)
- University of California-Division of Agriculture (Bradford et al. 1996)
- Breckenridge and Crockett (1995)
- Florida Cooperative Soil Survey Program (Chen et al., 1999)
- US agricultural soils (Holmgren et al., 1993)
- New York State Department of Environmental Conservation (McGovern, 1988)
- Michigan Department of Natural Resources (MDNR, 1991)
- New Hampshire Bureau of Health Risk Assessment (NHDPHS, 1991)
- State of Minnesota (Pierce et al,. 1982)
- Washington State Department of Ecology (WSDOE, 1994)
- Oak Ridge National Laboratory (Watkins et al. 1993)
- Delaware Department of Natural Resources and Environmental Control (Delaware DNR & EC 1998)
- Massachusetts Department of Environmental Protection (MADEP 1995)
- Illinois Environmental Protection Agency (ILEPA 1997)

Ames and Hawkins (1997). Ames and Hawkins (1997) collected background soil data from Clark County, Washington, to determine if soil concentrations from sites of suspected contamination were elevated above background. Seventy-nine samples were randomly collected from 11 different soil types from areas that were relatively undisturbed by human activity. Concentrations for 17 metals, including 13 inorganic priority pollutants listed by the EPA, were analyzed for all soil samples. Analyses by four methods examined including: total method, total recoverable method, an ASTM leaching method, and TCLP. Summary statistics calculated include detection frequency, arithmetic mean, median, standard deviation, minimum, maximum, and the 90th percentile. The The summary statistics for analyses of 55 soil samples using the total method from Ames and Hawkins (1997) were incorporated into the Background Soil Concentration Database.

Arizona Department of Environmental Quality. The Arizona Department of Environmental Quality (ADEQ) compiled approximately 62 data points on background soil concentrations obtained from the USGS survey and from independent statewide soil surveys. All samples were taken at depths ranging from 3 inches to 9 feet. The analytical raw data were provided in an appendix and the arithmetic mean, maximum, minimum and standard deviation values for each analyte are presented in Table 3-1 in document. This document also summarizes data from Shacklette and Boerngen (1984) for soils collected in Arizona. These data were obtained from the primary source and were not included from in the Background Soil Concentration Database. Summary statistics for ADEQ samples were incorporated into the Background Soil Concentration Database.

USGS Water Resources - New Jersey. USGS Water Resources of New Jersey conducted a study on the background soil concentrations of 23 metals in the vicinity of the Imperial Oil Company National Priority List (NPL) site (Barringer et al. 1998). This study singled out uncultivated, cultivated and residential sites outside the boundaries of the NPL site. Various soil types were collected including sand, silt and clay were included in the investigation and samples from 5 soil horizons (O, A, E, B and C). Summary statistics are not provided within the document, however the raw data is provided as an attachment. Summary statistics were calculated from the raw data for each of the soil horizons for each metal and entered into the Background Soil Concentration Database. For values reported as less than the detection limit, the detection limit was used to calculate the summary statistics. The calculated arithmetic mean, standard deviation, minimum detected concentration and maximum detected concentration for the undeveloped forest samples were incorporated into the Background Soil Concentration Database.

University of California-Division of Agriculture. The University of California Division of Agriculture conducted a large-scale investigation in 1967 to determine the background concentrations of metals in surficial soils (at approximately a 50 cm depth) for 22 different soil types. Bradford et al. (1998) report both the raw analytical data and the arithmetic and geometric means, standard deviation, minimum and maximum for each of 46 metals (Tables 2 and 3 in document). The arithmetic and geometric means, standard deviations, minimum and maximum detected concentrations were incorporated into the Background Soil Concentration Database.

Breckenridge and Crockett (1995). Breckenridge and Crockett (1995) published a report providing remedial project managers (RPMs) and others investigating hazardous waste sites with a summary of technical issues that should be considered when determining if a site has elevated concentrations of inorganics relative to local background soil and/or sediment concentrations. Background is defined as the concentration of inorganics found in soils or sediments surrounding a waste site, but which are not influenced by site activities or releases. The background data they provide as concentration ranges (minimum to maximum) and arithmetic mean values in selected surface soils for several United States soil types are taken from Kabata-Pendias and Pendias (1984). Background cadmium concentrations are not presented because its mobility is dependant upon soil pH and organic carbon content. The arithmetic mean soil concentrations reported by Breckenridge and Crockett (1995) were incorporated into the Background Soil Concentration Database.

Florida Cooperative Soil Survey Program. Chen et al. (1999) established background soil concentrations for 15 different trace elements in the state of Florida. Surface soil samples (n=448) were collected as part of the Florida Cooperative Soil Survey Program (FCSSP) conducted jointly by the University of Florida Soil and Water Science Department and the United States Department of Agriculture (USDA) Natural Resources Conservation Service to establish baseline levels. Summary statistics (range, median, arithmetic and geometric means and standard deviations) are presented for each metal (Table 2 in the source document). These data were incorporated into the Background Soil Concentration Database.

US Agricultural Soils. As part of an investigation of trace element uptake by major agricultural crops, Holmgren et al. (1993) collected 3,045 soil samples across the United States in agricultural production regions. Samples were analyzed for lead, cadmium, zinc, copper and nickel. For each metal, summary statistics were calculated across all samples. Arithmetic and geometric means and standard deviations along with concentration percentiles are summarized in Table 4 of the source document. The summary statistics presented in Holmgren et al. (1993) were incorporated into the Background Soil Concentration Database.

New York State Department of Environmental Conservation. The New York State Department of Environmental Conservation (NYDEC) prepared an unpublished report by McGovern (1988) that summarizes concentrations of 20 elements for New York and other East Coast states. These values were based on previously published literature from undisturbed and uncontaminated areas. The background concentrations were provided in a combination of geometric and arithmetic statistics. When possible, primary literature sources were obtained to verify and supplement the data cited in this document. Generally, arithmetic means were provided for most data sources for New York, Maine and New Jersey. Geometric means were typically provided for data generated for the eastern United States. The arithmetic and geometric mean values were incorporated into the Background Soil Concentration database.

Michigan Department of Natural Resources. The Michigan Department of Natural Resources (MDNR) has collected 348 soil samples from various hazardous waste sites since 1987. Background concentrations are available for 16 metals from soil samples collected from geographically distinct areas within the state of Michigan (MDNR 1991). Five types of soil samples were collected, topsoil, sand, silt, clay, and swamp-peat. MDNR (1991) provides the number of samples, arithmetic mean, standard deviation, minimum and maximum values for each soil type. Samples identified as swamp-peat were excluded because these are likely to be representative of sediments not soils. For values reported as less than the detection limit, one-half the detection limit was used to calculate summary statistics. These summary statistics were incorporated into the Background Soil Concentration Database.

New Hampshire Division of Public Health Services (NHDPHS). The New Hampshire Division of Public Health Services (NHDPHS) and the US Fish and Wildlife Service (USFWS) conducted a study to determine baseline concentrations of metals in soils throughout New Hampshire (NHDPHS 1991). Public schools from each state county were selected randomly and composite surface soil samples were collected in May and June of 1989. Raw data results are provided for arsenic, cadmium, chromium, mercury, nickel, and lead for each sample. After outliers were excluded, the arithmetic mean, standard deviation, varience, and concentration range of all samples were calculated (Table 2 in document). These data were incorporated into the Background Soil Concentration Database.

State of Minnesota. Soil background concentrations were retrieved from a paper published by Pierce et al. (1982) in which concentrations of six metals in some major Minnesota soils were reported. These soil types include the: Loess, Superior Lobe Till, Rainy Lobe Till, Lacustrine, Wadena Lobe Till, Percy Till, Des Moines Lobe Till (prairie), Des Moines Lobe Till (forest). Weighted mean total metals, weighted mean extractable metals and weighted standard deviations are reported (Tables 2, 3, and 4 in document). The weighted mean HNO_3 extractable metals summary statistics for all surface and subsurface soils were incorporated into the Background Soil Concentration database.

Washington State Department of Ecology. The Washington State Department of Ecology (WSDOE) published natural background concentrations for 12 metals in surficial soils throughout the state. A total of 490 soil samples were collected from 166 locations. The samples were collected across varying depths from undisturbed and undeveloped areas (WSDOE 1994). WSDOE (1994) provides the raw data in addition to providing geometric and arithmetic means, minimum, maximum and standard deviation values (1 record per metal - Section 11 in document). These summary statistics were incorporated into the Background Soil Concentration Database.

Oak Ridge National Laboratory (ORNL). The Oak Ridge National Laboratory (ORNL) conducted a study on the background soil concentrations of organics, metals and radionuclides in natural soil on the Oak Ridge Reservation. This study, known as the Background Soil Characterization Project, was part of the environmental restoration efforts undertaken by the ORNL (Watkins et al. 1993). Statistical data in the document includes median and upper confidence concentrations. Raw analytical data are included as an appendix. The arithmetic mean, standard deviation, minimum and maximum values were calculated from the raw data and incorporated into the Background Soil Concentration Database.

Delaware Department of Natural Resources and Environmental Control. The Delaware Department of Natural Resources and Environmental Control (DNR & EC) published "default" background standards to be used for remediation purposes. These default values for 20 metals are the upper value of the concentration range in soil samples collected at background locations at remediation sites across the state (Delaware DNR& EC 1998). The Delaware DNR & EC (1998) did not provide information on the type of mean value (arithmetic or geometric) presented. However, an agency representative was contacted and confirmed that the mean values represented are the arithmetic means. As a result of time and resource constraints these results were not incorporated into the Background Soil Concentration Database.

Massachusetts Department of Environmental Protection. The Massachusetts Department of Environmental Protection has published background soil concentrations for 20 metals that reportedly represent non-urban (suburban and rural) areas. These concentrations may be used in lieu of site-specific background concentrations for risk assessments in Massachusetts (MADEP1995). MADEP (1995) provides both the arithmetic and geometric mean background value. The background concentrations were collected from "counties within metropolitan statistical areas". Therefore, samples used to represent background concentration values could have the following biases [excerpted from MADEP 1995, page 2-44]:

1) the samples were taken in the vicinity of disposal sites and may in fact have been affected by the contamination at the sites;

2) background samples are more likely to be taken (and reported to MADEP) in areas with relatively high background concentrations; samples are less likely to be taken if the concentrations at the site are so low that they are "obviously" background;

3) it is possible that some samples taken as background at sites were not included in reports submitted to MADEP;

4) high background samples at sites may have been mistaken for contaminated samples and not identified as "background".

Given the uncertainty in the accuracy of this data set to represent natural background concentrations, these data were not incorporated into the Background Soil Concentration Database.

Illinois Environmental Protection Agency. The Illinois Environmental Protection Agency (ILEPA) has published background concentrations for 26 metals as part of the guidance for corrective action objectives (Section 742.405, Appendix A). These values were used for the development of remedial action objectives for public health risks as required under the State environmental regulations. The background concentrations as defined under these regulations, however, do not necessarily represent concentrations present under undisturbed conditions (ILEPA 1997). An agency representative was contacted to clarify the criteria used to define background conditions for the study. The representative stated that samples were collected from undisturbed and unimpacted sites within and outside of metropolitan areas. As a result of time and resource constraints these results were not incorporated into the Background Soil Concentration Database.

Other Studies. Upon review, several other studies were found either to not contain any background soil data or they provided data for chemicals or regions outside of the scope of the Eco-SSL effort. These studies are identified below.

Efroymson, R.A., M.E. Will, G.W. Suter, and A.C. Wooten. 1997. *Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants: 1997 Revision*. Oak Ridge National Laboratory ES/ER/TM-85/R3. November 1997.

Efroymson, R.A., M.E. Will, and G.W. Suter. 1997. *Toxicological Benchmarks for Contaminants of Potential Concern for Effects on Soil and Litter Invertebrates and Heterotrophic Process: 1997 Revision*. Oak Ridge National Laboratory ES/ER/TM-126/R2. November 1997.

Miesch, A.T. 1967. *Methods of Computation for Estimating Geochemical Abundances.* US Geological Survey Professional Paper 574-B.

Ontario Ministry of Environment and Energy. 1993. *Ontario Typical Range of Chemical Parameters in Soil, Vegetation, Moss Bags and Snow, Version 1.0a.* Ministry of Environment and Energy. December 1993.

Sell, J.L., F.D. Deitz, and M.L. Buchanan. 1975. Concentration of Mercury in Animal Products and Soils of North Dakota. *Archives of Environmental Contamination.* 3:278-288.

Additional studies of background concentrations of metal in soil may continue to be identified, reviewed, and incorporated into the Background Soil Concentration Database at a later date. Currently, several publications are identified but have not been added to the database. These include:

Fields, T.W., T.F. McNevin, and R.A. Harkov. 1993. *A summary of Selected Soil Constituents and Contaminants at Background Locations in New Jersey.* New Jersey Department Environmental Protection and Energy. September 1993.

Gough, L.P., R.C. Severson, and H.T. Shacklette. 1988. *Element Concentrations in Soils and Other Surficial Materials of Alaska*. US Geological Survey Professional Paper 1458.

Markert, B. and Z.D. Li. 1991. Natural Background Concentrations of Rare-Earth Elements in a Forest Ecosystem. *The Science of the Total Environment*. 103:27-35.

New Hampshire Department of Environmental Services. 1998. *Contaminated Sites Risk Characterization and Management Policy*. January 1998.

Walsh, L.M., M.E. Sumner, and D.R. Keeney. 1977. Occurrence and Distribution of Arsenic in Soils and Plants. *Environmental Health Perspectives* 19:67-71.

Wright, J.R., R. Levick, and H.J. Atkinson. 1955. Trace Element Distribution in Virgin Profiles Representing Four Great Soil Groups. *Soil Science Society Proceedings* 19(3):340-344.

2.3.3 Background Concentrations from CERCLIS-3 Records

The CERCLIS-3 database stores quantitative site data from each record of decision (ROD) that has been signed, generally since 1996. Although the CERCLIS-3 database is structured for easy retrieval of site-specific data, it was not possible to filter the background data set for surficial soils only. Therefore, all background concentrations in soil for the Eco-SSL metals were extracted. An EPA employee queried the CERCLIS-3 database yielding records reporting background concentrations in soil from 60 sites across the United States. The query output included the following information: EPA Region, state, site name, operable unit number, date the ROD was signed, metal name, metal background concentration, units of measure and the method used to determine the background concentration (e.g., 95% UCL, arithmetic mean, etc.). The data for each Superfund site are reported using a variety of descriptive statistics including the arithmetic mean, geometric mean, standard deviation, minimum or maximum concentrations.

For each of the metals, the 5^{th}, 25^{th}, 50^{th} (median), 75^{th} and 95^{th} percentiles of the arithmetic means were plotted as a "box-and-whisker" plot. Box-and-whisker plots provide a visual summary of where the bulk of background data are concentrated and the shapes of each distribution. These plots display data under four quartiles with each quartile corresponding to four equal sized sets based on their rank. Figure 2.1 provides a key to the box and whisker data

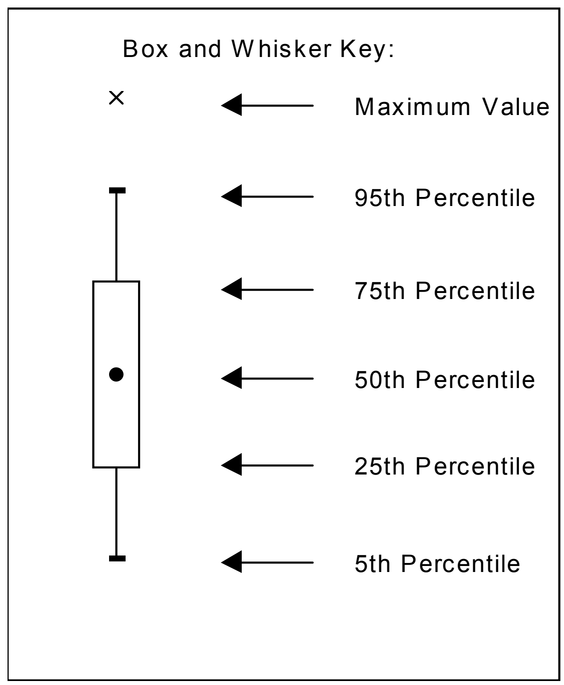

Figure 2.1 Key to Box and Whisker Plots

Figure 2.2 presents box-and-whisker plots of background metal concentrations in soil as reported by geographic region (eastern and western US) to discern relative differences in the distributional characteristics. The background data from CERCLIS-3 is plotted separately against the other eastern and western US data from the datasets discussed in the previous section (summarized in Table 2.2).

Due to the large number of maximum values higher than those reported by others, it is apparent from these plots that CERCLIS-3 captures data that may not be representative of background concentrations. Consequently, the CERCLIS-3 data was not incorporated into the Background Soil database.

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Figure 2.2 Box and Whisker Plots of Background Metals Concentrations

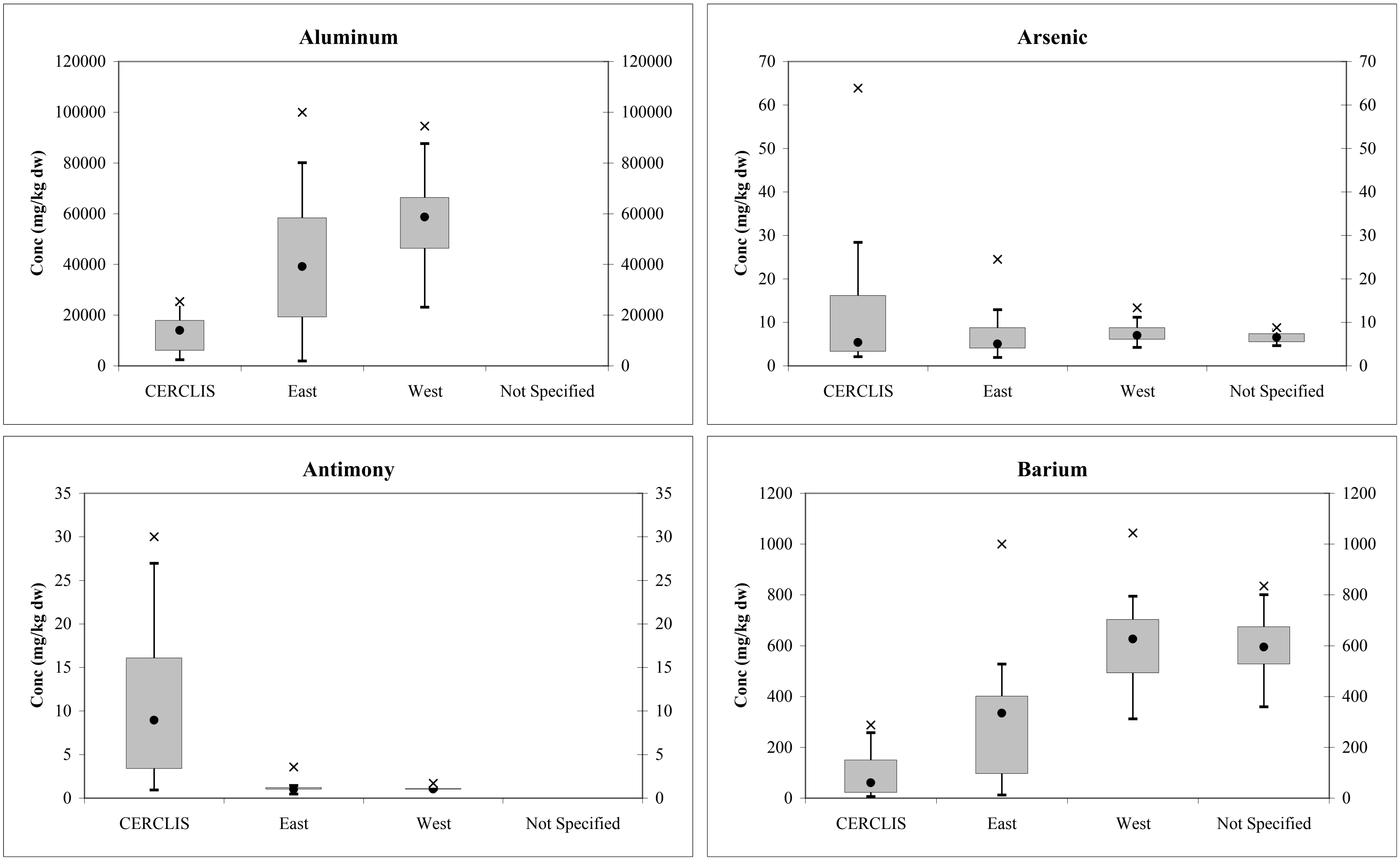
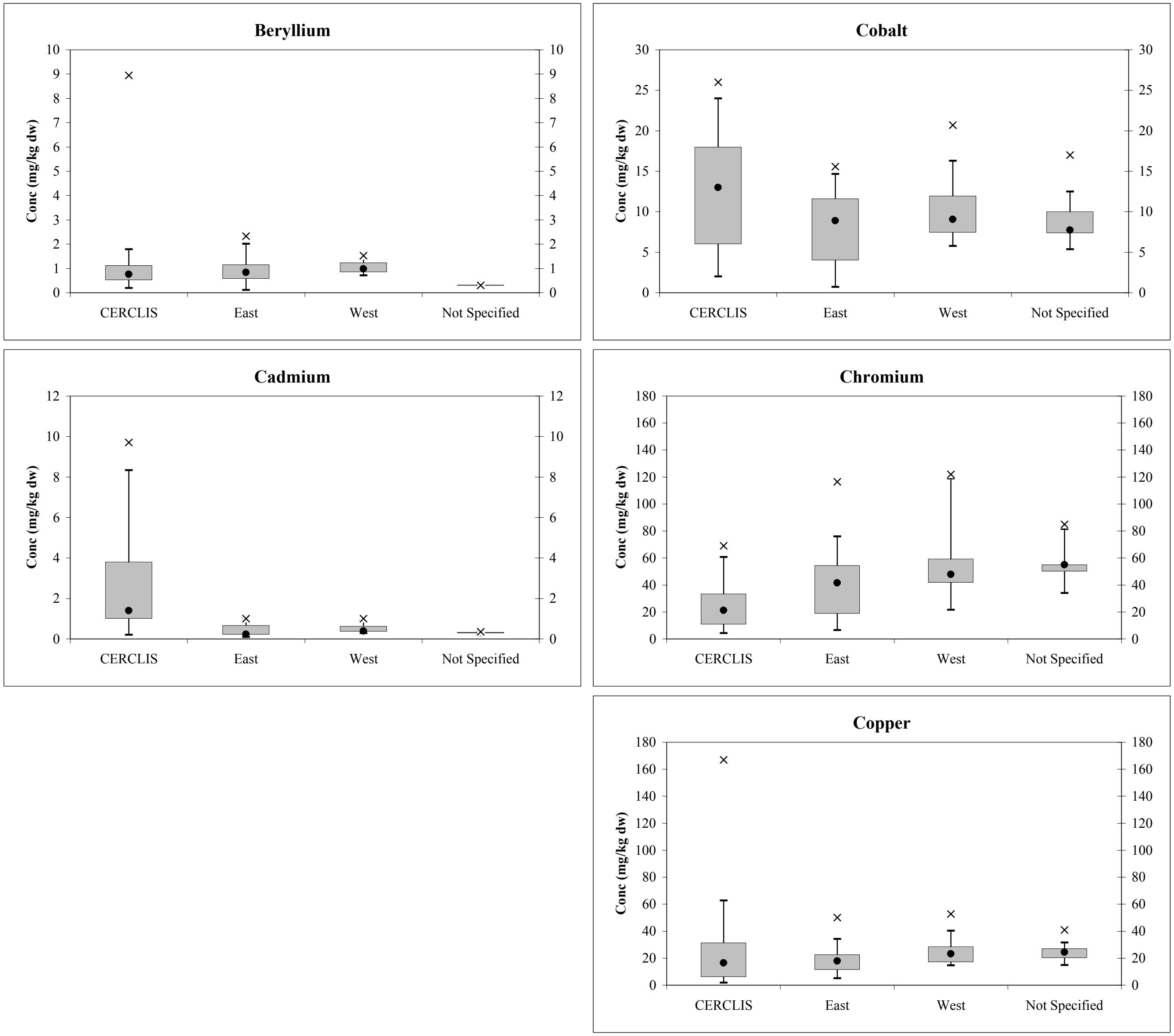


Figure 2.2 Box and Whisker Plots of Background Metals Concentrations



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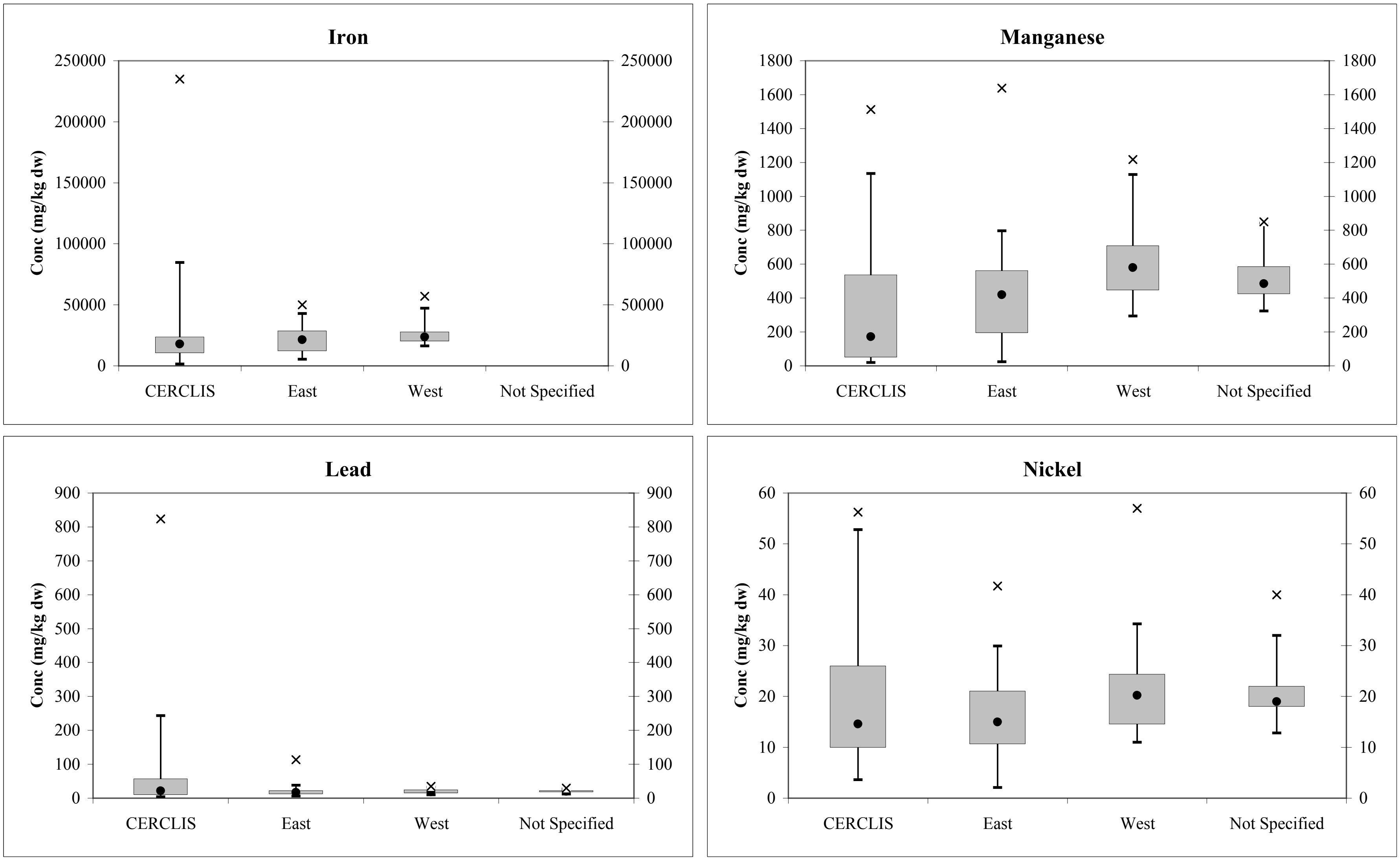

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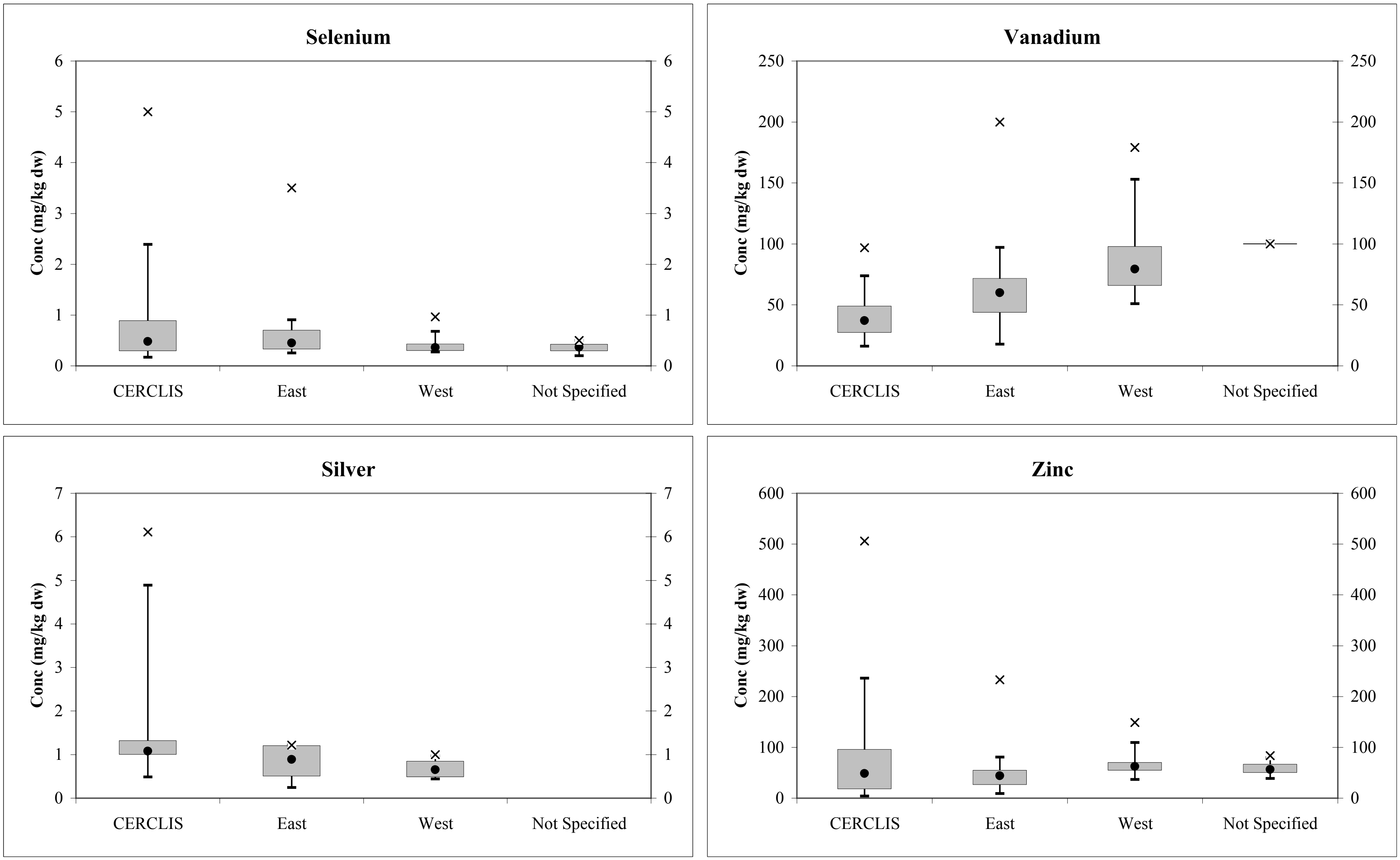


3.0 DATABASE DEVELOPMENT

A Microsoft Access® database was structured such that records for each Eco-SSL metal could be stored and retrieved by the soil type, geographic region, source document and statistics. The datasets included met all of the mandatory requirements. The database is provided in Appendix A as an electronic deliverable.

3.1 Data Evaluation

Table 3.1 provides a summary of the source data used in the database. Wherever soil depth was specified, only the soils samples closest to the surface were retained in the Background Soil Concentration Database. As seen in Table 3.1, information concerning optional data characteristics such as soil type, wet-weight versus dry-weight, sample preparation and analysis methods were often not available.

Because data incorporated into the Background Soil Concentration Database are mean values, these data (specifically non-detects) are already censored. In some cases, non-detect values were reported at one-half the detection limit. This is the standard approach used in risk assessments. In other cases, the non-detect values may have been reported at the detection limit. Unfortunately, most data sources are silent as to how non-detects were handled in the calculation of statistics. The few raw data points reported as non-detects in the database were evaluated at the detection limit.

The topic of unreported detection limits was an issue during database development. In instances where a publication reported non-detect values as "ND" and did not report the associated detection limit, the data point was removed from the database, since a numerical replacement could not be determined. As a result, the remaining data points may characterize a misleadingly high data set.

3.2 Transformation of Data

Most of the data sources used to compile data into the Background Soil Concentration Database provide arithmetic statistics only or both arithmetic and geometric statistics. However, in some cases a report may only present geometric statistics. This combination of different reported statistical data make meaningful comparisons across data sets difficult. Therefore, the source data was normalized in the Background Soil Concentration Database. Data for which geometric mean and standard deviation were available were transformed to arithmetic mean values using the following equation:

$$AM = \exp [\ln GM + (\ln GSD^2/2)]$$

A data set normalized to arithmetic mean (as opposed to geometric mean) was selected for two reasons. First, the source data primarily reports arithmetic means. Second, the arithmetic mean is historically used in risk assessment calculations such as determination of the 95% upper confidence limit, for example.

3.3 Distributional Characteristics

For each of the metals, the 5^{th}, 25^{th}, 50^{th} (median), 75^{th} and 95^{th} percentiles of the arithmetic means were determined and plotted as a "box-and-whisker" plot. Box-and-whisker plots provide a visual summary of where the bulk of background data are concentrated and the shapes of each distribution. These plots display data under four quartiles with each quartile corresponding to four equal sized sets based on their rank.

Figure 3.1 presents box-and-whisker plots of background metal concentrations in soil as reported by geographic region (eastern and western US) to discern relative differences in the distributional characteristics. Figure 3.2 provides a key to the box and whisker data.

Figure 3.1 Box and Whisker Plots of Background Metals Concentrations

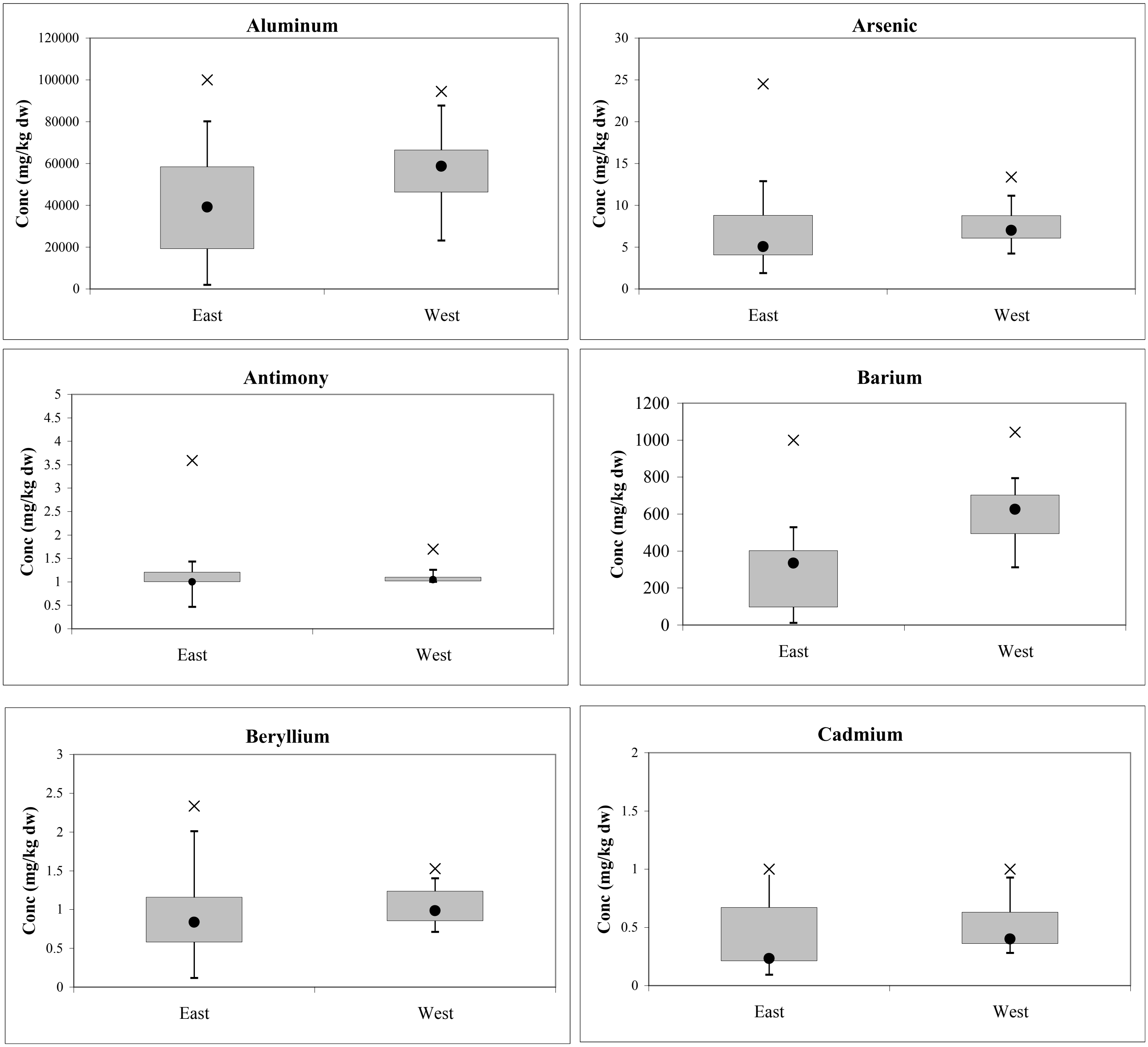


Figure 3.1 Box and Whisker Plots of Background Metals Concentrations

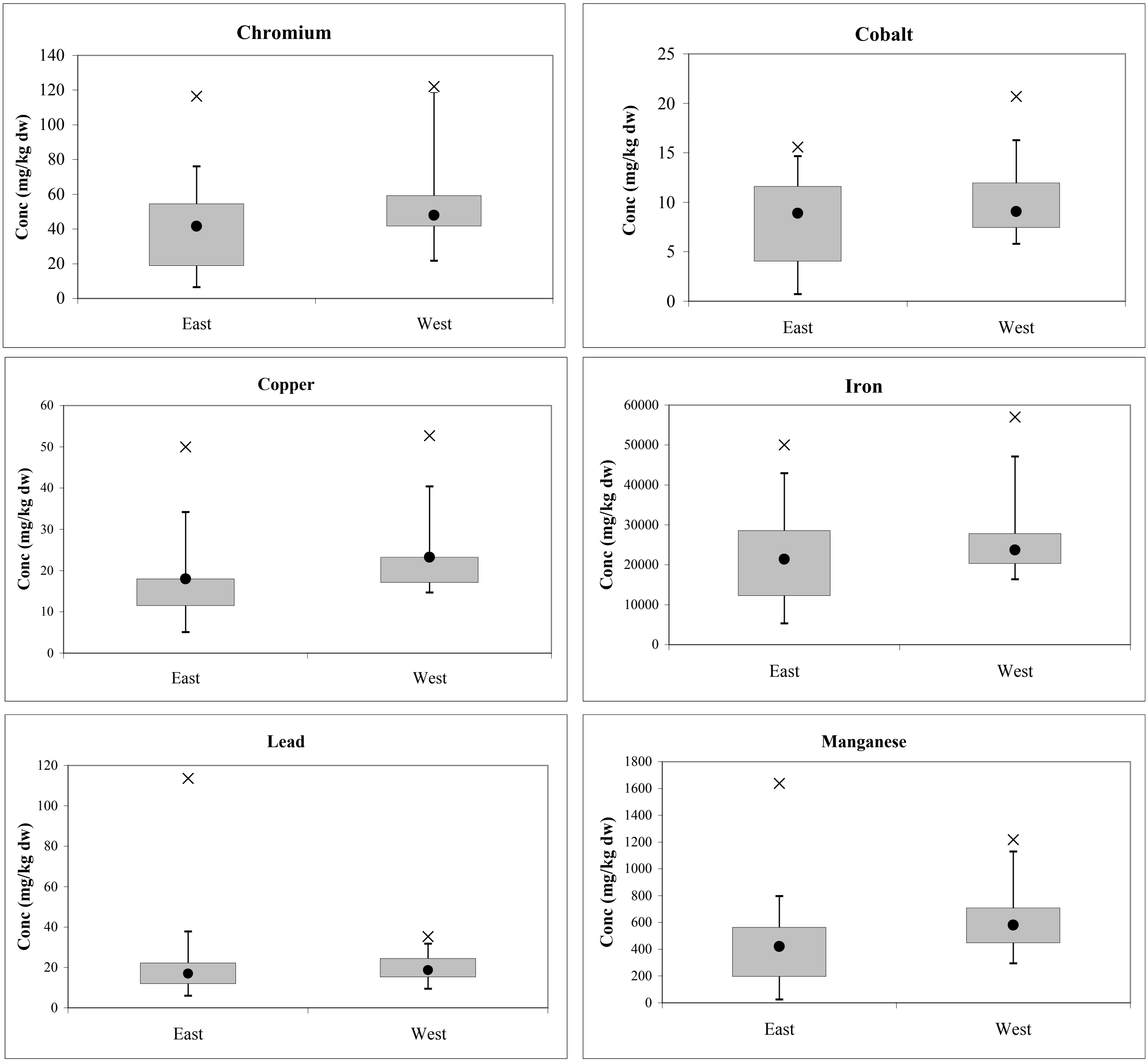
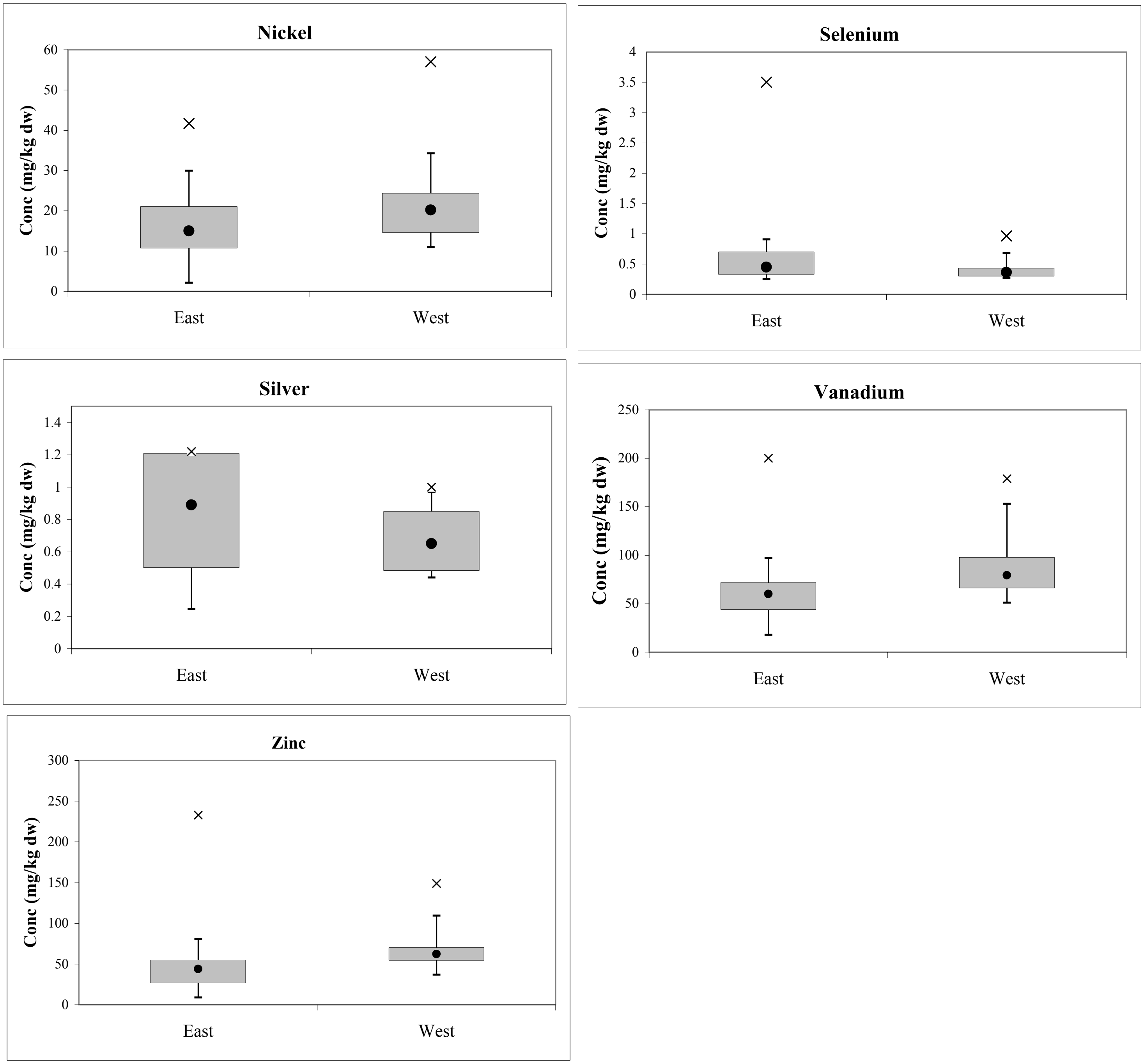


Figure 3.1 Box and Whisker Plots of Background Metals Concentrations



4.0 CONCLUSIONS

The box-and-whisker plots (Figure 3-1) provide an at-glance statistical summary for the background soil concentration data. These appear to indicate that:

- The median values generally reflect the central tendencies in the background data.
- Metals such as aluminum and iron were reported from all data sources and are consistently reported at very high concentrations (typically over 10,000 ppm).
- Metals such as aluminum, barium, iron and manganese display a wide concentration range. The wide range appears to be consistent across data sources and, therefore, represents the variability observed across the United States for these metals.
- Background concentrations of toxic heavy metals such as arsenic, beryllium, cadmium, copper, lead, and zinc fall are reported from most data sources within a relatively narrow concentration range.
- For a selected group of metals there is considerable regional variation (eastern versus western US) which likely reflects natural variation in the geochemical composition of soils.

5.0 REFERENCES

Ames, K.C. and D.B. Hawkins. 1997. *Statistical Analysis and Area Trends of Background Concentrations of Metals in Soils of Clark County, Washington.* USGS Water-Resources Investigations Report 96-4252, Tacoma, WA 1997.

Arizona Department of Environmental Quality, Groundwater Hydrology Section, (ADEQ). 1991. *Evaluation of Background Metal Concentrations in Arizona Soils. Prepared by the Earth Technology Corporation* (Source: Boerngen and Shacklette, 1981).

Barringer, J.L. Z. Szabo and T.H. Barringer. 1998. *Arsenic and Metals in Soils in the Vacinity of the Imperial Oil Company Superfund Site, Marlboro Township, Monmouth County, New Jersey*. USGS Water-Resources Investigations Report 98-4016. West Trenton, NJ. 1998.

Bradford, G.R., A.C. Chang, A.L. Page, D. Bakhtar, J.A. Frampton, and H. Wright. 1996. *Background Concentrations of Trace and Major Elements in California Soils*. University of California, Division of Agriculture and Natural Resources. March 1996.

Breckenridge, R.P. and A. B. Crockett. 1995. *Determination of Background Concentrations of Inorganics in Soils and Sediments at Hazardous Waste Sites*. Technology Innovation Office, Office of Solid Waste and Emergency Response, EPA/540/S-96/500, Washington, DC.

Chen, M., L.Q. Ma, and W.G. Harris. 1999. Baseline Concentration of 15 Trace Elements in Florida Surface Soils. *Journal of Environmental Quality*. 28:1173-1181.

Connor, J.J., and H.T. Shacklette. 1975. *Background Geochemistry of Some Rocks, Soils, Plants, and Vegetables in the Conterminous United States*. United States Government Printing Office, Washington DC.

Delaware Department of Natural Resources and Environmental Control (Delaware DNR & EC). 1997. *Delaware Default Background Remediation Standards*. Draft Final, December.

Efroymson, R.A., M.E. Will, and G.W. Suter II. 1997. *Toxicological Benchmarks for Contaminants of Potential Concern for Effects on Soil and Litter Invertebrates and Heterotrophic Process: 1997 Revision*. ES/ER/TM-126/R2. Prepared for the U.S. Department of Energy, Office of Environmental Management (EW20) by Lockheed Martin Energy Systems, Inc. Oak Ridge, TN. November 1997.

Efroymson, RA, ME Will, GW Suter II, AC Wooten. 1997. Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants: 1997 Revision. Oak Ridge National Laboratory ES/ER/TM-85/R3. November 1997.

Fields, T.W., T.F. McNevin, and R.A. Harkov. 1993. *A summary of Selected Soil Constituents and Contaminants at Background Locations in New Jersey*. New Jersey Department Environmental Protection and Energy. September 1993.

Gough, L.P., R.C. Severson, and H.T. Shacklette. 1988. *Element Concentrations in Soils and Other Surficial Materials of Alaska.* US Geological Survey Professional Paper 1458.

Holmgren, G.G.S., M.W. Meyer, R.L. Chaney and R.B. Daniels. 1993. Cadmium, Lead, Zinc, Copper, and Nickel in Agricultural Soils of the United States of America. *Journal of Environmental Quality*. 22:335-348.

Illinois Environmental Protection Agency (ILEPA). 1997. *Determining Area Background (Subpart D), under Title 35 of the Illinois Administrative Code, Environmental Protection, Subtitle G: Waste Disposal, Chapter I: Pollution Control Board, Sub-Chapter F: Risk-Based Cleanup Objectives*. Part 742. July.

Markert, B and ZD Li. 1991. Natural Background Concentrations of Rare-earth Elements in a Forrest Ecosystem. *Science of the Total Environment*. Vol. 103, No. 1, p. 27.

Massachusetts State Department of Environmental Protection (MADEP). 1995. *Guidance for Disposal Site Risk Characterization. MADEP Background Soil Concentrations*. Boston, MA.

McGovern, E.C. 1988. *Background Concentrations of 20 Elements in Soils with Special Regard for New York State*. New York State Department of Environmental Conservation Report (Unpublished).

Michigan Department of Natural Resources (MDNR). 1991. *Michigan Background Soil Survey (Revised), Michigan Department of Environmental Quality.* Technical Support Unit, Hazardous Waste Program Section, Waste Management Division. Lansing, Michigan.

Miesch, A.T. 1967. *Methods of Computation for Estimating Geochemical Abundances*. U.S. Geological Survey Professional Paper 574-B. Washington, DC.

New Hampshire Department of Environmental Services (NHDES). *Risk Characterization and Management Policy. Subsection 1.5*(4)(c). Table 1: Background Concentrations of Metals in Soil.

New Hampshire Division of Public Health Services (NHDPHS). 1991. *Preliminary Survey of Metal Concentrations in New Hampshire Soils-Final Report*. New Hampshire Division of Public Health Services, Bureau of Health Risk Assessment. DPHS Document No. 91-004. May 1991.

Ontario Ministry of Environment and Energy. 1993. *Ontario Typical Range of Chemical Parameters in Soil, Vegetation, Moss Bags and Snow, Version 1.0a*. Ministry of Environment and Energy. December 1993.

Pierce, F.J., R.H. Dowdy, and D.F. Grigal. 1982. Concentrations of Six Trace Metals in Some Major Minnesota Soil Series. *J. Environmental Quality*., Volume 11, pp. 416-422.

Sell, J.L., F.D. Deitz, and M.L. Buchanan. 1975. Concentration of Mercury in Animal Products and Soils of North Dakota. *Archives of Environmental Contamination* 3:278-288.

Shacklette, H.T., and J.G. Boerngen. 1984. *Element Concentrations in Soils and Other Surficial Materials of the Conterminous United States*. United States Government Printing Office, Washington DC.

United States Environmental Protection Agency (U.S. EPA). 2002. *Role of Background in the CERCLA Cleanup Program*. U.S. EPA Office of Solid Waste and Emergency Response, Office of Emergency and Remedial Response, April 26, 2002. OSWER 9285.6-07P.

United States Geological Survey (USGS). 2001. *Geochemical Landscapes of the Conterminous United States–New Map Presentations for 22 Elements*. USGS Professional Paper 1648.

Walsh, L.M., M.E. Sumner, and D.R. Keeney. 1977. Occurrence and Distribution of Arsenic in Soils and Plants. *Environmental Health Perspectives* 19:67-71.

Washington Department of Ecology (WSDOE). 1994. *Natural Background Soil Metals Concentrations in Washington State*. Pub. #94-115.

Watkins, D.R., J.T. Ammons, J.L. Branson, B.B. Burgoa, et al. 1993. *Final Report on the Background Soil Concentration Project at the Oak Ridge Reservation, Oak Ridge Tennessee, Vols. 1 and 2*. EE/ER/TM-84. Oak Ridge National Laboratory, Environmental Restoration Division.

Wright, J.R., R. Levick, and H.J. Atkinson. 1955. Trace Element Distribution in Virgin Profiles Representing Four Great Soil Groups. *Soil Science Society Proceedings.* 19(3):340-344.