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Hanford Site Soil Background

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Department of Energy
Richland, Washington

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EXECUTIVE SUMMARY

The determination of representative soil background is one of the most important activities supporting environmental restoration and waste management at the Hanford Site. Background is used in defining contamination and establishing cleanup levels. These uses involve determination of the upper limits for the range of compositions that exist in the Hanford Site vadose zone. It was indicated from previous data and models that the compositions of the soil in the vadose zone might represent a single compositional series. It also was indicated that a Site-wide approach to the characterization of soil background may, therefore, be justified because all waste management units impact a single vadose zone (soil and sediments). As a result, an effort to systematically sample and analyze samples representative of the vadose zone at the Hanford Site was initiated. This report contains a description of these efforts and a summary of results obtained to date, including background threshold levels for six organic analytes.

The conceptual model developed previously for what soil compositions represent, and the nature and scale of compositional variability, was used to guide sampling and analysis activities. The key elements of this model are that (1) the compositions of most vadose zone soils and sediments should be related because they have common origins and physical compositions and (2) the compositions of the entire vadose zone appear to be dominated by the amounts of two ubiquitous constituents in the soils. Thus the natural range of compositions should fall between these two end members for essentially all constituents except for those strongly influenced by volumetrically minor end members.

The primary objective of this study was to obtain a more complete and representative characterization of the range of chemical constituents that occur naturally in the vadose zone soil. These data are intended for use in establishing upper bounds of naturally occurring constituents that might be regarded as dangerous wastes if the constituents exceed background levels. Results of this study will be used to guide the interpretation of new data. This document contains the results to date of this sampling and analysis effort for the Hanford Site vadose zone. Based on the current understanding of the geology, hydrology, and geochemistry of the Hanford Site, preliminary assessment of these data corroborates the Site-wide soil background conceptual model.

Threshold values for six representative inorganic analytes (aluminum, calcium, iron, copper, lead, and sodium) were determined based on the complete analysis of the data and their quality. These soil compositions represent the variability of soil types in the Hanford formation and younger soils. The compositions of these soils with respect to these six analytes represent a single statistical population for each of the constituents with the exception of sodium. This is consistent with the variability in the natural repositories of sodium in the soils (e.g., minerals) and its geochemical behavior. Background threshold concentrations represent the levels that should not be exceeded 95 percent of the time with a confidence of 95 percent.

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In addition to the threshold values, the report also contains a description of sampling activities, justification of sampling site locations, and a description of the data evaluation process. This description of the methodology and approach in establishing soil background threshold valves is included to allow the regulators to furnish comments on the approach before finalizing the remainder of the evaluation. Results of data analysis should be considered tentative until all analyses are completed.

DOCUMENT CONTENTS

EXECUTIVE SUMMARY

ACRONYMS AND ABBREVIATIONS

DEFINITION OF TERMS

1.0 INTRODUCTION

2.0 MEDIA DESCRIPTION

3.0 DATA SOURCES

4.0 DATA EVALUATION

5.0 SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

6.0 REFERENCES

APPENDICES

A SOIL SAMPLING OBJECTIVES AND SITE DESCRIPTIONS

B SAMPLING NARRATIVE

C RAW DATA SOIL BACKGROUND

D BACKGROUND DATA ANALYSIS

1

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ACRONYMS AND ABBREVIATIONS

ASTM	American Society for Testing and Materials
BWIP	Basalt Waste Isolation Project
CDF	cumulative distribution function
CERCLA	*Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
CLP	contract laboratory program
CRB	Columbia River Basalts
DOE	U.S. Department of Energy
DQO	data quality objectives
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
GF/AA	graphite furnace atomic absorbance
ICP	inductively coupled plasma
LOD	limit of detection
LOQ	limit of quantification
MTCA	Model Toxics Control Act (WAC 173-340)
OVM	organic vapor monitor
PNL	Pacific Northwest Laboratory
ppm	parts per million
RCRA	*Resource Conservation and Recovery Act of 1976*
TOC	total organic carbon
VOA	volatile organic analysis
VOC	volatile organic chemicals
WAC	Washington Administrative Code
WMU	waste management unit
WPPSS	Washington Public Power Supply System
XRF	x-ray fluorescence

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DEFINITION OF TERMS

Definitions with unidentified sources are based on common usage. Several of the longer definitions have been abridged, as noted at the end of the definition.

Analyte. The element, ion, or compound of interest.

Anthropogenic. Involving the impact of man on nature: induced or altered by the presence and activities of man.

Aquifer. A lithologic unit or combination of units that has appreciably greater water transmissibility than adjacent units. An aquifer stores and transmits water commonly recoverable in economic useable quantities.

Area background. The concentrations of hazardous substances that are consistently present in the environment in the vicinity of a site that are the result of human activities unrelated to the releases from that site.[1]

Background threshold. Based on a tolerance interval approach, background threshold is the concentration level defining the upper limit of what will be considered as part of the background population. Calculating a threshold requires specifying the cumulative frequency distribution, the percentile level, and the coverage. The WAC 173-340-708(11)(d) specifies the 95 percentile and coverage of 95 percent. Departure from the tolerance interval approach requires approval by Ecology for those waste management units under Ecology jurisdiction.

Basalt. A dark- to medium-dark-colored mafic (iron-magnesium rich) extrusive igneous rock with small grains composed primarily of feldspar (calcic plagioclase), pyroxene, with or without olivine, and varying proportions of glass.[2]

Bulk composition. A complete chemical composition of a sample as performed by a method such as x-ray fluorescence or a spectroscopic analysis on a sample completely dissolved by acid digestion preparation techniques.

Cleanup level. The concentration of a hazardous substance in soil, water, air, or sediment that is determined to be protective of human health and the environment under specified exposure conditions.[1]

Cleanup standards. The standards promulgated under the Revised Code of Washington 70.105D.030(2)(d). Establishing cleanup standards requires specification of the following:

- Hazardous substance concentrations that protect human health and the environment ('cleanup levels')

- The location and site where those cleanup levels must be attained ('point of compliance')

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- Additional regulatory requirements that apply to a cleanup action because of the type of action and/or the location of the site.

These requirements are specified in applicable federal and state laws and generally are established following selection of a specific cleanup action.[1]

Conceptual model. A symbolic representation of the essential characteristics of a physical system. The representation can be in language, image, or mathematical form.

Contaminant. Any hazardous substance that does not occur naturally or occurs at greater than natural background levels.[1]

Data quality objectives. These are qualitative and quantitative statements that specify the quality of the data required to support agency (EPA) decisions during remedial response activities. For example, depending on the project phase, sufficient data may have to be collected to characterize the site, evaluate remedial alternatives, determine design criteria, or monitor site conditions and/or remedial action effectiveness (EPA/540/g-7/003).[3]

End member. (a) One of the two or more simple compounds of which an isomorphous (solid solution) series is composed. For example, the end members of the plagioclase feldspar series are albite ($NaAlSi_3O_8$) and anorthite ($CaAl_2Si_2O_8$). (b) One of the two extremes of a series, e.g., types of sedimentary rock or fossils.[4]

Eolian. (a) Pertaining to the wind; especially said of such deposits as loess and dune sand, of sedimentary structures such as wind formed ripple marks, or of erosion and deposition accomplished by the wind. (b) Said of the active phase of a dune cycle, marked by diminished vegetal control and increased dune growth.[4]

Feldspar. A group of silicate minerals that make up about 60 percent of the outer 15 km of the Earth's crust; the minerals are silicates of aluminum with the metals potassium, sodium, and calcium, and rarely, barium.[2]

Fluvial. (a) Of or pertaining to a river or rivers. (b) Existing, growing, or living in or about a stream or river. (c) Produced by the action of a stream or river.[4]

Groundwater. Water in a saturated zone or stratum beneath the surface of land or below a surface water[1].

Leachate. The liquid resulting from the partial acid digestion and dissolution of a sample. The material resulting from the acid digestion sample preparation method identified by regulatory protocol (e.g., Method 3050 in EPA's SW-846 guidance).

Local background. Same as area background.

Loess. A widespread, homogenous, fine-grained blanket deposit (generally less than 98.4 feet (30 meters) thick), consisting predominately of silt with subordinate grain sizes ranging from clay to fine sand. Loess is generally buff to light yellow or yellowish brown. Loess now is generally believed to be windblown dust of Pleistocene age, carried from desert surfaces, alluvial valleys, and outwash plains, or from unconsolidated glacial or glaciofluvial deposits. The mineral grains, composed mostly of silica and associated heavy minerals, are fresh and angular and generally are held together by calcareous cement. (abridged)[4]

Natural background. The concentration of a hazardous substance consistently present in the environment that has not been influenced by local human activities. For example, several metals naturally occur in the bedrock and soils of Washington State due to the geologic processes that formed these materials, and the concentration of these metals would be considered natural background. Also, low concentrations of some particularly persistent organic compounds such as polychlorinated biphenols (PCBs) can be found in the surficial soils and sediment throughout much of Washington State because of the global use of these hazardous substances. These low concentrations would be considered natural background. Similarly, concentrations of various radionuclides that are present at low concentrations throughout Washington State because of distribution of global radioactive fallout would be considered natural background.[1]

Nugget effect. The variation in sample concentration levels caused by the presence of a nugget of a mineral or phase that is modally subordinate in the parent material.

Operable unit. A group of contiguous past-practice waste sites related by site characteristics or operations so as to be considered collectively for purposes of environmental restoration under the CERCLA process.

Quartz. (a) Crystalline silica, an important rock-forming mineral: SiO_2. (b) A general term for a variety of noncrystalline or cryptocrystalline minerals having the same chemical composition as that of quartz, such as chalcedony, agate, and opal. (abridged)[4]

Sediment. (a) Solid fragmental material that originates from weathering of rocks and is transported by air, water, or ice, or that accumulates by other natural agents, such as chemical precipitation from solution or secretion by organisms; and that forms in layers on the Earth's surfaces at ordinary temperatures in a loose unconsolidated form; e.g., sand, gravel, silt, mud, till, loess, alluvium. (b) Strictly solid material that has settled from a state of suspension in a liquid. In the singular, the term is usually applied to material held in suspension in water or recently deposited from suspension. In the plural, the term is applied to all kinds of deposits, and refers to essentially unconsolidated materials.[4]

Site-wide background or Site background. The natural background of the Hanford Site. Includes all contributions from anthropogenic sources unrelated to the Hanford Site operations, e.g., regional agricultural chemicals, nuclear weapons testing fallout, etc.

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Soil. A mixture of organic and inorganic solids and biota that exists on the Earth's surface above bedrock.

TSD facility. Treatment, storage, and/or disposal facility. A RCRA designation for a facility that handles hazardous waste.

Unconfined aquifer. An aquifer having a water table; an aquifer containing unconfined groundwater.[4]

Unit background. Same as area background, applied to a waste management unit.

Vadose zone. Zone of aeration. A subsurface zone containing water under pressure less than that of the atmosphere, including water held by capillarity; and containing air or gases generally under atmospheric pressure. This zone is limited above by the land surface and below by the surface of the 'zone of saturation', i.e., the water table. (abridged)[4]

Waste management unit. A location on the Hanford Site where waste has or may have been placed, either planned or unplanned, as identified in the Tri-Party Agreement.

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[1] *Model Toxics Control Act Cleanup Regulations*, as amended, WAC Chapter 173-340.

[2] *Basalt Waste Isolation Project Glossary*, SD-BWI-PMP-005, Rockwell Hanford Operations, Richland, Washington.

[3] EPA documentation as referenced in each definition.

[4] Bates, R.L., 1990, "Glossary of Geology", J.A. Jackson, ed., American Geological Institute, Falls Church, Virginia.

CONTENTS

1.0 INTRODUCTION 1-1

1.1 SITE-WIDE APPROACH TO BACKGROUND CHARACTERIZATION 1-1

1.2 REPRESENTATIVE CHARACTERIZATION AND USE OF BACKGROUND 1-3

1.3 BACKGROUND CONCEPTUAL MODEL 1-4

1.4 REPORT ORGANIZATION 1-5

1

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1.0 INTRODUCTION

A fundamental principle in most environmental regulations is that the natural environment should be used as a baseline for defining contamination and cleanup levels (e.g., EPA 1986; Washington Administrative Code (WAC) 173-303 and 173-340). The implied concepts in these regulations are that (1) concentrations of chemicals that naturally occur in the environment generally are not harmful to human health and the environment and (2) the natural environment should not be remediated because remediation would serve no practical purpose. Determination of the range of naturally occurring chemicals is, therefore, one of the most important activities in the environmental restoration mission at the Hanford Site. The focus of this report is to provide a preliminary assessment of the establishment of soil background for nonradioactive, inorganic constituents at the Hanford Site.

The term 'background' generally refers to the composition of a medium that has not been effected by activities at a waste management unit (WMU; refer to Glossary for definitions of terms, abbreviations, and acronyms). Several different definitions of background exist in the regulatory guidelines. The ambient concentration of chemicals present in the environment uninfluenced by human activities is defined as natural background by the U.S. Environmental Protection Agency (EPA) (EPA 1989c). The concentration of chemicals consistently present in the environment due to human-made, nonsite sources (i.e., agriculture, automobiles) is defined by the EPA as anthropogenic background (EPA 1989c), and as natural background by the Washington State Department of Ecology (Ecology) (WAC 173-303). Background, as used in this report, is intended to be consistent with the EPA definition of natural background.

Background sampling generally is conducted to distinguish site-related contamination from naturally occurring or other non-site related levels of chemicals in media and also to establish baseline risk levels for the protection of human health and the environment (EPA 1989c). The background-based definition of contamination, i.e., concentrations larger than those that occur naturally, often supersedes more general standards in environmental restoration efforts because the concentration levels of natural background vary from region to region (EPA 1989c). In risk assessment activities, the natural range of chemical concentrations is used to constrain the levels of human and ecosystem exposure to chemicals that are normal for the site or region. Because the concentrations of chemicals that occur naturally are generally not regarded as harmful to humans or the environment, background compositions provide a lower bound for the levels of chemicals in the environment.

1.1 SITE-WIDE APPROACH TO BACKGROUND CHARACTERIZATION

The current approach for characterizing WMUs on the Hanford Site is to establish a local background for each treatment, storage, and/or disposal unit and each operable unit. The composition of soil and/or groundwater from each WMU is compared to the WMU-background to define contamination and assess risk.

This approach has lead to inconsistencies in identifying contamination and in the evaluation of restoration and baseline risk levels. Consequently, this approach yields different definitions of contamination and different assessments of remediation goals and risk for each WMU, even those WMUs that are adjacent or superimposed.

An alternative approach is to develop a single Hanford Site background for all the sediments in the vadose zone with the same basic characteristics, and a single background for groundwater in the unconfined aquifer. This approach is based on the premise that all the WMUs share a common sequence of vadose zone sediments and a single unconfined aquifer. In this approach, the range of natural compositions within these media is used to establish the Hanford Site background for soil.

To properly characterize the background levels on a local or regional level, the soil must be representative of the area. Regulatory protocols also require that background samples be unimpacted by activities in the WMU (EPA 1986). The validity of the Site-wide approach to background characterization is based on the fact that all the WMUs share a common sequence of vadose zone sediments. In this approach, the range of natural compositions within the vadose zone is used to establish the Hanford Site background for soil. Evaluation of the geochemistry of the soils will lead to a single background value for each constituent of concern.

The following objectives directed the gathering of data:

1. Demonstrate the validity of the Site-wide background concepts as described in *Characterization and Use of Soil and Groundwater Background for the Hanford Site* (WHC 1991a)

2. Determine the soil background threshold values, based on tolerance intervals as specified in Model Toxics Control Act (MTCA) Cleanup Regulation (WAC 173-340)

3. Determine that the data quality objectives specified as part of the *Site-wide Background Soil Sampling Plan* (WHC 1991b) were achieved.

Threshold values for six representative inorganic analytes (aluminum, calcium, iron, copper, lead, and sodium) were determined based on the complete analysis of the data described in this report. The soil compositions represent the variability of soil types in the Hanford formation and younger soils. The compositions of these soils with respect to these six analytes represent a single statistical population for each of the constituents with the exception of sodium. This is consistent with the variability in the natural repositories of sodium in the soils (e.g., minerals) and its geochemical behavior.

1.2 REPRESENTATIVE CHARACTERIZATION AND USE OF BACKGROUND

For the purpose of environmental restoration, natural background must represent the natural range of compositions within the medium of concern. The characterization of background also must be performed on the same scale as the environmental restoration activities to accurately represent the potential range of compositions.

Background levels obtained from individual WMUs might not represent natural background for an entire site, such as the Hanford Site, for the following reasons.

- The sampled soils would not necessarily be representative of the range of compositions found throughout the Hanford Site.
- Environmental restoration activities typically involve soil impacted by more than one WMU.
- Restoration activities are performed on the scale of the impacted medium rather than the scale of individual WMUs.

This last point addresses the concept that restoration activities must be evaluated and performed on the scale that considers past and present operations that have influenced the soil. In most cases, the scale that should be considered for background characterization in environmental restoration activities is larger than the dimensions of individual WMUs.

One concern regarding the use of a site background is whether levels of contamination within the range of natural background pose a risk to human health or the environment. The regulatory agencies recognize that not all contamination poses a threat to human health or to the environment or warrants remediation. For example, regulatory guidelines indicate that chemicals that are present within the range of naturally occurring levels do not pose a risk to human health or the environment unless the natural background levels themselves pose a risk (EPA 1989c). Concerns regarding ecosystem sensitivities to differences in the level of chemicals within the range of natural soil background also have been considered. However, there is no known ecosystem sensitivity of this type within the Hanford Site region, with the exception of small isolated localities in the Cold Creek Valley and West Lake Basin. In these areas, alkali soils that have developed naturally over the past 6,000 years preclude most vegetation, except those species that can tolerate high salt environments (Rickard 1964). Compositional outliers such as this are readily recognizable and are included in the data evaluation process.

Perhaps the most important difference between the WMU-based approach and the site-wide approach to background characterization is in the way that the background characterization impacts evaluations and decisions. Decisions concerning the identification of contamination using individual WMU backgrounds are subject to error because these backgrounds are subsets of the natural range of soil background compositions that exist laterally and vertically throughout the Hanford Site. For example, the composition of soil

that exceeds the local background threshold levels in one area, but that is within the range of the site-wide natural background, would be interpreted as contaminated using a WMU-based background approach. However, for the purposes of environmental restoration, it is impractical to define background, and consequently contamination and baseline risk levels, differently from one place to another for a common medium. Characterization of background has the added benefit of providing a scientific basis to justify as unnecessary the expenditure of resources on remediation efforts of the natural environment.

Representative characterization of the natural range of soil background compositions for the purposes of environmental restoration is best obtained using a Hanford Site-wide approach rather than a WMU-based approach. Site-wide background is intended for use as one of the most appropriate criterion for distinguishing contamination that practically can be considered for corrective action. The main benefits of a site-wide approach to the characterization of background for soil include the following:

- Single representative background as opposed to multiple backgrounds
- Single definition of contamination
- Single assessment of baseline risk for each element
- Greater efficiency in environmental restoration activities.

1.3 BACKGROUND CONCEPTUAL MODEL

Conceptual models are integral components of the recommended process for identifying the objectives and quality of data collection efforts (EPA 1987b). For the purpose of background characterization, the development of conceptual models is useful because the models provide the scientific and technical basis for what soil background compositions represent, and what the compositional populations are or are expected to be. Conceptual models describe the media in the context of the environment in which the media was formed and presently exists. These models are based on information regarding composition, factors that affect composition, and the processes responsible for the lateral, vertical, and temporal variation in composition. In addition, factors that potentially can affect the composition of the media at any point throughout the sampling or analysis process are identified. The conceptual models are revised until an adequate description of the system is obtained. The adequacy of the model is based on factual content and peer review. The model is revised further as new data are obtained and evaluated to improve the description of the natural systems.

The conceptual model that guided the work presented here was fully developed in the document *Characterization and Use of Soil and Groundwater Background for the Hanford Site* (WHC 1991a). The entire vadose zone of the Hanford Site can be represented as a range of compositions that can be defined by two end member compositions. The natural range of compositions should fall between these two end member compositions, with the exception of volumetrically minor constituents. This conceptual model is based on geologic, hydrologic, and geochemical principles. Data types (parameters) include the following:

- Field information on the geologic relationships and history
- Structure
- Stratigraphy
- Physical properties such as grain size
- Lithologic and mineralogic composition, etc.
- Chemical compositional data.

All of these types of data have been collected and evaluated in the course of this investigation.

1.4 REPORT ORGANIZATION

Description of the media on which this soil background model is based is presented in Chapter 2.0. Information regarding field relations is presented in Chapter 3.0. Data evaluation is discussed in Chapter 4.0. Summary and conclusions are presented in Chapter 5.0. Chapter 6.0 contains references used throughout the text and appendices.

Appendix A contains soil objectives and site descriptions. Appendix B contains a narrative for the collection of field samples. Appendix C presents tabular raw data for selected analytes obtained from samples. Appendix D presents the statistical analysis of the background data analysis.

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CONTENTS

2.0 MEDIA DESCRIPTION 2-1

2.1 GENERAL GEOLOGY 2-1

2.2 SUMMARY 2-5

FIGURE

2-1. Hanford Site F2-1
2-2. Generalized Geologic Cross Section through the Hanford Site F2-2

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2.0 MEDIA DESCRIPTION

This chapter discusses the geology of the Hanford Site and its importance to the evaluation of Site-wide soil background. A brief discussion of the chemistry of the soils and weathering products also is included.

2.1 GENERAL GEOLOGY

The Hanford Site is located in the Pasco Basin, which is a structural basin near the center of the Columbia Plateau (Figure 2-1). The Columbia Plateau is formed by a thick sequence of basalt flows known as the Columbia River Basalt Group (McKee et al. 1977, pp. 464-464; Tolan et al. 1989). The basalt bedrock within the Pasco Basin is comprised of several hundred individual flow units which have a total thickness of up to 3 miles (4.8 kilometers) (Orange and Berkman 1985; DOE 1988; Tolan et al. 1989). Intercalated between these basalt flows are volcaniclastic sediments of the Ellensburg Formation.

The suprabasalt sedimentary sequence consists of two main units, the Ringold Formation and the Hanford formation (Brown 1959, p. 6; Routson and Fecht 1979, p. 10; Tallman et al. 1981, pp. 1-2; Bjornstad 1984, 1985; DOE 1988, pp. 1.2-115). The Ringold Formation directly overlies the basalt and consists of moderately consolidated fluvial-lacustrine sediments, which is the principle member for the unconfined aquifers at the Hanford Site. The Ringold Formation is overlain by younger proglacial flood deposits of the Hanford formation. The Hanford formation is locally overlain by eolian dunes, loess deposits, and alluvial deposits largely derived from the reworking of the Hanford formation. These sediments range in thickness from zero to over 1,200 feet (366 meters). A diagrammatic cross section of the suprabasalt sedimentary sequence is shown in Figure 2-2.

The Hanford formation is a relatively unique sequence of sediments. Its unusual origin is associated with the episodic cataclysmic flooding that occurred between about 1 million and 6,000 years before present (Millineaux et al. 1978; Waitt 1980). These floods were the result of the periodic failure and breaching of ice dams associated with marginal lakes of the continental ice sheet (Bretz 1928, 1969; Atwater 1984; Waitt 1984; 1985). One such ice dam was ancient Lake Missoula, which was located in the vicinity of the Idaho Panhandle northeast of Spokane, Washington. The breaching of these ice dams allowed the rapid discharge of vast quantities of water to spread across eastern Washington and down the Columbia River gorge to the Pacific Ocean. These cataclysmic floods shaped the landscape of eastern Washington into a rare geographic province known as the channeled scablands. A small portion of the material that was eroded and mobilized by the flood waters still blankets much of the Columbia Plateau (Easterbrook 1979; Waitt 1984, 1985, 1987). Most of the sediments that form the land surface of the Hanford Site were deposited from these cataclysmic flood waters (Brown 1959; Tallman et al. 1979, pp. 39-49; Routson and Fecht 1979, pp. 20-21; Bjornstad 1984, 1985). The sediments deposited in the Pasco Basin by the ancestral Columbia

River during these periods of cataclysmic flooding are referred to as the Hanford formation.

The Hanford formation consists of a sequence of unconsolidated sedimentary deposits ranging in particle size from boulder gravel to clay. The proportions of particle sizes vary vertically and laterally throughout the formation, and primarily reflect the local energy regimes of the flood waters at various places and times within the episodes of cataclysmic flooding (Tallman et al. 1979, pp. 39-49; Routson and Fecht 1979, pp. 20-21; Bjornstad 1984, 1985; Waitt 1987). The finer grained sediments were deposited under conditions of slow-moving or slack water at channel margins, and in the distal areas of flooding. The coarser, denser, and hydraulically less-mobile gravel and basaltic sand were deposited primarily under conditions of faster flow within the primary flood channels. A succession of alternating and discontinuous layers of very high-energy, coarse-grained gravel deposits to low-energy silt deposits are found throughout the Hanford formation. These high-energy and low-energy flow conditions are responsible for the distinct lateral and vertical distribution of different sized sediments.

Although the silt, sand, and gravel deposits in the Hanford formation have a common origin, the deposits appear strikingly different in outcrop. The finer grained components in all these sediments consist of differing proportions of quartz and feldspar-rich sediment and basaltic-rich sediment. The quartz-feldspar-rich silt and sand is the dominant fine-grained constituent of the slack water deposits, and the basaltic sand is the dominant fine-to medium-grained component in the higher energy sediments. Thus, the primary difference in composition between the smaller particles is in the proportion of basaltic sand and quartz-feldspar-rich sand. It is evident from field investigations that there is a substantial gradation from dominantly quartz-feldspar to primarily basaltic sand within the finer-grained portions of these flood deposits.

Although there is no formalized stratigraphy for the Hanford formation, a preliminary working model has been developed. Four subdivisions have been recognized based on isotopic age dating (Mullineaux 1986; Srana-Wojcicki et al. 1987), and on the basis of paleomagnetics. Secondary structures such as clastic dikes, volcanic ash beds, soil layers, and caliche horizons also are found within the Hanford formation.

Along the Hanford reach of the Columbia River, the composition of the most recent fluvial deposits might or might not be expected to be consistent with the composition of sediments of the Hanford formation. The source regions of these most recent sediments might be considerably different from those of the cataclysmic flood deposits. As will be discussed later, these younger Columbia River sediments appear to be nearly indistinguishable from the array of Hanford Site sediments, even though these sediments have been modified by the effects of weathering and were deposited under different flow conditions.

The eolian deposits that locally veneer the Hanford formation are windblown deposits derived largely from erosion and winnowing of the unconsolidated Hanford formation (DOE 1988). These deposits are manifested as

dunes and/or a sediment veneer (loess) deposited mainly by west-southwesterly winds. The composition of these sediments represent physically fractionated subsets of the Hanford formation. The typically light colored loess and dunes that are dominant on the southern part of the Hanford Site are composed primarily of the remobilized quartz-feldspar rich sand and silt from the slack-water type material. Conversely, the darker colored loess and dunes, which occur on the northern part of the Hanford Site, have a larger component of basaltic sand material.

Subordinant members within the vadose zone, such as clastic dikes, ash beds, and soil and caliche horizons, would be expected to have compositions that differ from those of the Hanford formation. Caliche, for example, is primarily calcium carbonate with small amounts of strontium in solid solution with the calcium. Volcanic ashes deposited during the eruption of Cascade volcanoes are primarily dacitic to rhyolitic in composition. Each of these ash types have different trace element characteristics. In most cases, clastic dikes are derived from the fluidization of fine-to medium-grained sediments of the Hanford formation. Soil horizons result from the influence of plant and animal activity, which causes the composition of soils to differ from that of the parent sediments. The precipitation of salts occurs under certain conditions that can, over long periods, produce an appreciable *in situ* salt content in the upper few feet of the vadose zone. Alkali soils have developed naturally over the past 6,000 years in certain places on the Hanford Site; these soils preclude most vegetation, with the exception of those plants that can tolerate high salt environments (Rickard 1964).

The terms soil and sediment used in this report both describe the unconsolidated earth materials that comprise the vadose zone on the Hanford Site. These terms have specific meanings in environmental regulations that differ from those used in the scientific and engineering communities. For the purpose of this report, the terms soil and sediment are interchangeable and refer collectively to these materials in the vadose zone. However, the term sediment is used in the geologic context in describing the geology of the vadose zone materials, and the term soil is more specifically applied to that zone near the surface influenced by plants and other biologic activities.

These various types of subordinate members of the vadose zone are included in the soil background model and data evaluation process for completeness, and also to provide a basis for identifying natural compositional outliers. Components of the subordinate members are visually distinguishable from the Hanford formation, and thus can be avoided during field sampling, where appropriate, to reduce the impact of outlier data. Extreme compositions associated with these subordinate members of the vadose zone are to be regarded as separate subsets of natural background, and considered separately from the primary vadose zone soil population.

The portion of the sedimentary sequence that is of most concern to this soil background study is the upper several hundred feet of the Hanford formation that lies above the regional groundwater table, including the younger fluvial and windblown deposits that mantle the surface. It is these sediments within the vadose zone, of common origin, that are of major interest

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because these sediments have been most impacted by the release of waste from Hanford Site operations.

The sediments within the vadose zone are very heterogeneous with respect to their chemical composition and grain size. The bulk composition of the finer grained fraction of these sediments are expected to have compositions that reflect the variable proportions of these constituents. Therefore, mineralogy and grain size of the sediments will be major factors in the reported composition of the sediments. The compositions of these sediments therefore should be representable by a mixing line or a curve between quartz-feldspar and basaltic component compositions. The compositions of these samples also should constitute a single statistical distribution for each constituent.

The eolian sediments are the products of two or more episodes of remobilization and eolian fractionation from the Hanford formation and its counterparts in adjacent areas. Consequently, the composition of the eolian cover on the Hanford Site should be chemically indistinguishable from the composition of the Hanford formation.

The materials that comprise the secondary structures within the Hanford formation inadvertently could be included in a vadose zone soil background and/or WMU sample. Such samples might appear as compositional and statistical outliers. By recognizing that minor though possibly distinct members of the vadose zone exist, the technical basis for evaluating these outliers is improved.

Weathering processes, both physical and chemical, contribute to the breakdown of the sediments in the vadose zone. The importance of chemical weathering in the characterization of soil background depends on the extent to which the composition of the material in the vadose zone is influenced by this process (Leopold et al. 1964, pp. 40-46). Chemical weathering primarily involves reactions between water, air, and rock material. These reactions include hydrolysis, oxidation, and/or the precipitation of calcium carbonate and salts (Fairbridge 1972). The effects of chemical weathering on soil composition are most important only under certain conditions such as in wet climates or in rocks or soils that have reacted with water for sufficiently long periods. Weathering and soil formation in semiarid zones, however, generally is more mechanical than chemical or organic (Fairbridge 1972).

The Hanford Site is a semiarid region that receives about 6 to 8 inches (15 to 20 centimeters) of rainfall annually, most of which returns to the atmosphere by evapotranspiration. Soil moisture profiles (Last et al. 1976; Jones 1978) show that soil moisture generally is less than about 5 percent throughout most of the vadose zone, and that moisture is significantly less in the upper 10 to 20 feet (3 to 6 meters) during the summer months. Consequently, there is only a sparse development of soils over most of the Hanford Site, and these soils support plant growth (DOE 1988) that is largely restricted to the upper few inches of the vadose zone.

The influences of chemical weathering and attendant organic processes on the chemistry of the semiarid soils in the Pasco Basin are expected to be

minor and subordinate to physical weathering and fractionation processes. These relationships are reflected by the relatively unaltered nature of the mineral constituents in the sediments of the vadose zone, and the sparse development of soils that support plant growth. It also is notable that even where these are developed, primary soils in semiarid regions tend to reflect the composition of the underlying material without much change by leaching or chemical alteration (Fairbridge 1972, p. 548).

The chemistry of most vadose zone sediments is, therefore, expected to be controlled by the distribution and modal proportions of minerals and rock materials in the sediments. This control results from the primary depositional mechanisms and secondary eolian processes. The main exceptions are the subordinate members in the vadose zone, as identified previously.

2.2 SUMMARY

The Hanford formation comprises the uppermost portion of the vadose zone at the Hanford Site, and thus is of greatest concern to the Hanford Site-wide background project. This sedimentary unit was deposited by cataclysmic floods associated with glacial lakes, which periodically filled and emptied during the last Ice Age. Although the Hanford formation appears to be heterogeneous, it can be simply described as consisting of a mix of two end member compositions. The Hanford formation is locally overlain by eolian dune, loess deposits, and alluvial deposits largely derived from the reworking of the Hanford formation, which blankets much of the east-central Pasco Basin.

The essential points of the vadose zone are described as follows.

- The Hanford formation is a mixture of quartz-feldspar and basaltic silts and sands plus larger fractions of both types of materials.

- The proportion of quartz-feldspar sands and silts to basaltic sands is the primary factor governing the composition of an individual field sample.

- The occurrence of volumetrically minor components must be accounted for in the interpretation of statistical outliers.

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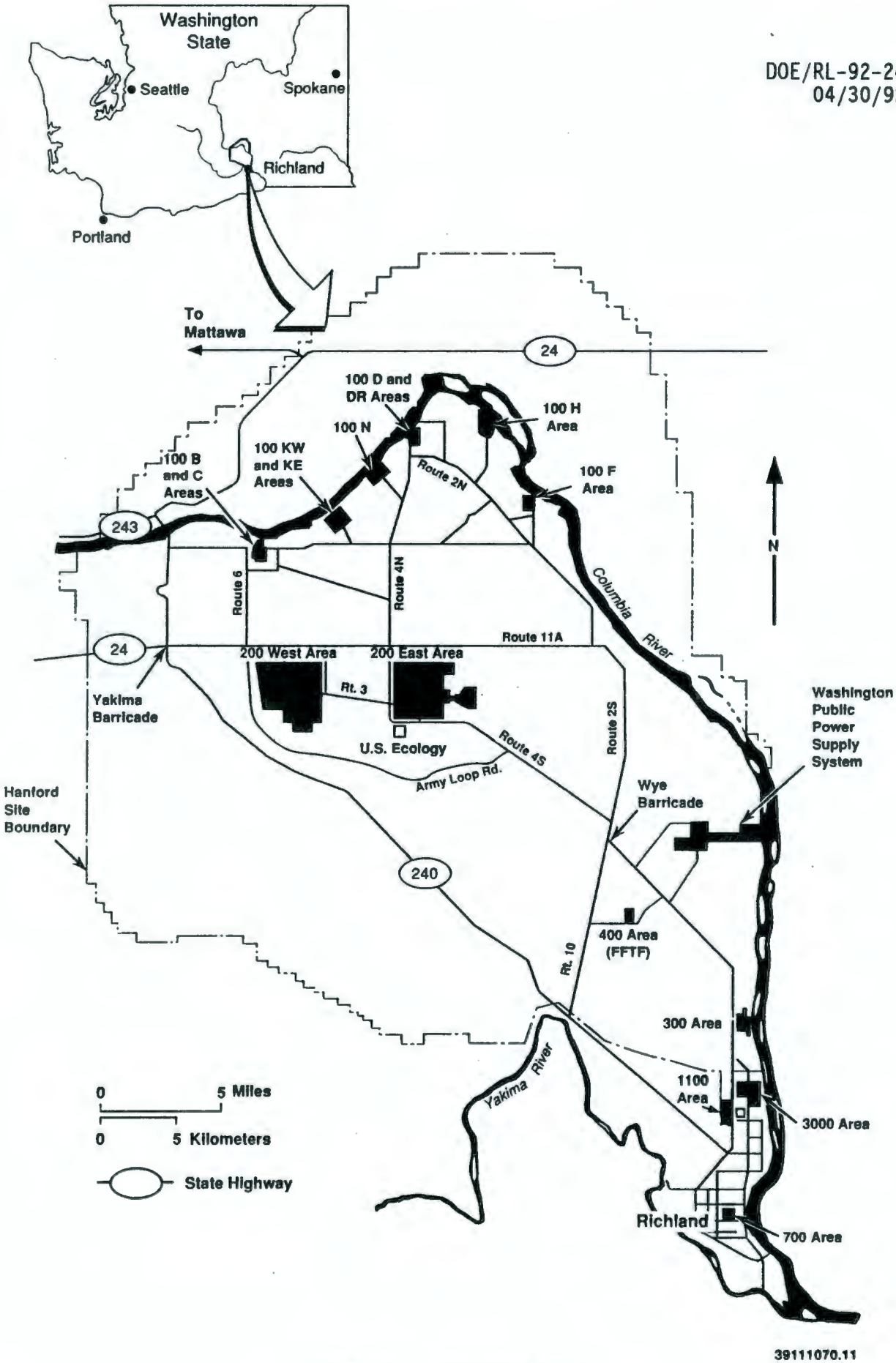

Figure 2-1. Hanford Site.

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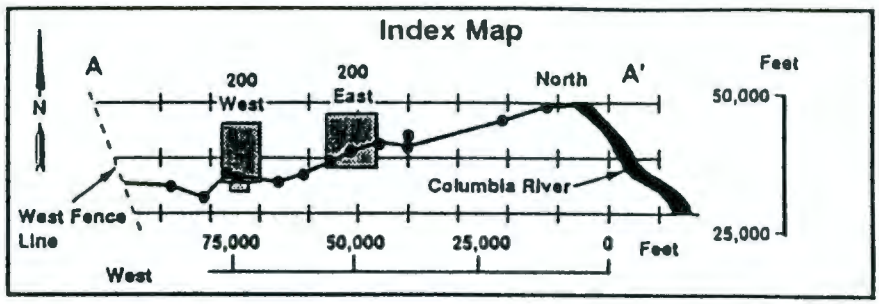

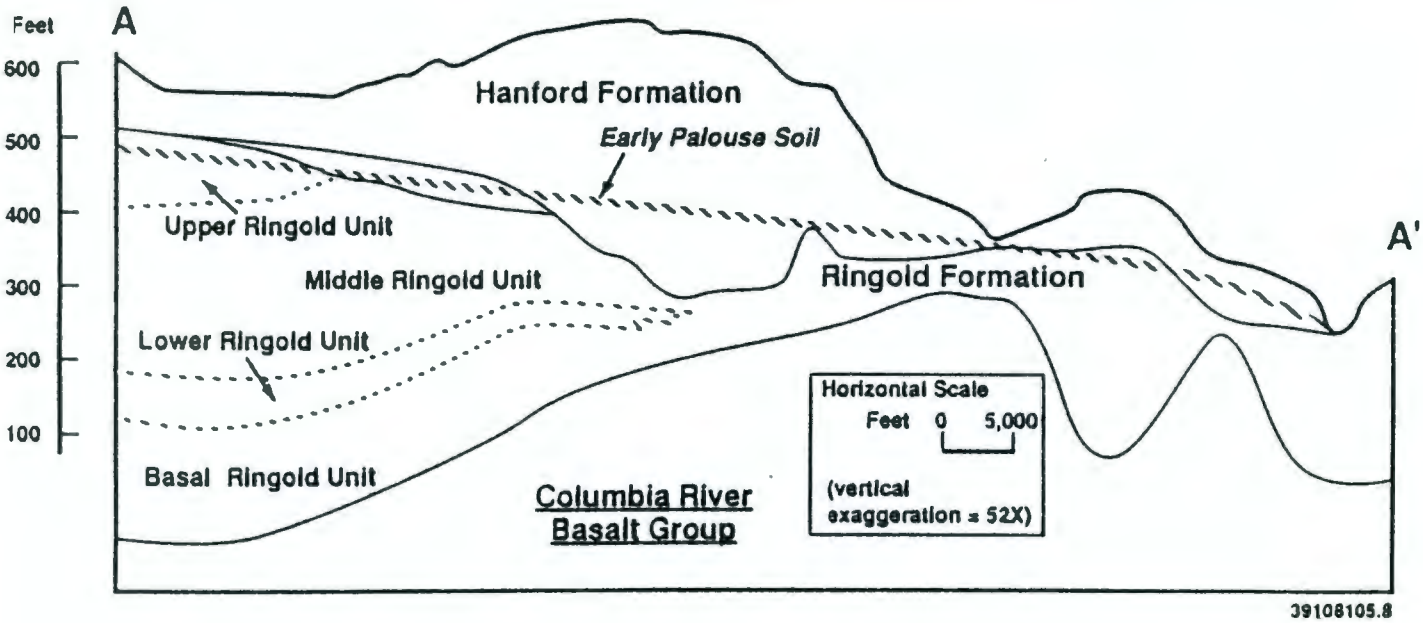

Figure 2-2. Generalized Geologic Cross Section through the Hanford Site (after Tallman et al. 1979, p. 20).

CONTENTS

3.0 DATA SOURCES 3-1

3.1 SITE-WIDE BACKGROUND PLAN SAMPLES 3-1
3.1.1 Inorganic Analytes 3-1
3.1.2 Organic Analytes 3-2

3.2 OTHER SITE CHARACTERIZATION SAMPLES 3-3

FIGURE

3-1. Map of Hanford Site Showing Locations of Sampling Sites. F3-1

TABLE

3-1. Target Analytes and Procedures T3-1

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3.0 DATA SOURCES

The various sources of data used in this report are described in this section. Information on the quality control and quality assurance parameters associated with these data also are described. The suitability of the data with respect to statistical considerations is presented in Chapter 4.0.

The data presented here, from analyses of soil recently collected on and around the Hanford Site, are of two general types:

(A) Samples collected and analyzed specifically for the *Site-wide Background Soil Sampling Plan* (hereafter referred to as the Sampling Plan) (WHC 1991b)

(B) Samples collected and analyzed in conjunction with other Hanford Site characterization efforts.

This report primarily focuses on those data generated from soils collected specifically for the Site-wide background soil study (type A samples). Discussion of type B sample results includes samples taken from boreholes drilled at Savage Island and the Yakima Barricade.

3.1 SITE-WIDE BACKGROUND PLAN SAMPLES

Over 200 samples were collected and analyzed specifically to support this study. The majority of these samples were collected for analysis of inorganic constituents, but a limited number were collected specifically for an organic sampling effort. The following sections describe sampling locations and procedures for inorganic and organic samples, as well as a discussion of the selection criteria for the organic sampling sites. The selection criteria for inorganic sample sites are described in detail in Appendix A.

3.1.1 Inorganic Analytes

Fourteen locations were chosen for inorganic sampling, as shown in Figure 3-1. Consideration was given to representativeness and completeness when choosing these sites, and multiple samples were collected at each location to ensure proper representation within each site. Sampling areas are described in Appendix A. All sampling sites were located to provide access to more than 10 feet (3 meters) of steeply inclined exposures so that the geologic relationships of the soils could be determined and a representative suite of samples could be collected. Twelve of the sampling sites were on the Hanford Site; the other two sites were east of the Columbia River, within the Hanford formation. A total of 163 samples were collected in this portion of the study.

Two types of samples were collected at each site: systematic random and judgment samples. Systematic random samples were collected from a single line perpendicular to the major strata at each site. The number of samples was

proportional to the vertical height of the exposure sampled, the distance between the sample points remaining constant. The field geologist chose the general section of the exposure most representative for sampling. The field team leader then randomly selected an initial sample location from the eligible surface.

Judgment sample locations were based solely on the professional judgment of the field geologist. These samples included selected end members, potential outliers, and samples representative of typical local lithology. These samples were taken to ensure completeness of the sample suite.

Field sampling began in September 1991 and ended in November 1991. All field work, shipping, and documentation was performed according to routine procedures found in or referenced by the *Environmental Investigations and Site Characterization Manual* (WHC 1988b). Appendix B provides a more detailed narrative of the sampling effort.

As a matter of policy, a laboratory radiological survey is required of all environmental media before shipment offsite or for analysis at certain onsite laboratory facilities. As a result of this policy, aliquots of all soil background samples received a laboratory radioactivity analysis. All aliquots were found to be below applicable administrative limits for release from all radiological controls.

Samples were submitted to two separate offsite commercial laboratories for chemical analyses. Analytes and referenced procedures are shown in Table 3-1.

Grain size (sieve) analyses and some carbonate analyses of certain samples were performed by the Hanford Site Geotechnical Engineering Laboratory. Other grain size/bulk composition studies were performed at Washington State University in support of this project. A summary of results from that study is contained in Chapter 4.0.

3.1.2 Organic Analytes

Sampling for organic components required a different approach than for inorganics. Many organic compounds do not occur naturally, so their presence would indicate that contamination is present.

Alternatively, non-waste sources of certain organic compounds can be very significant factors at any particular future site or sampling situation. Exposed slopes, chosen for accessibility as discussed above, were expected to have low concentrations of naturally-occurring organic compounds. It was recognized that the soil's resident biological community strongly influences the inventory of natural organic compounds present.

A botanist/soil scientist identified candidate sample locations within each main ecosystem where waste operations exist on the Hanford Site. Each of the following four ecosystem classifications has different vegetation assemblages that can be associated with naturally occurring organic compounds:

- Columbia River Plain: extending inland from the Columbia River westward to the Cold Creek Valley

- Old Field: pre-Hanford Site abandoned agricultural fields within the upper Columbia River Plain (representative of 100-F, 100-H, and 100-D Areas)

- 200 Area Plateau: broad elevated area topographically higher than the Columbia River Plain

- Riparian: A narrow zone alone the wetted shoreline of the Columbia River and spring streams in the Rattlesnake Hills.

Nine specific sites were authoritatively selected for sampling, that is, the sampling locations were determined on the authority or judgment of the technical personnel involved. These also are shown on Figure 3-1. All of these classifications were represented within the geographically diverse set. Soil samples were collected in late February 1992 beneath each site's dominant plant species.

Samples were submitted for volatile organic analysis, semivolatile analysis, pesticide/polychlorinated biphenyl analysis, and total organic carbon. Analytical work was performed by the same offsite commercial laboratory used for the majority of the previous inorganic analyses. Supporting work included inorganic analyses on these samples.

Additional analytical work also was performed with field instrumentation. A field laboratory method was developed and employed to measure organic vapor concentrations in the air (headspace) above soil in a sealed container. Aliquots of each sample from the nine specific organic sites were measured on the day of collection. Similar measurements were made during March 1992 on two or more new samples from each of the 14 inorganic sites discussed previously. A summary of this work can be found in Appendix B.

A prime requirement of all sample locations was that no known or suspected significant, localized soil contamination was present. The headspace screening method, described previously, served the purpose of validating background conditions as well as contributing to a baseline knowledge for future cost-effective waste site work.

3.2 OTHER SITE CHARACTERIZATION SAMPLES

In addition to the 14 surface sample sites discussed previously, two boreholes were sampled and analyzed. A discussion of this effort follows.

Savage Island Samples--In November 1990, soil samples were collected from a Pacific Northwest Laboratory (PNL) borehole across the Columbia River from the Hanford Site, north of the Ringold area in Franklin County (Figure 3-1). This was to be the site of a new PNL deep groundwater monitoring/research well.

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Soil samples were collected between the surface and a depth of 30 feet (9.1 meters) as drilling was performed. Saturated conditions were encountered at this level. The samples were stored and transferred to offsite laboratories under chain-of-custody protocols. Analyses performed included the following:

- Metals — Aluminum, antimony, barium, beryllium, cadmium, calcium, chromium, cobalt, copper, iron, magnesium, manganese, molybdenum, nickel, potassium, silicon, silver, sodium, titanium, vanadium, and zinc - EPA method 3050/6010

  Arsenic, lead, selenium, thallium, tin, and mercury - EPA methods 7060, 7421, 7740, 7841, 7870, and 7471, respectively
- Anions — Fluoride, chloride, nitrate, nitrite, sulfate and total phosphate) - EPA 340.2 for fluoride, SM-424 for total phosphate, and EPA 300.0 all others
- Ammonia — EPA 350.3
- Total organic carbon (TOC) — TP-186203.

Yakima Barricade Samples--These samples originated from a PNL borehole, located near the Yakima Barricade on the Hanford Facility. The purpose of the borehole was to study natural 'deep' soil microbes. Field work was performed in the fall of 1990. Geological observations and x-ray fluorescence analyses were performed in conjunction with the PNL study.

The samples collected and submitted for analysis in support of this project were selected from the archived materials, and submitted for chemical analysis in the fall of 1991. The analyte list was essentially the same as for those collected per the Sampling Plan, referred to previously, with the addition of lithium and the omission of carbonate. Lithium was requested because a lithium compound was added periodically to the borehole during the microbiology study. This element served as an excellent indicator of cross contamination of the selected geologic samples because of its low natural concentrations. It was decided that carbonate analysis was unnecessary for these samples. Samples were submitted to the same laboratories used in the Site-wide effort.

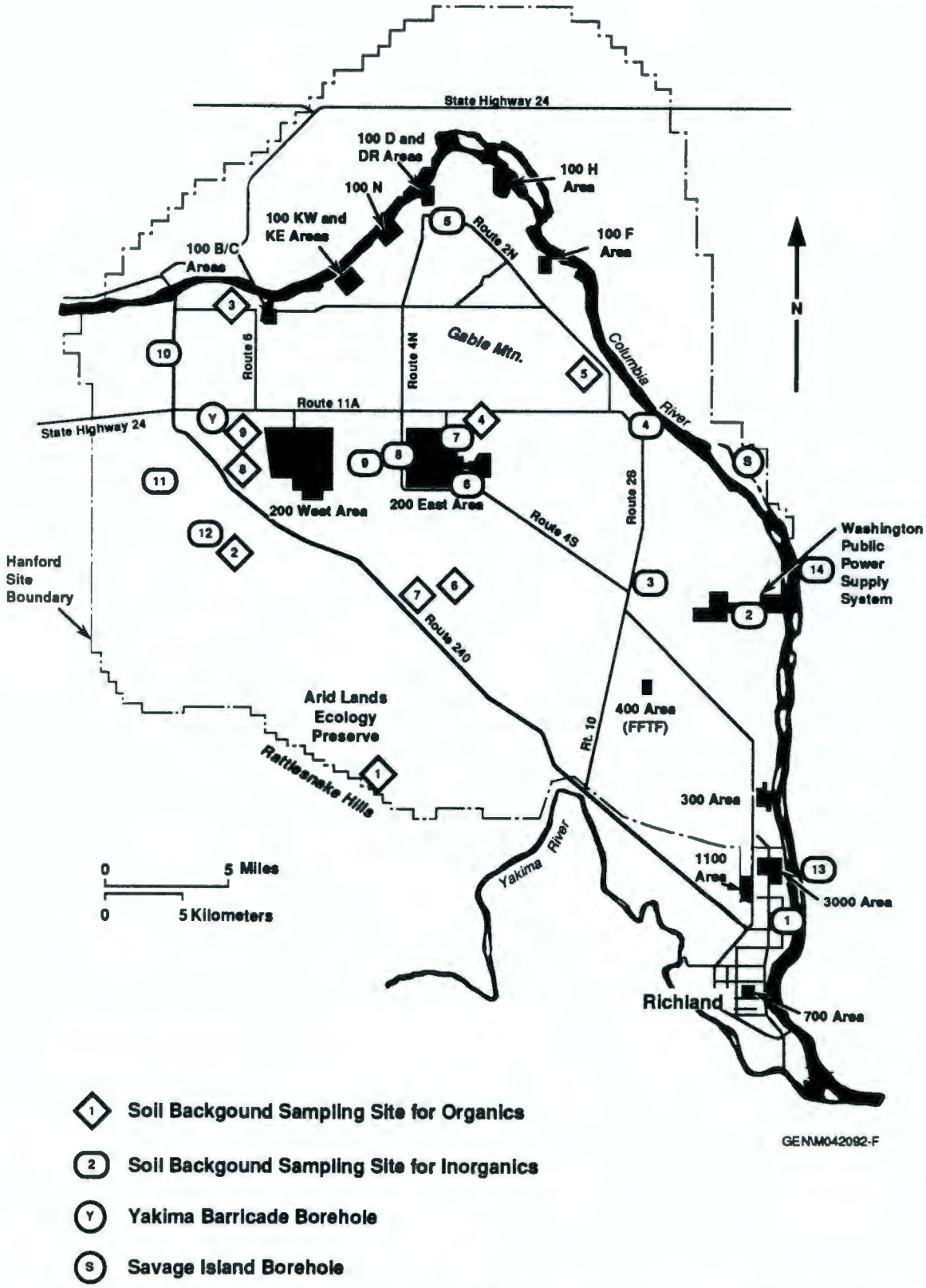

Figure 3-1. Map of Hanford Site Showing Locations of Sampling Sites.

Table 3-1. Target Analytes and Procedures.

Analyte	Analytical procedure	Analyte	Analytical procedure
Aluminum	200.7 CLP-M[a]	Mercury	245.5 CLP-M
Ammonium	ASTM D 3868 -79[b]	Molybdenum	7481
Antimony	204.2 CLP-M	Nickel	200.7 CLP-M
Arsenic	206.2 CLP-M	Nitrate	300.0
Barium	200.7 CLP-M	Nitrite	300.0
Beryllium	200.7 CLP-M	Phosphate	300.0
Cadmium	213.2 CLP-M	Potassium	200.7 CLP-M
Calcium	200.7 CLP-M	Selenium	270.2 CLP-M
Carbonate	ASTM D 4373 -84	Silicon	200.7 CLP-M
Chloride	300.0	Silver	272.2 CLP-M
Chromium	200.7 CLP-M	Sodium	200.7 CLP-M
Cobalt	200.7 CLP-M	Sulfate	300.0
Copper	200.7 CLP-M	Thallium	279.2 CLP-M
Fluoride	300.0	Titanium	200.7 CLP-M
Iron	200.7 CLP-M	Vanadium	200.7 CLP-M
Lead	239.2 CLP-M	Zinc	200.7 CLP-M
Magnesium	200.7 CLP-M	Zirconium	200.7 CLP-M
Manganese	200.7 CLP-M		

[a]Number indicates an EPA procedure.

[b]American Society for Testing and Materials (ASTM) procedures.

CONTENTS

4.0 DATA EVALUATION 4-1

4.1 LIMITATIONS OF DATA 4-1

4.2 SUITABILITY OF DATA 4-2

4.3 DATA QUALITY REVIEW 4-2
4.3.1 Detection Limits 4-2
4.3.2 Data Quality Objectives Parameters 4-3
4.3.3 Correlation 4-4

4.4 OUTLIERS 4-4

4.5 THRESHOLDS 4-5

4.6 JUDGMENT SAMPLES/SUBORDINATE END MEMBERS 4-5

4.7 MODEL VALIDATION 4-5

4.8 SAMPLE STRATIFICATION 4-6

4.9 GRAIN SIZE ANALYSIS 4-6

4.10 X-RAY FLUORESCENCE CALIBRATION 4-6

4.11 ORGANIC BACKGROUND 4-7

4.12 INTERPRETATIONS 4-7

FIGURES

4-1. Stratigraphy of the Hanford Site Vadose Zone for Use in Background Sampling F4-1
4-2. Scattergram for Aluminum, Arsenic F4-2.1
4-2. Scattergram for Barium, Beryllium F4-2.2
4-2. Scattergram for Calcium, Chromium F4-2.3
4-2. Scattergram for Cobalt, Copper F4-2.4
4-2. Scattergram for Iron, Lead F4-2.5
4-2. Scattergram for Magnesium, Manganese F4-2.6
4-2. Scattergram for Nickel, Potassium F4-2.7
4-2. Scattergram for Sodium, Vanadium F4-2.8
4-2. Scattergram for Zinc, Titanium F4-2.9
4-2. Scattergram for Zirconium, NH_3 . . . . . F4-2.10
4-2. Scattergram for Alkalinity, Silicon F4-2.11
4-2. Scattergram for Fluorine, Chlorine F4-2.12
4-2. Scattergram for Nitrate, Sulfate F4-2.13

FIGURES (cont)

4-3. Alkalinity vs. Calcium F4-3.1
4-3. Aluminum, Sodium vs. Calcium F4-3.2
4-4. Scattergram for Chlorine, Sulfate vs. Sodium F4-4

TABLES

4-1. Random Sample Outliers T4-1
4-2. Weibull Distribution Parameters T4-2

4.0 DATA EVALUATION

The following objectives directed the gathering of data:

1. Demonstrate the validity of the Site-wide background concepts as described in *Characterization and Use of Soil and Groundwater Background for the Hanford Site* (WHC 1991a)

2. Determine the soil background threshold values, based on tolerance intervals as specified in MTCA (WAC 173-340)

3. Determine that the data quality objectives specified as part of the *Sitewide Soil Background Sampling Plan* (WHC 1991b) were achieved.

The data collected falls into three basic categories: systematic random sample data, judgment sample data, and quality assurance and quality control sample data. The systematic random samples were the primary goal of the sampling program. The CLP (leachate) analysis of these samples is the basis for determining background threshold levels. These data have been evaluated with respect to their applicability and quality.

The different types of data were collected for different uses and, therefore, are limited with respect to certain applications. The following sections discuss for what these different data types can and cannot be used.

4.1 LIMITATIONS OF DATA

The judgment sample data set was included for the purposes of establishing the completeness of the sampling program. Because bias is involved in the collection of the data, these data cannot be used directly in the statistical calculations of thresholds. The primary use of these data are for the identification of potential subordinate end members, recognizable in the field by unique or distinctive lithologies. Comparison of the judgment samples to the ranges and thresholds determined from the systematic random data allows determination as to whether or not the identified lithologies form a chemically distinctive end member.

The quality assurance and quality control sample data set includes field duplicate samples, grain size effects samples, and blanks prepared at the analytical laboratory. The field duplicate samples ('splits') were collected and sent to a separate laboratory for analysis. These data provide a basis for measuring the performance of the primary laboratory. Of primary interest is an interlaboratory comparison for accuracy (bias) that can affect decisions based on the tolerance interval approach.

The grain size effects samples were collected for the purpose of determining the variability of the data as a result of variations in the grain size of the sample. Accompanying the analysis of these samples will be a parallel effort to correlate bulk XRF data (laboratory derived) with leachate

analysis. The analysis and interpretation of these samples will be reported under separate cover.

The laboratory blanks were intended to provide an indication of detection limits in the presence of matrix effects. Inquiries at the primary laboratory indicated that the laboratory routinely uses a pure silica sand as a solid matrix blank for their internal quality control program. The laboratory was requested to analyze and report on a silica sand sample with each batch submitted to the laboratory. The primary laboratory performed these analysis and reported the results as requested as regular samples. Unfortunately the reporting format contains an automatic filter that prevents less than detection limit data from being reported. Therefore, most of the data that came back was identified as less than values rather than actual measurements that could have been used to verify the claims for detection limit. This renders the blank data only suitable for identifying the gross presence of laboratory contamination or other nonstatistical applications.

4.2 SUITABILITY OF DATA

The systematic random data set has been designed to meet all the Hanford Site requirements. The data set was generated with the same sampling and measurement methods as will be required of WMU-based investigation and remediation sampling. The raw data are presented in tabular form in Appendix C.

The background thresholds developed here will provide an initial level of screening for contaminants of concern. Constituents that do not exceed threshold levels by statistically significant amounts can be dropped from further consideration in the investigation and remediation processes. These values also will provide a lower bound on proposed risk-based cleanup levels.

4.3 DATA QUALITY REVIEW

This section describes the various data quality parameters that were reviewed to ensure the laboratory analyses were usable. These parameters include detection limits, precision, accuracy, representativeness comparability, and completeness (PARCC).

4.3.1 Detection Limits

Detection limits for most analytes have been determined on the basis of reagent blanks prepared concurrently with the inductively coupled plasma (ICP) analytical batches at the primary laboratory. Separate attempts to obtain analysis of a pure silica sand (vendor internal quality control standard) failed to yield usable data. The data from the reagent blanks include all measurement errors except for interlaboratory bias and soil matrix interference effects. The true detection limit will be higher than that reported on the basis of the reagent blanks because of soil matrix interference effects [the exception will be those analytes (e.g., lead)

performed by methods other than ICP, which was the method used for the blanks]. Appendix D includes the statistical analysis of the reagent blank data.

The analysis of the leachate data for each analyte includes an estimate of the upper bound of the matrix interference effects. This estimate is based on the increased scatter of the data in the statistical plot and the corresponding lack of fit in the linear regression of the data with the cumulative distribution function (CDF). Matrix interference effects generally increase the scatter of the data sufficiently to prevent the data from being adequately fitted to the straight line (e.g., calcium, Appendix D, Figure 22; copper, Appendix D, Figure 26).

The detection limits required of CLP contractors are discussed in Appendix D. Because these detection limits are applicable to water samples and not soil samples, the detection limits are of little relevance to this study. The detection limits requested were based on little more than the anticipated ranges of data and appear to be inadequate to the task of judging laboratory performance.

4.3.2 Data Quality Objectives Parameters

The DQO parameters of precision and accuracy were satisfied by specifying the CLP protocols for analysis and data validation. Additional analyses with respect to accuracy were performed by sending duplicate samples ('field splits') to a second laboratory for analysis. Comparison of the distributions of data for each set of duplicates provides an indication of the degree of interlaboratory variability (bias). Appendix D, Table 6 provides a summary of the analysis of the split samples. There is detectable bias between the laboratories for sodium and lead. The bias for the remaining analytes is statistically indistinguishable from zero.

The representativeness of the data can best be demonstrated by referring to Figure 4-1. The sampling sites chosen cover the vadose zone stratigraphy, with the exception of the stratigraphic layer identified as Flood 3. No suitable sampling sites were located in this horizon. Flood 3 is a low volume horizon that was highly eroded by subsequent floods. This absence of sampling in Flood 3 is not expected to adversely impact the representativeness of the data. Flood 2, while heavily represented in the sampling sites, also is judged to represent the largest volume of sediment in the vadose zone. Thus, the additional sampling sites present in this horizon are appropriate. The graphs in Figure 4-2 show the data on a site-by-site basis.

The comparability of the data with other data sets to be generated in the future at individual WMUs is satisfied on two points. The first point is that the data were established under the same sampling protocols and analysis methods as established for WMU-specific data. The only potential differences are between *Resource Conservation and Recovery Act* (RCRA) *of 1976* and *Comprehensive Environmental Response, Compensation, and Liability Act* (CERCLA) *of 1980* areas and specification of the SW-846 protocols (EPA 1986). In this respect, the CLP protocols use nearly identical analytical methods, with

increased quality control reporting requirements and reagent quality, which is needed due to importance of background in remediation decisions. Thus, SW-846 based data can be compared to CLP based background thresholds.

The second point of comparability is based on the spatial coverage of the Hanford Site by the sampling locations. The ensemble of sampling locations covers the Hanford Site both horizontally and vertically through the stratigraphic section (Figure 4-1). It is not expected that any current or future WMU can be located in a portion of the Hanford formation that is not represented in the background data set.

The completeness of the data set is synonymous with coverage of the population to be sampled. The data set includes not only the surface exposures described in Appendix B, but also samples collected from the deep microbiological borehole drilled by PNL. Figure 4-1 is an idealized stratigraphy of the Hanford Site. Chapter 3.0, Figure 3-1 is a map showing the location of the sampling sites. These sites cover the range of sediment deposition environments at the Hanford Site, from the high energy main channel deposits (Sites 1, 3, 13, 14) to the low energy, slack water deposits (Sites 2, 4, 5, 11, 12). Sites such as 6, 7, 8, 9, and the PNL borehole cover the transition from high energy to low energy environments. These sites also cover the Hanford Site spatially from east to west and north to south. Background sampling sites have been identified as to their respective position in the sequence. The vertical coverage of the stratigraphy is nearly complete. The only vadose zone lithology not sampled is Flood 3 as described previously.

4.3.3 Correlation

A primary assumption of classical statistics is that the data are independent and identically distributed, e.g., that the data are not autocorrelated. This assumption is not always valid when dealing with geologic data. A primary tool for determining the presence of spatial correlations is the variogram. Variograms for selected representative analytes will be provided after completion of the evaluation of all inorganic constituents.

4.4 OUTLIERS

The statistical analysis of the random sample data has revealed the presence of statistical outliers in the data. These outliers might be due to laboratory measurement error or, more likely, to nuggets of subordinate minerals or lithologies. The use of CLP methods and validation protocols reduces the likelihood of an analytical error going undetected. Table 4-1 lists the outlier data and probable causes, while Figures 4-3 and 4-4 show the associated interelement correlations.

The calcium outliers are due to a caliche ($CaCO_3$) layer intercepted in the PNL borehole and to a calcium-rich plagioclase (or possibly clay mineral) in the Ringold Coulee site (Site 14). The sodium outliers are all associated

with the Rattlesnake Springs site (Site 12), established by Rickard (1964) as a high alkaline soil. Correlations with high chlorine and sulfate (Figure 4-4) data at the same sample locations readily establishes these samples as deposits high in salt.

4.5 THRESHOLDS

The statistical methods used to determine the background threshold levels have been described in the characterization document (WHC 1991a). It is based on computing the upper 95 percent confidence interval of the 95th percentile of the distribution of systematic random data as required by the Model Toxics Control Act [WAC 173-340-708(11d)]. The details of the analysis are presented in Appendix D. Table 4-2 presents a summary of the analytical results, including the background threshold values for: aluminum, calcium, copper, iron, lead, and sodium. The presence and level of matrix interference effects are developed directly from the statistical plots. The remaining number of analytes will be evaluated and included at a later date.

The geochemical methods used apply primarily to the identification of subordinate end members and the possible mineral sources of outlier data. The use of interelement correlations and stoichiometric relationships are used to identify specific minerals that can be the source of outlier data.

All the analytes produced exceptionally good fits to single distributions, with the exception of sodium. Sodium is an ubiquitous element, appearing in a number of repositories and environments. Specifically identified candidates for the Hanford Site are salts (NaCl, NaSO4), plagioclase, sodic feldspar, and basaltic glass. The factor analysis of both bulk XRF data and random sample leachate data (Appendix D) also indicates that sodium is associated with multiple factors (sources). The final analysis of sodium (Appendix D, Figure 40) demonstrates that sodium can be represented as a bivariate distribution.

4.6 JUDGMENT SAMPLES/SUBORDINATE END MEMBERS

Information in this section will be provided after completion of the evaluation of all inorganic constituents. This section will provide a comparison of the judgment sample data set against the threshold values. This comparison will be made to determine if lithologic criteria used to select the judgment samples represent subordinate end members that are significantly different from the random sample data set or previously identified subordinate end members.

4.7 MODEL VALIDATION

Information in this section will be provided after completion of the evaluation of all inorganic constituents. This section will provide a review of the data in terms of the conceptual model (WHC 1991a). This review will

identify those characteristics of the data that support the model along with revisions to the model required by the data.

4.8 SAMPLE STRATIFICATION

The sample sites were chosen on the basis of representativeness of the geologic section, access, extent of exposure, and the expectation that the sites were free of contamination from Hanford Site activities. This latter assumption can be verified by stratifying the random sample data set according to proximity to Hanford Site activities, e.g., 200 Areas. A simple observational test can be made by referring to the scattergram plots in Figure 4-2. Of particular interest is lead, as several of the sampling sites are located near vehicular routes, and the presence of lead in surface soils near highly travelled roads has been established in the literature. Sites 1, 6, 7, 8, 10, and 13 are located near roads. These sites do not stand out as being different from the other sites, with the possible exception of Site 10, which is elevated in a number of analytes associated with basaltic minerals. Appendix D includes a more detailed analysis for lead as well as chromium.

4.9 GRAIN SIZE ANALYSIS

An investigation of the effect of grain size on CLP analyses is being conducted in conjunction with this study. Because CLP analysis is only a partial dissolution of soil constituents, the effects of grain size, which is proportional to surface area, need to be considered. Preliminary results on a chemically homogeneous sample indicate that smaller grain sizes do yield systematically higher concentrations in CLP analyses. In addition, natural soils and sediment samples taken from the Hanford Site can be markedly inhomogeneous with respect to grain size; a sample biased toward a particular size fraction might not be completely representative of the medium being sampled. The final results of this study will be published as a separate document.

4.10 X-RAY FLUORESCENCE CALIBRATION

Because of the nature of CLP extraction and analysis, concentrations of some analytes reported by this method might be less than the total present in the sample. More refractory mineral phases in the sample might fail to dissolve in the CLP digestion procedure, and thus, their elemental constituents would go unreported. A separate study is being conducted to attempt to quantify this effect, and results will be published as a separate document. Preliminary results suggest that many variables contribute to the efficiency of extraction, most notably grain size and mineral species present. Concentrations of most analytes in a CLP analysis are less than present in a whole rock analysis, as measured by XRF techniques.

4.11 ORGANIC BACKGROUND

Analysis of organic samples measured in the field and at an onsite laboratory (separate methods) indicates that no detectable organics were found in any of the inorganic sampling sites or in any of the specifically chosen organic sampling sites. For more details of the analysis methodology, refer to Appendix B.

4.12 INTERPRETATIONS

Information in this section will be provided after completion of the evaluation of all inorganic constituents. This section will identify significant features of the data analyzed with respect to the geology, statistical relationships, and application of the data to Hanford Site activities.

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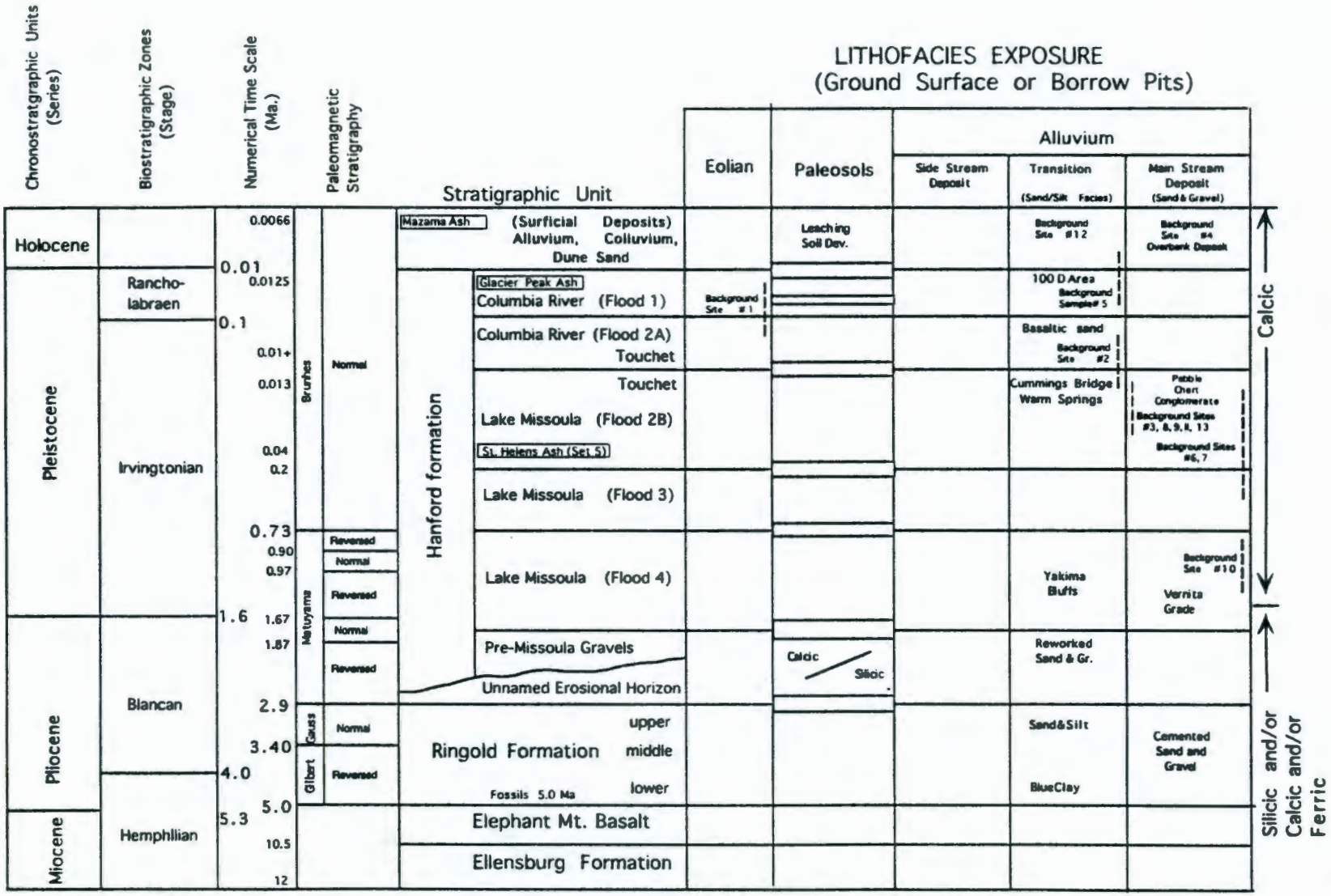

Figure 4-1. Stratigraphy of the Hanford Site Vadose Zone for Use in Background Sampling.

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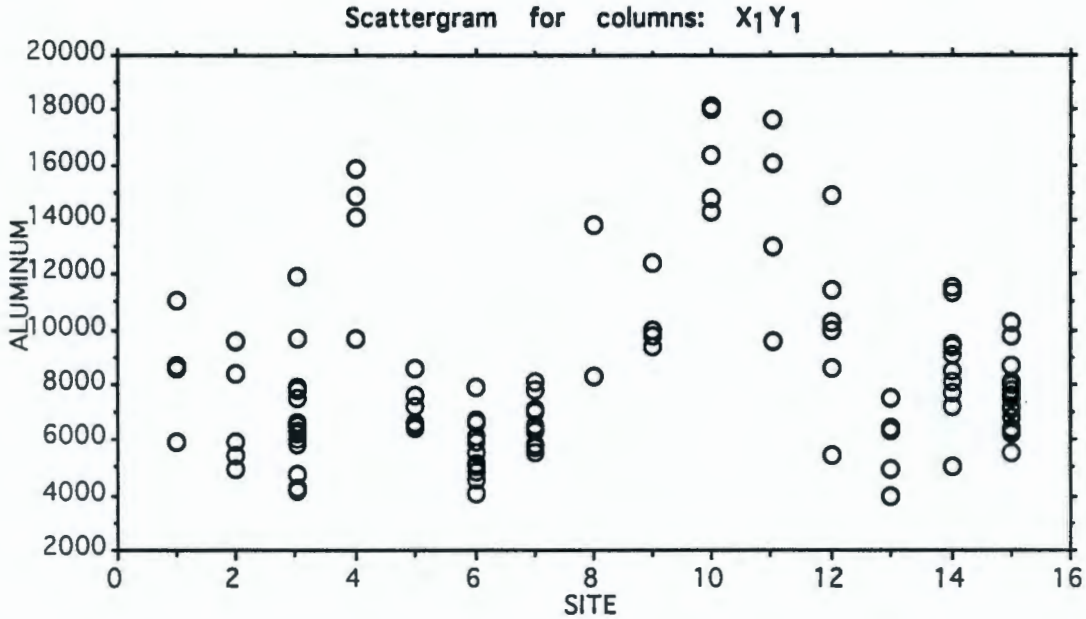


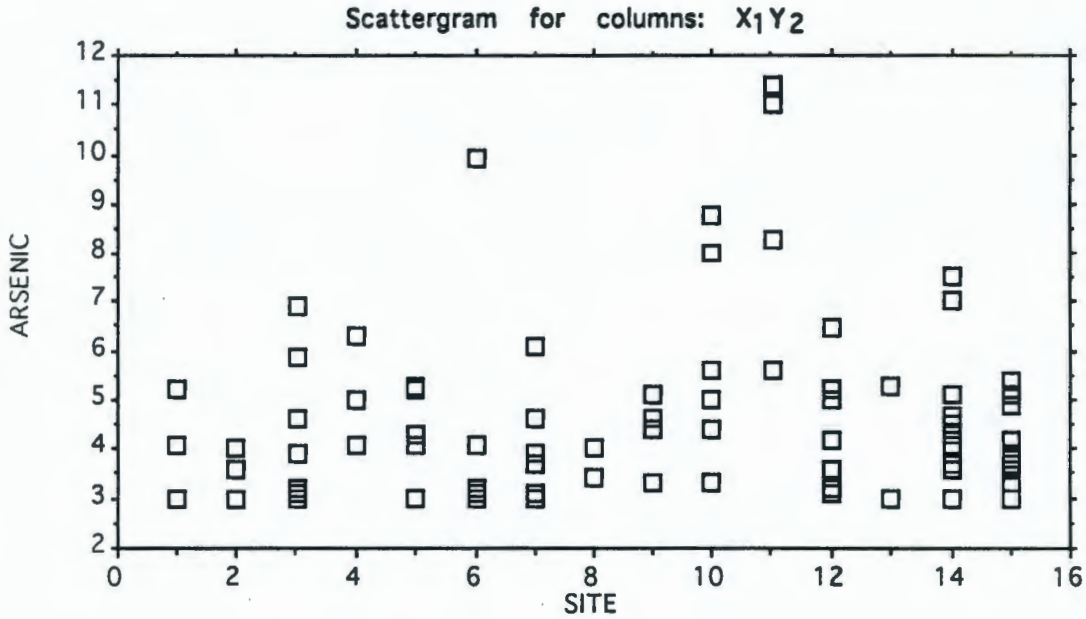
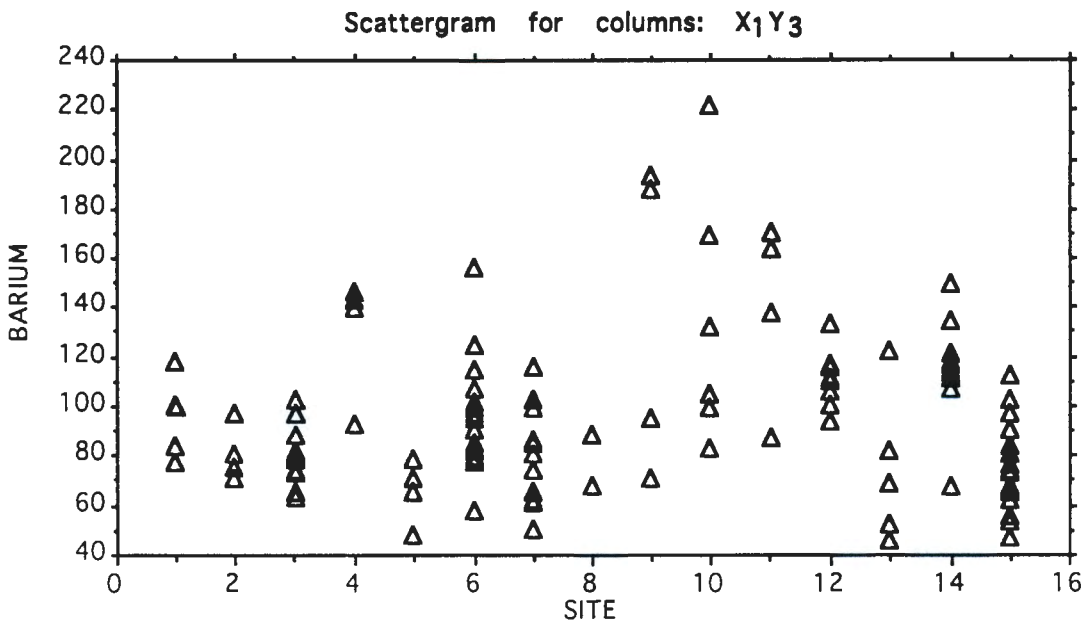


Figure 4-2. Scattergram for Aluminum, Arsenic. (sheet 1 of 13)



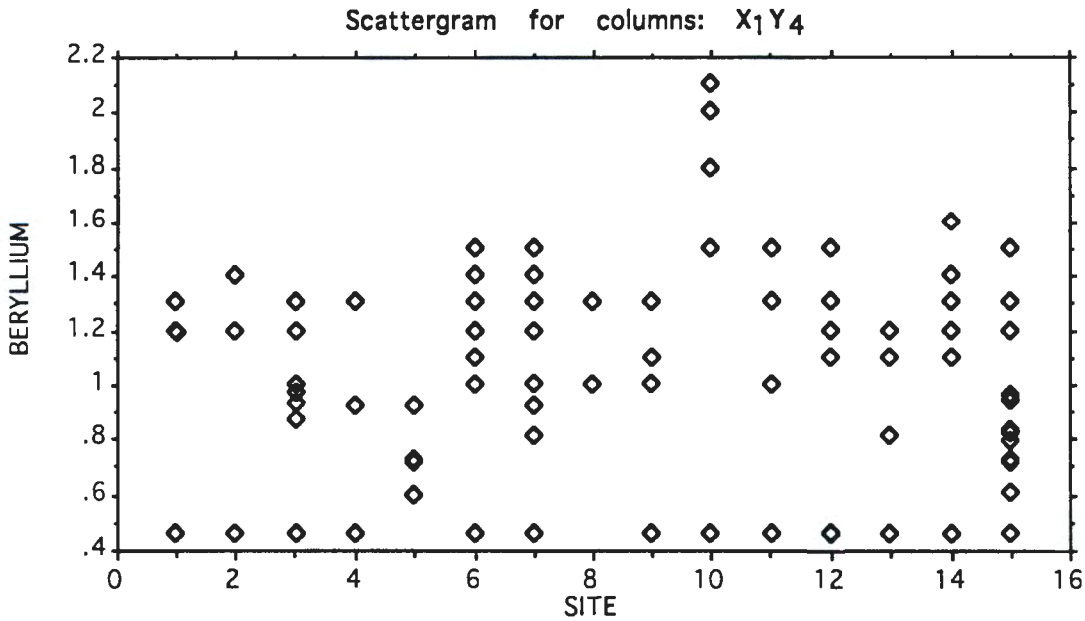
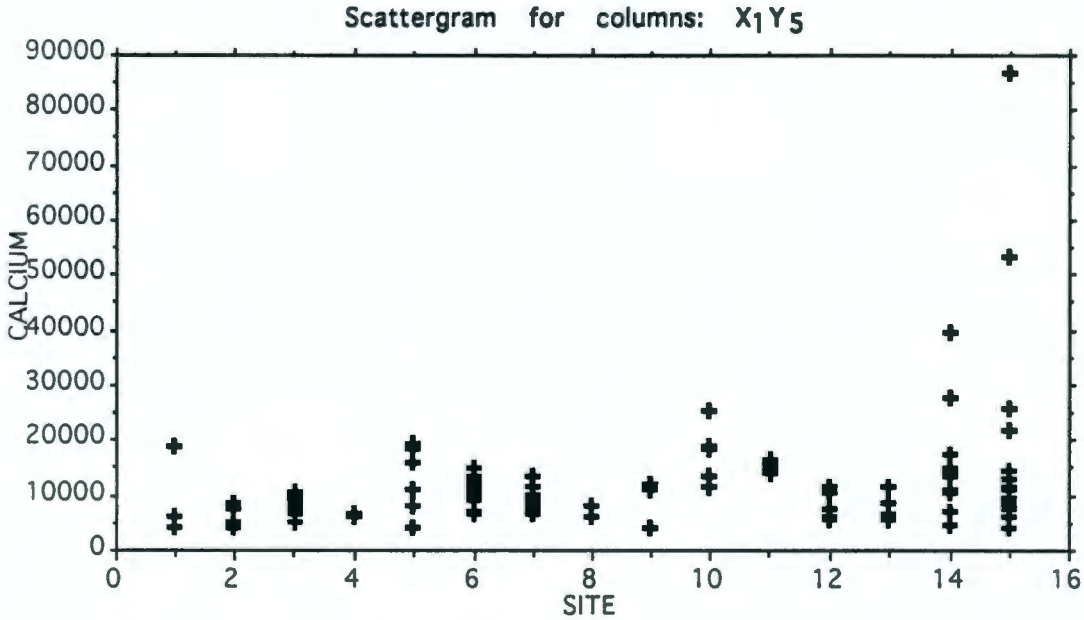


Figure 4-2. Scattergram for Barium, Beryllium. (sheet 2 of 13)



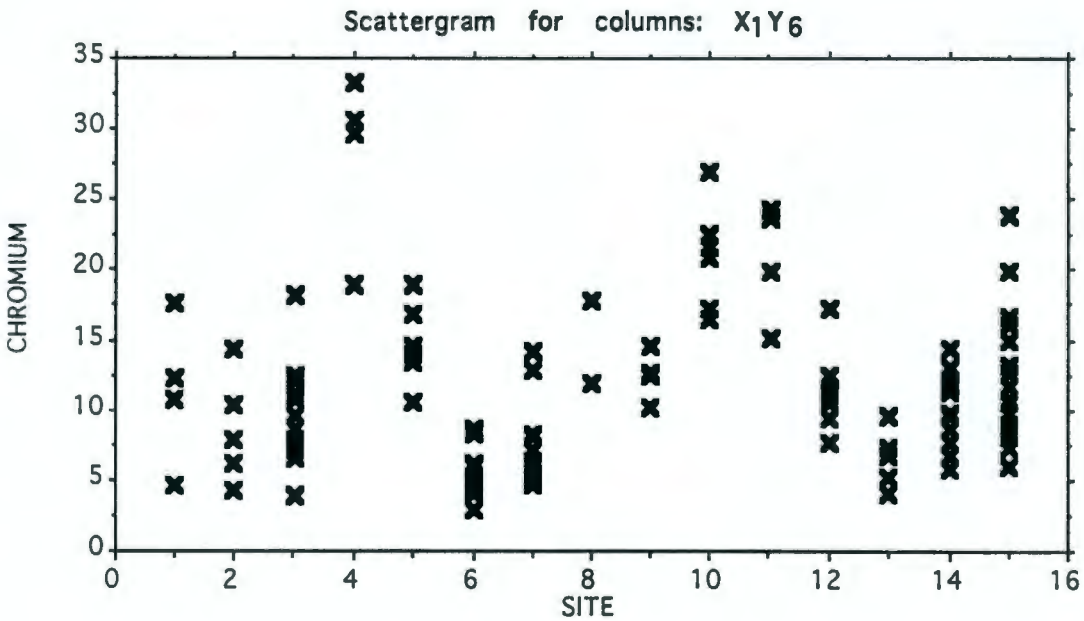


Figure 4-2. Scattergram for Calcium, Chromium. (sheet 3 of 13)

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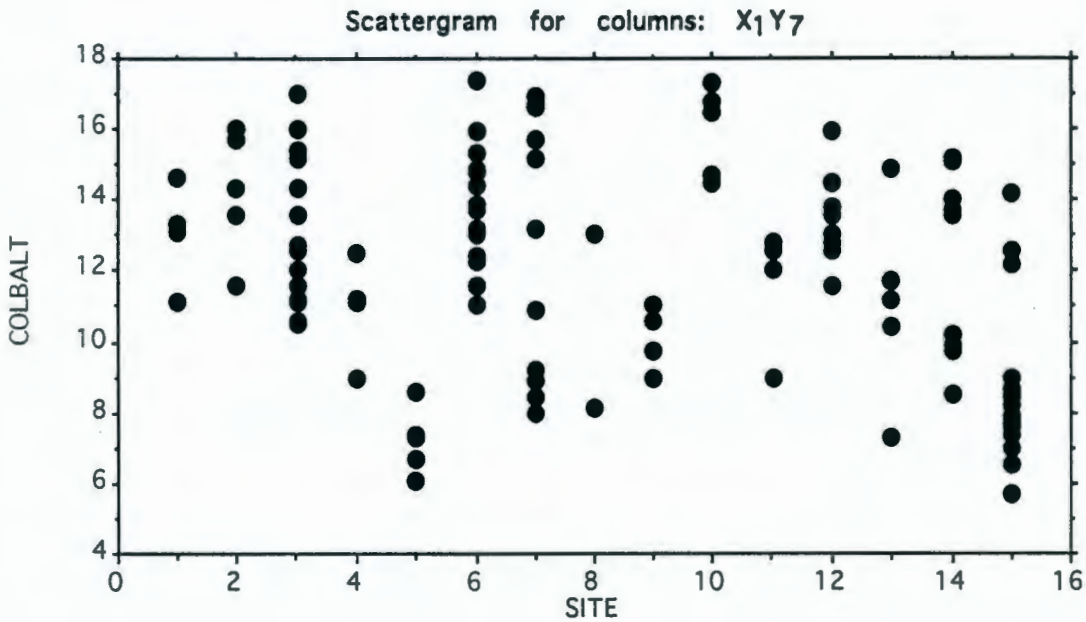

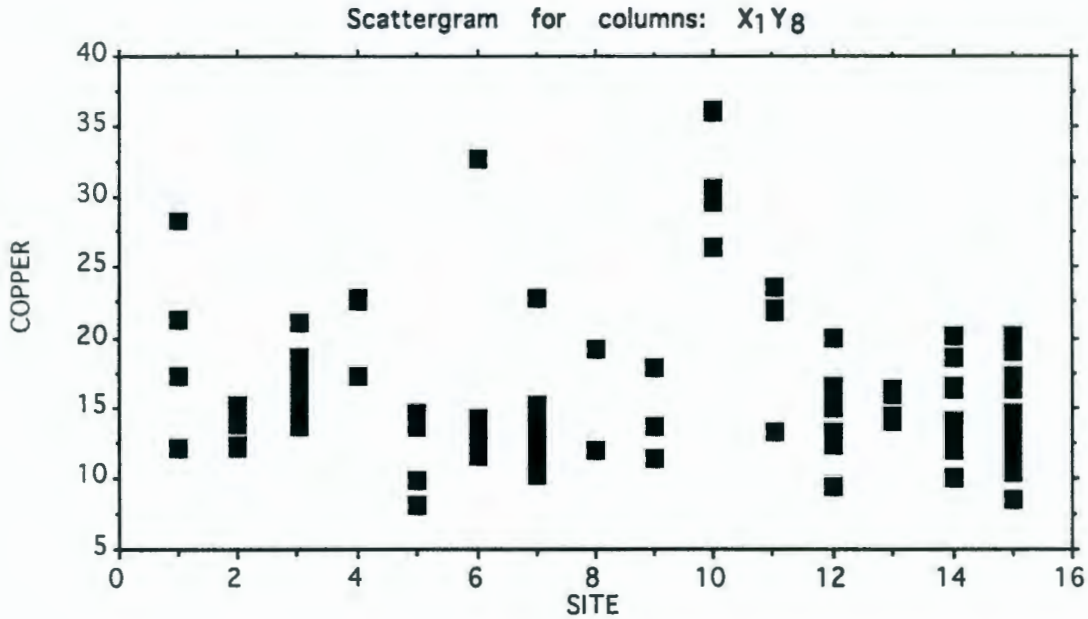

Figure 4-2. Scattergram for Copper, Cobalt. (sheet 4 of 13)

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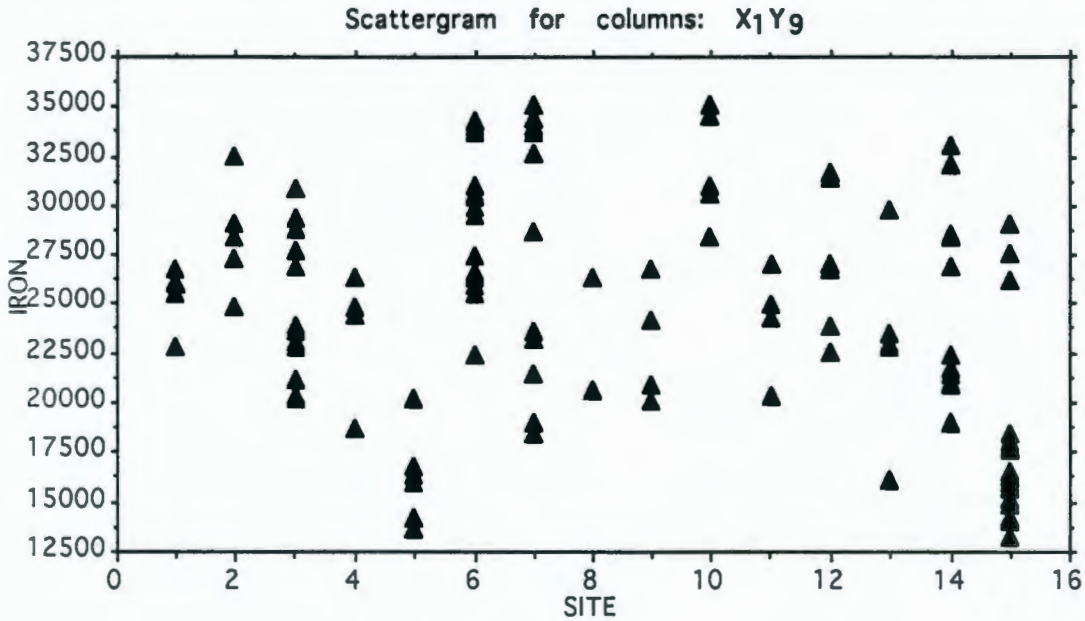


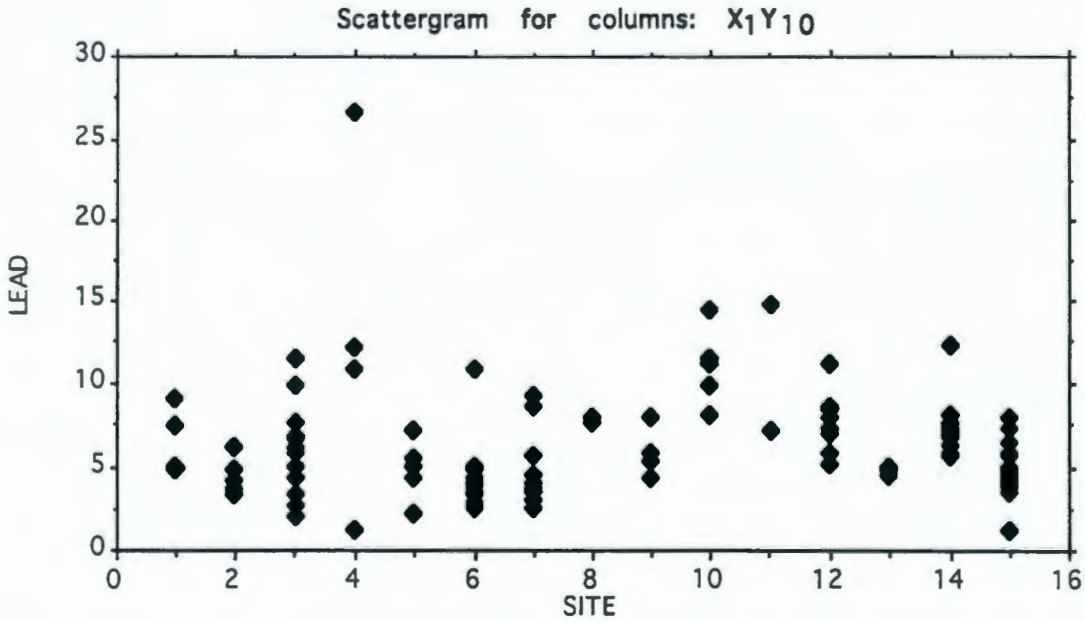
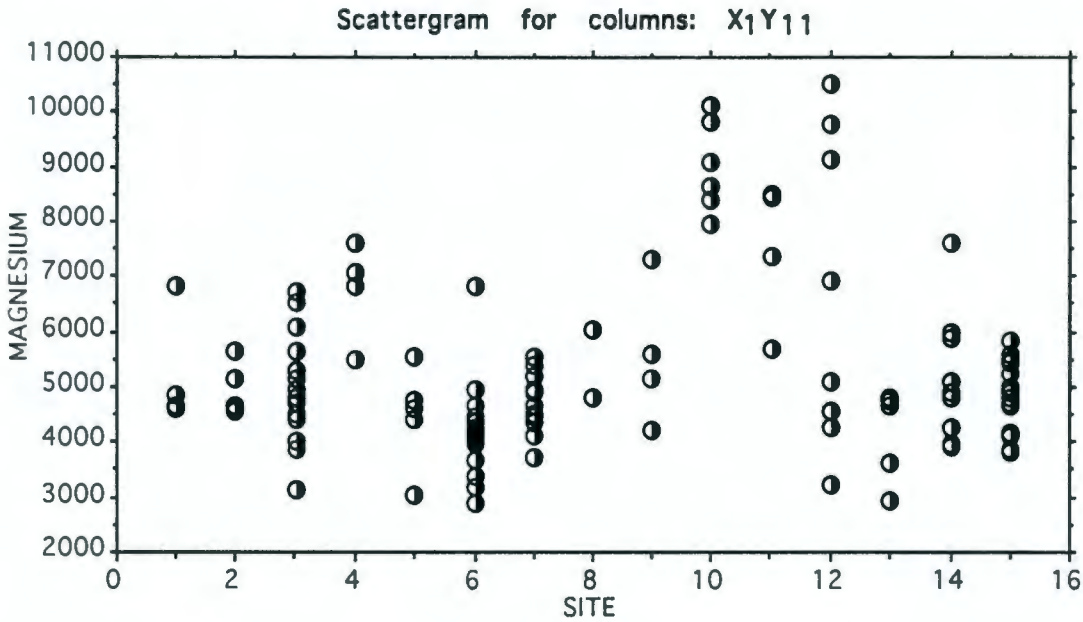


Figure 4-2. Scattergram for Iron, Lead. (sheet 5 of 13)



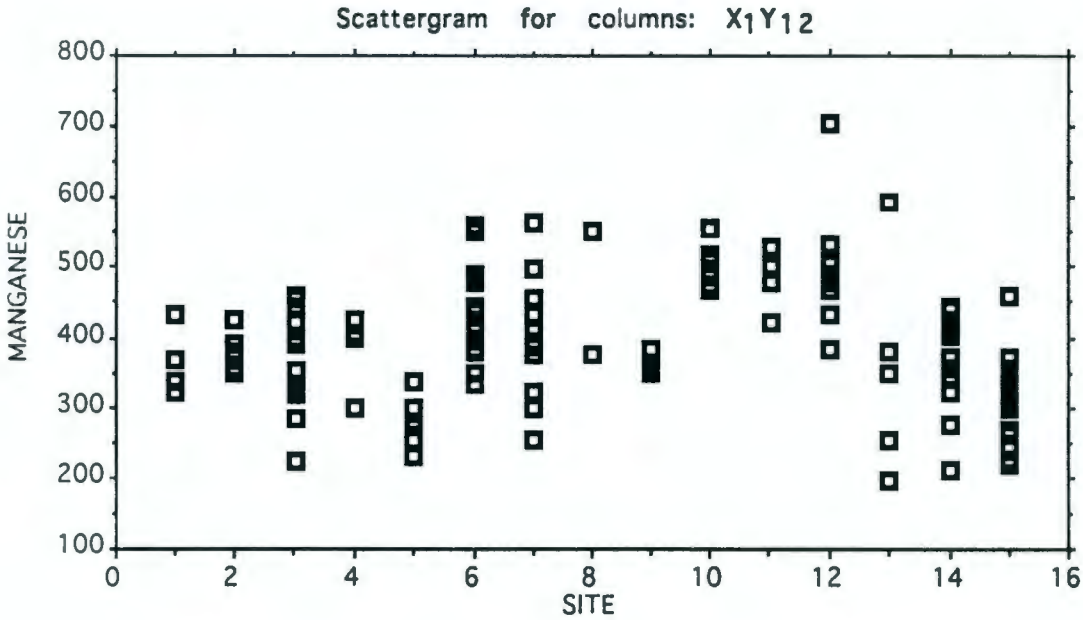
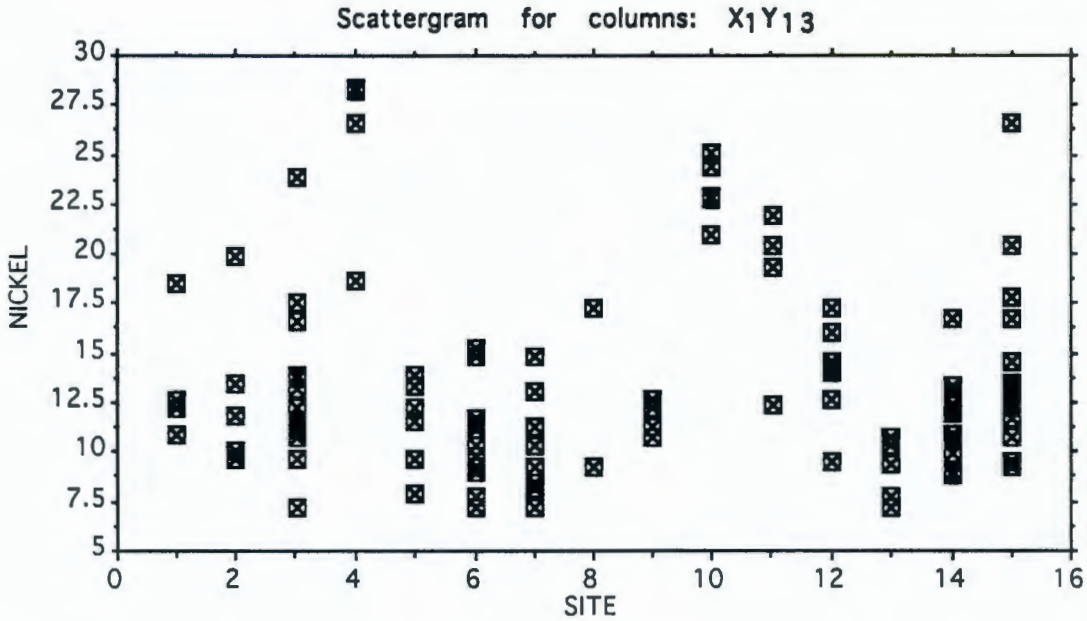


Figure 4-2. Scattergram for Magnesium, Manganese. (sheet 6 of 13)



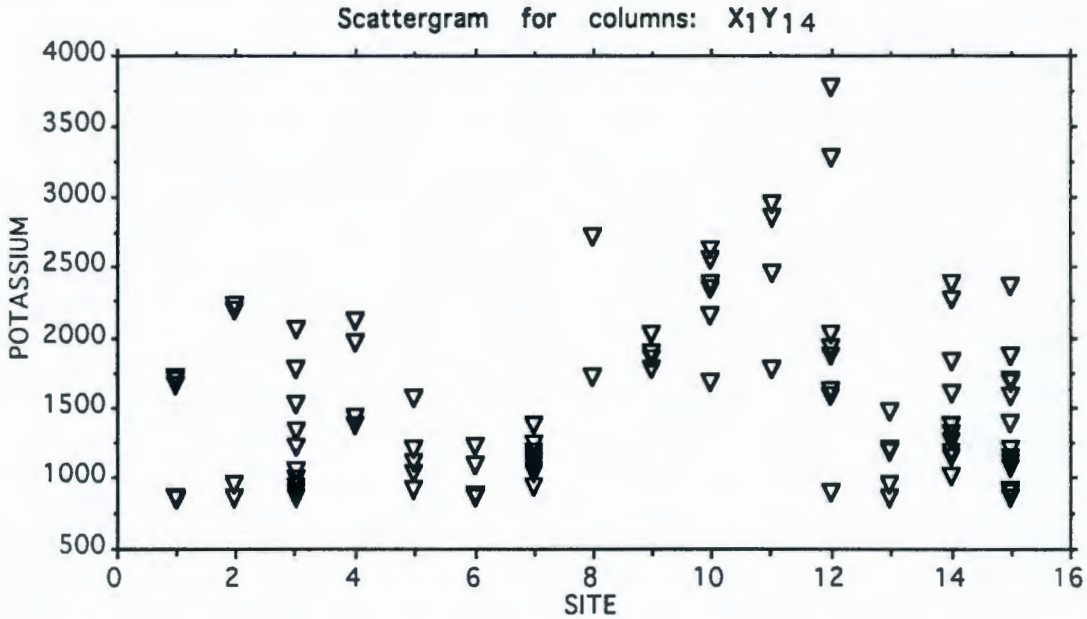
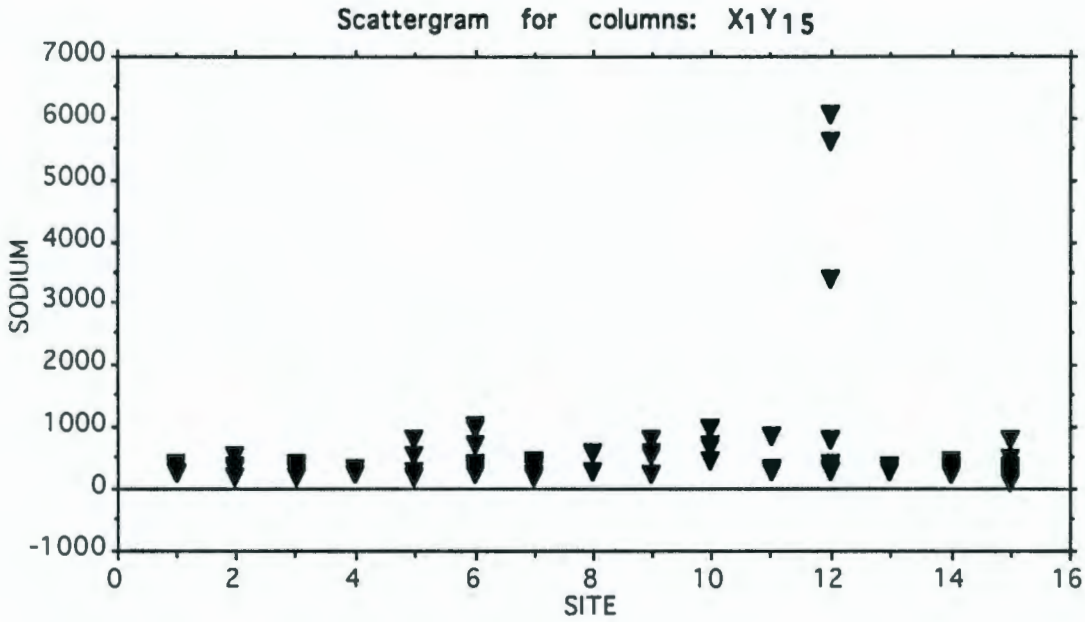


Figure 4-2. Scattergram for Nickel, Potassium. (sheet 7 of 13)

9 2 1 2 6 8 1 7 5 4



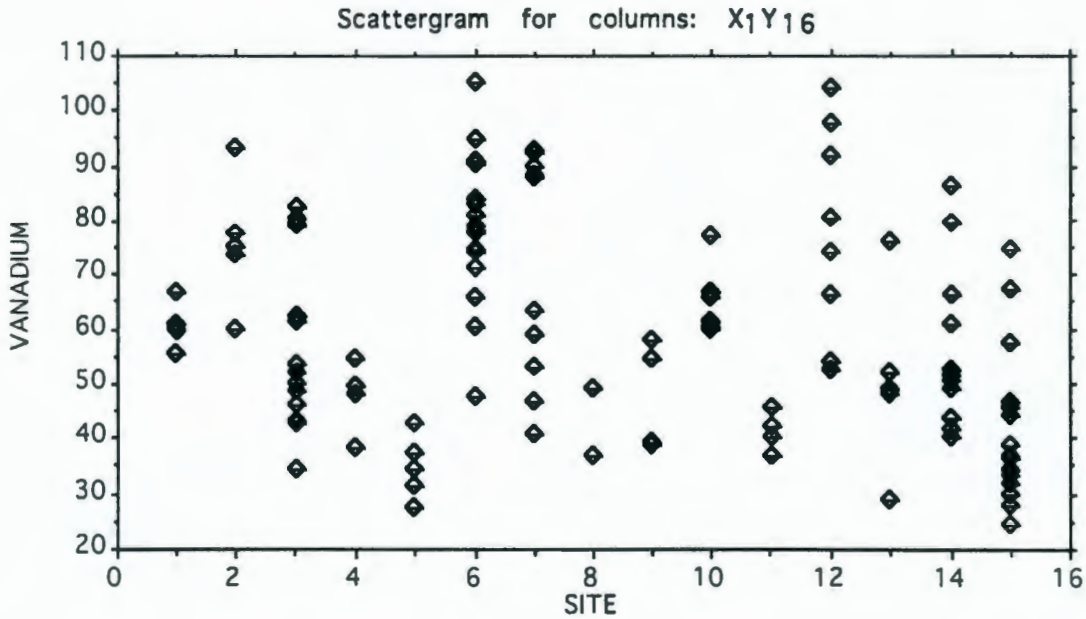
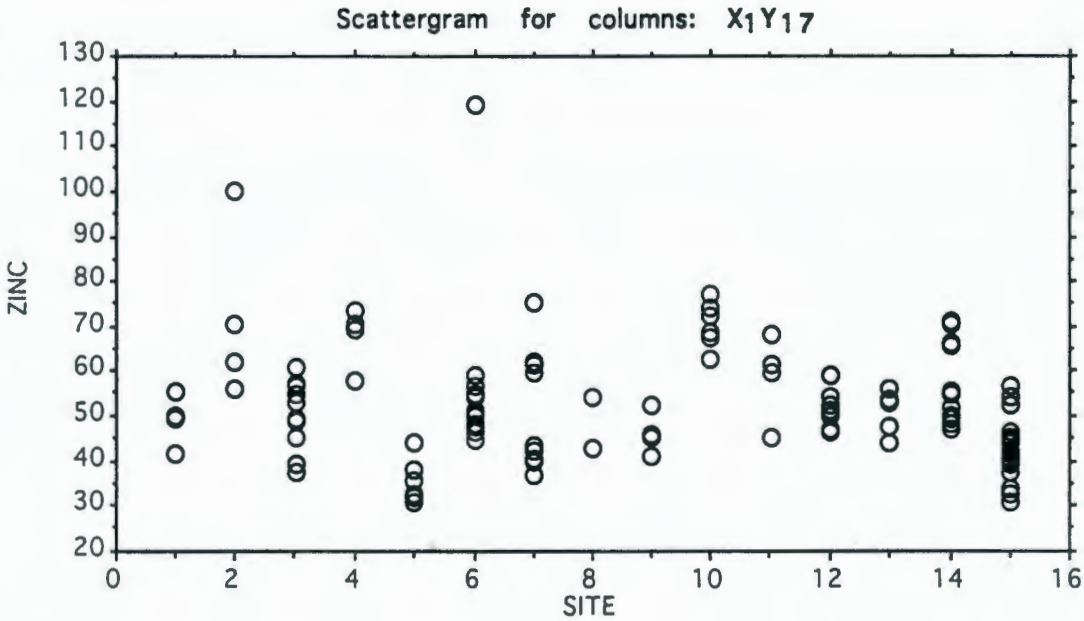


Figure 4-2. Scattergram for Sodium, Vanadium. (sheet 8 of 13)



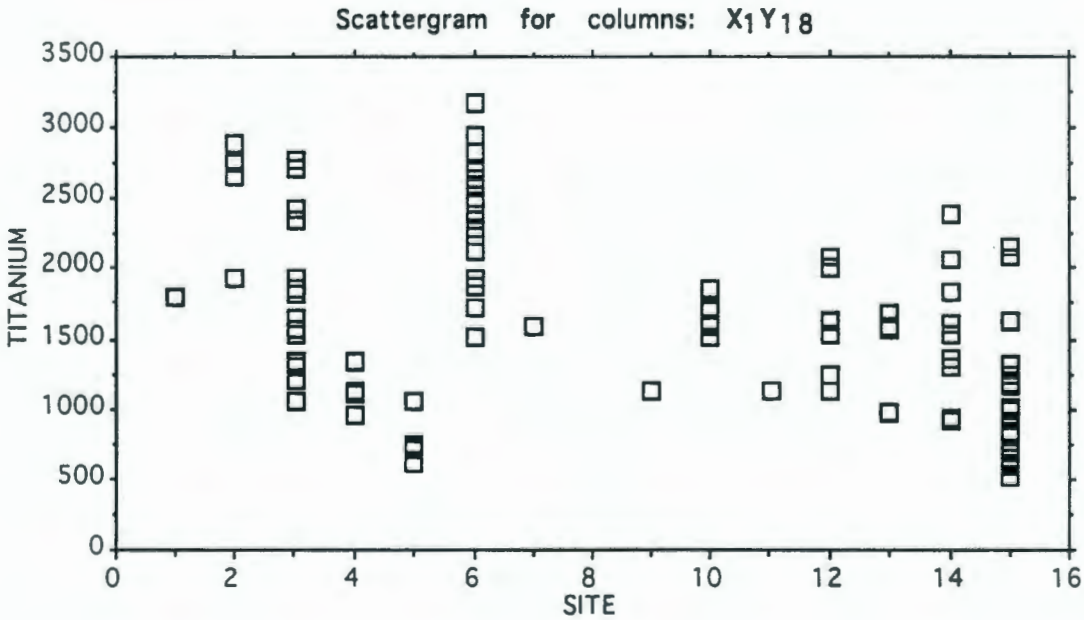
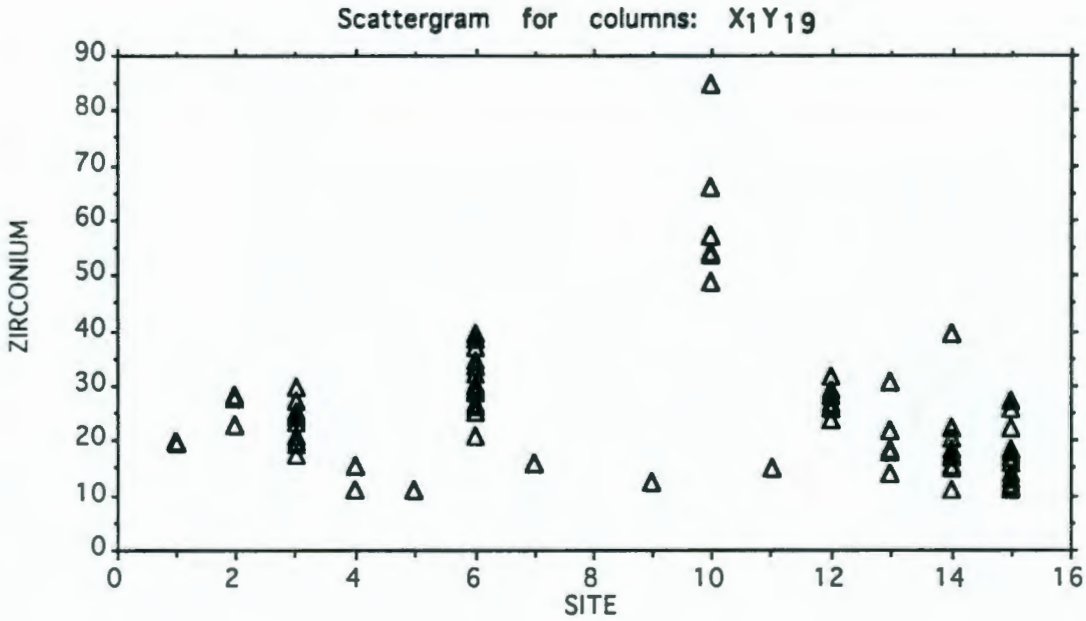


Figure 4-2. Scattergram for Zinc, Titanium. (sheet 9 of 13)

9 2 1 2 6 3 1 7 5 6



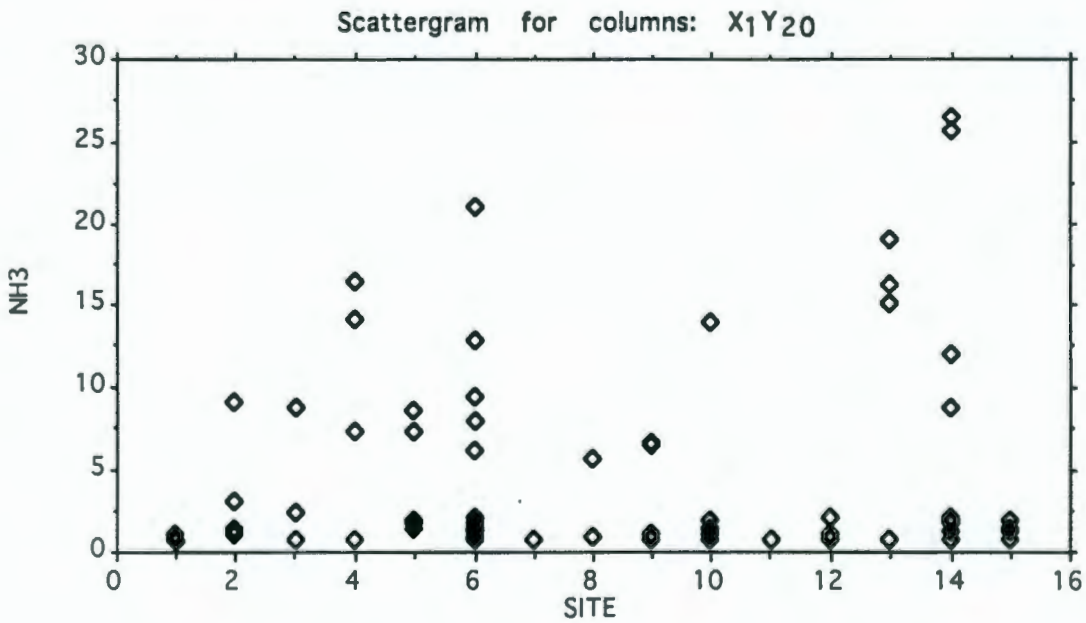
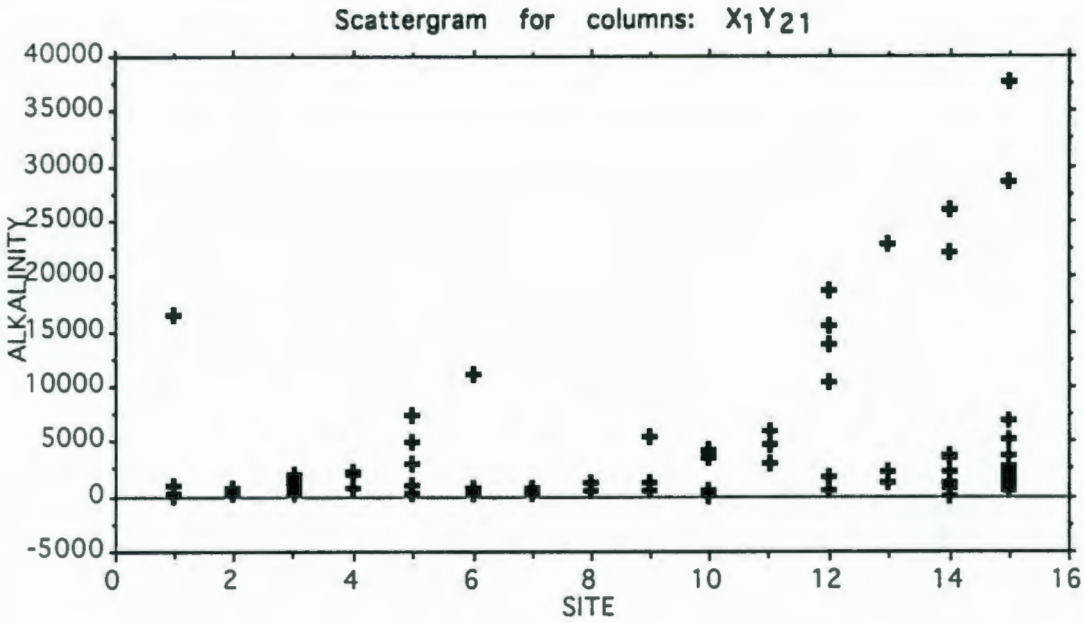


Figure 4-2. Scattergram for Zirconium, NH_3. (sheet 10 of 13)



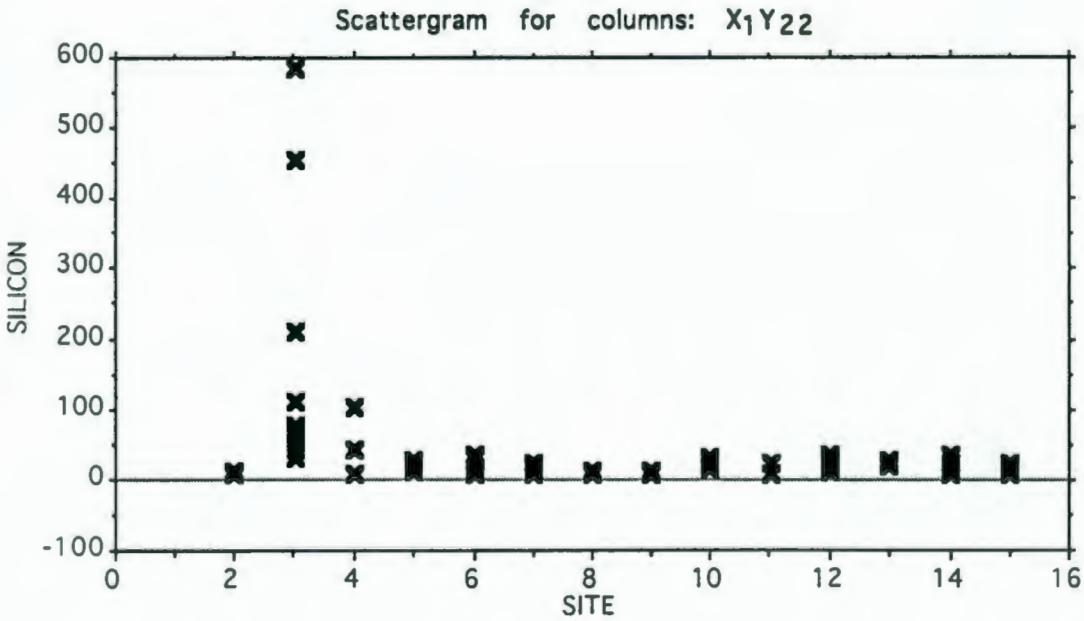
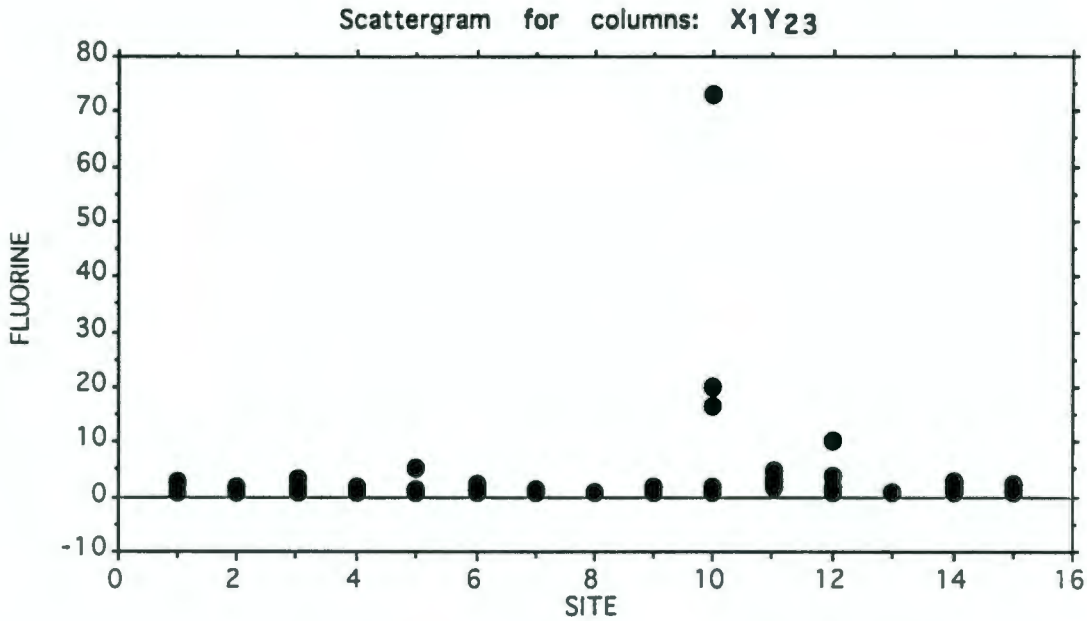


Figure 4-2. Scattergram for Alkalinity, Silicon. (sheet 11 of 13)



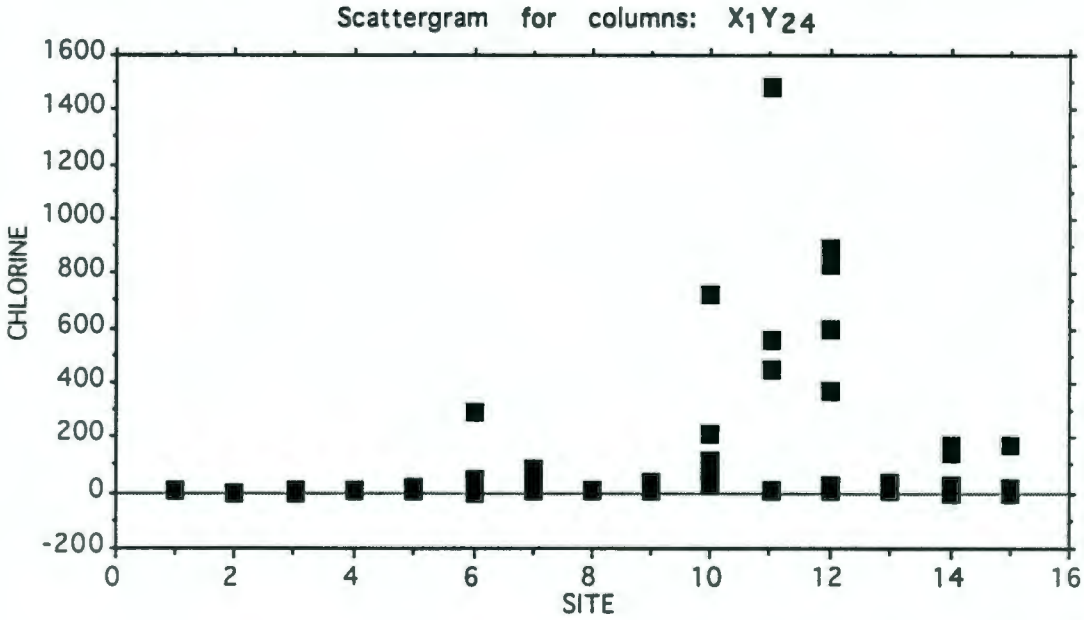
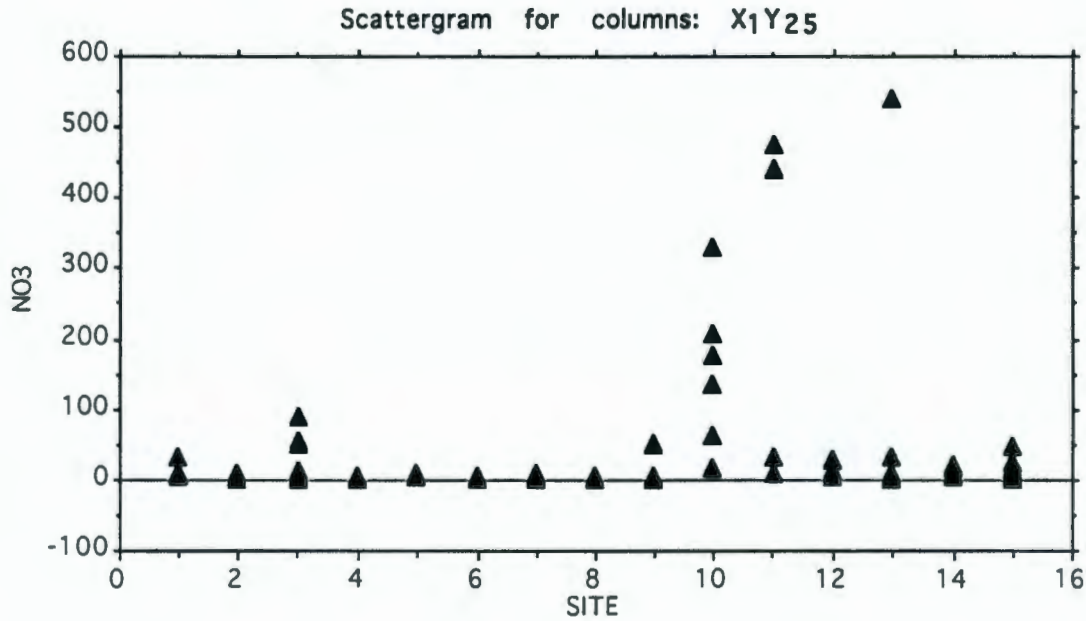


Figure 4-2. Scattergram for Fluorine, Chlorine. (sheet 12 of 13)



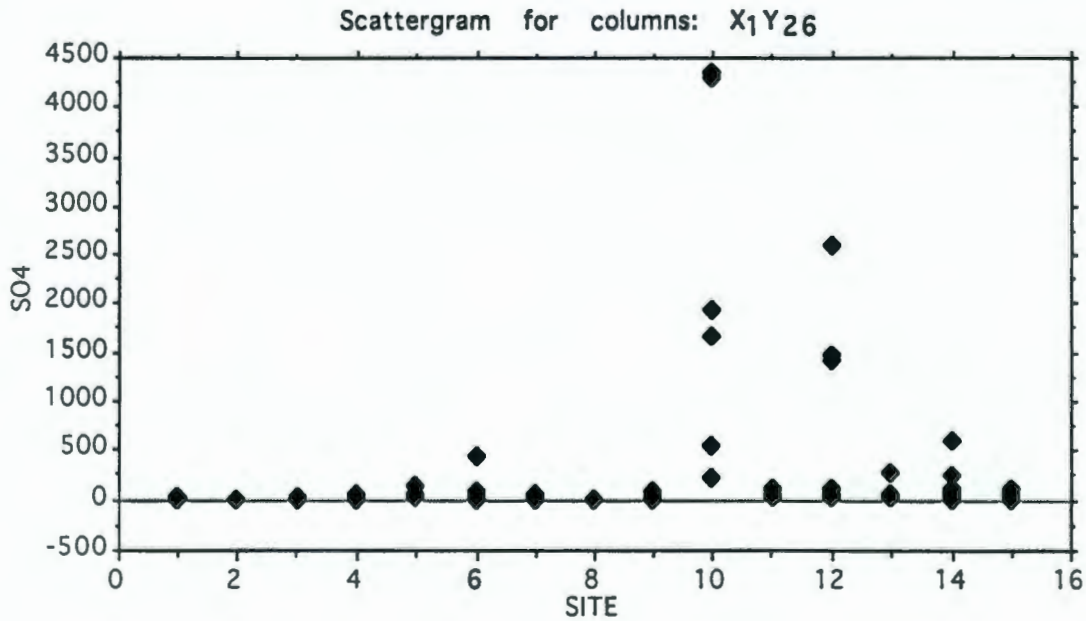


Figure 4-2. Scattergram for Nitrate, Sulfate. (sheet 13 of 13)

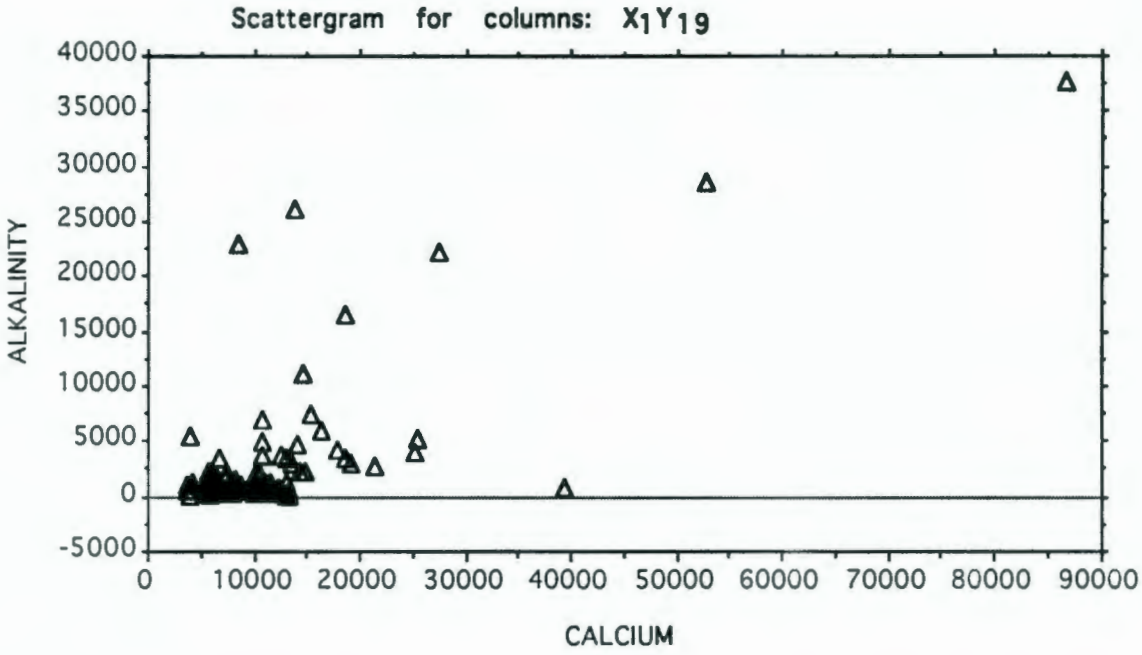
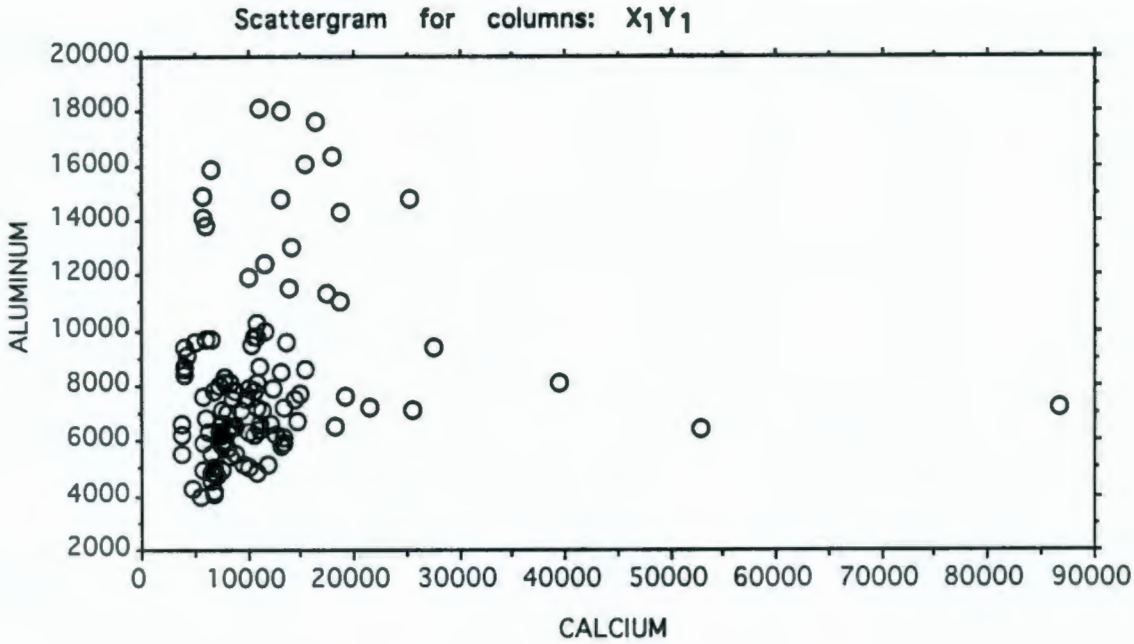


Figure 4-3. Alkalinity vs. Calcium. (sheet 1 of 2)



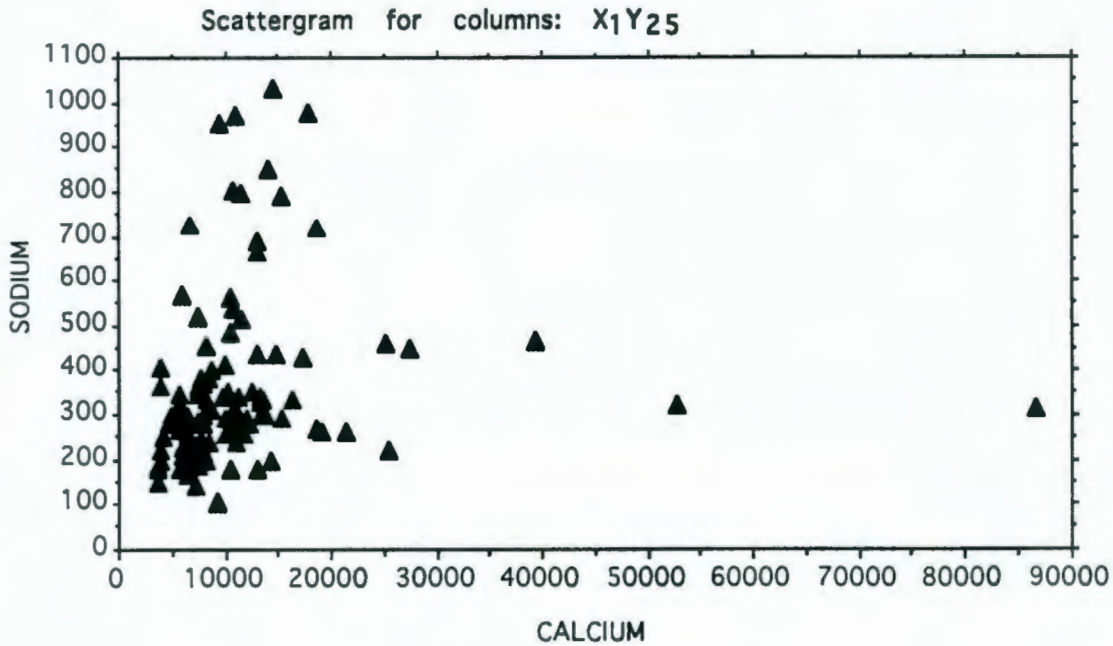
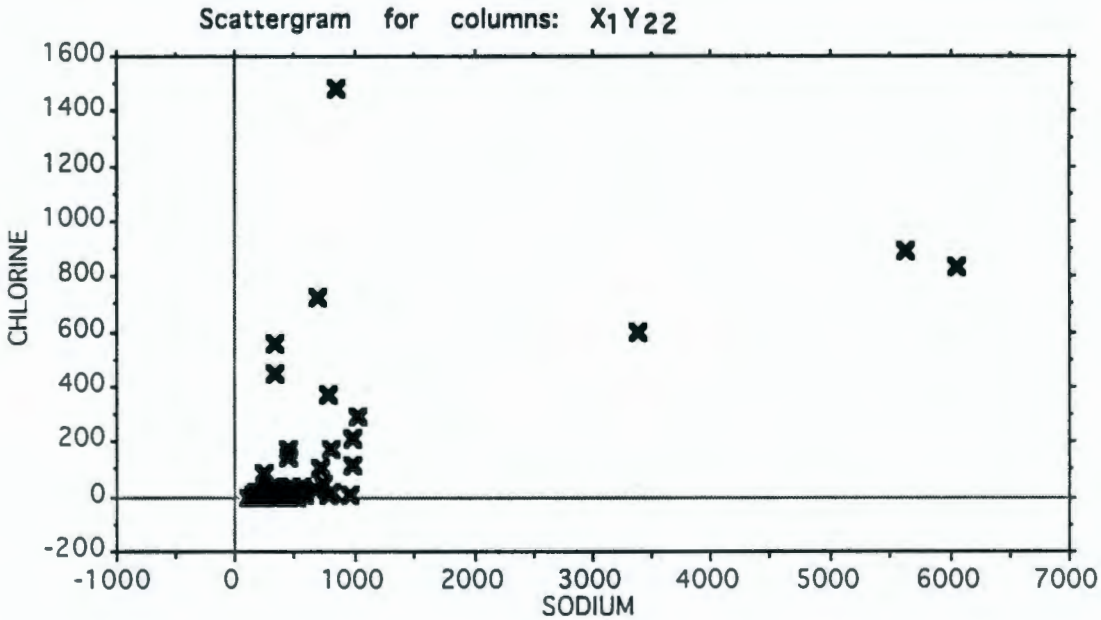


Figure 4-3. Aluminum, Sodium vs. Calcium. (sheet 2 of 2)



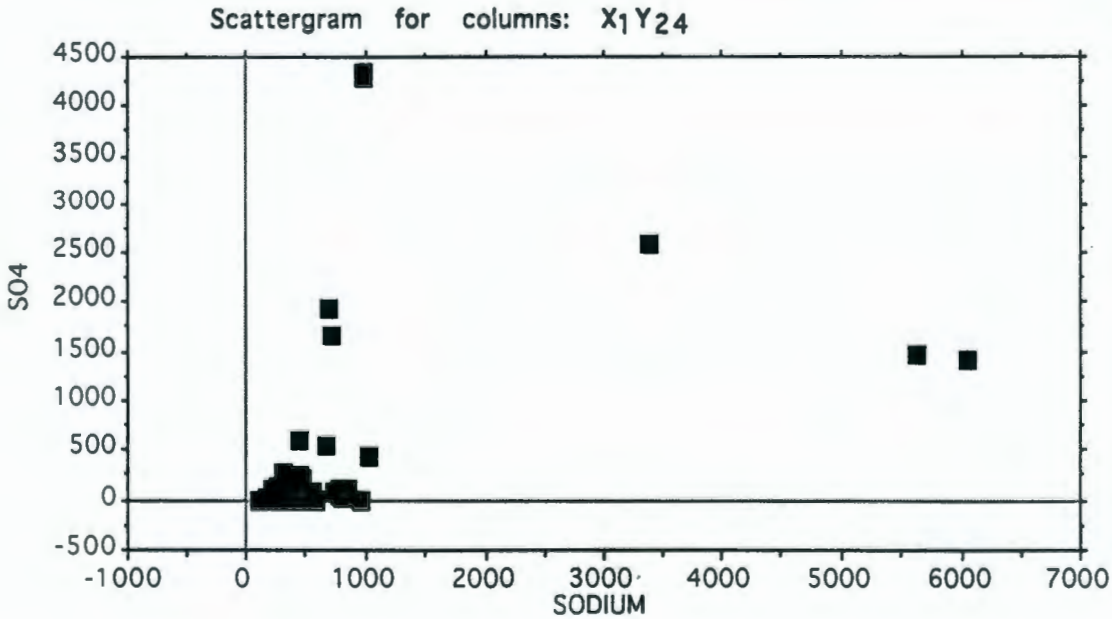


Figure 4-4. Scattergram for Chlorine, Sulfate vs. Sodium.

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TABLE 4-1

RANDOM SAMPLE OUTLIERS

ANALYTE	SAMPLE #	SITE	VALUE ppm	COMMENT
CALCIUM	B014K4	15	86600	SAME SAMPLE HIGHEST ALKALINITY: CALCIUM CARBONATE ENDMEMBER
CALCIUM	B014K5	15	52900	FIELD DUPLICATE OF B014K4, SECOND HIGHEST ALKALINITY
CALCIUM	BO1442	14	39500	ELEVATED AL AND NA, POSSIBLY Ca RICH FINE GRAINED PLAG OR CLAY MINERAL
SODIUM	B01423	12	6060	KNOWN HIGH ALKALI SOIL, HIGH CL, SO4: EVAPORITE DEPOSIT
SODIUM	B01422	12	5620	KNOWN HIGH ALKALI SOIL, HIGH CL, SO4: EVAPORITE DEPOSIT
SODIUM	BO1425	12	3390	KNOWN HIGH ALKALI SOIL, HIGH CL, SO4: EVAPORITE DEPOSIT

WEIBULL DISTRIBUTION PARAMETERS

ANALYTE	TRUNCATION VALUE* ppm	to ppm	ETA η ppm	BETA β	N**	CRITICAL R	R	THRESHOLD VALUE ppm	LOQ
ALUMINUM	0	3763	4987	1.61	119	0.976	0.991	15100	542
CALCIUM	5600	4646	5869	1.22	107	0.975	0.998	22000	206
COPPER	13	12.4	3	0.695	84	0.970	0.997	32.2	4
IRON	0	10996	15385	2.31	119	0.976	0.991	38200	318
LEAD	3.3	2.99	3.5	1.05	110	0.974	0.997	15.4	N/A
SODIUM #	190	122	211	1.86	76	0.969	0.998		
	380	122	181	0.855	28	0.942	0.968	974	167

* Based on scatter of data at low end of distribution
** Number of samples above truncation value + 1
\# Multiple distributions identified in the data set

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CONTENTS

5.0 SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS 5-1

5.1 CONCEPTUAL MODEL 5-1

5.2 SITE-WIDE BACKGROUND 5-1

5.3 RECOMMENDATIONS 5-2

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5.0 SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

It is indicated from the results obtained to date that the site-wide approach to the characterization and use of soil background in environmental restoration activities at the Hanford Site is viable and is technically preferable to the unit-based approach to characterization. These conclusions are provisional, however, because only the validated data from six inorganic metals have been completely evaluated in all aspects of data quality and interpretation. However, it is indicated from preliminary evaluation of other inorganic constituents that the data set is valid. Complete analysis and evaluation of all data collectively are required to draw conclusions and make recommendations that are technically defensible.

5.1 CONCEPTUAL MODEL

The results of current efforts corroborate the conceptual model (WHC 1991a) which suggested that the soils within the vadose zone on the Hanford Site were related in origin and physical compositions, and therefore should be related in chemical composition as well. This model was tested through a systematic sampling and analysis effort designed specifically for the purpose of characterizing the naturally occurring composition of soil at the Hanford Site. This effort was initiated and carried out utilizing the data quality objectives guidelines (EPA 1987b) to ensure that the data collected were representative and of appropriate quality for their intended purpose, i.e., corroboration of the conceptual model and characterization of the soil composition to establish natural background thresholds and comparison criteria. Additional refinement of the conceptual model regarding the dependency of soil composition on grain size, repository, and chemical behavior will provide additional insight into the interpretation of soil compositional data. These refinements will be incorporated into the conceptual model when all the data have been analyzed and evaluated.

5.2 SITE-WIDE BACKGROUND

Threshold values for six representative inorganic analytes (aluminum, calcium, iron, copper, lead, and sodium) were determined based on the complete analysis of the data and their quality. These soil compositions represent the range of lateral and vertical variability of soil types in the Hanford formation and younger soils. The compositions of these soils with respect to these six analytes represent a single statistical population for each of the constituents with the exception of sodium, which is consistent with the variability in the natural repositories of sodium in the soils (e.g., minerals) and its geochemical behavior. Background threshold concentrations represent the levels that should not be exceeded 95 percent of the time with a confidence of 95 percent.

5.3 RECOMMENDATIONS

Information in this section will be provided after completion of the evaluation of all inorganic constituents. This section will include the final results of the data evaluation and analysis in terms of the use of Hanford Site soil background threshold valves.

CONTENTS

6.0 REFERENCES 6-1

6.1 DOCUMENTS 6-1

6.2 FEDERAL AND STATE ACTS 6-4

6.3 WASHINGTON ADMINISTRATIVE CODE 6-4

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6.0 REFERENCES

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6.2 FEDERAL AND STATE ACTS

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Resource Conservation and Recovery Act of 1976, 42 USC 6901 et seq.

6.3 WASHINGTON ADMINISTRATIVE CODE

WAC 173-303, *Dangerous Waste Regulations*, Washington State Department of Ecology, Olympia, Washington.

WAC 173-340, *The Model Toxics Control Act Regulation*, Washington State Department of Ecology, Olympia, Washington.

APPENDIX A

SOIL SAMPLING OBJECTIVES AND SITE DESCRIPTIONS

APPENDIX A

CONTENTS

1.0 INTRODUCTION 1-1

2.0 ACTIVITY OBJECTIVES AND ADDITIONAL SOIL SAMPLING INFORMATION 2-1

2.1 SAMPLING ACTIVITY OBJECTIVES 2-1

2.2 CONCEPTUAL MODEL 2-2

2.3 SITE-WIDE SOIL BACKGROUND SAMPLING SITES 2-3

2.4 COMPOSITIONAL INTEGRITY OF 'SURFACE' SAMPLES 2-5

2.5 GENERALIZED STRATIGRAPHY AND CHRONOLOGY OF THE HANFORD FORMATION 2-5

3.0 SITE-WIDE SAMPLING SITE DESCRIPTIONS 3-1

FIGURE

2-1. Data Quality Objectives Three-Stage Process F2-1

1.0 INTRODUCTION

Provided herein is information on the criteria used to select the soil sampling sites in the context of the Hanford Site-wide soil background project objectives and the conceptual model. This information is supplemental to that provided in the *Characterization and Use of Soil and Groundwater Background for the Hanford Site* (WHC 1991a) and the *Site-wide Background Soil Sampling Plan* (WHC 1991b). This information focuses both on the general and site-specific geologic characteristics of the sampling sites, which served as the basis for their selection.

Section 2.0 addresses questions regarding the selection of specific sampling sites. This section includes discussions on sampling activity objectives, Site-wide soil background sampling sites, compositional integrity of 'surface' samples, generalized stratigraphy, and the chronology of the Hanford formation.

Section 3.0 contains photographs and a brief geological summary of each of the 14 soil sampling sites. The accompanying text addresses specific factors considered in selection of the sampling sites.

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2.0 ACTIVITY OBJECTIVES AND ADDITIONAL SOIL SAMPLING INFORMATION

This section discusses sampling activities, a general description of Site-wide soil background sampling sites, composite integrity of 'surface' samples, generalized stratigraphy, and presents a chronology of the Hanford formation.

2.1 SAMPLING ACTIVITY OBJECTIVES

The data quality objectives (DQO) process recommended by the U.S. Environmental Protection Agency (EPA 1987b) has been used as guidance for all activities associated with determination of the Hanford Site-wide background. The three stages of this DQO process are summarized in Figure 2-1. Most of the Stage 1 activities, including the evaluation of available data, development of a conceptual model, and the specification of objectives and decisions have been included in the *Characterization and Use of Soil and Groundwater Background for the Hanford Site* (WHC 1991a). The objectives of the soil background sampling and analysis effort are summarized briefly in the context of the soil background conceptual model as these and other DQOs have served as the basis for guiding the selection of the sampling sites.

The primary objective of the Hanford Site-wide soil background sampling and analysis effort is to obtain a more complete and representative characterization of the range of chemical constituents that occur naturally in the vadose zone soil. These background data are to be used in defining contamination, in establishing cleanup goals, and in baseline risk assessments for environmental restoration.

Justification for the Site-wide approach to soil background at the Hanford Site also is addressed (WHC 1991a). One of the most important reasons for initiating this new sampling effort was that previous soil sampling efforts were not guided by DQOs; i.e., there was no conceptual model of the vadose zone soil to guide the philosophy of sampling (e.g., to define 'representative' samples). Other factors in the justification of this effort include laboratory data quality concerns for some of the previously collected data.

Therefore, a dedicated effort was initiated to systematically collect representative samples of the vadose zone soil on the Hanford Site. The end use of the data is evaluation of the chemical concentrations of the Hanford Site soils and determination of background threshold values. Some of the most important considerations include: (1) the factors that affect the chemical composition of the Hanford Site soils, (2) how these factors influence the compositions obtained by regulatory protocols, and (3) the type of compositional variability that exists or that can be expected vertically and laterally within the vadose zone.

It first must be recognized that compositional data on soil obtained in accordance with regulatory protocols [e.g., SW-846 (EPA 1990) or Contract

Laboratory Program (CLP)] are not the composition of the total (i.e., bulk) soils/sediments. Analyses obtained by these methods only measure the compositions of acid leachates of the finer grained size fraction of the soil. Therefore, it is necessary to consider what material constitutes the finer grained material in these sediments, and how this material is distributed throughout the vadose zone. To answer this, a conceptual model was developed to explain what the vadose zone is, its geologic characteristics, and how the it was formed (WHC 1991a). This model is based on geologic data, and provides a basis for understanding lateral and vertical distribution of the finer grained constituents in the soil, the compositions of the constituents, and the nature and type of variability to be expected in vadose zone soil samples. The end result of this study will be a better understanding of the origin of the vadose zone.

2.2 CONCEPTUAL MODEL

In the conceptual model referred to previously, the physical characteristics of the Hanford Site vadose zone are described as consisting primarily of the Hanford formation sediments. These sediments are composed of alternating and intercalated layers and lenses of gravels, sands, and silt. The sediments of the Hanford formation were deposited in conjunction with cataclysmic flooding events during the Pleistocene between 16,000 and 12,000 years ago. The physical characteristics of these sediments appear to be highly variable when examined in outcrop. However, the compositions of the sediments and their lateral and vertical distribution across the Hanford Site are very systematic.

The systematic nature of the compositions stems from the size and spatial distribution of the coarse- and fine-grained material in the sediments, which reflect the way the materials were deposited by the Ice Age flood waters. The coarser sediments (i.e., gravels) occur in places that represent ancient high-energy (fast flowing) regimes (e.g., flood channel deposits). The finer grained sediments were deposited in areas of lower energy (e.g., channel margins, bars) and throughout the area in the late stages of flooding. The finer grained material in these sediments consists of two main components: a relatively dense basaltic sand component and a relatively low-density quartz/feldspar component. The basaltic sand component is prevalent in the higher-energy sediments, and the quartz/feldspar component is dominant in the low-energy sediments.

The vertical sequences and lateral variations throughout most of the Hanford formation soils/sediments actually are mixtures of these two main sediment types that were deposited in response to the changing nature of their depositional environment. Vertical variations in these sediments exist because the energy environment of deposition changed within each flood event (e.g., as flood waters were dammed and eventually drained away). A range of grain sizes and matrix materials were deposited simultaneously over areas extending from the main channels to the relatively calm channel margins. Finer grained materials were commonly superimposed over these areas during the low-energy slack-water stages at the end of individual flooding events. Shifts in the position of flood channels and bars from flood to flood were

manifested as both lateral and vertical variations in sediment type and the proportions of basaltic and quart/feldspar-rich matrix material. Thus, a spectrum of sediment types with various proportions of basaltic and quartz/feldspar-rich matrix material was deposited simultaneously during the successive stages of each flooding event.

This model explains the nature of the lateral distribution of coarse gravels, quartz/feldspar-rich sediments, and/or basalt-rich sediments on the Hanford Site. This model also explains the nature and distribution of alternating and/or repeated vertical sequences of coarse- to fine-grained layers that can be intercalated with fine-grained layers throughout much of the Hanford Site.

2.3 SITE-WIDE SOIL BACKGROUND SAMPLING SITES

The onsite sampling sites identified in the soil sampling plan (WHC 1991b) were selected from over 30 locations on the Hanford Site. Three offsite sampling sites also have been identified (two excavation sites and one borehole site). All of these sampling sites were evaluated in the context of the conceptual model as well as the criteria outlined in the *Characterization and Use of Soil and Groundwater Background for the Hanford Site* (Appendix D) (WHC 1991a). These selection criteria include the following:

- Areas free of contamination or influences from waste generation activities
- Type and quality of exposure
- Sediment type and/or range of sediment types exposed
- Extent of vertical exposure
- Lateral coverage/spatial distribution
- Relative stratigraphic position
- Logistical and/or regulatory considerations.

The main objective in the selection of sampling sites was the acquisition of samples representing the range of sediment types and compositions encountered in environmental restoration and closure activities across the Hanford Site. The sampling sites identified in the soil sampling plan (WHC 1991b) were chosen as the sites that expose the most representative variety of soil types within the stratigraphic sequence of the vadose zone with a minimum redundancy or bias of soil types, and that provide a reasonable degree of lateral coverage. These sites also were chosen because the sites expose sediments analogous to those found in the subsurface at various waste management units located on the Hanford Site. The range of sedimentary facies found in these exposures and outcrops correlates directly to those found in the subsurface because the facies represent exhumed parts of the vadose zone.

Many of the vadose zone exposures are excavation sites, also referred to as borrow pits, that have served as quarries of clean sand and gravel for building material use on the Hanford Site. The borrow pits, quarries, and areas excavated in conjunction with new construction (e.g., the Fast Flux Test Facility) constitute a majority of the sampling sites. The remaining sampling sites are locations of opportunity that are natural outcrop exposures (e.g., river bank and stream gully exposures, road cuts), and those that exist because of vadose zone excavations for construction purposes (e.g., Grout Treatment Facility). All of these sampling sites also have undergone screening for cultural resource impacts and environmental protection, including radioactivity surveys in conjunction with the excavation permits. Thus, the excavation and outcrop locations are preferred sampling sites for the following reasons:

- These locations meet all or most of the selection criteria
- These locations represent 'windows' into the upper vadose zone on and off the Hanford Site
- Thicknesses of up to 30 meters (about 100 feet) of the vadose zone both onsite and offsite are exposed at these excavation sites
- The upper few meters of the vadose zone are generally the soils of concern for most environmental restoration, permitting, and closure activities.

One advantage of the 'surface' sampling strategy is that these 'windows' into the vadose zone are available and reliable sources of information on geologic relationships of the vadose zone. Sampling at these sites of opportunity also is more cost effective and yields more overall information than other types of vadose zone sampling because the sites require no new drilling or excavation. Data obtained from samples in these exposures are superior to other types of vadose zone samples because the chemical composition of soil samples can be combined with geologic relationships that are directly observable (e.g., soil type, stratigraphic relationships, etc.), and also because the sample type and integrity are known. Based on the present understanding of the vadose zone, these sampling sites are interpreted as exposing representative samples of the lithologic types expected to occur in the subsurface of the Hanford Site. Brief geological descriptions of the individual soil sampling sites are provided in Section 3.0.

This surface sampling effort was supplemented with samples from two boreholes that traverse the entire thickness of the vadose zone. Splits of about 35 vadose zone soil samples from a deep borehole near the Yakima Barricade and about 12 samples from an offsite borehole on Savage Island was submitted for analysis as part of this effort. These samples were collected by Pacific Northwest Laboratory (PNL) in conjunction with other projects. Supporting information on bulk chemistry, mineral types, well logs, etc., generated by PNL in conjunction with these projects also was provided.

2.4 COMPOSITIONAL INTEGRITY OF 'SURFACE' SAMPLES

Significant modifications in the chemistry of soils due to exposure of the soils within an excavation for several years to tens of years is not a concern to data quality for inorganic analytes. The inorganic chemical composition of soil samples are representative of their unexhumed counterparts, with the exception of near surface samples clearly impacted by biologic processes (e.g., root zone soils that are to be considered separately). This is because the inorganic chemical composition of the soils and sediments is controlled by the constituent rock and mineral compositions that, under arid conditions, are relatively insensitive to changes potentially induced by short-term (i.e., tens to thousands of years) exposure to surficial processes (such as weathering). Even elements that are sensitive to changes in oxidation-reduction conditions [e.g., iron (Fe), manganese (Mn)] would be stable under changing conditions if they were locked into lattices of minerals present in the soil. The effectiveness of this mechanism is demonstrated in the Columbia River Basalts, in which Fe^{2+} concentrations and Fe^{2+}/Fe^{3+} ratios in most of the rocks and minerals have remained essentially unchanged following formation 15 to 10 million years ago. Thus, samples collected from the excavations can be considered to be compositionally representative of their subsurface counterparts with respect to their inorganic compositions.

2.5 GENERALIZED STRATIGRAPHY AND CHRONOLOGY OF THE HANFORD FORMATION

For the stratigraphy of the Hanford formation, a preliminary working model has been developed based on the collective experiences and interpretations of Hanford Site geoscientists. Four subdivisions tentatively have been recognized based on the relative stratigraphy observed in excavations and boreholes, and also on paleomagnetics and isotopic age dating. The type of depositional facies exposed in each outcrop was evaluated for physical characteristics and the observed relationship to lateral and vertical changes in the outcrop.

The youngest parts of the Hanford formation are 10,000 to 6,000 years old and have normal magnetic polarity. The oldest parts have been dated at about 750,000 years and are reversely polarized. Based on information from excavations and boreholes, the thickness of similar facies of the Hanford formation vary greatly across the Hanford Site. The presence or absence of whole stratigraphic sections also varies. For example, only the oldest parts of the Hanford formation are exposed at the surface at sampling site number 10 (described in Section 3.0), whereas the middle parts of the stratigraphic sequence comprise the Hanford formation nearest the surface at other sites (e.g., sampling sites number 6 and 7). Except for volcanic ashes, stratigraphic correlations laterally across the Hanford Site generally are not possible at this time because there are no adequate criteria for correlations, and also because of facies changes that occur on the scale of meters to tens of meters.

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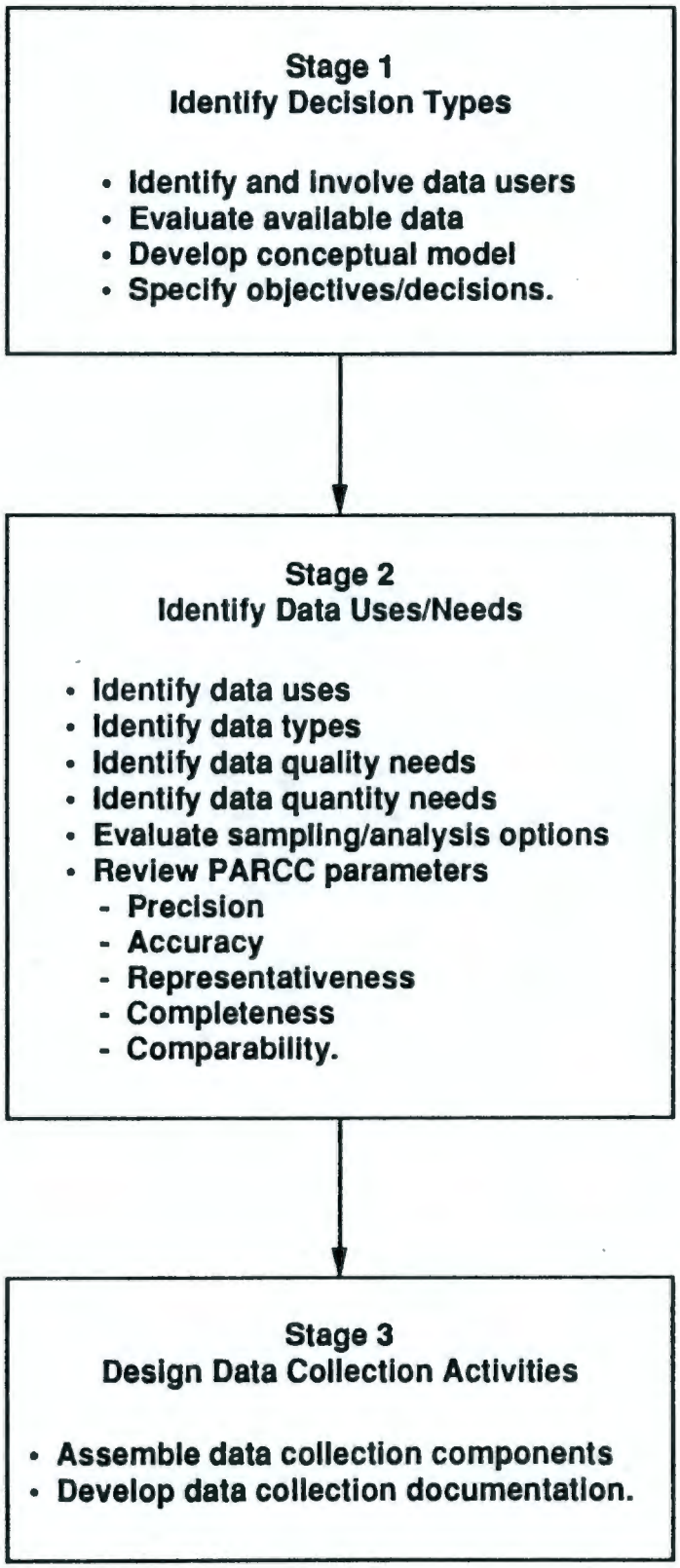


Figure 2-1. Data Quality Objectives Three-Stage Process.

9 2 1 2 6 8 1 7 3 6

3.0 SITE-WIDE SAMPLING SITE DESCRIPTIONS

SAMPLING SITE NO. 1. Port of Benton Off-loading Ramp (located south of 300 Area adjacent to the Columbia River) 3-2
SAMPLING SITE NO. 2. Excavation Exposures Upgrade from the Washington Public Power Supply System Solid Waste Pit 3-3
SAMPLING SITE NO. 3. Hanford Site Gravel Pit No. 9 3-4
SAMPLING SITE NO. 4. Alluvial Overbank Flood Deposits Adjacent to the Columbia River (south of the old Hanford townsite) 3-5
SAMPLING SITE NO. 5. Hanford Site Gravel Pit No. 21 (located in the 100 Area of the Hanford Site) 3-6
SAMPLING SITE NO. 6. Vadose Zone Exposed in Grout Treatment Facility Vault Pit (located in the 200 East Area) 3-7
SAMPLING SITE NO. 7. 218-E8-12B Trench 94 (located in the northeast corner of the 200 East Area) 3-9
SAMPLING SITE NO. 8. Gravel Pit West of the 200 East Area (located just outside of the 200 Area fence 3-11
SAMPLING SITE NO. 9. Old Batch Plant Sand and Gravel Quarry (for cement) 3-12
SAMPLING SITE NO. 10. Exposure of Lower Hanford formation Sediments (located just east of Highway 25 on the Vernita grade near mile marker 41) 3-13
SAMPLING SITE NO. 11. Cold Creek Slack-Water Facies of the Hanford formation on the Flank of Rattlesnake Mountain (located in the vicinity of Cold Creek, west of Highway 240 on the Arid Lands Ecology Reserve) 3-14
SAMPLING SITE NO. 12. Dry Creek Alluvial Deposits in Dry Creek Canyon Area (located west of Highway 240 on the Arid Lands Ecology Reserve) 3-16
SAMPLING SITE NO. 13. Offsite Gravel Quarry Exposures of the Hanford formation 3-17
SAMPLING SITE NO. 14. Offsite Exposure of Hanford formation Deposits (located at the mouth of Ringold Coulee, east side of the Columbia River across from the dune fields on the Hanford Site) 3-19

SAMPLING SITE NO. 1. Port of Benton Off-loading Ramp (located south of 300 Area adjacent to the Columbia River). (one photograph). Two sets of Hanford formation flood gravels overlain by Quaternary loess. High energy flood gravels with a relatively dark (basaltic sand) matrix are overlain by a sandy gravel unit with a higher proportion of quartz/feldspar matrix. These sediments are believed to belong stratigraphically to the middle part of the Hanford formation. These two units represent a transition from a depositional environment of relatively higher energy flood waters to somewhat lower energy. The overlying younger fine-grained sediments are typical of loess deposits found throughout the Hanford Site. The uppermost few inches to few feet above the loess deposits have been locally disturbed by construction activities and were not sampled.

9 2 1 2 6 - 3 1 7 3 8

SAMPLING SITE NO. 2. Excavation Exposures Upgrade from the Washington Public Power Supply System Solid Waste Pit. (one photograph). A thick section of dark-colored clast-free basalt-rich sands are overlain and locally intercalated with light-colored quartz/feldspar-rich sediments. The darker sands represent one of the best exposures found of a basalt-rich sand endmember. These sands were deposited in the late stages of a flooding event with a rapid transition to a slack-water environment from which the quartz/feldspar-rich sand/silts were deposited. The overlying light-colored sands/silts are typical of those found at the margins of the old flood channels (e.g., SAMPLING SITE NO. 11). These deposits are interpreted to be the early middle part of the stratigraphic sequence of the Hanford formation. The holes in the overlying light-colored sediments are swallow nests that were avoided during sampling. The white colored areas in the upper part of the basaltic sands appear to be concentrations of calcium carbonate; perhaps from replacement of old animal burrowings. These areas are restricted to the uppermost part of the basaltic sand unit, and some of these areas were included in the sampling effort. Red flags mark locations of samples.

9 2 1 2 6 0 3 1 7 8 9

SAMPLING SITE NO. 3. Hanford Site Gravel Pit No. 9. (one photograph). Thirty to 40 feet (9.1 to 12.2 meters) of the Hanford formation is exposed here in which several high energy (channel) gravel units of varying types can be readily distinguished. The sediment types range from very coarse, nearly open-framework gravels to finer grained gravels with matrices of both basalt-rich material and of quartz/feldspar-rich material. This sampling site was selected because the site represents one of the best sequences of high energy (channel) gravels with several transitions from high energy to lower energy within a flood channel environment. The sampling site is believed to represent both the early and the middle parts of the Hanford formation channel facies. Some excavation was performed on this site before sampling.

9 2 1 2 6 . 8 1 7 9 0

SAMPLING SITE NO. 4. Alluvial Overbank Flood Deposits Adjacent to the Columbia River (south of the old Hanford townsite). (one photograph). These fine-grained silts and sands ± clay originate from Quaternary Columbia River floods that are younger than and stratigraphically overlie the Hanford formation. Several paleosol horizons are visible in the overbank exposures. This site was selected because these sediments represent an important type of material in the vadose zone, i.e., non-Hanford formation alluvial deposits. These sediments are ubiquitous throughout the 100 Areas of the Hanford Site. Sampling at this site also represents an opportunity to characterize the chemical variations associated with an obvious soil-development profile.

Recent stabilized sand dunes also occur about 30 to 60 feet (9.1 to 18.3 meters) from the Columbia River at this location. These sand dunes are locally draped over the overbank deposits and/or Hanford formation sediments. Eolian deposits of this type have somewhat different characteristics from loess in that there is locally a high degree of small scale segregation of light and dark colored material. Samples of these stabilized dune deposits also will be collected at this location as this type of eolian material commonly comprises the upper few inches to upper few feet of the vadose zone at the Hanford Site. Red flags mark locations of samples.

9 2 1 2 6 7 3 1 7 9 1

SAMPLING SITE NO. 5. Hanford Site Gravel Pit No. 21 (located in the 100 Area of the Hanford Site). (one photograph). Four different lithologic types are exposed in this quarry. The finer grained facies of the middle Hanford formation are well exposed at this site, as well as a sequence of eolian sand layers above and below Mount Mazama ash (6,800 to 6,600 years old). The Hanford formation deposits range from open framework gravels to transitional flood sands and gravels that are typical of the lower energy depositional regimes found in the 100 Areas; these were deposited away from the main channel. Plane-laminated glaciofluvial sands also are exposed at the base of the quarry. Red flags mark locations of samples.

9 2 1 2 6 5 8 1 7 9 2

SAMPLING SITE NO. 6. Vadose Zone Exposed in Grout Treatment Facility Vault Pit (located in the 200 East Area). (three photographs). This site is one of the best continuous exposures of Hanford formation sediments that exists on the Hanford Site. These outcrops are exposures of opportunity resulting from the excavations for the Grout Treatment Facility. Exposed at this location is a thick section of interbedded basalt-rich and quartz/feldspar-rich sands that contain only a few cobbles and/or pebbles. These deposits are representative of the finer grained transition facies found in the 200 Area Plateau. These sediments were deposited on the lee side of a bar between the flood channels and the lower energy environments in back of the bar. This sequence of bar deposits forms a slight topographic high in the 200 Area where sediments accumulated as the flood waters flowed from the north-northwest to the southeast. Several unconformities, manifested as horizontal layers truncating foreset bedding, are evident at this location. These represent successive flood episodes and changes in the energy regime within flood episodes.

Also, the compositional diversity of the finer grained material in the Hanford formation is well illustrated, and includes clastic dikes, a well developed caliche horizon with calcified root casts in the upper part of the section, and paleosol development in the upper parts of eolian deposits that overlie the Hanford formation deposits. This sampling site was selected because of the unusually good continuous exposure of many tens of feet of the vadose zone in the 200 Area Plateau, the variety of soil types and depositional environment, and the uncontaminated nature of the site. This sampling site also afforded the opportunity to sample units laterally for tens of feet for the evaluation of lateral variability. Red flags mark locations of samples.

9 2 1 2 6 0 8 1 7 9 3

1 **SAMPLING SITE NO. 6**

9 2 1 2 6 - 8 1 7 9 4

SAMPLING SITE NO. 7. 218-E8-12B Trench 94 (located in the northeast corner of the 200 East Area). (two photographs). This site and the Grout Pit (Sampling Site No. 6) are two of the best continuous exposures of the vadose zone that exist on the Hanford Site. Several gravel and sand facies are exposed here, ranging from high-energy open framework gravels to transition facies sands and sandy gravels. The close proximity of this sampling site to the Grout Pit, located 0.9 miles (1.5 kilometers) to the south, provides insight into the scale of lateral variability of the Hanford formation. Sediments were deposited contemporaneously in both locations, but differ significantly in grain size over this short distance owing to local differences in the sedimentary environment. The Hanford formation in the area of Trench 94 represents sediments deposited in the vicinity of a bar on the side closest to the flood channel (medium-high energy environment), whereas the Grout Pit sediments were deposited on the lee side of the bar. These relationships provide information on the scale of variability in depositional environments and facies in the Hanford formation. This sampling site also is one of the best 'windows' into the upper 30 to 50 feet (9 to 15 meters) of the vadose zone on the Hanford Site. Sampling sites such as this contribute much to understanding the geology and physical composition of the Hanford Site vadose zone. Red flags mark locations of samples.

9 2 1 2 5 - 8 1 7 9 5

1 **SAMPLING SITE NO. 7**

9 2 1 2 6 - 8 1 7 9 6

SAMPLING SITE NO. 8. Gravel Pit West of the 200 East Area (located just outside of the 200 Area fence). (one photograph). At this sampling site, two to three high-energy regime flood gravel units are exposed. These units are locally intercalated with discontinuous lenses and layers of finer grained quartz/feldspar-rich sand. The gravels are laminated and show cyclic concentrations of dark and light colored material in their matrices. This deposit is a good example of transitional depositional facies that range from gravels deposited under flood conditions to finer, light-colored sands deposited under slack-water conditions. Red flags mark locations of samples.

9 2 1 2 6 = 8 1 7 9 9 7

SAMPLING SITE NO. 9. Old Batch Plant Sand and Gravel Quarry (for cement). (one photograph). The deposits exposed at this sampling site are similar in type to those exposed at Sampling Site No. 8, (i.e., high energy main channel gravels with some late stage, lower energy sandy interbeds). However, the gravels at this location differ from those at Sampling Site No. 8 in that these deposits reflect more highly variable environments of deposition. The gravels exposed here are highly structured, i.e., foreset- and cross-bedding truncated by successive depositional episodes or flood surges. Both the structure of these sediments and the repetition of relatively closely spaced sequences of coarse dark-colored gravels transitional to finer grained quartz/feldspar-rich sands attest to a high degree of variability in the energy of the depositional environment.

9 2 1 2 6 8 1 7 9 8

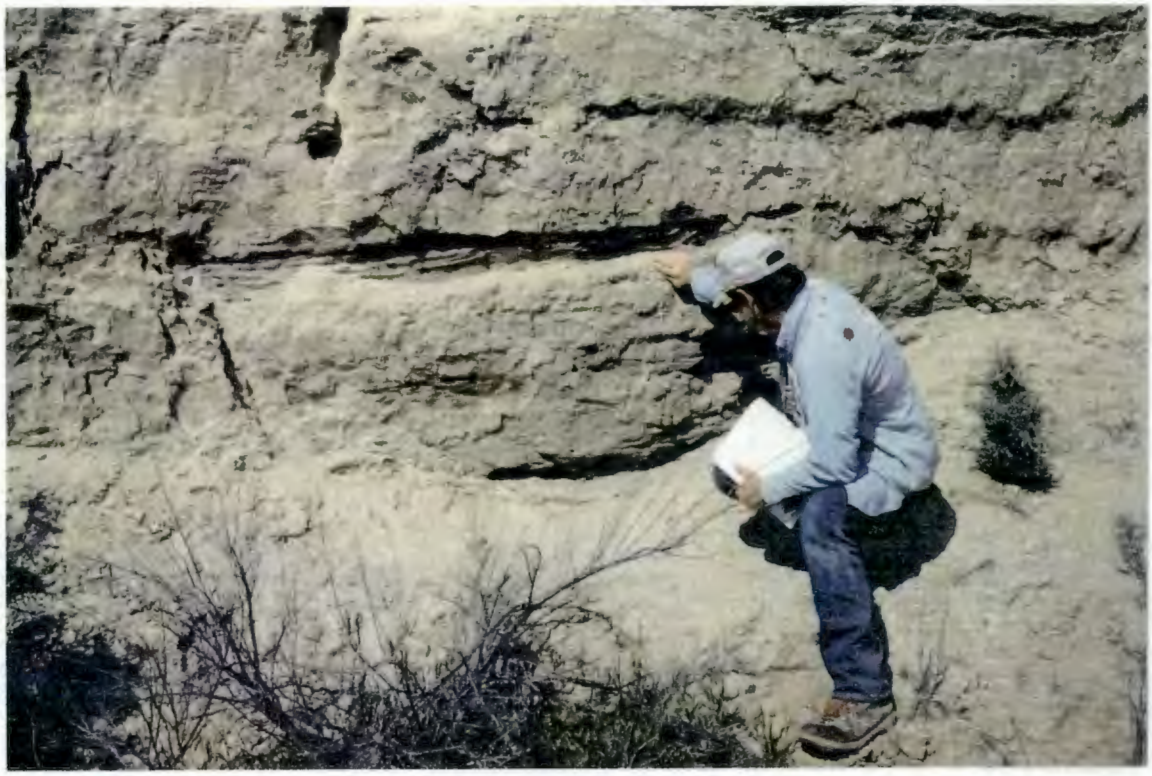
SAMPLING SITE NO. 10. Exposure of Lower Hanford formation Sediments (located just east of Highway 25 on the Vernita grade near mile marker 41). (one photograph). This outcrop exposes the basal part of the Hanford formation. Flood gravels in this area have an usually high basalt clast content and overlie a pre-Hanford formation orange-colored loess unit deposited unconformably on 15 to 10 million year old Columbia River basalt (not shown in photograph). This basal flood gravel is well exposed and is characterized by a relatively high degree of calcite cementation throughout the angular gravels. This is one of the only known locations where the lower part of the Hanford formation is exposed. This part of the Hanford formation is reversely polarized and is determined to be as old as 750,000 years. Although exposed here, this part of the Hanford formation occurs at depths of over 200 feet (61 meters) below the surface elsewhere on the Hanford Site. Red flags mark locations of samples.

9 2 1 2 6 - 8 1 7 9 9

SAMPLING SITE NO. 11. Cold Creek Slack-Water Facies of the Hanford formation on the Flank of Rattlesnake Mountain (located in the vicinity of Cold Creek, west of Highway 240 on the Arid Lands Ecology Reserve). (three photographs). The fine-grained quartz/feldspar-rich sand, silt, and clay sediments exposed in this stream gully represent sediment deposited at the distal margins of the flood channels contemporaneously with the Pasco gravels. These slack-water facies of the Hanford formation (Touchet beds) also represent one of the two compositional endmember materials that comprise the matrix of the Hanford formation deposits. Good vertical and lateral exposures of the rhythmically layered and finely laminated sediments exist at this sampling site, which reflect slack-water deposition from successive flood events. Clastic dikes of similar composition also occur at this location.

9 2 1 2 5 8 1 8 0 0

1 SAMPLING SITE NO. 11



9 2 1 2 6 - 8 1 8 0 1

SAMPLING SITE NO. 12. Dry Creek Alluvial Deposits in Dry Creek Canyon Area (located west of Highway 240 on the Arid Lands Ecology Reserve). (one photograph). These sediments represent Touchet bed material from the marginal facies of the Hanford formation that have been remobilized by local stream processes and are interbedded with volcanic ash (white colored layers). This material is very similar in appearance and composition to the fine-grained quartz/feldspar-rich sandy-silty deposits exposed in Cold Creek. However, these deposits are younger because the are remobilized and are interbedded with volcanic ash from Mount Mazama (6,800 to 6,600 years old).

These alluvial deposits are typical of one source of sediment that is transported across the Hanford Site and deposited as loess by eolian processes. The composition of these sediments will be compared and contrasted to those of the parental Touchet bed material, the eolian loess, and other fine-grained quartz/feldspar-rich sediments in the Hanford vadose zone. The Mazama ash was collected and analyzed as one type of natural outlier that can be expected to deviate from the population of other Hanford Site soil background compositions.

9 2 1 2 6 - 8 1 3 0 2

SAMPLING SITE NO. 13. Offsite Gravel Quarry Exposures of the Hanford formation. (three photographs). Excellent exposures of predominantly high energy gravels and subordinate amounts of sandy interbed transitional facies of the Hanford formation occur in an abandoned gravel quarry on the east side of the Columbia River across from the 300 Area. Quaternary loess deposits overlie the Hanford formation deposits. Good vertical and lateral exposures of several successive flood deposit sequences exist at this site.

This location was selected as a good soil background sampling site because it is one of the best offsite exposures of Hanford formation deposits known to exist. These deposits also represent the upper part of the Hanford formation sediments that exist elsewhere on the Hanford Site.

9 2 1 2 6 8 1 8 0 3

1 **SAMPLING SITE NO. 13**

9 2 1 2 6 7 8 1 8 0 4

SAMPLING SITE NO. 14. Offsite Exposure of Hanford formation Deposits (located at the mouth of Ringold Coulee, east side of the Columbia River across from the dune fields on the Hanford Site). (three photographs). The exposures of Hanford formation deposits at this location are perhaps the most variable of all sampling sites. Soils with both basaltic and quartz/feldspar rich fine-grained components occur in the same section. The lower to middle part of this exposed section consists of dark colored high energy main channel gravels and cross-bedded sands with a high proportion of basaltic matrix material. The upper part of the section consists of a succession of lighter colored gravels transitional to fine-grained light colored quartz/feldspar-rich slack-water sands and silts that show evidence of soft sediment deformation. One of the most distinctive features of the deposits at this sampling site is the difference between the dark and light colored gravels. The lower gravels are dominated by basaltic clasts and matrix material. The upper gravels, however, appear to be dominated by reworked material from the Ringold Formation. Another variety of channel gravels also is exposed stratigraphically below the basalt-rich gravels elsewhere at this location (not shown in photographs). This sampling site was selected because of the excellent lateral and vertical exposure of the Hanford formation deposits, its offsite location, and because the sampling site represents one of the most diverse stratigraphic section of Hanford formation sediments that has been observed to date in the Pasco Basin.

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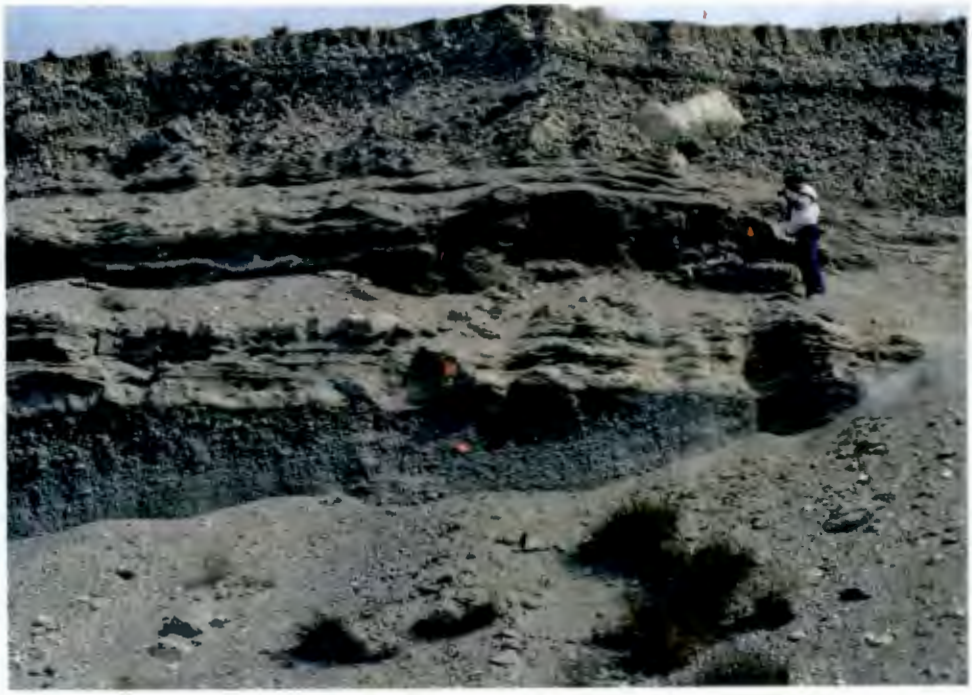
1 SAMPLING SITE NO. 14



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APPENDIX B

SAMPLING NARRATIVE

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APPENDIX B

CONTENTS

1.0 INTRODUCTION 1-1

1.1 INORGANIC SAMPLING 1-1
1.1.1 Site #1 1-2
1.1.2 Site #2 1-2
1.1.3 Site #3 1-3
1.1.4 Site #4 1-4
1.1.5 Site #5 1-4
1.1.6 Site #6 1-5
1.1.7 Site #7 1-5
1.1.8 Site #8 1-5
1.1.9 Site #9 1-6
1.1.10 Site #10 1-6
1.1.11 Site #11 1-7
1.1.12 Site #12 1-7
1.1.13 Site #13 1-8
1.1.14 Site #14 1-8

1.2 SURFACE SOIL ORGANIC SAMPLING 1-9
1.2.1 Site #1 1-10
1.2.2 Site #2 1-10
1.2.3 Site #3 1-11
1.2.4 Site #4 1-11
1.2.5 Site #5 1-12
1.2.6 Site #6 1-12
1.2.7 Site #7 1-12
1.2.8 Site #8 1-13
1.2.9 Site #9 1-13

2.0 VAPOR HEADSPACE MEASUREMENTS 2-1

2.1 METHOD 2-1

2.2 IMPLEMENTATION 2-2

2.3 SUMMARY OF RESULTS 2-3

2.4 CONCLUSION 2-4

FIGURE

1. Sampling Site Locations F-1

TABLES

1. Headspace Screening Sample Key T-1
2. Equilibrium Headspace Method - Field Data Sheets T-2

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1.0 INTRODUCTION

This appendix describes the collection of field samples performed in accordance with the *Site-wide Background Soil Sampling Plan* (WHC 1991b).

Field work was divided into two phases: inorganic and organic sampling. Samples for inorganic analysis were collected from 14 sites. All sites had vertical exposures from which multiple samples were collected. This work was performed from September through November of 1991. Sampling for organic constituents was conducted in late February and March of 1992, at nine locations different from those used for inorganic sampling. Samples from the organic sites were submitted for laboratory organic and inorganic analyses. Supplementary organic field screening measurements were made during this phase on fresh soil samples from both the initial 14 and the latter nine sites. The inorganic sampling sites identified in the Plan are described in detail in Appendix A. Raw data for selected analytes obtained from these samples are presented in Appendix C. Background data analysis is contained in Appendix D.

Splits of all samples are archived at the Hanford Geotechnical Sample Library.

1.1 INORGANIC SAMPLING

The sites were chosen with attention to size and type of geological exposure, lack of known contamination, geographic location, and practical considerations. Samples were not collected in sloughed material or in areas where there was evidence that the soil had been moved. Only in situ, native geologic material was collected.

At each sampling site, a systematic series of samples were collected along the fall line of the chosen slope. These samples were spaced at approximately 3-foot (0.9-meter) vertical intervals from a random starting point. Samples selected on this basis are referred to as systematic random samples. The top of the sampling line was marked with a stake before leaving the site.

Additional samples were collected to supplement the systematic samples. These samples were chosen by the field geologist when important lithologic features were not represented by the systematic samples. Samples selected on this basis will be referred to as judgment samples.

At least one position at each site was randomly selected for multiple sampling. One sample was submitted for analysis as a regular sample, another sample was sent to an alternate laboratory as a split sample, and a third sample was divided into two portions, given separate identification numbers, and submitted to a laboratory for grain size analysis.

All samples were collected with stainless steel trowels or spoons. Stainless steel bowls and screens also were used for some samples. Separate, clean equipment was used for each sample. Only laboratory cleaned, stainless

steel collection equipment was used. Samples were placed in new, manufacturer-cleaned glass sample jars. Samples for laboratory chemical analysis were cooled on collection, and maintained on ice during shipment to the analytical laboratory.

Before shipment offsite, portions of all samples were laboratory-screened for radioactive content in accordance with routine onsite requirements. Most samples were screened for total activity at the 222-S Analytical Laboratory. Samples from some sites (Sites #4 and #6) were screened for release from radiological controls by the onsite mobile health physics counting organization. The results of screening were the same in all cases. Laboratory testing showed no aliquots exceeded the criteria for release as nonradioactive in accordance with applicable requirements (WHC 1988a). This was consistent with all observed radiological field instrument readings.

The location of each of the sites is presented on Figure 1. A narrative of the sampling procedures for each site is presented as follows in the order of assigned number. The order of site sampling did not necessarily correspond with this designation. Numbers associated with gravel pits follow the Hanford Site numbering scheme.

1.1.1 Site #1

This site lies along the north side of a little-used gravel road leading to a heavy equipment offload ramp on the Columbia River, owned by the Port of Benton, Richland Washington. Sampling commenced on September 12, 1991. A vertical section of the hill was exposed when the road was built. A rocky, 32-foot (9.8-meter) wide section was selected as eligible for sampling.

Three sample locations represented the full height of the exposure. Samples were collected from the bottom upward to avoid the possibility of any cross contamination from the sampling process. Split samples for chemical analysis and grain size analysis were collected at the uppermost location, about 1 foot (0.3 meter) below the top edge of the exposed slope. No judgment samples were collected from this site.

1.1.2 Site #2

This site, currently leased to the Washington Public Power Supply System (WPPSS), was sampled on September 26, 1991, the third of 14 sites. The area is adjacent to other WPPSS operations in the southeast section of the Hanford Site. Access to the area is restricted by WPPSS.

The systematic samples were collected from four locations on an excavated, coarse sand hillside. Multiple samples from the uppermost location, about 1 foot (0.3 meter) below the top of the exposure, were submitted as regular, split, or grain size analysis samples.

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Two judgment samples were chosen to supplement the systematic data set. Several carbonate-rich masses were visible on the eligible area, and one of these was sampled. Another dark, basalt-rich sand sample was collected over 40 yards (36.6 meters) northeast of the line of systematic samples, stratigraphically lower in the section.

1.1.3 Site #3

This site is slightly over a mile (a kilometer) north of the Wye barricade on the Hanford Site, east of Route 2 South. Two separate sampling events occurred at Site #3. A continuous 12-foot (3.7-meter) high exposure was sampled on October 24, 1991. This site was later terraced, exposing 25 vertical feet (7.6 vertical meters) in a stairstep manner. Resampling was performed on November 21, 1991 to take advantage of this larger exposure. Although all other sites were sampled after a prolonged period of no significant precipitation, both sampling events at Site #3, particularly the latter, occurred when soil was moist from recent rain. Weather for background sampling, beginning the second week of September, generally was pleasant. Weather in the latter part of October changed abruptly from sunny, warm, and dry to overcast, cool, and rainy.

On October 24, 1991, samples were collected during light wind and rain from four systematic and six judgment locations. The line of systematic samples was chosen at random from a 40-foot (12.2-meters) horizontal section of gravelly exposure. There were 12 feet (3.7 meters) of exposure at this location, from which multiple samples were collected 2 feet (0.61 meter) from the top. This was the location of the uppermost systematic sample. Two judgment samples were collected from this area. These were located about 4 feet (1.2 meters) apart vertically, 30 feet (9.1 meters) north of the systematic line. Screens were used to help separate rocks from the finer fraction for all the samples.

Field sieving was only performed to aid in the removal of large rocks, and not to precisely separate the less than 2-millimeter fraction from site material. Screen mesh sizes varied. Laboratories performing chemical analysis were instructed to use the less than 2 millimeter size fraction of submitted samples. This size fraction is recommended by the MTCA (WAC 173-340-740).

Four judgment samples were collected from eolian sand deposits near this site. Sample B014G8 was removed from the vertical face of a sandy hill, located about 10.5 feet (3.2 meters) southwest of the systematic line, outside the defined zone. The three other samples were collected near the top edge of the sandy hill northwest of the pit. The sample locations lie in a line 27 feet (8.2 meters) and 43 feet (12.8 meters) from the lowest location as measured along the hill's slope. The hill changed pitch over the length of the transect. The sand composition was visibly different at each location. The lowest site was chosen for multiple sampling.

After excavation, approximately five 5-foot (1.52-meter) vertical slopes were exposed, separated by horizontal terraces 15 to 20 feet (4.6 to

6.1 meters) wide. New sites were marked and geologic observations were made on November 15, 1991. The systematic line of samples was selected from a defined 60-foot (18.3-meter) horizontal section of the embankment. The top 2 feet (0.61 meter) of the vertical section was not trusted to be original, in situ material, and so was excluded from consideration for sampling.

On November 20, 1991, the pit area was resampled. Samples were collected from a single line perpendicular to the stepped terraces of the new excavation. Old systematic sampling sites were obliterated when the new area was cleared. Eight locations were sampled; multiple samples were collected at the 14-foot (4.3-meter) depth. No additional judgment samples were collected at this time. The earlier exposed sand lens had been obliterated, and no similar lens was exposed.

1.1.4 Site #4

This site was the first of two sampled on October 3, 1991. The other was Site #10, near Vernita. Site #4 is south of the old Hanford townsite along the shore of the Columbia River. Samples were collected from a thick river overbank deposit. A line down the natural vertical bluff was chosen at random from a 46-foot (14-meter) horizontal section. Three sample locations represented the full height of the exposure. An additional split sample and samples for grain size analysis were collected at the lowest sampled location, 7 feet (2.1 meters) below the well-defined top edge.

1.1.5 Site #5

This site is farther north than any other background site. The site was located in a manmade pit, Pit 21, near the 100 D and DR Areas. Some preparation of this site was necessary because sand and wind-blown tumbleweeds had accumulated at the base of the target area. Project personnel arranged for a backhoe to re-excavate the desired face. This was completed October 16, 1991.

On October 18, 1991, the site was visited in the late afternoon, locations flagged for sampling, and observations made by the project geologist. A systematic line of samples was chosen at random from a 59-foot (17.9-meter) wide section of the embankment. Multiple samples were to be collected 4 feet (1.2 meters) from the top. Other systematic locations (four) were at approximately 3-foot (0.9-meter) intervals to the top and bottom of the exposure. Four additional judgmental sites were selected to supplement the data set, two within and two southeast of the above defined zone.

Sampling was performed on October 21, 1991. Although the weather was pleasant when sampling began, winds steadily increased during sampling. Sampling at the 4 foot (1.2 meters) level intercepted a small animal burrow tunnel. Visible associated non-soil remnants (vegetation, fur, food, bones, feces, etc.) were not apparent. All samples collected from Site #5 were fine grained.

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1.1.6 Site #6

This site, where the greatest number of systematic samples were collected, is a large pit excavated for placement of the grout disposal vaults at the Hanford Site. A series of systematic samples were selected from a 200-foot- (60.9-meter-) wide section comprising the majority of the south end of the pit. Fifteen sites were sampled. The slope of the sampled face was roughly 35 degrees. Vertical measurements were made using a marked pole and sighting to the next higher sample point.

A manmade berm had been formed along the top edge of the pit; sampling was avoided in this area because the soil was not original in situ material. Samples were collected on October 8, 1991. The uppermost sample was collected approximately 6.5 vertical feet (2.0 vertical meters) below the top of the berm. The lowest systematic sample was approximately 8.5 feet (2.6 meters) above the existing pit bottom. Material below this point was sloughed from above.

The samples were generally sandy, with few rocks, and were easily collected with trowels. Extra sample material reserved from this site showed condensation when placed in plastic bags. This was unusual; before the late October rains, most sample sites contained only very dry material.

1.1.7 Site #7

This site is located in Trench 94 of the Low-Level Burial Grounds. The site lies at the far northeast corner of the 200 East Area.

The line of systematic samples was selected from a 16-foot- (4.9-meter-) wide zone on the northwest wall of the trench. Ten systematic sample locations were collected from a random starting point within the eligible zone. Multiple samples were collected at the second lowest location.

Three additional judgment samples were collected from the west extension of the trench. Samples originated above, in, and below a narrow, moist silt/clay lens near the base of the trench. Even though there had been no significant precipitation for months, this zone was visibly moist at the surface. Similar zones were visible elsewhere in the trench. Two judgment samples also were collected in the general vicinity of the systematic samples, one on each side of the area from which the line was chosen.

1.1.8 Site #8

This site is located at Pit #29, east of Route 4 North and west of the 200 East Area. The site was sampled on October 9, 1991, after Site #9. Only small vertical exposures were present. Two samples in high-energy flood gravel deposits comprised the systematic samples. These were located along the east face of the pit at 2 feet (0.61 meter) and 5 feet (1.5 meters) below the top of the existing exposure. Both samples were collected using bowls and screens because of the preponderance of rocks.

Several judgment samples were collected at this site. A zone of fine-grained sediment between the two systematic samples was collected as judgment sample B014B5. This material was collected over a large lateral area, about 15 feet (4.6 meters), because of the narrowness of the layer and sample volume requirements. Material in the sample was predominantly from the finer zone, but some slight mixing with upper/lower zone material was unavoidable.

Another judgment sample was collected from the north side of the pit. Multiple samples (regular, split, and grain size aliquots) were collected at this location. The sampled media consisted predominantly of sand, with some coarser material. Material was chipped from the face into a stainless steel bowl; rocks were removed with trowels and sample bottles filled. The process was repeated until all jars were full.

1.1.9 Site #9

This site is located on the Hanford Site, north of Route 3, between the 200 West and 200 East Areas. An old cement batch plant was once located nearby. Gravel and fill have been quarried from the surrounding vicinity. Samples were collected from this site on October 9, 1991.

The sampled exposure was on the south-facing vertical slope, where a 20-foot- (6.1-meter-) wide section was chosen for sampling and an initial systematic point was selected at random. The exposure was approximately 12 feet (3.6 meters) tall, but the top 3 feet (0.9 meters) was not eligible for sampling. Evidence suggested the upper soil was mechanically moved in the past.

Three systematic locations were sampled at Site #9. Multiple samples were collected at the location 10 feet (3.0 meters) down from the top of the embankment. Three judgment samples also were selected from this exposure.

This was the first site at which sieves were employed (in the field) to assist in separating rocks from the smaller soil fractions. Screens were used when collecting material from the 7 foot (2.1 meters) and 10 foot (3.0 meters) level, and in the coarse-grained judgment sample B01499.

1.1.10 Site #10

This site is located east of State Highway 240, on the grade south of the Vernita Bridge. Access to the site is on foot, a short distance from the highway. This is a small exposure, which might have been a quarry in the past.

On the day of sampling, October 3, 1991, an overhang on the upper central portion of the exposure was observed, which was fractured and apparently unstable. This presented an unacceptable potential hazard to sampling personnel. The western edge of the north-facing exposure was judged by the onsite geologist to be fully representative of material at this outcrop.

Because the eligible area for systematic sampling was very narrow with no visible lateral variability, randomization was done only along the vertical axis to locate the initial systematic sampling point at this site. The top edge of the exposure was rounded, and not obviously defined.

Five systematic sample locations were taken over the full height of the exposure. Samples were located 1, 4, 7, 10, and 13 feet (0.3, 1.2, 2.1, 3.0, and 4.0 meters) from the top. All samples were chipped from the exposed face into a stainless steel bowl. This sediment generally was well-cemented. Sample jars were filled after discarding much coarse material from the sampling bowl. Multiple samples were collected at the 7 foot (2.1 meters) level. This included the regular sample, a split, and aliquots for grain size analysis. No judgment samples were chosen at this site.

1.1.11 Site #11

This site is located in fine-grained silt (Touchet beds) in the upper Cold Creek Valley. This was the most remote of all sampled sites. This natural exposure lies less than one-half mile (0.8 kilometer) north of a high voltage power line approximately 2.5 miles (4.0 kilometers) west of the nearest paved road, State Highway 240. Access was by four-wheel drive vehicle to the powerline road, and then by foot to the site. This site is located in the Arid Lands Ecology Reserve, which is a natural area set aside for ecological studies.

A line of samples was chosen from an eligible 23-foot (7.0-meter) section of exposed sediments on the north bank of a ravine. Sampling took place on October 15, 1991. Three samples represented the vertical height of the selected eligible area. The exposed slope was similar to Site #10 in that no clear feature distinguished the precise top of the vertical embankment. The height of the selected area was about 9 feet (2.7 meters). Samples were located 1, 4 and 7 feet (0.3, 1.2, and 2.1 meters) below the selected top reference point. Multiple samples were collected from the 1 foot (0.3 meter) level.

Two judgment samples supplemented the data set. Both samples originated from clastic dikes--one about 3 yards (2.7 meters) east, and another 55 yards (50.3 meters) east of the systematic samples. All samples were fine-grained and very dry.

1.1.12 Site #12

The site is located along Dry Creek near Rattlesnake Springs on the Hanford Site. The sampled face of this site is part of a small canyon formed by Dry Creek. Dry creek is fed by springs draining remote areas west and upgradient of onsite activities. This site also is part of the Arid Lands Ecology Reserve and was sampled on September 24, 1991.

A 90-foot (27.4-meter) horizontal section of the south-facing embankment was marked, and a random point was chosen for the line of systematic samples.

The eligible slope was 22 feet (6.7 meters) tall at the selected location. The lowest sampling point was outside the zone of heavy vegetation lining the base of the canyon. Samples were all very fine grained and dry. There was substantial cohesive strength to the material forming the canyon wall, but it was very dusty when crumbled. Multiple samples from the 5 foot (1.5 meters) level were collected in a stainless steel bowl and packaged for shipment.

Systematic samples were supplemented by two judgment samples, one from an ash layer and one from a carbonate-rich layer. These samples originated approximately 10 feet (3.0 meters) downstream from the vertical line of samples at the 7 and 12.5 foot (2.1 and 3.8 meter) level, respectively.

1.1.13 Site #13

This site is a small gravel pit in Franklin County near the intersection of Sagemoor Road and Road 68 was sampled on October 1, 1991. The top edge of the sampled area was poorly defined. The stake marking the position of the vertical line for systematic sampling was placed well up the hill from the referenced edge. All four sample locations contained predominantly coarse grained sediments. The third location from the top was also the origin of a split and grain size samples. No judgment samples were collected at Site #13.

1.1.14 Site #14

This site is located in a large gravel pit southeast of the Ringold fish hatchery and was sampled on October 1, 1991. This location offered accessible Hanford formation deposits at an offsite location. The deposits are located east of the Hanford Site across the Columbia River at the mouth of the Ringold coulee.

Because of the sheer size and steep pitch of the exposure, samples were taken in a vertical line down the slope only to a certain point, then shifted laterally and continued downslope to the floor of the pit. This was to ensure the safety of sampling personnel.

A 37-foot (11.3-meter) horizontal section of the exposure was selected as representative of the upper zone of the exposed material. A random point was chosen in the upper unit, and a systematic series of samples were collected. When talus was reached on the upper section, easily traceable strata were followed laterally to a second random point above the lower unit. Systematic sampling points on the lower line were continued at 3-foot (0.9-meter) vertical intervals determined by the initial series. Those sample 'depths' were thus referenced with respect to the original line. Multiple samples were collected from the 12 foot (3.6 meter) depth on the upper section. Some sample points at Site #14 were so coarse grained that it was difficult to find material less than two millimeters.

One judgment sample was collected at Site #14. This sample was from an area 38 feet (11.5 meters) further north of the second line where a stratagraphically lower unit could be sampled.

1.2 SURFACE SOIL ORGANIC SAMPLING

Background samples were collected to further develop an understanding of baseline natural levels of organic compounds detectable by the EPA contract laboratory program (CLP) standard methods. Fewer samples were collected in this phase of the project than the previously described inorganic phase. This partly reflects a premise that measurable concentrations of naturally-occurring regulated organic compounds are far less likely than they are for inorganic elements. Furthermore, where 'natural' concentrations of regulated organic compounds do occur, the importance of localized biogenic processes must be recognized for proper interpretation. This phase of the background study focused on widely separated sample collection points occupied by characteristic vegetation.

Sampling for this effort began on February 27, 1992. All sites were located on the Hanford Site; sampling sites were selected based on professional judgment. Samples were submitted for CLP volatile organic analysis (VOA), semivolatile analysis, pesticide/polychlorinated biphenyl analysis, and total organic carbon analysis. Inorganic analyses also were requested. Analytical method reference numbers can be found in Chapter 3.0.

In addition to these laboratory analyses, an organic vapor monitor (OVM) was used to monitor air at the point of sample collection, and to perform supplementary headspace screening at a field laboratory. The monitor uses a photoionization detector with a 10.6 eV lamp, and commonly is employed for safety monitoring at dangerous waste sites. Headspace screening measures the concentration of detectable vapors in the air (headspace) above the sample in a sealed container.

Before collecting the organic samples, a silica sand VOA blank was prepared. This sample accompanied field samples from collection through shipment to the offsite laboratory, but was never opened in the field.

Soil samples were collected with stainless steel trowels or spoons after removal of surface debris. Samples were collected from the top 6 inches (15.2 centimeters) of soil. Separate, clean equipment was used for each sample. Only laboratory cleaned, stainless steel collection equipment was used. Samples were placed in new, manufacturer-cleaned glass sample jars. Samples for laboratory chemical analysis were cooled on collection, and maintained on ice during shipment to the analytical laboratory. Samples were not sieved in the field, nor was the analytical laboratory instructed to use sieved soil aliquots.

All samples were surveyed in the field for radioactivity. No detectable contamination was found. Consistent with onsite shipping requirements, aliquots of all samples also were submitted for a laboratory radioactivity analysis. Results were consistent with field surveys, and all samples qualified for unconditional release from radiologic controls. Each sample location was marked with a post or flag after collection. Each of the sites are described in the following sections in the order in which the sites were visited.

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1.2.1 Site #1

The first background site, sampled on February 27, 1992, was on a southeast facing slope near the crest of Rattlesnake Mountain. Samples were collected 105 feet (32 meters) west of the access road to the radio telescope structure, midway between the structure and the main road (T11N R26E S32). This site is on the Arid Lands Ecology Reserve. Elevation at Site #1 is 3,400 feet (1,036 meters).

Two sample types were associated with this location, a sample that would be submitted for a full suite of analyses, and a duplicate for VOA. Aliquots of each sample were reserved for later headspace concentration measurements. Onsite air measurements with the OVM showed no detectable organic compounds. Fog and light rain were present.

Samples were taken from under the canopy of Three-tip Sage (*Artemisia tripartita*). Sparse shrubs and bunchgrass populate the site, and evidence of a recent range fire was visible. Associated primary bunchgrasses were Sandberg's Bluegrass (*Poa sandbergii*) and Bluebunch Wheatgrass (*Agropyron spicatum*). Other identifiable species include Grey Rabbitbrush (*Chrysothamnus nauseosus*), Big Sagebrush (*Artemisia tridentata*), Yarrow (*Achillea millefolium*), Balsamroot (*Balsamorhiza careyana*), Narrowleaf Goldenweed (*Haplopappus stenophyllus*), Cusick's Sunflower (*Helianthus cusickii*), Thymeleaf Buckwheat (*Eriogonum thymoides*), Russian Thistle (*Salsola kali*), Cheatgrass (*Bromus tectorum*), and Wildrye (*Elymus sp.*). Soil in this area had a high natural organic content. It is believed to be a Lickskillet silt loam.

1.2.2 Site #2

This site is several miles (kilometers) southwest of State Highway 240 on the Arid Lands Ecology Reserve. It is located at Rattlesnake Springs, about 300 yards (274 meters) southwest of Building 648 (T12N R25E S29). Elevation at Site #2 is 700 feet (213 meters).

One sample was collected from beneath the canopy of a large Greasewood (*Sarcobatus vermiculatus*). Large, separated shrubs, primarily Greasewood with a few scattered Grey Rabbitbrush and Spiny Hopsage (*Grayia spinosa*), are present in the immediate vicinity. The understory consists primarily of Saltgrass (*Distichlis stricta*) and Cheatgrass. Other identifiable species include Gray Ryegrass (*Elymus cinereus*), Rose (*Rosa woodsii*), Bluebunch Wheatgrass, Bottlebrush Squirreltail (*Sitanion hystrix*), small Big Sagebrush, a large bluegrass (perhaps *Poa nevadensis*), several Winterfat (*Cerotoides lanata*) and scattered Russian Thistle. The soil sample was moist dark brown silty sand, very fine, nonplastic, 10 to 20 percent nonplastic fines with much organic matter. It may be classified as Hezel sand or Esquatzel Silt loam.

1.2.3 Site #3

Two sites were sampled at this stop along the south shore of the Columbia River, approximately River Mile 385 (T13N R25E S3). Both sites are over a hundred yards from the Columbia River on level to gently sloping land. These sites are upstream from all 100 Area reactors. Elevation is approximately 400 feet (121 meters).

The first site selected was amid a healthy stand of Thickspike Wheatgrass (*Agropyron dasystachyum*). Several inches of plant matter were cleared before the sampled soil was exposed. Identifiable species in the area include Grey Rabbitbrush, Russian Knapweed (*Centaurea repens*), Common Mullein (*Verbascum thapsus*), Needle-and-Thread (*Stipa comata*), Gray Ryegrass, Sandberg's Bluegrass, Cheatgrass, Yarrow, Cocklebur (*Xanthium strumarium*), Plantain (*Plantago lanceolata*), Miners Lettuce (*Montia perfoliata*), Russian Thistle, Prairie Sage (*Artemisia ludoviciana*), Pacific Sage (*Artemisia campestris*), Baltic Rush (*Juncus balticus*), Hoary Aster (*Machaeranthera canescens*), Spring Whitlowgrass (*Draba verna*), horsetail (*Equisetum sp.*), Goldenrod (*Solidago sp.*), and Cudweed (*Gnaphalium sp*).

Onsite air measurements taken at the soil surface while the first sample was collected appeared to be slightly elevated, about 1.6 parts per million with a maximum reading of 3 parts per million (isobutlyene equivalent).

The second site was approximately 400 yards (365 meters) upstream of the first site, and roughly equidistant from the Columbia River. The sample collected at this site was just outside the drip zone of a Rocky Mountain Juniper (*Juniperus scopulorum*). Other species present include Sand Dropseed (*Sporobolus cryptandrus*), Gray's Lomatium (*Lomatium grayi*), Cranesbill (*Erodium cicutarium*), Thickspike Wheatgrass, Clover Fern (*Marsilea vestita*), Canada Thistle (*Cirsium arvense*), Cheatgrass, Spring Whitlowgrass, Russian Thistle, and Sneezeweed (*Helenium autumnale*). Topsoil at the second site, a brown gravelly silty sand, contained well rounded gravel and cobbles, about 10 to 20 percent. Topsoil at the first site was a medium brown sandy silt. Most soil in the area appeared to be Ephrata sandy loam and/or Pasco silt loam.

1.2.4 Site #4

The fourth stop was slightly more than a mile (kilometer) east-northeast of the 200 East Area, south of Route 11A near the former (BWIP) well DB-15 (T13N R27E S31). A soil sample was taken adjacent to the northwest corner of a fenced ecological study site. The area is a mature sagebrush steppe community. Elevation is approximately 470 feet (143 meters).

The sample was collected beneath Big Sagebrush. Understory was Cheatgrass. Soil type is Burbank loamy sand. There is some Sandberg's Bluegrass in the area. Other species present include Spiny Hopsage, Grey Rabbitbrush, Bottlebrush Squirreltail, Needle-and-Thread, Thickspike Wheatgrass, Balsamroot, Spring Whitlowgrass and Longleaf Phlox (*Phlox longifolia*).

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The observation was made that the OVM could very easily detect volatile compounds released from crushed sagebrush leaves. Readings could be made to exceed the display capabilities of the instrument, greater than 2,000 parts per million (isobutlyene equivalent).

1.2.5 Site #5

This site is a former agricultural field northwest of the old Hanford townsite (T13N R27E S23). The site lies over a mile (kilometer) north of the intersection of Route 11A with Route 2 North, about 35 yards (32 meters) north of the pistol range access road.

One sample was collected from within the Cheatgrass dominated field. Other common field vegetation includes Russian Thistle and Tumble Mustard (*Sisymbrium altissimum*). Near the access road are several specimens of Russian Knapweed, Needle-and-Thread and Hoary Aster. Soil in the upper 6 inches (15.2 centimeters) was damp, brown silty sand, mostly uniform, very fine. It contained about 10 percent nonplastic fines, and a few percent well-rounded gravel. Soil type is probably Rupert sand, possibly Ephrata sandy loam.

1.2.6 Site #6

This site lies north of Army Loop Road across from Goose Egg Hill (T12N R26E S28). This area is at the edge of a large 1984 wildfire. Elevation is 600 feet (182 meters). Two samples were collected at this stop.

The first soil sample was collected beneath Big Sagebrush, 285 feet (86.8 meters) from the edge of the road. The second sample was collected 65 feet (19.8 meters) further north under Grey Rabbitbrush. Other dominant plant species include Green Rabbitbrush (*Chrysothamnus viscidiflorus*), Cheatgrass, Sandberg's Bluegrass, and Indian Ricegrass (*Oryzopsis hymenoides*). Additional species present include Balsamroot, Pale Evening Primrose (*Oenothera pallida*), Wallflower (*Erysimum asperum*), Sand Beardtongue (*Penstemon acuminatus*), and Tumble Mustard. Understory was sparse. Soil in this area could be described as a coarse Burbank loamy sand. The soil was yellow brown sand, uniform, very fine, damp, with few nonplastic fines.

Onsite air measurements taken at the soil surface during collection near the Rabbitbrush location appeared to be slightly elevated, about 1.4 parts per million (isobutlyene equivalent).

1.2.7 Site #7

This site is near the previous site, lying west of Goose Egg Hill almost midway between Army Loop Road and State Highway 240 (T12N R26E S29).

This site was approached on foot from Army Loop Rd. On reaching the site, there is a distinct ecological change from the dry sandy environment,

similar to the former site, to a moist, less diverse, brown silty desert playa.

Spiny Hopsage is the major plant species present. Sandberg's Bluegrass and a suspected Woolly Sunflower (*Eriophyllum lanatum*) were among the very few other higher plant species. There was an pronounced cryptogamic crust at the site. Duplicate soil samples were collected from a common excavation beneath a hopsage. As usual, loose organic debris was removed from the surface per applicable procedures before collecting the soil sample (WHC 1988b). Soil type is uncertain, perhaps Esquatzel silt loam.

1.2.8 Site #8

This site was southwest of the 200 West area in the Cold Creek Valley (T12N R25E S10). It was located approximately 100 feet (30 meters) north of a seldom-used road extending due west from Army Loop Road. A soil sample was collected outside the southeast corner of a fenced ecological study area, adjacent to Big Sagebrush. An additional sample consisting of clean silica sand also was prepared at the same site and submitted as a control sample. This site is best described as a mature sagebrush/Sandberg's Bluegrass community. The community is not very diverse, and has good cryptogamic cover. In addition to large, healthy sagebrush, this area contains Cheatgrass, Russian Thistle, Spiny Hopsage and Scarlet Globemallow (*Sphaeralcea munroana*). Soil from the site was a brown silty sand--uniform, very fine, estimated 5 to 10 percent nonplastic fines, damp, loose topsoil.

1.2.9 Site #9

The final site, on the 200 Area Plateau (T13N R25E S34) was sampled on February 27, 1992. The site is was located west of the 200 West area, about 0.75 mile (1.2 kilometer) south of the intersection of Army Loop Road and Route 11A. A soil sample was removed from beneath a large Big Sagebrush, outside the southeast corner of a fenced area containing an ecological study site. This area consists of a mature sagebrush/Cheatgrass/Sandberg's Bluegrass plant community, and also includes Hoary Aster, Threadleaf Fleabane (*Erigeron filifolius*) and Turpentine Springparsley (*Cymopteris terebinthinus*). Soil from this location was a brown sand. It was uniform, very fine, estimated less than 5 percent fines, damp, and loose. Soil classification likely would be Rupert sand.

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2.0 VAPOR HEADSPACE MEASUREMENTS

Vapor headspace analysis is a method to rapidly and reliably detect volatile organic compounds (VOC) in soil samples in the low parts per million range. This method was used to further validate background conditions, and to build baseline knowledge for future cost-effective waste site work. Organic vapors were measured in the air (headspace) above background soils in sealed glass containers. The following summarizes the activity and results of these field headspace measurements.

2.1 METHOD

Samples were collected with stainless steel trowels and/or spoons as previously described. Samples were not sieved during collection. New, clean, wide-mouth, quart jars were swiftly filled half full with soil, immediately sealed and transported to a field laboratory. The samples remained sealed until analysis later the same day. Before analysis, samples equilibrated to room temperature for a minimum of one-half hour.

Analysis was performed using a closed loop system whereby vapors could be circulated from the sample headspace through a portable OVM and exhausted back to the headspace. The system used a 10.6-eV light source to ionize compounds for measurement. A current proportional to the number of ions produced was amplified and converted to a displayed numeric concentration. The instrument usually was set to display 5 second averages. Each sample was monitored for a series of readings for at least 5 minutes. Values were autologged into the instrument memory. Bar codes were used to mark data sets. A single reading also was manually recorded as a backup record after adequate time for equilibration.

The system was calibrated using a manufacturer supplied 101 parts per million (± 2 percent) isobutylene gas. The same gas cylinder was used in all calibration work for this project. Ambient air filtered through an organic vapor respirator cartridge provided a zero reference. A separate 9.51 parts per million isobutylene gas was used as a low range instrument check. Instrument check, filtered zero, and calibration gases were not recirculated. Between all recorded observations, ambient air was circulated through the instrument until readings returned to ambient levels. Successive check standard readings were made at least at the beginning and end of each sample process batch.

Numerous auxiliary measurements also were recorded. These included ambient VOC readings, collection and analysis times, gross and tare sample jar weights, ambient temperatures, headspace temperatures, and other observations. One clean sample jar without soil was included in each analysis batch as a blank. This 'sample' was monitored for the same prescribed time as a sample.

Further information regarding the equilibrium headspace method can be found in the Plan supplement, Engineering Change Notice 164706 (WHC 1991b).

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2.2 IMPLEMENTATION

Headspace sample measurements commenced on February 27, 1992. Fresh aliquots of each sample submitted for various organic measurements were transported to a field laboratory and analyzed. All the organic site samples were analyzed in a single batch on the day of collection. Extra check standards were run between each sample as well as at multiple times at the beginning, middle, and end of the batch. The date and origin of all these samples is contained in Table 1. Uninterpreted measurements and observations are compiled in the data sheets shown at the end of this section (Tables 2.1 to 2.6).

Subsequent measurements were made on March 5, March 6, March 9, and March 17, 1992, on batches of new, fresh samples gathered from the 14 inorganic sites. At least two fresh samples from each of the inorganic-only sites were screened for VOCs. Soil at the top and bottom of each former systematic line was sampled with the exception of the Grout Pit (Site #6). The pit had been backfilled, burying the lower half of the former sample locations. At Site #6, samples were collected 1 vertical foot (0.3 vertical meter) above the uppermost former site (B01491), slightly above the new existing pit bottom [19 vertical feet (5.8 vertical meters) from B01491], and midway between the two points. Only the uppermost old location was still visible, others had been obscured by erosion. In addition to samples taken along the previously established systematic sampling lines, samples were collected in the west extension of the Sub Pit, Site #7. These originated from the moist silt/clay lens associated with the former inorganic sample B014D5. Two samples were collected as batch duplicates from this location.

One analysis batch was processed each sampling day with the exception of March 17, 1992, when measurements were performed in morning and afternoon batches. Samples collected on February 27, 1992 were measured in a field laboratory trailer located in the 300 Area. Other samples were measured (by a separate analyst) at field locations in a truck-mounted field laboratory.

Quality control checks were performed for each batch of samples. Control parameter specifications were as follows:

Calibration check	± 2 percent
Instrument check	9.5 ± 2 parts per million
Ambient measurements	< 1 part per million
Blank	< 1 part per million

Quality control parameters were 10 percent for replicate sequential measurements and 25 percent for field duplicate measurements. Scale measurement checks were performed, where a weight standard periodically was used to check the accuracy of the scale. To minimize the potential effects of repositioning the scale, both tare and gross sample weights were made on a sample before moving the truck to a new location.

One of the sources of variability in this method is deciding which instrument reading to record. The instrument displayed readings to the nearest 0.1 part per million. The Plan instructed the analyst to record the

OVM reading when a change of less than 10 percent was observed over three successive readings. However, a certain amount of judgment was necessary regarding which value to record even after deciding on an equilibration period. Because readings were often less than 1 part per million and the display was limited to tenths of a part per million, background noise alone was greater than 10 percent (± 0.1 part per million). Recorded values were checked against electronic files for verification.

2.3 SUMMARY OF RESULTS

The raw data shown in Table 2 are summarized as follows:

Range of calibration standard check	100 - 102
Range of instrument check	8.8 - 10.6
LOD from field blanks (n=6)	0.9
LOQ from field blanks (n=6)	2.0
Range of ambient observations	0.0 - 1.2
Maximum observed sample headspace concentration	0.5

Performance on the low-level instrument check standard was one of the best indicators available for assessing system capabilities. The sample standard deviation of all check standards separated by more than the minimum sample measurement time is 0.41 part per million. A method detection limit (MDL) calculated using the 33 observations yields 1.0 part per million. This is in good agreement with the LOD estimated from the six batch blanks.

A Kruskal-Wallis test was used to assess if the batch means differed significantly from each other based on check standard performance. Check standards used for comparison were those whose measurement times were separated by at least the minimum sample equilibration time, 5 minutes. No statistically significant difference between batches were found. This test assumes the data in each batch are drawn from distributions of similar shape, but not necessarily normal or even symmetric distributions. The statistic would indicate whether at least one batch mean is significantly larger or smaller than at least one other batch at the chosen level of confidence.

Close examination of the data suggests that trends in the method exist. The total number of runs above or below the median of original order data can be used as a test of randomness. When this is applied to instrument check observations, the results show significant deviations from that expected if there were no trends or cyclical patterns. This statistic was significant, when the February 27, 1992 batch was considered individually or when all batches were combined chronologically. Because of the small number of separated observations in the other batches, no runs test was applied to any other individual batch.

It appears that values for check standards trend downward throughout a batch. Batches having far fewer instrument check observations are consistent with the trends present in the February 27, 1992 batch. Overall, five of the six batches have a final check observation lower than the initial check observation. The binomial probability of five successes out of six trials,

given an equal likelihood of two events, is 0.094. This means that, on the average, this result would happen only 9.4 times out of 100 given no upward or downward trend. This comparison makes use of only the first and last observations of the six batches.

The ambient measurement associated with sample B06140 exceeded the Plan criteria of 1 part per million. A short time before this measurement, ambient air was drawn through an respirator filter and a reading made. The filter was designed to remove organic vapors. The result suggests the system might have been biased slightly high. The reported observation (0.6 part per million) is close to the demonstrated capabilities of the measurement system. Nevertheless, sealed samples that were opened only very briefly before analysis did not reflect any elevated concentration.

Sample comparisons between batches cannot reliably be made because all sample observations are well below the normal 'noise' between batches. For instance, the fact that all February 27, 1992 observations are 0.0 and almost all March 9, 1992 observations are 0.3 does not allow one to conclude that there are real differences in the headspace concentrations of the two sets of samples. Both numbers are below levels that can be reliably assessed for interbatch comparisons. Sub-LOD measurements might largely reflect transitory measurement conditions. Soil headspace concentration comparisons between batches must consider the limitations of the measurement system. Otherwise, nonrandom errors easily can confound interbatch comparisons.

2.4 CONCLUSION

Concentrations of detectable compounds in the sample headspace were so low as to be unquantifiable by this method. All samples were consistent in this respect. The method is capable of detecting low parts per million concentrations of volatile compounds. These results support the premise that the soil at each site is uncontaminated by volatile dangerous waste.

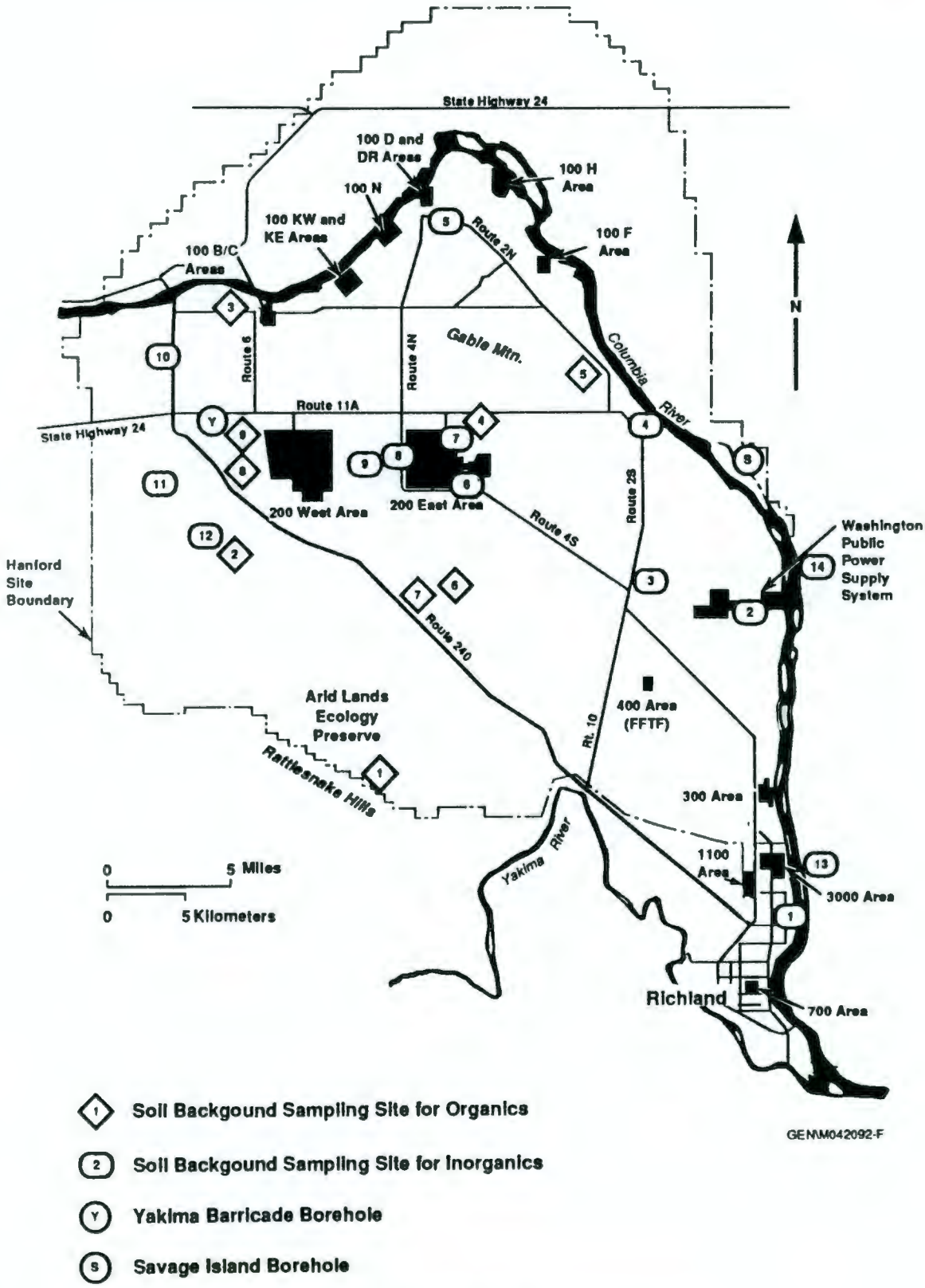

Figure 1. Sampling Site Locations.

Table 1. Headspace Screening Sample Key. (sheet 1 of 3)

Sample ID	Date	Origin
B06136	2/27/92	Equipment Store Room (VOA Trip Blank--unopened in the field)
B06137	2/27/92	Organic Site #1
B06138	2/27/92	Organic Site #1
B06139	2/27/92	Organic Site #2
B06140	2/27/92	Organic Site #3 (grass)
B06141	2/27/92	Organic Site #3 (juniper)
B06142	2/27/92	Organic Site #4
B06143	2/27/92	Organic Site #5
B06144	2/27/92	Organic Site #6 (sagebrush)
B06145	2/27/92	Organic Site #6 (rabbitbrush)
B06146	2/27/92	Organic Site #7
B06147	2/27/92	Organic Site #7 (Field duplicate of B06146)
B06148	2/27/92	Organic Site #8
B06149	2/27/92	Organic Site #8 (Blank)
B06150	2/27/92	Organic Site #9
B06151	3/5/92	Inorganic Site #13 (Bottom)
B06152	3/5/92	Inorganic Site #13 (Top)
B06154	3/5/92	Inorganic Site #14 (Bottom)
B06155	3/5/92	Inorganic Site #14 (Top)
B06156	3/5/92	Inorganic Site #14 (Top--Field duplicate of B06155)
B06157	3/5/92	Inorganic Site #14 (Blank)
B06158	3/6/92	Inorganic Site #2 (Top)
B06159	3/6/92	Inorganic Site #2 (Bottom)
B06160	3/6/92	Inorganic Site #2 (Bottom--Field duplicate of B06159)
B06161	3/6/92	Inorganic Site #6 (Top)

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Table 1. Headspace Screening Sample Key. (sheet 2 of 3)

	Sample ID	Date	Origin
1	B06162	3/6/92	Inorganic Site #6 (Existing bottom--refer to text)
2	B06163	3/6/92	Inorganic Site #6 (Midway between B06161 and B06162--refer to text)
3	B06164	3/6/92	Inorganic Site #9 (Top)
4	B06165	3/6/92	Inorganic Site #9 (Bottom)
5	B06166	3/6/92	Inorganic Site #8 (Top)
6	B06167	3/6/92	Inorganic Site #8 (Bottom)
7	B06168	3/6/92	Inorganic Site #8 (Blank)
8	B06169	3/9/92	Inorganic Site #1 (Bottom)
9	B06170	3/9/92	Inorganic Site #1 (Top)
10	B01B83	3/9/92	Inorganic Site #10 (Top)
11	B01B84	3/9/92	Inorganic Site #10 (Bottom)
12	B01B85	3/9/92	Inorganic Site #11 (Bottom)
13	B01B86	3/9/92	Inorganic Site #11 (Top)
14	B01B87	3/9/92	Inorganic Site #12 (Top)
15	B01B88	3/9/92	Inorganic Site #12 (Bottom)
16	B01B89	3/9/92	Inorganic Site #12 (Bottom--Field duplicate of B01B88)
17	B01B90	3/9/92	Yakima Barricade, site of 3/9 measurements (Blank)
18	B01B91	3/17/92	Inorganic Site #3 (Bottom)
19	B01B92	3/17/92	Inorganic Site #3 (Top)
20	B01B93	3/17/92	Inorganic Site #7 (Bottom)
21	B01B94	3/17/92	Inorganic Site #7 (Top)
22	B01B95	3/17/92	Inorganic Site #7 (West extension at former judgment site of B014D5)
23	B01B96	3/17/92	Inorganic Site #7 (Field duplicate of B01B95)
24	B064G1	3/17/92	Inorganic Site #7 (Blank)

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Table 1. Headspace Screening Sample Key. (sheet 3 of 3)

	Sample ID	Date	Origin
1	B064G2	3/17/92	Inorganic Site #4 (Bottom)
2	B064G3	3/17/92	Inorganic Site #5 (Bottom)
3	B064G4	3/17/92	Inorganic Site #5 (Top)
4	B064G5	3/17/92	Inorganic Site #4 (Bottom--Field duplicate of B064G2)
5	B064G6	3/17/92	Inorganic Site #4 (Top)
6	B064G7	3/17/92	Inorganic Site #4 (Blank)
7			

Table 2.1. Equilibrium Headspace Method - Field Data Sheet. (sheet 1 of 4)

Date: February 27, 1992 Project: Site-wide Background Instrument: OVM 580B, 10.6 eV lamp

Sample Data					Headspace Data					
		Weight, g				VOC conc, ppm		Temp, °C		
Sample	Time	tare	tot	Soil Description	Time	amb	hdspc	amb	hdspc	Comments
					2030		102			Calibration Check (101 ppm isobutlyene std)
					2032		10.1			Instrument Check (9.51 ppm isobutlyene std)
					2033		10.0			Instrument Check
					2033		10.0			Instrument Check
					2034		9.8			Instrument Check
					2035		10.0			Instrument Check
					2036		9.8			Instrument Check
					2039		10.3			Instrument Check
B06137	0920	478.0	913.6	Dark brown sandy silt, 10% very fine sand, non-plastic, moist	2041	0.1	0	20	19 1/4	
					2048		10.6			Instrument Check
B06138	0920	480.6	820.9	As above	2051	0.9	0	20	19 1/2	Field duplicate of B06138
					2057		10.1			Instrument Check

Sampler: R. McCain Date: 2/27/92

Analyst: R. McCain Date: 2/27/92 Reviewed by: C. Kramer Date: 4/3/92

Table 2.1. Equilibrium Headspace Method - Field Data Sheet. (sheet 2 of 4)

Date: February 27, 1992 Project: Site-wide Background Instrument: OVM 580B, 10.6 eV lamp

Sample Data					Headspace Data					
		Weight, g				VOC conc, ppm		Temp, °C		
Sample	Time	tare	tot	Soil Description	Time	amb	hdspc	amb	hdspc	Comments
					2059	1.2*	0.6			Zero -- Ambient air thru organic vapor respirator
B06139	1121	476.9	892.9	Dark brown silty sand, very fine, moist, 10-20% non-plastic fines	2102	0.9	0	20	19 3/4	
					2107		10.0			Instrument Check
B06140	1200	482.9	921.4	Medium brown sandy silt, damp, loose 5-10% very fine sand	2110	1.1*	0	20 1/4	19 3/4	
					2116		9.8			Instrument Check
B06141	1220	479.5	946.2	Brown gravelly silty sand - mostly fine to very fine, ~10% non-plastic fines, 10-20% well rounded gravel	2120	0.9	0	20	19 3/4	
					2126		10.0			Instrument Check
B06142	1345	481.2	1050.4	Brown silty sand, very fine to fine, damp	2129	0.9	0	20 1/4	20	
					2152		9.8			Instrument Check
					2153		9.6			Instrument Check
					2154		9.6			Instrument Check

Sampler: R. McCain Date: 2/27/92

Analyst: R. McCain Date: 2/27/92 Reviewed by: C. Kramer Date: 4/3/92

Table 2.1. Equilibrium Headspace Method - Field Data Sheet. (sheet 3 of 4)

Date: February 27, 1992 Project: Site-wide Background Instrument: OVM 580B, 10.6 eV lamp

Sample Data					Headspace Data					
		Weight, g				VOC conc, ppm		Temp, °C		
Sample	Time	tare	tot	Soil Description	Time	amb	hdspc	amb	hdspc	Comments
					2155		9.8			Instrument Check
					2156		9.8			Instrument Check
B06143	1410	479.4	1084.3	Brown silty sand, mostly uniform very fine, <10% non-plastic fines, damp	2158	0.4	0	20	19 1/2	(Forgot to turn on auto log)
					2211		9.6			Instrument Check
B06144	1450	479.5	954.9	Yellow brown sand, uniform, very fine, damp, trace fines	2213	0.7	0	20	19 1/2	
					2218		9.6			Instrument Check
B06145	1455	483.0	1093.0	Yellow brown sand, uniform, very fine, damp	2220	0.7	0	20	19 3/4	
					2225		9.2			Instrument Check
B06146	1510	477.9	885.7	Dark brown silt, damp, non-plastic to slightly plastic	2229	0.7	0	20 1/4	19 3/4	
					2235		9.5			Instrument Check
B06147	1510	482.9	1015.8	Duplicate of B06146	2239	0.7	0	20	20	Field Duplicate
					2245		9.2			Instrument Check

Sampler: R. McCain Date: 2/27/92

Analyst: R. McCain Date: 2/27/92 Reviewed by: C. Kramer Date: 4/3/92

Table 2.1. Equilibrium Headspace Method - Field Data Sheet. (sheet 4 of 4)

Date: February 27, 1992 Project: Site-wide Background Instrument: OVM 580B, 10.6 eV lamp

Sample Data					Headspace Data					
		Weight, g				VOC conc, ppm		Temp, °C		
Sample	Time	tare	tot	Soil Description	Time	amb	hdspc	amb	hdspc	Comments
B06148	1545	476.5	998.1	Brown silty sand, uniform, very fine, 5-10% non-plastic fines, damp	2246	0.7	0	20	20	
					2251		9.5			Instrument Check
B06150	1605	476.4	1058.7	Brown sand, uniform, very fine, <5% fines, damp	2253	0.7	0	20 1/4	20	
					2258		9.5			Instrument Check
B06149				Blank - no soil	2300	0.6	0.4	20	19 3/4	
					2307		9.3			Instrument Check
					2307		9.3			Instrument Check
					2308		9.2			Instrument Check
					2309		9.3			Instrument Check
					2310		9.3			Instrument Check

* Exceeds plan goal of maintaining ambient < 1 ppm

Sampler: R. McCain Date: 2/27/92

Analyst: R. McCain Date: 2/27/92 Reviewed by: C. Kramer Date: 4/3/92

Table 2.2. Equilibrium Headspace Method - Field Data Sheet. (sheet 1 of 2)

Date: March 5, 1992 Project: Site-wide Background Instrument: OVM 580B, 10.6 eV lamp

Sample Data					Headspace Data					
		Weight, g				VOC conc, ppm		Temp, °C		
Sample	Time	tare	tot	Soil Description	Time	amb	hdspc	amb	hdspc	Comments
					1313		101			Calibration Check (101 ppm isobutylene std)
					1315		9.7			Instrument Check (9.51 isob. std)
					1316		9.7			Instrument Check
					1317		9.5			Instrument Check
					1318		9.7			Instrument Check
					1318		9.7			Instrument Check
B06151	1140	482.7	1130.3	Coarse, moist sand, rocky	1323	0.0	0.5	21	22	Sample range to 0.7--(Forgot to autolog)
B06151	"	"	"	"	1339	0.1	0.1	21	22	RE-RAN sample w/autolog, range 0.0 to 0.7
B06152	1146	476.3	1311.5	Coarse, moist sand, rocky	1333	0.0	0.3	21	22	Sample range to 0.5
					1347	0.1	9.3			Instrument Check (Ambient to 0.3)
					1347		9.3			Instrument Check
B06154	1315	483.1	1297.6	Moist, finer grain sand w/small rocks	1355	0.0	0.1	22	22.5	

Sampler: C. Kramer Date: 3/5/92

Analyst: D. Jacques Date: 3/5/92 Reviewed by: C. Kramer Date: 4/3/92

Table 2.2. Equilibrium Headspace Method - Field Data Sheet. (sheet 2 of 2)

Date: March 5, 1992 Project: Site-wide Background Instrument: OVM 580B, 10.6 eV lamp

Sample Data					Headspace Data					
		Weight, g				VOC conc, ppm		Temp, °C		
Sample	Time	tare	tot	Soil Description	Time	amb	hdspc	amb	hdspc	Comments
B06155	1330	477.8	1090.7	Finer sand w/small rocks, moist	1401	0.0	0.1	22	22.5	
B06157	1408	476.5	476.5	Blank	1409	0.0	0.1	22	23	New, unused jar
B06156	1340	475.8	1100.4	Finer, moist sand w/small rocks	1416	0.0	0.0	22	23.5	Field duplicate of B06155
					1421		9.0			Instrument Check
					1422		9.2			Instrument Check
					1423		9.2			Instrument Check
					1423		9.0			Instrument Check
					1424		9.0			Instrument Check

Sampler: C. Kramer Date: 3/5/92

Analyst: D. Jacques Date: 3/5/92 Reviewed by: C. Kramer Date: 4/3/92

Table 2.3. Equilibrium Headspace Method - Field Data Sheet. (sheet 1 of 3)

Date: March 6, 1992 Project: Site-wide Background Instrument: OVM 580B, 10.6 eV lamp

Sample Data					Headspace Data					
		Weight, g				VOC conc, ppm		Temp, °C		
Sample	Time	tare	tot	Soil Description	Time	amb	hdspc	amb	hdspc	Comments
					1109		100			Calibration Check (101 ppm isobutylene std)
					1112		9.9			Instrument Check (9.51 isob. std)
					1113		9.9			Instrument Check
					1114		9.9			Instrument Check
					1115		9.9			Instrument Check
					1116		9.9			Instrument Check
B06158	0953	477.2	1037.4	Moist sand/silt, some roots & organic material	1121	0.3	0.4	20	21	
B06159	0947	480.0	1171.1	Moist sand	1128	0.3	0.4	20	21	
B06160	0947	477.1	1175.9	Moist sand	1135	0.3	0.4	20	21	Field duplicate
					1246		101			Calibration Check
					1247		10.0			Instrument Check
					1248		10.0			Instrument Check
					1251		10.0			Instrument Check
					1252		10.0			Instrument Check
					1253		9.9			Instrument Check

Sampler: C. Kramer Date: 3/6/92

Analyst: D. Jacques Date: 3/6/92 Reviewed by: C. Kramer Date: 4/4/92

Table 2.3. Equilibrium Headspace Method - Field Data Sheet. (sheet 2 of 3)

Date: March 6, 1992 Project: Site-wide Background Instrument: OVM 580B, 10.6 eV lamp

Sample Data					Headspace Data					
		Weight, g				VOC conc, ppm		Temp, °C		
Sample	Time	tare	tot	Soil Description	Time	amb	hdspc	amb	hdspc	Comments
B06161	1112	478.8	1087.5	Moist sand/silt	1258	0.4	0.3	21	22.5	
B06162	1117	482.6	1101.4	Moist, fine sand	1305	0.3	0.3	21	22	
B06163	1121	483.0	1158.7	Moist, coarse sand	1312	0.4	0.3	22	22.5	
B06164	1213	477.6	1272.9	Fine sand/silt, dry	1319	0.4	0.4	22	22.5	
					1324		9.9			Instrument Check
					1325		9.9			Instrument Check
					1327		9.9			Instrument Check
					1328		9.9			Instrument Check
					1328		9.9			Instrument Check
B06165	1210	480.0	1440.6	Dry sand w/rocks	1332	0.5	0.2	23	24	
B06166	1243	479.5	1354.0	Sand, moist w/large rocks	1339	0.4	0.3	23	24	
B06167	1240	483.3	1427.5	Rocks w/some sand	1346	0.5	0.3	23	23.5	
B06168				Field blank	1352	0.4	0.6	23	24	Empty jar
					1357		9.3			Instrument Check
					1358		9.3			Instrument Check
					1358		9.3			Instrument Check
					1359		9.3			Instrument Check

Sampler: C. Kramer Date: 3/6/92

Analyst: D. Jacques Date: 3/6/92 Reviewed by: C. Kramer Date: 4/4/92

Table 2.3. Equilibrium Headspace Method - Field Data Sheet. (sheet 3 of 3)

Date: March 6, 1992 Project: Site-wide Background Instrument: OVM 580B, 10.6 eV lamp

Sample Data					Headspace Data					
		Weight, g				VOC conc, ppm		Temp, °C		
Sample	Time	tare	tot	Soil Description	Time	amb	hdspc	amb	hdspc	Comments
					1359		9.3			Instrument Check

Sampler: C. Kramer Date: 3/6/92

Analyst: D. Jacques Date: 3/6/92 Reviewed by: C. Kramer Date: 4/4/92

Table 2.4. Equilibrium Headspace Method - Field Data Sheet.. (sheet 1 of 3)

Date: March 9, 1992 Project: Site-wide Background Instrument: OVM 580B, 10.6 eV lamp

Sample Data					Headspace Data					
		Weight, g				VOC conc, ppm		Temp, °C		
Sample	Time	tare	tot	Soil Description	Time	amb	hdspc	amb	hdspc	Comments
					1241		100.8			Calibration Check (101 ppm isobutylene std)
					1243		9.8			Instrument Check (9.51 isob. std)
					1244		9.8			Instrument Check
					1244		9.8			Instrument Check
					1245		9.8			Instrument Check
					1246		9.8			Instrument Check
					1247		9.8			Instrument Check
B06169	0953	475.5	1506.9	Coarse basaltic sand, large rocks, dry	1251	0.3	0.5	21	22.5	Tare & Gross wt @ collection-- Std weight (1219.1g) = 1217.2 g
B06170	0955	479.2	1109.5	Fine silt/sand, moist	1258	0.3	0.3	22	22.5	"
B01B83	1128	479.4	1119.0	Light, clumps, silt/sand slightly moist	1305	0.3	0.3	22	22.5	Tare & Gross wt @ collection-- Std weight (1219.1g) = 1217.7 g
B01B84	1125	477.5	1209.1	Very coarse sand & rock	1311	0.3	0.4	22	23	"

Sampler: C. Kramer Date: 3/9/92

Analyst: D. Jacques Date: 3/9/92 Reviewed by: C. Kramer Date: 4/10/92

Table 2.4. Equilibrium Headspace Method - Field Data Sheet. (sheet 2 of 3)

Date: March 9, 1992 Project: Site-wide Background Instrument: OVM 580B, 10.6 eV lamp

Sample Data					Headspace Data					
		Weight, g				VOC conc, ppm		Temp, °C		
Sample	Time	tare	tot	Soil Description	Time	amb	hdspc	amb	hdspc	Comments
B01B90				Blank	1318	0.3	0.4	23	23	Clean, empty jar
					1322	0.3	9.6			Instrument Check
					1325		9.6			Instrument Check
					1326		9.6			Instrument Check
					1326		9.6			Instrument Check
					1327		9.6			Instrument Check
B01B85	1225	478.7	1092.5	Dry, fine sand	1334	0.4	0.4	23	23	Tare & Gross wt @ collection-- Std weight (1219.1g) = 1218.8 g
B01B85					1349	0.3	0.3	23	24.5	Sample rerun with autolog on.
B01B86	1229	476.6	1009.2	Slightly moist, fine silt/sand	1344	0.3	0.3	23	24.5	Wts @ collection --Turned on autolog after 3 min., went 5 additional min.
B01B87	1307	477.8	1066.8	Dry silt loess	1356	0.3	0.3	23	24.5	
B01B88	1310	477.5	1035.0	Dry silty loess	1402	0.3	0.3	23	24	
B01B89	1311	478.7	1096.5	Slightly moist, silty loess	1408	0.3	0.3	23	23.5	Field Duplicate of B01B88

Sampler: C. Kramer Date: 3/9/92

Analyst: D. Jacques Date: 3/9/92 Reviewed by: C. Kramer Date: 4/10/92

Table 2.4. Equilibrium Headspace Method - Field Data Sheet. (sheet 3 of 3)

Date: March 9, 1992 Project: Site-wide Background Instrument: OVM 580B, 10.6 eV lamp

Sample Data					Headspace Data					
		Weight, g				VOC conc, ppm		Temp, °C		
Sample	Time	tare	tot	Soil Description	Time	amb	hdspc	amb	hdspc	Comments
					1414		8.8			Instrument Check
					1414		8.8			Instrument Check
					1415		8.8			Instrument Check
					1415		8.8			Instrument Check
					1416		8.8			Instrument Check

Sampler: C. Kramer Date: 3/9/92

Analyst: D. Jacques Date: 3/9/92 Reviewed by: C. Kramer Date: 4/10/92

Table 2.5. Equilibrium Headspace Method - Field Data Sheet. (sheet 1 of 2)

Date: 3-17-92 Project: Site-wide Background - VOA Headspace Instrument: 580B OVM, 10.6 eV lamp

Sample Data					Headspace Data					
		Weight, g				VOC conc, ppm		Temp, °C		
Sample	Time	tare	tot	Soil Description	Time	amb	hdspc	amb	hdspc	Comments
					0917		100			Calibration Check (101 ppm isobutylene std)
					0918		9.5			Instrument Check (9.51 isob. std)
					0919		9.5			Instrument Check
					0920		9.5			Instrument Check
					0921		9.5			Instrument Check
					0921		9.5			Instrument Check
B01B91	0817	478.0	1296.4	Coarse sand/gravel, some fine silt, moist	0926	0.3	0.5	19	20	Standard Weight (1219.1 g)= 1218.5 g @ Site #3
B01B92	0820	481.7	1323.5	Gravel, rocks, sand w/ fine silt material, dry	0933	0.4	0.5	19	20	-91 & -92 Tare and total wt @ Site #3
B064G1				Equipment Blank	0940	0.4	0.4	20	21	Empty, clean jar
					0945		9.5			Instrument Check
					0945		9.5			Instrument Check
					0946		9.5			Instrument Check
					0946		9.5			Instrument Check

Sampler: C. Kramer Date: 3/17/92

Analyst: D. Jacques Date: 3/17/92 Reviewed by: C. Kramer Date: 4/4/92

Table 2.5. Equilibrium Headspace Method - Field Data Sheet. (sheet 2 of 2)

Date: 3-17-92 Project: Site-wide Background - VOA Headspace Instrument: 580B OVM, 10.6 eV lamp

Sample Data					Headspace Data					
		Weight, g				VOC conc, ppm		Temp, °C		
Sample	Time	tare	tot	Soil Description	Time	amb	hdspc	amb	hdspc	Comments
					0947		9.5			Instrument Check
B01B93	0910	476.6	1193.3	Sand, moist	0951	0.5	0.4	20	21.5	Standard Weight (1219.1 g)= 1218.3 g @ Site #7
B01B94	0912	477.1	1302.3	Fine sand w/ small rocks, slightly moist	0957	0.4	0.4	20	21.5	-93 thru -96 Tare and total wt @ Site #7
B01B95	0919	477.7	1106.8	Silt loam, moist, some sand	1004	0.4	0.3	20	22	"
B01B96	0920	478.2	1186.9	Silt loam w/ sand, moist	1010	0.4	0.4	20	22	Field duplicate of B01B95
					1015		9.5			Instrument Check
					1016		9.5			Instrument Check
					1016		9.5			Instrument Check
					1017		9.5			Instrument Check
					1017		9.5			Instrument Check

Sampler: C. Kramer Date: 3/17/92

Analyst: D. Jacques Date: 3/17/92 Reviewed by: C. Kramer Date: 4/4/92

Table 2.6. Equilibrium Headspace Method - Field Data Sheet. (sheet 1 of 2)

Date: 3-17-92 Project: Site-wide Background - VOA Headspace Instrument: 580B OVM, 10.6 eV lamp

Sample Data					Headspace Data					
		Weight, g				VOC conc, ppm		Temp, °C		
Sample	Time	tare	tot	Soil Description	Time	amb	hdspc	amb	hdspc	Comments
					1218		100			Calibration Check (101 ppm isobutylene std)
					1219		10.1			Instrument Check (9.51 isob. std)
					1220		10.1			Instrument Check
					1221		10.1			Instrument Check
					1221		10.1			Instrument Check
					1221		10.1			Instrument Check
B064G3	1055	477.1	1115.5	Medium grade sand, moist	1226	0.3	0.4	21	22.5	Standard Weight (1219.1 g)= 1219.2 g @ Site #9
B064G4	1057	481.8	1126.0	Fine sand, dry	1233	0.4	0.3	22	22.5	"
B064G7				Equipment Blank	1240	0.3	0.4	22	22.5	Empty jar
					1244	0.3	10.1			Instrument Check
					1246		10.1			Instrument Check
					1247		8.9			Instrument Check
					1248		8.9			Instrument Check
					1248		8.9			Instrument Check

Sampler: C. Kramer Date: 3/17/92

Analyst: D. Jacques Date: 3/17/92 Reviewed by: C. Kramer Date: 4/4/92

Table 2.6. Equilibrium Headspace Method - Field Data Sheet. (sheet 2 of 2)

Date: 3-17-92 Project: Site-wide Background - VOA Headspace Instrument: 580B OVM, 10.6 eV lamp

Sample Data					Headspace Data					
		Weight, g				VOC conc, ppm		Temp, °C		
Sample	Time	tare	tot	Soil Description	Time	amb	hdspc	amb	hdspc	Comments
B064G2	1239	477.3	963.6	Silt loam, moist	1315	0.3	0.4	22	23	Standard Weight (1219.1 g)= 1219.2 g @ Site #4
B064G5	1240	479.5	994.1	"	1322	0.3	0.4	22	22.5	Duplicate of B064G2
B064G6	1245	481.5	866.7	Silt loam w/ roots, moist	1329	0.3	0.3	23	22.5	
					1334		8.9			Instrument Check
					1335		8.9			Instrument Check
					1335		8.9			Instrument Check
					1336		8.9			Instrument Check
					1336		8.9			Instrument Check

Sampler: C. Kramer Date: 3/17/92

Analyst: D. Jacques Date: 3/17/92 Reviewed by: C. Kramer Date: 4/4/92

APPENDIX C

RAW DATA SOIL BACKGROUND

1

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VALIDATED DATA: March 4, 1992 Detection limits added 3-24

Key for labs:

VENDOR QUALIFIER DEFINITIONS

S^3 = S-Cubed

DC = DataChem

(1)	Calculated by peak height
<	Less than the reported value
U	Analyzed for but not detected. Detection limit stated
N	Spiked sample recovery not within control limits
W	Post digestion spike for Furnace AA is out of control limits, while sample absorbance is less than 50% of spike absorbance
B	Reading greater than IDL but less than Contract Required Detection Limit
*	Duplicate analysis not within control limits
E	Estimated value due to interferences
S	Reported value was determined by the Method of Standard Additions
x/y	Lab QA review / OSM QA review

OSM QUALIFIER DEFINITIONS

						MAX QUOTED DETECTION LIMIT (mg/L):		18.1			189			0.018			7.1			1.1			98.7
J	Estimated					CONTRACT REQ. DET. LIMIT (mg/L):		0.2			5000			0.025			0.1			0.003			5
UJ	Undetected + estimated					ACHIEVED DETECTION LIMIT (mg/L):		174			82			1.2			103			n/a			56
U	Undetected					VALUE USED (mg/L):		174			189			1.2			103			1.1			98.7
R	Rejected																						

							Aluminum			Calcium			Copper			Iron			Lead			Sodium	
				COLLECTION			reported	qualifier	used	reported	qualifier	used	reported	qualifier	used	reported	qualifier	used	reported	qualifier	used	reported	qualifier	used
LAB	LAB ID	HEIS ID	SITE	DATE	TYPE	SELECTION	(mg/L)	(Lab/OSM)	(mg/L)	(mg/L)	(Lab/OSM)	(mg/L)	(mg/L)	(Lab/OSM)	(mg/L)	(mg/L)	(Lab/OSM)	(mg/L)	(mg/L)	(Lab/OSM)	(mg/L)	(mg/L)	(Lab/OSM)	(mg/L)
S^3	2628-7	B014K0	699-48-96	10/4/91	REG.	SYSTEMATIC	9810		9810	10900		10900	20.1		20.1	29000		29000	5.5	/J	5.85	798		798
S^3	2628-17	B014L0	699-48-96	10/4/91	REG.	SYSTEMATIC	5550		5550	3900		3900	12.9		12.9	17900		17900	3.9	/J	5.85	175	B	175
S^3	2628-13	B014K6	699-48-96	10/4/91	REG.	SYSTEMATIC	7520		7520	14500		14500	13.8		13.8	16400		16400	4.6	/J	5.85	190	B	190
S^3	2628-12	B014K5	699-48-96	10/4/91	REG.	SYSTEMATIC	6430		6430	52900		52900	13.9		13.9	15600		15600	4.8	/J	5.85	320	B	320
DC	8489	B014J8	699-48-96	9/20/91	SPLIT	SYSTEMATIC	10300		10300	10800		10800	17.1		17.1	18400		18400	5.8		5.85	304	BE	304
S^3	2618-10	B014H9	699-48-96	9/20/91	REG.	SYSTEMATIC	6230	*/J	6230	3820		3820	10.3		10.3	14800		14800	7.2	/J	7.2	143	B	143
S^3	2628-15	B014K8	699-48-96	10/4/91	REG.	SYSTEMATIC	7160		7160	25500		25500	13		13	17600		17600	4.3	/J	5.85	216	B	216
S^3	2628-14	B014K7	699-48-96	10/4/91	REG.	SYSTEMATIC	7170		7170	21600		21600	11.9		11.9	17600		17600	3.8	/J	5.85	260	B	260
S^3	2628-16	B014K9	699-48-96	10/4/91	REG.	SYSTEMATIC	6260		6260	10700		10700	11.5		11.5	14200		14200	4	/J	5.85	173	B	173
S^3	2618-15	B014J4	699-48-96	9/20/91	REG.	SYSTEMATIC	7650	*/J	7650	5930		5930	13.4		13.4	17700		17700	3.4	/J	5.85	177	B	177
S^3	2618-12	B014J1	699-48-96	9/20/91	REG.	SYSTEMATIC	8110	*/J	8110	7790		7790	17.2		17.2	16400		16400	4.1	/J	5.85	238	B	238
S^3	2618-16	B014J5	699-48-96	9/20/91	REG.	SYSTEMATIC	7150	*/J	7150	9340		9340	17.3		17.3	16500		16500	4.4	/J	5.85	101	U	101
S^3	2628-8	B014K1	699-48-96	10/4/91	REG.	SYSTEMATIC	6300		6300	8140		8140	8.5		8.5	14000		14000	4.9	/J	5.85	208	B	208
S^3	2618-13	B014J2	699-48-96	9/20/91	REG.	SYSTEMATIC	6800	*/J	6800	6140		6140	13.6		13.6	13200		13200	4.6	/J	5.85	204	B	204
S^3	2618-14	B014J3	699-48-96	9/20/91	REG.	SYSTEMATIC	8000	*/J	8000	7320		7320	14.3		14.3	15100		15100	7.8	/J	7.8	140	B	140
S^3	2628-11	B014K4	699-48-96	10/4/91	REG.	SYSTEMATIC	7210		7210	86600		86600	14.6		14.6	16200		16200	0.4	/J	5.85	314	B	314
S^3	2628-10	B014K3	699-48-96	10/4/91	REG.	SYSTEMATIC	6200		6200	12700		12700	18.9		18.9	26100		26100	4.3	/J	5.85	351	B	351

								Aluminum			Calcium			Copper			Iron			Lead			Sodium	
				COLLECTION			reported	qualifier	used	reported	qualifier	used	reported	qualifier	used	reported	qualifier	used	reported	qualifier	used	reported	qualifier	used
LAB	LAB ID	HEIS ID	SITE	DATE	TYPE	SELECTION	(mg/L)	(Lab/OSM)	(mg/L)	(mg/L)	(Lab/OSM)	(mg/L)	(mg/L)	(Lab/OSM)	(mg/L)	(mg/L)	(Lab/OSM)	(mg/L)	(mg/L)	(Lab/OSM)	(mg/L)	(mg/L)	(Lab/OSM)	(mg/L)
S^3	2618-11	B014J0	699-48-96	9/20/91	REG.	SYSTEMATIC	8710	*/J	8710	11100		11100	14.5		14.5	15900		15900	6.4	/J	6.4	235	B	235
S^3	2628-9	B014K2	699-48-96	10/4/91	REG.	SYSTEMATIC	7800		7800	10700		10700	16.2		16.2	27500		27500	4.9	/J	5.85	481	B	481
S^3	2597-1	B01411	1	9/12/91	REG.	SYSTEMATIC	5960	*	5960	5800		5800	17.2		17.2	26000	*	26000	5	N/J	5.85	265	B	265
S^3	2597-3	B01413	1	9/12/91	REG.	SYSTEMATIC	8670	*	8670	3970		3970	12		12	25500	*	25500	7.4	N/J	7.4	361	B	361
S^3	2597-2	B01412	1	9/12/91	REG.	SYSTEMATIC	11000	*	11000	18700		18700	21.3		21.3	26700	*	26700	9	N/J	9	264	B	264
DC	8384	B01414	1	9/12/91	SPLIT	SYSTEMATIC	8630	E/J	8630	4060	E/J	4060	28.3	N*	28.3	22700	E	22700	4.8	NS*	5.85	405	B	405
DC	8581	B01434	2	9/26/91	SPLIT	SYSTEMATIC	9580		9580	5060	*/J	5060	12.2		12.2	28400		28400	6	NS*	6	294	B	294
S^3	2628-2	B01430	2	9/26/91	REG.	SYSTEMATIC	5480		5480	8360		8360	15		15	27200		27200	3.6	/J	5.85	328	B	328
S^3	2628-3	B01431	2	9/26/91	REG.	SYSTEMATIC	4940		4940	7510		7510	15.1		15.1	29000		29000	3.3	/J	5.85	344	B	344
S^3	2628-1	B01429	2	9/26/91	REG.	SYSTEMATIC	5900		5900	7710		7710	13.8		13.8	32500		32500	4.1	/J	5.85	514		514
S^3	2628-4	B01433	2	9/26/91	REG.	SYSTEMATIC	8360		8360	3980		3980	12.1		12.1	24800		24800	4.7	/J	5.85	190	B	190
S^3	2724	B01B76	3	11/20/91	REG.	SYSTEMATIC	6480	/J	6480	8340		8340	16.5		16.5	20100	*/J	20100	6.6	/J	6.6	193	B	193
S^3	2663-3	B01469	3	10/24/91	REG.	SYSTEMATIC	11900	*	11900	10100		10100	18.5	*	18.5	23600		23600	9.8		9.8	255	B	255
S^3	2728	B01B72	3	11/20/91	REG.	SYSTEMATIC	6310	/J	6310	7270		7270	15.7		15.7	22700	*/J	22700	7.5	/J	7.5	231	B	231
S^3	2729	B01B71	3	11/20/91	REG.	SYSTEMATIC	7540	/J	7540	9880		9880	16.5		16.5	26900	*/J	26900	5.7	/J	5.85	338	B	338
S^3	2723	B01B77	3	11/20/91	REG.	SYSTEMATIC	9720	/J	9720	6520		6520	21.1		21.1	23800	*/J	23800	11.5	/J	11.5	165	B	165
DC	9385	B01B79	3	11/20/91	SPLIT	SYSTEMATIC	4310		4310	4780	*	4780	15		15	20300		20300	1.9	*	5.85	278	B	278
S^3	2725	B01B75	3	11/20/91	REG.	SYSTEMATIC	6230	/J	6230	7560		7560	14.2		14.2	28800	*/J	28800	4.2	/J	5.85	361	B	361
S^3	2727	B01B73	3	11/20/91	REG.	SYSTEMATIC	5850	/J	5850	7600		7600	14.7		14.7	30800	*/J	30800	5	/J	5.85	284	B	284
S^3	2726	B01B74	3	11/20/91	REG.	SYSTEMATIC	4190	/J	4190	6710		6710	14.2		14.2	22700	*/J	22700	3.3	/J	5.85	202	B	202
S^3	2722	B01B78	3	11/20/91	REG.	SYSTEMATIC	6670	/J	6670	7480		7480	14.7		14.7	23000	*/J	23000	5.8	/J	5.85	183	B	183
S^3	2663-4	B01B57	3	10/24/91	REG.	SYSTEMATIC	6070	*/J	6070	7840		7840	13.6	*	13.6	29300		29300	4.9		5.85	381	B	381
S^3	9026	B01B64	3	10/24/91	SPLIT	SYSTEMATIC	4800	*/J	4800	7060		7060	17		17	21100	/J	21100	2.6		5.85	144	/R	144
S^3	2663-1	B01467	3	10/24/91	REG.	SYSTEMATIC	7940	*	7940	10100		10100	18	*	18	27600		27600	6.8		6.8	291	B	291
S^3	2663-5	B01B58	3	10/24/91	REG.	SYSTEMATIC	7780	*/J	7780	8900		8900	14.9	*	14.9	30800		30800	6		6	304	B	304
S^3	2633-3	B01459	4	10/3/91	REG.	SYSTEMATIC	14900		14900	5830	*	5830	22.8	N*	22.8	24400		24400	12.1	N/JN	12.1	316	B*	316
S^3	2633-1	B01457	4	10/3/91	REG.	SYSTEMATIC	9640		9640	6050	*	6050	17.2	N*	17.2	18700		18700	26.6	N/JN	26.6	223	B*	223
S^3	2633-2	B01458	4	10/3/91	REG.	SYSTEMATIC	14100		14100	5790	*	5790	22.8	N*	22.8	24800		24800	1.1	N	5.85	295	B*	295
DC	8779	B01460	4	10/3/91	SPLIT	SYSTEMATIC	15900		15900	6480		6480	22.6		22.6	26300		26300	10.8	NS	10.8	297	BE	297
S^3	2652-4	B01460	5	10/21/91	REG.	SYSTEMATIC	7600	/J	7600	19300	/J	19300	13.6		13.6	16300		16300	4.2		5.85	256	/J	256
S^3	2652-1	B014F5	5	10/21/91	REG.	SYSTEMATIC	6420	/J	6420	8010	/J	8010	9.8		9.8	15900		15900	5		5.85	276	/J	276
S^3	2652-2	B014F6	5	10/21/91	REG.	SYSTEMATIC	8600	/J	8600	15500	/J	15500	14.5		14.5	20100		20100	5.4		5.85	785	/J	785
S^3	9025	B01461	5	10/21/91	SPLIT	SYSTEMATIC	6520	/J	6520	18100		18100	14		14	13600	/J	13600	2.1	/S	5.85	213	/R	213
S^3	2652-5	B01462	5	10/21/91	REG.	SYSTEMATIC	6590	/J	6590	3820	/J	3820	8.1		8.1	14100		14100	4.3		5.85	178	/J	178
S^3	2652-3	B014F7	5	10/21/91	REG.	SYSTEMATIC	7210	/J	7210	10900	/J	10900	14.5		14.5	16700		16700	7		7	535	/J	535
S^3	2633-20	B01488	6	10/8/91	REG.	SYSTEMATIC	5070		5070	10000	*	10000	12.4	N*	12.4	26500		26500	2.8	N/JN	5.85	335	B*	335
S^3	2633-22	B01490	6	10/8/91	REG.	SYSTEMATIC	4100		4100	6700	*	6700	12	N*	12	25500		25500	2.6	N/JN	5.85	721	*	721

							Aluminum			Calcium			Copper			Iron			Lead			Sodium	
				COLLECTION			reported	qualifier	used	reported	qualifier	used	reported	qualifier	used	reported	qualifier	used	reported	qualifier	used	reported	qualifier	used
LAB	LAB ID	HEIS ID	SITE	DATE	TYPE	SELECTION	(mg/L)	(Lab/OSM)	(mg/L)	(mg/L)	(Lab/OSM)	(mg/L)	(mg/L)	(Lab/OSM)	(mg/L)	(mg/L)	(Lab/OSM)	(mg/L)	(mg/L)	(Lab/OSM)	(mg/L)	(mg/L)	(Lab/OSM)	(mg/L)
S^3	2633-9	B01469	6	10/8/91	REG.	SYSTEMATIC	4520		4520	6610	*	6610	13.3	N*	13.3	25900		25900	3.3	N/JN	5.85	254	B*	254
S^3	2633-14	B01482	6	10/8/91	REG.	SYSTEMATIC	6590		6590	12100	*	12100	14.1	N*	14.1	30500		30500	4.2	N/JN	5.85	288	B*	288
S^3	2633-18	B01486	6	10/8/91	REG.	SYSTEMATIC	6150		6150	13300	*	13300	12.8	N*	12.8	34000		34000	3.8	N/JN	5.85	327	B*	327
S^3	2633-21	B01489	6	10/8/91	REG.	SYSTEMATIC	5520		5520	8880	*	8880	13.3	N*	13.3	30400		30400	3.4	N/JN	5.85	397	B*	397
S^3	2633-19	B01487	6	10/8/91	REG.	SYSTEMATIC	4870		4870	10900	*	10900	11.9	N*	11.9	27400		27400	3.3	N/JN	5.85	288	B*	288
S^3	2633-10	B01470	6	10/8/91	REG.	SYSTEMATIC	6610		6610	11000	*	11000	32.8	N*	32.8	29900		29900	5	N/JN	5.85	298	B*	298
DC	8780	B01480	6	10/8/91	SPLIT	SYSTEMATIC	6580		6580	11100		11100	13.6		13.6	34200		34200	2.5	N	5.85	237	BE	237
S^3	2633-16	B01484	6	10/8/91	REG.	SYSTEMATIC	5890		5890	13500	*	13500	12.3	N*	12.3	33700		33700	4	N/JN	5.85	293	B*	293
S^3	2633-13	B01473	6	10/8/91	REG.	SYSTEMATIC	5170		5170	11800	*	11800	12.1	N*	12.1	29900		29900	3.5	N/JN	5.85	251	B*	251
S^3	2633-23	B01491	6	10/8/91	REG.	SYSTEMATIC	6700		6700	14700	*	14700	13.5	N*/J	13.5	22400		22400	10.8	N/JN	10.8	1030	*/J	1030
S^3	2633-17	B01485	6	10/8/91	REG.	SYSTEMATIC	7890		7890	12500	*	12500	13.6	N*	13.6	30900		30900	4.9	N/JN	5.85	277	B*	277
S^3	2633-15	B01483	6	10/8/91	REG.	SYSTEMATIC	5160		5160	9730	*	9730	14.2	N*	14.2	29400		29400	4	N/JN	5.85	950	*	950
S^3	2633-11	B01471	6	10/8/91	REG.	SYSTEMATIC	4840		4840	6500	*	6500	12.6	N*	12.6	26300		26300	3.2	N/JN	5.85	254	B*	254
S^3	2633-12	B01472	6	10/8/91	REG.	SYSTEMATIC	4860		4860	6840	*	6840	11.5	N*	11.5	26600		26600	4.8	N/JN	5.85	212	B*	212
S^3	2633	B014C7	7	10/11/91	REG.	SYSTEMATIC	6290		6290	10000		10000	11.5	/J	11.5	33700	*/J	33700	3.6	*/J	5.85	408	B	408
S^3	2635	B014C5	7	10/11/91	REG.	SYSTEMATIC	7110		7110	7660		7660	10.5	/J	10.5	34400	*/J	34400	4.5	*/J	5.85	352	B	352
S^3	2636	B014C4	7	10/11/91	REG.	SYSTEMATIC	6520		6520	8970		8970	13.8	/J	13.8	34000	*/J	34000	5.5	*/J	5.85	306	B	306
S^3	2637	B014C3	7	10/11/91	REG.	SYSTEMATIC	5690		5690	7970		7970	12.9	/J	12.9	32600	*/J	32600	2.9	*/J	5.85	366	B	366
S^3	2632	B014C8	7	10/11/91	REG.	SYSTEMATIC	7120		7120	11500		11500	15.2	/J	15.2	28600	*/J	28600	8.6	*/J	8.6	339	B	339
DC	8894	B014D3	7	10/11/91	SPLIT	SYSTEMATIC	8110		8110	8450		8450	15		15	23200		23200	2.5		5.85	448	B	448
S^3	2638	B014C2	7	10/11/91	REG.	SYSTEMATIC	5570		5570	6470		6470	10.7	/J	10.7	18400	*/J	18400	3.4	*/J	5.85	197	B	197
S^3	2641	B01489	7	10/11/91	REG.	SYSTEMATIC	6530		6530	8620		8620	10.1	/J	10.1	21400	*/J	21400	5.6	*/J	5.85	234	B	234
S^3	2640	B014C0	7	10/11/91	REG.	SYSTEMATIC	7770		7770	6820		6820	22.8	/J	22.8	23500	*/J	23500	9.2	*/J	9.2	228	B	228
S^3	2634	B014C6	7	10/11/91	REG.	SYSTEMATIC	6990		6990	8100		8100	11.5	/J	11.5	35000	*/J	35000	4	*/J	5.85	294	B	294
S^3	2639	B014C1	7	10/11/91	REG.	SYSTEMATIC	5870		5870	13200		13200	11	/J	11	18900	*/J	18900	3.4	*/J	5.85	176	B	176
S^3	2646-1	B014B3	8	10/10/91	REG.	SYSTEMATIC	8300		8300	7790		7790	11.9	/J	11.9	20600	*/J	20600	7.5	*/J	7.5	284	B	284
S^3	2644	B014B4	8	10/10/91	REG.	SYSTEMATIC	13800		13800	6050		6050	19.1	/J	19.1	26300	*/J	26300	7.9	*/J	7.9	566	/J	566
DC	8895	B01480	9	10/10/91	SPLIT	SYSTEMATIC	9760		9760	10700		10700	11.4		11.4	20000		20000	4.2		5.85	561	B	561
S^3	2646-25	B01494	9	10/10/91	REG.	SYSTEMATIC	9950		9950	11700		11700	13.6	/J	13.6	20800	*	20800	5.2	*/J	5.85	511	/J	511
S^3	2646-26	B01495	9	10/10/91	REG.	SYSTEMATIC	12400		12400	11600		11600	17.8	/J	17.8	26700	*/J	26700	5.8	*/J	5.85	796	/J	796
S^3	2646-27	B01496	9	10/10/91	REG.	SYSTEMATIC	9350		9350	4000		4000	11.4	/J	11.4	24100	*/J	24100	7.9	*/J	7.9	217	B/J	217
S^3	2633-7	B01467	10	10/3/91	REG.	SYSTEMATIC	18000		18000	13100	*	13100	35.9	N*	35.9	35100		35100	14.4	N/JN	14.4	687	*	687
S^3	2633-6	B01464	10	10/3/91	REG.	SYSTEMATIC	14300		14300	18600	*	18600	29.6	N*	29.6	28400		28400	11.2	N/JN	11.2	717	*	717
DC	8781	B01465	10	10/3/91	SPLIT	SYSTEMATIC	14800		14800	13100		13100	26.5		26.5	34500		34500	8.1	NS	8.1	664	BE	664
S^3	2633-4	B01462	10	10/3/91	REG.	SYSTEMATIC	18100		18100	11200	*	11200	36.1	N*	36.1	35000		35000	9.8	N/JN	9.8	970	*	970
S^3	2633-5	B01463	10	10/3/91	REG.	SYSTEMATIC	16400		16400	18000	*	18000	29.6	N*	29.6	31000		31000	11.2	N/JN	11.2	976	*	976
S^3	2633-8	B01468	10	10/3/91	REG.	SYSTEMATIC	14800		14800	25300	*	25300	30.7	N*	30.7	30600		30600	11.4	N/JN	11.4	457	B*	457

								Aluminum			Calcium			Copper			Iron			Lead			Sodium	
				COLLECTION			reported	qualifier	used	reported	qualifier	used	reported	qualifier	used	reported	qualifier	used	reported	qualifier	used	reported	qualifier	used
LAB	LAB ID	HEIS ID	SITE	DATE	TYPE	SELECTION	(mg/L)	(Lab/OSM)	(mg/L)	(mg/L)	(Lab/OSM)	(mg/L)	(mg/L)	(Lab/OSM)	(mg/L)	(mg/L)	(Lab/OSM)	(mg/L)	(mg/L)	(Lab/OSM)	(mg/L)	(mg/L)	(Lab/OSM)	(mg/L)
S^3	2626	B01407	11	10/15/91	REG.	SYSTEMATIC	9570		9570	13600		13600	13.3	/J	13.3	20300	*/J	20300	7.1	*/J	7.1	331	B	331
S^3	2625	B01408	11	10/15/91	REG.	SYSTEMATIC	13000		13000	14100		14100	22.1	/J	22.1	24300	*/J	24300	14.7	*/J	14.7	850	/J	850
S^3	8896	B014F2	11	10/15/91	SPLIT	SYSTEMATIC	16100		16100	15400		15400	21.9		21.9	24900		24900	14.7		14.7	287	B	287
S^3	2622	B014F1	11	10/15/91	REG.	SYSTEMATIC	17600		17600	16400		16400	23.5	/J	23.5	27000	*/J	27000	14.8	*/J	14.8	331	B	331
S^3	2618-1	B01417	12	9/24/91	REG.	SYSTEMATIC	11400	*/J	11400	5660		5660	13.2		13.2	31300		31300	11.1	/J	11.1	379	B	379
S^3	2618-5	B01421	12	9/24/91	REG.	SYSTEMATIC	9980	*/J	9980	11200		11200	14.9		14.9	23800		23800	7.9	N/J	7.9	782		782
S^3	2618-7	B01425	12	9/24/91	REG.	SYSTEMATIC	8560	*/J	8560	7200		7200	12.3		12.3	22500		22500	7.2	/J	7.2	3390		3390
S^3	2618-3	B01419	12	9/24/91	REG.	SYSTEMATIC	5470	*/J	5470	6100		6100	9.4		9.4	27000		27000	5.1	N/J	5.85	268	B	268
DC	8488	B01423	12	9/24/91	SPLIT	SYSTEMATIC	14900		14900	10600		10600	19.9		19.9	31600		31600	5.8		5.85	6060	E	6060
S^3	2618-2	B01418	12	9/24/91	REG.	SYSTEMATIC	10300	*/J	10300	5230		5230	15.5		15.5	27000		27000	8.6	N/J	8.6	281	B	281
S^3	2618-6	B01422	12	9/24/91	REG.	SYSTEMATIC	10300	*/J	10300	10400		10400	16.5		16.5	23800		23800	8.3	/J	8.3	5620		5620
S^3	2618-4	B01420	12	9/24/91	REG.	SYSTEMATIC	10000	*/J	10000	10200		10200	13.3		13.3	26700		26700	6.9	N/J	6.9	312	B	312
S^3	2630-15	B01456	13	10/1/91	REG.	SYSTEMATIC	6440		6440	11100	*/J	11100	15.9	*/J	15.9	23400		23400	4.8	N	5.85	308	B	308
S^3	2630-14	B01453	13	10/1/91	REG.	SYSTEMATIC	4930		4930	5870	*/J	5870	16.2	*/J	16.2	22800		22800	4.7	N	5.85	341	B	341
S^3	2630-13	B01452	13	10/1/91	REG.	SYSTEMATIC	3940		3940	5600	*/J	5600	14	*/J	14	16000		16000	4.9	N	5.85	309	B	309
S^3	2630-12	B01451	13	10/1/91	REG.	SYSTEMATIC	7470		7470	8540	*/J	8540	16	*/J	16	22900		22900	5	N	5.85	376	B	376
DC	8583	B01454	13	10/1/91	SPLIT	SYSTEMATIC	6340		6340	6410	*/J	6410	14.3		14.3	29700		29700	4.4	N*	5.85	277	B	277
S^3	2630-6	B01445	14	10/1/91	REG.	SYSTEMATIC	9120		9120	4280	*/J	4280	11.9	*/J	11.9	20900		20900	6.7	N	6.7	244	B	244
DC	8582	B01440	14	10/1/91	SPLIT	SYSTEMATIC	11300		11300	17400	*/J	17400	16.5		16.5	33000		33000	7.5	NS*	7.5	424	B	424
S^3	2630-9	B01448	14	10/1/91	REG.	SYSTEMATIC	11500		11500	13800	*/J	13800	20.2	*/J	20.2	28400		28400	12.3	N	12.3	296	B	296
S^3	2630-4	B01443	14	10/1/91	REG.	SYSTEMATIC	7750		7750	14800	*/J	14800	13.4	*/J	13.4	21600		21600	5.8	N	5.85	433	B	433
S^3	2630-8	B01447	14	10/1/91	REG.	SYSTEMATIC	5040		5040	6870	*/J	6870	10	*/J	10	21400		21400	5.5	N	5.85	226	B	226
S^3	2630-1	B01438	14	10/1/91	REG.	SYSTEMATIC	9500		9500	10300	*/J	10300	12.9	*/J	12.9	28500		28500	6.2	N/J	6.2	349	B	349
S^3	2630-7	B01446	14	10/1/91	REG.	SYSTEMATIC	8100		8100	10900	*/J	10900	13	*/J	13	26900		26900	8.1	N	8.1	268	B	268
S^3	2630-2	B01439	14	10/1/91	REG.	SYSTEMATIC	7230		7230	13500	*/J	13500	13.9	*/J	13.9	22400		22400	6.9	N	6.9	336	B	336
S^3	2630-3	B01442	14	10/1/91	REG.	SYSTEMATIC	8140		8140	39500	/J	39500	13.6	*/J	13.6	18900		18900	8	N	8	464	B	464
S^3	2630-5	B01444	14	10/1/91	REG.	SYSTEMATIC	9380		9380	27500	*/J	27500	16.3	*/J	16.3	21000		21000	7.1	N	7.1	446	B	446
S^3	2630-10	B01449	14	10/1/91	REG.	SYSTEMATIC	8490		8490	13100	*/J	13100	18.6	*/J	18.6	32000		32000	7.2	N	7.2	430	B	430
JUDGEMENT																								
S^3	2628-5	B01435	2	9/26/91	REG.	JUDGEMENT	4190		4190	39300		39300	13.6		13.6	23500		23500	3.2	/J	5.85	287	B	287
S^3	2628-6	B01436	2	9/26/91	REG.	JUDGEMENT	5680		5680	9840		9840	18.1		18.1	29000		29000	4	/J	5.85	305	B	305
S^3	2663-9	B01B62	3	10/24/91	REG.	JUDGEMENT	13100	*/J	13100	12100		12100	19.3	*	19.3	27500		27500	8.9		8.9	349	B	349
S^3	2663-7	B01B60	3	10/24/91	REG.	JUDGEMENT	7890	*/J	7890	8300		8300	9.5	*	9.5	22100		22100	4.6		5.85	194	B	194
S^3	2663-2	B01468	3	10/24/91	REG.	JUDGEMENT	7420	*	7420	6330		6330	9.3	*	9.3	16600		16600	4.8		5.85	196	B	196
S^3	2663-10	B01B63	3	10/24/91	REG.	JUDGEMENT	8000	*/J	8000	9060		9060	15	*	15	33700		33700	8.2		8.2	385	B	385
S^3	2663-6	B01B59	3	10/24/91	REG.	JUDGEMENT	6330	*/J	6330	5740		5740	9	*	9	15200		15200	4.2		5.85	149	B	149
S^3	9027	B01B67	3	10/24/91	SPLIT	JUDGEMENT	5620	/J	5620	5280		5280	8.5		8.5	13000		13000	3.1		5.85	161	/A	161

9 2 1 2 5 3 1 8 5 4

								Aluminum			Calcium			Copper			Iron			Lead			Sodium	
				COLLECTION			reported	qualifier	used	reported	qualifier	used	reported	qualifier	used	reported	qualifier	used	reported	qualifier	used	reported	qualifier	used
LAB	LAB ID	HEIS ID	SITE	DATE	TYPE	SELECTION	(mg/L)	(Lab/OSM)	(mg/L)	(mg/L)	(Lab/OSM)	(mg/L)	(mg/L)	(Lab/OSM)	(mg/L)	(mg/L)	(Lab/OSM)	(mg/L)	(mg/L)	(Lab/OSM)	(mg/L)	(mg/L)	(Lab/OSM)	(mg/L)
S^3	2663-8	B01B61	3	10/24/91	REG.	JUDGEMENT	6490	*J	6490	6680		6680	10.1	*	10.1	16200		16200	4.1		5.85	163	B	163
S^3	2652-6	B01463	5	10/21/91	REG.	JUDGEMENT	6640	/J	6640	8260	/J	8260	13.1		13.1	15900		15900	3.9		5.85	330	/J	330
S^3	2652-8	B01465	5	10/21/91	REG.	JUDGEMENT	9780	/J	9780	13300	/J	13300	28.4		28.4	22500		22500	7.5		7.5	721	/J	721
S^3	2652-9	B01466	5	10/21/91	REG.	JUDGEMENT	6900	/J	6900	12200	/J	12200	13.1		13.1	16100		16100	3.8		5.85	210	/J	210
S^3	2652-7	B01464	5	10/21/91	REG.	JUDGEMENT	6610	/J	6610	9040	/J	9040	10.3		10.3	15000		15000	5		5.85	344	/J	344
S^3	2633-25	B01493	6	10/8/91	REG.	JUDGEMENT	7770		7770	18500	*	18500	13.5	N*/J	13.5	26700		26700	11.9	N/JN	11.9	748	*J	748
S^3	2633-24	B01492	6	10/8/91	REG.	JUDGEMENT	8430		8430	12900	*	12900	15.4	N*/J	15.4	32900		32900	7.4	N/JN	7.4	332	B*/J	332
S^3	2628	B014D5	7	10/11/91	REG.	JUDGEMENT	7900		7900	8900		8900	10.5	/J	10.5	19700	*J	19700	4.3	*J	5.85	183	B	183
S^3	2630	B014D0	7	10/11/91	REG.	JUDGEMENT	7330		7330	7790		7790	11	/J	11	31200	*J	31200	5.4	*J	5.85	372	B	372
S^3	2631	B014C9	7	10/11/91	REG.	JUDGEMENT	6580		6580	6660		6660	8.6	/J	8.6	17400	*J	17400	3.1	*J	5.85	142	B	142
S^3	2629	B014D4	7	10/11/91	REG.	JUDGEMENT	7020		7020	6440		6440	10.2	/J	10.2	17300	*J	17300	4.7	*J	5.85	167	B	167
S^3	2627	B014D6	7	10/11/91	REG.	JUDGEMENT	6130		6130	5640		5640	11.6	/J	11.6	21000	*J	21000	2.7	*J	5.85	210	B	210
DC	8893	B014B7	8	10/10/91	SPLIT	JUDGEMENT	11100		11100	7110		7110	11.9		11.9	21400		21400	7.6		7.6	399	B	399
S^3	2642	B014B6	8	10/10/91	REG.	JUDGEMENT	8110		8110	7250		7250	10.6	/J	10.6	19500	*J	19500	9.5	*J	9.5	317	B	317
S^3	2643	B014B5	8	10/10/91	REG.	JUDGEMENT	12400		12400	6900		6900	17.3	/J	17.3	24100	*J	24100	11.4	*J	11.4	374	B	374
S^3	2646-30	B01499	9	10/10/91	REG.	JUDGEMENT	10100		10100	25400		25400	15.4	/J	15.4	21400	*J	21400	7.2	*J	7.2	293	B	293
S^3	2646-28	B01497	9	10/10/91	REG.	JUDGEMENT	23000		23000	10600		10600	22.6	/J	22.6	37000	*J	37000	9.7	*J	9.7	976		976
S^3	2646-29	B01498	9	10/10/91	REG.	JUDGEMENT	10600		10600	10800		10800	16.2	/J	16.2	19800	*J	19800	6.3	*J	6.3	477	B	477
S^3	2623	B014F0	11	10/15/91	REG.	JUDGEMENT	15100		15100	13800		13800	17.1	/J	17.1	26300	*J	26300	8.2	*J	8.2	629	/J	629
S^3	2624	B014D9	11	10/15/91	REG.	JUDGEMENT	15700		15700	17000		17000	22.6	/J	22.6	26900	*J	26900	19.1	*J	19.1	473	B	473
S^3	2618-8	B01426	12	9/24/91	REG.	JUDGEMENT	6770	*J	6770	10800		10800	9.7		9.7	26400		26400	6	/J	6	309	B	309
S^3	2618-9	B01427	12	9/24/91	REG.	JUDGEMENT	7200	*J	7200	37500		37500	11.6		11.6	12300		12300	3.8	/J	5.85	2460		2460
S^3	2630-11	B01450	14	10/1/91	REG.	JUDGEMENT	6120		6120	21600	*J	21600	17.6	*J	17.6	27500		27500	7.8	N	7.8	306	B	306
PREP BLANKS																								
S^3	2630-16	B014A3	N/A	N/A	EXTRA P. B.	N/A	7.2	U	174	107	U*/J	189	1.8	U*/UJ	1.8	14.4		103	0.14	BN/UJ	5.85	98.7	U	98.7
S^3	2618-17	B014H0			PREP BLANK		7.2	*UJ	174	107	U	189	1.8	U	1.8	6.9	U	103	0.1	U/UJ	5.85	98.7	U	98.7
DC	8490	B014H1			PREP BLANK		2.6	/UJ	174	4	/UJ	189	0.8	U	1.2	1.2	U/UJ	103	0.42	BN/UJ	5.85	9.3	/U	98.7
S^3	2628-18	B014H2			PREP BLANK		7.2	U	174	107	U	189	1.8	U	1.8	10.2		103	0.9	/J	5.85	98.7	U	98.7
DC	8584	B014H4			PREP BLANK		4.7	B/U	174	5	B*/J	189	0.8	U	1.2	6.4	B	103	0.23	BN*/J	5.85	25.5	B	98.7
S^3	2633-26	B014H5			PREP BLANK		7.2	U/J	174	107	U*	189	1.8	UN*/UJ	1.8	7.1	U	103	1.1	UN	5.85	98.7	U*/UJ	98.7
DC	8782	B014H6			PREP BLANK		4.3	B	174	4	U	189	0.8	U	1.2	1.3	B	103	0.2	UN	5.85	4.7	BE	98.7
S^3	2615	B014H7			PREP BLANK		18.1	B	174	107	U	189	1.8	U	1.8	8.7	B*/J	103	0.3	U*/UJ	5.85	98.7	U	98.7
S^3	2614	B014H8			PREP BLANK		10.7	B	174	107	U	189	1.8	U	1.8	6.9	U*	103	0.55	*J	5.85	98.7	U	98.7
S^3	8897	B014J6			PREP BLANK		2.6	/U	174	4	/U	189	0.8		1.2	2.2	/U	103	0.2	/UJ	5.85	7.3	/U	98.7
S^3	2652-10	B014J7			PREP BLANK		7.2	/UJ	174	107	/UJ	189	1.8		1.8	9.4	/J	103	1.1		5.85	98.7	/UJ	98.7
S^3	2663-11	B014J9			PREP BLANK		22.8	*J	174	189	B	189	1.8	U*	1.8	58.9		103	1.1	U	5.85	98.7	U	98.7
S^3	9028	B01B70			PREP BLANK		2.6	/R	174	17.2	/R		1.4	/R		4.4	/R		0.2	/R		2.6	/R	

								Aluminum			Calcium			Copper			Iron			Lead			Sodium	
				COLLECTION			reported	qualifier	used	reported	qualifier	used	reported	qualifier	used	reported	qualifier	used	reported	qualifier	used	reported	qualifier	used
LAB	LAB ID	HEIS ID	SITE	DATE	TYPE	SELECTION	(mg/L)	(Lab/OSM)	(mg/L)	(mg/L)	(Lab/OSM)	(mg/L)	(mg/L)	(Lab/OSM)	(mg/L)	(mg/L)	(Lab/OSM)	(mg/L)	(mg/L)	(Lab/OSM)	(mg/L)	(mg/L)	(Lab/OSM)	(mg/L)
S^3	2721	B01B82			PREP BLANK		7.2	/UJ	174	107	/U	189	1.8	U	1.8	10.9	/J	103	0.66	BN/J	5.85	98.7	B	98.7
SPLIT PAIRS																								
S^3	2597-3	B01413	1	9/12/91	REG.	SYSTEMATIC	8670	*	8670	3970		3970	12		12	25500	*	25500	7.4	N/J	7.4	361	B	361
DC	8384	B01414	1	9/12/91	SPLIT	SYSTEMATIC	8630	E/J	8630	4060	E/J	4060	28.3	N*	28.3	22700	E	22700	4.8	NS*	5.85	405	B	405
S^3	2618-6	B01422	12	9/24/91	REG.	SYSTEMATIC	10300	*/J	10300	10400		10400	16.5		16.5	23800		23800	8.3	/J	8.3	5620		5620
DC	8488	B01423	12	9/24/91	SPLIT	SYSTEMATIC	14900		14900	10600		10600	19.9		19.9	31600		31600	5.8		5.85	6060	E	6060
S^3	2628-4	B01433	2	9/26/91	REG.	SYSTEMATIC	8360		8360	3980		3980	12.1		12.1	24800		24800	4.7	/J	5.85	190	B	190
DC	8581	B01434	2	9/26/91	SPLIT	SYSTEMATIC	9580		9580	5060	*/J	5060	12.2		12.2	28400		28400	6	NS*	6	294	B	294
S^3	2630-2	B01439	14	10/1/91	REG.	SYSTEMATIC	7230		7230	13500	*/J	13500	13.9	*/J	13.9	22400		22400	6.9	N	6.9	336	B	336
DC	8582	B01440	14	10/1/91	SPLIT	SYSTEMATIC	11300		11300	17400	*/J	17400	16.5		16.5	33000		33000	7.5	NS*	7.5	424	B	424
S^3	2630-14	B01453	13	10/1/91	REG.	SYSTEMATIC	4930		4930	5870	*/J	5870	16.2	*/J	16.2	22800		22800	4.7	N	5.85	341	B	341
DC	8583	B01454	13	10/1/91	SPLIT	SYSTEMATIC	6340		6340	6410	*/J	6410	14.3		14.3	29700		29700	4.4	N*	5.85	277	B	277
S^3	2633-3	B01459	4	10/3/91	REG.	SYSTEMATIC	14900		14900	5830	*	5830	22.8	N*	22.8	24400		24400	12.1	N/JN	12.1	316	B*	316
DC	8779	B01460	4	10/3/91	SPLIT	SYSTEMATIC	15900		15900	6480		6480	22.6		22.6	26300		26300	10.8	NS	10.8	297	BE	297
S^3	2633-6	B01464	10	10/3/91	REG.	SYSTEMATIC	14300		14300	18600	*	18600	29.6	N*	29.6	28400		28400	11.2	N/JN	11.2	717	*	717
DC	8781	B01465	10	10/3/91	SPLIT	SYSTEMATIC	14800		14800	13100		13100	26.5		26.5	34500		34500	8.1	NS	8.1	664	BE	664
S^3	2633-13	B01473	6	10/8/91	REG.	SYSTEMATIC	5170		5170	11800	*	11800	12.1	N*	12.1	29900		29900	3.5	N/JN	5.85	251	B*	251
DC	8780	B01480	6	10/8/91	SPLIT	SYSTEMATIC	6580		6580	11100		11100	13.6		13.6	34200		34200	2.5	N	5.85	237	BE	237
S^3	2646-25	B01494	9	10/10/91	REG.	SYSTEMATIC	9950		9950	11700		11700	13.6	/J	13.6	20800	*	20800	5.2	*/J	5.85	511	/J	511
DC	8895	B01480	9	10/10/91	SPLIT	SYSTEMATIC	9760		9760	10700		10700	11.4		11.4	20000		20000	4.2		5.85	561	B	561
S^3	2642	B01486	8	10/10/91	REG.	JUDGEMENT	8110		8110	7250		7250	10.6	/J	10.6	19500	*/J	19500	9.5	*/J	9.5	317	B	317
DC	8893	B01487	8	10/10/91	SPLIT	JUDGEMENT	11100		11100	7110		7110	11.9		11.9	21400		21400	7.6		7.6	399	B	399
S^3	2640	B01C0	7	10/11/91	REG.	SYSTEMATIC	7770		7770	6820		6820	22.8	/J	22.8	23500	*/J	23500	9.2	*/J	9.2	228	B	228
DC	8894	B01D3	7	10/11/91	SPLIT	SYSTEMATIC	8110		8110	8450		8450	15		15	23200		23200	2.5		5.85	448	B	448
S^3	2622	B01F1	11	10/15/91	REG.	SYSTEMATIC	17600		17600	16400		16400	23.5	/J	23.5	27000	*/J	27000	14.8	*/J	14.8	331	B	331
DC	8896	B01F2	11	10/15/91	SPLIT	SYSTEMATIC	16100		16100	15400		15400	21.9		21.9	24900		24900	14.7		14.7	287	B	287
S^3	2652-4	B01460	5	10/21/91	REG.	SYSTEMATIC	7600	/J	7600	19300	/J	19300	13.6		13.6	16300		16300	4.2		5.85	256	/J	256
DC	9025	B01461	5	10/21/91	SPLIT	SYSTEMATIC	6520	/J	6520	18100		18100	14		14	13600	/J	13600	2.1	/S	5.85	213	/R	
S^3	2618-11	B01J0	699-48-96	9/20/91	REG.		8710	*/J	8710	11100		11100	14.5		14.5	15900		15900	6.4	/J	6.4	235	B	235
DC	8489	B01J8	699-48-96	9/20/91	SPLIT		10300		10300	10800		10800	17.1		17.1	18400		18400	5.8		5.85	304	BE	304
S^3	2663-5	B01B58	3	10/24/91	REG.	SYSTEMATIC	7780	*/J	7780	8900		8900	14.9	*	14.9	30800		30800	6		6	304	B	304
DC	9026	B01B64	3	10/24/91	SPLIT	SYSTEMATIC	4800	*/J	4800	7060		7060	17		17	21100	/J	21100	2.6		5.85	144	/R	
S^3	2663-6	B01B59	3	10/24/91	REG.	JUDGEMENT	6330	*/J	6330	5740		5740	9	*	9	15200		15200	4.2		5.85	149	B	149
DC	9027	B01B67	3	10/24/91	SPLIT	JUDGEMENT	5620	/J	5620	5280		5280	8.5		8.5	13000		13000	3.1		5.85	161	/R	
S^3	2726	B01B74	3	11/20/91	REG.	SYSTEMATIC	4190	/J	4190	6710		6710	14.2		14.2	22700	/J	22700	3.3	/J	5.85	202	B	202
DC	9385	B01B79	3	11/20/91	SPLIT	SYSTEMATIC	4310		4310	4780	*	4780	15		15	20300		20300	1.9	*	5.85	278	B	278

APPENDIX D

BACKGROUND DATA ANALYSIS

9 2 1 2 6 0 8 1 8 5 7

APPENDIX D

CONTENTS

1.0 STATISTICAL ANALYSIS 1-1

1.1 DATA ANALYSIS METHODS 1-1
1.1.1 Data Validation 1-1
1.1.2 Data Transcription/Verification 1-1
1.1.3 Detection Limit Analysis 1-1
1.1.4 Factor Analysis 1-2
1.1.5 Variogram Analysis 1-2
1.1.6 Analysis of Field Split Samples 1-2
1.1.7 Distribution and Outlier Analysis 1-3
1.1.8 Threshold Analysis/Tolerance Interval 1-3
1.1.9 Subordinate End Member Analysis 1-3

2.0 DATA ANALYSIS 2-1

2.1 DATA DESCRIPTION 2-1

2.2 VALIDATION RESULTS 2-1

2.3 DETECTION LIMITS 2-1

2.4 FACTOR ANALYSIS 2-3

2.5 VARIOGRAMS 2-5

2.6 ANALYSIS OF SPLITS 2-5

2.7 DISTRIBUTION FITS 2-5

FIGURES

1. Detection Limit Comparison F-1
2. XRF Bulk Data, Orthogonal Factors F-2
3. XRF Bulk Data, Oblique Factors F-3
4. Leachate Data, Orthogonal Factors F-4
5. Leachate Data Oblique Factors F-5
6. Sulfide Concentration vs. Sieve Size F-6
7. Rare Earth Concentration vs. Sieve Size F-7
8. Variograms for selected representative analytes will be provided after completion of the evaluation of all inorganic constituents. F-8
9. Variograms for selected representative analytes will be provided after completion of the evaluation of all inorganic constituents. F-9

FIGURES (cont)

10. Variograms for selected representative analytes will be provided after completion of the evaluation of all inorganic constituents. F-10
11. Variograms for selected representative analytes will be provided after completion of the evaluation of all inorganic constituents. F-11
12. Variograms for selected representative analytes will be provided after completion of the evaluation of all inorganic constituents. F-12
13. Variograms for selected representative analytes will be provided after completion of the evaluation of all inorganic constituents. F-13
14. Field Sample Splits: Aluminum F-14
15. Field Sample Splits: Iron F-15
16. Field Sample Splits: Calcium F-16
17. Field Sample Splits: Copper F-17
18A. Field Sample Splits: Sodium F-18A
18B. Field Sample Splits: Sodium--Lab Bias Estimate F-18B
19A. Field Sample Splits: Lead F-19A
19B. Field Sample Splits: Lead--Lab Bias Estimate F-19B
20. Aluminum: Double-Sided Confidence Intervals F-20
21. Aluminum: Single-Sided Confidence Intervals F-21
22A. Calcium: Low End Scatter F-22A
22B. Calcium: 3 Outliers F-22B
23. Alkalinity vs. Calcium F-23
24. Iron vs. Calcium F-24
25. Calcium: Single-Sided Confidence Interval F-25
26. Copper: Initial Distribution F-26
27. Copper: Truncated Distribution F-27
28. Copper: Double-Sided Confidence Intervals F-28
29. Copper: Single-Sided Confidence Intervals F-29
30. Iron: Double-Sided Confidence Interval F-30
31. Normal Sample Based on Iron Mean and S.D. F-31
32. Uniform Sample Based on Iron Range F-32
33. Iron: Single-Sided Confidence Interval F-33
34. Lead: Initial Plot F-34
35. Lead: Adjusted for Bias F-35
36. Lead: Double-Sided Confidence Interval F-36
37. Lead: Single-Sided Confidence Interval F-37
38. Sodium: 3 Outliers F-38
39. Sodium: Multiple Populations, Adjusted for Bias F-39
40. Sodium. Single-Sided Confidence Intervals F-40

TABLES

1. Sample Data Reporting Statistics T-1
2. Pooled Data for Identified Blanks T-2
3. LOD/LOQ Summary Table T-3
4. XRF Data Factor Analysis T-4
5. Leachate Data Factor Analysis T-5
6. Estimate of Lab Bias T-6
7. Weibull Distribution Parameters T-7

1.0 STATISTICAL ANALYSIS

This section describes the statistical analyses performed on the data from the soil sampling activities. The following objectives directed these analyses:

1. Demonstrate the validity of the Site-wide background concepts as described in *Characterization and Use of Soil and Groundwater Background for the Hanford Site* (WHC 1991a)

2. Determine the soil background threshold values, based on tolerance intervals as specified in the Model Toxics Control Act Cleanup Regulation (WAC 173-340)

3. Determine if the DQOs specified as part of *Sitewide Soil Background Sampling Plan* (WHC 1991b) were achieved.

1.1 DATA ANALYSIS METHODS

Data analyses were performed to support these objectives. The individual analyses are described in the following paragraphs.

1.1.1 Data Validation

On receipt, the data packages were reviewed for conformance to the requirements of contract laboratory program (CLP) analyses. These checks included reviews of chain-of-custody records, instrument calibration, internal control standards, blanks analyses, matrix spikes, duplicate analyses, serial dilutions, and holding times. These checks ensured that the measurement process was consistent and within the specified control limits.

1.1.2 Data Transcription/Verification

After the data packages were validated, the data were transcribed into computer spreadsheets. For verification of data input, a printout of the spreadsheet was checked against the original hardcopy (received from the laboratory) by a second party. Corrections similarly were input and verified. These steps ensured that the validated data received from the vendor were correctly transferred to the data analysis software.

1.1.3 Detection Limit Analysis

Reagent blank analyses, performed concurrently with the soil analyses, were used to determine the minimum limit of detection (LOD) and the limit of quantitation (LOQ). The LOD is defined as the lowest concentration level that can be determined to be statistically different from a blank. The LOQ is the level above which quantitative results might be obtained with a specified

degree of confidence (ACS 1983). The results of the blank analyses contain all measurement error effects, including a limited amount of matrix interference effects. Matrix interferences from the actual soil samples are not included. For this reason, the LOD and LOQ values are considered minimums. Estimates of the matrix interference effects will be made as part of the analysis described in the following sections. This analysis provides a basis for determining if the required detection limits were achieved and screens out data dominated by noise in the measurement process.

1.1.4 Factor Analysis

The factor analysis provides both verification of the conceptual model developed in the *Characterization and Use of Soil and Groundwater Background for the Hanford Site* (WHC 1991a) and determination of representative analytes for further statistical analysis in support of the DQOs. Factor analysis is a statistical method used for attempting to reveal patterns within a set of multivariate observations. For example, strong correlations between FeO, TiO_2, MgO, and several other analytes can be related to the basalt component present in the soil sample, which is high in these compounds. Using this data, the analyses can be grouped into statistically significant associations and interpreted within the context of the vadose zone conceptual model.

1.1.5 Variogram Analysis

A variogram is a graphical tool for displaying the correlation structure of a spatially distributed variable. The classical statistics method, on which the tolerance interval determination is based, assumes that the data are independent and identically distributed. The variogram analysis determines the range over which this assumption is valid. Sampling at intervals that are less than the correlation range can introduce bias into the tolerance interval statistics. Constructing a variogram for selected, representative analytes demonstrates that the sampling intervals and locations have been appropriately determined. This analysis supports both the conceptual model and the DQOs with regard to representativeness of the sampling locations.

1.1.6 Analysis of Field Split Samples

Field split samples were routed to a separate laboratory for independent analysis. Field split samples provide a quality check on the performance of the primary laboratory. These results serve to reveal any consistent laboratory bias in the data.

Because soil split samples, unlike water split samples, cannot be considered identical, individual sample comparisons are difficult to evaluate. Variation in the percentage mixture of end members, especially for the minor and trace analytes, can cause variations in the results that are significantly larger than the accuracy of the measurement process. Therefore, the split samples are considered as a group and analyzed for similarity of distributions.

1.1.7 Distribution and Outlier Analysis

The analysis for the best fit distribution is based on Weibull and Lognormal forms. The *Characterization and Use of Soil and Groundwater Background for the Hanford Site* (WHC 1991a) describes the Weibull distribution and demonstrates that much of the data to be analyzed can be fitted with the Weibull distribution. The option to use a lognormal distribution is retained for completeness of analysis.

Suspect outliers will be determined based on the data points lying outside double-sided confidence intervals of the distribution of the data. Rejection or removal of the outliers depends on a review of the data in the context of the conceptual model and the quality assurance and quality control records for the data in question. Interelement correlations can determine if the data are related to a subordinate end member.

1.1.8 Threshold Analysis/Tolerance Interval

The background threshold is the statistical upper bound of the naturally occurring concentrations. This background threshold is defined by the MTCA [WAC-173-340-708(11d)] as the upper 95/95 tolerance interval. The tolerance interval will be determined based on a single-sided upper 95 percent confidence interval for the 95th percentile of the distribution of the randomly sampled data.

1.1.9 Subordinate End Member Analysis

Collection of judgment samples was included in the sampling strategy. Judgment samples are defined as those determined by the field geologist as having significant stratigraphic or lithologic characteristics, but not included in the random sampling activities. Collection of these samples was based solely on the professional judgment of the field geologist; criteria for judgment sample collection included selected end member samples, potential outlier samples, and samples that represent typical local lithology. These samples could include subordinate end members such as caliche, ash beds, and paleosols.

The analysis of these data is done by comparing the data to the tolerance interval. Data that significantly exceed the tolerance interval will be further analyzed to determine if the data represent subordinate end members that must be considered separately from the randomly sampled data.

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2.0 DATA ANALYSIS

The soil data were analyzed according to the previously described analytical methods. Background threshold values for six analytes (aluminum, calcium, copper, iron, lead, and sodium) were determined and are presented in the following sections.

2.1 DATA DESCRIPTION

Samples for inorganic analyses were collected at 14 surface sites and 2 boreholes. Because of difficulties in establishing validation of the data at one borehole (Savage Island) these data have not been included in the random data set. These data will be treated as judgment samples. In addition, inorganic analyses were performed on samples taken from a series of sites chosen specifically to provide preliminary information about organics background in soil. Sample site locations and descriptions are included in Appendix B.

Both systematic random and judgment samples were collected at all the inorganic sites (WHC 1991b). Additional sample types included field splits (for analysis at a separate independent laboratory), and samples taken specifically to examine the effects of grain size on analytical results. The results of the grain size analysis will be reported under separate cover. Only select results are included in this report.

2.2 VALIDATION RESULTS

A summary of the data reporting statistics for the systematic random, judgment, and preparation blank samples is presented in Table 1. A total of 5,765 analyses were requested. A total of 5,405 results passed the validation criteria giving an overall success rate of 94 percent. Lithium shows an acceptance rate of greater than 100 percent because 57 additional, not requested, results were returned.

The laboratories were inconsistent in reporting molybdenum, lithium, alkalinity, and silicon. Additionally, antimony, selenium, titanium, and zirconium suffered from high rejection rates. The rejection basis for these analytes appears to be due to percent spike recovery failures. In addition, one batch, consisting of one preparation blank and three split samples, was rejected because of laboratory contamination.

2.3 DETECTION LIMITS

Evaluation of the accuracy and precision of analyses reported by a laboratory is important in all efforts involving chemical data, especially when the samples contain low concentrations of analytes. In these cases, the quality of the data should be evaluated with respect to the detection limit

for each analyte; the detection limit should serve as a filter for identifying those data that do not meet the specified criteria for quality assurance.

The detection limit can be determined any number of ways. The CLP analyses report two different detection limits: instrument detection limit (IDL) and contract required detection limit (CRDL). The IDL typically is determined quarterly by the laboratory, using procedures set up by the instrument manufacturer designed to establish the lowest detectable concentration of an analyte under ideal conditions (e.g., pure single-element samples, no matrix, multiple replicates). The IDL is rarely, if ever, recognized as a practical detection limit for dissolved soil samples. A more conservative detection limit usually is specified in the contract between the laboratory and individual customers; this is referred to as the CRDL.

The most representative method of quantifying a detection limit is to measure the variation in the background signal near or on the spectral line for each analyte. Ideally, these measurements should approach as closely as possible the conditions under which the actual samples are being analyzed. This would have the advantage of building in and thus negating biases produced by unique matrix effects. In practice, this approach is unreasonable owing to nearly ubiquitous schedule constraints and lack of suitable samples for use as matrix blanks. The standard process for establishing detection limits based on spectral background is to use a preparation blank, which is an aliquot of analyte-free solution that has been subjected to the same processes as an unknown sample (i.e., digestion with acid, dilution with deionized water). These blanks are used to determine detection limits as well as the existence and magnitude of any laboratory contamination problems. There are several different definitions for detection limits other than those described previously. Some are qualitative and others are based on the standard deviation of sequential analyses (usually three) of a preparation blank. A few of these detections limits and their definitions are as follows:

LOD: limit of detection--the concentration that produces a signal approximately three times the standard deviation above the mean of blank analyses (APHA 1989)

IDL: instrumental detection limit--a concentration that produces a signal greater than five times the signal/noise ratio of the instrument; approximately 1.6 times the standard deviation of the preparation blank analyses (APHA 1989).

MDL: method detection limit--a signal level with a 99 percent probability that it is different from the blank; approximately 3.14 times the standard deviation of the preparation blank analyses (APHA 1989).

LOQ: limit of quantitation--the concentration that produces a signal sufficiently greater than the blank that it can be detected within specified limits by laboratories during routine analysis; typically 10 times the standard deviation of the preparation blank analyses (APHA 1989).

The LOQ is used as a minimum value to which a high degree of certainty can be attached. According to the American Chemical Society Committee on Environmental Improvement: "...quantitative interpretation, decision-making, and regulatory actions should be limited to data at or above the limit of quantitation." (ACS 1983).

The LOD and LOQ were determined from the results of reagent blanks included in the batch analysis. A total of 27 measurements were included in the calculations (9 blanks times 3 replicates analysis). The calculations are shown in Table 2 and summarized in Table 3.

The CRDL is a specified number based on deionized (DI) water blanks. The detection limits requested for this study were determined based on expected ranges of data. These requested detection limits were estimated with little information concerning overall ranges of data and effects of the matrix on the reagents used. The reported detection limits varied by batch. The largest value claimed is reported in the maximum claimed detection limit column (Appendix C). The last two columns of Table 3 summarize information from Table 2. The CRDL values show no apparent relevance for soil samples, but are reported as required by protocol. The LODs achieved represent the combined effect of all measurement errors as obtained from preparation blanks. The effects of the matrix for particular soil samples will be estimated during the statistical analysis of the systematic random data. No relationship is seen between either the requested or the maximum claimed detection limit and the LOD (Figure 1).

2.4 FACTOR ANALYSIS

Factor analysis is a statistic method for determining related groups of variables. Factor analysis expresses a large number of variables as a function of a much smaller set of reduced variables. For the purposes of this study, grouping the analytes allows for the selection of analytes that are representative of each of statistical group. These analytes have been subjected to a more complete statistical analysis than the rest of the data set.

Factor analysis was performed on two sets of data. The first set used compositional data produced by XRF techniques. These analyses were performed as part of the grain size study. The samples consisted of Hanford formation sediments and crushed Columbia River Basalts [(CRB), Umtanum flow]. The second set of data was the CLP analysis of the systematic random samples. The XRF data included control samples and were used as both a control and as an aid in interpreting the CLP leachate data. Tables 4A through 4I describe the results of the XRF data set factor analysis. Tables 5A through 5I describe the results of the factor analysis of the systematic random data set.

The factoring procedure used for both data sets was the principle components method. The number of factors determined was based on the greater of either the number of factors required to account for 75 percent of the matrix variance or the rank order of the eigenvalue at the inflection point of

the root curve. The number of factors determined for the XRF and CLP leachate data was 5 and 6, respectively.

The measure of variable sampling addresses the adequacy of homogeneity of the factors (i.e., that the data are drawn from the same statistical universe). Arguments have been made (Kaiser 1970) that for the assumption of homogeneity to hold, the total measure of sampling adequacy should be greater than 0.5. For the XRF and CLP leachate data, this measure was 0.8 and 0.81, respectively. Therefore, the data are considered suitable for factor analysis.

The Bartlett Test of Sphericity is a multivariate analog of the Chi-square test for non-zero correlations. Both the XRF and CLP leachate data show significant values for the Chi-square statistic, indicating that the interelement correlations are significantly different from zero. Level of significance is 1E-4.

The communality summary indicates the total proportion of the variance of each variable that can be predicted by the factors. The lowest predictive ability is achieved for Na, Nb, and La for the XRF data and Ba, Pb, Zn, and F for the CLP leachate data. For these elements less than 70 percent of the variance can be accounted for by the factor analysis.

The proportion of variance contributions identifies the relative contributions of each of the factors to the total variance of the data set. For the XRF data, the first factor contributes 50 percent of the total variance. This indicates a single dominant factor in the analysis, not unusual in light of the presence of the CRB control samples in the data set. For the CLP leachate analysis, the first factor accounts for 38 percent, while the second factor accounts for 28 percent of the total variance. This indicates that there are two major contributing factors to the variance of the CLP leachate data.

The solutions for the XRF data show the loadings of the various analytes onto each of the factors. The factors are represented graphically in Figures 2 and 3. The factor analysis of the CLP leachate data is represented in Figures 4 and 5. Tables 4G and 5G describe the oblique factor correlations and the variable complexity for the XRF and CLP leachate data set, respectively. The variable complexity table indicates how many factors are required to account for the variance of each analyte. The most simple structure is for each analyte to be represented by only one factor. This is the case for those analytes forming the basaltic end member. The remainder of the analytes are represented by approximately two factors, with the exception of sodium and potassium. Both potassium and sodium readily form a wide variety of minerals. In addition, sodium is readily dissolved and forms evaporites [sodium chloride (NaCl) and sodium sulfate ($NaSO_4$)], which is not expected to correlate well with factors attributable to mineralogy, deposition, or measurement processes.

Based on the described factor analysis, aluminum, iron, calcium, and sodium have been selected as representative of the first four factors of the CLP leachate data set. Additionally, lead and copper will be included to

represent the sulfides group and potential contaminants of interest. These elements will have further statistical testing performed in support of the conceptual model verification.

2.5 VARIOGRAMS

Variograms for selected representative analytes will be provided after completion of the evaluation of all inorganic constituents.

2.6 ANALYSIS OF SPLITS

The results of the analysis of the sample splits are shown in Table 6. The estimates of laboratory bias shown are based on comparing the distribution of data reported by each laboratory (Maxwell S-Cubed Division and Datachem Laboratories). Failure of the distributions to overlap (e.g., for the best fit regression line from each laboratory to fall within the confidence bounds of the other laboratory's data results) is taken as evidence of a laboratory bias in the measurement of the analyte. Table 6 is based on the distribution plots shown in Figures 14 through 19.

No statistically significant bias is found between laboratories for aluminum, iron, calcium, and copper. Bias is present for lead and marginally for sodium. The decision to accept a bias for sodium is based on the results of the distribution fit.

2.7 DISTRIBUTION FITS

The parameters of the best fit distributions are shown in Table 6. Before fitting the distributions to the lead and sodium data sets, the DataChem data were corrected for the apparent bias determined previously. The following discusses the distribution fit for each analyte.

ALUMINUM--The distribution fit for aluminum is straightforward with no outliers encountered. The data values are sufficiently large that scatter at the low end of the distribution does not effect the regression process. The variable complexity of aluminum (Tables 4-I and 5-I) for both the XRF and CLP leachate analysis is low, confirming that a single distribution should suffice to describe the data. The regression fit correlation coefficient (Table 7) is greater than the critical value. Cumulative distribution function (CDF) plots for aluminum are shown in Figures 20 and 21. The threshold for aluminum is 15,100 parts per million (Table 7).

CALCIUM--Scatter at the low end of the distribution is evident. A truncation value of 5,600 parts per million was determined on the basis of the initial distribution plot (Figure 22). Scatter at the low end is likely the result of several contributing factors of which matrix interference effects are expected to be a major contributor.

The distribution fit for calcium shows three potential outliers (Figure 22B) at the top of the double-sided distribution. Scattergrams of alkalinity and iron against calcium (Figures 23 and 24) show that the two largest data points are also the two highest alkalinity measurements and also are deficient in iron (e.g., basaltic minerals). The sample does however show elevated amounts of sodium indicating the possibility of a Ca-rich plagioclase mineral in the sample. All three samples met all quality assurance and quality control checks in the analysis, e.g. blanks, spike recoveries, calibrations, etc. were all within control limits. All three data points will be removed from the distribution as representing subordinate end members (2 calcium carbonate and 1 unknown), but will be retained as nugget data.

The single-sided confidence interval plot is shown in Figure 25. The value of the regression fit correlation coefficient is 0.998, which is greater than the critical value (0.975) for the number of samples retained. The threshold value is 22,000 parts per million (Table 7).

COPPER--The initial data plot is shown in Figure 26. The bend in the middle of the distribution indicates that the value of t_o is too small. The constraints on reducing t_o are the low end values, which are expected to be inaccurate because of matrix effects, as discussed previously. Analysis of copper data (WHC 1991a) indicated that an effective LOQ of about 13 parts per million was achievable for copper. This value was used as the truncation value. The resulting plot is shown in Figure 27. The improvement in the quality of the regression fit is obvious ($r = .997 > r_c = .970$). A double-sided confidence interval is applied in Figure 28. There are no outlier data. The threshold value based on the single-sided confidence interval is 32.2 parts per million (Figure 29 and Table 7).

IRON--The initial iron plot, with double-sided confidence interval, is shown in Figure 30; t_o is zero. Attempting to apply the t-shift to the iron data results in a negative t-shift, which is not being allowed for in environmental concentration data (WHC 1991a). There are no obvious matrix effects at the low end of the distribution. There are no outliers. The S-shape of the data about the regression line commonly occurs as result of a range limit in the data set. This is illustrated in Figures 31 and 32.

Figure 31 is a random sample of normal data with the same mean and standard deviation as the iron data. The tails of the distribution show a clean fit. Figure 32 is a random uniform distribution based on the range of the iron data. The S-shaped curve is obvious. Comparing these two figures with Figure 30, it is obvious that Figure 30 represents an intermediate situation. This is a natural result of a mixing model, which behaves approximately as a uniform distribution. This interpretation is consistent with the conceptual model of the Hanford formation developed previously (WHC 1991a). The distribution fit shown in Figure 30 is a reasonable approximation; the correlation coefficient is acceptable ($r = .991 > r_c = .976$). The threshold value, based on Figure 33 is 38,200 parts per million (Table 7).

LEAD--The initial plot for lead is shown in Figure 34. There is visible low end scatter present. The analytical method used was graphite furnace atomic

absorbance (GF/AA). However, the only reported blank data (LOD / LOQ, Tables 2 and 3) were from inductively coupled plasma (ICP) analyses, and therefore the blank analyses are not applicable to the data. The effective LOD based on the plot was estimated at 3.3 parts per million. Figure 35 reflects this limitation. The degree of fit is considerably improved. The data were corrected further for the identified bias between laboratories (1.7 parts per million added to the data from the secondary laboratory-DataChem Laboratories) and double-sided confidence intervals applied (Figure 36). No data are beyond the confidence interval. Figure 37 is the single-sided confidence interval. Background threshold value for lead is 15.4 parts per million (Table 7).

SODIUM--The initial plot for sodium is shown in Figure 38. There are three potential outliers, and low end scatter in the data. There is also bias in the split sample data as discussed previously. Two of the data points represent a split pair. All three data points are from Sample Site 12, Rattlesnake Springs, a known high alkali soil (Rickard 1964). The samples will be removed from the data set and retained as subordinate end member samples.

With the bias removed and the data set truncated at 190 parts per million, the result is presented in Figure 39. The bend in the CDF is the result of multiple distributions for sodium. The factor analysis described previously shows that sodium is ubiquitous, occurring in a number of different repositories: alkali feldspar, glass, salt, and plagioclase. Therefore, multiple distributions are a reasonable result. The data set was duplicated and further truncated at the breakpoint between the distributions. Data above the breakpoint were suspended for the low range distribution. The result is presented in Figure 40. The regression fit correlation coefficient is greater than the critical value (0.968 > 0.942). The threshold value for the high range CDF is 167 parts per million.

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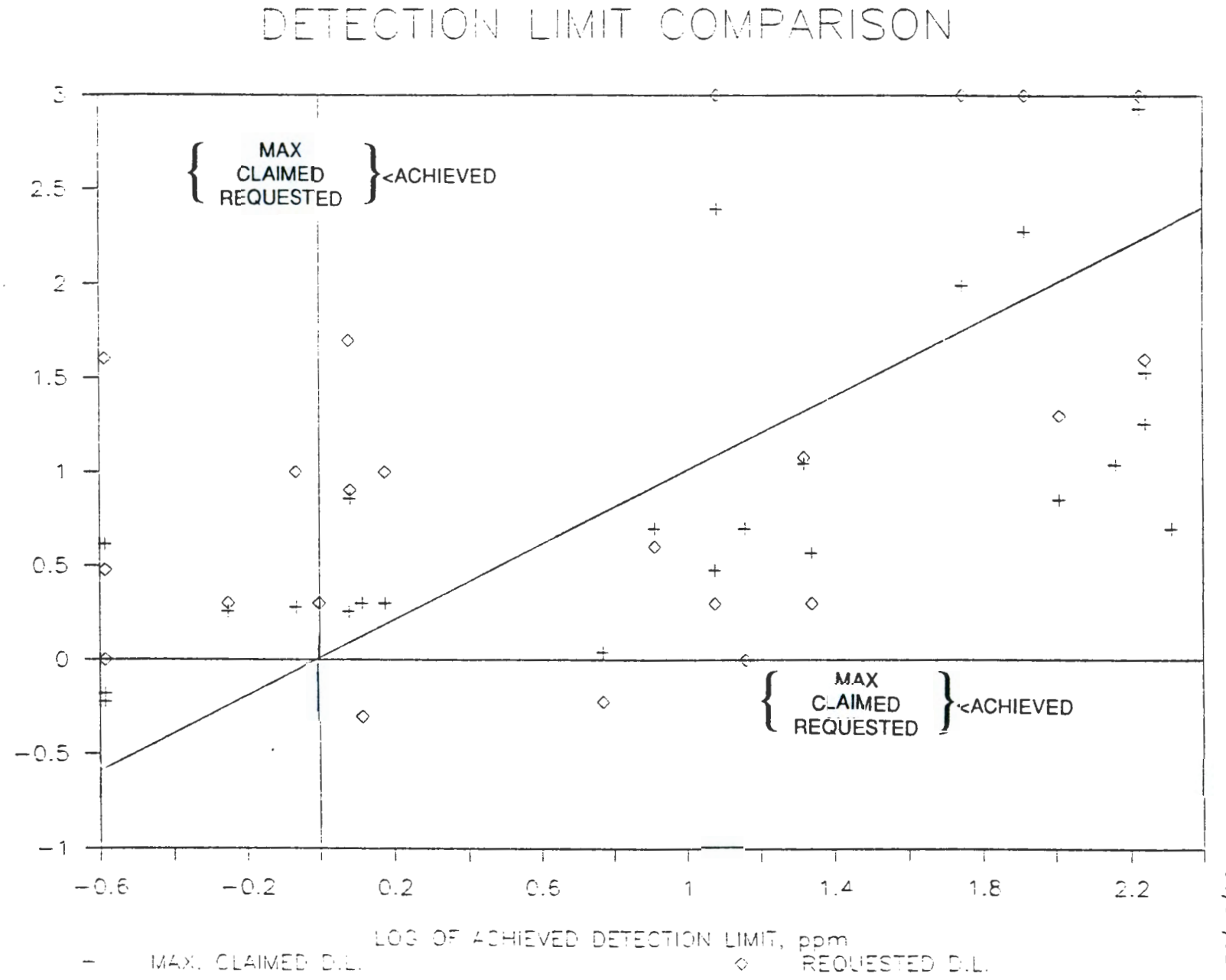


Figure 1. Detection Limit Comparison.

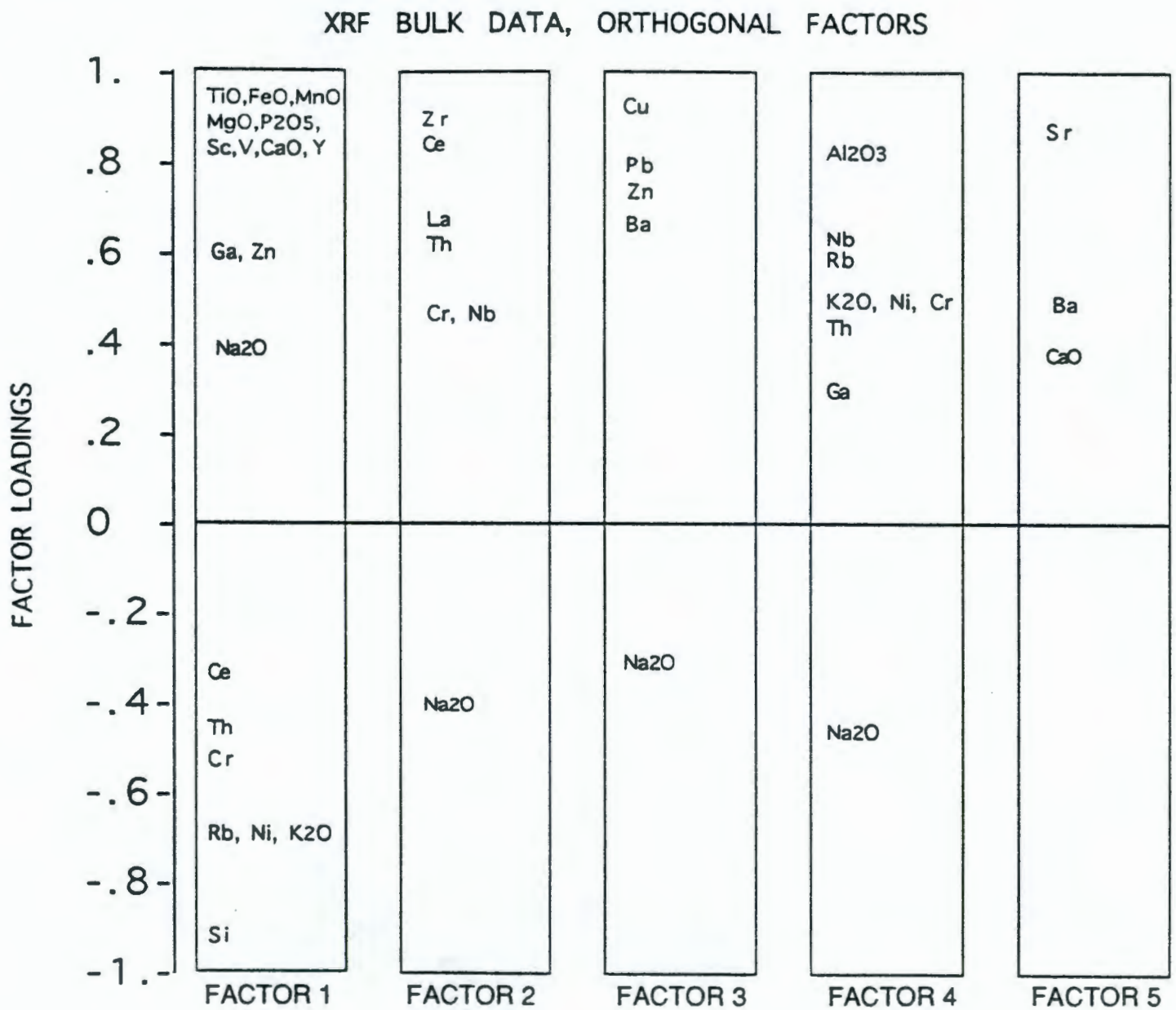


Figure 2. XRF Bulk Data, Orthogonal Factors.

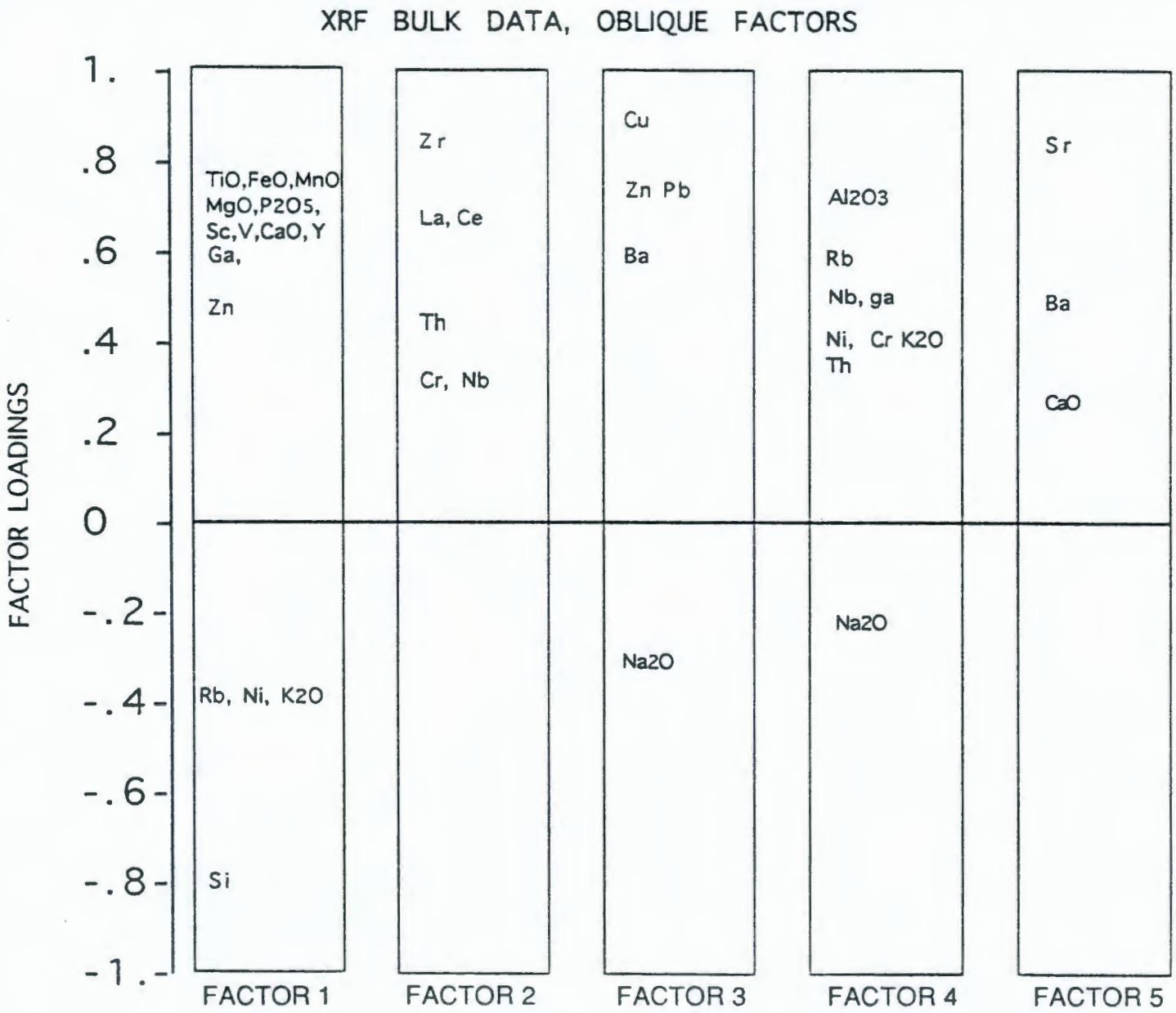


Figure 3. XRF Bulk Data, Oblique Factors.

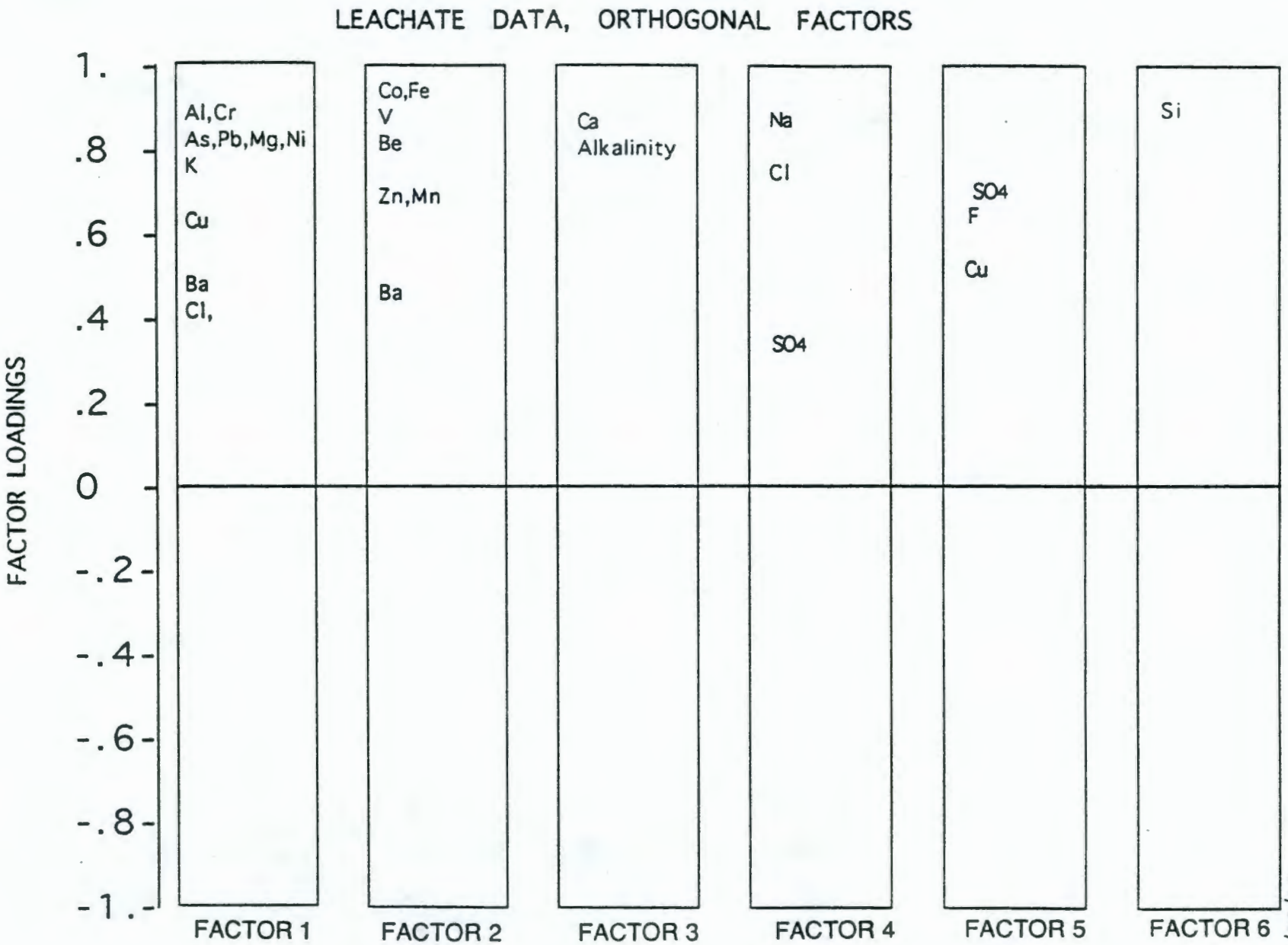


Figure 4. Leachate Data, Orthogonal Factors.

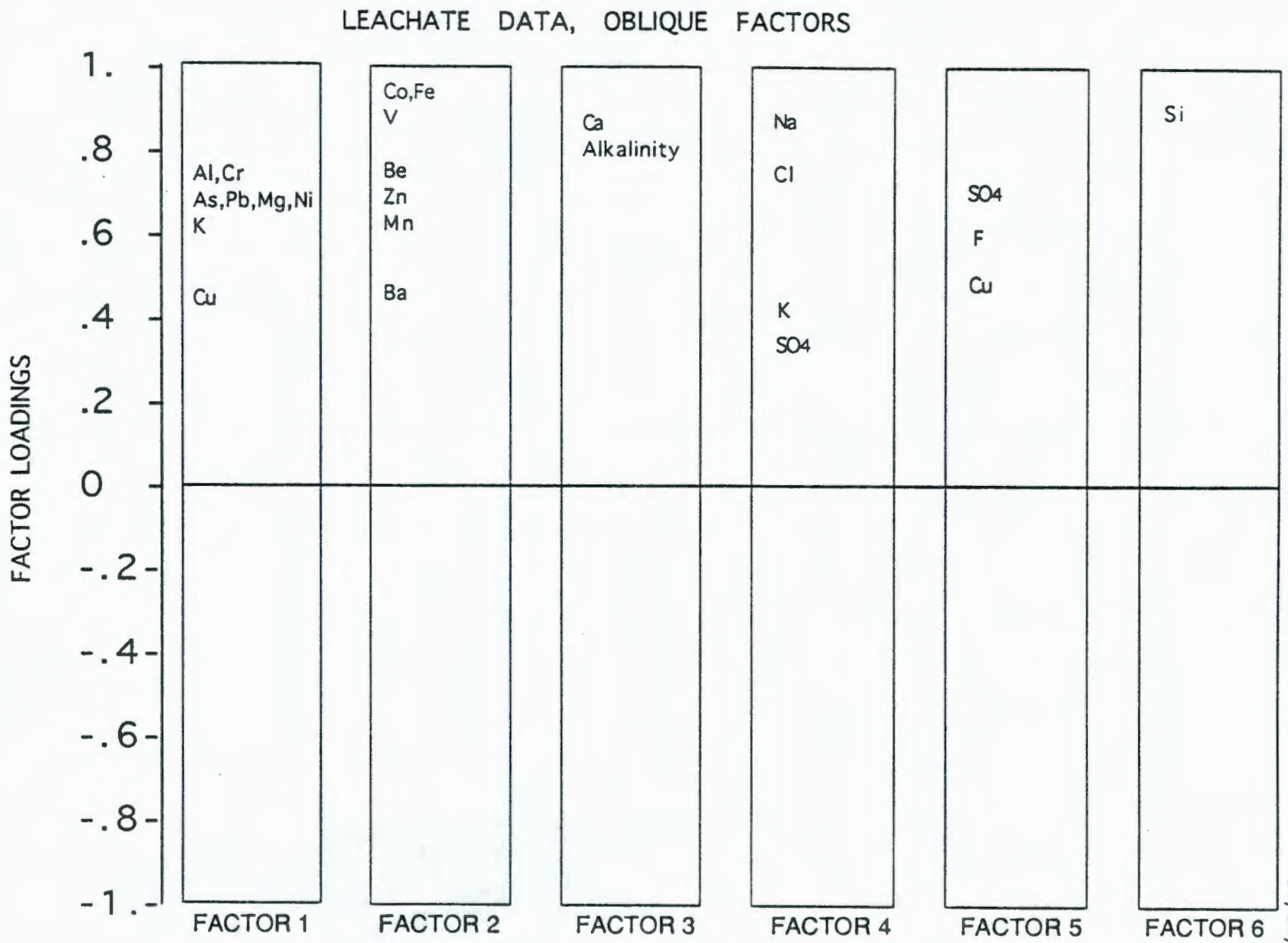


Figure 5. Leachate Data Oblique Factors.

SB-12 SAMPLES: SULFIDES

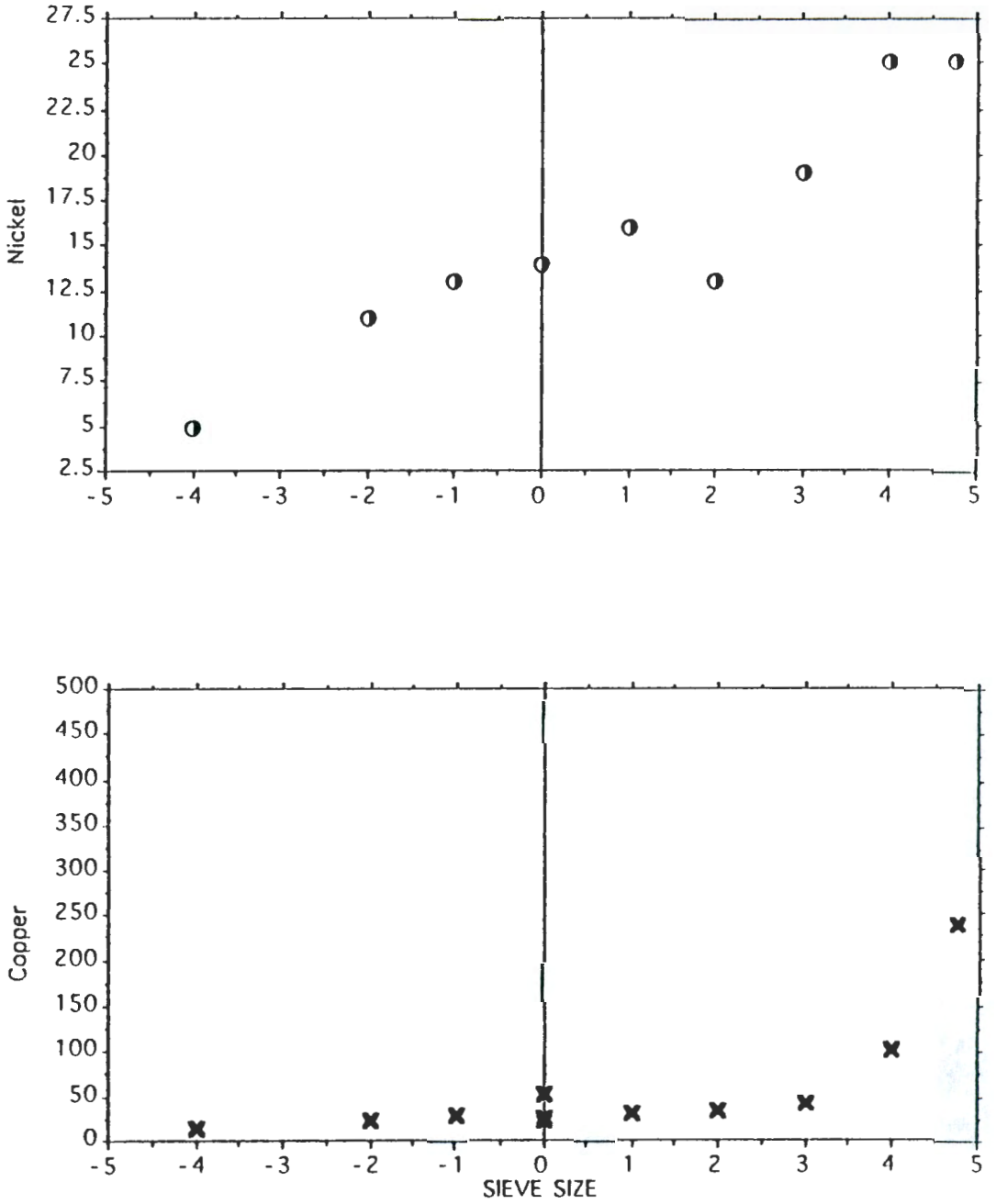


Figure 6. Sulfide Concentration vs. Sieve Size.

SB-12 SAMPLES: RARE EARTHS

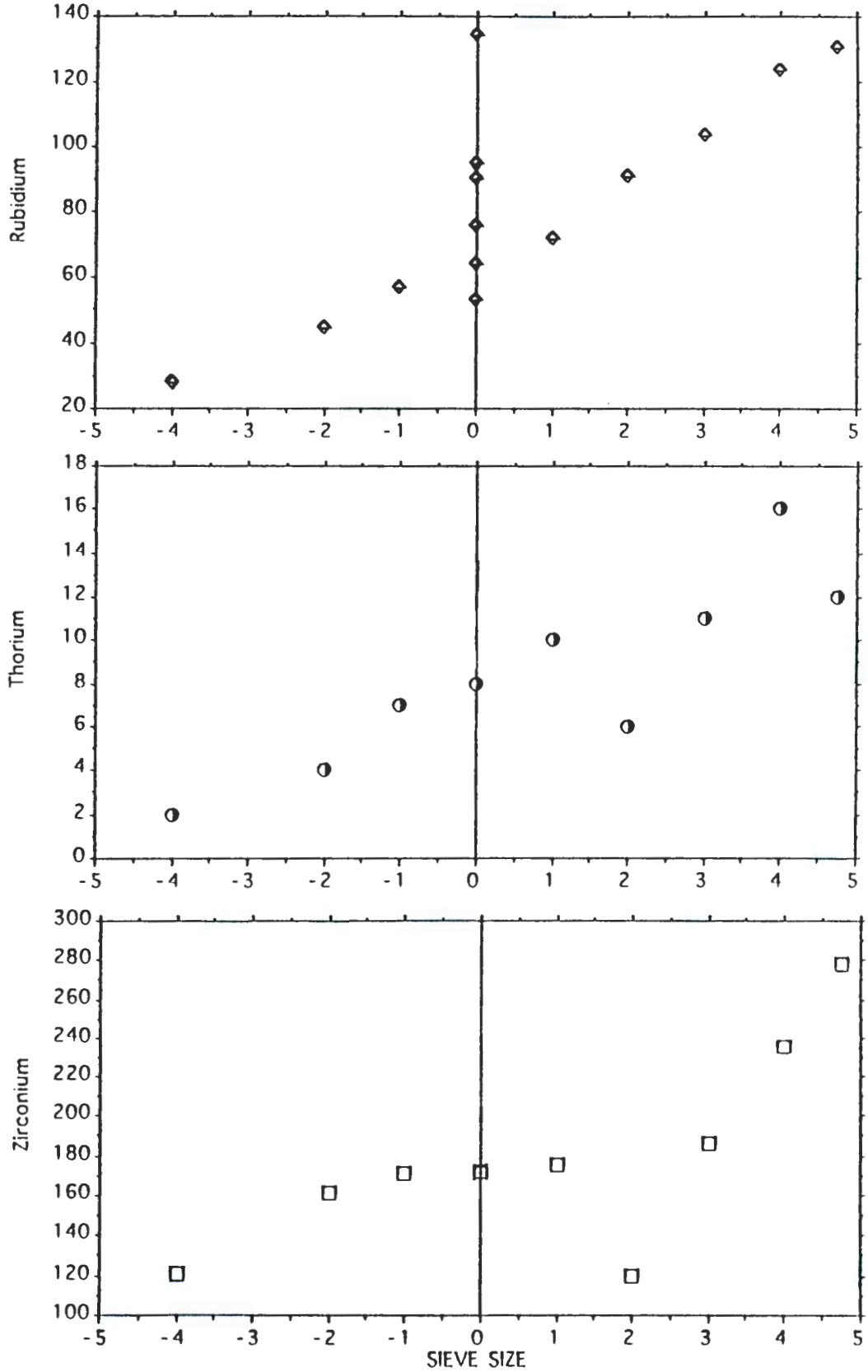


Figure 7. Rare Earth Concentration vs. Sieve Size.

9 2 1 2 6 8 1 8 3 0

Figure 8. Variograms for selected representative analytes will be provided after completion of the evaluation of all inorganic constituents.

9 2 1 2 6 8 1 8 8 1

Figure 9. Variograms for selected representative analytes will be provided after completion of the evaluation of all inorganic constituents.

Figure 10. Variograms for selected representative analytes will be provided after completion of the evaluation of all inorganic constituents.

Figure 11. Variograms for selected representative analytes will be provided after completion of the evaluation of all inorganic constituents.

Figure 12. Variograms for selected representative analytes will be provided after completion of the evaluation of all inorganic constituents.

9 7 1 2 6 8 1 8 8 5

Figure 13. Variograms for selected representative analytes will be provided after completion of the evaluation of all inorganic constituents.

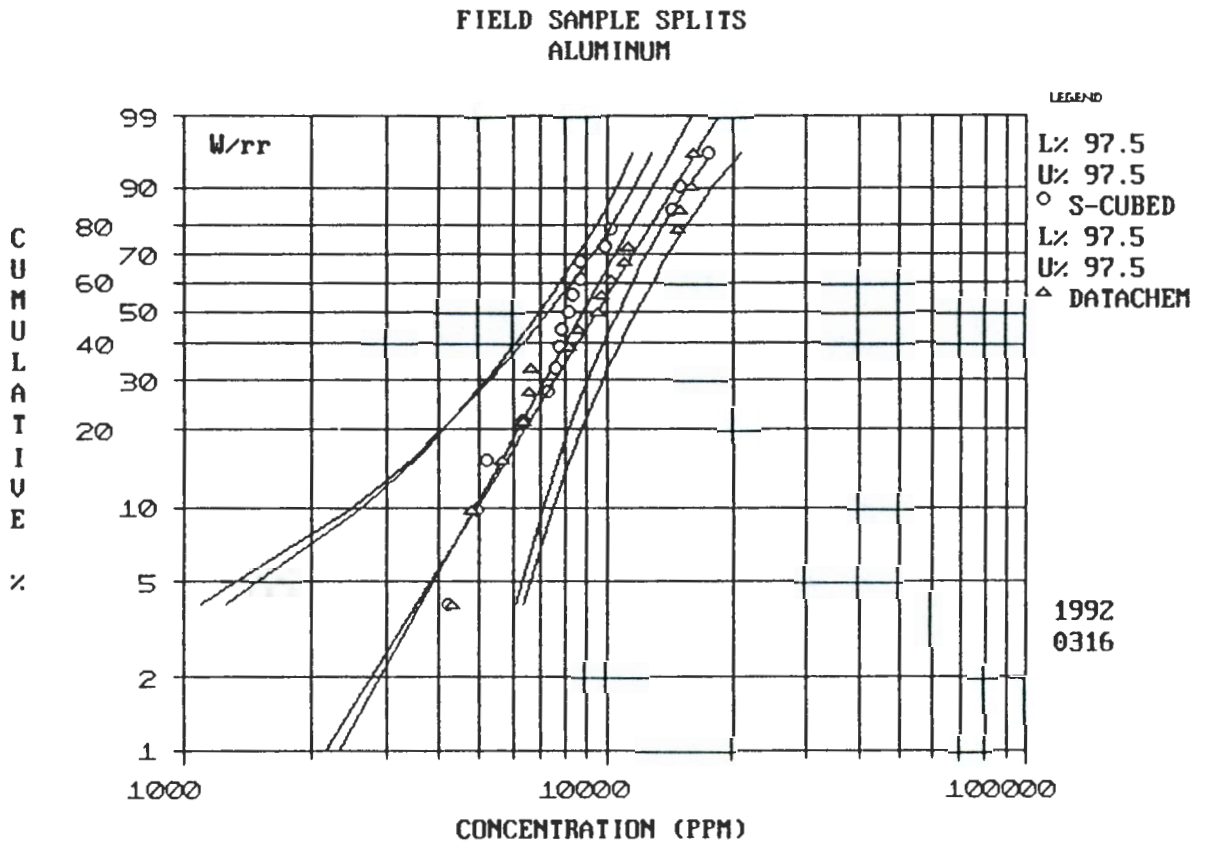


Figure 14. Field Sample Splits: Aluminum.

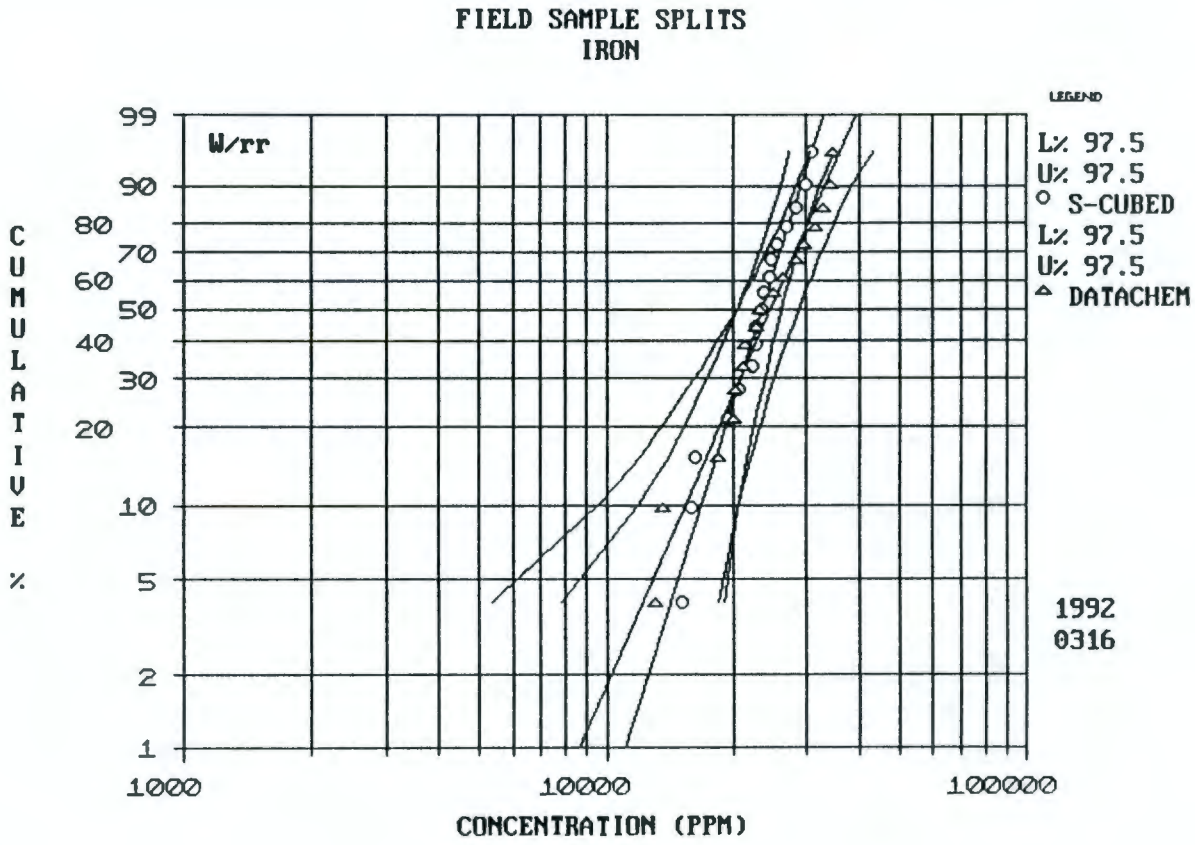


Figure 15. Field Sample Splits: Iron.

9 2 1 2 6 8 1 8 3 7

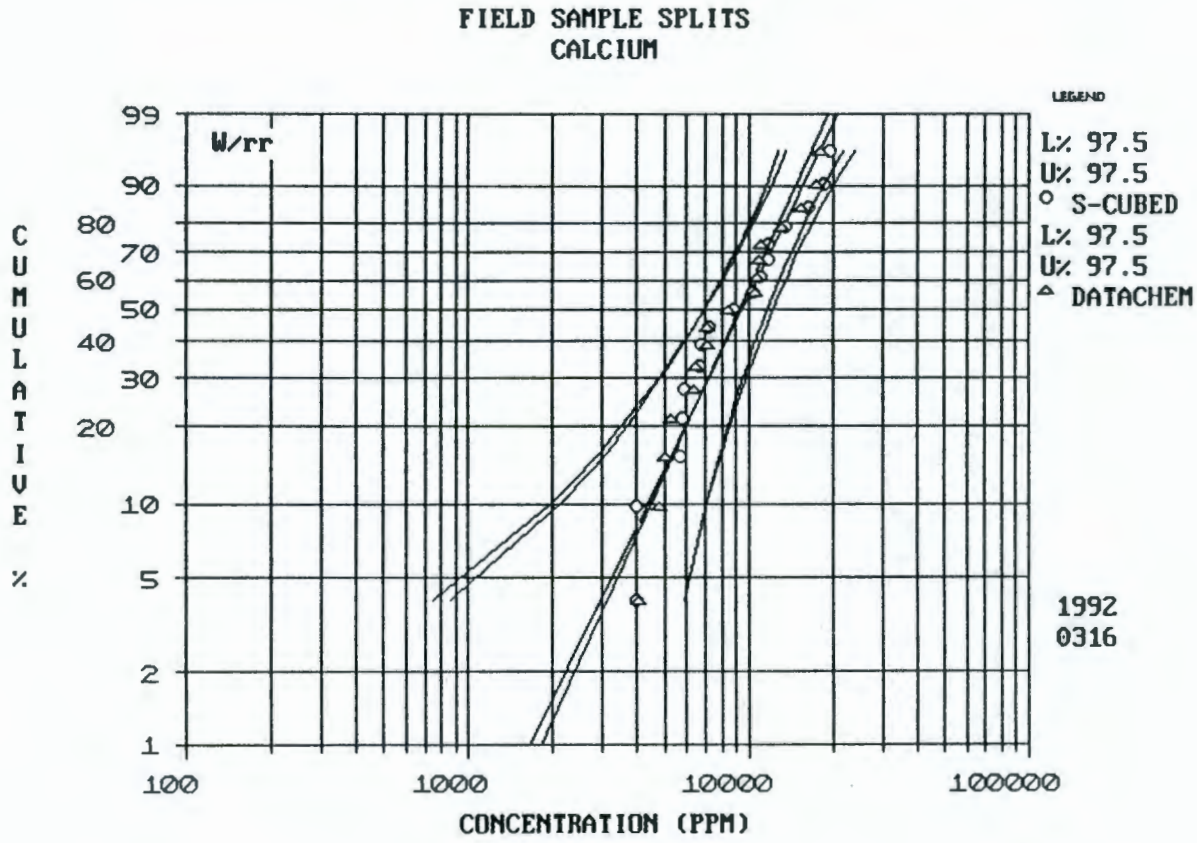


Figure 16. Field Sample Splits: Calcium.

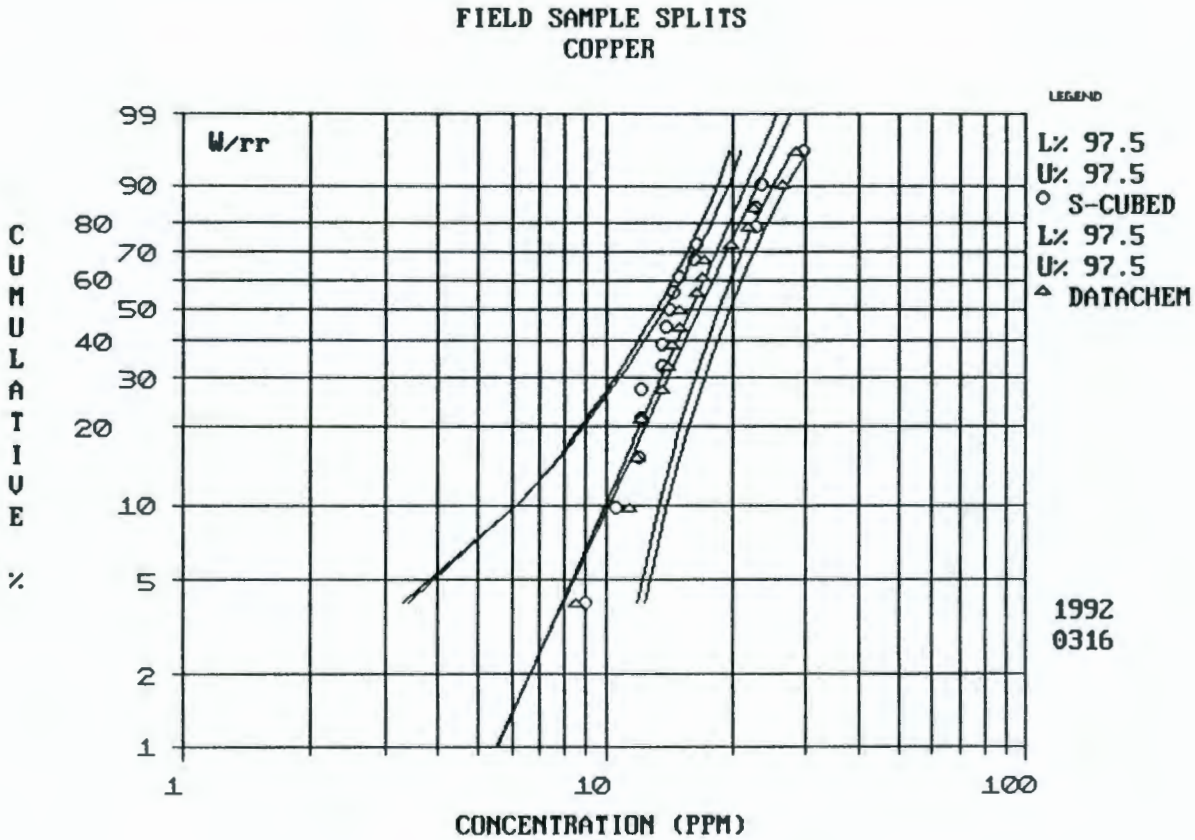


Figure 17. Field Sample Splits: Copper.

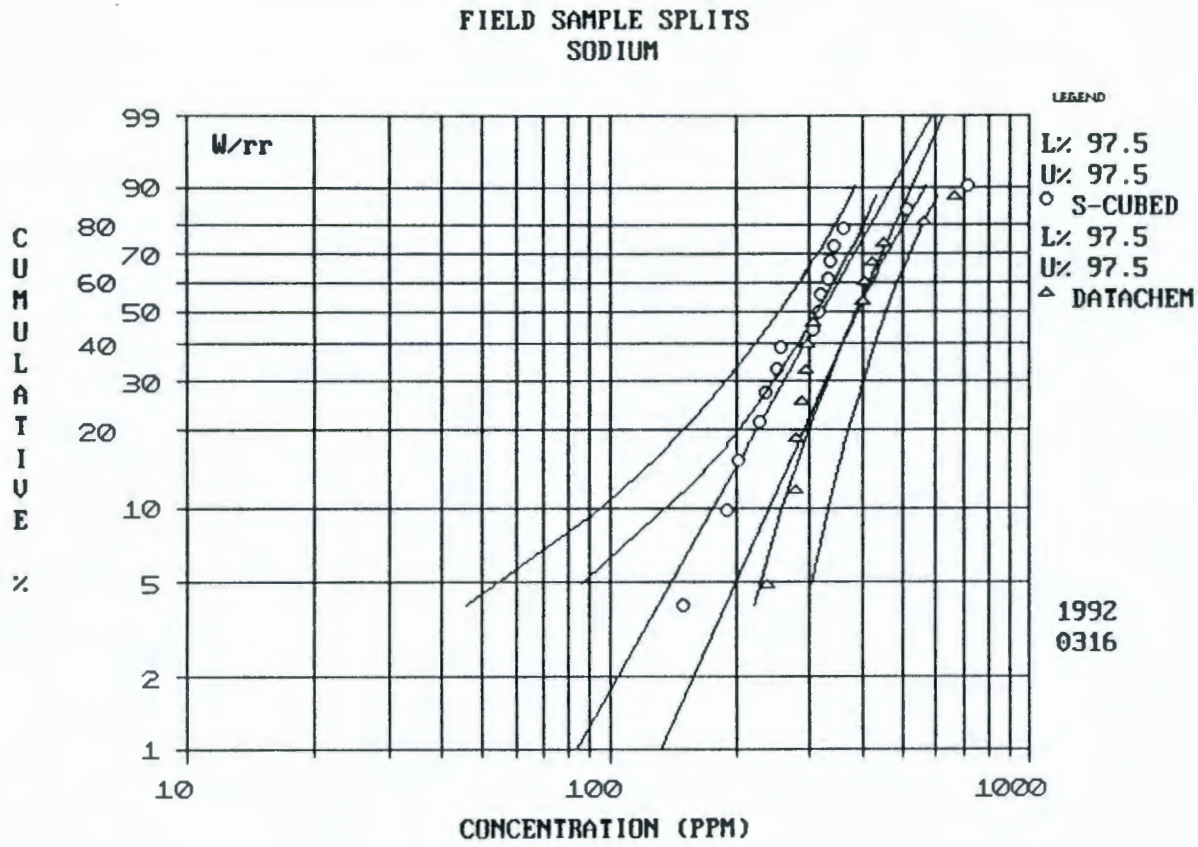


Figure 18A. Field Sample Splits: Sodium.

9 2 1 2 6 8 1 8 9 0

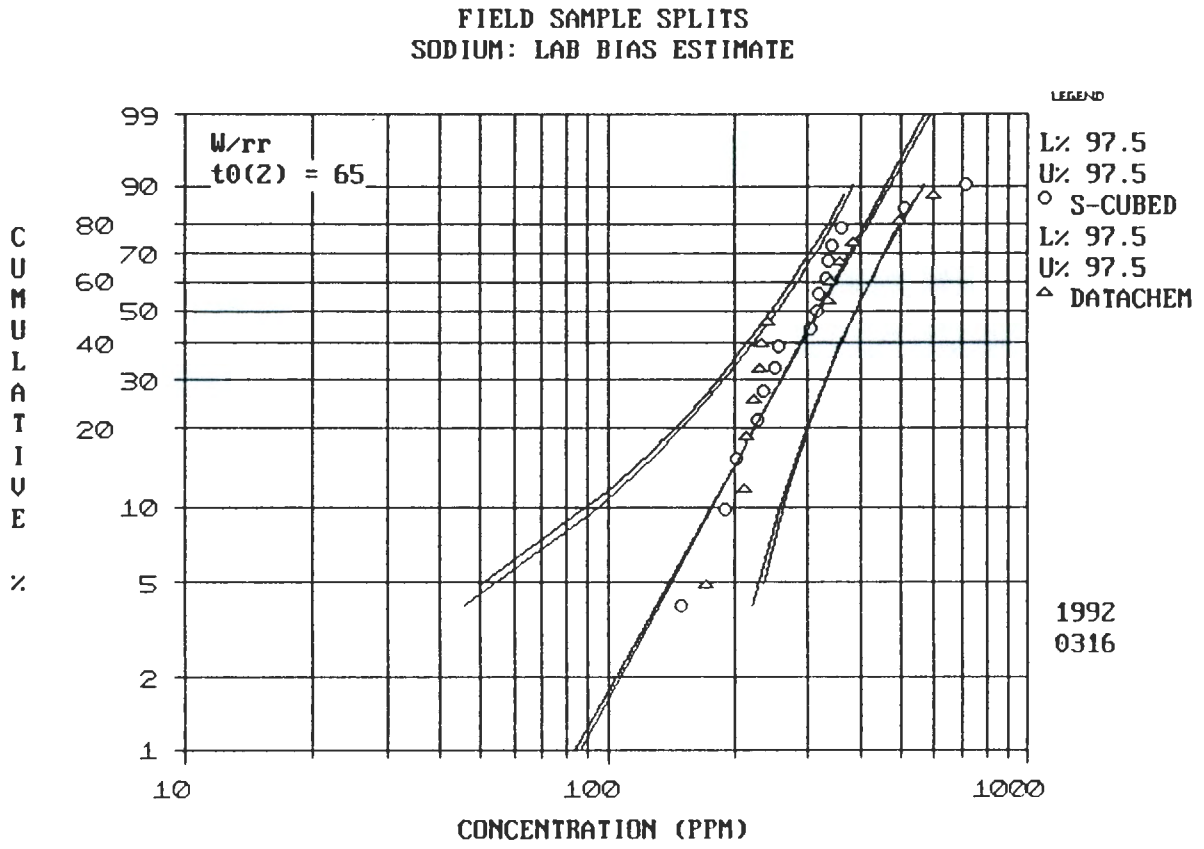


Figure 18B. Field Sample Splits: Sodium--Lab Bias Estimate.

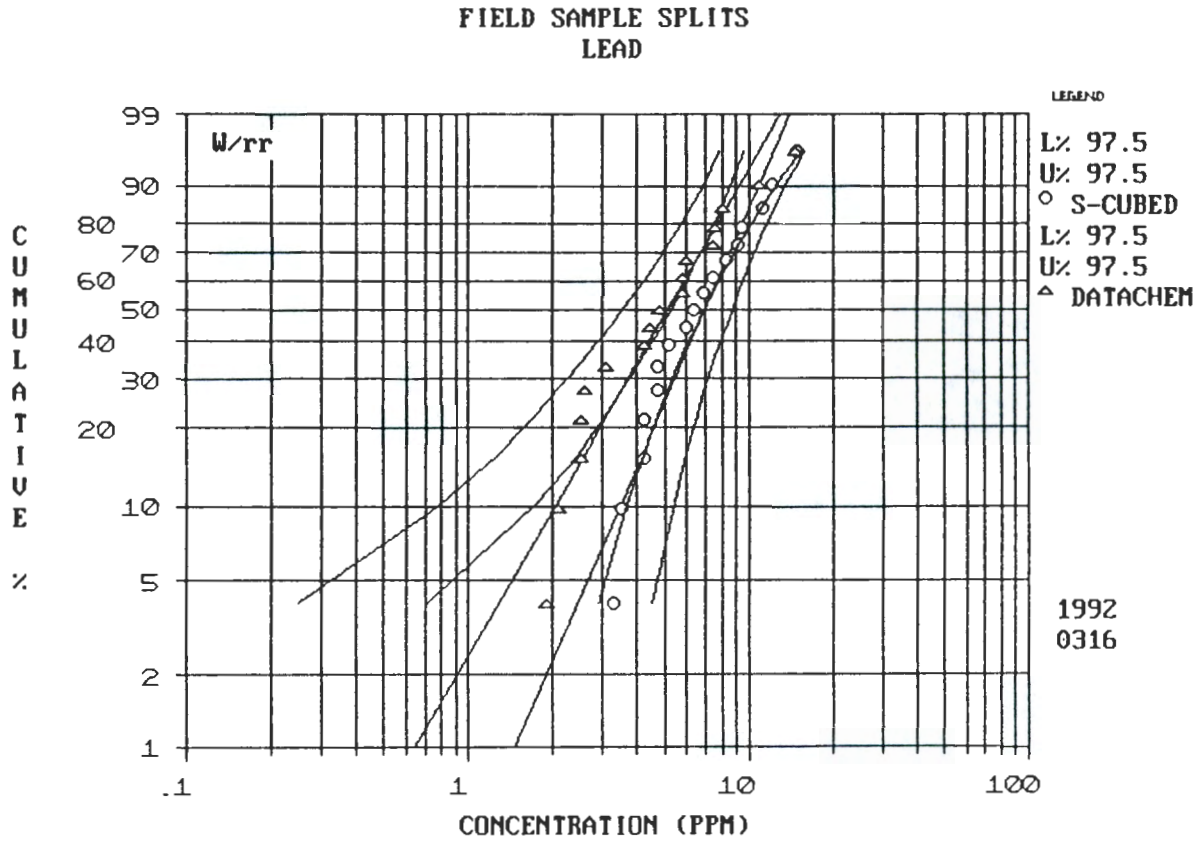
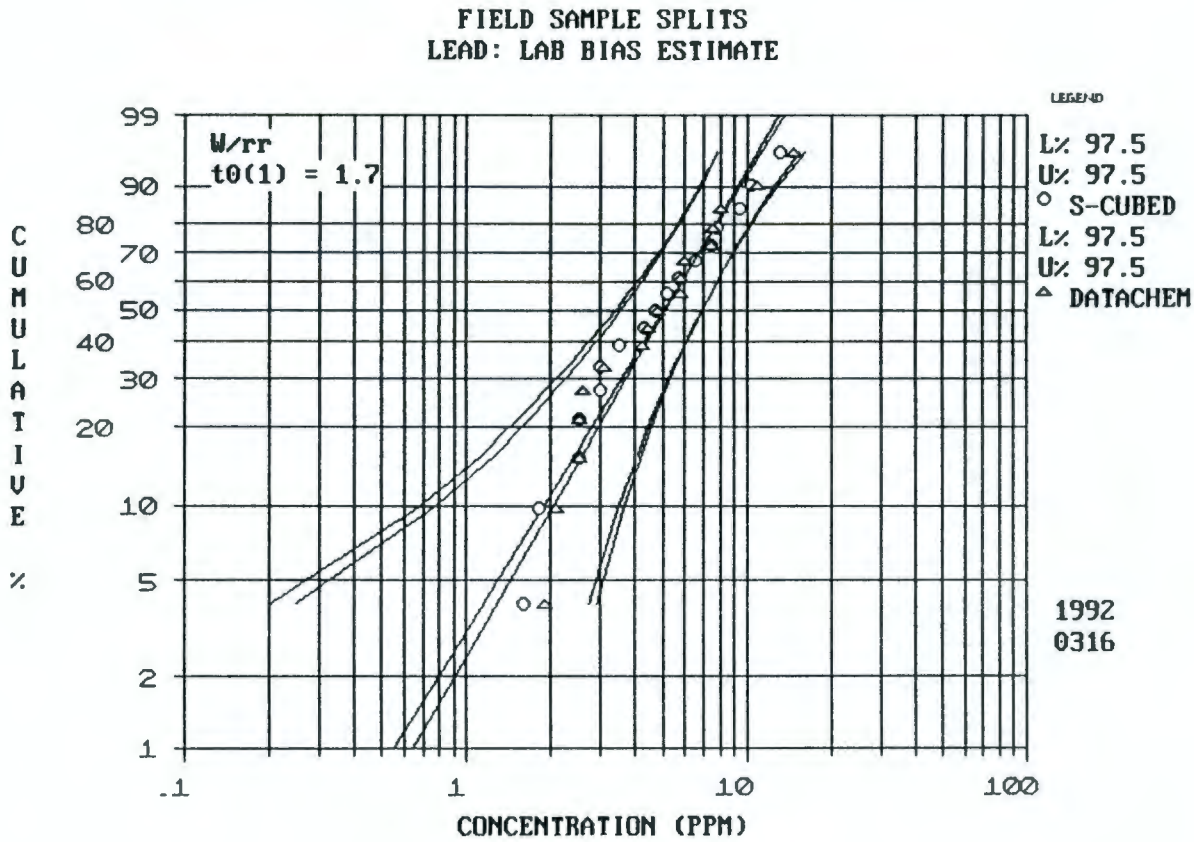


Figure 19A. Field Sample Splits: Lead.



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9 2 1 2 5 3 1 8 9 3

Figure 19B. Field Sample Splits: Lead--Lab Bias Estimate.

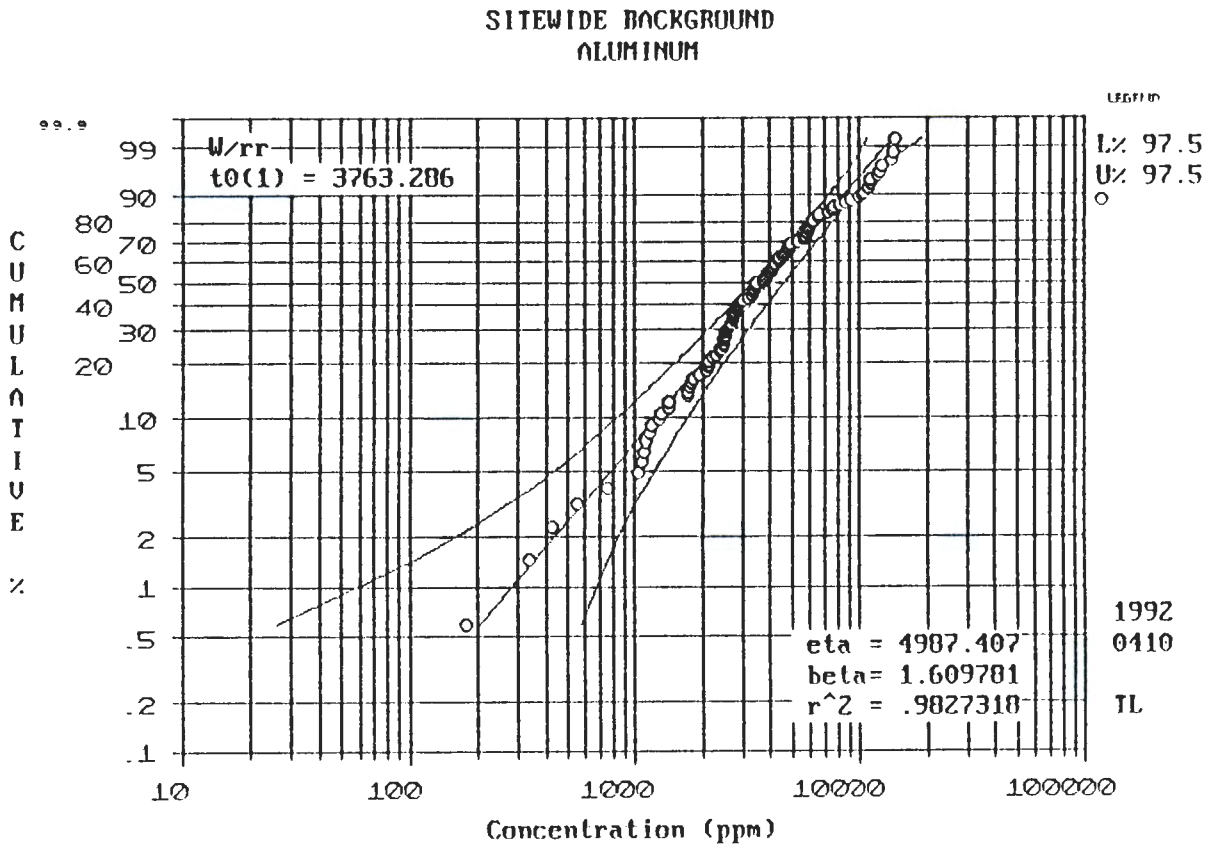

Figure 20. Aluminum: Double-Sided Confidence Intervals.

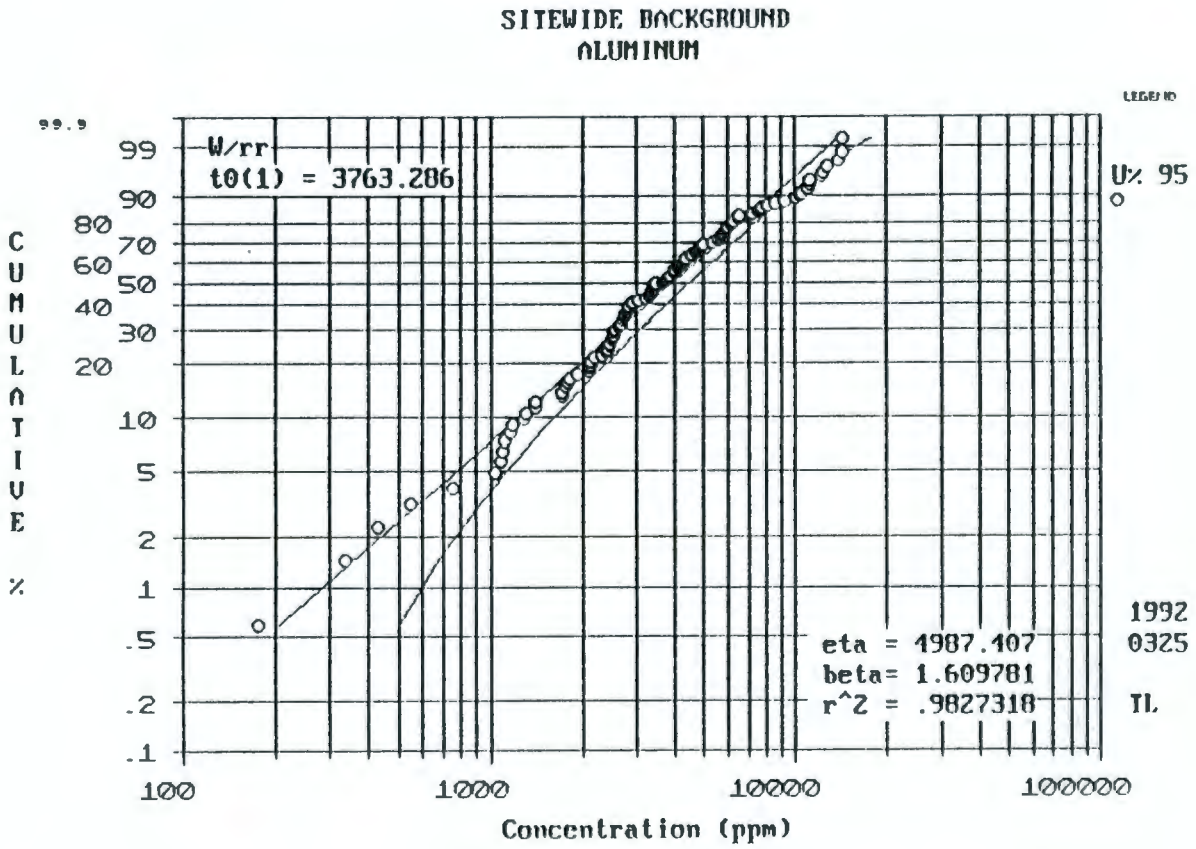

Figure 21. Aluminum: Single-Sided Confidence Intervals.

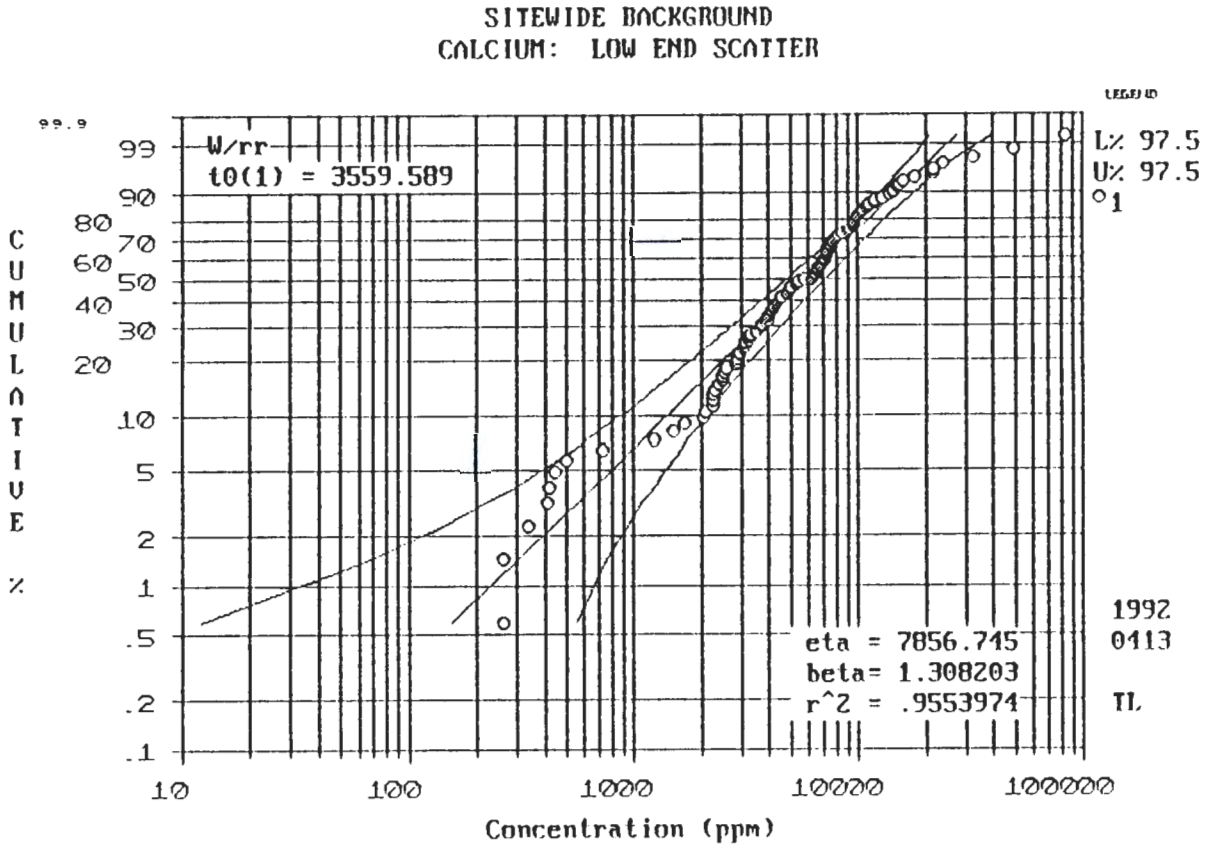

Figure 22A. Calcium: Low End Scatter.

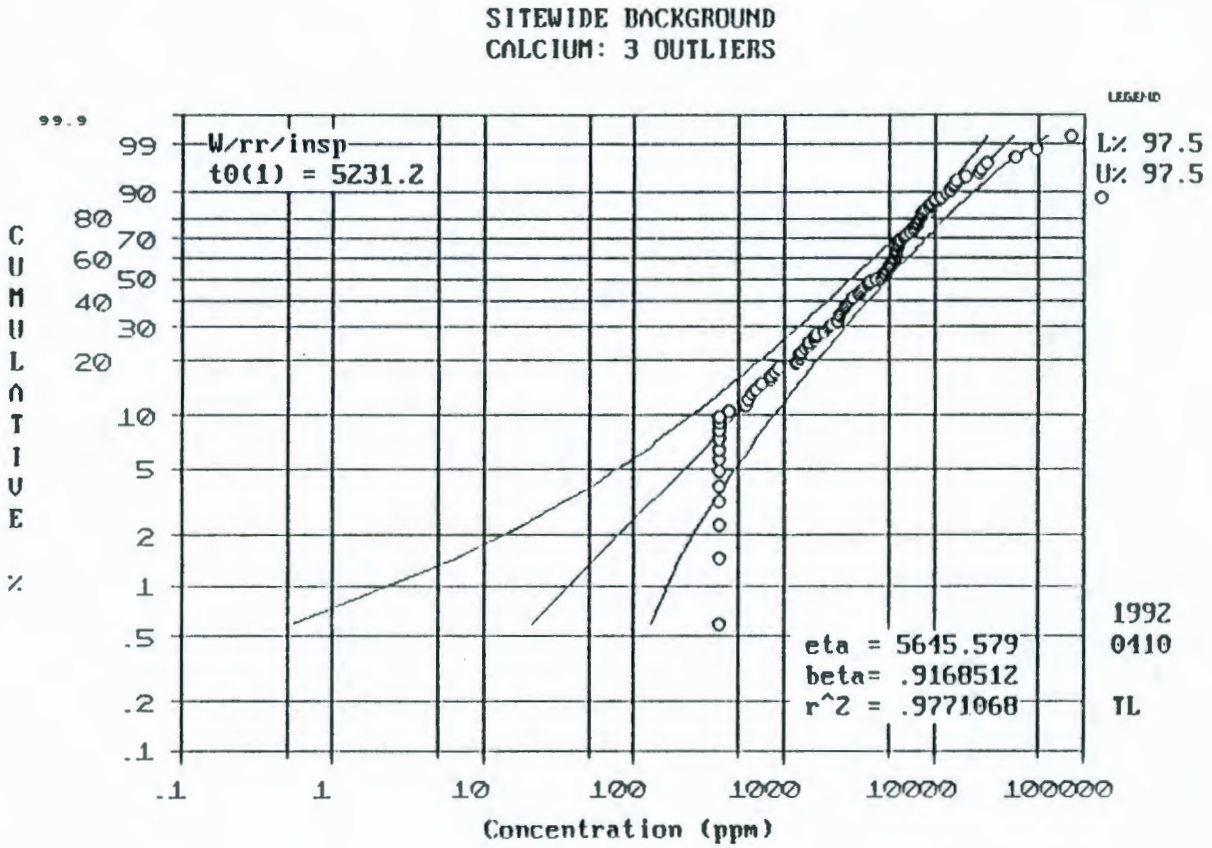

Figure 22B. Calcium: 3 Outliers.

9 2 1 2 6 0 3 1 3 9 7

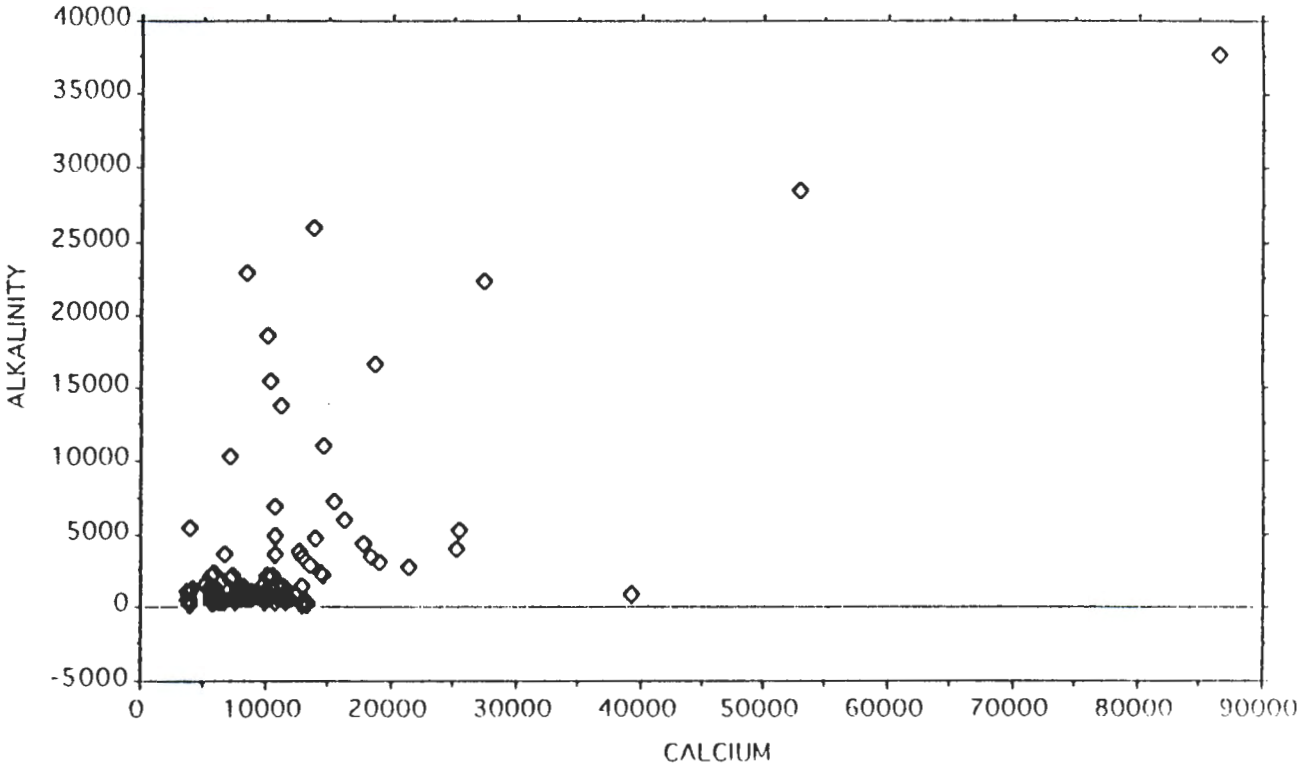

Figure 23. Alkalinity vs. Calcium.

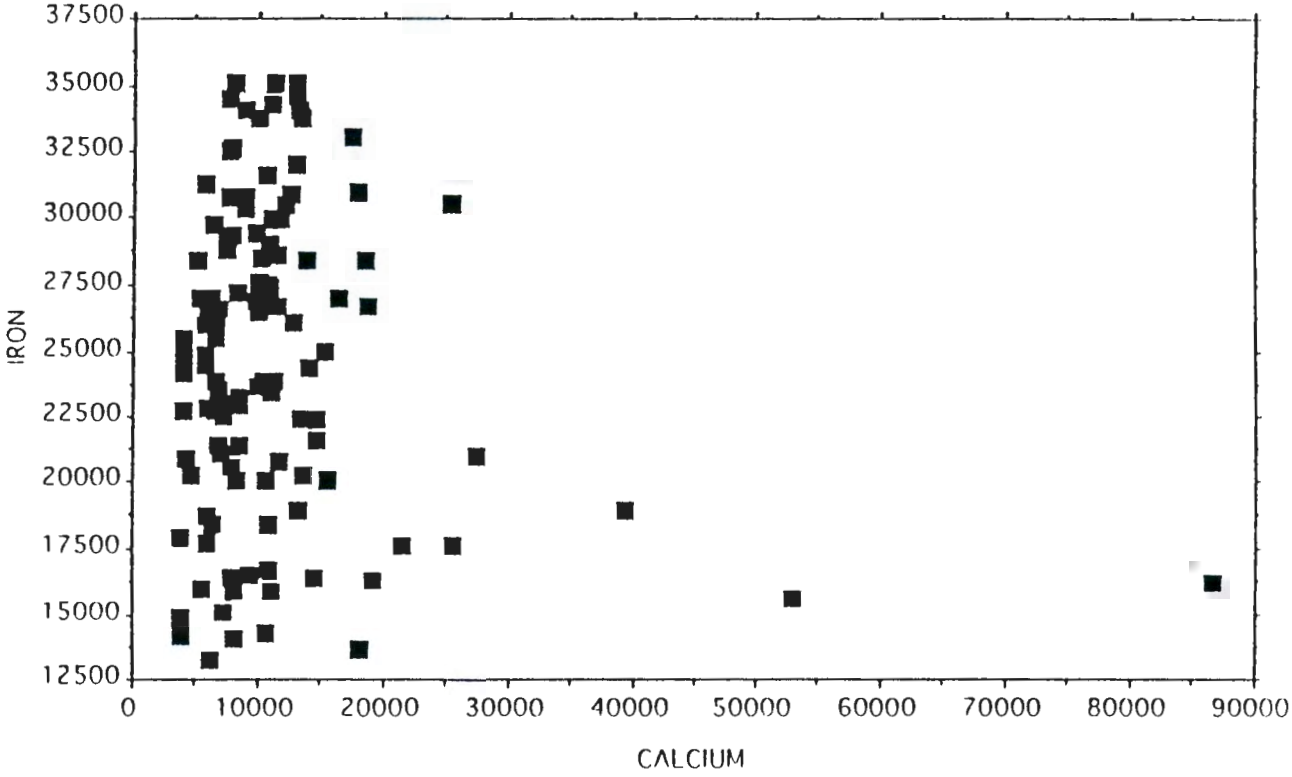

Figure 24. Iron vs. Calcium.

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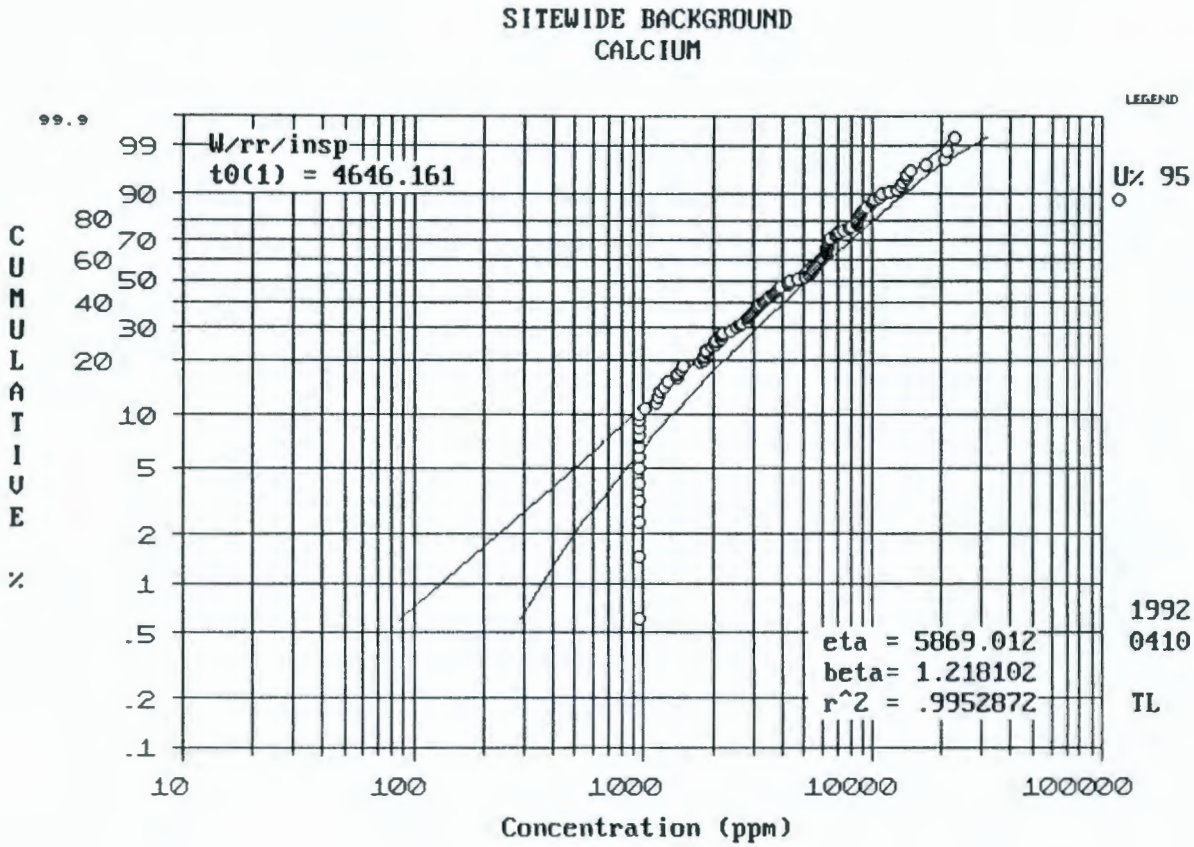

Figure 25. Calcium: Single-Sided Confidence Interval.

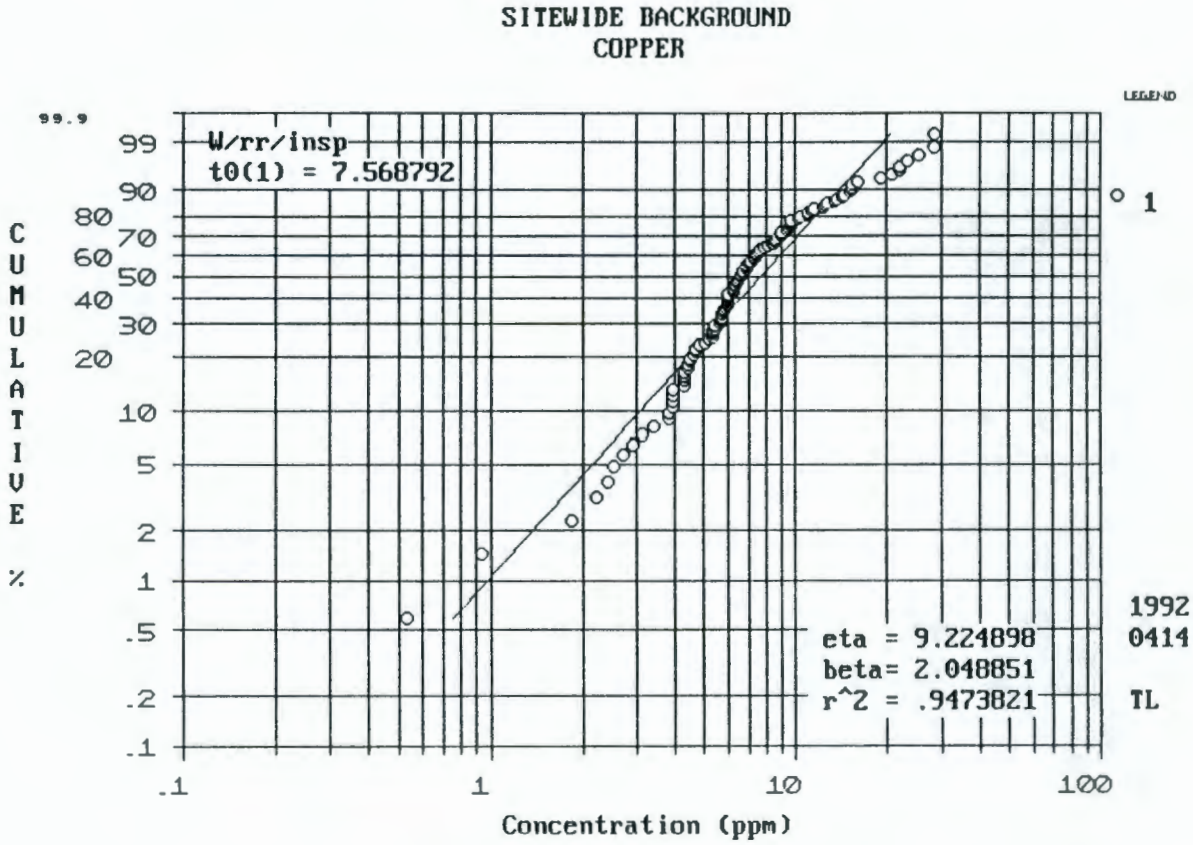

Figure 26. Copper: Initial Distribution.

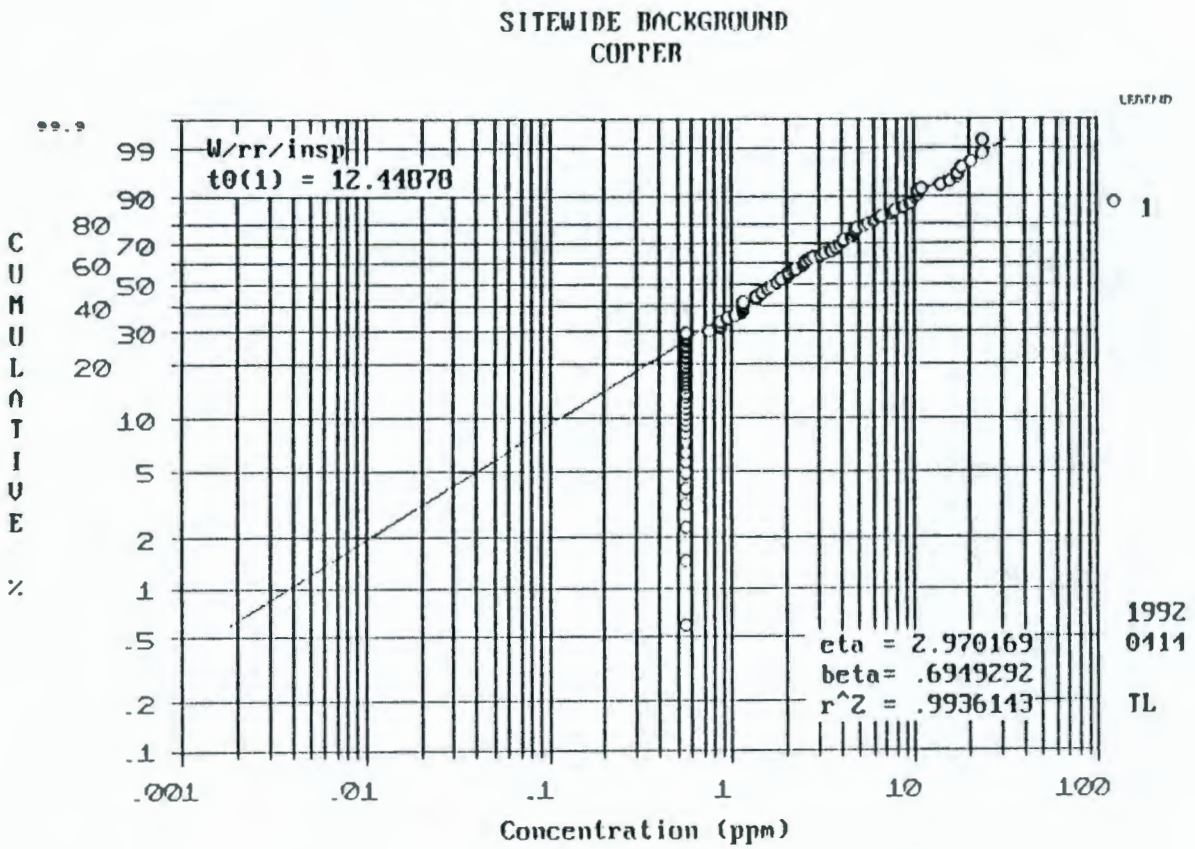

Figure 27. Copper: Truncated Distribution.

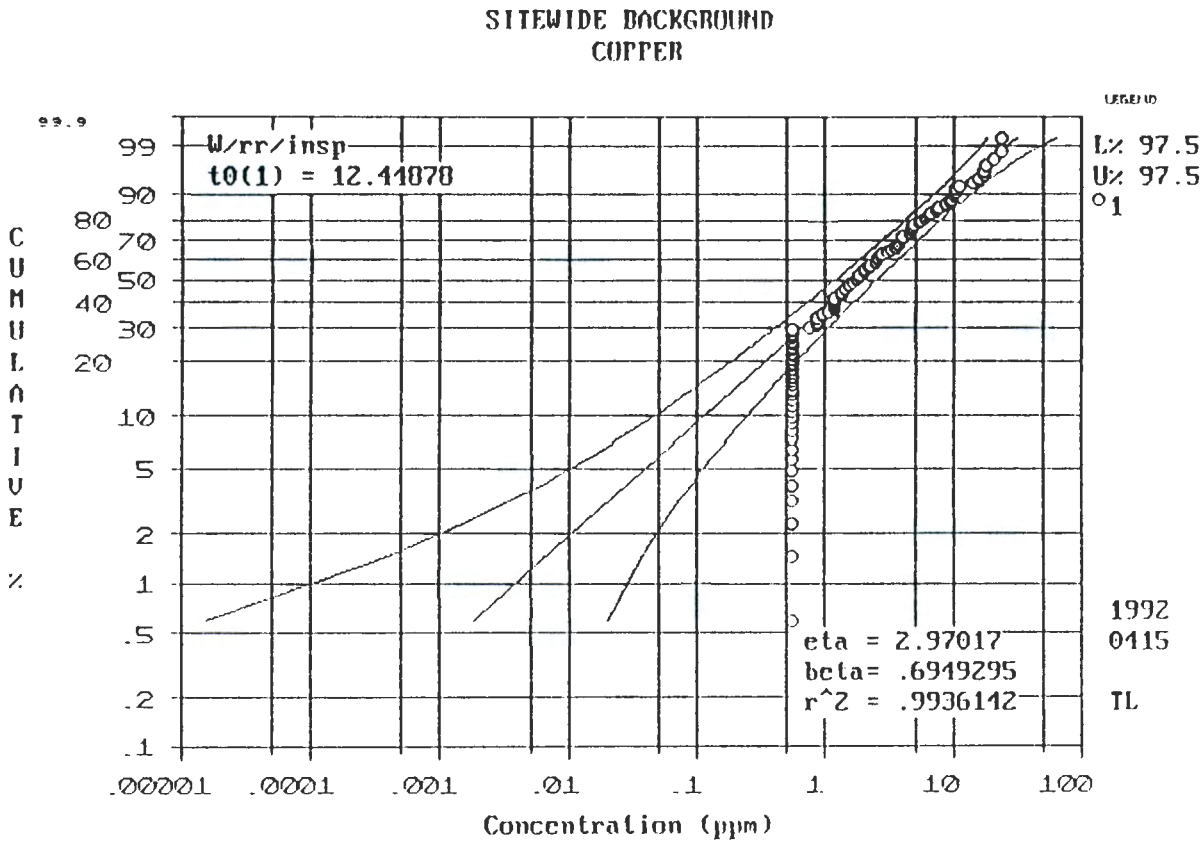

Figure 28. Copper: Double-Sided Confidence Intervals.

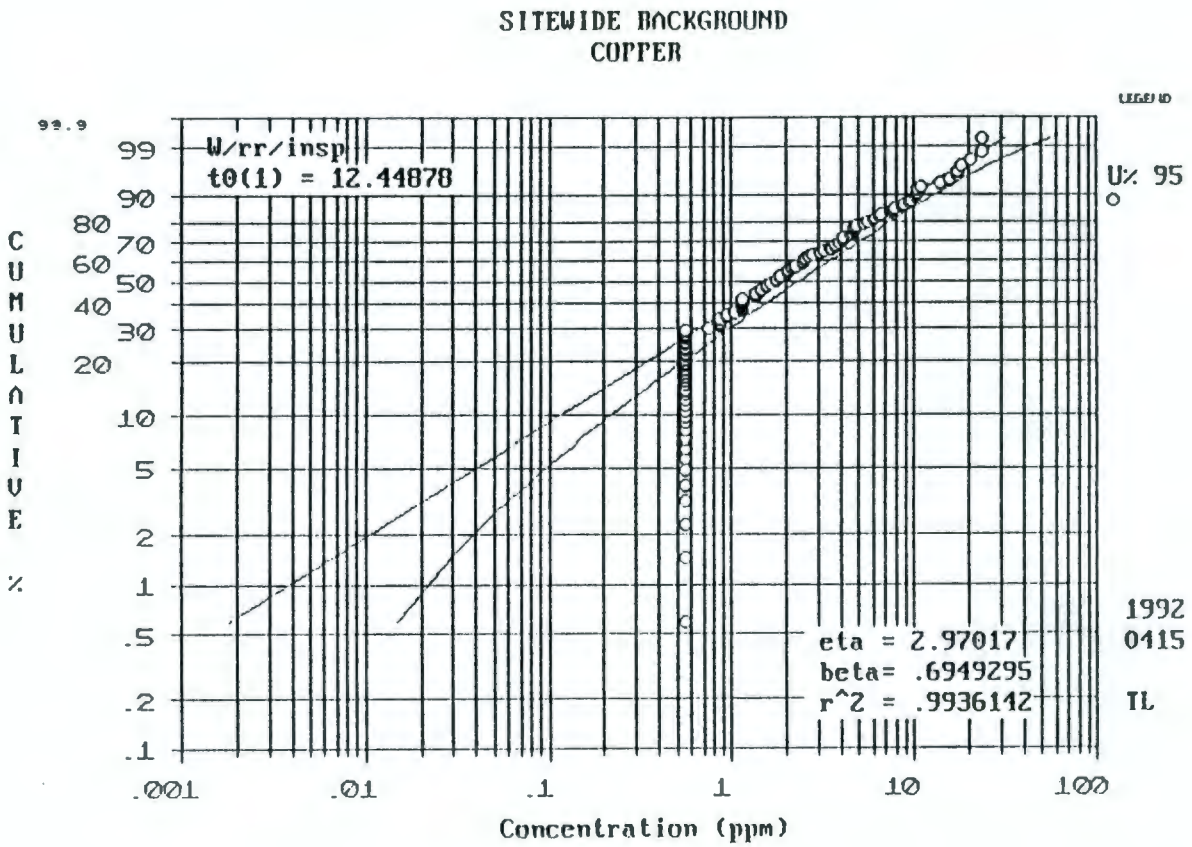

Figure 29. Copper: Single-Sided Confidence Intervals.

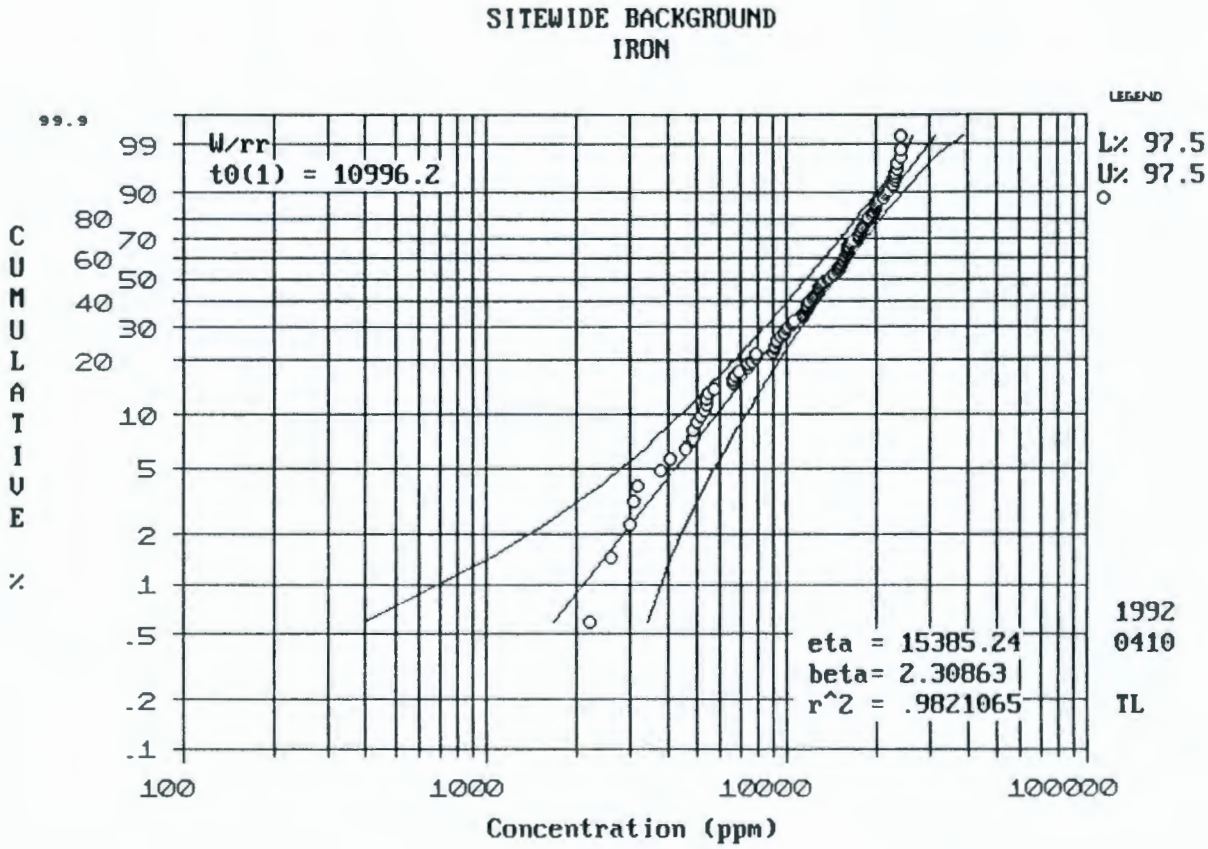

Figure 30. Iron: Double-Sided Confidence Interval.

9 2 1 2 6 8 1 9 0 5

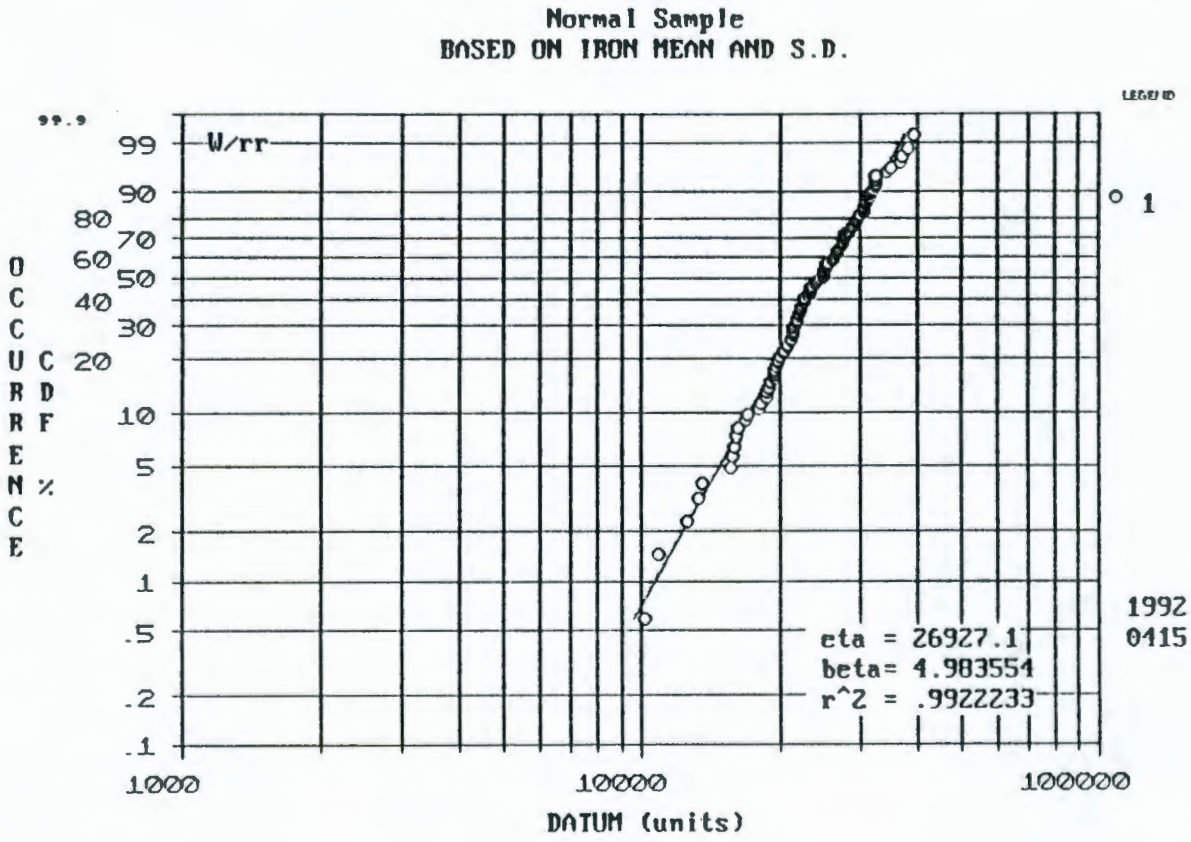

Figure 31. Normal Sample Based on Iron Mean and S.D.

9 2 1 2 5 8 1 9 0 6

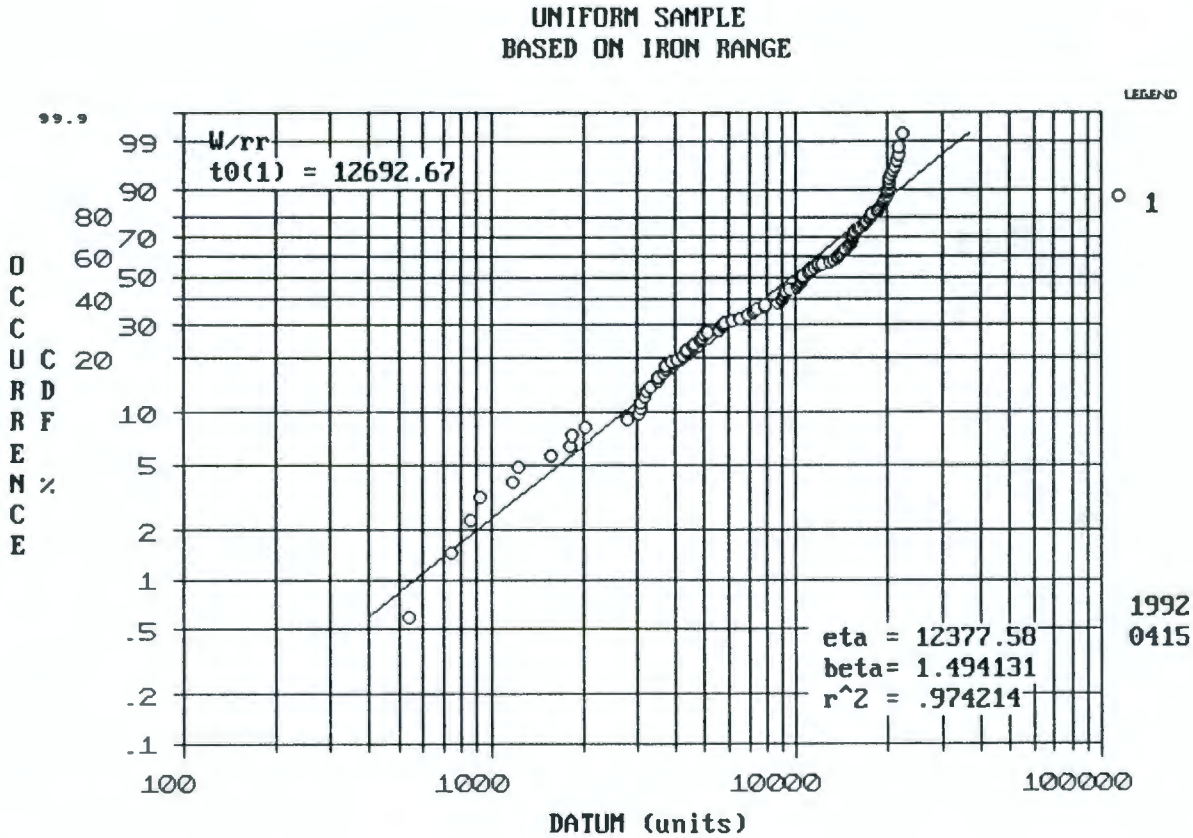

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Figure 32. Uniform Sample Based on Iron Range.

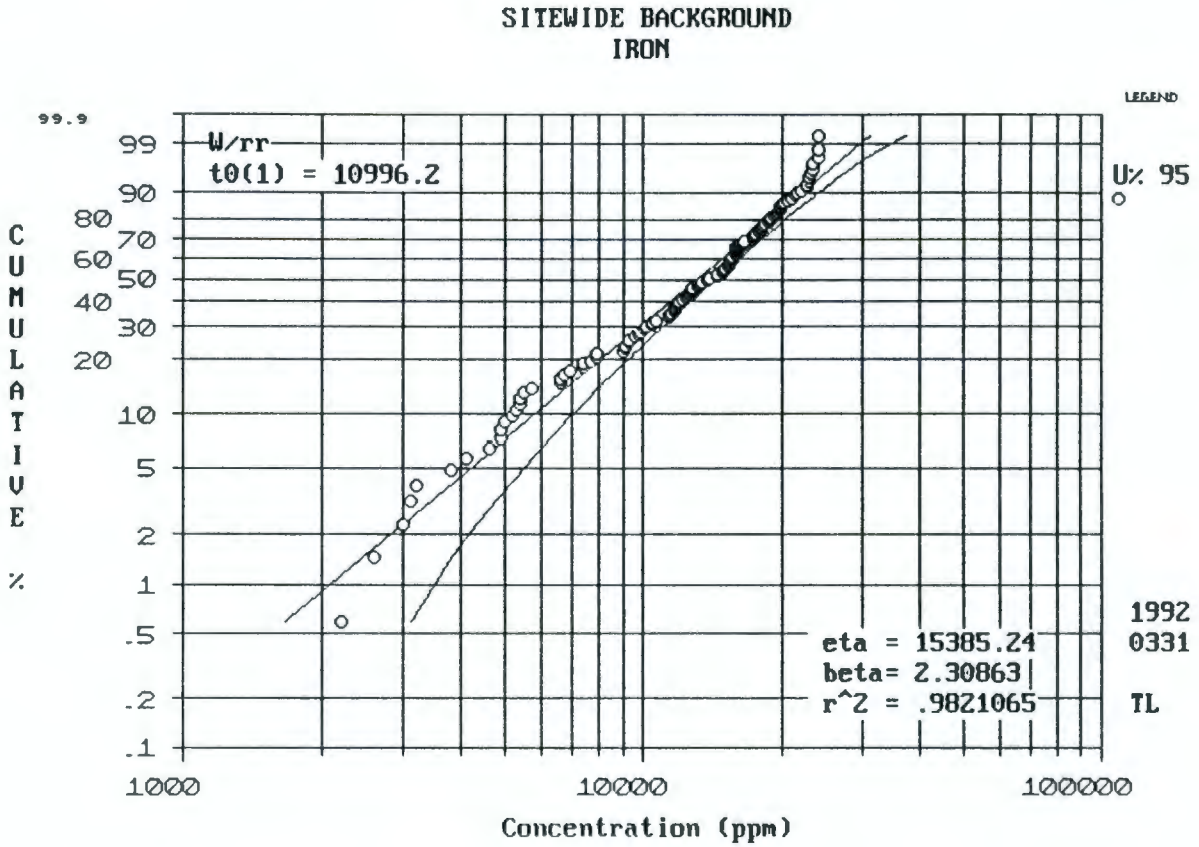

Figure 33. Iron: Single-Sided Confidence Interval.

9 2 1 2 6 8 1 9 0 8

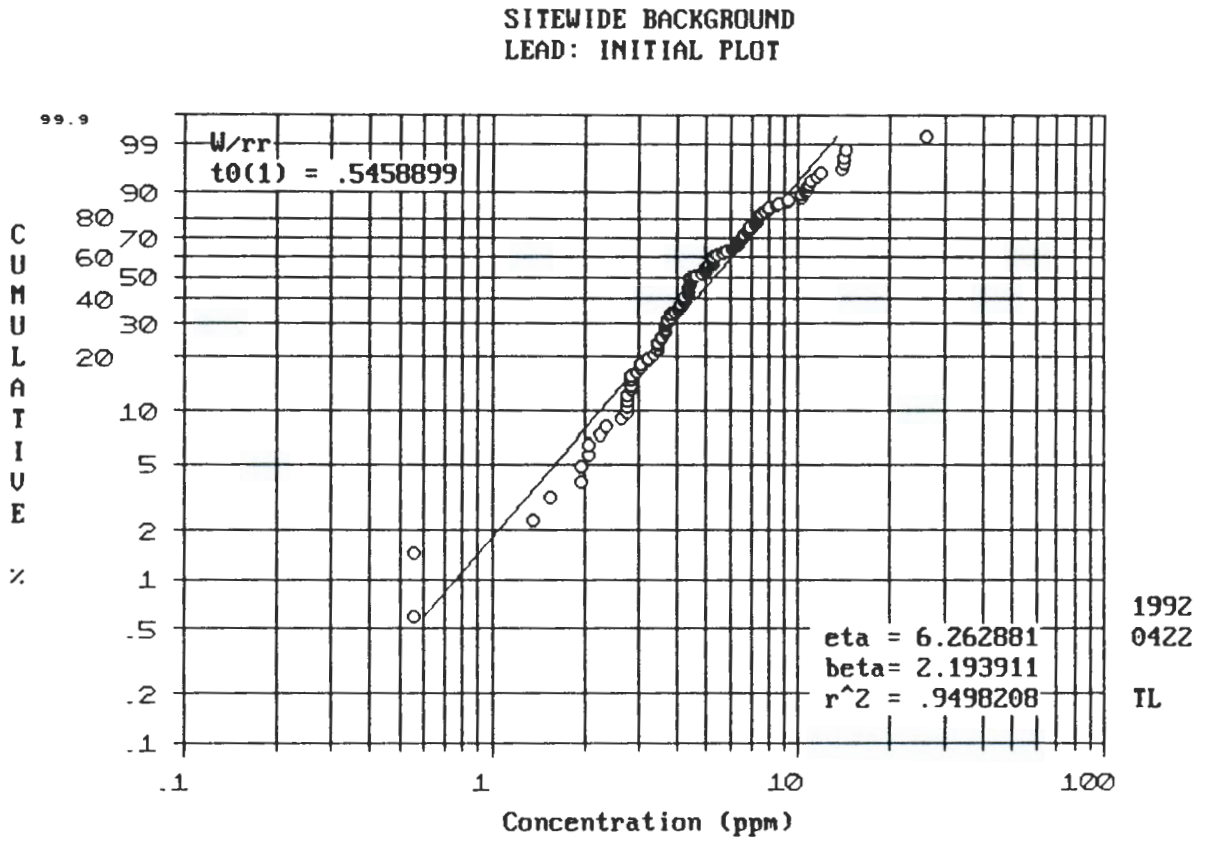

Figure 34. Lead: Initial Plot.

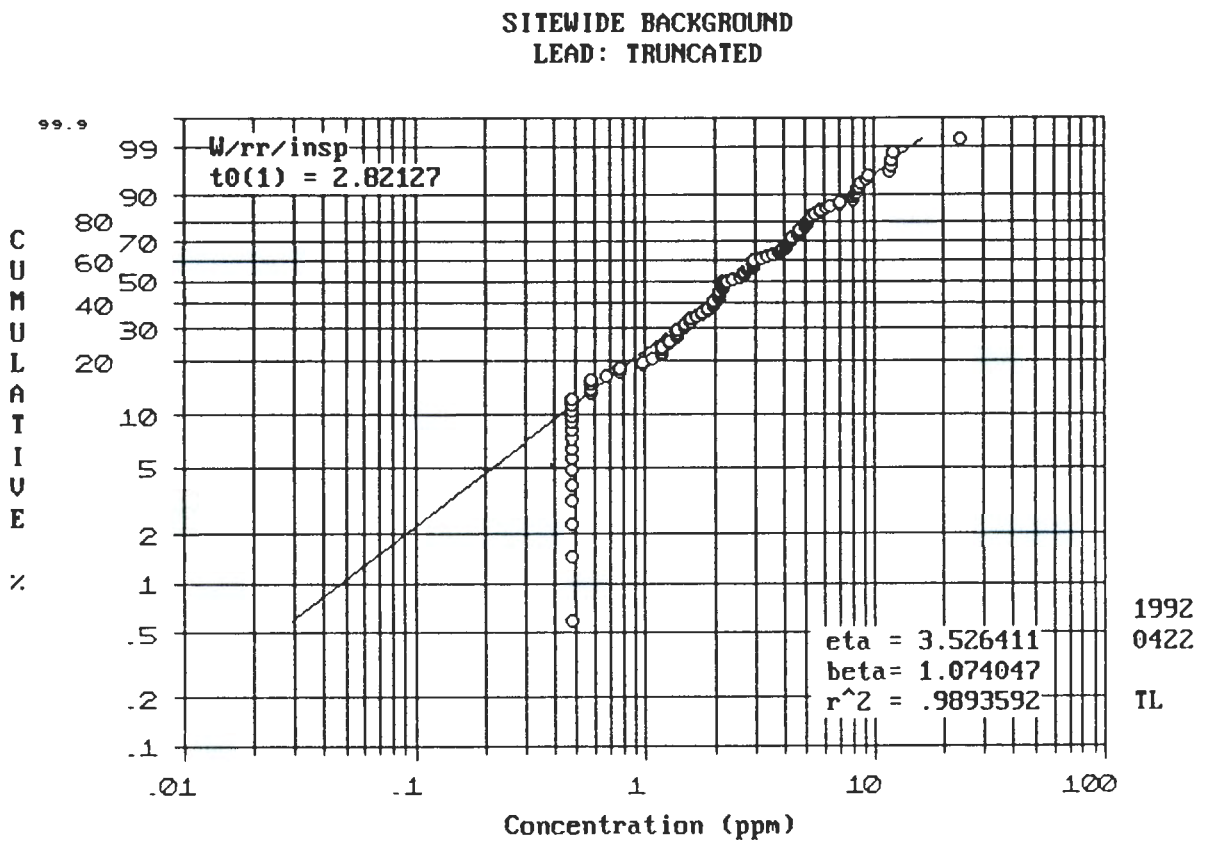

Figure 35. Lead: Adjusted for Bias.

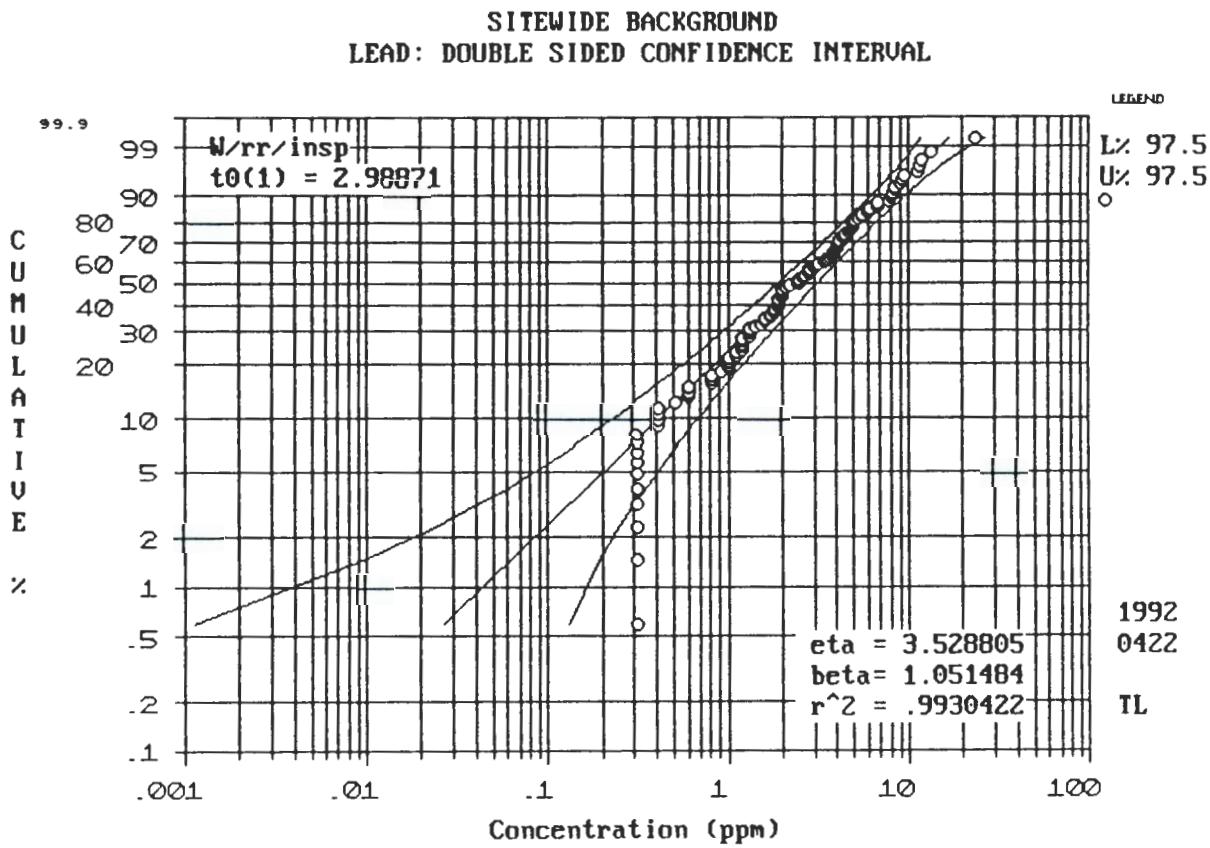

Figure 36. Lead: Double-Sided Confidence Interval.

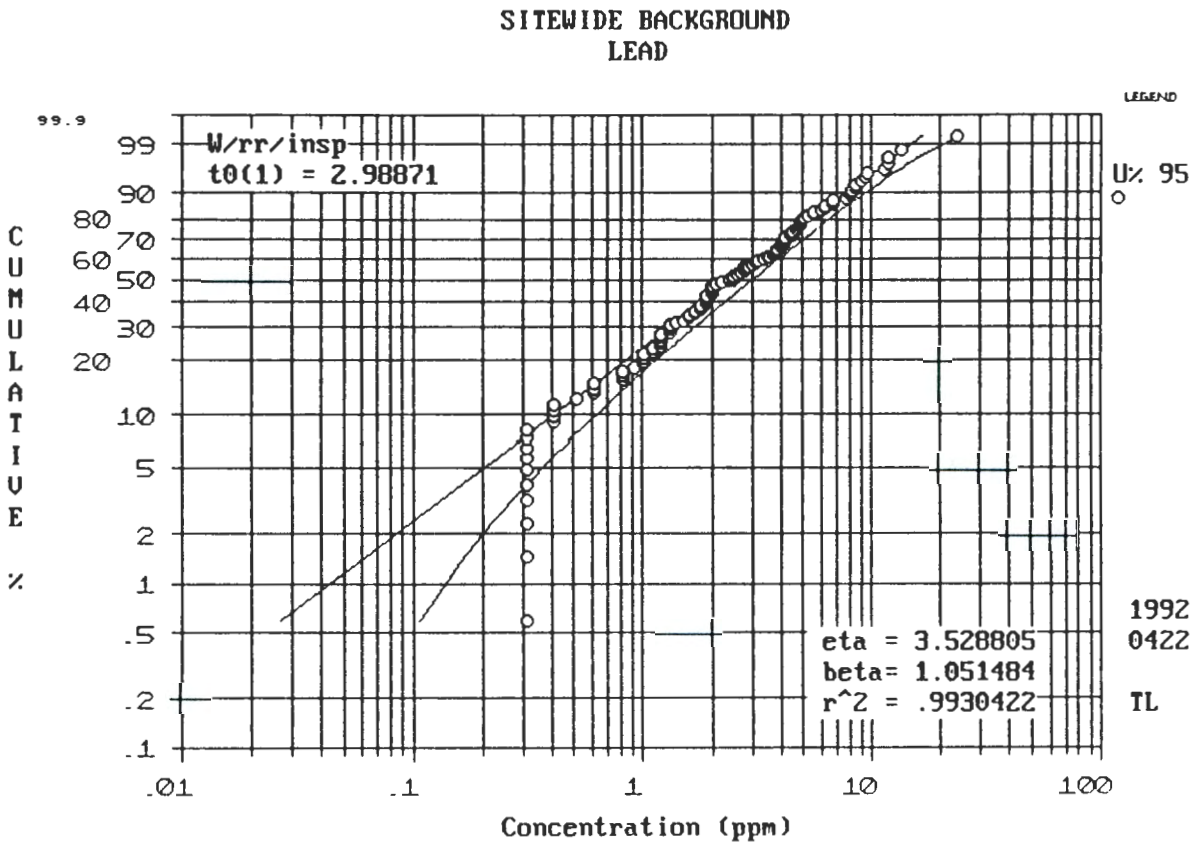

Figure 37. Lead: Single-Sided Confidence Interval.

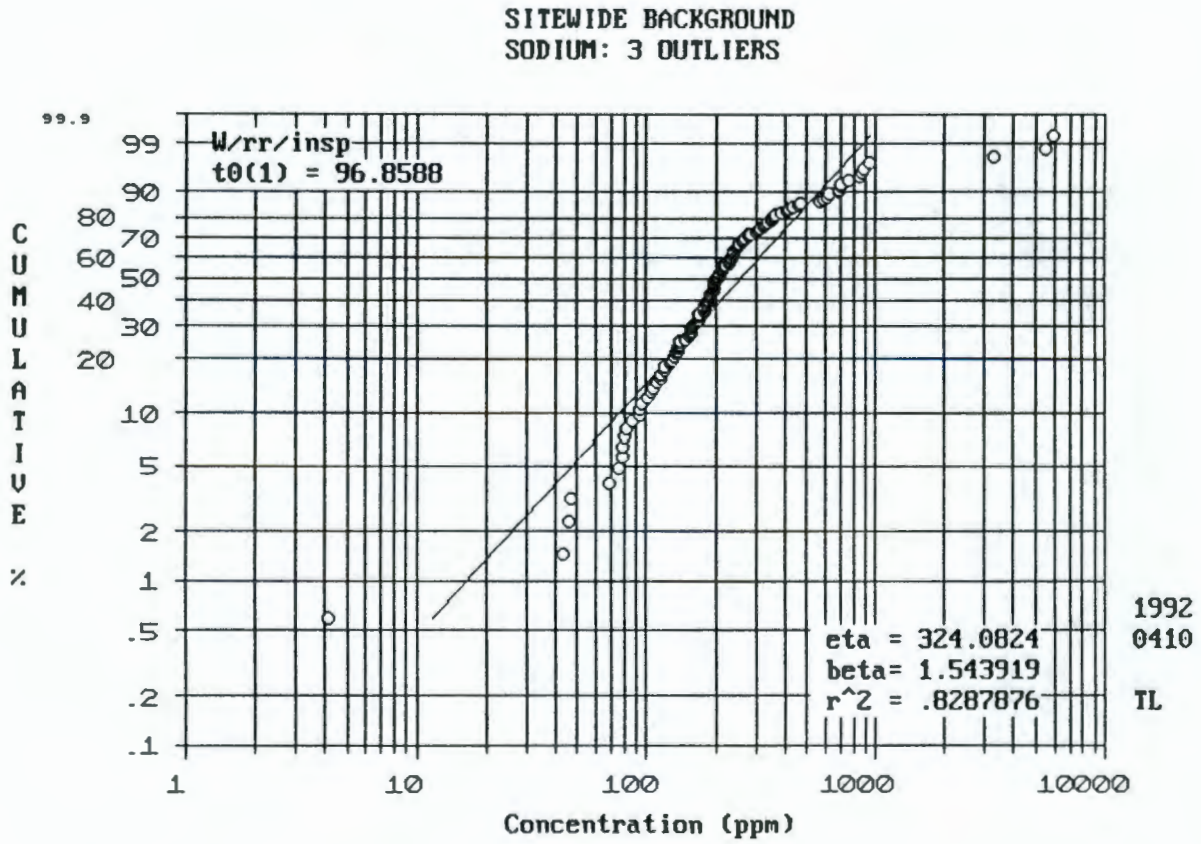

Figure 38. Sodium: 3 Outliers.

9 2 1 2 6 8 1 9 1 3

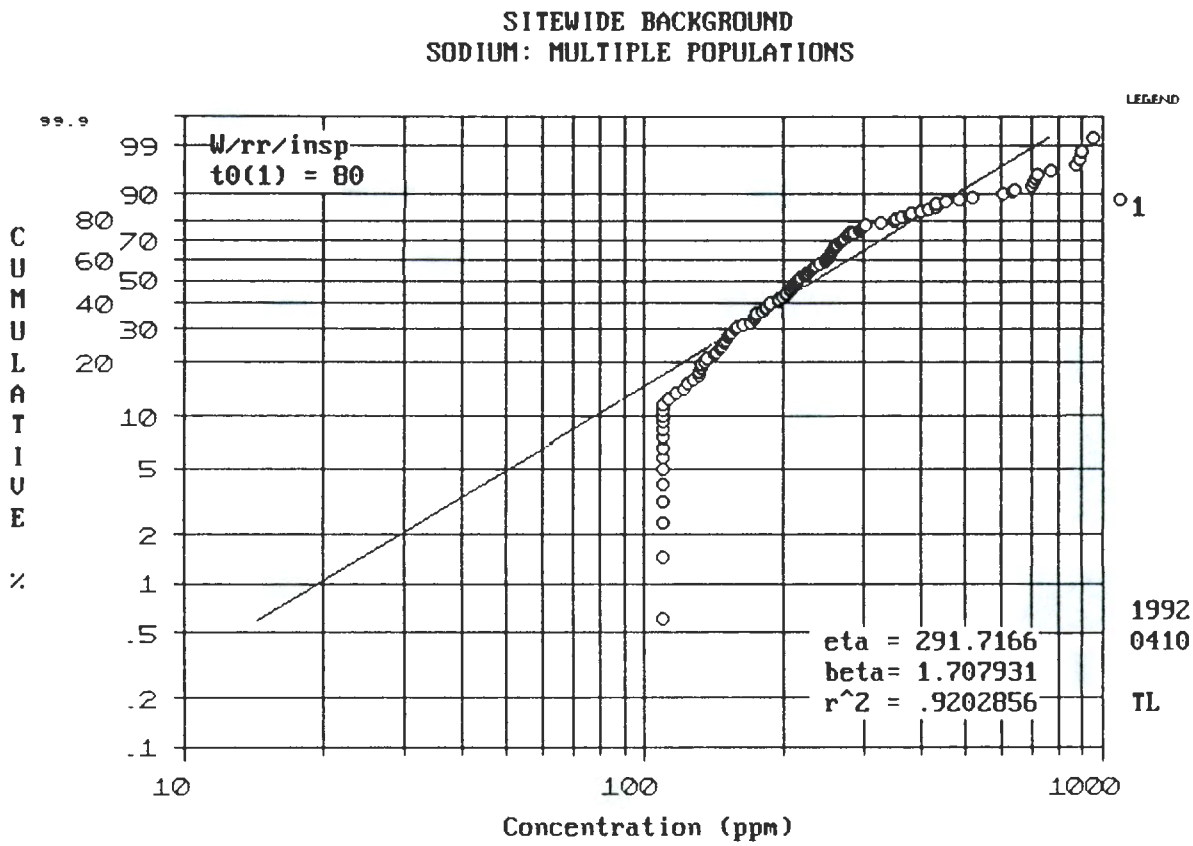

Figure 39. Sodium: Multiple Populations, Adjusted for Bias.

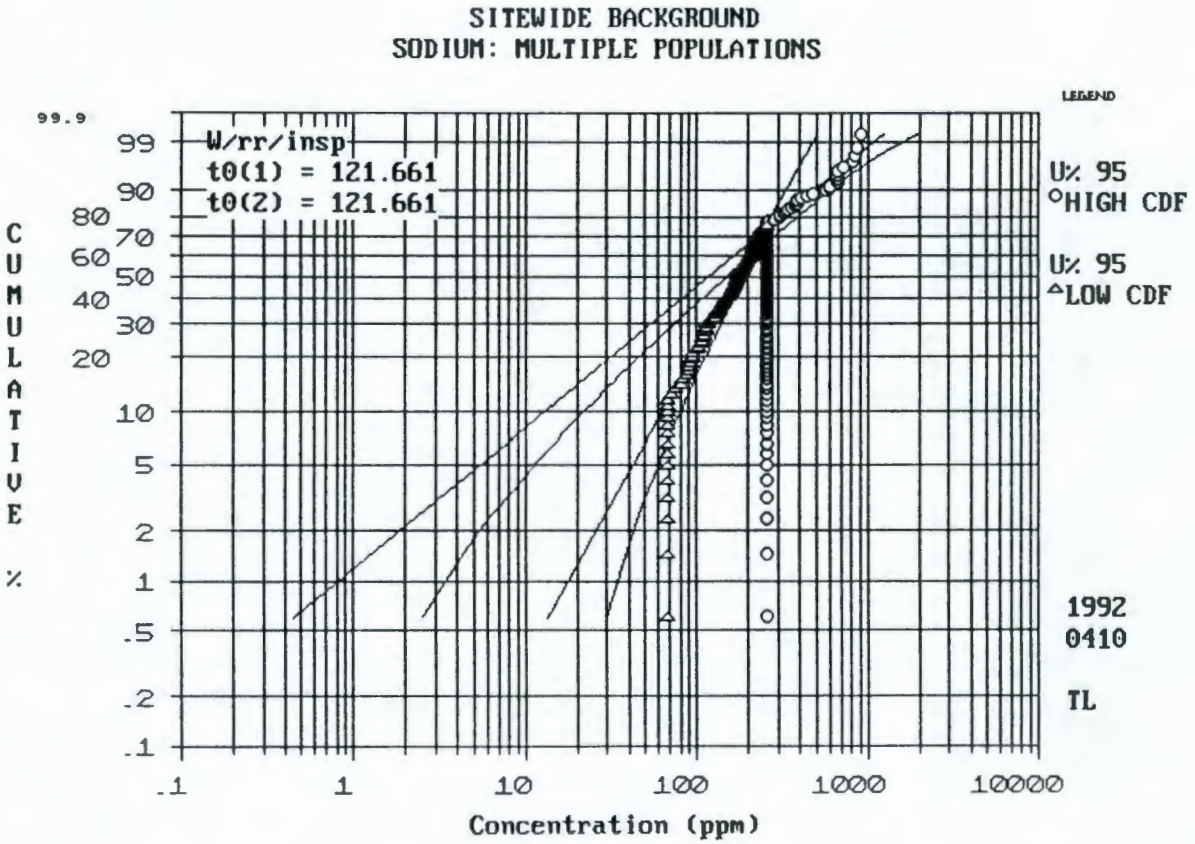

Figure 40. Sodium. Single-Sided Confidence Intervals.

9 2 1 2 6 8 1 9 1 5

Table 1. Sample Data Reporting Statistics.

SAMPLE DATA REPORTING STATISTICS

ANALYTE	RANDOM	JUDGEMENT	BLANKS	TOTAL	REQUESTED	DELTA	REJECTED	ACCEPTABLE	% ACCEPT.
Al	119	31	14	164	164	0	1	163	99.4
Sb	119	31	14	164	164	0	82	82	50.0
As	119	31	14	164	164	0	4	160	97.6
Ba	119	31	14	164	164	0	1	163	99.4
Be	119	31	14	164	164	0	4	160	97.6
Cd	119	31	14	164	164	0	4	160	97.6
Ca	119	31	14	164	164	0	1	163	99.4
Cr	119	31	14	164	164	0	1	163	99.4
Co	119	31	14	164	164	0	3	161	98.2
Cu	119	31	14	164	164	0	1	163	99.4
Fe	119	31	14	164	164	0	1	163	99.4
Pb	119	31	14	164	164	0	1	163	99.4
Mg	119	31	14	164	164	0	1	163	99.4
Mn	119	31	14	164	164	0	1	163	99.4
Hg	119	31	13	163	164	1	3	160	97.6
Ni	119	31	14	164	164	0	1	163	99.4
K	119	31	14	164	164	0	4	160	97.6
Se	119	31	14	164	164	0	31	133	81.1
Ag	119	31	14	164	164	0	4	160	97.6
Na	119	31	14	164	164	0	4	160	97.6
Tl	119	31	14	164	164	0	3	161	98.2
V	119	31	14	164	164	0	1	163	99.4
Zn	119	31	14	164	164	0	1	163	99.4
Mo	70	26	10	106	164	58	4	102	62.2
Li	68	7	7	82	25	-57	0	82	328.0
Ti	116	31	14	161	164	3	41	120	73.2
Zr	116	31	14	161	164	3	39	122	74.4
NH3	119	31	13	163	164	1	0	163	99.4
Alk.	106	29	10	145	164	19	0	145	88.4
Si	101	29	9	139	164	25	0	139	84.8
F	118	31	13	162	164	2	0	162	98.8
Cl	118	31	13	162	164	2	0	162	98.8
NO2	119	31	13	163	164	1	0	163	99.4
NO3	119	31	13	163	164	1	0	163	99.4
O-PO4	119	31	13	163	164	1	0	163	99.4
SO4	119	31	13	163	164	1	0	163	99.4

Table 2. Pooled Data for Identified Blanks. (sheet 1 of 3)

POOLED DATA FOR IDENTIFIED BLANKS
SITE WIDE SOIL SAMPLING

EDMC #: X00196	DILUTION 100			EDMC #: X00196	DILUTION 100			EDMC #: X00196	DILUTION: 100			EDMC #:
SAMPLE: PBS1014-1	LAB #: 2628			SAMPLE: PBS1014-2	LAB #: 2628			SAMPLE: PBS1014-3	LAB #: 2628			SAMPLE:
lg in 100ml=100X				lg in 100ml=100X				lg in 100ml=100X				lg in 10
DATE: 10/25/91	TIME: 13:52:45			DATE: 10/25/91	TIME: 13:52:45			DATE: 10/25/91	TIME: 13:52:45			DATE:
	run 1	run 2	run 3		run 1	run 2	run 3		run 1	run 2	run 3	
Ag	-0.007	-0.005	-0.011		-0.003	-0.003	-0.001		0.002	-0.006	-0.005	
Al	-0.012	-0.011	-0.025		0.008	0.033	0.014		-0.009	-0.033	0.018	
As	-0.015	0.041	-0.034		0.066	-0.024	-0.034		0.007	0.07	-0.015	
Ba	0	0	-0.001		-0.001	0	-0.001		0	0	0	
Be	0	0	0		0	0	0		0	0	0	
Ca	0.519	0.521	0.528		0.634	0.637	0.624		0.264	0.262	0.271	
Cd	0	-0.001	0.001		-0.001	0	0.001		-0.002	0	0.001	
Co	-0.008	-0.003	0		0.002	0.003	0.001		-0.005	-0.002	-0.005	
Cr	0	-0.001	-0.001		0.002	0.001	0		-0.002	-0.002	0	
Cu	-0.007	-0.009	-0.004		-0.002	-0.002	-0.002		-0.009	-0.002	-0.001	
Fe	0.012	0.011	0.013		0.022	0.026	0.025		0.007	0.01	0.006	
K	0.427	-1.47	-0.4		0.139	0.739	0.821		0.914	-1.11	0.364	
Mg	0.002	0.039	0.01		0.039	0.03	0.034		0.001	-0.001	0.018	
Mn	0	0.001	0		0	0	0.001		0	0.001	0	
Mo	0.004	0	0.004		-0.009	-0.003	0.002		-0.003	-0.001	0.004	
Na	0.174	0.094	-0.212		-0.132	0.276	-0.044		0.137	0.012	-0.362	
Ni	-0.002	0.003	0.002		0.003	0.004	0.006		0.003	0.005	0.008	
Pb	-0.016	-0.007	-0.004		-0.02	0.001	-0.029		0.001	-0.019	-0.04	
Sb	-0.072	-0.081	0.062		-0.018	0.084	0.007		0.113	0.093	0.033	
Se	-0.031	0.001	-0.07		-0.075	0.022	0.037		0.031	0.087	-0.018	
Tl	0.093	-0.065	-0.06		0.092	-0.02	0.049		0.017	0.064	0.051	
V	-0.013	-0.014	-0.009		-0.008	-0.006	-0.009		-0.012	-0.008	-0.014	
Zn	0.043	0.039	0.043		0.053	0.052	0.054		0.028	0.031	0.031	
Zr												
Fe												
Ca												
Al												
Mg												
Li												
Ti												

Table 2. Pooled Data for Identified Blanks. (sheet 2 of 3)

X00204	DILUTION	100	EDMC #: X00204	DILUTION	100	EDMC #: X00204	DILUTION	100	EDMC #: X00196	DILUTION
PBS0107-1	LAB #:	2751	SAMPLE: PBS0107-2	LAB #:	2751	SAMPLE: PBS0107-2	LAB #:	2751	SAMPLE: PBS1014-1	LAB#:
0ml=100X			lg in 100ml=100X			lg in 100ml=100X			lg in 100ml=100X	
01/31/92			DATE: 01/31/92			DATE: 01/31/92			DATE: 10/25/91	TIME:
run 1	run 2	run 3	run 1	run 2	run 3	run 1	run 2	run 3	run 1	run 2
-0.004	-0.007	-0.004	0	0.002	-0.005	0	0.002	-0.005	-0.007	-0.005
-0.059	-0.023	-0.014	0.002	-0.011	0	0.002	-0.011	0	0.049	0.044
-0.013	0.028	-0.016	-0.064	0.002	0.051	-0.064	0.002	0.051	0.04	0.02
0	0	0	0.001	0	-0.001	0.001	0	-0.001	0.001	0.001
0	0	0	0	0	0	0	0	0	0	0
0.126	0.125	0.131	0.204	0.198	0.195	0.204	0.198	0.195	0.217	0.211
0	0	0.001	0	0.001	-0.001	0	0.001	-0.001	0	0.001
-0.005	-0.005	-0.003	-0.003	-0.001	-0.003	-0.003	-0.001	-0.003	0.004	0.002
0	0.003	0.003	0.003	-0.001	0.003	0.003	-0.001	0.003	0	0.001
0.003	-0.003	0	0.003	0.004	0.001	0.003	0.004	0.001	0.003	0.007
0.01	0.01	0.01	0.018	0.014	0.013	0.018	0.014	0.013	0.027	0.021
-0.109	-0.217	-0.077	0.321	-0.381	-0.198	0.321	-0.381	-0.198	0.365	-0.646
0.003	-0.019	0.014	-0.002	-0.002	-0.01	-0.002	-0.002	-0.01	0.049	0.066
0.001	0.001	0.002	0.001	0	0.001	0.001	0	0.001	-0.001	0
-0.006	-0.008	-0.007	0.002	-0.006	-0.002	0.002	-0.006	-0.002	-0.001	-0.013
0.086	0.13	-0.072	0.217	0.329	0.162	0.217	0.329	0.162	0.04	0.073
0	-0.006	0.002	0.007	-0.001	0.004	0.007	-0.001	0.004	0.004	-0.001
-0.026	-0.047	-0.046	0.02	-0.027	0.001	0.02	-0.027	0.001	0.005	-0.025
-0.078	0.019	-0.02	0.004	-0.163	-0.047	0.004	-0.163	-0.047	-0.025	-0.055
-0.03	-0.125	-0.032	0.014	-0.082	-0.057	0.014	-0.082	-0.057	-0.014	-0.002
-0.003	-0.058	-0.031	0.061	0	-0.099	0.061	0	-0.099	0.108	-0.148
-0.004	-0.006	0.002	-0.005	-0.005	-0.004	-0.005	-0.005	-0.004	0.003	-0.001
0.004	0.004	0.003	0.007	0.005	0.006	0.007	0.005	0.006	0.028	0.028
0.002	0.002	0.005	0.003	0.005	0.002	0.003	0.005	0.002	1.03	1.04
-0.006	-0.003	-0.005	0.014	0.015	0.019	0.014	0.015	0.019	1.17	1.17
0.098	0.103	0.098	0.129	0.124	0.124	0.129	0.124	0.124	0.323	0.323
0.076	0.087	0.035	0.064	0.042	0.007	0.064	0.042	0.007	1.97	2
-0.024	-0.014	-0.069	-0.022	-0.053	-0.018	-0.022	-0.053	-0.018	0.001	0.064
0.004	0.002	0.003	0.001	0.001	0.001	0.001	0.001	0.001	1.2	1.24
									1.01	1.03

Table 2. Pooled Data for Identified Blanks. (sheet 3 of 3)

100 EDMC #: X00196 DILUTION 100
2628 SAMPLE: PBS1014-2 LAB#: 2628
lg in 100ml=100X
15:10:37 DATE: 10/25/91 TIME: 15:10:37

run 3	run 1	run 2	run 3		mean	s.d	LOD	LOQ
-0.004	-0.008	-0.003	-0.008	Ag	0	0.00334	1.00	3.35
0.057	0.037	-0.01	-0.016	Al	0.16335	0.52559	174.02	541.93
0.028	-0.044	0.04	-0.036	As	0.00362	0.03885	12.02	39.22
0.001	0.001	0.001	0.002	Ba	0.00016	0.00079	0.26	0.82
0	0	0	0	Be	0	0	0.00	0.00
0.196	0.52	0.502	0.497	Ca	0.29502	0.17663	82.49	206.14
-0.001	0	-0.001	-0.001	Cd	0	0.00086	0.26	0.86
-0.002	-0.001	-0.004	-0.004	Co	0	0.00285	0.86	2.85
0.001	0.001	0.001	-0.001	Cr	0.00066	0.00164	0.56	1.72
0.002	-0.001	0.002	0.002	Cu	0	0.00399	1.20	3.99
0.02	0.027	0.025	0.024	Fe	0.10410	0.30780	102.75	318.21
-0.451	0.295	-0.31	0.19	K	0	0.55936	167.81	559.37
0.066	0.084	0.049	0.037	Mg	0.01225	0.03648	12.17	37.71
-0.001	0.001	0	0.001	Mn	0.00045	0.00070	0.26	0.75
-0.002	-0.005	-0.005	0.001	Mo	0	0.00439	1.32	4.40
0.082	0.155	0.027	0.11	Na	0.08291	0.15912	56.03	167.41
0.003	0.003	0.004	0.003	Ni	0.00266	0.00314	1.21	3.41
0.005	-0.01	-0.046	-0.033	Pb	0	0.01949	5.85	19.50
-0.027	0.036	0.027	-0.05	Sb	0	0.06872	20.62	68.72
0.035	0.013	0.013	0.018	Se	0	0.04823	14.47	48.23
-0.14	0.052	0.015	0.061	Tl	0.00004	0.07243	21.73	72.44
-0.001	0	0.003	0.003	V	0	0.00511	1.53	5.11
0.032	0.046	0.042	0.047	Zn	0.02683	0.01827	8.17	20.96
1.03	0.002	0.001	0.003	Zr	0.209	0.41217	144.55	433.07
1.17	0.024	0.024	0.024					
0.311	0.507	0.51	0.5					
1.97	0.068	-0.036	-0.055					
0.048	0.084	0.037	0.044					
1.31	-0.006	-0.005	0.006	Li	0.25066	0.50008	175.09	525.16
1.03	-0.001	-0.001	-0.002	Ti	0.511	0.51237	204.81	563.48

Table 3. LOD/LOQ Summary Table.

LOD / LOQ SUMMARY TABLE

ANALYTE	CONTRACT REQUIRED DETECTION LIMIT ppm	REQUESTED DETECTION LIMIT ppm	MAXIMUM CLAIMED DETECTION LIMIT ppm	ACHIEVED LIMIT OF DETECTION ppm	ACHIEVED LIMIT OF QUANTITATION ppm
Al	0.2000	40	18.1	174	542
Sb	0.0600	12	11.1	21	69
As	0.0100	2	3	12	39
Ba	0.2000	40	4.1	0.26	0.82
Be	0.0050	1	0.46		
Cd	0.0050	1	0.66	0.26	0.86
Ca	5.0000	1000	189	83	206
Cr	0.0100	2	1.8	0.56	1.72
Co	0.0500	10	1.9	0.86	2.9
Cu	0.0250	50	1.8	1.2	4
Fe	0.1000	20	7.1	103	318
Pb	0.0030	0.6	1.1	5.9	19.5
Mg	5.0000	1000	249	12.2	38
Mn	0.0150	3	0.6	0.26	0.75
Hg	0.0002	0.2	0.16		
Ni	0.0400	8	7.2	1.21	3.4
K	5.0000	1000	851	168	559
Se	0.0050	1	5	14.5	48
Ag	0.0100	2	1.1	1	3.4
Na	5.0000	1000	98.7	56	167
Tl	0.0100	2	3.7	22	72.4
V	0.0500	10	2	1.5	5.1
Zn	0.0200	4	5	8.2	21
Mo		0.5	2	1.3	4.4
Li	0.3000		34	175	525
Ti	0.0100		5	205	563
Zr	0.1000		11	145	433
NH3		1	0.6		
Alk.			5		
Si			5.2		
F		1	1		
Cl		1	1		
NO2		1	21		
NO3		1	0.6		
O-PO4		2	2		
SO4		2	1		

* ANIONS NOT INCLUDED IN LOD, LOQ ANALYSIS

Table 4A. XRF Data Factor Analysis--Summary Information.

Summary Information

Factor Procedure	Principal Component Analysis
Extraction Rule	Method Default
Transformation Method	Orthotran/Varimax
Number of Factors	5

Table 4B. XRF Data Factor Analysis--Variable Sampling Adequacy.

Measures of Variable Sampling Adequacy

Total matrix sampling adequacy: .8

SiO2	.84	Strontium	.3
TiO2	.85	Zirconium	.76
Al2O3	.53	Yttrium	.79
FeO	.85	Niobium	.69
MnO	.9	Gallium	.81
MgO	.83	Copper	.42
CaO	.85	Zinc	.63
Na2O	.67	Lead	.81
K2O	.78	Lanthanum	.78
P2O5	.85	Cerium	.78
Nickel	.86	Thorium	.88
Chrome	.88		
Scandium	.93		
Vanadium	.88		
Barium	.74		
Rubidium	.77		

Bartlett Test of Sphericity- DF: 377 Chi Square: 2816.66 P: 1.000E-4

Table 4C. XRF Data Factor Analysis--Communality Summary.

Communality Summary

	SMC	Final Estimate
SiO2	1	.96
TiO2	1	.99
Al2O3	.96	.7
FeO	1	.97
MnO	.99	.93
MgO	.99	.91
CaO	.99	.92
Na2O	.99	.67
K2O	1	.9
P2O5	.99	.95
Nickel	.99	.94
Chrome	.97	.86
Scandium	.97	.93
Vanadium	1	.98
Barium	.94	.82
Rubidium	1	.94

	SMC	Final Estimate
Strontium	.92	.88
Zirconium	.95	.9
Yttrium	.96	.87
Niobium	.9	.69
Gallium	.82	.75
Copper	.98	.89
Zinc	.99	.98
Lead	.91	.88
Lanthanum	.78	.66
Cerium	.95	.91
Thorium	.96	.91

Table 4D. XRF Data Factor Analysis--Proportionate Variance Contributions.

Proportionate Variance Contributions

	Orthogonal	Oblique		
	Direct	Direct	Joint	Total
Factor 1	.49	.49	4.165E-3	.5
Factor 2	.19	.18	-4.221E-4	.18
Factor 3	.12	.12	1.847E-3	.12
Factor 4	.14	.14	4.971E-4	.14
Factor 5	6.59E-2	6.36E-2	2.757E-5	6.36E-2

Table 4E. XRF Data Factor Analysis--Correlation Matrix. (sheet 1 of 3)

CORRELATION MATRIX
BULK ANALYSIS - XRF
HANFORD VADOSE ZONE + CRB (UMTANUM) CONTROL SAMPLES

	SiO2	TiO2	Al2O3	FeO	MnO	MgO	CaO	Na2O	K2O	P2O5	Nickel
SiO2	1										
TiO2	-0.856	1									
Al2O3	0.055	-0.343	1								
FeO	-0.876	0.977	-0.347	1							
MnO	-0.88	0.947	-0.307	0.981	1						
MgO	-0.899	0.901	-0.189	0.924	0.921	1					
CaO	-0.946	0.87	-0.204	0.862	0.834	0.884	1				
Na2O	-0.312	0.623	-0.152	0.556	0.455	0.362	0.425	1			
K2O	0.628	-0.834	0.406	-0.779	-0.721	-0.758	-0.769	-0.673	1		
P2O5	-0.836	0.954	-0.273	0.934	0.905	0.823	0.831	0.616	-0.724	1	
Nickel	0.637	-0.889	0.575	-0.858	-0.792	-0.673	-0.73	-0.749	0.791	-0.851	1
Chrome	0.457	-0.724	0.527	-0.702	-0.628	-0.447	-0.56	-0.799	0.645	-0.721	0.927
Scandium	-0.835	0.954	-0.344	0.961	0.934	0.917	0.841	0.541	-0.762	0.907	-0.827
Vanadium	-0.852	0.988	-0.368	0.97	0.941	0.914	0.885	0.607	-0.846	0.934	-0.891
Barium	-6.2E-3	-0.382	0.254	-0.323	-0.287	-0.23	-0.05	-0.496	0.28	-0.412	0.427
Rubidium	0.531	-0.85	0.473	-0.791	-0.718	-0.674	-0.671	-0.829	0.943	-0.775	0.891
Strontium	-0.423	0.173	0.194	0.217	0.202	0.381	0.471	0.053	-0.296	0.119	-0.101
Zirconium	0.139	-0.298	0.183	-0.238	-0.238	-0.137	-0.208	-0.434	0.229	-0.267	0.443
Yttrium	-0.669	0.658	0.082	0.644	0.61	0.617	0.595	0.343	-0.425	0.71	-0.432
Niobium	-0.025	-0.26	0.497	-0.273	-0.201	-0.069	-0.146	-0.598	0.366	-0.282	0.551
Gallium	-0.695	0.627	0.104	0.656	0.678	0.622	0.598	0.326	-0.299	0.656	-0.463
Copper	-0.233	-2.7E-4	0.069	0.112	0.164	0.115	0.122	-0.239	-0.025	0.041	0.13
Zinc	-0.712	0.524	-0.032	0.612	0.647	0.562	0.58	0.085	-0.318	0.584	-0.345
Lead	0.034	-0.345	0.24	-0.239	-0.205	-0.218	-0.193	-0.533	0.439	-0.234	0.459
Lanthanum	0.165	-0.403	0.285	-0.356	-0.366	-0.262	-0.214	-0.426	0.371	-0.404	0.47
Cerium	0.391	-0.569	0.288	-0.529	-0.504	-0.375	-0.468	-0.609	0.488	-0.553	0.691
Thorium	0.452	-0.698	0.449	-0.66	-0.613	-0.491	-0.591	-0.743	0.737	-0.649	0.822

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Table 4E. XRF Data Factor Analysis--Correlation Matrix. (sheet 2 of 3)

CORRELATION MATRIX
BULK ANALYSIS - XRF
HANFORD VADOSE ZONE + CRB (UMTANUM) CONTROL SAMPLES

	Chrome	Scandium	Vanadium	Barium	Rubidium	Strontium	Zirconium	Yttrium	Niobium	Gallium	Copper	Zinc
Scandium	-0.655	1										
Vanadium	-0.729	0.946	1									
Barium	0.368	-0.397	-0.367	1								
Rubidium	0.799	-0.78	-0.853	0.5	1							
Strontium	-0.058	0.159	0.245	0.375	-0.112	1						
Zirconium	0.526	-0.211	-0.363	0.291	0.354	-0.113	1					
Yttrium	-0.263	0.666	0.582	-0.22	-0.42	-0.07	0.33	1				
Niobium	0.697	-0.242	-0.318	0.378	0.537	-0.011	0.455	0.159	1			
Gallium	-0.423	0.611	0.625	-0.203	-0.336	0.227	-0.295	0.498	-0.131	1		
Copper	0.095	-7.1E-3	-1.7E-3	0.595	0.124	0.28	0.295	0.077	0.103	0.061	1	
Zinc	-0.291	0.503	0.513	0.324	-0.228	0.283	0.042	0.481	0.022	0.483	0.785	1
Lead	0.434	-0.311	-0.37	0.616	0.549	0.077	0.557	0.074	0.413	-0.178	0.711	0.489
Lanthanu	0.483	-0.39	-0.433	0.4	0.48	0.072	0.641	0.109	0.383	-0.207	0.089	-0.123
Cerium	0.747	-0.481	-0.616	0.314	0.609	-0.234	0.842	0.049	0.564	-0.396	0.147	-0.197
Thorium	0.846	-0.605	-0.73	0.315	0.829	-0.192	0.667	-0.115	0.635	-0.35	0.037	-0.278

Table 4E. XRF Data Factor Analysis--Correlation Matrix. (sheet 3 of 3)

CORRELATION MATRIX
BULK ANALYSIS - XRF
HANFORD VADOSE ZONE + CRB (UMTANUM) CONTROL SAMPLES

	Lead	Lanthanum	Cerium	Thorium
Lead	1			
Lanthanum	0.395	1		
Cerium	0.48	0.661	1	
Thorium	0.494	0.624	0.867	1

Table 4F. XRF Data Factor Analysis--Orthogonal Solution.

Orthogonal Transformation Solution-Varimax

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
SiO2	-.93	.1	-.18		-.23
TiO2	.93	-.23		-.24	
Al2O3	-.12	.11		.81	.16
FeO	.94	-.21		-.23	
MnO	.92	-.22		-.14	
MgO	.93				.2
CaO	.88	-.13		-.12	.35
Na2O	.45	-.42	-.35	-.4	
K2O	-.7	.13	.17	.52	-.29
P2O5	.92	-.26		-.18	-.12
Nickel	-.71	.39	.14	.52	
Chrome	-.51	.54		.55	
Scandium	.93	-.16		-.21	
Vanadium	.9	-.29		-.26	
Barium	-.27	.24	.65	.16	.49
Rubidium	-.67	.28	.28	.58	
Strontium	.21	-.11	.17	.11	.89
Zirconium		.92	.2		-.1
Yttrium	.83	.34			-.25
Niobium		.53	.11	.64	
Gallium	.7	-.36		.35	
Copper	.1	.11	.92		.13
Zinc	.61		.77		
Lead	-.15	.4	.81	.2	
Lanthanum	-.19	.74		.18	.2
Cerium	-.32	.85		.22	-.14
Thorium	-.45	.66		.49	-.15

* BLANK ENTRIES < 0.1

Table 4G. XRF Data Factor Analysis--Oblique Solution.

Oblique Solution Reference Structure-Orthotran/Varimax *

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
SiO2	-.81		-.15	-.2	-.17
TiO2	.71				
Al2O3	.16			.74	.14
FeO	.72				
MnO	.73		.12		
MgO	.79	.12			.16
CaO	.69				.3
Na2O	.18	-.2	-.27	-.24	
K2O	-.42	-.15	.15	.41	-.29
P2O5	.72				-.16
Nickel	-.38	.13		.34	
Chrome	-.15	.31		.37	
Scandium	.74				
Vanadium	.66				
Barium	-.2	.1	.56		.45
Rubidium	-.35		.21	.42	
Strontium	.11				.85
Zirconium	.22	.82	.11	-.14	
Yttrium	.89	.41		.14	-.27
Niobium	.31	.35		.52	
Gallium	.65	-.31		.49	-.11
Copper			.89	-.11	
Zinc	.5	-.1	.76		
Lead		.19	.75		-.11
Lanthanum		.55			.23
Cerium		.69			-.1
Thorium		.43		.31	-.12

Zr, Y
Nb

* BLANK ENTRIES < 0.1

Table 4H. XRF Data Factor Analysis--Primary Intercorrelations.

Primary Intercorrelations-Orthotran/Varimax

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
Factor 1	1				
Factor 2	-.55	1			
Factor 3	-.1	.29	1		
Factor 4	-.56	.57	.23	1	
Factor 5	.17	-.15	.14	-1.53E-2	1

9 2 1 2 6 8 1 9 3 0

Table 4I. XRF Data Factor Analysis--Variable Complexity.

Variable Complexity-Orthotran/Varimax

	Orthogonal	Oblique
SiO2	1.25	1.23
TiO2	1.28	1.03
Al2O3	1.16	1.17
FeO	1.23	1.03
MnO	1.19	1.06
MgO	1.11	1.11
CaO	1.41	1.27
Na2O	3.87	3.83
K2O	2.49	3.02
P2O5	1.27	1.1
Nickel	2.56	2.29
Chrome	3.05	2.37
Scandium	1.18	1.03
Vanadium	1.41	1.06
Barium	2.71	2.43
Rubidium	2.75	2.34

	Orthogonal	Oblique
Strontium	1.25	1.11
Zirconium	1.13	1.24
Yttrium	1.55	1.64
Niobium	2	2.49
Gallium	2.02	2.46
Copper	1.1	1.07
Zinc	1.94	2.02
Lead	1.69	1.27
Lanthanum	1.41	1.18
Cerium	1.51	1.03
Thorium	2.83	1.96
Average	1.79	1.66

Table 5A. Leachate Data Factor Analysis--Summary Information.

Summary Information

Factor Procedure	Principal Component Analysis
Extraction Rule	Method Default
Transformation Method	Orthotran/Varimax
Number of Factors	6

Note: 18 cases deleted with missing values.
101 case retained.

9 2 1 2 , 8 1 9 3 2

Table 5B. Leachate Data Factor Analysis--Variable Sampling Adequacy.

Measures of Variable Sampling Adequacy

Total matrix sampling adequacy: .811

ALUMINUM	.833	ZINC	.919
ARSENIC	.775	ALKALINITY	.575
BARIUM	.878	SILICON	.149
BERYLLIUM	.886	FLUORINE	.747
CALCIUM	.463	CHLORINE	.715
CHROMIUM	.765	SO4	.823
COLBALT	.793		
COPPER	.929		
IRON	.821		
LEAD	.881		
MAGNESIUM	.93		
MANGANESE	.877		
NICKEL	.792		
POTASSIUM	.813		
SODIUM	.514		
VANADIUM	.781		

Bartlett Test of Sphericity- DF: 252 Chi Square: 2424.709 P: 1.0000E-4

Table 5C. Leachate Data Factor Analysis--Communality Summary.

Communality Summary

	SMC	Final Estimate
ALUMINUM	.957	.924
ARSENIC	.754	.776
BARIUM	.661	.563
BERYLLIUM	.927	.911
CALCIUM	.612	.881
CHROMIUM	.934	.859
COLBALT	.968	.951
COPPER	.737	.783
IRON	.972	.967
LEAD	.621	.685
MAGNESIUM	.82	.802
MANGANESE	.737	.706
NICKEL	.901	.788
POTASSIUM	.864	.787
SODIUM	.729	.827
VANADIUM	.928	.895

	SMC	Final Estimate
ZINC	.636	.659
ALKALINITY	.588	.832
SILICON	.211	.869
FLUORINE	.569	.553
CHLORINE	.692	.735
SO4	.64	.82

Table 5D. Leachate Data Factor Analysis--Proportionate Variance Contributions.

Proportionate Variance Contributions

	Orthogonal	Oblique		
	Direct	Direct	Joint	Total
Factor 1	.341	.321	-1.521E-3	.319
Factor 2	.28	.31	-2.713E-3	.307
Factor 3	.097	.101	-6.1530E-5	.101
Factor 4	.111	.109	-6.876E-3	.102
Factor 5	.111	.106	1.941E-3	.108
Factor 6	.06	.062	6.3880E-5	.062

9 2 1 1 2 0 8 1 9 3 5

Table 5E. Leachate Data Factor Analysis--Correlation Matrix. (sheet 1 of 2)

CORRELATION MATRIX
LEACHATE ANALYSIS
HANFORD VADOSE ZONE RANDOM SAMPLES

	ALUMINUM	ARSENIC	BARIUM	BERYLLIUM	CALCIUM	CHROMIUM	COLBALT	COPPER	IRON	LEAD	MAGNESIUM
ALUMINUM	1										
ARSENIC	0.629	1									
BARIUM	0.626	0.295	1								
BERYLLIUM	0.571	0.346	0.647	1							
CALCIUM	0.092	0.109	0.05	0.034	1						
CHROMIUM	0.799	0.514	0.312	0.129	0.048	1					
COLBALT	0.192	0.09	0.407	0.816	-0.139	-0.176	1				
COPPER	0.738	0.429	0.493	0.607	0.104	0.555	0.34	1			
IRON	0.209	0.095	0.416	0.842	-0.165	-0.171	0.969	0.338	1		
LEAD	0.634	0.679	0.36	0.313	-0.053	0.52	0.072	0.486	0.063	1	
MAGNESIUM	0.823	0.641	0.48	0.546	0.089	0.644	0.309	0.682	0.286	0.556	1
MANGANESE	0.454	0.252	0.575	0.657	-0.174	0.138	0.698	0.36	0.663	0.255	0.497
NICKEL	0.775	0.478	0.374	0.297	0.021	0.893	0.063	0.671	0.03	0.507	0.713
POTASSIUM	0.816	0.551	0.521	0.372	-0.055	0.6	0.071	0.474	0.059	0.629	0.708
SODIUM	0.203	0.138	0.206	0.154	0.011	0.05	0.13	0.126	0.088	0.136	0.345
VANADIUM	-0.107	-0.14	0.213	0.609	-0.134	-0.4	0.884	0.037	0.882	-0.169	2.8E-3
ZINC	0.338	0.242	0.433	0.713	-0.065	0.084	0.684	0.414	0.716	0.221	0.361
ALKALINITY	0.148	0.232	0.082	0.023	0.663	0.101	-0.108	0.066	-0.168	0.087	0.244
SILICON	-0.032	-0.109	-0.056	-6.6E-3	-0.074	-0.018	0.053	0.058	0.047	0.041	0.01
FLUORINE	0.477	0.277	0.197	0.427	0.042	0.363	0.226	0.53	0.244	0.301	0.439
CHLORINE	0.421	0.574	0.3	0.224	0.05	0.293	0.094	0.3	0.062	0.403	0.48
SO4	0.525	0.163	0.476	0.452	0.056	0.293	0.221	0.547	0.217	0.278	0.467

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Table 5E. Leachate Data Factor Analysis--Correlation Matrix. (sheet 2 of 2)

CORRELATION MATRIX
LEACHATE ANALYSIS
HANFORD VADOSE ZONE RANDOM SAMPLES

	MANGANESE	NICKEL	POTASSIUM	SODIUM	VANADIUM	ZINC	ALKALINITY	SILICON	FLUORINE	CHLORINE	SO4
MANGANESE	1										
NICKEL	0.266	1									
POTASSIUM	0.415	0.541	1								
SODIUM	0.249	0.101	0.439	1							
VANADIUM	0.528	-0.208	-0.182	0.143	1						
ZINC	0.422	0.229	0.198	0.026	0.541	1					
ALKALINITY	3.6E-4	0.076	0.172	0.247	-0.15	-0.081	1				
SILICON	-0.103	0.017	-0.09	-0.057	-0.021	5.0E-4	-0.057	1			
FLUORINE	0.204	0.358	0.305	0.111	0.048	0.216	0.018	-1.4E-3	1		
CHLORINE	0.306	0.264	0.518	0.574	-0.052	0.095	0.194	-0.073	0.378	1	
SO4	0.274	0.378	0.461	0.471	0.048	0.208	0.078	-0.053	0.503	0.343	1

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Table 5F. Leachate Data Factor Analysis--Orthogonal Solution.

Orthogonal Transformation Solution-Varimax

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6
ALUMINUM	.879	.15			.338	
ARSENIC	.807		.146	.209	-.231	
BARIUM	.471	.458		.13	.246	-.23
BERYLLIUM	.373	.832			.271	
CALCIUM			.922		.105	
CHROMIUM	.836	-.254		-.104	.282	
COLBALT		.966				
COPPER	.638	.275			.532	
IRON		.972				
LEAD	.79			.169		.139
MAGNESIUM	.79	.236	.115	.222	.243	
MANGANESE	.341	.693	-.121	.246		-.187
NICKEL	.804			-.121	.349	
POTASSIUM	.748			.426	.145	-.14
SODIUM				.876	.207	
VANADIUM	-.271	.903				
ZINC	.288	.743		-.138		
ALKALINITY	.154		.867	.213		
SILICON						.927
FLUORINE	.321	.145			.631	.143
CHLORINE	.434			.732		
SO4	.243	.157		.366	.77	

9 2 1 2 6 8 1 9 3 8

Table 5G. Leachate Data Factor Analysis--Oblique Solution.

Oblique Solution Reference Structure-Orthotran/Varimax

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6
ALUMINUM	.713				.241	
ARSENIC	.775		.162	.172	-.318	
BARIUM	.273	.37			.166	-.232
BERYLLIUM	.111	.759			.175	
CALCIUM			.926	-.151	.105	
CHROMIUM	.792	-.349		-.15	.222	
COLBALT	-.179	.94				
COPPER	.433	.168		-.137	.45	
IRON	-.179	.948	-.1			
LEAD	.748			.145	-.157	.131
MAGNESIUM	.618	.12	.123	.156	.143	
MANGANESE	.148	.627	-.141	.198		-.193
NICKEL	.705	-.143		-.175	.278	
POTASSIUM	.626			.373		-.145
SODIUM	-.108			.847	.17	
VANADIUM	-.444	.915	-.076			
ZINC	.117	.713		-.178		
ALKALINITY	.124	-.109	.853	.158		
SILICON						.925
FLUORINE	.126				.582	.145
CHLORINE	.321			.702		
SO4				.298	.721	

9 2 1 2 5 8 1 9 3 9

Table 5H. Leachate Data Factor Analysis--Primary Intercorrelations.

Primary Intercorrelations-Orthotran/Varimax

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6
Factor 1	1					
Factor 2	.355	1				
Factor 3	.021	.03	1			
Factor 4	.204	.182	.147	1		
Factor 5	.372	.274	.037	.163	1	
Factor 6	-.039	-.038	-.057	-.081	-.024	1

9 2 1 2 6 8 1 9 0

Table 5I. Leachate Data Factor Analysis--Variable Complexity.

Variable Complexity-Orthotran/Varimax

	Orthogonal	Oblique
ALUMINUM	1.396	1.248
ARSENIC	1.403	1.486
BARIUM	3.181	3.11
BERYLLIUM	1.651	1.181
CALCIUM	1.073	1.112
CHROMIUM	1.476	1.6
COLBALT	1.041	1.099
COPPER	2.442	2.595
IRON	1.05	1.109
LEAD	1.198	1.219
MAGNESIUM	1.618	1.369
MANGANESE	2.004	1.625
NICKEL	1.433	1.492
POTASSIUM	1.784	1.757
SODIUM	1.157	1.13
VANADIUM	1.196	1.508

	Orthogonal	Oblique
ZINC	1.395	1.182
ALKALINITY	1.22	1.188
SILICON	1.024	1.011
FLUORINE	1.794	1.239
CHLORINE	1.673	1.507
SO4	1.801	1.339
Average	1.546	1.459

ESTIMATE OF LAB BIAS
95% DOUBLE SIDED CONFIDENCE LIMITS
ON ETA

ANALYTE	S-CUBED ETA ppm	UPPER/LOWER 95% CONFIDENCE BOUNDS ppm	DATACHEM ETA ppm	UPPER/LOWER 95% CONFIDENC BOUNDS ppm	NUMBER OF SPLITS S-3/ DC	BIAS ppm
Aluminum	9874	11815 7983	10814	13197 8542	17 / 17	*
Calcium	11013	13923 8342	10604	13192 8185	17 / 17	*
Copper	17.4	20.1 14.7	18.5	21.5 15.5	17 / 17	*
Iron	24989	27641 22174	26959	31047 22805	17 / 17	*
Lead	7.9	9.8 6.2	6.1	8.1 4.4	17 / 17	1.7
Sodium	360	431 291	423	494 350	17 / 14	65 +

* BIAS NOT STATISTICALLY SIGNIFICANT
\+ DECISION FOR BIAS IS MARGINAL

Table 6. Estimate of Lab Bias.

Table 7. Weibull Distribution Parameters.

WEIBULL DISTRIBUTION PARAMETERS

ANALYTE	TRUNCATION VALUE* ppm	to ppm	ETA η ppm	BETA β	N**	CRITICAL R	R	THRESHOLD VALUE ppm	LOQ
ALUMINUM	0	3763	4987	1.61	119	0.976	0.991	15100	542
CALCIUM	5600	4646	5869	1.22	107	0.975	0.998	22000	206
COPPER	13	12.4	3	0.695	84	0.970	0.997	32.2	4
IRON	0	10996	15385	2.31	119	0.976	0.991	38200	318
LEAD	3.3	2.99	3.5	1.05	110	0.974	0.997	15.4	N/A
SODIUM #	190	122	211	1.86	76	0.969	0.998		
	380	122	181	0.855	28	0.942	0.968	974	167

* Based on scatter of data at low end of distribution

** Number of samples above truncation value + 1

\# Multiple distributions identified in the data set

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