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Soil Background for Interim Use at the Hanford Site

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Contractor for the U.S. Department of Energy
under Contract DE-AC06-08RL14788

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Environmental Calculation Cover Page

Part 1: Completed by the Responsible Manager

Project: Site-wide Application

Date: September 1, 2011

Calculation Title & Description: Soil Background for Interim Use at the Hanford Site

Preparer: J.D. Hoover	**Basis of Qualification:** Hanford Site Background Technical Expert
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Executive Summary

Existing Hanford Site soil background (HSB) documents provide site-wide background data for 30 nonradioactive analytes, 13 anthropogenic radionuclides, and six (6) naturally occurring vadose zone radionuclides (summarized in Appendix A and Appendix B) that continue to be adequate for most risk assessment applications. However, soil background data are needed for nine (9) additional nonradioactive analytes that have little or no data above detection in the Hanford Site soil background (HSB) data set to support risk-based screening and assessment of soil contamination in environmental restoration and remediation projects at the Hanford Site. These analytes include antimony (Sb), cadmium (Cd), lithium (Li), mercury (Hg), molybdenum(Mo), selenium (Se), silver (Ag), and thallium (Tl), and Boron, and are collectively referred to here as the "data gap" or gap analytes. These gap analytes are especially important in evaluation of ecological risks, and the protection of groundwater and/or surface water, because these exposure pathways can potentially drive risk assessments and remedial actions. The gap analytes are also important because the screening levels for these pathways can extend to concentrations in the range of background. Provisional background data for these gap analytes are needed to support and facilitate progress in environmental restoration and remediation activities until new background data are available in the revision and update of the Hanford Site soil background (HSB) data set.

The purpose of this Environmental Calculation is to evaluate and recommend provisional background data for the gap analytes from existing published background data sources, and to also document issues associated with the use of these data. Four sets of soil background data for nonradioactive analytes (e.g., metals) generated after publication of the HSB data are evaluated here, as candidates for provisional background on the gap analytes. The four data sets include soil background data for Washington State (State), Hanford Site soil data from Multi-Incremental Sampling of upland and riparian locations, and two soil background data sets reported by Pacific Northwest National Laboratory (PNNL) in conjunction with the Hanford Site environmental surveillance program. Based on the evaluation of these data against the provisional soil background acceptance criteria, one of the PNNL data sets (GEL data) is recommended as provisional background for all of the gap analytes except for Se. The Washington statewide background data for Se are recommended as the provisional background for this analyte. Table ES-1 is a summary of the statistical characteristic concentrations of these data that are recommended as provisional[1] background for the gap analytes.

Table ES-1. Summary of Recommended Provisional Soil Background Data for the "Gap" Analytes[a]

Analyte	CAS Number	Statistical Characteristic Concentrations (mg/kg)			
		Mean	50^{th} Percentile	90^{th} Percentile	Maximum
Antimony	7440-36-0	0.113	0.100	0.130	0.385
Boron	7440-42-8	2.25	2.09	3.89	5.86
Cadmium	7440-43-9	0.422	0.366	0.563	2.98
Lithium	7439-93-2	9.29	8.62	13.3	19.2
Mercury	7439-97-6	0.00608	0.00400	0.0131	0.0292
Molybdenum	7439-98-7	0.364	0.318	0.470	3.17
Selenium	7782-49-2	0.57	0.56	0.78	0.840

[1] "Provisional" data is not to be used for final RODs / site closure activities. Provisional data will be replaced with final background data currently under development.

Table ES-1. Summary of Recommended Provisional Soil Background Data for the "Gap" Analytes[a]

Analyte	CAS Number	Statistical Characteristic Concentrations (mg/kg)			
		Mean	50th Percentile	90th Percentile	Maximum
Silver	7440-22-4	0.118	0.109	0.167	0.273
Thallium	7440-28-0	0.129	0.118	0.185	0.523

[a] Percentiles are calculated nonparametric values (Kaplan-Meier) for all analytes except for Se. Values for Se are State values from San Juan, 1994.

Caveats and issues associated with the use of these data as provisional background at the Hanford Site include the following:

1. The data represent topsoil background compositions, which comprise a small part of the vadose zone soil.
2. The overall composition of this topsoil tends to be biased toward concentrations lower than those of HSB data (vadose zone) population for most analytes.
3. The concentrations of the gap analytes may also be biased toward lower values compared to those of the HSB population.

These provisional soil background data for the gap analytes have not been approved by the U.S. Department of Energy or the regulatory agencies for final regulatory compliance documentation. These data should, therefore, be used only to support and facilitate progress in environmental restoration and remediation activities in the interim until new data associated with revision and update of the HSB documents are available.

The main technical issue associated with the use of the provisional soil background data concerns the extent to which these data address the needs for the conduct of risk-based screening. Risk-based screening involves comparison of soil data to the larger of background or risk-based screening levels (RBSLs). But data cannot be screened if the soil data detection limit is larger than the screening metrics because no data above detection can be screened out.

The potential significance of this issue was evaluated by comparing the relative magnitudes of: (1) the provisional background levels, (2) routinely obtainable method detection limits (MDLs), and (3) RBSLs, to determine the extent to which the provisional background data on the gap analytes meet risk screening needs. Ecological soil screening levels (EcoSSLs) were used as RBSLs in the context of risk-driver values for the purposes of the comparison. The results of this comparison are summarized in Table ES-2, with determinant screening values and criteria highlighted in green and equivocal values and criteria highlighted in orange.

All of the gap analytes in the provisional background data other than Sb and possibly B should be conducive to screening soil data against current ecological screening levels and/or the provisional background data because the ecological screening levels are larger than both the background and MDLs for five of the gap analytes (Li, Hg, Mo, Ag, and Tl). The provisional background levels appear to be a determinant (largest) screening criterion for only two of the gap analytes (Cd and Se) because background data are only effective screening criteria if a majority of the data are above the detection limits of the soil samples to which they are compared. The ability for Sb and B to be screened is equivocal because the MDLs of the soil data are ≥ provisional background levels and/or ecological soil screening levels for these two analytes.

Most of these conclusions appear to be largely corroborated by preliminary data from the analysis of a subset of the original HSB samples. It is also indicated that a majority of soil data on the analyses of uncontaminated soil samples (including archived background samples) may not be detectable above detection for as many as five of the gap analytes (Sb, Cd, Hg, and Ag, and possibly Tl), with equivocal results for B. Although the detectability of background for Cd, Li, Hg, Se, Ag, and Tl in new background data is presently secondary to the magnitude of the protectiveness metrics for ecological risk screening, these relationships do not imply that background data (above detection) for the gap analytes are not important or needed for characterizing and defining baseline risk. Protectiveness and/or screening levels are subject to change, and protectiveness metrics for other pathways/receptors (e.g., river and/or groundwater protection) that have yet to be established, and can become the risk drivers. Efforts to obtain new background data above detection should be optimized because the intrinsic background levels are the only criteria that serve as the fundamental basis for defining baseline risk and protectiveness, that are not subject to change.

Table ES-2. Comparison of Provisional Background, Ecological Soil Screening Levels, and Laboratory Detection Limits (MDLs) for the Gap Analytes

Gap Analyte	Soil Concentration (mg/kg)			Screening Criteria: Largest of EcoSSL, MDL, Background Values
	Ecological Soil Screening Levels (EcoSSLs)	Routinely Achievable Detection Limit (MDL)[a]	Provisional Soil Background Data (P-Bkgr); 50th Percentile Values	
Sb	0.27	0.3	0.10	None?: EcoSSL ≈ MDL>P-Bkgr
B	0.50	4.1	2.1	None?: MDL > P-Bkgr ?
Cd	0.36	0.1	0.37	EcoSSL ≈ P-Bkgr
Li	35	0.4	8.6	EcoSSL
Hg	0.10	0.05	0.0040	EcoSSL
Mo	2.0	0.1	0.32	EcoSSL
Se	0.30	0.3	0.53	P-Bkgr
Ag	2.0	0.1	0.11	EcoSSL
Tl	1.00	0.1	0.12	EcoSSL

a. Lowest overall MDL value routinely obtainable at the Hanford WSCF laboratory (2010)

b. Based on preliminary results of analyses of archived background samples from the HSB study (DOE/RL 92-24)

Determinant screening values and criteria (green)

Equivocal screening values and criteria (orange)

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Terms

BL	background level
CAS	chemical abstract service
COPC	contaminants of potential concern
CVAA	cold vapor atomic absorption
DL	detection limit
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
FS	feasibility study
HRNM	Hanford Reach National Monument
HSB	Hanford Site soil background
MDL	method detection limit
MIS	Multi-Incremental Sampling
PL	protection levels
PNNL	Pacific Northwest National Laboratory
RI	remedial investigation
SME	subject matter expert
UCL	Upper Confidence Level
WDOH	Washington Department of Health
WSCF	Waste Site Characterization Facility

1 Purpose

The purpose of this environmental calculation is to identify soil background data that can be used in evaluations of risk to human health and screening contaminants of potential concern (COPCs) in soils at the Hanford Site. The primary focus of this environmental calculation involves the evaluation and recommendation of soil data for use as provisional background for nonradioactive analytes not measured or adequately detected in the Hanford Site background (HSB) data, referred to here as data “gap” analytes. Provisional soil background data for the gap analytes are needed to provide an improved basis for risk assessment applications and COPC screening to support and facilitate progress in environmental restoration and remediation activities in the interim until new data on the gap analytes are available in an upcoming revision and update of the Hanford Site soil background (HSB) data set. It is emphasized that these recommended provisional background data have not been approved by the U.S. Department of Energy (DOE) or the regulatory agencies for final regulatory compliance documentation. Summaries of the statistical characteristics of the existing non-radiological and radionuclide data that continue to be appropriate for use as Hanford Site soil background data are also provided in Appendix A and Appendix B for completeness.

2 Technical Background on Hanford Site Soil Background Data

The HSB data sets for nonradioactive analytes, and for radionuclides, have generally been regarded as adequate for human health risk assessment efforts for the past 15 to 20 years since publication of the Hanford Site background documents (e.g., DOE/RL-92-24; DOE/RL-96-12). However, useful background data for a number of nonradiological analytes have not been available because they were either not detectable in a sufficient number of the 104 Hanford Site systematic random soil background samples, or were not measured in the original characterization of soil background. Less than 7% of the data are above detection for antimony (Sb), cadmium (Cd), lithium (Li), and thallium (Tl), molybdenum (Mo), selenium (Se), and silver (Ag), and only 18% are above detection for mercury (Hg). These analytes are collectively referred to in this document as the gap analytes. There is also no soil background data for boron (B) because it was not measured in the original characterization of soil background, and is included here as a gap analyte.

The absence of data above detection limits for the gap analytes was not previously problematic because the levels protective of human health are generally well above the detection limits (DLs) of these analytes, and risk contributions from boron were not considered to be significant. However, many of these analytes have since become important in the risk assessment processes at the Hanford Site because protection levels for risk driver pathways (e.g., ecological) for these analytes can extend to concentrations below background levels. Thus, there has been a renewed interest in re-visiting the determination of the background levels for these analytes, because statistical information from data sets are not reliable or conducive to the use of parametric methods when the percentage of non-detects is high (e.g., >40%-50%) (EPA/600/R-07/041). All cationic analytes in the HSB data set have ≥ 80% of the data above detection except for these gap analytes, which have 0% to 18% of data above detection. These data gaps are also notable because data for these gap analytes with lower detection limits have since been reported for soils that are part of the Hanford Site background population. The issue of how best to address these data shortcomings and data gaps is underway, but will not be resolved in the timeframe needed to conduct COPC screening and preliminary risk assessment applications for some projects. Thus, other existing data on soil background are evaluated in this document to identify data may be acceptable as provisional background values for the gap analytes.

3 Methodology

The following methodology was used in the identification of soil background data appropriate for environmental applications at the Hanford Site, and for the evaluation of gap analyte data for use as provisional soil background:

1. Utilize the existing Hanford Site soil background data as the primary sources of soil background values for radionuclides and most nonradiological analytes.
2. Evaluate nonradiological soil background data generated after publication of the HSB documents for consideration as provisional soil background for the gap analytes based on acceptance criteria described in this section.
3. Also evaluate provisional background data in the context of their ability to meet the objective of providing an improved basis for risk assessment screening.

4 Assumptions and Inputs

The criteria and assumptions described in this section were used in the evaluation of soil background values to be considered as provisional soil background for interim use in environmental restoration and remediation activities at the Hanford Site. The assumptions include key aspects of the conceptual model associated with justification for the criteria and scale for characterization of soil background for the Hanford Site. Both the evaluation criteria and assumptions associated with the conceptual model are excerpted from the HSB documentation identified in Section 4.3.

4.1 Evaluation Criteria

The main criteria for evaluation and acceptance of soil data as background are summarized in Table 1. These criteria involve primarily involve components of representativeness, comparability, and completeness of the data that are used in the evaluation of the soil data considered for provisional background for the nonradiological gap analytes described in Section 6.2.

Table 1. Evaluation/Acceptance Criteria for Soil Background: Nonradiological Analytes

1. Sample location (representativeness):			
	a. Background samples from locations uncontaminated (e.g., by Hanford Site operations)		
	b. Locations acknowledged as acceptable background locations by the Tri-Parties		
	c. Sampling locations (and coverage) representative of the types and range of soils that occur naturally at the Hanford Site		
2. Representativeness and Comparability of Samples and Data:			
	a. Acceptable sample number		
	b. Appropriate sample preparation methods		
		i. Acceptable sampling methods/procedures	
		ii. Sample preparation and analysis conducted in accordance with, or sufficiently comparable to EPA methods and protocols prescribed for environmental regulatory applications (e.g., SW-846 methods)	
			• Physical preparation: Sieve recovery of < 2 mm-diameter sample material
			• Chemical preparation: Sample dissolution (partial) in acids/peroxide (consistent with/comparable to SW-846 methods) to produce leachate solution
	c. Appropriate analytical methods (e.g., consistent with SW-846 methods): Compositions determined from		

Table 1. Evaluation/Acceptance Criteria for Soil Background: Nonradiological Analytes

	acid leachate solution (extractable metal/analyte compositions) (vs. bulk compositions)
	d. Acceptable analytes list (includes all gap analytes?)
3. Other aspects of data quality:	
	a. Acceptable sample handling (chain of custody, holding times, etc.)
	b. Acceptable levels of detection
	c. Acceptable proportion of data above detection limits

4.2 Assumptions/Conceptual Model: Soil Background for Nonradiological Analytes

The following are the main assumptions and features associated with the conceptual model for nonradiological soil background at the Hanford Site:

1. The compositions of the HSB samples (for the vadose zone) comprise a population of concentrations for each analyte.
2. The population of soil background concentrations are related by the geologic processes associated with the origin and deposition of the sediments as cataclysmic flood deposits (Hanford formation).
3. The composition of the HSB samples is primarily an admixture of basaltic and quartzo-feldspathic components in various proportions.
4. The range of compositions in the soil background population is most appropriately characterized on the scale of the phenomenon associated with their origin and associated deposition processes (cataclysmic flood deposits), which for the Hanford Site, is on the scale of the Site, and/or the Pasco Basin.
5. The range of soil background compositions is dominated by the population of the vadose zone sediments, and also includes the sub-population of surface and near-surface sediments (e.g., topsoils), and other subordinate soil types (e.g., volcanic ashes, floral ecosystem soils, etc.).
6. The surface and near-surface sediments and topsoils primarily represent reworked vadose zone sediments, sorted/fractionated, and/or modified by surficial processes (e.g., eolian process, pedogenesis, bioaccumulation, etc.); and the physical and chemical composition of the population of surficial sediment compositions reflect the effects of these processes.
7. Digestate concentrations for many analytes vary inversely with particle (grain) size (i.e., samples with smaller grain size yield larger digestate concentrations due to greater effective surface area available for reaction with acidic solvents).

The following are the additional factors associated with evaluation of topsoil data generated since publication of the HSB documents as provisional background data for selected gap analytes:

- Topsoil and near-surface soils represent a population of analyte concentrations that are a subset of, and/or a population related to, the HSB data.
- The newer topsoil data are comparable to the HSB compositions.
- The newer topsoil data have significantly lower detection limits for the gap analytes.

- These newer data have significantly higher proportions of measured values above detection limits for the gap analytes.

The primary assumptions associated with the potential use of topsoil data as provisional background for the gap analytes is that the use of these data is reasonable, provided that the data are not inexplicably biased high compared to the HSB values.

4.3 Inputs

The data and information from the following sources were used as inputs in the evaluation of provisional soil background values for the gap analytes:

1. Hanford Site Background: Part 1, Soil Background for Nonradioactive Analytes (DOE/RL-92-24)
2. Washington State Department of Ecology, 1994. Natural Background Soil Metals Concentrations in Washington State, Publication 94-115.
3. PNNL, 2009. A Review of Metal Concentrations Measured in Surface Soil Samples Collected On and Around the Hanford Site. Fritz, BG., July 2009. PNNL-18577
4. Multi-Incremental Sampling Data from the 100 Area and 300 Areas of the Hanford Site (WCH 2006; WCH-2008)
    a. WCH-139, 2006, 100 Area and 300 Area Component of the River Corridor Baseline Risk Assessment Spring 2006 Data Compilation, Washington Closure Hanford, Richland, Washington.
    b. WCH-Interoffice Memoradum-139773, 2008, Multi-Incremental Sampling Performance Assessment report, Washington Closure Hanford, Richland, Washington.

Data and information from the following reports were used as inputs for the summary tables of existing soil background data for the nonradioactive analytes and radionuclides in Appendix A and Appendix B that continue to be appropriate for use at the Hanford Site:

1. Hanford Site Background: Part 1, Soil Background for Nonradioactive Analytes (DOE/RL-92-24)
2. Hanford Site Background: Evaluation of Existing Soil Radionuclides Data (DOE/RL-95-55)
3. Hanford Site Background: Part 2, Soil Background for Radionuclides (DOE/RL-96-12)

5 Software Applications

JMP® software was used to calculate statistical parameters for the various data sets. These calculations were performed on computer PX18975 using JMP version 8, HISI registration number 2692. The HISI registration entry also provides the IDMS Links to the JMP V&V documentation. Microsoft Office Excel 2007® software was used to construct summary tables and figures of soil background data. Excel™ is a "Site Licensed Client Software" and is exempt from formal control requirements of PRC-PRO-IRM-309 (2009), Controlled Software Management.

6 Calculation/Methodology Implementation

Implementation of the methodology described in Section 2 primarily involves qualitative and quantitative evaluations of soil background data sets using the criteria identified in Section 4.1. Few calculations are associated with these evaluations apart from simplistic comparisons of the data and the calculation of statistical characteristics for the provisional background data. The existing soil background data for the nonradioactive analytes and the existing radionuclide background data that should continue to be used for environmental remediation and restoration efforts at the Hanford Site are summarized in Appendix A and Appendix B. The evaluation of candidate data for consideration as provisional background for the gap analytes is presented in Section 6.2. A summary of the evaluation of the provisional background data in the context of its ability to provide an improved basis for COPC screening is presented in Section 6.4.

Statistical characteristics calculated for the data sets were performed using JMP statistical software as described in Section 5. Percentile values calculated for the provisional background data for the gap analytes in tables presented in this environmental calculation used a non-parametric calculation basis (Kaplan-Meier).

6.1 Soil Background Data for Nonradioactive Analytes Not Measured or Adequately Detected in the Hanford Site Background Data Set

Soil background data for the gap analytes were evaluated from data generated after publication of the Hanford Site background documents. This section describes the evaluation of candidate data for consideration as provisional background for the gap analytes following the methodology described Section 3.

The relevant sources of relevant soil background data that have been collected since DOE/RL-92-24 was first issued in 1992, include the report on the soil background levels within Washington State (San Juan, 1994), and two studies involving the determination of soil background levels in surface and near-surface soil in the vicinity of the Hanford Site (PNNL-18577; WCH-139). The evaluation of these data in the context of their potential usefulness as supplements to the HSB data, or provisional background levels for the “data gap” analytes, is described in the following sections. The evaluation includes a comparison of compositional characteristics of the Hanford Site background data, and data on the topsoil samples reported in PNNL-18577 and WCH-139 (MIS data) in the context of the criteria and conditions identified in Section 4.1. The evaluation includes comparisons of compositions of up to 22 non-radiological analytes in addition to the gap analytes. Tables 2 through 5 summarize the gap analyte data in these data sets. The results of this evaluation and calculated summary statistics for the recommended data for the gap analytes are presented in the following sections, and are summarized in Table 6 in the form of a checklist for the acceptability criteria identified in Table 1 of Section 4.1.

6.1.1 Washington State Background Values

The Washington State soil background data are based on the measurement of 490 samples from 166 sample locations that include regional soil background values for the entire state, values for the western and eastern sides of the state, and data sets for specific regions of the state, including samples from the Yakima and Spokane Basins. These data, particularly those from the eastern side of the state, and the Yakima and Spokane Basins have the greatest relevance to the HSB. Apart from location considerations, the data are comparable because both the HSB data and the state background data were obtained from samples collected, prepared, and analyzed using the same EPA protocols and methods. Based on comparison of the 90th percentile values, the soil metal concentrations for most analytes from eastern Washington locations are generally somewhat lower than the statewide values and those from western Washington locations. But the data for the eastern part of the state are largely comparable to the Hanford Site background data for most analytes. The value of this data set is that it includes some data above background for three of the data gap analytes, antimony, cadmium, and selenium. Two of the “data gap” analytes, Mo and Tl, were also largely not detected in the Washington State background data. Boron and lithium were not included as a measured analytes in this data set.

Although these data are not strictly site-specific to the region of the Hanford Site, the eastern Washington data are representative of adjacent and nearby regions that have soil background levels with greater similarities to each other, than to western Washington or overall Washington State background levels. A summary of the Washington State soil background data primarily from the Yakima Basin is provided in Table 2 for the gap analytes. The only Washington State background data reported for Sb, Se, and Ag, however, are statewide data. Table 6 provides a summary of the evaluation of these data against the provisional background acceptance criteria identified in Table 1.

Table 2. Washington State Soil Background Data: Summary Statistics for the Gap Analytes[a]

Analyte	CAS Number	No. Samples > MDL	Detection Limit (MDL)	Mean	50^{th} Percentile	90^{th} Percentile	Maximum Value
			Concentration (mg/kg)				
Antimony[b]	7440-36-0	50	3	4.1	4.02	5.2	7.6
Boron	7440-42-8	---	---	---	---	---	
Cadmium	7440-43-9	32	0.2-0.8	0.55	0.49	0.93	1.33
Lithium	7439-93-2	---	---	---	---	---	---
Mercury	7439-97-6	32	0.006	0.03	0.02	0.05	0.117
Molybdenum	7439-98-7	---	---	---	---	---	---
Selenium[b]	7782-49-2	14	5-15	0.57	0.56	0.78	0.84
Silver[b]	7440-22-4	33	0.3	0.43	0.41	0.61	0.75
Thallium	7440-28-0	0	5	< MDL	---	---	---

a. Summary statistics are from San Juan (1994). Data are for the Yakima Basin, except where otherwise noted

b. Based on statewide data (no regional data available)

6.1.2 MIS Soil Background Data

The Multi-Increment Sampling (MIS) data on nonradioactive analytes derives from 98 soil samples collected from upland and riparian sample locations at the Hanford Site to provide reference data in support of the River Corridor Baseline Risk Assessment (WCH-139). The soil data reported in WCH-139 include nonradioactive analyte concentrations for 33 analytes from 17 of the 34 discrete locations sampled. Up to 50 sub-samples were collected at each of the 17 locations from a systematic random grid with grid spacing of approximately 10 to 20 m (32 to 66 ft). At each of the 17 discrete locations, aliquots of the multiple sub-samples were physically composited and homogenized to provide 5 to 10 samples submitted for laboratory analysis from each sampling location. This sampling procedure is referred to as MIS. The analysis of the MIS samples was carried out in accordance with standard SW-846 methods.

These data have potential relevance to the evaluation of other sources of soil background information because they are site-specific, and include data on the analytes Sb, B, Cd, Mo, Se, and Tl. The main issues associated with the potential use of these data as a supplement to the HSB data, or as provisional background include the following:

1. All samples represent surficial samples (e.g., topsoil) only.
2. The sample locations were not selected to represent soil background sites, and have not been formally approved as background locations

3. The samples were not collected in accordance with EPA or Washington State guidelines for the determination of soil background
4. There are few data above detection for a third of the gap analytes (silver, thallium, and selenium)

The manner in which the MIS samples were collected is a significant issue because the MIS process effectively yields only one analysis per sampling area from the composite data. Thus, the 98 soil samples are effectively reduced to only 17 independent analyses (one per location) for evaluation and consideration as background. For most of the metal and non-metal analytes, only the calculated average concentrations from each of the 17 composite sample locations appear to be comparable to other soil background values discussed in this Section. However, sample location is also a significant issue. Although the selection of the MIS reference locations were approved by the Tri-Parties as areas uninfluenced by Hanford operations, the MIS sampling site locations have not undergone the same scrutiny and evaluation as the HSB samples, and have not formally been accepted as background locations by SMEs or the regulatory community. These sampling sites may ostensibly be background locations, but the absence of approval of the sampling sites as representative soil background locations acceptable to the regulatory agencies presently precludes this data set from consideration as a supplement to the Hanford Site background data set, or as provisional background data for the gap analytes based on the acceptance criteria outlined in Table 1. In addition, there are only 1%, 3%, and 6% of the MIS data above detection for silver, thallium, and selenium, respectively as shown in Table 3. These data are not completely adequate as candidates for provisional background for the gap analytes due to the lack of data above detection for a third of the gap analytes. Although this data set is not considered further here as a candidate for provisional background, the MIS data on the gap analytes (Table 3) are used in the evaluation for comparison of the relative magnitudes of these data to the gap analyte levels in the other data sets.

Table 3. MIS Data: Summary Statistics for the Gap Analytes

Analyte	CAS Number	Percentage of Samples > MDL	Detection Limit (MDL)	Mean	50th Percentile	90th Percentile	Maximum Value
			Concentration (mg/kg)				
Antimony	7440-36-0	12%	0.37-0.66	0.593	0.632	0.656	0.83
Boron	7440-42-8	95%	0.36	1.43	1.26	2.35	3.1
Cadmium	7440-43-9	63%	0.04-0.11	0.450	0.143	1.55	1.9
Lithium	7439-93-2	100%	< 4	8.81	9.00	11.7	13.8
Mercury	7439-97-6	46%	0.02	0.035	0.0249	0.075	0.113
Molybdenum	7439-98-7	63%	0.2-0.43	0.535	0.512	0.90	1.9
Selenium	7782-49-2	6%	0.2-0.7	0.671	0.698	0.81	1.2
Silver	7440-22-4	1%	0.07-0.22	---*	---*	---*	---
Thallium	7440-28-0	3%	0.34-1.0	0.940	1.0	1.03	1.1

* Meaningful statistical values cannot be calculated from data with only 1% of measurements above detection

6.1.3 PNNL Soil Background Data

Another source of newer soil background data are those reported by Fritz in 2009 (PNNL-18577) for up to 30 analytes from 158 topsoil samples collected in conjunction with the Hanford Site environmental surveillance program. These background data are evaluated in this document because they include analytical results on the gap analytes with significantly larger proportions of data above detection limits, and have lower detection limits than those associated with the DOE/RL-92-24 data, with the exception of selenium. The data are from 41 locations collected on and around the Hanford Site in 2008, and samples from 117 locations collected on the Hanford Reach National Monument (HRNM). The samples collected for these projects were drawn from locations centered around the Hanford Site, but the sampling locations ranged from Sunnyside, Washington, to the west; Walla Walla, Washington, to the east; as far north as George, Washington; and as far south as Umatilla, Oregon (Figure 1). Samples were collected in 2008 at established environmental monitoring locations (Bisping, 2008). The sampling and analysis plan prepared for the HRNM sampling effort provides detail about the methodology used to plan and conduct this soil sampling (Fritz et al., 2004; Fritz and Dirkes, 2005).

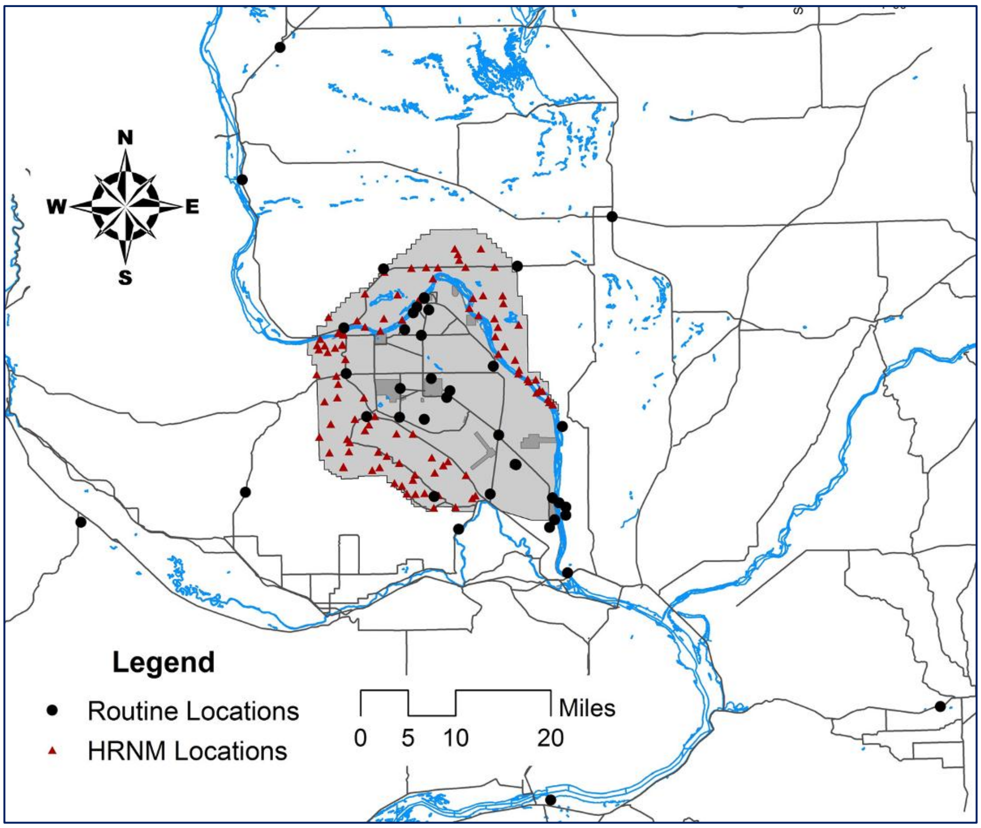

Figure 1. Locations of Soil Samples Collected in 2004, 2005, and 2008 and Analyzed for Metals in 2008. Shaded region is the Hanford Site.

The main issues associated with the acceptability of these data concern the comparability of the data to the HSB data, particularly in the context of sample type and sample preparation and analysis factors that include the following:

1. The acceptability of the samples and sampling locations as background
2. The comparability of samples (topsoil vs. vadose zone samples)

3. The comparability of data generated from samples prepared and analyzed using methods that differ in some aspects from those typically used in environmental cleanup activities (i.e., EPA SW-846 methods)
4. The comparability of the two data sets reported in PNNL-18577 to one another, and to the HSB data

The acceptability of the samples and sampling locations as background is a fundamental requirement for the consideration of soil data as representing background. This criterion is also typically one of the most stringent and demanding to demonstrate. But in the case of these PNNL data, the sampling sites were established environmental monitoring locations that have been sampled repeatedly for many years collected in conjunction with the Hanford Site environmental surveillance program (Poston et al., 2005). Moreover, these sampling locations were approved by the EPA and the Washington State Department of Ecology-Radiation Division, as acceptable for establishing the HSB levels for radionuclides (DOE/RL-95-55). Although these are not random or systematic sampling locations, they are appropriate for the characterization of soil background in the vicinity of the Hanford Site because they meet the necessary criteria for background sites.

The comparability of the data in terms of sample type is important because the PNNL data are exclusively surficial topsoil samples that comprise only a small part of the HSB data. Data from surficial (topsoil) samples are included in the systematic random HSB data set that represents all soil/sediment types in the vadose zone. Twelve topsoil samples are also included in the Focus (Judgment) sample data reported in DOE/RL-92-24. The composition of these topsoils are compared to the composition of the main population of HSB data and the other soil background data in Figure 2 and Figure 3 to evaluate the consistency and comparability of the two data sets reported in PNNL-18577.

The sample preparation issue concerns a deviation from the EPA SW-846 methodology typically used in environmental cleanup activities. Although the physical preparation of the PNNL samples for digestion and analysis included sieving using a 2 mm screen size, and drying in accordance with the SW-846 Methods (as were the samples in Hanford Site background report, the Washington State soil background study, and the MIS samples), the PNNL samples were also powdered using a ball mill to achieve a maximum particle size of 300 μm. The ball mill powdering of the PNNL samples is a potentially significant issue because this aspect of the physical preparation of the samples for analysis differs from the EPA SW-846 method which involves no physical size reduction of sample material other than sieving. The consequence of this deviation from the SW-846 methods is that the powdering of the samples can greatly increase the surface area of the soil material, which can increase the concentrations of extractable metals in the acid-based partial digestion leachate. Thus, where this factor is significant, the concentrations of most analytes for samples prepared in this manner could be biased in the direction of somewhat higher concentration levels than would otherwise result from samples that are not powdered, depending on the extent to which the increased surface area affects leachate concentrations.

The acid (partial) digestion/leaching procedures and analytical methods used are also significant factors. The PNNL data were obtained from samples analyzed at two different laboratories; one data set was obtained at the GEL Laboratories, LLC, (GEL data set), and the other data set was obtained from the PNNL Sequim, Washington, Marine Sciences Laboratory (MSL data set). The samples for the GEL data set were prepared using identified EPA methods largely comparable, though not identical to the SW-846 methods,[2] and analyzed using methods corresponding to those in the SW-846 guidelines. However, the MSL samples are reported as having been prepared using "modified" versions of EPA Methods 200.7 and 200.8 without further clarification of what the modifications involved. However, systematic differences

[2] Analytical methods involved EPA Method 6020 inductively coupled plasma-mass spectrometry (ICP-MS) and cold vapor atomic absorption (CVAA; EPA Method 7471) for mercury.

were observed in the measured concentrations of control samples included in both sample subsets. Both the control samples, and the overall concentrations measured in the MSL data set are consistently higher than those reported for the GEL data set. The MSL data were eliminated from the evaluation as a result of the uncertainty associated with the unspecified "modifications" to the EPA sample preparation methods for the MSL samples, which are presumed to the reason for the systematic differences in the control sample concentrations. Thus, only the data for the 158 samples in the GEL data set were further evaluated as candidates for provisional soil background data for the gap analytes (Table 4).

Table 4. PNNL GEL Data: Summary Statistics for the Gap Analytes*

Analyte	CAS Number	Percentage of Samples > MDL	Detection Limit (MDL)	Mean	50th Percentile	90th Percentile	Maximum Value
			Concentration (mg/kg)				
Antimony	7440-36-0	17%	0.10	0.113	0.100	0.130	0.385
Boron	7440-42-8	88%	0.8-4.5	2.25	2.09	3.89	5.86
Cadmium	7440-43-9	100%	0.02	0.422	0.366	0.563	2.98
Lithium	7439-93-2	100%	0.4-2.0	9.29	8.62	13.3	19.2
Mercury	7439-97-6	66%	0.004	0.00608	0.00400	0.0131	0.0292
Molybdenum	7439-98-7	100%	0.02	0.364	0.318	0.470	3.17
Selenium**	7782-49-2	1%	0.5	---	---	---	---
Silver	7440-22-4	100%	0.04	0.118	0.109	0.167	0.273
Thallium	7440-28-0	99%	0.05	0.129	0.118	0.185	0.523

* Percentiles are calculated nonparametric values (Kaplan-Meier)

** Meaningful statistical values cannot be calculated from data with only 1% of measurements above detection

6.1.4 Evaluation of PNNL GEL Data

The data reported in PNNL-18577 for the GEL data set listed in Attachment 1, and summarized in Table 4, include data for all of the gap analytes at levels above detection in most of the 158 analyzed samples, except for Se. A summary of gap analyte detection levels and percentages of the data above detection for the Hanford Site Background (systematic random) data, the PNNL-GEL data, and the MIS data are shown in Tables 5a, 5b, and 5c. Table 5a and Table 5b show the proportions of the data for the gap analytes above detection in the Hanford Site background data set and PNNL GEL data set. As shown in Table 5b, most of the gap analytes in the PNNL GEL data have 88% to 100% of the measured data values above detection. However, there are essentially no data (1%) for Se above detection. Although Sb and Hg were measured above detection in only 17% and 66% of the analyzed samples, respectively, these proportions of data above detection are significantly greater than those for both analytes in the Hanford Site background data set. It is also notable that the detection limits for the gap analytes in the PNNL GEL data set and the MIS data set (Table 5c) are both significantly lower than those achieved for these analytes in the Hanford Site background data set, and consequently yield more data above detection.

A fundamentally important criteria concerning the acceptability of the PNNL GEL data for the gap analytes as provisional background, is whether their overall compositions for other analytes are comparable to those of Hanford Site background and other background data from the region (e.g., no significant artificial bias toward higher concentrations). Twenty-one analytes in the PNNL GEL data set,

Table 5a. Hanford Site Background (Systematic Random) Data

Analyte	CAS Number[1]	No. Samples	No. Values > MDL	% Detected	MDL	Mean Concentration
					mg/kg	
Antimony	7440-36-0	104	4	4%	15.7	≤ MDL
Cadmium	7440-43-9	102	1	1%	0.66	≤ MDL
Lithium	7439-93-2	55	0	0%	34	≤ MDL
Mercury	7439-97-6	103	19	18%	0.16	0.26
Molybdenum	7439-98-7	68	3	4%	2	2.1
Selenium	7782-49-2	83	3	4%	5	≤ MDL
Silver	7440-22-4	102	7	7%	1.4	1.6
Thallium	7440-28-0	102	4	4%	3.7	≤ MDL

Table 5b. PNNL GEL Soil Background Data

Analyte	CAS Number[1]	No. Samples	No. Values > MDL	% Detected	MDL	Mean Concentration
					mg/kg	
Antimony	7440-36-0	158	27	17%	0.10	0.113
Boron	7440-42-8	158	139	88%	0.8 – 4.5	2.25
Cadmium	7440-43-9	158	158	100%	0.02	0.422
Lithium	7439-93-2	158	158	100%	0.4 – 2.0	9.29
Mercury	7439-97-6	41	27	66%	0.004	0.00608
Molybdenum	7439-98-7	158	158	100%	0.02	0.364
Selenium	7782-49-2	158	1	1%	0.5	≤ MDL
Silver	7440-22-4	158	158	100%	0.04	0.118
Strontium	7440-24-6	158	158	100%	0.4 – 2.0	39.6
Thallium	7440-28-0	158	157	99%	0.05	0.129

Table 5c. Hanford Multi-Incremental Sampling (MIS) Soil Data

Analyte	CAS Number[1]	No. Samples	No. Values > MDL	% Detected	MDL	Mean Concentration
					mg/kg	
Antimony	7440-36-0	17 (98)	12 of 98	12%	0.3 – 0.66	0.593
Boron	7440-42-8	17 (98)	93 of 98	95%	0.36	1.43
Cadmium	7440-43-9	17 (98)	62 of 98	63%	0.04 – 0.11	0.450
Lithium	7439-93-2	17 (98)	98 of 98	100%	< 4	8.814
Mercury	7439-97-6	17 (98)	43 of 98	46%	0.02	0.0354
Molybdenum	7439-98-7	17 (98)	62 of 98	63%	0.2 – 0.43	0.535
Selenium	7782-49-2	17 (98)	6 of 98	6%	0.2 – 0.7	0.671
Silver	7440-22-4	17 (98)	1 of 98	1%	0.07 – 0.22	≤ MDL
Thallium	7440-28-0	17 (98)	3 of 98	3%	0.34 – 1.0	0.940
Tin	7440-31-5	17 (98)	63 of 98	64%	0.8 – 1.6	1.88

HSB, Hanford Site topsoil background, MIS data, and Washington State background data[3] are compared and contrasted in Figures 2 and 3. In Figure 2, the average (mean) compositions of 20 to 22 analytes in the five data sets are compared. The analytes concentrations are similarly compared in Figure 3, on the basis of the 90th percentile values[4].

The following are the most notable features of the comparison of these data sets:

- The PNNL GEL data have generally lower concentrations than the HSB data for most analytes.
- The HSB topsoil has the largest concentrations for many of the analytes of the Hanford Site-specific samples.
- The analyte concentrations for the soil background data sets from eastern Washington State, and particularly those from the vicinity of the Hanford Site, have largely similar overall background compositions, with compositional ranges that appear to be largely consistent with the HSB conceptual model.
- The concentrations of the several specific analytes (Al, K, Ba, Pb, Zn, and Mn) that are somewhat higher in PNNL GEL data than those in the HSB data are even higher in the HSB topsoil.

Figures 2 and 3 show that the mean values for most analytes in the PNNL GEL data set are lower than the corresponding values from the HSB data set for 14 of the 20 to 22 metal/non-metal analytes. The mean concentrations of Al, K, Na, Ba, Pb, Zn, Mn, and Cr are somewhat higher than those of the HSB data. The 90th percentile values of the PNNL GEL data set are also lower than those in the HSB data set for 16 of the 20 to 22 analytes. The analytes Al, K, Ba, Pb, Zn, and Mn have somewhat higher values. The mean and 90th percentile values of the PNNL GEL data set for these analytes differ from the HSB values by more than one standard deviation for only two analytes—Al and K.

It is notable that the levels of most analytes in the HSB topsoil subpopulation (HSB-TopS) reported as Judgment samples in DOE/RL-92-24 are generally the largest, or nearly the largest of the other background data sets in Figures 2 and 3. Although the concentrations of Al, K, Ba, Pb, Zn, and Mn in the PNNL GEL data are somewhat larger than those in the HSB systematic random samples, it is particularly notable that the HSB topsoils has the same characteristics, and that the HSB topsoil data have even larger concentrations than those of the HSB systematic random data set. These relationships indicate that these topsoil samples have some distinct compositional characteristics that differ from those of the general population of vadose zone soils/sediments, which are consistent with the soil background conceptual model. The somewhat higher concentration of these analytes (e.g., Al, K, Ba, Pb, Zn, and Mn) is largely consistent with presence of greater proportions of alkali feldspar/clay/smectite components in the topsoil.

Based on the relationships between chemical composition and the physical composition in the HSB conceptual model, these relationships are consistent with the following interpretations and also serve as amendments to the conceptual model:

1. The Hanford Site topsoil subpopulation and the PNNL GEL data set represent topsoil samples (exclusively).
2. The Hanford Site topsoils are is generally regarded as a subpopulation within the larger population of vadose zone soils/sediments represented by the systematic random samples in the HSB data set.

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[3] State data are for the Yakima Basin for all analytes except Ag, Sb and Se (statewide averages), and Ba, Ca, Mg, and Ti (Spokane Basin data)

[4] Percentile values presented here are calculated nonparametric values (Kaplan-Meier). The 90th percentile values listed in PNNL-18577 are based on the assumption of normally distributed data (i.e., 90th percentile = mean+1.28σ)

3. The origin of topsoil in the Pasco Basin tends to be primarily associated with eolian processes involving wind-blown fractionation of soil/sediment components (i.e., basalt, quartzo-feldspathic material) based on particle size and density.
4. The physical composition of topsoils in the region may be expected to contain somewhat larger proportions of quartzo-feldspathic material due to density fractionation
5. Pedogenic soil-forming processes, which have generally minor effects on immature profiles in arid and semi-arid environments, can cause deviations in compositional mixing lines associated with varying proportions of component materials (basalt, quartzo-feldspathic material), and/or alteration products (clay, smectite).
6. The physical compositions and characteristics of the topsoil, which are derived from re-working the vadose zone parent material by eolian and pedogenic processes, can have proportions of basaltic and quartzo-feldspathic components that extend and/or vary from the typical range of component ratios found in vadose zone parent material, due to modifications of these processes.
7. Many of the topsoil samples in this region may be expected to have greater proportions of quartzo-feldspathic components than most of the vadose zone soils/sediments, and/or some alteration products of basaltic and feldspathic components (e.g., clay/smectite from incipient pedogenic processes, attributable to these supplemental processes associated with the origin and evolution of the topsoil.
8. The somewhat higher concentration of these analytes (e.g., Al, K, Ba, Pb, Zn, and Mn) is largely consistent with presence of somewhat higher proportions of alkali feldspar/clay/smectite components in the topsoil.

6.2 Comparison of Gap Analyte Concentrations in Candidate Data Sets

The gap analyte concentrations in the PNNL GEL, MIS, and Washington State soil background data sets are compared in Figures 4a and Figure 4b to evaluate the relative magnitude of the data for the gap analytes. These comparisons indicate that the PNNL GEL data have the lowest concentrations for Sb, Cd, Hg, Mo, Ag, and Tl of the three data sets. Only the concentrations of B and Li in the PNNL GEL data are larger than those in the MIS data set by factors of approximately 1.6 and 1.1, respectively. It is also notable that the concentrations for all of the gap analytes measured above detection limits in the Washington State data (Sb, Cd, Hg, Ag), except for Se, and are relatively large. However, the Washington State Se data are somewhat lower than those of the MIS data, which are the only other data with a significant amount of Se data measured above detection limits.

6.3 Recommended Provisional Background Data for the Gap Analytes

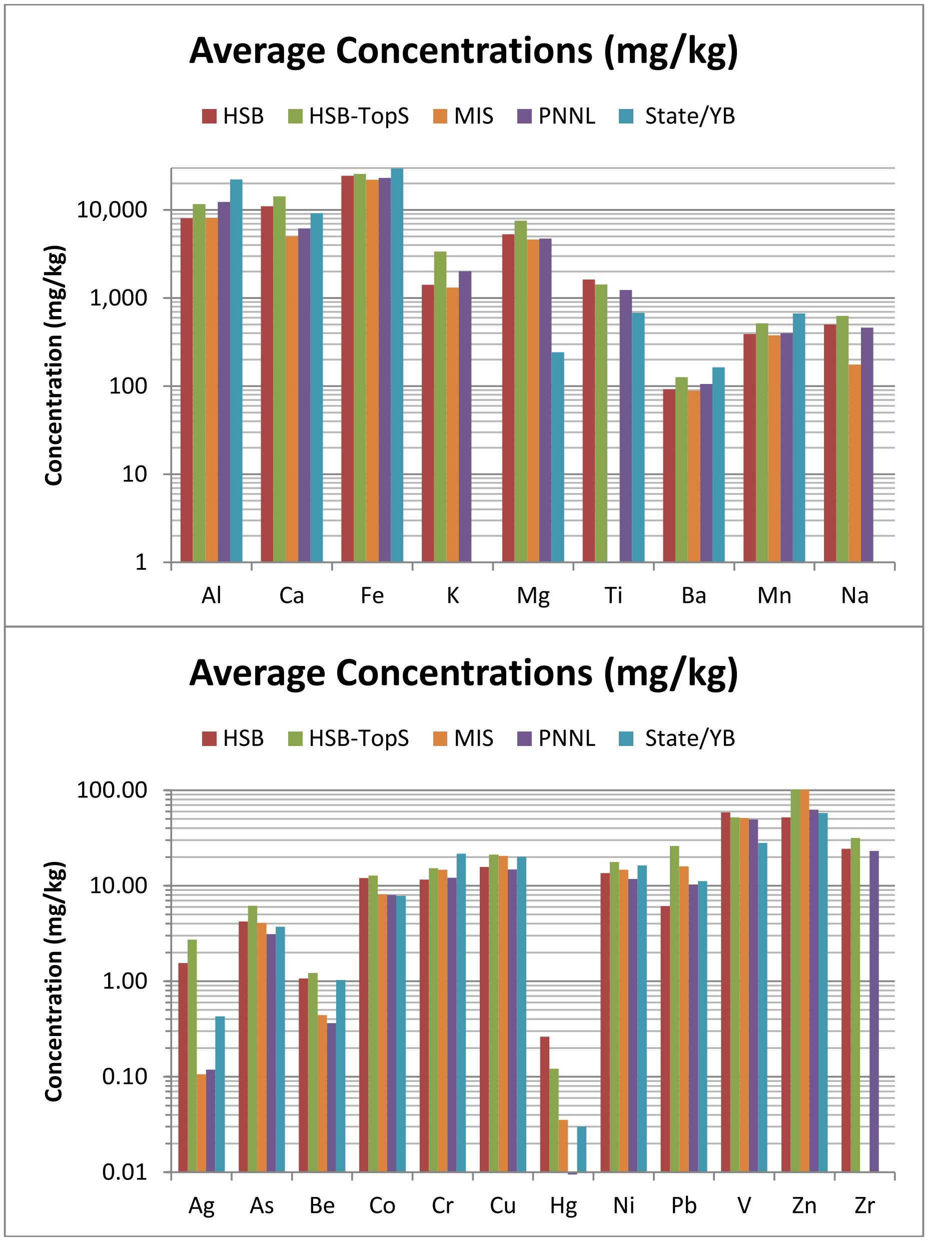
Based on the evaluation of the candidate data sets, the PNNL GEL data are recommended as provisional background data for all of the gap analytes except for Se (Table 6), and the Washington State background for Se is recommended as provisional background for Se (Table 7). The PNNL GEL data set best satisfy the acceptance criteria for consideration as provisional background for the gap analytes, except for Se. Comparisons of these soil background data sets also indicate that the concentrations of most metal and non-metal analytes measured in the PNNL GEL data set are not elevated compared to the HSB data, and are actually lower for most analytes. There also appears to be a rational explanation for somewhat higher concentrations of several analytes in the topsoils that is consistent with an amended version of the HSB conceptual model. These results indicate that the data do not have leachable multi-analyte concentrations that are systematically biased in the direction of abnormally higher concentrations compared to the comparable HSB data set, and not biased in the direction of values systematically higher than those of either the HSB systematic random data or the HSB topsoil data due to the previously described sample preparation (powdering) concern. Rather, the analyte concentrations (e.g., 90th percentile values) in the PNNL GEL data tend to be systematically lower than those in the HSB systematic random data, with the exception of major and trace analytes common to alkali feldspar/clay/smectite components, and other selected trace metals (e.g., Al, K, Ba, Pb, Zn, and Mn). The concentrations of most gap analytes in the PNNL GEL data set also appear to be lower than those in the Washington State and MIS data set. Based on the weight of this evidence, the PNNL GEL data is recommended as provisional background for most of the gap analytes with the following caveats:

1. The PNNL GEL data represent topsoil background compositions that are a subset of the vadose zone soils.
2. The compositions of the PNNL GEL topsoils tend to be biased toward lower, more conservative values, compared to those of the vadose zone population.
3. The concentrations of the gap analytes in the PNNL GEL data may similarly be expected to be biased toward lower, more conservative values, compared to those of vadose zone population.

The only exception to the recommendation of the PNNL GEL data set for provisional soil background for the gap analytes is for Se. In the absence of Se data above detection in the PNNL GEL data set, the Washington State soil background data were chosen as provisional background for Se because the data for this analyte meet more of the acceptance criteria than other data sets, and have no overriding basis for rejection. The PNNL GEL soil background data are preferable to the Washington State data, where data exist for both, as summarized in the acceptance criteria checklist in Table 6. The Washington State data for Se appear to be comparable to, and somewhat lower than the MIS data, which is the only other data set with soil background data above detection. The caveats concerning the use of the Washington State data for Se include all of the aforementioned caveats concerning the use of topsoils to represent the range of Hanford Site vadose zone sediments, in addition to the following:

- The Washington State soil background data on Se are from topsoil samples statewide vs. samples from eastern Washington or the Yakima Basin.
- The Washington State soil background data on Se are based on only 14 samples measured above background.

The implications of these additional factors in terms of bias are unclear because there appear to be components of both high and low bias associated with these caveats. The use of statewide background data versus eastern Washington State data could be a source of bias, because the western and statewide background levels of most analytes in Washington State tend to be higher than those in eastern Washington State (San Juan, 1994). However, the use of topsoil data, and only the data from the 14 statewide samples above detection, without also considering the 166 data below detection, are two potentially significant sources of bias toward concentrations lower than those of vadose zone soil, and lower than those for the statewide samples overall.

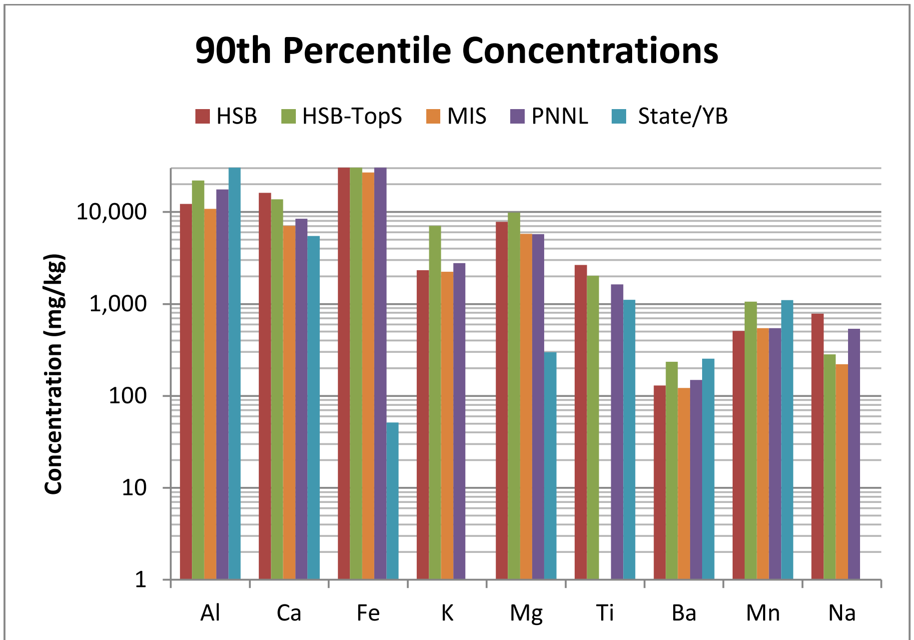


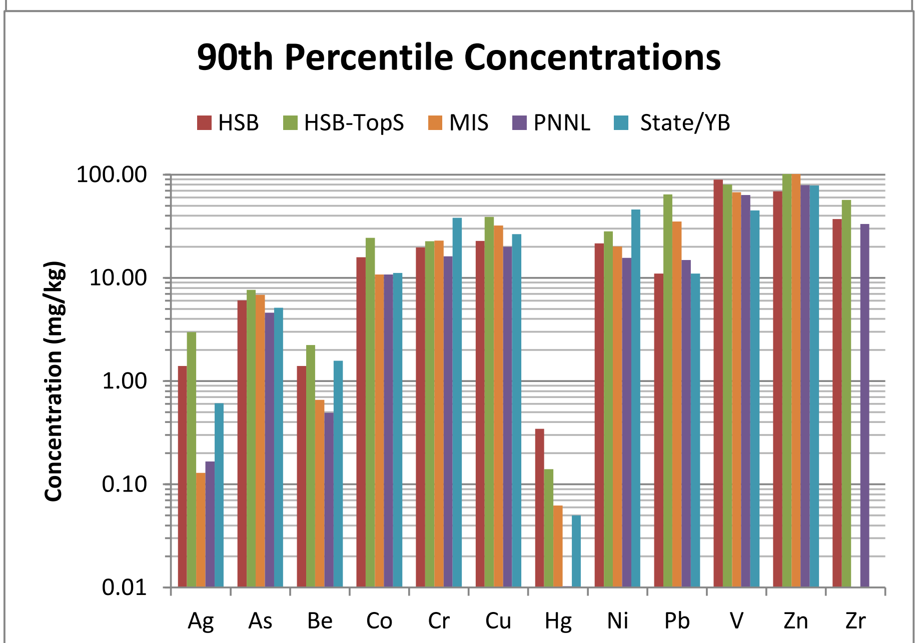
Notes: Figure 2 shows a comparison of the average soil background analyte concentrations[5] for the PNNL GEL data set (PNNL) to the HSB (systematic random) data (HSB), the Hanford Site topsoil background data (HSB-TopS), the MIS data (MIS), and the Washington State soil background levels for the Yakima Basin (State/YB).[6]

Figure 2. Average Soil Background Analyte Concentrations Comparison

[5] The data for Ag and Hg in the HSB data are anomalously high due to censoring at detection limits.

[6] Yakima Basin data plotted for all analytes except for Ag, Sb, and Se (only statewide averages—no regional data), and Ba, Ca, Mg, and Ti (Spokane Basin data—no Yakima Basin data)





Notes: Figure 3 shows a comparison of 90th percentile values of soil background analyte concentrations for the PNNL GEL data set (PNNL) to the Hanford Site background (systematic random) data (HSB), the Hanford Site topsoil background data (HSB-TopS), the MIS data (MIS), and the Washington State soil background levels for the Yakima Basin (State/YB).[7]

Figure 3. 90th Percentile Values of Soil Background Analyte Concentrations Comparison

[7] Yakima Basin data plotted for all analytes except for Ag, Sb, and Se (only statewide averages—no regional data), and Ba, Ca, Mg, and Ti (Spokane Basin data—no Yakima Basin data)

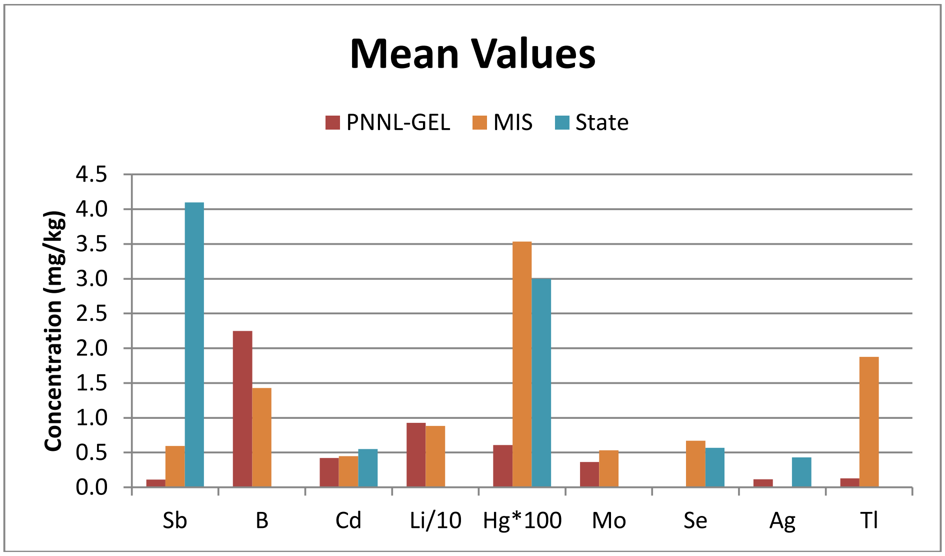


Figure 4a. Comparison of Mean Concentrations of the Gap Analytes in the PNNL GEL, MIS, and State Data Sets

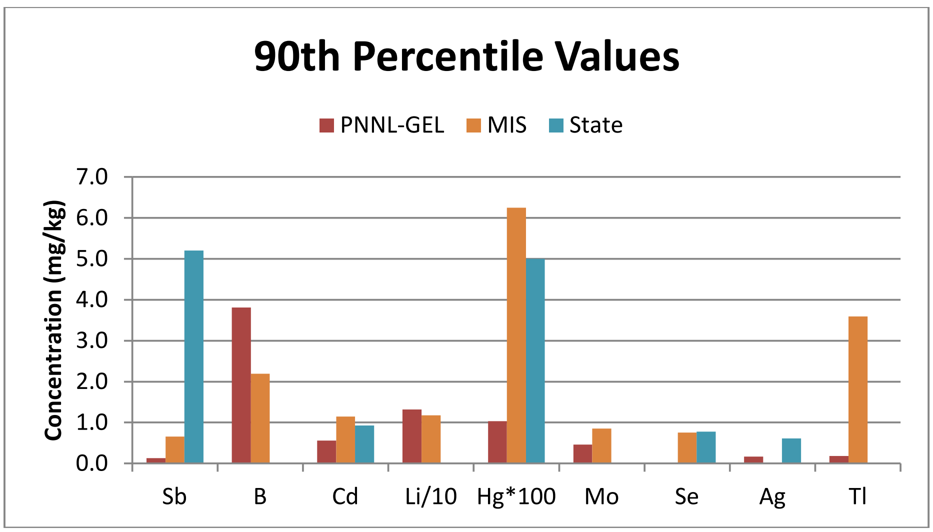


Figure 4b. Comparison of 90th Percentile Levels of the Gap Analytes in the PNNL GEL, MIS, and State Data Sets

Notes: Figures 4a and 4b show a comparison of soil data on the gap analytes for the PNNL GEL data set to the MIS data (MIS), and the Washington State soil background levels (State). Figure 4a is the comparison of mean values. Figure 4b is the comparison of 90th percentile values. State background data are for samples from Yakima Basin, except for Sb, Se, and Ag, which are for statewide data

6.4 Evaluation of Provisional Background Data for Risk Assessment Applications

Another important aspect of this evaluation concerns the extent to which the use of the provisional soil background data on the gap analytes address the data need issues for the conduct of risk assessments. The primary issue beyond the need for viable background data on the gap analytes is the extent to which these data are useful for risk-based applications, and specifically the assessment of risks associated with pathways/receptors such as ecological risk, that can dominate risk assessments and/or risk-based remedial actions. The criteria affecting the usability of the provisional and/or updated background data on the gap analytes for applications such as COPC screening against ecological protectiveness metrics include consideration of the following:

1. The amount of gap analyte data above detection limits
2. The detection limits for the gap analytes in soil data that are compared to background and/or protectiveness metrics
3. The relative magnitudes of the provisional background data and detection limits to:
   a) The protectiveness metrics/screening levels
   b) The detection limits routinely achievable for other soil samples that are compared to background

The first factor addresses the issue of whether the provisional background data provide an improved basis for risk-based screening compared to the general absence of data above detection for the gap analytes in the HSB data set. This is important to ensure that there are acceptable proportions of the data above detection to quantitatively describe the background population for each analyte and support risk-based screening. The detection limits and the proportions of the data above detection for the "gap" analytes were presented in Section 6.1.4 and are summarized in Tables 5a, Table 5b, and Table 6. As stated in Section 6.1.4, the PNNL GEL data have significantly detection limits for the gap analytes than those achieved for these analytes in the Hanford Site background data set, and consequently significant amounts of data above detection for the gap analytes. Thus, the PNNL GEL data do provide an improved basis for risk assessment applications in terms of background data above detection.

The second factor concerns both the comparability of the provisional background data to soil data, and the significance of the background data in risk-based screening. The comparability of the data is important in instances when the detection limits for the provisional background data differ from those achievable for other soil samples. The usefulness of the provisional background as screening criteria, for example, may be limited if these background data are below the detection limits of the soil data that are compared to background. The implications of this issue are illustrated in a test case summarized in Table 8. In this test case, the data recommended as provisional soil background for the gap analytes are compared to the MDLs of soil data typically obtained[8]. This test case simulates the proportion of the data that would be measured above detection if the PNNL GEL samples were analyzed at a laboratory with higher detection limits comparable to those presently obtained for Hanford soil samples. The results of this simulation are tabulated in Table 8 for MDLs routinely attainable for the EPA 6010 analytical method MCLs, and the EPA Method 200.8 ICP-MS[9]. Simulated results with over 50% of the data > MCLs are highlighted in green. Results with less than 50% of the data above MDLs are highlighted in red. Equivocal results are highlighted in orange. The actual percentages of the PNNL GEL data above detection are also shown for comparison.

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[8] Detection limits used in this example are for the Waste Site Characterization Facility (WSCF) which is the primary analytical laboratory for soil samples at the Hanford Site

Table 6. Evaluation and Acceptance Criteria Checklist: Summary of Results for Evaluation of Data Considered for Provisional Background for the Gap Analytes*

Evaluation/Acceptance Criteria for Provisional Hanford Soil Background	Criteria Met?			
	MIS Data	SEL (Sequim) Data	GEL Data	State Data
1. Sample location (representativeness):	No	Acceptable	Acceptable	Partial
a. Background samples from locations uncontaminated	Presumed Acceptable	√	√	√
b. Locations acknowledged as acceptable background locations by the Tri-Parties	No	√	√	√
c. Sampling locations (and coverage) representative of the types and range of soil that occurs naturally at the Hanford Site	Partial (topsoil)	Partial (topsoils)	Partial (topsoil)	Partial (topsoil); not site-specific
2. Representativeness and Comparability of Samples and Data:	Marginal	Not Acceptable	Acceptable	Partial
a. Acceptable sample number	Marginal (17)	Acceptable (57 - 124)	Acceptable (158)	Marginal to/Acceptable (~14 - 50)
b. Appropriate sample preparation methods	√	No	√	√
a. Acceptable sampling methods/procedures	√	√	√	√
b. Sample preparation and analysis conducted in accordance with, or sufficiently comparable to EPA methods and protocols prescribed for environmental regulatory applications (e.g., SW-846 Methods)	√	Acceptable	Acceptable	√
• Physical preparation: Sieve recovery of < 2 mm-diameter sample material	√	Acceptable	Acceptable	√
• Chemical preparation: Sample dissolution (partial) in acids/peroxide (consistent with/comparable to SW-846 methods) to produce leachate solution.	√	Unknown	Acceptable	√
c. Appropriate analytical methods (e.g., consistent with SW-846 Methods): Compositions determined from acid leachate solution (extractable metal/analyte compositions) (vs. bulk compositions)	√	√	√	√
d. Acceptable analyte list (includes gap analytes?)	√	√	√	No; partial
3. Other aspects of data quality:	Incomplete	?	√	Incomplete
a. Acceptable sample handling (chain of custody, holding times, etc.)	√	√	√	√
b. Acceptable levels of detection	Partial: High % of NDs for Sb, Ag, Se, Tl	?	(all but Se)	Partial: High % NDs for Sb, Ag, Se, Tl
c. Acceptable proportion of nondetect (ND)data	Partial: >94% NDs for Se, Ag, Tl	?	√	Partial: >97% NDs for Ag, Tl; 94% NDs for Se

* Evaluation results include comparisons of compositions of up to 22 non-radiological analytes in addition to the gap analytes

[red] Denotes unacceptable criteria or conditions for consideration as Hanford Soil Background

[orange] Denotes partial or marginally acceptable criteria or conditions for consideration as Hanford Soil Background

Table 7. Summary of Data Recommended for Use as Provisional Soil Background for the Gap Analytes*

Analyte	CAS Number	No. Samples	Method Detection Limit (MDL)	Percentage of Data > Detection[a]	Statistical Characteristic Concentrations (mg/kg)			
					Mean	50th Percentile	90th Percentile	Maximum
Antimony	7440-36-0	158	0.1	17%	0.113	0.100	0.130	0.385
Boron	7440-42-8	158	0.8 – 4.5	88%	2.25	2.09	3.89	5.86
Cadmium	7440-43-9	158	0.02	100%	0.422	0.366	0.563	2.98
Lithium	7439-93-2	158	0.4 – 2.0	100%	9.29	8.62	13.3	19.2
Mercury	7439-97-6	48	0.004	66%	0.00608	0.00400	0.0131	0.0292
Molybdenum	7439-98-7	158	0.02	100%	0.364	0.318	0.470	3.17
Selenium**	7782-49-2	14	0.5	~1%	0.57	0.56	0.78	0.840
Silver	7440-22-4	158	0.04	100%	0.118	0.109	0.167	0.273
Strontium	7440-24-6	158	0.4 – 2.0	100%	39.6	36.9	50.4	110
Thallium	7440-28-0	157	0.05	99%	0.129	0.118	0.185	0.523

* All data except for Se are from PNNL-GEL data (PNNL-18577)

** Selenium data from Statewide Soil Background (San Juan, 1994)

The results of this simulation indicate that soil samples analyzed with detection limits corresponding to the lower MDLs (EPA Method 200.8) could yield data with low percentages of data above detection for up to three or four of the gap analytes (i.e., Sb, B, Hg, and possibly Se, Ag, and Tl). The two most important implications from this simulation are that:

- The provisional background data do not improve the ability to conduct risk assessments for gap analytes with detection limits larger than most or all of the provisional background data
- Laboratory detection limits routinely obtainable for the gap analytes should preferably be within, or below the levels of the background data to improve the ability to conduct risk assessments

Table 8. Results of the Evaluation Simulating the Percentages of Gap Analyte Data Above Detection, Resulting from Analyses of Samples with Compositions Corresponding to the PNNL GEL Data

Gap Analyte	MDLs Routinely Obtainable for Hanford Soil Samples (mg/kg)		Predicted Percentage of Provisional Background Data > WSCF MDLs		Actual Percentage of Provisional Background Data > Detection[a]
	EPA Method		EPA Method		
	6010	200.8	6010	200.8	
Sb	4.7	0.3	0%	1%	17% [b]
B	4.1	4.1	6%	6%	88%
Cd	0.4	0.1	40%[b]	100%	100%
Li	0.4	0.4	100%	100%	100%
Hg	0.05	0.05	0%	0%	66%
Mo	0.4	0.1	15% [b]	99.4%	100%
Se	4.7	0.3	1%[c]	100%[c]	8%
Ag	0.7	0.1	0%	62%[b]	100%
Tl	4.9	0.1	0%	64%[b]	99%

a. Detection limits for the PNNL GEL data are listed in Table 5b.

b. Acceptable percentages of data above detection have not been established.

c. Only 1% of the Se data in the PNNL GEL data set were measurable above detection limit of 0.5 mg/kg; predicted percentages of values above the WSCF MDLs for this analyte are not meaningful.

(green) Simulated results with over 50% of the data > MCLs

(orange) Cases with equivocal simulation results

(red) Simulated results with less than 50% of the data > MCLs

The third factor is important because it adds consideration of the magnitude of protectiveness metrics to that of background data and detection limits in evaluating the relative importance of soil background as determinant criteria in ecological risk screening. Soil samples with analyte concentrations that are either below background, or below risk-based protectiveness levels, are regarded as protective, and are eliminated from further evaluation in the risk analysis (screening) process. Conversely, contaminated samples (exceeding background), that are also above risk-based protectiveness levels are carried forward in risk assessments. However, the detection limits (i.e., MDLs) of the screened soil data, must be less than the protection level, or sufficiently less than background, for either of these criteria to be useful as risk-based screening criteria. Thus, the relative magnitudes of the provisional background data, the protectiveness metric, and the detection limits of data for both background and other soil samples must all be considered in evaluating the usability of soil data for risk screening. The evaluation of relative magnitude of these metrics and the implications of various scenarios for risk-based screening are described in Appendix C. An initial check on inferences this aspect of the evaluation was also performed by comparing the relative magnitudes of preliminary (new) data on archived background samples to the detection limits (MDLs) and ecological screening metrics for the gap analytes is also described in Appendix C. The results of these evaluations are summarized in Section 7.

7 Results/Conclusions/Uncertainties

The existing soil background data for all of the nonradioactive analytes reported in DOE/RL-92-24 Rev. 4, other than the gap analytes, and the existing radionuclide background data reported in DOE/RL-95-55 and DOE/RL-96-12, should continue to be used for environmental remediation and restoration efforts at the Hanford Site. The documented statistical characteristics of these data are summarized in Appendix A and Appendix B respectively.

The following are the main results and conclusions of these evaluations concerning the evaluation of existing soil data that can be used as provisional soil background for the gap analytes in COPC screening and related risk assessment evaluations at the Hanford Site:

1. The PNNL GEL data are recommended as provisional background for the nonradioactive gap analytes (Sb, B, Cd, Li, Hg, Mo, Ag, and Tl), with specific caveats concerning the use of these data.
2. The Washington State soil background data is recommended as provisional background for Se, as the most suitable in the absence of Se data above detection in the PNNL GEL data set.

The PNNL GEL data set was selected as provisional soil background for most of the gap analytes based on evaluation of background data sets that included the Washington State soil background data, the Hanford MIS data, and two PNNL soil background data sets against acceptance criteria identified in Table 1. The PNNL GEL data set was determined to be the most suitable for consideration as supplemental/provisional soil background data to the DOE/RL-92-24 data set, because these data meet most of the acceptance criteria for all of the gap analytes other than Se. In the absence of Se data above detection in the PNNL GEL data set, the Washington State soil background data were chosen as provisional background for Se because the data for this analyte meet more of the acceptance criteria than other data sets, and have no overriding basis for rejection.

The caveats concerning the use of the provisional soil background data in risk assessment applications and ecological screening include the following:

- These provisional soil background data have not been approved by DOE or the regulatory agencies for final regulatory compliance documentation.
- These data should only be used only to support and facilitate progress in environmental restoration and remediation activities in the interim until new data associated with revision and update of the HSB documents are available.

- These data are based on the analyses of topsoils, which may not represent the range of analyte concentrations in the vadose zone soils at the Hanford Site.
- These topsoil concentrations for the gap analytes may be biased low compared to vadose zone concentrations, based on comparison of other analytes in the HSB data set and the provisional soil background data set.

The PNNL GEL data on the gap analytes have large proportions of measured values above detection for all of the gap analytes except for Sb (17%) and Se (1%) that can provide an improved basis for ecological risk screening. However, a majority of the data for some analytes (i.e., Sb, B, and Hg) have measured values that are below the detection limits (MDLs) routinely obtained for many Hanford Site soil samples (Table 9).

All of the gap analytes other than Sb and B in soil samples appear to be conducive to ecological risk screening because:

a) The ecological screening levels are larger than both the background and typical MDLs for five of the gap analytes (Li, Hg, Mo, Ag, and Tl), and

b) The provisional background appears to be the determinant (largest) screening criterion for two of the other gap analytes (Cd and Se).

The ability for Sb and B to be screened at all is equivocal if the MDLs of the soil data are ≥ background levels and/or ecological screening levels for these two analytes.

The results of preliminary data from new analyses of some of the original Hanford Site (vadose zone) soil background samples appear to corroborate most of the conclusions in this evaluation, with a few notable differences (Table 9). It is indicated from the preliminary data that selenium in background samples should be detectable at levels that can serve as the determinant criteria in ecological risk screening, provided that data above detection are obtained from the new analysis of vadose zone background samples. Although the detectability of background for Cd, Li, Hg, Se, Ag, and Tl is presently secondary to the magnitude of the protectiveness metrics for ecological risk screening, these preliminary data indicate that little or no background data above detection (MDLs) may result for as many as five of the gap analytes (Sb, Cd, Hg, Ag, and possibly Tl) based on the results of data representative of uncontaminated soil samples and the associated MDLs typical of those routinely obtainable for the analyses of many Hanford soil samples. It is still not known whether the boron levels in these data are detectable at levels that can serve as the determinant criteria in ecological risk screening because no reliable data for boron were obtained in these data. The extent to which soil data can be screened for boron is presently equivocal.

Thus, the provisional background data recommended in this document, together with ecological screening criteria should be adequate for ecological risk screening for most of the gap analytes, except for Sb and B. This is primarily because the ability to conduct ecological risk screening for most of the gap analytes appears to depend more on the magnitude of the screening level, than on background. However, these relationships should not be taken to mean that the characterization of background (above detection) for the gap analytes is not important or needed for establishing/defining baseline risk. Protectiveness and/or screening levels are subject to change, and protectiveness metrics for other pathways/receptors (e.g., river and/or groundwater protection) that have yet to be established, and can become the risk drivers. Although the range of vadose zone background levels for the gap analytes have not yet been fully characterized, it is recommended that efforts to obtain new background data above detection for all analytes be optimized within the context of the regulatory protocols for soil analyses, because the intrinsic background levels are the only criteria that serve as the fundamental basis for defining baseline risk and protectiveness, that are not subject to change.

Table 9. Comparison of Provisional Background, Ecological Screening Levels, and Laboratory Detection Limits (MDLs) for the Gap Analytes

Gap Analyte	Soil Concentration (mg/kg)				Screening Criteria: Largest of Eco Metric, MDL, Background Values
	Ecological Soil Screening Level (EcoSSL)	Detection Limit (MDL)[a]	Soil Background (50th Percentile)		
			Provisional Background (P-Bkgr)[b]	Representative Data on Uncontaminated Soil Samples[c]	
Sb	0.27	0.3	0.10	≤ MDL	None?: EcoSSL ≈ MDL>P-Bkgr
B	0.50	4.1	2.1	No reliable data?	None?: MDL > P-Bkgr ?
Cd	0.36	0.1	0.37	≤ MDL	EcoSSL ≈ P-Bkgr
Li	35	0.4	8.6	4.3	EcoSSL
Hg	0.10	0.05	0.0040	≤ MDL	EcoSSL
Mo	2.0	0.1	0.32	0.35	EcoSSL
Se	0.30	0.3	0.53	0.93	P-Bkgr
Ag	0.52	0.1	0.11	≤ MDL	EcoSSL
Tl	1.00	0.1	0.12	≈ MDL (0.1)	EcoSSL

[a] Lowest overall MDL value routinely obtainable at the Hanford WSCF laboratory (2010)
[b] Data from PNNL GEL data (PNNL-18577)
[c] Based on preliminary results of analyses of archived background samples from the HSB study (DOE/RL 92-24)

Determinant screening values and criteria (green)
Equivocal screening values and criteria (orange)

The main uncertainties in this evaluation are those associated with (1) the soil background data, and (2) the uncertainties in the comparisons regarding the detectability and usefulness of the provisional background data on the gap analytes for ecological risk screening. The uncertainties associated with the existing soil background data mainly involve the extent to which the samples and data represent the range of background in the area of interest, as well as accuracy and precision. These uncertainties are described in DOE/RL-92-24, DOE/RL-95-55, and DOE/RL-96-12 in the context of the comparability and representativeness the data represent. These uncertainties also apply to the data recommended as provisional background for the gap analytes, qualitatively summarized in the acceptability checklist in Table 6, and further described in conjunction with the caveats described in Section 6.4. These caveats include an acknowledged (low) bias of the provisional background data for the gap analytes expected for the compositions of topsoil, compared to those of vadose zone soils. The additional uncertainties in the provisional background data recommended for Se include factors related to potential biases in the data due to the representativeness and comparability of the sample locations (statewide vs. eastern Washington), the number of samples that the data set (14), and the exclusion of all "non-detect" data (as many as 152) from the data set. It is indicated from the comparison of the provisional background data on Se to the MIS and preliminary data of vadose zone samples that the provisional background data for Se is also biased low. Inherent accuracy and precision uncertainties stem from the acceptability range for laboratory control standard allowed by EPA Contract Laboratory Procedures, which is about +/- 20% for most inorganic analytes.

The uncertainties associated with the results of the comparisons between background data, ecological screening levels, and MDLs include the collective uncertainties associated with all three criteria. The uncertainties associated with the establishment of the soil data MDLs are at least in part associated with the use of non-soil matrices for MDL calibrations, and appear to involve bias in the MDLs toward larger, rather than smaller values. The uncertainties in the veracity of the ecological screening levels appear to be very large, but to be largely acceptable for the purposes of screening. Overall, the uncertainties in the conclusions drawn from this aspect of the evaluation only appear to be significant where the magnitude of the determinant screening criterion, either background or ecological screening levels, are similar to MDL levels. Based on the relative magnitude of the ratio for the determinant screening criteria (background or ecological screening level) to the MDLs from the information in Table APP-C2 and Table APP-C3 in Appendix-C, the uncertainties in the conclusions concerning the ability for the gap analytes to be screened (i.e., sensitivities for change in the result) are greatest for Sb, Cd, Hg, Se, and possibly B (ratios < 4.0). The ratios for Li, Mo, Ag, and Tl are relatively large (5 to 88), indicating that the results are largely insensitive to these uncertainties.

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APPENDIX A
EXISTING SOIL BACKGROUND DATA FOR NONRADIOLOGICAL ANALYTES

The Hanford Site background concentrations for most nonradioactive analytes are based on the data and calculated summary statistics reported in the Hanford Site soil background (HSB) documentation (e.g., DOE/RL-92-24), and are summarized in Table APP-A2. The summary statistics for total nitrogen in Table APP-A2 were recalculated from the values reported for nitrate in DOE/RL-92-24, Rev. 4, to facilitate comparison with the MCL identified for nitrate by the U.S. Environmental Protection Agency (EPA), and also because total nitrogen is a more appropriate way of handing nitrate and nitrite in fate and transport modeling. The soil background values listed in Table APP-A2 for nitrate + nitrite as nitrogen (N) are based only on nitrate data (i.e., nitrate converted to nitrogen) because nitrite was not detected in any of the systematic random samples (detection limit of 21 mg/kg).

As shown in Table APP-A1, the conversion of nitrate and nitrite concentration levels to total nitrogen (as N) involves calculation of the mass fraction of nitrogen (as N) in nitrate (NO_3^-), by dividing the molecular weight of nitrogen (14 g/mol) by the molecular weight of nitrate (62 g/mol), which yields a mass fraction of nitrogen (N) in nitrate of 0.2258. Similarly, the mass fraction of nitrogen (as N) in nitrite (NO_2^-), is calculated by dividing the molecular weight of nitrogen (14 g/mol) by the molecular weight of nitrite (42 g/mol), which yields a mass fraction of nitrogen (N) in nitrate of 0.3043. The concentration of nitrogen (N) in nitrate can then be calculated by multiplying the nitrate concentration by the mass fraction of nitrogen (as N) in nitrate; (i.e., for a nitrate concentration of 10 mg/kg, the concentration of nitrogen in nitrate is calculated by multiplying 10 mg/kg × 0.2258 = 2.258 mg/kg N in nitrate). The calculation of nitrogen in nitrite is similar, but uses the mass fraction of N in nitrite (0.3043) instead of 0.2258. Where there are both nitrate and nitrite data, the amount of nitrogen in nitrate and the amount in nitrite are added to yield total nitrogen (N) in nitrate and nitrite.

In Table APP-A1, for example, the 90th percentile for nitrate reported in DOE/RL-92-24 for the 104 systematic random samples is 52 mg/kg. The value listed in Table 3 for nitrogen in nitrate and nitrite was calculated in the manner described by Equation 1 using only the nitrate values because nitrite was not detected in any of the systematic random samples:

Table APP-A1. Calculated Statistical Parameters for Nitrogen (N) in Nitrate

Parameter	Equation Used	Outcome
Mean	30.1 mg/kg (nitrate) x 0.2258 (N/nitrate)	6.80 mg/kg
50th percentile	3.58 mg/kg (nitrate) x 0.2258 (N/nitrate)	0.808 mg/kg
90th percentile	52 mg/kg (nitrate) x 0.2258 (N/nitrate)	11.7 mg/kg
Maximum	538 mg/kg (nitrate) x 0.2258 (N/nitrate)	121.5 mg/kg
Overall Maximum	906 mg/kg (nitrate) x 0.2258 (N/nitrate)	204.6 mg/kg

Table APP-A2. Hanford Site Soil Background for Nonradioactive Analytes: Summary Statistics for Systematic Random Data[a]

Analyte	CAS Number[b]	Mean	50th Percentile	90th Percentile	Maximum	Overall Maximum
		Concentration (mg/kg)				
Aluminum	7429-90-5	8,080	7,600	11,800	18,100	28,800
Arsenic	7440-38-2	4.2	3.55	6.47	11.4	27.7
Barium	7440-39-3	92.7	88.4	132	221	480
Beryllium	7440-41-7	1.2	1.09	1.51	2.1	10
Calcium	7440-70-2	11,500	9,450	17,200	86,600	105,000
Chromium (total)	7440-47-3	10.9	9.57	18.5	30.6	320
Cobalt	7440-48-4	11.7	11.2	15.7	16.9	110
Copper	7440-50-8	15.5	14.4	22	36.1	61
Iron	7439-89-6	24,500	23,600	32,600	35,100	68,100
Lead	7439-92-1	6.3	5.45	10.2	26.6	74.1
Magnesium	7439-95-4	5,180	4,980	7,060	10,100	32,300
Manganese	7439-96-5	384	372	512	704	1,110
Nickel	7440-02-0	13.0	12.2	19.1	28.2	200
Potassium	7440-09-7	1,370	1,210	2,150	3,280	7,900
Silicon	7440-21-3	32.2	15.4	44	583	1,203
Sodium	7440-23-5	439	231	690	5,620	6,060
Titanium	7440-32-6	1,600	1,460	2,570	2,940	3,180
Uranium (metal)[d]	7440-61-1	-	-	3.21	-	-
Vanadium	7440-62-2	57.6	54.4	85.1	97.9	140
Zinc	7440-66-6	53.0	51.1	67.8	119	366
Zirconium	7440-67-7	23.6	20.6	39.8	84.8	84.8
Alkalinity	NA	3,410	1,100	7,710	37,600	150,000
Ammonia	7664-41-7	3.6	0.97	9.23	26.4	26.4
Chloride	16887-00-6	68.3	6.59	100	1,480	1,480
Fluoride	16984-48-8	2.4	0.8	2.81	73.3	73.3
Nitrate	14797-55-8	30.1	3.58	52	538	906
Nitrite	14797-65-0	--	--	--	--	--
Total N (in nitrate)	93037-13-9	6.80	0.808	11.7	121.5	204.6
O-Phosphate	98059-61-1	4.7	0.002	0.785	225	225
Sulfate	14808-79-8	192	10.4	237	4,340	12,600

a. Values were taken from the following tables in DOE/RL-92-24, Rev. 4, *Hanford Site Background: Part 1, Soil Background for Nonradioactive Analytes*, US Department of Energy, Richland Washington, January 2001:

Mean Table 6-1, pg. T6-1 — Maximum Summary Table 1, pg. ES viii

50th Summary Table 2, pg. ES ix — Overal Max. Summary Table 1, pg. ES viii

90th Summary Table 2, pg. ES ix

b. CAS numbers were populated from the Hanford Environmental Information System database (http://environet.rl.gov/EDA/index.cfm).

c. The uranium (metal) background value is calculated from the sum of the activities of the uranium isotopes (listed later in the table), converted to soil concentration (mg/kg) using their respective specific activities.

APPENDIX B
EXISTING SOIL BACKGROUND DATA FOR RADIONUCLIDES

Two general types of background radionuclides occur in the soil at the Hanford Site: (1) naturally occurring radionuclides, and (2) non-Hanford-related anthropogenic (i.e., man-made) radionuclides. The origin and spatial distribution and natural and anthropogenic background radionuclides in the soil column are inherently different. The following are the main aspects and assumptions associated with the conceptual model for radiological soil background at the Hanford Site:

3. Anthropogenic radionuclide background (e.g., non-Hanford Site-related cobalt-60, strontium-90, cesium-137, europium, and plutonium isotopes) is derived from global fallout, with the range and levels controlled by factors affecting the transport and distribution which includes wind, climate, and weather patterns; geography, and topography (DOE/RL-94-98).

4. The range and levels of naturally occurring radionuclides (e.g., potassium-40, radium-226, thorium-232, and uranium isotopes) are primarily attributable to relative proportions of naturally occurring constituent rock and minerals (e.g., basalt, quarto-feldspathic, carbonate components, etc.).

The anthropogenic background radionuclides are primarily restricted to the surface and near-surface soil, except where they may have become mixed with subsurface soil in excavations, or have been otherwise transported (by water) into the vadose zone. The naturally occurring radionuclides occur throughout the vadose zone, which includes both the topsoil and subsurface soils in the vadose zone. The deeper subsurface vadose zone sediments/soils, therefore, contains only the naturally occurring radionuclides except where anthropogenic background radionuclides have been introduced, as previously described. The radionuclide background data summarized here represent the soil background activities for both types of background radionuclides.

Soil background data and summary statistics for anthropogenic radionuclides in surface and near-surface soil summarized in Table APP-B1 are cited from Table 5-1 in DOE/RL-96-12 and involved no new calculations. Soil background data and summary statistics for naturally occurring radionuclides in subsurface vadose zone soil summarized in and APP-B2 are cited from Table 4-1 in DOE/RL-96-12 and also involved no new calculations.

Table APP-B1. Activity Concentrations and Background Dose for Anthropogenic and Naturally Occurring Radionuclides in Surface and Near-Surface Soils (from Table 5-1 in DOE/RL-96-12). (Summary statistics are based on log-normal data distributions)

Radionuclide	CAS No.	(Geometric) Background Mean	50th Percentile	90th Percentile	Maximum Concentration	Background Dose from 95% UCL (mrem/year)
		pCi/g				
Potassium-40	13966-00-2	13.1	12.8	16.6	19.7	41.3
Cobalt-60	10198-40-0	0.00132	0.00131	0.00842	0.0387	-
Strontium-90	10098-97-2	0.0806	0.0554	0.178	0.366	2.22
Cesium-137	10045-97-3	0.417	0.281	1.05	1.64	7.09
Europium-154	15585-10-1	0.000826	0.000516	0.0334	0.0790	-
Europium-155	14391-16-3	0.0234	0.0188	0.0539	0.0984	-
Radium-226	13982-63-3	0.561	0.53	0.815	1.16	90.9
Thorium-232	7440-29-1	0.945	0.909	1.32	1.58	39.9
Uranium-234	13966-29-5	0.793	0.762	1.10	1.51	0.35
Uranium-235	15117-96-1	0.0515	0.0327	0.109	0.386	0.22
Uranium-238	7440-61-1	0.763	0.733	1.06	1.21	0.47
Plutonium 238	13981-16-3	0.00158	0.000547	0.00378	0.0193	-
Plutonium-239/240	15117-48-3	0.00935	0.00661	0.0248	0.0331	-
Gross Beta	12587-47-2	19.78	19.45	22.96	25	-

Table APP-B2. Activity Concentrations and Background Dose for Naturally Occurring Radionuclides in Vadose Zone Soils (from Table 4-1 in DOE/RL-96-12). (Summary statistics are based on log-normal data distributions)

Radionuclide	CAS No.	(Geometric) Background Mean	50th Percentile	90th Percentile	Maximum Concentration (Measured)	Background Dose from 95% UCL (mrem/year)[9]
		pCi/g				
Potassium-40	13966-00-2	12.84	12.8	16.64	19.7	41.5
Radium-226	13982-63-3	0.530	0.505	0.815	1.16	90.1
Thorium-232	7440-29-1	0.909	0.949	1.315	1.58	33.8
Uranium-234	13966-29-5	0.762	0.743	1.098	1.51	0.35
Uranium-235	15117-96-1	0.0327	0.0328	0.109	0.386	0.22
Uranium-238	7440-61-1	0.733	0.718	1.059	1.21	0.47

[9] Background Dose values taken from Table 5-2 in DOE/RL-96-12

APPENDIX C
SUPPORTING EVALUATION OF PROVISIONAL BACKGROUND DATA FOR RISK ASSESSMENT APPLICATIONS

This section describes the evaluation of relative magnitude of the provisional background data, the ecological screening levels, and the detection limits of data for both background and other soil samples, and the implications of various scenarios for risk-based screening. One of the initial steps in the assessment of whether or not soil samples are contaminated or pose risk to human health or the environment, is to compare the analyte concentrations of samples to background and appropriate risk-based protectiveness metrics. Soil samples with analyte concentrations that are either below background, or below risk-based protectiveness levels, are regarded as protective, and are eliminated from further evaluation in the risk analysis process (i.e., screened). Conversely, contaminated samples (exceeding background), that are also above risk-based protectiveness levels are carried forward in risk assessments. However, the detection limits (i.e., MDLs) of the screened soil data, must be less than the protection level, or sufficiently less than background, for either of these criteria to be useful as risk-based screening criteria. Thus, the relative magnitudes of the background data, the protectiveness metric, and the detection limits of data for both background and other soil samples must all be considered in evaluating the usability of soil data for risk screening. The following is a description of example scenarios for the relative magnitude of these metrics and the implications of these scenarios for risk-based screening.

The various combinations of the relative magnitudes of background levels (BL), risk-based protection levels (PL), and DLs for soil data are summarized in Table APP-C1. The consequences of the scenarios for risk-based assessments of protectiveness (e.g., ecological risk screening) are color coded in Table APP-C1. The scenarios highlighted in grey denote cases for which soil data can be effectively screened by either PL or BL metrics, because the protection levels or background levels are > data detection limits (Scenarios 1 through 6 in Table APP-C1; Figure APP-C1a). The scenarios highlighted in red denote cases where the DL of the samples to be screened are greater than both the protection level and BL, and provide no basis for screening or evaluation of protectiveness (scenarios 7 through 9 in Table APP-C1; Figure APP-C1b). Because background is a range of values, there are also scenarios where the detection limit or the protectiveness metric can be within the background range (Figure APP-C1c); these scenarios are included in Table APP-C1. The only equivocal scenario is where the DL resides within the range of background values, and the protectiveness metric is less than both background and the DL (scenario 10 in Table APP-C1). This scenario is color coded orange in Table APP-C1, because the ability to assess protectiveness in this scenario depends on what constitutes an acceptable proportion of background data > detection.

An evaluation was then conducted comparing the relative magnitudes of the detection limits, the provisional background data, and current ecological risk screening levels for the “gap” analytes. The values used in this evaluation are summarized in Table APP-C2. The detection limits (MDLs) listed in Table APP-C2 are the lowest of the MDLs assumed to be routinely achievable for each of the analytes at the WSCF labs.

Table APP-C1. Summary of the possible scenarios of the relative magnitudes of the protectiveness level (PL), the background level (BL), and the detection limit (DL) to one another in the context of their usefulness to support risk-based decisions concerning protectiveness (i.e., usability)

<table>
<tr><th>1</th><th>2</th><th>3</th><th>4</th><th colspan="2">5</th><th colspan="2">6</th><th>7</th><th>8</th><th colspan="2">9</th><th colspan="2">10</th></tr>
<tr><td>PL</td><td>BL</td><td>BL</td><td>PL</td><td rowspan="3">BL</td><td></td><td colspan="2">PL</td><td>DL</td><td>DL</td><td colspan="2">DL</td><td rowspan="3">BL</td><td></td></tr>
<tr><td rowspan="2">BL</td><td rowspan="2">PL</td><td rowspan="2">DL</td><td rowspan="2">DL</td><td>PL</td><td rowspan="3">BL</td><td></td><td rowspan="2">BL</td><td rowspan="2">PL</td><td rowspan="3">BL</td><td></td><td>DL</td></tr>
<tr><td></td><td>DL</td><td>PL</td><td></td></tr>
<tr><td>DL</td><td>DL</td><td>PL</td><td>BL</td><td colspan="2">DL</td><td></td><td>PL</td><td>BL</td><td></td><td colspan="2">PL</td></tr>
</table>

PL = Protectiveness/Screening Level

DL = Detection Limit (of all data)

BL = Background Level

[green] PL and/or BL > DL; acceptable for risk analysis/screening

[red] DL > PL and BL; unacceptable/inappropriate for risk analysis/screening

[orange] DL within the range of BL; BL and DL> PL; Acceptability dependent on the proportion of background data > DL

The results of this aspect of the evaluation are presented in Table APP-C2 for the various scenarios for the combination of protectiveness values, detection limit values, and background values. The results shown in Table APP-C2 also identify the cases that are, and are not, conducive to ecological risk screening. The various scenario outcomes are color coded in the same manner as Table APP-C1. Scenarios highlighted in red denote cases that provide no basis for ecological risk screening because the detection level (MDL) of the soil data are above both the protection level and background level. Scenarios highlighted in green denote cases for which soil data can be effectively screened by either the ecological risk screening level or background, because the protection levels or background levels are > detection limits. The scenarios highlighted in orange denote cases where the ability to screen soil data is equivocal because there is little difference between the detection limit (MDL) and the protectiveness metric, and/or the MDL is within the range of background values.

It is indicated from the results of this evaluation that all of the “gap” analytes other than Sb, and B may be conducive to ecological risk screening, based on the relative magnitudes of the provisional background data, the ecological risk screening levels, and the laboratory MDLs for soil sample data. It is also indicated that a majority of the data for Cd, Li, Mo, Se, and possibly Ag, and Tl should be measurable above detection for uncontaminated soil samples within the range of the provisional background data for most soil sample data. However, the provisional background data may serve as determinant screening criteria for only two of the gap analytes (Cd and Se) because the ecological screening levels are larger than background and/or the MDLs for Li, Hg, Mo, Ag, and Tl. It is also indicated that there may still be no basis for ecological risk screening for B or Ca, because the soil sample MDLs appear to be larger, or comparable to provisional background levels, and/or the ecological screening levels for these analytes.

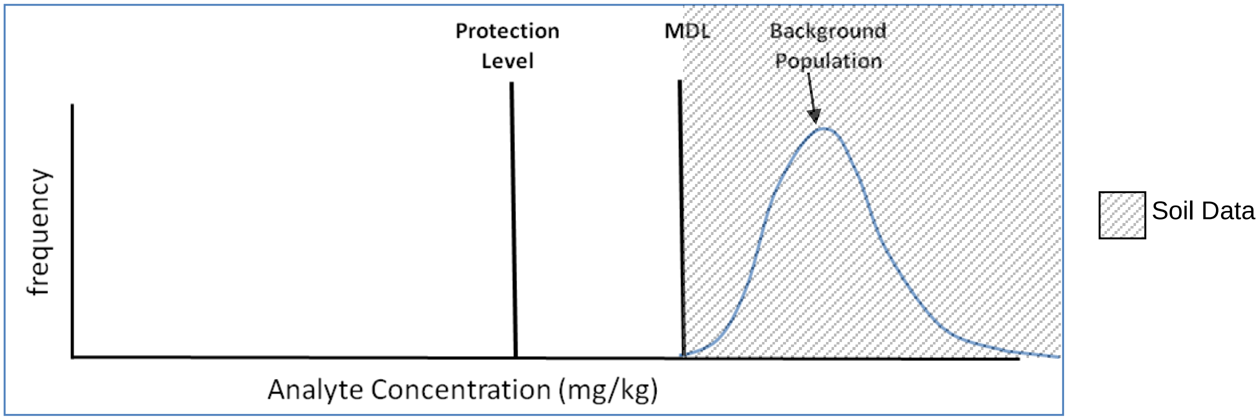

Figure APP-C1a. Background > MDL > Protection Level

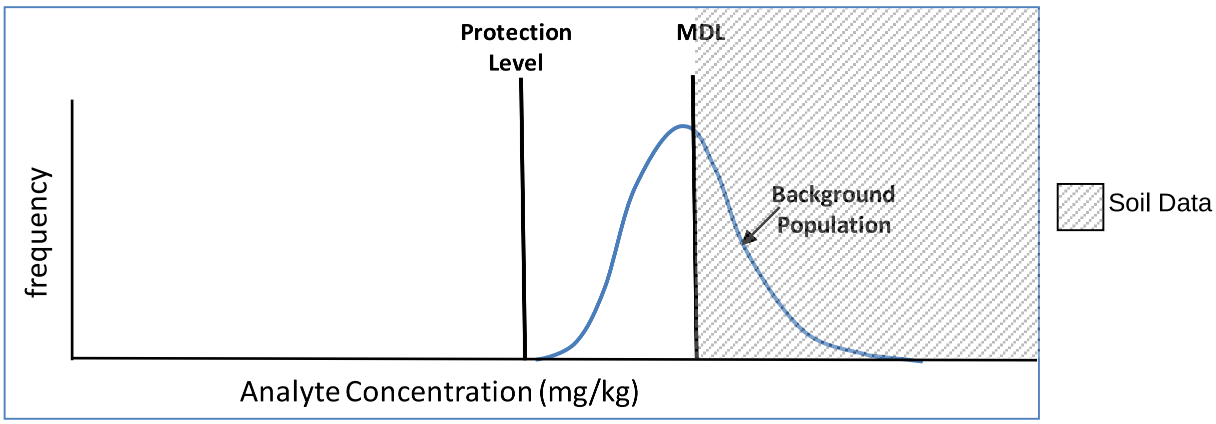

Figure APP-C1b. Background > MDL< Background > Protection Level

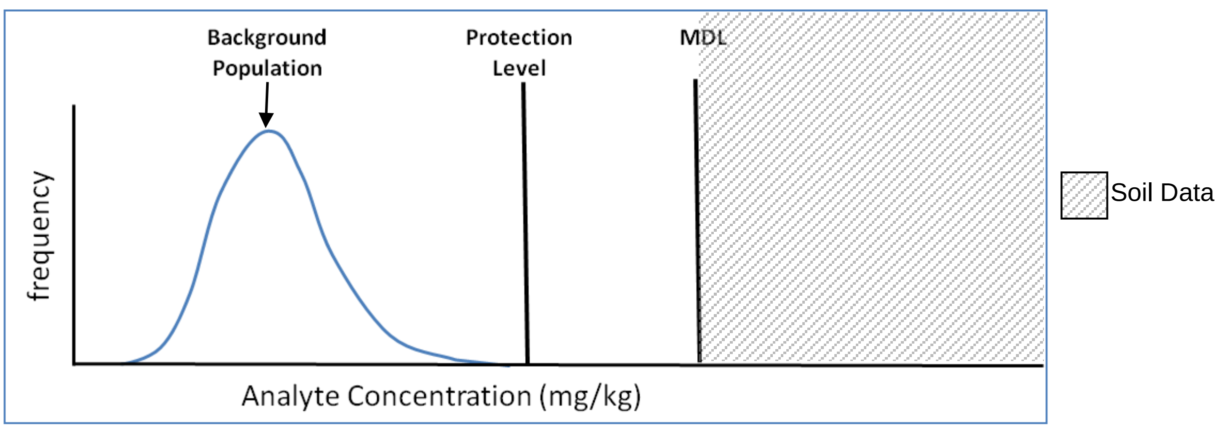

Figure APP-C1c. MDL > Protection Level > Background

Figure APP-C1. Examples of the Relative Magnitudes of Background Data, Protectiveness Metrics, and the Method Detection Limit (MDL) of Soil Data

Preliminary data from the recent analyses of an archived subset of the original soil background on vadose zone samples from the DOE/RL-92-24 study provides an initial check on the inferences from this aspect of the evaluation and insight concerning the detectability of the “gap” analytes in routinely measured soil data, and on the usefulness of the provisional data as well as new background data on the “gap” analytes in ecological risk screening. It is indicated from these preliminary data on the “gap” analytes for these vadose zone samples that the conclusions from the evaluation based on the provisional background data appear to be largely corroborated, with the following exceptions:

- Background data on selenium in HSB and other uncontaminated soil samples may be detectable and conducive to ecological risk screening
- The extent to which soil data for boron (B), cadmium (Cd), and thallium (Tl) are conducive to ecological risk screening is equivocal because these analytes cannot be screened if they are largely undetectable in background and other uncontaminated samples

Table APP-C2 shows a comparison of the relative magnitudes of provisional background data, detection limits (MDLs), and ecological risk screening levels for the gap analytes. The results are color coded in terms of capability for ecological risk screening. Green denotes scenarios conducive to screening; red denotes scenarios not conducive to screening; orange denotes scenarios that are equivocal for screening. The implications of these results for the detectability of the “gap” analytes, and ecological risk screening are summarized in Table APP-C3, which shows a comparison of the relative magnitudes of preliminary (new) data for vadose zone samples to ecological screening metrics and laboratory detection limits (MDLs) for the “gap” analytes. Highlighted cells summarize the percent of preliminary data above detection, and ability for the “gap” analytes to be evaluated in ecological risk screening. The cases highlighted in green in Figures APP-C2 and APP-C3 denote those that are conducive to screening, and orange denotes equivocal cases. Cases highlighted in red denote those where MDL>background, and/or where there is no determinant screening criteria > MDL.

Table APP-C2. Comparison of Comparison of the Relative Magnitudes of Provisional Background Data, Detection Limits (MDLs), and Ecological Risk Screening Levels for the Gap Analytes

Gap Analyte	Provisional Background Data		Soil Data Detection Limit (MDL)	Ecological Soil Screening Level (EcoSSL)	Provisional Background > Soil Data MDL?	Largest of Background (Bkgr), Detection Limits (MDL), and Ecological Risk Screening (Eco) Values
	50th Percentile	90th Percentile				
	Soil Concentration (mg/kg)					
Sb	0.100	0.130	0.3	0.27	No (1%)	**MDL** ≈ **EcoSSL** > Bkgr
B	2.09	3.89	4.1	0.50	No (6%)	**MDL** > Bkgr > EcoSSL
Cd	0.366	0.563	0.1	0.36	Yes (100%)	**Bkgr** ≈ **EcoSSL** > MDL
Li	8.62	13.3	0.4	35	Yes (100%)	**EcoSSL** >> Bkgr > MDL
Hg	0.004	0.0131	0.05	0.10	No (0%)	**EcoSSL** > MDL > Bkgr
Mo	0.318	0.470	0.1	2.0	Yes (99.4%)	**EcoSSL** > Bkgr > MDL
Se	0.525	0.805	0.3	0.30	Yes (100%)	**Bkgr** > MDL ≈ EcoSSL
Ag	0.109	0.167	0.1	0.52	?? (62%)	**EcoSSL** > Bkgr ≈ MDL
Tl	0.118	0.185	0.1	1.00	?? (64%)	**EcoSSL** >> Bkgr ≈ MDL

Table APP-C3. Comparison of Representative Gap Analyte Soil Data to Provisional Background, Ecological Screening Levels, and Laboratory Detection Limits (MDLs)

Gap Analyte	Representative Data on Uncontaminated Soil Samples*		Soil Data Detection Limit (MDL)	Ecological Screening Level	Background > Soil Data MDL?	Largest of Background (Bkgr), Detection Limits (MDL), and Ecological Risk Screening (Eco) Values
	50th Percentile	90th Percentile				
	Soil Concentration (mg/kg)					
Sb	≤ 0.30	≤ 0.30	0.3	0.27	No (7%)	**MDL** ≈ **EcoSSL**; ~No Bkgr
B	? (no reliable data)		4.1	0.50	??	MDL > EcoSSL; ~No Bkgr
Cd	0.1	0.15	0.1	0.36	No (17%)	**EcoSSL** > MDL ≈ Bkgr
Li	4.28	9.66	0.4	35	Yes (93%)	**EcoSSL** >> Bkgr > MDL
Hg	≤ 0.05	≤ 0.05	0.05	0.10	No (0%)	**EcoSSL** > MDL; ~ No Bkgr
Mo	0.352	0.504	0.1	2.0	Yes (93%)	**EcoSSL** > Bkgr > MDL
Se	0.93	1.64	0.3	0.30	Yes (87%)	**Bkgr** > MDL ≈ EcoSSL
Ag	≤ 0.1	≤ 0.10	0.1	0.52	No (0%)	**EcoSSL** > MDL; ~No Bkgr
Tl	0.1	0.141	0.1	1.00	?? (47%)	**EcoSSL** >> Bkgr ≈ MDL

* Based on preliminary results of analyses of archived background samples from the HSB study (DOE/RL 92-24)

- (green) Denotes cases conducive to screening
- (orange) Denotes cases that are equivocal for screening
- (red) Denotes cases not conducive to screening because MDL>background, and/or where there is no determinant screening criteria > MDL