Quality Assurance Project Plan

Evaluating the Toxicity of Arsenic and Lead in the Soils of the Tacoma Smelter Plume Footprint and Hanford Site Old Orchards Areas

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Author and Contact Information

Janice Sloan
P.O. Box 47600
Environmental Assessment Program
Washington State Department of Ecology
Olympia, WA 98504-7710

Communications Consultant
Phone: 360-407-6834

Washington State Department of Ecology - www.ecy.wa.gov/

○ Headquarters, Olympia	360-407-6000
○ Northwest Regional Office, Bellevue	425-649-7000
○ Southwest Regional Office, Olympia	360-407-6300
○ Central Regional Office, Yakima	509-575-2490
○ Eastern Regional Office, Spokane	509-329-3400

Cover photos: Left - Hanford Old Orchards; Right – Burton Acres Park, Vashon Island.

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Approved by:

Signature:	Date: June 2010
David Sternberg, Client, Information and Policy, TCP	
Signature:	Date: June 2010
Martha Hankins, Client's Unit Supervisor, Information and Policy, TCP	
Signature:	Date: June 2010
Dave Bradley, Client's Section Manager, Information and Policy, TCP	
Signature:	Date: June 2010
Jerry Yokel, Client, Nuclear Waste Program, Richland Office	
Signature:	Date: June 2010
Janice Sloan, Author / Project Manager / Principal Investigator / EIM Data Engineer, EAP	
Signature:	Date: June 2010
Dale Norton, Author's Unit Supervisor, Toxics Studies Unit, EAP	
Signature:	Date: June 2010
Will Kendra, Author's Section Manager, Statewide Coordination Section, EAP	
Signature:	Date: June 2010
Stuart Magoon, Director, Manchester Environmental Laboratory, EAP	
Signature:	Date: June 2010
Bill Kammin, Ecology Quality Assurance Officer	

Signatures are not available on the Internet version.
TCP – Toxics Cleanup Program
EAP – Environmental Assessment Program

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Abstract

Historic smelting operations at the ASARCO facility in Tacoma and use of lead arsenate pesticides in fruit orchards within the Hanford Site have resulted in widespread arsenic and lead contamination. Cleanup activities at both of these sites have focused primarily on human health risks.

The Washington State Department of Ecology (Ecology) will evaluate impacts of arsenic and lead contaminated soils on wildlife to determine the suitability of current ecological soil screening levels under the Model Toxics Control Act in both contaminated areas. Results of the study will be used to help establish ecologically-based cleanup levels that protect wildlife at sites in the Tacoma Smelter Plume footprint and in the Hanford Old Orchards area.

Twenty-five locations in the Tacoma Smelter Plume and 11 locations in the Hanford Old Orchards representing a range of arsenic and lead concentrations in different soil types will be sampled. Soil, native plant, and earthworm or beetle samples will be analyzed for arsenic and lead. Twenty-one of the soil samples will also be analyzed for copper and lettuce and earthworms bioassay success. In addition, arsenic species will be analyzed in 16 of the soil samples. Soil and habitat characteristics will be observed at each location. This study design provides a framework for determining how well soil type predicts toxicity and how different levels of arsenic and lead affect wildlife.

Each study conducted by Ecology must have an approved Quality Assurance Project Plan. The plan describes the objectives of the study and the procedures to be followed to achieve those objectives. After completion of the study, a final report describing the study results will be posted to the Internet.

Background

Arsenic and lead are elements present in most soils. However, elevated levels of these metals can pose a risk to humans and wildlife. Risks from arsenic and lead exposure include increased occurrences of cancer, birth defects, infertility, and neurological disorders (Eisler, 1988a and b). In the state of Washington, air emissions from metal smelters and the use of lead arsenate pesticides has resulted in widespread arsenic and lead soil contamination well above natural background concentrations.

This study will focus on arsenic and lead contamination from the American Smelting & Refining Company (ASARCO) smelter located in Tacoma, WA (Tacoma Smelter) and lead arsenate pesticides used in old orchards within the U.S. Department of Energy Hanford Site[1] (Figure 1). The ecological impacts of arsenic and lead contamination in these two areas are poorly understood. We need more data to determine ecologically-relevant cleanup standards for arsenic and lead contaminated soils. This study will evaluate the risks to wildlife posed by contaminated soils to determine if current soil screening levels accurately predict risks to wildlife in the

[1] Hereafter referred to as "Hanford Old Orchards"

Tacoma Smelter Plume footprint and Hanford Old Orchards. The results of this study will be used to help establish ecologically-based cleanup levels that protect wildlife at sites and prioritizing cleanup of sites within the Tacoma Smelter Plume footprint and Hanford Old Orchards.

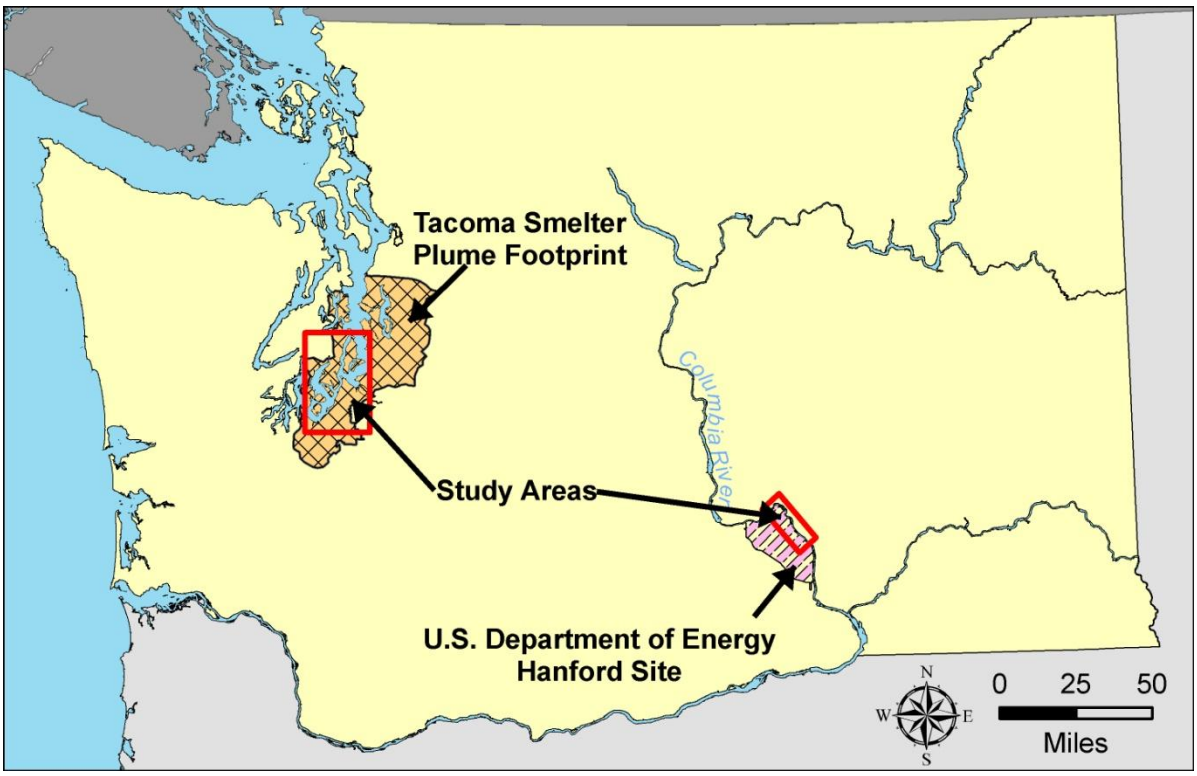

Figure 1. Map of Washington with sampling areas.

Tacoma Smelter

The Tacoma Smelter was built in 1887 and began smelting lead in 1890. ASARCO purchased the smelter in 1905 and converted it from lead to copper smelting by 1912. During operations as a copper smelter, the Tacoma Smelter also manufactured 10,000 tons of arsenic annually from smelting by-products. In 1983 the Tacoma Smelter and surrounding portions of Commencement Bay were designated as an Environmental Protection Agency (EPA) superfund cleanup site. Copper smelting ceased in 1985 and the smelter closed in 1986. The superfund cleanup site includes the areas adjacent to the smelter; however, emissions from the stack contaminated a much larger area, approximately 1,000 square miles. This larger area is called the Tacoma Smelter Plume footprint (Figure 1). (Pacific Groundwater Group and TeraStat Inc., 2005; EPA, 2010; Ecology, 2007).

Under the Model Toxics Control Act (MTCA) method A human health cleanup standards for soils are 20 parts per million (ppm) for arsenic and 250 ppm for lead. Soil concentrations in the Tacoma Smelter Plume footprint range from 0.48 to 1,100 ppm for arsenic and 1 to 6,700 ppm

for lead. Large portions of the Tacoma Smelter Plume footprint fail to meet the MTCA method A standards.

Currently cleanup in the Tacoma Smelter Plume footprint is primarily focused on child-use areas. Child-use areas are prioritized for cleanup if the:

- Average arsenic or lead levels are above the interim action trigger levels, 20 and 250 ppm respectively.
- Maximum concentration at the site of arsenic is above 40 ppm or lead is above 500 ppm.
- Average arsenic concentration is 100 ppm or a maximum above 200 ppm or average lead concentration is above 250 or a maximum above 500 ppm. Child-use areas in this category are considered high priority sites for personalized follow-up and funding (Landau Associates, 2006).

The high priority criteria will also be used in future efforts to screen residential properties participating in the soil safety program (personal communication: Amy Hargrove)

The current cleanup strategies in the Tacoma Smelter Plume footprint focus on human health concerns, particularly those of children. This study specifically looks at the impacts to wildlife of arsenic and lead contamination in the Tacoma Smelter Plume footprint.

Old Orchards

Old orchards located in Eastern Washington have a different source of contamination for arsenic and lead. In the 1800s a number of areas in Eastern Washington were settled and subsequently planted with orchards. By the early 1900s, lead arsenate pesticides were widely used to control insects in the orchards. In 1947, Dichlorodiphenyltrichloroethane (DDT) replaced lead arsenate as a more effective pesticide in orchards. The focus area in Eastern Washington for this study is the Hanford Old Orchards area within the US Department of Energy's Hanford Site (Figure 1). The Hanford Old Orchards area was settled in the mid 1800s and abandoned with the start of the Manhattan Project in 1943 (Yokel and Delistraty, 2003).

It can reasonably be expected that DDT was used for some period of time in most old orchards that previously used lead arsenate pesticides. Therefore, determination of toxicity due to lead arsenate pesticides in these old orchards is confounded by the presence of DDT. Since the Hanford Old Orchards were abandoned before widespread use of DDT, they provide a unique example of old orchards. It is important to recognize that contaminants other than DDT may be present in Hanford Old Orchards soils due to Hanford site operations.

Similar to the Tacoma Smelter Plume footprint, old orchard areas in Eastern Washington have been cleaned up primarily for human health reasons with a focus on child-use areas. Cleanup of the Hanford Site has primarily focused on areas contaminated during the operation of plutonium reactors. The Hanford site is not open to the public so the arsenic and lead contamination does not immediately impact human health. Therefore cleanup of the Hanford Old Orchards will have an increased focus on ecological impacts to the variety of wildlife present at the site with consideration for future public use of this area.

Terrestrial Ecological Evaluations

The Tacoma Smelter Plume and Hanford Old Orchards have previously been studied for arsenic and lead contamination in soil (Yokel, Delistraty, 2003; EHD-PD, 2000; 2001; Pearman et al., 2003; Glass, 2004; Pacific Groundwater Group and TeraStat Inc, 2005; TPCHD, 2004; Golding, 2001). However, it is difficult to translate these soil concentrations to actual ecological risks for wildlife due to a lack of associated toxicity information.

To determine ecological risk the Washington State Department of Ecology (Ecology) uses terrestrial ecological evaluations (TEE), which are performed at contaminated sites per WAC 173-340-7490 through 7494. Part of this process entails comparing concentrations of arsenic and lead present at a site to soil screening levels (SSL). SSLs are derived from a wildlife exposure model per the TEE process. If SSLs are exceeded, the SSL may be used as a conservative cleanup level for the site, or additional, site-specific evaluations may be performed.

SSLs have been developed for a variety of toxic chemicals and are generally considered protective of wildlife. However, arsenic and lead SSLs may overestimate risks to wildlife because they rely on laboratory toxicity tests on spiked soil [2]. Multiple studies have found that spiked soils exhibit toxicity at lower concentrations than in-situ concentrations of arsenic and lead (Button et al., 2009; Ma et al., 2009; Pascoe et al., 1996; Suedel et al., 2006). This difference is due to factors such as metal speciation, pH, weathering, and particle size which influence the toxicity of contaminated soils and are unaccounted for in laboratory toxicity tests on spiked soil (Beaulieu and Savage, 2005; Ma et al., 2009; Suedel et al., 2006). We lack local data exploring the effects of soil characteristics on the toxicity of arsenic and lead in Washington soils. Therefore we don't know whether soil cleanup levels based on current SSL values accurately predict the risks to wildlife in Washington.

It is important that SSLs adequately protect wildlife while considering the ecological[3] and monetary expense of setting these values too low. The Tacoma Smelter Plume footprint and Hanford Old Orchards are very large areas, making it difficult to conduct thorough TEE investigations in every impacted area. A purpose of this study is to focus ecologically-based site evaluations and cleanups on the sites that pose the greatest risk to wildlife. Increasing our knowledge of the factors that influence arsenic and lead toxicity in Washington soils will help project managers to prioritize cleanups. Increased knowledge of these factors may also lead to TEE methods that more accurately set cleanup levels at a site.

[2] Laboratory- spiked soil are produced from the combination of clean field collected or laboratory- created soils and the contaminant of interest. This soil preparation is then used to test the toxicity of the contaminant to various organisms. This process allows for various levels of contamination to be tested in a controlled environment.
[3] Ecological risks of low cleanup levels pertain to habitat destruction as a result of the cleanup efforts. For example the ecological value of a forest with 100 year old trees is substantially different from a remediated forest of sapling trees.

Soil Type

One way to group the various factors that may influence the toxicity of arsenic and lead in soils is soil type. Each soil type typically has its own unique set of characteristics such as grain-size distribution, organic matter content, and pH. Grouping areas by soil type provides a foundation for assessing sites not sampled as part of this project. Site managers can determine what soil type and total concentrations of arsenic and lead are present at their site. They can use data from this project to relate that information to relative risks to wildlife to prioritize further investigation.

Project Description

This project is designed to sample areas with a range of known (very high, high, medium, and low) arsenic and lead levels across different soil types. A total of 36 samples representing a large range of arsenic and lead concentrations will be collected from five soil types in the Tacoma Smelter Plume and two soil types in the Hanford Old Orchards. Soil, native plant, and earthworm or beetle samples will be analyzed for arsenic and lead. Twenty-one of the soil samples will also be analyzed for copper and for lettuce and worm bioassay success. In addition, arsenic species will be analyzed in 16 of the soil samples. Soil and habitat characteristics will be recorded at each location. This approach will determine how predictive soil type is of toxicity and the effects of different levels of arsenic and lead on wildlife.

Study Objectives

The objectives of this study are to:

- Determine if alternative ecologically relevant cleanup levels based on soil type are practical for use in the Tacoma Smelter Plume and Hanford Old Orchards; define the information required to make decisions at cleanup sites.

- Collect and analyze data for risks to wildlife in the Tacoma Smelter Plume and Hanford Old Orchards, based on current[4] and modified[5] wildlife exposure models.

- Increase knowledge of soil types and physical characteristics that influence arsenic and lead toxicity and speciation.

[4] The "current wildlife exposure model" is based on laboratory derived toxicity and accumulation values.
[5] The "modified wildlife exposure model" will be based on field data collected as part of the study.

Organization and Schedule

The following people are involved in this project.

Table 1. Organization of project staff and responsibilities.

Staff (all are EAP except client)	Title	Responsibilities
David Sternberg Toxics Cleanup Program (TCP) Headquarters Phone: (360) 407-7146	Client (TCP)	Clarifies scopes of the project. Provides internal review of the QAPP and approves the final QAPP.
Jerry Yokel Nuclear Waste Program (NWP) Richland Phone: (509) 372-7937	Client (NWP)	Clarifies scopes of the project. Provides internal review of the QAPP and approves the final QAPP.
Janice Sloan Toxics Studies Unit, SCS Phone: (360) 407-6553	Project Manager and Principal Investigator	Writes the QAPP. Oversees field sampling and transportation of samples to the laboratory. Conducts QA review of data, analyzes and interprets data. Writes the draft report and final report.
Staff Toxics Studies Unit, SCS Phone: N/A	Field Assistant	Helps collect samples and records field information.
Dale Norton Toxics Studies Unit, SCS Phone: (360) 407-6765	Unit Supervisor for the Project Manager	Provides internal review of the QAPP, approves the budget, and approves the final QAPP.
Will Kendra Toxics Studies Unit, SCS Phone: (360) 407-6698	Section Manager for the Project Manager	Reviews the project scope and budget, tracks progress, reviews the draft QAPP, and approves the final QAPP.
Misty Kennard-Mayer Brooks Rand Labs Phone: (206) 753-6125	Project Manager for Brooks Rand Labs	Analyzes arsenic speciation.
Cat Curran Nautilus Environmental Laboratories Phone: (253) 922-4296	Project Manager for Nautilus Environmental	Conducts bioassay testing.
Dean Momohara MEL Phone: (360) 871-8808	Unit Supervisor	Oversees general and metals analyses.
Stuart Magoon MEL Phone: (360) 871-8801	Director	Reviews the draft QAPP and approves the final QAPP.
William R. Kammin EAP Phone: (360) 407-6964	Ecology Quality Assurance Officer	Reviews the draft QAPP and approves the final QAPP.

EAP – Environmental Assessment Program.
QAPP – Quality Assurance Project Plan.
SCS – Statewide Coordination Section
MEL - Manchester Environmental Laboratory

Table 2. Proposed schedule for completing project milestones.
Milestones include field and laboratory analysis and reports.

Field and laboratory work	Due date	Lead staff
Field work completed	May 2010	Janice Sloan
Laboratory analyses completed	July 2010	
Environmental Information System (EIM) database		
EIM user study ID	NA	
Product	Due date	Lead staff
EIM data loaded	NA	
EIM QA	NA	
EIM complete	NA	
Final report		
Author lead	Janice Sloan	
Schedule		
Draft to supervisor	October 2010	
Draft to client/peer reviewer	November 2010	
Draft to external reviewer(s)	December 2010	
Final to publications coordinator	January 2011	
Final report posted on web	February 2011	

Quality Objectives

Quality objectives ensure that data collected during this study are representative of the environment, acceptable for their intended use, and meets the goals and objectives of the project. Environmental representativeness will be achieved by following the study design and procedures detailed in the sections below. Features of the study design and procedures such as sampling location and sample type were developed to reflect the goals and objectives of the study. This QA Project Plan will be taken into the field to ensure the procedures outlined here are followed.

Measurement Quality Objectives

The measurement quality objectives are performance criteria for field measurements and laboratory analyses performed during this study. These objectives specify the techniques and measurements that will be performed to assess the precision and bias of the results produced.

Field measurements are expected to adhere to the measurement quality objectives in Table 3. Laboratories are expected to meet the measurement quality objectives outlined in Tables 4 and 5. The lowest concentrations of interest reflect levels below current screening levels for the protection of wildlife and achievable with the methods specified.

Table 3. Soil measurement quality objectives for measurements taken in the field.

Parameter (Units)	Instrument/ Method	Calibration	Standards Check	Range	Accuracy	Resolution
pH	Orion pH meter/ EPA method 9045D	Must be calibrated at a minimum of 2 points that bracket the expected pH values. The temperature of the buffer must be <2°C different from the samples.	<±0.1 pH units of buffer solution, check performed prior to sampling, after every 10th sample, and post-sampling	-2.0 to 14.0	±0.01	0.01
Arsenic (ppm)	XRF/ EPA method 6200	Must be standardized with clip or token included with instrument prior to use and after every 4- hour period or as directed by the display.	<±20% of standard reference material or soil sample of a known concentration, check performed prior to sampling, after every 20th sample, and post-sampling	>8	±10%	1
Lead (ppm)						

XRF = X-ray Fluorescence Instrument.

Table 4. Measurement quality objectives for laboratory chemical analyses.

Analysis (Units)	Lab	Calibration	Method Blank	Laboratory Control Sample[1]	Duplicates	Matrix Spikes	Lowest Concentration of Interest
Total Organic Carbon (%)	MEL	Follow method / instrument specific calibration procedures	<0.1	-	RSD ≤20%	-	0.1
Total Solids (%)			-	-		-	1.0
As, Cu, Pb (mg/Kg dw)			0.1	80-120% RPD ≤25%	RPD ≤20%	75-125%	0.1
As Species (mg/Kg dw)	BRL						
Grain Size (%)	N/A	-	-	-		-	5

MEL = Manchester Environmental Laboratory.
BRL = Brooks Rand Labs.
RPD = Relative percent difference.
RSD = Relative standard deviation.
N/A = Not Applicable.
As = Arsenic, Cu = Copper, Pb = Lead.
dw = dry weight.
[1]A known matrix spiked with analytes representative of the target analytes used to document laboratory performance.

Table 5. Measurement quality objectives for bioassay tests.

Bioassay Test	Test Conditions				Control Performance
	Temperature	Photoperiod	Soil Moisture Content	Soil pH	
Lettuce	20-30°C	16 hrs light/8 hours dark	-	-	Mean germination ≥ 90%
Earthworm	20-24°C	24 hours light	35-45%	5.0-9.0	Survival ≥ 90%

Process Design (Experimental Design)

The MTCA contains the rules for cleanup of contaminated sites based on human health and ecological risk. Within MTCA the terrestrial ecological evaluation (TEE) (WAC 173-340-7490 through 7494) details the process of assessing ecological risk and selecting cleanup levels relevant to wildlife at a site. This study will use the TEE process as a framework for assessing the ecological risk presented by area-wide contamination of arsenic and lead in the Tacoma Smelter Plume footprint and Hanford Old Orchards. For the most part the TEE process will be followed; however, since this is not a site-specific study, certain elements do not apply.

Terrestrial Ecological Evaluations

The problem formulation step of the TEE process requires an assessment of the potential impact that contaminants may have on wildlife at a site. If cleanup of a site under the human health-based portion of MTCA is sufficient to also address the risk to wildlife, no further action is needed. However, if the human health-based cleanup will not address ecological risks, an additional ecological cleanup level should be established for the site. Table 6 describes each part of the problem formulation step and the use of the step in this study.

Once it is determined that an ecologically-based cleanup is needed, SSLs specified in the TEE may be used as the ecological cleanup level, or alternative methods can be selected to determine the cleanup level (WAC 173-340-7493 Table 749-3, Table 7). When SSLs are unavailable for the contaminant of concern, or there is reason to believe that the SSLs are inappropriate for the site, it is appropriate to use alternative methods for establishing a cleanup level. The choice of which alternative methods to use at a site depends on the characteristics of the site and the availability of data. Table 8 summarizes the alternative methods used for determining ecological cleanup levels, the details about each method, and which methods will be used in this study.

Table 6. Terrestrial Ecological Evaluation - problem formulation.

<table>
<tr><th>Step/General Description</th><th>Details</th><th>This Study</th></tr>
<tr><td>Contaminants of ecological concern</td><td>What chemicals may cause a problem?

Any chemical that exceeds the SSLs is considered a contaminant of concern until proven otherwise at a site.</td><td>Arsenic and Lead</td></tr>
<tr><td>Exposure pathways for each receptor</td><td>How are plants and animals exposed to the chemicals?

Determine if a complete potential exposure pathway for plants and animals to the chemical of concern is present. A complete exposure pathway means that the contaminants in the soil have the potential to enter an organism and cause harm (e.g., direct ingestion of soil). An exposure pathway is considered incomplete when a barrier such as buildings, paved roads, pavement, or other physical barriers prevents the contaminants from entering the organism.</td><td>Complete exposure pathways are assumed for all plants and animals</td></tr>
<tr><td>Ecological receptor species groups</td><td>What particular plants and animals are likely to be exposed at the site?

Identify current or potential future terrestrial species groups reasonably likely to live or feed at the site. Ecological receptors are the plants and animals that have the potential of being harmed by the contamination. The default species groupings for ecological receptors are vascular plants, soil biota, ground-feeding birds, ground-feeding small mammal predators, and herbivorous small mammals. If present, protected species are given special consideration as receptors.</td><td>Due to the size of the areas being evaluated, default TEE receptors will be used for the Tacoma Smelter Plume footprint and alternative receptors suggested by Doctor, 2000 will be used for the Hanford Old Orchards.
<table>
<tr><th>Species Group</th><th>Tacoma Smelter Plume</th><th>Hanford Old Orchards</th></tr>
<tr><td>Birds</td><td>American Robin</td><td>Western Meadowlark</td></tr>
<tr><td>Predator Mammal</td><td>Shrew</td><td>Deer Mouse</td></tr>
<tr><td>Herbivorous Mammal</td><td>Vole</td><td>Northern Pocket Gopher</td></tr>
<tr><td>Soil Biota</td><td>Earthworm</td><td>Darkling Beetle</td></tr>
<tr><td>Vascular Plants</td><td>Not Specified</td><td>Cheatgrass</td></tr>
</table></td></tr>
<tr><td>Significant adverse effects on each ecological receptor</td><td>If plants and animals are exposed, what effects do the chemicals have on them at the site?

Identify significant adverse effects in the ecological receptors of concern that may result from exposure to the chemicals of concern, based on toxicological literature.</td><td>Not examined.</td></tr>
</table>

Table is derived from WAC 173-340-7493.

Table 7. Arsenic and lead ecological soil screening in mg/Kg dw.

Contaminant	Reference	Screening Concentrations[1]				Range of Concentrations in Study Areas[2]	
		Plants	Soil biota	Avian	Mamma-lian	Tacoma Smelter Plume[3]	Hanford Old Orchards[4]
Arsenic III	WAC 173-340-7493	-	-	-	**7**		
Arsenic V	WAC 173-340-7493	**10**	60	150	132		
Arsenic	EPA, 2005	**18**	-	43	46	0.48-1,100 (7)	2.9-270 (5)
Lead	WAC 173-340-7493	**50**	500	118	125	1-6,700 (24)	6.5-1,900 (11)
	EPA, 2005	120	1,700	**11**	56		

[1] The soil screening level (SSL) is the lowest screening concentration (bold).
[2] Values in parentheses indicate the background concentration for that area (San Juan, 1994).
[3] Pacific Groundwater Group and TeraStat Inc, 2005.
[4] Yokel and Delistraty, 2003.

Table 8. Terrestrial Ecological Evaluation - evaluation methods.

Step/General Description	Details	This Study
Literature Surveys	New soil screening concentrations are developed, based on literature for chemicals not listed in the TEE, or existing screening concentrations are modified to be more relevant to the site.	Literature will be used to derive total arsenic SSLs and may be used to modify some wildlife exposure model variables due to improved knowledge of these variables since the TEE was last revised.
Soil bioassays	For areas with existing or potential threats to plants, a lettuce bioassay is used to determine site-specific toxicity. For threats to soil biota, an earthworm bioassay is used. Other bioassays more relevant to the site may be used with approval.	Lettuce and earthworm bioassays will be performed on a sub-set of the locations. Bioassays are useful because they integrate the toxicity of all the factors associated with the soil. For example, other contaminants may be present in the soil that were not measured here or the specific soil conditions such as pH may make arsenic and lead more bioavailable to organisms resulting in a toxic effect. Therefore, the bioassays will provide key insights into the interactions between the soil and biota in a controlled environment.
Wildlife exposure model modifications	This model, used to calculate soil screening concentrations, may be changed if alternative values are more relevant to site-specific conditions, addition of a receptor, or substitution of a receptor.	Area- specific variables based on the results of this study will be calculated and used in the wildlife exposure model. Alternative receptors will be substituted in the Hanford Old Orchards.
Biomarkers	This method is used when biomarkers or sub lethal indicators have a high probability of detecting a significant adverse effect.	Not Applicable.
Site-specific field studies	Site-specific field studies that involve hypothesis testing, e.g., there are less earthworms per square foot in the contaminated area than in a clean area.	Not Applicable.
Weight of evidence or use of other methods	Any combination of the above methods or methods not described in the TEE approved for use by Ecology.	A weight of evidence approach will be used to determine site-specific toxicity using the methods detailed above.

Table is derived from WAC 173-340-7493.

Site Selection

It is important that a variety of locations are sampled to cover a range of factors and concentrations. Sampling locations were selected based on the following criteria. Each site must:

- Be within the study areas (Tacoma Smelter Plume footprint or Hanford Old Orchards).
- Represent a range of major soil types.
- Represent a range of arsenic and lead concentrations.
- Be accessible for sampling.
- Be relevant to or part of a cleanup site.
- Support or have the potential to support wildlife.

These criteria reflect the objectives of this project to increase knowledge of soil types and physical characteristics that influence arsenic and lead toxicity, and also to address the lack of field data for arsenic and lead soil toxicity in the state of Washington.

Major Soil Series

There are many classification levels used for soils. This study will use soil series as the basis for distinguishing between soil types. This approach was selected because each series has a unique set of characteristics. Each soil series is characterized by:

- Presence of, depth to, thickness of, and expression of horizons[6]
- Texture
- Grain size distribution
- Mineralogy[7]
- Cation-exchange capacity[8]
- Calcareous[9] and pH content
- Soil moisture
- Soil temperature
- Organic matter content
- Climate
- Slope

[6] Horizons are the layers of soil parallel to the earth's surface; each layer has characteristics that make it different from the layers above and below it.
[7] Mineralogy of a soil is the mixture of minerals or solid components that make up a soil. Each mineral has its own unique characteristics and properties. Salt, gypsum, and calcite are all examples of minerals that may be present in a soil.
[8] Cation-exchange capacity is the ability of a soil to retain cations or positively charged particles. Cations are an important component of soil fertility.
[9] Calcareous soils consist of or contain a high amount of calcium carbonate and typically have a high pH values.

Five soil series were selected in the Tacoma Smelter Plume footprint. Soil series in the Hanford Old Orchards have yet to be selected (Table 9). Each selected series in the Tacoma Smelter Plume footprint represents more than 10 square miles footprint. Together the selected series represent a variety of soil conditions.

Table 9. Tacoma Smelter Plume footprint selected soil series.

Series Name	Square Miles Represented by Series in TSP Footprint[1]	% of Footprint
TSP footprint	1207	-
Selected Series		
Alderwood	306	25
Everett	92	8
Harstine	94	8
Kitsap	25	2
Spanaway	43	4
Co-occurring Series[2]		
Alderwood and Kitsap	33	3
Everett-Alderwood	16	1
Total Represented:	609	50
Other Series		
Indianola[3]	31	3
Nisqually[3]	11	1
Spanaway-Nisqually[3]	1	<1
Other Mapped Series	249	21
Unmapped Area	306	25

[1]TSP = Tacoma Smelter Plume. Areas do not include water.
[2]Mapping was not detailed enough to distinguish between these series. When sampling in these areas every attempt will be made to target the series of interest at that location.
[3]These series are similar to one or more of the selected series.

Tacoma Smelter Plume Footprint Soil Series

In the Tacoma Smelter Plume footprint, 5 soil series were selected as areas of focus. These are the Alderwood, Everett, Harstine, Spanaway, and Kitsap soil series. All of these series were originally formed due to glacial activity. The selected series in the Tacoma Smelter Plume footprint are listed in Table 9 and individual sampling locations in Table 10 and Figure 2. Alternative sampling locations are shown in Appendix C and soil classification details are in Appendix D.

The Alderwood, Everett, and Harstine soil series are all well-drained, gravelly sandy loams in the top 6 inches, but they have their own unique characteristics. The Everett series has higher

gravel content than the Alderwood and Harstine series. The Alderwood series is well-drained but is more vulnerable to saturation due to higher water tables than Everett and Harstine soils. The Harstine series is strongly acidic in the surface layers, unlike the more neutral Alderwood and Everett series. The Indianola series is similar to the Everett series but doesn't contain as much gravel. The Indianola series was not selected because it represents a much smaller area of the Tacoma Smelter Plume footprint than the Alderwood, Harstine, and Everett series and can be represented by these more common series.

The Spanaway and Nisqually series are characterized by a prairie-type soil that has a black to dark surface layer with high organic matter content. Only the Spanaway series was selected as it represents a larger, more contaminated portion of the Tacoma Smelter Plume footprint and can represent the Nisqually series. Kitsap soils are derived from glacial lakebeds and therefore contain a high amount of silts and are poorly drained. (Soil Survey Staff, 2008 and personal communication with Chuck Natsuhara at the Natural Resource Conservation Service)

Hanford Old Orchards Soil Series

Specific soil series have not been selected in the Hanford Old Orchards because the locations of the individual orchards relative to the mapped soil series are unknown. Therefore, it is not practical at this time to choose site locations or soil series. Sites will be chosen based on the site selection criteria above. All sampling will occur in areas identified as old orchards. No sampling will occur in restricted areas regardless of the presence of old orchards.

The Hanford Old Orchards has 3 dominant soil series. These dominant soil series are Rupert[10], Ephrata, and Burbank. Rupert soils are sandy throughout. Ephrata is a sandy loam and has a cambric horizon. Burbank is loamy sand.

Minor amounts of Pasco and Riverwash are scattered throughout the Hanford Old Orchards. Pasco is a silt loam and is calcareous. All the soils in Hanford Old Orchards are moderately acidic. Riverwash is a miscellaneous mix of sand to boulders deposited by the Columbia River and is not generally considered a true soil series. Figure 3 shows the general area with old orchards and facilities within the Hanford site. (Hajek, 1966)

[10] Also known as Quincy Sand.

Table 10. Tacoma Smelter Plume footprint sampling locations.

General Soil Series	Site Name	General Location	Sampling Scheme	Arsenic[1]					Lead[1]				
				Target Range	Min	Max	Mean	Count	Target Range	Min	Max	Mean	Count
Alderwood	King Co. Marine Park	Vashon Island	Full	V. High	23	430	189	13	V. High	120	680	493	7
	Colgate Park	University Place	Full	V. High	67	220	142	6	V. High	140	470	255	6
	Dockton Park	Vashon Island	Basic	High	1.6	200	58	43	Medium	8.4	360	98	35
	Sunset Terrace Park	University Place	Basic	Medium	2.1	67	23	18	Low	2.4	79	44	18
	Winghaven Park	Vashon Island	Basic +	Low	1.6	26	10	18	Medium	5.3	900	81	18
Everett	King Co. Owned	Vashon Island	Full	V. High	28	220	125	4	Medium	33	310	186	4
	Morningside Farm	Vashon Island	Basic	High	1.3	261	56	249	Medium	1.6	441	72	249
	Burton Acres	Vashon Island	Full	High	2.7	150	45	37	Medium	8.7	430	101	36
	Island Center Forest	Vashon Island	Basic	Medium	20	41	31	5	Medium	30	210	78	5
	Fort Steilacoom Park	Lakewood	Basic	Medium	21	37	28	6	Medium	43	91	62	6
	Cormorant Park	Steilacoom	Basic +	Low	2.7	4.6	3.7	18	Low	5.3	15	9.1	18
Harstine	Eagle Ridge	Kitsap Peninsula	Full	V. High	13	160	107	-	Medium	29	580	226	-
	Morford's Open Space	Kitsap Peninsula	Full	High	8.7	93	47	13	Medium	36	310	106	13
	Lowell Johnson Park	Anderson Island	Basic	Medium	14	63	33	4	Medium	21	92	51	4
	Kopachuck SP	Kitsap Peninsula	Basic +	Low	2.0	5.2	3.5	24	Low	4.5	16	10	24
Kitsap	King Co. Marine Park	Vashon Island	Full	V. High	23	430	189	13	V. High	120	680	493	7
	Bonneville International	Vashon Island	Basic	High	29	190	84	10	Medium	19	710	168	10
	Neill Point Natural Area	Vashon Island	Basic	High	39	85	-	2	Medium	130	280	-	2
	Pt. Robinson Park	Vashon Island	Full	Medium	1.8	84	27	32	Low	5.9	130	42	30
	Winghaven Park	Vashon Island	Basic +	Low	1.6	26	10	18	Medium	5.3	900	81	18
	Kopachuck SP	Kitsap Peninsula	Basic	Low	2.0	5.2	3.5	24	Low	4.5	16	10	24
Spanaway	Tacoma Cemetery	University Place	Full	High	26	180	93	6	Medium	47	410	187	6
	Fort Steilacoom Golf C.	Lakewood	Full	High	35	90	49	7	Medium	53	210	94	7
	Fort Steilacoom Park	Lakewood	Basic	Medium	5.3	67	21	16	Low	6.2	110	33	16
	Idlewild School	Lakewood	Basic+	Low	5.5	25	9.9	8	Low	11	56	24	8

[1]Arsenic and lead data presented here are from EIM. The data are either from the site or an average of the surrounding area.
Full = Soil, earthworm, and plant + Bioassays + Arsenic species.
Basic + = Soil, earthworm, and plant + Bioassays.
Basic = Soil, earthworm, and plant.

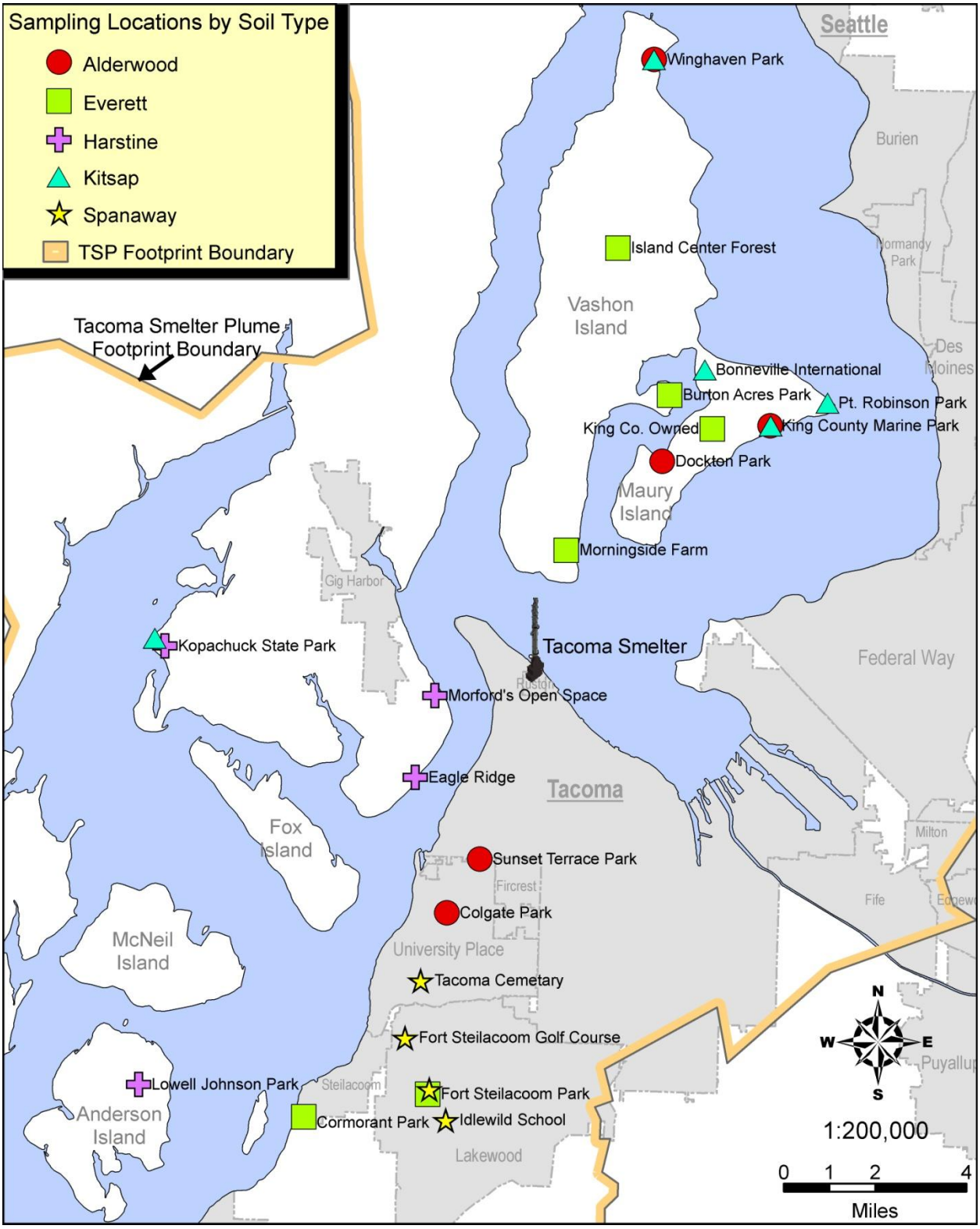

Figure 2. Map of Tacoma Smelter Plume (TSP) footprint boundary with sampling locations.

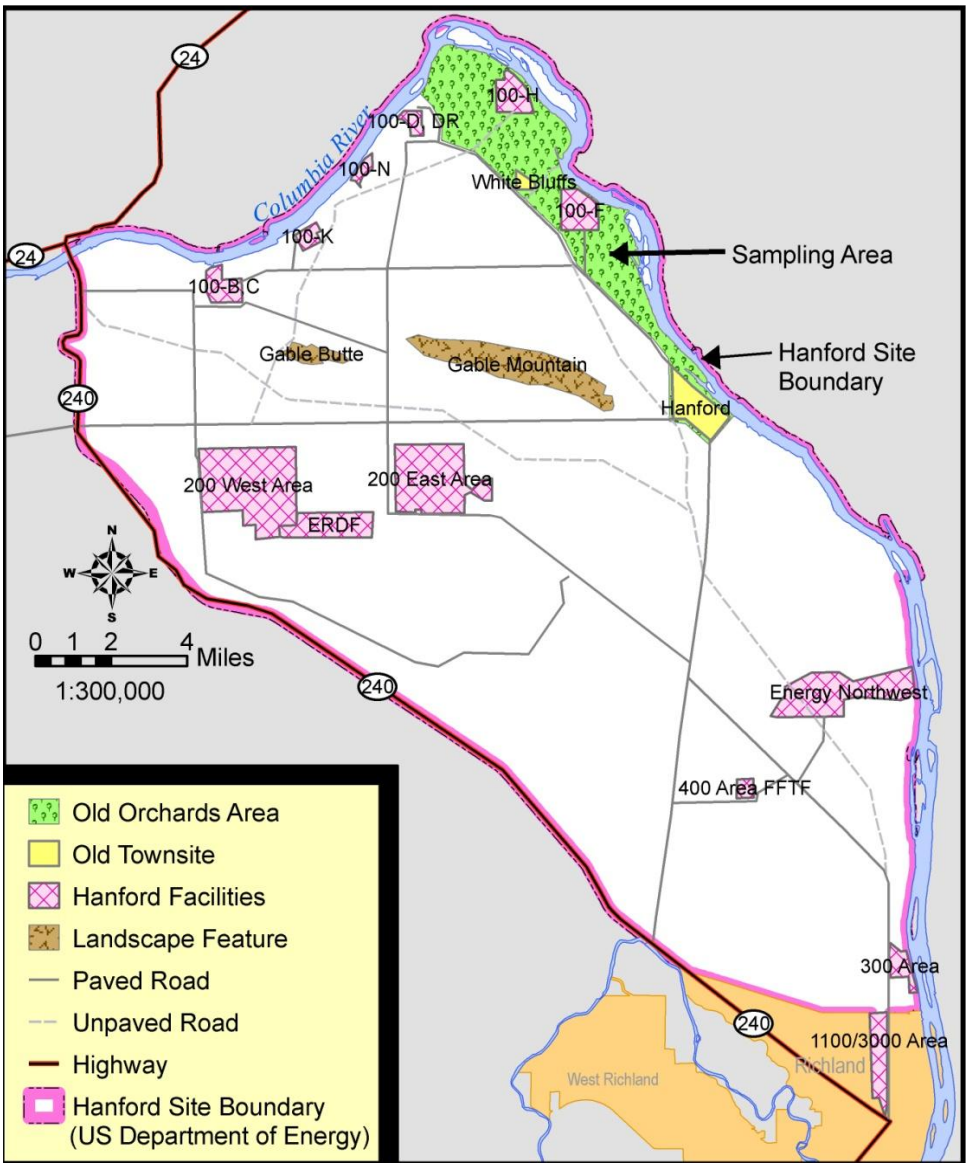

Figure 3. Map of Old Orchards within the US Department of Energy Hanford Site.

Arsenic and Lead Concentration Ranges

Large portions of the Tacoma Smelter Plume footprint and Hanford Old Orchards have arsenic and lead concentrations above the current SSL values that are not currently being addressed in the human health cleanup action plans (Table 7). Therefore this study will evaluate applicability of the current SSLs using site-specific wildlife exposure model modifications and soil bioassays.

This study uses SSLs, MTCA method A levels, and interim action levels to delineate arsenic contamination ranges. The target total arsenic concentration ranges are:

- Low = Non-Detect-20 mg/kg (below MTCA method A).
- Medium = 20-43 mg/kg (above MTCA method A, below wildlife screening concentration).
- High = 43-100 ppm (above wildlife screening concentration and Ecology-established interim action level for schools, childcares).
- Very High = 100+ mg/kg (above which child-use areas are categorized as high priority for personalized follow-up and funding cleanup)

Target lead concentration ranges follow the same logic as the arsenic ranges by using cleanup levels as the range boundaries:

- Low = Non-Detect-50 mg/Kg (below ecological SSL).
- Medium = 50-250 mg/Kg (above ecological SSL and below MTCA method A Cleanup Level).
- High = 250+ mg/Kg (above MTCA method A Cleanup Level).

Locations were selected so that within each soil type samples will represent different target arsenic ranges. Arsenic concentrations used to screen potential locations were based on data from Ecology's Environmental Information Management database (EIM). Using this data sites from at least two ranges were selected in each soil type, the most common and contaminated soil types will have more ranges represented (Table 10 and Figure 2). Confirmation that soils collected for this study fall within specified ranges will be achieved at each location using an X-ray Fluorescence Instrument (XRF) prior to collection of samples.

In the TSP, arsenic values tend to fail cleanup criteria more frequently than lead. Therefore, arsenic concentrations will be considered before lead concentrations when making sampling decisions. Previous studies indicate that arsenic and lead co-occur in the study areas. In addition, lead tends to follow a similar pattern as arsenic concentration levels (Yokel and Delistraty, 2003; EHD-PD and Glass, 2000). Therefore using arsenic as a surrogate for lead should insure that a range of concentrations will be sampled for both metals.

Arsenic Species

The SSLs for arsenic included in the TEE are based on laboratory toxicity values for trivalent arsenic (As(III)) and pentavalent arsenic (As(V)) species (Table 7). This separation reflects the higher toxicity of As(III) versus As(V) (Jain and Ali, 2000). However, soils are typically analyzed for total arsenic not individual species, resulting in very little arsenic species data. One reason for this may be that arsenic species in soils can change depending on the conditions present. This dynamic nature makes it difficult to predict As(III) to As(V) ratios over time without extensive and costly sampling schemes.

Beaulieu and Savage (2005) found that arsenic on Vashon-Maury Islands in Puget Sound is predominantly present as As(V). This is not surprising given that under aerobic, oxygen-rich conditions, As(V) is expected to dominate where As(III) is expected to be more abundant in anaerobic conditions such as wetland sediments. Yang et al. (2005) spiked As(III) into 19 different soils. After 48 hours, 62.6% of the bioavailable arsenic was present as As(V). This suggests As(III) rapidly oxidized to As(V) even in controlled laboratory conditions. This study will measure As(III) and As(V) in each evaluated soil type to determine the ratios of these two species present in Washington soils. If the results of this study show that As(V) is the dominant species, use of total arsenic toxicity values may be justified in the future for aerated, unsaturated soils.

Wildlife Exposure Model

The wildlife exposure model describes the transfer of arsenic and lead contamination from the soil into each receptor and what soil concentrations present a risk to wildlife. Figure 4 is a conceptual diagram of the components of the default model and includes the Hanford receptors. Appendix B shows the receptor values used for each component of the model. The lowest screening concentration derived from the model for wildlife for each contaminant is the SSL used for TEE evaluations (Table 7).

Site-Specific Modifications

This study will measure total arsenic and lead concentrations in the soil, plants, and soil biota, enabling site-specific invertebrate bioaccumulation factors (BAFs) and plant uptake coefficients (K) to be calculated as follows:

$$BAF = \frac{Concentration\ in\ Soil\ Biota}{Concentration\ in\ Soil}$$

$$K = \frac{Concentration\ in\ Plants}{Concentration\ in\ Soil}$$

Use of these site-specific values in the wildlife exposure model will result in modified screening concentrations and therefore SSLs that more accurately reflect the conditions in the specific soils sampled. Bioassay results will be used to evaluate the accuracy of both the default and modified SSLs.

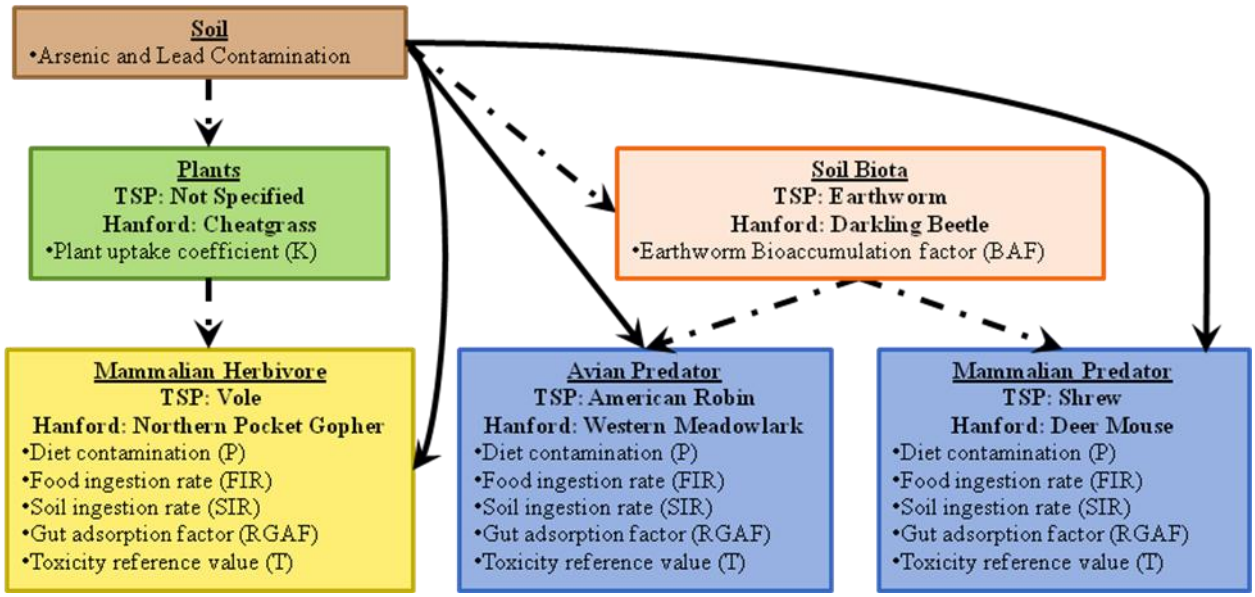

Figure 4. Diagram of the wildlife model used in a terrestrial ecological evaluation.

Outline of receptor species group parameters for the default (Tacoma Smelter Plume) and alternate receptors (Hanford) used in the terrestrial ecological evaluation wildlife model. Dotted lines represent the food pathway while solid lines represent the direct ingestion of soil pathway for arsenic and lead to enter organism. TSP = Tacoma Smelter Plume.

Analyses

Every location will be analyzed for arsenic and lead in soil, plants, and invertebrates. A sub-set of locations will also be analyzed for arsenic species in soil, copper in soil, and lettuce and earthworm bioassays. One location in the low arsenic concentration category and two locations in the high or very high arsenic concentration categories in each of the soil types will be tested for lettuce and earthworm bioassay success. The locations with low arsenic concentrations will serve as a reference for each soil type since they are not expected to show significant toxicity. By using the high/very high category locations the worst case scenario will be evaluated to gauge toxicity in the Tacoma Smelter Plume and Hanford Old Orchards.

Since copper was also emitted from the Tacoma Smelter there is a high probability of copper co-occurring with arsenic and lead in the Tacoma Smelter Plume footprint. Copper has a high toxicity potential and therefore will be measured in the Tacoma Smelter Plume sites selected for bioassays. Copper co-occurrence is not expected to be an issue in the Hanford Old Orchards but will be measured for consistency.

Arsenic species will be analyzed only in those locations that are in the high or very high arsenic concentration category and were selected for bioassays testing. This approach assumes the locations with the most arsenic present have a greater chance that some of it is present as As(III). A few additional locations may be analyzed for arsenic species if conditions increase the chance

of As(III) being present at the site. These conditions include recent or current inundation with water or unusually low pH.

Sampling Procedures

Site Characterization

When project staff arrive at a sampling location, they will assess the site. They will note any wildlife or any signs of wildlife (e.g., droppings, prints, hair) present at the site. They will also note any recent soil disturbances, especially in the case of plowing or construction activities that may influence sampling. Staff will write a general habitat description that describes the general flora and landscape type (e.g., prairie, forest, or scrubland). Staff will also note weather: temperature, general wind speed, cloudiness, and precipitation.

Abiotic

Soil series verification will take place when staff arrive at a sampling location. A small surface soil sample will be collected. This sample will be evaluated for texture characteristics (Appendix D), approximate grain size distribution (if needed), pH, and color. These measurements and the characteristics of the series will be compared and used to determine if the location matches the anticipated soil series. If the series description does not match the measured results, then other areas of the site will be evaluated until the correct conditions are found. If appropriate, an alternative location may be used.

Detailed soil series verification is a time- and labor- intensive process that may involve digging holes several feet deep. Therefore only one detailed soil series verification will be performed at each site and only if the soil series is in question. Those sites where the soil series is not clear include: (1) where a soil series occurs in close proximity to another series (not distinguished from one another when mapped); (2) where the site is located near the boundary of a mapped series. Surface soil verification will be performed at all sites to ensure the surface soil matches the soil series description.

Once the series is verified, an Innov-X Systems X-ray Fluorescence Instrument (XRF) will measure the arsenic and lead concentration. This measurement will be used to assess if the location falls within the anticipated concentration range. If the location does not fall within the anticipated range, every effort will be made to find a location within the site that meets both the soil series and anticipated concentration range requirements of the site. If the series is verified and the concentrations are out of range, the project manager may elect to use the alternative location or proceed with sampling, noting that the concentration is not within the specified range.

Once the soil series and concentration ranges are confirmed, the center of the sampling area will be marked with a stake and recorded with a global positioning system (GPS).

Soil Collection

Soil samples will be collected from the 0-6 inch depth horizon. The 0-6 inch depth has been used in a variety of other Tacoma Smelter Plume studies. Also, deeper soils have been shown to be less contaminated than the 0-6 inch layer. (EHD-PD and Glass, 2000; 2001; Glass, G. 2004; Pacific Groundwater Group and TeraStat Inc, 2005; TPCHD, 2004.) A study of Hanford Old Orchards also showed arsenic and lead concentrations generally decrease with soil depth indicating the surface layers are more heavily contaminated (Yokel and Delistraty, 2003). The surface soils are also more likely to be contacted or ingested by wildlife.

Soil samples will be collected using a soil auger, stainless steel hand trowel, or stainless steel spoon and will be placed in a stainless steel bowl. Roots and other debris such as rocks will be carefully removed from the soil sample. A sieve may be used to gently remove roots, twigs, and large rocks (>2 mm). A wind barrier will be used during collection and homogenization to minimize the loss of fine particles.

All sampling equipment (soil auger, hand trowel, spoon, sieve, and collection bowl) will be cleaned before use at each site. The cleaning process includes washing with water and phosphate-free detergent, rinsing with 10% nitric acid, and then rinsing three times with distilled water to remove any metals that may contaminate the sample.

At least five sub-samples will be collected at each site and composited into one sample. One sub-sample will be taken in the center of the site and then the remaining four will be collected between 2 and 12 feet from the center in each cardinal direction. The distance from center will be randomized using a die in the field. The face value will be multiplied by 2 to obtain a distance. If an obstacle such as a large boulder is present at a sample location the sample will be collected adjacent to the obstruction or the die will be rolled again. Each sub-sample will be evaluated for acceptance according to the following criteria:

- Characteristics of the sub-sample represent the soil series for that location.
- Measurement with the XRF is within the specified arsenic concentration range for that location.

If a sub-sample fails to meet this criteria the sub-sample may be re-randomized, the sampling area may be extended, or the center sub-sample location may be moved. If 5 acceptable sub-samples cannot be obtained, then less than 5 sub-samples may be composited for the sample.

Each soil sample will be homogenized in a stainless steel bowl with a stainless steel spoon. Once homogenized the sample will be split in the field for analysis of pH; grain size; total arsenic, lead and copper; arsenic species As(III) and As(V); total organic carbon content; percent solids; or bioassays. Parameters analyzed vary by site and are described in Table 11.

Table 11. Number of locations analyzed for each parameter.

Parameter	Total Number of Locations							
	Full		Basic +		Basic		Total	
	TSP[1]	HOO	TSP[1]	HOO	TSP[1]	HOO	TSP	HOO
pH	10	6	5	-	10	5	25	11
XRF	10	6	5	-	10	5	25	11
Grain Size	10	6	5	-	10	5	25	11
Arsenic and Lead	10	6	5	-	10	5	25	11
Copper	10	6	5	-	-	-	15	6
Arsenic Species	10	6	-	-	-	-	10	6
TOC	10	6	5	-	10	5	25	11
% Solids	10	6	5	-	10	5	25	11
Plant As and Pb	10	6	5	-	10	5	25	11
Soil Biota As and Pb	10	6	5	-	10	5	25	11
Freeze Drying Tissue	20	12	10	-	20	10	50	22
Lettuce Bioassay	10	6	5	-	-	-	15	6
Earthworm Bioassay	10	6	5	-	-	-	15	6

[1]See Table 10 for specific locations in each category (i.e., full, basic+, basic).
TSP = Tacoma Smelter Plume. HOO = Hanford Old Orchards.
As = arsenic. Pb = lead.

Biotic

Plants

Plants will be targeted for collection of leaves, stems, and roots. Collection of the entire plant reflects the foraging habits of the vole and northern pocket gopher. These receptors eat the leaves, stems, and roots of plants at different times of the year (Cosens, 2004; Long, 2003; Neuburger, 1999; VanderLinden, 2002). Every attempt will be made to collect plants within the soil sample area boundary. However, it will be more important to consistently collect the same plant species than stay within the soil sampling area. Due to this fact, collection will be allowed within 10 feet of any soil sample. When a plant is collected outside the soil sampling area boundary, a GPS and XRF measurement will be taken at that location.

Ten dry grams of plant material will be collected at each site and will be a composite of no less than three individual plants. An additional plant sample may be collected at a site if there are multiple dominant understory plant species or if there are other site-specific reasons. Some examples of acceptable species include salal, bunch grass, cheatgrass, and herbaceous plants.

Plants will be inspected for obvious abnormalities and deformities. In the field, all will be noted and photographed. These deformities, tumors, and lack of root hairs can be indications of stress or damage caused by the presence of heavy metals such as arsenic and lead.

After plants have been collected they will be placed in plastic bags and transported back to Ecology. In the lab, dust and soil particles will be rinsed from the surface of each plant with de-ionized water (Walsh et al., 1977). After being rinsed, plants will be cut up and placed in an eight ounce jar and sent to Manchester Environmental Lab (MEL). Upon arriving at MEL, they will be freeze-dried, ground, homogenized, and analyzed for arsenic and lead.

Soil Biota

In the Tacoma Smelter Plume footprint and Hanford Old Orchards earthworms and darkling beetles, respectively, will be collected to represent the soil biota. If no earthworms or beetles are found in the sampling area, other localized macroinvertebrates may be substituted. Substitutions must be noted. At least 5 macroinvertebrates of a single kind must be collected. More than 5 may be needed for analysis, depending on the size of the macroinvertebrates. An amount of greater than 5 g dry weight should provide sufficient material for analysis. Additional soil biota may be collected if earthworms are not the dominant soil biota at a site. Soil biota of the same kind will be composited into one sample for each site.

Every attempt will be made to collect soil biota within the soil sample area boundary. However, it will be more important to consistently collect the same kind of organism than to stay rigorously within the soil sampling area. Due to this fact, collection will be allowed within 10 feet of any soil sample. When soil biota are collected outside the soil sampling area boundary, a GPS and XRF measurement will be taken at that location. Soil biota will be collected by digging or by pitfall traps for the Tacoma Smelter Plume and Hanford Old Orchards, respectively. Obvious deformities, tumors, and lack of response to stimuli will be photographed and noted as these can be indications of stress or damage caused by the presence of heavy metals such as arsenic and lead.

After soil biota have been collected, dust and soil particles will be rinsed from the surface of each individual macroinvertebrate with de-ionized water. Macroinvertebrates will then be placed in a jar containing a moistened Kim Wipe and transported back to Ecology. Collected earthworms and any other invertebrates will be kept alive for 48 hours in jars containing moistened Kim Wipes and stored at 4°C to evacuate soil in the gut (Button et al., 2009; Ma et al., 2009; Langdon et al., 2005). This gut evacuation procedure will ensure that the arsenic and lead in the earthworm or other invertebrates is being measured not the soil so an accurate BAF can be calculated. After rinsing and holding is complete, the soil biota will be frozen and sent to MEL in jars. Upon arriving at MEL they will be freeze-dried, ground, homogenized, and analyzed for arsenic and lead concentrations.

Additional analyses of earthworm samples may be conducted by the University of Washington-Tacoma. These additional analyses will look at biomarkers or proteins whose presence indicates stress due to exposure to metals. For this reason, earthworm samples will be kept in a -80°C freezer before freeze-drying to prevent protein degradation.

Sample Labeling, Storage, and Handling

All sample containers will be labeled with the site name, date and time of collection, sample matrix, MEL sample ID, and analysis to be performed. Three field replicates for each analysis will be collected during the study and labeled in a similar manner for use as quality control samples.

After collection, all samples will be stored on ice and transported to Ecology storage facilities. All samples will be held at 4°C or frozen at -18°C, depending on the analysis storage condition requirements and when testing will occur. Samples to be analyzed for arsenic species will be frozen with dry ice immediately following collection to preserve the species. Table 12 shows recommended containers, storage conditions, and holding times for the analyses that will be performed.

Table 12. Sampling containers, preservation method, and holding times.

Analysis	Matrix	Laboratory	Container Size	Container Material	Storage Conditions	Holding Time	Dry Mass Required
Chemistry							
pH	Soil	N/A	4 oz.	Glass	Ambient	<1 day	20 g
TOC		Manchester Environmental Laboratory	2 oz.		0-6°C	14 days	25 g
					≤-18ºC	6 months	
% Solids			4 oz.		0-6°C ≤-18ºC	7 days 6 months	25 g
As, Cu, Pb (ICP/MS)					0-6°C	6 months	10 g
As, Pb (ICP/MS)	Plant Tissue		8 oz.		0-6°C	6 months	10 g
As, Pb (ICP/MS)	Invertebrate Tissue		2 oz.		0-6°C	6 months	5 g
As Speciation	Soil	Brooks Rand Labs	4 oz.	Plastic	≤-18ºC	6 months	50 g
Grain Size	Soil	N/A	8 oz.		0-6°C	6 months	50 g
Bioassays							
Lettuce	Soil	Nautilus Environmental Laboratory	3- liters	Plastic	Cool to≤6°C	14 days	1000 g
Earthworm							700 g

N/A = Not applicable
As = Arsenic
Pb = Lead
Cu = Copper

Decontamination

Decontamination of equipment will target priority metals contamination. All equipment used to collect samples will be stainless steel or Teflon-coated and will be cleaned before use at each site as follows:

- Pre-cleaned with phosphate-free Liquinox® detergent.
- Rinsed with a 10% nitric acid solution.
- Rinsed at least three times with distilled water.

Sampling equipment, such as augers, trowels, spoons, and sieves, used at multiple sites will be fully cleaned prior to use at the next location. Nitrile powder- free gloves will be worn while collecting samples to further prevent contamination between sites.

To prevent the spread of invasive species all field gear will be visually inspected for dirt and seeds. Any dirt or seeds found will be brushed or washed off at the site before moving to the next site. Field personnel will follow this same process for their shoes and clothing.

Waste Management

All excess soil and rinse water will be returned to the sampling location. The nitric acid rinsate and pH standards will be collected and disposed of at Ecology according to Ecology's chemical hygiene plan. Disposable materials produced in the field such as gloves and paper towels will be collected in garbage bags and removed from the study site for proper disposal in a waste receptacle.

Safety

All pertinent safety protocols will be followed when in the field and laboratory. Gloves will be worn when handling samples to prevent dermal contact with any contaminants. Dust masks and safety goggles may be used in the field to prevent inhalation or contact with eyes, if the soil particles are likely to be air-borne (e.g., dry conditions with wind). Staff will stay up-wind of soils disturbed during sampling when soil particles are likely to become air-borne.

The XRF will only be operated by staff who have received the manufacturer's training for *Level one Radiation Safety Training for XRF Operation.* Other staff present while the XRF is in use will follow the instructions of the operator to prevent accidental exposure to radiation.

At the US Department of Energy Hanford Site, all directions from staff, escort, and signage will be followed. Staff with visitor status at the Hanford Site will be accompanied by an authorized Ecology escort at all times while on the site. Before samples can be transported off the Hanford site they must be tested with a hand-held Geiger meter for radioactive contamination.

Chain of Custody

Chain of custody is a procedure meant to ensure that samples are handled, stored, and transported appropriately and no evidence of sample tampering exists. This procedure ensures creditable results that can be used for a variety of purposes. When samples are collected, the date and time of collection and also the sample ID will be recorded on the container and in the notes. Once the samples arrive at Ecology, they will be inventoried and a standard chain of custody form will be filled out. Custody of the samples will be transferred and documented on the form to a parcel shipping firm (if sent to a contract laboratory), to analytical laboratory staff, and to couriers. A copy of the completed form will be returned to the project manager to keep in the project files.

Shipping

Plants, soil biota, and soil to be analyzed by MEL will be shipped in coolers via an Ecology courier. Soil to be analyzed or tested by Brooks Rand or Nautilus Environmental laboratories will either be shipped with a tracking number to track progress or will be couriered by Ecology staff. Upon receipt, MEL and contract lab staff will note on the chain of custody form any coolers that are not 4°C±2°C.

Measurement Procedures

Table 13 shows the laboratory methods and reporting limits for analysis of plant tissue, animal tissue, and soil samples. Soil texture determinations will be made using the flowchart in Appendix D. Grain size will be determined volumetrically in the field using 2-mm and 63-µm sieves. Grain size will only be conducted on-site when expected to aid in soil verification (method similar to Wakeman, 1990). A split of the sample from each site will be retained for gravimetric grain size analysis if warranted. Soil color will be determined by comparing soils to a Munsell soil chart. Upon return to Ecology, the split sample for gravimetric grain size analysis will be used to determine dry colors if needed.

Table 13. Methods and reporting limits for measurements and analyses.

Analysis	Instrument/ Technique	Analytical Method	Reporting Limits/ Resolution
Field Measurements			
pH	Orion pH meter	EPA method 9045D	0.1
Arsenic	XRF	EPA method 6200 & Instrument Manual	10 ppm
Lead			10 ppm
Laboratory Analyses			
Total Organic Carbon	-	PSEP, 1997	0.1%
Total Solids	-	SM 2540G	1%
Arsenic (As) Copper (Cu) Lead (Pb)	ICP/MS	EPA Method 200.8	As = 0.1 mg/Kg dw Cu = 0.1 mg/Kg dw Pb = 0.1 mg/Kg dw
Arsenic Speciation	HPLC-HG-ICP-MS w/DRC	BRL SOP	As(III) = 0.1 mg/Kg dw As(V) = 0.1 mg/Kg dw
Grain Size	Sieve	ASTM D6913-04	1%

PSEP = Puget Sound Estuary Program.
ICP/MS = Inductively coupled plasma mass spectrometry.
BRL SOP = Brooks Rand Labs Standard Operating Procedures.
HPLC-HG-ICP-MS w/DRC = High-Pressure Liquid Chromatography (HPLC) system coupled to an Inductively-Coupled Plasma-Mass Spectrometer (ICP-MS) using Hydride Generation (HG) post-column and dynamic reaction cell (DRC) technology ICP-MS.
XRF = X-ray Fluorescence Instrument.

Table 14 shows the bioassay tests that will be conducted on soil samples and the measured endpoints of those tests. The use of these particular bioassay tests is consistent with WAC 173-340-7493 Section 3b (alternative methods section of the TEE).

Table 14. Laboratory procedures for bioassay analyses.

Bioassay	Endpoints Measured	Method
Lettuce	Mortality, Biomass	Norton, 1996a
Earthworm	Mortality, Morphological and Behavioral Alterations	Norton, 1996b

Quality Control Procedures

The quality control procedures listed in Table 15 are designed to evaluate adherence to the measurement quality objectives and ensure they are reasonably met.

Table 15. Frequency of quality control procedures.

Analysis	Field Replicates	Method Blank	LCS	Analytical Duplicate	Matrix Spike	Standard Reference Material
Field Measurements						
pH	1/20 samples	-	-	-	-	1/10 samples
XRF	1/20 samples	-	-	1/ day	-	1/ day
Laboratory Analyses						
TOC	1/20 samples	-	-	1/ batch	-	-
% Solids	1/20 samples	-	-	1/ batch	-	-
Grain Size	1/20 samples	-	-	2/ batch	-	-
As, Pb, Cu (ICP/MS)	1/20 samples	1/ batch	1/ batch	1/ batch	1/ batch	1/ batch
Arsenic Speciation	1/10 samples	1/ batch	1/ batch	1/ batch	1/ batch	1/ batch

As = Arsenic.
Pb = Lead.
Cu = Copper.
XRF = X-ray Fluorescence Instrument.

Table 16. Budget for this study.

Analysis	Matrix	Number of Samples	QC[1]	Cost per Sample ($)	Total ($)
Manchester Environmental Laboratory Chemistry Analyses[2]					
TOC	Soil	36	2	42	1,596
% Solids	Soil	36	2	11	418
Arsenic and Lead (ICP/MS)	Soil	36	5	65	2,665
Copper (ICP/MS)[3]	Soil	21	4	18	450
Freeze-Drying	Plants and Soil Biota	91	4	16	1,520
Arsenic and Lead (ICP/MS)	Plants and Soil Biota	91	7	65	6,370
Contract Laboratory Chemistry Analyses[4]					
As Speciation	Soil	20	2	315	6,930
Nautilus Environmental Laboratory Bioassay Analyses					
Lettuce	Soil	21	-	900	18,900
Earthworm	Soil	21	-	720	15,120
Equipment/Miscellaneous					
pH Probe and Buffers					273
Ferry					91
Other					600
Project Total					
					54,941

[1]1/20 samples field replicate, lab duplicate, matrix spike, and standard reference material analyses.
[2]Costs include 50% discount for Manchester Laboratory.
[3]Preparation not included, will be prepared and analyzed with arsenic and lead.
[4]Method blank, standard reference material, laboratory duplicate, and Matrix spike are included in the cost.

Data Management Procedures

Field notes will be taken during all sampling events. All notes must include the date and sampling location. Notes recorded at all sampling locations will include time and Global Positioning System (GPS) location of soil sample collection, number of worms collected and GPS locations, general type of plant collected, number of plants collected and GPS locations. Soil-specific details will also be recorded at each site: time of pH analysis, pH analysis results and calibration slope, volumetric grain size results (if performed), soil texture, general soil moisture at time of sample collection, soil series determination. General notes on habitat, wildlife, overall description of the site, and weather will also be included. Photos will be taken at each site to document site conditions. See example data sheets in Appendix E.

Results of laboratory analyses will be submitted to the project manager as follows:

- MEL will submit all results in electronic or hard copy format, including case narratives, individual results including relevant qualifiers, and quality assurance results.

- The contract chemistry laboratory will provide all test and QA samples for arsenic speciation and percent solids. The lab will include case narratives describing the methods, QA results, and deviations from the specified method. The lab must submit deliverables to MEL in printed or electronic format. MEL staff will perform data verification. Once verification is complete, MEL will transfer the printed or electronic deliverables, including the MEL narrative of the verification, to the project manager.

- The contract bioassay laboratory will provide a case narrative and results for all toxicity tests, including all control and test samples. The lab will also provide test exposure conditions both in a summarized format and as raw bench sheets. The lab will submit a hard and electronic copy of the laboratory report that includes an interpretation of the results relative to regulatory requirements.

Ecology will assess all data for this project for completeness, accuracy, and usability. This assessment will include an evaluation comparing the results of this study to the quality objectives listed in Tables 3, 4, and 5. The completeness goal for this project is 90%.

Audits and Reports

Audits

MEL participates in performance and systems audits of various analytical procedures. MEL's audit results are available upon request. The Laboratory Accreditation Unit within Ecology has accredited the bioassay laboratory for the methods used in this study. The arsenic speciation contract laboratory is not specifically accredited for the method being used, due to the developmental status of the technique. Therefore a waiver for accreditation has been approved by Ecology's Quality Assurance Officer in this case. The accreditation process includes performance testing and periodic lab assessments. No additional audits are planned as part of this study.

EPA may perform a separate audit of the study at their discretion since EPA has provided funding for a portion of this project.

Reports

The project manager for this study shall prepare a report summarizing the results of the study. Prior to finalization the draft will undergo a peer review process. The final report will be prepared by the end of February 2011.

The final report will:

- Describe the study design and methods used for the study.
- Describe the sampling location including latitude, longitude, maps, and pertinent information from the field logs.
- Include all chemistry and bioassay data.
- Assess the toxicity of locations where bioassays were performed.
- Include a wildlife exposure model modified using data collected during this study.
- Compare the current and modified wildlife exposure model screening concentrations.
- Compare the arsenic and lead toxicity between soil types.
- Evaluate the use of study results to predict toxicity in other locations of the same soil type.
- State conclusions and recommendations resulting from this study.

Public access to electronic versions of the data and reports generated from this project will be available via Ecology's internet homepage (www.ecy.wa.gov).

Data Verification and Validation

Data Verification

Data verification is the process of evaluating the data for completeness, accuracy, and compliance with the quality control acceptance criteria. Field measurements will be verified in the field before leaving the site. Laboratory results will be examined by qualified and experienced staff. Results of the verification process and a case narrative will be submitted to the project manager.

Data verification includes checking that:

- Data are consistent, correct, and complete, with no errors or omissions.
- Results for quality control samples are reported with the sample results.
- Established criteria for the quality control samples were met.
- Appropriate data qualifiers have been applied.
- Data specified in this QA Project Plan were obtained.
- Methods and protocols were followed during analyses.

The project manager will review all data collected as part of this project for the proper verification and determine if the measurement quality objectives were achieved. For chemistry results this includes reviewing the performance of laboratory replicates, laboratory control standards, matrix spikes, and method blanks. Data will also be evaluated for meeting the target reporting limits. Non-detect results will be reviewed to determine if any values exceed the lowest concentration of interest.

Data Validation

Extra validation is not proposed as part of this study.

Data Quality (Usability) Assessment

After verification the data will be assessed for usability as determined by their quality, quantity, and adherence to this QA Project Plan by the project manager. Data will then be analyzed to meet the objectives of this study. Statistical analyses will be used when warranted; however, due to the limited number of samples collected in this study, general comparisons, simple statistics, and graphical representations of the data may be more appropriate. Data will be used to modify the current wildlife exposure model. Results from this modification will be compared to the original model. Bioassay results will be used to evaluate toxicity at each location. Arsenic species will be compared as a ratio to determine which species is more prevalent in the soil environment. Conclusions from these analyses will address the objectives of the study.

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Appendices

Appendix A. Glossary, Acronyms, and Abbreviations

Glossary

Bioassay: Usually a laboratory test which exposes organisms to the medium of interest (e.g., amphipod exposure to sediment). Results indicate the toxicity of the medium to that particular organism.

Calcareous soils: Soils consisting of or containing a high amount of calcium carbonate and typically having high pH values.

Cation-exchange capacity: The ability of a soil to retain cations or positively charged particles. Cations are an important component of soil fertility.

Complete exposure pathway: No barriers exist that prevent contaminants from entering organisms.

Grain size distribution: The relative amounts of different-sized particles in a soil or sediment, spanning the spectrum of expected sizes from gravel to clay.

Gravimetric: Measurement based on gravity, typically mass.

Horizons: The layers of soil parallel to the earth's surface; each layer has characteristics that make it different from the layers above and below it.

Incomplete exposure pathway: Barriers such as buildings, pavement, or other physical structures that prevent contaminants from entering organisms.

Interim action level: A contaminant level that triggers an interim action to occur. Interim actions allow early actions at a site before completion of the final cleanup plan. Interim actions also apply when meeting the cleanup standard under MTCA is not technically feasible for a given contaminant.

Invertebrate: Animal lacking a backbone.

Macroinvertebrate: Organisms which lack backbones and are large enough to see with the naked eye.

Mineralogy: The mixture of minerals or solid components that make up a soil. Each mineral has its own unique characteristics and properties. Salt, gypsum, and calcite are all examples of minerals that may be present in a soil.

Parameter: A physical chemical or biological property whose values determine environmental characteristics or behavior.

pH: A measure of the acidity or alkalinity of water. A low pH value (0 to 7) indicates that an acidic condition is present, while a high pH (7 to 14) indicates a basic or alkaline condition. A pH of 7 is considered to be neutral. Since the pH scale is logarithmic, a water sample with a pH of 8 is ten times more basic than one with a pH of 7.

Pollution: Such contamination, or other alteration of the physical, chemical, or biological properties, of any waters of the state. This includes change in temperature, taste, color, turbidity, or odor of the waters. It also includes discharge of any liquid, gaseous, solid, radioactive, or other substance into any waters of the state. This definition assumes that these changes will, or are likely to, create a nuisance or render such waters harmful, detrimental, or injurious to (1) public health, safety, or welfare, or (2) domestic, commercial, industrial, agricultural, recreational, or other legitimate beneficial uses, or (3) livestock, wild animals, birds, fish, or other aquatic life.

Receptor: Plants and animals that have the potential of being harmed by a contaminant in the environment.

Soil: A mixture of organic and inorganic solids, air, water, and biota that exists on the earth's surface above bedrock, including materials of anthropogenic sources such as slag, sludge, etc.

Soil Series: A type of soil. The type is determined by characteristics that are unique to that soil and may include parameters such as drainage, slope, elevation, grain size, pH, color, or mineralogical makeup.

Soil biota: Invertebrate multi-cellular animals that live in the soil or in close contact with the soil.

Species: A kind, type, or variety that forms a unique group:

> *Metals:* A grouping of different forms of a particular metal/element. Example, arsenic is an element that has many different species. Trivalent and pentavalent arsenic are two of these species defined by the number of electrons that surround the nucleus of the arsenic atom.
>
> *Biological:* Plants and animals are grouped based on common traits. Generally individuals are grouped as a species if they are similar enough to be able to reproduce with one another. There may be exceptions to this where an isolated group develops unique traits that define it but individuals may be able to reproduce with the larger population.

Toxicity: Negative effect on an organism caused by some stimulus. Mortality, decreased growth, and abnormal growth are examples of negative effects.

Wildlife: Any nonhuman vertebrate animal other than fish.

XRF: Instrument that measures metals concentrations using X-rays.

Acronyms and Abbreviations

Following are acronyms and abbreviations used frequently in this report.

As	arsenic
As(III)	arsenic three, trivalent arsenic
As(V)	arsenic five, pentavalent arsenic
BRL	Brooks Rand Labs
Cu	copper
DDT	dichlorodiphenyltrichloroethane
Ecology	Washington State Department of Ecology
EIM	Environmental Information Management database
EPA	U.S. Environmental Protection Agency
GPS	global positioning system
HOO	Hanford Old Orchards
MEL	Manchester Environmental Laboratory
MTCA	Model Toxics Control Act
N/A	not applicable
Pb	lead
QA	quality assurance
RPD	relative percent difference
RSD	relative standard deviation
SOP	standard operating procedures
SSL	soil screening levels
TSP	Tacoma Smelter Plume
WAC	Washington Administrative Code
XRF	X-ray fluorescence instrument

Units of Measurement

°C	degrees centigrade
cm	centimeter
dw	dry weight
ft	feet
m	meter
mm	millimeter
mg/Kg	milligrams per kilogram (parts per million)
mV	millivolts
ppm	parts per million
µm	micrometer or micron

Appendix B. Wildlife Exposure Model Values

Table B- 1. Default Tacoma Smelter Plume receptors wildlife exposure model values and screening levels for arsenic and lead.

Contaminant↓	Toxicity Reference Value	Food Ingestion Rate	Diet Contamination	Bioaccumulation Factor	Plant Uptake Coefficient	Soil Ingestion Rate	Gut Adsorption Factor	Screening Concentration
Abbreviation→	T	FIR	P	BAF	K	SIR	RGAF	SC
Units→	$\frac{mg/Kg}{day}$	$\frac{\text{Kg dry Food}}{\frac{\text{Kg Body Weight}}{day}}$	-	$\frac{mg/Kg\ SB}{mg/Kg\ Soil}$	$\frac{mg/Kg\ Plant}{mg/Kg\ Soil}$	$\frac{\text{Kg dry Soil}}{\frac{\text{Kg Body Weight}}{day}}$	-	mg/Kg
Mammalian herbivore (MH)								
As(III)	1.15	0.315	1	-	0.06	0.0079	1	43
As(V)	35	0.315	1	-	0.06	0.0079	1	1,306
Pb	20	0.315	1	-	0.0047	0.0079	1	2,132
Mammalian predator (MP)								
As(III)	1.89	0.45	0.5	1.16	-	0.0045	1	7
As(V)	35	0.45	0.5	1.16	-	0.0045	1	132
Pb	20	0.45	0.5	0.69	-	0.0045	1	125
Avian predator (AP)								
As(III)	-	0.207	0.52	1.16	-	0.0215	1	-
As(V)	22	0.207	0.52	1.16	-	0.0215	1	150
Pb	11.3	0.207	0.52	0.69	-	0.0215	1	118

Values from WAC 173-340-900.
SB=soil biota, an earthworm.

Equations:

Mammalian herbivore: $$SC_{MH} = \frac{(T_{Vole})}{(FIR_{Vole,DW} * P_{Plant,Vole} * K_{Plant}) + (SIR_{Vole,DW} * RGAF_{Soil,Vole})}$$

Mammalian predator: $$SC_{MP} = \frac{(T_{Shrew})}{(FIR_{Shrew,DW} * P_{SB,Shrew} * BAF_{SB}) + (SIR_{Shrew,DW} * RGAF_{Soil,Shrew})}$$

Avian predator: $$SC_{AP} = \frac{(T_{Robin})}{(FIR_{Robin,DW} * P_{SB,Robin} * BAF_{SB}) + (SIR_{Robin,DW} * RGAF_{Soil,Robin})}$$

Table B- 2. Hanford receptors wildlife exposure model values and screening levels for arsenic and lead.

Contaminant↓	Toxicity Reference Value	Food Ingestion Rate[2]	Diet Contamination[2]	Bioaccumulation Factor[1]	Plant Uptake Coefficient[1]	Soil Ingestion Rate[1]	Gut Adsorption Factor[1]	Screening Concentration
Abbreviation→	T	FIR	P	BAF	K	SIR	RGAF	SC
Units→	$\frac{mg/Kg}{day}$	$\frac{Kg\ dry\ Food}{\frac{Kg\ Body\ Weight}{day}}$	-	$\frac{mg/Kg\ SB}{mg/Kg\ Soil}$	$\frac{mg/Kg\ Plant}{mg/Kg\ Soil}$	$\frac{Kg\ dry\ Soil}{\frac{Kg\ Body\ Weight}{day}}$	-	mg/Kg
Mammalian herbivore (MH)								
As(III)	1.15[1]	0.315	1		0.06	0.0079	1	43
As(V)	35[1]	0.315	1		0.06	0.0079	1	1,306
Pb	20[1]	0.315	1		0.0047	0.0079	1	2,132
Mammalian predator (MP)								
As(III)	1.89[1]	0.26	0.25	1.16		0.0045	1	24
As(V)	35[1]	0.26	0.25	1.16		0.0045	1	438
Pb	20[1]	0.26	0.25	0.69		0.0045	1	405
Avian predator (AP)								
As(III)	-	0.207	0.25			0.0215	1	--
As(V)	22[1]	0.207	0.25	1.16		0.0215	1	270
Pb	11.3[1]	0.207	0.25	0.69		0.0215	1	198

[1] Toxicity Reference Values from WAC 173-340-900.
[2] Values from Doctor et al. (2000).
SB = soil biota, a darkling beetle.

Equations:

Mammalian herbivore: $$SC_{MH} = \frac{(T_{Gopher})}{(FIR_{Gopher\ DW} * P_{Plant,\ Gopher} * K_{Plant}) + (SIR_{Gopher,DW} * RGAF_{Soil,Gopher})}$$

Mammalian predator: $$SC_{MP} = \frac{(T_{Mouse})}{(FIR_{Mouse,\ DW} * P_{SB,Mouse} * BAF_{SB}) + (SIR_{Mouse,DW} * RGAF_{Soil,Mouse})}$$

Avian predator: $$SC_{AP} = \frac{(T_{Meadowlark})}{(FIR_{Meadowlark,\,DW} * P_{SB,Meadowlark} * BAF_{SB}) + (SIR_{Meadowlark,DW} * RGAF_{Soil,Meadowlark})}$$

Appendix C. Alternative Sampling Locations

Table C- 1. Alternative sampling locations.

General Soil Series	Site Name	General Location	Arsenic					Lead				
			Target Range	Min	Max	Mean	Count	Target Range	Min	Max	Mean	Count
Alderwood	Piner Point Natural Area	Vashon Island	V. High	100	460	192	9	V. High	41	1100	611	9
	Thelma Gilmer Park	Fircrest	Medium	15	34	22	8	Low	23	130	70	8
	Wainwright School	University Place	Medium	2.7	142	23	42	Medium	3	382	55	42
	Argen Park	Vashon Island	Low	3.2	24	9	17	Medium	5.4	150	79	17
Everett	Dockton Park	Vashon Island	High	1.6	200	100	43	Medium	8	360	149	70
	Sunset Primary School	University Place	Low	4.4	53	14	16	Medium	11	238	59	16
Harstine	TSPPC527	Kitsap Peninsula	High	23	130	68	6	Medium	9.5	180	76.3	6
	Tacoma Narrow Park	Kitsap Peninsula	High	13	160	107	8	Medium	29	580	226	8
	Goodman Middle School	Vashon Island	Low	1	38	7.5	32	Low	1.4	87	17.7	
Kitsap	Piner Point Natural Area	Vashon Island	V. High	100	460	192	9	V. High	41	1100	611	9
Spanaway	Washington Park	Lakewood	Low	2.2	70.7	19	16	Medium	2	311	53	16

Appendix D. Soil Classification

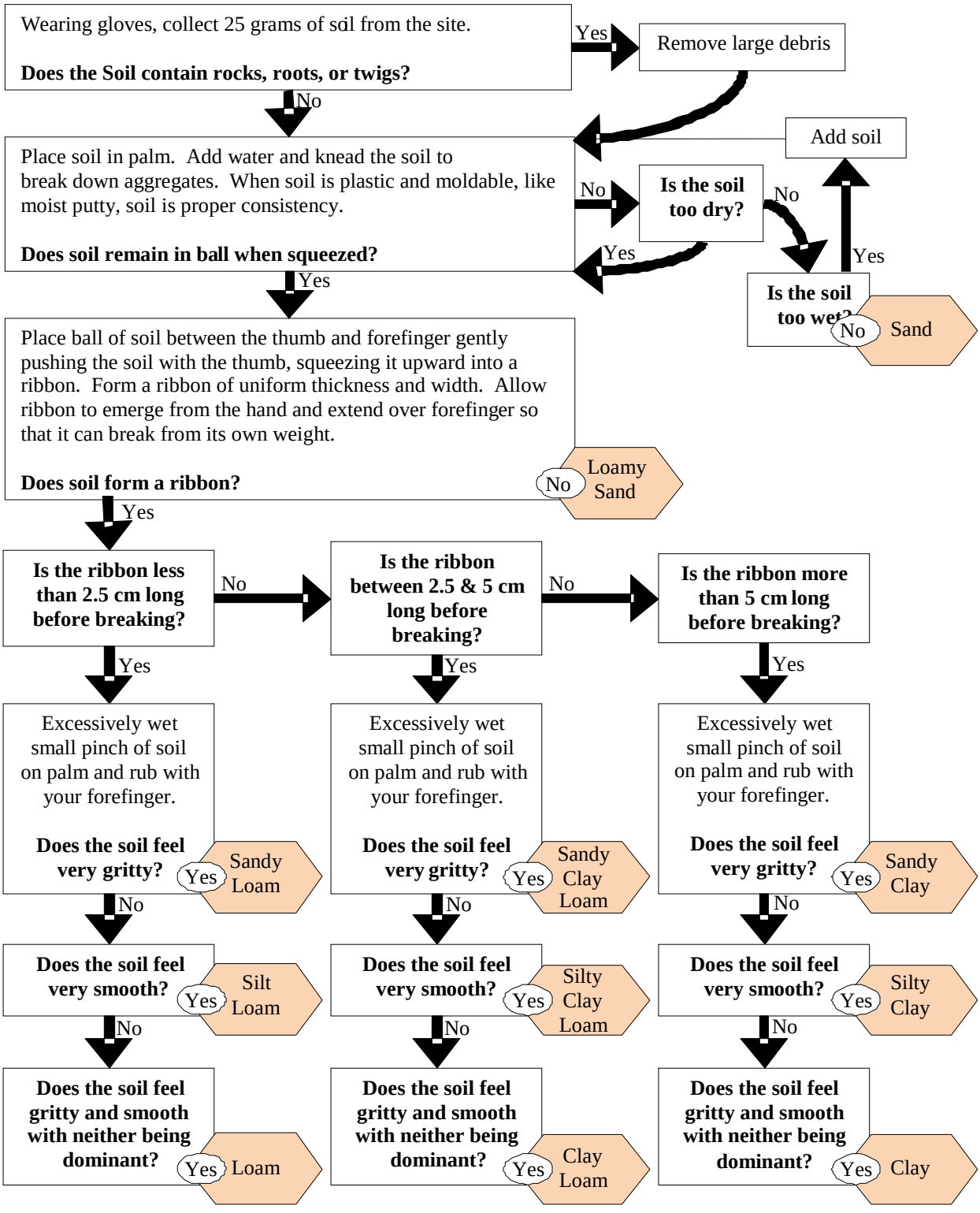

Figure D-1. Flow diagram of soil texture determination.

Modified from Natural Resources Conservation Service.

Table D- 1. Detailed soil series descriptions for the Tacoma Smelter Plume footprint.
Descriptions from the Natural Resources conservation service (Soil Survey Staff, 2008).

Soil Series	Origin	Drainage	Texture - Use	0-6 in Description
Alderwood	formed in glacial till	moderately well drained soils	gravelly ashy sandy loam, forest	**0 to 7 inches**; very dark grayish brown (10YR 3/2) gravelly ashy sandy loam, brown (10YR 5/3) dry; moderate fine granular structure; slightly hard, very friable, slightly sticky and slightly plastic; many fine roots; few fine irregular pores; slightly acid (pH 6.2); abrupt smooth boundary. (3 to 7 inches thick)
Everett	formed in glacial outwash or alluvium with an admixture of volcanic ash on terraces, moraines, and terrace escarpments	somewhat excessively drained soils	very gravelly sandy loam, forest.	**0 to 2 inches**; very dark brown (10YR 2/2) very gravelly sandy loam, dark grayish brown (10YR 4/2) dry; weak very fine subangular blocky structure; soft, very friable, nonsticky and nonplastic; many roots; 55 percent gravel; moderately acid (pH 5.6); clear smooth boundary. (1 to 3 inches thick) **2 to 8 inches**; dark yellowish brown (10YR 3/4) very gravelly sandy loam, yellowish brown (10YR 5/4) dry; weak fine subangular blocky structure; soft, very friable, nonsticky and nonplastic; many roots; 55 percent gravel; moderately acid (pH 5.8); gradual wavy boundary. (5 to 7 inches thick)
Harstine	formed in sandy glacial till on uplands	moderately well drained soils.	gravelly ashy sandy loam, forested	**0 to ½ inch**; slightly decomposed twigs and needles; very strongly acid (pH 4.8); abrupt wavy boundary. **½ to 1 inch**; decayed needles; very strongly acid (pH 4.8); abrupt wavy boundary. **1 to 6 inches**; dark yellowish brown (10YR 3/4) gravelly ashy sandy loam, brown (10YR 5/3) dry; weak very fine subangular blocky structure; soft, very friable; slightly plastic; many roots; very strongly acid (pH 5.0); clear wavy boundary. (3 to 6 inches thick)
Kitsap	formed in lacustrine sediments	moderately well drained soils	silt loam - pasture	**0 to 6 inches**; very dark grayish brown (l0YR 3/2) silt loam, grayish brown (l0YR 5/2) dry; moderate fine subangular blocky structure; slightly hard, friable, slightly sticky and slightly plastic; many very fine roots; moderately acid (pH 5.8); abrupt smooth boundary. (3 to 6 inches thick)
Spanaway	formed in glacial outwash and volcanic ash on terraces and plains at elevations of 100 to 500 feet	somewhat excessively drained soils	gravelly sandy loam - fern-grass prairie	**0 to 1 inch**; black (10YR 2/1) well decomposed organic matter, very dark brown (10YR 2/2) dry; mostly from grass roots and moss. (0 to 1 1/2 inches thick) **1 to 15 inches**; black (10YR 2/1) gravelly sandy loam, very dark grayish brown (10YR 3/2) dry; weak fine granular structure; soft, very friable, nonsticky and nonplastic; many fine roots; very high in organic matter content, has mellow, sooty feel; 35 percent pebbles; strongly acid (pH 5.4); clear smooth boundary. (10 to 20 inches thick)

Table D- 2. Detailed soil series descriptions for the Hanford Old Orchards.

Descriptions from the Natural Resources conservation service.

Soil Series	Origin	Drainage	Texture - Use	0-6 in Description
Burbank	formed in basaltic glacial outwash or alluvium	excessively drained soils	loamy sand - grassland	**0 to 5 inches**; grayish brown (10YR 5/2) loamy sand, very dark grayish brown (10YR 3/2) moist; single grained; loose; many roots; 5 percent pebbles; slightly alkaline (pH 7.4); gradual wavy boundary. (0 to 5 inches thick) **5 to 16 inches**; grayish brown (10YR 5/2) loamy fine sand, very dark grayish brown (10YR 3/2) moist; single grained; loose; few roots; 10 percent gravel; slightly alkaline (pH 7.6); gradual wavy boundary. (10 to 24 inches thick)
Ephrata	formed in glacial outwash mixed with loess in the upper part on outwash plains and terraces	well drained soils	sandy loam - cultivated	**0 to 6 inches**; light brownish gray (10YR 6/2) sandy loam, dark grayish brown (10YR 4/2) moist; weak fine granular structure; soft, very friable, nonsticky and nonplastic; many roots; slightly alkaline (pH 7.4); abrupt smooth boundary. (4 to 8 inches thick)
Pasco	formed in recent alluvium accumulating under ponded drainage conditions	poorly and moderately well drained	silt loam, pasture	**0 to 6 inches**; grayish brown (10YR 5/2) silt loam, very dark grayish brown (10YR 3/2) moist; few fine faint mottles; weak fine and medium granular structure; soft, friable, slightly sticky, slightly plastic; many roots; few fine pores; slight effervescence with dilute HCl; moderately alkaline (pH 8.2); clear smooth boundary. (4 to 12 inches thick)
Quincy	formed in sands on dunes and terraces	excessively drained soils	fine sand-grassland	**0 to 15 inches**; grayish brown (10YR 5/2) fine sand, dark brown (10YR 3/3) moist; single grain; loose; many fine roots; porous; moderately alkaline (pH 8.0); clear wavy boundary. (0 to 20 inches thick)
Riverwash				Riverwash consists of long, narrow areas of sand, gravel, and stones along channels of the larger streams. Some areas are barren of vegetation and others support scattered cottonwoods, willows, and other trees and shrubs. Overflow and alteration by severe erosion and deposition are frequent.

Appendix E. Field Log Examples

Site Information

Sample Location Name:		
Site Description:		
Picture Description/Number:		
Date:	Crew:	
Latitude:	Longitude:	Datum:
Weather:		

Measurements

pH:	Time:	Filtered or Settled?	
Notes:			

Quick Grain Size:	% >2mm	% 63µm-2mm	% <63µm
Notes:			

Soil Texture:	Soil Moisture (General):
Soil Series Determination:	Notes:

Samples (check samples collected)

Soil Time:_____ As & Pb (4 oz.) TOC/Solids (2 oz.) As Species (4 oz.) Bioassay (1 Gallon) Field Replicates As & Pb (4 oz.) TOC/Solids (2 oz.) As Species (4 oz.)	Plant Time:_____ As & Pb (4 oz., 1 gram dw) Number collected_____ Field Replicate (4 oz., 1 gram dw) Number collected_____	Soil Biota Time:_____ As & Pb (4 oz., 1 gram dw) Number collected_____ Field Replicate (4 oz., 1 gram dw) Number collected_____

Plants

#	Latitude	Longitude	Type	Notes

Soil Biota

#	Latitude	Longitude	Type	Notes

Additional Notes:

Habitat Characteristics

Sample Location Name _____Date _____Recorder Initials___
Land owner name_____

Landscape

Primary Land Use _____ Secondary Land Use _____
Land use codes shown below. What is the major function of the landscape surrounding the sampling location?
Forest Type _____ if no forest present, describe landscape_____
Forest Type codes below. What is the dominant forest type?
Primary Riparian Vegetation (<5 m) _____ Secondary Riparian Vegetation (<5m) _____
Vegetation codes shown below. What vegetation is present within 5 meters of the sampling location?
Primary Riparian Trees DBH (<5m, cm) 00-03 03-15 15-30 30-50 50-90 90+
What is the primary diameter at breast height (DBH) range for the majority of trees less than 5 meters from the sampling location?
Elevation (ft): _____

Wildlife

What wildlife is present at the sampling location?_____
What wildlife is likely to be present at the sampling location (evidenced by nests, droppings, hair, prints, etc.)? _____

Codes:

Land use

R – Recreational (e.g., State Park)
NAT – Natural Area (e.g., National Park)
AG – Agriculture (e.g., crops)
G-Grazing (e.g., cattle pasture lands)
TH-Timber Harvest (e.g., lands used for logging)
LR – Low Residential, Average lot size 3+ acres
MR- Medium Residential: Average lot size 1-3 acres
HR-High Residential: Average lot size ½ acre
I – Commercial (e.g., grocery store/gas station)
TR – transportation corridor (e.g., road)

Forests

C – Conifer
D – Deciduous
M – Mixed

+

CC – Clear Cut (no trees to yearlings)
ST – Second Timber (15-50cm DBH)
MT – Mature Timber (50-90cm DBH)
OG – Old Growth (90+ cm DBH
DBH = diameter at breast height

Vegetation

T – Trees
S – Shrubs (woody but not in the form of a tree)
G – Grasses
F – Forbs (ferns, herbaceous plants)
B – Barren, Exposed Rock/Soils