UPPER COLUMBIA RIVER

FINAL
Remedial Investigation Report for OU 3

Prepared for

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ACRONYMS AND ABBREVIATIONS

AAS	atomic absorption spectrometry
ADA	aerial deposition area
Agreement	June 2, 2006, Settlement agreement for implementation of remedial investigation and feasibility study at the Upper Columbia River Site
AOI	area of interest
ARAR	applicable or relevant and appropriate requirement
ASAOC	Administrative Settlement Agreement and Order on Consent for Removal Action
ASTM	ASTM International
BAB	bioavailability-adjusted benchmarks
BC ENV	British Columbia Ministry of Environment and Parks
BERA	baseline ecological risk assessment
BTV	background threshold value
CCT	Confederated Tribes of the Colville Reservation
CEC	cation exchange capacity
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CHIRU	Colville High Intensity Resource User
CI	confidence interval
CLP	Contract Laboratory Program
COC	chemical of concern
COPC	chemical of potential concern
CSM	conceptual site model
CV	coefficient of variation
CVAA	cold vapor atomic absorption
CVAFS	cold vapor atomic fluorescence spectrometry
DOE	U.S. Department of Energy
DQO	data quality objective
DU	decision unit
EC	exposure concentration
Ecology	Washington State Department of Ecology
ED	effective dose
EE/CA	engineering evaluation/cost analysis
Environment Canada	Environment and Climate Change Canada

EPA	U.S. Environmental Protection Agency
EPC	exposure point concentration
ERA	ecological risk assessment
FE	federal endangered
FS	feasibility study
GAM	generalized additive model
HHRA	Final Site-Wide Human Health Risk Assessment: Upper Columbia River Site (USEPA 2021)
HI	hazard index
HQ	hazard quotient
HSSR	Hydrogeochemical and Stream Sediment Reconnaissance
HUC	hydrologic unit code
IC	incremental composite
ICP-AES	inductively coupled plasma-atomic emission spectrometry
ICP-MS	inductively coupled plasma-mass spectrometry
IEUBK	Integrated Exposure Uptake Biokinetic
IJC	International Joint Commission
INAA	instrumental neutron activation analysis
IVBA	in vitro bioaccessibility
KIVCET	Russian acronym for flash-cyclone-oxygen-electric-smelting
LOESS	locally estimated scatterplot smoothing
log10	log-transformed
MIST	multi-incremental sampling tool
MSD	mass soil-to-dust transfer factor
MTCA	Model Toxics Control Act
MVT	Mississippi Valley-type
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NLSDB	National Land Status Database
NPRI	National Pollution Release Inventory
NRCS	Natural Resources Conservation Service
NURE	National Uranium Resource Evaluation
O&M	operations and maintenance
OU	operable unit
P3	no greater than a 5 percent probability of exceeding a blood lead level of 3 μg/dL

P5	no greater than a 5 percent probability of exceeding a blood lead level of 5 µg/dL
P8	no greater than a 5 percent probability of exceeding a blood lead level of 8 µg/dL
P10	10th percentile
P50	50th percentile
P90	90th percentile
p-RfD	provisional reference dose
PA/SI	preliminary assessment and site inspection
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
$PM_{2.5}$	particulate matter 2.5 µm and smaller
PM_{10}	particulate matter 10 µm and smaller
PM_{50}	particulate matter 50 µm and smaller
PRG	preliminary remediation goal
PSEP	Puget Sound Estuary Program
PSWP	property-specific work plan
QA/QC	quality assurance/quality control
RAO	remedial action objective
RBA	relative bioavailability
RBC	risk-based concentration
RCRA	Resource Conservation and Recovery Act
RfC	reference concentration
RfD	reference dose
RFDA	relict floodplain deposition area
rho	rank correlation coefficient
RI	remedial investigation
RI/FS	remedial investigation and feasibility study
RMAO	risk management-based action objectives
RME	reasonable maximum exposure
ROD	record of decision
RSS DU	residential soil study decision unit
SA	sampling area
SALM	strong acid leaching procedure
SATES	Soil Amendment Technology Evaluation Study
SCDPW	Stevens County Department of Public Works
SD	standard deviation

SDU	sediment decision unit
SE	state endangered
SedEx	sedimentary exhalative
Site	Upper Columbia River site
SGS	sequential Gaussian simulation
SM	standard method
SPLP	synthetic precipitation leaching procedure
STI	Spokane Tribe of Indians
SU	sampling unit
TA DU	tribal allotment decision unit
TAI	Teck American Incorporated
TAL	target analyte list
TCLP	toxicity characteristic leaching procedure
TCRA	time-critical removal action
TOC	total organic carbon
TRV	toxicity reference value
UCL	upper confidence limit
UCR	Upper Columbia River
UDU	upland decision unit
UK	universal kriging
USGS	U.S. Geological Survey
UTL	upper tolerance limit
UTM	Universal Transverse Mercator
VOC	volatile organic compound
VRA	voluntary removal action
WAC	Washington Administrative Code
WBD	USGS Watershed Boundary Dataset
WDNR	Washington State Department of Natural Resources
WEPC	Waneta Expansion Power Corporation
WRF	Weather Research and Forecasting
WRIA	water resource inventory area
WSDA	windblown sediment deposition area
XRF	x-ray fluorescence

UNITS OF MEASURE

amsl	above mean sea level
bgs	below ground surface
cm	centimeter(s)
yd^3	cubic yard(s)
dL	deciliter(s)
°C	degree(s) Celsius
°F	degree(s) Fahrenheit
ft	foot/feet
gpm	gallon(s) per minute
g	gram(s)
in.	inch(es)
kg	kilogram(s)
kg/day	kilogram(s) per day
km	kilometer(s)
L	liter(s)
L/day	liter(s) per day
m	meter(s)
µg/m^3	microgram(s) per cubic meter
µg/day	microgram(s) per day
µg/dL	microgram(s) per deciliter
µm	micrometer(s)
mi	mile(s)[1]
mg	milligram(s)
mg/kg	milligram(s) per kilogram
mg/kg bw/day	milligram(s) per kilogram of body weight per day
mg/kg-dw	milligram(s) per kilogram-dry weight
mg/L	milligram(s) per liter
mm	millimeter(s)
ppm	part(s) per million
ft^2	square foot/feet
km^2	square kilometer(s)
mi^2	square mile(s)[2]

[1] The narrative of this report spells out the term mile(s); the figures, maps, and tables use the abbreviation mi.

[2] The narrative of this report spells out the term square mile(s); the figures, maps, and tables use the abbreviation mi^2.

EXECUTIVE SUMMARY

INTRODUCTION

This document presents a Final Remedial Investigation (RI) Report for the upland terrestrial portion of Operable Unit (OU) 3 of the Upper Columbia River site (UCR Site or Site[1]) in northeastern Washington. Teck American Incorporated (TAI) has prepared this document (hereafter, the Upland RI report) pursuant to the Settlement Agreement for Implementation of Remedial Investigation and Feasibility Study at the Upper Columbia River Site (USEPA 2006[2]), the Final Remedial Investigation and Feasibility Study (RI/FS) Work Plan (USEPA 2008[3]), and applicable U.S. Environmental Protection Agency (EPA) guidance documents. Discharges from the Trail smelter in Trail, British Columbia (hereafter, Trail Facility), now owned and operated by Teck Metals Ltd., contributed to releases of hazardous substances, as defined in the Comprehensive Environmental Response, Compensation, and Liability Act, at the Site. Additional sources, including the former Le Roi/Northport Smelter in Northport, Washington, which has been the subject of action by both EPA and the Washington State Department of Ecology (Ecology) and is identified by different site numbers,[4] also contributed to releases of hazardous substances at the Site.

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[1] Per the June 2, 2006, Settlement Agreement for Implementation of Remedial Investigation and Feasibility Study (RI/FS) at the Upper Columbia River Site (referred to herein as the UCR Site or Site), the Site consists of the areal extent of hazardous substances contamination within the United States in or adjacent to the Upper Columbia River, including the Franklin D. Roosevelt Lake, from the U.S.-Canada border south to the Grand Coulee Dam, and all suitable areas in proximity to such contamination necessary for implementation of the response actions (RI/FS) described therein.

[2] Settlement Agreement for Implementation of Remedial Investigation and Feasibility Study at the Upper Columbia River Site. Agreement between the U.S. Environmental Protection Agency and Teck Cominco American Incorporated. June 2, 2006. Environmental Protection Agency, Washington, DC.

[3] Upper Columbia River Work Plan for the Remedial Investigation and Feasibility Study, Volume I. U.S. Environmental Protection Agency, Washington, DC.

[4] The Le Roi/Northport Smelter site number for EPA is WAD988507323 and for Ecology is 47 (USEPA 2025; Ecology 2025a). The Northport Waterfront site number for Ecology is 14874 (Ecology 2025b).

USEPA. 2025. Superfund Site Information, Le Roi Co Smelter. U.S. Environmental Protection Agency, Washington, DC. https://cumulis.epa.gov/supercpad/cursites/csitinfo.cfm?id=1001661. Accessed on February 19, 2025.

Ecology. 2025a. Cleanup and Tank Search, LeRoi Co Smelter. Washington State Department of Ecology. https://apps.ecology.wa.gov/cleanupsearch/site/47. Accessed on February 19, 2025.

Ecology. 2025b. Cleanup and Tank Search, Northport, Waterfront. Washington State Department of Ecology. https://apps.ecology.wa.gov/cleanupsearch/site/14874. Accessed on April 4, 2025.

In 2022, EPA subdivided the Site into three OUs for management purposes. OU 1 and OU 2 are the aquatic OUs (USEPA 2022[5]), which together cover the Upper Columbia River aquatic system from the U.S.-Canada border to Grand Coulee Dam, including relict floodplains, beaches, windblown sediment deposition areas, and riparian areas along the river channel. Historical releases to the Columbia River from smelter operations (e.g., slag and liquid effluent) are the focus of OU 1 and OU 2. OU 3 is the terrestrial upland portion of the Site that may have been influenced by historical aerial deposition of metals from smelter operations. The OU 3 boundary is not formally defined. However, for the purposes of this Upland RI report, the OU 3 study area is defined as the terrestrial upland area within the boundary of the Upper Lake Roosevelt Water Resource Inventory Area (WRIA 61) (Map ES-1[6]). Sediments in the river, relict floodplains, beaches, windblown sediment deposition areas, and riparian soils along the river channel and banks will be evaluated in the Aquatic RI report. EPA believes there may be a data gap associated with the upland lakes and wetlands, which may be addressed in the future and reported under a separate cover.

The RI work stream includes completion of a baseline human health risk assessment, a baseline ecological risk assessment (BERA), and RI reports for each OU. EPA completed the Final Site-Wide Human Health Risk Assessment: Upper Columbia River Site (hereafter, HHRA) in 2021 (USEPA 2021[7]). EPA issued a revised Baseline Ecological Risk Assessment for Upland Terrestrial Habitat (hereafter, Upland BERA) in 2023 (USEPA 2023a[8]). TAI has sought technical review of the Upland BERA (TAI 2024a[9]).

The information presented in the HHRA, Upland BERA, and Upland RI report will be used in the Feasibility Study for OU 3 (hereafter, Upland FS) to estimate the areal extent and volume of soil with metals concentrations that may result in unacceptable risks to human health and/or the environment. The Upland FS will present a detailed evaluation of remedial action alternatives

[5] Personal correspondence (letter to Denise Mills, TAI, dated July 25, 2022, from Bonnie Arthur, EPA Remedial Project Manager, Re: Schedule Addendum to the Upper Columbia River "Workplan for the Remedial Investigation and Feasibility Study," dated December 2008). U.S. Environmental Protection Agency Region 10, Seattle, WA.

[6] Executive Summary figure, maps, and table are provided below.

[7] Final Human Health Risk Assessment: Upper Columbia River Site. Prepared for the U.S. Environmental Protection Agency Region 10 and Environmental Response Team by SRC, Inc. February.

[8] Final Baseline Ecological Risk Assessment for Upland Terrestrial Habitat. Upper Columbia River Site, Stevens County, Washington. Prepared for U.S. Environmental Protection Agency Region 10 by CH2M HILL, Inc., Greenwood Village, CO.

[9] Personal communication (letter to Larry Douchand, Director, Office of Superfund Remediation & Technology Innovation, EPA, dated October 18, 2024, from Rob Orr, TAI, regarding Technical Review, Upper Columbia River Remedial Investigation and Feasibility Study – EPA's Upland Baseline Ecological Risk Assessment [December 2023]). File No. 01-773180-000. Teck American Incorporated, Spokane, WA.

that could mitigate or eliminate potential unacceptable risks to human health or the environment by reducing contaminant concentrations or eliminating exposure pathways.

SUMMARY OF OU 3 STUDY AREA CHARACTERISTICS

As described above, for the purposes of this Upland RI report, the OU 3 study area is defined as the boundary of WRIA 61 (Map ES-1). The topography of the OU 3 study area, which includes the UCR valley, is characterized by a deeply incised, inner gorge with steep banks and terraces that gently slope toward the surrounding hills and mountains, with elevations ranging from 1,290 to 7,308 ft amsl. The OU 3 study area extends from the U.S.-Canada border to the confluence of the Upper Columbia and Colville Rivers and includes multiple streams that are fed by lakes and wetlands in the higher elevation areas.

The OU 3 study area is within the Northern Rockies ecoregion, which includes coniferous forest interspersed with montane grasslands that reflect warm, dry summers and moist, cold winters with heavy snowfall (McNab et al. 2007[10]). This ecoregion reportedly supports 98 species of upland mammals and 250 species of birds. Mining and logging activities have taken place in some areas, and the region has a history of wildfires. Current land uses in the OU 3 study area include federal, state, and private forest, parks/undeveloped nonresidential areas, residential neighborhoods with developed and undeveloped lands, utility and transportation rights of way, agriculture, retail and other services, manufacturing, and land designated for cultural or recreational uses. The current mix of land cover and land uses in the OU 3 study area is not expected to change significantly in the foreseeable future.

Metals evaluated in the Upland RI report occur naturally in mineralized zones within the various geologic units that are present throughout the OU 3 study area, such as the Kootenay Arc rock assemblages, and are exposed in rock outcrops near the surface at several locations across the study area. Those metals may also be present in soils abutting or overlying these units where bedrock is near the surface. The OU 3 study area is in a region of Washington State known to have abundant, economically viable, and once-productive ore deposits, including the prevalent lead occurrences of the Northport Mining District, and the area has a long history of metallic and nonmetallic mining and mining-related operations. Rocks of the Kootenay Arc, which are prevalent in the northern and central portions of the OU 3 study area and are exposed at the surface, have been mined extensively. Mineral deposits in these rocks include lead, silver, zinc, copper, gold, cadmium, cobalt, tungsten, gallium, germanium, iron, and

[10] Description of Ecological Subregions: Sections of the Conterminous United States [CD-ROM]. General Technical Report WO-76B. Forest Service, U.S. Department of Agriculture, Forest Service, Washington, DC.

molybdenum. Other rock units in the OU 3 study area that have been the target for historical metallic mining operations include rocks of the Rossland Group, which are prevalent and exposed at the surface in the northern part of the OU 3 study area and have been mined for copper, silver, gold, and lead; rocks of the Unnamed Triassic and Permian metasedimentary rocks, which are prevalent and exposed in the northern, central, and southern portions of the OU 3 study area and have been mined for gold, copper, and silver; and the Sheppard Granite, located in the northern portion of the OU 3 study area, which has been mined for gold (Derkey et al. 1990[11]; Stoffel et al. 1991[12]).

Groundwater supply wells are present at many locations within the OU 3 study area. However, the groundwater exposure pathway was determined to be incomplete for Site-related metals of concern and, therefore, was not evaluated in the HHRA and is not evaluated in this Upland RI report.

RISK ASSESSMENT SUMMARY

The following sections provide a summary of the evaluation of human health risk and ecological risk, which are being conducted separately and are in different stages of completion. The purpose of this summary is to provide context for interpreting the nature and extent, transport and fate, conceptual site model (CSM), and conclusions presented in the Upland RI report.

Human Health

Summaries of the HHRA and remedial action objectives (RAOs) for human health risks in the UCR Site are provided below.

HHRA Summary

The HHRA evaluated risks to human health associated with exposure to metals in environmental media in the OU 3 study area based on various cumulative exposure scenarios (i.e., current and potential future residential, recreational, and outdoor worker exposure

[11] Metal Mines of Washington – Preliminary Report. Washington Division of Geology and Earth Resources Open File Report 90-18. Washington State Department of Natural Resources, Olympia, WA.

[12] Geologic map of Washington – Northeast quadrant. Washington Department of Natural Resources, Olympia, WA.

scenarios).[13] Potential risks for the Colville High Intensity Resource User (CHIRU) population are evaluated in Appendix 1 of the HHRA. The HHRA evaluates exposures in both the upland and aquatic areas of the Site. However, the summary included in this Upland RI report is limited to evaluation of exposure pathways in upland areas, specifically the OU 3 study area.

Based on the findings of the HHRA, the main chemical contributors to risk in soil were lead and arsenic. Lead risks that include both potential environmental and dietary exposures together were evaluated based on three selected residential risk benchmarks of P3, P5, and P8.[14] The following generalizations can be made about the results of the HHRA for residential, recreational, and outdoor worker populations:

- Risks for residential exposure to lead in residential soil study decision unit (RSS DU) and aerial deposition area decision unit (ADA DU) soil exceeded risk benchmarks at certain decision units (DUs). Of 588 RSS DUs evaluated, 389 exceeded P3 (66 percent), 87 exceeded P5 (15 percent), and 12 exceeded P8 (2 percent). Of the 142 ADA DUs evaluated, 139 exceeded P3 (98 percent), 71 exceeded P5 (50 percent), and 16 exceeded P8 (11 percent).
- Risks for residential exposure to metals other than lead in soil did not exceed risk benchmarks for all but one RSS DU (146-H1) and two ADA DUs (ADA-144 and ADA-162). Those risks were driven by a combination of arsenic and thallium. These DUs also exceeded the P3, P5, and P8 lead risk benchmarks.
- Risks for recreational exposure to lead in Bossburg upland decision unit (UDU) soil exceeded risk benchmarks. Of the six Bossburg UDUs evaluated, six exceeded P3 (100 percent), one exceeded P5 (17 percent), and one exceeded P8 (17 percent). Risks for

[13] The chemicals of potential concern (COPCs) evaluated in the HHRA varied by exposure medium, with 11 or 12 metals included for ADA or RSS soil/dust, including aluminum, antimony, arsenic, cadmium, chromium, cobalt, iron, lead, manganese, nickel (only for RSS DUs), thallium, and vanadium, as well as arsenic, chromium, and lead for the Bossburg UDUs. For air, only arsenic, cadmium, and lead were included as COPCs. In the CHIRU HHRA, the 12 metals plus mercury were COPCs for plants. Beryllium, mercury, and selenium were COPCs for upland birds and game along with arsenic, cadmium, lead, and nickel. Nine metals were included as COPCs for fish. Fish ingestion will be evaluated in the Aquatic RI report, but consumption of some fish species was identified as a contributor to risk to residents in the Site-Wide HHRA.

[14] The HHRA evaluates potential lead risks for young children (up to 72 months) who currently, or may in the future, reside in OU 3. The HHRA selected a blood lead level of 3 μg/dL as the lower end of the risk range evaluated. Risk targets were set as no greater than a 5 percent probability of exceeding each target, i.e., no greater than 5 percent probability of having a blood lead level greater than 3 μg/dL (termed P3), 5 μg/dL (termed P5), or 8 μg/dL (termed P8). These blood lead levels were used to estimate preliminary remediation goals (PRGs), where the P3 corresponds to a PRG of 50 mg/kg, the P5 corresponds to a PRG of 200 mg/kg, and the P8 corresponds to a PRG of 400 mg/kg.

recreational exposure to metals other than lead in Bossburg UDU soil did not exceed risk benchmarks.

- Exposure of residents, recreators, and outdoor workers to outdoor and indoor air was below risk benchmarks. None of the four metals (i.e., arsenic, cadmium, lead, and zinc) monitored in ambient air from 2002 to 2009 at the Sheep Creek monitoring station near Northport exceeded risk benchmarks.
- Risks to outdoor workers from exposure to upland soil at the Bossburg UDUs were minimal. Except for two UDUs that exceeded the P3 lead risk benchmark, all other UDUs were below risk benchmarks.

Additionally, the following generalizations regarding risk for the CHIRU population can be made based on the results in Appendix 1 of the HHRA[15]:

- Risks for exposure to lead in tribal allotment decision unit (TA DU) soil exceeded lead risk benchmarks at certain TA DUs. Of the 35 TA DUs evaluated, 21 exceeded P3 (60 percent), 17 exceeded P5 (49 percent), and 6 exceeded P8 (17 percent) when assessed for residential exposure.
- Risks for exposure to metals other than lead in soil were below risk benchmarks except for two TA DUs (401 and 441). Those risks were driven by a combination of arsenic and thallium. These DUs also exceeded the P3, P5, and P8 lead risk benchmarks.
- Exposure to outdoor air does not pose a substantial risk to the CHIRU population. Exposure to metals in outdoor air did not exceed risk benchmarks.
- Estimated lead intakes were above the 1 µg/day benchmark for consumption of upland birds and five terrestrial plants. Lead intakes were below 1 µg/day for consumption of upland game and eight terrestrial plants.
- Risks for exposure to metals other than lead via consumption of upland birds, upland game, and terrestrial plants did not exceed risk benchmarks except for one plant (i.e., spring beauty/Indian potato). Thallium was the risk driver.

[15] In the CHIRU HHRA, exposures that were predicted to contribute < 1 µg/day of lead were classified as minimal because the Integrated Exposure Uptake Biokinetic (IEUBK) model predicts that intakes of at least 1 µg/day of lead are needed to decrease the soil PRG by approximately 20 mg/kg for a target risk goal of 5 percent exceeding a blood lead level of 5 µg/dL (P5).

Human Health RAOs

Based on the results of the HHRA, EPA issued RAOs for human health risks in the UCR Site in a letter dated January 4, 2023 (USEPA 2023b[16]). This letter specified four RAOs for the UCR Site. Portions of two of the RAOs apply to the upland portion of the Site (i.e., OU 3), as follows:

- **RAO 1.** Reduce exposure of residents to lead and arsenic in soil and sediment to levels that do not result in unacceptable Site-related risks.
- **RAO 2.** Reduce exposure of tribal communities to lead and arsenic in soil, sediment, and plants to levels that do not result in unacceptable Site-related risks.

The following excerpt from the RAO letter further clarifies the RAOs for lead: "For lead, this is defined as having no more than a 5% probability of having a blood lead level of 5 μg/dL; for non-cancer risks a hazard index of no more than 1; or a cancer risk of no more than 10^{-4}."

Ecological

The Upland BERA (USEPA 2023a) identified nine ecological chemicals of concern (COCs) in the Terrestrial Study Area as presenting unacceptable ecological risk to one or more ecological assessment endpoints. EPA concluded that cadmium, lead, and zinc present the greatest and most widespread risk in the Terrestrial Study Area but also identified arsenic, barium, copper, manganese, mercury, and selenium as ecological COCs that need to be evaluated in the Upland RI.

Ecological risk-based concentrations (RBCs) were developed for each ecological COC and ecological receptor group identified as presenting unacceptable risk in the Upland BERA to provide context to the discussion of nature and extent. Ecological RBCs are concentrations in soil (mg/kg-dw) equivalent to a hazard quotient of 1 for a specific COC and receptor pair. The most sensitive receptor and toxicity endpoint were used for birds and mammals. The ecological RBCs presented in this Upland RI report may be further refined as new information is made available and developed into ecological preliminary remediation goals (PRGs) for use in the Upland FS.

Ecological RAOs will be developed by TAI after the Upland RI report is approved by EPA, in accordance with a letter from EPA regarding Schedule Addendum to the Upper Columbia River, Workplan for the Remedial Investigation and Feasibility Study (USEPA 2022).

[16] Human Health Remedial Action Objectives for the Upper Columbia River Site. U.S. Environmental Protection Agency Region 10, Superfund and Emergency Management Division.

NATURE AND EXTENT OF COCs IN SOILS

Environmental studies conducted in the region and within the OU 3 study area since the early 1990s were used to evaluate the nature and extent of metals concentrations in soil. Some of these studies were completed as part of the UCR RI/FS (including data collection for the HHRA and Upland BERA), while others were conducted for other purposes in the U.S. and Canada but generated data that are usable for the Upland RI. A summary of the studies used in the Upland RI is provided in Table ES-1.[17]

An upland soil background assessment was conducted by TAI under EPA's oversight to estimate natural background soil concentrations, which are used in the Upland BERA and this Upland RI to identify areas where measured metals concentrations in soil are likely to be greater than natural background (TAI 2020[18]). Data considered for use in the background assessment were compiled from numerous studies spanning a broad area in northeastern Washington and extending well beyond the UCR Site. The approach for assessing soil background metals concentrations included compiling, filtering, and analyzing the existing data to calculate background threshold values (BTVs).

The nature and extent of the human health COCs (i.e., lead and arsenic) and ecological COCs (i.e., arsenic, barium, cadmium, copper, lead, manganese, mercury, selenium, and zinc) was evaluated using a combination of statistical analyses and mapping methods. The following subsections provide a summary of the findings of the statistical analyses, followed by a summary of the areal and vertical nature and extent of COCs in soil within the OU 3 study area.

Statistical Analyses

The statistical analyses used to evaluate the nature and extent of COCs in soil within the OU 3 study area include an exploratory data analysis, generalized additive model (GAM), small-scale variability assessment, and geostatistical modeling. The findings of these analyses are summarized in the following subsections.

[17] Table ES-1 also lists other documents and their abbreviated names mentioned in the Upland RI report.

[18] Personal communication (letter to Kathryn Cerise, EPA Regional Project Manager, from Kris McCaig, TAI, dated July 7, 2020, Subject: Upper Columbia River Remedial Investigation and Feasibility Study – Response to EPA Comments on March 26, 2020, Revised Draft Final Technical Memorandum – Assessment of Background Concentrations of Metals and Metalloids in Upland Soils).

Exploratory Data Analysis

The exploratory data analysis was performed as a precursor to other Upland RI statistical analyses to examine soil metals concentrations and physical variables for patterns, inconsistencies, and outliers. The exploratory data analysis produced several outputs, including a metal-metal correlation matrix, scatterplots of soil metals concentrations versus physical variables (elevation and northing), and boxplots of soil metals concentrations by study. One key output, the metal-metal correlation matrix, is carried forward for the nature and extent evaluation to assess patterns of covariation among COCs.

The correlation matrix for the nine COCs shows that arsenic, cadmium, copper, lead, mercury, and zinc have moderate to strong positive correlations with each other (i.e., concentrations of one metal increase when concentrations of the other increase). Barium, manganese, and selenium exhibit variable correlation patterns with the other six COCs. However, barium and manganese have a strong positive correlation with each other, and selenium has a low positive correlation with barium and manganese. These patterns of covariation among COCs in the data set are useful when considering similarities and differences in the nature and extent of COC concentrations in surface soil within OU 3.

Generalized Additive Model

The extent to which physical attributes are associated with soil metals concentrations was evaluated using a GAM. The GAM evaluated the relationship between metals concentrations in soil and physical parameters, including Universal Transverse Mercator (UTM) northing (as a proxy for distance from the Trail Facility), elevation, slope, lateral distance from the river, side of river (i.e., east or west), and depth of sample. The parameters exhibiting the most pronounced relationship with surface soil COC concentrations in the GAM are UTM northing, lateral distance from the river, and elevation. The GAM results for UTM northing and elevation[19] are summarized below for all COCs except selenium. For selenium, several studies included high frequencies of nondetected values and/or elevated detection limits, which complicate interpretations from the GAM for this COC. Therefore, GAM results for selenium are not summarized.

The following patterns are observed in the UTM northing/distance from Trail Facility GAMs:

- Arsenic, barium, cadmium, copper, lead, mercury, and zinc concentrations show a broad concentration peak centered at or near the Trail Facility and concentrations decline to

[19] A strong relationship was also exhibited for distance from river. Because distance from river and elevation are highly correlated, discussing both would be redundant. Therefore, only elevation is discussed here.

the north and to the south toward the U.S.-Canada border. Manganese concentrations show a relatively flat line in Canada, with a small increase centered at the Trail Facility.

- Concentrations of arsenic, cadmium, lead, and zinc show a relatively steep decline after an initial peak south of the U.S.-Canada border, and copper concentrations show a more moderate decline. Concentrations continue to decline to the south, with peaks for cadmium, copper, and lead centered around Northport, Washington,[20] and peaks for arsenic, cadmium, lead, and zinc near Marble, Washington.
- Concentrations of barium and manganese level off after an initial increase south of the U.S.-Canada border, followed by a decline south of Northport and a leveling off. Barium and manganese concentrations in the U.S. are elevated above concentrations in the vicinity of the Trail Facility.
- Concentrations of mercury show a gradual decline after an initial increase south of the U.S.-Canada border, followed by a leveling off.[21]

The patterns described in the bullets above indicate that the nature and extent of arsenic, cadmium, copper, lead, mercury, and zinc is consistent with aerial deposition from smelter emissions. Barium and manganese exhibit different north-south patterns than the other COCs.

There were three general relationships between elevation and COCs exhibited in the GAM, which varied by metal. These relationships are as follows:

- Lead, cadmium, and copper exhibit steeply decreasing concentrations with increasing elevation across the lowest elevation band (less than 1,500 ft amsl) and partway into the second elevation band (1,500 to 1,800 ft amsl). Above 1,800 ft amsl, there are variable patterns between increasing and decreasing concentrations.[22]
- Arsenic and zinc do not exhibit a strong relationship with elevation. As such, these COCs do not show a decrease in concentration with increasing elevation across the lowest elevation bin (less than 1,500 ft amsl).

[20] Of the 242 soil samples in and around Northport that were analyzed for arsenic, cadmium, copper, and lead in the 2004 EPA Le Roi Removal Action Study, only 11 samples were analyzed for mercury, selenium, and zinc, and none were analyzed for barium or manganese.

[21] There are fewer samples along the UCR valley for mercury than for other metals, which may contribute to the different pattern shown for mercury.

[22] The decreasing trend across the lowest elevation band is driven least in part by the many soil samples at lower elevations in the Northport area that were analyzed for cadmium, copper, and lead as part of the 2004 EPA Le Roi Smelter Removal Action Study.

- Barium, manganese, and mercury show a gradual increase in concentrations with increasing elevation beginning in the lowest elevation band (less than 1,500 ft amsl) and extending to 2,700 ft amsl for mercury and above 2,700 ft amsl for barium and manganese.

The pattern of higher concentrations at low elevations (i.e., along the river valley) that decrease with increasing elevation, as observed for lead, cadmium, and copper, is consistent with transport and deposition of particulate emissions from the Trail Facility and the Le Roi/Northport Smelter. This is consistent with the GAM results for these metals based on UTM northing/distance from the Trail Facility. Zinc, arsenic, and mercury patterns appear influenced by smelter emissions based on the GAM for UTM northing/distance from Trail Facility but not based on the elevation GAM. This could be a result of differences in data sets (zinc and mercury were not analyzed in some studies) and/or a result of the complexities from different sources of metals (including background), variable topography, and the large geographic extent of the data used in the analysis. Overall, the GAM results show that the nature and extent of lead, cadmium, and copper show overall patterns that are consistent with smelter emission sources, and that zinc, arsenic, and mercury show patterns that are less clearly influenced by smelter emissions than those for lead, cadmium, and copper. The trends exhibited in the GAMs for barium and manganese are different from the other COCs and are not consistent with smelter emission sources.

Small-Scale Variability Analysis

A small-scale variability analysis was performed for lead, cadmium, and zinc to assess the inherent variability (heterogeneity) in soil concentrations for these three COCs in the OU 3 study area and how the variability differs spatially and by metal. Understanding the variability in soil metals concentrations is an important consideration when using the nature and extent evaluation for RI/FS decision-making purposes or for designing monitoring programs.

The small-scale variability assessment compared soil sample results for sets of samples that were collected close together under a given study. In this approach, small-scale variability was assessed as the coefficient of variation, also referred to as relative standard deviation. Assessing coefficients of variation for sets of samples allows for comparison to data quality indicators for precision and for other typical statistical applications, such as comparisons to thresholds or monitoring program designs.

The analysis indicates that lead, cadmium, and zinc concentrations in soil are variable across the scales of DUs, sampling areas, and properties that have been sampled in the OU 3 study area. This variability can be due to a variety of factors, including analytical precision, soil sampling and processing techniques, inherent heterogeneity of soil, differences in land uses, topography,

vegetation cover, and/or influences of different sources and interplay between natural and anthropogenic sources. The variability exhibited by these Site data suggests that there will be high uncertainty when predicting soil concentrations in unsampled areas, which should be considered carefully when using the geostatistical model results summarized below. Given the high degree of intrinsic variability in soil metals concentrations, the collection of additional samples within areas with no samples or low sample density would not be expected to significantly reduce the prediction uncertainty.

Geostatistical Model

A geostatistical model was prepared for the Upland RI to estimate the concentrations of lead, cadmium, and zinc at unsampled locations within the OU 3 study area. The Upland RI data set was generated from multiple studies that included different study objectives, sampling designs, and study areas. As a result, the soil data coverage across the OU 3 study area is variable, with some areas having a relatively high density of soil samples (e.g., along the river valley in the northern portion of the OU 3 study area), while other areas have fewer data.

The objective of the geostatistical model was to characterize the nature and extent of lead, cadmium, and zinc in the OU 3 study area based on geostatistical analysis of existing surface soil data. The outputs from the geostatistical model include the following:

1. Maps showing interpolated and extrapolated concentrations in surface soil
2. Maps illustrating the uncertainty of predicted soil concentrations at unsampled location
3. Maps illustrating the likelihood that a given soil concentration is exceeded.

The geostatistical tools used for modeling surface soil metals concentrations in the OU 3 study area included sequential Gaussian simulation and universal kriging. The sequential Gaussian simulation-universal kriging geostatistical model was prepared for the Upland RI using the Upland RI data set.

The results from the geostatistical model illustrate the complexity and uncertainty associated with predicting soil metals concentrations across the large expanse of the OU 3 study area. There is considerable uncertainty associated with modeled concentrations based on both the spatial correlation exhibited by the sample data and the underlying sample data distributions. This uncertainty should be considered carefully when using modeled concentration maps for RI/FS decision-making purposes. Based on the geostatistical model and small-scale variability analysis results, the collection of additional samples within areas with no samples or low sample density would not be expected to significantly reduce the prediction uncertainty.

Areal Nature and Extent of COCs

A summary of the areal nature and extent of COCs and the comparison of COC concentrations to ecological RBCs are provided in the following sections.

Summary of the Areal Nature and Extent of COCs

The following provides a summary of the areal nature and extent of the nine COCs in surface soil within the OU 3 study area:

- Lead, cadmium, and zinc concentrations above their respective BTVs occur throughout the OU 3 study area. The concentrations of these three COCs show considerable spatial variation but generally are highest at low elevations along the UCR valley between the U.S.-Canada border and Northport; at higher elevations in the upland areas on either side of the river valley immediately south of the U.S.-Canada border; and in the vicinity of Northport, in areas associated with historical mines and mineral processing facilities, and the vicinity of Bossburg. Concentrations generally decrease with distance southward along the river valley and with increasing elevation and lateral distance away from the river in both directions (east and west).
- Most arsenic, copper, and mercury concentrations are less than their respective BTVs. Concentrations of these three COCs that exceed BTVs are generally at low elevations along the UCR valley between the U.S.-Canada border and Northport, and in the vicinity of historical mines and mineral processing facilities. Concentrations are observed to generally decrease with distance toward the south along the river and decrease or remain relatively stable with increasing elevation and lateral distance away from the river in both directions (east and west).
- Most barium and manganese concentrations are also less than their respective BTVs. However, the distributions of barium and manganese concentrations in soil that exceed the BTVs differ significantly from the lead, cadmium, and zinc distributions because elevated concentrations are generally at high elevations in upland areas on both sides of the UCR valley. Barium and manganese concentrations are relatively stable along the river between the U.S.-Canada border and Northport and decrease to the south of Northport.
- Similar to lead, cadmium, and zinc, selenium concentrations show considerable spatial variation, with elevated concentrations present at low elevations along the UCR valley between the U.S.-Canada border and Northport, at higher elevations in the upland areas on both sides of the river valley, and in the vicinity of historical mines and mineral processing facilities. Selenium concentrations also generally decrease moving south

along the river from the U.S.-Canada border. However, selenium concentrations generally increase with higher elevation and lateral distance from the river in both directions (east and west), which differs from the patterns observed for lead, cadmium, and zinc.[23]

Comparison of COC Concentrations to Ecological RBCs

Soil concentrations for each of the nine COCs were compared to the lowest ecological RBC selected from the range of relevant ecological receptors. For any COC where the lowest ecological RBC was less than the BTV calculated from total recoverable metals concentrations, the BTV was selected as the lowest ecological RBC.[24]

Of the nine COCs, zinc shows the greatest spatial distribution of samples exceeding the lowest ecological RBC. Concentrations of zinc exceed the lowest ecological RBC of 111 mg/kg[25] throughout the OU 3 study area, except for a few samples to the west of the Columbia River near the U.S.-Canada border, a small area near the northeast OU 3 study area boundary, around Bossburg, and in the Van Stone Mine/Mill area. Of the three COCs for which geostatistical modeling was performed (i.e., lead, cadmium, and zinc), zinc had the largest footprint, where the modeled zinc concentration exceeded the lowest ecological RBC (Map ES-2). Therefore, the lowest ecological RBC exceedances for lead, cadmium, arsenic, barium, copper, manganese, mercury, and selenium were compared to the zinc footprint to assess the relative spatial distribution of RBC exceedances.

The following bullets compare the spatial distribution of modeled zinc concentrations greater than the lowest ecological RBC with the distribution of samples used in the geostatistical model with measured concentrations of other COCs exceeding their respective lowest ecological RBCs:

- Lead and cadmium sample concentrations exceed their respective lowest ecological RBCs throughout the area where modeled zinc concentrations are above the lowest zinc ecological RBC. There are few sample locations outside of the modeled zinc RBC exceedance area where cadmium (three samples) and/or lead (four samples) exceed their lowest ecological RBCs. Arsenic, barium, and manganese do not show widespread

[23] Several studies included high frequencies of nondetected values and/or elevated detection limits for selenium, which complicate interpretations of the spatial distribution.

[24] The RBC comparisons were performed using the samples collected in the OU 3 study area that were used in the geostatistical model and the samples designated as "mine and mill" samples, which were not used in the geostatistical model but are considered in the interpretation of the model outputs.

[25] The lowest ecological RBC for zinc is below the BTV. Therefore, the total recoverable BTV of 111 mg/kg was selected as the lowest ecological RBC for zinc for this analysis.

exceedances of lowest ecological RBCs within the OU 3 study area. These COCs do not exceed their lowest ecological RBCs at any location without a corresponding modeled zinc RBC exceedance.

- Copper, mercury, and selenium also do not show widespread exceedances of their lowest ecological RBCs within the OU 3 study area. These COCs each have one or more sample locations outside of the modeled zinc ecological RBC exceedance area that exceed their respective lowest ecological RBCs: 4 sample locations for copper, 1 sample location for mercury, and 13 sample locations for selenium.

Based on the lowest ecological RBC comparisons, the area where modeled zinc exceeds its lowest ecological RBC effectively captures areas where other COCs have sample locations that exceed their respective lowest ecological RBCs. There are some exceptions for lead, cadmium, copper, mercury, and selenium where few sample locations exceed their lowest ecological RBCs outside of the zinc footprint. However, these locations are isolated and/or are bounded by areas where zinc is predicted to exceed its lowest ecological RBC.

Vertical Nature and Extent

A vertical nature and extent assessment was conducted to evaluate whether COC concentrations in soil are enriched in the surface compared to subsurface concentrations, whether there are geographical patterns in the surface-to-subsurface soil concentration ratios, and the vertical extent of COC contamination in soil within the OU 3 study area. The data available for evaluating vertical nature and extent were limited primarily to the river valley and adjacent areas. Overall, the degree of surface enrichment and the vertical distribution of COC concentrations were found to vary both spatially and within study data sets. Findings for the vertical nature and extent evaluation included the following:

- Surface soil enrichment, as expressed by the ratio of surface-to-subsurface concentrations, tended to be highest for cadmium, lead, zinc, and, where analyzed, mercury.
- At most locations where vertical concentration profiles are available, the regression lines for lead, cadmium, and zinc concentrations decrease to values close to or below total recoverable BTVs between ground surface and about 6 in. bgs, indicating that lead, cadmium, and zinc enrichment is typically limited to soil depths of about 6 in..
- Arsenic, barium, copper, manganese, and mercury showed generally decreasing concentration trends with depth; however, the trend lines for these metals were below their respective total recoverable BTVs at all depths. There were limited data available to

evaluate selenium concentration-depth relationships, but selenium was elevated above the BTV at all depths with no apparent vertical trend.

PHYSICAL/CHEMICAL CSM

Refinement of the OU 3 physical/chemical CSM incorporates the Upland RI analyses and findings, which have contributed to an improved understanding of the sources of COCs, their nature and extent in upland soil in the OU 3 study area, and their primary transport and fate processes. The primary sources and transport and fate processes are summarized below.

Sources of COCs

Based on the evaluations and analyses presented in this Upland RI report, the known and potential sources of metals to the OU 3 study area include smelter operations (Trail Facility and Le Roi/Northport Smelter), mining operations and mineral processing facilities, other anthropogenic sources and land uses (e.g., roads), geology and geogenic background, and ambient atmospheric sources. Overall, the nature and extent evaluations indicate that historical aerial emissions from smelter operations at the Trail Facility and the Le Roi/Northport Smelter are the predominant source of regional occurrences of cadmium, lead, and zinc—and to a lesser extent arsenic, copper, and mercury—to soil within the OU 3 study area. Concentrations of these COCs show considerable spatial variation across the OU 3 study area but are generally highest at low elevations along the UCR valley between the U.S.-Canada border and Northport; at higher elevations in the upland areas on both sides of the river valley immediately south of the U.S.-Canada border; and in the vicinity of Northport, areas associated with historical mining and mineral processing, and in the vicinity of Bossburg. Concentrations of these COCs are observed to generally decrease moving south along the river from the U.S.-Canada border and with higher elevation and lateral distance from the river in both directions (east and west). Whereas lead, cadmium, and zinc exceed their respective BTVs throughout the OU-3 study area, most arsenic, copper, and mercury concentrations in soil are less than their respective BTVs.

Numerous investigations have evaluated potential impacts to soil and other environmental media at historical mine and mill sites present within Stevens County, Washington. The extent of soil impacts surrounding the historical mine and mill sites is expected to be localized; however, the available data are not adequate to fully delineate the spatial distribution of effects at all these sites. Given the absence of adequate characterization data at many of these sites, further characterization may be needed to refine the CSM if areas in OU 3 identified for remedial action are located near historical mine and mill sites.

The studies evaluated in the Upland RI were not designed to assess the locations or contribution of COCs to soils within the OU 3 study area from geogenic background, non-smelter-related ambient atmospheric deposition, or other anthropogenic features or land uses. Given the absence of this information, further characterization may also be needed to refine the CSM if areas identified for remedial action are thought to be influenced by these sources.

Transport and Fate of COCs

The evaluations and analyses performed for this Upland RI report support an assessment of the transport and fate of COCs associated with aerial smelter emissions and other sources. Release and transport mechanisms for the COCs are illustrated in the CSM diagram (Figure ES-1). Several different physical, chemical, and biological transport and fate mechanisms influence the distribution of COCs from their sources to locations in the OU 3 study area. COCs may be transported by atmospheric suspension and deposition of COC-bearing particulates through wind dispersion (i.e., sorbed to airborne soil particles or other particulate matter) or in biological matrices (i.e., bioaccumulated in terrestrial organisms). The forms (species) and phases in which the COCs occur influence their transport, fate, and bioavailability. The form of each COC depends on its chemical properties as well as local environmental conditions (e.g., temperature, pH, oxidation-reduction conditions, cation exchange capacity, particle size, moisture content, and organic matter) and the time since deposition.

The movement of COCs through the environment occurs via primary, secondary, and tertiary release mechanisms. The primary release mechanism is the direct discharge of metals from sources to environmental media. Based on the available data, it does not appear that the COCs from aerial deposition of smelter emissions and other sources are affected greatly by secondary and tertiary transport mechanisms. However, the studies evaluated in the Upland RI were not designed to fully assess the transport and fate pathways associated with ambient atmospheric sources, historical mining and mineral processing facilities, other anthropogenic features or land uses, or geogenic sources within the OU 3 study area. Given the absence of this information, further characterization may be needed to refine the CSM if areas identified for remedial action are thought to be influenced by these sources.

UPLAND RI CONCLUSIONS

This Upland RI report provides a robust characterization of the OU 3 study area at the UCR Site and has refined the physical/chemical CSM to a stage where it can effectively support the FS evaluation of potential remedial actions for the OU 3 study area.

Arsenic and lead are identified as human health COCs, and arsenic, barium, cadmium, copper, lead, manganese, mercury, selenium, and zinc are identified as ecological COCs. Based on the evaluations and analyses presented in this Upland RI report, historical smelter emissions from the Trail Facility and Le Roi/Northport Smelter are a source of the COCs posing risks to human and ecological receptors in the OU 3 study area. Historical mines and mineral processing facilities and other anthropogenic, ambient atmospheric, and geogenic sources may also contribute to elevated concentrations of metals. Of these sources, smelter operations and ambient atmospheric constituents have the potential for regional impacts across the OU 3 study area, while historical mining operations and mineral processing facilities, other anthropogenic sources, and geology and geogenic background are more likely to have localized impacts; however, the non-smelter-related sources have not been well characterized nor have additional analyses that address the sources been included in the Upland RI.

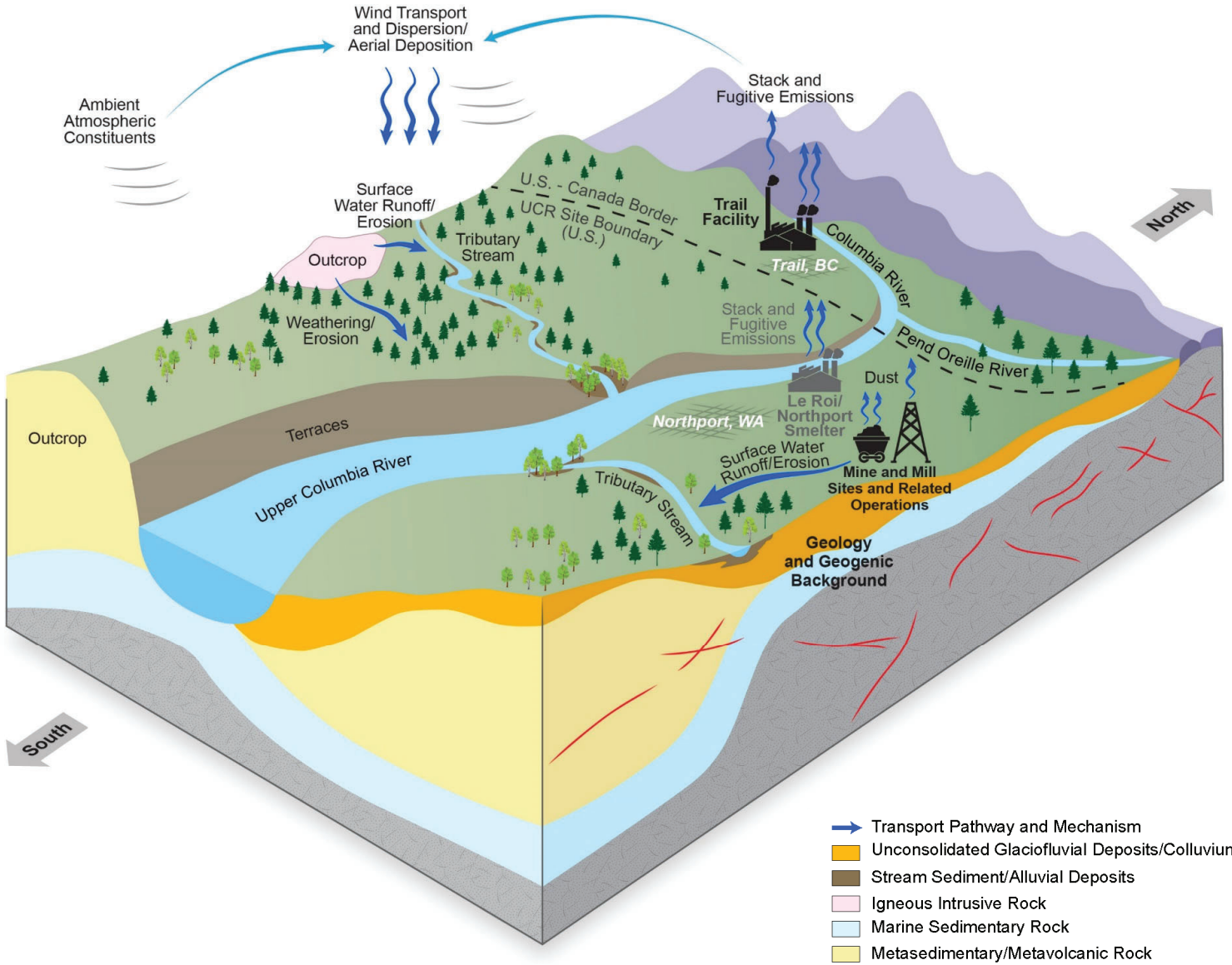
Concentrations of COCs in surface soil are above their respective BTVs in many sample locations, with cadmium, lead, and zinc exceeding their BTVs throughout the OU 3 study area. Overall, the relationships and patterns identified in the nature and extent evaluations for cadmium, lead, and zinc (and to a lesser extent arsenic, copper, and mercury, because most sample locations for these three COCs have concentrations less than their BTVs) are consistent with transport and deposition from historical aerial emissions (both stack and fugitive) from smelter operations at the Trail Facility and the Le Roi/Northport Smelter. Concentrations of the COCs correlated with smelter emissions show considerable spatial variation across the OU 3 study area but are generally highest at low elevations along the UCR valley between the U.S.-Canada border and Northport, at higher elevations in the upland areas on both sides of the river valley immediately south of the U.S.-Canada border, and in the vicinity of Northport. Concentrations of these COCs are observed to generally decrease moving south along the river from the U.S.-Canada border and with higher elevation and lateral distance from the river in both directions (east and west).

Several physical, chemical, and biological transport and fate mechanisms influence the distribution of COCs in the OU 3 study area. COCs are transported by atmospheric suspension and deposition of COC-bearing particulates through wind dispersion (i.e., sorbed to airborne soil particles or other particulate matter) or in biological matrices (i.e., bioaccumulated in terrestrial organisms). The primary release mechanism is the direct discharge of metals from sources to environmental media. Once released to the environment, COCs present in environmental media (i.e., air, dust, and soil) are distributed through secondary and tertiary release mechanisms, such as suspension and wind dispersion, adsorption/desorption (i.e., attachment or detachment of metals to soil particles), and physical processes like

decrepitation/weathering/erosion (i.e., the wasting or breaking up of particles resulting in metal releases).

The results of the Upland RI for the OU 3 study area will be used in the Upland FS to develop and/or refine RAOs and PRGs and to support the evaluation of potential remedies. The information presented in this Upland RI report will be used as a starting point to identify specific locations within OU 3 that may require remediation to achieve the RAOs and PRGs. The physical/chemical CSM presented herein will be used to develop preliminary soil volume estimates for the development and evaluation of potential remedial action alternatives in the Upland FS.

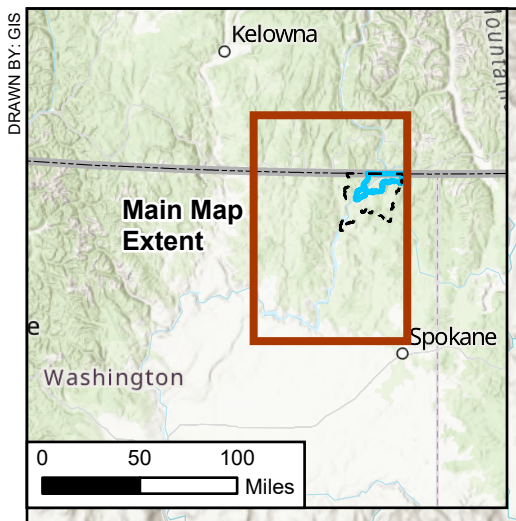
EXECUTIVE SUMMARY
FIGURE/MAPS/TABLE



Notes:
This diagram is not to scale.
Other anthropogenic sources (e.g., roads, railways) are not shown.
Mine and mill sites and related operations include solid waste or tailings disposal.

Figure ES-1. Physical/Chemical CSM
Final Upland RI Report
Upper Columbia River, Washington

DRAWN BY: GIS



Columbia River
Bonnington Range
Christina Range
Rossland Range
2306 m
2272 m
Trail Smelter
Trail
Greenwood Smelter
Boundary Falls Smelter
Granby Smelter
U.S. - Canada Border
Pend Oreille River
Waneta Dam
Northport
Le Roi/Northport Smelter
Lime Creek Mountain
Kettle River
Onion Creek
Thompson Ridge
Bossburg
Evans
7139 ft
Republic
Marcus
OU 1
OU 2
Kettle Falls
Colville
Colville Smelter
Colville Valley
Okanogan County
Ferry County
Columbia River
North Basin
Huckleberry Range
Stevens County
Pend Oreille County
6380 ft
6771 ft
6009 ft
6853 ft
Iron Mountains
Sanpoil River
Oregon City Ridge
Colville Indian Reservation
Colville River
Summit Valley
Gold Mountain Ridge
Huckleberry Mountains
Douglas County
Coulee Dam
Grand Coulee Dam
Columbia River
Spokane Indian Reservation
Walkers Prairie
Grant County
Deer Meadows
Lincoln County
4367 ft
4636 ft
Bald Ridge
Prairie

Legend
- City/Town
- Major Dam
- Smelter
- ADA as Defined by the 2014 Soil Study (TAI 2015a)
- OU 3 Study Area
- Reservation
- County Boundaries

ERM
Environmental Resources Management
www.erm.com

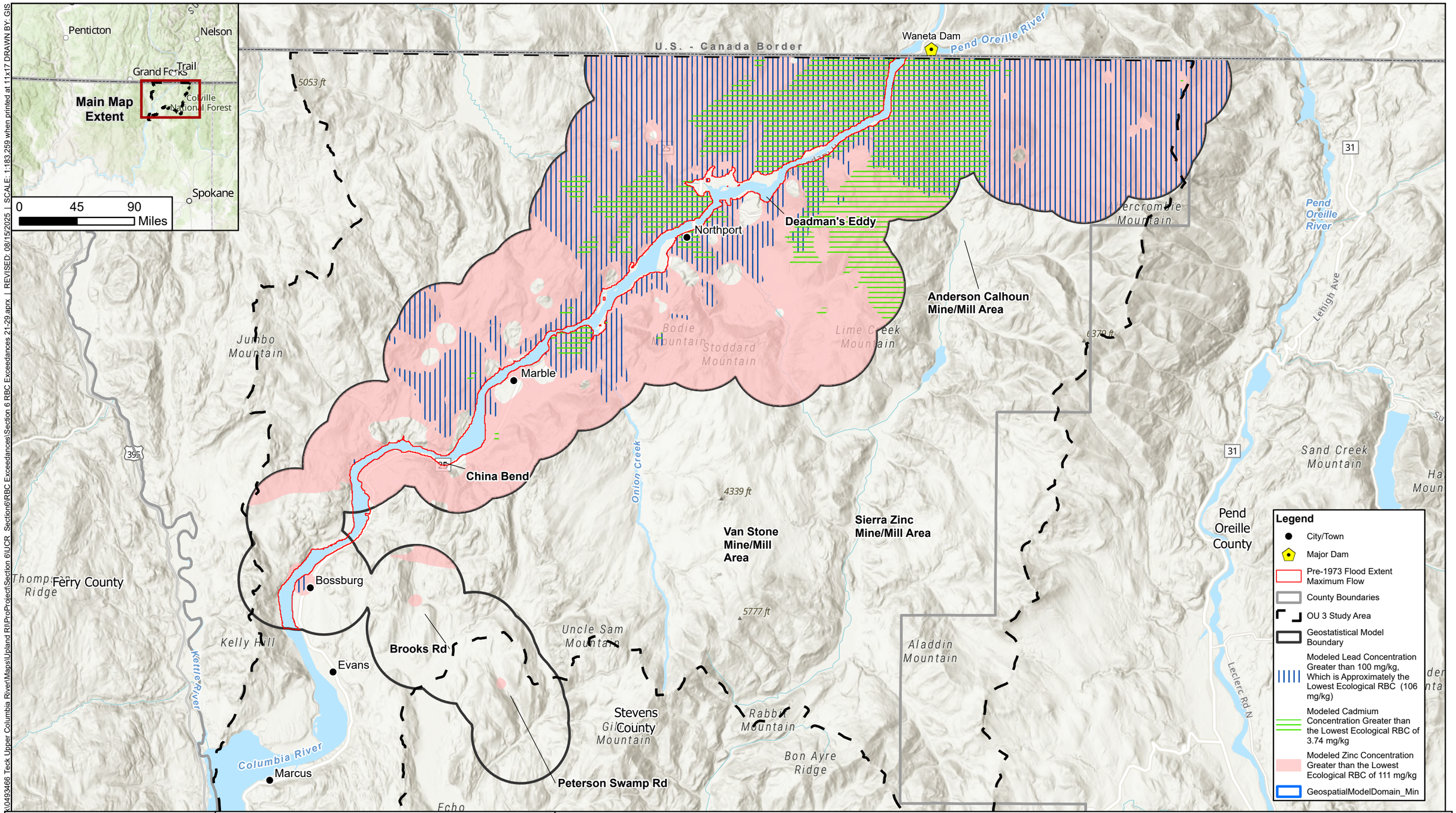
0 3.75 7.5 15 Miles

N

Map ES-1. **Regional Map of the Upper Columbia River Site**
Final Upland RI Report
Upper Columbia River, Washington

Source: Esri - World Topographic Map; NAD 1983 UTM Zone 11N

FILE: M:\US\Projects\S-U\Teck\0493466 Teck Upper Columbia River\Maps\Upland RI\ProProject\Section 1\UCR_Section 1\Upland RI Section 1.aprx | REVISED: 08/13/2025 | SCALE: 1:500,000 when printed at 11x17



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Map ES-2. **Areas with Modeled Lead, Cadmium, and Zinc Ecological RBC Exceedances**
Final Upland RI Report
Upper Columbia River, Washington

Source: Esri - World Topoographic Map; NAD 1983 UTM Zone 11N

Table ES-1. Document Titles and Abbreviated Study Names Used in the Upland RI Report

Document Title	Abbreviated Study Name for Upland RI Report	Report Citation
Upper Columbia River Final Soil Study Data Summary Report	2014 Soil Study	TAI (2015a)
Upper Columbia River Upland Soil Sampling Study, Stevens County, Washington	2012 Ecology Upland Soil Study	Ecology (2013a)
UCR Residential Soil Study Field Sampling and Data Summary Report	2014 Residential Soil Study	USEPA (2016a)
Action Memorandum for the Upper Columbia River Site Residential Properties Soil Removal near Northport, Stevens County, Washington	2015 TCRA Memorandum	USEPA (2015b)
Time-Critical Removal Action Final Completion Report	2015 TCRA	TAI (2016b)
Upper Columbia River Final Residential Soil Study Data Summary Report	2016 Residential Soil Study	TAI (2017a)
Voluntary Removal Action Final Completion Report Northport, Washington	2017–2018 VRA	TAI (2019a)
Final Soil Amendment Technology Evaluation Study Phase IA Test Plot Selection and Characterization Data Summary Report	2017 SATES Test Plot Characterization	TAI (2019b)
Upper Columbia River Final Plant Tissue Study Data Summary Report	2018 Plant Tissue Study	TAI (2019c)
Inactive and Abandoned Mine Lands (IAML) — Young America Mine, Bossburg Mining District, Stevens County, Washington	WDNR Young America Mine Site Characterization	WDNR (2008)
Young America Mine Removal Assessment Trip Report Evans, Stevens County, Washington	2011 EPA Young America Mine Removal Assessment	USEPA (2012a)
Final Bossburg Flat Beach Refined Sediment and Soil Study Data Summary Report	2015 Bossburg Study	TAI (2016c)
Preliminary Assessments and Site Inspections Report, Upper Columbia River Mines and Mills, Stevens County, Washington	2001 EPA Stevens County Mines and Mills PA/SI	USEPA (2002a)
Le Roi Smelter Removal Action Report, Northport, Stevens County, Washington	2004 EPA Le Roi Smelter Removal Action	USEPA (2005)
Van Stone Mine Remedial Investigation	2011–2012 Ecology Van Stone RI	Ecology (2013b)
Feasibility Study, Van Stone Mine, Onion Creek, Washington	2014–2015 Ecology Van Stone FS	Ecology (2017a)
Engineering Evaluation/Cost Analysis Anderson Calhoun Work Group. Anderson Calhoun Mine. Colville, Washington.	2003–2004 EPA Anderson Calhoun EE/CA	USEPA (2007a)
Soil Remediation, Boundary Land Port of Entry, Stevens County, Washington	2011 Port of Entry Soil Remediation	Shannon and Wilson (2011)
Voluntary Cleanup Report, Brooks Road/Bonanza Mine Roadbed Materials, Stevens County, Washington	2007 Brooks Road/Bonanza Mine Roadbed Voluntary Cleanup	SCDPW (2008a)
Voluntary Cleanup Report, Peterson Swamp/Bonanza Mine Roadbed Materials, Stevens County, Washington	2007 Peterson Swamp/Bonanza Mine Roadbed Voluntary Cleanup	SCDPW (2008b)
Heavy Metal Contamination in Soil and Lichen Tissue in the Colville National Forest, Washington, USA	Wells Lichen Study	Wells (2015)
Geochemical and Mineralogical Data for Soils of the Conterminous United States	2007–2010 USGS Soil Study	USGS (2013)
Natural Background Soil Metals Concentrations in Washington State	Ecology Natural Background Soil Study	Ecology (1994)
National Uranium Resource Evaluation (NURE) Hydrogeochemical and Stream Sediment Reconnaissance (HSSR) data	USGS Reformatted NURE-HSSR Program	USGS (2006)
Determination of Premining Geochemical Background and Delineation of Extent of Sediment Contamination in Blue Creek Downstream from Midnite Mine, Stevens County, Washington	USGS Midnite Mine Sediment Study	USGS (2008a)
The National Geochemical Survey—Database and Documentation: Version 5.0. USGS Open-file Report 2004-1001	USGS NURE Sample Reanalysis	USGS (2008b)
Terrestrial Ecological Risk Assessment for the Teck Metals Ltd. Smelter at Trail, BC	Trail Smelter Terrestrial ERA	Teck Metals Ltd. (2011)

Table ES-1. Document Titles and Abbreviated Study Names Used in the Upland RI Report

Document Title	Abbreviated Study Name for Upland RI Report	Report Citation
Preliminary Assessment of Background Concentrations of Elements in Soil from the Trail Area	2001 Trail Area Soil Background Assessment	Goodarzi et al. (2001)
Waneta Hydroelectric Expansion Project Investigation of Proposed Worksites for Contamination and Remedial Measures	2005 Waneta Expansion Project	WEPC (2005)
Accumulation of Trace Elements on the Surface Soil Around the Trail Smelter, British Columbia, Canada	2001 Trail Area Moss Bag Study	Goodarzi et al. (2002)
Final Human Health Risk Assessment: Upper Columbia River Site	HHRA	USEPA (2021)
Upper Columbia River Work Plan for the Remedial Investigation and Feasibility Study (RI/FS)	RI/FS Work Plan	USEPA (2008a)
Letter to Denise Mills, TAI, dated July 25, 2022, from Bonnie Arthur, EPA Remedial Project Manger, Re: Schedule Addendum to the Upper Columbia River "Workplan for the Remedial Investigation and Feasibility Study," dated December 2008	RI/FS Schedule Addendum	USEPA (2022a)
Baseline Ecological Risk Assessment for Upland Terrestrial Habitat	Upland BERA	USEPA (2023a)
Feasibility Study for OU 3	Upland FS	TAI (to be prepared)
Baseline Ecological Risk Assessment for OU 1 and OU 2	Aquatic BERA	TAI (2024b)
Draft Remedial Investigation Report for OU 1 and OU 2	Aquatic RI	TAI (to be prepared)

Notes:

BERA - Baseline Ecological Risk Assessment
Ecology - Washington State Department of Ecology
EE/CA - engineering evaluation/cost analysis
ERA - ecological risk assessment
FS - feasibility study
HHRA - Final Human Health Risk Assessment: Upper Columbia River Site (USEPA 2021)
PA/SI - preliminary assessment and site inspection
RI - remedial investigation
SATES - Soil Amendment Technology Evaluation Study
TCRA - time-critical removal action
USGS - U.S. Geological Survey
VRA - voluntary removal action
WDNR - Washington State Department of Natural Resources
WEPC - Waneta Expansion Power Corporation

1 INTRODUCTION

This document presents a Final Remedial Investigation (RI) Report for the upland terrestrial portion of Operable Unit (OU) 3 of the Upper Columbia River site (UCR Site or Site[26]) in northeastern Washington. Teck American Incorporated (TAI) has prepared this document, hereafter the Upland RI report, pursuant to the Settlement Agreement for Implementation of Remedial Investigation and Feasibility Study at the Upper Columbia River Site (Agreement) (USEPA 2006), Upper Columbia River Work Plan for the Remedial Investigation and Feasibility Study (RI/FS) (hereafter, the RI/FS Work Plan) (USEPA 2008a), and applicable U.S. Environmental Protection Agency (EPA) guidance documents (e.g., USEPA 1988, 1997a,b). Discharges from the Trail smelter in Trail, British Columbia (hereafter, Trail Facility), now owned and operated by Teck Metals Ltd., have contributed to releases of hazardous substances, as defined in the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), at the Site. Additional sources, including the Le Roi/Northport Smelter, which has been the subject of action by both EPA and the Washington State Department of Ecology (Ecology) and is identified by different site numbers,[27] have also contributed to releases of hazardous substances at the Site.

In 2022, EPA subdivided the Site into three OUs for management purposes. OU 1 and OU 2 are the aquatic OUs (USEPA 2022a), which together cover the Upper Columbia River aquatic system from the U.S.-Canada border to Grand Coulee Dam, including relict floodplains, windblown sediment deposition areas (WSDAs), beaches, and riparian areas along the river channel. OU 3 is the terrestrial upland portion of the Site that may have been influenced by historical deposition of metals. The OU 3 boundary is not formally defined. However, for the purposes of this Upland RI report, the OU 3 study area is defined as the terrestrial upland area within the boundary of the Upper Lake Roosevelt Water Resource Inventory Area

[26] Per the June 2, 2006, Settlement Agreement for Implementation of Remedial Investigation and Feasibility Study at the Upper Columbia River Site (referred to herein as the UCR Site or Site), the Site consists of the areal extent of hazardous substances contamination within the United States in or adjacent to the Upper Columbia River, including the Franklin D. Roosevelt Lake, from the U.S.-Canada border south to the Grand Coulee Dam, and all suitable areas in proximity to such contamination necessary for implementation of the response actions (RI/FS) described therein.

[27] The Le Roi/Northport Smelter site number for EPA is WAD988507323 and for Ecology is 47 (USEPA 2025; Ecology 2025a). The Northport Waterfront site number for Ecology is 14874 (Ecology 2025b).

(WRIA 61)[28] (Map 1-1). EPA believes there may be a data gap associated with the upland lakes and wetlands.

This Upland RI report also includes regional data from Ferry County, Stevens County, and the northern portion of Lincoln County (i.e., the tri-county area) to provide context for the detailed descriptions and analyses for the OU 3 study area. The aerial deposition area (ADA) was defined in the Final Soil Study Quality Assurance Project Plan (TAI 2014) as the area potentially influenced by smelter particulate deposition in the northern portion of the Site. The ADA is discussed later in this report and is shown on Map 1-1 for reference.

As described in the RI/FS Work Plan (USEPA 2008a), the purpose of the RI/FS is to investigate the nature and extent of contamination at the Site, provide information to support the baseline risk assessments for human health and the environment, and to develop and evaluate potential remedial alternatives for the Site.

Per National Oil and Hazardous Substances Pollution Contingency Plan (NCP) regulations, the RI/FS process comprises two major work streams: the RI and the FS. The objectives of the RI are to determine the nature and extent of contamination; identify sources of contamination at the Site, including the potential for ongoing chemical release(s) and the potential mobility and persistence of chemicals; characterize potential risks within the Site; and characterize transport and fate processes related to current and reasonably foreseeable future conditions that may affect Site risk. The objective of the FS is to identify a range of remedial alternatives that meet NCP requirements, analyze the remedial alternatives, and present the information necessary for EPA to select a remedy for the Site, which will be documented in a record of decision (ROD).

The RI work stream includes completion of a baseline human health risk assessment, and a baseline ecological risk assessment (BERA) and RI reports for each OU. EPA completed the Final Site-Wide Human Health Risk Assessment: Upper Columbia River Site (hereafter, HHRA) in 2021 (USEPA 2021). EPA issued a revised Baseline Ecological Risk Assessment for Upland Terrestrial Habitat (hereafter, Upland BERA) in 2023 (USEPA 2023a). TAI has sought technical review of the Upland BERA (TAI 2024a).

[28] WRIAs are geographical divisions in Washington State that were established for natural resource management, typically for the study and regulation of water resources and for planning purposes. Ecology is the state agency responsible for the development and management of these administrative and planning boundaries. The geographic definitions for the 62 WRIAs in the state were formalized under Washington Administrative Code (WAC) 173-500-040 and authorized under the Water Resources Act of 1971, Revised Code of Washington 90.54. WRIA boundaries are based on watershed and drainage characteristics. WRIA boundaries were originally decided jointly by Washington State's natural resource agencies (the departments of Ecology, Natural Resources, and Fish and Wildlife) in 1970 and were last updated in 2000.

This Upland RI report incorporates the results from the HHRA and Upland BERA to characterize media-specific occurrences of human health and ecological chemicals of concern (COCs). Detailed evaluations in this Upland RI report include characterization of sources of contamination, nature and extent, and transport and fate for COCs in the OU 3 study area. Data and reports from many studies were used to support development of this report. Table 1-1 presents a summary of document titles and their abbreviations used throughout this report.

This Upland RI report focuses on upland soils. Sediments in the river, beaches, relict floodplains, WSDAs, and riparian soils in the river that may have elevated metals concentrations (i.e., sediments in OU 1 and OU 2) will be evaluated in the Draft Remedial Investigation Report for OU 1 and OU 2[29] (hereafter, Aquatic RI report). The pre-1973 flood extent maximum topographic elevations[30] were used to define upland soils evaluated in this Upland RI report (i.e., soils above the pre-1973 flood extent maximum that are assumed to not be influenced by aquatic sources, consistent with the 2014 Soil Study [TAI 2015a]). Soil samples located within the historical pre-1973 flood extent maximum will be evaluated in the Aquatic RI report. EPA believes there is a data gap associated with the upland lakes and wetlands.

The information presented in the HHRA, Upland BERA, and Upland RI report will be used in the Feasibility Study for OU 3[31] (hereafter, Upland FS) to estimate the areal extent and volume of soil with COC concentrations that may result in unacceptable risks to human health and/or the environment. The Upland FS will be a detailed evaluation of remedial action alternatives that could mitigate or eliminate potential unacceptable risks to human health or the environment by reducing contaminant concentrations or eliminating exposure pathways.

1.1 REPORT ORGANIZATION

The remaining sections of the Upland RI report are organized as follows.

- **Section 2 OU 3 Study Area Characteristics.** Provides an overview of the OU 3 study area and a summary of regional and OU 3 study area physical characteristics, including setting, meteorology, geology, hydrogeology, surface water hydrology, demographics, history and land use, and ecological setting. This section also presents a summary of known and potential sources of metals to soil.

[29] Final title of this document is subject to change.

[30] The pre-1973 flood extent maximum topographic elevations were selected as the historical floodplain limit because coordinated flood control operations on the Columbia River upstream of Grand Coulee Dam began in 1973, which resulted in reduced flood intensities after that time.

[31] Final title of this document is subject to change.

- **Section 3 Studies Conducted in the OU 3 Study Area and Canada.** Describes the studies and data compiled and evaluated for use in the Upland RI report.
- **Section 4 Soil Background.** Summarizes the natural soil background evaluation conducted for the UCR Site.
- **Section 5 Risk Assessment Summary.** Summarizes the approach and analyses conducted for the risk characterization and the results for the parts of the HHRA that pertain to OU 3, as well as the human health exposure conceptual site model (CSM) as presented in the HHRA. Human health preliminary remediation goals (PRGs) and human health remedial action objectives (RAOs) are summarized. This section also includes a description of the ecological COCs identified by EPA in the Upland BERA and develops ecological risk-based concentrations (RBCs) for use in the Upland RI.
- **Section 6 Nature and Extent of Contamination.** Describes preparation of the data used to evaluate the nature and extent, the results of the statistical analyses conducted for the Upland RI report, and the areal and vertical nature and extent of COCs.
- **Section 7 Physical/Chemical CSM.** Presents a discussion of the transport and fate mechanisms for COCs along with a physical/chemical CSM for the Site.
- **Section 8 Uncertainty Assessment and Process for Assessing Data Gaps.** Summarizes uncertainties and data limitations and discusses the process for addressing data gaps.
- **Section 9 Upland RI Conclusions.** Presents the summary and conclusions of the Upland RI.
- **Section 10 References.**

In addition to these sections, this Upland RI report includes the following appendices:

- Appendix A Summary of Mine and Mill Investigations in Stevens County, Washington
- Appendix B Time-Critical Removal Actions and Voluntary Removal Actions Completed in the OU 3 Study Area
- Appendix C Technical Memorandum—Assessment of Background Concentrations of Metals and Metalloids in Upland Soils (July 2020)
- Appendix D RBA-Adjusted Lead Concentrations and Upland RI Data Set
- Appendix E Digital Data Exploration Tool
- Appendix F Statistical Analyses Completed for the OU 3 Study Area
- Appendix G Geostatistical Modeling for the OU 3 Study Area
- Appendix H COC Concentrations That Exceed Ecological Risk-Based Concentrations

2 OU 3 STUDY AREA CHARACTERISTICS

This section provides an overview of the OU 3 study area followed by a description of the physical setting and the meteorology, geology, hydrogeology, surface water hydrology, demographics, history and land use, and ecological setting of the OU 3 study area. This section also presents a summary of known and potential sources of metals in upland soils.

2.1 OU 3 STUDY AREA OVERVIEW

For the purpose of this Upland RI report, the OU 3 study area is defined by the boundary of WRIA 61 (Map 1-1), which is located almost entirely in Stevens County. Detailed descriptions of Site characteristics are provided for the OU 3 study area as well as descriptions of regional characteristics in Stevens County, Ferry County, and the northern portion of Lincoln County, which are also pertinent to the Site.

The OU 3 study area includes the ADA decision units (DUs) that were established in TAI (2014) and the town of Northport, Washington. Also included within the OU 3 study area are the residential soil study DUs (RSS DUs) established in the Quality Assurance Project Plan Upper Columbia River Residential Soil Study (USEPA 2014) and the Final 2016 Residential Soil Study Quality Assurance Project Plan (TAI 2016a).

2.2 SETTING

The following sections describe the regional physical and geologic setting for the UCR Site to provide important context for the Upland RI. The UCR Site is in northeastern Washington and extends along the Columbia River from the U.S.-Canada border to the Grand Coulee Dam (Map 1-1). The Site is situated within two physiographic provinces: the Okanogan[32] Highlands and the Columbia Basin. The Okanogan Highlands and Columbia Basin physiographic provinces, along with geologic features that occur at the Site, are identified on Map 2-1 and described further in Sections 2.2.1 and 2.2.2 below. The geology as it pertains to the OU 3 study area is described in Section 2.4.

The topography of the UCR Site includes the UCR valley, which is characterized by a deeply incised inner gorge with steep banks and terraces that gently slope toward the surrounding

[32] Okanogan is spelled Okanogan in the U.S. but is spelled Okanagan in Canada. Throughout the text, figures, and maps in this report, the U.S. spelling is used for consistency.

hills and mountains. Elevations for the terrain in and around the Upper Columbia River basin are depicted on Map 2-2 and range from 1,290 ft amsl (the full-pool elevation of Lake Roosevelt) to 7,308 ft amsl at Abercrombie Mountain, east of Northport.

2.2.1 Okanogan Highlands

The Okanogan Highlands extend north into south-central British Columbia and are bounded to the north in British Columbia by the Shuswap Highland, to the east by the Rocky Mountains in Idaho, to the south by the Spokane River and the Columbia River, and to the west by the Okanogan River. The Columbia River runs along the divide between the east and west Okanogan Highlands geographic regions, and, therefore, both shorelines of the Columbia River upstream of the confluence with the Spokane River lie within the Okanogan Highlands (Map 2-1). The Selkirk, Chewelah, and Huckleberry Mountains are east of the Columbia River, and the Kettle, Sanpoil, and other mountains are west of the Columbia River (Lasmanis 1991) (Map 2-2). The Okanogan Highlands are characterized by glacially rounded mountains reaching to over 8,000 ft amsl and by deep, narrow valleys. All of the OU 3 study area lies within the Okanogan Highlands (Map 2-1).

2.2.2 Columbia Basin

The Columbia Basin Physiographic Province abuts the southern end of the Site in Lincoln County. South from the confluence with the Spokane River, the Columbia Basin province borders the southern shoreline of the Columbia River (Map 2-1). The Columbia Basin, also known as the Columbia Plateau, makes up the entire south-central portion of Washington State. It is a wide, arid to semiarid lowland that is bounded by the Okanogan Highlands to the north, the Idaho Rockies to the east, and the Cascade Range to the west, and it extends south into eastern Oregon and northern Nevada. The Columbia Basin consists of incised rivers, extensive plateaus, and anticlinal ridges that rise up to 4,000 ft amsl (Lasmanis 1991). The geology is dominated by more than 300 basalt lava flows that make up the Miocene-aged Columbia River Basalt Group, interspersed with sedimentary strata formed between volcanic events (WDNR 2019a).

2.3 METEOROLOGY

Information about the climatology of the UCR valley is provided in Ferguson (1999). Overall, the UCR Site exhibits a predominantly continental-type climate, characterized by warm, dry summers and cold, moist winters. However, the Site is very large, and there is significant variation in climate and vegetation with elevation and aspect (i.e., the direction a topographic slope faces, such as north or south). Precipitation and temperature can also vary substantially

across the Site as a result of complex topography and the varying weather patterns in the region. Understanding weather and climate is pertinent to the evaluation of the transport and deposition of historical aerial smelter emissions and possible contributions to soil metals concentrations at the Site and for assessing atmospheric circulation (or air flows).

The complex regional terrain at the UCR Site results in varied effects on the climate, with increased precipitation to the north and east and increased snowfall at higher elevations. Areas to the north and east receive an average of 20 in. of rainfall per year and an average of 47 in. per year of snowfall. The climate in the southern part of the region is more arid, with average annual precipitation at Grand Coulee Dam being approximately 11 in. per year. In this area, precipitation occurs mostly in the winter and spring, while summer months are generally hot and dry. During the summer months, temperatures range from 75 to 90°F in the daytime, dropping to 50 to 70°F at night. Fall and spring seasons are characterized by sunshine and mild temperatures, which vary between 50 and 80°F during the day and 30 and 50°F at night. Winters can be cold, with large-scale cold winds originating from the arctic sweeping across the area. Daytime temperatures are between 25 and 40°F, and nighttime average temperatures may be as low as 15 to 20°F. The temperature and precipitation data summarized here came from the 1991 to 2020 climate normals provided by the National Oceanic and Atmospheric Administration's National Centers for Environmental Information (NCEI 2025).

The larger-scale regional climate is a result of interactions between the following three distinct types of air masses (Ferguson 1999):

- Moist marine air from the west that moderates seasonal temperatures
- Continental air from the east and south that is dry and cold in winter and hot with convective precipitation and lightning in summer
- Dry arctic air from the north that brings cold air to the area in winter and helps cool the area in summer, depending on the location of the jet stream.

The meteorology across the Upper Columbia River region is strongly influenced by orography. Orographically forced mesoscale (i.e., on a scale of 12 to 124 miles) circulations, such as topographic channeling and diurnal thermally forced mountain-valley flows, will result in spatially variable wind characteristics across this region. A detailed report on the meteorology of this region can be found in Dean and Swain (1944) and Ferguson (1998).

The complex topography in the region has a direct impact on the larger-scale air masses as they move through the UCR valley, contributing to spatial and temporal variations in wind speed and direction. The prevailing winds conform to the orientation of the river valleys and topographic ridges, resulting in a high frequency of winds along the valley axis. The Columbia River itself is curved throughout the region, with some areas in the valley containing steep

slopes surrounding the river at many locations. Additionally, topography of tributary catchments connecting to the Columbia River can contribute to localized, spatially variable winds (Dean and Swain 1944). For example, where the UCR valley is oriented north-south, the wind statistics show a high frequency of northerly and southerly wind flow. Where large bodies of east-west oriented water flow into the Columbia River, such as the Pend Oreille[33] River, the prevailing east-west flowing winds can impact the north-south prevailing winds found over the Columbia River.

Orographically induced flows result in complex spatially and temporally varying wind fields on the mesoscale as follows. Mesoscale thermally forced circulations will result in katabatic (downslope) flows and down-valley flows during nighttime radiative cooling and anabatic (upslope) and up-valley flows during daytime heating. Katabatic flows during the nighttime are shallow drainage flows that move down along sloping terrain. These downslope flows can converge into the river valleys. During the day, surface heating results in anabatic flows. In addition, thermally forced pressure gradients develop along the valley axis due to differential heating, and this results in down-valley flow at night and up-valley flow during the day (Ferguson 1998).

- Surface wind speed variations result from changes in surface roughness. For example, air moving over the Columbia River can move more rapidly and uniformly than air moving over mountains or land surfaces with larger surface roughness elements where the surface drag is greater. This variation in wind direction and speed can occur at a small scale. Overland surfaces with larger roughness elements result in increased mechanically generated turbulent flow.
- Conditions in the UCR valley are different in summer and winter months. During the summer, the surface insolation is greater and contributes to increased boundary layer mixing and increased mixing depths (Ferguson 1998). A steeper temperature lapse rate (decrease of temperature with height) creates stronger instability and leads to more turbulent mixing and higher surface wind speeds (Dean and Swain 1944). In contrast, during the winter, the Earth's surface does not heat as readily during the day, and the temperature lapse rates typically are less. At times, during winter, the combination of cold air masses with cloud cover and weaker insolation can result in lower daytime mixing depth.

[33] Pend Oreille is spelled Pend Oreille in the U.S. and Pend-d'Oreille in Canada. Throughout the text, figures, and maps of this report, the U.S. spelling is used for consistency.

In addition to the seasonal variation, a diurnal wind pattern is present (Dean and Swain 1944). During the day when more surface heating occurs, the boundary layer height rises and the air becomes less stable, promoting convection and vertical mixing. Radiative cooling at night increases the atmospheric stability, and the mixing depth is redefined closer to the ground, leaving an elevated mixed layer aloft at higher heights. Further, a low-level thermal inversion may develop. As the nighttime-reduced mixing depth develops, the air in the lowest layers becomes decoupled from the air at higher heights, and the air can become trapped in the lowest atmospheric layers. In the UCR valley, air can sink down from higher elevations into areas along and near the bottom of the valley (Allwine and Whiteman 1988). When solar heating commences after sunrise, the mixing layer deepens, and the trapped air begins to circulate and can be forced down to the ground level or may disperse up and out of the valley.

Overall, the meteorology in this region exhibits considerable spatial and temporal variability due to orographic forcing. Both topographic channeling of the larger-scale flow and thermally forced diurnal circulations are important factors that affect the meteorological characteristics of the region. Large-scale flows dominate the larger air masses that generally move through the region at various points throughout the year, but localized meteorological conditions are strongly affected by differences in elevation and surface roughness that occur throughout the region.

2.4 GEOLOGY

Metals evaluated in this Upland RI report occur naturally in surface geological formations and soils in northeastern Washington. Mineralized areas have been identified, and higher-grade mineral deposits have been exploited through numerous commercial mining projects in and around the OU 3 study area from both bedrock and placer mines. The sections below describe the geology of the region and the OU 3 study area.

Regional geologic features are identified on Map 2-1. The regional geology includes metamorphosed Precambrian continental slope deposits (e.g., the Priest River and Windermere Groups), which were subducted, intertwined, and highly faulted with Paleozoic pre-accretion deposits (e.g., the Kootenay Arc). Following Mesozoic terrane accretion (e.g., Quesnel terrane) and emplacement of subduction zone-sourced granitic and volcanic rocks (e.g., the Spirit pluton and Kaniksu batholith), a subsequent onset of Eocene crustal extension resulted in widespread metamorphism, igneous intrusion, and volcanism, which further complicated area geology. Along with the faulting and structural deformation, circulation of magmatic fluids and in situ consolidation caused metallic mineral accumulation (Cheney 2010; Lasmanis and Cheney 1994; McKee 1972; Stoffel et al. 1991; Weissenborn 1970).

The in-depth geological descriptions in the sections below are limited to the surficial geology of the OU 3 study area, where most of the data used for the analyses presented in this Upland RI report were collected. Surficial geology of the OU 3 study area and adjacent upland areas is depicted on Map 2-3. Unconsolidated materials, including glacial deposits, of the OU 3 study area are described in Section 2.4.1, and rock units present in the OU 3 study area are described in Section 2.4.2. Exposed mineralized rock units in the OU 3 study area are described in Section 2.4.3. The abbreviations for the geologic units depicted on Map 2-3 are included below in parentheses alongside their respective units.

2.4.1 Unconsolidated Materials

Unconsolidated materials in the OU 3 study area comprise Quaternary alluvium, glacial deposits, and soil. Alluvium (Qa) present in the OU 3 study area includes silt, sand, and gravel in stream beds, floodplains, and terraces and stratified sand and gravel in alluvial fans. The glacial deposits are likely sourced from a variety of parent materials from the U.S. and Canada and comprise glacial outwash (Qgo), glaciofluvial sediments), till (Qgt), drift (Qgd), and glaciolacustrine deposits (Qgl). Glacial outwash sediments are present predominantly in the river and stream valleys and at lower elevations in the OU 3 study area, and glacial till is primarily in higher elevation areas and may occur within outwash and lacustrine deposits along the Columbia River and its tributaries. The glacial sediments are Pleistocene in age and were deposited during the Wisconsin glaciation period (Joseph 1990; Stoffel et al. 1991). The glaciolacustrine sediments were deposited in Glacial Lake Columbia. Glaciation in northeastern Washington is described in further detail below.

2.4.1.1 Glacial and Post-Glacial Effects

During the most recent continental glaciation episode (Wisconsin) between about 21,000 and 13,000 years ago, northeastern Washington was buried under glacial ice of the Columbia lobe of the Cordilleran Ice Sheet at the time of maximum glacial advance (Hanson and Clague 2016). The extent of glaciation and glacial deposits in the region is depicted on Map 2-4. The Columbia lobe flowed southward down the current valley of the Columbia River from coalesced alpine glaciers in British Columbia. The ice in the area scoured soil and bedrock across the region, reworked stream locations and flows, and left deposits of glacial till, glacial outwash, and glaciolacustrine sediments, described above, primarily as terraces in the UCR valley and lower reaches of tributary streams.

Glacial Lake Columbia formed at the southern edge of the Columbia lobe as the Columbia River was blocked near the current location of Grand Coulee Dam by the advance of the Okanogan lobe, also flowing southward from glaciated highlands in British Columbia (Atwater 1986). The

northern limit of Glacial Lake Columbia was defined by the southern terminus of the Okanogan and Columbia lobes. As the glacial ice of the Columbia lobe retreated northward in the UCR valley, Glacial Lake Columbia extended into the deglaciated portions of the UCR valley within the OU 3 study area.

The Purcell Trench lobe from the Cordilleran Ice Sheet, located adjacent to the eastern extent of the Columbia lobe, advanced southward into the Clark Fork River valley in present-day northern Idaho and northwestern Montana. The southern end of the Purcell lobe repeatedly dammed the river to create Glacial Lake Missoula. Catastrophic failures of the ice dam periodically sent massive floods across unglaciated areas of eastern Washington, leaving extensive erosional and depositional evidence of flooding across the landscape (Waitt 2016). Many of these floods discharged water into Glacial Lake Columbia. The farthest upriver evidence of Glacial Lake Missoula flood effects consists of flood deposits about 20 river miles upstream of the mouth of the Spokane River. Glacial deposits associated with these flood sediments indicate that the terminus of the Columbia lobe was at this position at that time (Hanson and Clague 2016). Thus, the OU 3 study area, farther upstream, remained ice-covered as of the date of the last of the Lake Missoula floods and was unaffected by these flood events.

At some point between 200 and 400 years after the final Glacial Lake Missoula flood, the portion of the Okanogan lobe that was blocking the Columbia River at Grand Coulee was breached, allowing Glacial Lake Columbia to rapidly discharge downriver (Waitt 2016). This time frame corresponds with the relatively rapid deglaciation of the OU 3 study area and retreat of the terminus of the Columbia lobe to at least the area of the present-day U.S.-Canada border (Atwater 1986). Lack of glacial ice within the OU 3 study area at the time of the Glacial Lake Columbia drainage is evidenced by river terraces on both sides of the Columbia River that include glaciolacustrine sediments deposited, at least in part, in the upper extent of the glacial lake. The terrace sediments reflect ice-contact or near-ice glacial outwash and glaciolacustrine depositional environments (Joseph 1990). Additionally, the elevations of the glaciolacustrine and uppermost outwash sediments in the terraces correspond to the reported 1,640 ft amsl elevation of late-stage Glacial Lake Columbia (Atwater 1986). In addition to glacial lake sediments, these deposits also likely include sediments transported by the subglacial and proglacial Columbia River laden with sediment from the retreating Columbia lobe. Breaching of the ice dam that impounded Glacial Lake Columbia would have resulted in rapid incision by the Columbia River to near current channel bottom elevation, resulting in large-scale landsliding of the sediments (Bucy and Funk 1996). The upper, intermediate, and lower terrace surfaces in the OU 3 study area were most likely formed through the downcutting of the Columbia River following the release of Glacial Lake Columbia, large flows of glacial meltwater

during the retreat of the Columbia lobe as the sediment load decreased, and outburst flooding from British Columbia, described below.

A final glacial outburst flood from an unconfirmed source in British Columbia, likely Glacial Lake Kootenay, filled the Columbia River in the OU 3 study area at an estimated stage of greater than 100 ft above normal flow levels about 13,300 years ago (Waitt 2016, 2021). This event likely further modified the valley bottom and the lower and intermediate sediment terraces along the river by erosion and deposition and is the final significant terrain-modifying event of the Wisconsin glacial period in the area (Bucy and Funk 1996).

2.4.2 Rock Units

In addition to the unconsolidated materials described above in Section 2.4.1, surficial geology of the OU 3 study area includes rock-derived regolith and various rock outcrops. The surficial rock units are depicted on Map 2-3. In general, the oldest rock assemblages are found in the eastern part of the OU 3 study area, with progressively younger assemblages underlying the central and western areas. Mineralization events that resulted in concentration of metallic minerals in the region occurred in the Paleozoic, Cretaceous, and Eocene. Early mineralization processes included concentrations of lead, manganese, silver, and zinc, generally in the eastern Okanogan Highlands east of the Columbia River. Later mineralization events resulted in accumulation of copper and uranium and were more prevalent in the western Okanogan Highlands (Mills 1977; Weissenborn 1970). Rock assemblages present in the OU 3 study area are described in the following subsections.

2.4.2.1 Proterozoic North American Sequences

In the OU 3 study area, Proterozoic units include the Middle Proterozoic Priest River Group and the Late Proterozoic to Early Paleozoic Windermere Group. The Priest River Group is a sequence of metasedimentary rocks including an upper argillite unit (Yar), a carbonate unit (Ycb), a lower argillite unit (Yar), and a quartzite unit (Yq) (Stoffel et al. 1991). The Priest River Group is overlain by the Late Proterozoic Windermere Group, which includes the Shedroof and Toby formations (Zcg); Leola volcanics, conglomerate, and greenstone members of the Huckleberry Formation (Zmv); the Monk Formation (Zmm); and the Three Sisters Formation (Zq). Major rock types in the Windermere Group include mafic volcanic rocks, sandstones, conglomerates, and diamictites (Stoffel et al. 1991).

2.4.2.2 Kootenay Arc/Eastern Assemblage

The Kootenay Arc deposits consist of Early- to Middle-Paleozoic continental sediments and shallow to deep marine sediments deposited on the western margin of the North American

craton. During a long period of compression due to accretion and subduction along the continental margin, the Kootenay Arc sediments were extensively folded into coaxially refolded, northeast-striking, west-verging, and recumbent isoclines as subduction advanced. The Jumpoff Joe thrust fault (Map 2-1) marks the boundary between the younger Kootenay Arc sediments and the older Proterozoic metasedimentary rocks described above. The Kootenay Arc is bounded by the Columbia River Basalt Group (Miocene volcanic rocks) south of the Columbia River, the Columbia River on the west, and the Pend Oreille River on the east, and it extends along a northeast-trending band north into Canada (Lund 2008; Cheney 2015; Weissenborn 1970) (Map 2-1).

The eastern Kootenay Arc rock assemblages in the OU 3 study area include sediments that were deposited at an initially relatively passive continental margin in the Early Paleozoic that became more tectonically active in the Middle and Late Paleozoic and consist of shale and sandstone facies that are typically overlain by carbonates. The basal sandstone units include the Cambrian Addy and Gypsy formations (CZq), both consisting of quartzite. These formations are conformably overlain by the Cambrian Maitlen phyllite (Ccb and Cmm), a light-green, green-gray, and dark-gray phyllite with thin beds of quartzite, carbonate, and sericite schist. The Maitlen phyllite also hosts limestone and dolomite, including the Reeves Limestone Member (Ccb), a white to gray, laminated to massive limestone, and dolomitic limestone interbedded with other lithologies of the Maitlen phyllite. The Maitlen phyllite hosts pyrite, galena, tetrahedrite, sphalerite, scheelite, and cerussite, which occur as disseminated grains, streaks, lenses, and masses parallel with foliation, and as masses in quartz veins.

The Metaline Formation (OCcb) overlies the Maitlen phyllite with contacts that are conformable, gradational, and faulted, depending on the location, and consists of thin-bedded lime mudstone, dolostone, and carbonate breccia units (the Fish Creek breccia and Josephine breccia). The Josephine breccia is the host rock for many of the zinc-lead deposits identified in Stevens and Pend Oreille Counties. The Metaline Formation contains galena, sphalerite, pyrite, chalcopyrite, and pyrrhotite, which occur as disseminated grains, stratiform deposits, breccia-fill deposits, sulfide veins, and in quartz veins. The Metaline limestone and Maitlen phyllite are two primary lead-bearing formations (Lund 2008; Weissenborn 1970) in the Kootenay Arc; Metaline limestone and Maitlen phyllite outcrops are prominent at some locations in the OU 3 study area, for example, south of Marble, around China Bend, and east of Northport (Map 2-3).

The Ledbetter slate (Oar) forms the upper part of this sequence. This is a black carbonaceous slate and argillite with minor quartzite, limy argillite, and dolostone that overlies the Metaline limestone. The Ledbetter slate contains galena, tetrahedrite, chalcopyrite, sphalerite, and pyrite, which occur as breccia-fill deposits and in quartz veins. Additional sequences of the eastern Kootenay Arc include Carboniferous through Devonian metasedimentary and metavolcanic

rocks of the Grass Mountain, Pend Oreille, and Flagstaff Mountain sequences (CDcb, CDmm, CDmt, and CDmv), collectively known as the "black shale belt." They consist of black siliceous and carbonaceous phyllite and argillite, schist, gray quartzite, limestone and metalimestone, conglomerate greenstone, and metatuff. Pyrite, pyrrhotite, chalcopyrite, sphalerite, galena, and tetrahedrite are present as disseminated grains and lenses and irregular masses, as well as in quartz veins. The Flagstaff Mountain barite deposit, located southeast of Northport, contains massive barite-bearing limestone along with argillite anomalously high in vanadium and barium. These deposits occur in the Carboniferous through Devonian metasedimentary rocks of the Flagstaff Mountain sequence (Jackson 1986; Joseph 1990; Stoffel et al. 1991; Derkey et al. 1990).

Rock units present in the western portion of the Kootenay Arc in the OU 3 study area include three formations ranging in age from Ordovician to Carboniferous. The two older formations, members of the Covada Group (Ocb, Omm, and Omv), are the Daisy and Butcher Mountain successions. The Daisy succession is a thick-bedded, medium- to coarse-grained, poorly sorted subarkosic wacke and arenite with finer-grained interbeds. The younger Butcher Mountain succession consists of pillow basalt, volcanic tuff, massive basalt, and limestone. Lead, silver, and zinc occurrences are also present in Covada Group sediments, especially near Stranger Mountain in Ferry County. The western side of the Kootenay Arc is bounded by the Kettle Fault, which is a northeast-trending, low-angle normal detachment fault (Cheney 2015; Joseph 1990; Derkey et al. 1990).

In the OU 3 study area, lead, silver, zinc, copper, gold, cadmium, cobalt, tungsten, gallium, germanium, iron, and molybdenum deposits have been mined from Kootenay Arc rocks (Derkey et al. 1990). The distribution and abundance of mineral deposition was controlled by the nature of the rift segments that produced sedimentary subbasins and conduits for hydrothermal fluids. Presentation of mineral deposits in Kootenay Arc rocks include stratiform, disseminated, breccia-fill, and vein deposits of sulfide mineralization. Early mineralization in the Kootenay Arc rocks occurred lithogenically and included two reported types of deposition: sedimentary exhalative (SedEx) deposits and carbonate-hosted Mississippi Valley-type (MVT) deposits (Derkey et al. 1990; Lund 2008; Weissenborn 1970).

Within the Kootenay Arc, SedEx deposits that formed during extensional tectonic episodes along the North American trough segments, are important sources of lead, zinc, and barite, as well as silver, copper, gold, bismuth, and tungsten. SedEx deposits were formed by the mixing of ore-bearing hydrothermal fluids and hydrogen sulfide on the sea floor, resulting in the precipitation of metals in the Kootenay Arc rocks. Manganese has also been associated with SedEx deposits, occurring in gangue minerals in the same sedimentary horizons (Emsbo et al. 2016).

Carbonate-hosted MVT lead-zinc deposits also occur near reactivated structures that formed during the Late Devonian to Early Carboniferous as well as throughout the Mesozoic. MVT deposits form by the combination of hydrocarbon pyrolysis liberating zinc and lead ions and sulfur to form an acidic solution, which dissolves the host carbonate formation and replaces it with massive sulfide accumulations. Metaline limestone is the principal host for MVT lead-zinc mineralization in northeastern Washington (Derkey et al. 1990; Mills 1977; Weissenborn 1970). Limestone from the Metaline limestone is also quarried in the region (WDNR 2019b).

Lead, zinc, silver, copper, and gold also occur in the Carboniferous through Devonian metasedimentary and metavolcanic rocks of the Grass Mountain, Pend Oreille, and Flagstaff Mountain sequences (Derkey et al. 1990). Early lithogenic mineralization in Kootenay Arc rocks was further impacted where the host rocks have been altered by Mesozoic and Cenozoic deformation and magmatism. Kootenay Arc rocks were exposed to regional metamorphism through folding and faulting during the Early Triassic through the Late Jurassic, as well as thermal metamorphism through intrusive activity in the Cretaceous and Eocene, discussed further in Section 2.4.2.5 (Jackson 1986; Lund 2008; Mills 1977).

2.4.2.3 Quesnel Terrane

The Quesnel terrane, mostly present west of the Columbia River, comprises island-arc assemblages that accreted onto the western margin of the North American continent during the Mesozoic. Deposits include the Jurassic Rossland Group and Triassic Brooklyn Group, consisting of the Cave Mountain Formation. The Jurassic Rossland Group metavolcanics and metasedimentary rocks (Jcg and Jmv) are present in the northern part of the OU 3 study area, west of the Columbia River (Map 2-3). The Rossland Group in the OU 3 study area includes a greenstone unit (Jmv) and a conglomerate unit (Jcg). The greenstone unit includes augite, augite-biotite, and augite-hornblende basalt, basaltic andesite, and trachyandesite flows, flow breccia, and tuff. The greenstone is dominantly volcanic breccia, and interbedded siltite and conglomerate are present. The conglomerate contains limestone, quartzite, chert, and wacke with minor bedded quartzite to wacke and includes probable Jurassic-aged carbonate and the Upper Cretaceous Sophie Mountain Formation (Kcg(2)). The Triassic Cave Mountain Formation (TRcb and TRmm) consists of a carbonate unit and a metasedimentary unit. The carbonate unit, consisting of limestone and dolomite interbedded with argillite, phyllite, and argillaceous limestone, is commonly recrystallized and contains quartz, chlorite, sericite, plagioclase, and carbonaceous matter. The metasedimentary unit consists of argillaceous limestone and phyllite with minor interbeds of quartzite (Joseph 1990; Stoffel et al. 1991).

Rock units present in the OU 3 study area that are provisionally included in Quesnel terrane rocks include the following:

- Parts of the Flagstaff Mountain sequence, described above in Section 2.4.2.2
- The Permian Mount Roberts Formation (PMmm) present in the northern part and southern part of the OU 3 study area (Map 2-3) and consisting of arenite and wacke with lesser amounts of siltstone, chert-bearing fossiliferous limestone, sandy limestone, metasediments, conglomerate, and metavolcanics
- Parts of the Spectacle Formation and Anarchist Group (PMcb) present in the southern part of the OU 3 study area, east of the Columbia River (Map 2-3) and a metacarbonate unit consisting of metalimestone.

Adjacent to the Mount Roberts Formation and Spectacle Formation rocks in the area around Marcus and Bossburg, on each side of the Columbia River, lie unnamed Triassic and Permian rocks (TRPMmm, TRPMmt, and TRPMmv) consisting mainly of metasedimentary argillite, metawacke, metasiltstone, and metaconglomerate, as well as metavolcanic greenstone. In the region, the Quesnel terrane abuts rocks of the Kootenay Arc to the east and is bounded on the west by the Sherman Fault that forms the eastern boundary of the Republic graben (Stoffel et al. 1991; Stoffel 1992; Joseph 1990; Lasmanis and Cheney 1994).

In the OU 3 study area, copper, silver, gold, and lead have been mined from rocks of the Rossland Group, and gold, copper, and silver have been mined from the unnamed Triassic and Permian metasedimentary rocks (Derkey et al. 1990).

2.4.2.4 Mesozoic and Cenozoic Plutonism

The region in and surrounding the UCR Site has undergone multiple igneous intrusion events associated with Mesozoic and Cenozoic tectonism. Significant intrusive bodies include the Mesozoic Spirit pluton and Kaniksu batholith to the east and the Cenozoic Colville Igneous Complex to the west (described in Section 2.4.2.5). The Spirit pluton (Kiaa, Kig), south of Northport, intruded the Kootenay Arc during a period of mountain-building in the Cretaceous and is composed of quartz monzonite, granodiorite, and a coarse-grained granite interior. The Cretaceous Kaniksu batholith (Kia, Kig, Kig,[34] Kiat, and Kiaa) is east of Colville and primarily composed of quartz monzonite and granodiorite. The Spirit pluton and Kaniksu batholith formed during the mountain-building period that ended in the Eocene. Intrusion of the Spirit

[34] According to Stoffel et al. (1991), the mapped rock unit Kig is listed for both the Spirit pluton and the Kaniksu batholith.

pluton and Kaniksu batholith enhanced mineralization in nearby Kootenay Arc rocks through contact metamorphism in which sulfide minerals underwent varying degrees of remobilization, recrystallization, and annealing (Mills 1977; Weissenborn 1970).

2.4.2.5 Extrusive Colville Igneous Complex

The Colville Igneous Complex (Eocene) consists of sedimentary, volcanic, and plutonic rocks and is associated with the cessation of mountain-building and the onset of crustal extension (Morris et al. 2000; Kant et al. 2018). Crustal extension resulted in the formation of the Republic graben, Toroda Creek graben, and Keller graben, which are surrounded by the Colville Igneous Complex. The Colville Igneous Complex comprises both intrusive and extrusive phase rocks described below.

The Challis sequence (Ecg(1), Evc(1), and Evd(1)) was deposited atop older rock assemblages during extrusive phases of the Colville Igneous Complex. These deposits are most prominent in the southern part of the OU 3 study area near Bossburg and also occur in the northern part of the OU 3 study area, west of the Columbia River. The Mid-Eocene Challis sequence is composed of sedimentary, volcanoclastic, and volcanic rocks consisting of the O'Brien Creek Formation at the base and the Sanpoil volcanics and Klondike Mountain Formation at the top. The O'Brien Creek Formation (Ecg(1) and Evc(1)) consists predominantly of tuffaceous and feldspathic sandstone and siltstone. The Sanpoil volcanics (Evd(1)), formed during the first extrusive phase, consist of biotitic rhyodacite and minor volcaniclastic rocks (Fox 1994).

The intrusive phase present in the OU 3 study area is represented by the Sheppard Granite (Eig) located north of Northport, a leucocratic granite and syenite (Joseph 1990). Mineralization during the Eocene volcanic period included epithermal gold and silver deposition as well as felsic intrusive impacts to sulfide mineralization in Kootenay Arc rocks, similar to effects of the Cretaceous Spirit pluton and Kaniksu batholith, due to remobilization in zones of contact metamorphism in surrounding country rock (Weissenborn 1970).

2.4.3 Exposed Mineralized Rock Units

Map 2-5 depicts the Natural Resources Conservation Service (NRCS) Web Soil Survey rock outcrops and rock outcrop complexes in the OU 3 study area (Soil Survey Staff 2022). Rock units that outcrop in the OU 3 study area and that are known to be mineralized and have historically been mined for metallic sulfide ore include the following:

- Jurassic Rossland Group (Jcg and Jmv) covering approximately 7,801 acres
- Unnamed Permian through Triassic metasedimentary rocks (TRPMmm, TRPMmt, and TRPMmv) covering approximately 3,135 acres

- Carboniferous through Devonian metasedimentary and metacarbonate rocks of the Grass Mountain, Flagstaff Mountain, and Pend Oreille sequences (CDcb, CDmm, CDmt, and CDmv) covering approximately 13,979 acres
- Ordovician Metaline Formation and Ledbetter slate (oCcb and Oar) covering approximately 23,878 acres
- Cambrian Maitlen phyllite (Ccb and Cmm) covering approximately 11,134 acres.

Geologic formations enriched in lead and zinc in mineable concentrations are present in outcrops in the UCR area and are often associated with calcareous materials, such as limestone and dolomite. The occurrence of formations enriched in lead and zinc is reported in Lovering (1976), not as uniform occurrences in country rock, but in mineralized zones where lead emplacement occurred regionally. The occurrence of these enriched formations in Washington is reported in Weissenborn (1970), Lucas (1976), and Mills (1977). These rock types are prevalent in Stevens County in the Northport and Metaline Mining Districts. They are found throughout the northeastern portion of the OU 3 study area and extend north into Canada.

In the OU 3 study area, epithermal gold, silver, and copper ore has been mined from the exposed Sheppard Granite (Eig) (Derkey et al. 1990). The Sheppard Granite is prevalent and crops out at several locations in the OU 3 study area along the U.S.-Canada border west of the Columbia River.

Quaternary unconsolidated materials, including soils, at the Site have likely been partially derived from weathering shallow underlying bedrock. These materials were transported by glacial and hydraulic events and dispersed across the Site.

2.4.4 Geology Summary

The complex geology of northeastern Washington, and within the OU 3 study area specifically, hosts a wide variety of unconsolidated material and rock types across geographically diverse terrain, as described above in Sections 2.4.1 and 2.4.2. The various rock types contain different mineral assemblages within which metals naturally occur and from which metals have been historically mined. Deposits in Kootenay Arc rocks include lead, silver, zinc, copper, gold, cadmium, cobalt, tungsten, gallium, germanium, iron, and molybdenum (Derkey et al. 1990). In 1924, the state of Washington ranked eleventh in the U.S. for lead production, with most of the lead coming from northeastern Stevens County (Jenkins 1924). The limestone of the Metaline Formation is the host for all stratiform lead-zinc deposits in Stevens and Pend Oreille Counties, except for the deposit that was mined at the Sierra Zinc Mine, according to Mills (1977). Additional Kootenay Arc rocks mined in the OU 3 study area include the Carboniferous through Devonian metasedimentary and metacarbonate rocks of the Grass Mountain, Flagstaff Mountain,

and Pend Oreille sequences (CDcb, CDmm, CDmt, and CDmv); Ordovician Ledbetter slate; and Cambrian Maitlen phyllite (Derkey et al. 1990). Various other rock types in the OU 3 study area, ranging in age and lithology, host metalliferous deposits as described in Sections 2.4.2 and 2.4.3.

2.5 HYDROGEOLOGY

This section presents a summary of regional and local groundwater occurrence, gradients, flow, and use in the OU 3 study area. Groundwater supply wells are present at many locations within the OU 3 study area, but the groundwater exposure pathway[35] was determined to be incomplete for Site-related metals of concern and was, therefore, not evaluated in the HHRA (USEPA 2021). Although the HHRA Work Plan (USEPA 2009a) initially included ingestion of groundwater as a potentially complete exposure pathway, a subsequent evaluation of water quality monitoring records for all public water systems (including well-sourced systems) in the northern portion of the Site concluded that the groundwater exposure pathway for human and ecological receptors is incomplete.

While groundwater may be used by local residents, there is no complete pathway for Site-related chemicals of potential concern (COPCs) to groundwater (CH2M HILL 2018[36]; USEPA 2021; USEPA 2023a). Therefore, a detailed description of groundwater investigations conducted at the Site is not included in this Upland RI report.

2.5.1 Regional Groundwater Occurrence

Groundwater occurs in pore spaces between particles of unconsolidated aquifers and in fractures or voids of bedrock aquifers. These aquifers receive recharge from percolation of precipitation, snowmelt, and runoff into the ground and leakage from surface water bodies (Whitehead 1994). Generally, on the regional scale, groundwater flows from recharge areas at higher elevations to lower elevations where it discharges to surface water bodies, such as springs, streams, lakes, ponds, or wetlands, or is pumped from wells that supply various uses.

Shallow perched groundwater has been observed at elevations up to 160 ft above the full pool level of Lake Roosevelt (Riedel et al. 1997). A study by Thompson (1977), using thermal infrared

[35] As per the HHRA (USEPA 2021), "Exposure is the process by which receptors (representing hypothetical populations) contact chemicals in the environment. Receptors can be exposed to chemicals in soil, sediment, water, air, or food, and these exposures can occur through several pathways: ingestion, dermal contact, and inhalation . . . Only exposure pathways considered complete (known with certainty to occur) and for which data were available were carried through the remainder of this HHRA."

[36] CH2M HILL (2018) is included as Appendix 10 to the HHRA.

imagery, identified extensive areas of bank seepage, spring discharge, stream inflow, and subsurface discharge into Lake Roosevelt. Observations of bank seepage and groundwater discharge were correlated with the presence of unconsolidated glacial sediments rather than bedrock. Shallow groundwater seepage into the reservoir has been identified as a contributor to soil instability and landslides (Jones et al. 1961).

Movement of water between the reservoir and the adjacent geologic strata depends on many factors, including reservoir stage; bank storage and discharge in response to changes in reservoir stages; elevation and gradients of adjacent shallow aquifers; and regional discharge of groundwater into the reservoir from deeper aquifers (Thompson 1977). A comparison of trends among water levels in wells completed in the unconsolidated glacial deposits near the Columbia River and Lake Roosevelt water levels in WRIA 53 (Lower Lake Roosevelt) shows strong hydraulic continuity with Lake Roosevelt (Johnson et al. 2011).

2.5.2 Aquifers in the Site Vicinity

Aquifers present in the OU 3 study area are in the Columbia Plateau Basalts (south of the lower reach of Lake Roosevelt) and alluvial and unconsolidated glacial deposits adjacent to the Columbia River and its tributaries. With the exception of the Columbia Plateau Basalts, much of the UCR Site is underlain by geologic formations that do not store or yield significant quantities of groundwater for water supply uses (USGS 1985).

Local aquifers of limited extent are present in the UCR Site vicinity in permeable glacial deposits and in permeable sedimentary rocks (e.g., sandstone and limestone) (Whitehead 1994). Based on water level and bank seepage observations described in Section 2.5.1, groundwater in shallow unconsolidated sediment aquifers generally discharge to the Columbia River and, locally, to tributary systems, lakes, and wetlands at higher elevations. The aquifer that provides the water supply for the town of Northport is an example of a permeable glacial deposit that contains usable quantities of groundwater. The sand and gravel deposits that compose this aquifer extend from ground surface to depths greater than 200 ft, with static water levels approximately 75 ft bgs (Weston 2004). Water supply wells in this aquifer are completed to depths ranging from 101 to 226 ft bgs, and maximum pumping rates from these wells range from 20 to 100 gpm (Weston 2004).

Water-bearing units within the Columbia Plateau Basalts are the major aquifer in eastern Washington (Whitehead 1994). Three basalt units have been assessed and mapped in detail (Whitehead 1994), in order of increasing depth: the Saddle Mountains Basalt, Wanapum Basalt, and Grande Ronde Basalt. In the vicinity of the Site, these units are present in Lincoln County along the southern shore of the Columbia River and also in the southern part of Stevens County. Large quantities of groundwater are present in fractures and rubble zones that occur

between lava flows in each of these basalt units. Wells completed in the Columbia Plateau Basalts are capable of yields on the order of 3,000 gpm (USGS 1985).

2.5.3 Groundwater Use

Groundwater from wells and springs in the Site vicinity is used for public and domestic potable water supply, irrigation, power generation, and industry. However, as stated above and as documented in the HHRA, the groundwater exposure pathway for human consumption and ingestion of groundwater supplied from Site aquifers has been determined to be incomplete for Site-related metals of concern (CH2M HILL 2018; USEPA 2021). Based on available records for water supply wells in the area and groundwater studies completed in WRIAs 53 and 59 (the Lower Lake Roosevelt and Colville WRIAs), wells nearest Lake Roosevelt are completed in local glaciofluvial aquifers. Where glaciofluvial sediments are absent or thin, wells are completed in fractured bedrock (Ely and Kahle 2004; CH2M HILL 2018; Ecology 2011a).

Based on information from the Washington State Department of Health, numerous water wells and springs are used for public and domestic water supply, irrigation, power generation, and industry that draw groundwater from locations within 5 miles of the Columbia River shoreline (CH2M HILL 2018; USEPA 2021).

2.6 SURFACE WATER HYDROLOGY

The hydrological setting for the Site includes the Columbia River and the areas it drains between the U.S.-Canada border and Grand Coulee Dam, including its major tributaries and several smaller tributaries. This section provides a summary of the surface water hydrology of the Columbia River system. Surface water hydrology in and around the UCR Site and, more specifically, in the OU 3 study area are described below in Sections 2.6.1 and 2.6.2, respectively. Additional details about the hydrology and fluvial processes at the Site will be provided in the forthcoming Aquatic RI report.

2.6.1 Regional Surface Water Hydrology

The Columbia River watershed includes an area of approximately 260,452 square miles that encompasses parts of seven states (Washington, Oregon, Nevada, Utah, Idaho, Wyoming, and Montana) and British Columbia (USEPA 2008a). The Columbia River watershed encompasses areas drained by several major tributaries, including the Pend Oreille, Kootenay, Kettle, Colville, Sanpoil, and Spokane Rivers in the upper part of the basin (Map 2-6); the Okanogan, Wenatchee, Yakima, and Snake Rivers in the middle part of the basin in central and southeastern Washington; the Deschutes River in north-central Oregon; and the Willamette,

Cowlitz, and Lewis Rivers farther downstream in northwestern Oregon and southwestern Washington. From its head at Columbia Lake in Canal Flats, British Columbia, the Columbia River flows approximately 1,245 miles (including approximately 470 miles in Canada) before reaching the Pacific Ocean near Astoria, Oregon. The Columbia River enters the U.S. in northeastern Washington at Waneta, just south of the confluence with the Pend Oreille River.

Franklin D. Roosevelt Lake Watershed (8-digit U.S. Geological Survey [USGS] Hydrologic Unit Code [HUC][37]) is the primary watershed of the Columbia River within the hydrological setting boundary for the UCR Site (Map 2-6). It covers areas that drain directly to the Columbia River in Canada and areas that drain directly to Lake Roosevelt in the U.S. Nested within the Lake Roosevelt watershed and south of the U.S.-Canada border, the Franklin D. Roosevelt Lake Watershed is further partitioned in Washington State into WRIAs 61, 58, and 53. A regulated flow regime has been in effect on the Columbia River since construction of Grand Coulee Dam was completed in 1942 and other upstream dams in Canada were constructed and began operating. Upstream dams in Canada and the U.S. that influence discharge into the Columbia River are Hugh Keenleyside Dam on the Columbia River, Brilliant Dam on the Kootenay River, Waneta Dam on the Pend Oreille River, and Long Lake Dam on the Spokane River (Map 2-6).

Grand Coulee Dam is operated to maximize storage capacity of the reservoir for retention of flood waters during spring runoff, to meet irrigation demand and downstream flow targets during the dry summer months (USBR 2007), and to maintain high pool levels for maximum power generation the rest of the year. In general, reservoir elevation is reduced from January through April to prevent flooding during spring runoff; allowed to increase during May and June; allowed to decrease slightly through July and August, when recharge is diminished; and allowed to increase from September through December as a response to increased autumn precipitation. Coordinated flood control operations between U.S. and Canadian dam operators on the Columbia River upstream of Grand Coulee Dam began in 1973. As a result, the size and frequency of flooding events on the Columbia River have diminished.

[37] The HUCs in the USGS Watershed Boundary Dataset (WBD) form a standardized system for organizing, collecting, managing, and reporting hydrologic information for U.S. watersheds. The HUCs in the WBD are arranged in a nested, hierarchical system, with each HUC in the system identified using a unique code. The 8-digit code (HUC 8) is a mid-level scale for the HUC, nesting halfway between the 2- and 16-digit endpoints of the system (USGS 2018).

2.6.2 OU 3 Study Area Surface Water Hydrology

The OU 3 study area is defined as the boundary of Upper Lake Roosevelt WRIA (i.e., WRIA 61) and extends from the U.S.-Canada border to the confluence of the Columbia and Colville Rivers (Map 2-7).

Several streams converge with the Columbia River in the OU 3 study area, including Fifteenmile Creek, Flat Creek, Crown Creek, Onion Creek, Deep Creek, and Sheep Creek. Most of these streams have smaller tributaries draining from higher elevations in the OU 3 study area (Map 2-7), and there are numerous other minor streams that flow into the Columbia River. Many streams in the OU 3 study area are fed by lakes and wetlands in the higher elevation areas.

2.7 DEMOGRAPHICS

This section describes the demography of the OU 3 study area and the potential human receptors evaluated in the HHRA. The numbers included in this section are the most current available at the time of this writing (Table 2-1). As evidenced by this information, the overall population density of the UCR Site is low.

The population in Stevens County was approximately 46,445 in 2020 (U.S. Census Bureau 2025a) (Table 2-1). Stevens County is sparsely populated, with the town of Colville being its only significant population center, representing about 10 percent of the Stevens County population (Table 2-1). The population of Colville was approximately 4,917 in 2020, consisting of 2,074 households and 1,177 families. The median age of residents was 42.5 years old; 22.0 percent of residents were under age 18 (Table 2-1). Colville is approximately 10 miles southeast of the OU 3 study area along the Colville River (Map 1-1). Several towns and communities in the OU 3 study area are described in more detail below.

Northport is approximately 10 river miles south of the U.S.-Canada border on the east bank of the Columbia River (Map 1-1). The population of Northport in 2020 was 297, consisting of 135 households and 54 families (U.S. Census Bureau 2025a). The median age of residents was 50.3 years old; 18.3 percent of residents were under age 18 (Table 2-1).

Marcus is approximately 36.9 river miles south of the U.S.-Canada border on the eastern bank of the Columbia River (Map 1-1). The population of Marcus in 2020 was 216, consisting of 76 households and 53 families (U.S. Census Bureau 2025a). The median age of residents was 53.5 years old; 17.1 percent of residents were under age 18 (Table 2-1).

Kettle Falls is approximately 42.1 river miles south of the U.S.-Canada border on the eastern bank of the Columbia River (Map 1-1). The population of Kettle Falls in 2020 was 1,636,

consisting of 740 households and 372 families (U.S. Census Bureau 2025a). The median age of residents was 44.0 years old; 23.4 percent of residents were under the ages of 18 (Table 2-1).

Ferry and Lincoln Counties have populations of 7,178 and 10,876, respectively. The population within the bounds of the Colville Reservation and Off-Reservation Trust Land in 2020 was 7,259, consisting of 3,489 households. The median age of the Colville Reservation and Off-Reservation Trust Land population was 41.7 years old; 19.5 percent of residents were under the age of 18. The population within the bounds of the Spokane Reservation and Off-Reservation Trust Land in 2020 was 1,884, consisting of 834 households. The median age of the Spokane Reservation and Off-Reservation Trust Land population was 39.5 years old; 33.2 percent of residents were under the age of 18 (U.S. Census Bureau 2025b) (Table 2-1).

2.8 HISTORY AND LAND USE

This section describes the human settlement and cultural resources for the UCR Site (Section 2.8.1) and land use in the region and OU 3 study area (Section 2.8.2). The information presented provides context and a framework for interpreting the environmental data and technical analyses presented in this Upland RI report.

Section 2.8.1 provides an overview of the prehistory, native peoples, and Euro-American historical settlement and development of the Upper Columbia River drainage system, as described in the RI/FS Work Plan (USEPA 2008a). Section 2.8.1 also provides historical context relating to the diverse cultural resources of this area. Primary sources of information on the prehistory of the area are Ames et al. (1998), Goodale et al. (2004), and Pokotylo and Mitchell (1998); for native peoples, the sources are Kennedy and Bouchard (1998), Lahren (1998), Miller (1998), and Ross (1998); and for Euro-American history, McKay and Renk (2002).

Section 2.8.2 describes the current land uses in and around the OU 3 study area. Included are descriptions of significant communities, public and private land uses, public works projects, and conservation activities. This section also provides an overview of human populations that could potentially be exposed to metals in soil and air, as is evaluated in the HHRA (USEPA 2021) and summarized later in this report.

2.8.1 Human Settlement and Cultural Resources

The discussion of human settlement and cultural resources that follows has been copied verbatim from Section 3.1.1 of the RI/FS Work Plan (USEPA 2008a). Citations, acronyms, and map callouts in this section are from the RI/FS Work Plan and are not all included in this Upland RI report.

Human prehistory of the UCR area extends back at least 10,000 years. Although settlements were dispersed and occupied for short periods of time, major resource locations such as Kettle Falls were already being intensively utilized. Kettle Falls is one of the most significant cultural sites in the Western Hemisphere; early artifacts of human occupation there date from about 8,800 to 9,600 years ago (Chance 1986). Permanent villages at Kettle Falls and other locations along the UCR, supported by a substantial salmon fishery, have existed for at least 3,000 years (Kennedy and Bouchard 1998; Lahren 1998; Miller 1998; Ross 1998). Approximately 3,000 years ago, the general patterns of land and resource use among native peoples are evident in the archaeological record. These patterns include residence through the winter at established village locations, with seasonal shifts to resource locations during the summer (although some villages may have been occupied year-round). Native groups were much larger and less mobile than during the early millennia of human occupation. Salmon increasingly dominated the diet of native peoples, eventually becoming the single most important element in the diet. There is evidence of considerable cultural continuity from this period through Euroamerican contact in the late 1700s and early 1800s. At the time of initial Euroamerican presence in the region, which began in the early 1800s, Native American tribes and their sub-groups in the UCR area included: Lakes (sngaytskstx), Colville (sxweyi'7lhp), Sanpoil (snpgwa`ylxex), Lower Spokane (skasi`lhni) and Moses (snk`e7`iwsx) (Bouchard and Kennedy 1979). The Lakes people are named for their lands around Lower and Upper Arrow lakes and Slocan Lake but their homeland extended down the Columbia River to the vicinity of modern Northport, Washington. By the later 1800s, there were Lakes villages as far south as Kettle Falls. The Colville occupied the Columbia River valley south of the Lakes people to near the mouth of Wilmont Creek. Below the Colville on the Columbia River were the Spokane on the east bank of the Columbia and in the Spokane River drainage and the Sanpoil on the west bank.

There were no boundaries in a modern sense between these groups, and group homelands were defined primarily by geographic areas of traditional and regular use. Furthermore, the extensive network of kin, marriage, and exchange relationships that radiated across the Columbia Plateau made the homeland "boundaries" highly permeable. In addition, major resource locations such as Kettle Falls attracted hundreds, if not thousands, of visitors from within and outside the region to fish, trade, and socialize.

Contacts between native populations and Euroamericans in the UCR region began in the early 1800s as Canadian and American fur companies established trading posts throughout the Pacific Northwest. Spokane House was founded on the lower Spokane River in 1810 and a nearby competing post, Fort Spokane, was founded in 1812. Both

posts were eventually abandoned and a new one established at Kettle Falls, known as Fort Colville. These furtrading operations dominated Euroamerican use of the UCR region into the early 1850s.

A harbinger of growing American interest in the region was the Tshimakain Mission, founded in 1838 near the modern location of Ford, and St. Paul's Mission built in 1847 near Kettle Falls (NPS 2007). The discovery of gold in the upper Columbia drainage spurred a mining boom beginning in the late 1850s and continuing through the late nineteenth century. Conflicts between Indians and miners led to the 1855 Yakama War; in 1880–1882, a military post (Fort Spokane) was established at the mouth of the Spokane River (the fort was closed as a military post in 1899 and operated as an Indian school from 1900 to 1908). Other federal acts during this era further impacted tribal cultures as individual allotments of lands were made to tribal members in efforts to contain tribal movement and provide lands and resources for settlers and development.

Many of the modern towns in the UCR region were founded from the late 1850s through the 1880s as mining communities or as supply centers for the mining districts. Farming, grazing, and timber grew increasingly important to the development of the area through the early 1900s. By the late nineteenth century, European farmers and loggers had settled widely in central Washington. Chinese immigrant miners and other laborers also arrived during this time. Irrigation-dependent farming rose to prominence in the early twentieth century.

With the growing demand of settlers, treaties were signed in 1855 to cede Indian lands to the federal government. Only one of these treaties (the Yakima Treaty) included groups in the present study area. The Yakima Treaty created the modern Yakama Reservation, which is to the southwest of the UCR region. The Colville Reservation was created by executive order in 1872; the Spokane Reservation was created by executive order in 1881. Portions of the UCR Site are located within the Colville and Spokane reservations. The present boundaries of the reservation include approximately 1.4 million acres (2,200 square miles), including northern and western shorelines of approximately 93 miles of the UCR extending upstream from Grand Coulee Dam (Map 1-1; CCT 2008). The reservation is the home of members of The Confederated Tribes of the Colville Reservation [CCT], which include the Colville, the Nespelem, the San Poil, the Lakes, the Palus, the Wenatchee, the Chelan, the Entiat, the Methow, the Okanogan, the Moses Columbia, and the Nez Perce (CCT 2008).

The original north boundary of the reservation was the Canadian border; this former "North Half" of the Colville Indian Reservation continues to be an important homeland to the CCT. The CCT exercises certain management and regulatory authority in this area

from the northern boundary of the current reservation north to the Canadian border, bounded by the Okanogan and Columbia rivers. CCT-owned land and individual tribal members reside on the North Half and use the lands, waters, and natural resources for cultural and subsistence uses as they do on the reservation. In Antoine v. Washington, the Supreme Court affirmed the Colville Tribes' rights to hunt and fish on the North Half (Alexander Antoine v. State of Washington 420 US 194. 1975). The total population of the Colville Reservation in the year 2000 was estimated to have been approximately 7,600 people (Washington State Office of Financial Management [OFM] 2006).

The Spokane Reservation is the home of members of three bands of the Spokane Tribe of Indians (STI): Upper, Middle, and Lower Spokane (STI 2008). The Spokane Reservation originally consisted of 154,602 acres. A joint resolution of Congress was passed in 1902 to allot the reservation. The Secretary of the Interior was authorized to sell unallotted surplus lands in 1908, and it was opened up for homestead entry in 1909. The Upper and Middle Spokane signed an agreement in 1887, ratified in 1892, to be removed to the Coeur d'Alene Reservation. In 1958, 2,752 acres was restored to the Spokane Indian Reservation by an act of Congress. Today, the reservation includes approximately 160,000 acres of land (250 square miles), including an eastern shoreline of approximately 8 miles of the UCR extending upstream from the confluence with the Spokane River (Map 1-1) (STI 2008). The total population of the Spokane Reservation in the year 2000 was estimated to have been approximately 2,000 people (OFM 2006). The UCR Site remains the permanent homeland for the STI people today.

A western power shortage associated with World War II led Franklin D. Roosevelt to authorize the Columbia Basin Project, including the Grand Coulee Dam and Banks Lake, a holding reservoir. The implementation of this project altered the historical, cultural, and natural resources of the UCR, leading to present day conditions. The construction of Grand Coulee Dam in the late 1930s and the creation of Lake Roosevelt also created opportunities for recreation that have gained greater importance in the local economies over the past 30 to 40 years as mining and timber production have declined. Historic-period communities that were located along the Columbia River and were either destroyed or relocated with the creation of Lake Roosevelt included Keller, Peach, Lincoln, Gerome, Gifford, Inchelium, Daisy, Kettle Falls, Marcus, Boyds, and Fort Colville.

Physical traces of past human settlement in the UCR region can be seen in the hundreds of prehistoric archaeological sites recorded along the river, the dozens of historically documented Indian village locations, and the remains of historic-period farms, ranches, and communities. All cultural and historical sites along the river are protected under state and/or federal law.

Development of the Grand Coulee Dam and concerns about inundation of archeological sites along the waterways where aboriginal tribes had camps stimulated much of the documentation of the prehistory of the UCR Valley. The EPA (EPA 2004e) identifies four phases of archeological investigations: pre-inundation investigations during the 1930s and 1940s by the Columbia Basin Archaeological Survey, post-inundation salvage excavations by the University of Idaho and Washington State University in the 1960s and 1970s, numerous cultural resource surveys of portions of the reservoir from the 1960s through 1996, and since 1996, archeological and cultural investigations instituted by an intensive compliance agreement program managed and implemented by federal agencies (Bonneville Power Administration [BPA], USBR, and NPS) and the tribes. As of 2006, more than 600 archaeological sites have been recorded between the Canadian border and the dam (EPA 2007d). The archaeological record with respect to cultural historical sequence, prehistoric land use, subsistence, settlement/housing, and trade was reviewed by Galm and Luttrell (1994, as cited in EPA 2004e).

The majority of the project area is in federal or tribal jurisdiction, but some areas outside these jurisdictions may be subject to Washington laws that address Indian burials, historic cemeteries, and archaeological and historical resources.

In addition to archeological cultural resources, continuing use of some areas by tribal peoples and other communities may constitute traditional cultural properties that are also legally protected. In addressing cultural and natural resources, it is important to note that many traditional communities do not distinguish between "natural" and "cultural" resources. Most—if not all—plants and animals also have cultural meaning and play important roles in the cultural life of the community, as do many natural landmarks and features. Elements such as clean water or salmon, which Western culture tends to view as distinct from human life, are often viewed as integral to both individual and group identity. Natural and cultural resources are therefore considered so interwoven that they cannot be addressed separately. In a somewhat similar manner, salmon have achieved an iconic status in the Pacific Northwest as part of the distinctive identity of the region. (USEPA 2008)

2.8.2 Land Use

Historically, metallic mining and mining-related operations (e.g., milling and smelting) have taken place in and around the UCR Site for more than 150 years, starting in the mid- to late-nineteenth century (Mills 1977). The OU 3 study area is in a region of Washington State known to have abundant, economically viable, and productive metallic ore deposits, and the Northport Mining District has been described as having the largest number of lead occurrences

in the region (Huntting 1956). All metal mining operations are currently inactive within the OU 3 study area, but there are ongoing nonmetal mining operations (e.g., limestone and gravel quarries). More specific information about the types and scale of metals mined in the area is provided in Section 2.4 above, and additional details about mining and mining-related operations are provided in Section 2.10.2 below.

Current regional land use is shown on Map 2-8, and land use in the OU 3 study area is shown on Map 2-9. The land use presented is based on zoning data from Stevens, Ferry, and Lincoln Counties (Stevens County, Washington, Ordinances Chapter 3, Section 02; Ferry County, Washington, Ordinances Chapter 2016, Section 04; Lincoln County, Washington, Ordinances Title 17). Land uses include federal, state, and private forest, parks/undeveloped nonresidential areas, and residential neighborhoods with developed and undeveloped lands, utility and transportation rights of way, agriculture, retail and other services, manufacturing, and land designated for cultural or recreational uses. A general description of regional land use by county is presented below, followed by more detailed information about land use in the OU 3 study area.

Forest land, undeveloped rural, or agricultural land are currently the predominant land uses in Stevens County, representing 42 percent, 41 percent, and 5 percent, respectively, of the designated land uses (Map 2-8). The northern end of Stevens County is largely undeveloped, and there is overlap with the Colville National Forest to the west and the northeast. The Spokane Reservation is in the southern portion of Stevens County and represents 10 percent of the designated land use in the county. Stevens County is predominately rural, with residential land accounting for less than 0.1 percent of land use. The R-1, R-2, Rural Area-5, and Rural Area-10 land use codes are supportive of potential residential development in Stevens County.

Agriculture and timber account for 33 percent and 44 percent, respectively, of land use designations in Ferry County (Map 2-8). Industry in Ferry County is dominated by mining and logging (WA ESD 2022a). The southern part of Ferry County is within the CCT Reservation, while the northern half of Ferry County is part of Colville National Forest. Ferry County is largely rural with limited transportation routes, and less than 18 percent of the land is privately owned (WA ESD 2022a). The long-term agricultural and forest lands are primarily devoted to commercial production but have the potential for residential development with restrictions on land/lot size, soil quality, and dwelling density (Ferry County Planning Department, no date).

Agricultural and recreational zoning are the primary land uses in Lincoln County, representing 95 percent and 4 percent, respectively (WA ESD 2022b) (Map 2-8). Most of the recreational land is along the shorelines of the Spokane and Columbia Rivers.

Within the OU 3 study area, retail businesses, manufacturing, and recreational land uses are present in Northport, Bossburg, and other communities. There are many large parcels of land distributed across the OU 3 study area that are coded as "residential," but residential land use only accounts for less than 0.1 percent of land use (Map 2-9). The Residential and Multi-Family land use codes from Northport, Kettle Falls, Marcus, and Colville are supportive of potential residential development as well as R-1, R-2, Rural Area-5, and Rural Area-10 land use codes from Stevens County. Various agricultural activities, including orchards, have been documented around Northport and extending northward to the U.S.-Canada border since the early 1900s (Dominion of Canada 1936). Based on aerial imagery covering the period from 2015 to 2019 (Esri 2020), land uses on some of these lands appear to remain agricultural, mostly being either single-family farms or large plots of lightly developed or undeveloped private land. Timber harvesting is prevalent in the area, occurring mostly on private forest land, with a small percentage of trees harvested from state and federal lands.

Several secondary roads run through the OU 3 study area. State Highway 25 and Northport Flat Creek Road both run parallel to the Columbia River through the middle of the OU 3 study area to Northport, where they converge near the western end of the Northport Bridge, and then Highway 25 continues northwest through the western part of the OU 3 study area. Northport-Boundary Road/Northport-Waneta Road, managed by Stevens County, veers eastward from Highway 25 at the northern end of Northport and continues to the U.S.-Canada border parallel to the eastern shoreline of the Columbia River. A railway runs parallel to this route to the U.S.-Canada border.

Based on information available, the current mix of land cover and land uses described above is not expected to change significantly in the foreseeable future (Ramboll and ERM 2020).

2.9 ECOLOGICAL SETTING

This section describes habitat types and wildlife found in the BERA Terrestrial Study Area. The BERA Terrestrial Study Area was designated and used operationally in the Upland BERA (USEPA 2023a) to refer to the upland terrestrial portions of the UCR Site. It was defined by the spatial extent of the upland soil data set used for the risk analyses presented in the Upland BERA. The soil chemistry data set used in the Upland BERA included samples from three studies: 2014 Soil Study (TAI 2015a), 2012 Ecology Upland Soil Study (Ecology 2013a), and 2015 Bossburg Study (TAI 2015b). These studies are described in Section 3 of this Upland RI report. Based on the spatial extent of these studies, the BERA Terrestrial Study Area in the Upland BERA was effectively the area covered by the ADA plus the area in and around the town of Bossburg.

2.9.1 Terrestrial Habitat

The BERA Terrestrial Study Area falls within the Northern Rockies ecoregion (Omernik 1987). The native vegetation is primarily coniferous forest ecosystems interspersed with montane grasslands, reflecting the cool climate with warm, dry summers and moist, cold winters with heavy snowfall (McNab et al. 2007). Ecological habitat composes most of the BERA Terrestrial Study Area and is interspersed with agriculture, residential neighborhoods, rural residential lots, and land designated for cultural or recreational use (NatureServe 2009) (Map 2-10). Of the 16 ecosystems identified in the area, the most common ecosystem types (those that cover 5 percent[38] or more of the BERA Terrestrial Study Area) are as follows:

- **Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest.** This ecosystem is characterized by a mix of Douglas-fir (*Pseudotsuga menziesii*) and ponderosa pine (*Pinus ponderosa*), with ponderosa pine typically occurring at lower elevations or in drier areas. The forest understory is dominated by grasses and sedges, including bluebunch wheatgrass (*Pseudoroegneria spicata*), pine grass (*Calamagrostis rubescens*), and Ross's sedge (*Carex rossii*), with a variety of shrubs, including juniper (*Juniperus communis*) and mallow-leaf ninebark (*Physocarpus malvaceus*).
- **Northern Rocky Mountain Ponderosa Pine Woodland and Savanna.** This ecosystem occurs at the lower tree line at the ecotone between grasslands and coniferous forests, typically on warmer, drier sites. The tree canopy is dominated by ponderosa pine, although Douglas-fir may also occur. The understory can be shrubby and may include big sagebrush (*Artemisia tridentata*), bearberry (*Arctostaphylos* spp.), antelope bitterbrush (*Purshia tridentata*), rose (*Rosa* spp.), and Saskatoon berry (*Amelanchier alnifolia*) as common species. In more open savanna areas, shrubs are uncommon, and the understory comprises fire-resistant cool-season bunch grasses and forbs, including bluebunch wheatgrass, fescue (*Festuca* spp.), and needle-and-thread grass (*Hesperostipa comata).*
- **Northern Rocky Mountain Mesic Montane Mixed Conifer Forest.** This forested ecosystem is typically found on moist areas, such as on toe slopes. The tree species canopy in this ecosystem is dominated by western red cedar (*Thuja plicata*) and western hemlock (*Tsuga heterophylla*) with Douglas-fir. Common shrub species include

[38] The 16 ecosystem types included in the count are those that make up at least 0.1 km^2 (0.04 square mile) or 5 percent or more of the BERA Terrestrial Study Area. Excluded from this count are ecosystems composing less than 5 percent of the BERA Terrestrial Study Area, or less than 0.1 km^2, as well as those that are nonvegetated (e.g., developed area, cliff, bedrock, open water). These ecosystems are grouped as "Other" on Map 2-10.

twinflower (*Linnea borealis*), Oregon boxwood (*Paxistima myrsinites*), gray alder (*Alnus incana*), thimbleberry (*Rubus parviflorus*), and huckleberry (*Vaccinium membranaceum*).

- **Harvested forest-tree regeneration.** This ecosystem is anthropogenically impacted and consists of regenerated areas of forest after lumber harvesting. Depending on land ownership and forest management practices, tree species in formerly harvested lands may be less diverse if active replanting of specific species has occurred.
- **Northern Rocky Mountain Lower Montane, Foothill and Valley Grassland.** The grassland ecosystem is characterized by the same cool-season perennial bunchgrasses that occur in the low-elevation pine woodlands and savannah, including bluebunch wheatgrass, fescue, and needle-and-thread grass, with a sparse shrub layer that may include rose, Saskatoon berry, juniper, and snowberry or buckbrush (*Symphoricarpos* spp.) (NatureServe 2009). Limited areas of sagebrush shrubland and sagebrush steppe also occur.
- **Northern Rocky Mountain Montane-Foothill Deciduous Shrubland.** This shrubland ecosystem is found in the lower montane and foothill regions around the Columbia Basin, typically below the tree line and on steep slopes of canyons. The most common dominant shrubs include mallow-leaf ninebark, cherry (*Prunus* spp.), rose, sumac (*Rhus glabra*), maple (*Acer glabrum*), Saskatoon serviceberry, snowberry or buckbrush, and ocean spray (*Holodiscus discolor*).
- **Northern Rocky Mountain Lower Montane Riparian Woodland and Shrubland.** Consisting of deciduous, coniferous, and mixed conifer-deciduous forest, this ecosystem occurs on streambanks and river floodplains of the lower montane and foothill zones of the northern Rocky Mountains and experiences annual flooding and hydric soils throughout the growing season. This ecosystem is identified by the key indicator species, balsam poplar (*Populus balsamifera*), but other trees, such as birch (*Betula* spp.) and spruce (*Picea* spp.), can be mixed in the canopy. Shrubs, ferns, and forbs, such as red osier dogwood (*Cornus sericea*), alder, lady fern (*Athyrium filix-femina*), and arrowleaf ragwort (*Senecio triangularis*), are commonly present.

All the common ecosystem types are found throughout the BERA Terrestrial Study Area. As shown on Map 2-10, the higher slopes are predominantly conifer forest with some areas of savanna. Some areas are logged, sometimes by clear cutting, and the region has a history of wildfires.

2.9.2 Wildlife

Regional information on the presence and distribution of terrestrial wildlife has been compiled by several resource agencies (Hebner et al. 2000; Creveling and Renfrow 1986; CTFWD 2006; McCaffrey et al. 2003; Rodhouse 2005). Hebner et al. (2000) listed the wildlife species in the area from Grand Coulee Dam to the U.S.-Canada border and the reservoir to the surrounding ridges, while Quigley et al. (2001) and Marcot et al. (2003) have reported species data for the entire interior Columbia Basin area. Cited in these documents are 98 species of upland mammals and 250 species of birds. Species that only occupy the sagebrush grasslands and shrub-steppe habitats characteristic of the southern section of the Columbia Basin region are not relevant to the BERA Terrestrial Study Area. Four amphibian and seven reptile species, collectively referred to as herpetofauna, might occur within the BERA Terrestrial Study Area. Expanded discussions of bird, mammal, and herpetofauna species are presented in the Upland BERA (USEPA 2023a).

2.9.3 Threatened and Endangered Species

There is the potential for one state-listed endangered plant species to occur in the BERA Terrestrial Study Area: Gastony's cliffbrake (*Pellaea gastonyi*)[39] (Table 2-2). Only one occurrence of this rare species has been documented by the Washington State Department of Natural Resources (WDNR) (Map 2-10). Gastony's cliffbrake has a narrow habitat preference of calcareous rock, often limestone or dolomite (Brunton 1979; Windham 1993; Friesen and Murray 2015). This species lives in montane and subalpine areas, on often dry calcareous cliffs, in crevices, and on edges of limestone outcrops in cracks in the rock (Friesen and Murray 2015; NatureServe 2009; WDNR 2023a). Because Gastony's cliffbrake grows in areas that do not contain a significant amount of soil (i.e., cliffs, crevices, ledges), exposure to soil is expected to be minimal; thus, this species was not evaluated in the Upland BERA.

There is the potential for two federally listed threatened mammal species to occur in northeastern Washington State: Canada lynx (*Lynx canadensis*) and grizzly bear (*Ursus arctos*) (USFWS 2024a). The gray wolf (*Canis lupus*) was federally listed as endangered until November 3, 2020, at which time the U.S. Fish and Wildlife Service published a final rule that

[39] Michigan moonwort (*Botrychium michiganense*) is found in northern Washington but does not occur within the BERA Terrestrial Study Area (WNHP 2021). Columbia crazyweed (*Oxytropis campestris* var. *columbiana*) occurs solely along gravel bars or stony shores along the Columbia River, and most populations have been extirpated as a result of habitat destruction by the construction of the Grand Coulee Dam (WDNR 2023b). Because Columbia crazyweed (*Oxytropis campestris* var. *columbiana*) exposure occurs in the relict floodplains of the river, this species will be evaluated in the Aquatic BERA and Aquatic RI report.

delisted the gray wolf. The delisting rule was vacated by a court order on February 10, 2022, which resulted in all gray wolves being protected, except for those within the Northern Rocky Mountain region, which includes the UCR Site (USFWS 2023). The U.S. Fish and Wildlife Service issued a finding for the gray wolf on February 7, 2024, concluding that the gray wolf "does not meet the definition of an endangered or threatened species" either in the Western United States or within the Northern Rocky Mountain region (89 Fed. Reg. 8391 [to be codified at 50 CFR Part 17]).

There are four state-listed endangered mammal species: gray wolf, fisher (*Pekania pennanti*), grizzly bear, and Canada lynx, that also potentially occur in northeastern Washington State (USFWS 2024a; WDFW 2024). However, the only state-listed mammal species regularly observed in the BERA Terrestrial Study Area is the gray wolf (Table 2-2) (USEPA 2023a).

One federally listed threatened and state-listed endangered bird species, the yellow-billed cuckoo (*Coccyzus americanus*), is potentially present in northeastern Washington (USFWS 2024b; WDFW 2024). However, the yellow-billed cuckoo does not occur in the BERA Terrestrial Study Area, based on available information (Cornell Lab of Ornithology 2024; Wiles and Kalasz 2017). Thus, no federally or state-listed bird species are present in the BERA Terrestrial Study Area.

No amphibian or reptile species that are currently federally or state listed as threatened or endangered occur in the BERA Terrestrial Study Area.

2.10 KNOWN AND POTENTIAL SOURCES OF METALS

The Agreement specifies that "[t]he known sources include Teck Cominco's Trail, B.C. facility, and [unrelated] pulp and paper mills as well as historic mining and smelting [including the Le Roi/Northport Smelter] operations in the streams draining into Lake Roosevelt." This section provides an overview of known and potential sources of metals present in soil within the OU 3 study area. Broadly, the sources of metals can be grouped into the following categories: 1) smelter operations, 2) mining operations and mineral processing facilities, 3) other anthropogenic sources, 4) geology and geogenic background, and 5) ambient atmospheric constituents. Of these sources, smelter operations and ambient atmospheric constituents are expected to have regional impacts, and mining operations and mineral processing facilities, other anthropogenic sources, and geology and geogenic background are expected to have localized impacts. While regional sources can result in more widespread elevated COC concentrations, localized sources are important to consider when evaluating elevated COC concentrations and making cleanup decisions for specific locations. Each of these source categories is described in the following sections.

2.10.1 Smelter Operations

During early investigations at the UCR Site, both the smelter in Trail, British Columbia (Trail Facility), and the former Le Roi/Northport Smelter in Northport, Washington, were identified as sources of metals to the UCR Site (USEPA 2008a). The Trail Facility is approximately 10 river miles upstream of the U.S.-Canada border outside the Site, while the Le Roi/Northport Smelter is located in Northport within the OU 3 study area. The following sections summarize the operational history of these smelters. The only potential source of metals from the smelters to upland soils within the OU 3 study area is historical atmospheric emissions (both stack and fugitive). Other discharges from the smelters (slag and liquid effluents) are to the aquatic portion of the UCR Site, which will be discussed in the Baseline Ecological Risk Assessment for OU 1 and OU 2 (hereafter, Aquatic BERA) and the Aquatic RI report [40].

2.10.1.1 Trail Facility

The Trail Facility is located atop the west bank of the Columbia River in Canada, approximately 10 river miles upstream from the U.S.-Canada border. The facility is not within the UCR Site. The Trail Facility is one of the world's largest fully integrated zinc and lead smelting and refining complexes, with metallurgical operations that produce refined zinc and lead, a variety of precious and specialty metals, chemicals, and fertilizer products (Teck Resources Limited 2024). There have been changes in ownership and many changes in operations during the 120+ years that the Trail Facility has been operating. The period of operation, primary metals produced, and the location of major sources of ore for the Trail Facility are summarized in Table 2-3. A summary of the operational history of the Trail Facility is provided below, with additional details provided in Table 2-4.

Smelting and refining operations have been ongoing at Trail since 1896, when the original facilities were built to smelt copper and gold ores from the Rossland, British Columbia, mines. Onsite operations were originally designed to separate gold and copper thermally from gold ores. At that time, roasting technology was crude and limited to the heap method, in which ore was piled with cordwood and limestone intermixed and set aflame. With this technology, the smelter was capable of producing a matte of 50 percent pure copper (i.e., industrially worthless until further refined), while the lead, which was prevalent within local ores, could not be extracted (USEPA 2008a).

Competition for ore and labor from the former Le Roi/Northport Smelter (which began operations in February 1898) caused smelting operations at the Trail Facility to be temporarily

[40] Final title of this document is subject to change.

halted. In March 1898, the Canadian Pacific Railway negotiated the purchase of the Trail Facility and associated railway rights and immediately began to modernize the facility. By July 1898, the facility, under the name Canadian Smelting Works, was tied into the West Kootenay power grid, and by December 1898, smelting operations were underway (Cominco 2000). As the number of lead mines in the region (i.e., Canada and the western U.S.) grew, the decision was made in 1901 to broaden the smelter's base and include lead furnaces. The new furnaces were unsophisticated, however, and until 1902, the resulting impure bullion was transported to the American Smelting and Refinery Company's plant in Tacoma, Washington, for further processing. With the development of the Betts electrolytic process in 1902, the Trail Facility was able to produce pure lead, fine silver, and gold. Recognizing the value of securing a source of ore and concentrate, Canadian Smelting Works began working toward the consolidation of surrounding area mines with the smelting facility. This consolidation process culminated in 1906, and the Canadian Smelting Works became known as the Consolidated Mining and Smelting Company of Canada (Wilson 2023), also known as Cominco. Zinc production began in 1916. By 1925, the facility consisted of a complex of structures housing a lead plant, an electrolytic zinc plant, a foundry, a machine shop, and a copper-rod mill (Wilson 2023). Acid and fertilizer plants were built at the Trail Facility in 1930, facilitating the production of sulfuric acid and both nitrogen- and phosphorus-based fertilizers (MacDonald 1997), and a heavy water plant was constructed and operated from 1944 to 1955 (Wilson 2023). Ammonia, ammonium sulfate, and phosphate fertilizers were produced at the plant until August 1994, when production of the phosphate-based fertilizer was terminated (MacDonald 1997).

After Teck Corp. purchased Cominco Ltd. in 2001, Teck Cominco Metals Ltd. became the operator and owner of the Trail Facility, which became Teck Metals Ltd. in 2008. Major production at the facility includes primary smelting of zinc and lead concentrates and secondary smelting for production of other metal products (e.g., antimony, bismuth, cadmium, cobalt, copper, germanium, gold, indium, mercury, silver, and thallium), arsenic products, granular and crystallized ammonium sulfate fertilizers, sulfur, sulfuric acid, sulfur dioxide, and ferrous granules (i.e., granulated slag) (USEPA 2008a).

The Sullivan (1913 to 2001), Pine Point (1964 to 1988), and Red Dog (1989 to current) mines were the predominant sources of lead and zinc concentrates to the Trail Facility metallurgical operations (Queneau 2010). Table 2-4 summarizes the Trail Facility's history of operations, with an emphasis on processes that contributed to historical atmospheric emissions. This summary was compiled from information included in the RI/FS Work Plan (USEPA 2008a), the expert opinion report prepared by P.B. Queneau for Joseph A. Pakootas et al. v. Teck Cominco Metals Ltd. (Queneau 2010), the Teck Trail operations website

(https://www.teck.com/operations/canada/operations/trail-operations/), and a local history of southern British Columbia (USEPA 2008a).

Soil investigations and removal actions have been conducted in Canada in the vicinity of the Trail Facility. Descriptions of the work performed in Canada are provided on the Trail Area Health and Environment Program website (https://thep.ca/programs/soil/).

2.10.1.1.1 Trail Facility Arbitration

Beginning in 1926, certain Northport citizens formally complained via letters to Cominco and the U.S. and Canadian governments that sulfur dioxide emissions from the smelter at Trail were causing damage to crops, livestock, forest, and real property (United Nations 2006, 1917–18). In 1927, the U.S. government, acting on behalf of the citizens, presented these claims to the Canadian government, and sought to collect damages from the Canadian government (United Nations 2006, 1918). The claims were referred to an arbitral panel of the International Joint Commission (IJC) for resolution, which took up the matter in 1928 (United Nations 2006). The extent of the sulfur dioxide damage area was quantitatively defined based on a visual assessment of injury to trees and shrubs on sample plots as reported by Scheffer and Hedgcock (1955).

On February 28, 1931, the IJC rendered an Advisory Opinion (i.e., an opinion not binding on the parties), recommending that the Government of Canada pay the United States $350,000 for past damages and anticipated damages through January 1, 1932 (United Nations 2006). Based on the Advisory, the United States and Canada entered into a Convention for Settlement of Difficulties Arising from Operation of Smelter at Trail, B.C. (hereafter, Convention) on April 15, 1935 (United Nations 2006, 1907–10). Article I of that Convention settled all damages that occurred in the United States prior to and including January 1, 1932, for the recommended $350,000 (United Nations 2006, 1907). Articles II and III of the Convention provided for the formation of an arbitration tribunal (Tribunal) to address 1) any damages after January 1, 1932, and 2) what should be done regarding future smelter operations (United Nations 2006, 1907–08).

In its first decision, issued April 16, 1938, the Tribunal found $78,000 in damages caused by the Trail smelter in the state of Washington for the period after January 1, 1932, up to October 1, 1937 (United Nations 2006, 1931). The Tribunal further ordered additional studies of the smelter operations, meteorology of the area of northeast Washington, air quality monitoring, and the fumes coming from the smelter (United Nations 2006, 1934–37). Those studies took place over the next 3 years and showed that, although fumes continued to travel from the Trail smelter across the border into northeast Washington, they did so at lower concentrations than the previous years (United Nations 2006, 1946). This was thanks to the

"certain changes and additions" Cominco had made to the smelter (or sic) "with the intention and purpose of lessening the sulfur contents of its emissions" (United Nations 2006, 1946).

The Tribunal's section Decision, issued March 11, 1941, reflected Cominco's successful implementation of these then-state-of-the-art controls at the Trail smelter in two distinct ways. First, the Tribunal found no damages for the period from October 1, 1937, through October 1, 1940: "[T]he United States has failed to prove that any fumigation between October 1, 1937, and October 1, 1940, has caused injury to crops, trees or otherwise." (United Nations 2006, 1959); "No damage caused by the Trail Smelter in the State of Washington has occurred since the first day of October, 1937, and prior to the first day of October, 1940, and hence no indemnity shall be paid therefor[e]." (United Nations 2006, 1962). Second, to address the question of what should be done to control future smelter operations emissions, the Tribunal adopted a monitoring and control regime informed and inspired by Cominco's successful efforts (United Nations 2006, 1974–78). Wirth (1996, 36–37), states, "By 1937, [Cominco] had deployed innovative technologies to reduce by two-thirds the emission of sulphur into the atmosphere . . . Instead, technical and meteorological measures solved the problem: chemical recovery using refinements on existing technology and the operating regime. This was enough to satisfy the tribunal and far more than any other smelter in Norther [sic] America had done to control point-source emissions. [Cominco] emerged with its reputation for progressive management enhanced." Specifically, the Tribunal outlined a regime of further controls to be applied to the Trail smelter operations, including the establishment and maintenance of meteorological instruments; sulfur dioxide air monitoring equipment at Columbia Gardens, Waneta, and Northport; and a requirement that Trail's stacks be maintained at a height no lower than that of the present stacks (United Nations 2006, 1974–75). The regime also set forth maximum permissible sulfur emissions, with provisions to modify those limits based on meteorological conditions and results from the sulfur dioxide air monitoring (United Nations 2006, 1975–78). This regime was to remain in force unless modified in accordance with the provisions set forth under the regime, which provided for an amendment or suspension of the regime if conditions should warrant or require, such as if scientific advancements were made in fume control, or at the request of either government (United Nations 2006, 1973, 1978).

2.10.1.1.2 Trail Smelter Emissions, Permitting, and Monitoring

Atmospheric sulfur emissions were historically a significant component of facility emissions in the early years. In response to these emissions, sulfur dioxide control measures were established at the facility beginning in 1914 with the construction of the first two sulfuric acid plants at the facility. Through the 1930s, additional control measures implemented at the facility (among others) included construction of three sulfuric acid plants, an ammonia and ammonium sulfate plant, two units for reduction and absorption of sulfur in the zinc smelter, an absorption plant

for gases from the lead roasters, and the installation and continuous monitoring of a weather station. Subsequent development and modernization at the Trail Facility led to further reductions in historical emissions. The modernization and operational improvements, including installation of the KIVCET[41] lead smelter in 1997, have resulted in reduced historical emissions of lead and other metals from the smelter stacks by over 99 percent since the 1990s. Targeted fugitive dust emission control projects began in 2011, and, in 2012, Teck initiated a program to inventory and reduce fugitive dust emissions from the Trail Facility (Teck Metals Ltd. 2022).

Since the beginning of modern environmental regulation in the 1970s, the Trail Facility has operated under permits from the British Columbia Ministry of Environment and Parks (BC ENV). The Trail Facility currently has three permits from BC ENV related to air emissions: Permit 2690 for fertilizer operations, Permit 2691 for lead operations, and Permit 2692 for zinc operations (Teck Metals Ltd. 2022). With respect to aerial emissions, the facility's permits require monitoring and reporting of multiple constituents at the stacks, as well as a network of ambient air quality monitoring stations in the lower Columbia River valley in Canada. Teck Metals Ltd. reports annual emissions from stacks to Environment and Climate Change Canada (Environment Canada) as part of the National Pollution Release Inventory (NPRI) program. The emissions reported to Environment Canada, which are available for the modern reporting era of 1993 to 2023, are considered accurate and reliable. The current monitoring program for aerial emissions from the stacks includes total particulate matter, sulfur dioxide, and the following metals and their compounds: antimony, arsenic, cadmium, chromium, cobalt, copper, lead, manganese, mercury, selenium, silver, thallium, and zinc (Table 2-5).

Trail Facility emissions that may have relevance to the OU 3 study area include historical aerial emissions (stack and fugitive) that may have been deposited onto upland soils. Particles emitted from smelter stacks derive from thermal treatment of ore concentrates and are emitted from tall stacks; thus, these emissions are comprised of small particles (< 2.5 μm) with a low fallout rate, which may result in wider spread and longer-range transport compared to fugitive emissions generally comprised of larger particles (Goodarzi et al. 2003). There is, therefore, greater gravitational deposition of fugitive dust particles and a more substantial decrease in deposition rate of fugitive releases with distance from the sources at the Trail Facility. Beyond the facility boundary, stack emissions are the main source of lead to the vicinity, with maximum deposition occurring between 0.6 and 1.1 miles from the facility and then decreasing rapidly with distance (Goodarzi et al. 2003). Based on the differences in particle sizes and their associated transport behavior, as well as the facility's 10 river mile distance from the northern border of the UCR

[41] KIVCET is a Russian acronym for flash-cyclone-oxygen-electric-smelting.

Site, fugitive dust emissions from the Trail Facility are much less likely to have influenced the UCR Site than historical stack emissions.

2.10.1.2 Le Roi/Northport Smelter

The Le Roi/Northport Smelter is a former smelter located within the OU 3 study area on the eastern side of the river, approximately 7 river miles south of the U.S.-Canada border in Northport, Washington. The property is approximately 32 acres, and the former smelter occupied approximately the eastern two-thirds of the property, while a former lumber mill occupied the remaining portion. The smelter buildings, which are no longer standing, included the furnace building and the crusher and ore building (USEPA 2008a). The periods of operation, primary metals produced, approximate maximum tons per day of processed ore, and the location of major sources of ore for the Le Roi/Northport Smelter are summarized in Table 2-3 and Table 2-6.

Beginning in 1898, the Le Roi/Northport Smelter processed copper and gold tellurium ores using heap roasting. At peak operation, the smelter processed 500 tons of ore per day (Ecology 2022). Operations were suspended in 1909 and then resumed around 1916 to process lead ore from Leadpoint, Washington, to meet government demand during World War I. When operations were resumed, the lead smelter was a retrofit of the earlier copper smelter that used the original blast furnaces, flue, and stack. In 1916, the smelter was fitted with new furnaces and sintering machines to improve smelting efficiency for lead-sulfide ores (Quivik 2010). Smelter operations ceased permanently in 1921, after a total of 18 years of operation.

The Le Roi/Northport Smelter site remained inactive until 1953, and the furnace, roaster, crusher, and ore buildings were removed during this period of inactivity. From 1953 through 2001, the western portion of the site was used as a lumber mill. Mill processes included cutting, drying, and shipping wood products. Mill operations ran on propane. No wood treatment or chemical use was reported during this period of operation (USEPA 2004; Ecology 2019a).

Historical emissions from the Le Roi/Northport Smelter that have relevance to the OU 3 study area include atmospheric emissions (stack and fugitive) that likely deposited onto upland soils. Other potential discharges from the Le Roi/Northport Smelter (slag and liquid effluent) were to the aquatic portion of the Site, and those discharges are discussed in the Aquatic BERA and Aquatic RI report.

In 1993, EPA completed a site inspection for the Le Roi/Northport Smelter. In 2001, EPA completed preliminary assessments and site inspections (PA/SIs) at several contaminated sites in and around the OU 3 study area, including the Le Roi/Northport Smelter site. In 2003 and 2004, EPA conducted a removal site evaluation to characterize contamination at the Le Roi/Northport Smelter site and at residential and commercial properties in Northport,

Washington. Removal assessment activities included sampling of residential and commercial properties in and around Northport, sampling of public areas, and collecting drinking water samples from residences. All soil sampling results were compared to then-regulatory levels established by Ecology for response actions conducted at Northport (USEPA 2005). Based on the results, sampled properties were identified for emergency removal or containment actions if either 1) soil lead concentrations were greater than 1,000 mg/kg or soil arsenic concentrations were greater than 230 mg/kg or 2) soil lead concentrations were 700 to 1,000 mg/kg or soil arsenic concentrations were 101 to 230 mg/kg and children were present. EPA conducted an emergency soil removal action on the Le Roi/Northport Smelter property and 29 residential properties in Northport in 2004 (USEPA 2005). Contaminated soils were consolidated at the smelter site (an 11-acre area), covered with a polyethylene sheet and clean soil, and vegetated.

In 2019, EPA performed an additional removal site evaluation of properties in Northport that contained soil lead concentrations near or above 700 mg/kg during the 2003/2004 removal evaluations, but where no soil removal action was taken previously. The 2019 removal site evaluation was completed to support a time-critical removal action (TCRA) in Northport, using a removal action level of 700 mg/kg. EPA visited properties in October 2019, during which the agency documented the condition and layout of each property designated for potential cleanup, interviewed each property owner regarding property use and changes to the property since the 2003/2004 soil sampling, and collected and analyzed soil samples to better delineate the horizontal extent of contamination and assist in removal planning (i.e., disposal and cost estimating). Based on EPA's removal site evaluation completed in 2019, another 16 residential properties and common use areas were identified for cleanup. EPA completed cleanup activities at 15 residential properties and common use areas in August and September 2020 (USEPA 2020a), while 1 residential property owner declined to participate in the removal action.

In 2021, EPA conducted a removal site evaluation at 43 properties in Northport that had not been sampled previously. The criteria for a TCRA (i.e., lead concentrations in soil near or above the action level of 700 mg/kg) were met at 16 of the properties. These properties include residential properties and a common use area (USEPA 2022b). Removal actions at these 16 properties were completed in 2022 (USEPA 2023b).

Data collected within Northport were not evaluated in the HHRA; however, they are included in the Upland RI data set for use in the evaluation of the nature and extent of metals in soil in OU 3.

2.10.1.3 Other Smelters

Other smelters that historically operated in the region outside the UCR Site include those approximately 35 to 50 miles west of Trail in Grand Forks, Greenwood, and Boundary Falls in

southern British Columbia, a smelter 30 miles northeast of Trail in Nelson, British Columbia, and a smelter at Colville, Washington (Map 1-1). Periods of operation, primary metals produced, and the location of major sources of ore for these smelters are summarized in Table 2-3. Aerial emissions from these smelters may have contributed metals to soil regionally, but no data collection or analysis was performed to quantify potential impacts or lack of impact on the OU 3 study area.

2.10.2 Mining Operations and Mineral Processing Facilities

Mining and mining-related operations have occurred throughout northeastern Washington and southeastern British Columbia since the late 1800s. In addition to the smelters described above, there have been numerous metal and nonmetal mining and mining-related operations in the region. All metal operations are currently inactive within the OU 3 study area, but there are ongoing nonmetal operations (e.g., limestone and gravel quarries). Active, inactive, and historical mining and mining-related operations resulted in localized occurrences of metals in soils above regional natural background concentrations and may have contributed metals to soils regionally.

Map 2-11 through Map 2-14 illustrate the number, distribution, and types of known mining operations in the region and OU 3 study area. The locations on these maps are based on the WDNR mining database (WDNR 2015a,b, 2019b,c), the USGS Mineral Resources Data System (USGS 2022), USEPA (2002a), Cox and Hollister (1955), Derkey et al. (1990), and Huntting (1956). These were selected to create a comprehensive list of known mining and mining-related operations in the OU 3 study area. Map 2-11 shows the locations for metallic mining operations within the region, and Map 2-12 presents metallic mining operations in and around the OU 3 study area. Map 2-13 shows the locations for nonmetallic mining operations in and around the region, and Map 2-14 presents nonmetallic mining operations in and around the OU 3 study area. In addition to locations with known production, either permitted or unpermitted, shown on the preceding maps, numerous mining claims have been staked in the region (Map 2-15) and within the OU 3 study area (NLSDB 2023) (Map 2-16).[42]

Several mining and mining-related operations within the OU 3 study area have been investigated by others. These include the Young America Mine/Mill site, which is located near the historic town of Bossburg, Washington (WDNR 2008; USEPA 2012a) and 39 sites along tributaries to the Upper Columbia River in Stevens County that were evaluated as part of the 2001 EPA Stevens County Mines and Mills PA/SI (USEPA 2002a) (Map 2-11 and Map 2-12). The purpose of the

[42] The National Land Status Database (NLSDB) "contains case groups derived from Legal Land Descriptions (LLD) contained in the U.S. Bureau of Land Management's BLM LR2000 Case Recordation Database, and geocoded (mapped) using the Public Land Survey System (PLSS) derived from the most accurate survey data available through BLM Cadastral Survey workforce."

PA/SI was to identify and investigate potential sources of contamination to the Upper Columbia River and evaluate potential impacts to receptors via the surface water pathway. Eighteen of the sites investigated by EPA met criteria for sample collection, which included 1) the identification of potential sources of contamination and 2) observation of possible impacts to receptors via the surface water migration pathway.[43] Soil, sediment, surface water, waste rock, and/or tailings were sampled at these facilities. Table 2-6 includes dates of operation, geologic unit(s) mined, primary commodity(ies) produced, estimated total production, and site status for each site evaluated during the PA/SI. The samples and data collected during the PA/SI are described in more detail in Section 3.6, and a detailed summary of the PA/SI sampling activities and findings for a select number of sites is presented in Appendix A. These sites were selected for evaluation in the Upland RI report because they are the sites investigated by EPA; however, this list is not inclusive of all mines and mining-related operations in the OU 3 study area.

Five sites recommended by EPA for further action under CERCLA at the time of the PA/SI included Anderson Calhoun Mine/Mill, Last Chance Mine/Mill, L-Bar/Northwest Magnesite, Le Roi/Northport Smelter, and Van Stone Mine/Mill (USEPA 2002a). Additional activities and further actions have been completed and/or are ongoing at the Anderson Calhoun Mine/Mill, Last Chance Mine/Mill, L-Bar/Northwest Magnesite, Le Roi/Northport Smelter, and Van Stone Mine/Mill sites, as well as the Sierra Zinc Mine/Mill and Deep Creek Mine sites. Additional work has also been completed at the Young America Mine/Mill. Data from investigations at several of these facilities are evaluated in the Upland RI and described in Section 3. These include the Young America Mine/Mill (Section 3.4), the Van Stone Mine/Mill (Section 3.8), and the Anderson Calhoun Mine/Mill (Section 3.9). The former Le Roi/Northport Smelter is described above in Section 2.10.1.2. Upland soil investigation activities associated with the Le Roi/Northport Smelter are discussed in Section 3.7, and removal actions are described in Appendix B. The L-Bar/Northwest Magnesite facility is near Chewelah, Washington, outside the OU 3 study area (Map 2-11) and is not described in detail herein.

Synopses of the investigations and, where applicable, cleanup activities completed at the Anderson Calhoun Mine/Mill, Deep Creek Mine, Last Chance Mine/Mill, Sierra Zinc Mine/Mill, Van Stone Mine/Mill, and Young America Mine/Mill are provided in Appendix A along with summaries of the findings from the original PA/SI study. The extent of soil impacts around mine/mill sites is expected to be generally localized; however, because the PA/SI was focused on evaluating potential impacts to the Upper Columbia River via the surface water pathway, the

[43] Two sites, the Le Roi/Northport Smelter and Deep Creek Mine, were also evaluated for the soil exposure pathway.

data collected during the PA/SI are insufficient to support an evaluation of the extent of soil metals impacts at or surrounding the subset of sites that were selected for sampling.

2.10.3 Other Anthropogenic Sources

Roads, railways, and landfills represent other potential anthropogenic sources that are not directly mining or mining-related. The EPA-approved data quality objectives (DQOs) for the TAI Upland Soil Background Assessment specified that samples used to calculate background values should be at least 50 m away from roads or railways and at least 500 m away from landfills (TAI 2018a; USEPA 2018).[44] Pulp and paper mills are mentioned in the Agreement, but there are no pulp or paper mills in the OU 3 study area. Therefore, pulp and paper mills are not carried through into the list of other anthropogenic sources in this Upland RI report. The following bullets summarize how roads, railroads, and landfills may contribute to metals contamination in soils in the OU 3 study area.

- **Roads.** Roadway areas may be contaminated by historical use of leaded gasoline, imported roadbed materials, and fugitive dust from hauling loads without tarps or other containment. Metals emissions commonly associated with roads are chromium, copper, lead, manganese, and zinc (Gunawardena et al. 2015).
- **Railroads.** Railway areas may be contaminated by imported roadbed materials and fugitive dust from hauling loads without tarps or other containment (Szmagliński et al. 2021). The Kettle Falls International Railway runs from the U.S.-Canada border along the eastern shoreline of the Columbia River (WSDOT 2023). Metals emissions commonly associated with railroad areas are cadmium, chromium, copper, lead, nickel, and zinc (Szmagliński et al. 2021).
- **Landfills.** Areas around landfills may be contaminated by placement of waste materials on land surfaces. The Stevens County Landfill is located south of Kettle Falls, Washington, on the boundary of the OU 3 study area (Stevens County 2023). Metals emissions commonly associated with landfills are arsenic, cadmium, chromium, lead, and mercury (Hussein et al. 2020).

[44] The DQOs for the TAI Upland Soil Background Assessment included additional filtering criteria related to other types of sources.

2.10.4 Geology and Geogenic Background

As discussed in Section 2.4, metals are present in soils and in underlying bedrock and exposed bedrock (outcrops) in the OU 3 study area as a result of natural processes. For example, in the OU 3 study area, lead, silver, zinc, copper, gold, cadmium, cobalt, tungsten, gallium, germanium, iron, and molybdenum deposits are mined from the Kootenay Arc rocks (Derkey et al. 1990), and the Metaline limestone and Maitlen phyllite are two primary lead-bearing formations (Lund 2008; Weissenborn 1970) in the Kootenay Arc. Additionally, lead, zinc, silver, copper, and gold occur in the Carboniferous through Devonian metasedimentary and metavolcanic rocks of the Grass Mountain, Pend Oreille, and Flagstaff Mountain sequences (Derkey et al. 1990). These rock units as well as the Jurassic Rossland Group and unnamed Permian through Triassic metasedimentary rocks described in Section 2.4.3 are known to crop out within the OU 3 study area (Map 2-5).

As described above and in Section 2.4, natural chemical and physical weathering of geologic units enriched in metals can influence or contribute to natural background metals concentrations in surface soils, sediments, and surface water. Natural background is discussed further in Section 4.

2.10.5 Ambient Atmospheric Constituents

Ambient atmospheric constituents are transported to and deposited at the Site from global or regional atmospheric sources and are not connected to a specific point source (USEPA 2008a). These include mercury and lead, which are found in surficial soils and sediment due to global distribution of these elements from activities such as fuel combustion and/or power generation. Similarly, concentrations of various radionuclides that are present at low concentrations throughout the state due to global distribution of fallout from bomb testing and nuclear accidents would be considered natural background. Geologic deposits of mercury, volcanoes, volatilization from the ocean, and re-released mercury stored in vegetation and soils are natural sources of atmospheric mercury (USGS 2000, 2016). Ambient atmospheric constituents contribute to natural background concentrations of COPCs at the Site. Natural background is discussed in more detail in Section 4 below.

3 STUDIES CONDUCTED IN THE OU 3 STUDY AREA AND CANADA

Environmental data have been collected in the region and within the OU 3 study area since the early 1990s. This section describes the environmental studies conducted in the OU 3 study area and Canada. Some of these studies were completed as part of the UCR RI/FS project, while others were performed for other purposes but have data that are usable in the Upland RI. This includes studies that produced data collected for and used in either the HHRA or the Upland BERA and data collected in Canada. The environmental studies evaluated in this Upland RI report are listed in Table 3-1, along with the abbreviated study names used in the Upland RI report. Table 3-1 also identifies the studies used in the Upland BERA and the HHRA, which are discussed further in Section 5.

The remainder of this section summarizes the sampling and analyses that were performed for each study listed in Table 3-1. To the extent possible, based on the documentation available for each study, each summary identifies the objective, sampling methods, sample numbers,[45] sample types, and sample preparation and analysis methods.[46] Where appropriate, the summaries also identify limitations introduced by sampling design that are relevant for the nature and extent evaluation in this Upland RI report.

Specific uses of the data evaluated in this Upland RI report are described in further detail in Section 6.1.

3.1 2014 SOIL STUDY

The 2014 Soil Study (TAI 2015a) was performed by TAI as part of the UCR RI/FS project under the EPA-approved Final Soil Study Quality Assurance Project Plan (TAI 2014). The primary goal of this study was to generate data to characterize the exposure of ecological and human receptors to metals in upland soil at the UCR Site. Soil samples were collected from three subareas of interest: the ADA, relict floodplain deposition areas (RFDAs), and WSDAs. Only soil

[45] The study summaries presented in Section 3 of this report use the sample numbers reported by the study authors. Data analyses performed for this report used data primarily from the UCR RI/FS database; in some cases, the number of sample results in the database differed from the number reported by the study authors. There are several reasons why the number of sample results may differ, including inclusion/exclusion of split samples, laboratory QC samples (e.g., laboratory duplicates), results from multiple analyses performed on a single sample, or other reasons.

[46] The measurement units described in Section 3 of this report are consistent with the units as reported for each study.

samples collected from the ADA in the 2014 Soil Study are evaluated in the Upland RI report. The samples from relict floodplain and WSDAs[47] will be evaluated in the Aquatic RI report.

The ADA was designated in the Final Soil Study Quality Assurance Project Plan (TAI 2014) as an area that may have received aerial deposition from historical smelter stack emissions (from the smelters in Trail, British Columbia, and Northport, Washington). The ADA is in the northernmost 100 square miles of the OU 3 study area. It extends from the U.S.-Canada border south along the ridge located east of the river to Ryan, Washington. The western boundary of the ADA is less distinct because it is bisected by relatively large drainages (e.g., Little Sheep Creek and Big Sheep Creek), but, in general, it follows a line northward to the U.S.-Canada border (Map 3-1). A 23-square-mile corridor along the Upper Columbia River, south of the U.S.-Canada border, was designated for more intensive (high-density) sampling due to the perceived likelihood of higher historical deposition rates in that area. A reserve sampling area (SA) of about 16 square miles situated east of the primary study area was included in case samples could not be collected from the primary areas (TAI 2015a).

The selection of ADA DUs[48] considered factors such as accessibility for sample collection (e.g., areas with less than 30-degree slope due to safety concerns, areas within 550 m of roads to minimize travel time for field personnel to reach sampling locations). ADA DUs were not located within 50 m of roads and railways or within 100- to 500-m no-sample buffer zones[49] established for active and abandoned mine sites (TAI 2015a).

Soil sampling from the ADA DUs was completed from September 9 through October 23, 2014 (TAI 2015a). Incremental composite (IC) soil samples were collected from a total of 142 ADA DUs[50] that were approximately 25 acres each (Map 3-1). Select ADA DUs were sampled in triplicate to assess the precision of the sampling process (TAI 2014). Triplicate samples were collected from 16 ADA DUs using IC sampling methods for a total of 48 triplicate samples and a total of 174 IC samples collected (TAI 2015a).

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[47] Certain WSDA samples are included in the natural background soil data set, as described in Section 4.

[48] The HHRA prepared by USEPA (2021) refers to the ADA DUs as "ADAs."

[49] A 500-m, no-sample buffer zone was established for mine sites within the ADA that were sampled as part of the assessment detailed in the 2001 EPA Stevens County Mines and Mills PA/SI (USEPA 2002a). A 100-m, no-sample buffer zone was established around the other known mine sites in the study area, including those identified as "producer," "past producer," "occurrence," "prospect," or "unknown."

[50] As per the ITRC (2012) guidance on IC sampling, DUs "are based on project-specific needs and Site-specific DQOs; both considerations specify and constrain the appropriate end use of the data." The size of a DU "represents the smallest volume of soil about which a decision is to be made" and "can depend on whether the primary objective is to inform a risk assessment (i.e., DU is an exposure area) or to select a remedy (i.e., DU is a remediation unit)."

Increments were collected from 30 randomly placed, predetermined locations within each ADA DU (TAI 2015a). Locations were first inspected by cultural resource monitors for artifacts and cleared, and then surface debris was removed to expose soil. Increments were collected from the top 0 to 7.5 cm of soil using a 5-cm-diameter Art's Manufacturing & Supply core sampler (soil punch). Each increment was placed in a dedicated, plastic, zippered storage bag and examined for cultural materials by a cultural resource monitor or archaeologist. Once the soil increment passed the cultural inspection, sampling continued. Upon completion of sampling at an ADA DU, all 30 increments for that DU were composited in a laboratory-decontaminated, 2-gallon plastic bucket to form a single IC sample representative of the entire DU (TAI 2015a).

The contents of each bucket were homogenized, and an aliquot was analyzed for grain size distribution by the Puget Sound Estuary Program (PSEP) protocol and pH by EPA Method 9045D (TAI 2015a). The remaining sample was sieved into two size fractions: < 2 mm for ecological risk assessment (ERA)-related analyses and < 149 μm[51] for human health risk assessment-related analyses.

Both the < 2-mm-size and < 149-μm-size fractions were analyzed for total solids by EPA Method 160.3, and total recoverable metals (target analyte list [TAL] metals and molybdenum) were analyzed by EPA Methods 6010C, 6020A, and 7471B. In addition, the < 2-mm-size fractions were analyzed for cation exchange capacity (CEC) by EPA Method 9080 and total organic carbon (TOC) according to ASTM International (ASTM) Method D4129-05 (TAI 2015a).

In consultation with EPA, approximately 20 percent of the < 149-μm-size fraction samples with lead concentrations greater than 100 mg/kg were selected for in vitro bioaccessibility (IVBA) assay analysis (Preparation Method 9200.2-86 and Analysis Method 6010B) (TAI 2015a). A subsample was apportioned for IVBA TAL metals analysis; these samples were prepared according to the Ruby extraction method and analyzed by the EPA 6020A Ruby bioaccessibility method (TAI 2015a). IVBA data provide an estimate of the Site-specific oral relative bioavailability (RBA) for metals in soil to support risk characterization (TAI 2015a).

[51] The study summaries presented in Section 3 of this report describe size fractions as reported in the individual study reports.

3.2 2012 ECOLOGY UPLAND SOIL STUDY

The 2012 Ecology Upland Soil Study was conducted independent of the UCR RI/FS project. The primary objectives of this study were to collect data representative of surface and shallow subsurface soil conditions in part of the UCR valley near the U.S.-Canada border and analyze soil samples for smelter-related metals and other soil parameters (Ecology 2013a). The study was performed in general accordance with the procedures described in the Sampling and Analysis Plan and Quality Assurance Project Plan (Ecology 2012). Surface and shallow subsurface soil samples were collected from October 30 through November 10, 2012, by Ecology. Surface soil composite samples were collected at 106 locations within approximately 2 miles of the U.S.-Canada border (Ecology 2013a). The total study area covered approximately 15 to 20 square miles and extended roughly 4 miles east and 6.5 miles west of the Columbia River (Map 3-2). Soil samples were targeted in 13 irregularly shaped subareas that each covered approximately 1 to 2 square miles. In each of the 13 subareas, 7 to 10 surface soil samples were collected, and 1 subsurface boring was completed. The surface sample locations were geographically distributed within each subarea to encompass varying soil types, underlying geology, elevation, slope, and aspect (Ecology 2013a).

Surface soil samples were collected as four-point composites of grab samples obtained from within an approximate 20 ft radius of a fixed station point.

The surface samples were collected from the upper 3 in. of the soil horizon below any nondecomposed surface litter using a pre-cleaned, stainless-steel spoon, trowel, bulb planter, or other coring device and placed into a stainless-steel bowl (Ecology 2013a). The soil was homogenized in the bowl using the collection spoon, separated into four parts, then one spoonful of soil from each quarter was placed into a clean sample jar until full.

In each of the 13 subareas, a shallow borehole up to 2 ft deep was hand excavated to collect depth-discrete soil samples for evaluation of vertical changes in metal concentrations in shallow subsurface soil (Ecology 2013a). Vertical profile samples were collected from up to four discrete depth intervals: 0 to 3 in., 3 to 6 in., 6 to 12 in., and 12 to 24 in.

Soil analysis for each sample was limited to the < 2-mm-size fraction, by passing the material through a No. 10 sieve. Soil samples were analyzed for total recoverable metals (TAL metals) by EPA Methods 200.8, 6010B, 6020, and 7471A; TOC by USEPA (1981); soil pH by EPA Method 9045; and total solids by Standard Method (SM) 2540B (Ecology 2013a).

3.3 RESIDENTIAL SOIL SAMPLING PROGRAMS

Residential soil sampling programs were completed as part of the UCR RI/FS in 2014 and 2016.[52] EPA conducted soil sampling on certain residential properties and tribal allotments in 2014 (USEPA 2016a). TAI then conducted residential soil sampling at additional properties in 2016 (TAI 2017a). Both residential soil studies were designed to characterize RSS DUs by the collection and analysis of IC samples, with some properties having multiple DU types. Additional characterization work and/or removal actions were performed at certain RSS DUs based on the results from the residential soil sampling programs.

This section summarizes the residential soil studies and subsequent characterization completed within RSS DUs and/or tribal allotment DUs (TA DUs) that were sampled for the residential soil sampling programs. These studies include the following:

- 2014 Residential Soil Study (USEPA 2016a)
- 2015 TCRA Memorandum, which identified residential properties for cleanup and included the results of additional soil sampling to delineate soil cleanup extents (USEPA 2015b)
- 2015 TCRA (TAI 2016b), which documents soil cleanup voluntarily completed by TAI in 2015 under an Administrative Settlement Agreement and Order on Consent for Removal Action (ASAOC) (USEPA 2015c)
- 2016 Residential Soil Study (TAI 2017a)
- 2017–2018 VRA, which documents soil cleanups voluntarily completed in 2017 and 2018 by TAI under another ASAOC (TAI 2019a; USEPA 2017a)
- 2017 Soil Amendment Technology Evaluation Study (SATES) Test Plot Characterization, which included detailed soil characterization activities completed at test plots located on TA DUs (TAI 2019b)
- 2018 Plant Tissue Study, which included collection of plant tissue and co-located soil samples at certain TA DUs, ADA DUs, and other areas (TAI 2019c).

The TCRA and voluntary removal action (VRA) summaries below are focused on the associated soil sampling and analyses that provided data being evaluated (e.g., for nature and extent) in

[52] As described in Section 2.10.1.2, residential soil sampling and soil cleanup activities in Northport, Washington, have been undertaken by EPA since 1993. This work was not part of the UCR RI/FS; however, data from the 2004 Northport Removal Action are evaluated in this Upland RI report (see Section 3.7).

this Upland RI report. Both the TCRA and VRA were completed voluntarily[53] by TAI. Additional information on TCRAs and VRAs is provided in Appendix B.

3.3.1 2014 Residential Soil Study

The objective of the 2014 Residential Soil Study was to generate analytical data from surface soil samples to be used to refine metal-exposure estimates for residents in the northernmost reaches of the UCR valley (USEPA 2016a). Reconnaissance, sampling, and analyses were conducted under the Quality Assurance Project Plan Upper Columbia River Residential Soil Study (USEPA 2014). Surface soils were collected from rural residential properties in the UCR valley from north of Northport, Washington, and extending to the U.S.-Canada border. Landowners were contacted to gain access agreements for participation in this voluntary study. Once access agreements were signed, field reconnaissance activities were conducted to determine DU sampling locations.

The locations, extent, and sampling depths for each DU for each property were determined based on property-specific information (e.g., paved areas, unpaved areas). Sampling depths at each DU accounted for possible exposure to soil with depths of 0 to 1 in. bgs, 0 to 3 in. bgs, 0 to 6 in. bgs, 0 to 12 in. bgs, and 0 to 18 in. bgs. DU types included house, agricultural, dripline, and play area (0 to 1 in. bgs); garden (0 to 12 in. or 0 to 18 in. bgs); animal activity areas (0 to 3 in. bgs); CCT tribal allotment (0 to 3 in. bgs); and residential beach DUs[54] (0 to 6 in. bgs). Surface soil sampling activities were conducted from August 18 to October 3, 2014. Soil samples were collected from 235 RSS DUs at 74 properties during the field effort (USEPA 2016a) (Map 3-3a and Map 3-3b). Soil samples were collected using an IC sampling design. Each IC sample consisted of 30 increments or subsamples located within the boundaries of each RSS DU. Sampling was generally performed using a Cold Regions Research and Engineering Laboratory multi-incremental sampling tool (MIST) or trowel for shallow (0 to 1 in. bgs) sample increments and the Oakfield soil core sampler or trowel for deeper interval sample increments. Leaf litter and surface debris were cleared, and soil was inspected by the cultural resources team prior to and after sample collection. Soil depth was measured below the thatch or root zone. Soil was

[53] The Site is the subject of an ongoing lawsuit by the CCT and the State of Washington against Teck Metals Ltd. Relevant for the upland portion of the Site, the U.S. Court of Appeals for the Ninth Circuit held in 2016 that Teck Metals Ltd. is not liable under CERCLA for aerial emissions of metals from the Trail Facility in British Columbia insofar as they may have deposited in the United States. Particularly, such emissions do not constitute "disposal" for purposes of establishing arranger liability under the statute (Pakootas v. Teck Cominco Metals Ltd., 830 F.3d 975, 9th Cir. 2016).

[54] One residential beach DU was TA 411. Residential beach DUs will be evaluated in the Aquatic RI.

placed into plastic bags and then into pre-cleaned plastic buckets. Duplicate or triplicate (collectively, "replicate") IC samples were collected at 153 DUs. In total, 541 IC samples were collected from 235 RSS DUs during the field effort (USEPA 2016a).

In addition to the IC samples, discrete grab samples were collected at random locations within a selected RSS DU for each property to provide information on the vertical nature and extent of contamination at each property (USEPA 2016a). Typically, five discrete grab samples were collected at the DU closest to the residence, but four to six samples were collected in some DUs. Discrete grab samples were collected from a total of 350 locations. The discrete grab samples were collected using hand trowels from 1 to 6 in. bgs and were collected from separate locations from the IC increments within the DU. Soil was placed into plastic bags and homogenized after cultural inspection and then placed into glass jars. Field duplicate samples were collected at 52 of the 350 discrete grab sample locations, resulting in a total of 402 discrete grab samples analyzed. Field duplicate samples were collected to assess the homogeneity of discrete grab samples and the precision of the field sampling process (USEPA 2016a).

The IC and discrete grab samples were air-dried, homogenized, and sieved into the appropriate fraction (< 150 μm for soil, < 250 μm for beach sand) for subsampling (IC samples only), digestion, and analysis (USEPA 2016a). All soil samples were analyzed for total solids by EPA Method 160.3 and total recoverable metals (TAL metals, except mercury) by EPA Methods 6010C and 6020A. IVBA testing was also conducted on a subset of IC samples with maximum lead concentrations ≥ 100 ppm or arsenic concentrations ≥ 20 ppm. Samples for IVBA testing were prepared according to EPA Method 9200.2-86 and analyzed for lead and arsenic according to EPA Method 6010B (USEPA 2016a).

3.3.2 2015 TCRA Memorandum

Based on the soil lead and arsenic results from the 2014 Residential Soil Study, EPA identified 14 residential properties having one or more DUs designated for removal activities based on a time-critical removal lead action level of 700 mg/kg (USEPA 2015b) (Map 3-3a and Map 3-3b). The objective of the TCRAs was to remove lead- and arsenic-contaminated soil with the potential to pose imminent risk to human health. In May 2015, the EPA Region 10 Removal Program conducted a removal site evaluation that included documenting the condition and layout of each property designated for cleanup, coordinating with each of the property owners, and collecting and analyzing additional soil samples to further characterize the vertical and horizontal extent of contamination to prepare for soil removal. At some of the properties, EPA either extended the size of some DUs or added new DUs based on additional observations of property use and interviews with the landowners that indicated areas of the property with a high likelihood of human exposure to contaminated soil. Based on the May 2015 removal site

evaluation and soil sampling, EPA prepared property-specific work plans (PSWPs) (USEPA 2015b) for each property identified for a removal action. The PSWPs consisted of a field sampling plan and quality assurance project plan (USEPA 2015b). These PSWPs were included as attachments to the 2015 TCRA Memorandum that provided a TCRA action level of 700 mg/kg and a cleanup level of 250 mg/kg or less for lead.

During the May 2015 removal site evaluation, EPA collected samples from 6 to 12 in. bgs to characterize the vertical extent of contamination at RSS DUs that had been sampled in 2014 (USEPA 2015b). At new DUs, EPA collected grab samples at intervals of 0 to 6 in. and 6 to 12 in. bgs. The samples were analyzed in the field using field-portable x-ray fluorescence (XRF) instruments, and a subset of the samples were analyzed at an offsite laboratory. A total of 480 discrete grab soil samples were collected from 14 residential properties from 0 to 6 in. or 6 to 12 in. bgs and analyzed by XRF, and 100 of these were sent to an offsite analytical laboratory. All laboratory soil samples were analyzed for lead and arsenic. The sample preparation and analytical methods used for laboratory analyses were not specified by EPA; however, it is assumed that samples were analyzed for total recoverable metals based on the methods used for the 2014 Residential Soil Study. EPA also submitted five of the samples for toxicity characteristic leaching procedure (TCLP) lead and arsenic analyses at the offsite laboratory to determine if the contaminated site soil was a characteristic hazardous waste.

3.3.3 2015 TCRA

On August 11, 2015, TAI and EPA entered into an ASAOC (USEPA 2015c). Under the ASAOC, TAI voluntarily agreed to conduct TCRAs at select residential properties and tribal allotments. Sampling and analysis were done under the EPA-approved field sampling plan and quality assurance project plan (TAI 2015c). The TCRAs were performed by TAI with EPA oversight from August through November 2015 at 25 DUs located at 13 of the 14 privately owned properties listed in the ASAOC and 2 DUs at Tribal Allotment 151-H 195 (Map 3-3a and Map 3-3b and Map 3-4). The actions were performed by excavating soil to a depth of 6 in. bgs and then analyzing the underlying soil using XRF to identify areas with lead and/or arsenic above project-specific cleanup levels (250 and 20 mg/kg, respectively) that required additional excavation. Soil was excavated to a maximum depth of 12 in. bgs (24 in. bgs for gardens). The exception to the excavation process was areas where trees and/or tree roots were present. Areas around trees were removed to the maximum reasonable depth that would not damage root structure and compromise health of the tree. Discrete grab confirmation samples were taken at the center of each excavated grid cell and submitted for laboratory analysis of lead and arsenic to verify cleanup. If soil sample results were higher than the project-specific cleanup levels for lead and arsenic, excavation was resumed at those locations until project-specific cleanup levels

were achieved or to a total depth of 12 in. bgs. A total of 590 confirmation soil samples, including quality assurance/quality control (QA/QC) samples, were collected during the soil removal activities (TAI 2016b).

Confirmation soil samples were analyzed for total recoverable metals (lead and arsenic) by TestAmerica using EPA Method 6010C or 6020A (TAI 2016b).

3.3.4 2016 Residential Soil Study

In 2015, EPA directed TAI to further study residential soils within and beyond the prior 2014 Residential Soil Study boundary. Consistent with the 2014 Residential Soil Study, the purpose of the 2016 study was to collect data to support refinement of exposure estimates for residents to support the HHRA. The 2016 Residential Soil Study was conducted by TAI, extended the southern boundary of EPA's 2014 Residential Soil Study, and included residences previously not sampled in 2014 because the owner did not volunteer for sampling during that study. This was performed under the EPA-approved quality assurance project plan (TAI 2016a), which represents an addendum to the 2014 EPA-approved quality assurance project plan (USEPA 2014).

Letters were sent to property owners in January 2016 to pursue voluntary participation for this soil study. TAI received responses from 273 property owners, of which 141 properties and 8 tribal allotments granted access. Letters from property owners continued to be received during the field reconnaissance and field sampling phases. In spring 2016, TAI visited each of the eligible properties where permission to access was granted, property owners were interviewed, and properties mapped to define exposure areas (or DUs). Soil sampling activities were conducted from August 1 to September 26, 2016. The area in and around Northport, Washington, designated as the "Northport Exclusion Area"[55] (Map 3-5), was not included in the 2016 Residential Soil Study (USEPA 2015a). Sampling was planned at 141 residences; however, 3 residences withdrew consent for sampling, and six access agreements were received after the approval of the QAPP Addendum, for a total of 144 residences.

IC soil samples were collected from a total of 452 RSS DUs at 144 residences (TAI 2017a) (Map 3-5). The 2016 study included 7 residential beach DUs[56] and 19 TA DUs at 8 undeveloped allotments. DU classifications and the associated sampling depths were the same as for the

[55] Per an August 11, 2015, letter from Laura Buelow (EPA) to Kris McCaig (TAI), EPA revised the scope of its March 5, 2015, directive to TAI to conduct additional residential sampling by specifying that "the 2016 sampling zone will not include the area depicted in the map as 'Northport Exclusion Area Inset'" (USEPA 2015a).

[56] Residential beach DUs will be evaluated in the Aquatic RI.

2014 Residential Soil Study (described in Section 3.3.1). In addition to the IC samples, discrete grab samples were collected from the 0- to 1-in. bgs and 1- to 6-in. bgs depth intervals at five locations within 29 DUs, where the IC sampling depth was 0 to 1 in. bgs (TAI 2017a).[57]

Soil increments for each IC sample were collected from 30 randomly placed, predetermined locations within each DU (TAI 2017a). Triplicate IC samples were collected at 144 DUs, which resulted in collection of a total of 740 IC samples during the study. Triplicate samples were collected to ensure reliable estimates of the mean concentration of target analytes within the DU. Field duplicate discrete grab samples were collected to assess the precision of the discrete grab soil sampling process. One field duplicate was taken at each DU where discrete grab samples were collected. A total of 348 discrete grab samples (including duplicate samples) were submitted for analysis (TAI 2017a).

Once the locations were cleared of surface debris, surface soil increments (for IC samples) or grabs (for discrete grab samples) were collected using a MIST or EZ-Probe sampling device (for IC samples) or decontaminated stainless-steel hand trowel (for discrete samples) (TAI 2017a). Each increment or discrete grab was placed in a dedicated, plastic, zippered storage bag and examined for cultural materials by a cultural resource monitor or an archaeologist. Once the soil increment or discrete grab sample passed the cultural inspection, the soil was transferred from the plastic bag to a decontaminated plastic bucket designated for collection of all increments for that IC sample or to a laboratory-supplied 16-ounce jar for discrete grab samples. The same process followed for discrete grab samples from 0 to 1 in. bgs was repeated at the same location for collection of the discrete grab sample of soil from the 1- to 6-in. bgs depth interval (TAI 2017a).

At the laboratory, the contents of each bucket (IC samples) or jar (discrete grab samples) were homogenized, weighed, air-dried, and passed through a No. 10 sieve (< 2 mm) to remove large debris (e.g., sticks, stones) present in the sample (TAI 2017a). The < 2-mm-size fraction was weighed and then passed through either a No. 60 or No. 100 sieve to isolate the target particle size of < 250 μm for residential beach DUs or < 149 μm for nonbeach DUs, respectively. IC and discrete grab samples were analyzed for solids by EPA Method 160.3, and TAL metals

[57] The discrete grab sampling conducted in the 2016 study differed from the 2014 study. Discrete grab samples were only collected from 1 to 6 in. bgs during the 2014 study because the IC sample depth at most of the DUs designated for discrete sample collection was 0 to 1 in. bgs. However, the lack of discrete grab sample data for the 0- to 1-in. bgs depth interval contributed to uncertainty regarding correspondence of the IC and discrete grab sample results, further limiting the interpretive value of the 1- to 6-in. discrete grab sample data regarding the vertical nature and extent of contamination. Given these factors, discrete grab samples from both the 0- to 1-in. and 1- to 6-in. bgs depth intervals were collected during the 2016 study.

(excluding mercury) were analyzed by EPA Methods 6010C and 6020A. Samples for IVBA analysis of lead and arsenic in soil were prepared according to the Ruby extraction method and analyzed by the EPA 6020A Ruby bioaccessibility method on a subset of DUs where the lead or arsenic concentration in nondripline IC samples was greater than or equal to 100 or 20 mg/kg, respectively (TAI 2017a).

3.3.5 2017–2018 VRA

The objective of the 2017–2018 VRA was to remove lead- and arsenic-contaminated soil at properties with concentrations of lead and arsenic in soil exceeding the action levels of 600 mg/kg[58] and 20 mg/kg, respectively, to ensure the protection of public health, welfare, or the environment (TAI 2019a). The VRA was done in accordance with the procedures described in the field sampling plan and quality assurance project plan (TAI 2018b). Eight DUs on four properties were initially identified based on the results of the 2014 and 2016 Residential Soil Studies for VRA activities, and two more were added at the request of one property owner (TAI 2019a) (Map 3-6).

Pre-excavation IC sampling was done in May 2018 to refine cleanup areas within the DUs. As a result of the pre-excavation sampling, only one DU[59] was modified. Removal actions were initiated in October 2017 with removal of soil from three DUs on two properties and completed in September 2018 with removal of soil from seven DUs on three properties (TAI 2019a). The initial excavation removed the first 6 in. of soil within each DU. Once the first 6 in. of soil were excavated, the base of the DU was screened with an XRF instrument to evaluate if areas remained with lead and/or arsenic concentrations greater than the project-specific cleanup levels. If the XRF instrument suggested concentrations of lead and/or arsenic at or near project-specific cleanup levels, additional soil was removed in lifts to a maximum depth of 12 in. bgs, and screening with the XRF instrument was repeated. If the XRF instrument indicated

[58] The 2017 ASAOC did not provide a reference or basis for the 600 mg/kg or 20 mg/kg VRA action levels. The VRA action levels were established in a June 14, 2017, letter (USEPA 2017b) from Laura Buelow (EPA Project Manager) to Kris McCaig (TAI) resolving two disputes raised by TAI. These disputes related to EPA's December 8, 2016, directive to TAI to fund EPA to conduct terrestrial plant sampling and tissue analysis and EPA's July 22, 2016, Level of Effort for Assessment and Estimations of Upland Soils (background study). The June 14, 2017, dispute resolution agreement letter states: "While not directly related to the dispute, as discussed during the informal dispute resolution, TAI has also voluntarily agreed to conduct removal actions at four upland residential properties, sampled in 2016, that have measured lead concentrations above 600 ppm."

[59] The results of the pre-excavation sampling showed Sampling Units (SUs) SU-B, SU-C, and SU-D of DU-1030 were below the lead and arsenic EPA TCRA action levels; therefore, removal was not performed at these SUs.

concentrations of lead and arsenic less than project-specific cleanup levels, soil samples were collected for laboratory analysis (TAI 2019a).

Composite soil samples for laboratory analysis were generally collected for excavation confirmation on a 25-ft grid pattern (TAI 2019a). During the soil removal activities, 252 confirmation soil samples were taken, including QA/QC samples (TAI 2019a). Confirmation soil samples were analyzed for total lead and total arsenic by TestAmerica using EPA Method 6010C.

3.3.6 2017 SATES Test Plot Characterization

The objective of the 2017 SATES Test Plot Characterization (TAI 2019b) was to identify a soil amendment technology or technologies that could be applied to appropriately and cost-effectively reduce the long-term potential for human exposure to lead in shallow soils at the UCR Site. This study was conducted in accordance with the final work plan (TAI 2017b), ensuring that laboratory quality and procedural methods were sufficient. In 2017, TAI started the four-phase study in collaboration with the SATES Technical Team.[60] SATES was conducted on TA DUs located on three CCT tribal allotments that were sampled during the 2014 Residential Soil Study (DUs 258, 401, and 441) (Map 3-7) and found to have soil lead concentrations above the TCRA action level of 700 mg/kg for RBA-adjusted lead (TAI 2019b).

Phase IA Part 1 involved collection of soil samples from the six test plots for chemical analysis, and based on the analytical results, specific test plots were selected for further detailed characterization in Phase IA Part 2 (TAI 2019b).

Data collected in Phase IA Part 1 were used to establish baseline conditions at each test plot and to support the design of laboratory-scale and field-scale testing to evaluate different soil treatment technologies in subsequent SATES phases (TAI 2019b). Soil sampling at the six initial test plots was conducted from August 16 through 22, 2017. This involved collection of 105 shallow (near-surface) discrete grab soil samples from each test plot, including co-located field duplicate samples at randomly selected locations. Each test plot covered an approximate 100-ft-by-100-ft area that was divided into a grid consisting of 100 sampling subareas (grid cells) measuring 10 ft by 10 ft. Samples were collected from the 0- to 3-in. depth interval, below the loose duff layer, using a decontaminated 2-in.-diameter, stainless-steel soil punch inserted into the soil. Each sampling location was screened by a cultural resource monitor or an archaeologist

[60] The SATES Technical Team is a collaboration between EPA Region 10, EPA Office of Research and Development, CCT, Ecology, STI, U.S. Department of the Interior, and Citizens for a Clean Columbia.

prior to sampling, and soil collected for each discrete grab sample was examined by a cultural resource monitor or an archaeologist prior to transferring to sample containers (TAI 2019b).

During Phase IA Part 1, a total of 630 discrete grab soil samples (including field duplicate samples) were collected from the six test plots. Samples were passed through a No. 10 sieve (< 2 mm) and analyzed for total solids by EPA Method 160.3 and lead and arsenic by EPA Method 6010 (TAI 2019b).

Four test plots that met pre- and post-screening criteria were identified in Phase IA Part 2. Test plots were each divided into four, 50-by-50-ft subplots, then several discrete grab soil samples were collected from October 2 through 18, 2017, from 16 shallow test pits at the locations with the highest lead concentration in initial screening soil samples. One test pit was placed in each subplot (four per test plot). The test pits were approximately 2 ft wide, 2 ft long, and 18 in. deep. Prior to excavation, discrete grab samples from each test pit were collected beneath the loose duff layer from 0 to 3 in. bgs using a decontaminated, stainless-steel trowel. All discrete grab samples were passed through a No. 10 sieve (< 2 mm) at the laboratory prior to analysis for arsenic and lead by EPA Method 6010 (TAI 2019b).

Next, the test pits were excavated to 18 in. bgs and additional depth-discrete soil samples were collected from the northern sidewall of the test pit at 2-in. intervals using stainless-steel trowels from 0 to 12 in. bgs for analysis of TAL metals (excluding mercury) by EPA Method 6010 (TAI 2019b). After these samples were collected and test pit observations were completed, TAI collected IC samples from the larger subplots using 2-in.-diameter soil coring tools from 0 to 3 in. bgs from 30 increment locations in each subplot. IC samples were homogenized, dried, and then passed through either a No. 10 sieve (< 2 mm) or a No. 100 sieve (< 150 µm) at the laboratory prior to analysis (TAI 2017c). These samples were analyzed for total metals, leachable metals, bioaccessible metals, and general soil chemistry parameters. A total of 19 IC soil samples were collected (18 parent samples from the subplots plus 1 duplicate sample) (TAI 2019b).

Subsequent phases of SATES included Phase IB—soil amendment technology screening and design, Phase II—bench-scale treatability studies, Phase III—test plot field implementation, and Phase IV—test plot monitoring. The final sampling event conducted for Phase IV was completed in May 2023. Data from SATES Phases IB through IV are not evaluated in this Upland RI report but will be evaluated in the Upland FS.

3.3.7 2018 Plant Tissue Study

The primary objectives of the 2018 Plant Tissue Study were to collect representative plant tissue from wild upland plants and co-located soil samples from SAs identified within TA DUs previously sampled during the 2014 and 2016 Residential Soil Studies (USEPA 2016a;

TAI 2017a) and the 2014 Soil Study (TAI 2015a) (Map 3-3a, Map 3-3b, and Map 3-8). All sampling and chemical analyses were conducted in accordance with the EPA-approved quality assurance project plan (TAI 2019c). TAI collected the samples to characterize metal concentrations in the tissues of wild upland plants that are ingested, mouthed (e.g., for weaving), or otherwise used by CCT members to understand risk for human consumers. The plant tissue and co-located soil samples were collected during three sampling events in 2018: April 24 through May 2 (spring), June 18 through 20 (June), and August 20 through 28 (August). Plants and co-located soil samples were collected from 12 SAs; 3 of the SAs were considered high-lead SAs due to previous IC samples that yielded lead concentrations greater than the TCRA action level of 700 mg/kg. The remaining nine SAs were considered low-lead SAs based on the range of lead concentrations (< 700 mg/kg) measured in previous soil studies conducted as part of the UCR RI/FS. Two of the lower-lead SAs (SA15 and SA16) were exclusively sampled for willows, and all other SAs were sampled for upland plant species (TAI 2019c). Soil data collected during the 2018 Plant Tissue Study are described in the following paragraphs; the plant tissue data are discussed in Section 3.17.2.

A total of 174 soil and plant samples were collected. Samples were either collected as individual or composite samples. For the individual soil samples, a co-located soil sample was collected next to where the plant tissue sample was collected. For composite plant samples, the co-located soil sample was collected for each individual plant sampled, and soil was composited in the field proportionally to the weight of the plant tissue from each plant in the composite. The exception was for soil associated with the black tree lichen samples. For these samples, a 20-m-diameter circle was selected as a plot where black tree lichen was picked from the trees in that area. The soil sample associated with these samples was collected from the center of the 20-m circular plot in each SA (TAI 2019c).

Prior to soil sampling, the organic duff layer was removed. Soil samples were collected from 0 to 3 in. bgs using either a decontaminated auger, coring, or spade tool. Soil samples were inspected by a cultural resource monitor, then hand-mixed in a resealable plastic bag and transferred to a laboratory-supplied sample jar. Soil samples were air-dried and passed through a No. 100 sieve to isolate particle sizes < 150 µm at the laboratory prior to analysis. All 174 soil samples were analyzed for total solids by EPA Method 160.3, and TAL metals, except calcium, magnesium, potassium, and sodium, were analyzed by EPA 6020A inductively coupled plasma-mass spectrometry (ICP-MS). A subset of 63 samples was also analyzed for total mercury by EPA Method 1631E cold vapor atomic fluorescence spectrometry (CVAFS) (TAI 2019c).

3.4 STUDIES ASSOCIATED WITH THE YOUNG AMERICA MINE/MILL

The Young America Mine was a lead, zinc, and silver mine located in Bossburg, Washington, that was active from the late 1900s through the mid-1950s (Appendix A). A mill also operated next to the mine. Investigations associated with the Young America Mine/Mill or its vicinity that conducted soil sampling and analysis included WDNR Young America Mine Site Characterization (WDNR 2008) and 2011 EPA Young America Mine Removal Assessment (USEPA 2012a). These investigations are described in the sections that follow.

3.4.1 WDNR Young America Mine Site Characterization

A characterization of the Young America Mine was completed by the WDNR Division of Geology and Earth Resources in 2008 as part of the Inactive and Abandoned Mine Lands program (WDNR 2008). This work was completed independent of the UCR RI/FS project. The purpose of the WDNR Young America Mine Site Characterization was to provide documentation on mines or groups of mines within specific mining districts or counties. This report provided specific information about access, ownership, geologic setting, mine openings (cliff, shaft, or stope), materials and structures, water, milling operations, waste rock dumps, and general information. One discrete grab sample was taken during the study from subsurface tailings material (Map 3-9) and analyzed for total recoverable metals (arsenic, cadmium, copper, lead, zinc, and antimony) by ICP-MS following EPA Method 6010 (WDNR 2008).

3.4.2 2011 EPA Young America Mine Removal Assessment

The 2011 EPA Young America Mine Removal Assessment was performed by EPA. This work was completed independent of the UCR RI/FS. The primary objective of the study was to assess potential risks to human and ecological health from contaminated soil, sediment, and water originating from mining operations at the former Young America Mine. EPA prepared a Site-Specific Sampling Plan and Quality Assurance Plan for collecting samples during this project (USEPA 2011a). The Superfund Technical Assessment and Response Team (START-3) performed XRF field analysis for hazardous metals within the mill and impoundment area to delineate boundaries of soils contaminated above selected action levels (USEPA 2012a). The samples were collected during two periods: July 5 to 7 and August 23 to 24, 2011. To verify the accuracy of the field screening data, seven discrete grab samples were collected by the START-3 from six locations (five soil samples, one sediment sample, and one duplicate sediment sample), with the highest lead results in July and August 2011 (Map 3-9). These samples were collected from 0.5 to 3 ft below any nondecomposed surface litter. The sediment sample from this study will be evaluated in the Aquatic RI report.

Samples were analyzed for total recoverable metals (antimony, arsenic, barium, beryllium, cadmium, chromium [total], cobalt, copper, lead, manganese, nickel, selenium, silver, thallium, vanadium, and zinc) by EPA Method 6010B, and synthetic precipitation leaching procedure (SPLP) metals were analyzed by EPA Method 1312/200.8. Two soil samples were analyzed for TCLP metals by EPA Method 1311/6010 (USEPA 2012a).

3.5 2015 BOSSBURG STUDY

The 2015 Bossburg Study was performed as part of the UCR RI/FS by TAI under an EPA-approved quality assurance project plan (TAI 2015b). The primary objective of the 2015 Bossburg Study was to determine exposure levels and evaluate risk for human health and ecological receptors from nearshore sediment and soil downstream and adjacent to the former Young America Mine/Mill, including the former cable ferry landing, Bossburg Flat Beach, and Evans Campground Beach (TAI 2016c). Sediment samples were collected from 10 DUs at Bossburg Flats Beach and one former cable landing area in the Columbia River, and soil samples were collected from six upland DUs (UDUs[61]) (Map 3-9). Soil samples were collected from April 14 through May 8, 2015. Sediment samples from this study will be evaluated in the Aquatic RI report.

Six surface samples were collected at sample depths of 0 to 6 in. bgs using IC sampling methods typically as 30-point composites, but a 29-point composite was collected at one location. Discrete grab and discrete core sampling methods were used to collect 24 surface and 18 subsurface samples from depths of 0 to 6 in., 6 to 12 in., and 12 to 18 in. bgs. The locations for discrete core subsurface samples were informed by results of field screening using XRF. All samples were homogenized and sieved into two size fractions: < 2 mm and < 150 µm. Data from the < 2-mm-size fraction were used for evaluation of risk to ecological receptors, and data from the < 150-µm-size fraction were used to evaluate risk to human receptors. A total of eight IC soil samples were collected, one each from five UDUs and triplicate IC samples at one UDU. A total of 18 soil cores were collected, with three samples from each core at various depth intervals (TAI 2016c).

After clearing the locations of surface debris, IC samples were collected using a 4-cm-diameter coring tool and placed into clean, dedicated plastic bags. Each bag was passed through cultural inspection prior to being transferred into a 5-gallon bucket labeled with the sample

[61] The term upland DUs and the acronym UDU were used specifically for the 2015 Bossburg Study to differentiate upland soil DUs from beach sediment DUs that were also evaluated as part of the study. The DU nomenclature for the 2015 Bossburg Study was discussed during a call with EPA on January 31, 2022, and EPA agreed to this nomenclature in their final comments on the Draft Interim Partial Upland RI Report (USEPA 2022c).

identification, sampler initials, and sampling date and time. Once all 30 bags were collected, they were emptied into the 5-gallon bucket, and the composite sample was placed on ice (if composites were collected over more than 1 day, samples were placed on ice at the end of each day) (TAI 2016c).

Core samples were collected at locations with the three highest XRF measurements greater than 400 mg/kg, locations where one or two XRF measurements exceeded 400 mg/kg, plus one additional location either randomly selected or based on visual observations (TAI 2016c). After clearing the location of surface debris, soil core samples were collected using a coring tool from depths of 0 to 6 in., 6 to 12 in., and 12 to 18 in. bgs. IC and core samples were analyzed for grain size distribution (PSEP protocol), pH (EPA Method 9045D), percent solids and percent moisture (EPA Method 160.3), TOC (ASTM Method D4129-05) (< 2-mm-size fraction), CEC (EPA Method 9080) (< 2-mm-size fraction), total recoverable metals (TAL metals; EPA Methods 6010C, 6020A, and 7471B) (< 2-mm- and < 150-µm-size fractions), and IVBA (Ruby extraction, EPA Method 6020A) for lead and arsenic (< 150-µm-size fraction) (TAI 2016c).

3.6 2001 EPA STEVENS COUNTY MINES AND MILLS PA/SI

As described in Section 2.10.2 above, EPA conducted PA/SIs at 39 sites along tributaries to the Upper Columbia River in Stevens County in 2001 and published the 2001 EPA Stevens County Mines and Mills PA/SI (USEPA 2002a). The objectives of these PA/SIs were to identify potential sources of contamination to the Upper Columbia River, determine which mines or mills may be releasing contaminants, document threats to public health or the environment, and assess the need for additional investigations. Field activities were conducted in accordance with an approved sampling and quality assurance plan through a combined effort involving START-2 contractor firms, Ecology and Environment, Inc. and Roy F. Weston, Inc., from June 17 to 30 and September 9 to 15, 2001 (E&E 2001). Sampling activities were conducted at 18 of the 39 mine and mill sites visited in Stevens County. This work was performed outside the UCR RI/FS.

A total of 159 surface soil discrete grab samples, 44 sediment samples, and 13 surface water samples were collected and analyzed during the investigation. Soil sample locations are shown in Map 3-10. Some of the soil and sediment samples contained tailings and waste rock. Before sampling, grass, leaves, other vegetative material, and rocks were removed from soil sample locations. Surface soil samples were collected with dedicated plastic spoons and scoops from 0 to 6 in. bgs. Samples were homogenized in dedicated plastic bowls prior to placement in sample jars (USEPA 2002a).

Soil samples were analyzed for total recoverable metals (TAL metals) by EPA Contract Laboratory Program (CLP) methods. Additional COCs for select samples included EPA CLP

chlorinated pesticides/polychlorinated biphenyls (PCBs) and semivolatile organic compounds (USEPA 2002a).

Of the 18 mine sites where samples were collected and analyzed, 5 sites were recommended by EPA for further action under CERCLA at the time of the PA/SI, including Anderson Calhoun Mine/Mill, Last Chance Mine/Mill, L-Bar/Northwest Magnesite, Le Roi/Northport Smelter, and Van Stone Mine/Mill. Table 2-6 provides dates of operation, geologic unit(s) mined, primary commodity(ies) produced, estimated total production, and site status[62] for each site evaluated during the PA/SI. (USEPA 2002a). Additional activities and further actions have been completed and/or are ongoing at the Anderson Calhoun Mine/Mill (Section 3.9), Last Chance Mine/Mill, L-Bar/Northwest Magnesite, Le Roi/Northport Smelter (Section 3.7), and Van Stone Mine/Mill sites (Section 3.8) as well as the Sierra Zinc Mine/Mill and Deep Creek Mine sites. Additional work has also been completed at the Young America Mine/Mill. Appendix A summarizes the investigations, and where applicable, cleanup activities.

3.7 2004 EPA LE ROI SMELTER REMOVAL ACTION

The objectives of the 2004 EPA Le Roi Smelter Removal Action were to collect and analyze soil and groundwater samples to characterize the Le Roi/Northport Smelter site, conduct oversight of the removal action, and conduct air monitoring and sampling during the removal action (USEPA 2005). This work was performed outside the UCR RI/FS. The QC requirements are described in the Le Roi Smelter Removal Site Evaluation Site-Specific Sampling Plan (USEPA 2004). Sampling activities for the 2004 EPA Le Roi Smelter Removal Action took place from May to September 2004 and included residential and commercial properties in and around Northport as well as public land use areas distinct from the former smelter site ("Outer Area" samples as recorded by EPA). Sampling occurred in four phases and included 11 Outer Area samples and 101 sampling units (SUs) at 39 residential/commercial properties (Map 3-11). Unpaved areas at each property were divided into one or more area types: front yard, back yard, side yard, driveway, garden area, and/or play area. A five-point composite soil sample was collected from each area type and at each of three depths: 0 to 1 in., 1 to 6 in., and 6 to 12 in. At residential properties, if a play area was present, soil samples were also collected from 12 to 18 in. If a garden area was present at the property, additional soil samples were collected from depths of 12 to 18 in. and 18 to 24 in. to evaluate contamination to a depth of rooting vegetables. Gravel or dirt driveways were sampled only at the surface (0 to 1 in.).

[62] The current site status is compiled from Ecology (2024).

Soil samples were analyzed for total recoverable metals (lead, arsenic, cadmium, and copper) following EPA CLP Statement of Work 5.3 and EPA SW846 Method 6010B (USEPA 2005). The list of analytes is consistent with EPA standard practice for sampling at smelter sites. Analytical results for other metals were not reported in the 2004 EPA Le Roi Smelter Removal Action Report but were provided to TAI by EPA contractors during initial development of the UCR RI/FS database (TAI 2019d). The sample-size fraction(s) analyzed for this study is not known.

From July to October 2004, EPA initiated TCRAs at the abandoned smelter and in nearby Northport. Three excavation areas at the former smelter site were identified for removal and were excavated to varying depths of 12 to 24 in. During the former smelter excavation, low-flow air sampling pumps were deployed on the perimeter of the smelter and on excavation equipment to monitor dust and exposure levels. High-volume samplers were staged around Northport to monitor heavy metals concentrations in particulates, and three post-excavation confirmation soil samples were collected following completion of removal activities (USEPA 2005).

Residential removals were based on analytical results from the four sampling phases (USEPA 2005). Thirty-three properties qualified for removal or containment measures, and four of these properties were not included in the removal phase due to hazardous building structural conditions. Residential excavations varied from 6 to 12 in. Post-excavation, composite surface soil samples were collected from the excavated areas at each of the 29 residential properties where removals were completed (USEPA 2005). No removal activities were required or completed at commercial properties other than the abandoned smelter site.

3.8 ECOLOGY VAN STONE MINE RI/FS

The Van Stone Mine operated intermittently from 1938 to 1993 as an underground and open-pit lead and zinc mine (Table 2-6 and Appendix A). This mine is currently being managed as a cleanup site by Ecology, who is developing a cleanup action plan to address metals contamination in soils at the site and surface water discharging into tributaries of Onion Creek (Ecology 2023). The 2011–2012 Ecology Van Stone RI and the 2014–2015 Ecology Van Stone FS have been completed by Ecology, but the RI and FS are not part of the UCR RI/FS. The Van Stone Mine/Mill is one of the sites that was recommended for further action in the 2001 EPA Stevens County Mines and Mills PA/SI (USEPA 2002a). The following subsections summarize data from the 2011–2012 Ecology Van Stone RI and 2014–2015 Ecology Van Stone FS that are relevant to the Upland RI.

3.8.1 2011–2012 Ecology Van Stone RI

The purpose of the 2011–2012 Ecology Van Stone RI was to evaluate the potential environmental impacts from historical mining operations and the extent of ongoing releases of contaminants at the site. All analyses were performed in a manner consistent with the methods and guidelines stated in the Sampling and Analysis Plan/Quality Assurance Project Plan (Ecology 2012). RI fieldwork was conducted during three field events in October and November 2011 and June 2012 to collect samples from the tailings piles, waste rock piles, haul roads, mill area, and streambanks along Onion Creek and the tributaries draining the site features (Ecology 2013b) (Map 3-12a and Map 3-12b). The RI established five areas of interest (AOIs) that were delineated based on the geographic location within the upper watershed, potential environmental impacts associated with mining activities, transport mechanisms for potentially impacted media, and the time sequence associated with the operation of the mine (Ecology 2013b) (Map 3-12b). Discrete grab samples were collected at specific locations based on review of documentation of historical mine operations and visual observations during fieldwork (Ecology 2013b).

Fifteen discrete grab samples of background soil were collected from the upper watershed area to characterize the area's natural background concentrations (Ecology 2013b) (Map 3-12a and Map 3-12b). To evaluate the nature and extent of contamination at the site, surface soil discrete grab samples were collected along transects, stained areas, tailings piles, or eroded waste rock at 159 locations within the five AOIs. Nine 30-point composite samples and two five-point composite samples were collected from waste rock piles in AOI-1 (mill facility, open pits, and waste rock). Three five-point composite samples were collected from the Upper Tailings Pile and Lower Tailings Pile in AOI-2 and AOI-3. All samples were collected from the upper 3 in. below any nondecomposed surface litter. The surface sample locations were geographically distributed within each subarea to encompass varying soil types, underlying geology, elevation, slope, and aspect (Ecology 2013b).

Soil analysis for each sample was limited to the < 2-mm-size fraction, obtained by passing the material through a No. 10 sieve. Soil samples were analyzed for total recoverable metals (TAL metals) by EPA Methods 6010B, 6020, and 7471A; total petroleum hydrocarbons by Northwest Total Petroleum Hydrocarbon - Semivolatile Petroleum Products (Extended) Method (subset of samples); PCBs by EPA Method 8082 (subset of samples); volatile organic compounds (VOCs) by EPA Method 8260B (subset of samples); polycyclic aromatic hydrocarbons (PAHs) by EPA Method 8270D (subset of samples); and total solids by SM 2540B (Ecology 2013b).

Surface water and sediment samples were also collected as part of the 2011–2012 Ecology Van Stone RI; however, these media are not being evaluated in the Upland RI report, and therefore these samples are not described here.

3.8.2 2014–2015 Ecology Van Stone FS

The objectives of the 2014–2015 Ecology Van Stone FS were to develop and evaluate cleanup alternatives to address contamination identified in the RI and select a preferred cleanup alternative (Ecology 2017a). Additional investigations were conducted in support of the FS after the completion of the RI to evaluate the extent or presence of metals and asbestos, evaluate leaching and acid-generating potentials, and determine geotechnical properties of the tailings. To better define lateral and vertical extents of contamination in the mill area and evaluate leaching and acid-generating potential of waste rock in the mining area, 18 test pits (MS-19 through MS-36) were excavated in AOI-1 in October 2015 (Ecology 2017a) (Map 3-12a and Map 3-12b). One sample was taken from each of the 18 test pits at depths of 6 to 12 in. bgs or various depths from 3 to 8 ft bgs. Six hollow-stem-auger borings were advanced in AOI-2 in January 2015, and three samples were taken from each boring at various depths from 31 to 62 ft bgs for a total of 18 samples. Five hollow-stem-auger borings and two shallow test pits were advanced in AOI-3 in December 2014 and October 2015, and multiple samples were collected from each boring at various depths from 27 to 97 ft bgs, for a total of 23 samples (Ecology 2017a).

Soil analysis for each sample was limited to the < 2-mm-size fraction by passing the material through a No. 10 sieve (Ecology 2017a). Soil samples were analyzed for total recoverable metals (TAL metals) by EPA Methods 6010B, 6020, and 7471A; asbestos by 40 CFR 763.109 Appendix A; total petroleum hydrocarbons (where suspected) by Northwest Total Petroleum Hydrocarbon - Semivolatile Petroleum Products (Extended) and Volatile Petroleum Products (Extended) Methods; SPLP metals by EPA Method 1312/6020A; TCLP metals by EPA Method 1312/6020A or 7470A; acid/base accounting by EPA Method Modified Sobek 3.2; and total solids by SM 2540B (Ecology 2017a).

3.9 2003–2004 EPA ANDERSON CALHOUN EE/CA

The Anderson Calhoun Mine/Mill is a former barium, lead, and zinc mine and mill that operated from 1910 to the early 1980s (Table 2-6 and Appendix A). The site was recommended for further action in the 2001 EPA Stevens County Mines and Mills PA/SI (USEPA 2002a). The site was addressed under CERCLA, and an engineering evaluation/cost analysis (EE/CA) was performed in 2004. This work was performed outside the UCR RI/FS project.

The objectives of the 2003–2004 EPA Anderson Calhoun EE/CA were to summarize the nature and extent of contamination associated with the Anderson Calhoun Mine/Mill site and to evaluate alternatives for the purpose of selecting an appropriate response action to address such contamination (USEPA 2007a). In October 2004, SECOR International Incorporated completed an EE/CA investigation at the site. Two types of soil investigations were conducted as part of this EE/CA: a soil screening survey of the mine/mill area and a soil transect survey downwind of the tailings impoundment. Additional investigation was conducted on the transformer area, former assay dump, underground storage tank, and oil-stained areas; these areas were excluded from this study review. For the soil screening survey of the mine/mill area, a coordinate grid system with 50-by-50-ft square grids was established in the area, and a surface soil sample (0 to 2 in.) was collected at each grid node. XRF was used to screen the concentrations of metals at each grid node, and every 20th sample point from the grid system was submitted for laboratory analysis for a total of seven samples (Map 3-13). For the soil transect survey downwind of the tailings impoundment, a soil sampling transect was established along the southern side to quantify the dispersion of tailings materials from north/northwest and down-valley winds. Twelve surface soil discrete grab samples (SS-WND samples) were collected at the surface (0 to 2 in.) at 100-ft intervals starting at the berm of the tailings impoundment and extending downwind of the impoundment (USEPA 2007a).

Source investigations were also completed as follows. Samples from three white crystalline waste piles (WCWP-1 through WCWP-3) were collected (0 to 2 in.) and analyzed to determine the presence or absence of barium carbonate and other metals (USEPA 2007a). In addition, several small piles of waste material were present south of the mill building and four were sampled (0 to 2 in.) by digging with a spade and hand auger (SS MILL samples). The vertical extent of tailings in the impoundment was delineated by excavating three test pits (TP-4 through TP-6) by backhoe. The three test pits were aligned similar to, but offset from, test pit locations TP-1 through TP-3 that were excavated as part of the site reconnaissance. Samples were collected from each of the three test pits (USEPA 2007a).

Samples were analyzed for total recoverable metals (barium, cadmium, copper, lead, selenium, and zinc) using EPA Method 6010 inductively coupled plasma-atomic emission spectrometry (ICP-AES) (USEPA 2007a).

3.10 2011 PORT OF ENTRY SOIL REMEDIATION

The 2011 Port of Entry Soil Remediation (Shannon and Wilson 2011) included implementation of a cleanup action that was completed in 2011 independent of the UCR RI/FS. The cleanup action was performed to address soil contamination issues and remediation associated with the

construction of a U.S. Customs and Border Protection Land Port of Entry facility near the U.S.-Canada border in Stevens County, Washington. The Land Port of Entry facility reportedly extends southwest from the U.S.-Canada border by approximately 1,900 ft. During planning for Land Port of Entry facility construction, surface and subsurface soil samples were collected and analyzed[63] to screen site soils that may have been contaminated with metals from historical aerial emissions from the smelter in Trail, British Columbia (Shannon and Wilson 2011). Soil sampling and analyses completed in April and May 2011 identified concentrations exceeding screening levels[64] for lead and arsenic in surface soil (0 to 6 in. bgs) and cadmium in subsurface soil (0 to 3 ft bgs) (Shannon and Wilson 2011).

A cleanup action plan was prepared and implemented by U.S. Customs and Border Protection to remediate soil within the construction footprint (Shannon and Wilson 2011). The remediation was done in two phases, with confirmation soil sampling performed after the completion of each phase. Phase 1 consisted of a general site-wide excavation of the entire construction area removing approximately 10 in. below grade. Following the Phase 1 soil removal, confirmation samples were collected using a grid sampling approach at a frequency of one sample per approximately 3,140 ft^2. Confirmation samples were collected as discrete grab samples at a depth of 0 to 3 in. below the post-excavated grade, which corresponds to a depth of 10 to 13 in. below the original ground surface (Map 3-14). A total of 58 confirmation soil samples (including 3 duplicates) were collected during Phase 1 and were analyzed for total recoverable metals (lead, arsenic, and cadmium) by EPA Method 6020 (Shannon and Wilson 2011).

Based on the Phase 1 confirmation sample results, three locations were identified as exceeding soil cleanup criteria and were determined to require further excavation in Phase 2 (Shannon and Wilson 2011). Phase 2 consisted of spot excavations to a depth of 8 to 12 in. below grade (approximately 10 in.) in these locations. A total of 12 Phase 2 confirmation samples (including 1 duplicate) were collected as discrete grab samples at a depth of 0 to 3 in. below the post-excavated grade, which corresponded to a depth of approximately 20 to 23 in. below original ground surface. Phase 2 confirmation samples were also analyzed for total recoverable metals (arsenic, cadmium, and lead) by EPA Method 6020 (Shannon and Wilson 2011).

[63] The April and May 2011 pre-removal samples are not available and were not included in the Upland RI data set.
[64] Soil samples results were compared to Washington MTCA Method A soil cleanup levels for unrestricted land use. The MTCA Method A cleanup levels were also used to confirm completion of soil remediation at the Land Port of Entry facility. The MTCA Method A soil cleanup levels for unrestricted land use for arsenic, cadmium, and lead are 20 mg/kg, 2 mg/kg, and 250 mg/kg, respectively.

3.11 BONANZA MINE ROADBED CLEANUPS

Two cleanups were completed by the Stevens County Department of Public Works (SCDPW) in 2007 to remove roadbed materials sourced from the Bonanza Mine property that had been used in road construction activities. The Bonanza Mine is a historical mine where lead-zinc ore was mined from the early 1900s to the 1950s (SCDPW 2008a). Rock from an outcrop near the Bonanza Mine was mined, crushed, and screened by SCDPW, then transported and placed as roadbed material on Brooks Road and Peterson Swamp Road. The cleanup work was completed independent of the UCR RI/FS.

At the time of construction, SCDPW was not aware that the roadbed material contained metals (arsenic, cadmium, and lead) at concentrations exceeding Model Toxics Control Act (MTCA) Method A soil cleanup levels. Expedited removal actions were initiated by SCDPW after being notified by Ecology of the potential for elevated metals concentrations in the roadbed materials. The removal actions were completed under Ecology's Voluntary Cleanup Program and included removing the roadbed material originating from the Bonanza Mine, returning the roadbed material to the source at the Bonanza Mine property, and collecting confirmation samples to document the removal of the roadbed material. Field screening was performed using a portable XRF device during removal activities to measure lead concentrations, and all of the confirmation samples were analyzed at a laboratory for total recoverable lead by EPA Method 6010B. Selected samples were also analyzed for arsenic, cadmium, copper, and zinc by EPA Method 6010B (total recoverable metals) and mercury by EPA Method 7471 (SCDPW 2008a,b).

The following subsections describe soil sample results from the voluntary cleanup actions that are evaluated in the Upland RI report. These actions are summarized in the 2007 Brooks Road/Bonanza Mine Roadbed Voluntary Cleanup, and the 2007 Peterson Swamp/Bonanza Mine Roadbed Voluntary Cleanup.

3.11.1 2007 Brooks Road/Bonanza Mine Roadbed Voluntary Cleanup

The Brooks Road site consists of an approximately 2.5-mile-long, north-to-south trending roadway in Stevens County, Washington (SCDPW 2008a). Potentially elevated metals-impacted roadbed material sourced from the Bonanza Mine was removed from Brooks Road during March and April 2007, and confirmation sampling was completed in late April 2007. The Bonanza Mine material was encountered at a thickness of 3 to 6 in. across the surface of the roadway, although thicknesses of up to 12 in. were encountered in some locations. A total of 80 confirmation samples were collected. These included 56 discrete grab soil samples collected at a frequency of 2 samples from every 500 ft along the roadway, 19 samples from the intersection of residential driveways and Brooks Road, and 5 background samples. Only the

background soil samples are used in this Upland RI report. The background soil sample locations are shown on Map 3-15. Confirmation samples were collected as discrete grab samples from 0 to 3 in. bgs (SCDPW 2008a).

Based on the results of the first sampling event, additional surface material was removed from the roadbed and driveways in select areas where laboratory or XRF results exceeded the cleanup level of 250 mg/kg for lead. The second sampling event included collecting soil samples for laboratory analysis from 21 locations on May 30, 2007.

3.11.2 2007 Peterson Swamp/Bonanza Mine Roadbed Voluntary Cleanup

A voluntary cleanup action was performed to excavate roadbed materials along Peterson Swamp Road and remove streambed sediment along Harbison Gulch in Stevens County, Washington (SCDPW 2008b). Potentially elevated metals-impacted roadbed material sourced from the Bonanza Mine was removed from Peterson Swamp Road in March 2007. Sediment along a seasonal creek within Harbison Gulch that trends along Peterson Swamp Road was also removed. The initial removal of roadbed materials along Peterson Swamp Road was completed on approximately May 15, 2007. The first confirmation sampling event occurred from May 15 to May 29, 2007. After removal activities, confirmation soil sampling was performed at both locations at approximately 500-ft intervals along the roadway. In total, 156 laboratory confirmation samples of the upper 3 in. of roadbed and road bank material remaining after the removal action were collected for laboratory analyses (SCDPW 2008b). These included 116 discrete grab soil samples collected at a frequency of 2 samples from every 500 ft along the roadway, 15 background samples offset from the roadway, and 25 confirmation soil samples collected at the intersection of each residential driveway with Peterson Swamp Road and Queen of Sheba Road along the length of the survey area. Only the background soil samples are used in this Upland RI report. The background soil sample locations are shown on Map 3-16.

Based on the results of the first sampling event, additional surface material was removed from the roadbed and driveways in areas where laboratory or XRF results exceeded the lead cleanup level of 250 mg/kg. The second sampling event was to confirm the removal of the residual contaminated roadbed material from 17 roadbed and 4 driveway locations on June 19, 2007 (SCDPW 2008b).

3.12 WELLS LICHEN STUDY

A 2015 dissertation by Kevin Wells, the Wells Lichen Study, describes a study of heavy metal contamination in soil and lichen tissue in the Colville National Forest. The objective of this study, which was completed independent of the UCR RI/FS, was to characterize concentrations

of heavy metals, nitrogen, and sulfur within collected lichen tissue and soil samples from sampling plots within the Colville National Forest (Wells 2015). Co-located soil and lichen tissue samples were collected from 23 plots inside the Colville National Forest boundary from 0.8 to 25 miles from the U.S.-Canada border (Map 3-17). Seventeen of the plots are located within or in the vicinity of the OU 3 study area; the other six locations are outside of Stevens, Ferry, and Lincoln Counties and are not included in the Upland RI data set. The lichen tissue and soil samples were collected during one sampling event from June 9 to 21, 2015. Six-point composite soil samples were collected within a radius of approximately 50 ft or less from the center of each 1-acre plot (Wells 2015) (Map 3-17).

Leaf litter and woody debris were removed prior to collecting the soil samples. Soil samples were collected using a decontaminated stainless-steel trowel and a stainless-steel measuring cup (Wells 2015). Soil samples were collected from the top of the soil layer to 3 in. bgs. The soil samples were homogenized, dried, crushed with a mechanical grinder, and passed through a stainless-steel 2-mm sieve. Soil organic matter was determined by loss on ignition, and total sulfur and total Kjeldahl nitrogen were analyzed by flow injection analysis. After the loss on ignition analysis, residual material was analyzed for 13 metals, including cadmium, zinc, and lead, by a microwave-assisted nitric acid digestion process and by ICP-AES (Wells 2015). By oxidizing the sample before digestion, the dissolution properties of the samples were modified (Appendix C).

3.13 2007–2010 USGS SOIL STUDY

The report 2007–2010 USGS Soil Study (USGS 2013) describes a study completed by USGS from 2007 to 2010 with the objective of estimating the abundance and spatial distribution of chemical elements and minerals in soils of the conterminous U.S. Surface and subsurface samples were collected from 4,875 sites across the conterminous U.S. To ensure the quality of the study's chemical analyses, samples were randomized prior to analysis, international reference materials were provided, project standards were inserted, and analytical duplicates of project samples were included. The sampling sites were determined via a low-density grid formation of approximately one site per 1,600 km^2. A total of nine sites were located in the region, within Stevens, Ferry, and Lincoln Counties (USGS 2013) (Map 3-18).

Three samples were taken at most sites: a surface soil sample from a depth of 0 to 5 cm, a core of the soil A horizon (the uppermost mineral soil), and a sample from the soil C horizon (generally partially weathered parent material) or, if the top of the C horizon was deeper than 1 m, a sample from about 80 to 100 cm (USGS 2013).

Each sample was air-dried at ambient temperature, disaggregated, and sieved to < 2 mm (USGS 2013). The < 2-mm material was then crushed to < 150 μm prior to chemical analysis. Samples were analyzed for total digestion metals (41 metals) using a four-acid (hydrochloric, nitric, hydrofluoric, and perchloric) digestion and analysis by ICP-AES, ICP-MS, and atomic absorption spectrometry. Total recoverable mercury was determined by cold vapor atomic absorption (CVAA) spectrometry after dissolution in a mixture of nitric and hydrochloric acids (USGS 2013).

3.14 ECOLOGY NATURAL BACKGROUND SOIL STUDY

The purpose of this study, Ecology Natural Background Soil Study, was to define a range of values that represent the natural concentration of metals in surficial soils throughout Washington State (Ecology 1994). This study does not reference a quality assurance project plan, but used check standard, duplicate, spike, and blank samples (Ecology 1994). The statewide natural background assessment sampling program included collection of 60 samples from 12 main geologic and urban areas in 1990, and then collection of 389 samples from 4 major urban areas from 1991 to 1993 (Ecology 1994). Of the areas sampled, the Spokane Basin was the only area that included samples in the UCR Site region.

Soil samples were collected from 27 locations in the Spokane Basin upstream from the Columbia River, with three soil samples located in Lincoln County in an area south of the Spokane River and south of Davenport, Washington (Ecology 1994) (Map 3-19). At five locations, a soil sample was collected from 2 to 3 ft bgs. At the remaining 22 locations, samples included a "surficial" composite soil sample collected from approximately 2 ft bgs and vertical composite samples. Composite "surficial" samples were collected from hand-dug test pits at the center and the four corners of a 1-acre plot. A soil auger was used to collect material from the bottom 6 in. of each test pit. Vertical profile samples were collected from hand-dug holes completed to a total depth of up to 3 ft bgs at the center of each plot. Vertical profile samples were then collected from the A, B (mineral horizon below the A horizon), and C soil horizons (Ecology 1994).

Soil samples were sieved to 19.0 mm in the field before submitting for laboratory analysis. Samples were sieved to sizes < 2 mm at the laboratory and analyzed for total recoverable metals

(15 metals) by EPA Method 6010 (ICP-AES), EPA Method 7471 (CVAA, for mercury), and EPA Methods 7060 and 7740 (for arsenic and selenium[65]) (Ecology 1994).

3.15 NURE-HSSR PROGRAM

The objectives of the National Uranium Resource Evaluation (NURE) Hydrogeochemical and Stream Sediment Reconnaissance (HSSR) program were to acquire and compile geologic information to assess the magnitude and distribution of uranium resources and to determine areas favorable for the occurrence of uranium in the U.S. (USGS 2006). The program was initiated by the U.S. Atomic Energy Commission (now the U.S. Department of Energy [DOE]) in 1973 and began in 1975 under the responsibility of four DOE national laboratories. Each DOE laboratory developed its own sample collection, analytical, and data management methodologies and hired contractors to collect the samples. Field sampling teams from the Savannah River National Laboratory and Lawrence Livermore National Laboratory collected numerous stream sediment and soil samples in Ferry, Lincoln, and Stevens Counties as part of the study, including many within the UCR Site and surrounding areas. Soil sampling methods differed slightly between laboratory teams and for sediments versus soil; however, all samples were collected as five-point composite surface samples (USEPA 2016a). Sediment and soil samples were sieved to 150 µm and analyzed for total digestion metals using a variety of methods, including instrumental neutron activation analysis (INAA), atomic absorption, and other methods. Samples analyzed at Lawrence Livermore National Laboratory were also ground to 500 mesh before analysis (USGS 2006).

A subset of the NURE-HSSR samples underwent reanalysis decades after the original collection date (USGS 2008a,b). The reanalyses included a more complete list of metals and used well-documented analytical techniques (Appendix C) that are consistent with analytical methods used for modern environmental studies. These reanalyses are described in the following subsections.

The NURE-HSSR samples were collected from 1977 to 1979, which may be before more recent and current anthropogenic sources were present in the locations sampled, and this will be considered when interpreting the NURE-HSSR results in the Upland RI relative to specific anthropogenic features.

[65] Detection limits for selenium were elevated in this study (5 to 15 mg/kg) and only 2 of the 14 selenium samples were reported as detected. Selenium results were therefore not incorporated into the UCR RI/FS database and were not used in this RI.

3.15.1 USGS Reformatted NURE-HSSR Program

Reformatted[66] data from the original analyses of NURE-HSSR samples are available from USGS (2006) (Map 3-20). These data include results for up to 41 elements (including arsenic, cadmium, copper, mercury, lead, and zinc) by INAA, sequential atomic absorption analysis, emission spectrography, and/or fluorescence spectroscopy/mass spectrometry (USGS 2006).

3.15.2 USGS Midnite Mine Sediment Study

The purpose of this study, USGS Midnite Mine Sediment Study, was to provide an evaluation of the extent of downstream impact of the Midnite Mine site on Blue Creek and Lake Roosevelt (USGS 2008a). The Midnite Mine-related sediment cores collected during this study represent sediment influenced by the Spokane Arm of Lake Roosevelt; therefore, these samples are not included for evaluation in the Upland RI or described here. Part of this evaluation included examining and reanalyzing previous stream sediment samples. In 1979, soil and sediment were sampled in the tributary streams in the Blue Creek and Sand Creek drainage basins under the NURE-HSSR program. Select samples collected during the NURE-HSSR program in the vicinity of the Midnite Mine were retrieved from the USGS archive (USGS 2003) and reanalyzed to support the Midnite Mine sediment study (USGS 2008a) (Map 3-20). Those samples were analyzed for total recoverable metals (47 elements) by ICP-MS following digestion by EPA Method 3050.

3.15.3 USGS NURE Sample Reanalysis

The USGS NURE Sample Reanalysis conducted by USGS "produced [a] body of geochemical data for the United States based primarily on stream sediments that were analyzed using a consistent set of methods" (USGS 2008b). The objective of the National Geochemical Survey was "to analyze at least one stream-sediment sample from across the U.S. at a frequency of one sample per every 289 km^2 area." Other solid sample media (i.e., soil) were substituted for stream sediment where necessary. The National Geochemical Survey used existing analysis and reanalysis of samples in USGS archives as well as analysis of new samples (USGS 2008b). No sampling was completed in the area of the UCR Site specific to the National Geochemical Survey; however, as part of this survey, in the early 2000s, USGS reanalyzed various archived NURE-HSSR samples that included samples collected in and around the UCR Site (Map 3-20). USGS reanalyzed a total of 1,488 archived NURE-HSSR samples.

[66] USGS reformatted the original NURE-HSSR data by adding or correcting coordinates from the original field maps or published tables and removed duplicate records (USGS 2006).

These data were reanalyzed for 40 metals using ICP-AES. Arsenic and selenium were analyzed by flameless atomic absorption-hydride generation. Mercury was analyzed using CVAA spectrometry (USGS 2008b).

3.16 STUDIES CONDUCTED IN CANADA

Several soil studies conducted in Canada near the Trail Facility or in the surrounding region collected data that are useful for the Upland RI. The following subsections describe the soil sample results from these studies. These samples were not collected within the OU 3 study area, and it is not the intent or purpose of this Upland RI report to assess the nature and extent of metals concentrations in soil in Canada. However, these data can be used to inform the evaluation of nature and extent of metals in upland soil in the OU 3 study area and their transport and fate and, therefore, the physical/chemical CSM for metals in soil in the OU 3 study area.

3.16.1 Trail Smelter Terrestrial ERA

The purpose of the Trail Smelter Terrestrial ERA was to determine whether there are or could be ecological effects attributable to operation of the smelter at the Trail Facility, the significance of those effects, and the factors influencing those effects. The Trail Smelter Terrestrial ERA soil sampling methods are summarized in the quality assurance management plan (Teck Cominco Metals Ltd. 2006). A total of 489 five-point composite samples were taken, with each composite sample made of soil from the central point and points 10 m out from that point in each cardinal direction. Composite samples were collected from depths of 0 to 6 in. bgs from 2001 to 2004 (Teck Metals Ltd. 2011) (Map 3-21). Before sampling the soil, the litter, fiber, and humus layer was removed, photographed, and refrigerated. Clean and dried, t-handled stainless-steel augers were used to collect the soil at the main rooting medium of the site vegetation. Cores were also taken at the center point and at the four cardinal points (Teck Metals Ltd. 2011).

Samples were analyzed for total recoverable metals concentrations for 29 elements (including arsenic, cadmium, copper, mercury, lead, and zinc) using the British Columbia Ministry of Environment and Climate Change Strategy strong acid leachable metals extraction method (Teck Metals Ltd. 2011).

3.16.2 2001 Trail Area Soil Background Assessment

The purpose of the 2001 Trail Area Soil Background Assessment was to establish the local background levels of elements in soil in the Trail Facility vicinity. A total of 37 soil samples were collected, plus duplicates, from the following locations: Sheep Creek, King George

National Park, Blueberry Creek, Strawberry Creek, Champion Lake, Erie Creek, Salmo River, and the Pend Oreille Dam (Goodarzi et al. 2001) (Map 3-22). These locations span from west of the Rossland Range to east of the Bonnington Range. The sampling sites chosen had limited recent anthropogenic (e.g., camping sites) and natural (e.g., landslide) disturbances and varied in slope and aspect. The soil samples were collected from the 0- to 15-cm portion of the soil profile (A horizon) using a soil-coring device. Leaf litter and other undecomposed organic material were removed prior to coring to ensure that the 15-cm interval was representative of the soil. Duplicate soil cores were taken at each site to ensure that samples were representative of the sampling site. Slope of the SA (using a Brunton compass), soil color (using a Munsell color chart), soil texture/grain size, and soil pH were documented for each of the samples (Goodarzi et al. 2001).

Soil samples were air-dried at room temperature for 72 hours, then sieved to < 2-mm-size fraction. Soil samples were analyzed for total recoverable metals (44 elements) using ICP-MS following a hot digestion with nitric and hydrochloric acids. Total recoverable mercury was analyzed by CVAA (Goodarzi et al. 2001).

3.16.3 2005 Waneta Expansion Project

The purpose of the 2005 Waneta Expansion Project was to identify the remedial approach to be applied at the Waneta forebay worksite and establish worksite environmental baseline soil conditions for construction purposes (WEPC 2005). Soil in the proposed dredging areas was known to have significant metals contamination, and any disturbance could have released the metals into the river for transport. Six areas of potential environmental concern were chosen to establish the worksite environmental baseline soil conditions for reference during dredging (Map 3-23a).

To establish the baseline soil conditions, 15 test pits and 23 surficial test holes were dug and sampled across the following six areas: Powerplant site (7 test holes and 9 test pits), Site C (2 test holes and 4 test pits), Site A1 (5 test holes), Site A3 (4 test holes and 2 test pits), Site E (2 test holes), and Site F (3 test holes) (WEPC 2005) (Map 3-23b). The test pits were excavated using a backhoe and sampled from 0 to 3 m below grade on May 26, 2005. The surficial test holes were hand excavated and sampled with a hand auger from 0 to 0.2 m below grade on May 25 and 26 and June 1 and 21, 2005. The test pits and test holes were logged for soil type, presence or absence of fill material, odors and/or visual staining, and hydrocarbon vapor concentrations (WEPC 2005).

Select soil samples were analyzed for 30 metals by total recoverable metals by ICP-AES, ICP-MS, and CVAA. Select samples were also analyzed for petroleum hydrocarbons, PAHs, VOCs, pH, moisture, and/or chlorophenols (WEPC 2005).

3.16.4 2001 Trail Area Moss Bag Study

The purpose of the 2001 Trail Area Moss Bag Study was to 1) assess the correlation between the concentrations of arsenic, cadmium, copper, mercury, lead, and zinc in the soil around the Trail Facility and their measured rates of aerial deposition onto moss bags and 2) use this correlation to indicate the possible effect of airborne material on soil geochemistry (Goodarzi et al. 2002). Composite surface soil samples were collected at 21 locations from the 0- to 10-cm upper part of the soil profile (A horizon) (Map 3-24). Two or three soil samples were taken within a few meters of each other and mixed to serve as a composite for each sampling location (Goodarzi et al. 2002).

The composite soil samples were air-dried, and the < 2-mm-size fraction was recovered by dry-sieving with a stainless-steel sieve. The recovered materials were then ground and homogenized before analysis. Total cadmium, copper, lead, and zinc were measured using ICP-MS following a hot digestion with nitric-perchloric-hydrofluoric acids. Arsenic was measured using the atomic absorption-hydride procedure after digesting the sample with aqua regia. Mercury was measured using CVAA after digesting the sample with aqua regia (Goodarzi et al. 2002).

3.17 OTHER STUDIES USED TO SUPPORT THE HHRA

In addition to metals in soil, the HHRA (USEPA 2021) evaluated potential human health risks from exposure to air and indoor dust. Applicable air data used in the HHRA are summarized in Section 3.17.1 below. Indoor dust was evaluated in the HHRA using DU-specific soil data and default EPA assumptions for soil-to-dust transfer.

Additional upland-associated media evaluated for CCT high-intensity resource users in Appendix 1 to the HHRA included plant tissue, upland birds, and upland game. Of these media, plant tissue was directly sampled, and upland bird and game concentrations were derived using uptake models from surface water and soil. Plant tissue data used in the HHRA are described in Section 3.17.2 below.

The HHRA also evaluated potential human health risks from exposure to surface water, beach sediment, fish tissue, and macroinvertebrate tissue. These media will be addressed in the Aquatic BERA and Aquatic RI reports.

3.17.1 Air

The air data used in the HHRA are described in Section 2.6.3 of the HHRA (USEPA 2021). From 1994 to 2009, Teck Metals Ltd. operated an outdoor air monitoring station at Sheep Creek near Northport, Washington. Every 6 days, a composite air sample was collected and analyzed for arsenic, cadmium, lead, zinc, and particulate matter 10 μm and smaller (PM_{10}).[67] The 2002 to 2009 data from the Sheep Creek air quality monitoring station were used in the HHRA to evaluate exposure to indoor and outdoor air for all human receptor populations (including the CCT and STI populations in Appendices 1 and 2 of the HHRA). The 2002 to 2009 date range was selected because metal and particulate concentrations in outdoor air at the Site are assumed to be lower at present than those measured at the Sheep Creek station from 1994 to 2002 (USEPA 2021).

The most recent data reported to the Environment Canada National Pollutant Release Inventory indicate that emissions of arsenic, cadmium, and lead have decreased since 2009 and are currently lower than levels prior to 2009 (USEPA 2021). However, individual metals may be emitted at varying and sometimes higher rates. EPA concluded in the HHRA that the existing data were sufficient to determine present-day risk for the purposes of the HHRA based on historical data, which is likely an overestimate. EPA used more recent data collected between 2012 and 2014 by Teck Metals Ltd. at the Columbia Gardens air quality monitoring station, approximately 3 miles north of the U.S.-Canada border, to further evaluate potential uncertainty in air concentrations between the Trail Facility and Northport.

Sheep Creek data were analyzed for arsenic, cadmium, lead, zinc, and PM_{10} in a total of 390 samples from 2002 through 2009. Arsenic, cadmium, lead, and zinc were detected at a frequency greater than 5 percent and were retained as chemicals of interest in the HHRA. The results of the air data evaluation in the HHRA are further discussed in Section 5.1 of this Upland RI report.

3.17.2 Terrestrial Plants

The 2018 Plant Tissue Study (see Section 3.3.7) was designed to characterize the concentrations of metals in the tissues of wild, culturally important terrestrial plants in the OU 3 study area that are used for food or cultural purposes (TAI 2019c). The target species list for the 2018 Plant Tissue Study was developed based on information provided by CCT on parts of plants consumed, mouthed (e.g., for weaving), or otherwise used by CCT members (TAI 2019c). A list

[67] PM_{10} describes inhalable particles with diameters that are generally 10 μm and smaller.

of the plant tissues sampled as part of this study is provided in Table 3-2. Data collection efforts focused on obtaining information that could be used in the exposure assessments for people (adults and children) who ingest, mouth, or otherwise use plants from the UCR Site.

TAI collected plant tissue and co-located soil samples during three sampling events in 2018: April 24 through May 2 (spring), June 18 through 20 (June), and August 20 through 28 (August) (TAI 2019c). Co-located soil sampling methodology is discussed in Section 3.3.7. Plant tissues targeted for collection were determined based on their expected stage of growth in each season, typical collection times (Fraser 2017), and field observations during reconnaissance and sampling events. Plants were collected from one nonresidential and nine TA DUs in the ADA. These included three TA DUs that were sampled in the 2014 Residential Soil Study (USEPA 2016a) that had bioavailability-adjusted soil lead concentrations > 700 mg/kg and other TA DUs with lower soil lead concentrations measured during the 2014 and 2016 Residential Soil Studies (USEPA 2016a; TAI 2017a). Willows were not found on the TA DUs that were surveyed during the August 2017 field reconnaissance (TAI 2017d), although willows were collected from two additional SAs located along the Columbia River shoreline that were identified during the August 2018 sampling event.

Six plant tissue samples were targeted for collection from the anticipated high- and low-lead sample areas for each plant species and tissue type. Plant tissue samples were collected from an individual plant or, if necessary to meet sample mass requirements for the laboratory analyses, from two or more adjacent individual plants to form a composite sample. Samples were submitted for analysis of TAL metals (except calcium, magnesium, potassium, and sodium). Total mercury was analyzed in a subset of samples of stem and leaf tissue based on studies that have demonstrated mercury is highest in these tissues (Li et al. 2017).

Chemistry data for plant parts targeted in the study were used in the HHRA to evaluate the potential for metals uptake into plants and the potential human exposure to metals by ingestion or other uses of the plant parts that were analyzed in the study (TAI 2019c). The co-located soil sample results were used in tissue uptake models to estimate muscle concentrations of metals in upland birds and game (mammals); the average soil concentration was used as the soil exposure point concentration (EPC) in the HHRA.

3.18 LEAD ISOTOPE REPORTS AND STUDY

Stable lead isotope data have been collected in OUs 1, 2, and 3 and elsewhere in northeastern Washington.[68] Specifically, stable lead isotopes were measured in sediment samples from the Upper Columbia River, upland lakes in OU 3, and elsewhere in northeastern Washington[69], and other media associated with mining/milling and smelter operations. However, stable lead isotope data in upland soils are not available, and delineating the likely extent of smelter impacts is not an objective of this Upland RI report.[70]

As directed by EPA, the following sections provide summaries of the lead isotope data collection efforts that have occurred in northeastern Washington, but these data are not considered further in this Upland RI report.

3.18.1 Vlassopoulos Expert Reports

Dr. Dimitrios Vlassopoulos was retained by the State of Washington and CCT in the case of Pakootas et al. v. Teck Cominco Metals Ltd. (Case No. CV-04-0256 United States District Court for Eastern Washington) to provide opinions in support of Plaintiffs. Dr. Vlassopoulos produced three expert reports discussed herein—one from 2010, one from 2014, and one from 2022—that relied on stable lead isotope data (Vlassopoulos 2010, 2014, 2022).

3.18.1.1 2010 Vlassopoulos Expert Report

The 2010 Vlassopoulos Expert Report purports to evaluate and fingerprint the occurrence and release of Trail Facility discharges into the Columbia River in Canada and possible downstream sediment accumulation areas. Dr. Vlassopoulos used two "fingerprinting" approaches to support his opinions that metals in UCR sediments had been discharged from the Trail Facility: geochemical fingerprinting and lead isotope fingerprinting.

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[68] These studies were all directly or indirectly associated with the Pakootas v. Teck Metals Ltd. Lawsuit (Pakootas v. Teck Cominco Metals Ltd., Case No. CV-04-0256-LRS, United States District Court for the Eastern District of Washington.)

[69] In addition to the studies listed, Ecology performed lead isotope analysis on sediments obtained from a single lake core in 2012 for the purpose of estimating sedimentation rates (Ecology 2013c). This lake was also sampled to provide data for the 2014 Vlassopoulos Expert Report.

[70] In comments on the Draft Final Upland RI Report, EPA directed TAI to eliminate all discussion of relative source contribution on the basis that it constitutes source attribution and delineation (USEPA 2024d). Consequently, no discussion of lead isotope data interpretations relating to source (smelter) attribution are presented here or in later sections of the Final Upland RI Report.

Dr. Vlassopoulos relied on 31 sediment core samples collected by CCT in 2010 and 8 archived samples obtained from Ecology (2007), all of which were analyzed at the University of Washington Isotope Geochemistry Laboratory using high-precision isotope ratio mass spectrometry. He used literature values for the lead isotope composition of the ores historically processed at the Trail Facility and ore deposits within tributaries of the UCR in the report.

3.18.1.2 2014 Vlassopoulos Expert Report

The main objective of the 2014 Vlassopoulos Expert Report was to opine on impacts from smelter metals emissions in northeastern Washington. Stable lead isotope analyses were performed on archived lake sediment composite and core samples collected by Ecology and lake sediment cores collected by Dr. Vlassopoulos.

The archived lake sediment composite and core sediment samples collected by Ecology in 2010 and 2011 included 19 lakes[71] and 2 wetlands[72] across northeastern Washington (Ecology 2011b, 2013c). Dr. Vlassopoulos collected sediment cores from three lakes (Cedar Lake, Ellen Lake, and Bonaparte Lake). The archived sediment composite and core samples collected by Ecology, as well as the sediment core samples collected by Dr. Vlassopoulos, were analyzed for stable lead isotopes at the University of Washington.

3.18.1.3 2022 Vlassopoulos Expert Report

The main objective of the 2022 Vlassopoulos Expert Report was to build on and update previous reports related to the evaluation and fingerprinting of the occurrence and release of metals from Trail Facility discharges into the Columbia River in Canada and possible downstream sediment accumulation areas. Consistent with the 2010 expert report, Dr. Vlassopoulos used geochemical fingerprinting and lead isotope fingerprinting to support his opinions.

The lead isotope data used by Dr. Vlassopoulos in the report included the same samples from CCT and Ecology that were analyzed for the 2010 expert report as well as the literature values for the lead isotope composition of the ores historically processed at the Trail Facility and ore deposits within tributaries of the UCR. Other lead isotope data used in the 2022 expert report include samples of slag from smelters at Trail, British Columbia, and Northport, Washington,

[71] Lakes sampled by Ecology include Swan Lake, Davis Lake, Ellen Lake, South Twin Lake, Summit Lake, Pierre Lake, Cedar Lake, Pepoon Lake, Williams Lake, Bayley Lake, Sullivan Lake, Leo Lake, Browns Lake, Bead Lake, Phillips Lake, Silver Crown Lake, Elbow Lake, Phalon Lake, and Dilly Lake (Ecology 2011b, 2013c).

[72] Wetlands sampled by Ecology include Bowen Lake and Peterson Swamp (Ecology 2013c).

and lead isotope analysis of archived UCR and tributary sediment samples collected by the Natural Resource Trustees in 2013.[73]

3.18.2 2010 Riese Expert Report

Dr. Arthur C. ("Sandy") Riese was retained by Teck Metals Ltd. to give expert opinions (Riese 2011) in the case of Pakootas et al. v. Teck Cominco Metals Ltd. (Case No. CV-04-0256 United States District Court for Eastern Washington). This work was performed outside the UCR RI/FS. The main objective of the report was to develop opinions regarding the release of metals from Teck Metal Ltd.'s smelter and the occurrence of metals in waters, sediments, and tailings in the UCR. Samples were collected from slag from the Le Roi/Northport Smelter; slag from the Trail Facility's pre-KIVCET fuming furnace; tailings from Bossburg, Iroquois, and Van Stone Mines; and sediments adjacent to campgrounds and other locations. In total, 31 samples were collected and analyzed for stable lead isotopes and metals concentrations.

3.18.3 2018 Child et al. Isotope Study

The objective of Child et al. (2018) isotope study was to expand the spatial extent of work done by Vlassopoulos (2010, 2014) and Ecology (2013c) and "build an expanded footprint for the Trail smelter using lead isotope analysis." Six lakes[74] were sampled during the study. The lakes were selected based on a distance of greater than 50 km from the Trail Facility, their location relative to "likely airborne distribution plumes in the Columbia River valley," and their elevation. Sediment cores were collected at the deepest portion of each lake using a box corer, and sediment samples were sectioned into 1-cm intervals from the top 6 cm of sediment and 2-cm intervals from depths below 6 cm. For lake sediment core sampling, the sectioned sediment samples were freeze-dried, homogenized, and analyzed at the Radiogenic Isotope and Geochronology Laboratory at Washington State University. The lake sediment core samples were dated using the ^{210}Pb method, and lead isotope composition was determined for "environmentally available" metal concentrations from aqua regia and 1 molar hydrochloric acid dissolutions using multicollector ICP-MS.

[73] Several archived samples collected by the Natural Resources Trustees were also analyzed for stable copper and zinc isotopes.

[74] Simpson Lake, Roberta Lake, North Twin Lake, South Twin Lake, Owhi Lake, and Buffalo Lake were chosen for the 2018 Child et al. Study.

4 SOIL BACKGROUND

As discussed in Sections 2.4 and 2.10, the metals considered in this Upland RI report occur in the bedrock and soils in the OU 3 study area as the result of natural mineralization and geologic processes. Natural chemical and physical weathering of these geological materials can release and mobilize metals to the environment and contribute to natural background of metals found in soil, surface water, sediment, and biota. The effects of weathering, and the degree to which some portion of metals in these media may be derived from geogenic materials, are expected to vary geographically and are dependent on local geology, terrain, and other conditions. Additionally, ambient atmospheric constituents are transported to and deposited at the UCR Site from global or regional atmospheric sources that are not connected to a specific point source (USEPA 2008a) and contribute to natural background of metals at the Site.

4.1 DEFINITIONS OF BACKGROUND

This section provides the definitions of the different types of background as established by the State of Washington and EPA.

The State of Washington uses the terms "area background" and "natural background" defined as follows (Washington Administrative Code [WAC] 173-340-200 [MTCA definitions]):

> *"'Area background' means the concentrations of hazardous substances that are consistently present in the environment in the vicinity of a site, which are the result of human activities unrelated to releases from that site."*
>
> *"'Natural background' means the concentration of hazardous substance consistently present in the environment that has not been influenced by localized human activities. For example, several metals and radionuclides naturally occur in the bedrock, sediments, and soils of Washington state due solely to the geologic processes that formed these materials and the concentration of these hazardous substances would be considered natural background. Also, low concentrations of some particularly persistent organic compounds such as polychlorinated biphenyls (PCBs) can be found in surficial soils and sediment throughout much of the state due to global distribution of these hazardous substances. These low concentrations would be considered natural background. Similarly, concentrations of various radionuclides that are present at low concentrations throughout the state due to global distribution of fallout from bomb testing and nuclear accidents would be considered natural background."*

EPA uses the terms "anthropogenic background" and "naturally occurring background," defined below (USEPA 2002b):

> *Anthropogenic – natural and human-made substances present in the environment as a result of human activities (not specifically related to the CERCLA release in question)*
>
> *Naturally occurring – substances present in the environment in forms that have not been influenced by human activity.*

This Upland RI report uses the definitions of natural and area background defined by the State of Washington in MTCA.

4.2 PREVIOUS CALCULATIONS OF BACKGROUND AT THE UCR SITE

Natural soil background concentrations have been estimated for use in the UCR RI/FS by TAI in the Technical Memorandum – Assessment of Background Concentrations of Metals and Metalloids in Upland Soils (hereafter, TAI Upland Soil Background Assessment; included as Appendix C), by EPA in the HHRA (USEPA 2021), in regional studies for Washington State (Ecology 1994, 2019b), and for soils around Trail, British Columbia (Sanei et al. 2007). The natural background values calculated in these studies are presented in Table 4-1.

Soil metals concentrations in this Upland RI report are compared to the background values calculated in the TAI Upland Soil Background Assessment (Appendix C) and presented in Section 4.3. Background values calculated for use in the HHRA (USEPA 2021) are described in Section 4.4, and their use in the HHRA is described in Section 5.1.1.6.

4.3 TAI UPLAND SOIL BACKGROUND ASSESSMENT

The TAI Upland Soil Background Assessment, included as Appendix C to this Upland RI report, was conducted under EPA's direction to ascertain natural background soil concentrations for use in this Upland RI report and the Upland BERA, to identify areas where measured metals concentrations in soil are greater than natural background. The background assessment was completed in accordance with the EPA-approved DQOs (TAI 2018a; USEPA 2018) and EPA's level of effort memorandum regarding the assessment and estimation of background elemental concentrations in upland soils from the UCR Site (USEPA 2016b). The approach described in EPA's level of effort built on earlier work from Church (2010).

Data considered for use in the background assessment were compiled from numerous studies spanning a broad area in northeastern Washington and extending well beyond the UCR Site. The approach for assessing soil background metals concentrations described in the DQOs and implemented for this study included compiling, filtering, and analyzing existing data to calculate soil background concentrations as background threshold values (BTVs).

4.3.1 Upland Soil Natural Background Data Set Development

Initially, data were evaluated from 13 studies considered usable for compiling a natural background data set. Primary data usability criteria were that samples have a known location (i.e., known spatial coordinates and depth) that is near the UCR Site and were collected in areas outside the following influences:

- The 100-year Columbia River floodplain
- The 1931 "zone of sulfur dioxide injury" to trees by sulfur dioxide from smelters, described by Scheffer and Hedgcock (1955) (hereafter, "1931 sulfur dioxide plume area")
- Areas affected by human activity (e.g., roads, railways, landfills, mines, mills, and selected land use categories such as manufacturing)
- Areas affected by natural processes, such as landslides, that may expose lithic materials that are not representative of surficial soils.

The compiled data were also evaluated for soil sampling depth, sampling method (discrete grab samples versus multipoint composite samples), soil fraction analyzed (bulk soil, < 2 mm and/or < 149 μm), and sample digestion and analysis methods; samples were excluded as appropriate. The compiled data set included a combination of samples sieved to < 2 mm and < 149 μm, which are most representative for ecological and human health exposures, respectively. Because the 2014 Soil Study (TAI 2015a) measured metals and metalloids for many samples from both fractions (< 2 mm and < 149 μm), to avoid overweighting these locations, only the < 2-mm samples were included in the initial background data set.

Through this work, EPA and TAI agreed that samples prepared for metals analyses by partial digestion (i.e., total recoverable) and total digestion methods should be treated separately. The output from implementing the data-filtering steps specified in the final DQOs was three background soil data sets based on the sample digestion and analysis method: a partial digestion data set, a total digestion data set, and a mercury data set.

In comments provided to TAI on May 29, 2020 (USEPA 2020b), EPA required additional partial digestion sample results be removed from the data set used to calculate the BTVs; no further refinements were required for the total digestion and mercury data sets. The exclusions from the partial digestion data set were based on multivariate analyses conducted by EPA that used partial digestion sample results for selected metals. By applying this screening step, additional samples beyond the 1931 sulfur dioxide plume area were removed, which included all partial digestion results for samples located in WRIA 61 plus one sample from WRIA 54 and one sample from WRIA 62 (USEPA 2020b). TAI disagreed with this additional screening step and described the bases for its disagreement in an objection letter dated July 7, 2020 (TAI 2020).

Despite this disagreement, TAI agreed to perform the additional data set refinements directed by EPA and calculated the BTVs presented in Table 4-1. The studies with samples that were included in the final data set used to calculate the BTVs are identified in Table 3-1.

4.3.2 Final Natural Background Data Set and BTVs

BTVs were calculated as one-sided 95 percent upper confidence limits (UCLs) on the 95th percentile, or the 95/95 upper tolerance limits (UTLs), of the final data sets using ProUCL 5.1 (USEPA 2015d,e), as specified in the DQOs (TAI 2018a). Quantile-quantile plots of measured or log-transformed (log10) soil metals concentrations, depending on distributional assessment, were used to identify anomalous high concentrations that would overly influence the BTVs in conjunction with formal outlier tests. Outliers, if identified, were excluded if the resulting BTV was more conservative (i.e., the BTV with outliers excluded was lower than the BTV with outliers included). BTVs were calculated using parametric or nonparametric methods based on the distributional assessment output from ProUCL.

Table 4-1 summarizes the BTVs derived for each metal for each data set (total metals [i.e., total digestion], partial digestion [i.e., total recoverable], and mercury). The sample locations of the final partial digestion background data set for all metals (excluding mercury) are shown on Map 4-1. The locations of the final background data set for mercury are shown on Map 4-2. The locations of the final total digestion background data set for all metals (excluding mercury) are shown on Map 4-3. Detailed methodology for the derivation of BTVs, including a discussion of uncertainty, is included as Appendix C.

4.4 HHRA BACKGROUND APPROACH

Site-wide background concentrations for soil COPCs were developed separately for use in the HHRA using DQOs for human health receptors (i.e., using soil data sieved to the < 149 µm particle size), and consideration of background soil concentrations was included as part of the uncertainty analysis for the HHRA (USEPA 2021). As stated in the HHRA, "[c]haracterizing such 'background' information is important to risk managers because the CERCLA program does not clean up to concentrations below natural or anthropogenic background levels because doing so would likely result in recontamination and a return to background levels" (USEPA 2002b as cited in USEPA 2021).

The background values calculated for use in the HHRA are presented in Table 4-1; however, the Upland RI report does not use these values. The Upland RI report uses the BTVs calculated in the TAI Upland Soil Background Assessment (Appendix C).

5 RISK ASSESSMENT SUMMARY

This section includes information related to the assessment of human health risk (Section 5.1) and ecological risk (Section 5.2) at the UCR Site. The evaluation of human health risk and ecological risk are being conducted separately and are in different stages of completion. Therefore, the subsections in Sections 5.1 and 5.2 are not identical. Section 5 is intended to provide context for interpreting the nature and extent, transport and fate, CSM, and conclusions presented in later sections of this Upland RI report.

5.1 HUMAN HEALTH

This section includes a summary of the methodology and results of the Site-wide HHRA (USEPA 2021) as it pertains to the OU 3 study area (Section 5.1.1), a description of the human health PRGs established in the HHRA (Section 5.1.2), and the human health RAOs issued by EPA (USEPA 2023c) (Section 5.1.3). The objective of this section is to describe the current understanding of human health risk at the Site and the basis for selection of human health COCs and human health PRGs evaluated in subsequent sections of this Upland RI report.

5.1.1 HHRA Summary

The HHRA (USEPA 2021) calculated potential health risks caused by exposures in both the upland and aquatic areas of the Site to the people residing, recreating, or working there. Risks in the HHRA were summed across upland and aquatic exposure pathways. However, the summary presented in this Upland RI report is limited to evaluation of exposure pathways for metals in soil, indoor dust, and air in the OU 3 study area. Evaluation of exposure pathways for metals in the aquatic portion of the Site (i.e., in sediment, relict floodplain soil, WSDA soil, surface water, and fish) will be summarized in the Aquatic RI report. A list of all media evaluated in the HHRA with upland media highlighted is provided in Table 5-1. Methods for assessing health risks of lead differ from methods used for other metals. Therefore, after summarizing the exposure assessment approach, this HHRA summary presents methods and results for lead, followed by methods and results for other metals.

Soil data used in the HHRA for evaluation of exposure pathways in the OU 3 study area were derived from the following studies (further detailed in Table 3-1): 2014 Soil Study (TAI 2015a), 2014 Residential Soil Study (USEPA 2016a), 2016 Residential Soil Study (TAI 2017a), 2018 Plant Tissue Study (TAI 2019c), and 2015 Bossburg Study (TAI 2016c). While the 2004 EPA Le Roi Smelter Removal Action was not included in the HHRA, data collected during this study are evaluated in later sections of this Upland RI report.

There are two Native American populations with reservations in the UCR Site vicinity, CCT and STI. Specialized human health risk assessments for these populations are included in Appendix 1 and Appendix 2 of the HHRA, respectively. Appendix 1 is referred to as the Colville High Intensity Resource User (CHIRU) population human health risk assessment. It evaluates potential risks for members of the CCT community who obtain some of their food by fishing, hunting, and gathering at the UCR Site and who participate in traditional activities such as basket-weaving and sweat lodges. The CHIRU population human health risk assessment is summarized in Section 5.1.1.4 below. The STI population human health risk assessment is focused on aquatic exposures and will, therefore, be reviewed in the Aquatic RI report.

5.1.1.1 Exposure Assessment

The HHRA evaluates potential risks associated with current and reasonably foreseeable future uses by residents, recreational visitors, and outdoor workers who may contact environmental media at the Site. Figure 5-1, adapted from the CSM presented in the HHRA, presents a CSM describing exposure pathways for upland-related activities by residents, outdoor workers, and recreational users. The CSM also includes exposure pathways for tribal receptors. However, potential risks for tribal populations are evaluated separately from risks for residents, recreational visitors, and outdoor workers in the HHRA and are discussed in Section 5.1.1.4 below. Primary media relevant to assessing human health risks in upland areas include soil and air. Indoor dust was evaluated using DU-specific soil data and default EPA assumptions for soil-to-dust transfer at current RSS and ADA DUs. Potential CHIRU population exposures to upland biota are described in Section 5.1.1.4.

The HHRA uses data from a Site-specific exposure survey: the recreational consumption and resource use survey (IEc 2012). Site-specific exposure information from the survey was subsequently summarized in a data analysis report (SRC 2019a) and used to generate average and upper-bound exposure rates for the HHRA. The recreational use survey was primarily used to inform exposure estimates pertaining to aquatic exposures at the Site, including fish consumption rates and frequency of beach, camping, and boating visits. However, exposure frequency estimates derived from the recreational use survey are applied to Bossburg UDUs.

The HHRA evaluated metals concentration data in the < 150-µm[75] size fraction of soil samples collected from 142 ADA DUs sampled as part of the 2014 Soil Study (TAI 2015a) (see Section 3.1)

[75] Some studies reported this size fraction as < 149 µm, and some studies reported it as < 150 µm. For consistency, the remainder of the Upland RI report uses the < 150-µm-size fraction to refer collectively to data reported for the < 149-µm-size fraction and data reported for the < 150-µm-size fraction.

and 588 RSS DUs on 169 residential properties[76] sampled as part of the 2014 and 2016 Residential Soil Studies (USEPA 2016a; TAI 2017a) (see Sections 3.3.1 and 3.3.4). The 2014 and 2016 Residential Soil Studies relied on voluntary sampling. Not every landowner with a residential property eligible for sampling gave approval for sampling. Evaluation of 35 DUs located on tribal allotments (TA DUs),[77] also sampled as part of the 2014 and 2016 Residential Soil Studies, is included in the CHIRU human health risk assessment (Appendix 1 of the HHRA) and summarized in Section 5.1.1.4 below. RSS DUs and ADA DUs were evaluated for current and potential future residential use, respectively. Current and future residents are assumed to contact soil and soil-derived indoor dust on their property and be exposed to outdoor and indoor air. Most ADA DUs (i.e., greater than 90 percent of total ADA DU land) are located on private and public forest lands and are not currently developed for residential use. However, the ADA DUs were evaluated for risk to potential future residents in the HHRA. Recreational users and outdoor workers are most likely to have current exposure to ADA DUs. The HHRA does not assess risks for individuals accessing ADA DUs for recreation or work. Risks for workers and recreators in these areas will be lower than risks for potential future residents. Bossburg UDUs were evaluated for recreational use. Recreational visitors are assumed to contact soil in Bossburg UDUs while camping, boating, or completing a beach trip and be exposed to outdoor air.

In the HHRA, exposure areas (the area where a receptor population may be exposed to one or more environmental media) vary by medium (see Table 5-1). Individual RSS DUs and ADA DUs are defined as individual exposure areas. Thus, risk estimates are provided for each DU. For RSS DUs, risks are evaluated for each DU as if 100 percent of exposure occurs at that DU, as opposed to averaging exposure over the entire property (as represented by all DUs tested on that property). Locations for DUs were based on interviews with landowners regarding where on the property they spent most of their time.

A risk-based screening process was used to select COPCs to be evaluated in the HHRA for air, ADA DU soil, and RSS DU soil. All COPCs selected in the risk-based screening process for upland exposure media were metals. COPCs identified in RSS DU soil and ADA DU soil were assumed to be COPCs in indoor dust, and COPCs in outdoor air were assumed to be COPCs in

[76] Note that dripline RSS DUs were excluded from risk calculations. DU 172-01 was also excluded from risk calculations because of its former use as a small ore mill or ore stockpiling site.

[77] Tribal allotments are for the CCT population, not the STI population. Archived NURE soil samples collected on the Spokane Reservation were used in Appendix 2 of the HHRA to evaluate the STI population's exposure to soil because the 2014 and 2016 Residential Soil Studies did not include locations on the Spokane Reservation (USEPA 2021).

indoor air. COPCs quantitatively evaluated in the HHRA by environmental medium are displayed in Table 5-2.

EPCs were calculated for each COPC by exposure area within each environmental medium. Consistent with EPA guidance, lead EPCs for both the Integrated Exposure Uptake Biokinetic (IEUBK) model and the Adult Lead Methodology were the arithmetic mean, while for all other metals, EPCs were the 95 percent UCL or equivalent (USEPA 1992). For RSS DUs with a single IC result, a confidence factor was applied to estimate the EPC, as described in Section 3.3 and Appendix 12 of the HHRA.

EPCs for soil were estimated for the < 150-µm-size fraction in surface soil collected by IC sampling, as described in Sections 3.1, 3.3.1, and 3.3.4. For DUs where a TCRA or VRA were completed (see Appendix B and Sections 3.3.2, 3.3.3, and 3.3.5), the maximum measured COPC concentration in soil used to backfill excavated areas during the removal actions was used as the EPC for each COPC in risk calculations[78] (USEPA 2021).

Because metals in soil are not completely solubilized by the gastrointestinal tract when ingested, an RBA adjustment is applied during the exposure assessment to reflect the amount of metal that may be absorbed with greater accuracy. Consistent with EPA guidance, in the HHRA, only lead and arsenic EPCs in soil were adjusted for RBA. The RBA values used in the HHRA for lead and arsenic in soil were based on results from Site-specific IVBA data measured at select DUs.[79] Specifically, as discussed in Section 3 above, IVBA analyses were performed on a subset of soil samples that had lead concentrations greater than 100 mg/kg. According to USEPA (2020c) guidance, IVBA data are used to calculate RBA values for lead and arsenic based on algorithms from studies comparing RBA in animal models with IVBA values for the same samples. RBA estimates for arsenic and lead in soil are presented in Table 5-3.

In the ADA DU soil samples, IVBA was measured for 10 additional metals. EPA does not consider the IVBA data for these metals to be validated for deriving RBA values for use in the HHRA. Therefore, in the HHRA, these other metals were assumed to have 100 percent RBA. This assumption likely overestimates exposures for some metals.

[78] The list of DUs provided in the HHRA and used in the HHRA analysis that documents where TCRAs and VRAs were completed differs from documentation provided in the final TCRA and VRA reports. The discrepancies are described in Appendix B.

[79] In 2022, a laboratory reporting error was discovered for the lead IVBA result in ADA-162. The corrected IVBA result yields a lead RBA of 90.7 percent for ADA-162 (reported as 67.4 percent in the HHRA) and an average Site-wide ADA DU lead RBA of 71.5 percent (reported as 70.6 percent in HHRA). The updated lead RBA values and resulting impacts on property counts above lead risk benchmarks are reflected in this Upland RI report per communication with EPA (Stifelman 2023).

Outdoor and indoor air EPCs were calculated using data collected near Northport at the Sheep Creek air quality monitoring station (last data collected in 2009; see Section 3.17.1). Indoor air EPCs were assumed to be equivalent to outdoor air EPCs, which the HHRA acknowledges may overestimate exposures in indoor air.

5.1.1.2 Lead Assessment

Lead toxicity to humans is evaluated by comparing estimated blood lead levels to specified risk management target blood lead levels. EPA's final Updated Residential Soil Lead Guidance for CERCLA Sites and RCRA Corrective Action Facilities (USEPA 2024a) establishes screening levels based on blood lead level targets of 3.5 and 5 µg/dL, depending on the presence or absence of cumulative sources of exposure. As EPA's guidance was under evaluation when the HHRA was finalized, the HHRA includes evaluation of risks for three blood lead levels (see Table 5-4) "within which the risk management decision will most likely be made, from 3 to 8 µg/dL" (USEPA 2021, Executive Summary).

Lead risks were calculated for children using EPA's IEUBK model (version 1.1, build 11), with updates that reflected changes to the IEUBK model version 1.1 input parameter default values recommended by EPA's Superfund Technical Review Workgroup for Lead. These changes were based on recent advances in scientific information and will be incorporated in the IEUBK model (version 2).[80] For adults, lead risks were calculated using EPA's Adult Lead Methodology.

The HHRA selected 3 µg/dL as the lower end of the risk range evaluated. Risk targets were set as no greater than a 5 percent probability of exceeding each target, i.e., no greater than a 5 percent probability of exceeding a blood lead level of 3 µg/dL (termed P3), 5 µg/dL (termed P5), or 8 µg/dL (termed P8). It should be noted that the HHRA determined that background soil lead concentrations are close to the soil lead concentration associated with a blood lead level of 3 µg/dL (approximately 50 mg/kg lead) predicted by the IEUBK model. The HHRA states that a risk benchmark of P2 (no greater than a 5 percent probability of having a blood lead level greater than 2 µg/dL) cannot be used with the IEUBK model because the risk goal is exceeded by the current default exposures in the IEUBK model (without any soil exposure).

EPA defaults were used in the IEUBK and Adult Lead models, except for Site-specific RBA values and the Site-specific air concentration (air concentration was used in IEUBK only). Lead risks for adults are only assessed for scenarios such as occupational exposures that do not include children. This is because children are the most sensitive to the effects of lead. In the

[80] The differences between the IEUBK version 2 and version 1.1 models with the updated input parameter values shown in Table 3-30 and Table 3-31 of the HHRA are too small to meaningfully impact the results of the HHRA.

HHRA, the Adult Lead Methodology was only used to evaluate occupational exposure to subsurface soil and sediment.

The IEUBK model predicts the probability of children (ages 0 to 6 years) exceeding a specific blood lead concentration based on inputs to the model. The model applies central tendency exposure parameters to estimate the geometric mean blood lead level and then applies a geometric standard deviation to generate a distribution of predicted blood lead levels. Risks are then described as the probability of a child having a blood lead level in excess of a specified risk management target blood lead level.

Lead risk results for current and future residents (children) include combined exposure to residential house soil, soil-derived indoor dust, and air at the Site in addition to default background lead exposures incorporated in the IEUBK model, such as diet and drinking water. Because the IEUBK model incorporates all potential lead exposures, including dietary lead, lead risks for children were assessed using the IEUBK model with and without including consumption of fish caught at the Site. Consumption of fish from the Columbia River was determined to pose a small (relative to lead intake from soil) additional risk to some residents. Because this report focuses on upland media, lead intake from fish consumption is not discussed further in this summary. A more detailed discussion can be found in the HHRA (USEPA 2021).

Lead risk results for the RSS DUs, ADA DUs, and Bossburg UDUs are summarized in Table 5-5. Of 588 RSS DUs evaluated (not including residential beach DUs, TA DUs, dripline DUs, or a DU that was used as a potential ore stockpile), 389 DUs exceeded P3 (66 percent), 87 exceeded P5 (15 percent), and 12 exceeded P8 (2 percent).[81] Of the 142 ADA DUs, 139 exceeded P3 (98 percent), 71 exceeded P5 (50 percent), and 16 exceeded P8 (11 percent).[82] The locations of RSS DUs (including TA DUs) and ADA DUs exceeding the P3, P5, and P8 risk benchmarks are shown on Map 5-1 through Map 5-9 and listed in Appendix D Table D-1. Lead risks were not evaluated in the HHRA for adult residents, outdoor workers, or child or adult recreational visitors in these areas but are expected to be lower than lead risks for child residents.

[81] The distribution of lead concentrations and percentage of properties exceeding lead risk benchmarks at residential properties are influenced by various factors including the voluntary sampling design, whether a property had a TCRA or VRA completed, and individual factors at the residence. The HHRA provides a point-in-time snapshot of properties exceeding lead risk benchmarks, and the results should be qualified if used to determine the likelihood of lead benchmark exceedance in remaining properties.

[82] The counts of ADA DUs exceeding lead risk benchmarks differ slightly from what is reported in the HHRA because the corrected IVBA result for ADA-162 is incorporated per communication with EPA (Stifelman 2023).

For exposure to surface soil in the six Bossburg UDUs (inclusive of beach day trips, camping, and boating trips to Bossburg Flat Beach), all UDUs exceeded P3, and one UDU exceeded P5 and P8 with or without consumption of Upper Columbia River fish when risk for children was assessed using the IEUBK model. Bossburg UDUs are not shown on the maps. The lead risk results for recreational users in Bossburg UDUs include combined exposure to a time-weighted combination of residential house soil (using an approach described in the HHRA to identify a surrogate concentration when no house is present) and UDU soil, surface water, and air at the Site in addition to default background lead exposures incorporated into the IEUBK model, such as diet and drinking water. Risks for adult outdoor workers exposed to subsurface UDU soil exceeded the P3 risk benchmark at UDU-01 and UDU-04. The P5 and P8 risk benchmarks were not exceeded at any Bossburg UDUs.

5.1.1.3 Metals Other Than Lead

For exposure to metals other than lead (see Table 5-2 for a list by exposure medium), the intake or dose of each metal is quantified and compared to its respective toxicity value (reference dose [RfD] or reference concentration [RfC] for non-cancer effects, and slope factor or inhalation unit risk factor for cancer effects). The dose, or daily intake, is calculated using the EPC and exposure parameters specific to the exposure routes evaluated, as summarized in Equation 5-1 below. Detailed dose calculation descriptions for all exposure routes (i.e., ingestion, dermal, inhalation) are provided in Section 3.4 of the HHRA (USEPA 2021). Exposure routes evaluated in the HHRA relevant to the Upland RI are summarized in Figure 5-1. EPA default and Site-specific exposure parameters were used in the HHRA. Site-specific exposure parameters, such as exposure frequency for recreational users, were based on Site-specific survey data (SRC 2019a).

Equation 5-1:

$$DI = C \times \left(\frac{IR}{BW}\right) \times \left(\frac{EF \times ED}{AT}\right) \times RBA$$

where:

DI = Daily intake of chemical (mg of chemical per kg of body weight [BW] per day).

C = Concentration of the chemical in the contaminated environmental medium (soil, sediment, water, food) to which receptor is exposed. The units are mg/L for water, and mg/kg for solid media.

IR = Intake rate of the contaminated environmental medium. The units are L/day for aqueous media, and kg/day for solid media.

BW = Body weight of the receptor (kg).

EF = Exposure frequency (days/year). How often receptor is likely to be exposed to the contaminated medium over the course of a typical year.

ED = Exposure duration (years). How long receptor is likely to be exposed to the contaminated medium during their lifetime.

AT = Averaging time (days). The number of days over which the average dose is calculated. Usually, two different ATs are considered. "Chronic" exposure includes ATs on the scale of years (typically ranging from 7 to 70 years). This exposure duration is used when assessing non-cancer hazards. "Lifetime" exposure employs an AT of 70 years. This exposure interval is selected when evaluating cancer risks.

RBA = Relative bioavailability.

For exposure to metals other than lead via air, exposures are evaluated in accordance with the inhalation dosimetry methodology (USEPA 2009b), and the inhaled exposure concentration (EC) for chronic exposures is calculated as:

Equation 5-2:

$$EC = C \times (ET \times EF \times ED / AT)$$

where:

EC = Exposure concentration ($\mu g/m^3$). This is the time-weighted concentration based on the characteristics of the exposure scenario being evaluated.

C = Concentration of the chemical in air ($\mu g/m^3$) to which the receptor is exposed.

ET = Exposure time (hours/day). How long receptor is likely to be exposed to the contaminated medium over the course of a typical day.

EF = Exposure frequency (days/year). How often receptor is likely to be exposed to the contaminated medium over the course of a typical year.

ED = Exposure duration (years). How long receptor is likely to be exposed to the contaminated medium during their lifetime.

AT = Averaging time (hours). Length of time over which the time-weighted average concentration is calculated.

5.1.1.3.1 Risk Calculations for Non-Cancer Effects

For metals with non-cancer effects, the dose quantified from contact with environmental media is divided by the RfD for ingestion and dermal exposures, or RfC for inhalation exposures to calculate a hazard quotient (HQ). To evaluate the effect of exposure to multiple chemicals that act on the body in a similar manner, the HQs from each exposure route (i.e., ingestion, dermal, inhalation) and medium (i.e., soil, air) evaluated are summed to determine a non-cancer hazard index (HI) for soil and air exposure pathways. The HHRA includes a preliminary step where

HIs are calculated by summing all metals, regardless of target organ/system of effect. If these "total HIs" were less than or equal to 1, no further action was taken. If the total HI exceeded 1, HIs by target organ/system of effect were then calculated. If HQs or target organ/system HIs are less than or equal to 1, no adverse health effects are expected. If the calculated value is greater than 1, then further evaluation is needed.

5.1.1.3.2 Risk Calculations for Cancer Effects

For metals with cancer effects (limited to only arsenic for ingestion/dermal and arsenic and cadmium for inhalation, based on the available toxicity data), the incremental probability that an individual will develop cancer during their lifetime due to exposure to Site-related metals is quantified by multiplying the dose by the cancer slope factor for ingestion and dermal exposures, or RfC for inhalation exposures. Cancer risks are summed across exposure routes and the environmental media contributing to exposure for a given population. According to the HHRA (USEPA 2021), "In general, EPA considers excess cancer risks below 10^{-6} [1 in 1,000,000] to be negligible and risks above 10^{-4} [1 in 10,000] to warrant action. Excess cancer risks that range between 10^{-6} and 10^{-4} are generally considered to be acceptable" (Section 5.2.2 of the HHRA). Thus, cancer risks less than 10^{-4} were considered acceptable, and risks above 10^{-4} were considered unacceptable in the HHRA.

5.1.1.3.3 Risk Results

Risks for metals other than lead were evaluated for current and future residents, recreational users, and outdoor workers in soil and air for upland-related pathways.[83] Cancer and non-cancer risks for ingestion and dermal exposures for the RSS DUs, ADA DUs, and Bossburg UDUs are summarized in Table 5-6; risks for inhalation are summarized in Table 5-7; and risks for ingestion, dermal contact, and inhalation combined are summarized in Table 5-8. Risks were below cancer benchmarks for all media and were below non-cancer risk benchmarks for all Bossburg UDUs and all but a few RSS DUs and ADA DUs. No additional risk benchmarks were exceeded when risks for air and soil exposure pathways were combined.

When evaluated for residential use, cancer risks for metals other than lead were below the EPA cancer risk benchmark of 10^{-4} in all RSS DUs and ADA DUs. When non-cancer HIs were summed by target organ/system, all were below the risk benchmark except for one RSS DU (146-H1) and two ADA DUs (ADA-144 and ADA-162). For the RSS DUs and ADA DUs that were above the benchmark, HIs above 1 were for the skin/hair/nails pathway. Metals in soil

[83] The HHRA evaluated risks across upland and aquatic areas of the Site and summed risks across all media. The summary presented here is only for upland media.

contributing to this pathway include arsenic, thallium, and vanadium. The HHRA does not provide the specific HQs associated with each metal for individual RSS DUs and ADA DUs, but it can be inferred that the exceedances are driven by a combination of arsenic and thallium because the range of HQ values presented in the HHRA tables are higher for arsenic and thallium than vanadium. Risks for Bossburg UDUs were below cancer and non-cancer risk benchmarks when evaluated for recreational and occupational exposure.

Cancer and non-cancer risks for arsenic and cadmium in air were below cancer and non-cancer benchmarks for the residential, recreational, and outdoor worker scenarios. For residents, indoor air was the dominant contributor to risks. The assumption that COPC concentrations in indoor air are equivalent to outdoor air concentrations is conservative and may overestimate risks. Based on a study by Allen et al. (2012) and the climate at the Site, it is reasonable to assume an outdoor-to-indoor air infiltration rate of 60 percent. Because people spend much more time indoors than outdoors (> 80 percent according to the HHRA), this indicates that the overall exposures to airborne metals presented in the HHRA are up to twice the expected exposures when reduced indoor air concentrations are considered. Recreational visitors and outdoor workers were assumed to be exposed to outdoor air only. The HHRA used air monitoring data collected from 2002 through 2009 at the Sheep Creek air quality monitoring station near Northport (see Section 3.17.1). To the extent that the Trail Facility may have contributed to these air concentrations, it is relevant to note that emissions of lead have decreased by about half since 2009 (see summary of Trail Facility operations in Section 2.10.1.1).

5.1.1.4 CHIRU Population Human Health Risk Assessment

Appendix 1 of the HHRA presents the human health risk assessment for the CHIRU population. The CHIRU population includes members of the CCT community who obtain some of their food by fishing, hunting, and gathering at the UCR Site and who participate in traditional activities, such as basket-weaving and sweat lodges. Exposure to COPCs in surface soil, indoor dust, air, surface water, surface sediment, fish, plants, mussels, crayfish, amphibians/reptiles, birds (waterfowl and upland birds), and upland game (mammals) was evaluated for the CHIRU adult and child receptor populations in the CHIRU human health risk assessment. Figure 5-1 presents the exposure pathways and media relevant to the CHIRU population (referred to as Tribal in the figure) in the OU 3 study area. The summary provided in the Upland RI report is limited to upland media (i.e., surface soil, indoor dust, air, plants, upland birds, and upland game). Of the upland biota, plant tissue was directly sampled, and upland bird and game concentrations were derived using uptake models from surface water and soil.

The CHIRU human health risk assessment uses data from a Site-specific exposure survey: the tribal consumption and resource survey (Westat 2012). Site-specific exposure information from

the surveys was subsequently summarized in a data analysis report (SRC 2019b) and used to generate average and upper-bound exposure rates for the CHIRU human health risk assessment. The tribal use survey is used in the human health risk assessment to inform CCT-specific consumption rates for upland and aquatic biota and exposure frequency for contact with environmental media such as beach sediment. Additional Site-specific plant consumption rate information provided by CCT is also used in Appendix 1 to the HHRA (Fraser 2017, 2019a,b,c,d,e).

Soil COPCs identified for the 2014 and 2016 RSS DUs were also considered COPCs for TA DU soil. COPCs were selected for the following secondary and tertiary upland media: terrestrial wild/cultural plants, upland birds, and upland game. COPCs identified in surface water and TA DU surface soil were selected as COPCs in upland bird and game tissue. Surface soil COPCs were also assumed to be COPCs for terrestrial plants. Despite not being selected as a COPC in soil, mercury was included as a COPC in stem and leaf tissues at CCT request. Similarly, metals expected to bioaccumulate in animal tissue (e.g., cadmium, mercury) were included as COPCs for upland birds and game despite not being identified as COPCs in surface water and soil. Only COPCs with scientifically validated uptake models for upland bird and game tissue were quantitatively evaluated in the human health risk assessment. COPCs quantitatively evaluated in the CHIRU human health risk assessment by environmental medium are shown in Table 5-9.

CHIRU EPCs for soil, indoor dust, and air were derived in the same manner as for the upland human health risk assessment (Section 5.1.1.1). Upland plant EPCs were calculated using plant tissue data directly sampled during the 2018 Plant Tissue Study (TAI 2019c) (Section 3.3.7). EPCs for upland birds and game were derived using uptake models (OEHHA 2015; Latta and Donaldson 1986a,b) and Site-specific EPCs for surface soil, surface water, and terrestrial plants. The soils used to model tissue concentrations in upland birds and game were 0- to 3-in. surface soil samples collected from TA DUs during the 2018 Plant Tissue Study (co-located with the plant tissue samples).

The approach for assessing lead risks from exposure to soil and air is described in Section 5.1.2. Lead risks for consumption of upland biota (i.e., terrestrial plants, upland birds, and game) were assessed by comparison with a benchmark intake of 1 μg/day because, according to the CHIRU human health risk assessment, intakes less than 1 μg/day are not expected to contribute appreciably to lead exposures.

Of the 35 TA DUs, 21 DUs exceeded P3 (60 percent), 17 DUs exceeded P5 (49 percent), and 6 DUs exceeded P8 (17 percent) when assessed for residential exposure (Table 5-10). The TA DU locations are included along with the RSS DU locations on Map 5-1 through Map 5-3 and Map 5-7 through Map 5-9.

Consumption of upland birds and some upland plants resulted in lead intakes in excess of 1 µg/day for children. Estimated lead intakes were less than the benchmark of 1 µg/day for upland game and eight terrestrial plants (chokecherry [*Prunus virginiana*], huckleberry, rose hips and rose stem/leaves, kinnikinnick [*Arctostaphylos uva-ursi*], wild mint [*Mentha arvensis*], hazelnut [*Corylus cornuta* var. *californica*], and ponderosa pine). Estimated lead intakes were above 1 µg/day for consumption of upland birds, and the following terrestrial plants: black tree lichen (*Bryoria fremontii*), sarvisberry, lomatium (*Lomatium tritermatum*), camas (*Camassia quamash*), and spring beauty/Indian potato (*Claytonia lanceolata*). Lead concentrations in upland bird tissue were modeled using transfer factors derived from a study of 1- to 20-day-old chickens given lead in their diet (Latta and Donaldson 1986a,b).

Cancer and non-cancer risks for ingestion and dermal exposures for the TA DUs are summarized in Table 5-11, risks for inhalation are summarized in Table 5-12, and risks for ingestion, dermal contact, and inhalation combined are summarized in Table 5-13. The CHIRU human health risk assessment did not find unacceptable cancer risks associated with exposure to soil, air, or with consumption of upland birds and game, and terrestrial plants. Non-cancer risks were also generally below risk benchmarks except for exposure to soil in two TA DUs (401 and 441) and one terrestrial plant (spring beauty/Indian potato). For soil exposure, the highest aggregated non-cancer risk level (HI) by target organ/system was 2 for skin, hair, and nails, primarily due to thallium. Thallium was also the driver of the elevated target organ/system risk for consumption of spring beauty/Indian potato. As described in in the uncertainty analysis of the HHRA, thallium does not have adequate toxicity data to support derivation of a reliable RfD. Risks for inhalation of outdoor air were below risk benchmarks. When risks for soil and air were combined, one additional TA DU (801-O2) had a target organ/system HI of 2 for the nervous system, due to a combination of HQs less than 1 for manganese and aluminum in soil and arsenic in air. Risks for soil and air combined were below non-cancer risk benchmarks at all other TA DUs and were below cancer risk benchmarks at all TA DUs.

5.1.1.5 Summary of HHRA Results

The following generalizations can be made about the results of the HHRA for the residential, recreational, and outdoor worker populations:

- Risks for residential exposure to lead in RSS DU and ADA DU soil exceeded risk benchmarks at certain DUs. Of 588 RSS DUs evaluated, 389 DUs exceeded P3 (66 percent), 87 exceeded P5 (15 percent), and 12 exceeded P8 (2 percent). Of the 142 ADA DUs, 139 exceeded P3 (98 percent), 71 exceeded P5 (50 percent), and 16 exceeded P8 (11 percent).

- Risks for residential exposure to metals other than lead in soil did not exceed risk benchmarks for all but one RSS DU (146-H1) and two ADA DUs (ADA-144 and ADA-162). Those risks were driven by a combination of arsenic and thallium. These DUs also exceeded the P3, P5, and P8 lead risk benchmarks.
- Risks for recreational exposure to lead in Bossburg UDU soil exceeded risk benchmarks. Of the six Bossburg UDUs evaluated, six exceeded P3 (100 percent), one exceeded P5 (17 percent), and one exceeded P8 (17 percent). Risks for recreational exposure to metals other than lead in Bossburg UDU soil did not exceed risk benchmarks.
- Exposure of residents, recreators, and outdoor workers to outdoor and indoor air was below risk benchmarks. None of the four metals (arsenic, cadmium, lead, and zinc) monitored in ambient air from 2002 to 2009 at the Sheep Creek monitoring station near Northport exceeded risk benchmarks.
- Risks to outdoor workers from exposure to upland soil at the Bossburg UDUs were minimal. Except for two UDUs that exceeded the P3 lead risk benchmark, all other UDUs were below risk benchmarks.

Additionally, the following generalizations regarding risk for the CHIRU population can be made based on the results in Appendix 1 to the HHRA:

- Risks for exposure to lead in TA DU soil exceeded lead risk benchmarks at certain TA DUs. Of the 35 TA DUs, 21 DUs exceeded P3 (60 percent), 17 DUs exceeded P5 (49 percent), and 6 DUs exceeded P8 (17 percent) when assessed for residential exposure.
- Risks for exposure to metals other than lead in soil were below risk benchmarks except for two TA DUs (401 and 441). Those risks were driven by a combination of arsenic and thallium. These DUs also exceeded the P3, P5, and P8 lead risk benchmarks.
- Exposure to outdoor air does not pose a substantial risk to the CHIRU population. Exposure to metals in outdoor air did not exceed risk benchmarks.
- Estimated lead intakes were above the 1 μg/day benchmark for consumption of upland birds and five terrestrial plants. Lead intakes were below 1 μg/day for consumption of upland game and eight terrestrial plants.
- Risks for exposure to metals other than lead via consumption of upland birds and game and terrestrial plants did not exceed risk benchmarks except for one plant, spring beauty/Indian potato. Thallium was the risk driver.

Based on the findings of the HHRA (USEPA 2021), the main chemical contributors to risk in soil were lead and arsenic.

5.1.1.6 Uncertainties in the HHRA

The HHRA includes an uncertainty analysis that discusses the uncertainty associated with potentially influential parameters used to estimate risk. The HHRA addresses uncertainty in four subsections: "Site-Specific Uncertainty Considerations," "Uncertainty in Lead Risks," "Uncertainty in Risks from Exposure to Nonlead COPCs," and "Consideration of Background." Appendix 1 of the HHRA describes uncertainties specific to the evaluation of risks for the CHIRU population. Selected key uncertainties impacting the HHRA results most relevant to the Upland RI are discussed here.

5.1.1.6.1 IEUBK Model Inputs

A strong body of evidence supports alternate values for two inputs to the IEUBK model, the mass soil-to-dust transfer factor (MSD) and the dietary lead intakes. The HHRA mentions the uncertainties associated with the two values but does not quantify the impact on the lead risk results.

First, the IEUBK model includes a factor to estimate the soil lead contribution to lead in indoor dust, termed MSD. The default MSD is 0.7. The HHRA acknowledges that use of the default MSD "…likely over predicts indoor dust lead concentration as shown at other sites (Schoof et al. 2019); however, Site-specific information is not available from the UCR Site to derive an alternative Site-specific estimate applicable to the UCR" (USEPA 2021). Although not Site-specific, multiple analyses of MSD across western mine and smelter sites yield MSD estimates much less than 0.7 (Brattin and Griffin 2011; USEPA 2016c; Tu et al. 2020). These studies collectively support a default MSD of 0.4, even in the absence of site-specific data.

Second, the default dietary lead intakes included in the IEUBK model for the HHRA are higher than more recent dietary intakes estimated by the U.S. Food and Drug Administration (Spungen 2019; Hoffman-Pennesi et al. 2024), and EPA's Office of Research and Development (Zartarian et al. 2017). The HHRA acknowledges the difference in the dietary lead intake estimates but does not evaluate the impact if the alternate dietary intake values were used in the lead risk calculations. Notably, the most recent intakes estimated by the U.S. Food and Drug Administration (Hoffman-Pennesi et al. 2024) are less than one-third of the values used in the HHRA.

5.1.1.6.2 Thallium Toxicity Value

Thallium is a primary contributor to non-cancer risks above risk benchmarks in the HHRA; however, there is significant uncertainty associated with the toxicity value for thallium. The HHRA acknowledges that risk estimates derived for thallium should be interpreted with caution. USEPA (2012b) has determined that thallium does not have adequate toxicity data to support derivation of a reliable RfD. The thallium RfD is based on effects in rats, such as alopecia (hair loss), that are not believed to be applicable to humans. From their analysis of the toxicity data for thallium, including review of a study by Brockhaus et al. (1981) in which a large human population was exposed to thallium at concentrations up to 100 times greater than the RfD, USEPA (2008b) determined that there was a negative correlation between thallium exposure and hair loss. The RfD used in the HHRA is from an appendix of the Provisional Peer-Reviewed Toxicity Value thallium review (USEPA 2012b) that states, "Appendix A of this document contains Screening Values (screening subchronic and chronic p-RfD) that may be useful in certain instances." Appendix A of the review states, "For the reasons noted in the main document, it is inappropriate to derive a subchronic or chronic p-RfD for thallium. However, information is available which, although insufficient to support derivation of a provisional toxicity value, under current guidelines, may be of limited use to risk assessors." The HHRA states the 3,000-fold uncertainty factor applied in the screening provisional reference dose (p-RfD) makes it likely that thallium risks are overestimated.

5.1.1.6.3 Consideration of Background

The HHRA recognizes that many of the COPCs identified in the HHRA may be influenced by geogenic or anthropogenic sources. Soil background is discussed in Section 4 of this Upland RI report. The HHRA uncertainty analysis also includes a characterization of soil background for the Site and discusses the implications on the risk results. Of most relevance to the characterization of risks in this Upland RI is the HHRA's assessment of soil lead background on the interpretation of the lead risk benchmarks. As stated in the HHRA "…consideration of background soil lead concentration at the Site is unlikely to influence results based on using the P5 or P8 risk benchmark. Because the Site background soil lead concentration (35 ppm[84]) is close to the P3 soil lead PRG (50 ppm) consideration of background may be important for risk management for that PbB [blood lead level] target."

[84] The background value for lead used in the HHRA (35 mg/kg) is different than the BTV used for lead in this Upland RI report (27.2 mg/kg).

5.1.2 Human Health PRGs for Lead

As described above in Section 5.1.1.2, the HHRA includes evaluation of lead risks for three blood lead levels: P3, P5, and P8. As reported in the HHRA, the IEUBK model was used to derive human health PRGs for residential soil lead exposures for each of the three risk benchmarks as follows:

- P3 was associated with a soil concentration of approximately 50 mg/kg lead.
- P5 was associated with a soil concentration of approximately 200 mg/kg lead.
- P8 was associated with a soil concentration of approximately 400 mg/kg lead.

5.1.3 Human Health RAOs

According to the Agreement, risk management-based action objectives (RMAOs) shall have the same meaning as RAOs in the NCP, and their development shall be consistent with the NCP. For the purposes of this Upland RI report, the term RAO will be used because it was used in USEPA (2023c), and it has the same meaning as RMAO as defined in the Agreement.

Based on the results of the HHRA, EPA issued final RAOs for human health in a letter dated January 4, 2023 (USEPA 2023c). This letter specified four RAOs for the UCR Site. Portions of two of the RAOs apply to the upland portion of the Site (OU 3), as follows:

- **RAO 1.** Reduce exposure of residents to lead and arsenic in soil and sediment to levels that do not result in unacceptable Site-related risks.
- **RAO 2.** Reduce exposure of tribal communities to lead and arsenic in soil, sediment, and plants to levels that do not result in unacceptable Site-related risks.

The following excerpt from the RAO letter further clarifies the RAOs for lead: "For lead, this is defined as having no more than a 5% probability of having a blood lead level of 5 μg/dL; for non-cancer risks a hazard index of no more than 1; or a cancer risk of no more than 10^{-4}."

Application of the RAOs for lead should consider relative risks, such as the influence key uncertainties in the IEUBK model can have on the number of properties appearing to exceed lead risk benchmarks and on the derivation of soil cleanup levels to meet lead RAOs. As described in Section 5.1.1.6, application of two updated parameters in the IEUBK model would significantly reduce the number of properties that appear to exceed the P3, P5, and P8 risk benchmarks and would provide a guide for where to focus further evaluation in the Upland FS.

5.2 ECOLOGICAL

This section includes a description of the ecological COCs (Section 5.2.1) as identified in the Upland BERA (USEPA 2023a) and a description of the calculated ecological risk-based concentrations (RBCs) (Section 5.2.2).

5.2.1 Ecological COCs

The Upland BERA (USEPA 2023a) identified nine ecological COCs in the Terrestrial Study Area as presenting unacceptable ecological risk to one or more ecological assessment endpoints. EPA concluded that cadmium, lead, and zinc present the greatest and most widespread risk in the Terrestrial Study Area but also identified arsenic, barium, copper, manganese, mercury, and selenium as ecological COCs that need to be evaluated in the Upland RI. The nature and extent of these ecological COCs is discussed further in Section 6.

5.2.2 Ecological Risk-Based Concentrations

Ecological RBCs are concentrations in soil (mg/kg-dw) equivalent to an HQ of 1 for a specific COC and receptor pair. In the Upland RI, ecological RBCs provide context to the discussion of nature and extent. Ecological RBCs may be further refined as new information is made available and developed into ecological PRGs for use in the Upland FS.

Ecological RBCs were developed for each ecological COC and ecological receptor group identified as presenting unacceptable risk (for birds and mammals the most sensitive receptor and toxicity endpoint were used) in the Upland BERA (see Table ES-1 from USEPA 2023a). For each ecological COC and ecological receptor pair, inputs from the Upland BERA (USEPA 2023a) were used to develop the ecological RBCs as follows:

- Plants and Invertebrates
    - If bioavailability-adjusted benchmarks (BABs) were available for a COC-receptor group, then the ecological RBC was set to the low end of the range of BABs presented in Table 4-5 of the Upland BERA (USEPA 2023a).
    - If no BABs were available, then the ecological RBCs were set equivalent to the soil screening-level benchmarks in Table 4-5 of the Upland BERA (USEPA 2023a).
- Birds and Mammals
    - Inputs to the ecological RBC equation (based on the dietary model) used the default exposure inputs from the Upland BERA (USEPA 2023a) and toxicity reference values

(TRVs) for all three toxicological endpoints (survival, reproduction, and growth) when available, with the following exceptions.

- Lead for birds—The default reproduction TRV used in the Upland BERA was also supplemented with the alternative TRV from Sample et al. (2019) of 9.8 mg/kg bw/day.
- Mercury for birds—The default reproduction TRV used in the Upland BERA was also supplemented with the alternative TRV from Burgess and Meyer (2008) of 0.02 mg/kg bw/day.

○ For those metals that had RBA values measured in soil, the maximum RBA was used (see Table E3.A-1 from Appendix E of the Upland BERA) as a conservative estimate.

Table 5-14 presents the ecological RBCs developed for each ecological COC and ecological receptor pair as described above. BTVs from the TAI Upland Soil Background Assessment (Appendix C) are also included. Ecological RBCs for each ecological COC used for context in the Upland RI report were selected from the values in Table 5-14. To provide conservative context, the lowest ecological RBC was selected from the relevant receptors for each ecological COC. In the case where the lowest ecological RBC was less than the BTV, the BTV was selected as the ecological RBC.

6 NATURE AND EXTENT OF CONTAMINATION

As described in Section 1, an administrative decision was made to focus the Upland BERA and Upland RI reports on the terrestrial portion of the UCR Site (i.e., OU 3), which includes upland soils that may have been influenced by historical deposition of metals. This section presents the nature and extent of the human health and ecological COCs in soils within the OU 3 study area.

Based on the findings of the HHRA, the main chemical contributors to risk in soils within the OU 3 study area are lead and arsenic (see Section 5.1.1.5; USEPA 2021), and Human Health RAOs were developed for lead and arsenic (see Section 5.1.3; USEPA 2023c). Therefore, lead and arsenic are evaluated as human health COCs in this Upland RI report. The Upland BERA (USEPA 2023a) identified arsenic, barium, cadmium, copper, lead, manganese, mercury, selenium, and zinc as ecological COCs in soils within the OU 3 study area.

As described in USEPA (1988), the basic questions to be addressed by a nature and extent evaluation are:

1. What are contaminant concentration levels found in environmental media (soil) in the study area?
2. What is the areal and vertical extent of contamination in soil?
3. What are the spatial trends in contamination?

These questions are evaluated in the Upland RI through a combination of statistical analyses and mapping methods. Section 6.1 describes preparation of the Upland RI data set and the data selected for use in the nature and extent evaluation. Section 6.2 describes the statistical analyses conducted to support the nature and extent evaluation, including an exploratory data analysis, generalized additive model (GAM), small-scale variability assessment, and geostatistical model. Sections 6.3 and 6.4 discuss the areal and vertical nature and extent of the COCs in soil, respectively. The exploratory data analysis and GAM were focused on all COCs, while the small-scale variability assessment and the geostatistical model were run on a subset of COCs (cadmium, lead, and zinc)[85]. Collectively, these evaluations support a holistic assessment of COC occurrences and distribution in upland soils in and around the UCR Site.

[85] As directed by EPA in an email from Bonnie Arthur to Rob Orr on August 1, 2024 (USEPA 2024b), the areal distribution of cadmium, lead, and zinc concentrations in surface soils within the OU 3 study area is modeled in the Upland RI using a geostatistical modeling approach.

6.1 DATA SET PREPARATION

The Upland RI data set was prepared to minimize the chance that data of potential importance to the nature and extent evaluations would be inadvertently excluded. Initially, all available studies were considered for potential use in the Upland RI. Subsequently, certain studies were screened out based on criteria such as inappropriate sample types and/or sample preparation methods.

Soil metals concentration data were compiled from 30 separate studies conducted in northeastern Washington and south-central British Columbia to create the Upland RI data set. These studies are listed in Table 3-1, and descriptions are provided in Section 3 of this report. Soil metals concentration data for the studies were downloaded from the UCR project database[86]. Several basic data management steps, consistent with the RI/FS Data Management Plan (TAI 2019d), were applied to produce the Upland RI data set. Analytical results for field duplicate and replicate samples were averaged, nondetected values were substituted with the value in the measurement value field[87] in the database, and estimated ("J" qualified) values were used at their reported value (TAI 2019d).

Additionally, not all data collected as part of the 30 compiled studies were appropriate for use in the Upland RI. For example, some studies (e.g., 2016 Residential Soil Study) collected samples from beaches, which will be evaluated in the Aquatic RI report. Other studies (e.g., 2017 SATES Test Plot Characterization) collected multiple samples from DUs that were sampled during a previous study, and inclusion of these samples had the potential to bias the statistical results. The general data selection and filtering criteria applied across all studies (where applicable) for developing the Upland RI data set are provided in Table 6-1a. Table 6-1b describes the data selection and filtering criteria that were applied on a study-by-study basis. Data included in the Upland RI data set are provided in Appendix D, and concentrations of COCs and other metals are mapped in the digital data exploration tool (an HTML file; see Appendix E). The locations of samples in the Upland RI data set are shown on Map 6-1.

Table 6-2 provides a list of the studies included in each nature and extent analysis and the rationale for each study that was excluded from a given analysis. Table 6-3 identifies the complete list of metals included in each analysis. The locations of samples used for the GAM and geostatistical model are shown on Map 6-2.

[86] Accessible to registered users at https://teck-ucr.equisonline.com.

[87] Per the Data Management Plan (TAI 2019d), "For values flagged as nondetected values, the measurement value field will contain either the MDL [method detection limit], MRL [method reporting limit], or other value."

Data from the 2004 EPA Le Roi Smelter Removal Action Study and the 2014 and 2016 Residential Soil Studies are used in the Upland RI to support the nature and extent evaluations. However, these studies represent pre-removal data. Multiple properties sampled during these studies were remediated during the 2004 EPA Le Roi Smelter Removal Action, 2015 TCRA, and 2017–2018 VRA (Appendix B) and do not represent current conditions at all the locations investigated.

6.2 SUMMARY OF STATISTICAL ANALYSES

The nature and extent evaluations include the exploratory data analysis, the GAM, a small-scale variability assessment, and a geostatistical model. Each of these analyses is summarized in the subsections below, which include the specific study question(s) being addressed by each analysis and the findings relevant to the nature and extent evaluation, the transport and fate evaluation, and the physical/chemical CSM. Each of the analyses presented in this section helps characterize the extent of elevated metals concentrations in soil in the OU 3 study area. While the descriptions in this report are specific to the COCs, some of the statistical analyses were performed for an expanded list of metals in order to provide a more holistic picture of metals concentrations in soil at the Site. Table 6-3 identifies the complete list of metals included in each analysis.

6.2.1 Exploratory Data Analysis

The exploratory data analysis is included in Appendix F and was performed as a precursor to other statistical analyses to examine soil metals concentrations and physical variables for patterns, inconsistencies, and outliers. The exploratory data analysis was performed using data from all studies in the Upland RI data set, except those screened out based on general data selection and filtering criteria (Table 6-2). Outputs from the exploratory data analysis include a metal-metal correlation matrix, scatterplots of soil metals concentrations versus physical variables (elevation and northing), and boxplots of soil metals concentrations by study. A detailed discussion of the methods and results is provided in Appendix F.

One element of the exploratory data analysis, the correlation matrix, is carried forward for the nature and extent evaluation. Understanding metal-metal correlations in the Upland RI data set helps validate the presence or absence of similar patterns when comparing the nature and extent of individual COCs.

The correlations between soil metals concentrations were reviewed to identify patterns in the data set and pairwise relationships of metals. Table 6-4 and Figure 6-1 show Spearman's rank correlation coefficients (rho) for COCs. These results include all pairwise complete observations (i.e., any sample for which both analytes in a pair were measured was included in the calculations). In the correlation coefficient matrix (Figure 6-1), blue squares indicate a positive

correlation (i.e., concentrations of one metal increase when concentrations of the other increase), and red squares indicate a negative correlation (i.e., concentrations of one metal decrease when concentrations of the other increase). The shade of the square indicates the strength of the correlation, with darker squares indicating strong correlations and lighter squares indicating weak correlations. Correlation coefficients (rho) can be categorized into bins that are indicative of the strength of the relationship between the two variables. Rho of 0 to ± 0.20 is considered very low or none; rho of ± 0.20 to ± 0.40 is considered low; rho of ± 0.40 to ± 0.60 is considered moderate; rho of ± 0.60 to ± 0.80 is considered strong; and rho greater than or equal to ±0.8 is considered very strong.

The correlation coefficient matrix for the nine COCs shows that arsenic, cadmium, copper, lead, mercury, and zinc have moderate to strong positive correlations with each other. Barium, manganese, and selenium exhibit variable correlation patterns with the other six COCs. However, barium and manganese have a strong positive correlation with each other, and selenium has a low positive correlation with barium and manganese. These patterns of covariation among COCs in the data set are useful when considering similarities and differences in the nature and extent of COC concentrations in surface soil within OU 3.

6.2.2 GAM

The extent to which physical attributes are associated with soil metals concentrations was evaluated using a GAM. The purpose of using a GAM was to answer the following question:

1. What is the statistical relationship between metals concentrations in soil and physical attributes?

A GAM is similar to a linear model, but instead of estimating a linear slope relationship, a flexible smoothing function is used to allow for nonlinear relationships (e.g., curves). GAMs have the advantage of interpretability and flexibility, making them a high-performing alternative to traditional linear regression modeling techniques. The GAM was used to evaluate the relationship between metals concentrations in soil and physical parameters, including distance from the Trail Facility, as measured by Universal Transverse Mercator (UTM) northing; elevation; slope; and lateral distance from the river, side of river (i.e., east or west), and depth of sample. UTM northing and distance from river for each sample were calculated using digital mapping tools and elevation and slope were calculated from a digital elevation model.

The GAM was performed using data from six studies from the OU 3 study area (wholly located in the U.S.) and the Trail ERA study data set in Canada (Table 6-2). Whereas the geostatistical model (described in Section 6.2.4) used only samples from the Trail ERA study that were

located within 1 km of the U.S.-Canada border,[88] the entire Trail ERA data set was used for the GAM. The entire data set from the Trail ERA was used in the GAM to support a more complete evaluation of the trends in metals concentrations within the UCR valley and in upland areas.

The parameters exhibiting the most pronounced relationship with surface soil COC concentrations in the GAM are UTM northing (as a proxy for distance from the Trail Facility), lateral distance from the river, and elevation. The GAM results for UTM northing and elevation[89] are discussed below for all COCs except selenium. For selenium, several studies included high frequencies of nondetected values and/or elevated detection limits, which complicate interpretations from the GAM for selenium. Therefore, GAM results for selenium are shown in figures but are not interpreted below.Other sources of uncertainty in the GAM include variable sample density and the combination of data from different studies where samples were collected using different methods and from different depths and were analyzed at different analytical laboratories.

Additional details regarding the GAM results for UTM northing and elevation, along with the results for the other physical parameters, are presented in Appendix F. These relationships are used in the nature and extent evaluation to explain how concentrations tend to vary spatially (e.g., down the river valley, with elevation).

The GAM results for the COCs versus UTM northing (distance from the Trail Facility) are provided in Figure 6-2a through Figure 6-2i, and a plot including GAM results for UTM northing for all nine COCs is provided in Figure 6-3. The following specific patterns are observed in the UTM northing GAMs used to evaluate relationships with distance from the Trail Facility (Figure 6-3):

1. Arsenic, barium, cadmium, copper, lead, mercury, and zinc concentrations show a broad peak centered at or near the Trail Facility, with concentrations that decline to the north and to the south toward the U.S.-Canada border. Manganese concentrations show a relatively flat line in Canada with a small increase centered at the Trail Facility.

[88] Samples from the Trail ERA study that were located within 1 km of the U.S.-Canada border were used in the geostatistical model to improve the reliability of the model estimates immediately south of the border, as directed by EPA in an EPA-TAI Geostatistical Modeling Focused Working Group Meeting held on August 13, 2024. The data set used for the geostatistical model was approved by EPA on August 23, 2024, in email correspondence from Bonnie Arthur to Rob Orr (USEPA 2024c).

[89] A strong relationship was also exhibited for distance from river. Because distance from river and elevation are highly correlated, discussing both would be redundant, and therefore, only elevation is discussed here.

2. Concentrations of arsenic, cadmium, lead, and zinc show a relatively steep decline after an initial peak south of the U.S.-Canada border, and copper shows a more moderate decline. Concentrations continue to decline to the south, with peaks for cadmium, copper, and lead centered around Northport, Washington,[90] and peaks for arsenic, cadmium, lead, and zinc near Marble, Washington (UTM Northing 5411070).
3. Concentrations of barium and manganese level off after an initial increase south of the U.S.-Canada border, followed by a decline south of Northport and a leveling off. Barium and manganese concentrations in the U.S. are elevated above concentrations in the vicinity of the Trail Facility.
4. Concentrations of mercury show a gradual decline after an initial increase south of the U.S.-Canada border, followed by a leveling off. Because mercury was not analyzed in soil samples from the 2014 and 2016 Residential Soil Studies, there are fewer samples along the UCR valley for mercury than for other metals, which may contribute to the different pattern shown for mercury.

The patterns described in the bullets above indicate that the nature and extent of the COCs arsenic, cadmium, copper, lead, mercury, and zinc is consistent with aerial deposition from smelter emissions. Barium and manganese exhibit different north-south patterns than the other COC metals.

The GAM results for the COCs versus elevation are provided in Figure 6-4a through Figure 6-4i, and a plot including GAM results for elevation for all nine COCs is provided in Figure 6-5. To help interpret the GAM results for elevation, these figures show elevation bands that were selected by dividing the sample set into four categories (bands) based on the quartiles of elevations of samples. These elevation bands are shown on Map 6-3 and include less than 1,500 ft amsl, 1,500 to 1,800 ft amsl, 1,800 to 2,700 ft amsl, and greater than or equal to 2,700 ft amsl.

There were three general relationships between elevation and metals exhibited in the GAM, which varied by COC. These relationships are as follows:

1. Lead, cadmium, and copper exhibit steeply decreasing concentrations with increasing elevation across the lowest elevation band (less than 1,500 ft amsl) and partway into the second elevation band (1,500 to 1,800 ft amsl). Above 1,800 ft amsl, there are variable

[90] Of the 242 soil samples in and around Northport that were analyzed for arsenic, cadmium, copper, and lead in the 2004 EPA Le Roi Removal Action Study, only 11 samples were analyzed for mercury, selenium, and zinc, and none were analyzed for barium or manganese.

patterns between increasing and decreasing concentrations. The decreasing trend across the lowest elevation band is driven at least in part by the many soil samples at lower elevations in the Northport area that were analyzed for cadmium, copper, and lead as part of the 2004 EPA Le Roi Smelter Removal Action Study. The pattern of higher concentrations at low elevations (i.e., along the river valley) that decrease with increasing elevation would be expected for metals that are transported and deposited from smelter emissions.

2. Arsenic and zinc do not exhibit a strong relationship with elevation. As such, these COCs do not show a decrease in concentration with increasing elevation across the lowest elevation bin (less than 1,500 ft amsl).
3. Barium, manganese, and mercury show a gradual increase in concentrations with increasing elevation beginning in the lowest elevation band (less than 1,500 ft amsl) and extending to 2,700 ft amsl for mercury and above 2,700 ft amsl for barium and manganese.

The pattern of higher concentrations at low elevations (i.e., along the river valley) that decrease with increasing elevation, as observed for lead, cadmium, and copper, is consistent with transport and deposition of particulates emissions from the Trail Facility and the Le Roi/Northport Smelter. This is consistent with the GAM results for these metals based on UTM Northing/distance from the Trail Facility. Zinc, arsenic, and mercury patterns appear influenced by smelter emissions based on the GAM for UTM Northing/distance from Trail Facility but not based on the elevation GAM. This could be a result of differences in data sets (zinc and mercury were not analyzed in some studies) and/or a result of the complexities from different sources of metals (including background), variable topography, and the large geographic extent of the data used in the analysis.

Overall, the GAM results show that the nature and extent of lead, cadmium, and copper show overall patterns that are consistent with smelter emission sources, and that zinc, arsenic, and mercury show patterns that are less clearly influenced by smelter emissions than those for lead, cadmium, and copper. The trends exhibited in the GAMs for barium and manganese are different from the other COCs and are not consistent with smelter emissions sources.

6.2.3 Small-Scale Variability of Metals Concentrations

The objective of the small-scale variability analysis was to assess the variability (heterogeneity) of soil metals concentrations in the OU 3 study area and how the variability differs spatially and by metal. Understanding the variability in soil metals concentrations is an important consideration when using the nature and extent evaluation for RI/FS decision-making purposes

or for designing monitoring programs. The small-scale variability in soil metals concentrations was evaluated two ways as part of the Upland RI.

First, as described in this section, the small-scale variability assessment compared soil sample results for sets of samples that were collected close together under a given study. In this approach, small-scale variability was assessed as the coefficient of variation (CV), also referred to as relative standard deviation. The CV is a common data quality indicator for precision that quantifies the degree of variability as the ratio of the sample standard deviation to the sample mean. Assessing CVs for sets of samples allows for comparison to data quality indicators for precision and for other typical statistical applications, such as comparisons to thresholds or monitoring program designs.

Second, as described in Section 6.2.4, results from field duplicate samples were used to estimate the relative nugget effect used in the geostatistical model. The nugget is a parameter that represents independent error, measurement error, or microscale variation at spatial scales that are too fine to detect.[91] The relative nugget effect and its implications regarding uncertainty for predicted soil concentrations are described in Section 6.2.4.

The remainder of this section describes the results of the small-scale variability assessment for lead, cadmium, and zinc in surface soil. The assessment considered study, sample type, and location, and used the following sets of samples:

- Replicate IC samples, composite samples, or discrete grab samples that were collected within a DU
- Multiple SUs that were sampled within a DU
- Multiple DUs that were sampled at a property
- Composite samples that were collected in a subarea.

Only DUs, properties, and subareas with groups of three or more samples were used for this analysis because at least three samples are required to calculate a meaningful standard deviation. The following studies include qualifying sample sets (sets of three or more samples collected close together) within a DU, property, or subarea:

- **2012 Ecology Upland Soil Study.** Multiple four-point composite samples were collected from each of the 13 sampling subareas evaluated in this study. The number of composite samples per sampling subarea ranges from 6 to 10. This study is described in Section 3.2.

[91] https://support.esri.com/en-us/gis-dictionary/nugget

- **2014 Residential Soil Study.** Results are available for three or more replicate IC samples collected at 114 DUs, and there were 23 properties where multiple (three or more) DUs were sampled at a property. Results are also available for a series of discrete grab samples collected at a subset of DUs; however, for this study, the discrete grab samples were collected from 1 to 6 in. bgs. Because these samples did not include the surface interval (i.e., the interval from 0 to 1 in. bgs), the discrete grab samples from the 2014 Residential Soil Study were not used in this small-scale variability analysis. The 2014 Residential Soil Study is described in Section 3.3.1.
- **2014 Soil Study.** Replicate IC samples, typically triplicates, were collected at 16 DUs. Of these, 10 DUs were in the primary sampling area, and 6 DUs were in the high-density sampling area. The 2014 Soil Study is described in Section 3.1.
- **2015 TCRA Memorandum and 2015 TCRA.** There were five DUs where three or more pre-removal surface discrete grab samples were collected for the TCRA. The number of grab samples in each DU ranged from 3 to 12. TCRA samples were not analyzed for cadmium or zinc; therefore, small-scale variability is evaluated only for lead for this study. The 2015 TCRA is described in Appendix B, and associated soil sampling and analyses are described in Sections 3.3.2 and 3.3.3.
- **2016 Residential Soil Study.** Small-scale variability can be evaluated using three approaches for the 2016 Residential Soil Study. First, three or more replicate IC sample results are available for 130 DUs. Second, results are available for a series of discrete grab samples (typically five) collected at a subset of 28 DUs sampled for this study. Third, there were 70 properties where multiple DU types (three or more) were sampled at a property. The 2016 Residential Soil Study is described in Section 3.3.4.
- **2017 SATES Test Plot Characterization.** During Phase IA Part 1, discrete grab samples were collected from within six test plots located at three DUs, then during Phase 1A Part 2, discrete grab samples were collected from four 50-ft-by-50-ft subplots within each of three 100-ft-by-100-ft test plots. The total number of individual (discrete grab) samples within each DU ranged from 103 to 304. During Phase 1A Part 2, IC samples were collected from the subplots, with the number of IC samples collected within each DU ranging from 8 to 16. The 2017 SATES Test Plot Characterization is described in Section 3.3.6.
- **2018 Plant Tissue Study.** This study included collection of composite and discrete grab samples. There were multiple (3 or more) composite soil samples from six SAs where plant tissue was collected, with the number of composite samples per SA ranging from 3 to 11, and there were 3 or more discrete grab samples collected at eight SAs, with the

number of grab samples ranging from 3 to 22 per SA. The 2018 Plant Tissue Study is described in Section 3.3.7.

The numbers of DUs and subareas with qualifying sample sets and the associated CVs are summarized in Table 6-5, and properties with multiple (more than three) different DUs with associated CVs are summarized in Table 6-6. The CV calculations were performed on a study-by-study basis, and results are presented by study. Because the studies followed different sampling designs and focused on different areas within the OU 3 study area, combining studies would introduce variability that could confound the interpretations. The CVs for lead, cadmium, and zinc within DUs and subareas with qualifying sample sets are summarized and shown spatially in Figure 6-6a through Figure 6-6c, respectively, and for properties with multiple DUs in Figure 6-7a through Figure 6-7c, respectively.

The patterns in small-scale variability, expressed as CVs, are described below. The patterns varied 1) as a function of the types of samples evaluated, 2) by study, 3) spatially, and 4) by metal. The patterns described below are organized by type of samples evaluated. For each type of samples evaluated, patterns are described, when observed, by study, spatially, and by metal.

- **IC replicates within DUs.** CVs for IC sample replicates were generally lower than for the other sample types evaluated here (Table 6-5), which is expected given the theory and objective of the IC sampling methodology. The mean and median CVs were less than 0.30[92] for each metal and for all studies except the 2017 SATES Test Plot Characterization. The SATES data showed mean CVs of 0.39 for lead, 0.40 for cadmium, and 0.38 for zinc, with median CVs being nearly equal to the mean CVs (Table 6-5). For the 2014 Soil Study, CVs tended to be greater in the high-density sampling area than in the primary sampling area. Overall, the replicate IC samples indicate that within-DU variability is low for IC samples that represent the entire DU, but higher for IC samples collected from subareas within DUs (i.e., 50-ft-by-50-ft subplots sampled for the 2017 SATES Test Plot Characterization). This suggests that even a rigorous sampling methodology designed to produce a representative sample for an sampling unit does not in all cases mitigate for the small-scale variability in soil metals concentrations.
- **Composite samples within subareas or DUs.** Composite samples collected from within subareas or DUs exhibited intermediate variability (Table 6-5). Mean and median CVs are greater than 0.50 for all metals for the 2012 Ecology Upland Soil Study, with

[92] The precision data quality indicator for triplicate IC samples was 30 percent relative standard deviation (CV = 0.30) for the 2016 Residential Soil Study (TAI 2017a) and 35 percent relative standard deviation (CV = 0.35) for the 2014 Soil Study (TAI 2015a).

maximum CVs for lead and cadmium of 1.04 and 0.95, respectively. Mean and median CVs for the 2018 Plant Tissue Study were in the range of about 0.20 to 0.30, with maximum CVs ranging from 0.35 for cadmium to 0.60 for zinc. The 2018 Plant Tissue Study sample collection areas (Map 3-8) were at lower elevations, closer to the river, and farther from the U.S.-Canada border (Map 3-8) than the 2012 Ecology Upland Soil Study samples (Map 3-2).

- **Discrete grab samples within DUs.** Discrete grab samples collected within DUs exhibited some of the greatest variability of the sample types evaluated (Table 6-5). Mean CVs range from 0.30 for zinc for the 2016 Residential Soil Study to 0.74 for lead in the 2017 SATES Test Plot Characterization. The ranges of minimum to maximum CVs for each metal were greatest for the 2016 Residential Soil Study, but the highest mean CV for each metal was from the 2017 SATES Test Plot Characterization. These relatively high CVs for discrete samples from the SATES study, where many hundreds of samples were collected and analyzed within DUs, illustrate that collecting a greater number of samples does not necessarily reduce the uncertainty in soil metals concentrations.
- **Multiple DUs at a property.** Looking at both the 2014 and 2016 Residential Soil Studies, the mean and median CVs were equal to or greater than 0.36 for cadmium and lead and 0.30 or less for zinc (Table 6-6), and maximum CVs ranged from 0.73 to 1.07 for all three metals. The CVs tended to be greater for properties with multiple DUs sampled during the 2014 Residential Soil Study than properties with multiple DUs sampled during the 2016 Residential Soil Study. The 2016 Residential Soil Study included sampling at properties farther from the U.S.-Canada border (Map 3-5) than residential properties sampled in 2014 (Map 3-3a and b).

The spatial representation for CVs shown for DUs and sampling areas with qualifying sample sets in Figure 6-6a through Figure 6-6c and shown for properties with multiple DUs in Figure 6-7a through Figure 6-7c, illustrate that high and low CVs are distributed throughout the OU 3 study area. While elevated CVs (> 0.5)[93] may appear to occur more frequently near the U.S.-Canada border for lead (Figure 6-6a) and cadmium (Figure 6-6b), numerous DUs also exhibit elevated CVs farther from the border. While differences in CVs were noted above for

[93] There are no accepted limits and few rules of thumb for the interpretation of CVs. What constitutes low or high precision depends on context and what a "normal" amount of variation would be for the variable in question. Some guidelines are available; for example, according to Wilding (1985), CVs for soil properties can be classified into three categories: low variation (CV < 15%), moderate variation (15% < CV ≤ 35%), and highly variable (CV > 35%). For the CV interpretations in this Upland RI report, a CV of < 0.25 is assumed to indicate low variation, a CV of > 0.5 indicates high variation, and a CV between 0.25 and 0.5 indicates moderate variation.

studies that covered different areas, there does not appear to be a pattern in small-scale variability as a function of distance from the U.S.-Canada border or the Columbia River.

Collectively, the small-scale variability analysis indicates that lead, cadmium, and zinc concentrations in soil are variable across the scales of DUs, sampling areas, and properties that have been sampled in the OU 3 study area. This variability can be due to a variety of factors, including analytical precision, soil sampling and processing techniques, the inherent heterogeneity of soil, differences in land uses, topography, vegetation cover, and/or the influences of different sources and the interplay between natural and anthropogenic sources. The variability exhibited by these Site data illustrate that prediction of soil concentrations across unsampled areas, if required, should be performed and interpreted carefully.

6.2.4 Geostatistical Model

The Upland RI data set compiled for use in the Upland RI (see Section 6.1) was generated from multiple studies that included different study objectives, sampling designs, and study areas. As a result, the coverage of soil data across the OU 3 study area is variable, with some areas having a relatively high density of soil samples (e.g., along the river valley in the northern portion of the OU 3 study area) and other areas having fewer data. Also, due to the size of the OU 3 study area, even specific areas that were sampled using an approach to provide complete spatial coverage (e.g., the ADA sampled during the 2014 Soil Study) may have large distances (on the order of miles) between sample locations.

Given the variable sample coverage within the OU 3 study area, estimating the concentrations of metals at unsampled locations can improve the understanding of the nature and extent of COCs. Such estimates require addressing the following questions:

1. To what extent can soil metals concentrations be predicted by modeling for unsampled locations and beyond the extent of data coverage?
2. What is the uncertainty of modeled soil concentrations?

Geostatistical modeling was selected as the tool to answer these questions because it aims to provide accurate estimates of metals concentrations in soil at unsampled locations. The objective of the geostatistical model was to characterize the nature and extent of lead, cadmium, and zinc in the OU 3 study area based on geostatistical analysis of existing surface soil data. The outputs from the geostatistical model include the following:

1. Maps showing interpolated and extrapolated concentrations in surface soil
2. Maps illustrating the uncertainty of predicted soil concentrations at unsampled locations
3. Maps illustrating the likelihood that a given soil concentration is exceeded.

The geostatistical tools used for modeling surface soil metals concentrations in the OU 3 study area included sequential Gaussian simulation (SGS) and universal kriging (UK). SGS is an advanced geostatistical method used for spatial prediction and uncertainty quantification (ITRC 2016). It is a Monte Carlo-based technique that generates multiple simulations of a spatial variable, each with a different realization of the spatial correlation structure of the variable. UK is applied for estimating local probability distributions when local trends exist. The SGS and UK geostatistical tools are described in Appendix G.

An SGS-UK geostatistical model was prepared for the Upland RI using the Upland RI data set, as described in Section 6.1 and summarized in Table 6-2 and Appendix D Table D-2. The SGS-UK approach employs geostatistical modeling to analyze the spatial distribution of lead, cadmium, and zinc and involved running 100 simulations using UK in the U.S. for lead, cadmium, and zinc. The model domain is presented on Map 6-4 and includes a buffer of 2.5 km from the outermost samples, which was used to limit the extent of extrapolation beyond the data coverage area. Estimated spatial distributions beyond this buffer area will be highly uncertain and would be unreliable for RI/FS decision-making purposes.

The data set used for the geostatistical model included results from 11 different studies in the U.S. and Canada (Table 6-2). For the studies in the U.S., sample results associated with mines and mills (e.g., soil and waste samples from waste rock dumps or tailings facilities) were excluded from the modeling data set based on two factors. First, many of the samples associated with mines and mills were collected around historical mining and milling operations that are spatially removed from most soil sample locations within the UCR valley and adjacent upland areas. Second, analysis of the spatial variation in the two subsets showed that the range of correlation is low for the mines-and-mills data, and their short-scale variation is very high (see Appendix G). Together, these factors indicate that attempting to use the samples associated with mines and mills for predicting surface soil concentrations would lead to unreliable results. Theses samples are plotted separately as “mines and mill samples” on the maps showing modeling output. For the studies in Canada, only sample locations located within 1 km of the U.S.-Canada border were used in the geostatistical model. These samples were included to help inform predictions in the U.S. However, model output is limited to only the U.S. because the UCR Site is located wholly within Washington State.

Results from the 100 simulations were post-processed to produce a geostatistical model that enables the prediction of soil metals concentrations at unsampled locations in the OU 3 study

area. Specific outputs from the geostatistical model that address the questions posed above for the nature and extent evaluation include the following:

- **Median concentration maps**. These maps depict the median (or 50th percentile [P50]) soil concentration from the 100 SGS-UK simulations and correspond approximately to the average concentration from the model. These maps are presented and discussed in the areal nature and extent evaluations for lead, cadmium, and zinc in Sections 6.3.1.6, 6.3.2.5, and 6.3.3.5, respectively.
- **Prediction uncertainty maps.** These maps depict the uncertainty in predicted metals concentrations as expressed as difference between the 90th percentile (P90) and the 10th percentile (P10) from the 100 SGS-UK simulations.

The results from the geostatistical model illustrate the complexity and uncertainty associated with predicting soil metals concentrations across the very large expanse of the OU 3 study area. There is considerable uncertainty associated with modeled concentrations based on both the spatial correlation exhibited by the sample data and the underlying sample data distributions.

Spatial correlation is expressed by the variogram, which includes a nugget effect (variability at zero distance) and the range (maximum distance of spatial correlation). The relative nuggets for cadmium, lead, and zinc range from 0.4 for zinc to 0.55 for lead. This magnitude of nuggets indicated that about half (50 percent) of the variability in soil metals concentrations is accounted for in samples collected at the same location. Given this degree of variability in soil metals concentrations, the collection of additional samples within areas with no samples or low sample density would not be expected to significantly reduce the prediction uncertainty. This uncertainty should be considered carefully when using modeled concentration maps for RI/FS decision-making purposes.

6.3 AREAL NATURE AND EXTENT OF COCs IN SOIL

The areal nature and extent evaluation incorporates a digital data exploration tool (provided electronically in HTML format as Appendix E) that contains all COCs and other metals represented in the Upland RI data set; maps of measured soil concentrations at individual sample locations (i.e., post maps) for each COC; and geostatistically modeled soil concentration maps for cadmium, lead, and zinc. The results of the statistical analyses described in Section 6.2 and Appendix F are also used to support the nature and extent descriptions below. Table 6-2 lists the data and studies included in each component of the areal nature and extent evaluation. The post maps and modeled soil concentration maps are grouped by COC in Map 6-5 through Map 6-20.

Descriptions of the digital exploration tool, surface soil concentration post maps, surface soil concentration maps developed using the geostatistical model, and boxplots prepared for the data included on the concentration post maps, are provided below:

- The digital data exploration tool contains all the surface soil data (i.e., samples with an upper depth of 0 in. and variable lower depths) included in the Upland RI data set for the ecological and human health COCs for the OU 3 study area as well as surface soil data for other metals included in the data set. Data for all size fractions and all sample preparation methods are mapped. The data exploration tool allows filtering by study, size fraction, and sample preparation method, and it allows the viewer to zoom into areas with high sample density so that individual sample points can be viewed. Data collected in the U.S. and Canada in the studies summarized in Section 3 are included in the tool (Appendix E).
- Surface soil concentration post maps (Map 6-5, Map 6-6, Map 6-9, Map 6-12, and Map 6-15 through Map 6-20) were prepared for measured metal concentrations and calculated RBA-adjusted lead concentrations in surface soil using only data collected in the U.S. For the measured soil metal concentration post maps, samples prepared using total recoverable methods for the < 2-mm-size fraction are shown as circles, samples prepared using total recoverable methods for the < 150-µm-size fraction[94] are shown as diamonds, and samples prepared using total recoverable methods for samples with an unknown size fraction are shown as triangles. Samples prepared using total digestion methods are shown as squares. For the calculated RBA-adjusted lead post map, the symbols differentiate samples from each of the four studies that collected IVBA data.
- Surface soil concentration maps developed using the geostatistical model were prepared for lead (Map 6-7), cadmium (Map 6-10), and zinc (Map 6-13) (Section 6.2.4, Appendix G). Surface soil samples (samples with an upper depth of 0 in.) that were prepared using total recoverable methods for the < 2-mm-size fraction, < 150-µm-size fraction, and unknown size fraction were included in the geostatistical model.
- Boxplots for the data included on the surface soil concentration post maps are provided in Figure 6-8a through Figure 6-8j. Summary statistics for these data are provided in Table 6-7.

[94] This Upland RI report uses the < 150-µm-size fraction to refer collectively to data reported for the < 149-µm-size fraction and data reported for the < 150-µm-size fraction.

The following sections describe the areal nature and extent for the COCs in surface soil within the OU 3 study area. Soil concentrations are described relative to the BTVs (total recoverable and total digestion) for all size fractions. Concentrations are also compared to the relevant human health PRGs for residential land use established in the HHRA and/or ecological RBCs, as appropriate. The areal nature and extent of COC concentrations in surface soil is also described for each COC relative to geographical locations, such as the border, Northport, Bossburg, historical mines and mineral processing facilities, and other geographical features. These descriptions are not intended to suggest source attribution, but to provide a factual narrative description of spatial patterns.

6.3.1 Areal Nature and Extent of Lead

Lead concentrations in surface soil are shown on Map 6-5, and calculated RBA-adjusted lead concentrations are shown on Map 6-6. Modeled lead concentrations are shown on Map 6-7. For the data included on Map 6-5 and Map 6-6, summary statistics are provided in Table 6-7, and boxplots for lead and RBA-adjusted lead are presented in Figure 6-8a and Figure 6-8b, respectively. Soil lead concentrations are also available in the data exploration tool (Appendix E).

On Map 6-5 and Map 6-6, measured soil lead concentrations and calculated RBA-adjusted lead concentrations, respectively, are binned to show the following concentrations:

- Bin 1—Less than the total recoverable BTV of 27.2 mg/kg (or 30.0 mg/kg for total digestion samples)
- Bin 2—Greater than or equal to the BTVs and less than 100 mg/kg, which is approximately the lowest ecological RBC (106 mg/kg; protective of the reproduction endpoint for the masked shrew)
- Bin 3—Greater than or equal to 100 mg/kg and less than the P5 human health PRG[95] of 200 mg/kg
- Bin 4—Greater than or equal to the P5 human health PRG and less than the P8 human health PRG of 400 mg/kg

[95] The P5 PRG, P8 PRG, and TCRA action level are human health benchmarks. They are lead benchmarks specific to soil most relevant for human exposure (i.e., the < 150-µm-size fraction in surface soil) and incorporate the default USEPA RBA-adjustment for lead in soil (60 percent). Therefore, these benchmarks are mainly applicable to lead concentrations in surface soil samples in the < 150-µm-size fraction that have been RBA-adjusted. However, these benchmarks are applied to all soil lead concentrations in the OU 3 study area for the purpose of characterizing the nature and extent of lead in soil.

- Bin 5—Greater than or equal to the P8 human health PRG and less than the human health TCRA action level of 700 mg/kg
- Bin 6—Greater than or equal to the human health TCRA action level and less than 100 times the total recoverable BTV (2,700 mg/kg)
- Bin 7—Greater than or equal to 2,700 mg/kg.

Nondetected values are symbolized separately on Map 6-5.

Overall, lead concentrations show considerable spatial variation. In general, they are highest at low elevations along the UCR valley between the U.S.-Canada border and Northport; at higher elevations in the upland areas on both sides of the river valley, immediately south of the U.S.-Canada border; and in the vicinity of Northport, the area surrounding the Van Stone Mine/Mill, and the vicinity of Bossburg. Concentrations generally decrease with distance southward along the river valley and with increasing elevation and lateral distance away from the river in both directions (east and west) (Figure 6-4a, Map 6-5, Map 6-7; Appendix F). Detailed descriptions of the spatial distribution of lead are provided in the following subsections.

6.3.1.1 Total Recoverable Data in the < 2-mm-Size Fraction

Soil lead concentrations for the < 2-mm total recoverable data in the OU 3 study area range from 2.6 to 26,000 mg/kg, with a median of 150 mg/kg. Of 498 samples, 100 percent are detected values, and 400 samples (80 percent) are greater than or equal to the total recoverable BTV of 27.2 mg/kg (Table 6-7). Samples with concentrations below the total recoverable BTV include one or more samples from the 2011–2012 Ecology Van Stone RI (Ecology 2013b) and the 2015 Bossburg Study (TAI 2016c) (Map 6-5 and Appendix E).

Samples collected between the U.S.-Canada border and Northport and within approximately 3 miles of the river on either side of the valley generally exceed 200 mg/kg, with periodic exceedances on both sides of the river valley south to approximately 2.5 miles east of Marble. Samples collected within approximately 2 miles of the U.S.-Canada border and near Northport are periodically greater than or equal to 400 mg/kg within approximately 1 to 2 miles of the river on both sides of the valley. Beyond approximately 3 miles from the river on both sides and south along the river valley from Northport, lead concentrations are generally less than 200 mg/kg but are greater than or equal to the total recoverable BTV (27.2 mg/kg). Soil concentrations greater than or equal to 200 and 400 mg/kg also occur intermittently at lower elevation sample locations within approximately 1 mile on both sides of the river valley south to approximately 4 miles south of Marble. Exceedances of 700 mg/kg occur intermittently within 2.5 miles of the U.S.-Canada border, at Northport, and in a small area near Bossburg (Map 6-5).

Lead concentrations in the vicinity of Bossburg and the Van Stone Mine/Mill exceed 400 mg/kg. Samples with concentrations greater than or equal to 2,700 mg/kg are limited to those collected as part of the 2011–2012 Ecology Van Stone RI (Ecology 2013b), more than 5 miles away from the Columbia River in the uplands (Map 6-5).

6.3.1.2 Total Recoverable Data in the < 150-µm-Size Fraction

Soil lead concentrations for the < 150-µm total recoverable data in the OU 3 study area range from 8.9 to 1,920 mg/kg, with a median of 98.7 mg/kg. Of 1,192 samples, 100 percent are detected values, and 1,141 samples (96 percent) are greater than or equal to the total recoverable BTV of 27.2 mg/kg (Table 6-7).

Lead concentrations in the < 150-µm-size fraction show a similar distribution to the < 2-mm-size fraction, with exceedances of 400 and/or 700 mg/kg at low elevations in the UCR valley from the U.S.-Canada border to about 2 miles south, immediately north of Deadman's Eddy on the western side of the river, across the river from Northport, north and across the river from Marble, and in Bossburg.[96] Concentrations also exceed 400 mg/kg in several isolated locations in the uplands approximately 3 to 4 miles west of the river (Map 6-5).

Concentrations of lead are intermittently exceed 200 mg/kg from the U.S.-Canada border to approximately 4 miles south of Marble. Exceedances of 200 mg/kg are limited to within approximately 2 miles of both sides of the river, but there are isolated exceedances in the uplands approximately 3 to 4 miles west of the river (Map 6-5).

Lead concentrations exceed the total recoverable BTV (27.2 mg/kg) from the U.S.-Canada border to Bossburg and are measured in samples collected in the uplands to approximately 7 to 8 miles away from the river and 3 to 4 miles south of the border. Concentrations less than the total recoverable BTV are measured sporadically throughout the OU 3 study area (Map 6-5). Two samples in the < 150-µm-size fraction were collected as part of the USGS Midnite Mine Sediment Study (USGS 2008a). These sample locations are approximately 55 miles south of the ADA; one is less than the total recoverable BTV, and the other is greater than or equal to the total recoverable BTV but less than 200 mg/kg (Appendix E).

6.3.1.3 Total Recoverable Data from Samples with Unknown Grain Size

Soil lead concentrations for total recoverable data from samples with unknown grain size in the OU 3 study area range from 6.8 to 181,000 mg/kg, with a median of 240 mg/kg. Of 366 samples,

[96] Data for the < 150-µm-size fraction samples collected during the 2014 Soil Study and 2015 Bossburg Study are not shown on Map 6-5 but can be viewed in Appendix F.

100 percent are detected values, and 337 samples (92 percent) exceed the total recoverable BTV of 27.2 mg/kg (Table 6-7).

Samples with unknown grain size are from the 2001 EPA Stevens County Mines and Mills PA/SI (USEPA 2002a), the 2004 EPA Le Roi Smelter Removal Action (USEPA 2005), the 2003--2004 EPA Anderson Calhoun EE/CA (USEPA 2007a), the 2007 Brooks Road/Bonanza Mine Roadbed Voluntary Cleanup (SCDPW 2008a), and the 2007 Peterson Swamp/Bonanza Mine Roadbed Voluntary Cleanup (SCDPW 2008b). These samples were collected in localized areas around these operations, and all sample locations are within the OU 3 study area. Most of the samples exceed the total recoverable BTV, except for a subset of samples from each of the studies (Map 6-5).

Samples collected in and around Northport as part of the 2004 EPA Le Roi Smelter Removal Action (USEPA 2005) generally exceed the total recoverable BTV (27.2 mg/kg) and 100, 200, 400, and/or 700 mg/kg (Map 6-5).

Most of the samples collected from upland areas associated with historical mines and mills during the 2001 EPA Stevens County Mines and Mills PA/SI exceed 700 mg/kg, and the highest lead concentrations in the OU 3 study area were measured for samples in this study.

The majority of samples collected near the Anderson Calhoun Mine/Mill during the 2003--2004 EPA Anderson Calhoun EE/CA exceed the total recoverable lead BTV (27.2 mg/kg). Three samples also exceed 200 mg/kg, and one sample exceeds 700 mg/kg.

Samples collected during the 2007 Brooks Road/Bonanza Mine Roadbed Voluntary Cleanup and the 2007 Peterson Swamp/Bonanza Mine Roadbed Voluntary Cleanup range from less than the total recoverable BTV (27.2 mg/kg) to above the BTV but less than 200 mg/kg.

6.3.1.4 Total Digestion Data

Soil lead concentrations for the total digestion data in the OU 3 study area range from 24.1 to 129.77 mg/kg, with a median of 53.7 mg/kg. Of 11 samples, 100 percent are detected values, and 10 samples (91 percent) exceed the total digestion BTV of 30.0 mg/kg (Table 6-7).

On Map 6-5, total digestion samples are binned to show concentrations less than the total digestion BTV of 30.0 mg/kg; the other bins are the same as those for the total recoverable samples. Two samples near the southeastern corner of the OU 3 study area and one sample immediately west of the OU 3 study area are less than the total digestion BTV. Total digestion samples exceed the total digestion BTV but are less than 200 mg/kg in the remainder of the OU 3 study area and immediate vicinity (Map 6-5).

6.3.1.5 RBA-Adjusted Lead Data

As discussed in Section 3, a subset of soil samples from the RSS DUs and ADA DUs that had soil lead concentrations greater than 100 mg/kg in the < 150-µm-size fraction were analyzed for lead IVBA. Lead IVBA results were converted to RBA in accordance with USEPA (2020c) guidance. RBA estimates for lead in soil are presented in Appendix D-1 and Table 5-3. The mean lead RBA for RSS DUs sampled in the 2014 Residential Soil Study (50.5 percent) was significantly lower than the mean for RSS DUs sampled in the 2014 Residential Soil Study (63.9 percent; *t*-test, $p < 0.001$) (USEPA 2021). The overall average RBA for ADA DUs (71.5 percent[97]) indicates that lead in soil from these DUs is on average more bioavailable than EPA's assumed RBA (60 percent).

RBA-adjusted lead concentrations were calculated for all RSS DU and ADA DU IC soil samples following the procedures described in the HHRA (USEPA 2021), in which the sample-specific RBA results are used for DUs where IVBA analysis was performed, and surrogate (average) values are used for DUs without IVBA analysis.[98] To ensure appropriate comparison of RBA-adjusted soil lead concentrations to the human health P5 PRG of 200 mg/kg, P8 PRG of 400 mg/kg, and TCRA action level of 700 mg/kg, soil lead concentrations are multiplied by the ratio of the Site-specific soil lead RBA value to EPA's default RBA for lead in soil (60 percent).

The distribution of RBA-adjusted soil lead in the OU 3 study area is shown on Map 6-6. RBA-adjusted lead concentrations range from 8.9 to 3,770 mg/kg, with a median of 115 mg/kg. Of 1,596 samples, 1,541 samples are greater than or equal to the total recoverable BTV[99] (27.2 mg/kg); 440 are greater than or equal to the human health P5 PRG of 200 mg/kg; 154 are greater than or equal to the human health P8 PRG of 400 mg/kg; and 61 are greater than or equal to the human health TCRA action level of 700 mg/kg prior to removal actions (Table 6-7). Boxplots of RBA-adjusted lead concentrations by study are shown in Figure 6-8b.

6.3.1.6 Geostatistically Modeled Lead Concentrations

Geostatistically modeled soil lead concentrations are shown on Map 6-7, which presents the median (50 percent probability) concentration from the geostatistical model (Appendix G). Concentrations across the modeled area are symbolized using a subset of the concentration bins

[97] The ADA DU RBA was reported as 70.6 in the HHRA. The ADA DU RBA was updated to 71.5 due to a correction to a laboratory error, as described in Section 5.1.1 herein.

[98] Adjustments for RBA are described in Section 4.6 and Appendix 11 of the HHRA (USEPA 2021).

[99] The total recoverable BTV (27.2 mg/kg) is not RBA-adjusted. Comparisons of RBA-adjusted soil for lead to the BTV should be interpreted with this in mind.

that are used on Map 6-5. The geostatistical lead concentration modeling results include the following:

- Modeled soil lead concentrations exceed the total recoverable BTV of 27.2 mg/kg throughout the entire modeled area, except for isolated areas in the vicinity of Brooks Road and Peterson Swamp Road and a small area just north of the Columbia River to the west of China Bend.
- Modeled soil lead concentrations exceed the P5 PRG of 200 mg/kg along and adjacent to the Columbia River from the U.S.-Canada border to approximately Marble and in a small area in the vicinity of Bossburg.
- Modeled soil lead concentrations exceed the P8 PRG of 400 mg/kg in the river valley intermittently in the OU 3 study area within 5 miles of the U.S.-Canada border, in the vicinity of Northport, intermittently around Onion Creek, and near Bossburg.
- Modeled soil lead concentrations exceed the TCRA action level of 700 mg/kg intermittently within 2.5 miles of the U.S.-Canada border and at Northport. As noted in Section 6.1, pre-removal soil data are used for properties where removal actions were completed in association with the 2004 EPA Le Roi Smelter Removal Action Study and the 2014 and 2016 Residential Soil Studies. The pre-removal data that were used do not represent current conditions at the Site.

The modeled concentration map (Map 6-7) differs from Map 6-5 in that it provides estimates of soil lead concentration in areas with no samples or low sample densities and uses a 2.5-km buffer around sample locations. Extrapolation beyond the buffer is not supported by the data, as described in Section 6.2.4 and Appendix G.

The uncertainty in modeled soil lead concentrations is illustrated on Map 6-8, which shows the difference between the P90 and P10 of the 100 simulation outputs of the SGS-UK model. Areas with the highest uncertainty (greater than 400 mg/kg) are generally limited to the interior of the model domain along the river valley and adjacent uplands between the U.S.-Canada border and south of Marble. Along the model boundary, prediction uncertainty is most commonly 100 to 200 mg/kg, but there are areas along the model boundary with higher or lower prediction uncertainty bands. A more detailed discussion of uncertainty in the modeled surface soil COC concentrations is provided in Section 6.2.4 and Appendix G.

6.3.2 Areal Nature and Extent of Cadmium

Cadmium concentrations in surface soil are shown on Map 6-9, and geostatistically modeled cadmium concentrations are shown on Map 6-10. For the data included on Map 6-9, summary

statistics are provided in Table 6-7, and boxplots are presented in Figure 6-8c. Soil cadmium concentrations are also available in the data exploration tool (Appendix E).

On Map 6-9 cadmium concentrations are binned to show the following concentrations:

- Bin 1—Less than the total recoverable BTV of 0.74 mg/kg (or 0.54 mg/kg for total digestion samples)
- Bin 2—Greater than or equal to the BTVs and less than 3.74 mg/kg, which is the lowest ecological RBC (this RBC is protective of the survival endpoint for the masked shrew)
- Bin 3—Greater than or equal to 3.74 mg/kg and less than 5.45 mg/kg, which is the second lowest ecological RBC (this RBC is protective of the reproduction endpoint for the American robin)
- Bin 4—Greater than or equal to 5.45 mg/kg and less than 10 times the total recoverable BTV (7.4 mg/kg)
- Bin 5—Greater than or equal to 7.4 mg/kg and less than 100 times the total recoverable BTV (74 mg/kg)
- Bin 6—Greater than or equal to 74 mg/kg.

Nondetected values are symbolized separately on Map 6-9.

Overall, cadmium concentrations show considerable spatial variation. In general, they show a similar distribution to lead, with the highest values at low elevations along the UCR valley between the U.S.-Canada border and Northport, at higher elevations in the upland areas on both sides of the river valley, and in the vicinity of several mines and mills sampled as part of the 2001 EPA Stevens County Mines and Mills PA/SI. Concentrations generally decrease with distance southward along the river valley and with increasing elevation and lateral distance away from the river in both directions (east and west) (Figure 6-4b, Map 6-9, Map 6-10; Appendix F). Detailed descriptions of the spatial distribution of cadmium are provided in the following subsections.

6.3.2.1 Total Recoverable Data in the < 2-mm-Size Fraction

Soil cadmium concentrations for the < 2-mm total recoverable data in the OU 3 study area range from 0.046 to 180 mg/kg, with a median of 3.53 mg/kg. Of 498 samples, 100 percent are detected values, and 404 samples (81 percent) exceed the total recoverable BTV of 0.74 mg/kg (Table 6-7).

Concentrations exceed the total recoverable BTV (0.74 mg/kg) throughout the OU 3 study area, except for two samples approximately 3 miles west of the river, immediately south of the U.S.-Canada border; two samples on the eastern edge of the OU 3 study area; four samples near

Bossburg; and many samples collected in the Van Stone Mine/Mill area. Concentrations of cadmium greater than or equal to the total recoverable BTV (0.74 mg/kg) and less than 3.74 mg/kg occur throughout the OU 3 study area, from the U.S.-Canada border to approximately 4 miles south of Marble and in Bossburg and the Van Stone Mine/Mill area (Map 6-9).

Cadmium concentrations greater than or equal to 3.74 mg/kg are present from the U.S.-Canada border to just north of Northport within approximately 7 to 8 miles of the river on both sides and from Northport to 4 miles south of Marble within approximately 1 to 3 miles of both sides of the river. Cadmium concentrations greater than or equal to 5.45 mg/kg and less than 7.4 mg/kg are present from the U.S.-Canada border to Northport within 6 to 7 miles of the river on both sides of the river. Concentrations of cadmium that are greater than or equal to 7.4 mg/kg are present from the U.S.-Canada border to Northport within approximately 3 miles of the river on both sides and intermittently at lower elevation sample locations approximately 1 mile on both sides of the river valley from Northport to approximately 3 miles south of Marble. Concentrations greater than or equal to 7.45 mg/kg and less than74 mg/kg are also present within the northeastern corner of the OU 3 study area, in Bossburg, and in the Van Stone Mine/Mill area. Concentrations of cadmium greater than or equal to 74 mg/kg are only present in the Van Stone Mine/Mill area (Map 6-9).

6.3.2.2 Total Recoverable Data in the < 150-µm-Size Fraction

Soil cadmium concentrations for the < 150-µm total recoverable data in the OU 3 study area range from 0.263 to 45.6 mg/kg, with a median of 2.55 mg/kg. Of 1,191 samples, 100 percent are detected values, and 1,141 samples (96 percent) are greater than or equal to the total recoverable BTV of 0.74 mg/kg (Table 6-7).

Cadmium concentrations in the < 150-µm total recoverable data are generally greater than or equal to the total recoverable BTV (0.74 mg/kg) from the U.S.-Canada border to approximately 4 miles south of Marble and again in Bossburg within approximately 10 miles of the river on both sides. Cadmium concentrations in the < 150-µm total recoverable data are greater than or equal to 7.4 mg/kg from the U.S.-Canada border to Northport and sporadically between Northport and approximately 4 miles south of Marble within approximately 3 miles of the river on both sides. Concentrations of cadmium in this size fraction do not exceed 74 mg/kg.

6.3.2.3 Total Recoverable Data from Samples with Unknown Grain Size

Soil cadmium concentrations for the total recoverable data from samples with unknown grain size in the OU 3 study area range from 0.05 to 1,090 mg/kg, with a median of 5.20 mg/kg. Of

366 samples, 96 percent are detected values, and 344 samples (94 percent) are greater than or equal to the total recoverable BTV of 0.74 mg/kg (Table 6-7).

Samples with unknown grain size are from the 2001 EPA Stevens County Mines and Mills PA/SI (USEPA 2002a), the 2004 EPA Le Roi Smelter Removal Action (USEPA 2005), the 2003--2004 EPA Anderson Calhoun EE/CA (USEPA 2007a), the 2007 Brooks Road/Bonanza Mine Roadbed Voluntary Cleanup (SCDPW 2008a), and the 2007 Peterson Swamp/Bonanza Mine Roadbed Voluntary Cleanup (SCDPW 2008b). These samples were collected in localized areas around these operations, and all sample locations are within the OU 3 study area. Most of the samples exceed the total recoverable BTV, except for several samples from the 2001 EPA Stevens County Mines and Mills PA/SI, the 2004 EPA Le Roi Smelter Removal Action, and the 2003--2004 EPA Anderson Calhoun EE/CA (Map 6-9).

Samples in and around Northport collected as part of the 2004 EPA Le Roi Smelter Removal Action generally exceed either the total recoverable BTV (0.74 mg/kg) or 7.4 mg/kg (Map 6-9).

Nearly all samples collected at mines and mills in the uplands during the 2001 EPA Stevens County Mines and Mills PA/SI exceed the total recoverable BTV (0.74 mg/kg). The majority of the samples exceed 7.4 mg/kg, and multiple samples exceed 74 mg/kg (Map 6-9).

All but one sample collected near the Anderson Calhoun Mine/Mill during the 2003–2004 EPA Anderson Calhoun EE/CA exceed the total recoverable BTV (0.74 mg/kg). Five samples exceed 7.4 mg/kg, and two samples exceed 74 mg/kg (Map 6-9).

Samples collected during the 2007 Brooks Road/Bonanza Mine Roadbed Voluntary Cleanup and the 2007 Peterson Swamp/Bonanza Mine Roadbed Voluntary Cleanup are all greater than or equal to the total recoverable BTV (0.74 mg/kg) and less than 7.4 mg/kg (Map 6-9).

6.3.2.4 Total Digestion Data

Cadmium concentrations for the total digestion data range from 0.027 to 12.465 mg/kg, with a median of 1.42 mg/kg. Of 10 samples, 90 percent are detected values, and 8 samples (80 percent) exceed the total digestion BTV of 0.54 mg/kg (Table 6-7).

On Map 6-9, total digestion samples are binned to show concentrations less than the total digestion BTV of 0.54 mg/kg; the other bins are the same as those for the total recoverable samples. Cadmium concentrations in the total digestion samples range from less than the total digestion BTV (0.54 mg/kg) to 7.4 mg/kg, except for two samples in the northeastern portion of the OU 3 study area that are greater than 7.4 mg/kg.

6.3.2.5 Geostatistically Modeled Cadmium Concentrations

Modeled soil cadmium concentrations are shown on Map 6-10, which presents the median (50 percent probability) concentrations from the geostatistical model (Appendix G). Concentrations across the modeled area are shown using a subset of the concentration bins that are used on Map 6-9. The geostatistical cadmium concentration modeling results include the following:

- Modeled soil cadmium concentrations are above the total recoverable BTV of 0.74 mg/kg throughout the entire modeled area.
- Modeled soil cadmium concentrations are above the BTVs but less than 3.74 mg/kg over most of the modeled area. Areas with modeled cadmium concentrations above 3.74 mg/kg but below 5.45 mg/kg include the river valley and adjacent uplands between the U.S.-Canada border and near Deadman's Eddy, extending about 3 miles north of the river and to the model domain boundary (about 5 miles) to the south. There are also areas with modeled cadmium concentrations greater than or equal to 3.74 mg/kg and less than 5.45 mg/kg around Northport, around Onion Creek, and in small areas south of Marble.
- Modeled soil cadmium concentrations are greater than or equal to 5.45 mg/kg but less than 7.4 mg/kg intermittently along the river and in the adjacent uplands between the U.S.-Canda border and Deadman's Eddy, around Northport, and several small areas near Onion Creek.
- Modeled soil cadmium concentrations exceed 7.4 mg/kg along the river valley within 2 miles of the U.S.-Canada border, extending about 2 miles from the river on both sides. There are also small areas modeled to exceed 7.4 mg/kg around Deadman's Eddy and Northport.

The modeled concentration map (Map 6-10) differs from Map 6-9 in that it provides estimates of soil cadmium concentrations in areas with no samples or low sample densities and uses a 2.5-km buffer around sample locations. Extrapolation beyond the buffer is not supported by the data, as described in Section 6.2.4 and Appendix G.

The uncertainty in modeled soil cadmium concentrations is illustrated in the P90 minus P10 values shown on Map 6-11. Areas with the highest uncertainty band (greater than 10 mg/kg) are along the U.S.-Canada border in the central portion of the OU 3 study area and intermittently along the river valley between Deadman's Eddy and Onion Creek. Except for an area around Cedar Lake at the model boundary, the areas with the greatest uncertainty in predicted cadmium concentrations are in the interior, where there is a relatively higher sample density.

Along the model boundary within the Site, prediction uncertainty was most commonly 5 to 10 mg/kg or 2 to 5 mg/kg in the northern portion of the model domain, 2 to 5 mg/kg in the central portion of the model area, and less than 2 mg/kg in the southern portion of the model domain. A more detailed discussion of uncertainty in the modeled surface soil COC concentrations is provided in Section 6.2.4 and Appendix G.

6.3.3 Areal Nature and Extent of Zinc

Zinc concentrations in surface soil are shown on Map 6-12, and geostatistically modeled zinc concentrations are shown on Map 6-13. For the data included on Map 6-12, summary statistics are provided in Table 6-7, and boxplots are presented in Figure 6-8d. Soil zinc concentrations are also available in the data exploration tool (Appendix E).

On Map 6-12, zinc concentrations are binned to show the following concentrations:

- Bin 1—Less than the total recoverable BTV of 111 mg/kg (or 99.0 mg/kg for total digestion samples)
- Bin 2—Greater than or equal to the BTVs and less than 220 mg/kg, which is the lowest ecological RBC that is above the BTVs (this RBC is protective of the growth endpoint for the masked shrew)
- Bin 3—Greater than or equal to 220 mg/kg and less than 378 mg/kg, which is the second lowest ecological RBC that is above the BTVs (this RBC is protective of the grown endpoint for the black capped chickadee)
- Bin 4—Greater than or equal to 378 mg/kg and less than 10 times the total recoverable BTV (1,110 mg/kg)
- Bin 5—Greater than or equal to 1,110 mg/kg and less than 100 times the total recoverable BTV (11,100 mg/kg)
- Bin 6—Greater than or equal to 11,100 mg/kg.

Nondetected values are symbolized separately on Map 6-12.

Overall, zinc concentrations show considerable spatial variation. In general, they show a distribution similar to lead, with the highest values at low elevations along the UCR valley between the U.S.-Canada border and Northport, at higher elevations in the upland areas on both sides of the river valley, and in the vicinity of several mines and mills sampled as part of the 2001 EPA Stevens County Mines and Mills PA/SI. Concentrations generally decrease with distance toward the south along the river and with increasing elevation and lateral distance away from the river in both directions (east and west) (Figure 6-4c, Map 6-12, Map 6-13;

Appendix F). Detailed descriptions of the spatial distribution of zinc are provided in the following subsections.

6.3.3.1 Total Recoverable Data in the < 2-mm-Size Fraction

Soil zinc concentrations for the < 2-mm total recoverable data range from 8.1 to 37,000 mg/kg, with a median of 238 mg/kg. Of 498 samples, 98 percent are detected values, and 396 samples (80 percent) are greater than or equal to the total recoverable BTV of 111 mg/kg (Table 6-7).

Concentrations of zinc exceed the total recoverable BTV (111 mg/kg) throughout the OU 3 study area, except for a few samples west of the river and near the U.S.-Canada border, a small area near the northeast OU 3 study area boundary, a few samples around Bossburg, and in the Van Stone Mine/Mill area (Map 6-12).

Concentrations of zinc greater than or equal to the total recoverable BTV (111 mg/kg) and less than 220 mg/kg are measured from the U.S.-Canada border to approximately 4 miles south of Marble, near Bossburg, and in the Van Stone Mine/Mill area (Map 6-12).

Zinc concentrations greater than or equal to 220 mg/kg and less than 378 mg/kg are measured from the U.S.-Canada border to approximately 4 miles south of Marble, near Bossburg, and in the Van Stone Mine/Mill area. Zinc concentrations greater than or equal to 378 and less than 1,110 mg/kg are present from the U.S.-Canada border to Northport and intermittently at lower elevation sample locations approximately 3 miles on both sides of the river valley from Northport to approximately 4 miles south of Marble. Zinc concentrations greater than or equal to 378 and less than 1,100 mg/kg are also present in the Van Stone Mine/Mill area, in Bossburg, and in isolated spots on the eastern side of the OU 3 study area. Zinc concentrations greater than or equal to 1,100 mg/kg and less than 11,000 mg/kg are present in isolated areas near the U.S.-Canada border and in the Van Stone Mine/Mill area. Zinc concentrations greater than or equal to 11,100 mg/kg are limited to the vicinity of the Van Stone Mine/Mill (Map 6-12).

6.3.3.2 Total Recoverable Data in the < 150-µm-Size Fraction

Soil zinc concentrations for the < 150-µm total recoverable data in the OU 3 study area range from 41.1 to 1,900 mg/kg, with a median of 171 mg/kg. Of 1,191 samples, 100 percent are detected values, and 938 samples (79 percent) are greater than or equal to the total recoverable BTV of 111 mg/kg (Table 6-7).

The distribution of zinc concentrations in the < 150-µm total recoverable samples is generally similar to the other size fractions, with concentrations greater than or equal to the total recoverable BTV (111 mg/kg) occurring from the U.S.-Canada border to approximately 4 miles south of Marble, again in Bossburg within approximately 10 miles of each side of the river, and

north of Northport, with intermittent occurrences at lower elevation sample locations approximately 1 mile on both sides of the river valley from Northport to approximately 3 miles south of Marble. However, 21 percent of samples in this size fraction are less than the total recoverable BTV (111 mg/kg). Zinc concentrations exceed 220 mg/kg throughout the study area from the U.S.-Canada border to Northport, then exceed 200 mg/kg less frequently south to near China Bend, and in Bossburg. Zinc concentrations in the < 150-µm total recoverable data exceed 378 mg/kg from the U.S.-Canada border to Northport and sporadically between Northport and approximately 4 miles south of Marble within approximately 10 miles of the river on both sides. Zinc concentrations exceed 1,110 mg/kg in six samples located sporadically between the U.S.-Canada border and approximately 4 miles south of Marble. Concentrations of zinc in this size fraction do not exceed 11,100 mg/kg (Map 6-12).

6.3.3.3 Total Recoverable Data from Samples with Unknown Grain Size

Soil zinc concentrations for total recoverable samples with unknown grain size in the OU 3 study area range from 30.1 to 431,000 mg/kg, with a median of 4,680 mg/kg. Of 135 samples, 100 percent are detected values, and 120 samples (89 percent) exceed the total recoverable BTV of 111 mg/kg (Table 6-7).

Samples with unknown grain size are from the 2001 EPA Stevens County Mines and Mills PA/SI (USEPA 2002a), the 2004 EPA Le Roi Smelter Removal Action (USEPA 2005), the 2003--2004 EPA Anderson Calhoun EE/CA (USEPA 2007a), the 2007 Brooks Road/Bonanza Mine Roadbed Voluntary Cleanup (SCDPW 2008a), and the 2007 Peterson Swamp/Bonanza Mine Roadbed Voluntary Cleanup (SCDPW 2008b). Therefore, these samples were collected in localized areas around these operations, and all sample locations are within the OU 3 study area. Most of the samples from each of these studies exceed the total recoverable BTV (111 mg/kg).

Five out of 11 samples in the vicinity of Northport collected as part of the 2004 EPA Le Roi Smelter Removal Action are less than the total recoverable BTV (111 mg/kg). Of the remaining six samples that exceed the BTV (111 mg/kg), one exceeds 378 mg/kg but is less than 1,110 mg/kg (Map 6-12).

Nearly all samples collected at mines and mills in the uplands during the 2001 EPA Stevens County Mines and Mills PA/SI exceed the total recoverable BTV for zinc (111 mg/kg), and most of the samples also exceed 378 mg/kg. The highest zinc concentrations in the OU 3 study area were measured in samples in this study, and 43 samples exceed 11,100 mg/kg (Map 6-12).

All but three samples collected near the Anderson Calhoun Mine/Mill during the 2003--2004 EPA Anderson Calhoun EE/CA exceed the total recoverable BTV (111 mg/kg). Twelve samples exceed

378 mg/kg, five samples exceed 1,110 mg/kg, and two samples exceed 11,100 mg/kg (Map 6-12; Appendix F).

Samples collected during the 2007 Brooks Road/Bonanza Mine Roadbed Voluntary Cleanup and the 2007 Peterson Swamp/Bonanza Mine Roadbed Voluntary Cleanup range from less than the total recoverable BTV (111 mg/kg) to greater than or equal to the ecological RBC of 378 mg/kg. No samples from these studies exceed 1,100 mg/kg (Map 6-12).

6.3.3.4 Total Digestion Data

Soil zinc concentrations for the total digestion data range from 52.3 to 909.53 mg/kg, with a median of 120 mg/kg. Of 11 samples, 100 percent are detected values, and 9 samples (82 percent) exceed the total digestion BTV of 99.0 mg/kg (Table 6-7).

On Map 6-12, total digestion samples are binned to show zinc concentrations less than the total digestion BTV of 99.0 mg/kg; the other bins are the same as those for the total recoverable samples. Concentrations of zinc in the total digestion samples range from less than the total digestion BTV (99.0 mg/kg) to greater than or equal to 378 mg/kg. No total digestion samples have zinc concentrations greater than or equal to 1,110 mg/kg (Map 6-12).

6.3.3.5 Geostatistically Modeled Zinc Concentrations

Modeled soil zinc concentrations are shown on Map 6-13, which presents the median (50 percent probability) concentration from the geostatistical model (Appendix G). Concentrations across the modeled area are symbolized using the same concentration bins that are used on Map 6-12.

The geostatistical zinc concentration modeling results show the following patterns:

- Modeled soil zinc concentrations are greater than the total recoverable BTV of 111 mg/kg throughout the modeled area except for several isolated, intermittent areas on both sides of the river between Deadman's Eddy and approximately 4 miles south of Marble (Map 6-13) and the southern portion of the model domain, beginning about 2.5 miles north of Bossburg.
- Modeled soil zinc concentrations are greater than or equal to the total recoverable BTV (111 mg/kg) but less than 220 mg/kg throughout the modeled area, from the U.S.-Canada border to approximately 2.5 miles north of Bossburg. Areas with modeled zinc concentrations greater than or equal to 220 mg/kg occur on both sides of the river intermittently between the U.S.-Canada border to just south of Marble in the vicinity of China Bend.

- Modeled soil zinc concentrations are greater than or equal to 378 mg/kg in the river valley and adjacent uplands near the U.S.-Canada border, in isolated areas in the river valley between the border and approximately Northport, and at the northwestern corner of the model boundary.
- Modeled soil zinc concentrations exceed 1,110 mg/kg in only three areas just south of Waneta Dam near the U.S.-Canada border.
- No modeled soil zinc concentrations exceed 11,100 mg/kg.

The modeled concentration map (Map 6-13) differs from Map 6-12 in that it provides estimates of soil zinc concentrations in areas with no samples or low sample densities and uses a 2.5-km buffer around sample locations. Extrapolation beyond the buffer is not supported by the data, as described in Section 6.2.4 and Appendix G.

The uncertainty in modeled soil zinc concentrations is illustrated in the P90 minus P10 values shown on Map 6-14. Areas with the highest uncertainty (greater than 400 mg/kg) are along the river valley and adjacent uplands near the U.S.-Canada border in the central portion of the model domain, intermittently along the river valley and adjacent uplands between Deadman's Eddy and China Bend, and in upland areas in the northeastern portion of the model domain. Along the model boundary, prediction uncertainty is most commonly 200 to 400 mg/kg, but there are areas along the model boundary with higher or lower prediction uncertainty bands. A more detailed discussion of uncertainty in the modeled surface soil COC concentrations is provided in Section 6.2.4 and Appendix G.

6.3.4 Areal Nature and Extent of Arsenic

Arsenic concentrations in surface soil are shown on Map 6-15. For the data included on Map 6-15, summary statistics are provided in Table 6-7, and boxplots are presented in Figure 6-8e. Soil arsenic concentrations are also available in the data exploration tool (Appendix E).

On Map 6-15, arsenic concentrations are binned to show the following concentrations:

- Bin 1—Less than the total recoverable BTV of 23.3 mg/kg (or 12.0 mg/kg for total digestion samples)
- Bin 2—Greater than or equal to the BTVs and less than 26 mg/kg[100]

[100] The data bins for arsenic concentrations greater than the BTVs are based on the distribution of the soil arsenic concentrations because the lowest ecological RBC (protective of plants) is less than the total recoverable BTV.

- Bin 3—Greater than or equal to 26 mg/kg and less than 29 mg/kg
- Bin 4—Greater than or equal to 29 mg/kg and less than 35 mg/kg
- Bin 5—Greater than or equal to 35 mg/kg and less than 49 mg/kg
- Bin 6—Greater than or equal to 49 mg/kg.

Nondetected values are symbolized separately on Map 6-15.

Most soil arsenic concentrations are less than the BTVs (Table 6-7). Arsenic concentrations that exceed the BTVs are generally at low elevations along the UCR valley between the U.S.-Canada border and Northport and in the vicinity of historical mines and mills in the uplands. Concentrations generally decrease with distance toward the south along the river (Figure 6-4d, Map 6-15; Appendix F). Detailed descriptions of the spatial distribution of arsenic are provided in the following subsections.

6.3.4.1 Total Recoverable Data in the < 2-mm-Size Fraction

Soil arsenic concentrations for the < 2-mm total recoverable data in the OU 3 study area range from 0.5 to 55.5 mg/kg, with a median of 10.8 mg/kg. Of 498 samples, 100 percent are detected values, and 42 samples (8 percent) exceed the total recoverable BTV of 23.3 mg/kg (Table 6-7).

Concentrations exceed the total recoverable BTV intermittently from the U.S.-Canada border to approximately 4 miles south of Marble within 5 miles on both sides of the river. Fourteen samples have concentrations of arsenic greater than or equal to the total recoverable BTV (23.3 mg/kg) and less than 26 mg/kg throughout the OU 3 study area, from the U.S.-Canada border to just south of Marble (Map 6-15).

Arsenic concentrations greater than or equal to 26 and less than29 mg/kg are present in 13 samples from the U.S.-Canada border to approximately 7 miles south of Northport within approximately 3 miles of the river on both sides. Arsenic concentrations greater than or equal to 29 and less than 35 mg/kg are present in six samples from the U.S.-Canada border to within 7 miles of the U.S.-Canada border and within 3 miles of the river on both sides as well as in the Van Stone Mine/Mill area. Concentrations of arsenic greater than or equal to 35 and less than 49 mg/kg are present in eight samples from the U.S.-Canada border to within approximately 3 miles of the river on both sides and in the Van Stone Mine/Mill area. One sample with an arsenic concentration greater than or equal to 49 mg/kg is located within 3 miles of the U.S.-Canada border (Map 6-15).

6.3.4.2 Total Recoverable Data in the < 150-µm-Size Fraction

Soil arsenic concentrations for the < 150-µm total recoverable data in the OU 3 study area range from 2.25 to 151 mg/kg, with a median of 10.2 mg/kg. Of 1,192 samples, 100 percent are detected values, and 123 samples (10 percent) exceed the total recoverable BTV of 23.3 mg/kg (Table 6-7).

Concentrations exceed the total recoverable BTV intermittently from the U.S.-Canada border to Northport within 3 miles on both sides of the river and sporadically south of Northport to approximately 4 miles south of Marble. Intermittent samples have concentrations of arsenic greater than or equal to the total recoverable BTV (23.3 mg/kg) and less than 26 mg/kg throughout the OU 3 study area, from the U.S.-Canada border to south of Marble (Map 6-15).

Arsenic concentrations between 26 and 29 mg/kg are present in samples from the U.S.-Canada border to approximately 8 miles south of Northport within approximately 3 miles of the river on both sides. Arsenic concentrations greater than or equal to 29 and less than 35 mg/kg are present in multiple samples from the U.S.-Canada border to approximately 8 miles south of Northport within 3 miles of the river on both sides. Concentrations of arsenic greater than or equal to 35 and less than 49 mg/kg are present in samples from the U.S.-Canada border to approximately 8 miles south of Northport within 3 miles of the river on both sides. Samples sporadically have arsenic concentrations greater than 49 mg/kg from the U.S.-Canada border to approximately 8 miles south of Northport, within 2 miles of the river on both sides (Map 6-15).

6.3.4.3 Total Recoverable Data from Samples with Unknown Grain Size

Soil arsenic concentrations for total recoverable samples with unknown grain size in the OU 3 study area range from 0.96 to 297 mg/kg, with a median of 10.7 mg/kg. Of 341 samples, 97 percent are detected values, and 64 samples (19 percent) exceed the total recoverable BTV of 23.3 mg/kg (Table 6-7).

Samples with unknown grain size are from the 2001 EPA Stevens County Mines and Mills PA/SI (USEPA 2002a), the 2004 EPA Le Roi Smelter Removal Action (USEPA 2005), the 2007 Brooks Road/Bonanza Mine Roadbed Voluntary Cleanup (SCDPW 2008a), and the 2007 Peterson Swamp/Bonanza Mine Roadbed Voluntary Cleanup (SCDPW 2008b). Therefore, these samples were collected in localized areas around these operations, and all sample locations are within the OU 3 study area. Most of the samples exceed the total recoverable BTV (23.3 mg/kg), except for several samples from each study.

Approximately 80 percent of the samples in the vicinity of Northport collected as part of the 2004 EPA Le Roi Smelter Removal Action have arsenic concentrations that are less than the total recoverable BTV (23.3 mg/kg). Of the remaining approximately 20 percent of samples, approximately half of them are greater than 35 mg/kg. The remaining approximately 20 samples

are greater than or equal to the total recoverable BTV (23.3 mg/kg) and less than 35 mg/kg (Map 6-15).

Approximately 80 percent of samples collected at mines and mills in the uplands during the 2001 EPA Stevens County Mines and Mills PA/SI are less than the total recoverable BTV for arsenic (23.3 mg/kg). Of the samples that are reported with concentrations greater than the total recoverable BTV (23.3 mg/kg), approximately 90 percent of them are reported with concentrations greater than or equal to 35 mg/kg. The highest arsenic concentrations in the OU 3 study area are measured in samples in this study (Map 6-15).

Samples collected during the 2007 Brooks Road/Bonanza Mine Roadbed Voluntary Cleanup and the 2007 Peterson Swamp/Bonanza Mine Roadbed Voluntary Cleanup have arsenic concentrations less than the total recoverable BTV (23.3 mg/kg) (Map 6-15).

6.3.4.4 Total Digestion Data

Soil arsenic concentrations for the total digestion data range from 2 to 11 mg/kg, with a median of 9.30 mg/kg. Of three samples, 100 percent are detected values, and no samples exceed the total digestion BTV of 12.0 mg/kg (Table 6-7).

On Map 6-15, total digestion samples are binned to show arsenic concentrations less than the total digestion BTV of 12.0 mg/kg; the other bins are the same as those for the total recoverable samples. Concentrations of arsenic in the OU 3 study area in the total digestion samples are less than the total digestion BTV (Map 6-15).

6.3.5 Areal Nature and Extent of Barium

Barium concentrations in surface soil are shown on Map 6-16. For the data included on Map 6-16, summary statistics are provided in Table 6-7, and boxplots are presented in Figure 6-8f. Soil barium concentrations are also available in the data exploration tool (Appendix E).

On Map 6-16, barium concentrations are binned to show the following concentrations:

- Bin 1—Less than the total recoverable BTV of 395 mg/kg (or 722 mg/kg for total digestion samples)
- Bin 2—Greater than or equal to the BTVs and less than 425 mg/kg[101]

[101] The data bins for barium concentrations greater than the BTVs are based on the distribution of the soil barium concentrations because the lowest ecological RBC (protective of invertebrates) is less than the total recoverable BTV.

- Bin 3—Greater than or equal to 425 mg/kg and less than 482 mg/kg
- Bin 4—Greater than or equal to 482 mg/kg and less than 585 mg/kg
- Bin 5—Greater than or equal to 585 mg/kg and less than 900 mg/kg
- Bin 6—Greater than or equal to 900 mg/kg.

Nondetected values are symbolized separately on Map 6-16.

Most soil barium concentrations are less than the BTVs (Table 6-7). Barium concentrations that exceed the BTVs are generally at high elevations in the uplands. Concentrations are relatively stable with distance toward the south along the river between the U.S.-Canada border and Northport, with a decrease south of Northport and an increase with increasing elevation (Figure 6-4e, Map 6-16; Appendix F). Detailed descriptions of the spatial distribution of barium are provided in the following subsections.

6.3.5.1 Total Recoverable Data in the < 2-mm-Size Fraction

Soil barium concentrations for the < 2-mm total recoverable data in the OU 3 study area range from 34.8 to 2,590 mg/kg, with a median of 268 mg/kg. Of 316 samples, 100 percent are detected values, and 87 samples (28 percent) exceed the total recoverable BTV of 395 mg/kg (Table 6-7).

Concentrations exceed the total recoverable BTV intermittently from the U.S.-Canada border to Northport, particularly at higher elevations within 15 miles on both sides of the river, and sporadically south of Northport to approximately 4 miles south of Marble within 5 miles on both sides of the river. Twenty-one samples have concentrations of barium greater than or equal to the total recoverable BTV (395 mg/kg) and less than 425 mg/kg throughout the OU 3 study area, from the U.S.-Canada border to approximately 4 miles south of Marble (Map 6-16).

Barium concentrations greater than or equal to 425 mg/kg to less than 482 mg/kg are present in 18 samples from the U.S.-Canada border to south of Marble within approximately 15 miles of the river on both sides near the border to within 3 miles of the river farther south. Barium concentrations greater than or equal to 482 mg/kg and less than 585 mg/kg are present in 19 samples from the U.S.-Canada border to Northport and within 15 miles of the river on both sides. Concentrations of barium that are greater than or equal to 585 mg/kg and less than 900 mg/kg are present in 20 samples from the U.S.-Canada border to south of Northport within approximately 15 miles of the river on both sides. Nine samples have barium concentrations greater than or equal to 900 mg/kg and are located between the U.S.-Canada border and Northport (Map 6-16).

6.3.5.2 Total Recoverable Data in the < 150-µm-Size Fraction

Soil barium concentrations for the < 150-µm total recoverable data in the OU 3 study area range from 45.3 to 4,690 mg/kg, with a median of 173 mg/kg. Of 1,191 samples, 100 percent are detected values, and 20 samples (2 percent) exceed the total recoverable BTV of 395 mg/kg (Table 6-7).

Approximately 98 percent of the barium concentrations are less than the total recoverable BTV (395 mg/kg). Concentrations exceed the total recoverable BTV intermittently from the U.S.-Canada border to Northport within 3 miles on both sides of the river and sporadically south of Northport to approximately 4 miles south of Marble. Five samples have barium concentrations greater than or equal to the total recoverable BTV (395 mg/kg) and less than 425 mg/kg throughout the OU 3 study area, from the U.S.-Canada border to south of Northport (Map 6-16).

Barium concentrations greater than or equal to 425 mg/kg are present in 15 samples from the U.S.-Canada border to approximately 4 miles south of Marble. Eleven samples have barium concentrations greater than or equal to 482 mg/kg, seven samples have barium concentrations greater than or equal to 585 mg/kg, and one sample has a barium concentration greater than 900 mg/kg (Map 6-16).

6.3.5.3 Total Recoverable Data from Samples with Unknown Grain Size

Soil barium concentrations for total recoverable samples with unknown grain size in the OU 3 study area range from 1.4 to 122,000 mg/kg, with a median of 82.5 mg/kg. Of 119 samples, 99 percent are detected values, and 24 samples (20 percent) exceed the total recoverable BTV of 395 mg/kg (Table 6-7).

Samples with unknown grain size are from the 2001 EPA Stevens County Mines and Mills PA/SI (USEPA 2002a) and the 2003--2004 EPA Anderson Calhoun EE/CA (USEPA 2007a) studies. Therefore, these samples were collected in localized areas around these operations, and all sample locations are within the OU 3 study area. Most of the samples are less than the total recoverable BTV (395 mg/kg), except for several samples from each study.

Approximately 90 percent of samples collected at mines and mills in the uplands during the 2001 EPA Stevens County Mines and Mills PA/SI are less than the total recoverable BTV for barium (395 mg/kg). Of the samples that were reported with concentrations greater than the total recoverable BTV for barium, 9 out of 11 of them are reported with concentrations greater than 900 mg/kg. The highest barium concentrations in the OU 3 study area are measured in samples in this study (Map 6-16).

Approximately 50 percent of the samples collected during the 2003--2004 EPA Anderson Calhoun EE/CA have barium concentrations greater than or equal to the total recoverable BTV (395 mg/kg), and of these 25 samples, 9 are greater than 900 mg/kg (Map 6-16).

6.3.5.4 Total Digestion Data

There are two soil samples for which barium was analyzed using total digestion data. These samples had detected barium concentrations of 260 and 990 mg/kg, with a median of 625 mg/kg (Table 6-7). The total barium concentration is less than the total digestion BTV (722 mg/kg) in the sample near the southern portion of the study area and greater than the BTV in the sample near Evans (Map 6-16).

6.3.6 Areal Nature and Extent of Copper

Copper concentrations in surface soil are shown on Map 6-17. For the data included on Map 6-17, summary statistics are provided in Table 6-7, and boxplots are presented in Figure 6-8g. Soil copper concentrations are also available in the data exploration tool (Appendix E).

On Map 6-17, copper concentrations are binned to show the following concentrations:

- Bin 1—Less than the total recoverable BTV of 41.5 mg/kg (or 37.0 mg/kg for total digestion samples)
- Bin 2—Greater than or equal to the BTVs and less than 49 mg/kg[102]
- Bin 3—Greater than or equal to 49 mg/kg and less than 56 mg/kg
- Bin 4—Greater than or equal to 56 mg/kg and less than 70 mg/kg, which is the only ecological RBC that is above the BTVs (this RBC is protective of the reproduction endpoint for the masked shrew)
- Bin 5—Greater than or equal to 70 mg/kg and less than 126 mg/kg
- Bin 6—Greater than or equal to 126 mg/kg.

Nondetected values are symbolized separately on Map 6-17.

Most soil copper concentrations are less than the BTVs (Table 6-7). Copper concentrations that exceed the BTVs are generally at low elevations along the UCR valley between the U.S.-Canada

[102] The data bins for copper concentrations greater than the BTVs are based on available ecological RBCs and the distribution of the soil copper concentrations.

border and Northport, in the vicinity of Bossburg, and in the vicinity of historical mines and mills in the uplands. Concentrations generally decrease with distance toward the south along the river and with increasing elevation and lateral distance away from the river in both directions (east and west) (Figure 6-4f, Map 6-17; Appendix F). Detailed descriptions of the spatial distribution of copper are provided in the following subsections.

6.3.6.1 Total Recoverable Data in the < 2-mm-Size Fraction

Soil copper concentrations for the < 2-mm total recoverable data in the OU 3 study area range from 0.78 to 640 mg/kg, with a median of 18.2 mg/kg. Of 498 samples, 94 percent are detected values, and 41 samples (8 percent) exceed the total recoverable BTV of 41.5 mg/kg (Table 6-7).

Concentrations exceed the total recoverable BTV intermittently from the U.S.-Canada border to Northport within 5 miles on both sides of the river and sporadically south of Northport to approximately 4 miles south of Marble within 3 miles on either side of the river. Twelve samples have concentrations of copper greater than or equal to the total recoverable BTV (41.5 mg/kg) and less than 49 mg/kg throughout the OU 3 study area, from the U.S.-Canada border to Northport and in the vicinity of Bossburg and the Van Stone Mine/Mill area (Map 6-17).

Copper concentrations greater than or equal to 49 mg/kg to 56 mg/kg are present in eight samples near the U.S.-Canada border, Northport, and Bossburg. Copper concentrations greater than or equal to 56 mg/kg and less than 70 mg/kg are present in seven samples near the U.S.-Canada border, Northport, and the Van Stone Mine/Mill area. Concentrations of copper that are greater than or equal to 70 mg/kg and less than 126 mg/kg are present in eight samples near the U.S.-Canada border and the Van Stone Mine/Mill area. Six samples with copper concentrations greater than or equal to 126 mg/kg are located in the Van Stone Mine/Mill area (Map 6-17).

6.3.6.2 Total Recoverable Data in the < 150-µm-Size Fraction

Soil copper concentrations for the < 150-µm total recoverable data in the OU 3 study area range from 7.57 to 118 mg/kg, with a median of 21.2 mg/kg. Of 1,191 samples, 100 percent are detected values, and 123 samples (10 percent) exceed the total recoverable BTV of 41.5 mg/kg (Table 6-7).

Concentrations exceed the total recoverable BTV intermittently from the U.S.-Canada border to Northport within 5 miles on both sides of the river and sporadically south of Northport to approximately 4 miles south of Marble. Forty-five samples have copper concentrations greater than or equal to the total recoverable BTV (41.5 mg/kg) and less than 49 mg/kg throughout the OU 3 study area, from the U.S.-Canada border to approximately 4 miles south of Marble (Map 6-17).

Copper concentrations greater than or equal to 49 mg/kg and less than 56 mg/kg are present in 33 samples from the U.S.-Canada border to approximately 4 miles south of Marble. Copper concentrations greater than or equal to 56 mg/kg and less than 70 mg/kg are present in 17 samples from the U.S.-Canada border to approximately 7 miles south of Northport. Twenty-eight samples have copper concentrations greater than or equal to 70 mg/kg and less than 126 mg/kg from the U.S.-Canada border to approximately 7 miles south of Northport. No samples have copper concentrations greater than 126 mg/kg (Map 6-17).

6.3.6.3 Total Recoverable Data from Samples with Unknown Grain Size

Soil copper concentrations for total recoverable samples with unknown grain size in the OU 3 study area range from 3.5 to 14,700 mg/kg, with a median of 49.4 mg/kg. Of 366 samples, 100 percent are detected values, and 198 samples (54 percent) exceed the total recoverable BTV of 41.5 mg/kg (Table 6-7).

Samples with unknown grain size are from the 2001 EPA Stevens County Mines and Mills PA/SI (USEPA 2002a), the 2004 EPA Le Roi Smelter Removal Action (USEPA 2005), the 2003--2004 EPA Anderson Calhoun EE/CA (USEPA 2007a), the 2007 Brooks Road/Bonanza Mine Roadbed Voluntary Cleanup (SCDPW 2008a), and the 2007 Peterson Swamp/Bonanza Mine Roadbed Voluntary Cleanup (SCDPW 2008b) studies. Therefore, these samples were collected in localized areas around these operations, and all sample locations are within the OU 3 study area. Approximately 50 percent of the samples are less than the total recoverable BTV (41.5 mg/kg).

Approximately 60 percent of the samples in the vicinity of Northport collected as part of the 2004 EPA Le Roi Smelter Removal Action are greater than or equal to the total recoverable BTV. Fifty-three samples are greater than or equal to the total recoverable BTV (41.5 mg/kg) and less than 70 mg/kg. Ninety-two samples are greater than or equal to 70 mg/kg, and 43 of those samples are greater than or equal to 126 mg/kg (Map 6-17).

Approximately 50 percent of samples collected at mines and mills in the uplands during the 2001 EPA Stevens County Mines and Mills PA/SI exceed the total recoverable BTV (41.5 mg/kg) for copper. Seventeen samples have copper concentrations greater than or equal to the total recoverable BTV and less than 70 mg/kg. Six samples are greater than or equal to 70 mg/kg and less than 126 mg/kg, and 26 samples are greater than or equal to 126 mg/kg. The highest copper concentrations in the OU 3 study area were measured in samples in this study (Map 6-17).

Five samples collected near the Anderson Calhoun Mine/Mill during the 2003--2004 EPA Anderson Calhoun EE/CA exceed the total recoverable BTV (41.5 mg/kg). Three samples exceed 70 mg/kg, and no samples are greater than or equal to 126 mg/kg (Map 6-17 and Appendix F).

Samples collected during the 2007 Brooks Road/Bonanza Mine Roadbed Voluntary Cleanup and the 2007 Peterson Swamp/Bonanza Mine Roadbed Voluntary Cleanup are less than the total recoverable BTV (41.5 mg/kg; Map 6-17).

6.3.6.4 Total Digestion Data

Soil copper concentrations for the total digestion data range from 2.09 to 34.6 mg/kg, with a median of 11.0 mg/kg. Of 11 samples, 100 percent are detected values, and no samples exceed the total digestion BTV of 37.0 mg/kg (Table 6-7, Map 6-17).

6.3.7 Areal Nature and Extent of Manganese

Manganese concentrations in surface soil are shown on Map 6-18. For the data included on Map 6-18, summary statistics are provided in Table 6-7, and boxplots are presented in Figure 6-8h. Soil manganese concentrations are also available in the data exploration tool (Appendix E).

On Map 6-18, manganese concentrations are binned to show the following concentrations:

- Bin 1—Less than the total recoverable BTV of 1,240 mg/kg (or 1,380 mg/kg for total digestion samples)
- Bin 2—Greater than or equal to the BTVs and less than 1,330 mg/kg
- Bin 3—Greater than or equal to 1,330 mg/kg and less than 1,470 mg/kg[103]
- Bin 4—Greater than or equal to 1,470 mg/kg and less than 1,610 mg/kg
- Bin 5—Greater than or equal to 1,610 mg/kg and less than 2,135 mg/kg
- Bin 6—Greater than or equal to 2,135 mg/kg.

Nondetected values are symbolized separately on Map 6-18.

Most soil manganese concentrations are less than the BTVs. Manganese concentrations that exceed the BTVs are generally at high elevations in the uplands. Concentrations are relatively stable with distance toward the south along the river between the U.S.-Canada border and Northport, with a decrease south of Northport and an increase with increasing elevation

[103] The data bins for manganese concentrations greater than the BTVs are based on the distribution of the soil manganese concentrations because the lowest ecological RBC (protective of plants) is less than the total recoverable BTV.

(Figure 6-4g, Map 6-18; Appendix F). Detailed descriptions of the spatial distribution of manganese are provided in the following subsections.

6.3.7.1 Total Recoverable Data in the < 2-mm-Size Fraction

Soil manganese concentrations for the < 2-mm total recoverable data in the OU 3 study area range from 43.6 to 5,290 mg/kg, with a median of 860 mg/kg. Of 316 samples, 100 percent are detected values, and 78 samples (25 percent) are greater than or equal to the total recoverable BTV of 1,240 mg/kg (Table 6-7).

Concentrations exceed the total recoverable BTV intermittently from the U.S.-Canada border to Northport within 15 miles on both sides of the river and sporadically south of Northport to approximately 4 miles south of Marble within 5 miles on both sides of the river. Fifteen samples had concentrations of manganese greater than or equal to the total recoverable BTV (1,240 mg/kg) and less than 1,330 mg/kg throughout the OU 3 study area, from the U.S.-Canada border to south of Northport (Map 6-18).

Manganese concentrations greater than or equal to 1,330 mg/kg and less than 1,470 mg/kg are present in 15 samples from the U.S.-Canada border to south of Marble. Manganese concentrations greater than or equal to 1,470 mg/kg and less than 1,610 mg/kg are present in 14 samples from the U.S.-Canada border to south of Northport. Concentrations of manganese that are greater than or equal to 1,610 mg/kg and less than 2,135 mg/kg are present in 17 samples from the U.S.-Canada border to Northport in the higher elevations, within 10 miles of the river near the border, and within 5 miles of the river near Northport. Seventeen samples had manganese concentrations greater than or equal to 2,135 mg/kg at higher elevations from the U.S.-Canada border to Northport, within 10 miles of the river near the border, and within 5 miles of the river near Northport (Map 6-18).

6.3.7.2 Total Recoverable Data in the < 150-µm-Size Fraction

Soil manganese concentrations for the < 150-µm total recoverable data in the OU 3 study area range from 175 to 1,860 mg/kg, with a median of 485 mg/kg. Of 1,191 samples, 100 percent are detected values (Table 6-7).

Approximately 99 percent of manganese concentrations are less than the total recoverable BTV (1,240 mg/kg). Ten samples are greater than or equal to the total recoverable BTV (1,240 mg/kg) for manganese; these sample sites are located intermittently from the U.S.-Canada border to Northport, generally on the west side of the river and within 10 miles on both sides of the river, and sporadically south of Northport to approximately 4 miles south of Marble on the west side of the river (Map 6-18). Two samples exceed 1,610 mg/kg near Northport, and no samples exceed 2,135 mg/kg.

6.3.7.3 Total Recoverable Data from Samples with Unknown Grain Size

Soil manganese concentrations for total recoverable samples with unknown grain size in the OU 3 study area range from 30.3 to 14,800 mg/kg, with a median of 286 mg/kg. Of 94 samples, 100 percent are detected values, and 10 samples (11 percent) exceed the total recoverable BTV of 1,240 mg/kg (Table 6-7).

Samples with unknown grain size are from the 2001 EPA Stevens County Mines and Mills PA/SI (USEPA 2002a) study. Therefore, these samples were collected in localized areas around these operations, and all sample locations are within the OU 3 study area. Approximately 89 percent of the samples are less than the total recoverable BTV (1,240 mg/kg).

Approximately 11 percent of samples collected at mines and mills in the uplands during the 2001 EPA Stevens County Mines and Mills PA/SI exceed the total recoverable BTV for manganese. No samples have manganese concentrations greater than or equal to the total recoverable BTV (1,240 mg/kg) and less than 1,330 mg/kg. One sample is greater than or equal to 1,330 mg/kg and less than1,470 mg/kg, one sample is greater than or equal to 1,470 mg/kg and less than 1,610 mg/kg, two samples are greater than or equal to 1,610 mg/kg and less than 2,135 mg/kg, and six samples are greater than or equal to 2,135 mg/kg. The highest manganese concentrations in the OU 3 study area were measured in samples in this study (Map 6-18).

6.3.7.4 Total Digestion Data

Soil manganese concentrations for the total digestion data range from 20 to 3,107.2 mg/kg, with a median of 810 mg/kg. Of 132 samples, 99 percent are detected values and 12 samples (9 percent) exceed the total digestion BTV of 1,380 mg/kg (Table 6-7).

On Map 6-18, total digestion samples are binned to show manganese concentrations less than the total digestion BTV of 1,380 mg/kg; the other bins are the same as those for the total recoverable samples. Manganese concentrations in the total digestion samples in the OU 3 study area exceed the total digestion BTV in approximately 9 percent of samples and are generally located along the outer edges of the OU 3 boundary, more than 5 miles from the river. Exceptions to this include four samples south of Kettle Falls (Map 6-18).

6.3.8 Areal Nature and Extent of Mercury

Mercury concentrations in surface soil are shown on Map 6-19. For the data included on Map 6-19, summary statistics are provided in Table 6-7, and boxplots are presented in Figure 6-8i. Soil mercury concentrations are also available in the data exploration tool (Appendix E).

On Map 6-19, mercury concentrations are binned to show the following concentrations:

- Bin 1—Less than the BTV of 0.12 mg/kg[104]
- Bin 2—Greater than or equal to the BTV and less than 0.15 mg/kg[105]
- Bin 3—Greater than or equal to 0.15 mg/kg and less than 0.21 mg/kg
- Bin 4—Greater than or equal to 0.21 mg/kg and less than 0.325 mg/kg, which is the lowest ecological RBC that is above the BTV (this RBC is protective of the survival endpoint for the American robin)
- Bin 5—Greater than or equal to 0.325 mg/kg and less than 0.88 mg/kg
- Bin 6—Greater than or equal to 0.88 mg/kg.

Nondetected values are symbolized separately on Map 6-19.

Most soil mercury concentrations are less than the BTV (Table 6-7). Mercury concentrations that exceed the BTV are generally at low elevations along the UCR valley between the U.S.-Canada border and Northport, in the vicinity of Bossburg, and in the vicinity of mines and mills in the uplands. Concentrations generally decrease with distance toward the south along the river and are relatively stable with elevation and lateral distance away from the river in both directions (east and west) (Figure 6-4h, Map 6-19; Appendix F). Detailed descriptions of the spatial distribution of mercury are provided in the following subsections.

6.3.8.1 Total Recoverable Data in the < 2-mm-Size Fraction

Soil mercury concentrations for the < 2-mm total recoverable data in the OU 3 study area range from 0.0042 to 2.8 mg/kg, with a median of 0.0663 mg/kg. Of 492 samples, 98 percent are detected values, and 82 samples (17 percent) are greater than or equal to the mercury BTV of 0.12 mg/kg (Table 6-7).

Concentrations exceed the total recoverable BTV intermittently from the U.S.-Canada border to Deadman's Eddy within 15 miles on both sides of the river, sporadically south of Northport to approximately 4 miles south of Marble within 2 miles on both sides of the river, and near Bossburg and the Van Stone Mine/Mill area. Twenty-nine samples have mercury concentrations greater than or equal to the total recoverable BTV (0.12 mg/kg) and less than 0.15 mg/kg

[104] There is only one BTV for mercury.

[105] The data bins for mercury concentrations greater than the BTV are based on available ecological RBCs and the distribution of the soil mercury concentrations.

throughout the OU 3 study area, from the U.S.-Canada border to south of Northport and the Van Stone Mine/Mill area (Map 6-19).

Mercury concentrations greater than or equal to 0.15 mg/kg and less than 0.21 mg/kg are present in 27 samples from the U.S.-Canada border to Northport and near Bossburg and the Van Stone Mine/Mill area. Mercury concentrations greater than or equal to 0.21 mg/kg and less than 0.325 mg/kg are present in 11 samples from the U.S.-Canada border to Northport and near Bossburg and the Van Stone Mine/Mill area. Mercury concentrations greater than or equal to 0.325 mg/kg and less than 0.88 mg/kg are present in 12 samples near the U.S.-Canada border, Bossburg, and the Van Stone Mine/Mill area. Three samples with mercury concentrations greater than or equal to 0.88 mg/kg are located near the Van Stone Mine/Mill area (Map 6-19).

6.3.8.2 Total Recoverable Data in the < 150-µm-Size Fraction

Mercury samples were not analyzed from the < 150-µm-size fraction.

6.3.8.3 Total Recoverable Data from Samples with Unknown Grain Size

Soil mercury concentrations for the total recoverable samples with unknown grain size in the OU 3 study area range from 0.04 to 26.4 mg/kg, with a median of 0.265 mg/kg. Of 110 samples, 80 percent are detected values, and 71 samples (65 percent) are greater than or equal to the mercury BTV of 0.12 mg/kg (Table 6-7).

Samples with unknown grain size are from the 2001 EPA Stevens County Mines and Mills PA/SI (USEPA 2002a), the 2004 EPA Le Roi Smelter Removal Action (USEPA 2005), the 2007 Brooks Road/Bonanza Mine Roadbed Voluntary Cleanup (SCDPW 2008a), and the 2007 Peterson Swamp/Bonanza Mine Roadbed Voluntary Cleanup (SCDPW 2008b) studies. Therefore, these samples were collected in localized areas around these operations, and all sample locations are within the OU 3 study area. Approximately 60 percent of the samples exceed the total recoverable BTV (0.12 mg/kg).

Mercury concentrations exceed the total recoverable BTV (0.12 mg/kg) throughout the OU 3 study area, except for a few samples intermittently from the U.S.-Canada border to east of Evans (Map 6-19). Four samples had concentrations of mercury greater than or equal to the total recoverable BTV (0.12 mg/kg) and less than 0.15 mg/kg in the mines and mills areas (Map 6-19). Mercury concentrations greater than or equal to 0.15 mg/kg and less than 0.21 mg/kg are present in seven samples in multiple mines and mills areas and the Peterson Swamp Road area. Mercury concentrations greater than or equal to 0.21 mg/kg and less than 0.325 mg/kg are present in nine samples from the outer edges of the OU 3 boundary. Concentrations of mercury that are greater than or equal to 0.325 mg/kg and less than 0.88 mg/kg are present in 25 samples from the outer edges of the OU 3 boundary. Twenty-seven samples with mercury

concentrations greater than or equal to 0.88 mg/kg are located in localized areas around OU 3 and the Van Stone Mine/Mill area (Map 6-19). The highest mercury concentrations in the OU 3 study area were measured in samples in the 2001 EPA Stevens County Mines and Mills PA/SI.

6.3.8.4 Total Digestion Data

One soil sample was analyzed for mercury by total digestion. Mercury was detected in the sample at 0.03 mg/kg, below the mercury BTV of 0.12 mg/kg (Table 6-7). On Map 6-19, the total digestion mercury sample is located northeast of Evans.

6.3.9 Areal Nature and Extent of Selenium

Selenium concentrations in surface soil are shown on Map 6-20. For the data included on Map 6-20, summary statistics are provided in Table 6-7, and boxplots are presented in Figure 6-8j. Soil selenium concentrations are also available in the data exploration tool (Appendix E).

On Map 6-20, selenium concentrations are binned to show the following concentrations:

- Bin 1—Less than the total recoverable BTV of 0.098 mg/kg (or 3.0 mg/kg for total digestion samples)
- Bin 2—Greater than or equal to the BTVs and less than 0.20 mg/kg[106]
- Bin 3—Greater than or equal to 0.20 mg/kg and less than 0.27 mg/kg
- Bin 4—Greater than or equal to 0.27 mg/kg and less than 0.37 mg/kg
- Bin 5—Greater than or equal to 0.37 mg/kg and less than 0.503 mg/kg, which is the lowest ecological RBC that is above the BTV (this RBC is protective of the growth endpoint for the masked shrew)
- Bin 6—Greater than or equal to 0.503 mg/kg.

Nondetected values are symbolized separately on Map 6-20.

Overall, selenium concentrations show considerable spatial variation, with elevated concentrations present at low elevations along the UCR valley between the U.S.-Canada border and Northport, at higher elevations in the upland areas on both sides of the river valley, and in the vicinity of historical mines and mills investigated as part of the 2001 EPA Stevens County

[106] The bins for selenium concentrations greater than the BTVs are based on available ecological RBCs and the distribution of the selenium soil data.

Mines and Mills PA/SI. Concentrations generally decrease with distance toward the south along the river and increase with increasing elevation and lateral distance away from the river in both directions (east and west) (Figure 6-4i, Map 6-20; Appendix F). Detailed descriptions of the spatial distribution of selenium are provided in the following subsections

6.3.9.1 Total Recoverable Data in the < 2-mm-Size Fraction

Soil selenium concentrations for the < 2-mm total recoverable data range from 0.1 to 5.2 mg/kg, with a median of 0.380 mg/kg. Of 492 samples, 71 percent are detected values, and 100 percent of the 492 samples (including all nondetected values) exceed the total recoverable BTV of 0.098 mg/kg (Table 6-7).

Selenium concentrations (including nondetected values) exceed the total recoverable selenium BTV (0.098 mg/kg) throughout the OU 3 study area (Map 6-20). Fifty-two concentrations of selenium greater than or equal to the total recoverable selenium BTV and less than 0.20 mg/kg are measured from the U.S.-Canada border to approximately 4 miles south of Marble, in Bossburg, and north of the Abercrombie Mountain area (Map 6-20). Selenium concentrations greater than or equal to 0.20 mg/kg and less than 0.27 mg/kg are present at 81 locations from the U.S.-Canada border to Northport and intermittently at lower elevation sample locations approximately 1 mile on both sides of the river valley from Northport to north of Bossburg. Selenium concentrations greater than or equal to 0.20 mg/kg and less than 0.27 mg/kg are also present in the Van Stone Mine/Mill area. Selenium concentrations greater than or equal to 0.27 mg/kg and less than 0.37 mg/kg are present at 103 locations from the U.S.-Canada border to just south of Northport, in the Van Stone Mine/Mill area, and in isolated spots on the eastern and western sides of the OU 3 study area. Selenium concentrations greater than or equal to 0.37 mg/kg and less than 0.503 mg/kg are present at 181 locations from the U.S.-Canada border to approximately 4 miles south of Marble, to the west near Abercombie Mountain, and in the vicinity of Van Stone Mine/Mill. Selenium concentrations greater than or equal to 0.503 mg/kg are present at 75 locations from the U.S.-Canada border to approximately 4 miles south of Marble and within the vicinity of the Van Stone Mine/Mill area (Map 6-20).

6.3.9.2 Total Recoverable Data in the < 150-µm-Size Fraction

Soil selenium concentrations for the < 150-µm total recoverable data range from 0.08 to 5.76 mg/kg, with a median of 0.280 mg/kg. Of 1,191 samples, 100 percent are detected values, and 1,188 samples (almost 100 percent) exceed the total recoverable BTV of 0.098 mg/kg (Table 6-7).

The distribution of selenium concentrations in the < 150-µm total recoverable samples is generally similar to the other size fractions, with concentrations greater than the total

recoverable BTV (0.098 mg/kg) occurring from the U.S.-Canada border to approximately 4 miles south of Marble, again in Bossburg within approximately 10 miles of each side of the river, and north of Northport, with intermittent occurrences at lower elevation sample locations approximately 1 mile on both sides of the river valley from Northport to south of Marble. However, three samples in this size fraction are less than the total recoverable BTV (0.098 mg/kg). Selenium concentrations in the < 150-µm total recoverable data greater than or equal to the BTV and less than 0.20 mg/kg are present at 258 locations from the U.S.-Canada border to Northport and sporadically between Northport and approximately 4 miles south of Marble within approximately 10 miles of the river on both sides. Selenium concentrations greater than or equal to 0.20 mg/kg and less than 0.27 mg/kg are present at 282 locations from the U.S.-Canada border to Northport within approximately 3 miles of the river on both sides and in the vicinity of Marble and south of Marble. Selenium concentrations greater than or equal to 0.27 mg/kg and less than 0.37 mg/kg are present at 262 locations sporadically between the U.S.-Canada border and approximately 4 miles south of Marble. Concentrations of selenium in greater than or equal to 0.37 mg/kg and less than 0.503 mg/kg are present at 166 locations from the U.S.-Canada border to Bossburg, with one sample present on the eastern edge of the OU 3 study area. A total of 220 samples with concentrations greater than or equal to 0.503 mg/kg are present throughout the OU 3 study area, from the U.S.-Canada border to approximately 4 miles south of Marble (Map 6-20).

6.3.9.3 Total Recoverable Data from Samples with Unknown Grain Size

Soil selenium concentrations for total recoverable samples with unknown grain size range from 0.69 to 35 mg/kg, with a median of 0.900 mg/kg. Of 119 samples, 33 percent are detected values, and 100 percent of the 119 samples (including all nondetected values) exceed the total recoverable BTV of 0.098 mg/kg (Table 6-7).

Samples with unknown grain size are from the 2001 EPA Stevens County Mines and Mills PA/SI (USEPA 2002a), the 2004 EPA Le Roi Smelter Removal Action (USEPA 2005), and Anderson Calhoun Mine/Mill (USEPA 2007a). Therefore, these samples were collected in localized areas around these operations, and all sample locations are within the OU 3 study area. All the samples are greater than or equal to 0.503 mg/kg (Map 6-20).

6.3.9.4 Total Digestion Data

Soil selenium concentrations for the total digestion data range from 0.2 to 1 mg/kg, with a median of 0.600 mg/kg. Of the two samples, one is a detected value, and neither exceeds the total recoverable selenium BTV of 3.0 mg/kg (Table 6-7).

Map 6-20 presents the two total digestion selenium samples from USGS NURE Sample Reanalysis. Selenium concentrations in the total digestion samples in the OU 3 study area are less than the total digestion BTV (Map 6-20). One sample is located near Evans and is binned to show selenium concentrations less than the BTV of 3.0 mg/kg. The other sample, to the west of Kettle Falls, is a nondetected value.

6.3.10 Overlapping Areas with COC Exceedances of Ecological RBCs

Surface soil concentrations for the nine COCs were compared to the lowest ecological RBCs selected from the range of relevant receptors described in Section 5.2.2 and presented in Table 5-14. For COCs where the lowest ecological RBC was less than the total recoverable BTV, the BTV was selected as the lowest ecological RBC. This comparison was performed to evaluate how the areas with ecological RBC exceedances for each COC overlap and to identify which COCs show the most extensive area of ecological RBC exceedances.

The analysis was performed using the geostatistically modeled concentrations of lead, cadmium, and zinc (see Sections 6.3.1.6, 6.3.2.5, and 6.3.3.5) as well as the measured COC concentrations in samples that were used in the geostatistical model (Section 6.2.4). Measured COC concentrations in samples designated as "mine and mill" samples, which were not used in the geostatistical model because the sample locations generally fall outside of the model boundary, were also considered. The data set used for this analysis is provided in Appendix H.

Areas with geostatistically modeled concentrations of lead, cadmium, and zinc in surface soil that are greater than the lowest ecological RBC are shown on Map 6-21[107]. Of these three COCs, zinc shows the greatest areal extent of estimated ecological RBC exceedances within the model boundary. The areas with modeled lead and cadmium concentrations greater than the lowest ecological RBC fall entirely within the area of modeled zinc exceedances. Therefore, to evaluate the relative spatial distribution of ecological RBC exceedances, locations with measured concentrations of arsenic, barium, cadmium, copper, lead, manganese, mercury, and selenium above the lowest RBC were compared to the modeled zinc exceedance footprint.

Sample locations with COC concentrations exceeding the lowest ecological RBC are shown on Map 6-22 through Map 6-29 along with the modeled zinc ecological RBC exceedance footprint. A sample-by-sample comparison of measured COC exceedances and modeled zinc exceedances is also provided for each location in Appendix H and summarized in Table 6-8. The following

[107] For lead, the area shown on Map 6-21 represents the area with geostatistically modeled concentrations of lead in surface soil greater than 100 mg/kg. This is approximately the lowest ecological RBC (106 mg/kg), which is protective of the reproduction endpoint for the masked shrew.

bullets summarize the spatial distribution of ecological RBC exceedances for lead, cadmium, arsenic, barium, cadmium, copper, lead, manganese, mercury, and selenium relative to the modeled zinc exceedance footprint:

- Lead (Map 6-22) and cadmium (Map 6-23) sample concentrations exceed their respective lowest ecological RBCs throughout the area where modeled zinc concentrations are above the lowest zinc ecological RBC. Three of the locations with cadmium exceedances (approximately 1 percent) are outside the zinc ecological RBC exceedance footprint (Table 6-8). Four of the lead exceedances (also approximately 1 percent) are located outside the zinc ecological RBC exceedance footprint (Table 6-8). These include locations in the southern portion of the geostatistical model domain, southeast of Bossburg, and within several isolated areas on both sides of the river that are bounded by modeled zinc concentrations above the lowest ecological RBC (Map 6-22 and Map 6-23).
- Arsenic, barium, and manganese (Map 6-24, Map 6-25, and Map 6-27, respectively) do not show widespread ecological RBC exceedances within the OU 3 study area. These COCs also do not exceed the lowest ecological RBC at any locations outside the modeled zinc ecological RBC exceedance footprint (Table 6-8).
- Copper, mercury, and selenium (Map 6-26, Map 6-28, and Map 6-29, respectively) also do not show widespread ecological RBC exceedances within the OU 3 study area, but these COCs each have some sample locations outside the modeled zinc ecological RBC exceedance footprint that exceed their respective lowest ecological RBC (Table 6-8). These include four isolated locations for copper (2 percent of results exceeding the lowest ecological RBC) southwest and southeast of Northport, one location for mercury (3 percent of results exceeding the lowest ecological RBC) near the southern boundary of the geostatistical model domain, and 13 locations for selenium (8 percent of results exceeding the lowest ecological RBC)[108] within several isolated areas on both sides of the river between Deadman's Eddy and approximately 4 miles south of Marble as well as in the vicinity of Bossburg (Map 6-26, Map 6-28, and Map 6-29, respectively). Except for the locations near Bossburg and those near the southern model domain boundary, all the exceedance areas for copper, mercury, and selenium are bounded by areas with modeled zinc concentrations above the lowest ecological RBC.

Overall, zinc shows the greatest areal extent of ecological RBC exceedances within the geostatistical model boundary, and there is nearly complete overlap between the lead,

[108] One of the selenium results that exceeds the lowest ecological RBC outside the modeled zinc ecological RBC exceedance footprint is a nondetected value.

cadmium, arsenic, barium, copper, manganese, mercury, and selenium ecological RBC exceedances and the modeled zinc ecological RBC exceedance footprint. Similarly, for the mine and mill data set, only copper (1 sample, or 1 percent), mercury (1 sample, or 1 percent), and selenium (18 samples,[109] or 13 percent) exceed the lowest ecological RBC at locations without a corresponding measured zinc exceedance (Table 6-8).

6.4 VERTICAL NATURE AND EXTENT OF METALS IN SOIL

The vertical nature and extent of COCs in soil, which identifies the depth of contamination in soil, was evaluated using the data from applicable studies in several ways. The vertical nature and extent evaluation seeks to answer the following questions:

1. Are soil metals concentrations enriched in the surface compared to subsurface concentrations? If so, are there geographical patterns in the surface-to-subsurface concentration ratios?
2. What is the vertical extent of metals contamination in soil?

The data available for evaluating vertical nature and extent were limited primarily to the river valley and adjacent areas because these are the areas with the greatest number of locations where surface and subsurface soil samples were collected.

The primary approach involved calculating and displaying the ratios or relationship (i.e., increasing or decreasing) between surface and subsurface soil concentrations. These ratios and relationships were evaluated statistically, spatially, and graphically, as described below in Section 6.4.1. This approach was used because it is supported by the largest amount of data in the Upland RI data set. A summary of statistics for the data used in the surface to subsurface soil concentration ratios evaluation is presented in Table 6-9. Surface-to-subsurface soil concentration comparisons are summarized in Table 6-10, Figure 6-9, and Figure 6-10a through Figure 6-10i and plotted on Map 6-30 through Map 6-38.

The second approach involved graphing the concentration-depth relationship at sampling locations where vertical soil profile samples were collected. This approach was supported by data from fewer studies and is presented in Section 6.4.2. Vertical soil profile plots are provided in Figure 6-11a through Figure 6-11i.

[109] Three of the selenium results that exceed the lowest ecological RBC without a corresponding measured zinc exceedance are nondetected values.

Third and finally, a qualitative discussion of subsurface soil data from studies that only included subsurface soil samples or where co-located surface-subsurface soil results are not available (as identified in Table 3-1) is provided in Section 6.4.3.

The data analysis for the vertical nature and extent evaluation led to similar conclusions for the COCs lead, cadmium, and zinc, where these metals showed concentrations that were enriched in surface soil generally greater than total recoverable BTVs and that concentrations decreased with depth. At most locations where data are available to assess vertical concentration profiles, lead, cadmium, and zinc concentrations decrease to values close to or below total recoverable BTVs between ground surface and about 6 in. bgs, indicating that lead, cadmium, and zinc enrichment is typically limited to soil depths of about 6 in. Because mercury was not included as an analyte for several studies, there are fewer data available to evaluate vertical nature and extent for mercury. Where mercury data are available, surface concentrations were typically below the mercury BTV, but mercury concentrations did exhibit decreasing concentration with depth. Collectively, these results support surface deposition as a primary source/release mechanism for lead, cadmium, mercury, and zinc within the OU 3 study area. The degree of surface enrichment for lead, cadmium, and zinc varies spatially across the OU 3 study area, with no strong spatial pattern (Map 6-30 through Map 6-32). There are not sufficient data available to evaluate spatial patterns for mercury surface-to-subsurface concentration ratios (Map 6-37).

The other COCs (arsenic, barium, copper, manganese, and selenium) have concentrations that are below their BTVs and either showed variable enrichment patterns in surface soil (arsenic, copper, and manganese) or did not show statistically significant enrichment (barium and selenium). Evaluations of the surface-to-subsurface soil concentration ratios and soil concentration depth profiles are provided in the following subsections, along with a qualitative assessment of subsurface soil data.

6.4.1 Surface-to-Subsurface Soil Concentration Ratios

Surface-to-subsurface soil concentration ratios were calculated on a sample location basis as a metric to describe the degree to which the surface soil concentration was greater than or less than the subsurface soil concentration. The ratios were calculated by dividing the log10 surface concentration by the log10 subsurface concentration for the relevant samples from the following studies: 2012 Ecology Upland Soil Study, 2016 Residential Soil Study, 2014 Residential Soil Study, 2015 Bossburg Study, 2004 EPA Le Roi Smelter Removal Action, and 2017 SATES Test Plot Characterization. For these calculations, the surface sample was considered to be the sample collected from mineral soil with an upper depth of 0 in. The subsurface sample for calculating a ratio was the next incremental depth sampled in a study. For example, if samples

were collected from 0 to 1 in. bgs, 1 to 6 in. bgs, and 6 to 12 in. bgs, the surface and subsurface soil results from 0 to 1 in. bgs and 1 to 6 in. bgs, respectively, were used to calculate surface-to-subsurface soil concentration ratios for the analysis. Summary statistics for the calculated ratios are presented in Table 6-10 for all nine COCs. Boxplots presenting the distributions of ratios for COCs, by study, are plotted in Figure 6-9.

For this evaluation, studies were kept separate because of the different sample depths and sample types and because the studies generally covered different areas. The evaluation was also performed using the combined data from three studies that had similar land uses (2016 Residential Soil Study, 2014 Residential Soil Study, and 2004 EPA Le Roi Smelter Removal Action) and that used consistent surface and subsurface sample depths. Ratios greater than 1 indicate surface concentrations greater than subsurface concentrations, with a higher ratio indicating a greater percent difference in the surface versus subsurface. For example, a ratio of 1.56 represents a log10 surface concentration that is 56 percent greater than the log10 subsurface concentration, while a ratio of 1.04 shows a log10 surface concentration that is only 4 percent greater than the log10 subsurface concentration. Probability (p-value) was calculated to understand the statistical significance of the observed difference; p-values less than 0.05 were considered to have a statistically significant difference from 1 (Table 6-10). The 95 percent confidence interval range for the mean ratio is presented in Table 6-10, and boxplots for ratios are presented in Figure 6-9 to illustrate the variability in the data.

This approach of evaluating surface-to-subsurface soil concentration ratios and significance testing results, while illustrative, does not by itself identify whether differences are meaningful. For example, a statistically significant but small ratio, such as 1.13 for arsenic in the 2012 Ecology Upland Soil Study, may not indicate a meaningful difference in concentrations because both surface and subsurface samples had arsenic concentrations below the BTV in all but one surface-subsurface sample pair.

When examined by study, the mean surface-to-subsurface soil concentration ratios are greater than 1 and most commonly statistically significant for cadmium, lead, zinc, and mercury; however, mercury was only analyzed in two of the studies. Arsenic, copper, and manganese had differences that were statistically significant but were greater than 1 or less than 1, depending on the study. Ratios for barium were not statistically significant in any study, and selenium exhibited statistically significant ratios in only one study.

Of the COCs, surface-to-subsurface soil concentration ratios tended to be highest for cadmium, lead, zinc, and, if analyzed for the study, mercury. The 2017 SATES Test Plot Characterization and/or 2012 Ecology Upland Soil Study tended to have the highest ratios for all four of these metals. The 2014 and 2016 Residential Soil Studies had statistically significant results for

cadmium, lead, and zinc (mercury was not analyzed in the residential soil studies), but the enrichment of these metals at the surface was much less, with ratios ranging from 1.04 to 1.30, compared to the 2017 SATES Test Plot Characterization and 2012 Ecology Upland Soil Study, where ratios ranged from 1.15 to 1.72 and 1.27 to 1.67, respectively.

Three studies, the 2016 Residential Soil Study, 2014 Residential Soil Study, and 2004 EPA Le Roi Smelter Removal Action, were also analyzed collectively because they had the same surface (0 to 1 in. bgs) and subsurface (1 to 6 in. bgs) sample depth intervals. The surface-to-subsurface soil concentration ratios for the combined studies for lead, cadmium, and zinc were 1.09, 1.06, and 1.07, respectively (Table 6-10). The ratios from the combined studies were statistically significant for these three metals. Arsenic, barium, copper, manganese, and selenium all have ratios less than 1 in the combined set of study data. Of these metals, the differences between surface and subsurface soil concentrations were statistically significant only for arsenic and manganese.

Surface-to-subsurface soil concentration ratios for all COCs were plotted by location on maps (Map 6-30 to Map 6-38) to understand the spatial variation of the ratios. The maps show that the ratios vary spatially across the OU 3 study area, with no strong spatial pattern. In many instances, very high and very low ratios occur within a small area and are highly variable. The distribution of sample locations shown on the maps illustrate that, except for the 2012 Ecology Upland Soil Study, which included higher-elevation sampling locations in the far northern portion of the OU 3 study area, almost all data available for evaluating the vertical nature and extent of metals in soil are located at lower elevations along the river valley, where sampling was associated with residential properties. The available data do not provide adequate representation of higher-elevation areas to support an evaluation of how the vertical extent of metals varies with elevation.

Figure 6-10a through Figure 6-10i present boxplots of the log10 soil concentrations for all the COCs in surface and subsurface samples to illustrate the variability within and between studies. In each of these studies, the overall concentration trends decrease from the surface to subsurface. The boxplots show that, while the overall trends in concentration for these metals generally decrease from surface to subsurface, the data within the studies are variable and do not always follow the trend.

6.4.2 Soil Concentration Depth Profiles

To understand the vertical extent of the metals in the subsurface, vertical profiles were plotted as log10 soil concentration (y-axis) versus upper sample depth (x-axis) for each metal using data from the four studies where soil samples were collected and analyzed from multiple depths at a

given location: 2012 Ecology Upland Soil Study, 2015 Bossburg Study, 2004 EPA Le Roi Smelter Removal Action, and 2017 SATES Test Plot Characterization. These depth profile plots are presented in Figure 6-11a through Figure 6-11i for the COCs.

Soil concentrations for COCs lead, cadmium, and zinc are generally above their total recoverable BTVs at the surface and show overall decreasing regression lines from surface to subsurface. Concentrations of lead, cadmium, and zinc generally decrease to below their BTVs. The other COCs were generally below their BTVs in surface soil. The general patterns evident based on the locally estimated scatterplot smoothing (LOESS) regression lines in the depth profile plots for metals are summarized as follows:

- Lead profiles (Figure 6-11a) show that the regression lines decrease to below the total recoverable BTV by a depth of 6 in. bgs, except for soil concentrations in the 2015 Bossburg Study and the 2004 EPA Le Roi Smelter Removal Action, where average concentrations stay above the BTV to depths of 12 to 17 in. bgs.
- Cadmium (Figure 6-11b) and zinc (Figure 6-11c) profiles show decreasing concentrations with depth, and the average concentrations decrease to below their respective total recoverable BTVs within 5 to 10 in. bgs, except for the 2004 EPA Le Roi Smelter Removal Action study, where the cadmium average concentration stays above the BTV to the depth of 18 in. bgs, and the 2015 Bossburg Study, where the zinc average concentration decreases below the BTV at a depth of about 2.5 in. bgs.
- Arsenic (Figure 6-11d) regression lines show slightly decreasing concentrations with depth. The regression lines are uniformly below the total recoverable BTV, except for the 2017 SATES Test Plot Characterization data, where concentrations decrease below the BTV at a depth of about 2 in. bgs.
- Barium (Figure 6-11e) and manganese (Figure 6-11g) are below their respective total recoverable BTVs through all depths.
- Copper (Figure 6-11f) is below the total recoverable BTV, except for the 2004 EPA Le Roi Smelter Removal Action, where the regression line shows a decreasing trend with depth and goes below the total recoverable BTV at about 8 in. bgs.
- Mercury (Figure 6-11h) regression lines are always below the total recoverable BTV in the two studies with mercury data (2012 Ecology Upland Soil Study and 2015 Bossburg Study), which were located in different parts of the OU 3 study area.
- Selenium (Figure 6-11i) does not exhibit a consistent slope, and selenium regression lines are uniformly above the total recoverable BTVs.

In addition to the vertical profile evaluation described above, lead concentrations from the 2014 and 2016 Residential Soil Studies were compared to the pre- and post-removal samples collected in the 2017–2018 VRA, 2015 TCRA Memorandum, and 2015 TCRA.[110] Average concentrations were calculated for each DU for surface soil, depths from 1 to 6 in. bgs, and subsurface soil, depths greater than 6 in. bgs (Table 6-11). Except for two DUs,[111] the average lead concentration in surface soil exceeded the average concentration for 1 to 6 in. bgs, which exceeded the average concentration at depths 6 in. bgs or greater. This analysis indicates that lead in these DUs was enriched in surface samples compared to subsurface samples. The elevated lead concentrations were generally limited to the upper 6 in. of soil depth. The TCRA and VRA studies assumed 6-in. removal depths where confirmation samples were collected; however, for a limited number of DUs, excavation up to 12 in. was required. Boxplots for the lead concentrations for the TCRA and VRA data, presented in Figure 6-12, illustrate the decreasing concentration trends from surface to subsurface soil.

6.4.3 Qualitative Subsurface Soil Data Assessment

Two studies were identified for evaluation in this Upland RI report that included subsurface soil samples without accompanying co-located surface samples: the USGS Midnite Mine Sediment Study, which was also used for developing BTVs, and the 2011 Port of Entry Soil Remediation (Table 3-1). The USGS Midnite Mine Sediment Study included reanalysis of soil and sediment samples collected in 1979 as part of the NURE-HSSR program. Because the investigation area for the USGS Midnite Mine Sediment Study is outside the OU 3 study area (see Map 3-20), the few subsurface soil samples from this study are not evaluated in this Upland RI report.

As described in Section 3.10, the soil chemistry data from the 2011 Port of Entry Soil Remediation are for post-removal confirmation soil samples collected from about 10 to 13 in.

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[110] There is a discrepancy between field duplicate IDs and sample coordinates for one QA/QC sample collected during the 2015 TCRA confirmation soil sampling. Sample 201G-082815-BD1 is identified in the TCRA completion report as the field duplicate of sample 201G-082815-C4-06; however, sample 201G-082815-BD1 has the same location coordinates as sample 201G-090815-E4-06. Because duplicates were paired with parent samples based on coordinates, not the duplicate sample ID, the results for 201G-082815-BD1 were averaged with the results for 201G-090815-E4-06. The uncertainty in which primary sample was used to calculate average arsenic and lead results for this single field duplicate/parent sample pair is expected to have a negligible impact on the vertical nature and extent evaluation.

[111] For 2014 RSS DU 39, the average concentration from confirmation samples collected at 6 in. below original ground surface (20 mg/kg) was greater than the lead concentration in the single sample collected from 1 to 6 in. bgs for the 2015 TCRA Memorandum (9.4 mg/kg). Sampling completed in post-removal for the VRA excavation at DU DEA-A found a lower concentration in the single grab sample collected from 4 in. (62 mg/kg) than in the averaged concentration (63 mg/kg) from 18 grab samples collected at depths greater than 6 in.

and 20 to 23 in. below the original ground surface. Pre-removal (surface soil) data are not available for the study. Also, the confirmation samples were only analyzed for arsenic, cadmium, and lead. Because there are no surface soil data against which to compare the subsurface sample results, only a qualitative assessment of the vertical nature and extent of metals can be completed using these data.

The ranges of soil metals concentrations detected in samples and their comparison with BTVs are as follows:

- Arsenic concentrations ranged from 1.65 to 23.3 mg/kg, with all 48 sample results less than or equal to the total recoverable BTV of 23.3 mg/kg.
- Cadmium concentrations ranged from not detected at 0.145 mg/kg to detected at 7.82 mg/kg, with 41 of 51 samples below the total recoverable BTV of 0.74 mg/kg.
- Lead concentrations ranged from 2.16 to 361 mg/kg, with 37 of 48 samples below the total recoverable BTV of 27.2 mg/kg.

Based on these comparisons between soil concentrations detected in subsurface samples to BTVs, soil with elevated metals concentrations at the Port of Entry near the U.S.-Canada border appear to be limited to the upper 10 in., although this may be an overestimation because data for shallower soil at this location are not available. This assessment is consistent with information provided in the study report (Shannon and Wilson 2011) (see Section 3.10), which described elevated metals concentrations at the Port of Entry area as being generally shallow and limited to depths of 0 to 10 in., with a few small areas exhibiting elevated concentrations identified that required additional excavation to a total depth of 20 in. The pattern of vertical nature and extent indicated by this qualitative assessment using the 2011 Port of Entry Soil Remediation data is consistent with the findings from the assessment of vertical concentration depth profiles provided in Section 6.4.2.

7 PHYSICAL/CHEMICAL CSM

A CSM considers the sources of contaminants and the physical and chemical processes that control chemical fate (i.e., the physical transport and chemical reaction pathways that are important to explain the concentrations, distribution, and movement of chemicals over time and space). The physical/chemical CSM presented in this section identifies the known and potential sources and the release and transport mechanisms for metals in soil in the OU 3 study area. The current focus of the physical/chemical[112] CSM for the OU 3 study area is on Site characterization; however, after the Upland RI is completed, the focus will shift toward remedial technology evaluation and selection, followed by remedial design and implementation.

The terms "primary source" and "secondary and tertiary sources" in the CSM are used according to the definitions established in the RI/FS Work Plan (USEPA 2008a), where "'[p]rimary' refers to the original source (e.g., discharge point) of a chemical constituent, while 'secondary' and 'tertiary' sources are environmental media (abiotic or biotic) that receive chemical inputs from a primary or secondary source through direct discharge or through chemical transport and fate mechanisms." This is also consistent with the definition of primary source provided in the HHRA (USEPA 2021).

The following sections describe the physical/chemical CSM for the OU 3 study area, including the known and potential sources of metals (Section 7.1) and the physical and chemical transport and fate pathways for metals in the OU 3 study area (Section 7.2).

7.1 SOURCES OF COCs

Section 2.10 lists five categories of known and potential primary sources of COCs to the OU 3 study area upland soils: 1) smelter operations, 2) mining operations and mineral processing facilities, 3) other anthropogenic sources, 4) geology and geogenic background, and 5) ambient atmospheric constituents. These categories are depicted generally on the CSM diagram (Figure 7-1) and discussed in the following sections in the context of the evaluations and analyses completed as part of the Upland RI. Of these sources, smelter operations and ambient atmospheric constituents have the potential for regional impacts across the OU 3 study area, while mining operations and mineral processing facilities, other anthropogenic sources, and geology and geogenic background are more likely to have relatively localized impacts.

[112] The identifier "physical/chemical" is to differentiate this from the exposure CSMs used for risk assessment, as described and presented in Section 5 of this Upland RI report.

The nature and extent evaluations presented and discussed in Section 6 were used to further evaluate the patterns of COC concentrations in soils in the OU 3 study area that have resulted as a function of transport and fate from various sources. These analyses show occurrences of COCs in soil in many areas within the OU 3 study area at concentrations above their respective BTVs.

7.1.1 Smelter Operations

The nature and extent evaluations presented in Section 6 describe the correlations between COCs; the statistical relationships between COC concentrations in surface soil and physical attributes (e.g., distance from the Trail Facility and elevation); and the areal and vertical nature and extent of COCs in surface soil within the OU 3 study area. Key findings from these analyses include the following:

- Patterns observed in the GAM for UTM northing (as a proxy for distance from the Trail Facility) versus COC concentrations in surface soil suggest that arsenic, cadmium, copper, lead, mercury, and zinc concentrations are consistent with aerial deposition from smelter emissions. Barium and manganese exhibit different north-south patterns than the other COC metals. For selenium, several studies included high frequencies of nondetected values and/or elevated detection limits, which complicate interpretations from the GAM for selenium.
- Patterns observed in the GAM for elevation versus COC concentrations in surface soil indicate that cadmium, copper, and lead exhibit patterns of higher concentrations at low elevations (i.e., along the river valley) that decrease with increasing elevation. This would be expected for metals that are transported and deposited from smelter emissions. Arsenic and zinc do not exhibit a strong relationship with elevation, and barium, manganese, mercury, and selenium show a gradual increase in concentrations with increasing elevation.
- Soil metals concentrations decreased between surface and subsurface samples most commonly for cadmium, lead, and zinc. This is consistent with deposition of smelter emissions being a primary source of impacts to soil for these metals. Decreasing concentrations between surface and subsurface samples were less frequently indicated for copper, arsenic, and manganese.
- The correlation coefficient matrix for the nine COCs shows that arsenic, cadmium, copper, lead, mercury, and zinc have moderate to strong positive correlations with each other, which is consistent with these metals all having soil concentrations that are influenced by smelter emissions. Barium, manganese, and selenium exhibit variable correlation patterns with the other six COCs; however, barium and manganese have a

strong positive correlation with each other, and selenium has a low positive correlation with barium and manganese.

Overall, the relationships and patterns identified in the nature and extent evaluations for cadmium, lead, and zinc (and to a lesser extent arsenic, copper, and mercury) are consistent with transport and deposition from historical aerial emissions (both stack and fugitive) from smelter operations at the Trail Facility and the Le Roi/Northport Smelter. Concentrations of the COCs correlated with smelter emissions show considerable spatial variation across the OU 3 study area but are generally highest at low elevations along the UCR valley between the U.S.-Canada border and Northport, at higher elevations in the upland areas on both sides of the river valley immediately south of the U.S.-Canada border, and in the vicinity of Northport. Concentrations of these COCs generally decrease with distance southward along the river valley and with increasing elevation and lateral distance away from the river in both directions (east and west); however, most arsenic, copper, and mercury concentrations in soil are less than the BTVs.

7.1.2 Mining Operations and Mineral Processing Facilities

The aerial nature and extent evaluations in Section 6 show elevated soil COC concentrations in the vicinity of historical mines and mills in the uplands and to the south of Northport in the vicinity of Bossburg. Mining operations and mineral processing facilities have occurred throughout northeastern Washington and southeastern British Columbia since the late 1800s. In addition to the smelters described above, there have been numerous metal and nonmetal mining and mining-related operations in the region. All metal-related operations are currently inactive within the OU 3 study area, but there are ongoing nonmetal-related operations (e.g., limestone and gravel quarries).

As described in Section 2 and Appendix A, numerous investigations have evaluated potential impacts to soil and other environmental media at historical mine and mill sites in Stevens County, Washington. Most of the samples collected during these investigations have concentrations of cadmium, lead, and zinc that are an order of magnitude or more over their respective BTVs[113]. The descriptions of operations and environmental data provided in these studies combined with the nature and extent evaluations provided in Section 6 suggest that the extent of soil impacts surrounding these sites is localized relative to the wider distribution of COCs correlated with smelter emissions; however, the available data are not adequate to fully delineate the spatial distribution of effects at all these historical mines and mills. Given the

[113] Soil samples from mines and mills studies were analyzed for total recoverable metals. These results are compared to the partial digestion BTVs described in Section 4.3.2.

absence of adequate characterization data at many of these sites within the OU 3 study area, further characterization may be needed if areas near these sites are identified for remedial action.

7.1.3 Other Anthropogenic Sources

Land use in the OU 3 study area is varied and includes federal, state, and private forests, parks/undeveloped areas, residential neighborhoods, utility rights-of-way, agriculture, retail and other services, manufacturing, and land designated for cultural or recreational use. Some of the existing land uses were identified in the DQOs for determining BTVs for upland soil as potential anthropogenic sources of COCs to soil within the OU 3 study area (Appendix B). The identified land uses included roads, railways, and landfills (TAI 2018a; USEPA 2018); however, the studies evaluated in the Upland RI were not designed to assess how anthropogenic features or land uses might have contributed to COC occurrences in upland soils, and no further evaluation was completed in this RI report to characterize potential contributions from these sources. Additional characterization may be warranted if areas identified for remedial action are thought to be influenced by non-smelter anthropogenic sources.

7.1.4 Geology and Geogenic Background

As described in Section 2.4, Section 4, and the nature and extent analyses presented and described in Section 6, there is evidence that in some areas in the OU 3 study area the presence of geogenic sources (i.e., geologic features and processes) is contributing to elevated metals concentrations in soil. The mineralization in bedrock within the OU 3 study area, which overlaps with the Northport Mining District, is well documented and includes the COCs lead, zinc, copper, and cadmium. Numerous outcrops of mineralized rock units in the OU 3 study area have historically been mined for metallic sulfide ore and include the following:

- The Jurassic Rossland Group (Jcg and Jmv)
- Unnamed Permian through Triassic metasedimentary rocks (TRPMmm, TRPMmt, and TRPMmv)
- Carboniferous through Devonian metasedimentary and metacarbonate rocks of the Grass Mountain, Flagstaff Mountain, and Pend Oreille sequences (CDcb, CDmm, CDmt, and CDmv)
- Ordovician Metaline Formation and Ledbetter slate (OCcb and Oar)
- Cambrian Maitlen phyllite (Ccb and Cmm).

These rock units and mapped rock outcrops and outcrop complexes are shown on Map 2-5.

The available data are not sufficient to evaluate the degree to which specific formations or soil types might contribute to locally elevated COC concentrations in soil; therefore, further

characterization may be needed to support remedial action decision-making in areas suspected to be influenced by geogenic sources.

7.1.5 Ambient Atmospheric Sources

The studies included in the data set evaluated in this Upland RI were not designed to assess the contribution of metals to soil from global or regional ambient atmospheric constituents; therefore, no further evaluation is presented in this RI report for these sources. Given the absence of this information, further characterization may be needed if areas identified for remedial action are thought to be influenced by non-smelter ambient atmospheric sources.

7.2 TRANSPORT AND FATE OF COCs

Release and transport mechanisms for the COCs are illustrated in the CSM diagram (Figure 7-1), which includes release and transport mechanisms for COCs identified in previous Site documents (USEPA 2008a, 2009a; TAI 2011, 2014), the ecological exposure CSM included in the Upland BERA (USEPA 2023a), and the human exposure CSM presented in the HHRA (USEPA 2021).

Several different physical, chemical, and biological transport and fate mechanisms influence the distribution of COCs in the OU 3 study area. COCs are transported by atmospheric suspension and deposition of COC-bearing particulates through wind dispersion (i.e., sorbed to airborne soil particles or other particulate matter) or in biological matrices (i.e., bioaccumulated in terrestrial organisms). The forms (species) and phases in which the COCs occur influence their transport, fate, and bioavailability (USEPA 2007b). The form of each COC depends on its chemical properties as well as local environmental conditions (e.g., temperature, pH, oxidation-reduction conditions, CEC, particle size, moisture content, and organic material) and the time since deposition.

The movement of COCs through the environment occurs via primary, secondary, and tertiary release mechanisms. The primary release mechanism is the direct discharge of metals from sources to environmental media. Once released to the environment, COCs present in environmental media (i.e., air, dust, and soil) are distributed through the following secondary and tertiary release mechanisms:

- **Air and dust.** COCs in the air and sorbed to dust particles can be transported via wind dispersion, which is the process by which metals are transported locally, regionally, or globally via wind currents to different locations. The COCs are deposited from the air to soil, sediment, surface water, or biota by wet or dry depositional processes. Topographic conditions and local meteorological conditions likely play a significant role in

determining the direction, elevation, and horizontal and vertical dispersion of air particulates, subsequently affecting the distribution and magnitude of COC deposition within the OU 3 study area (TAI 2011).

- **Soil.** COCs present in soil are subject to physical, chemical, and biological processes. Physical transport processes occur through suspension and wind dispersion of soil or particulate matter. Chemical processes include adsorption/desorption (i.e., attachment or detachment of metals to soil particles) and physical processes like decrepitation/weathering/erosion (i.e., the wasting or breaking up of particles resulting in metal releases). In addition, biological uptake of metals from soil (e.g., via incidental ingestion or uptake by plants) may lead to the bioaccumulation of metals in the tissues of ecological and human receptors. Partitioning of metals in the soil matrix is dependent on several environmental conditions that can enhance or retard adsorption and desorption of metals to soil particles (e.g., temperature, pH, reduction-oxidation conditions, CEC, particle size, moisture content, and organic matter).

The following sections describe the transport and fate of COCs within the OU 3 study area for each of the primary sources.

7.2.1 Smelter Operations

The primary release mechanisms of historical airborne pollutants are smelter stack and fugitive emissions from the Trail Facility and Le Roi/Northport Smelter operations. Stack emissions are emitted through a flue to a smokestack (a point source) and are typically associated with one or more specific processes occurring at a smelter (e.g., boiler operation). Fugitive emissions are typically uncontrolled or partially uncontrolled gaseous or particulate emissions that are released through a range of physical processes. Fugitive emissions can also be generated as dust from traffic on roadways, loading and unloading operations, excavation activities, and wind erosion and transport processes. The transport of stack and fugitive emissions is impacted by the geometry (area elevation above ground) of the sources. Stack emissions occur as point sources at the height of the stack, while fugitive emissions tend to be more like localized sources and are emitted at or closer to ground surface than stack emissions and are less likely to result in regional impacts. The Le Roi/Northport Smelter closed in 1921, and no further smelting has occurred in the area since that time. The Trail Facility continues to operate, but improvements to processing and controls on emissions have greatly reduced the amount of metals that could be transported and deposited to soil within the OU 3 study area.

Metals in aerial smelter emissions are released as particulates rather than as gases; however, smaller particulates (e.g., in the range of particulate matter 2.5 μm and smaller [$PM_{2.5}$] to PM_{10}) may be transported and dispersed similarly to some gases, which are controlled by diffusion

and turbulent mixing. The transport of particulate matter 50 μm and smaller (PM_{50}) is controlled more by gravitational settling processes. Particulate smelter emissions are transported in air via wind transport, and dispersion and deposition are influenced by local and regional topography and particle size (smaller particles will travel farther). Particulates carried in air are deposited on soil through wet and/or dry aerial deposition.

Once deposited onto soil, metals can be transported by several different physical transport mechanisms. Metal particulates may be resuspended by wind, transported as dust, and then redeposited in other areas. This pathway is expected to affect the transport and fate of the metals in a similar way. Metals in soil may also be transported as suspended particulates (solids) or dissolved constituents in surface water runoff, eventually being redeposited in soil or washed into local water bodies. The physical transport of soil particulates in runoff is expected to be similar for all the metals. However, the transport of dissolved-phase metals will be influenced by the chemical conditions present, which will differentially affect the dissolution and desorption of metals from soil. The desorption of metals from soil depends on the pH and reduction-oxidation conditions of the soil and surface water that it contacts. For example, the adsorption of lead, cadmium, and zinc onto soil particles is greater when the soil pH or the organic material content is higher, making them less likely to be released into solution. The presence of calcium carbonate can affect the desorption of these metals from soil. The high pH and oxidizing conditions in calcareous soils promote the precipitation and adsorption of these metals onto the soil particles. Because of the prevalence of calcareous parent material in upland soils, these metals are less likely to be desorbed when the soil contacts surface water. Elevated organic material, pH, and oxidizing conditions will maintain the concentrations of metals in the soil.

The solubility of the COCs can vary substantially with changes in pH. For example, cadmium and zinc are more mobile in near-neutral pH than lead. The solubility for these three metals tends to increase as the pH decreases, and at very low pH values (below pH 4), they can become highly soluble. At higher pH values (above pH 8), they tend to form insoluble compounds and become less soluble. Reduction-oxidation conditions also play a crucial role in the desorption of these metals. The unsaturated aerobic conditions prevalent throughout the upland area promote the oxidized forms of these metals, which tend to be more stable and are unlikely to desorb from soil particles. Saturated, reduced organic soils contain organic compounds that adsorb metals like cadmium, lead, and zinc quite strongly, generally inhibiting their mobility in the soil profile. However, soluble organic compounds, such as humic and fulvic acids, may effectively mobilize these metals as chemical complexes, depending on the soil conditions (White 2020).

Metals in soil may also be accumulated in organisms through root uptake (plants) or by inhalation, ingestion, or direct contact (animals). Bioaccumulation of the COCs will vary depending on the bioavailability of each metal and the form of each metal in soil as well as soil

conditions. Ultimately, COCs from smelter emissions will be incorporated into soil, surface water, sediment, or biota.

7.2.2 Mining Operations and Mineral Processing Facilities

The primary release mechanisms of the COCs from mining operations and facilities include surface water and stormwater runoff and disposal of solid waste, slag, and/or tailings. These materials may be released directly to soil or stored in stockpiles that are susceptible to secondary transport mechanisms, such as wind transport as dust or surface water runoff. These mechanisms may release metals at concentrations relative to the content of the materials processed at a given operation or facility. As described above for smelter emissions, once in soil, these metals are subject to tertiary release mechanisms that may include wind transport of dust, entrainment of particulates and dissolved constituents in surface water runoff, or bioaccumulation. COCs will be influenced in similar ways by physical transport pathways, but chemical and biological transport pathways will differentially affect the metals in soil, as described in Section 7.2.1. The fate of COCs from mining operations and facilities will be incorporated into soil, surface water, sediment, or biota.

The extent of soil impacts surrounding the historical mine and mill sites is expected to be relatively localized; however, the available data are not adequate to fully evaluate the transport and fate pathways associated with these sites. Given the absence of this information at many of these sites, further characterization may be needed if areas near these sites within the OU 3 study area are identified for remedial action.

7.2.3 Other Anthropogenic Sources

The primary release mechanisms of COCs from other anthropogenic sources include solid or liquid waste, fugitive and point emissions, and nonpoint releases. Liquid and solid materials may be released directly to soil. Solid materials may also be stockpiled and then affected by secondary transport mechanisms (e.g., wind transport as dust or surface water runoff). These release mechanisms will release the metals at concentrations relative to the type and content of the materials generated by a specific activity or through uses at residential properties or in agricultural areas. As described in the preceding sections for the other sources, once in soil, metals from other anthropogenic sources are subject to tertiary release mechanisms that may include wind transport of dust, entrainment of particulates and dissolved constituents in surface water runoff, or bioaccumulation. The metals will be influenced in similar ways by physical transport pathways, but chemical and biological transport pathways will differentially affect the metals. The fate of COCs from anthropogenic sources will be incorporated into soil, surface water, sediment, or biota.

The studies evaluated in the Upland RI were not designed to assess the specific locations or character of releases from other anthropogenic features or land uses within the OU 3 study area. Given the absence of this information, further characterization may be needed if areas identified for remedial action are thought to be influenced by these sources.

7.2.4 Geology and Geogenic Background

Releases from geologic materials (rock, overburden, and soil) will occur through physical and chemical weathering and erosion. COCs may be released from geologic materials at concentrations relative to their original content in the rocks. Physical weathering will influence the metals equally, while chemical weathering may affect the metals differently because different metals react differently to changes in temperature, pH, oxidation-reduction conditions, CEC, particle size, moisture content, and organic material. Once in soil, metals derived from geological materials will be subject to the secondary and tertiary release and transport mechanisms described above for other sources. COCs from geogenic sources will ultimately end up incorporated into soil, surface water, sediment, or biota comingled with metals from other sources.

The studies evaluated in the Upland RI were not designed to fully assess the specific locations or character of releases associated with geogenic sources within the OU 3 study area. Given the absence of this information, further characterization may be needed if areas identified for remedial action are thought to be influenced by these sources.

7.2.5 Ambient Atmospheric Sources

The removal of particulate metals from the atmosphere is governed by the rates of wet and dry deposition. Whereas larger coarse particles (i.e., greater than 10 μm) tend to rapidly fall out of the air and have short atmospheric lifetimes, the fine particles comprise ambient atmospheric air pollutants that have relatively lower dry deposition velocities and longer atmospheric lifetimes, which contribute to their persistence and uniformity throughout the atmosphere. Particulate metals that are deposited from the atmosphere can come to reside on the surface of vegetation, in leaf litter or other organic soil layers, and in the uppermost mineral soil layer (USEPA 2007b).

The studies evaluated in the Upland RI were not designed to fully assess transport and fate pathways associated with ambient atmospheric sources of COCs. Further characterization may be needed if areas identified for remedial action within the OU 3 study area are thought to be influenced by these sources.

8 UNCERTAINTY ASSESSMENT AND PROCESS FOR ASSESSING DATA GAPS

The nature and extent evaluations presented in Section 6 are mostly a post-hoc application of data that were collected for other purposes. In some cases, these data are not adequate to completely address the nature and extent questions or to definitively refine the physical/chemical CSM. As such, there is uncertainty associated with the evaluations presented herein. Additional data or analyses may be helpful in addressing these uncertainties if deemed necessary to risk management decision-making. This section summarizes the CSM elements that have significant uncertainties and discusses the process to address potential data gaps.

8.1 UNCERTAINTY AND DATA LIMITATIONS

In the RI/FS process, the RI serves to collect, compile, and analyze data and information necessary to assess risks to human health and the environment, to determine the nature and extent of impacts, and develop a CSM that is based on current Site conditions. The RI results are also used to design and conduct treatability testing to evaluate the potential performance and cost of the treatment technologies that may be considered. The FS is the mechanism for the development, screening, and detailed evaluation of response technologies and the development of remedial action alternatives. Uncertainties in the RI can affect confidence in its conclusions and lead to uncertainties in subsequent phases (such as treatability studies or the FS); however, the significance of these uncertainties depends on the RAOs developed for the project, the specific alternatives evaluated in the FS, and other risk management related topics. Subsequently, uncertainties related to Site characterization may or may not need to be addressed to complete the RI/FS.

As described in Sections 3 and 6, the soil data used in this Upland RI report were compiled from 30 studies conducted in and around the OU 3 study area. Some of these studies were part of the systematic planning process conducted specifically for the Site RI/FS, in accordance with the RI/FS Work Plan (USEPA 2008a) and pursuant to the Agreement (USEPA 2006), but many were not. Although data from these studies were determined to be adequate for use in the RI (albeit not all studies could be used for all analyses), much of the data were not specifically collected for use in answering questions related to source characterization, nature and extent, and the transport and fate of contaminants, which may have limitations that introduce uncertainty.

The following subsections provide a summary of OU 3 physical/chemical CSM uncertainties that are grouped into the following four categories: 1) nature and extent, 2) transport pathways, 3) human health risk, and 4) ecological risk.

8.1.1 Nature and Extent

Uncertainties and data limitations are described below for nature and extent:

- Substantial differences in soil metals concentrations between some studies in Canada and the U.S. introduce uncertainty in evaluating COC concentration trends across the U.S.-Canada border in the GAM.
    - Several of the analyses completed for the Upland RI report rely on data sets that combine samples collected in Canada with samples collected in the U.S.; however, concentrations of some metals are substantially different between studies conducted in Canada and the U.S., and this is most evident for soil samples located near the U.S.-Canada border. Review of the available data does not indicate that the methodological differences completely account for the differences observed between data collected in Canada compared to data collected in the U.S.
- Variability in soil metals concentrations introduces uncertainty in large-scale modeling and mapping of COC concentrations.
    - Maps of cadmium, lead, and zinc distributions in the OU 3 study area generated using a geostatistical model that predicted soil concentrations across unsampled areas show a relatively high degree of uncertainty in some locations. The uncertainty was estimated by subtracting the P10 from the P90 of the 100 simulated values for each grid cell in the model (Map 6-8, Map 6-11, and Map 6-14). The analysis shows considerable uncertainty associated with modeled concentrations based on both the spatial correlation exhibited by the sample data and the underlying sample data distributions. The spatial correlation is expressed as the nugget of the correlogram, and the relative nuggets for cadmium, lead, and zinc range from 0.4 for zinc to 0.55 for lead. This magnitude of nuggets indicated that about half (50 percent) of the variability in soil metals concentrations is accounted for in samples collected at the same location. Given this degree of variability in soil metals concentrations, it may not be possible to reduce prediction uncertainty through the collection of samples within areas with no samples or low sample density. This uncertainty should be considered carefully when using modeled concentration maps for RI/FS decision-making purposes.
- Highly variable vertical distributions of COCs in soil and a lack of vertical data in higher elevations create challenges in characterizing vertical extent.
    - Surface soil concentrations of cadmium, lead, and zinc were generally greater than their BTVs and decreased with depth; however, vertical concentration gradients are

highly variable within small areas for these COCs. Arsenic, barium, copper, manganese, and selenium either did not consistently show enrichment in surface soil concentrations or did not show declining concentration trends with depth. Limited data were available for evaluating the vertical trends for mercury, but where data were available, mercury concentrations in surface soil tended to be below the mercury BTV.

  - Most of the data available for evaluating the vertical nature and extent of these metals are from samples located at lower elevations along the river valley and associated with residential properties. The available data, therefore, do not provide adequate representation of higher-elevation areas (i.e., greater than 2,700 ft amsl) to support an evaluation of how the vertical extent of metals varies with elevation. The uncertainty in the vertical extent of COCs should be considered prior to using these data to estimate upland soil volumes to be carried forward into the FS.

- The Upland RI data set is not adequate to explain high small-scale variability.
  - There is high small-scale variability in the concentrations of cadmium, lead, and zinc in soil; however, the current data set is insufficient to discern the causes of this small-scale heterogeneity. This uncertainty should be considered prior to using these data to estimate the volumes of upland soil in areas identified for remedial action. Small-scale variability was not quantitively assessed for the other COCs (arsenic, barium, copper, manganese, mercury, or selenium) due to insufficient data.
- The current data used to develop the geostatistical model are not sufficient to produce a model that predicts locations where soil concentrations of cadmium, lead, and zinc are below their respective BTV in the OU 3 study area.
  - The geostatistically modeled soil concentration maps provide estimates of cadmium, lead, and zinc concentrations in soil in areas with no samples or low sample densities (Map 6-7, Map 6-10, and Map 6-13). The spatial extent and coverage of these maps, which use a 2.5-km buffer around sample locations, are greater than the post maps. The model extent does not reach a sufficient distance to consistently estimate where soil concentrations are expected to decrease to their respective BTV, and extrapolation beyond the 2.5-km buffer is not supported by the data, as described in Section 6.2.4 and Appendix G.
  - Although the uncertainty in the geostatistically modeled soil concentrations should be carefully considered if used for cleanup decision-making, this uncertainty is not expected to significantly affect FS remedy evaluations as long as the final PRGs and/or cleanup levels are above the BTVs.

- The data from the 2004 EPA Le Roi Smelter Removal Action Study (USEPA 2004) and the 2014 and 2016 Residential Soil Studies (USEPA 2014, 2016a) represent pre-removal data. Multiple properties sampled during these studies were remediated during the 2005 EPA Le Roi Smelter Removal Action (USEPA 2005), 2015 TCRA (USEPA 2015c), and 2017–2018 VRA (Appendix B); therefore, data from these locations do not represent current conditions. These data sets are relevant for assessing the nature and extent of COC concentrations in soil in the surrounding areas that were not addressed as part of a removal action (e.g., to support the geostatistical modeling); however, this limitation should be understood and considered when using the modeled maps of COC distribution in the OU 3 study area to estimate upland soil volumes to be carried forward into the FS.

8.1.2 Transport Pathways

The data limitations and recommendations related to transport pathways are described below:

- A lack of data creates uncertainty in characterizing migration of COCs from soil to sediment.
  - The physical/chemical CSM includes a soil-to-sediment COC migration pathway via surface water runoff, but there are currently no data available to characterize this transport mechanism.
- Inadequate data exist to characterize migration of COCs from mineralized bedrock to soil.
  - The CSM included a COC migration pathway via the weathering of mineralized bedrock to general soil parent material. The current data set is not adequate to characterize the mineralogy of the parent material and evaluate how its composition is related to the local and regional bedrock; therefore, this pathway could not be assessed further in the CSM presented in the Upland RI.

8.1.3 Human Health Risk

Selected key uncertainties impacting the HHRA results most relevant to the Upland RI are summarized below:

- Uncertainties associated with IEUBK model inputs affect the derivation of lead risk benchmarks.
  - The default assumptions for two inputs to the IEUBK model, the MSD and the dietary lead intakes, have been shown to be much higher than those supported by

the most recent peer-reviewed literature (these studies are noted in Section 5.1.6). The HHRA mentions the uncertainties associated with the two inputs but does not quantify the impact on the lead risk results, which could be substantial and may ultimately affect the PRGs if the default values are updated.

- Uncertainty associated with the thallium toxicity value likely overestimates risk to human health from thallium.
    - Thallium is a primary contributor to non-cancer risks above risk benchmarks in the HHRA; however, there is significant uncertainty associated with the toxicity value for thallium. EPA has determined that thallium does not have adequate toxicity data to support derivation of a reliable RfD. The HHRA uses a screening p-RfD with a 3,000-fold uncertainty factor to quantify thallium risks. The HHRA states that use of the screening p-RfD makes it likely that thallium risks are overestimated.
- Uncertainty regarding lead background concentrations impacts the interpretation of the P3 lead risk benchmark.
    - The HHRA recognizes that many of the COPCs identified in the HHRA may be influenced by geogenic or anthropogenic sources. Of most relevance to the characterization of risks in this Upland RI report is the HHRA's assessment of soil lead background on the interpretation of the lead risk benchmarks. As stated in the HHRA "…consideration of background soil lead concentration at the Site is unlikely to influence results based on using the P5 or P8 risk benchmark. Because the Site background soil lead concentration (35 ppm) is close to the P3 soil lead PRG (50 ppm) consideration of background may be important for risk management for that PbB [blood lead level] target."

8.1.4 Ecological Risk

The Upland BERA (USEPA 2023a) included an uncertainty analysis for the risk assessment.

8.2 PROCESS FOR ADDRESSING DATA GAPS

As described in Section 7, development of a CSM is an iterative, dynamic process that creates an integrated assessment of the nature and extent and transport and fate of contaminants that helps project teams and stakeholders use the available information to support technical and regulatory decisions. In this iterative approach, data gaps that drive high levels of uncertainty in the physical/chemical CSM will be identified and addressed, if necessary, throughout the FS, proposed plan, ROD, and remedial design/remedial action stages of the project. The

uncertainties discussed in the previous subsection will be reassessed as the required tasks set forth in the Agreement are completed and as key decisions and project milestones are reached. These periodic reassessments will identify the elements of the CSM with unacceptable uncertainty and may lead to the identification of data gaps to be addressed during additional phases of Site investigation, remedy evaluation, and/or remedy design and implementation.

Decision-making steps completed by regulators and stakeholders will also provide key information to identify unacceptable uncertainty from significant data gaps and help determine which data gaps need to be addressed.[114] For example, the need for refinement of the physical/chemical CSM may not become apparent until the evaluation of remedial alternatives in the FS when the range of general response options is developed based on the RI Site characterization. This is often an iterative process where the results of each step influence the others (USEPA 1997c). For example, the resolution of COC delineation is often dependent on specific response alternatives, whereby a detailed fine-scale mapping of the extent of COCs may not be necessary to evaluate a monitored natural recovery remedy, although it is for a removal remedy.

The following points summarize how uncertainties might be considered and integrated into future stages of the RI/FS process:

- The COCs will be used to finalize RAOs and PRGs to estimate the volume of media that must be addressed in the FS and to fully characterize Site-specific geochemical characteristics of COCs that may need to be considered as part of the remedial technology screening and alternative selection (e.g., pH/reduction-oxidation transformations and reactions that may drive phase changes and control transport and exposures).
- An assessment of data necessary to characterize significant sources of COCs and potential migration pathways is often necessary to understand the effectiveness and permanence of remedial actions; therefore, once the general response actions and locations are better defined, the need for additional OU 3 source delineation information to reduce the uncertainty of specific elements of the CSM may be assessed. If a data gap is identified, additional characterization may be required prior to conducting the FS.
- An estimate of the volume of impacted media (i.e., the areal and vertical extent of all COCs) is fundamental for the FS. The information needed to develop an estimate of the

[114] EPA believes that data gaps may exist for upland lakes/wetlands, characterization of upland COCs related to human health risk, and sampling and analysis to support delineation of ecological COCs and the development of ecological PRGs (USEPA 2024d).

volume of impacted media, with appropriate accuracy, includes both the RAOs and PRGs; however, as described above, the degree of resolution of COC impacts is often dependent on the specific general response actions selected for evaluation in the FS, specifically if the development of a conceptual design alternative and the cost and effectiveness of implementation is strongly dependent on the volume of COC-impacted media. Subsequently, refinement of the CSM may be necessary prior to conducting the FS to reduce uncertainty in the estimate of the volume of impacted media.

- Iterative improvement of the CSM may be needed through the collection of remedial action-specific data (e.g., bench and pilot treatability testing) necessary to reduce Site-specific uncertainty associated with remedy design and implementation. This CSM refinement step is often done during multiple stages of the FS and continues into the preliminary remedial action design stage of the project.
- Preliminary applicable or relevant and appropriate requirements (ARARs) were prepared by EPA and presented in the RI/FS Work Plan (USEPA 2008a). These include tribal environmental standards potentially applicable or relevant and appropriate to the Site based on available information about Site conditions and contaminants. The preliminary ARARs will be revised as the RI/FS process proceeds and additional Site information becomes available, specifically related to the volume of impacted media and the location(s) of proposed remedial actions. The ARAR revision process is often iterative where the consideration of additional ARARs is dependent on the type and scale of proposed remedial actions and vice-versa so that each alternative can be evaluated for compliance with the substantive requirements of each ARAR.
- Identification of general response actions is the first step in the FS process and provides a screening to evaluate technologies applicable to each general response action to eliminate those that cannot be implemented at the Site and to narrow the scope of actions that will be assembled into detailed remedial alternatives to be evaluated in the FS. An understanding of the general response actions is necessary to evaluate the importance of uncertainties in the CSM and to identify potential data gaps that may need to be addressed to assemble specific remedial alternatives and complete the FS evaluation.
- Information needed to develop a preliminary design CSM necessary for the development of remedial alternative conceptual designs for the FS may identify data gaps that should be addressed to evaluate the Site-specific applicability of remedial alternative technologies, such as bench-scale treatability studies and field-scale pilot

tests, to better estimate performance capabilities and costs of specific remedial technologies in the FS.

- After selection of the remedial alternatives to be included in the FS evaluation, the principal factor to consider is how quickly RAOs must be achieved and whether the remedial alternatives can achieve them. Estimation of this factor will have a significant impact on the remedy selected as well as the cost of that remedy. Data collected from bench-scale treatability studies and field-scale pilot tests and/or modeling may be used to develop a sufficiently accurate remediation timeframe, but data gaps may become apparent and require additional refinement of the OU 3 CSM.

In summary, the uncertainties in the RI should be reviewed in the context of FS information needs to assess whether there are significant data gaps for identifying and evaluating the remedial alternatives that can successfully be implemented at the Site.

9 UPLAND RI CONCLUSIONS

This Upland RI report provides a robust characterization of the OU 3 study area at the UCR Site and has refined the physical/chemical CSM to the stage whereby the CSM can support the FS evaluation of potential remedial actions for the OU 3 study area. This section summarizes the Upland RI conclusions regarding the risk to human health and the environment, the nature and extent of COCs in the OU 3 study area, and the physical/chemical CSM.

Arsenic and lead are identified as human health COCs and arsenic, barium, cadmium, copper, lead, manganese, mercury, selenium, and zinc are identified as ecological COCs. Based on the evaluations and analyses presented in this Upland RI report, historical smelter emissions from the Trail Facility and Le Roi/Northport Smelter are a source of the COCs posing risks to human and ecological receptors in the OU 3 study area. Historical mines and mineral processing facilities and other anthropogenic, ambient atmospheric, and geogenic sources may also contribute to elevated concentrations of metals. Of these sources, smelter operations and ambient atmospheric constituents have the potential for regional impacts across the OU 3 study area, while historical mining operations and mineral processing facilities, other anthropogenic sources, and geology and geogenic background are more likely to have relatively localized impacts; however, the non-smelter-related sources have not been well characterized, nor have additional analyses that address the sources been included in the Upland RI. Given the absence of this information, further characterization may be needed if areas identified for remedial action are thought to be influenced by non-smelter-related sources.

Concentrations of COCs in surface soil are above BTVs in many sample locations, with cadmium, lead, and zinc exceeding their respective BTVs throughout the OU 3 study area. Overall, the relationships and patterns identified in the nature and extent evaluations for cadmium, lead, and zinc (and to a lesser extent arsenic, copper, and mercury because most sample locations for these three COCs have concentrations less than their respective BTVs) are consistent with transport and deposition from historical aerial emissions (both stack and fugitive) from smelter operations at the Trail Facility and Le Roi/Northport Smelter. Concentrations of the COCs correlated with smelter emissions show considerable spatial variation across the OU 3 study area but are generally highest at low elevations along the UCR valley between the U.S.-Canada border and Northport, at higher elevations in the upland areas on both sides of the river valley immediately south of the U.S.-Canada border, and in the vicinity of Northport. Concentrations of these COCs generally decrease with distance southward along the river valley and with increasing elevation and lateral distance away from the river in both directions (east and west).

Several physical, chemical, and biological transport and fate mechanisms influence the distribution of COCs in the OU 3 study area. COCs are transported by atmospheric suspension and deposition of COC-bearing particulates through wind dispersion (i.e., sorbed to airborne soil particles or other particulate matter) or in biological matrices (i.e., bioaccumulated in terrestrial organisms). The forms (species) and phases in which the COCs occur influence their transport, fate, and bioavailability. The form of each COC depends on its chemical properties and local environmental conditions, and the movement of COCs through the environment occurs via primary, secondary, and tertiary release mechanisms. The primary release mechanism is the direct discharge of metals from sources to environmental media. Once released to the environment, COCs present in environmental media (i.e., air, dust, and soil) are distributed through secondary and tertiary release mechanisms, such as suspension and wind dispersion, adsorption/desorption (i.e., attachment or detachment of metals to soil particles), and physical processes like decrepitation/weathering/erosion (i.e., the wasting or breaking up of particles resulting in metal releases).

The results of the Upland RI for the OU 3 study area will be used in the Upland FS to develop and/or refine RAOs and PRGs and to support the evaluation of potential remedies. The information presented in this Upland RI report will be used as a starting point to identify specific locations within OU 3 that may require remediation to achieve the RAOs and PRGs. The physical/chemical CSM presented herein will be used to develop preliminary soil volume estimates for the development and evaluation of potential remedial action alternatives in the Upland FS. Depending on the remedy selected by EPA, additional data may be needed to reduce uncertainty in the volume estimates before the remedial action is implemented.

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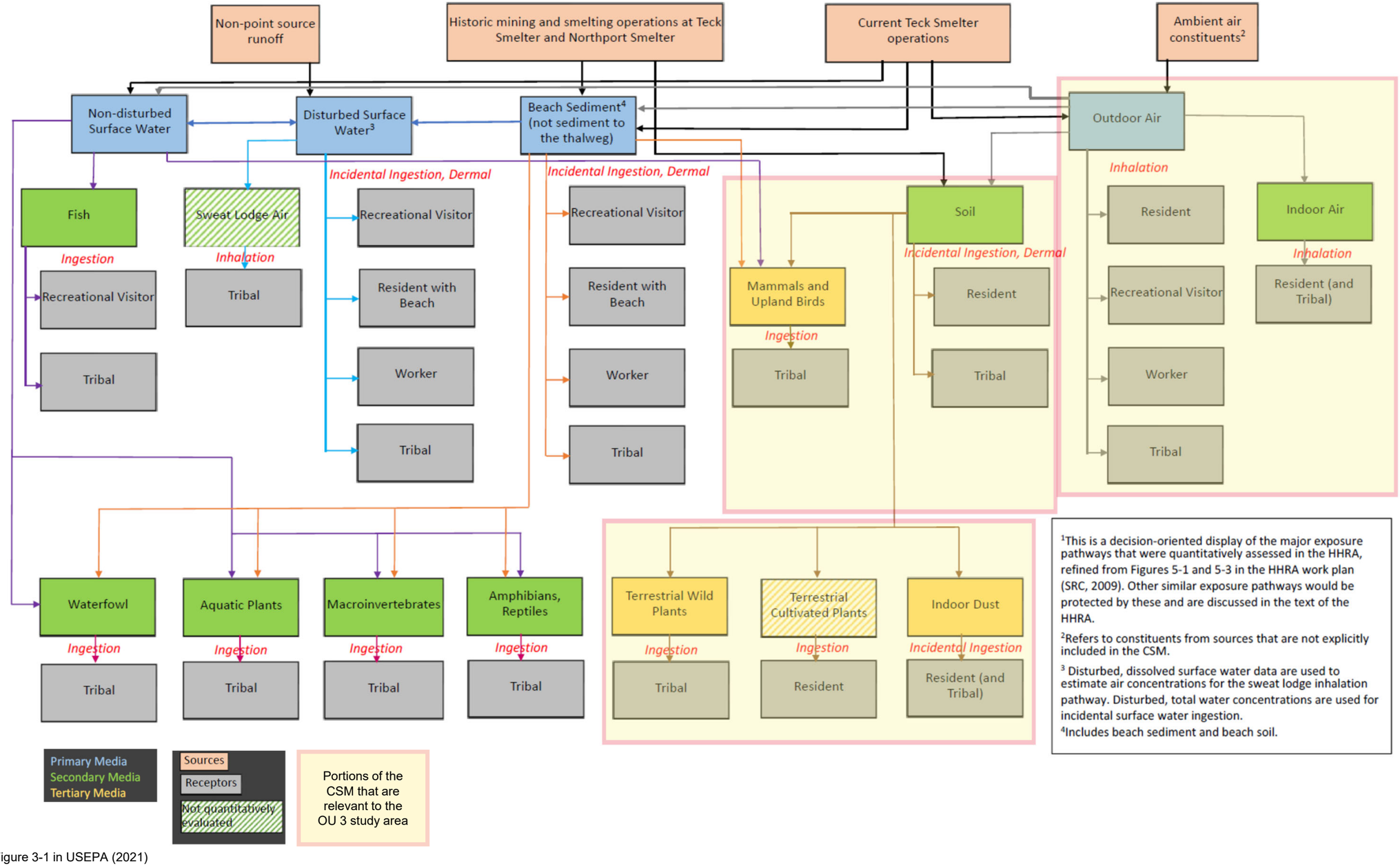
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FIGURES



Source: Figure 3-1 in USEPA (2021)

Figure 5-1. Portions of the HHRA CSM Relevant to the Upland RI

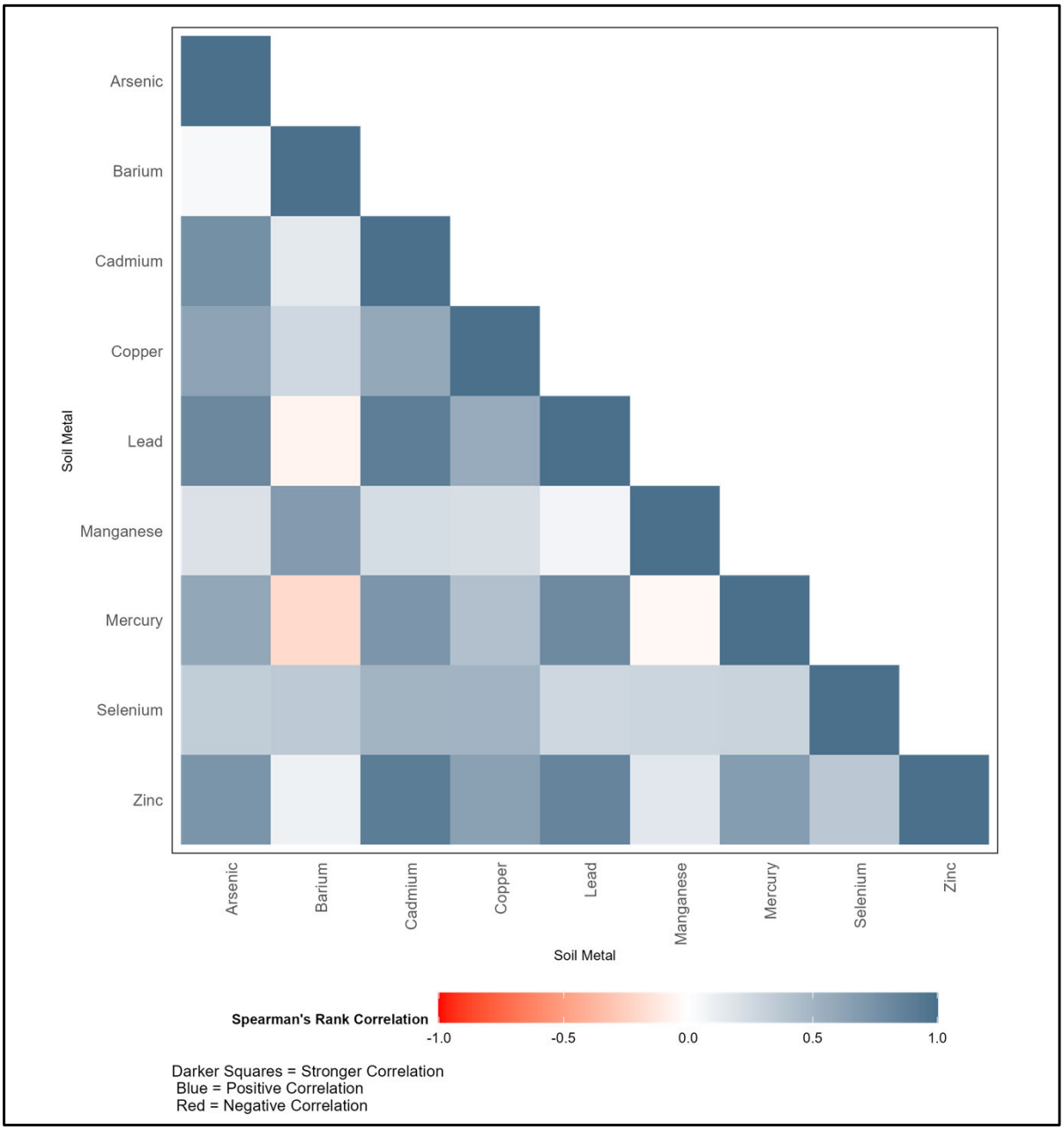


Figure 6-1. Spearman's Rank Correlation Coefficients of COC Soil Metals Concentrations for Detected Concentrations Only

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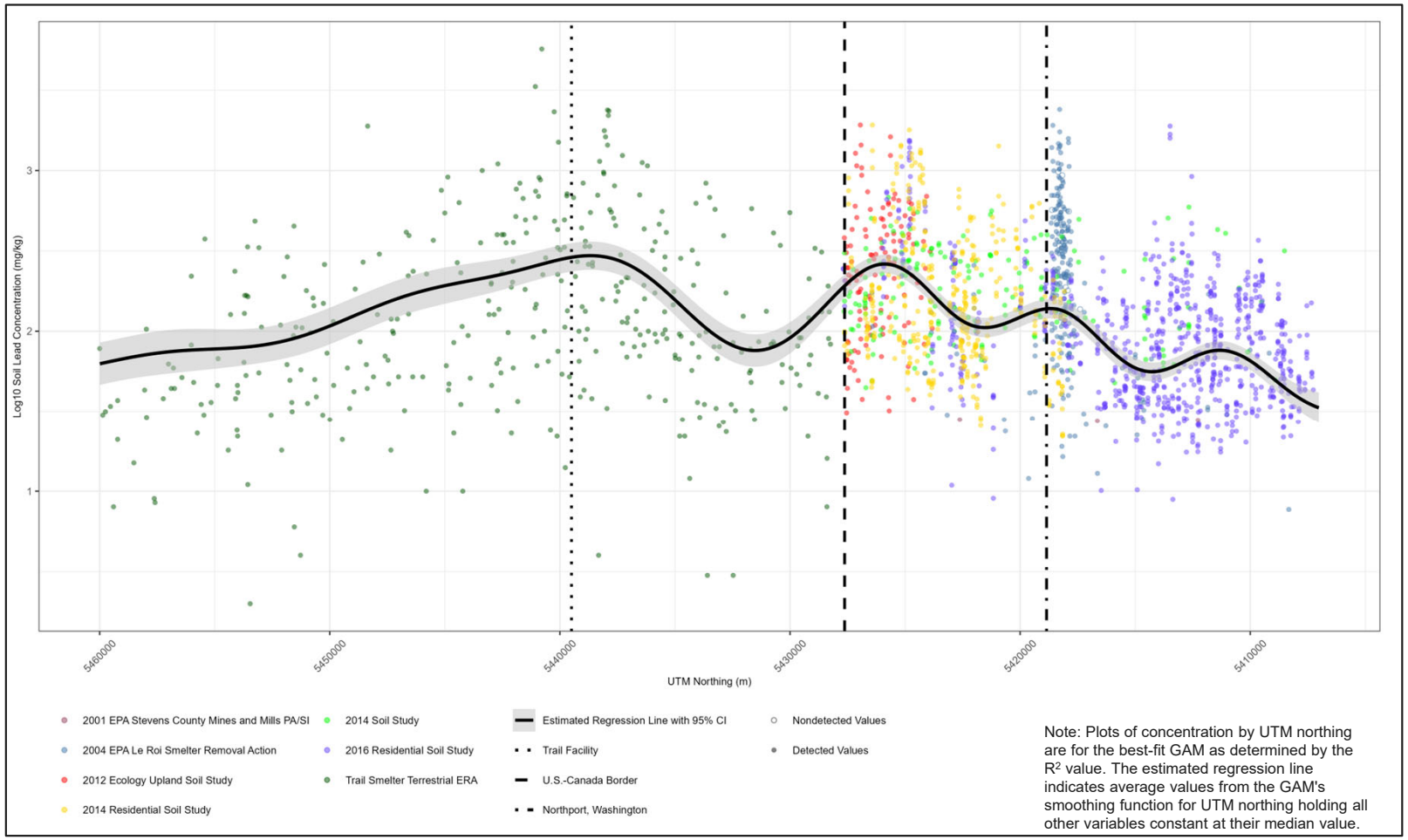


Figure 6-2a. Soil Lead Concentrations versus Distance from the Trail Facility
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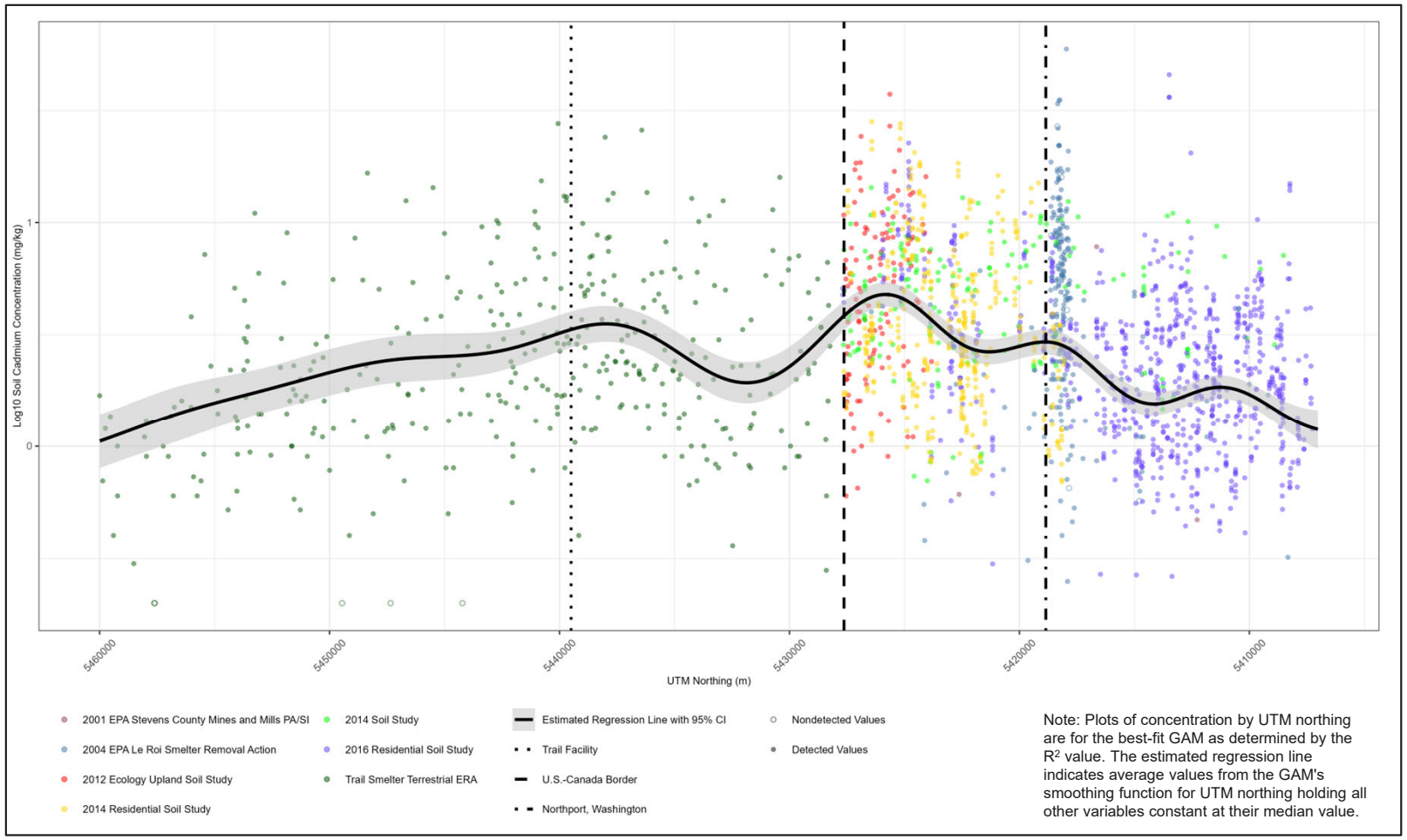


Figure 6-2b. Soil Cadmium Concentrations versus Distance from the Trail Facility

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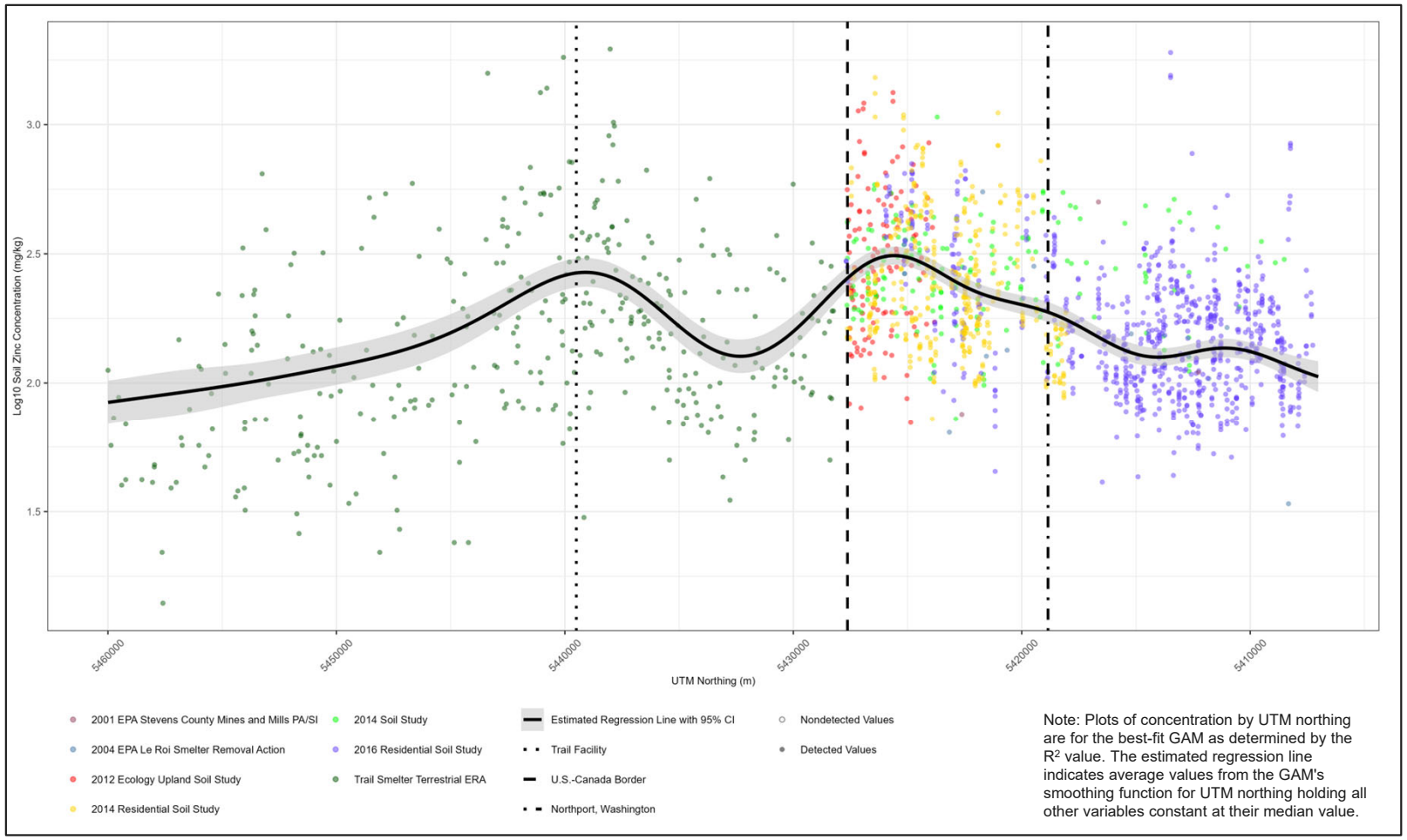


Figure 6-2c. Soil Zinc Concentrations versus Distance from the Trail Facility

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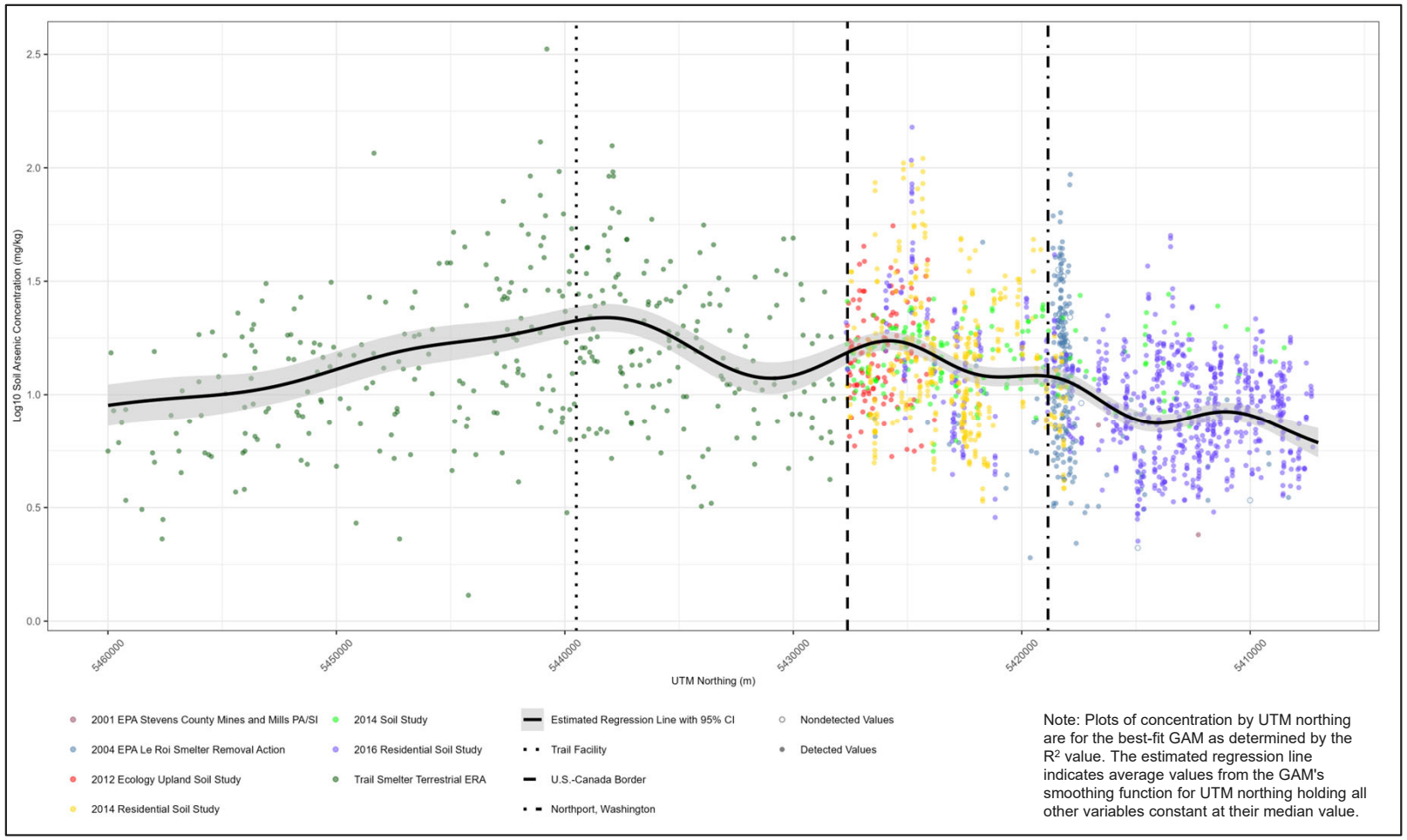


Figure 6-2d. Soil Arsenic Concentrations versus Distance from the Trail Facility

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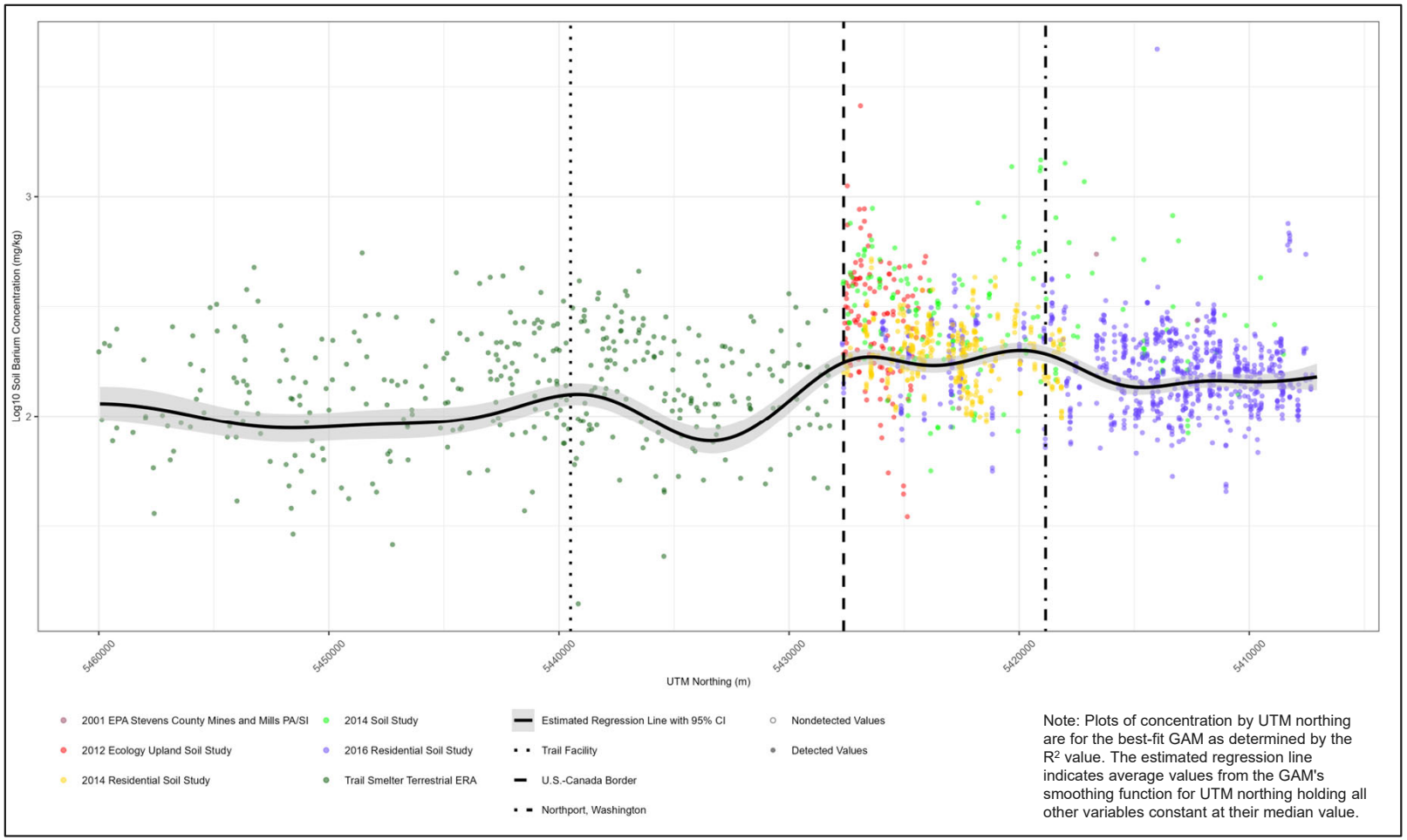


Figure 6-2e. Soil Barium Concentrations versus Distance from the Trail Facility
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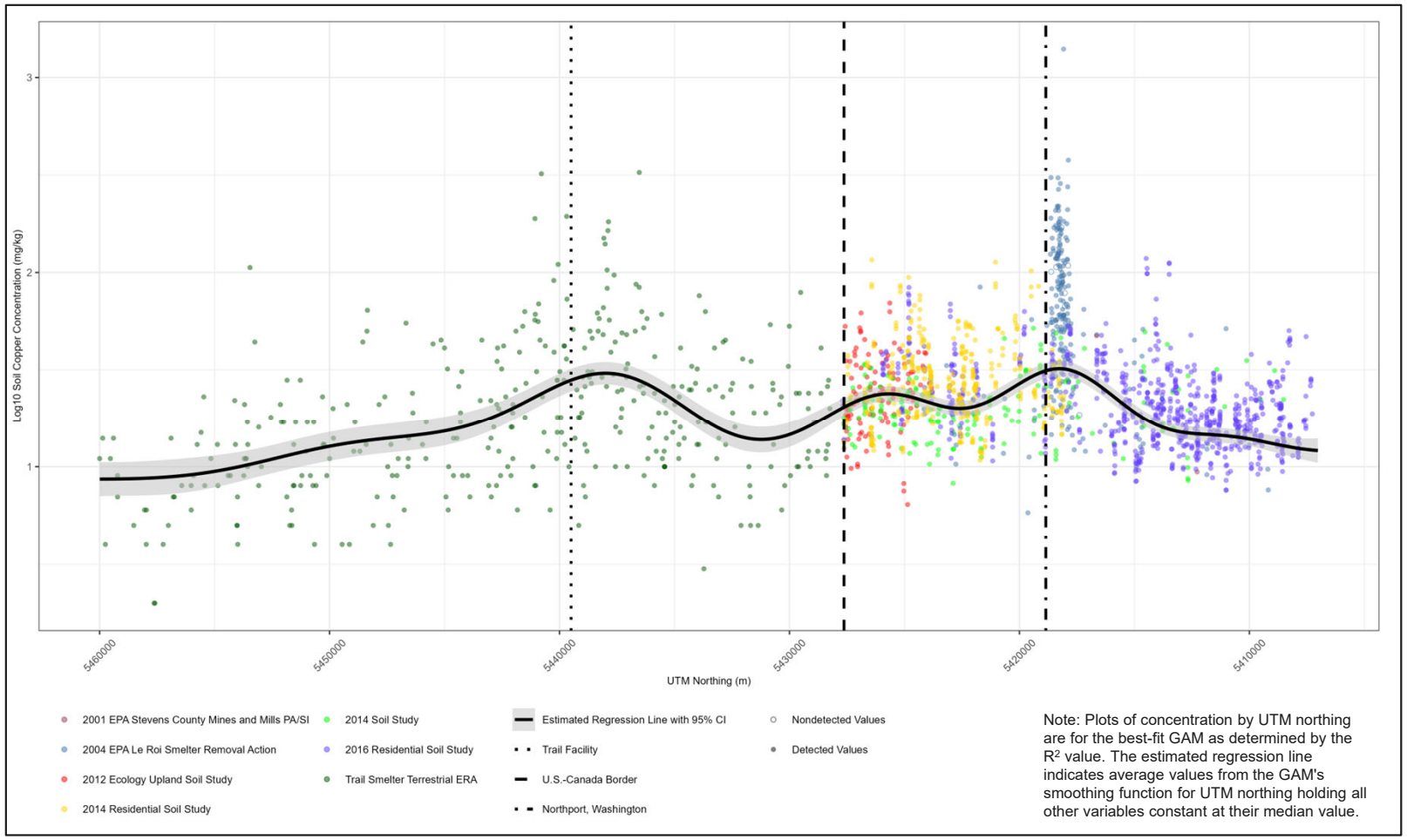


Figure 6-2f. Soil Copper Concentrations versus Distance from the Trail Facility
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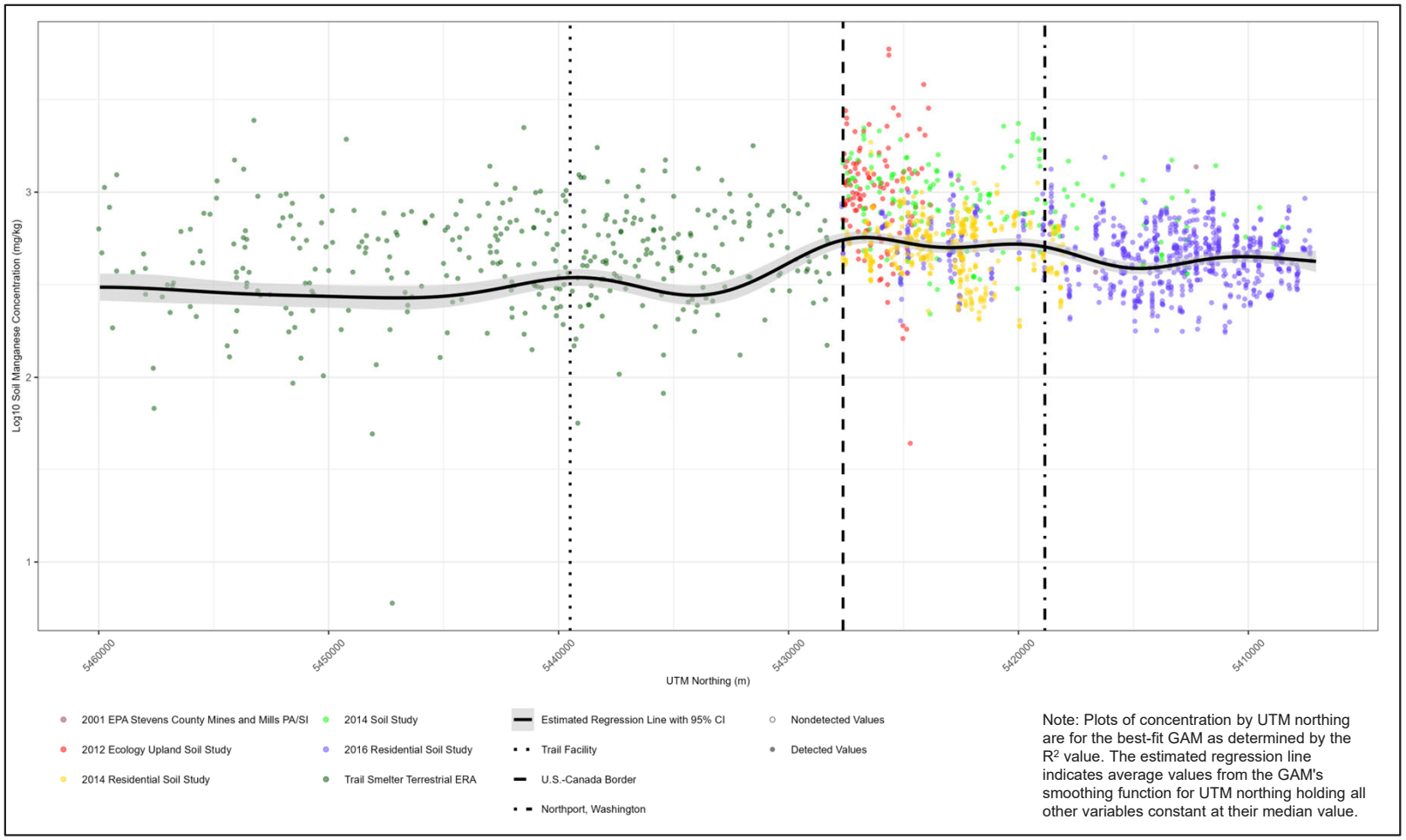


Figure 6-2g. Soil Manganese Concentrations versus Distance from the Trail Facility

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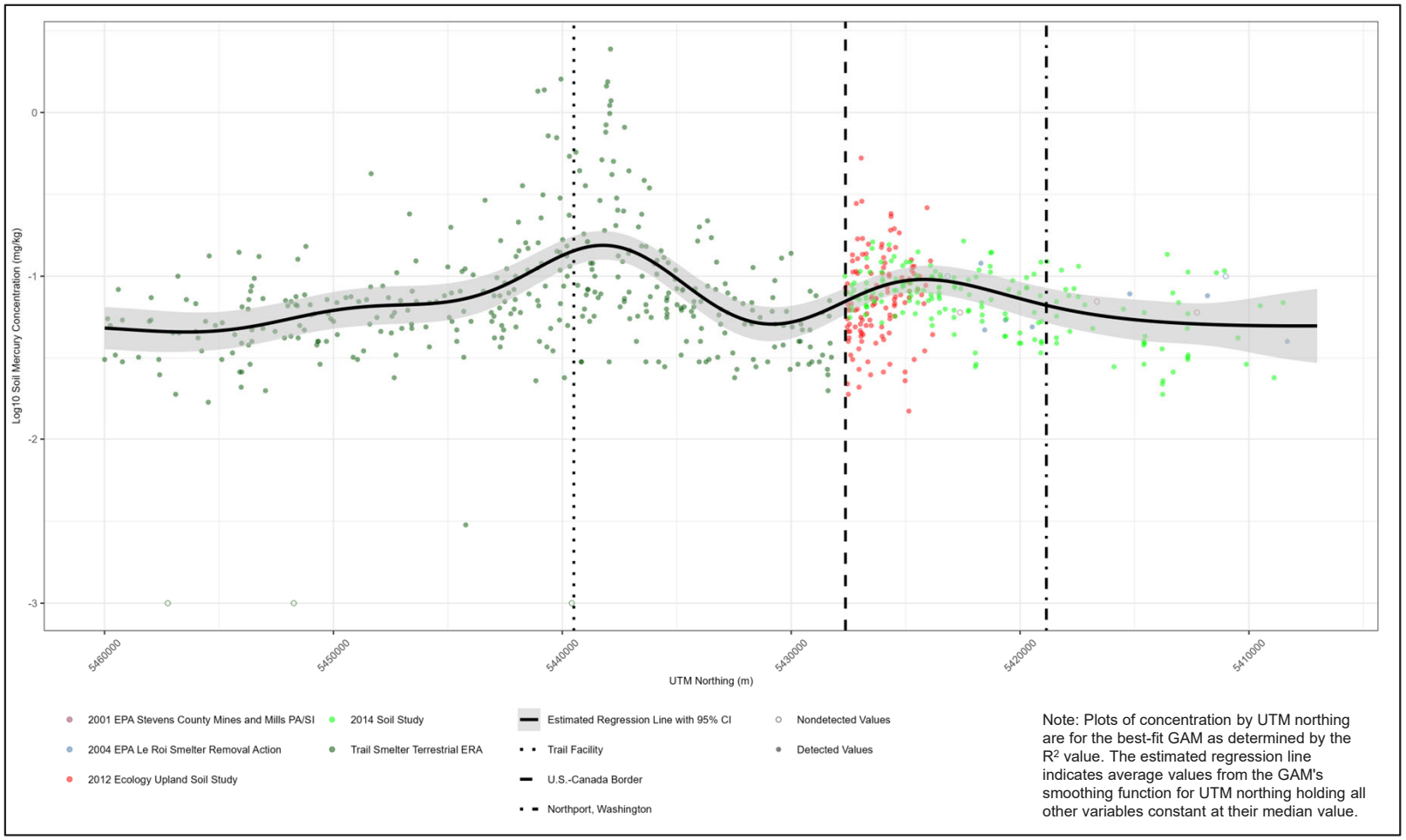


Figure 6-2h. Soil Mercury Concentrations versus Distance from the Trail Facility
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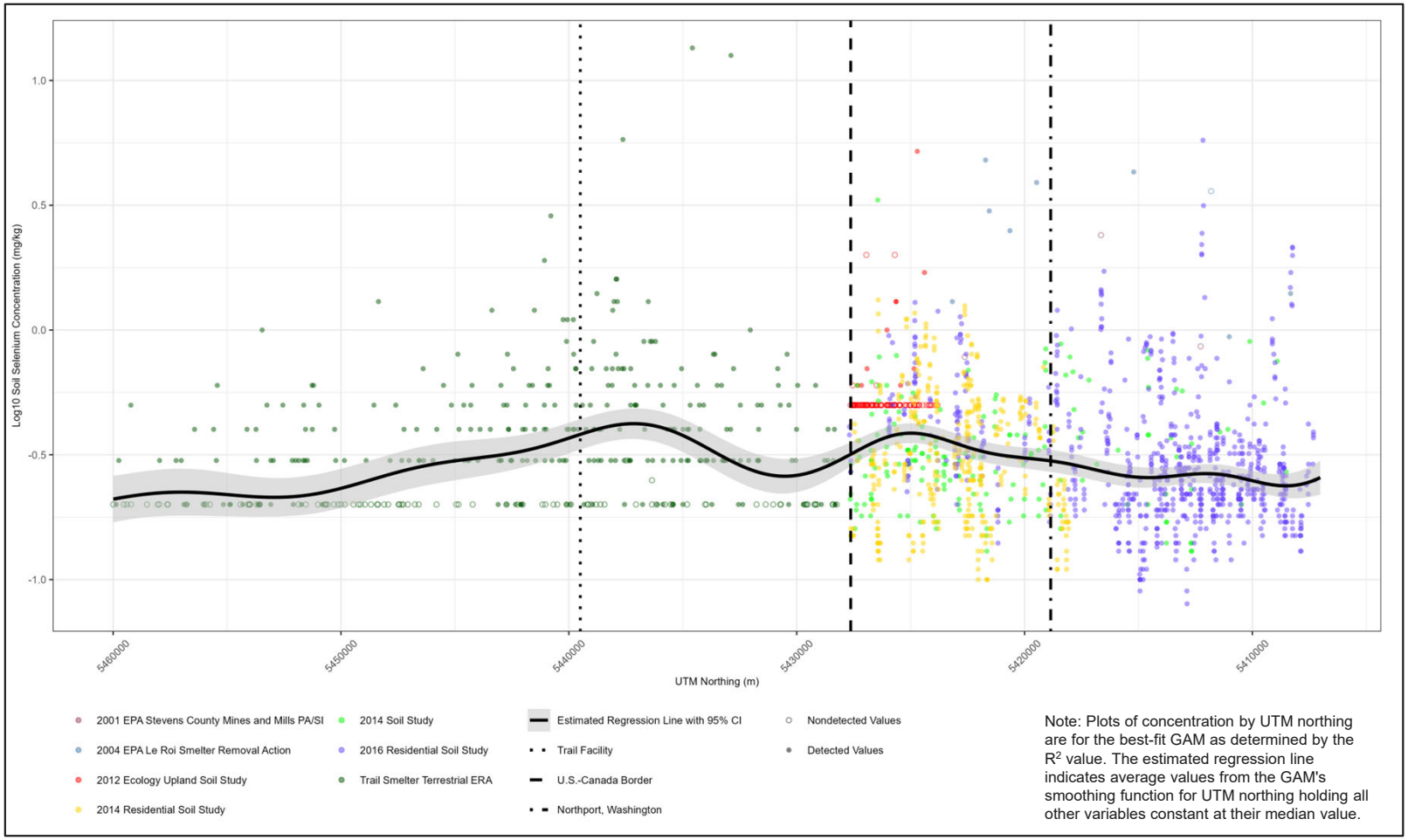


Figure 6-2i. Soil Selenium Concentrations versus Distance from the Trail Facility
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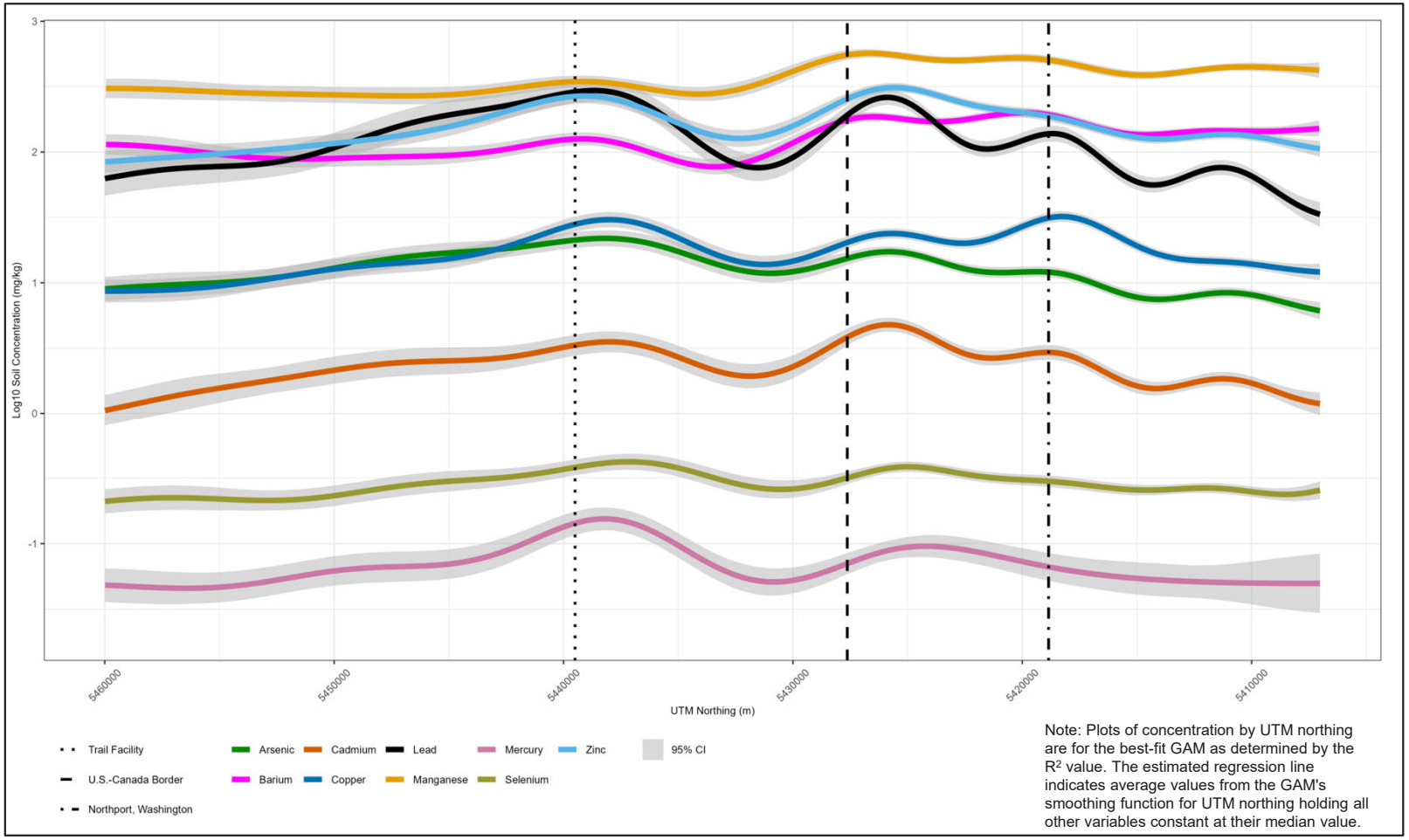


Figure 6-3. Soil COC Concentrations versus Distance from the Trail Facility

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Figure 6-4a. Soil Lead Concentrations versus Elevation
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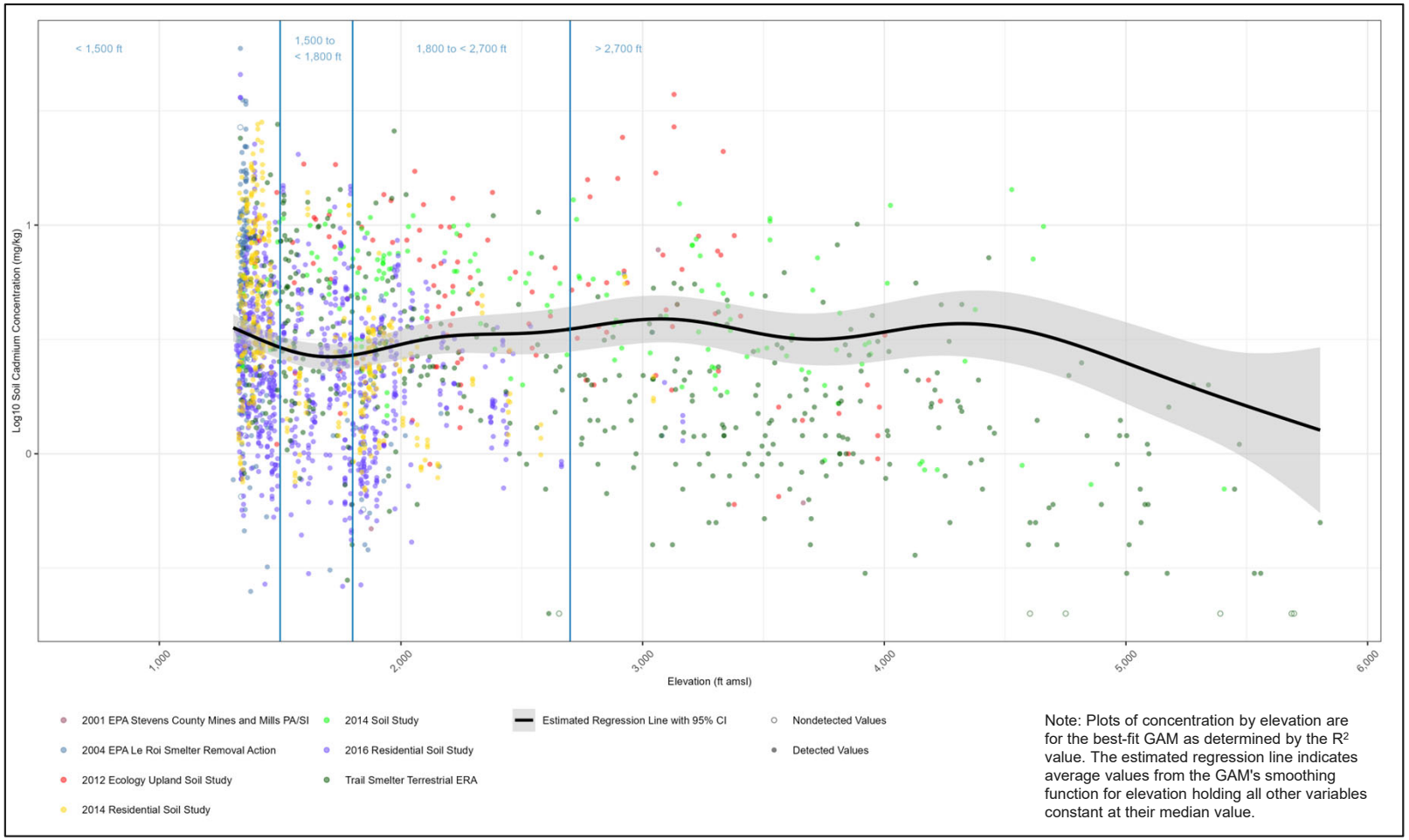


Figure 6-4b. Soil Cadmium Concentrations versus Elevation
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Upper Columbia River, Washington

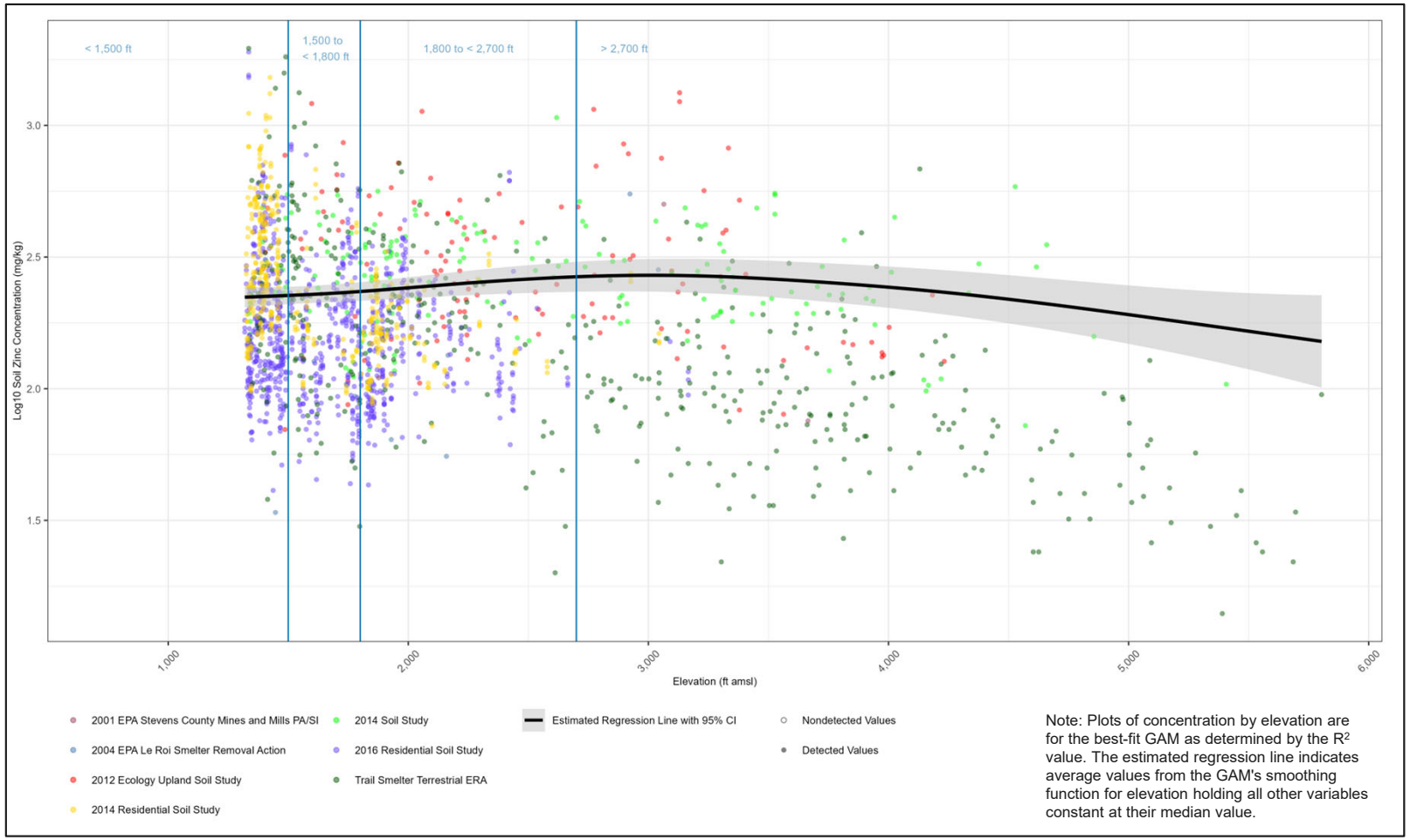


Figure 6-4c. Soil Zinc Concentrations versus Elevation

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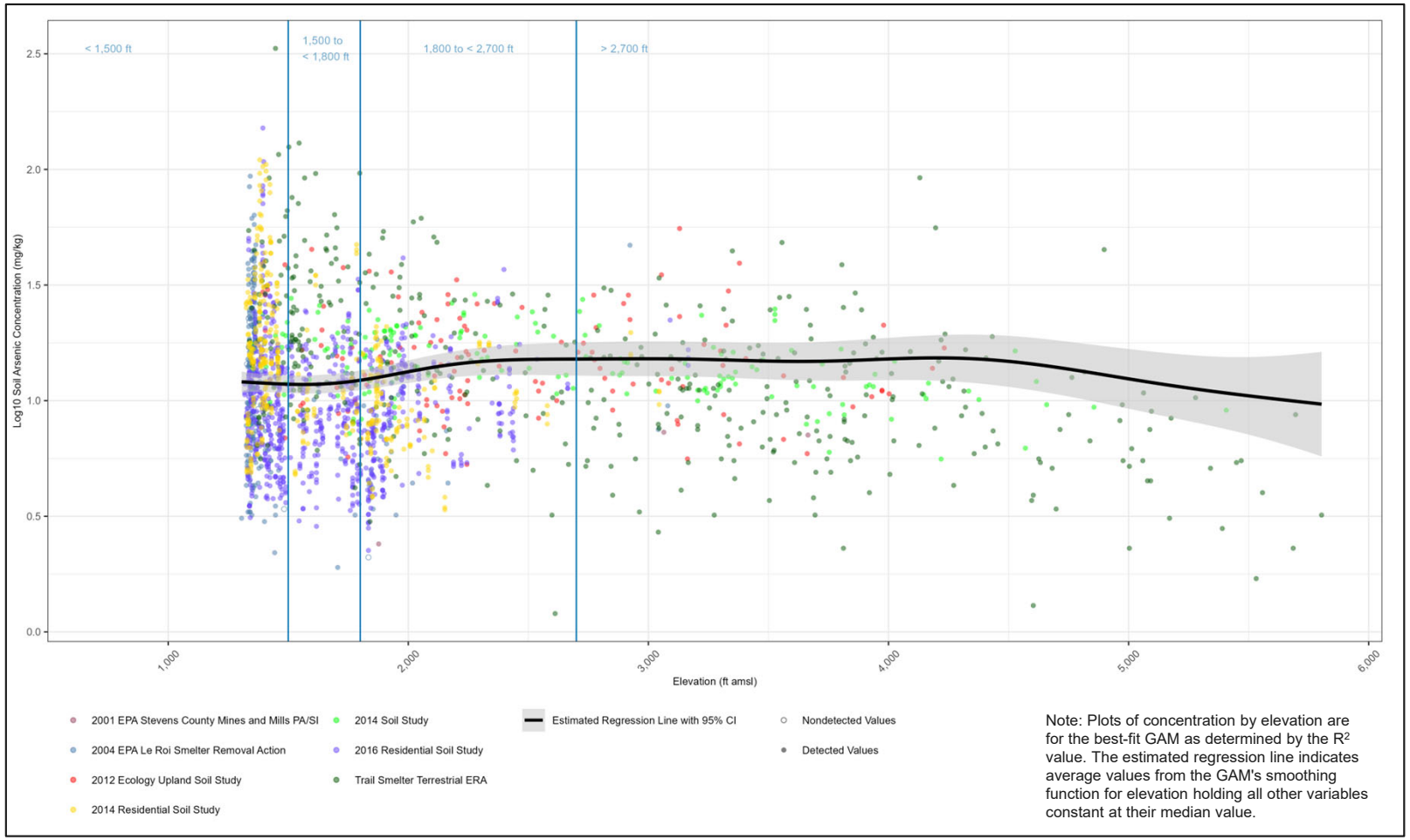


Figure 6-4d. Soil Arsenic Concentrations versus Elevation
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Upper Columbia River, Washington

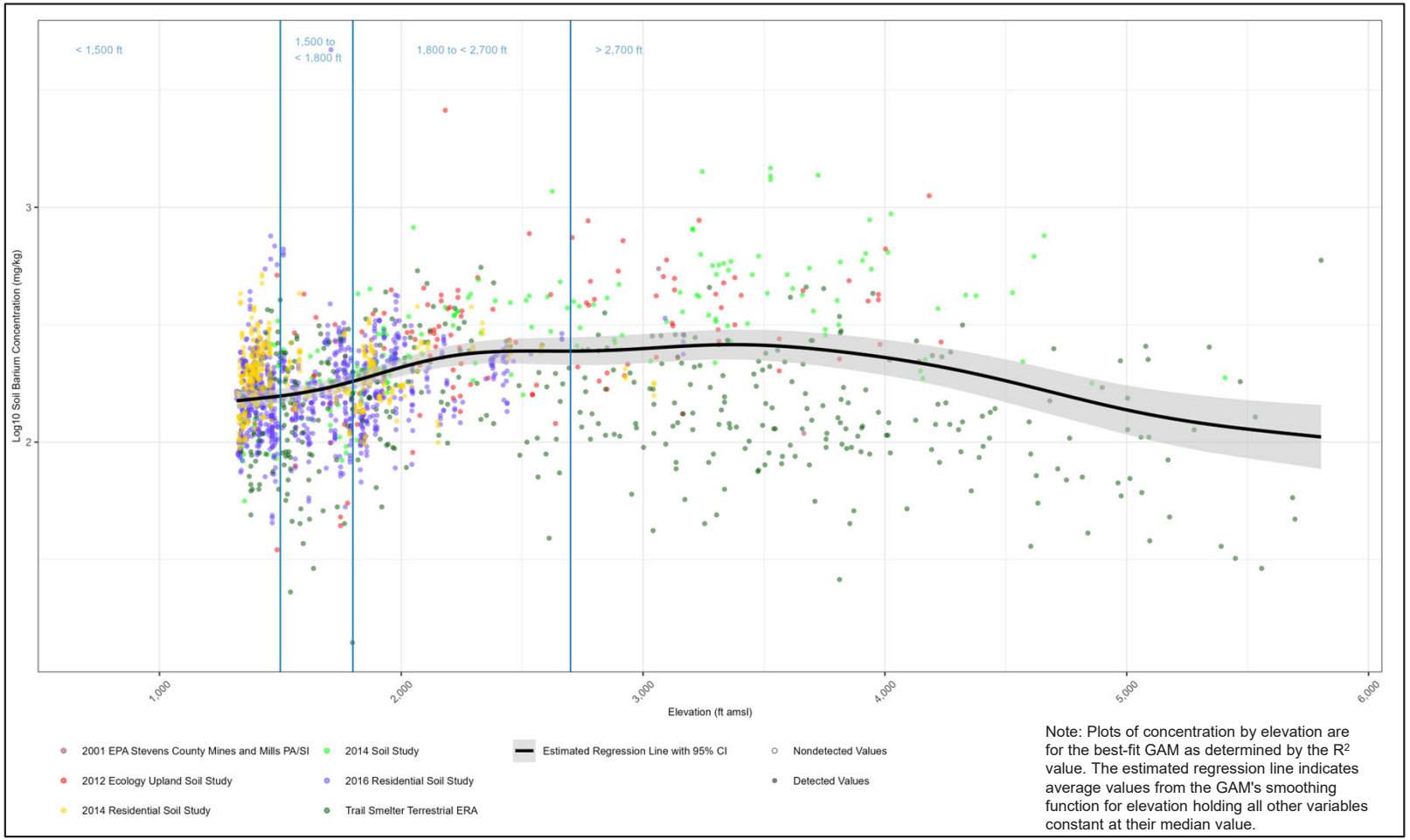


Figure 6-4e. Soil Barium Concentrations versus Elevation
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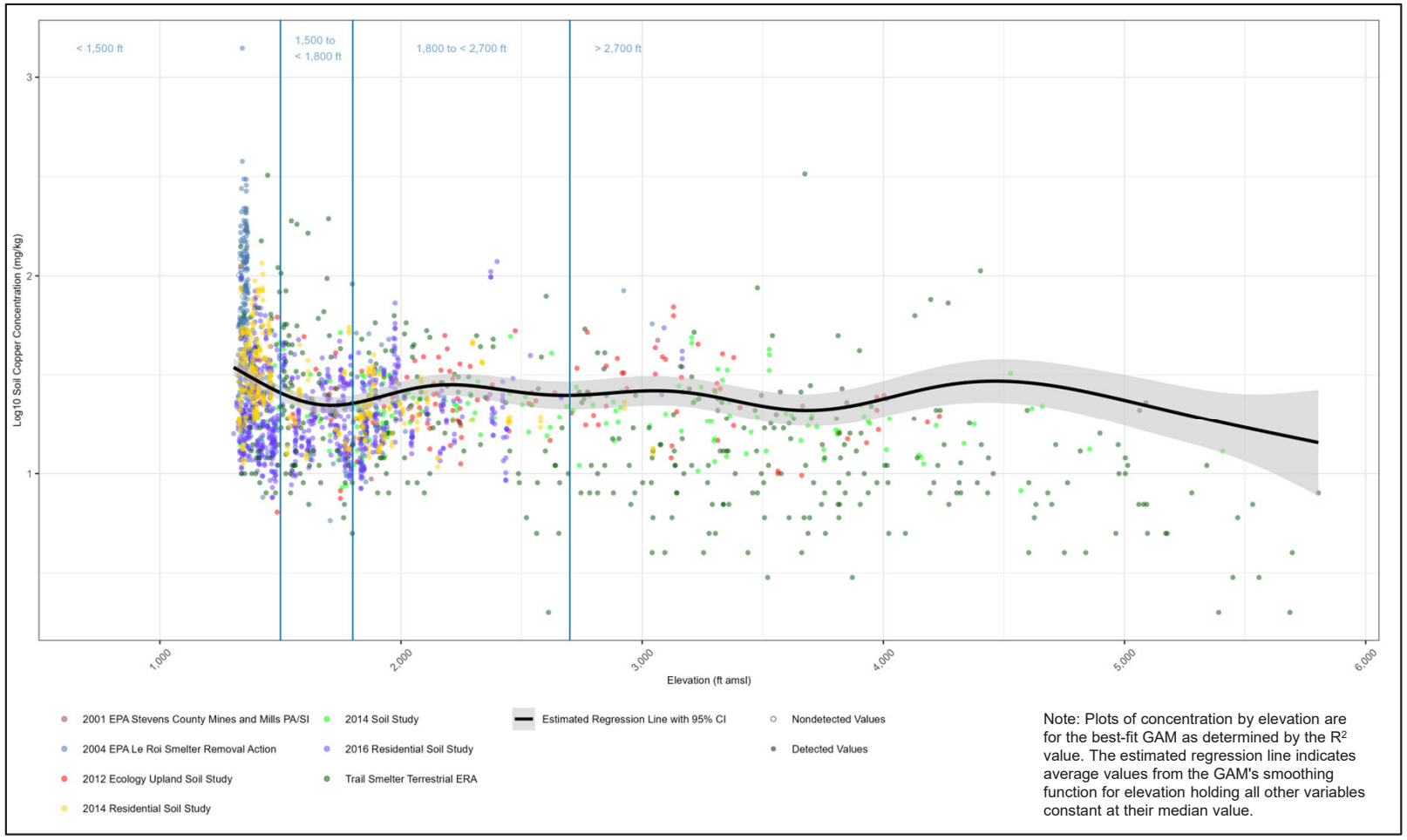


Figure 6-4f. Soil Copper Concentrations versus Elevation
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Upper Columbia River, Washington

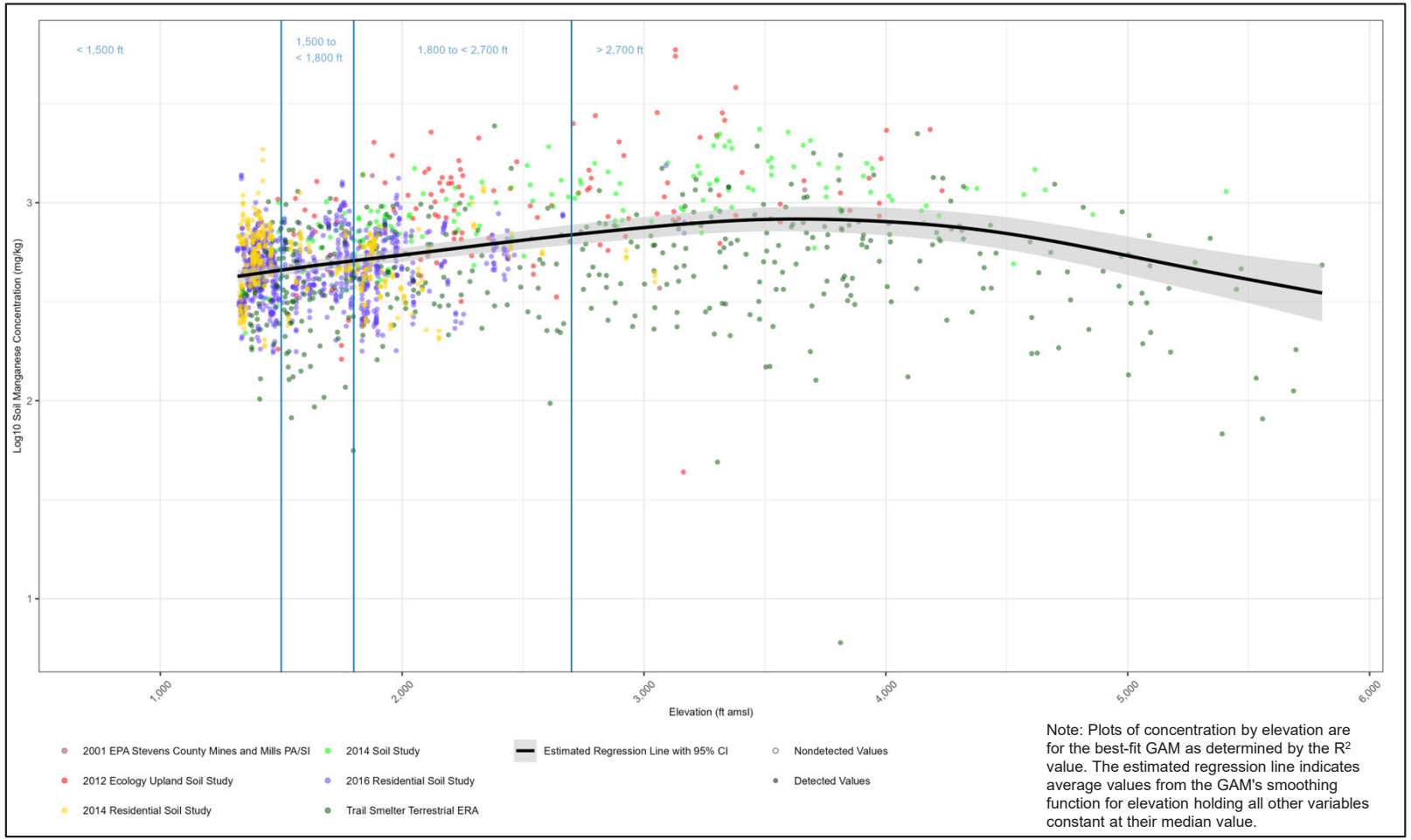


Figure 6-4g. Soil Manganese Concentrations versus Elevation
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Upper Columbia River, Washington

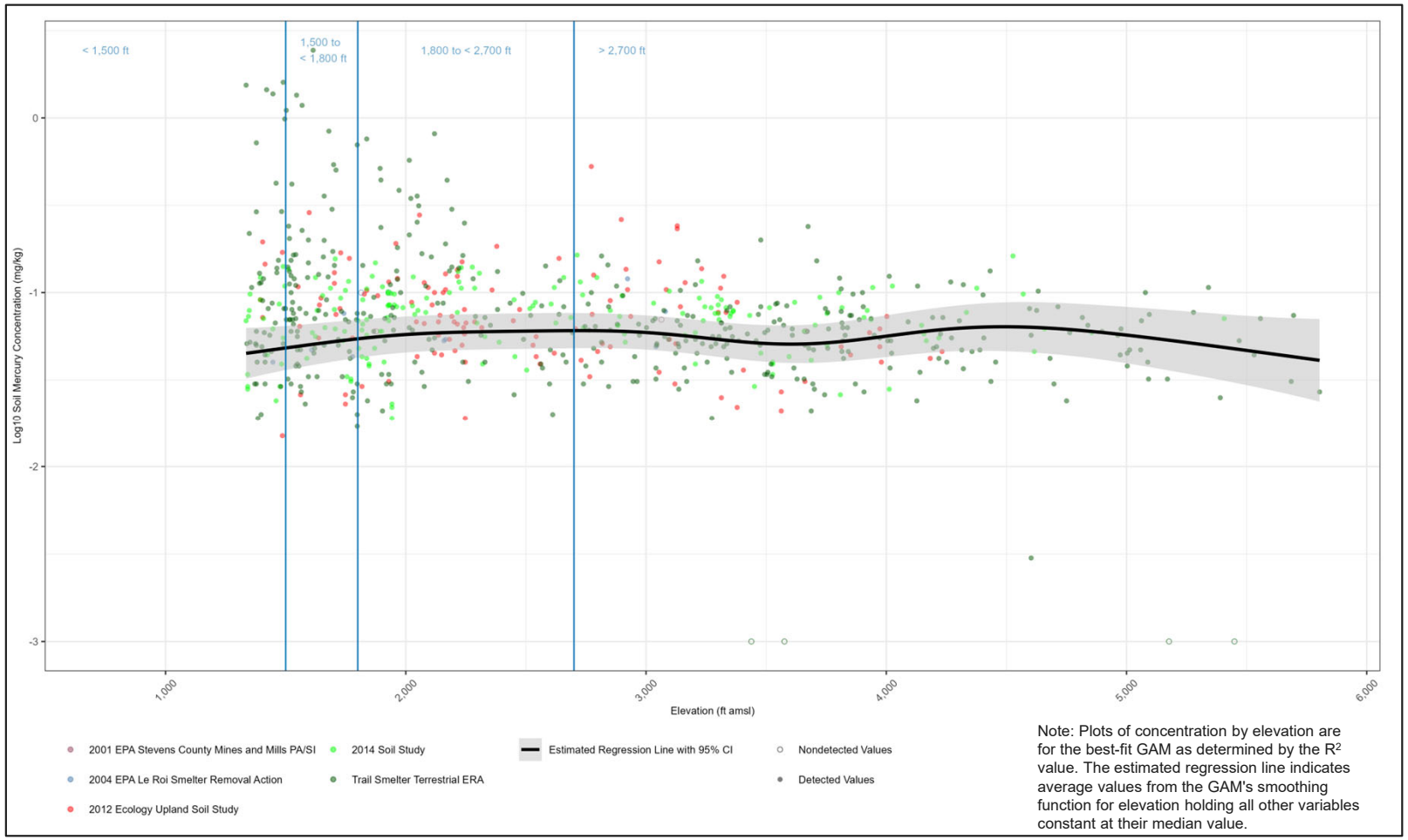


Figure 6-4h. Soil Mercury Concentrations versus Elevation
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Upper Columbia River, Washington

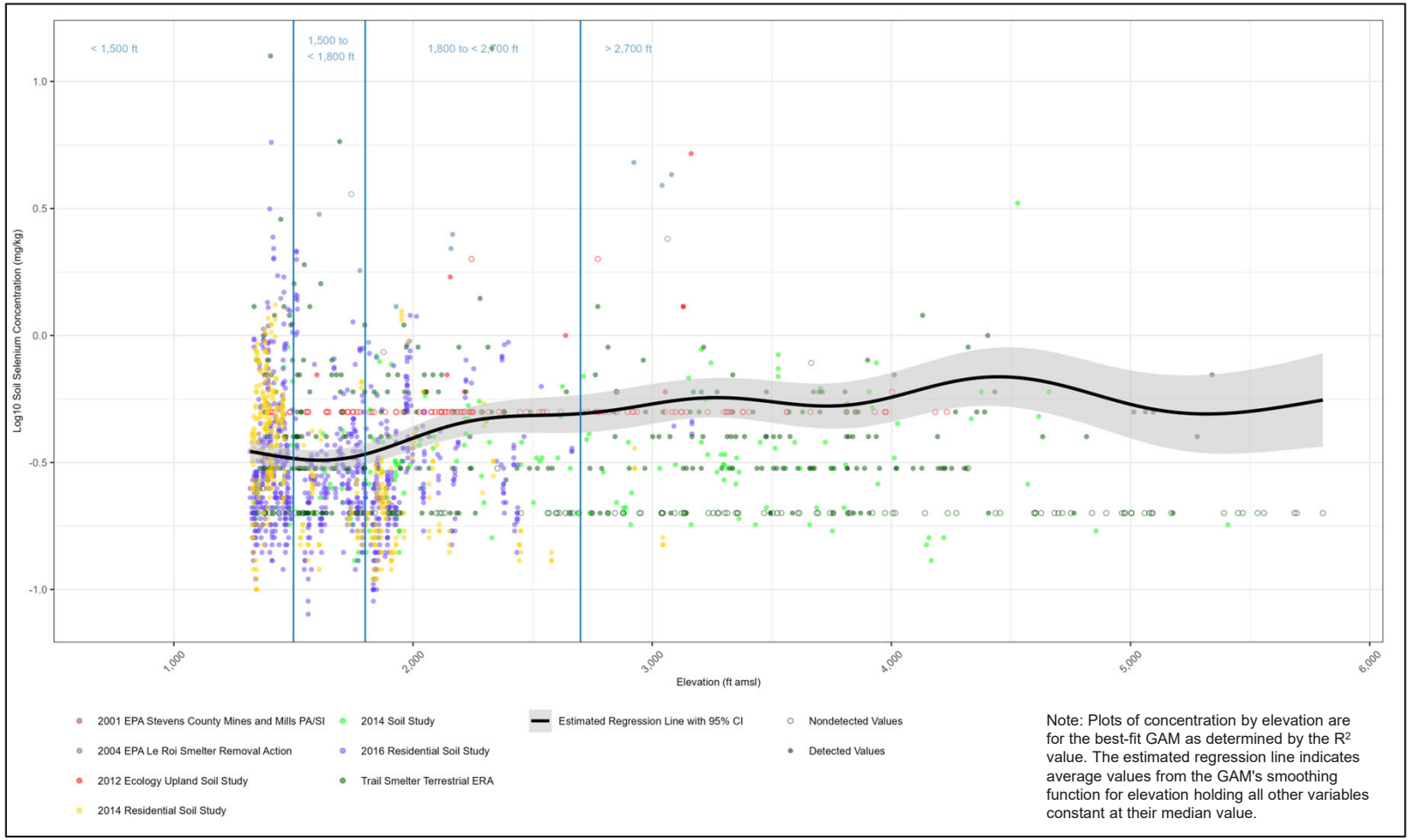


Figure 6-4i. Soil Selenium Concentrations versus Elevation
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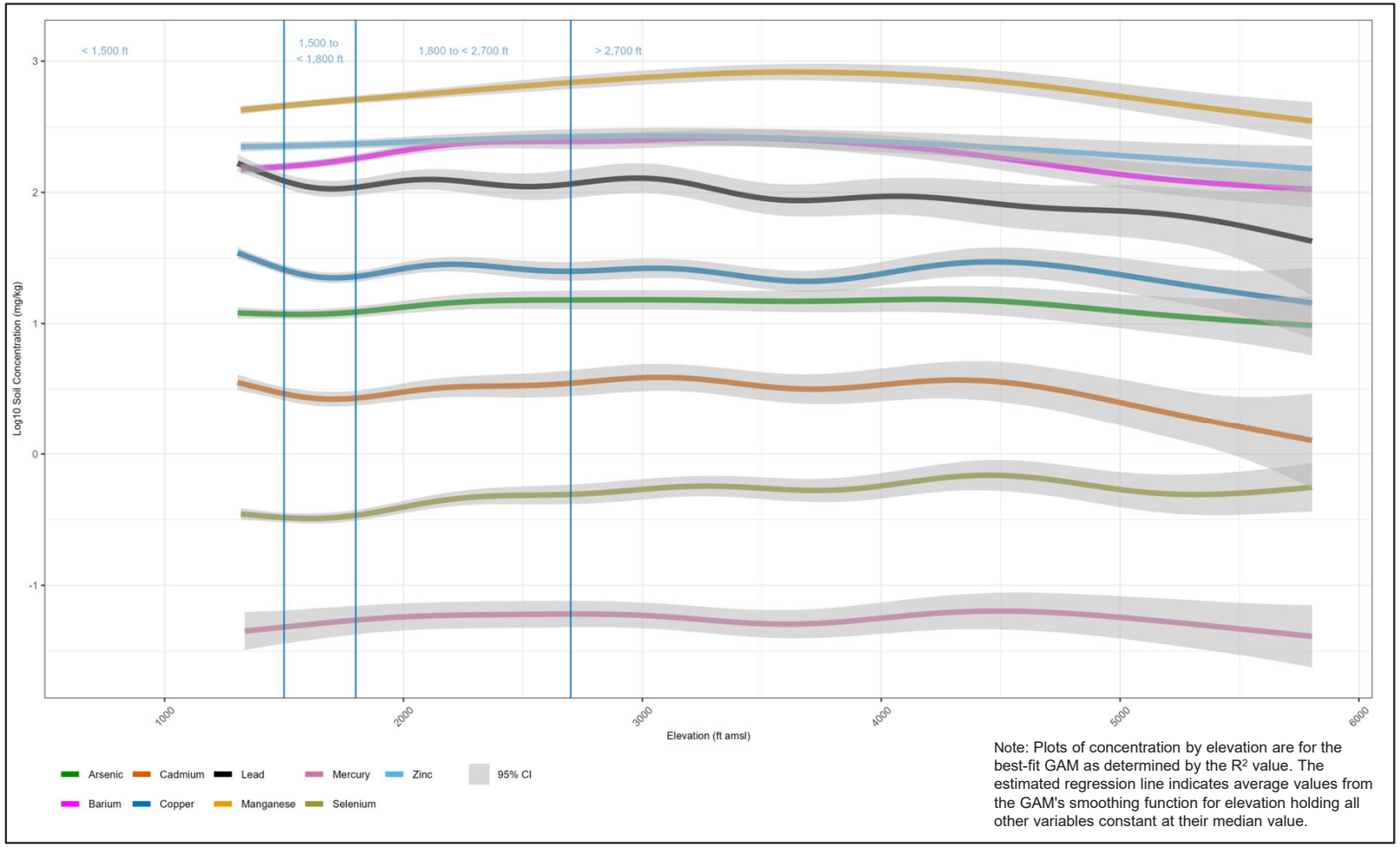
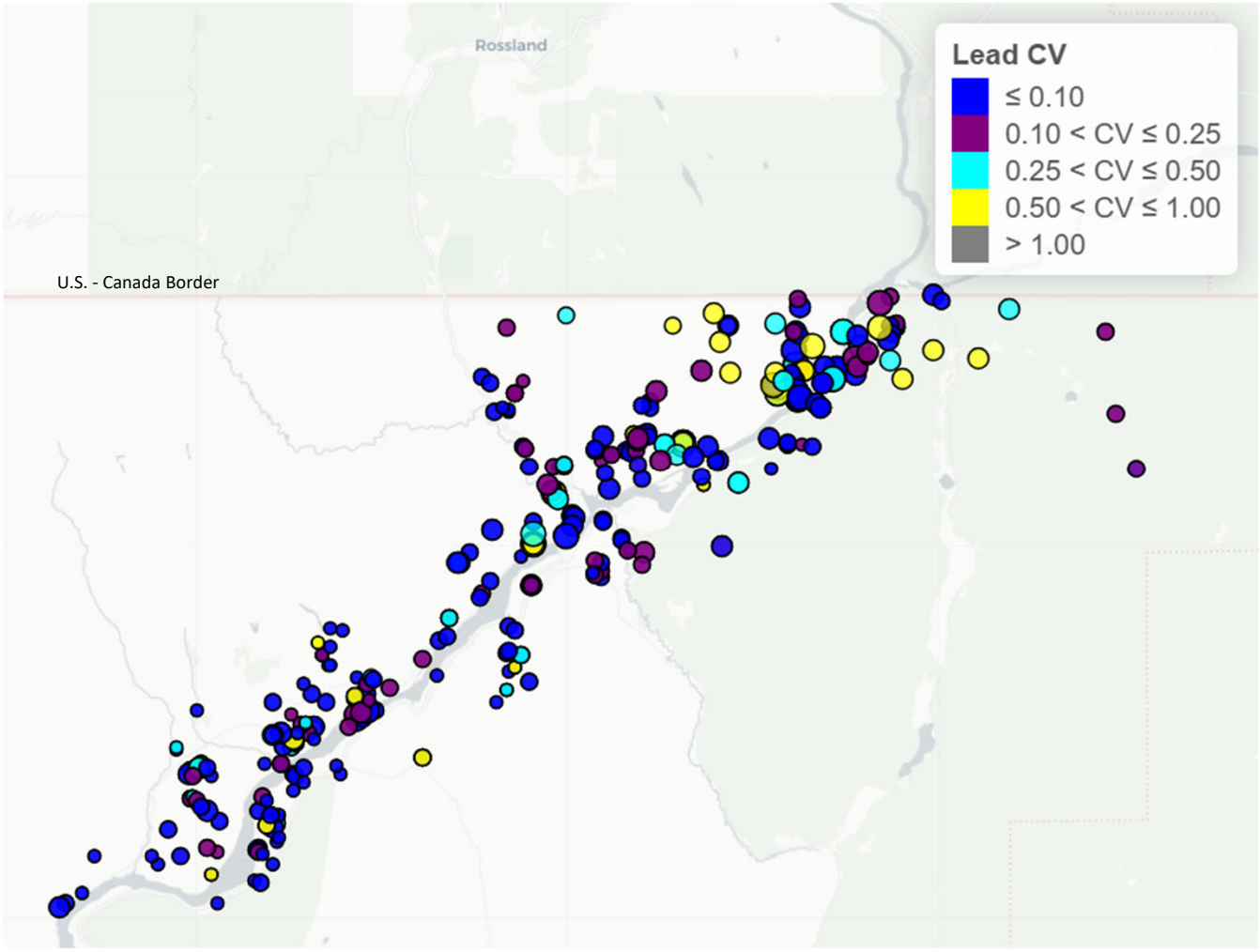


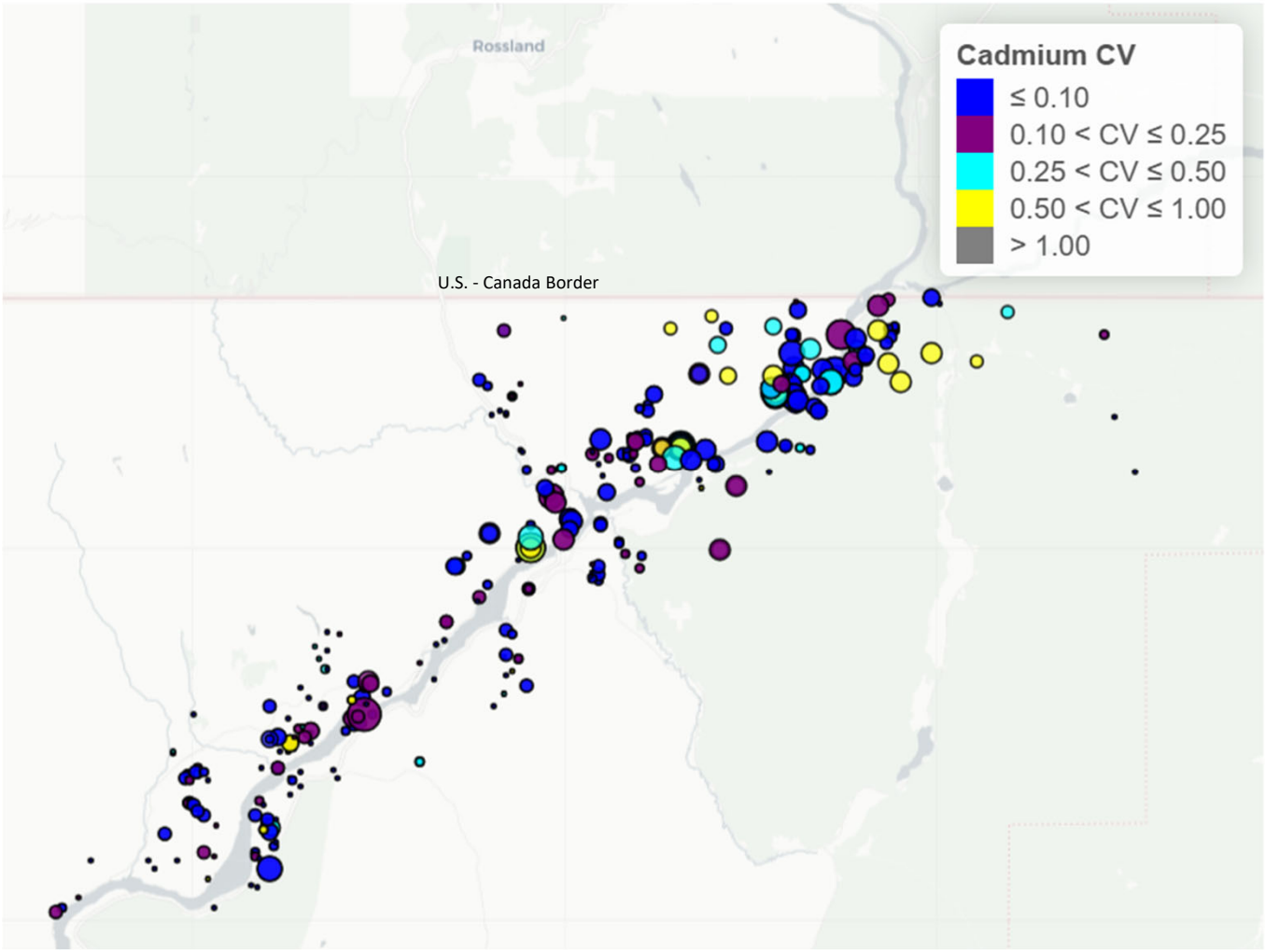
Figure 6-5. Soil COC Concentrations versus Elevation
Final Upland RI Report
Upper Columbia River, Washington



Note:
Dot size is proportional to the log10 of the average concentration for the DU or sampling area.

Study	Replicate Type	Number of DUs/Areas	Minimum	Maximum	Mean	Median
2012 Ecology Upland Soil Study	composite	13	0.33	1.04	0.65	0.67
2014 Residential Soil Study	IC	114	0.01	0.61	0.10	0.08
2014 Soil Study, high density area	IC < 150 µm	6	0.11	0.31	0.19	0.17
2014 Soil Study, high density area	IC < 2 mm	6	0.07	0.35	0.21	0.20
2014 Soil Study, primary area	IC < 150 µm	10	0.05	0.14	0.09	0.10
2014 Soil Study, primary area	IC < 2 mm	10	0.02	0.15	0.09	0.09
2015 TCRA	single	5	0.21	0.67	0.34	0.22
2016 Residential Soil Study	multipoint	130	0.01	0.37	0.07	0.06
2016 Residential Soil Study	single	28	0.17	1.04	0.49	0.41
2017 SATES Test Plot Characterization	IC	3	0.22	0.55	0.39	0.39
2017 SATES Test Plot Characterization	single	3	0.55	0.86	0.74	0.81
2018 Plant Tissue Study	composite	6	0.27	0.47	0.33	0.30
2018 Plant Tissue Study	individual	8	0.28	0.84	0.55	0.52

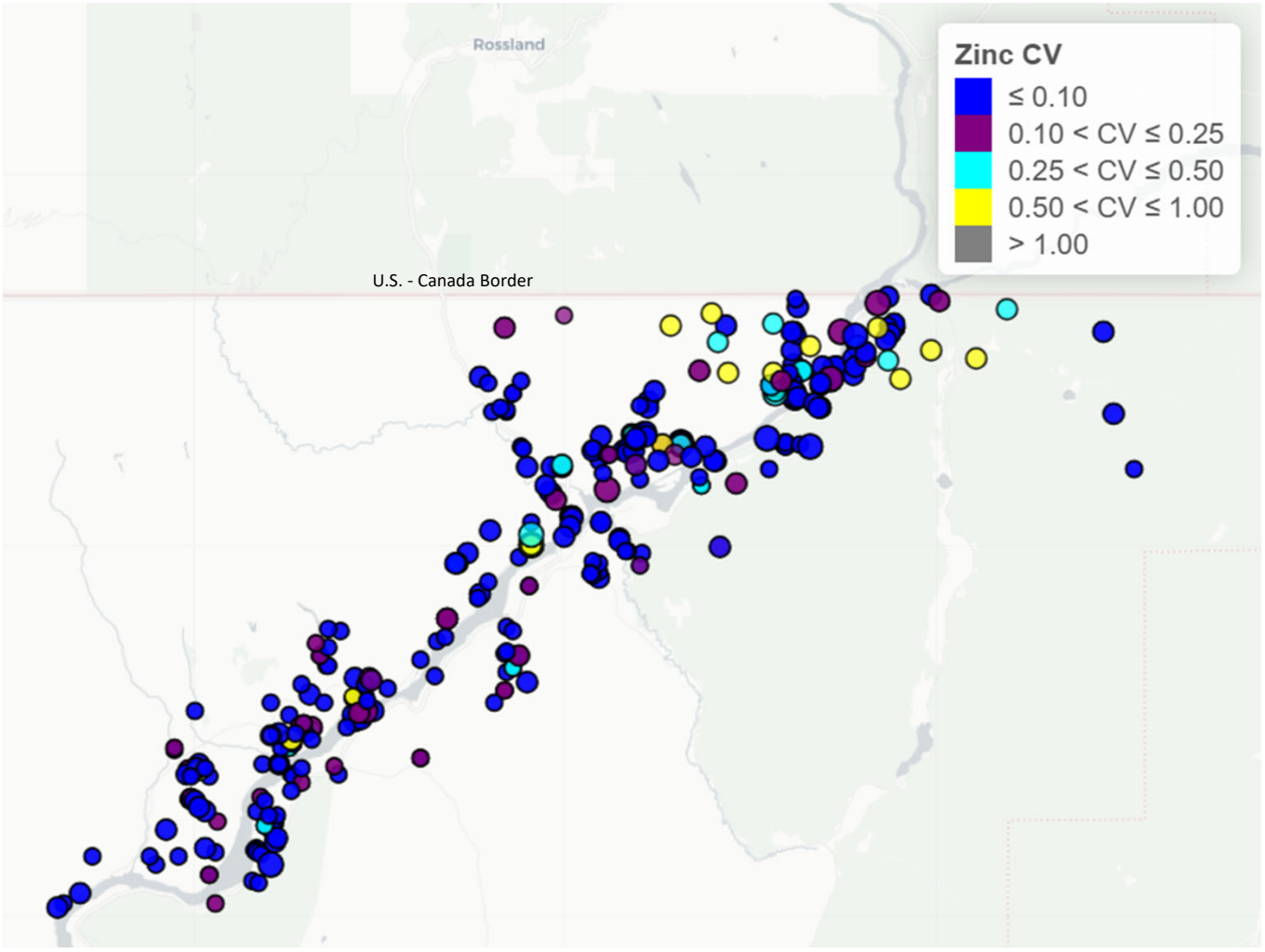
Figure 6-6a. CVs for Lead Within DUs and Other Sampling Areas with Multiple Samples



Note:
Dot size is proportional to the log10 of the average concentration for the DU or sampling area.

Study	Replicate Type	Number of DUs/Areas	Minimum	Maximum	Mean	Median
2012 Ecology Upland Soil Study	composite	13	0.36	0.95	0.62	0.56
2014 Residential Soil Study	IC	114	0.01	0.44	0.08	0.06
2014 Soil Study, high density area	IC < 150 µm	6	0.08	0.24	0.14	0.14
2014 Soil Study, high density area	IC < 2 mm	6	0.04	0.25	0.14	0.12
2014 Soil Study, primary area	IC < 150 µm	10	0.07	0.16	0.11	0.10
2014 Soil Study, primary area	IC < 2 mm	10	0.02	0.14	0.09	0.10
2016 Residential Soil Study	multipoint	130	0.00	0.28	0.07	0.06
2016 Residential Soil Study	single	28	0.15	1.03	0.43	0.38
2017 SATES Test Plot Characterization	IC	3	0.24	0.53	0.40	0.42
2017 SATES Test Plot Characterization	single	3	0.43	0.97	0.66	0.59
2018 Plant Tissue Study	composite	6	0.10	0.35	0.22	0.24
2018 Plant Tissue Study	individual	8	0.34	0.71	0.51	0.51

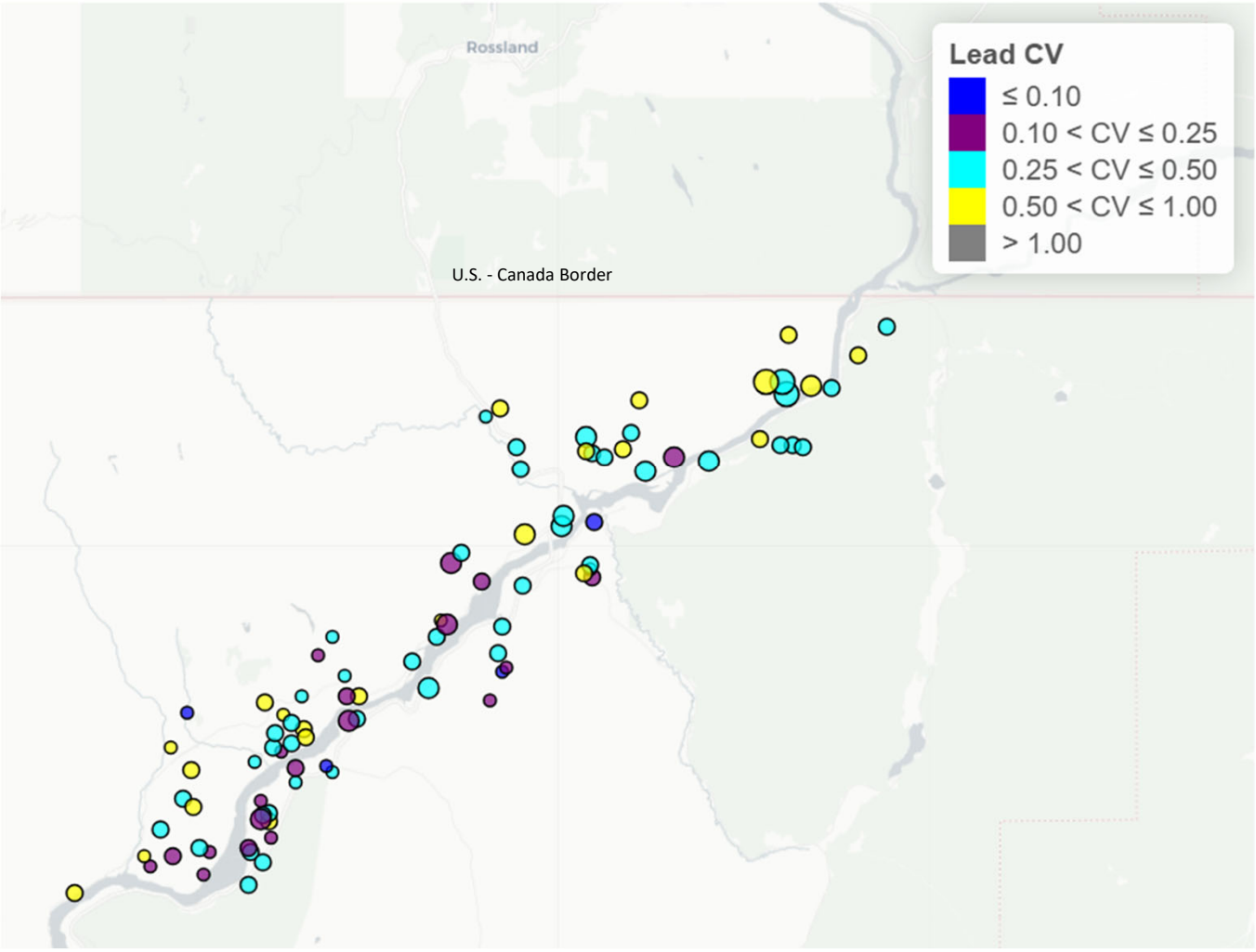
Figure 6-6b. CVs for Cadmium Within DUs and Other Sampling Areas with Multiple Samples



Note:
Dot size is proportional to the log10 of the average concentration for the DU or sampling area.

Study	Replicate Type	Metal	Number of DUs/Areas	Minimum	Maximum	Mean	Median
2012 Ecology Upland Soil Study	composite	zinc	13	0.21	0.75	0.51	0.58
2014 Residential Soil Study	IC	zinc	114	0.01	0.38	0.06	0.05
2014 Soil Study, high density area	IC < 150 µm	zinc	6	0.03	0.18	0.11	0.11
2014 Soil Study, high density area	IC < 2 mm	zinc	6	0.04	0.24	0.13	0.12
2014 Soil Study, primary area	IC < 150 µm	zinc	10	0.03	0.12	0.07	0.05
2014 Soil Study, primary area	IC < 2 mm	zinc	10	0.04	0.12	0.07	0.07
2016 Residential Soil Study	multipoint	zinc	130	0.00	0.26	0.06	0.05
2016 Residential Soil Study	single	zinc	28	0.08	0.92	0.30	0.24
2017 SATES Test Plot Characterization	IC	zinc	3	0.29	0.50	0.38	0.36
2017 SATES Test Plot Characterization	single	zinc	3	0.28	0.75	0.47	0.37
2018 Plant Tissue Study	composite	zinc	6	0.19	0.60	0.33	0.24
2018 Plant Tissue Study	individual	zinc	8	0.23	0.68	0.43	0.41

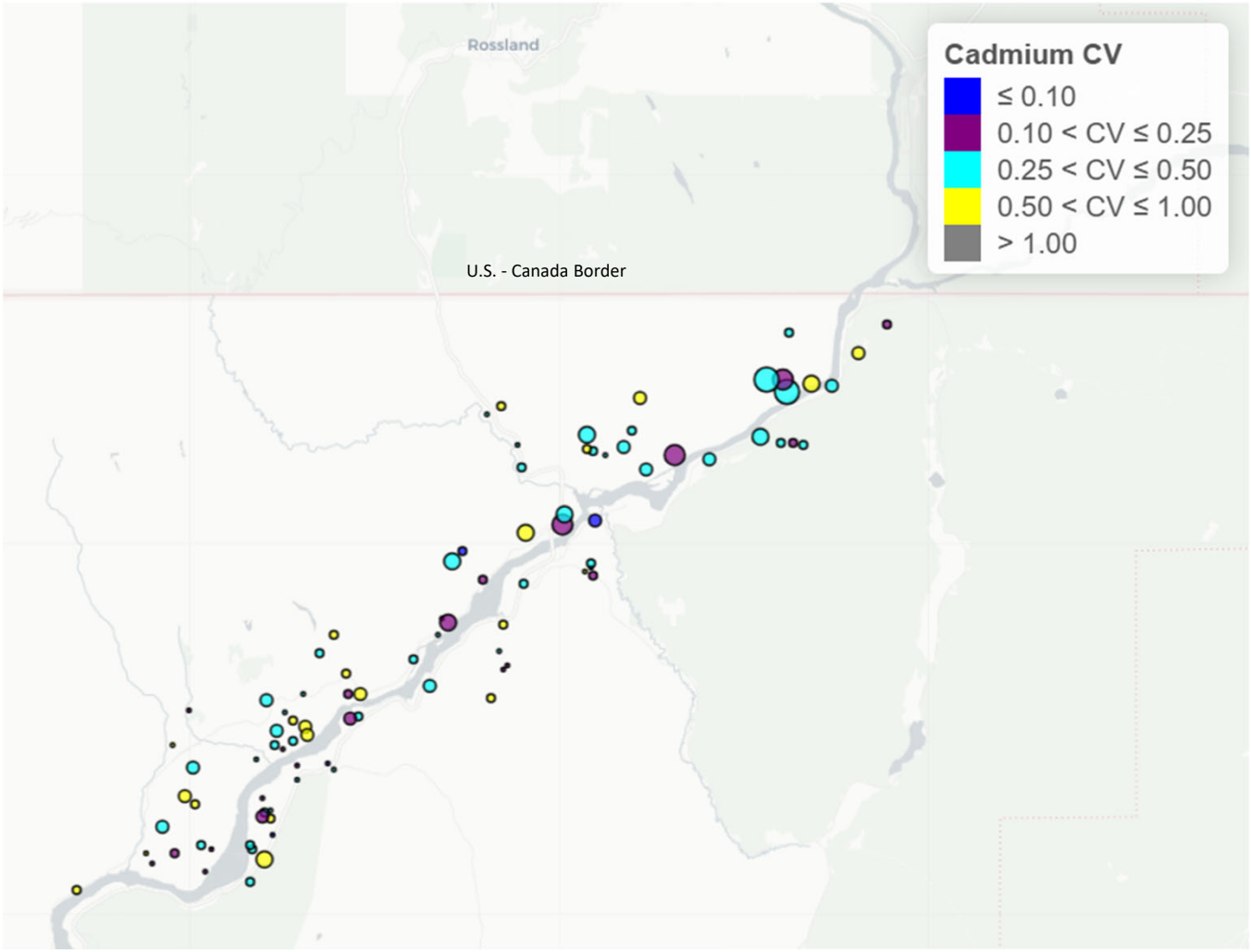
Figure 6-6c. CVs for Zinc Within DUs and Other Sampling Areas with Multiple Samples



Note:
Dot size is proportional to the log10 of the average concentration for the DU or sampling area.

Study	Replicate Type	Number of Properties	Minimum	Maximum	Mean	Median
2014 Residential Soil Study	IC	23	0.17	0.91	0.48	0.43
2016 Residential Soil Study	multipoint	70	0.04	1.07	0.37	0.36

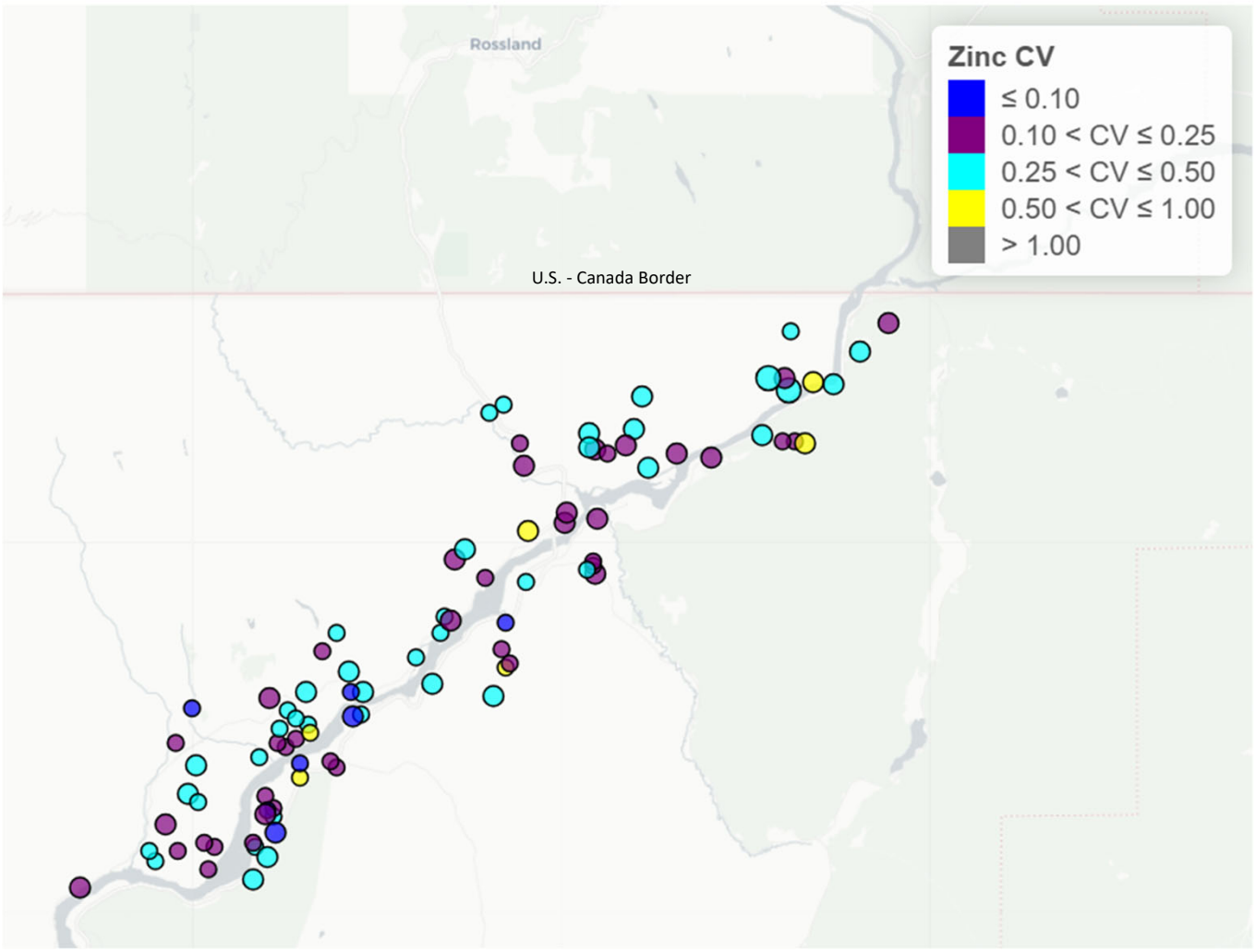
Figure 6-7a. CVs for Lead Within Properties with Multiple DUs
(Residential Properties and Tribal Allotments)



Note:
Dot size is proportional to the log10 of the average concentration for the DU or sampling area.

Study	Replicate Type	Number of Properties	Minimum	Maximum	Mean	Median
2014 Residential Soil Study	IC	23	0.18	0.84	0.44	0.42
2016 Residential Soil Study	multipoint	70	0.03	0.91	0.36	0.37

Figure 6-7b. CVs for Cadmium Within Properties with Multiple DUs
(Residential Properties and Tribal Allotments)



Note:
Dot size is proportional to the log10 of the average concentration for the DU or sampling area.

Study	Replicate Type	Number of Properties	Minimum	Maximum	Mean	Median
2014 Residential Soil Study	IC	23	0.10	0.73	0.30	0.26
2016 Residential Soil Study	multipoint	70	0.03	1.03	0.26	0.24

Figure 6-7c. CVs for Zinc Within Properties with Multiple DUs
(Residential Properties and Tribal Allotments)

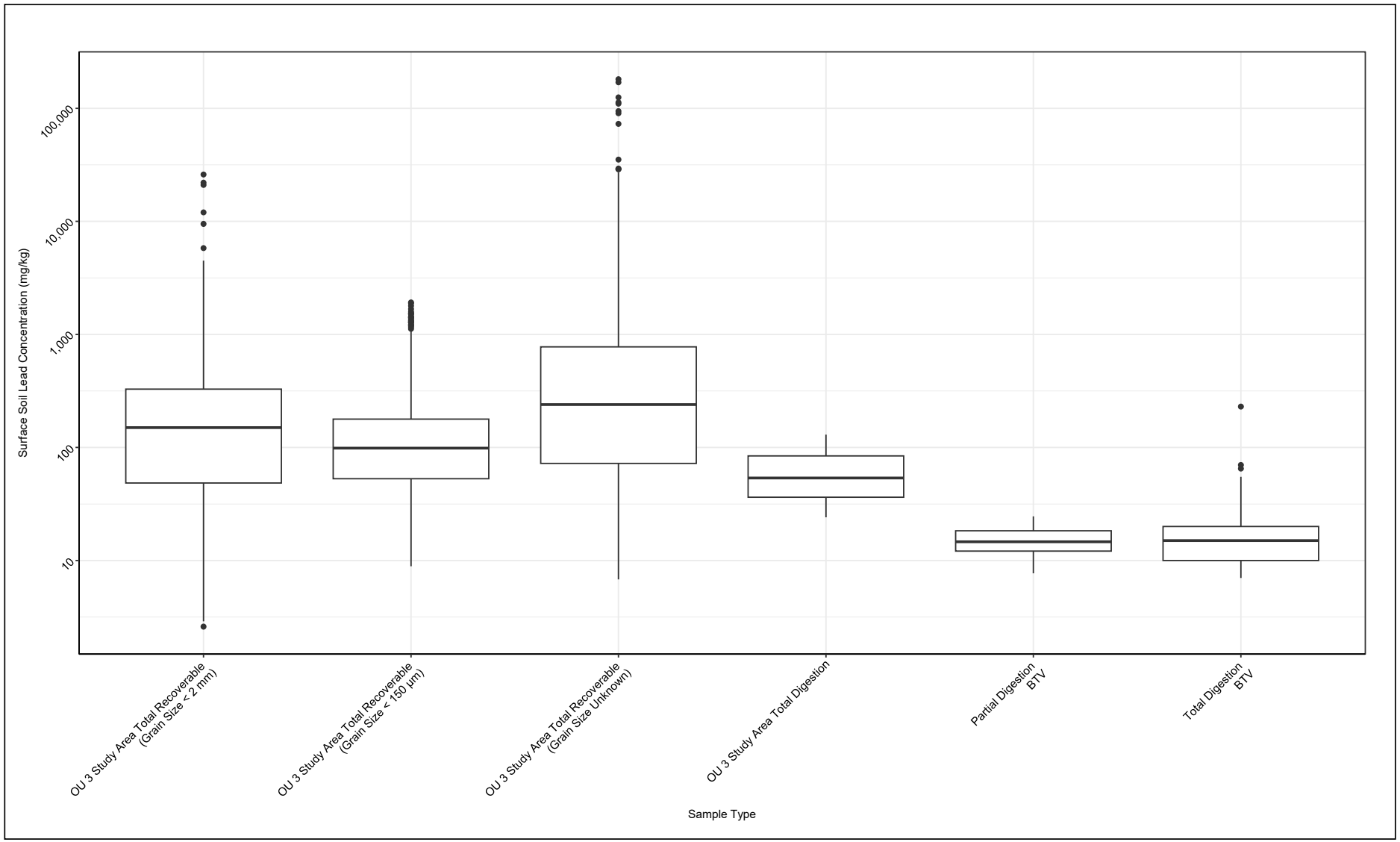


Figure 6-8a. Boxplots of Surface Soil Lead Concentrations in the Data Used for Nature and Extent Mapping

Final Upland RI Report
Upper Columbia River, Washington

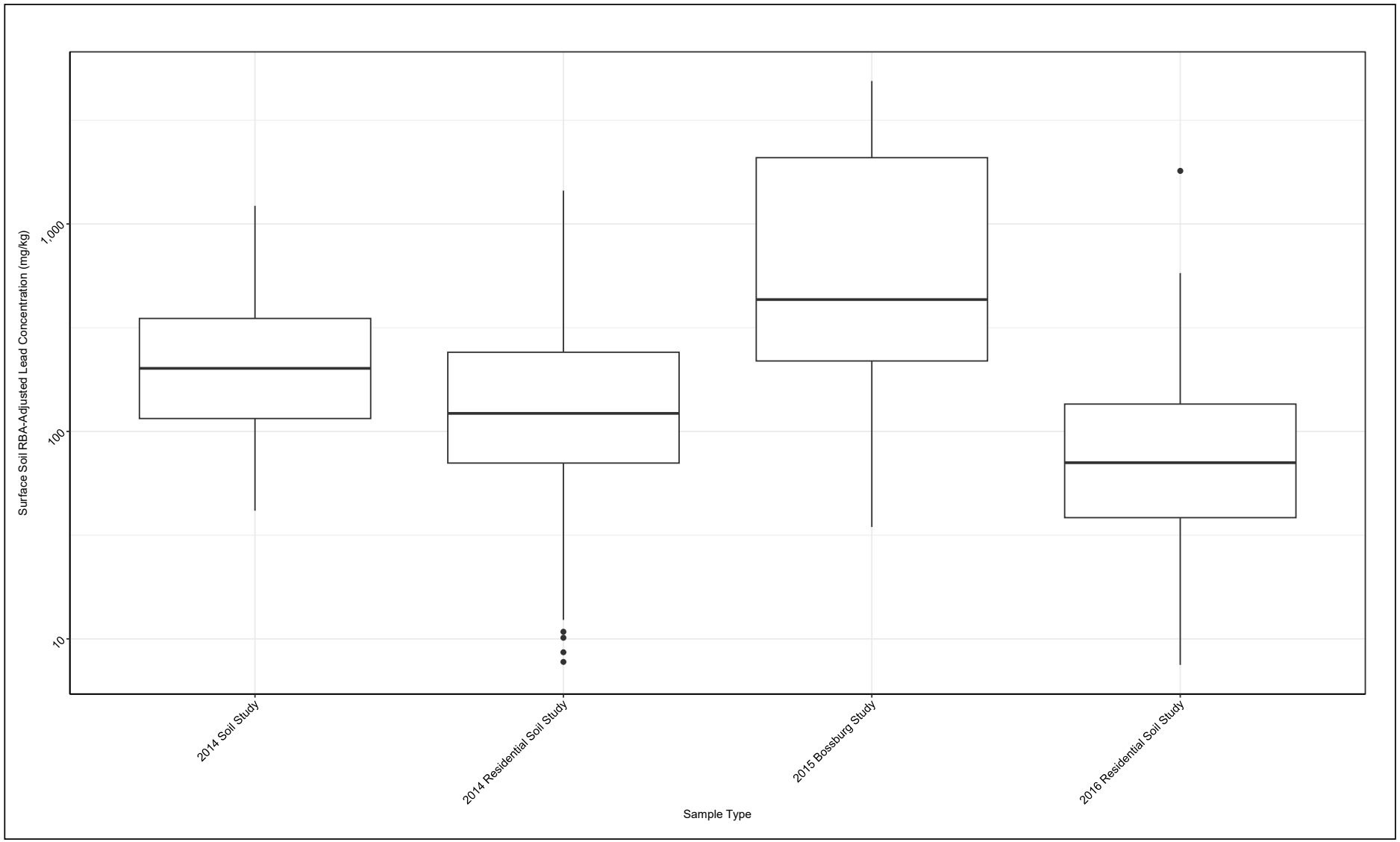


Figure 6-8b. Boxplots of RBA-Adjusted Surface Soil Lead Concentrations in the Data Used for Nature and Extent Mapping

Final Upland RI Report
Upper Columbia River, Washington

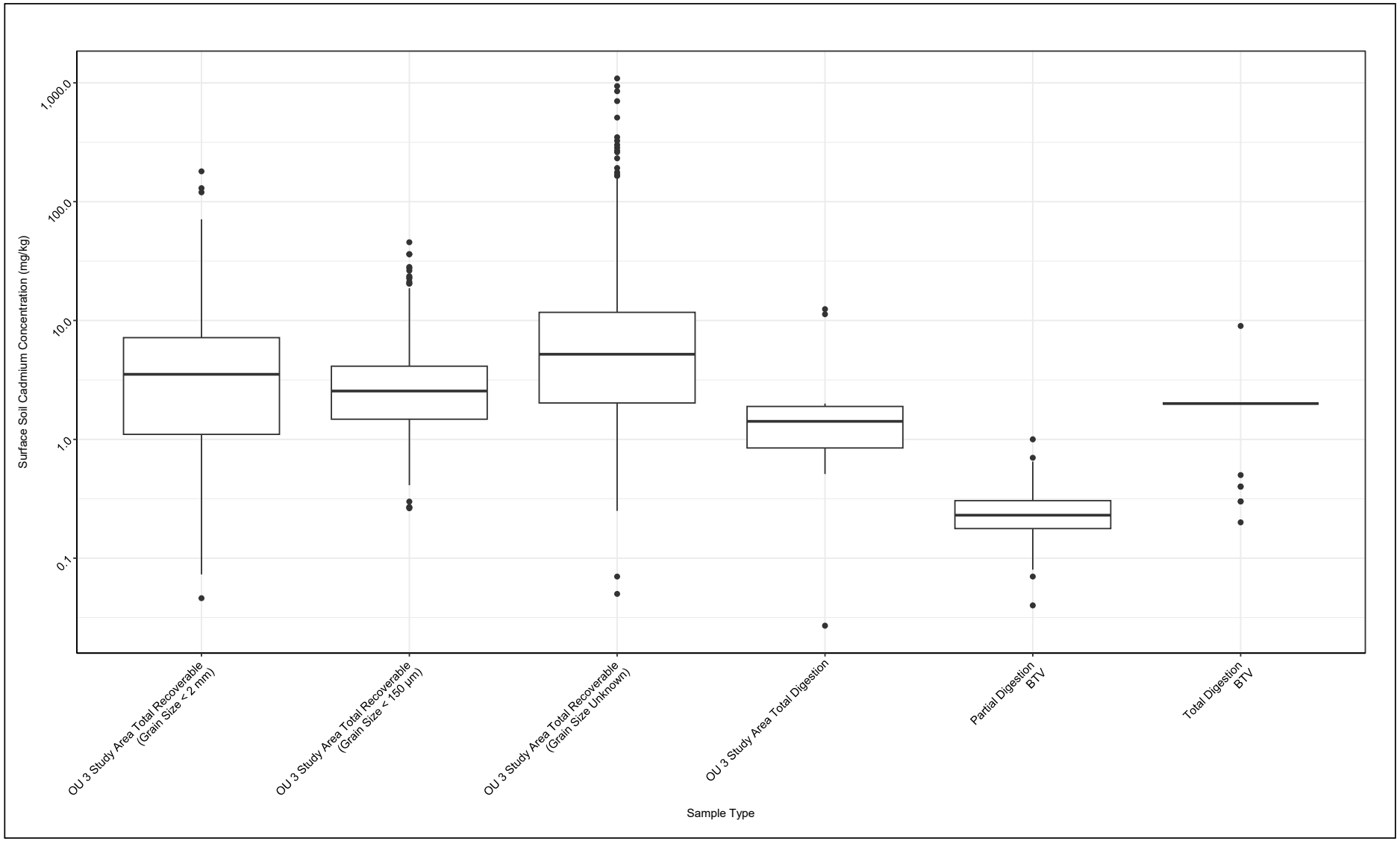


Figure 6-8c. Boxplots of Surface Soil Cadmium Concentrations in the Data Used for Nature and Extent Mapping

Final Upland RI Report
Upper Columbia River, Washington

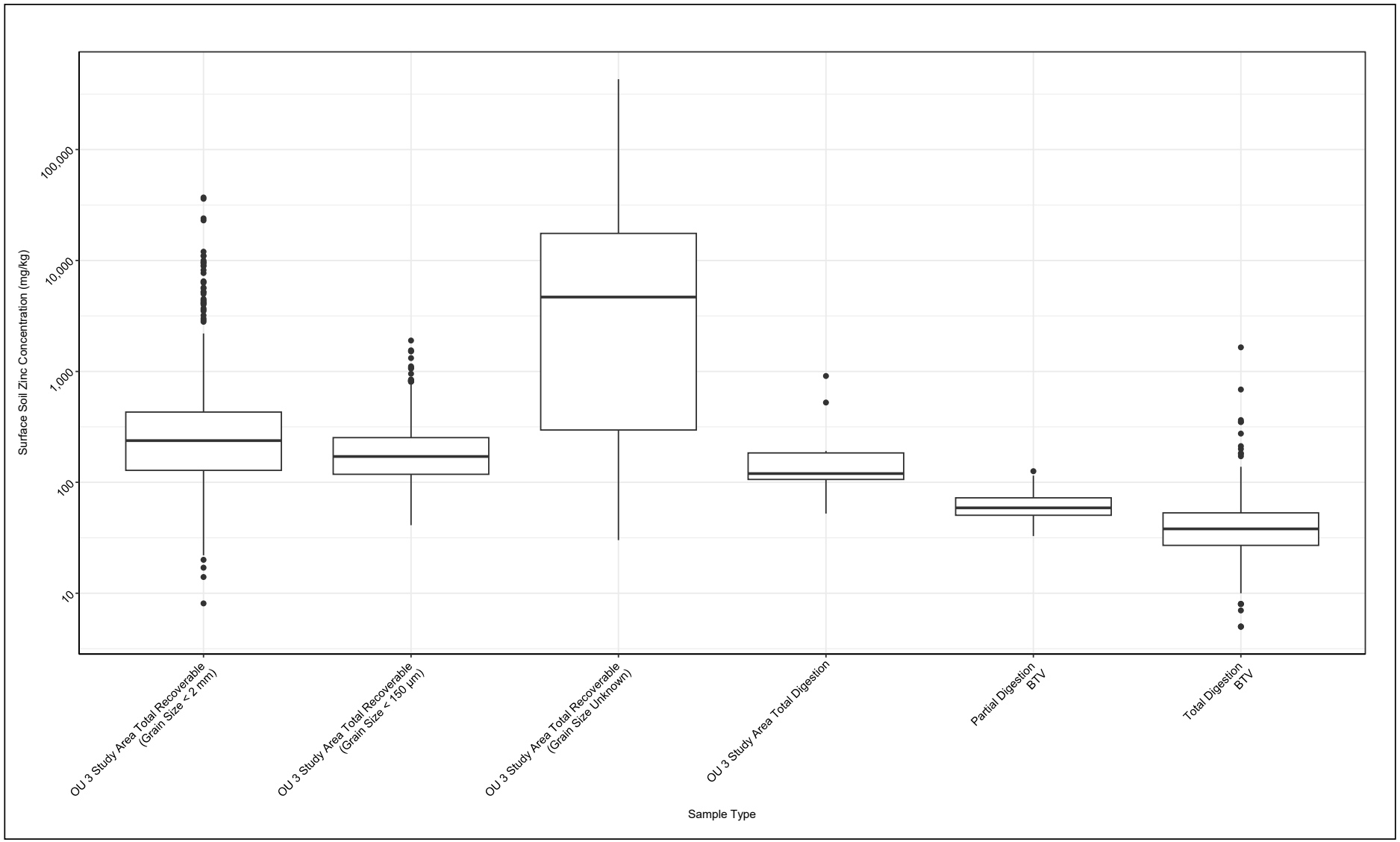


Figure 6-8d. Boxplots of Surface Soil Zinc Concentrations in the Data Used for Nature and Extent Mapping

Final Upland RI Report
Upper Columbia River, Washington

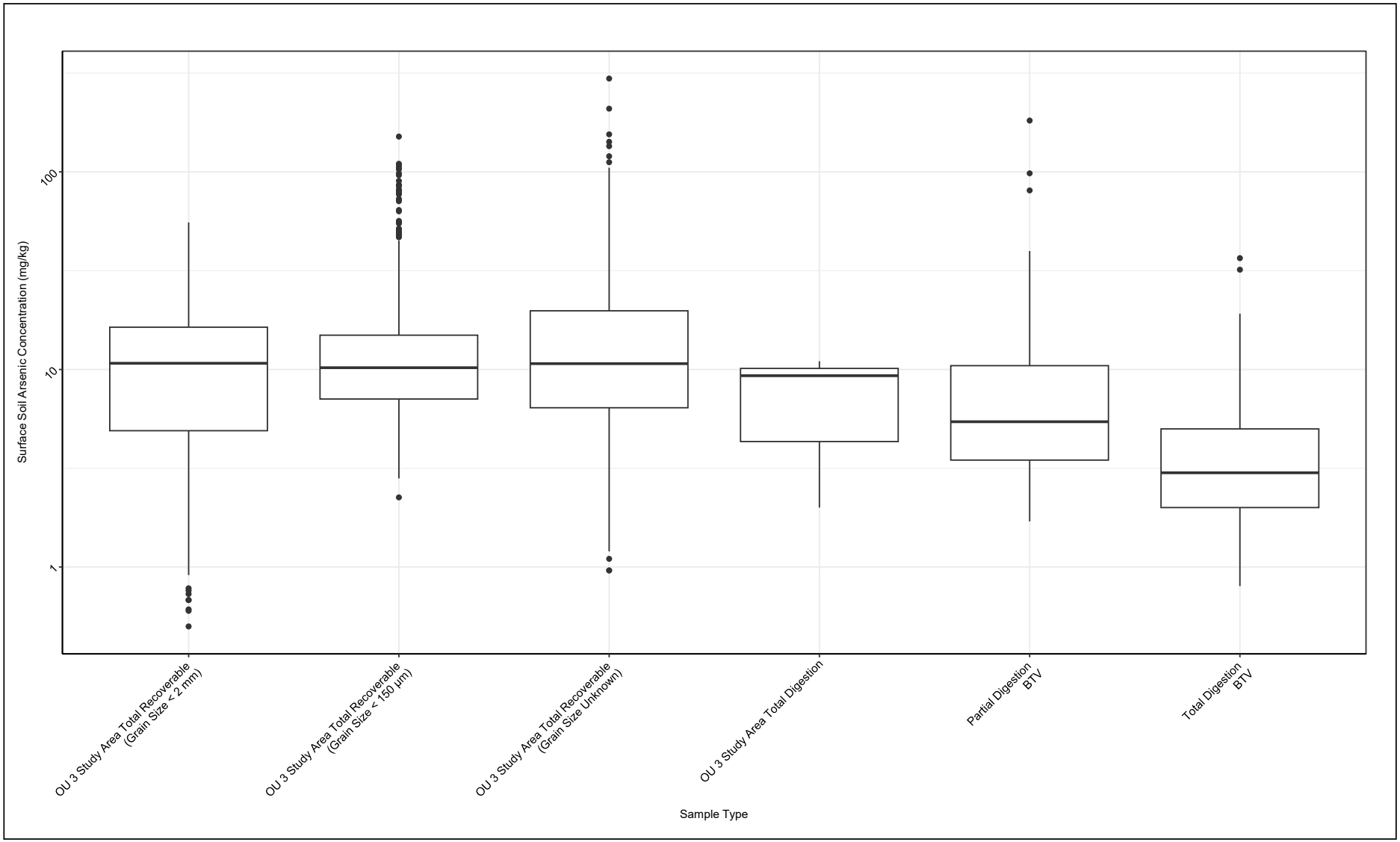


Figure 6-8e. Boxplots of Surface Soil Arsenic Concentrations in the Data Used for Nature and Extent Mapping

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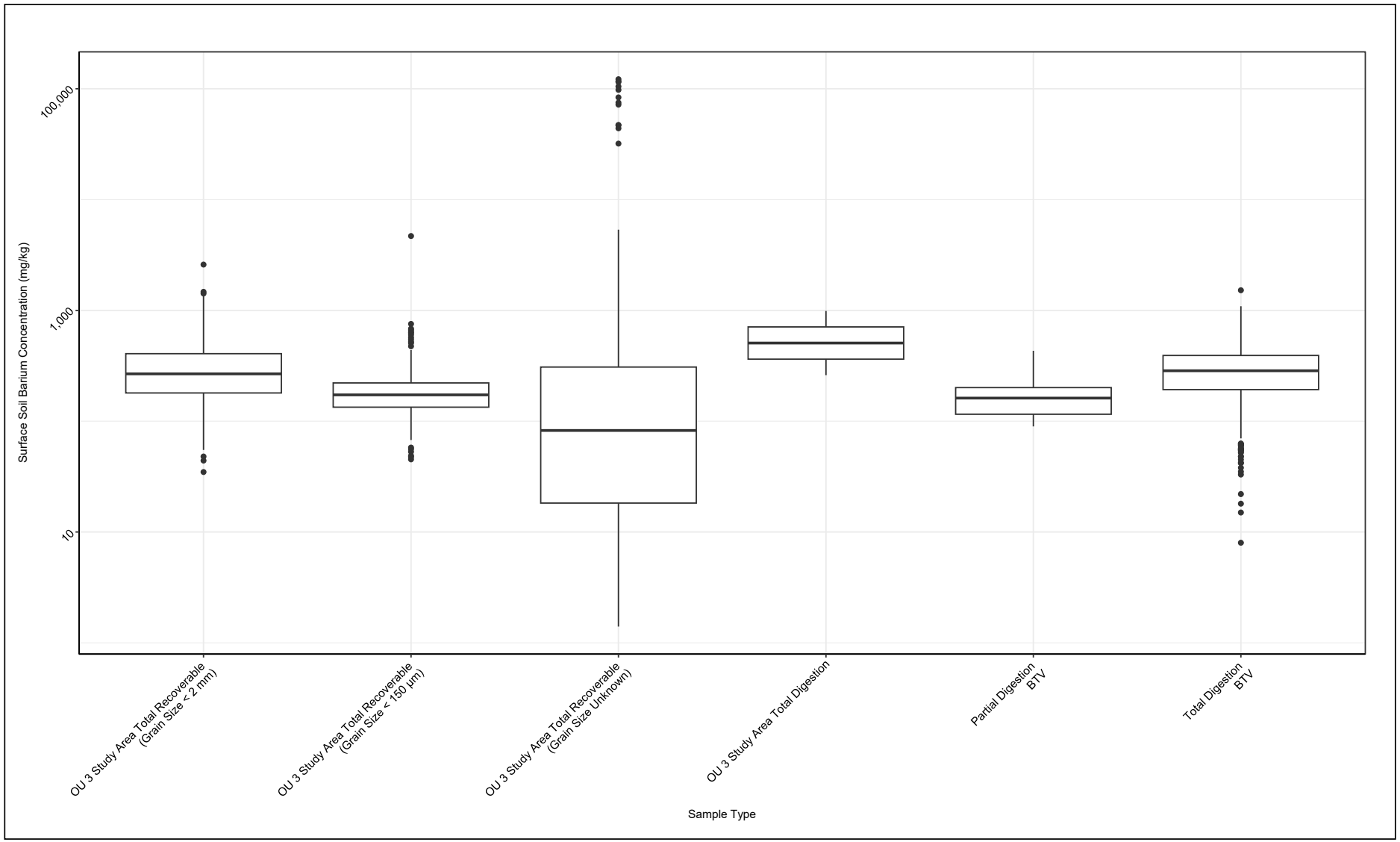


Figure 6-8f. Boxplots of Surface Soil Barium Concentrations in the Data Used for Nature and Extent Mapping

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Upper Columbia River, Washington

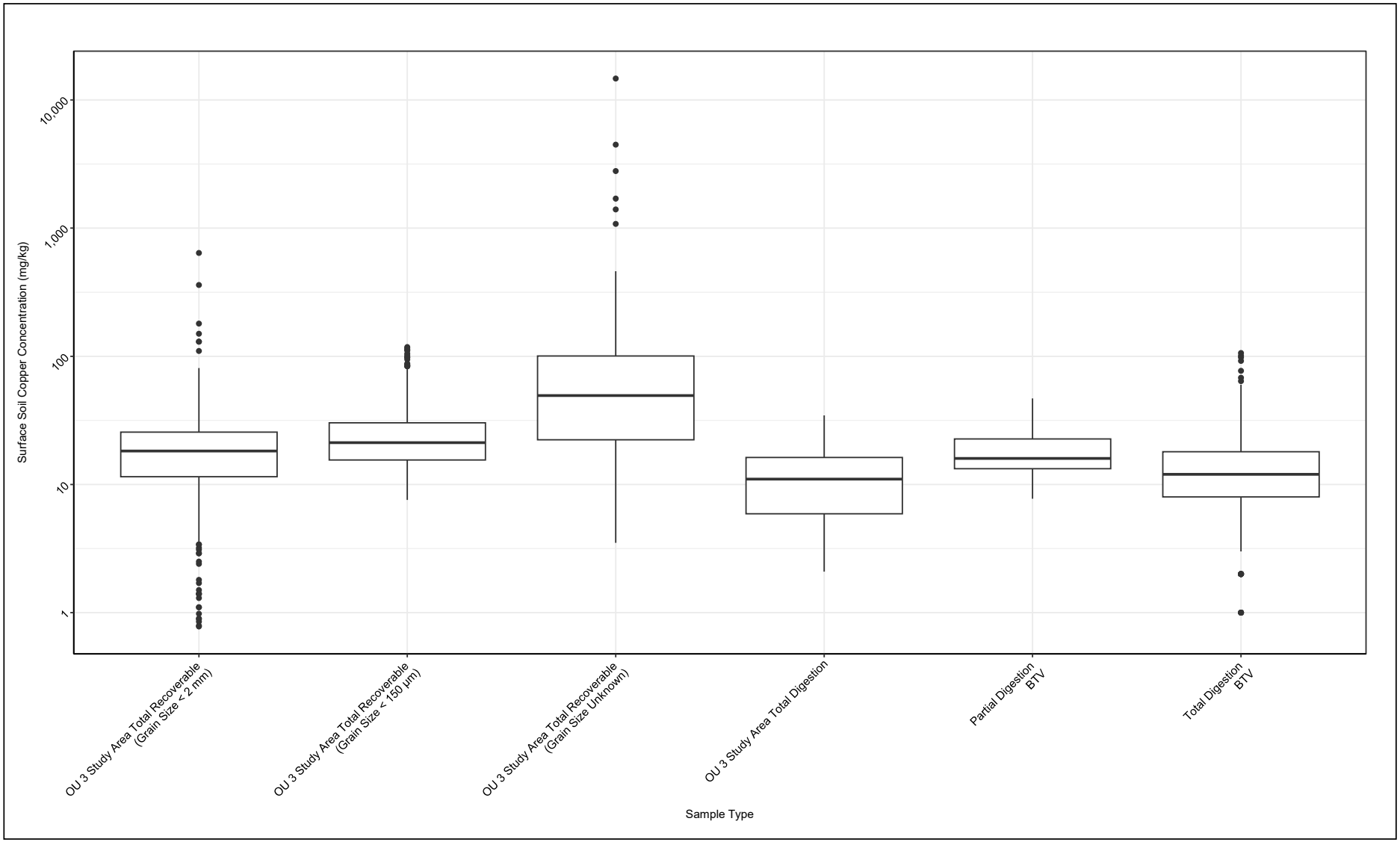


Figure 6-8g. Boxplots of Surface Soil Copper Concentrations in the Data Used for Nature and Extent Mapping

Final Upland RI Report
Upper Columbia River, Washington

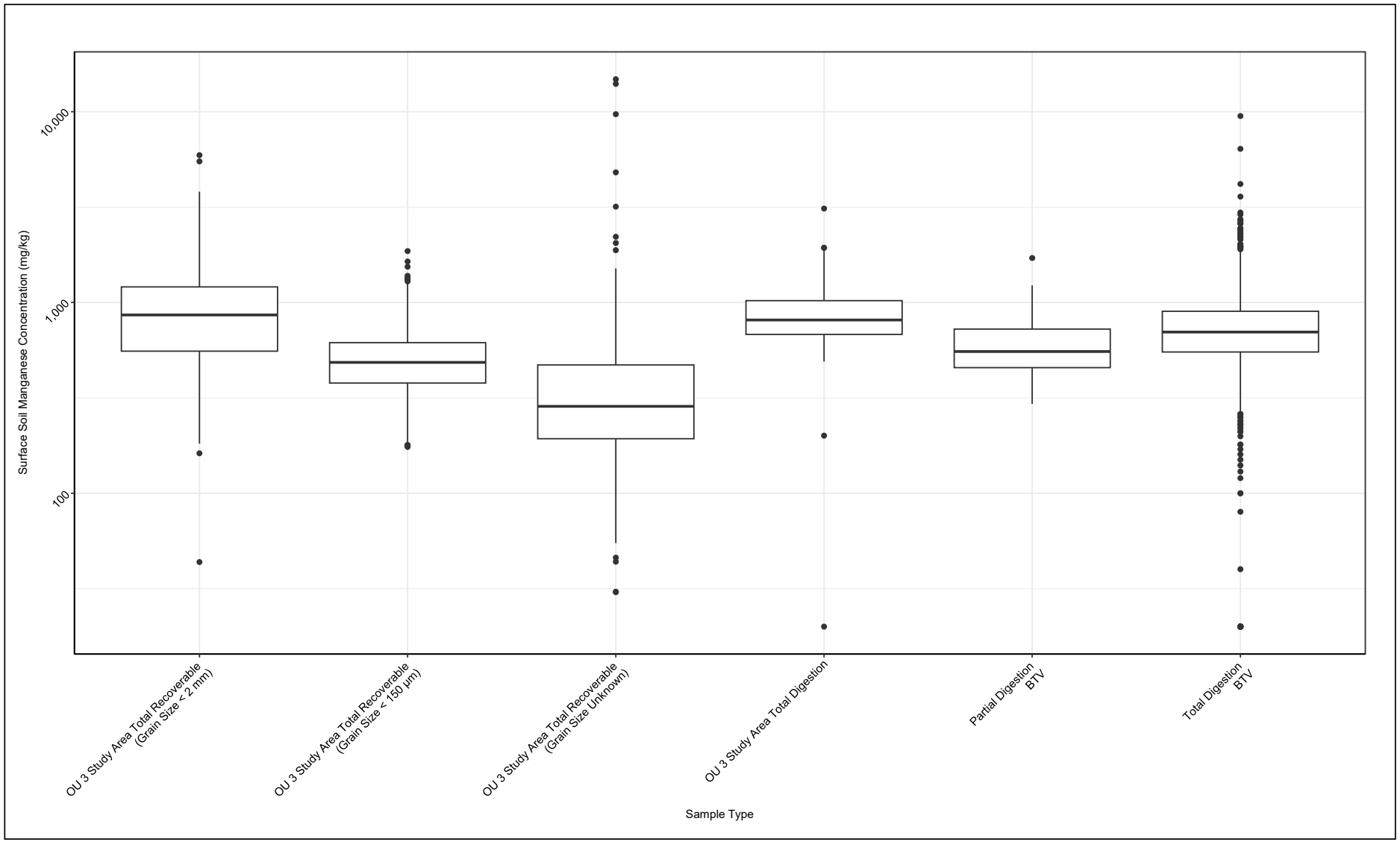


Figure 6-8h. Boxplots of Surface Soil Manganese Concentrations in the Data Used for Nature and Extent Mapping

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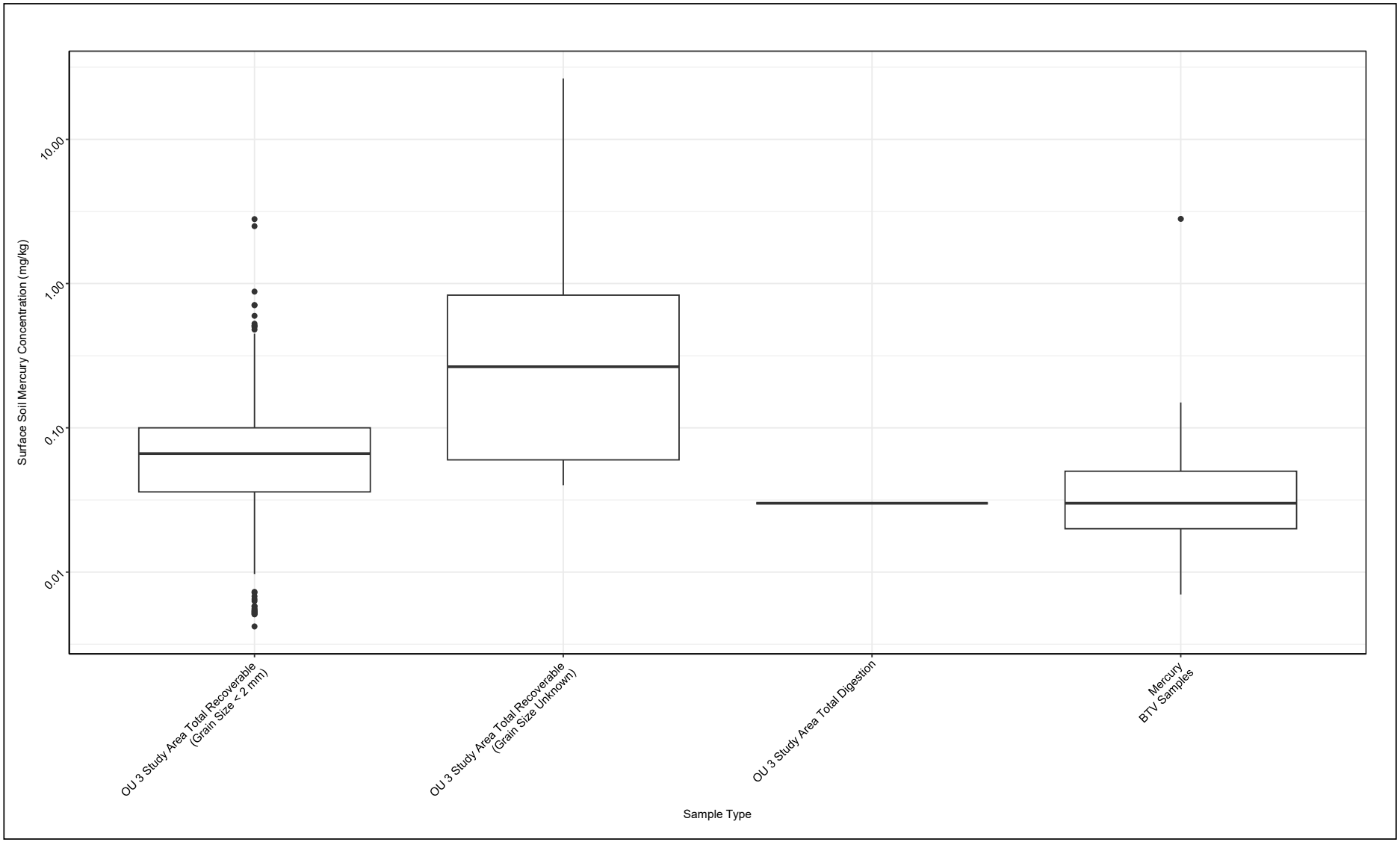


Figure 6-8i. Boxplots of Surface Soil Mercury Concentrations in the Data Used for Nature and Extent Mapping

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Upper Columbia River, Washington

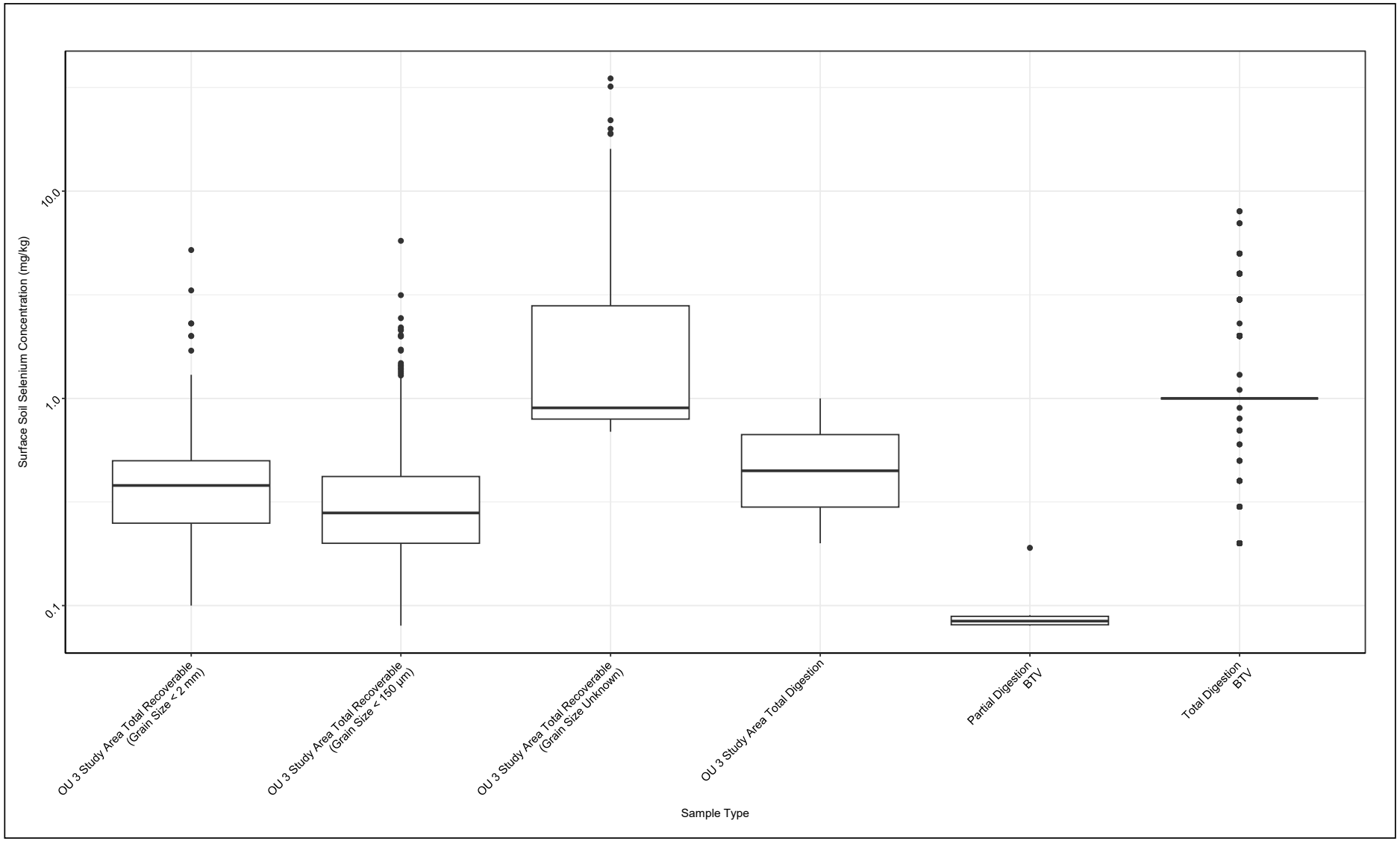


Figure 6-8j. Boxplots of Surface Soil Selenium Concentrations in the Data Used for Nature and Extent Mapping

Final Upland RI Report

Upper Columbia River, Washington

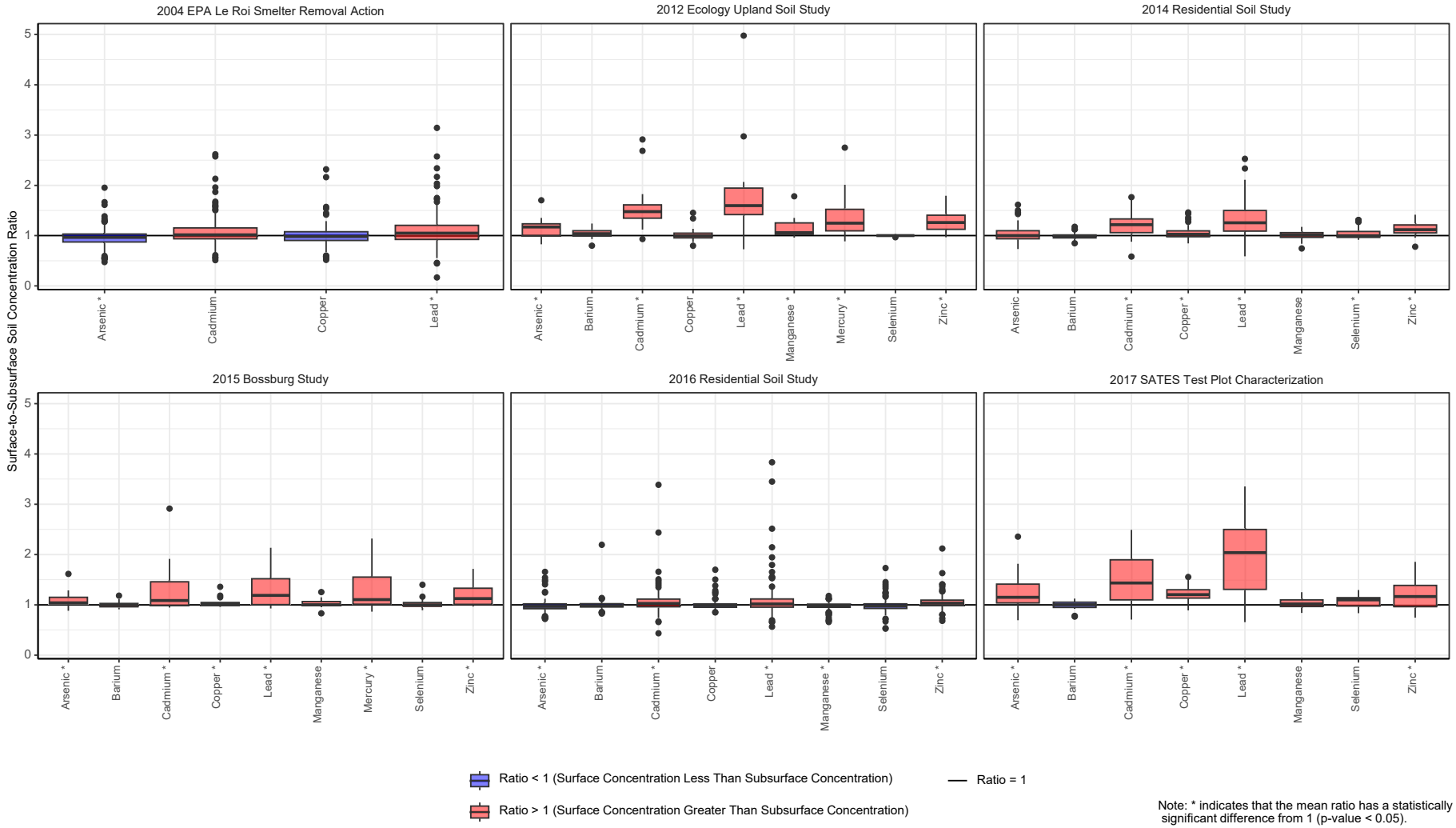


Figure 6-9. Surface-to-Subsurface Soil Concentration Ratios of Metals by Study

Final Upland RI Report

Upper Columbia River, Washington

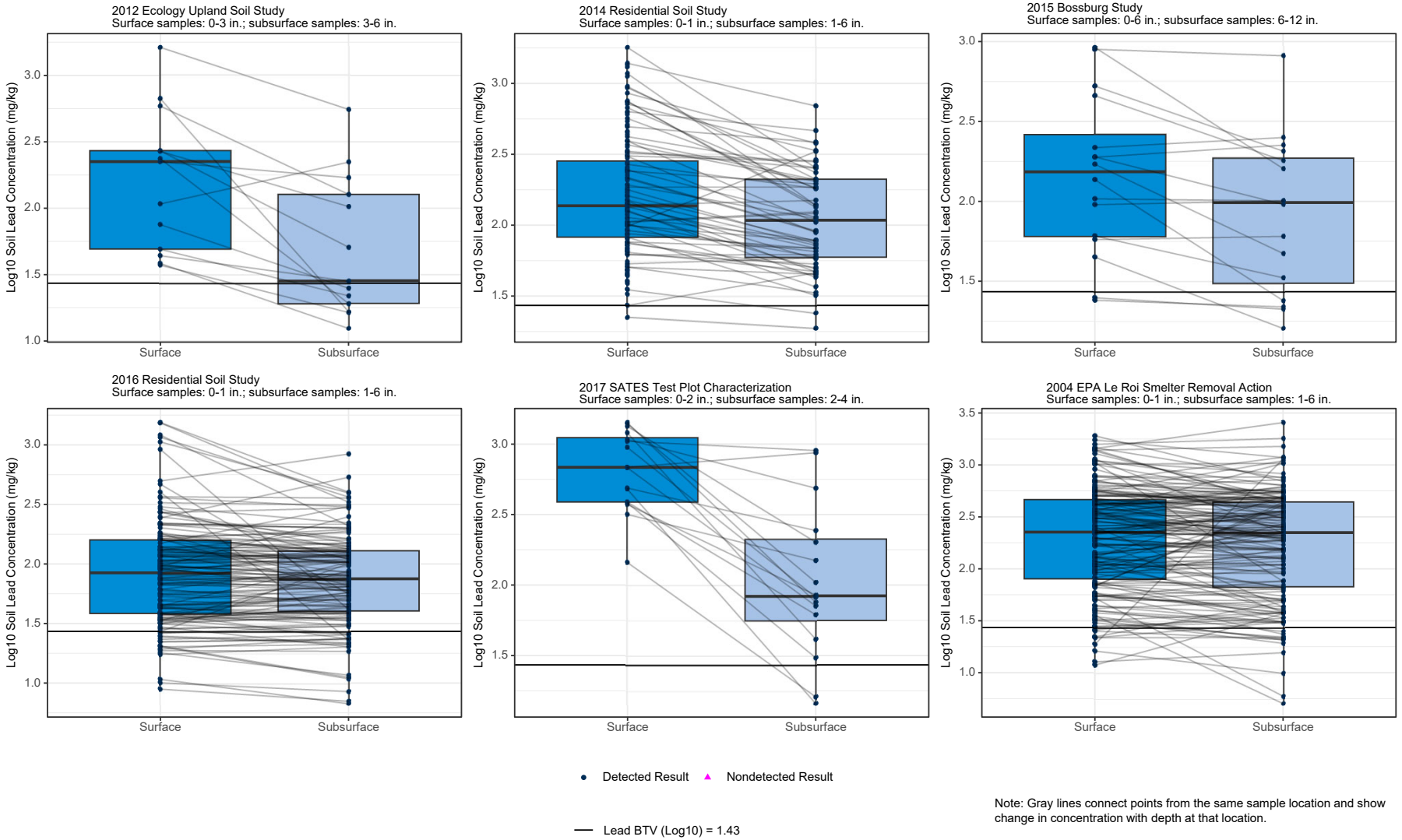


Figure 6-10a. Surface versus Subsurface Soil Lead Concentrations

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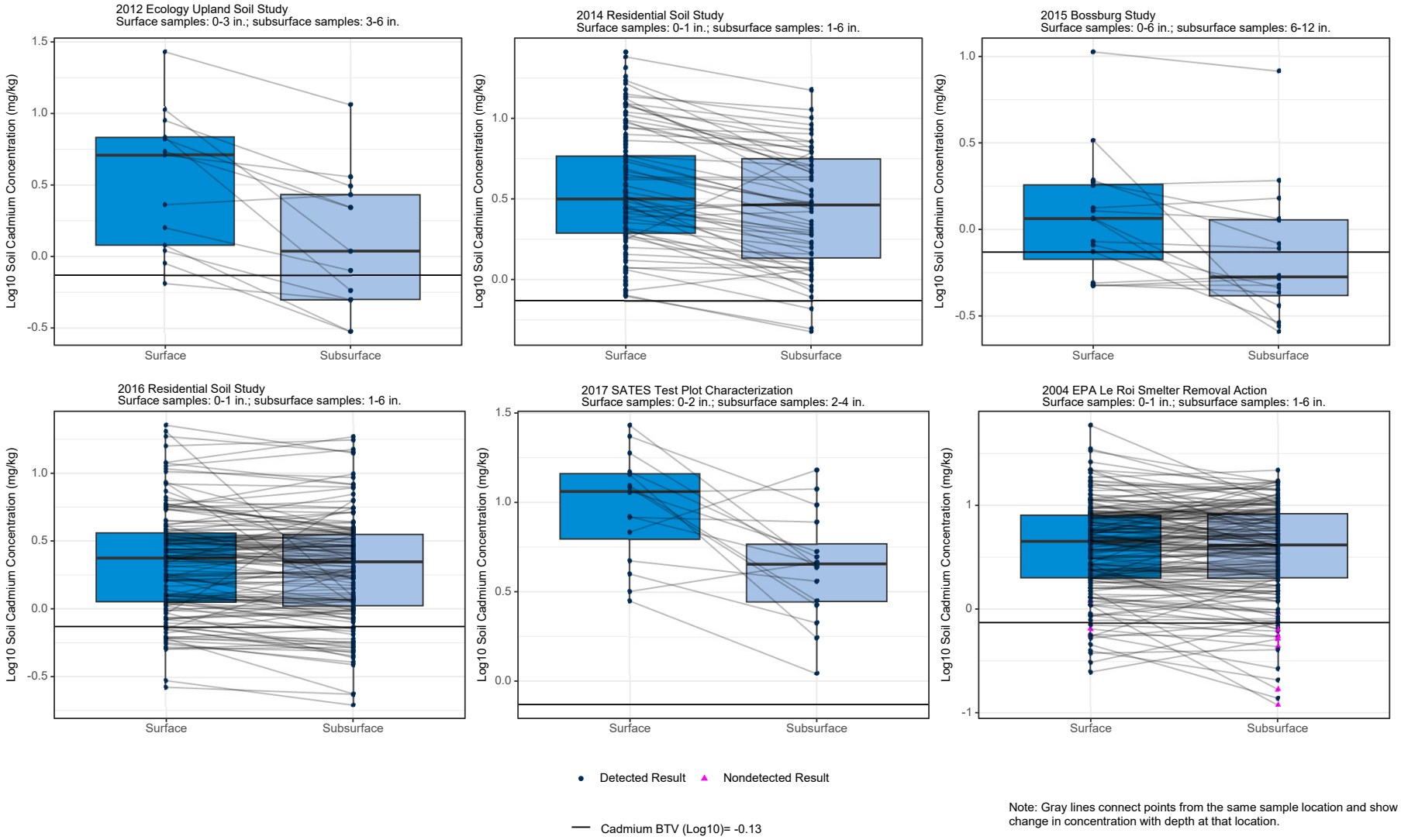


Figure 6-10b. Surface versus Subsurface Soil Cadmium Concentrations

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Upper Columbia River, Washington

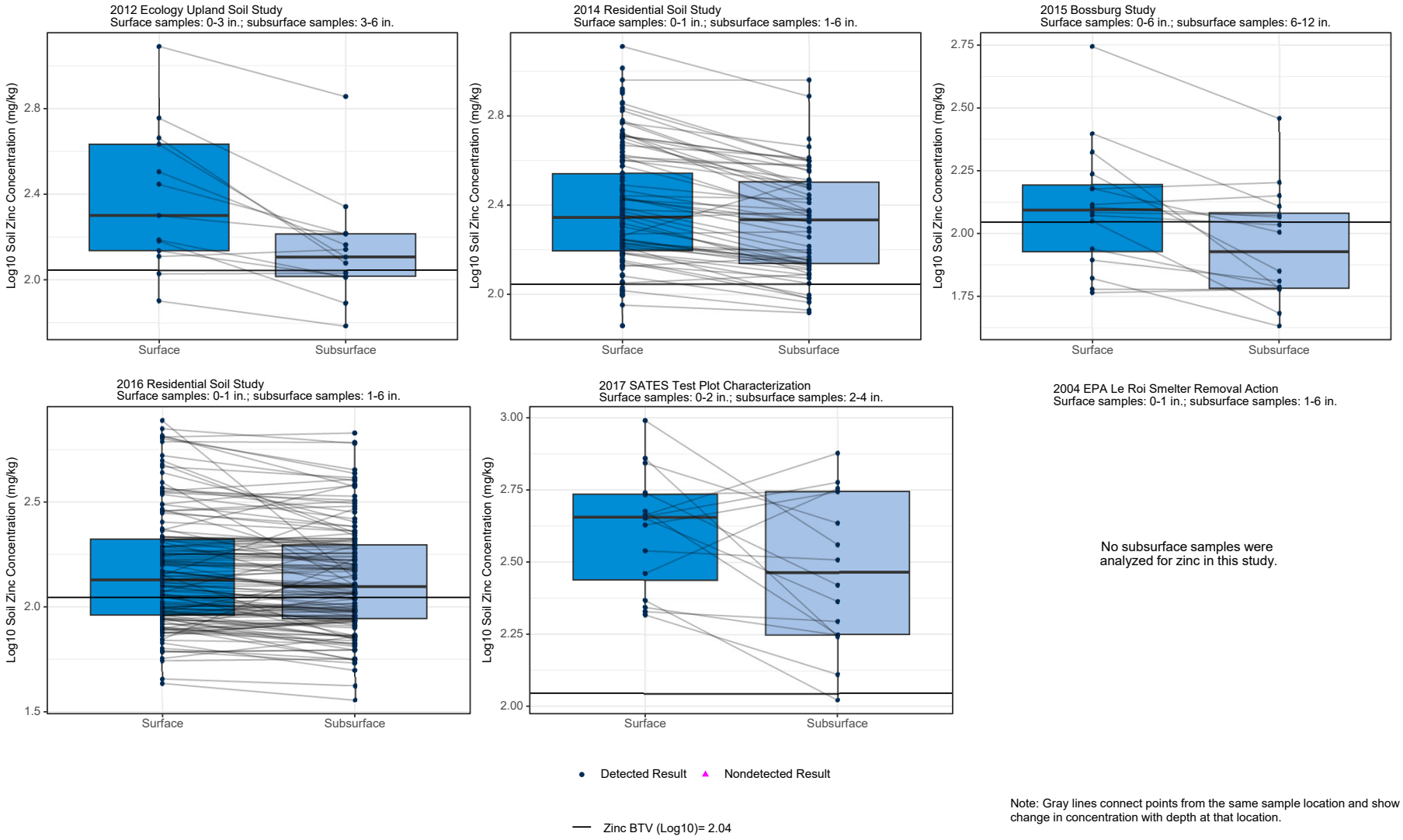


Figure 6-10c. Surface versus Subsurface Soil Zinc Concentrations

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Upper Columbia River, Washington

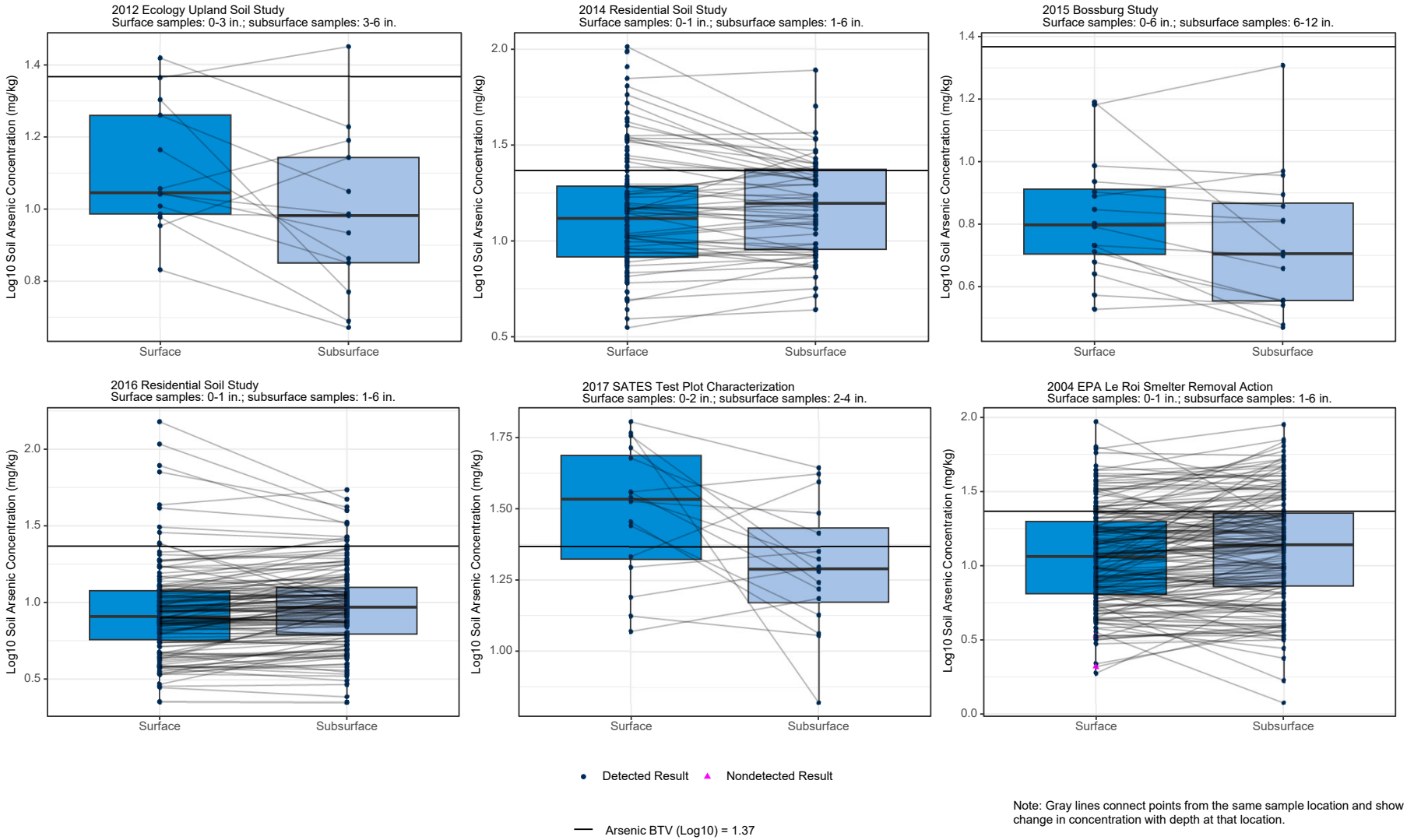


Figure 6-10d. Surface versus Subsurface Soil Arsenic Concentrations

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Upper Columbia River, Washington

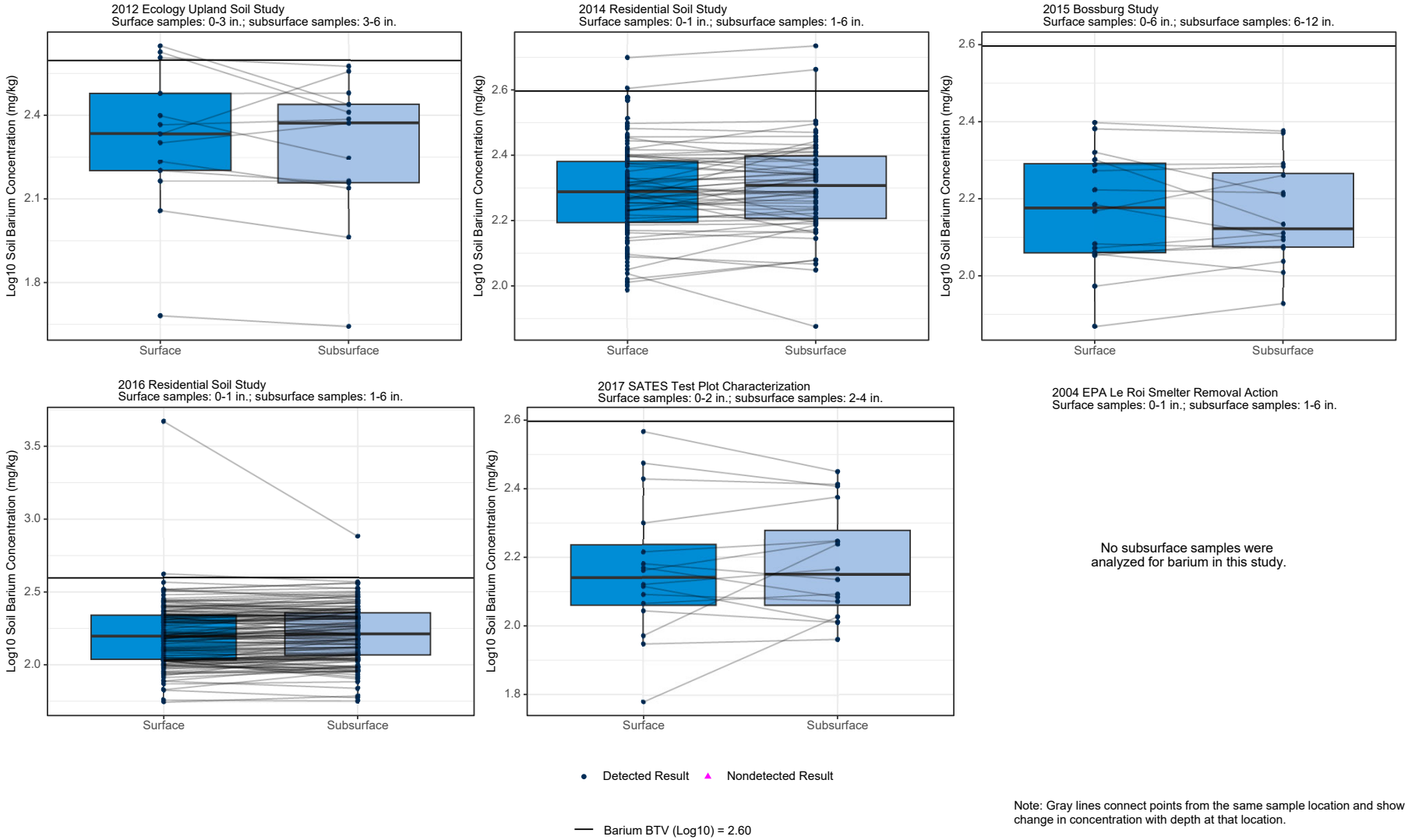


Figure 6-10e. Surface versus Subsurface Soil Barium Concentrations

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Upper Columbia River, Washington

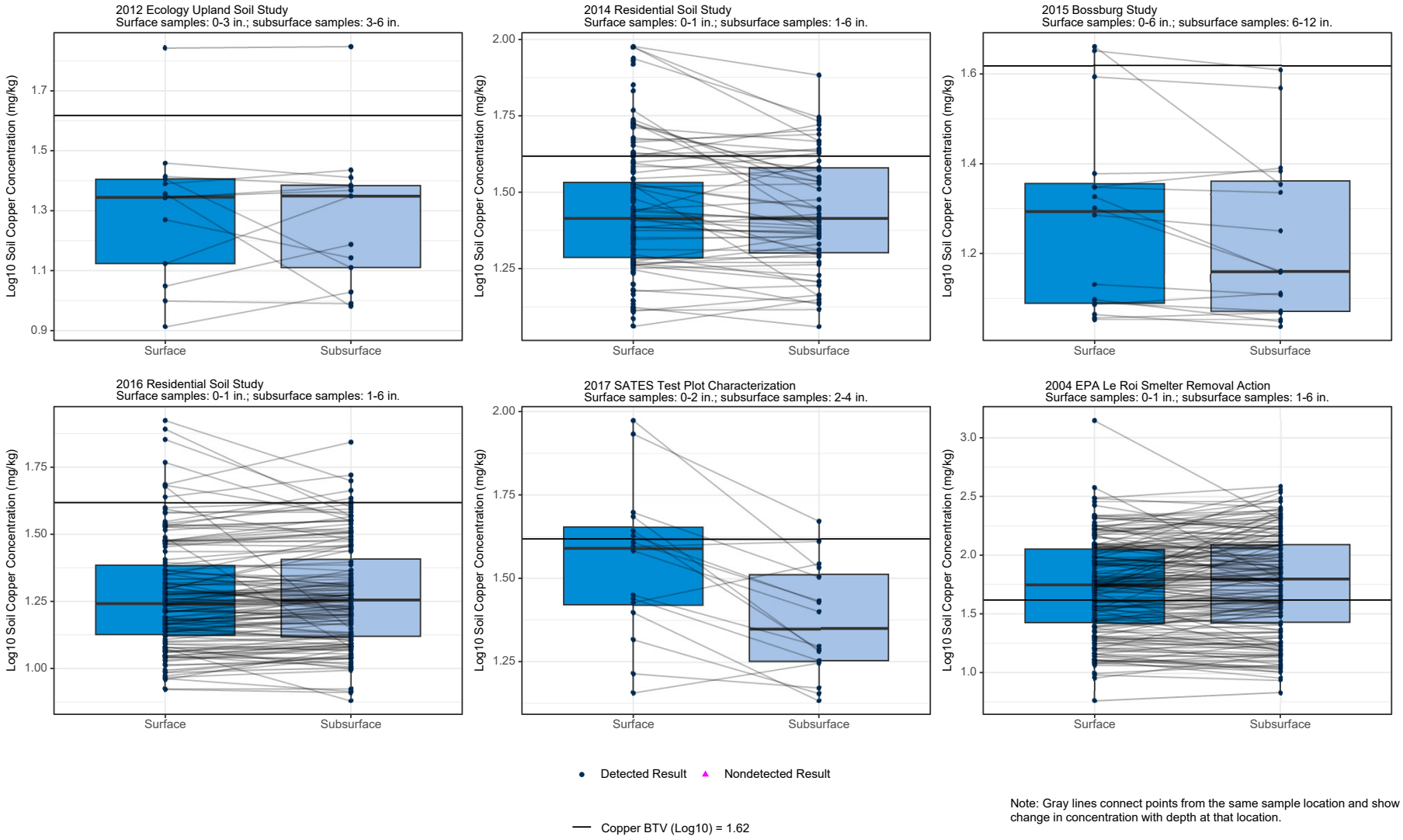


Figure 6-10f. Surface versus Subsurface Soil Copper Concentrations

Final Upland RI Report

Upper Columbia River, Washington

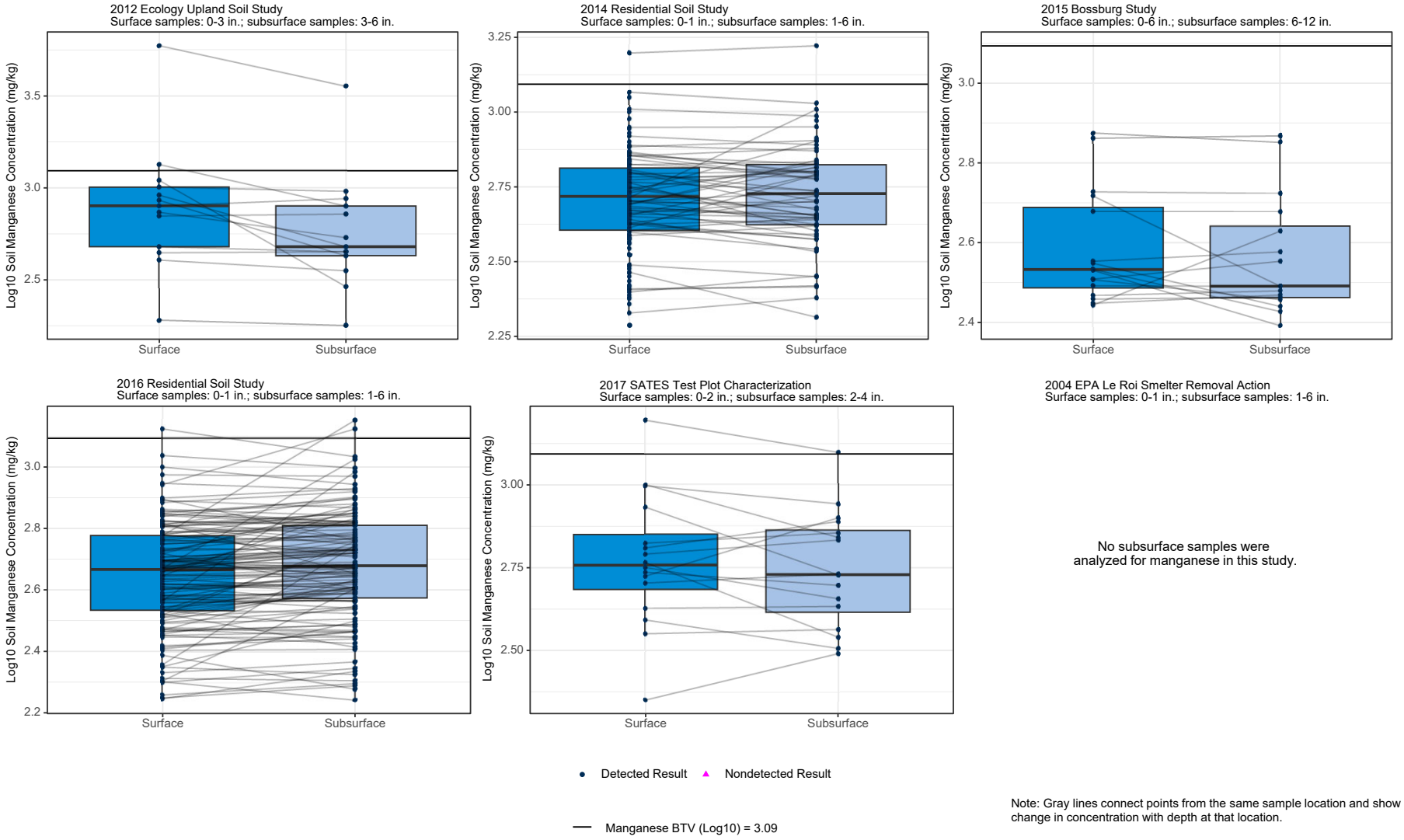
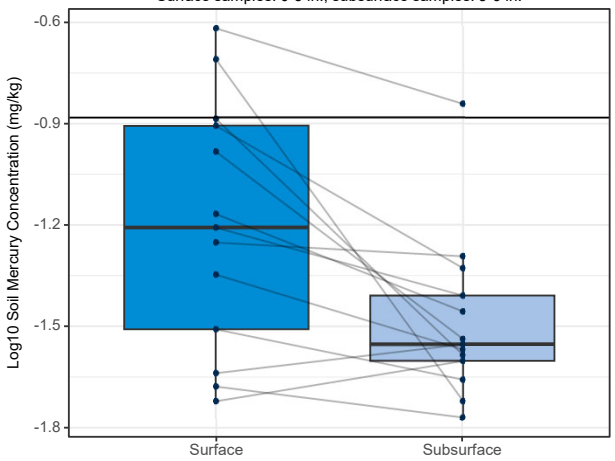


Figure 6-10g. Surface versus Subsurface Soil Manganese Concentrations

Final Upland RI Report

Upper Columbia River, Washington

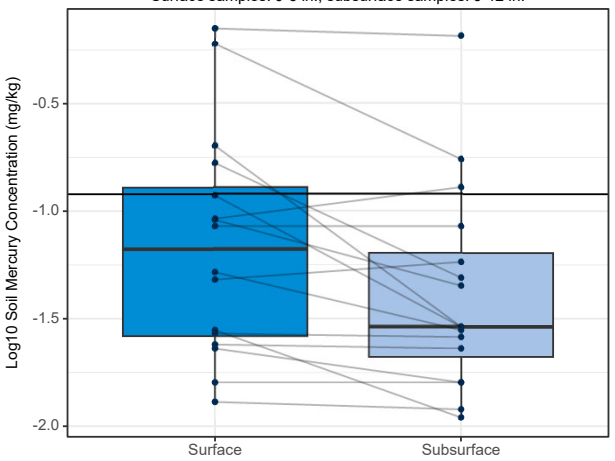
2012 Ecology Upland Soil Study
Surface samples: 0-3 in.; subsurface samples: 3-6 in.



2014 Residential Soil Study
Surface samples: 0-1 in.; subsurface samples: 1-6 in.

Mercury was not analyzed in this study.

2015 Bossburg Study
Surface samples: 0-6 in.; subsurface samples: 6-12 in.



2016 Residential Soil Study
Surface samples: 0-1 in.; subsurface samples: 1-6 in.

Mercury was not analyzed in this study.

2017 SATES Test Plot Characterization
Surface samples: 0-2 in.; subsurface samples: 2-4 in.

Mercury was not analyzed in this study.

2004 EPA Le Roi Smelter Removal Action
Surface samples: 0-1 in.; subsurface samples: 1-6 in.

No subsurface samples were analyzed for mercury in this study.

● Detected Result ▲ Nondetected Result

— Mercury BTV (Log10) = -0.85

Note: Gray lines connect points from the same sample location and show change in concentration with depth at that location.

Figure 6-10h. Surface versus Subsurface Soil Mercury Concentrations
Final Upland RI Report
Upper Columbia River, Washington

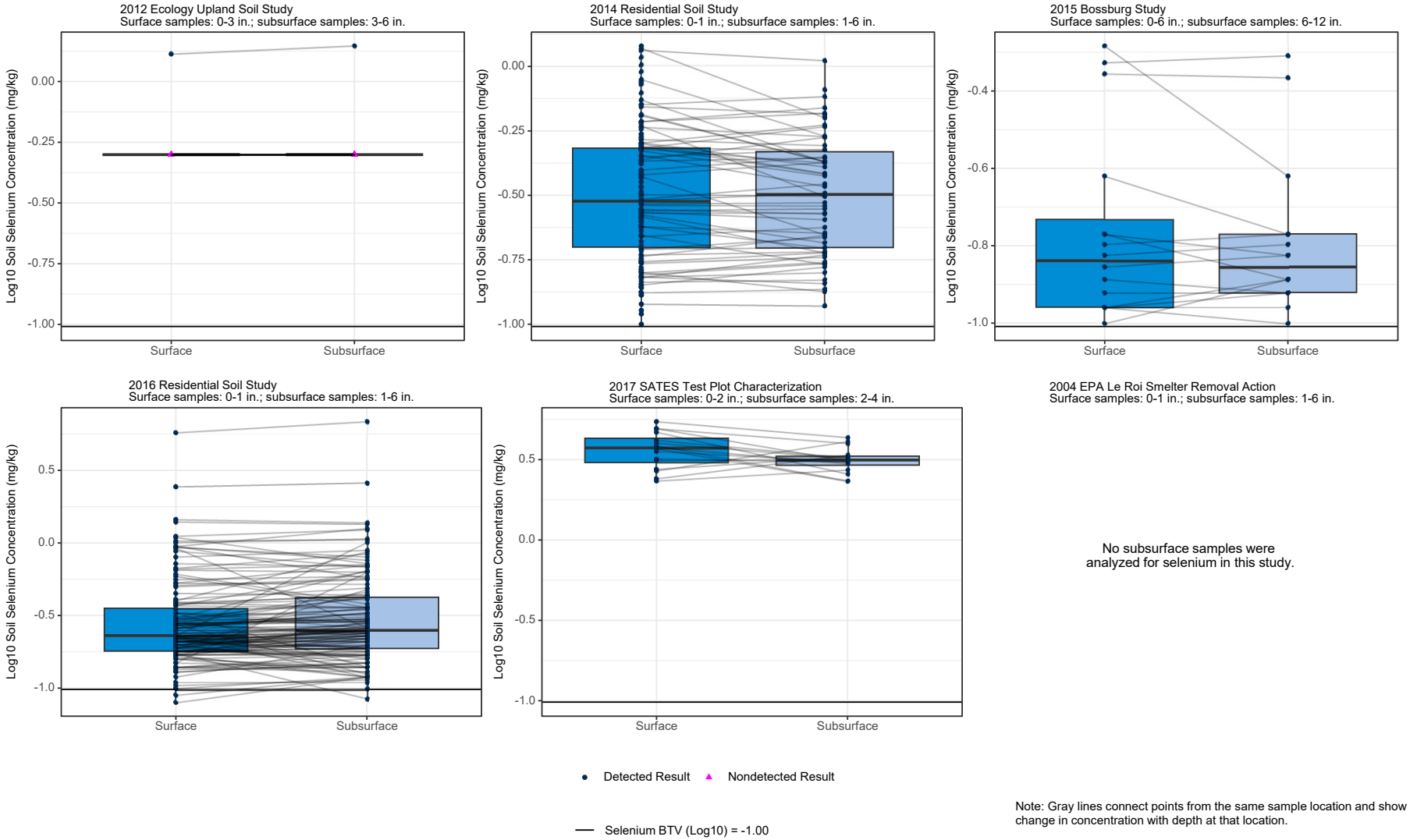


Figure 6-10i. Surface versus Subsurface Soil Selenium Concentrations

Final Upland RI Report

Upper Columbia River, Washington

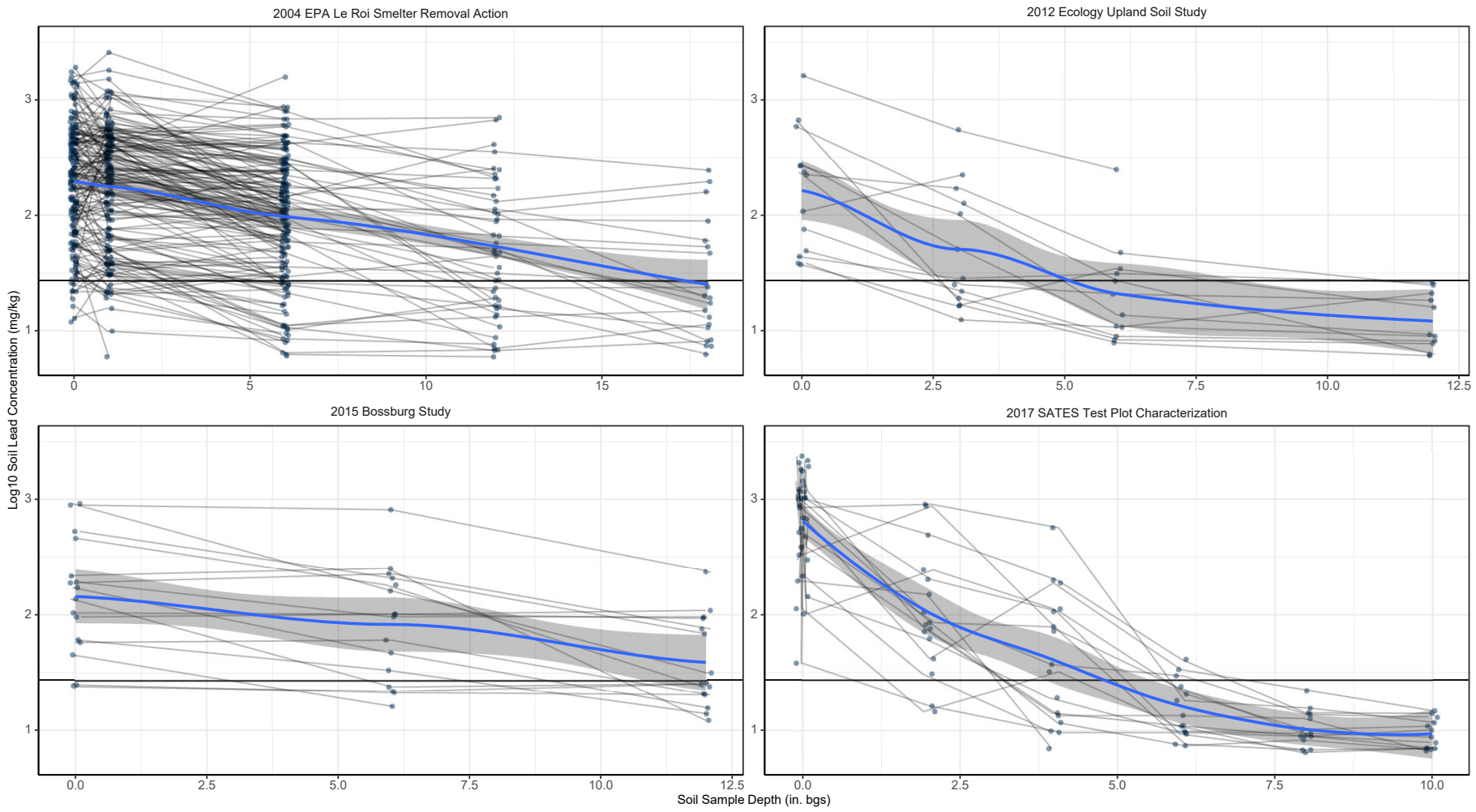


Figure 6-11a. Soil Depth Profiles of Lead Concentrations

Final Upland RI Report

Upper Columbia River, Washington

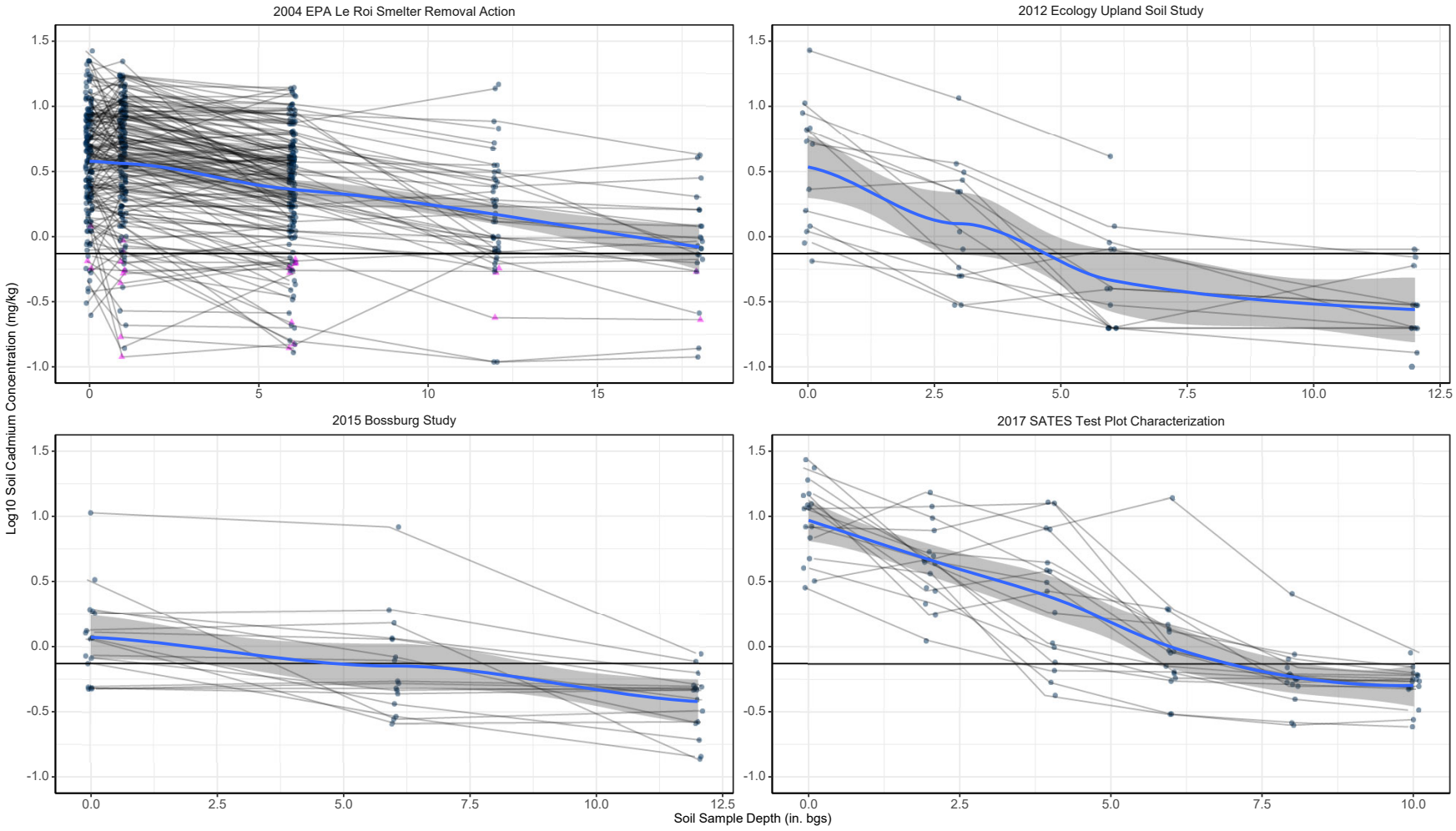


Figure 6-11b. Soil Depth Profiles of Cadmium Concentrations

Final Upland RI Report

Upper Columbia River, Washington

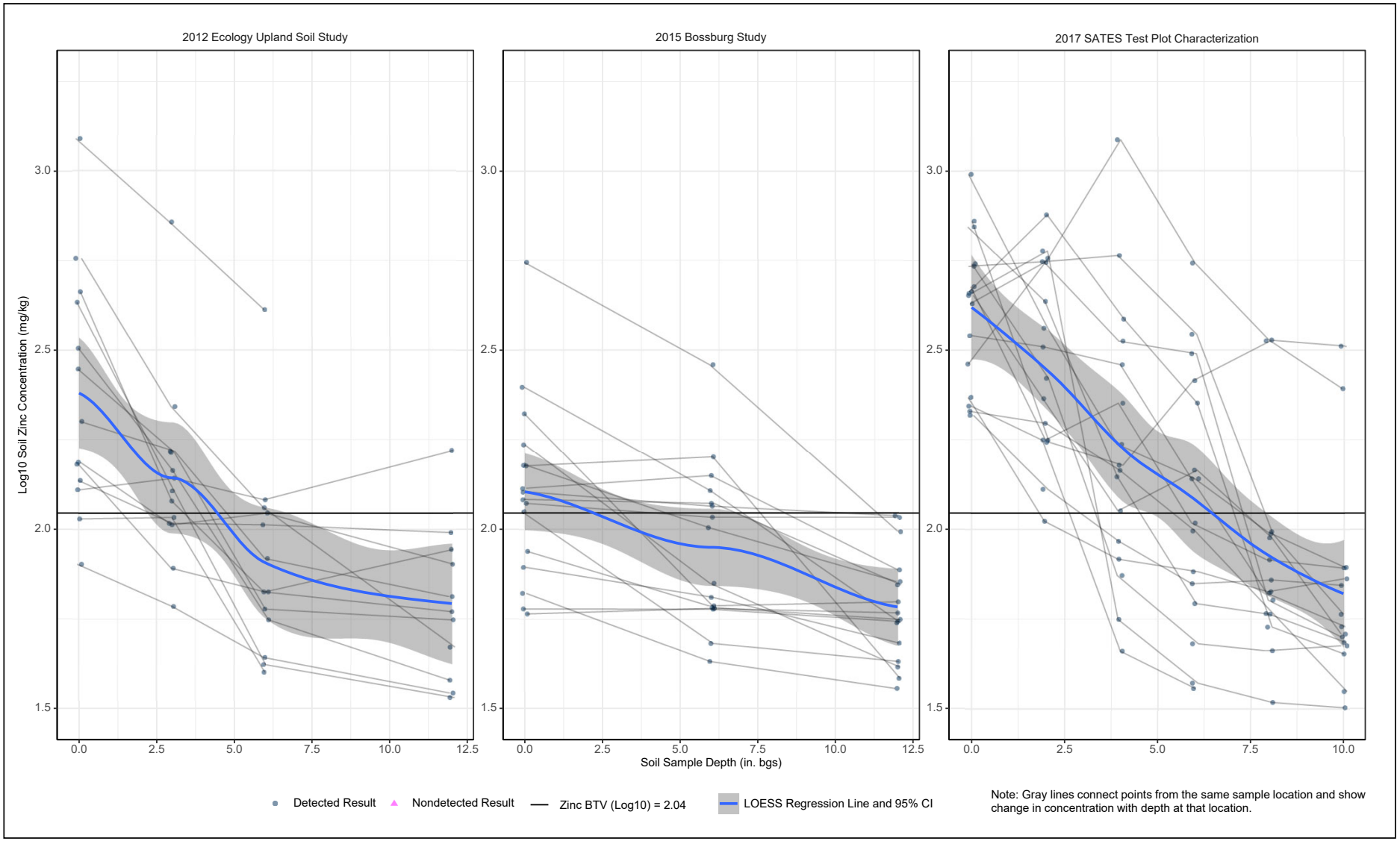


Figure 6-11c. Soil Depth Profiles of Zinc Concentrations
Final Upland RI Report
Upper Columbia River, Washington

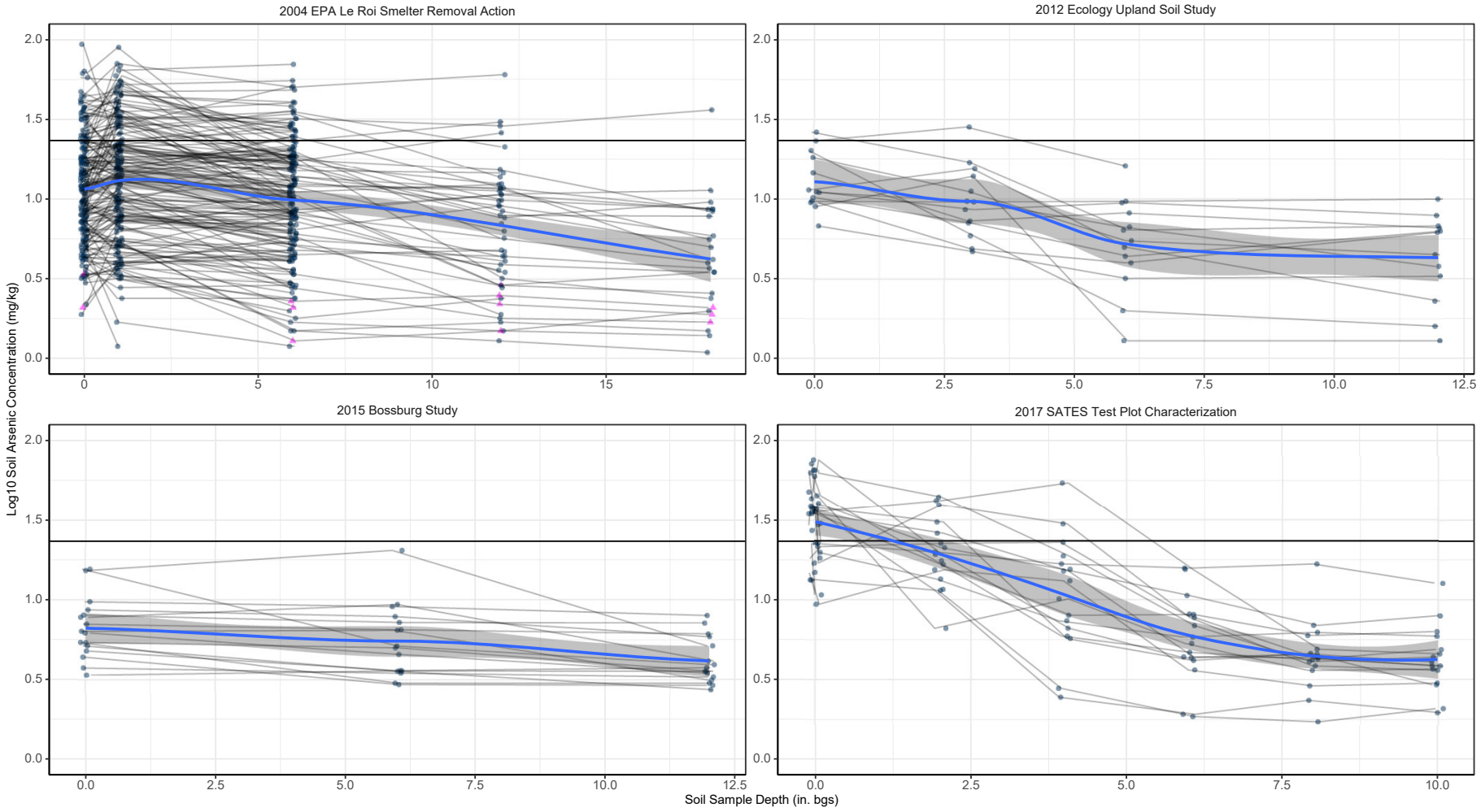


Figure 6-11d. Soil Depth Profiles of Arsenic Concentrations
Final Upland RI Report
Upper Columbia River, Washington

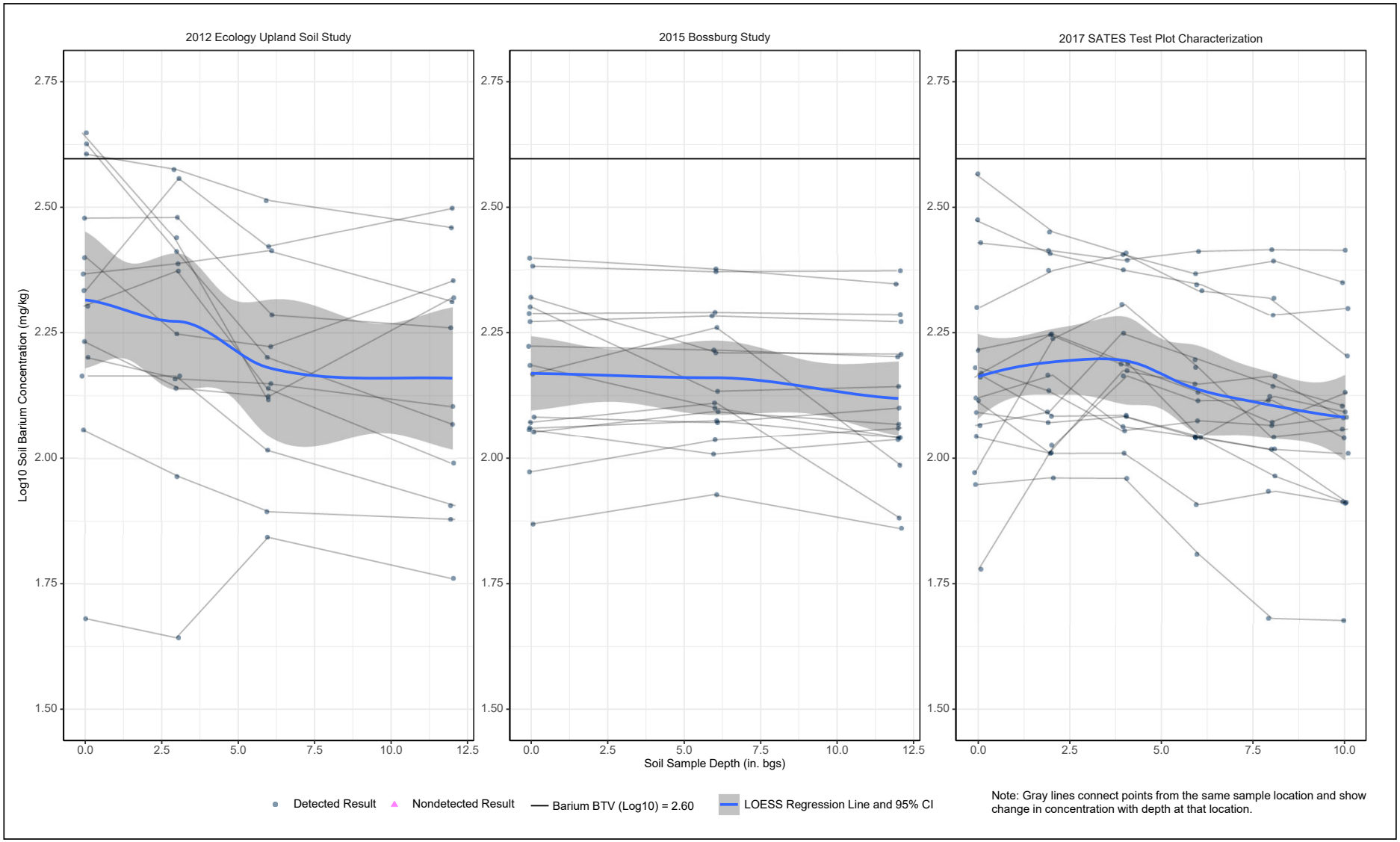


Figure 6-11e. Soil Depth Profiles of Barium Concentrations

Final Upland RI Report

Upper Columbia River, Washington

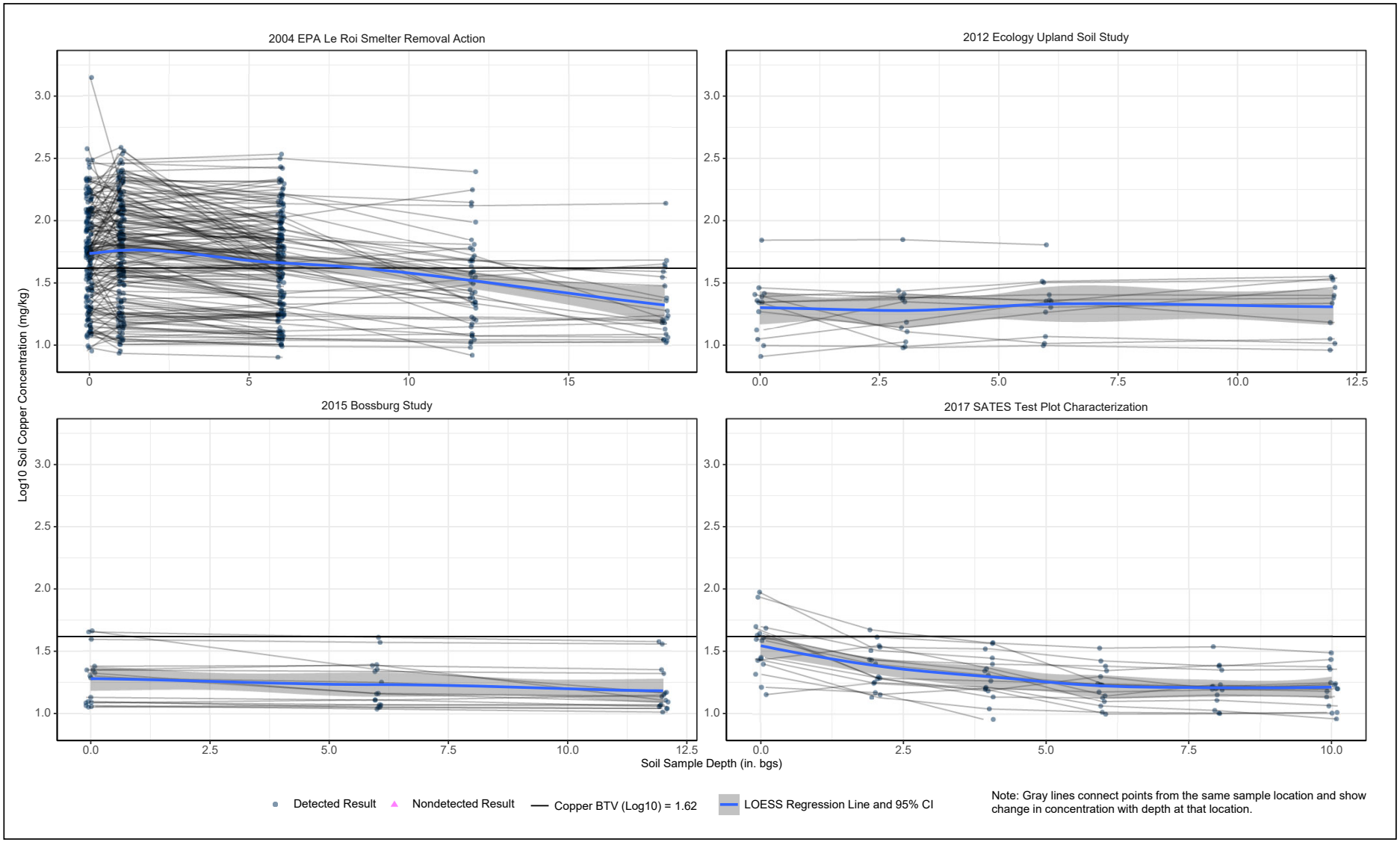


Figure 6-11f. Soil Depth Profiles of Copper Concentrations
Final Upland RI Report
Upper Columbia River, Washington

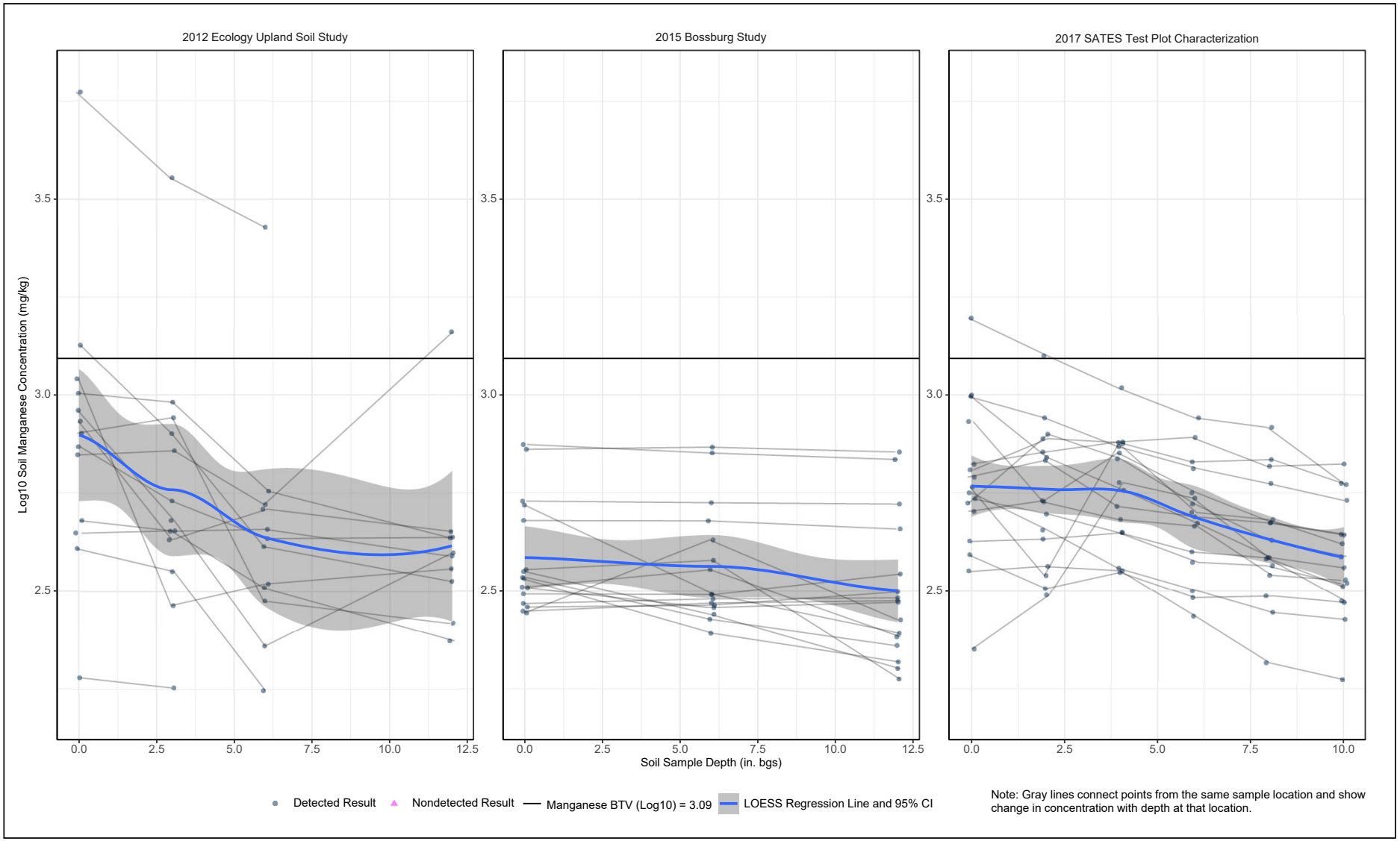


Figure 6-11g. Soil Depth Profiles of Manganese Concentrations

Final Upland RI Report

Upper Columbia River, Washington

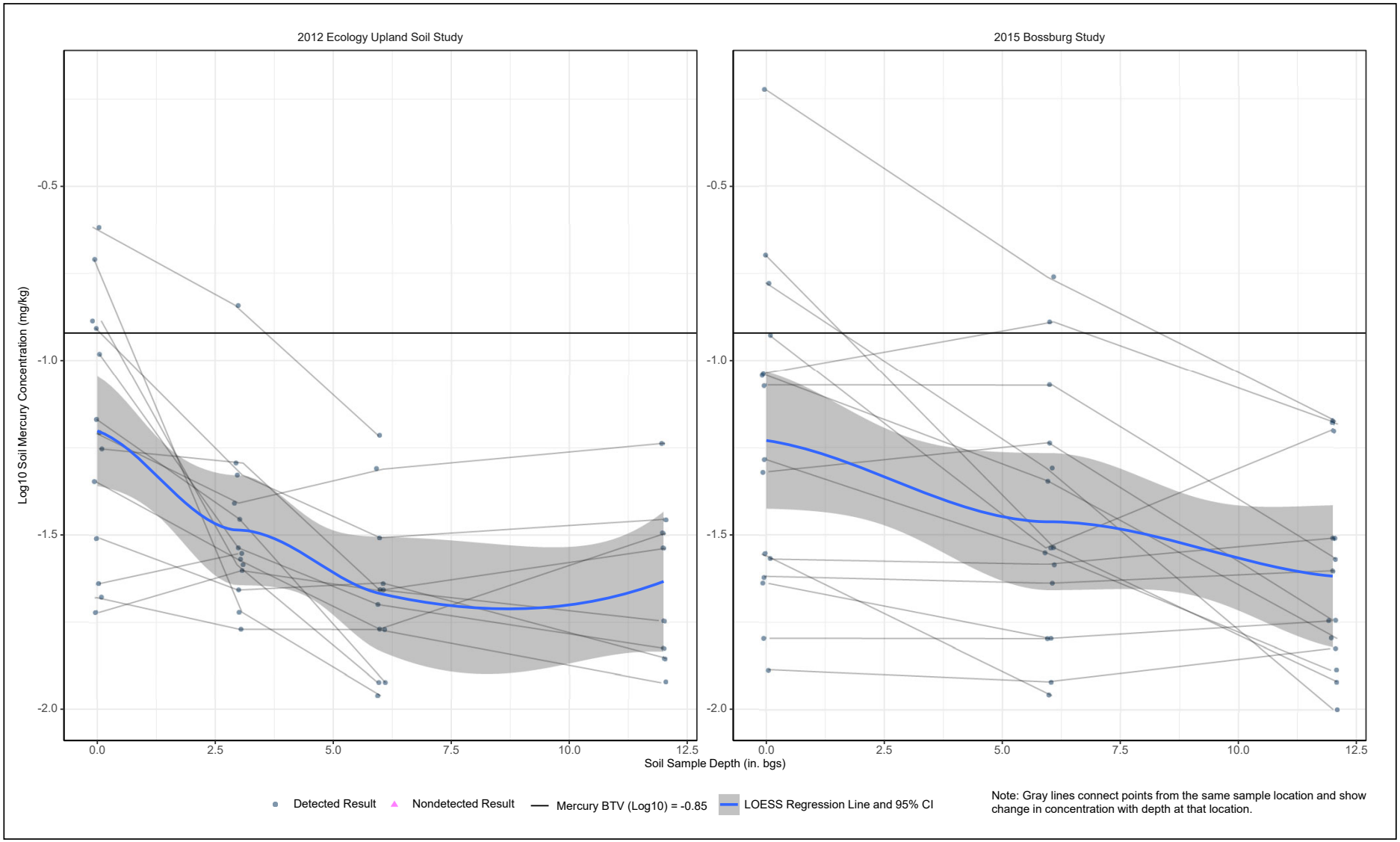


Figure 6-11h. Soil Depth Profiles of Mercury Concentrations
Final Upland RI Report
Upper Columbia River, Washington

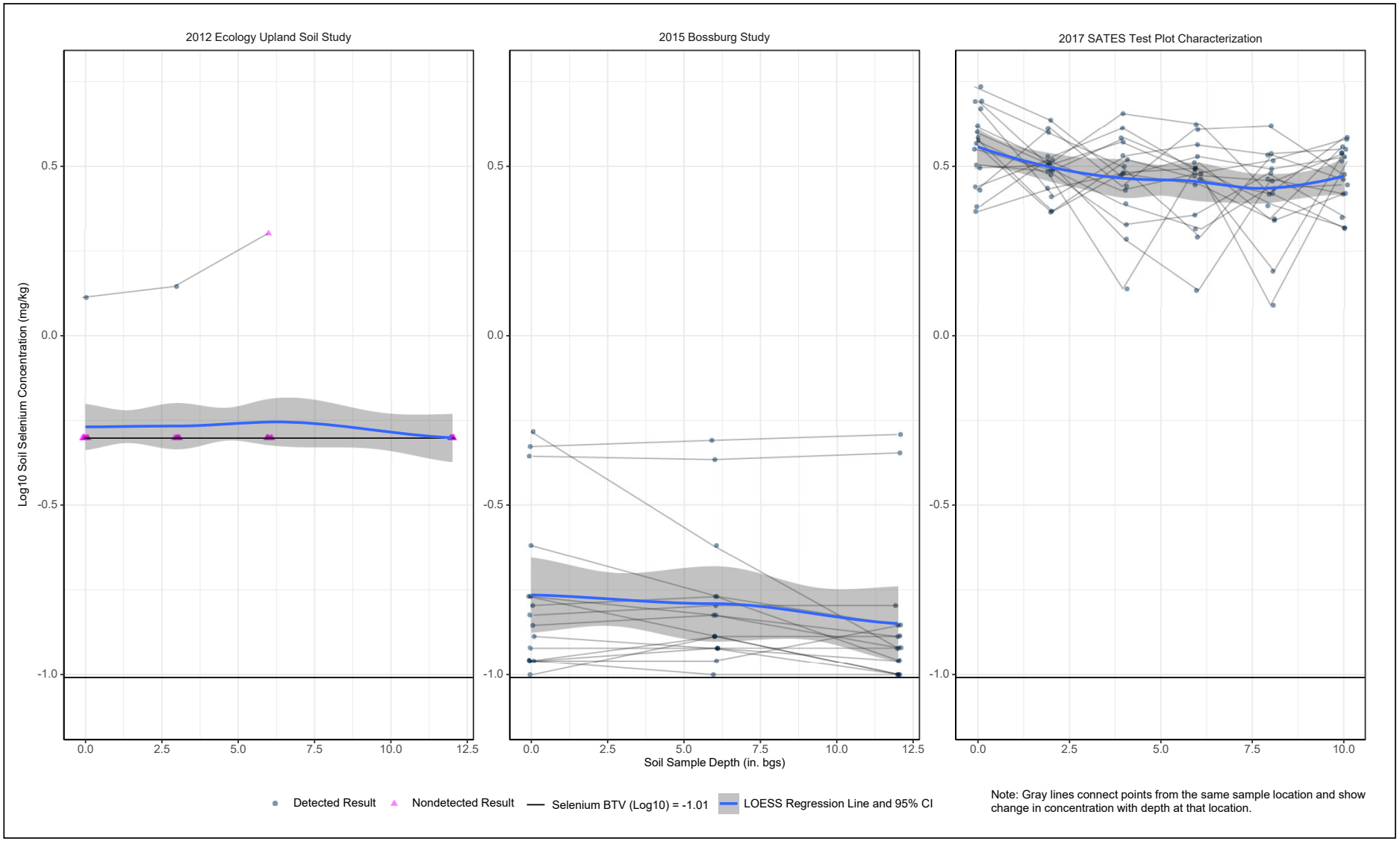


Figure 6-11i. Soil Depth Profiles of Selenium Concentrations

Final Upland RI Report

Upper Columbia River, Washington

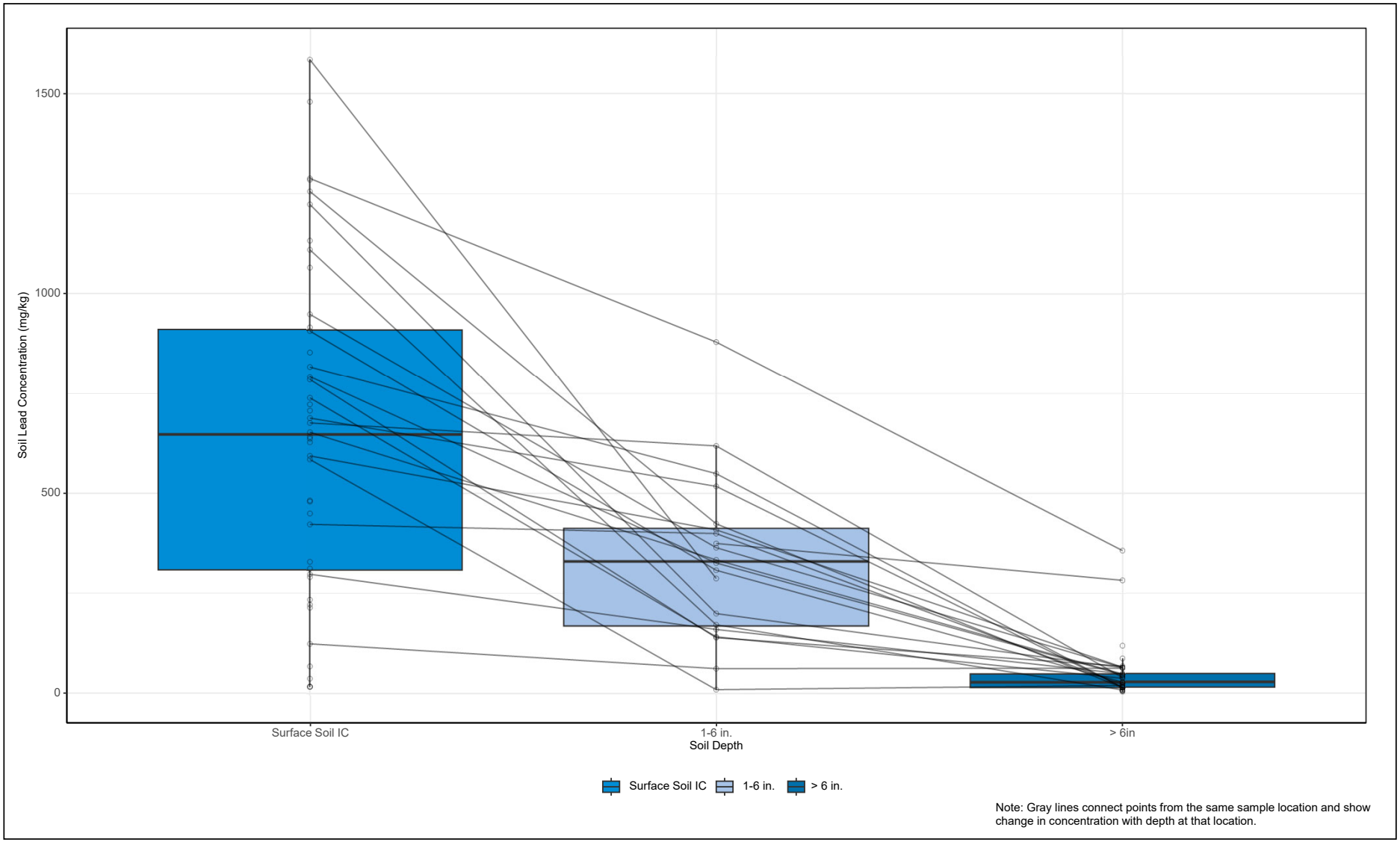
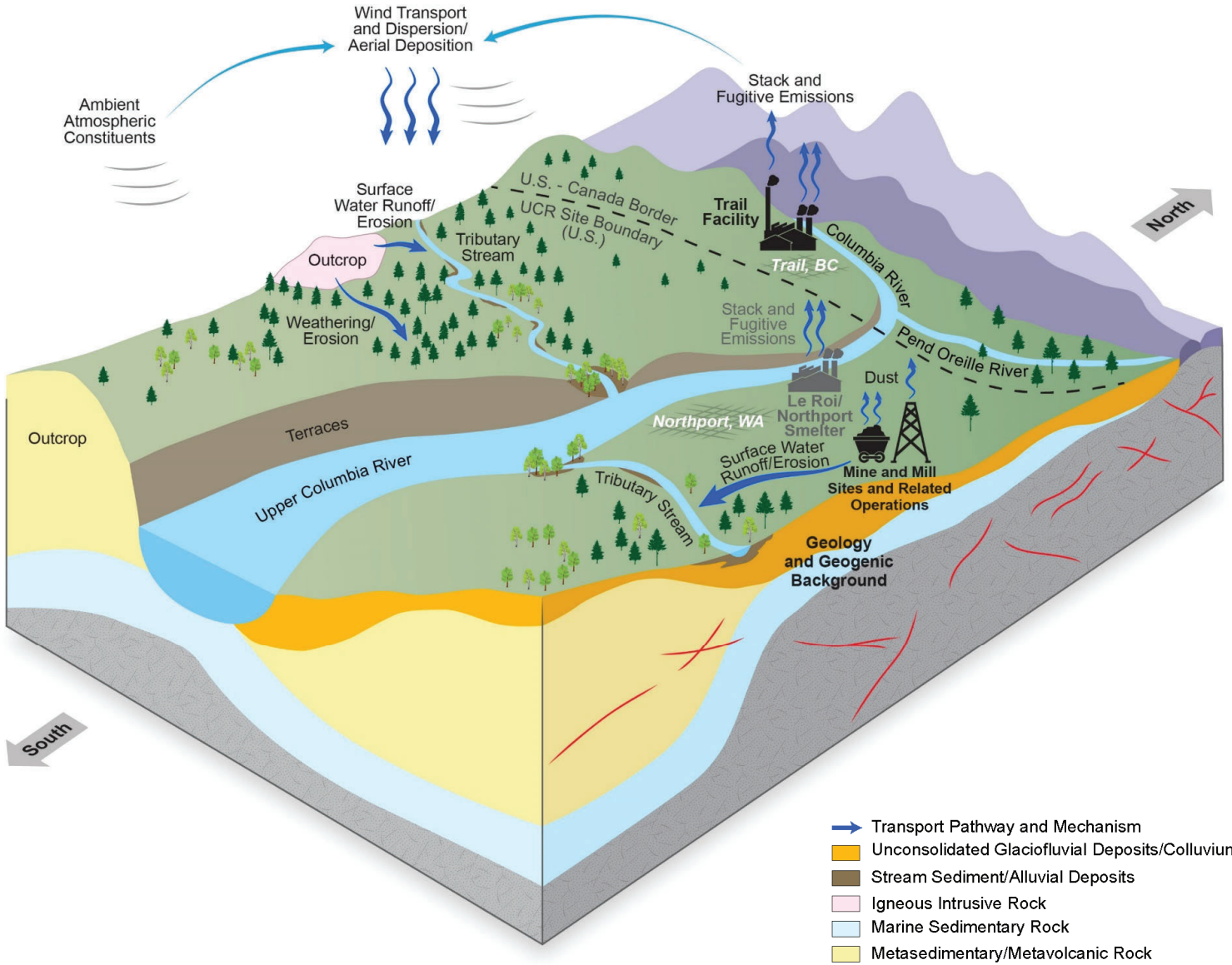


Figure 6-12. Boxplots of Soil Lead Concentrations by Depth from the 2014 and 2016 Residential Soil Studies, 2015 TCRA and TCRA Memorandum, and 2017–2018 VRA

Final Upland RI Report
Upper Columbia River, Washington

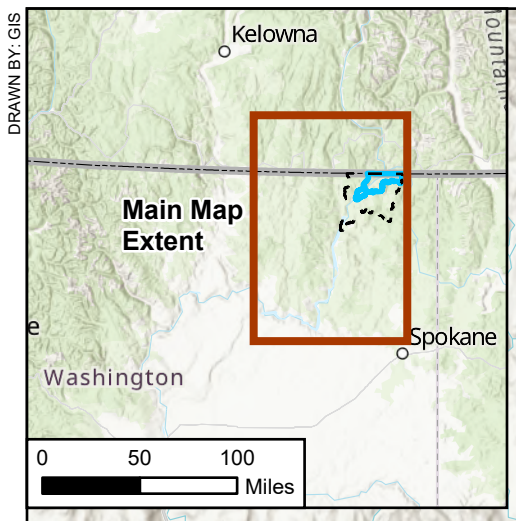


Notes:
This diagram is not to scale.
Other anthropogenic sources (e.g., roads, railways) are not shown.
Mine and mill sites and related operations include solid waste or tailings disposal.

Figure 7-1. Physical/Chemical CSM
Final Upland RI Report
Upper Columbia River, Washington

Maps

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Columbia River
Bonnington Range
Christina Range
Rossland Range
2306 m
2272 m
Trail Smelter
Trail
Greenwood Smelter
Boundary Falls Smelter
Granby Smelter
U.S. - Canada Border
Pend Oreille River
Waneta Dam
Northport
Le Roi/Northport Smelter
Lime Creek Mountain
Kettle River
Onion Creek
Thompson Ridge
Bossburg
Evans
7139 ft
Republic
Marcus
OU 1
OU 2
Kettle Falls
Colville
Colville Smelter
Okanogan County
Ferry County
Columbia River
Colville Valley
North Basin
Huckleberry Range
Stevens County
Pend Oreille County
6380 ft
6771 ft
6009 ft
6853 ft
Iron Mountains
Sanpoil River
Oregon City Ridge
Summit Valley
Colville River
Colville Indian Reservation
Gold Mountain Ridge
Huckleberry Mountains
Douglas County
Coulee Dam
Grand Coulee Dam
Columbia River
Spokane Indian Reservation
Walkers Prairie
Grant County
Deer Meadows
Lincoln County
4367 ft
4636 ft
Bald Ridge
Prairie

Legend

- City/Town
- Major Dam
- Smelter
- ADA as Defined by the 2014 Soil Study (TAI 2015a)
- OU 3 Study Area
- Reservation
- County Boundaries

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0 3.75 7.5 15 Miles

N

Map 1-1. **Regional Map of the Upper Columbia River Site**
Final Upland RI Report
Upper Columbia River, Washington

Source: Esri - World Topographic Map; NAD 1983 UTM Zone 11N

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GEOLOGIC UNITS

VOLCANIC AND SEDIMENTARY ROCKS

Subgreenschist-Grade Metamorphism

- Mv — Miocene volcanic rocks
- Os — Oligocene sedimentary rocks
- Evs — Eocene volcanic and sedimentary rocks
- TKs — Tertiary to Cretaceous sedimentary rocks
- Kvs — Cretaceous volcanic and sedimentary rocks
- KJvs — Cretaceous and Jurassic volcanic and sedimentary rocks

METAVOLCANIC AND METASEDIMENTARY ROCKS

Subgreenschist- (West) and Greenschist- (East) Grade Metamorphism

- Jvs — Jurassic rocks

Greenschist-Grade Metamorphism

- TrPvs — Triassic and Permian rocks
- Pzs — Paleozoic metasedimentary rocks
- COvs — Carboniferous to Ordovician rocks
- CZs — Carboniferous to Late Proterozoic Z metasedimentary rocks
- Zvs — Proterozoic Z rocks
- Ys — Proterozoic Y metasedimentary rocks

METAMORPHIC ROCKS

Amphibolite-Grade (Thermal) Metamorphism

Layered Metamorphic Rocks

- pTm — pre-Tertiary rocks
- pJm — pre-Jurassic rocks
- TrPm — Triassic and Permian rocks
- pCm — Precambrian rocks

Mixed Metamorphic and Igneous Rocks

- TKmi — Tertiary and Cretaceous rocks
- Kmi — Cretaceous rocks
- KJmi — Cretaceous and Jurassic rocks

Thermal and/or Dynamic Metamorphism

- Pzog — Paleozoic orthogneiss
- pTog — pre-Tertiary orthogneiss
- Mzog — Mesozoic orthogneiss
- Kog — Cretaceous orthogneiss
- KJog — Cretaceous and Jurassic orthogneiss
- Jog — Jurassic orthogneiss
- TrPg — Triassic orthogneiss

INTRUSIVE ROCKS

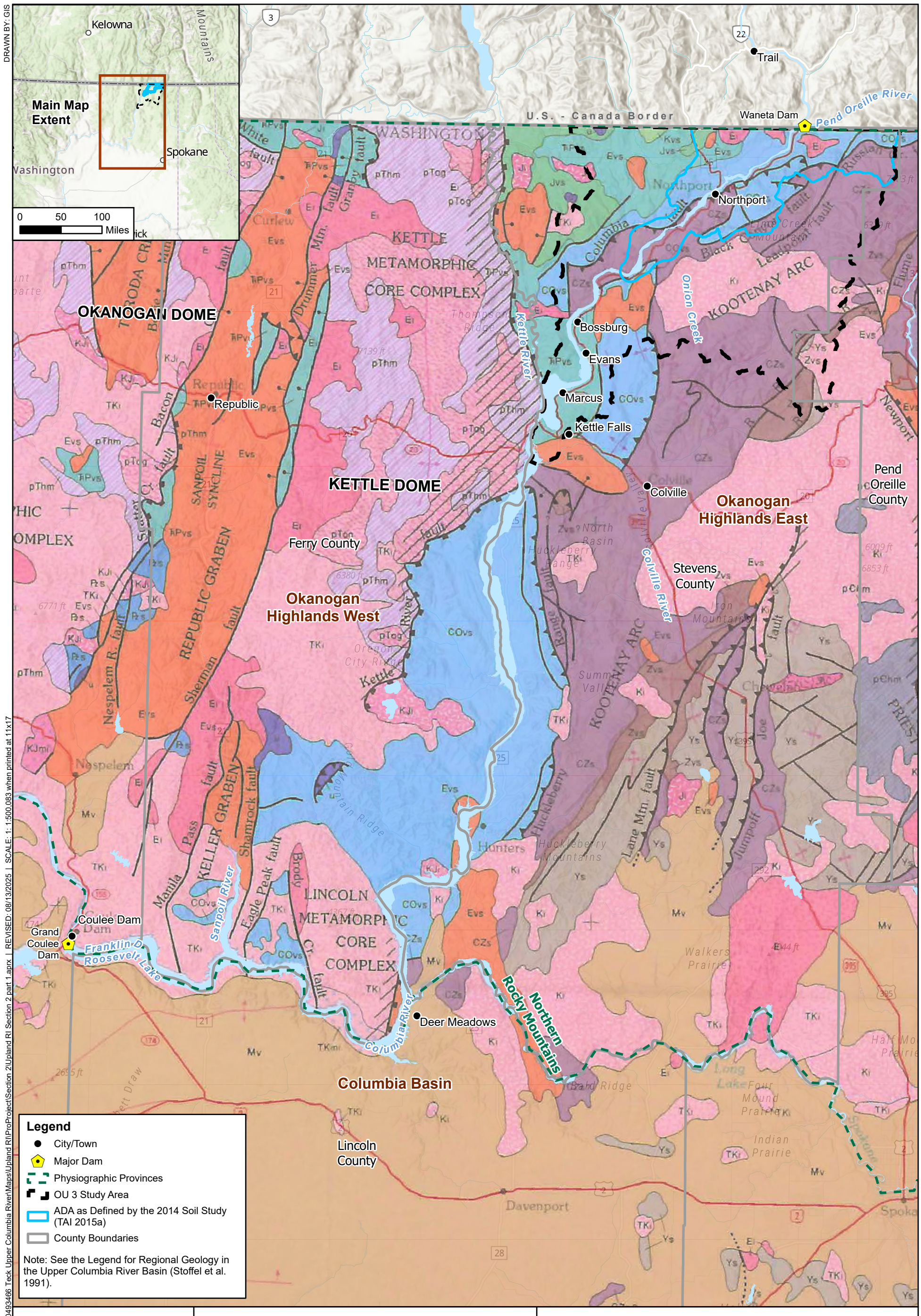
Not Metamorphosed

- Ei — Eocene rocks
- Pi — Paleocene rocks
- TKi — Tertiary and Cretaceous rocks
- Ki — Cretaceous rocks
- KJi — Cretaceous and Jurassic rocks
- Ji — Jurassic rocks
- TrPi — Triassic rocks
- u — Ultrabasic rocks (age uncertain)

Source: Stoffel et al. (1991)

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Legend for Regional Geology in the Upper Columbia River Basin
Final Upland RI Report
Upper Columbia River, Washington



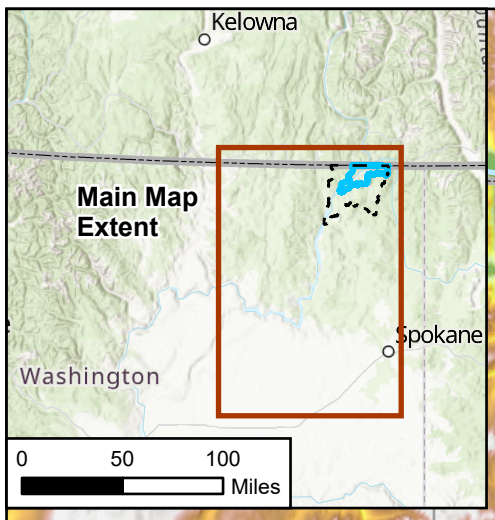
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Map 2-1. **Physiographic Provinces and Regional Geology in the Upper Columbia River Basin**
Final Upland RI Report
Upper Columbia River, Washington

Source: Esri - World Topographic Map; NAD 1983 UTM Zone 11N

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DRAWN BY: GIS



Trail
U.S. - Canada Border
Waneta Dam
Pend Oreille River
Abercrombie Mountain
North Stone Mountain Area
Northport
Kettle River
Onion Creek
Kettle Mountains
Bossburg
Evans
Marcus
Republic
Kettle Falls
Selkirk Mountains
Colville
Pend Oreille County
Ferry County
Stevens County
Colville River
Columbia River
Stranger Mountain
Chewelah Mountains
Sanpoil Mountains
Sanpoil River
Huckleberry Mountains
Coulee Dam
Grand Coulee Dam
Franklin D Roosevelt Lake
Deer Meadows
Lincoln County

Legend

- City/Town
- Major Dam
- OU 3 Study Area
- ADA as Defined by the 2014 Soil Study (TAI 2015a)

Elevation (ft amsl)

10,000

500

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0 2.5 5 10 Miles

N

Map 2-2. **Regional Topography**
Final Upland RI Report
Upper Columbia River, Washington

Source: Esri - World Topographic Map; NAD 1983 UTM Zone 11N

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Proterozoic

- Yar-Proterozoic Y, Metasedimentary and Metavolcanic Rocks, Priest River Group, Meta-argillite
- Ycb-Proterozoic Y, Metasedimentary and Metavolcanic Rocks, Priest River Group, Metacarbonate
- Yib-Proterozoic Y, Intrusive Rocks, Basic (Mafic) Intrusive Rocks
- Yms(1)-Proterozoic Y, Metasedimentary and Metavolcanic Rocks, Belt Supergroup, Belt Supergroup, Prichard Formation
- Yms(2)-Proterozoic Y, Metasedimentary and Metavolcanic Rocks, Belt Supergroup, Ravalli Group, Consists of the Belt Supergroup, Ravalli Group, St Regis, Revett, and Burke Formations
- Yms(3)-Proterozoic Y, Metasedimentary and Metavolcanic Rocks, Belt Supergroup, Belt Supergroup, Wallace Formation
- Yq-Proterozoic Y, Metasedimentary and Metavolcanic Rocks, Priest River Group, Quartzite
- Zcg-Proterozoic Z, Metasedimentary and Metavolcanic Rocks, Windermere Group, Metaconglomerate, Consists of the Conglomerate Member of the Huckleberry Formation (Campbell and Loofbourow, 1962) and the Shedroof Conglomerate
- Zib-Proterozoic Z, Intrusive Rocks, Basic (Mafic) Intrusive Rocks
- Zmm-Proterozoic Z, Metasedimentary and Metavolcanic Rocks, Windermere Group, Marine Metasedimentary Rocks, Consists of the Monk Formation
- Zmv-Proterozoic Z, Metasedimentary and Metavolcanic Rocks, Windermere Group, Metavolcanic Rocks, Consists of the Greenstone Member of the Huckleberry Formation (Campbell and Loofbourow, 1962) and the Leola Volcanics
- Zq-Proterozoic Z, Metasedimentary and Metavolcanic Rocks, Windermere Group, Quartzite, Consists of the Three Sisters Formation

Precambrian

- pChm-Precambrian, Metamorphic Rocks, Sedimentary Protolith, Heterogeneous Metamorphic Rocks, Includes the Gneiss Near Chester Creek (Weis, 1968) and the Gneiss Near Round Mountain (Weis, 1968)

Cambrian

- CZq-Cambrian and Proterozoic Z, Metasedimentary and Metavolcanic Rocks, Quartzite, Consists of the Addy and Gypsy Quartzites
- Ccb-Cambrian, Metasedimentary and Metavolcanic Rocks, Metacarbonate, Includes the Reeves Limestone Member of the Maitlen Phyllite
- Cmm-Cambrian, Metasedimentary and Metavolcanic Rocks, Marine Metasedimentary Rocks, Consists of Part of the Maitlen Phyllite

Ordovician

- Ocb-Ordovician, Metasedimentary and Metavolcanic Rocks, Metacarbonate, Consists of Part of the Covada Group
- Omm-Ordovician, Metasedimentary and Metavolcanic Rocks, Marine Metasedimentary Rocks, Consists of Part of the Covada Group
- Omv-Ordovician, Metasedimentary and Metavolcanic Rocks, Metavolcanic Rocks, Consists of Part of the Covada Group
- Oar-Ordovician, Metasedimentary and Metavolcanic Rocks, Meta-argillite, Consists of the Ledbetter Slate
- OCcb-Ordovician and Cambrian, Metasedimentary and Metavolcanic Rocks, Metacarbonate, Consists of the Metaline Formation

Silurian

- Smm-Silurian, Metasedimentary and Metavolcanic Rocks, Marine Metasedimentary Rocks

Devonian

- Dcb-Devonian, Metasedimentary and Metavolcanic Rocks, Metacarbonate
- Dcg-Devonian, Metasedimentary and Metavolcanic Rocks, Metaconglomerate

Carboniferous

- CDcb-Carboniferous and Devonian, Metasedimentary and Metavolcanic Rocks, Metacarbonate, Consists of Part of the Grass Mountain Sequence (Yates, 1971)
- CDmm-Carboniferous and Devonian, Metasedimentary and Metavolcanic Rocks, Marine Metasedimentary Rocks, Consists of the Kelly Hill Phyllite (Bowman, 1950) and Parts of the Flagstaff Mountain, Grass Mountain, and Pend Oreille Sequences (Yates, 1971)
- CDmt-Carboniferous and Devonian, Metasedimentary and Metavolcanic Rocks, Metasedimentary and Metavolcanic Rocks, Undivided, Consists of Parts of the Flagstaff Mountain and Pend Oreille Sequences (Yates, 1971)
- CDmv-Carboniferous and Devonian, Metasedimentary and Metavolcanic Rocks, Metavolcanic Rocks, Consists of Part of the Flagstaff Mountain Sequence (Yates, 1971)
- COcg-Carboniferous to Ordovician, Metasedimentary and Metavolcanic Rocks, Metaconglomerate
- COmm-Carboniferous to Ordovician, Metasedimentary and Metavolcanic Rocks, Marine Metasedimentary Rocks

Permian

- PMcb-Permian, Metasedimentary and Metavolcanic Rocks, Metacarbonate, Includes Parts of the Spectacle Formation and Anarchist Group, Undivided
- PMmm-Permian, Metasedimentary and Metavolcanic Rocks, Marine Metasedimentary Rocks, Includes the Mount Roberts and Bullfrog Mountain Formations and Parts of the Spectacle Formation and Anarchist Group, Undivided

Triassic and Permian

- TRPMmm-Triassic and Permian, Metasedimentary and Metavolcanic Rocks, Marine Metasedimentary Rocks
- TRPMmt-Triassic and Permian, Metasedimentary and Metavolcanic Rocks, Metasedimentary and Metavolcanic Rocks, Undivided
- TRPMmv-Triassic and Permian, Metasedimentary and Metavolcanic Rocks, Metavolcanic Rocks

Triassic

- TRcb-Triassic, Metasedimentary and Metavolcanic Rocks, Metacarbonate, Includes the Dark Gray Metalimestone Member and the Metadolomite and Metalimestone Member of the Cave Mountain Formation (Rinehart and Fox, 1976) and Part of the Flagstaff Mountain Sequence (Yates, 1971)
- TRmm-Triassic, Metasedimentary and Metavolcanic Rocks, Marine Metasedimentary Rocks, Consists of the Slate and Metalimestone Member and the Metasiltstone Member of the Cave Mountain Formation (Rinehart and Fox, 1976) and Parts of the Flagstaff Mountain Sequence (Yates, 1971) and Metamorphic Complex of Conconully (Rinehart and Fox, 1976)

Jurassic

- Jcg-Jurassic, Metasedimentary and Metavolcanic Rocks, Metaconglomerate, Consists of Parts of the Rossland Group and Ellemeham Formation
- Jib-Jurassic, Intrusive Rocks, Basic (Mafic) Intrusive Rocks
- Jik-Jurassic, Intrusive Rocks, Alkalic Intrusive Rocks, Consists of the Shankers Bend Alkalic Complex (Rinehart and Fox, 1972), Intrusive Rocks of Shasket Creek (Parker and Calkins, 1964), and Part of the Similkameen Composite Pluton (Daly, 1912; Rinehart and Fox, 1972)
- Jiq-Jurassic, Intrusive Rocks, Quartz Diorite
- Jmv-Jurassic, Metasedimentary and Metavolcanic Rocks, Metavolcanic Rocks, Consists of Parts of the Rossland Group and Ellemeham Formation

Cretaceous

- Kcg(2)-Cretaceous, Sedimentary and Volcanic Rocks, Conglomerate, Consists of the Sophie Mountain Formation and Part of the Virginian Ridge Formation
- Kia-Cretaceous, Intrusive Rocks, Plutonic Rocks, Acidic Intrusive Rocks
- Kiaa-Cretaceous, Intrusive Rocks, Plutonic Rocks, Alaskite-aplite-pegmatite, Includes Parts of the Spirit Pluton (Yates, 1964, 1971) and Equigranular Granite of Virginia Lake (Atwater and Rinehart, 1984)
- Kiat-Cretaceous, Intrusive Rocks, Plutonic Rocks, Two-mica Granite, Includes the Blickensderfer Quartz Monzonite, Phillips Lake Granodiorite, Granodiorite of Dubious Creek (Miller, 1982B), Granodiorite of Hall Mountain (Miller and Theodore, 1982), Monzogranite of Hungry Mountain (Miller, 1982C), Monzogranite of Gleason Mountain (Miller, 1982C), Monzogranite of Granite Pass (Miller, 1983), and Part of the Mount Spokane Granite (Bickford and Others, 1985)
- Kig-Cretaceous, Intrusive Rocks, Plutonic Rocks, Granite, Includes the Park Granite Stock (Daly, 1912), Little Roundtop Pluton (Miller, 1974C), Granite of Felix Creek (Atwater and Rinehart, 1984), Monzogranite of Sand Creek (Burmester and Miller, 1983), and Parts of the Equigranular Granite of Virginia Lake (Atwater and Rinehart, 1984) and Spirit Pluton (Yates, 1971)
- Kigd-Cretaceous, Intrusive Rocks, Plutonic Rocks, Granodiorite, Consists of the Granodiorite of Granite Point (Hooper and Rosenberg, 1970).

Tertiary and Cretaceous

- TKia-Tertiary and Cretaceous, Intrusive Rocks, , Acidic Intrusive Rocks, Includes the Fifteenmile Creek Pluton (Bowman, 1950), Storm King Pluton (Cheney And Others, 1982; Holder and Holder., 1988); Porphyritic Granodiorite of Manila Creek (Atwater and Rinehart, 1984), Granite of George Creek (Atwater And Rinehart, 1984), and Parts of the Plutonic Complex of Johnny George (Atwater and Rinehart, 1984), Granite of Swawilla Basin (Atwater and Rinehart, 1984), Mount Bonaparte Pluton (Fox, 1978; Holder and Holder, 1988), and Moses Mountain Pluton (Atwater and Rinehart, 1984)

Pre-Tertiary

- pTam-Pre-Tertiary, Metamorphic Rocks, Igneous Protolith, Amphibolite, Includes the Greenstone Near Roaring Creek (Atwater and Rinehart, 1984) and Parts of the Metamorphic Rocks of Tenas Mary Creek (Parker and Calkins, 1964; Cheney and Others, 1982)
- pThm-Pre-Tertiary, Metamorphic Rocks, Sedimentary Protolith, Heterogeneous Metamorphic Rocks, Includes Part of the Metamorphic Rocks of Tenas Mary Creek (Parker and Calkins, 1964; Cheney and Others, 1982) and the Paragneiss and Orthogneiss of Hall Creek (Atwater and Rinehart, 1984)
- pTqz-Pre-Tertiary, Metamorphic Rocks, Sedimentary Protolith, Quartzite, Consists of Part of the Metamorphic Rocks of Tenas Mary Creek (Cheney and Others, 1982)
- pTsc-Pre-Tertiary, Metamorphic Rocks, Sedimentary Protolith, Schist, Includes Part of the Metamorphic Rocks of Tenas Mary Creek (Parker and Calkins, 1964; Cheney and Others, 1982)
- pTmb-Pre-Tertiary, Metamorphic Rocks, Sedimentary Protolith, Marble, Consists of Part of the Metamorphic Rocks of Tenas Mary Creek (Parker and Calkins, 1964; Cheney and Others, 1982)
- pTog-Pre-Tertiary, Metamorphic Rocks, Igneous Protolith, Orthogneiss, Consists of Part of the Napeequa Schist.

Tertiary

- Ecg(1)-Tertiary, Sedimentary and Volcanic Rocks, Conglomerate, Includes Part of the O'Brien Creek Formation
- Ecg(2)-Tertiary, Sedimentary and Volcanic Rocks, Conglomerate, Consists of the Tiger Formation and Part of the Chumstick Formation
- Evc(1)-Tertiary, Sedimentary and Volcanic Rocks, Volcaniclastic Rocks, Includes Part of the O'Brien Creek Formation
- Evc(2)-Tertiary, Sedimentary and Volcanic Rocks, Volcaniclastic Rocks, Includes the Middle and Tom Thumb Tuff Members of the Klondike Mountain Formation (Muessig, 1962, 1967)
- Evd(1)-Tertiary, Sedimentary and Volcanic Rocks, Dacite and Andesite Flows, Includes the Shellrock Point Volcanics (Menzer, 1983) and Parts of the Sanpoil Volcanics, Andesite of Twin Peaks (Rinehart and Fox, 1976), Dacite of Carter Mountain (Rinehart and Fox, 1976), and Volcanics of Island Mountain (Staatz and Others, 1971)
- Evd(2)-Tertiary, Sedimentary and Volcanic Rocks, Dacite and Andesite Flows, Includes the Basalt Member of the Klondike Mountain Formation (Muessig, 1962, 1967)
- Evt(2)-Tertiary, Sedimentary and Volcanic Rocks, Tuff, Consists of Part of the Klondike Mountain Formation

Eocene

- Eib-Eocene, Intrusive Rocks, Plutonic Rocks, Basic (Mafic) Intrusive Rocks
- Eida-Eocene, Intrusive Rocks, Hypabyssal Intrusive Rocks, Dacite and Andesite, Includes the Scatter Creek Rhyodacite, Goat Mountain Porphyry (Raviola, 1988), Hypabyssal Intrusive Suite of Cody Lake (Atwater and Rinehart, 1984), and Part of the Volcanics of Island Mountain (Staatz and Others, 1971)
- Eik-Eocene, Intrusive Rocks, Plutonic Rocks, Alkalic Intrusive Rocks
- Eis-Eocene, Intrusive Rocks, Plutonic Rocks, Syenite, Consists of the Coryell Intrusive Rocks (Daly, 1912; Yates, 1971)
- Eig-Eocene, Intrusive Rocks, Plutonic Rocks, Granite, Includes the Sheppard Granite, Monument Peak Stock (Tabor And Others, 1968), Granite of Deadhorse Creek (Atwater and Rinehart, 1984), Granite of Upper Stepstone Creek (Atwater and Rinehart, 1984), and Parts Of The Fire Mountain Pluton (Holder and Holder, 1988), Bridge Creek Intrusions (Holder and Holder, 1988), Duncan Hill Pluton (Cater and Wright, 1967), and Long Alec Creek Pluton (Parker And Calkins, 1964)
- Eigd-Eocene, Intrusive Rocks, Plutonic Rocks, Granodiorite, Includes the Fuller Mountain Plug (Tabor and Others, 1993), the Granite Falls Stock and Associated Plutons (Yeats and Engels, 1971), the Railroad Creek Pluton (Cater and Crowder, 1967), the Larch Lakes Pluton (Cater, 1982), the Castle Peak Stock (Daly, 1912), and the Biotite Granodiorite and Granite Near Holden (Cater and Wright, 1967).
- Eimd-Eocene, Intrusive Rocks, Plutonic Rocks, Monzodiorite, Includes the Swimptkin Creek Pluton (Fox and Others, 1976), Kettle Crest Pluton (Holder and Holder, 1988), Henry Creek Diorite (Holder and Holder, 1988), and Friedlander Meadows Pluton (Atwater and Rinehart, 1984) and Part Of The Devils Elbow Pluton (Atwater and Rinehart, 1984)
- Eiqm-Eocene, Intrusive Rocks, Plutonic Rocks, Quartz Monzonite, Consists of the Ordway Creek Stock (Livingston, 1966).

Quaternary

- Qa-Quaternary, Unconsolidated Sediments, Nonglacial, Alluvium
- Qd-Quaternary, Unconsolidated Sediments, Nonglacial, Dune Sand
- Qgd-Quaternary, Unconsolidated Sediments, Glacial, Drift
- Qgl-Quaternary, Unconsolidated Sediments, Glacial, Glaciolacustrine Deposits, Includes Part of the Nespelem Silt
- Qgo-Quaternary, Unconsolidated Sediments, Glacial, Outwash
- Qgt-Quaternary, Unconsolidated Sediments, Glacial, Till
- Qls-Quaternary, Unconsolidated Sediments, Nonglacial, Mass-Wasting Deposits

Other

- tz-Tectonic Zone
- u-Uncertain Age, Intrusive Rocks, Ultrabasic (Ultramafic) Rocks, Includes the Serpentine Near Parmenter Creek (Atwater and Rinehart, 1984), Ultramafic and Mafic Rocks Near Bridge Creek (Atwater and Rinehart, 1984), and Part of the Chopaka Intrusive Complex (Hibbard, 1971)
- wtr-Water

Source: Stoffel et al. (1991)

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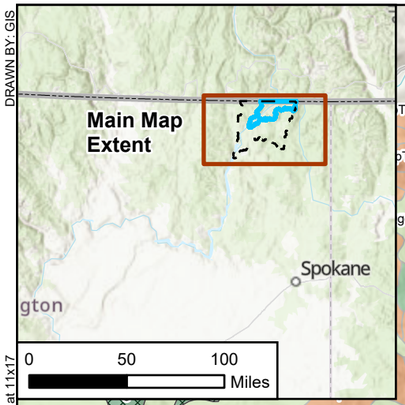
Legend for Surficial Geology in the OU 3 Study Area

Final Upland RI Report
Upper Columbia River, Washington

DRAWN BY: GIS

REVISED: 08/20/2025 | SCALE: 1:250,328 when printed at 11x17

FILE: M:\US\Projects\S-U\Teck\0493466 Teck Upper Columbia River\Maps\Upland RI\ProjectSection 2\Upland RI Section 2 part 1.aprx | REVISED



U.S. - Canada Border

Waneta Dam

Pend Oreille River

Northport

Marble

China Bend

Stevens County

Ferry County

Pend Oreille County

Bossburg

Evans

Marcus

Kettle Falls

Colville

Columbia River

Kettle River

Onion Creek

Colville River

Jumbo Mountain

Taylor Ridge

Echo Valley

Old Douglas

Molybdenite Mountain

Green Mountain

Bon Aire Mountain

Haft Mountain

Sand Creek Mountain

Addin Mountain

Lafayette Mountain

Kelly Hill

Gold Hill

Cr Mountain

Boundary Hwy

Deer Creek Rd

Legend

- City/Town
- Major Dam
- OU 3 Study Area
- County Boundaries
- ADA as Defined by the 2014 Soil Study (TAI 2015a)
- (Eig) Eocene Sheppard Granite Associated with Metallic Mining

Paleozoic Rocks Hosting Sulfide Mineralization in the OU 3 Study Area

- (CDmm and CDmt) Carboniferous to Devonian Metasedimentary and Metavolcanic Rocks of the Flagstaff Mountain, Grass Mountain, and Pend Oreille Sequences
- (OCcb) Ordovician and Cambrian Metaline Formation
- (Cmm and Ccb) Cambrian Maitlen Phyllite
- (Oar) Ordovician Ledbetter Slate

Note: See the Legend for Surficial Geology in the OU 3 Study Area (Stoffel et al. 1991).

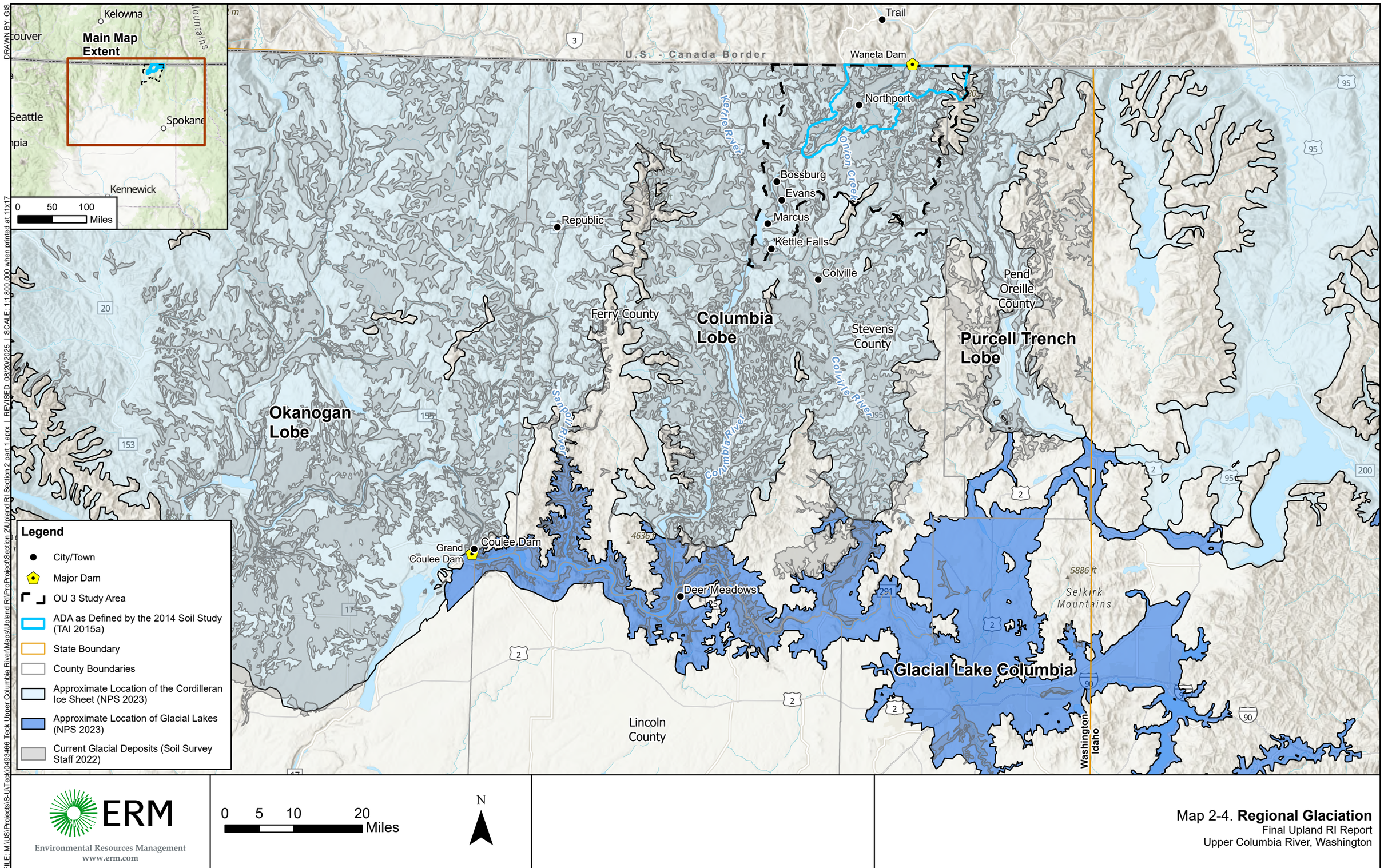
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0 1.25 2.5 5
Miles

N

Map 2-3. **Surficial Geology and Mineral Occurrences in the OU 3 Study Area**
Final Upland RI Report
Upper Columbia River, Washington

Source: Esri - World Topographic Map; NAD 1983 UTM Zone 11N

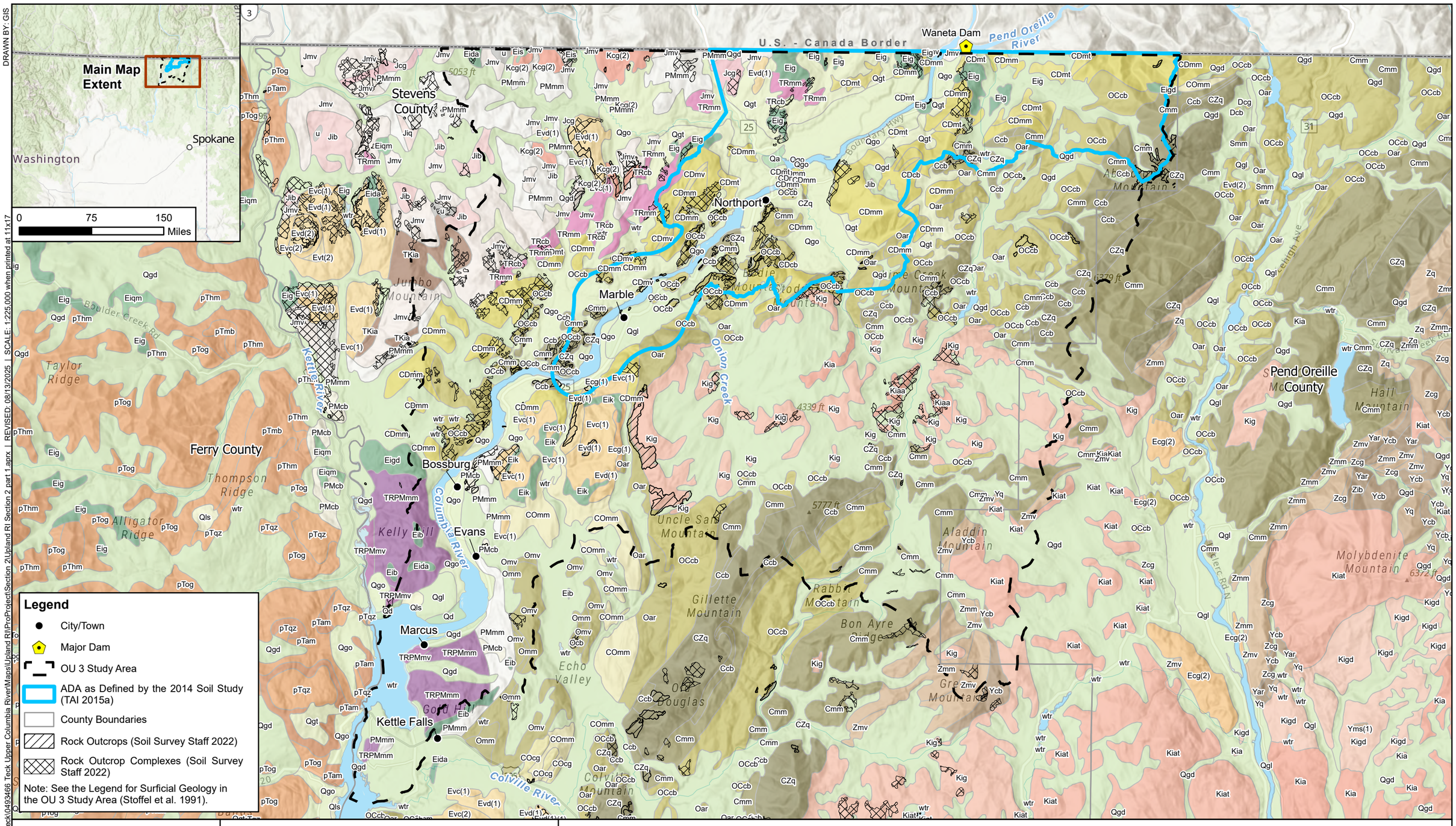


Map 2-4. **Regional Glaciation**
Final Upland RI Report
Upper Columbia River, Washington

Source: Esri - World Topographic Map; NAD 1983 UTM Zone 11N

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Map 2-5. **Rock Unit Outcrops in the OU 3 Study Area**
Final Upland RI Report
Upper Columbia River, Washington

Source: Esri - World Topographic Map; NAD 1983 UTM Zone 11N

DRAWN BY: GIS | SCALE: 1:225,000 when printed at 11x17 | REVISED: 08/13/2025
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DRAWN BY: GIS

Main Map Extent

Kelowna

Spokane

Washington

0 50 100 Miles

Okanagan Highlands

Beaverdell Range

Midway Range

Monashee Mountains

Christina Range

Columbia River

Columbia Mountains

Slocan Watershed

Lower Kootenay Watershed

Franklin D. Roosevelt Lake Watershed

Hugh Keenleyside Dam

Brilliant Dam

Pend Oreille Watershed

Kettle Watershed

Okanogan Watershed

Rossland Range

Trail

U.S. - Canada Border

Waneta Dam

Pend Oreille River

OU 3 Study Area

Northport

WRIA 60

WRIA 61

Kettle River

Onion Creek

Bossburg

Evans

Marcus

Kettle Falls

Republic

WRIA 52

Sanpoil Watershed

Ferry County

Colville

WRIA 62

WRIA 59

Colville Watershed

WRIA 58

Sanpoil River

Columbia River

Pend Oreille County

Chief Joseph Watershed

WRIA 53

Coulee Dam

Grand Coulee Dam

Franklin D Roosevelt Lake

Deer Meadows

Stevens County

Little Spokane Watershed

Long Lake Dam

WRIA 54

Lower Spokane Watershed

Banks Lake Watershed

Lincoln County

Upper Crab Watershed

Legend

- City/Town
- Major Dam
- Major Stream
- Major Water Body
- ADA as Defined by the 2014 Soil Study (TAI 2015a)
- OU 3 Study Area
- WRIA Boundary
- Hydrological Boundary
- County Boundaries
- Watershed Boundary/8-digit HUC (USGS 2018)

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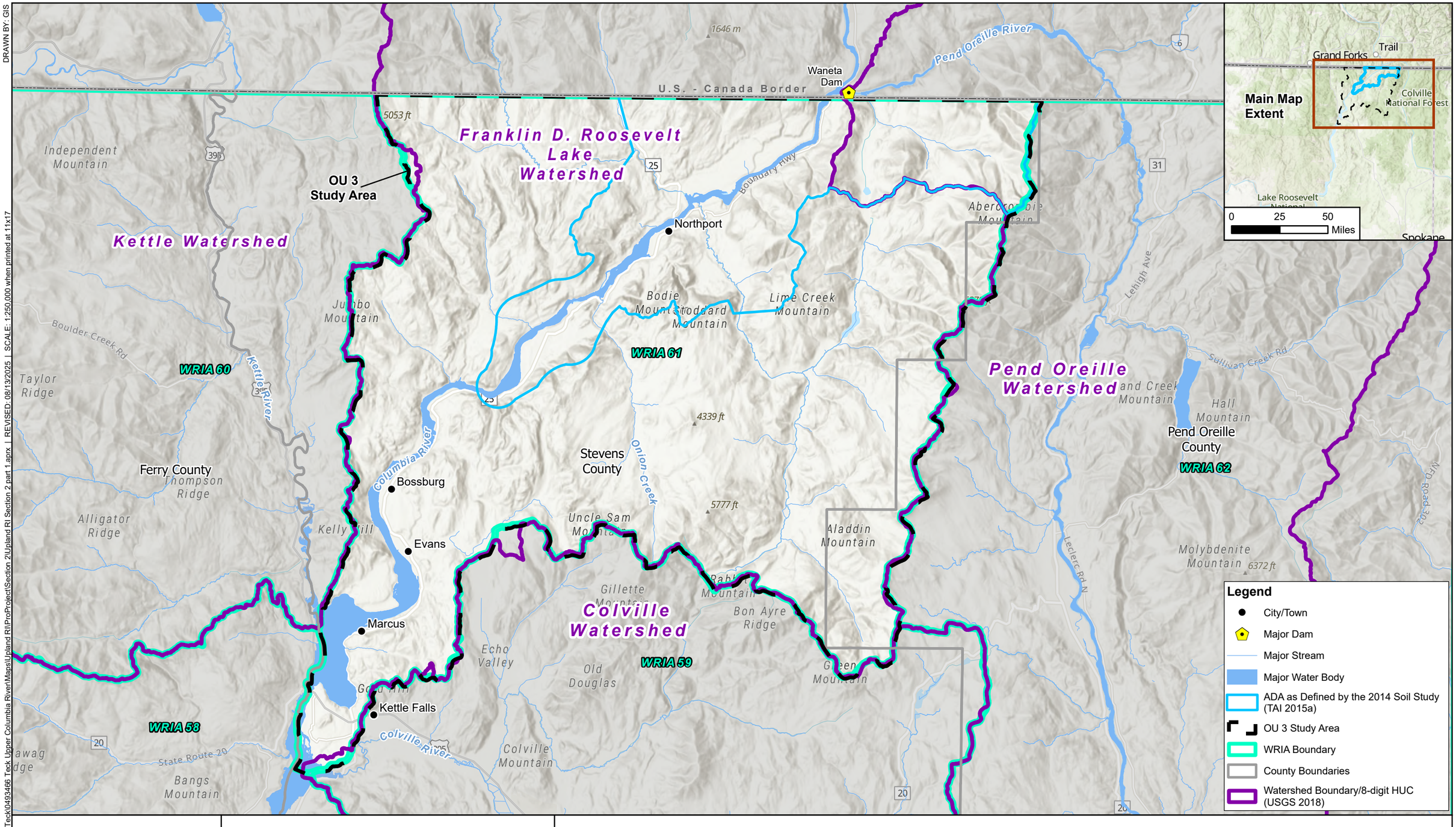
0 5 10 20 Miles

N

Map 2-6. **Regional Hydrology**
Final Upland RI Report
Upper Columbia River, Washington

Source: Esri - World Topographic Map; NAD 1983 UTM Zone 11N

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0 2.5 5 Miles

N

Map 2-7. **Hydrology in the OU 3 Study Area**
Final Upland RI Report
Upper Columbia River, Washington

Source: Esri - World Topographic Map; NAD 1983 UTM Zone 11N

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Lincoln County Zoning
- Agricultural
- Commercial
- Incorporated
- Industrial
- Public Facilities
- Recreational

Ferry County Term Areas
- Agriculture Long Term
- Timber Long Term

City of Chewelah Zoning Districts
- Airport/Golfcourse-1
- Airport/Golfcourse-2
- Airport/Golfcourse-3
- Commercial Facility
- Commercial Industry
- Public
- Residential
- Multi Family
- Retail Business
- Residential Suburban
- Street

City of Colville Zoning Districts
- Airport Facility
- Central Business
- General Commercial
- General Residential
- Industrial
- Light Industrial
- Multi-Family Residential
- Open Space and Conservation
- Single Family Residential
- Single Family Suburban

City of Kettle Falls Zoning Districts
- Central Commercial
- Downtown Commercial
- Heavy Industrial
- Industrial
- Manufactured Home
- Multiple Family Resident
- Residential Duplex
- Single Family Residential
- Suburban Residential

Town of Marcus Zoning Districts
- City Owned
- Commercial/Residential
- Light Industrial
- Open Space
- Residential

Town of Northport Zoning Districts
- Commercial
- Industrial
- Multi-Family
- Open
- Public
- Residential

Town of Springdale Zoning Districts
- Agriculture Urban
- Industrial
- Public Facilities
- Residential
- Retail Business

Stevens County Limited Areas of More Intensive Rural Development Districts
- Business
- Crossroads
- Industrial
- Residential
- Resort

Stevens County Zoning Districts
- Business
- Crossroads
- Industrial
- Natural Resource Agriculture
- Natural Resource Forest
- Open Space
- R-1 Residential
- R-2 Residential
- Rural Agriculture
- Rural Area - 5: characterized by relatively gentle topography and slopes; are well served for access by state and county roads; sufficient and reasonably available water to meet demand; or areas that are already developed or platted with lots five acres in size or smaller.
- Rural Area - 10: characterized by moderate to steep topography; access via state or county roads, but with fewer options than in 5-acre density areas; lower water supplies or water that is available only through drilling deep to very deep wells; or areas that can provide a transition to Agricultural or Forest Resource lands.
- Rural Area - 20: characterized by steep topography; limited access via state or county roads; low water supplies or water that is available only through drilling very
- Resort

Sources: Stevens County, WA Ordinances ch. 3 § 02; Ferry County, WA Ordinances ch. 2016, § 04; Lincoln County, WA Ordinances title 17; City of Colville Ordinances title 17; City of Chewelah Ordinances title 18; City of Kettle Falls Ordinances title 17; Town of Marcus Unified Development Ordinance; Town of Northport Unified Code and Comprehensive Plan; Town of Springdale Ordinance 342

Note: Gifford, Bossburg, Evans, Republic, Coulee Dam, and Deer Meadows follow Stevens County zoning and do not have city specific zoning districts.

Source: Esri - World Topographic Map; NAD 1983 UTM Zone 11N

U.S. - Canada Border
Waneta Dam
Pend Oreille River
Northport
Kettle River
Onion Creek
Bossburg
Evans
Marcus
Kettle Falls
Colville River
Colville
Republic
7139 ft
Ferry County
Stevens County
Pend Oreille County
Gifford
Chewelah
Sanpoil River
Colville Indian Reservation
Columbia River
Springdale
Coulee Dam
Grand Coulee Dam
Franklin D Roosevelt Lake
4636 ft
Spokane Indian Reservation
Deer Meadows
Lincoln County
3
22
31
20
155
231
291
25
395
2

Main Map Extent
Kelowna
Spokane
Washington
0 50 100 Miles

Legend
- City/Town
- Major Dam
- ADA as Defined by the 2014 Soil Study (TAI 2015a)
- OU 3 Study Area
- County Boundaries
- Reservation

N

0 5 10 20 Miles

Map 2-8. **Regional Land Use**
Final Upland RI Report
Upper Columbia River, Washington

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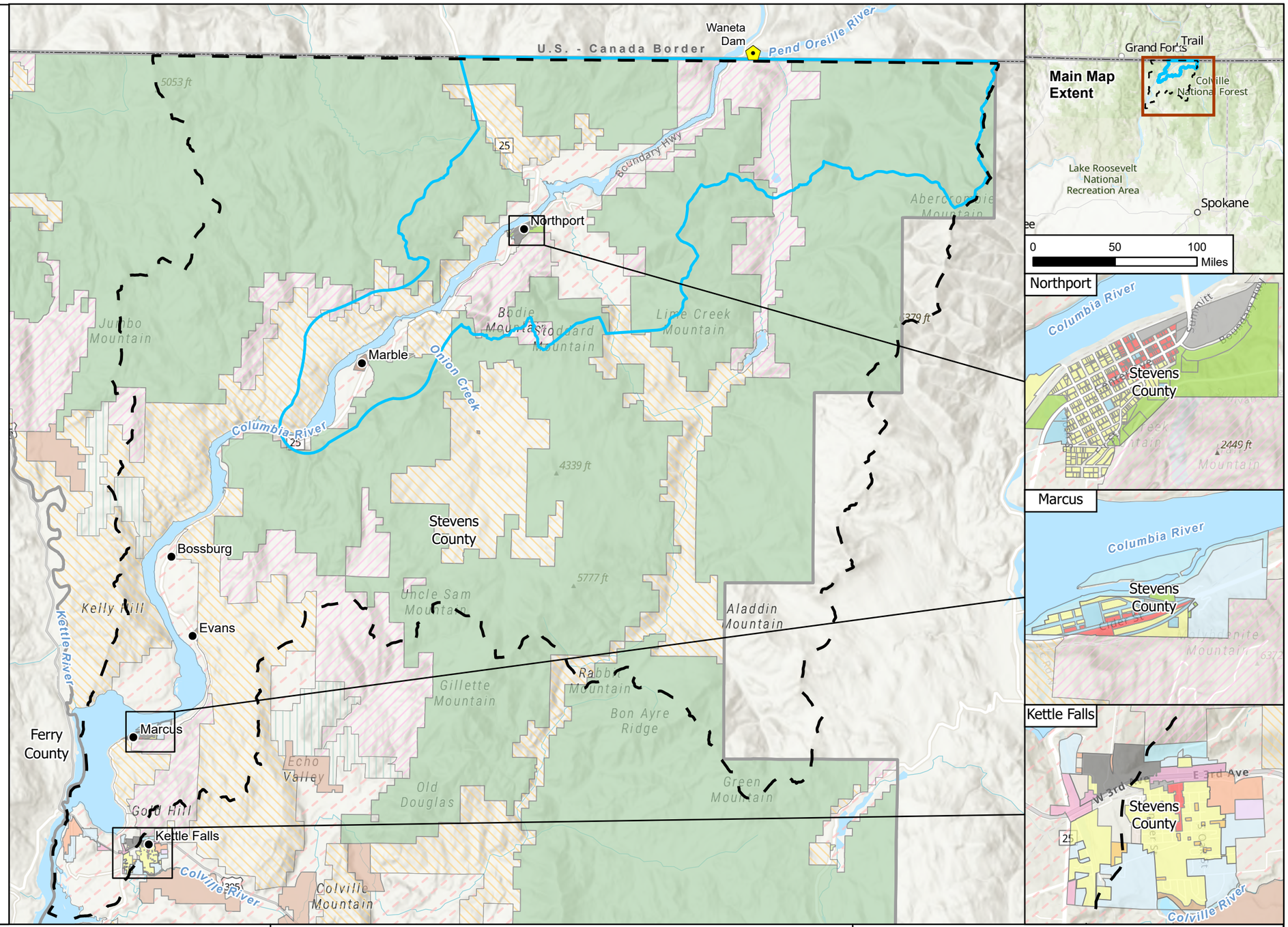
Town of Northport Zoning Districts
- Commercial
- Industrial
- Multi-Family
- Open
- Public
- Residential

Town of Marcus Zoning Districts
- City Owned
- Commercial/Residential
- Light Industrial
- Open Space
- Residential

City of Kettle Falls Zoning Districts
- Central Commercial
- Downtown Commercial
- Heavy Industrial
- Industrial
- Manufactured Home
- Multiple Family Resident
- Residential Duplex
- Single Family Residential
- Suburban Residential

Stevens County Zoning Districts
- Business
- Crossroads
- Industrial
- Natural Resource Agriculture
- Natural Resource Forest
- Open Space
- R-1 Residential
- R-2 Residential
- Rural Agriculture
- Rural Area - 5: characterized by relatively gentle topography and slopes; are well served for access by state and county roads; sufficient and reasonably available water to meet demand; or areas that are already developed or platted with lots five acres in size or smaller.
- Rural Area - 10: characterized by moderate to steep topography; access via state or county roads, but with fewer options than in 5-acre density areas; lower water supplies or water that is available only through drilling deep to very deep wells; or areas that can provide a transition to Agricultural or Forest Resource lands.
- Rural Area - 20: characterized by steep topography; limited access via state or county roads; low water supplies or water that is available only through drilling very deep wells; or areas that can provide a transition to Forest Resource lands.
- Resort

Sources:
Stevens County, WA Ordinances ch. 3 02; City of Kettle Falls Ordinances title 17; Town of Marcus Unified Development Ordinance; Town of Northport Unified Code and Comprehensive Plan
Note: City of Bossburg and City of Evans follow Stevens County zoning and do not have city specific zoning districts.



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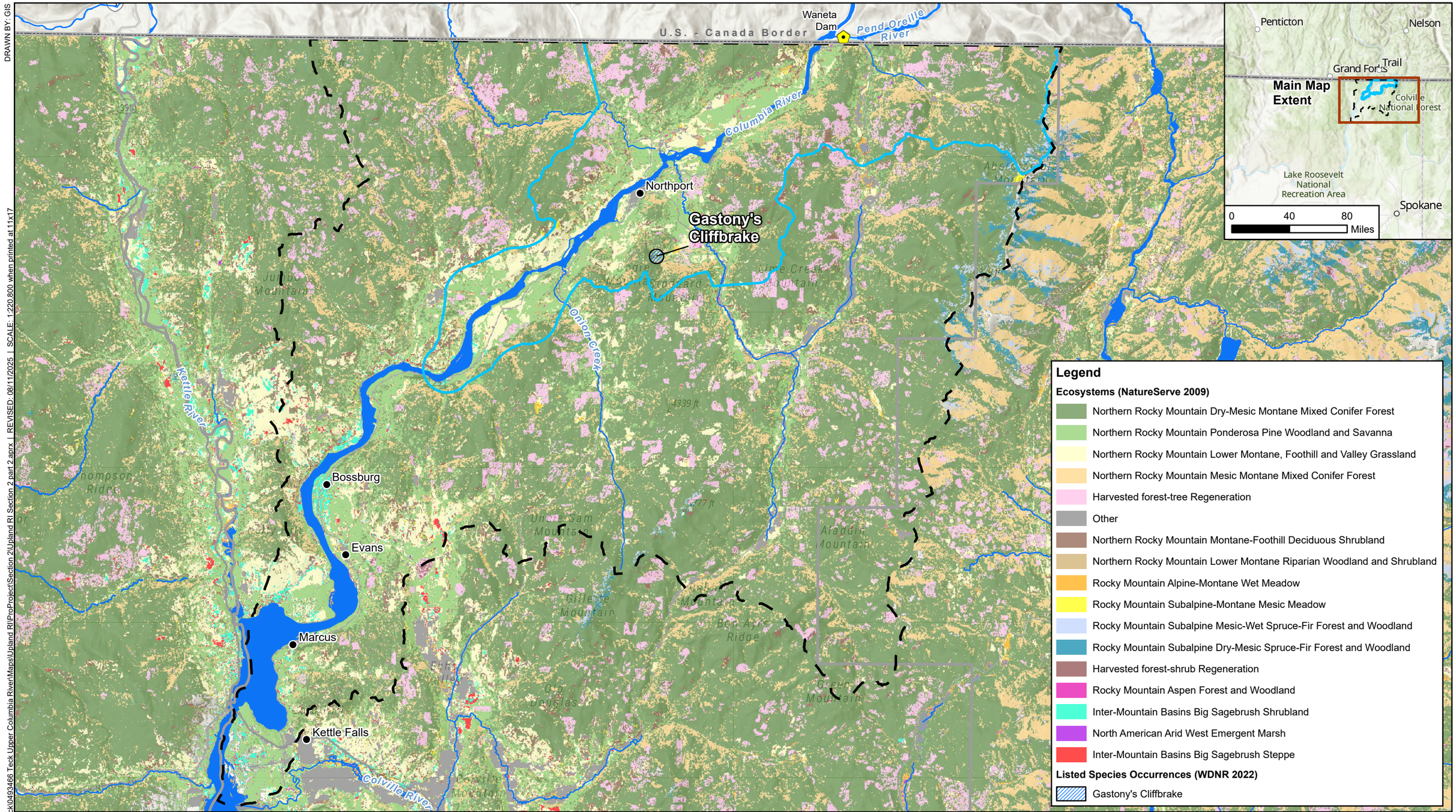
0 1.25 2.5 5 Miles

N

Legend
- City/Town
- Major Dam
- OU 3 Study Area
- ADA as Defined by the 2014 Soil Study (TAI 2015a)
- County Boundaries

Map 2-9. **Land Use in the OU 3 Study Area**
Final Upland RI Report
Upper Columbia River, Washington

Source: Esri - World Topographic Map; NAD 1983 UTM Zone 11N



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0 1.25 2.5 5
Miles

N

Legend
- City/Town
- Major Dam
- OU 3 Study Area
- ADA as Defined by the 2014 Soil Study (TAI 2015a)
- County Boundaries

Map 2-10. **Terrestrial Ecosystems in the BERA Terrestrial Study Area**
Final Upland RI Report
Upper Columbia River, Washington

Source: Esri - World Topographic Map; NAD 1983 UTM Zone 11N

DRAWN BY: GIS

Main Map Extent

Spokane

0 50 100 Miles

Greenwood Smelter

Boundary Falls Smelter

Granby Smelter

U.S. - Canada Border

Trail Smelter

Trail

Boundary Transfer Station

Waneta Dam

Pend Oreille River

Northport

Le Roi/Northport Smelter

Lime Creek Mountain

Kettle River

Onion Creek

Thompson Ridge

7139 ft

Bossburg

Evans

Marcus

Kettle Falls

Colville River

Pend Oreille County

Republic

Ferry County

6380 ft

6771 ft

Sanpoil River

Oregon City Ridge

Columbia River

North Basin

Huckleberry Range

Colville

Colville Smelter

Stevens County

6009 ft

6853 ft

Iron Mountains

Summit Valley

Chewelah

9205

Huckleberry Mountains

4367 ft

4636 ft

Coulee Dam

Grand Coulee Dam

Franklin D. Roosevelt Lake

Grand Coulee Smelter

Deer Meadows

Walkers Prairie

4044 ft

Half Moon Prairie

2675 ft

Bald Ridge

Four Mound Prairie

Indian Prairie

Malloy Prairie

Bennett Meadow

2566 ft

Legend

- City/Town
- Major Dam
- Railroad Stations
- Site Investigated in the 2001 EPA Stevens County Mines and Mills PA/SI (USEPA 2002a)
- Railroad
- ADA as Defined by the 2014 Soil Study (TAI 2015a)
- County Boundaries
- OU 3 Study Area

Permitted Mining, Ore Processing, and Refining Operations (WDNR 2019b)

(Primary Commodity: Metals)

- Smelter (Active)
- Smelter (Inactive)
- Mill (Active)
- Mill (Inactive)

Unpermitted/Historical Mines (WDNR 2015a, 2019c; USGS 2022; Cox and Hollister 1955; Derkey et al. 1990; Huntting 1956)

(Primary Commodity: Metals)

- Lead
- Zinc
- Copper
- Gold
- Silver
- Iron
- Uranium
- Other
- Unknown

Note: See the Legend for Surficial Geology in the OU 3 Study Area (Stoffel et al. 1991).

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0 5 10 20 Miles

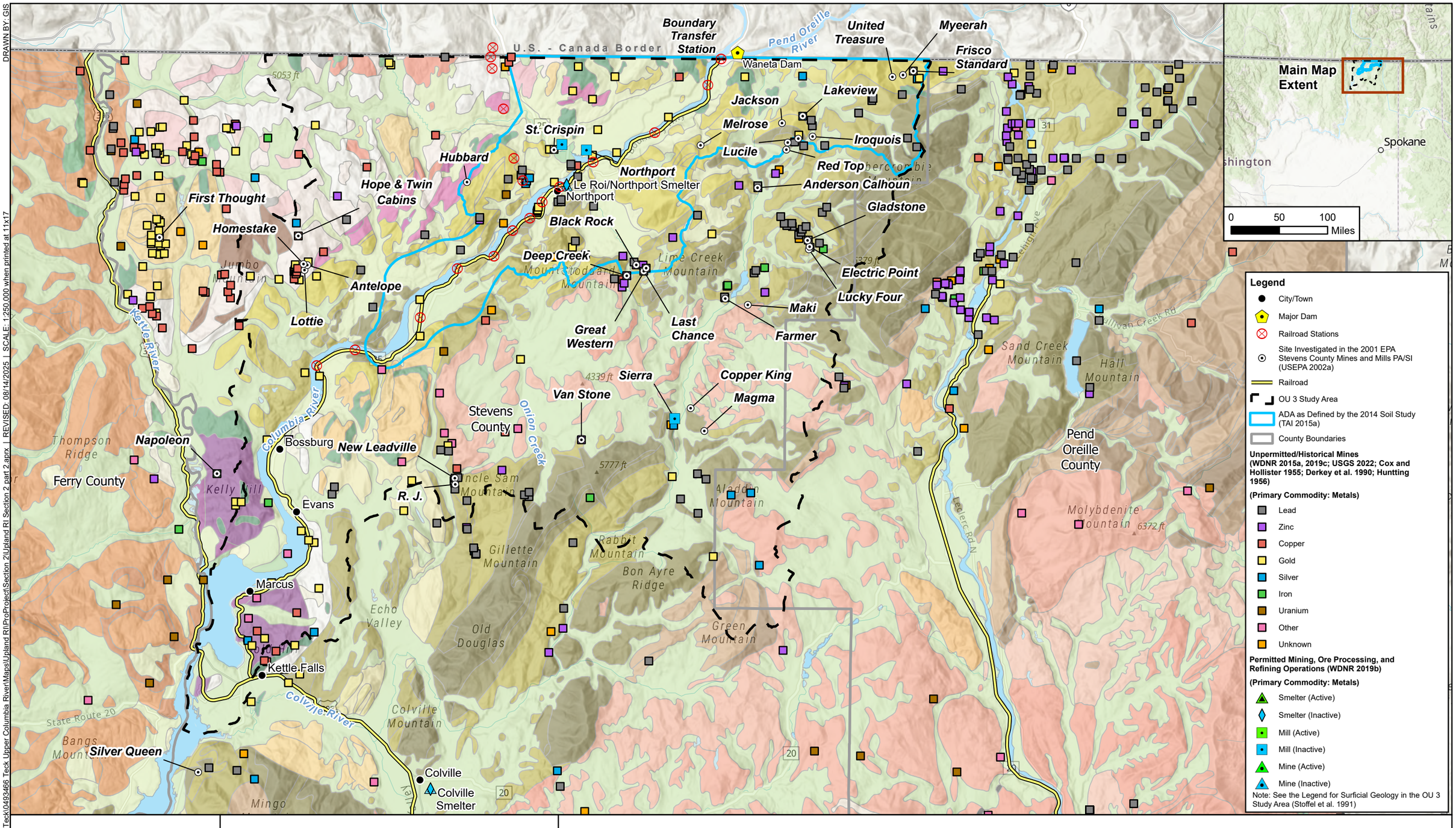
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Map 2-11. **Regional Metallic Mining and Mining-Related Operations**

Final Upland RI Report
Upper Columbia River, Washington

Source: Esri - World Topographic Map; WGS 1984 UTM Zone 11N

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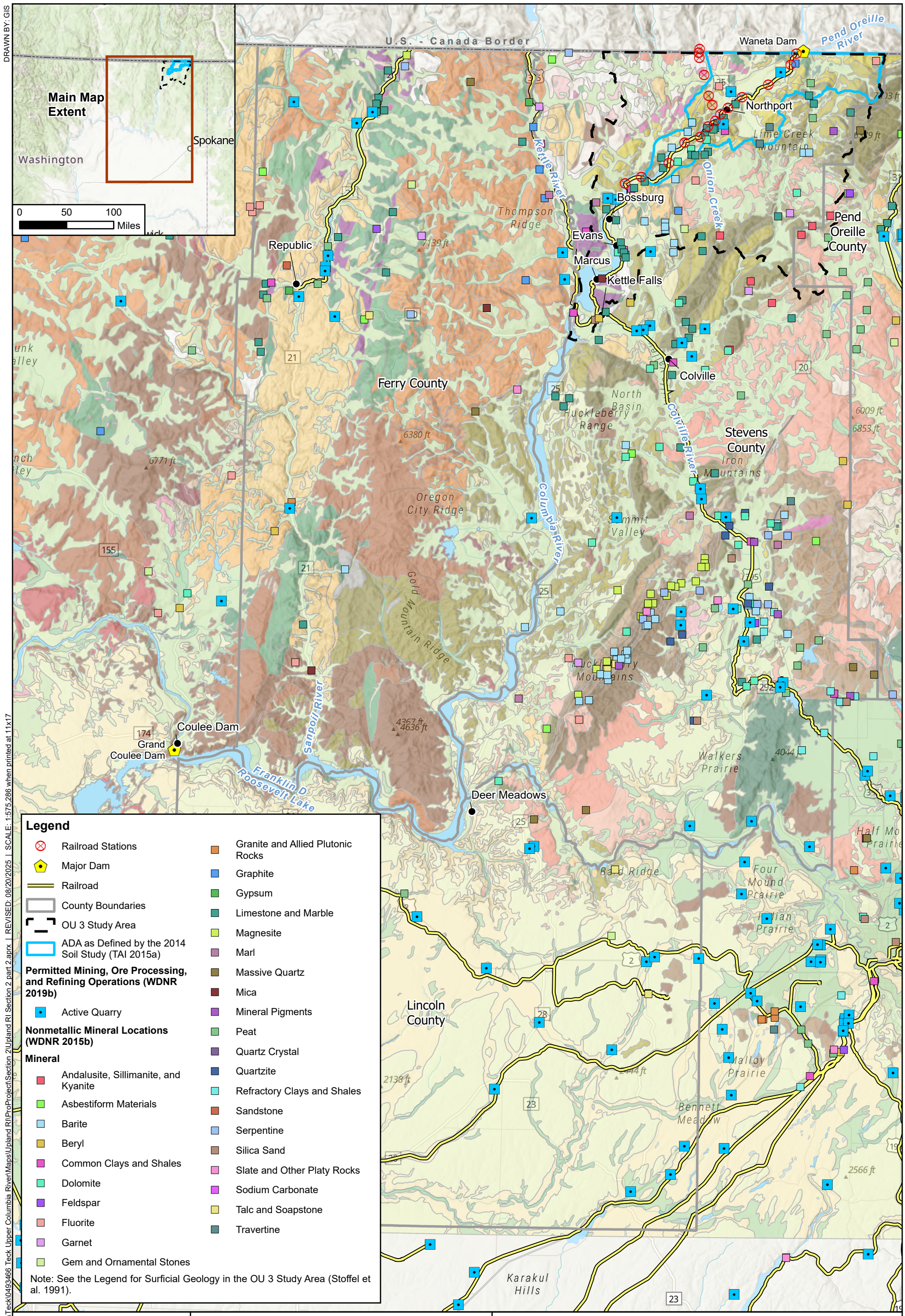
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0 2.5 5 10 Miles

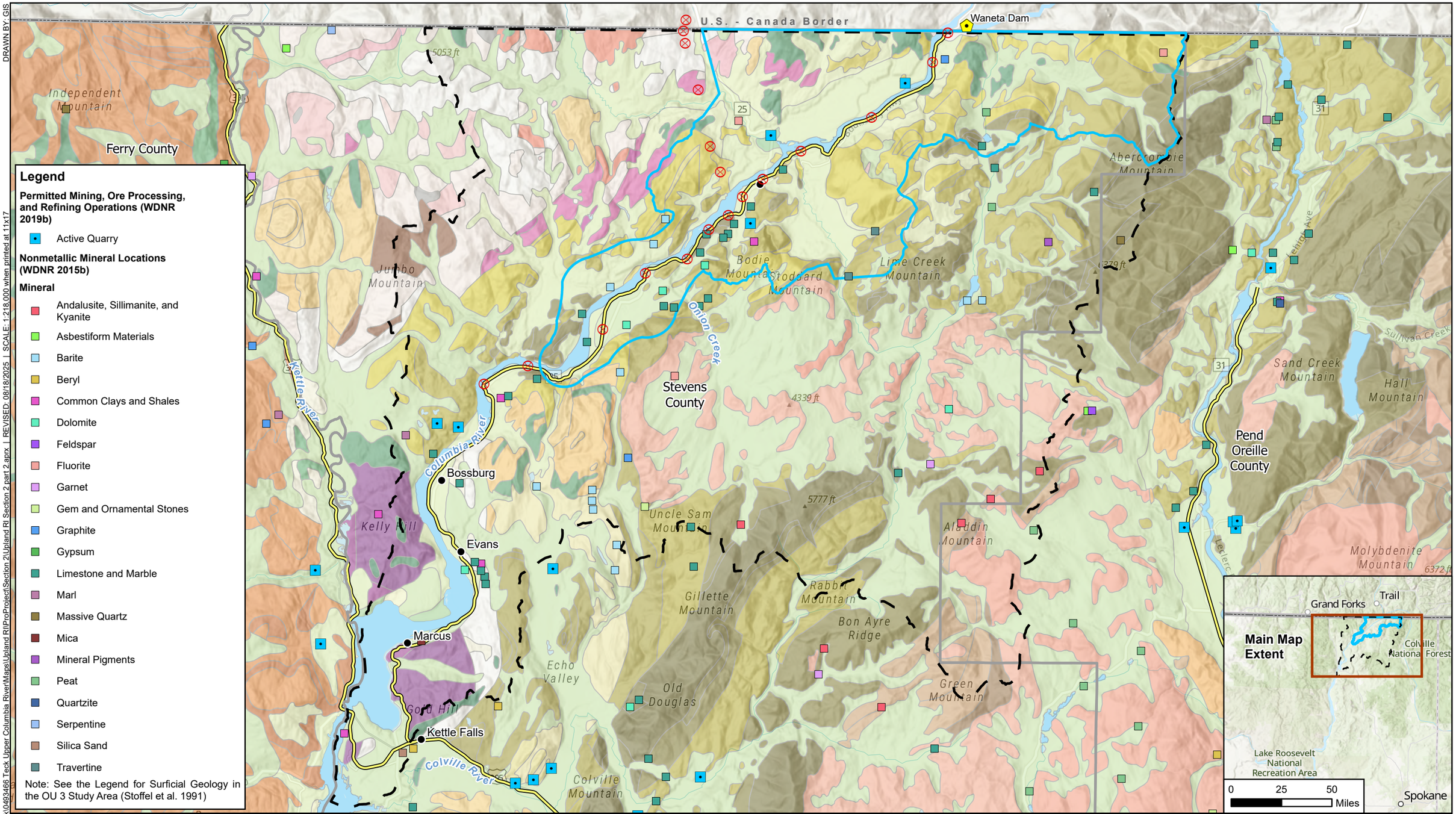
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Map 2-12. **Metallic Mining and Mining-Related Operations in the OU 3 Study Area**
Final Upland RI Report
Upper Columbia River, Washington

Source: Esri - World Topographic Map; NAD 1983 UTM Zone 11N


Main Map Extent
Spokane
Washington
0 50 100
Miles
U.S. - Canada Border
Waneta Dam
Pend Oreille River
Northport
Lime Creek Mountain
6539 ft
Kettle River
Onion Creek
Bossburg
Thompson Ridge
Evans
Marcus
Kettle Falls
Pend Oreille County
Republic
7139 ft
Colville
Ferry County
North Huckleberry Range
6380 ft
6009 ft
6853 ft
Stevens County
Iron Mountains
6771 ft
Oregon City Ridge
Columbia River
Summit Valley
Gold Mountain Ridge
Huckleberry Mountains
Sanpoil River
4367 ft
4636 ft
Coulee Dam
Grand Coulee Dam
Franklin D. Roosevelt Lake
Deer Meadows
Walkers Prairie
4044
Half Moon Prairie
Four Mound Prairie
Indian Prairie
Bald Ridge
Lincoln County
2138 ft
2444 ft
Malloy Prairie
Bennett Meadow
2566 ft
Karakul Hills
155
21
25
20
174
23
28
292
2
Legend
Railroad Stations
Major Dam
Railroad
County Boundaries
OU 3 Study Area
ADA as Defined by the 2014 Soil Study (TAI 2015a)
Permitted Mining, Ore Processing, and Refining Operations (WDNR 2019b)
Active Quarry
Nonmetallic Mineral Locations (WDNR 2015b)
Mineral
Andalusite, Sillimanite, and Kyanite
Asbestiform Materials
Barite
Beryl
Common Clays and Shales
Dolomite
Feldspar
Fluorite
Garnet
Gem and Ornamental Stones
Granite and Allied Plutonic Rocks
Graphite
Gypsum
Limestone and Marble
Magnesite
Marl
Massive Quartz
Mica
Mineral Pigments
Peat
Quartz Crystal
Quartzite
Refractory Clays and Shales
Sandstone
Serpentine
Silica Sand
Slate and Other Platy Rocks
Sodium Carbonate
Talc and Soapstone
Travertine
Note: See the Legend for Surficial Geology in the OU 3 Study Area (Stoffel et al. 1991).
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0 2.5 5 10
Miles
N
Map 2-13. Regional Nonmetallic Mining and Mining-Related Operations
Final Upland RI Report
Upper Columbia River, Washington
Source: Esri - World Topographic Map; NAD 1983 UTM Zone 11N
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Legend

Permitted Mining, Ore Processing, and Refining Operations (WDNR 2019b)

- Active Quarry

Nonmetallic Mineral Locations (WDNR 2015b)

Mineral

- Andalusite, Sillimanite, and Kyanite
- Asbestiform Materials
- Barite
- Beryl
- Common Clays and Shales
- Dolomite
- Feldspar
- Fluorite
- Garnet
- Gem and Ornamental Stones
- Graphite
- Gypsum
- Limestone and Marble
- Marl
- Massive Quartz
- Mica
- Mineral Pigments
- Peat
- Quartzite
- Serpentine
- Silica Sand
- Travertine

Note: See the Legend for Surficial Geology in the OU 3 Study Area (Stoffel et al. 1991)

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0 1.75 3.5 7 Miles

N

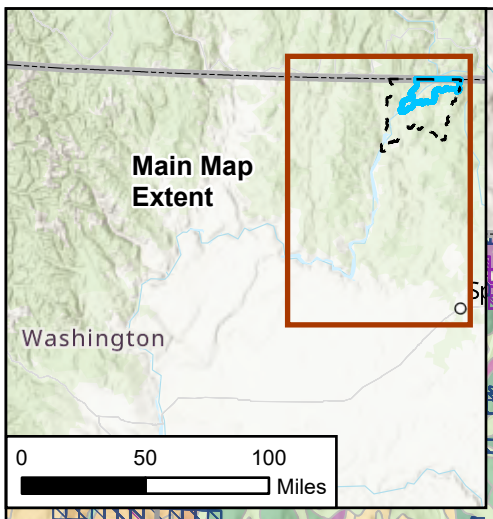
Legend

- City/Town
- Railroad Stations
- Railroad
- OU 3 Study Area
- ADA as Defined by the 2014 Soil Study (TAI 2015a)
- County Boundaries

Map 2-14. **Nonmetallic Mining and Mining-Related Operations in the OU 3 Study Area**
Final Upland RI Report
Upper Columbia River, Washington

Source: Esri - World Topographic Map; NAD 1983 UTM Zone 11N

DRAWN BY: GIS



U.S. - Canada Border

Trail

Waneta Dam

Pend Oreille River

Northport

Bossburg

Evans

Marcus

Kettle Falls

Colville

Pend Oreille County

Stevens County

Ferry County

Republic

Thompson Ridge

Kettle River

Onion Creek

Colville River

North Basin Huckleberry Range

Iron Mountains

Oregon City Ridge

Summit Valley

Gold Mountain Ridge

Huckleberry Mountains

Columbia River

Sanpoil River

Franklin D. Roosevelt Lake

Deer Meadows

Bald Ridge

Corbett Draw

Lincoln County

7139 ft

6380 ft

6009 ft

6853 ft

4367 ft

4636 ft

22 21 25 31 20 395 292 2 28

Legend

- City/Town
- Major Dam
- OU 3 Study Area
- ADA as Defined by the 2014 Soil Study (TAI 2015a)
- County Boundaries

Active Mining Claims (NLSDB 2023)

- Lode Claim
- Placer Claim

Closed Mining Claims

- Lode Claim
- Placer Claim
- Tunnel Site
- Mill Site

Note: See the Legend for Surficial Geology in the OU 3 Study Area (Stoffel et al. 1991).

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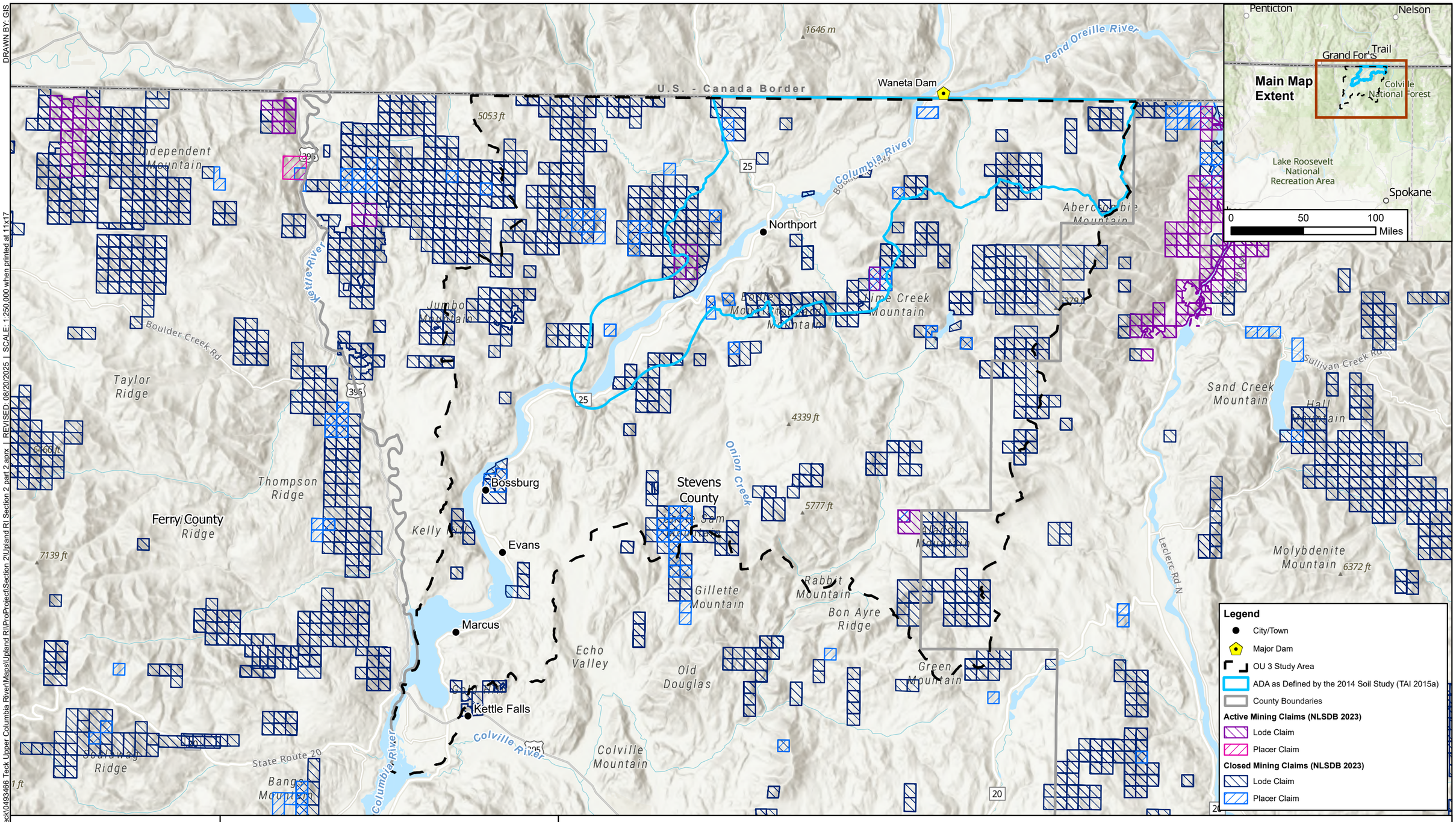
0 2.5 5 10 Miles

N

Map 2-15. **Regional Mine Claims**
Final Upland RI Report
Upper Columbia River, Washington

Source: Esri - World Topographic Map; NAD 1983 UTM Zone 11N

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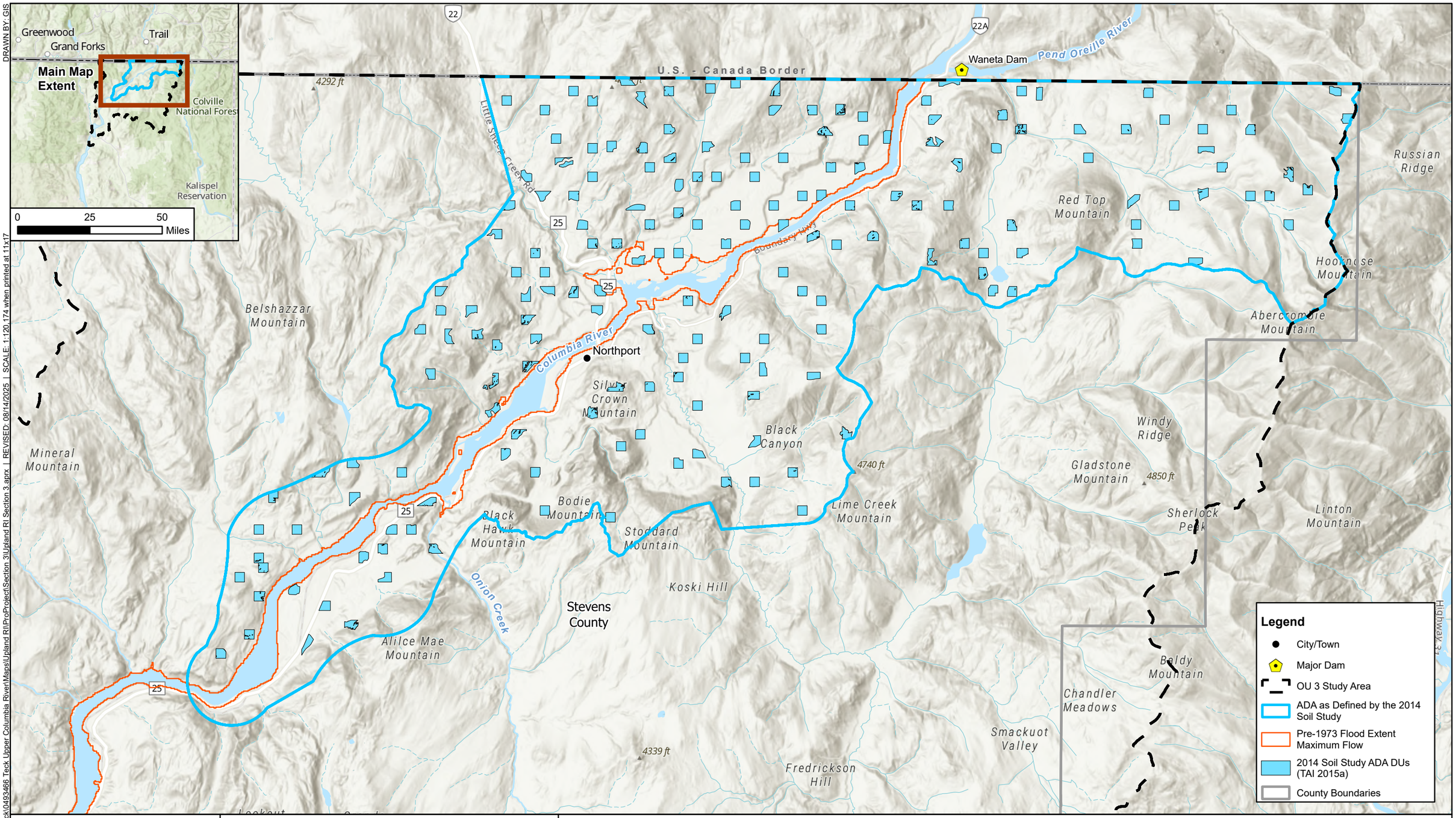
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Map 2-16. **Mine Claims in the OU 3 Study Area**
Final Upland RI Report
Upper Columbia River, Washington

Source: Esri - World Topographic Map; NAD 1983 UTM Zone 11N

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0 0.75 1.5 3 Miles

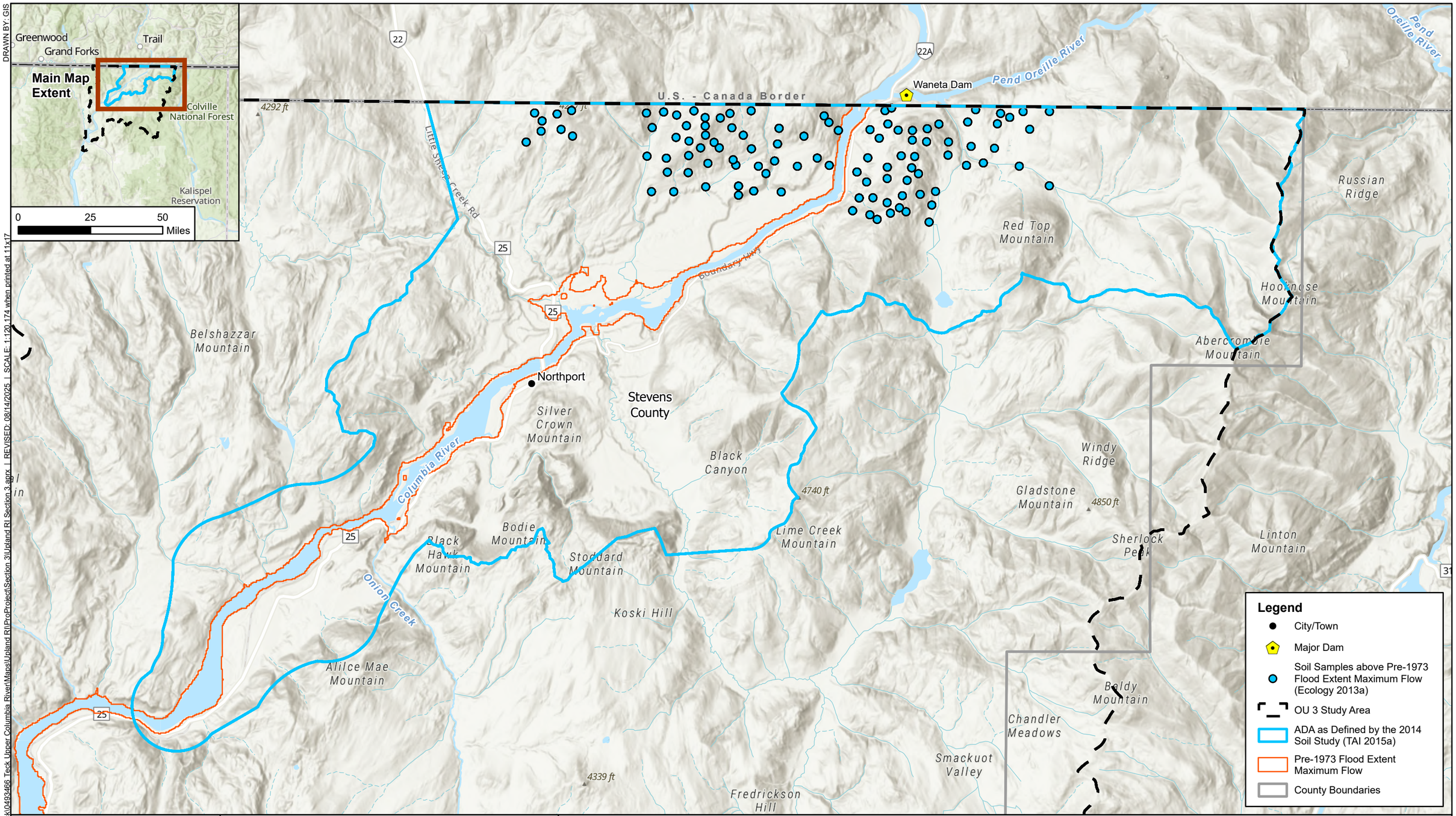
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Map 3-1. **DUs Sampled During the 2014 Soil Study**
Final Upland RI Report
Upper Columbia River, Washington

Source: Esri - World Topographic Map; NAD 1983 UTM Zone 11N

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0 0.75 1.5 3 Miles

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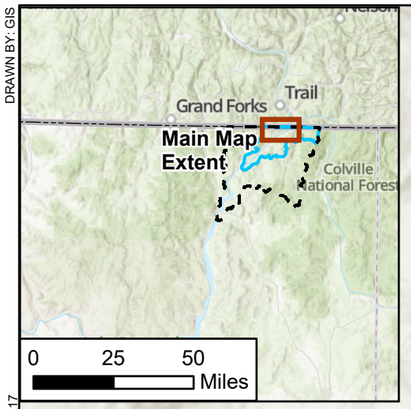
Map 3-2. **Sample Locations from the 2012 Ecology Upland Soil Study**
Final Upland RI Report
Upper Columbia River, Washington

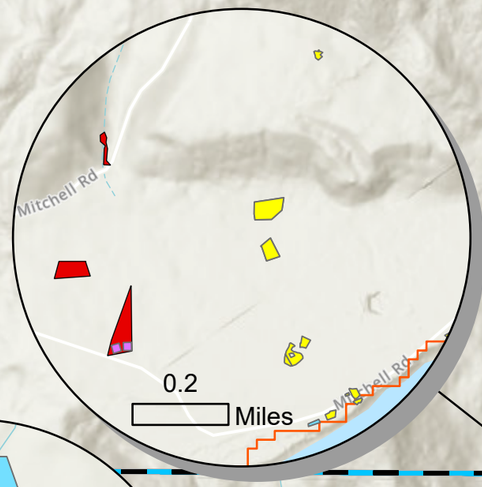
Source: Esri - World Topographic Map; NAD 1983 UTM Zone 11N

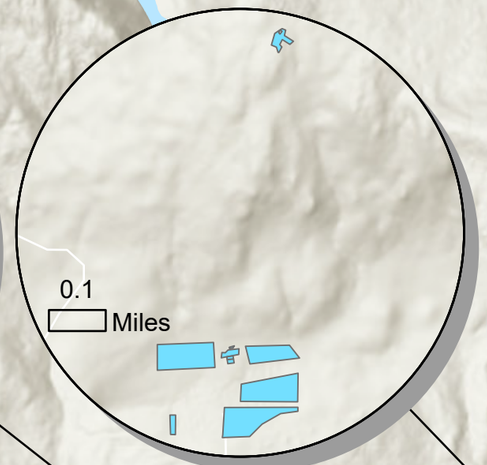
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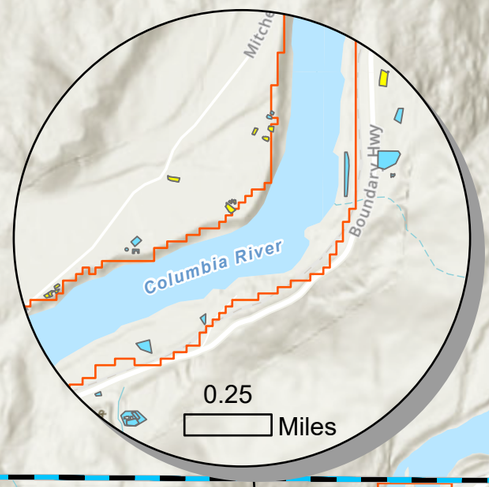
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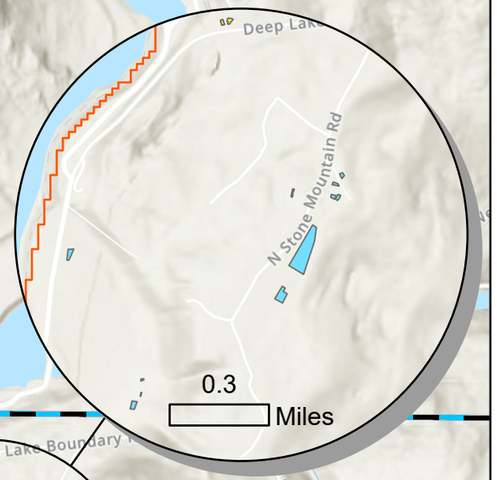
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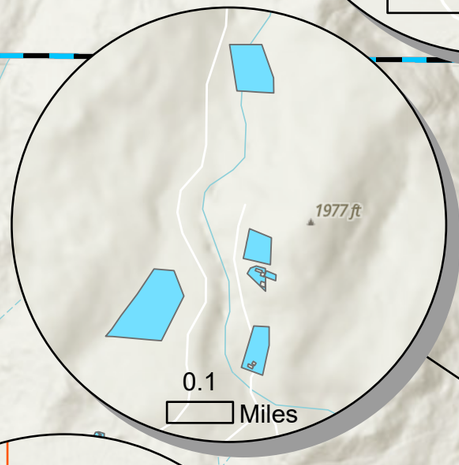




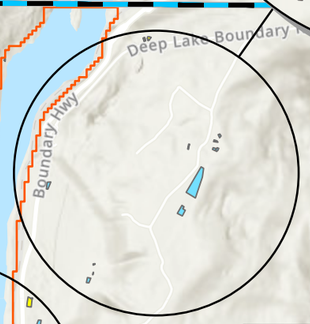


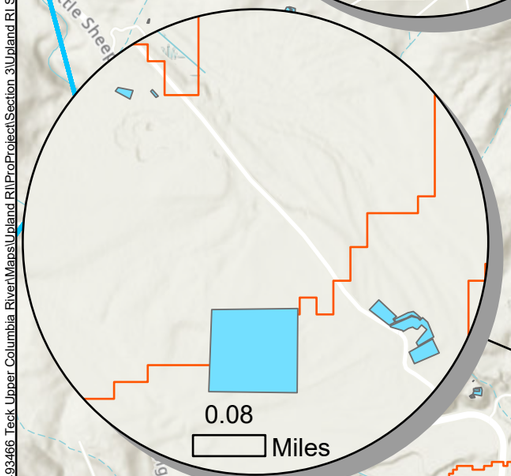
U.S. - Canada Border

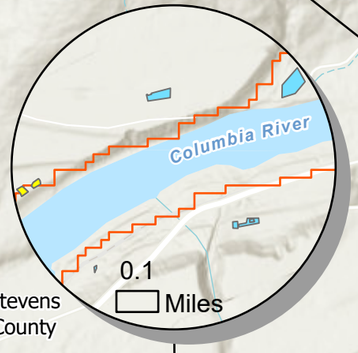
Mitchell Mountain



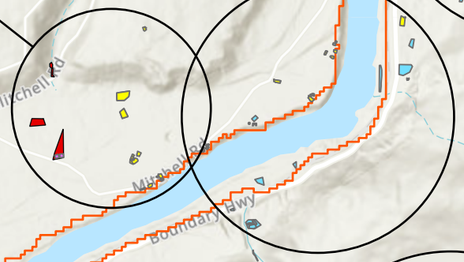








Stevens County













Legend

- OU 3 Study Area
- ADA as Defined by the 2014 Soil Study (TAI 2015a)
- Pre-1973 Flood Extent Maximum Flow
- DUs Sampled During the 2014 Residential Soil Study (USEPA 2016a)
- DUs Resampled During the 2017 SATES Test Plot Characterization (TAI 2019b)
- DUs Included as SAs During the 2018 Plant Tissue Study (TAI 2019c)
- DUs Remediated During the 2015 TCRA (TAI 2016b)

Note: SA16 is not shown because it is outside the OU 3 study area.

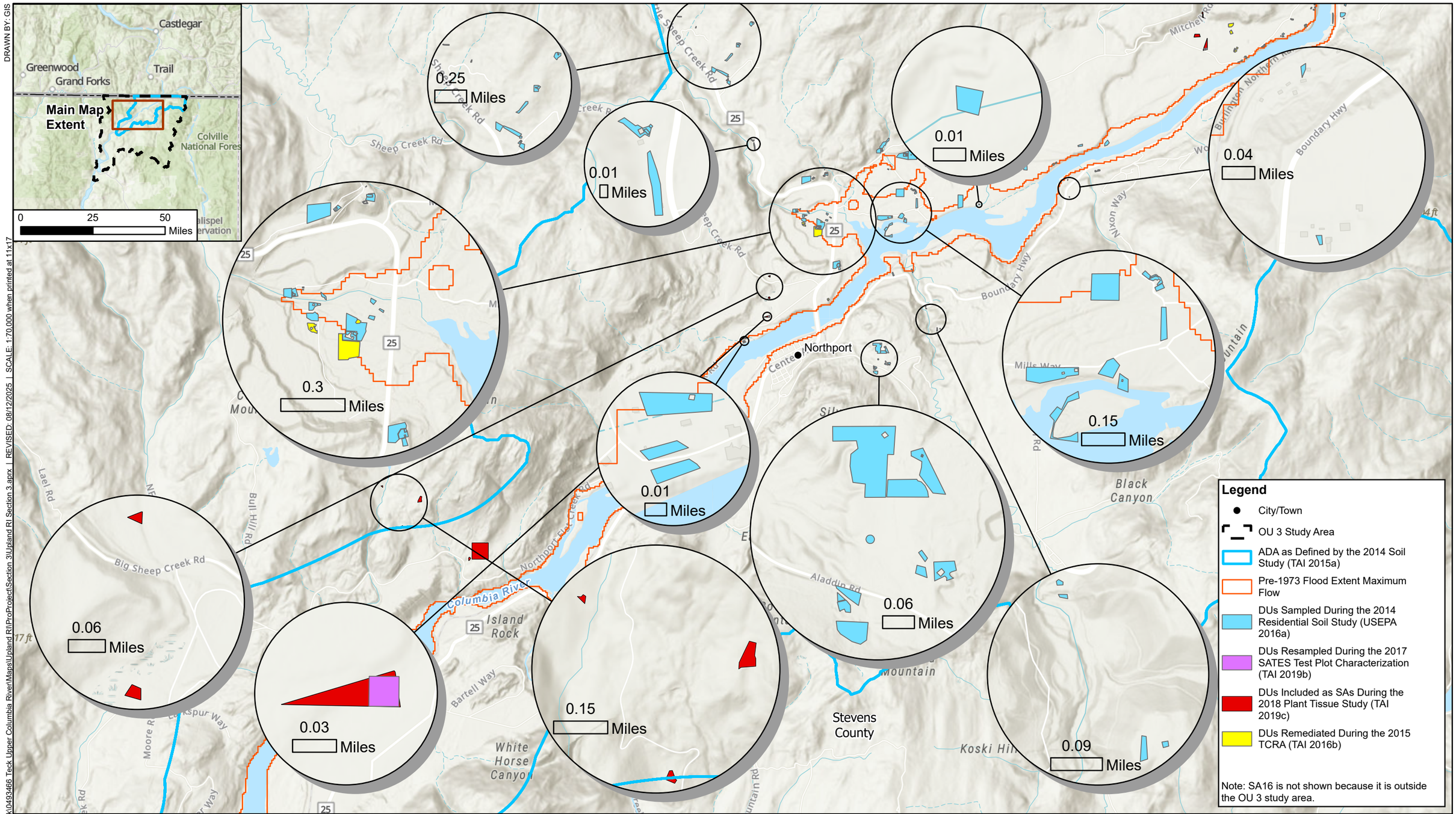
ERM
Environmental Resources Management
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0 0.25 0.5 1 Miles

N

Map 3-3a. **DUs Sampled During the 2014 Residential Soil Study, DUs Resampled During the 2017 SATES Test Plot Characterization, DUs Included as SAs During the 2018 Plant Tissue Study, and DUs Remediated During the 2015 TCRA (Northern Locations)**
Final Upland RI Report
Upper Columbia River, Washington

Source: Esri - World Topographic Map; NAD 1983 UTM Zone 11N



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0 0.5 1 2 Miles

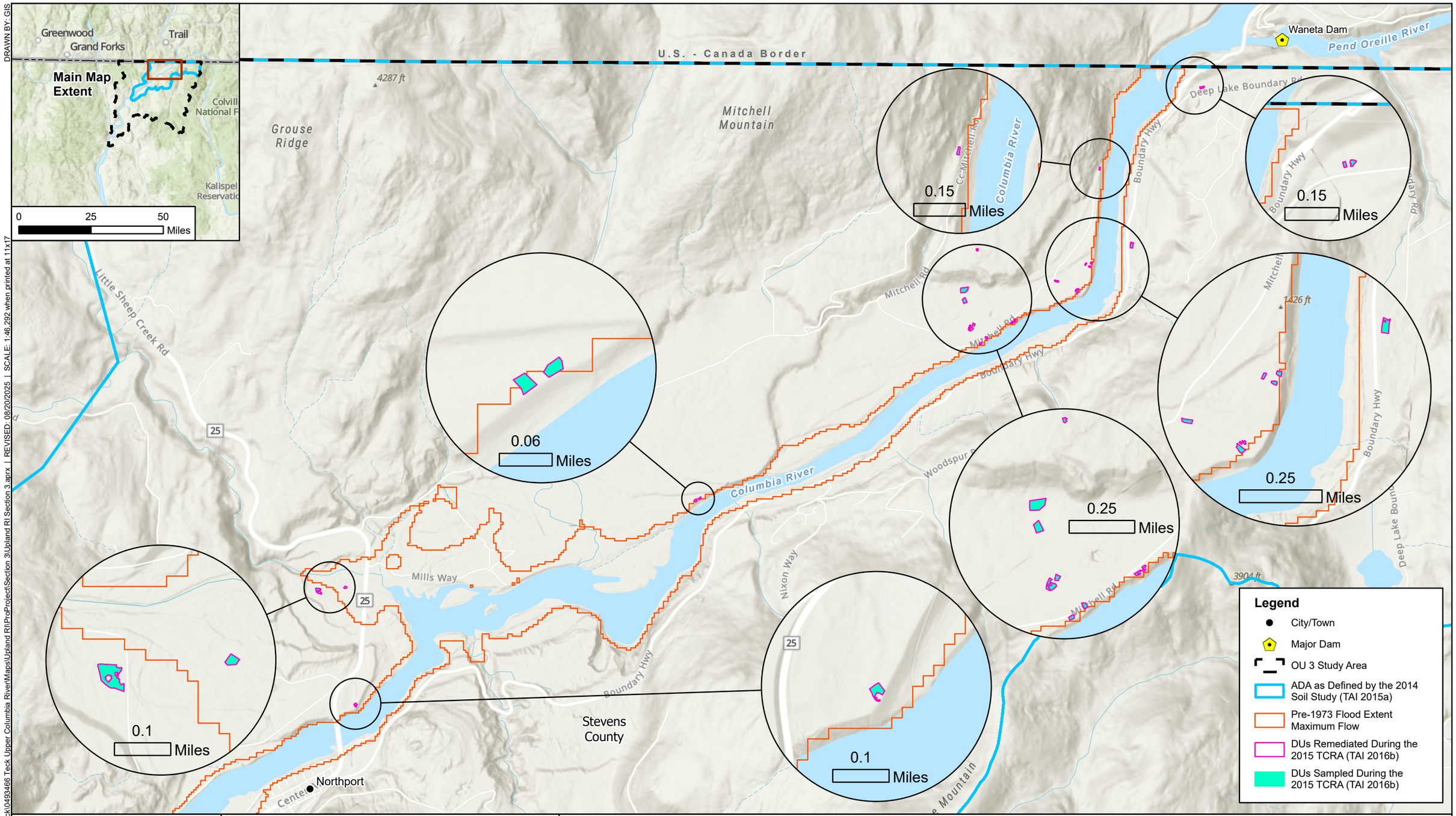
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Map 3-3b. **DUs Sampled During the 2014 Residential Soil Study, DUs Resampled During the 2017 SATES Test Plot Characterization, DUs Included as SAs During the 2018 Plant Tissue Study, and DUs Remediated During the 2015 TCRA (Southern Locations)**

Final Upland RI Report
Upper Columbia River, Washington

Source: Esri - World Topographic Map; NAD 1983 UTM Zone 11N

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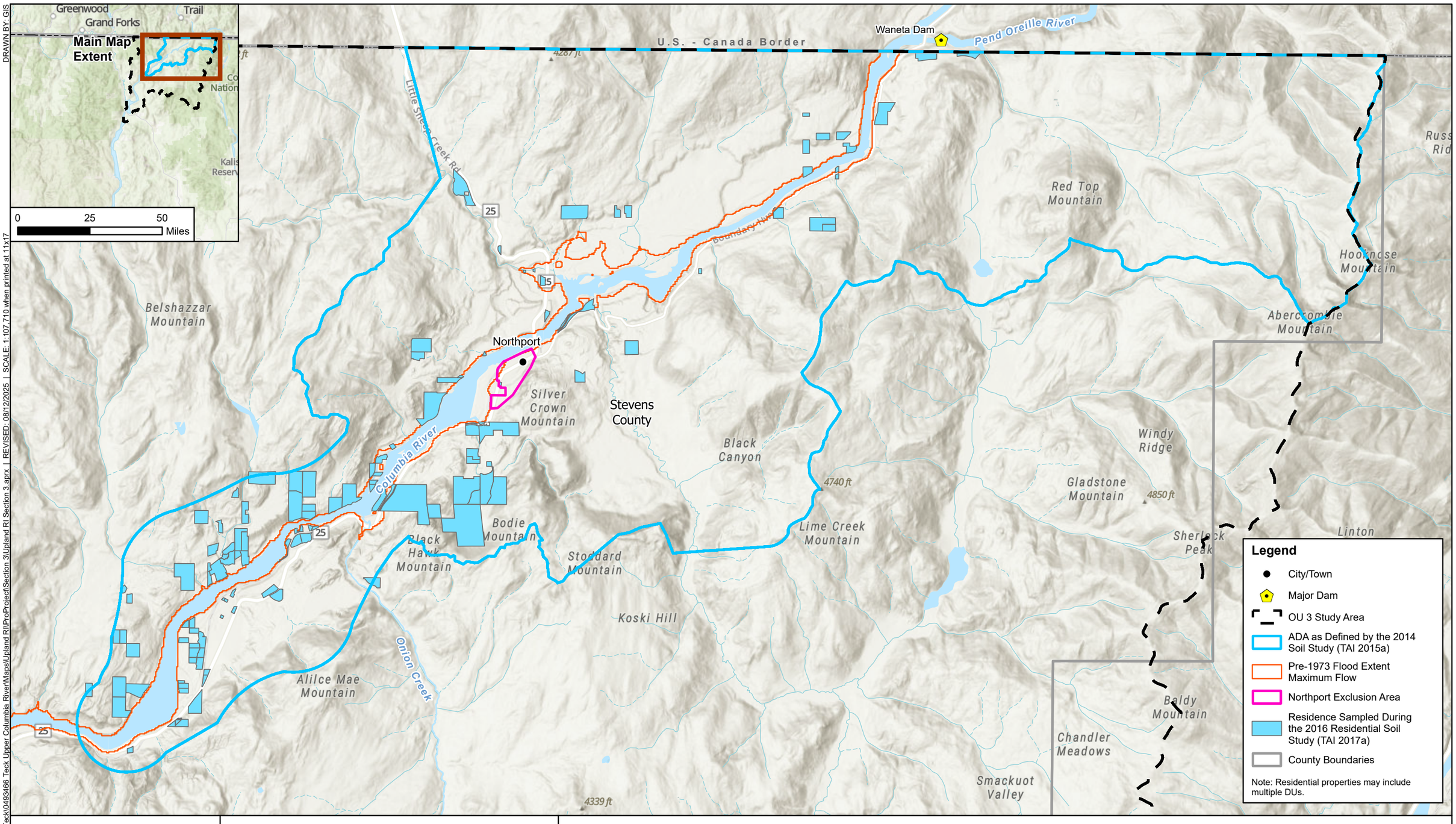
0 0.375 0.75 1.5 Miles

N

Map 3-4. **DUs Sampled and Remediated During the 2015 TCRA**
Final Upland RI Report
Upper Columbia River, Washington

Source: Esri - World Topographic Map; NAD 1983 UTM Zone 11N

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0 0.75 1.5 3 Miles

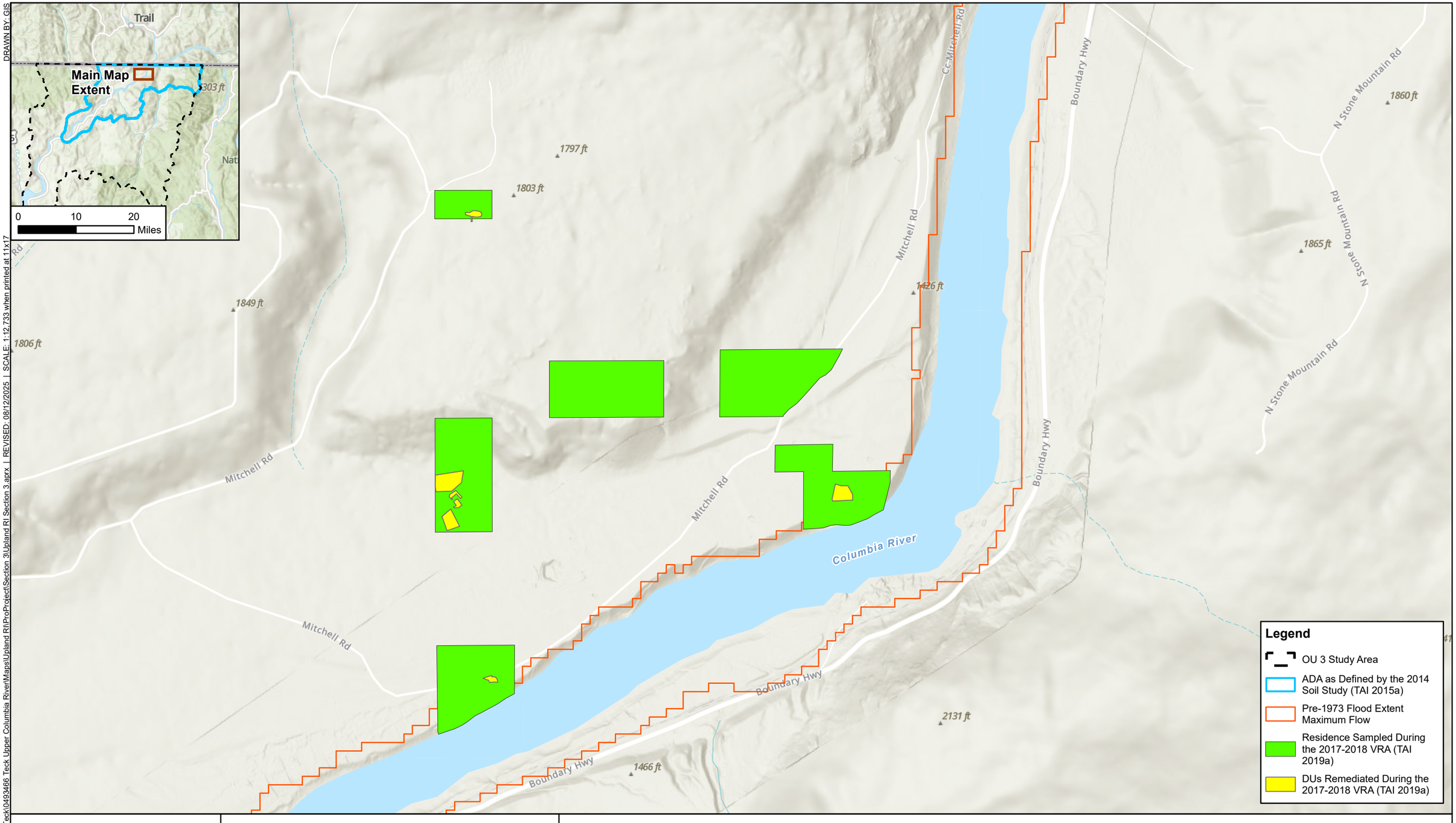
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Map 3-5. **Residential Properties Sampled During the 2016 Residential Soil Study**
Final Upland RI Report
Upper Columbia River, Washington

Source: Esri - World Topographic Map; NAD 1983 UTM Zone 11N

DRAWN BY: GIS | REVISED: 08/12/2025 | SCALE: 1:107,710 when printed at 11x17

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0 0.1 0.2 0.4 Miles

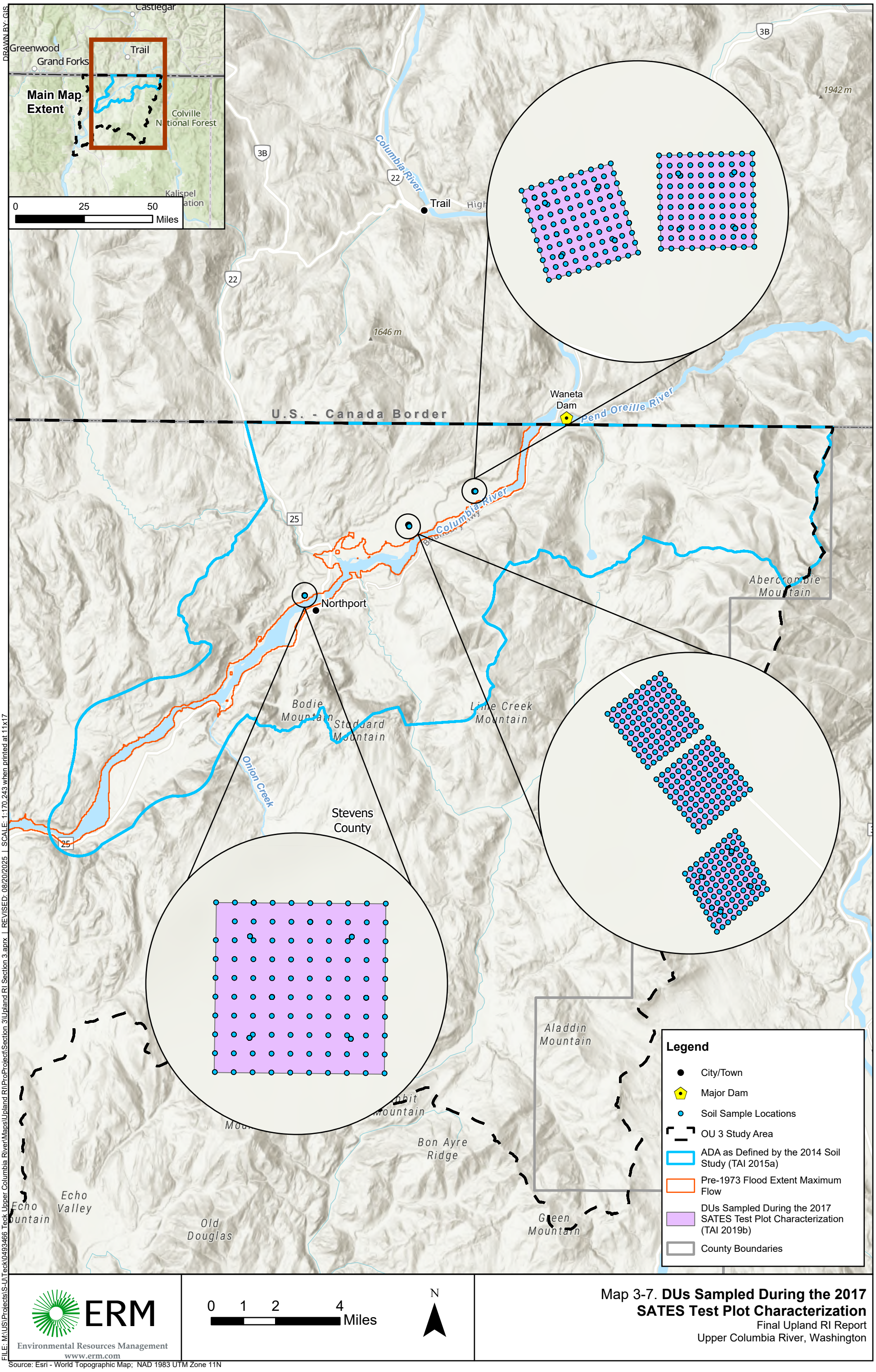
N

Map 3-6. **Residential Properties Sampled and DUs Remediated During the 2017-2018 VRA**
Final Upland RI Report
Upper Columbia River, Washington

Source: Esri - World Topographic Map; NAD 1983 UTM Zone 11N

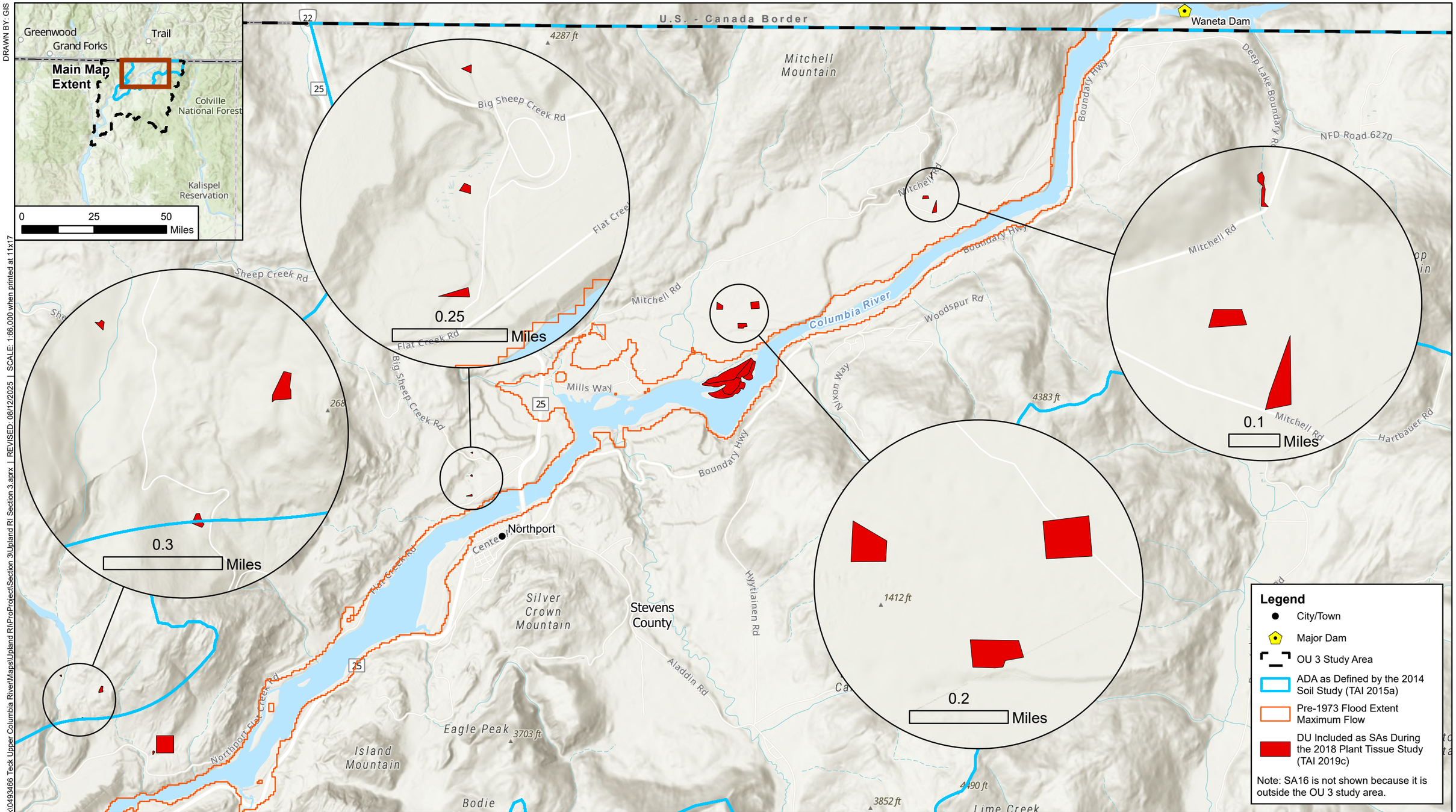
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Castlegar
Greenwood
Grand Forks
Trail
Main Map Extent
Colville National Forest
Kalispel
0 25 50 Miles
DRAWN BY: GIS
3B
22
Columbia River
Trail
1942 m
1646 m
U.S. - Canada Border
Waneta Dam
Pend Oreille River
25
Boundary Hwy
Northport
Abercrombie Mountain
Bodie Mountain
Stoddard Mountain
Lime Creek Mountain
Onion Creek
Stevens County
Aladdin Mountain
Bon Ayre Ridge
Echo Valley
Old Douglas
Green Mountain
Legend
City/Town
Major Dam
Soil Sample Locations
OU 3 Study Area
ADA as Defined by the 2014 Soil Study (TAI 2015a)
Pre-1973 Flood Extent Maximum Flow
DUs Sampled During the 2017 SATES Test Plot Characterization (TAI 2019b)
County Boundaries
ERM
Environmental Resources Management
www.erm.com
0 1 2 4 Miles
N
Map 3-7. DUs Sampled During the 2017 SATES Test Plot Characterization
Final Upland RI Report
Upper Columbia River, Washington
Source: Esri - World Topographic Map; NAD 1983 UTM Zone 11N
FILE: M:\US\Projects\S-U\Teck\0493466 Teck Upper Columbia River\Maps\Upland RI\ProProject\Section 3\Upland RI Section 3.aprx | REVISED: 08/20/2025 | SCALE: 1:170,243 when printed at 11x17

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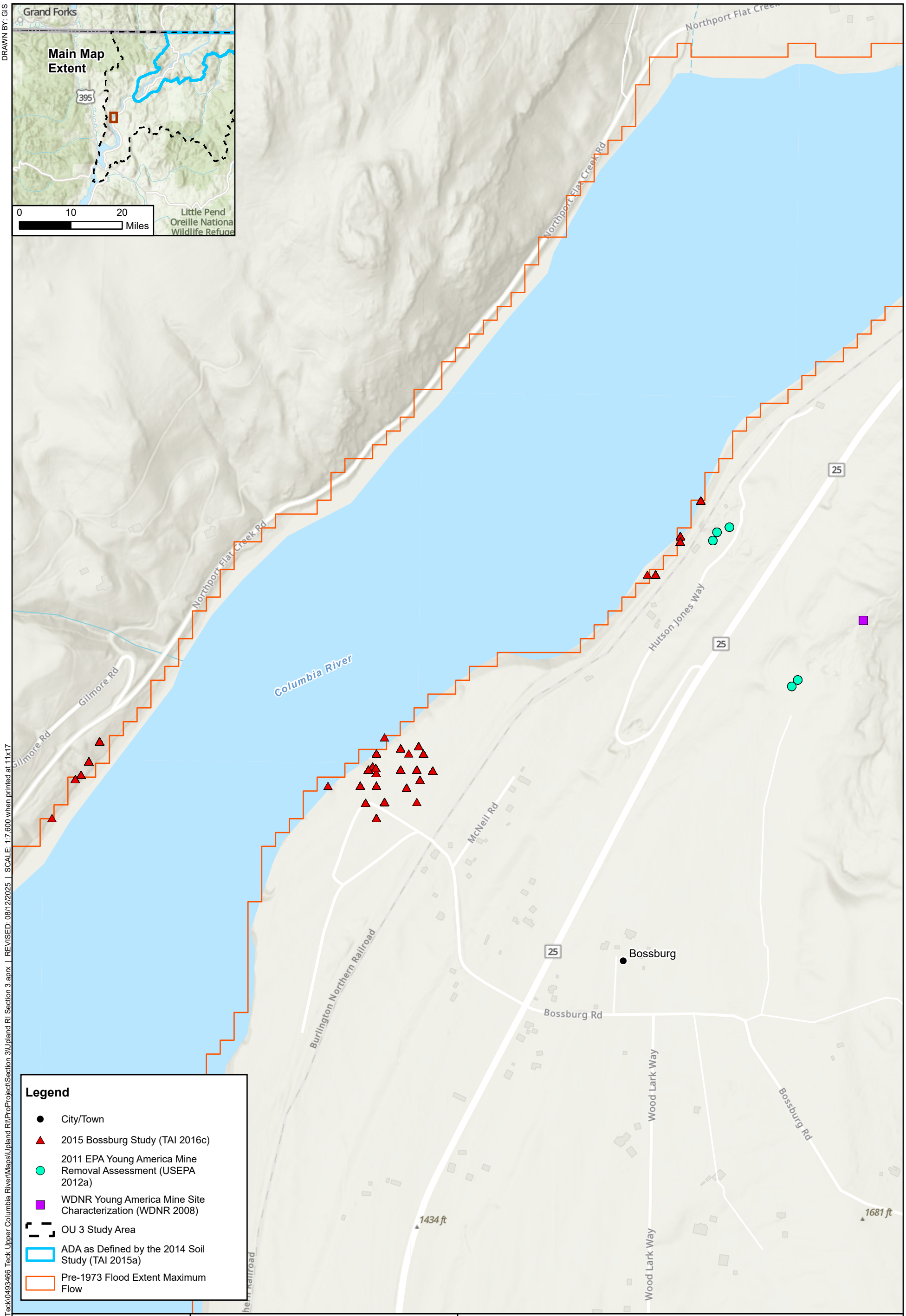
ERM
Environmental Resources Management
www.erm.com

0 0.5 1 2 Miles

N

Map 3-8. **DUs Included as SAs During the 2018 Plant Tissue Study**
Final Upland RI Report
Upper Columbia River, Washington

Source: Esri - World Topographic Map; NAD 1983 UTM Zone 11N



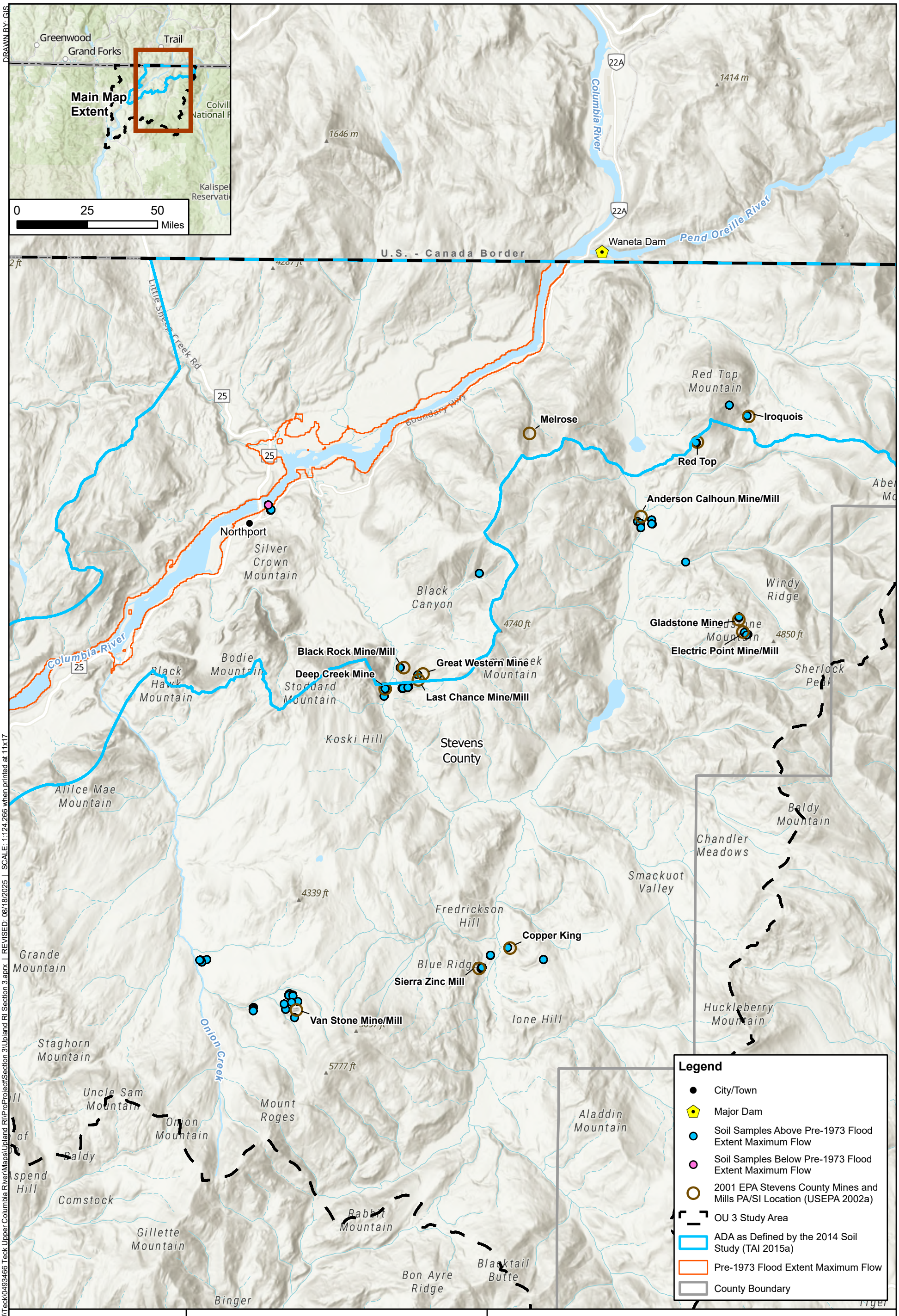
Map 3-9. **Soil Sample Locations from the WDNR Young America Mine Site Characterization, 2011 EPA Young America Mine Removal Assessment, and 2015 Bossburg Study**

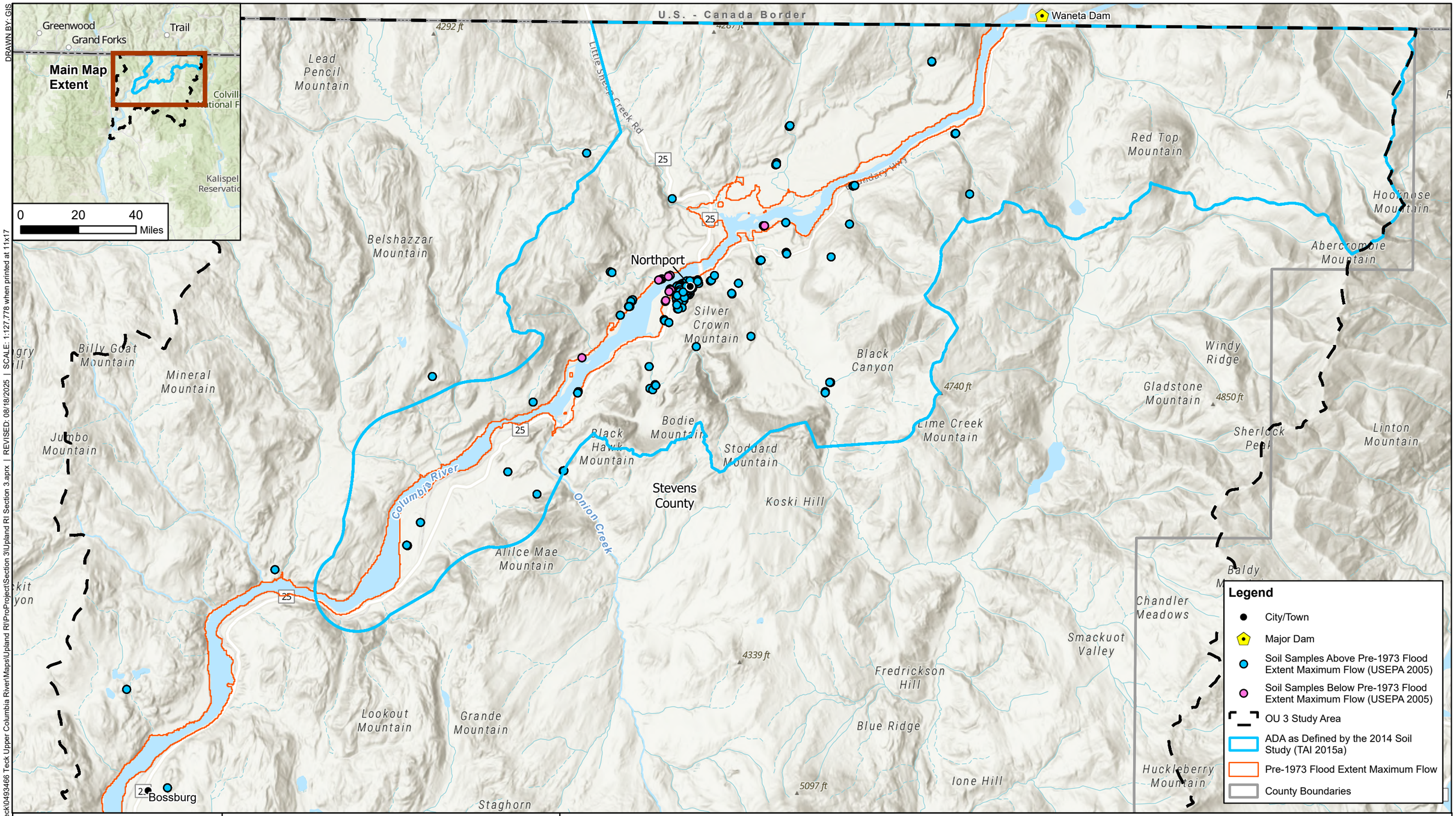
Final Upland RI Report
Upper Columbia River, Washington

Source: Esri - World Topographic Map; NAD 1983 UTM Zone 11N

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DRAWN BY: GIS
Greenwood
Grand Forks
Trail
Main Map Extent
0 25 50 Miles
Columbia River
22A
1414 m
1646 m
Pend Oreille River
Waneta Dam
U.S. - Canada Border
Little Sheep Creek Rd
25
Boundary Hwy
Red Top Mountain
Melrose
Iroquois
Red Top
Anderson Calhoun Mine/Mill
Northport
Silver Crown Mountain
Black Canyon
4740 ft
Windy Ridge
Gladstone Mine
Electric Point Mine/Mill
4850 ft
Columbia River
Black Hawk Mountain
Bodie Mountain
Black Rock Mine/Mill
Great Western Mine
Deep Creek Mine
Last Chance Mine/Mill
Stoddard Mountain
Koski Hill
Stevens County
Sherlock Peak
Alilce Mae Mountain
Baldy Mountain
Chandler Meadows
Smackuot Valley
4339 ft
Fredrickson Hill
Copper King
Blue Ridge
Sierra Zinc Mill
Huckleberry Mountain
Ione Hill
Van Stone Mine/Mill
Onion Creek
5777 ft
Staghorn Mountain
Uncle Sam Mountain
Mount Roges
Onion Mountain
Aladdin Mountain
Baldy
Aspend Hill
Comstock
Gillette Mountain
Rabbit Mountain
Bon Ayre Ridge
Blacktail Butte
Binger
Grande Mountain
Legend
City/Town
Major Dam
Soil Samples Above Pre-1973 Flood Extent Maximum Flow
Soil Samples Below Pre-1973 Flood Extent Maximum Flow
2001 EPA Stevens County Mines and Mills PA/SI Location (USEPA 2002a)
OU 3 Study Area
ADA as Defined by the 2014 Soil Study (TAI 2015a)
Pre-1973 Flood Extent Maximum Flow
County Boundary
ERM
Environmental Resources Management
www.erm.com
0 0.75 1.5 3 Miles
N
Map 3-10. Soil Sample Locations from the 2001 EPA Stevens County Mines and Mills PA/SI
Final Upland RI Report
Upper Columbia River, Washington
Source: Esri - World Topographic Map; NAD 1983 UTM Zone 11N
FILE: M:\US\Projects\S-U\Teck\0493466 Teck Upper Columbia River\Maps\Upland RI\ProProject\Section 3\Upland RI Section 3.aprx | REVISED: 08/18/2025 | SCALE: 1:124,266 when printed at 11x17



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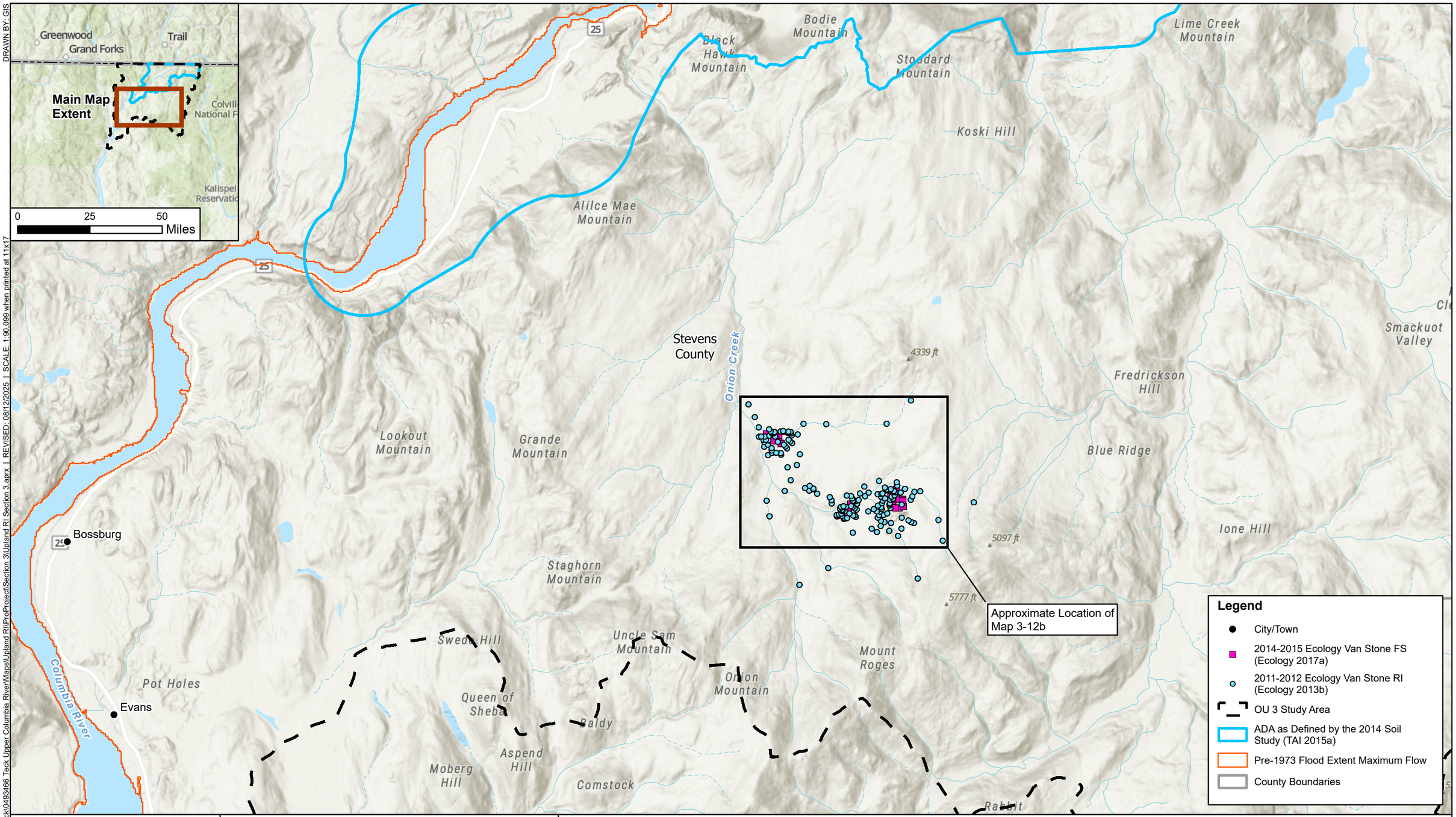
0 1 2 4 Miles

N

Map 3-11.**2004 EPA Le Roi/Northport Smelter Removal Action**
Final Upland RI Report
Upper Columbia River, Washington

Source: Esri - World Topographic Map; NAD 1983 UTM Zone 11N

DRAWN BY: GIS | SCALE: 1:127,778 when printed at 11x17 | REVISED: 08/18/2025 | FILE: M:\US\Projects\S-U\Teck\04934466 Teck Upper Columbia River\Maps\Upland RI\ProProject\Section 3\Upland RI Section 3.aprx



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0 0.5 1 2 Miles

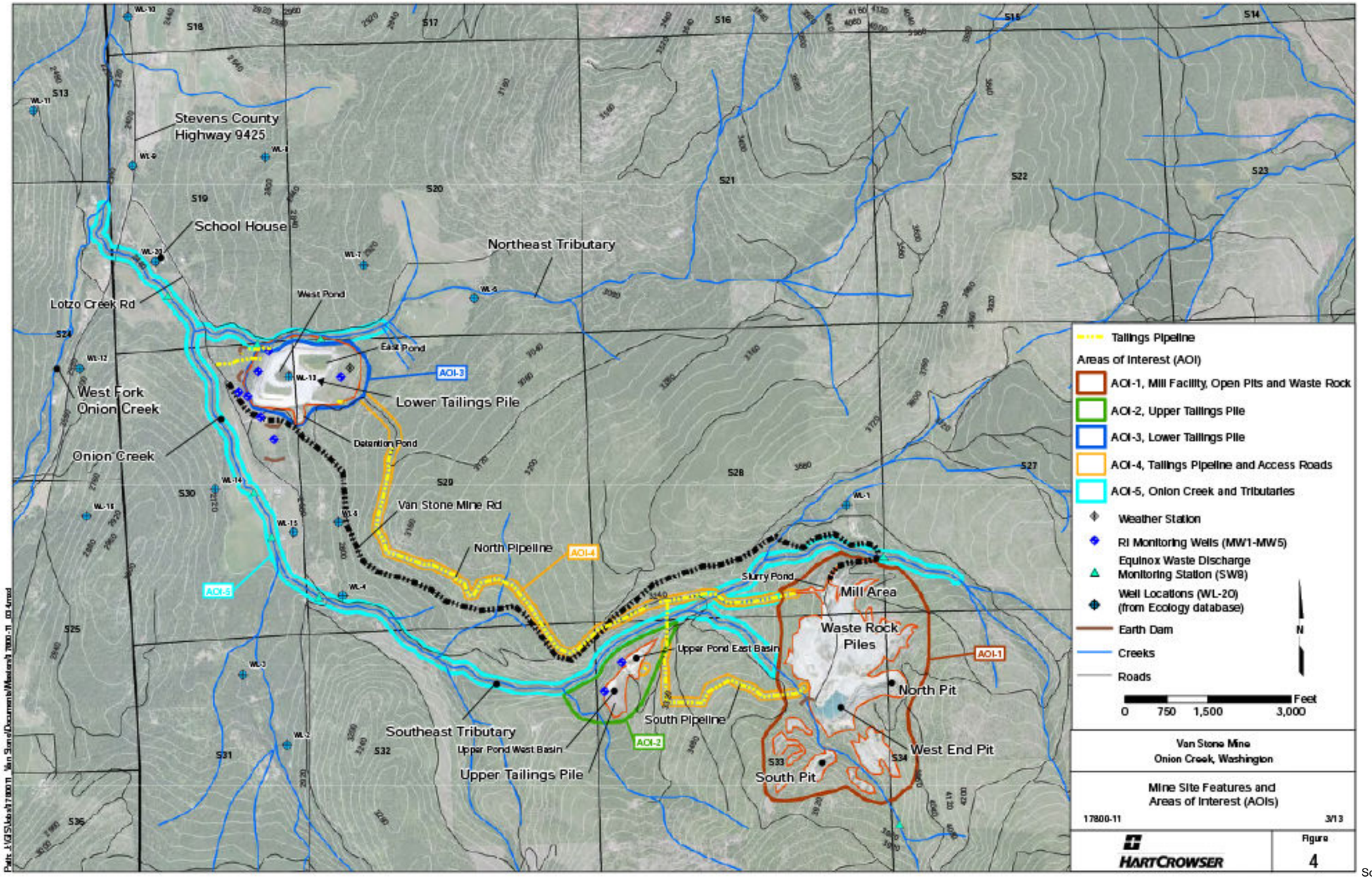
N

Map 3-12a. **Sample Locations from the 2011-2012 Ecology Van Stone RI and 2014-2015 Ecology Van Stone FS**
Final Upland RI Report
Upper Columbia River, Washington

Source: Esri - World Topographic Map; NAD 1983 UTM Zone 11N

DRAWN BY: GIS | REVISED: 08/12/2025 | SCALE: 1:90,099 when printed at 11x17

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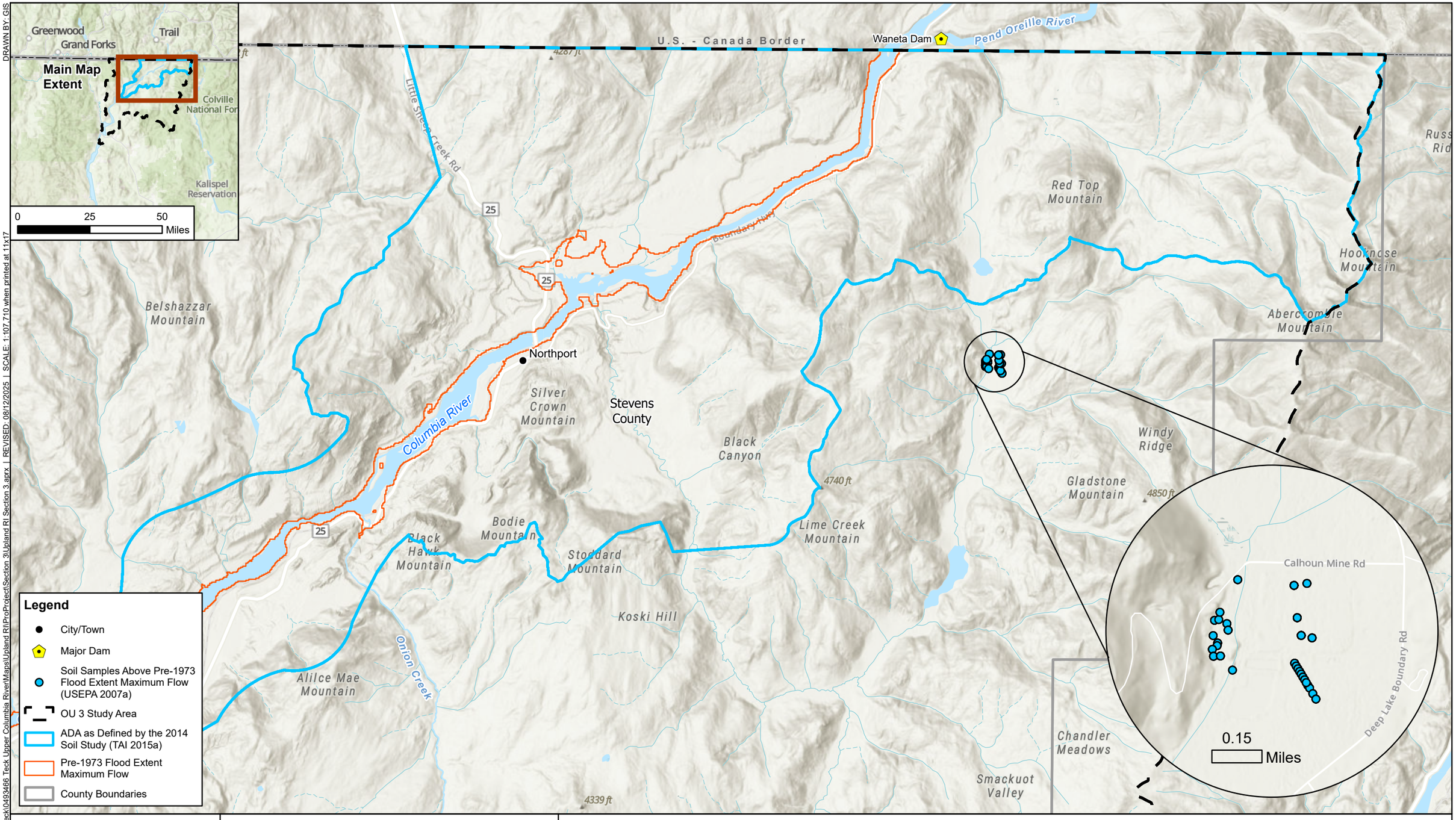
Source: Ecology (2013b)

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Map 3-12b. **AOIs from the 2011-2012 Ecology Van Stone RI and 2014-2015 Ecology Van Stone FS**
Final Upland RI Report
Upper Columbia River, Washington

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FILE: M:\US\Projects\S-U\Teck\0493466 Teck Upper Columbia River\Maps\Upland RI\ProProjectSection 3\Upland RI Section 3.aprx | REVISED: 08/12/2025



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0 0.75 1.5 3 Miles

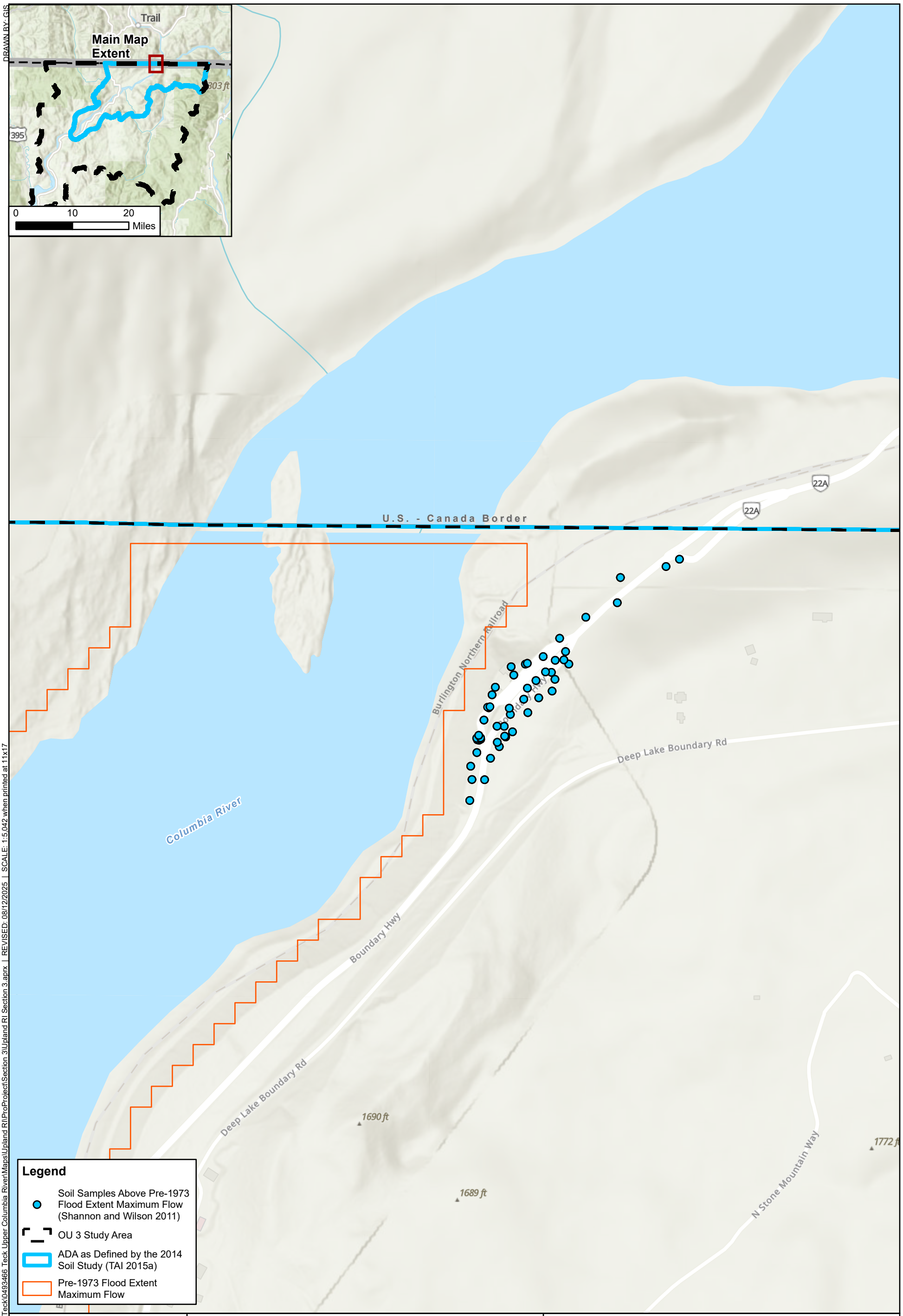
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Map 3-13. **Sample Locations from the 2003-2004 EPA Anderson Calhoun EE/CA**
Final Upland RI Report
Upper Columbia River, Washington

Source: Esri - World Topographic Map; NAD 1983 UTM Zone 11N

DRAWN BY: GIS | REVISED: 08/12/2025 | SCALE: 1:107,710 when printed at 11x17

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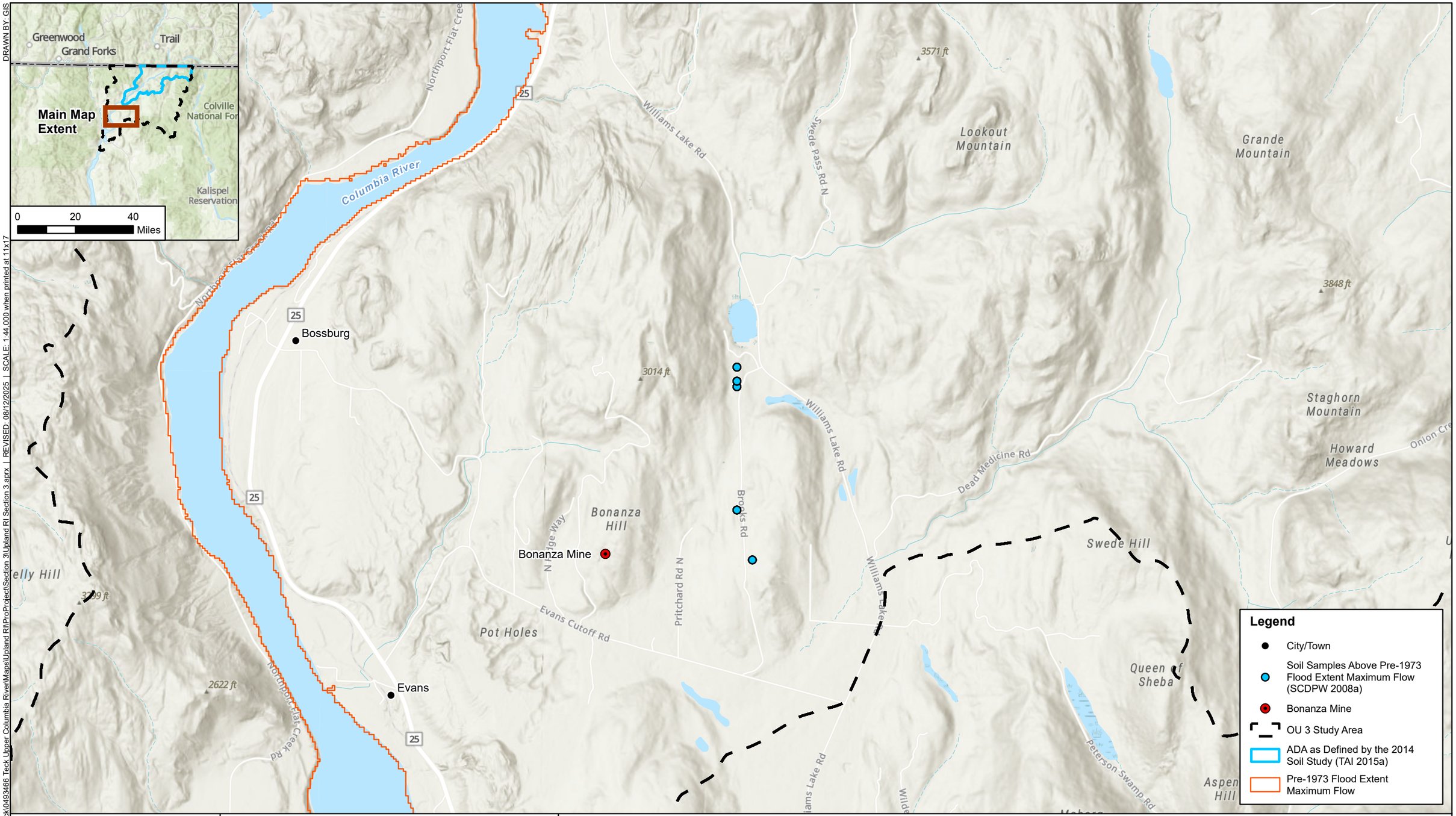
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Map 3-14. **Soil Sample Locations from the 2011 Port of Entry Soil Remediation**
Final Upland RI Report
Upper Columbia River, Washington

Source: Esri - World Topographic Map; NAD 1983 UTM Zone 11N

FILE: M:\US\Projects\S-UT\eck\0493466 Teck Upper Columbia River\Maps\Upland RI\ProProject\Section 3\Upland RI Section 3.aprx | REVISED: 08/12/2025 | SCALE: 1:5,042 when printed at 11x17

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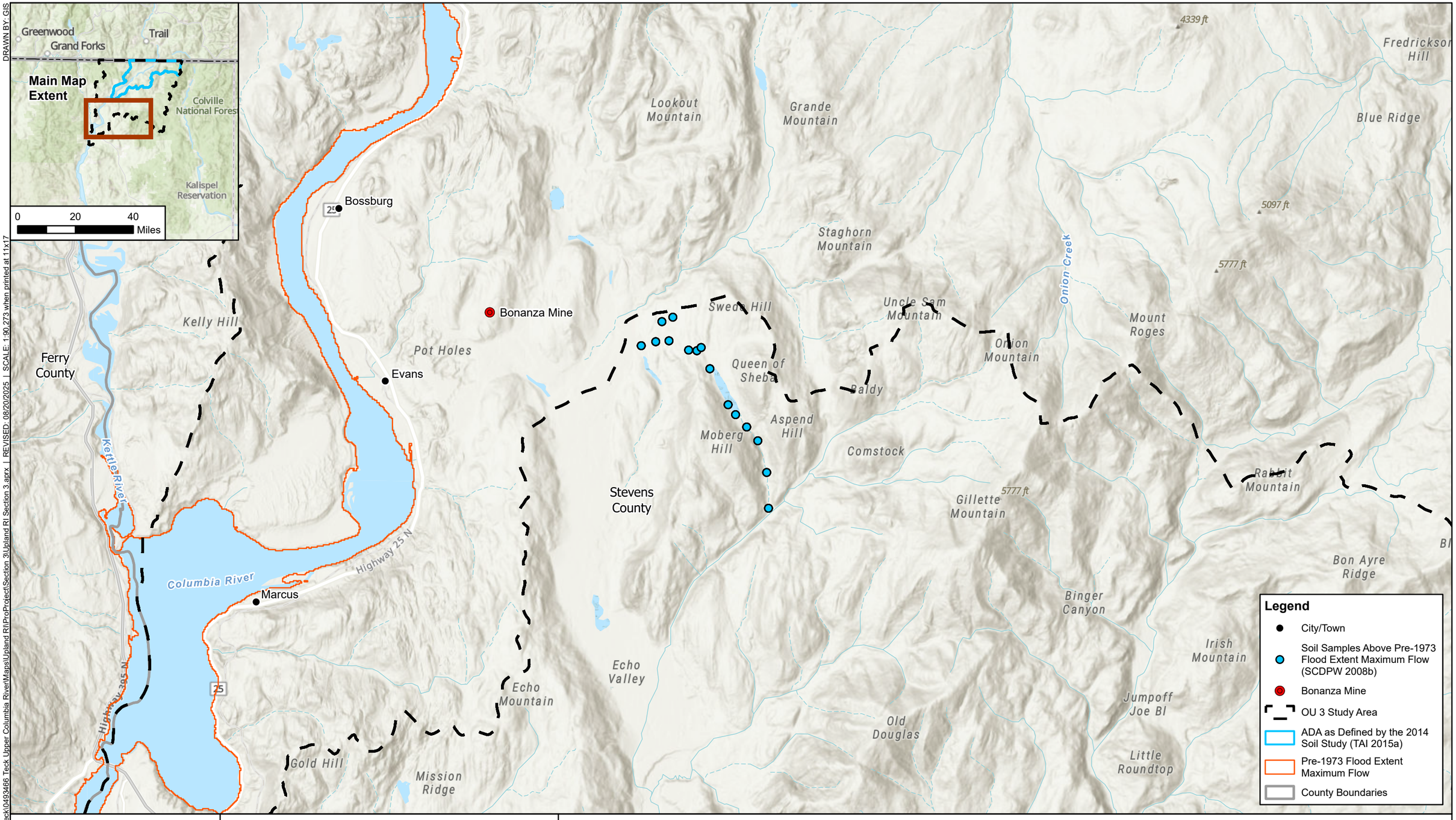
ERM
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www.erm.com

0 0.5 1 Miles

N

Map 3-15. **Background Soil Sample Locations from the 2007 Brooks Road/Bonanza Mine Roadbed Voluntary Cleanup**
Final Upland RI Report
Upper Columbia River, Washington

Source: Esri - World Topographic Map; NAD 1983 UTM Zone 11N



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0 0.5 1 2 Miles

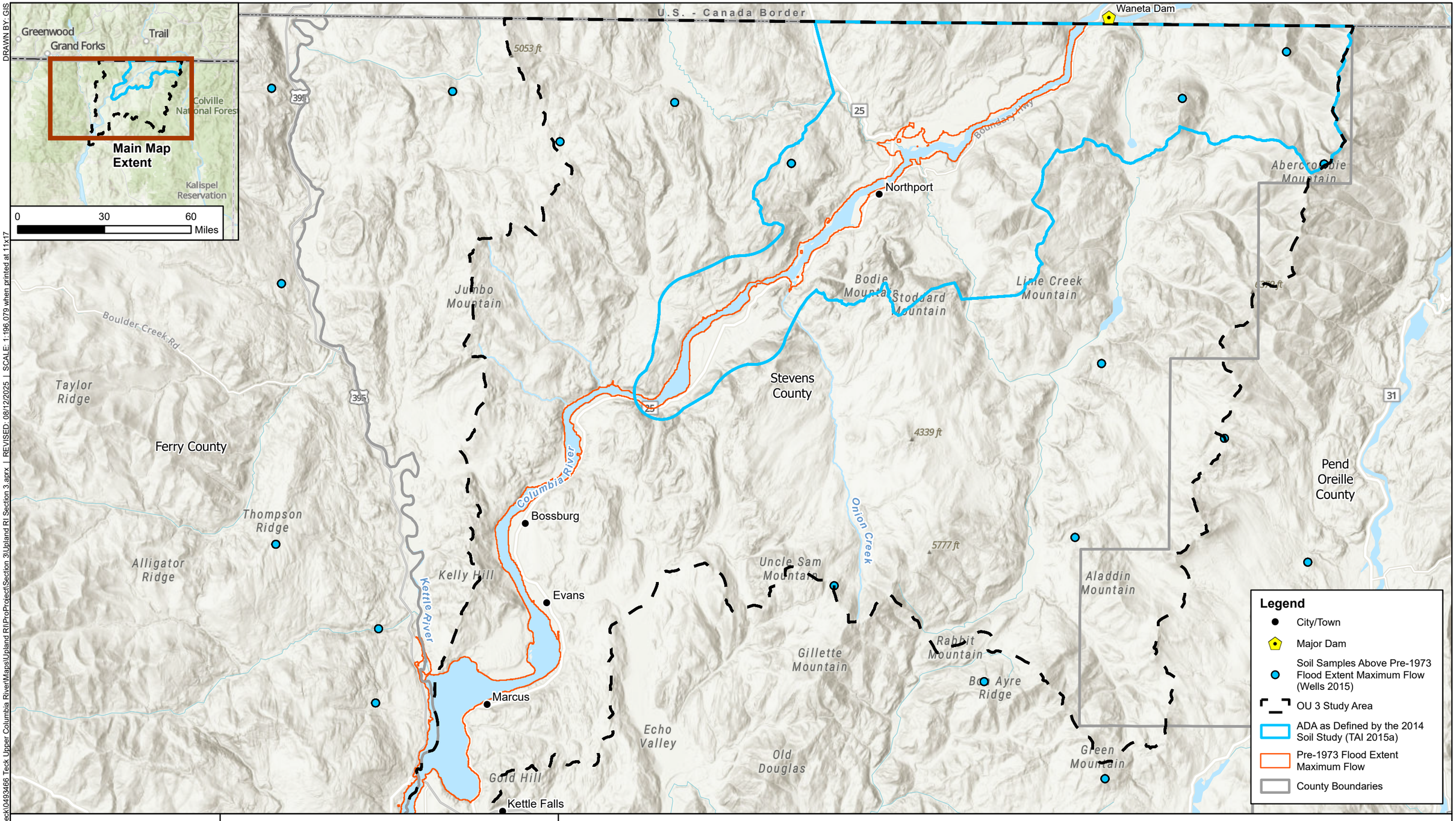
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Map 3-16. **Background Soil Sample Locations from the 2007 Peterson Swamp/Bonanza Mine Roadbed Voluntary Cleanup**
Final Upland RI Report
Upper Columbia River, Washington

Source: Esri - World Topographic Map; NAD 1983 UTM Zone 11N

DRAWN BY: GIS | REVISED: 08/20/2025 | SCALE: 1:90,273 when printed at 11x17

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0 1.5 3 6 Miles

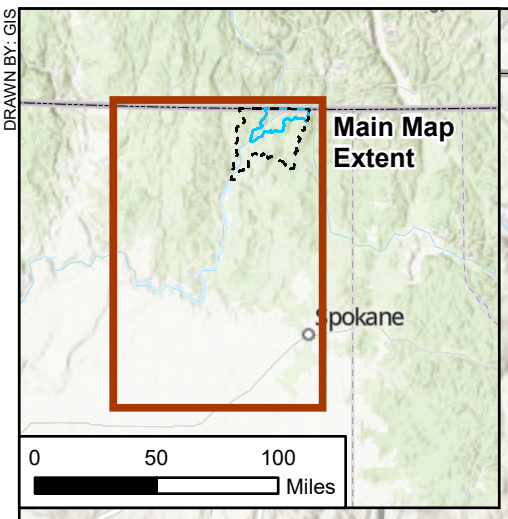
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Map 3-17. **Soil Sample Locations from the Wells Lichen Study**
Final Upland RI Report
Upper Columbia River, Washington

Source: Esri - World Topographic Map; NAD 1983 UTM Zone 11N

DRAWN BY: GIS | REVISED: 08/12/2025 | SCALE: 1:196,079 when printed at 11x17 | FILE: M:\US\Projects\S-U\Teck\0493466 Teck Upper Columbia River\Maps\Upland RI\ProProject\Section 3\Upland RI Section 3.aprx

DRAWN BY: GIS



U.S. - Canada Border
Waneta Dam
Pend Oreille River
Northport
Lime Creek Mountain
Onion Creek
Thompson Ridge
Kettle River
Bossburg
Evans
Marcus
Kettle Falls
Republic
Ferry County
Colville
Colville River
North Huckleberry Range
Columbia River
Iron Mountains
Oregon City Ridge
Summit Valley
Gold Mountain Ridge
Sanpoil River
Stevens County
Huckleberry Mountains
Coulee Dam
Grand Coulee Dam
Franklin D. Roosevelt Lake
Deer Meadows
Walkers Prairie
Half Moon Prairie
Four Mound Prairie
Indian Prairie
Bald Ridge
Corbett Draw
Lincoln County
Bennett Meadow
Rocky Coulee
7139 ft
6771 ft
6380 ft
6009 ft
6853 ft
2695 ft
4367 ft
4636 ft
4044 ft
2138 ft
2444 ft

Legend

- City/Town
- Major Dam
- Soil Samples Above Pre-1973 Flood Extent Maximum Flow (USGS 2013)
- OU 3 Study Area
- ADA as Defined by the 2014 Soil Study (TAI 2015a)
- Pre-1973 Flood Extent Maximum Flow
- County Boundaries

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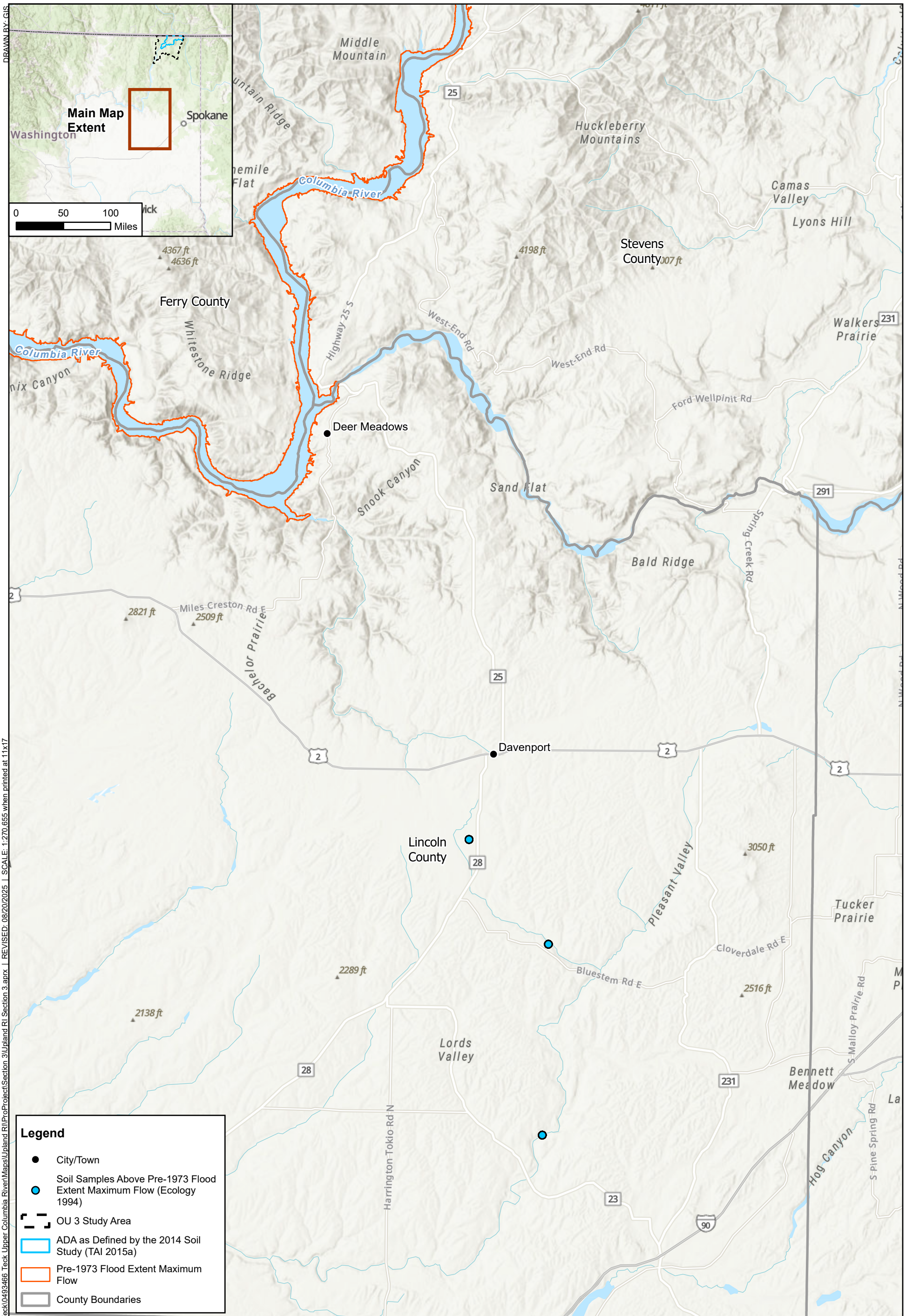
0 4 8 16 Miles

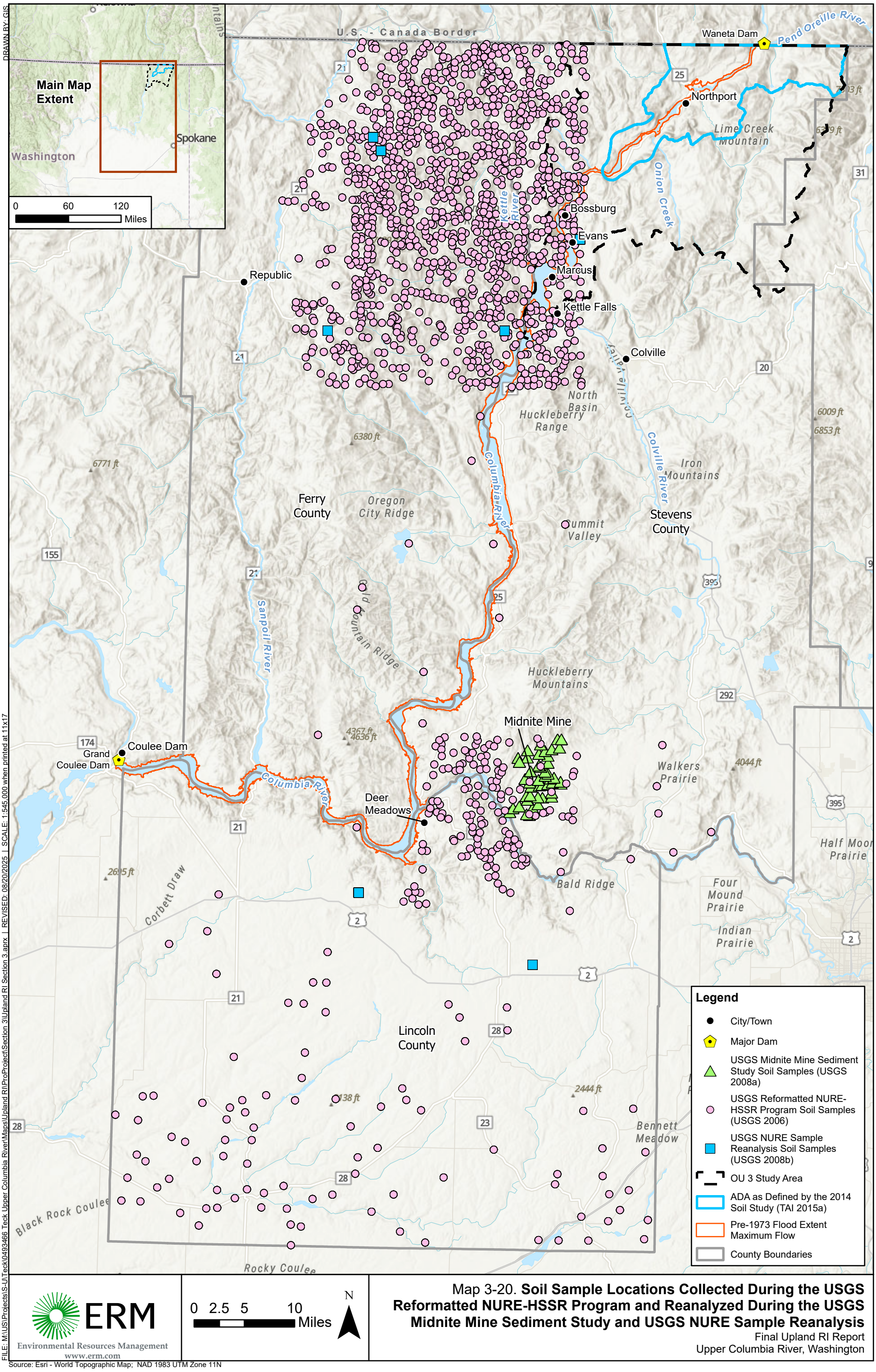
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Map 3-18. **Soil Sample Locations from the 2007-2010 USGS Soil Study**
Final Upland RI Report
Upper Columbia River, Washington

FILE: M:\US\Projects\S-U\Teck\0493466 Teck Upper Columbia River\Maps\Upland RI\ProProject\Section 3\Upland RI Section 3.aprx | REVISED: 08/20/2025 | SCALE: 1:545,000 when printed at 11x17

Source: Esri - World Topographic Map; NAD 1983 UTM Zone 11N


Main Map Extent
Spokane
Washington
0 50 100
Miles
Middle Mountain
Huckleberry Mountains
Columbia River
Camas Valley
Lyons Hill
Stevens County
4198 ft
4367 ft
4636 ft
Ferry County
Whitestone Ridge
Highway 25 S
West-End Rd
Walkers Prairie
231
Deer Meadows
Snook Canyon
Sand Flat
291
Bald Ridge
Spring Creek Rd
2821 ft
2509 ft
Miles Creston Rd E
Batchelor Prairie
25
Davenport
2
Lincoln County
28
3050 ft
Pleasant Valley
Tucker Prairie
Cloverdale Rd E
Bluestem Rd E
2289 ft
2516 ft
2138 ft
Lords Valley
Harrington Tokio Rd N
Bennett Meadow
S Malloy Prairie Rd
S Pine Spring Rd
Hog Canyon
23
90
Legend
City/Town
Soil Samples Above Pre-1973 Flood Extent Maximum Flow (Ecology 1994)
OU 3 Study Area
ADA as Defined by the 2014 Soil Study (TAI 2015a)
Pre-1973 Flood Extent Maximum Flow
County Boundaries
ERM
Environmental Resources Management
www.erm.com
0 1.5 3 6
Miles
N
Map 3-19. Soil Sample Locations from the Ecology Natural Background Soil Study
Final Upland RI Report
Upper Columbia River, Washington
Source: Esri - World Topographic Map; NAD 1983 UTM Zone 11N
DRAWN BY: GIS
FILE: M:\US\Projects\S-UT\eck\0493466 Teck Upper Columbia River\Maps\Upland RI\ProProject\Section 3\Upland RI Section 3.aprx | REVISED: 08/20/2025 | SCALE: 1:270,655 when printed at 11x17



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Environmental Resources Management
www.erm.com

0 2.5 5 10 Miles

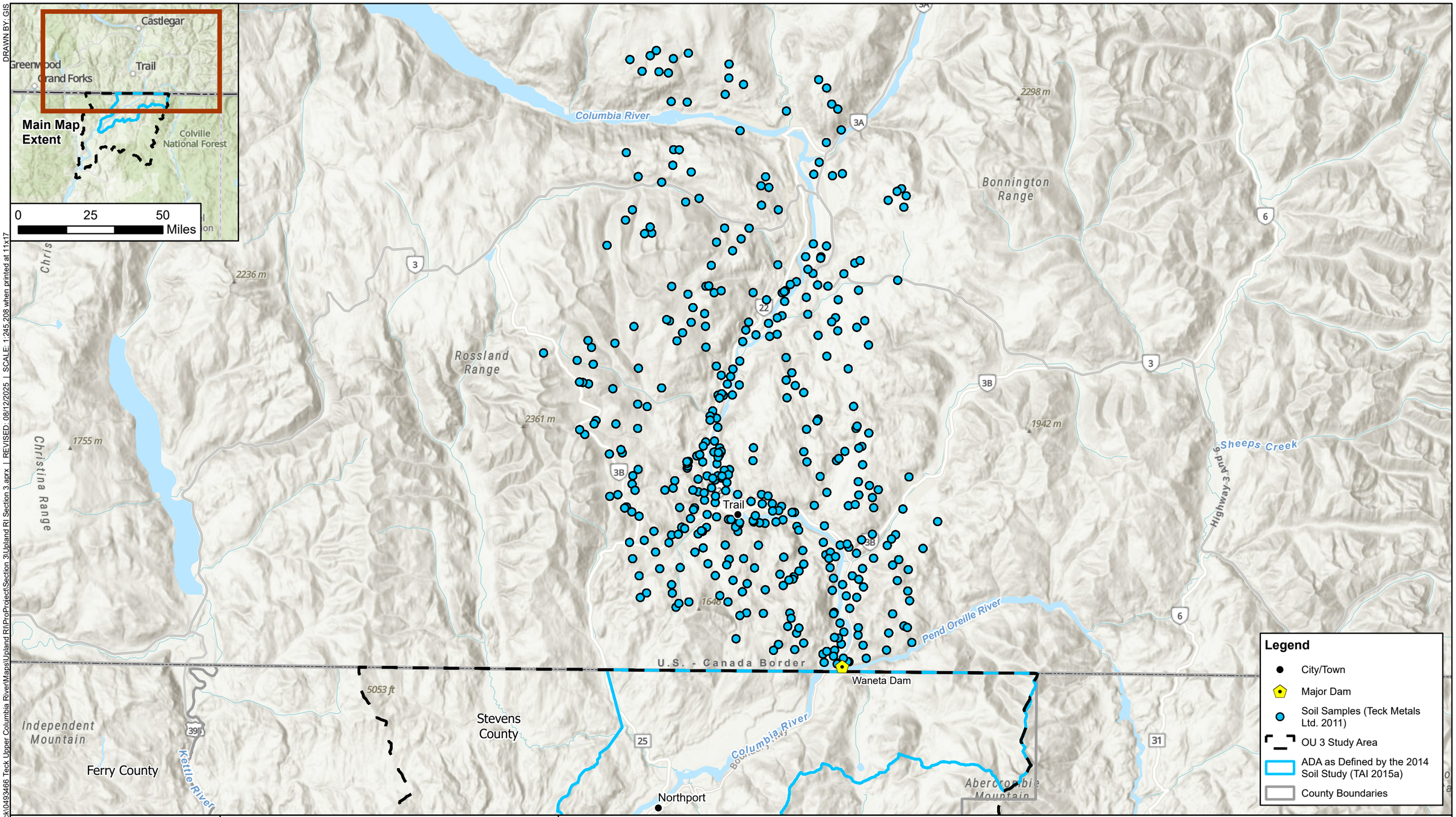
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Map 3-20. **Soil Sample Locations Collected During the USGS Reformatted NURE-HSSR Program and Reanalyzed During the USGS Midnite Mine Sediment Study and USGS NURE Sample Reanalysis**

Final Upland RI Report
Upper Columbia River, Washington

Source: Esri - World Topographic Map; NAD 1983 UTM Zone 11N

DRAWN BY: GIS | FILE: M:\US\Projects\S-U\Teck\0493466 Teck Upper Columbia River\Maps\Upland RI\ProProject\Section 3\Upland RI Section 3.aprx | REVISED: 08/20/2025 | SCALE: 1:545,000 when printed at 11x17



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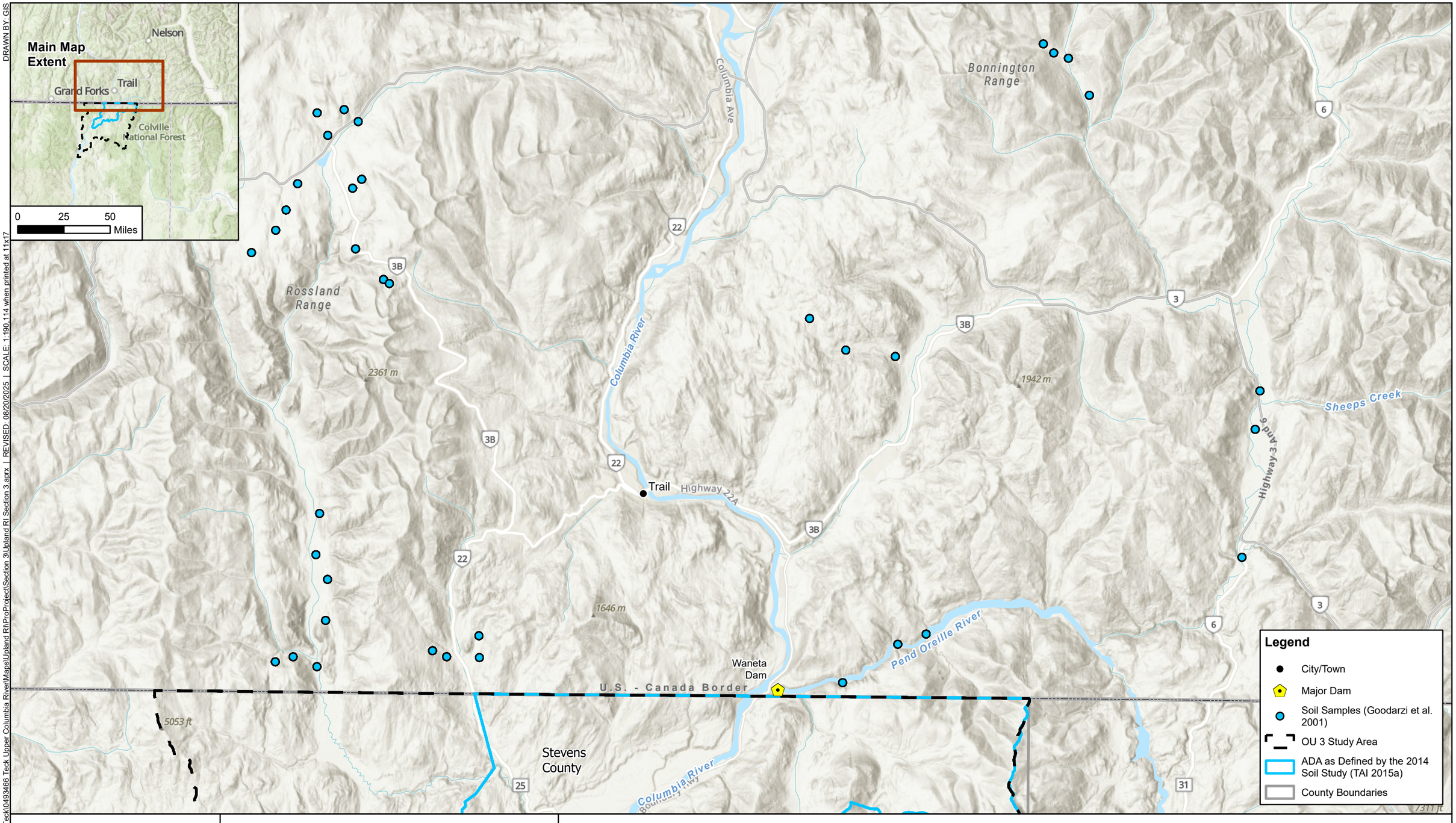
0 2.5 5 10 Miles

N

Map 3-21. **Soil Sample Locations from the Trail Smelter Terrestrial ERA**
Final Upland RI Report
Upper Columbia River, Washington

Source: Esri - World Topographic Map; NAD 1983 UTM Zone 11N

DRAWN BY: GIS | REVISED: 08/12/2025 | SCALE: 1:245,208 when printed at 11x17 | FILE: M:\US\Projects\S-U\Teck\0493466 Teck Upper Columbia River\Maps\Upland RI\ProProject\Section 3\Upland RI Section 3.aprx



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Environmental Resources Management
www.erm.com

0 1.25 2.5 5 Miles

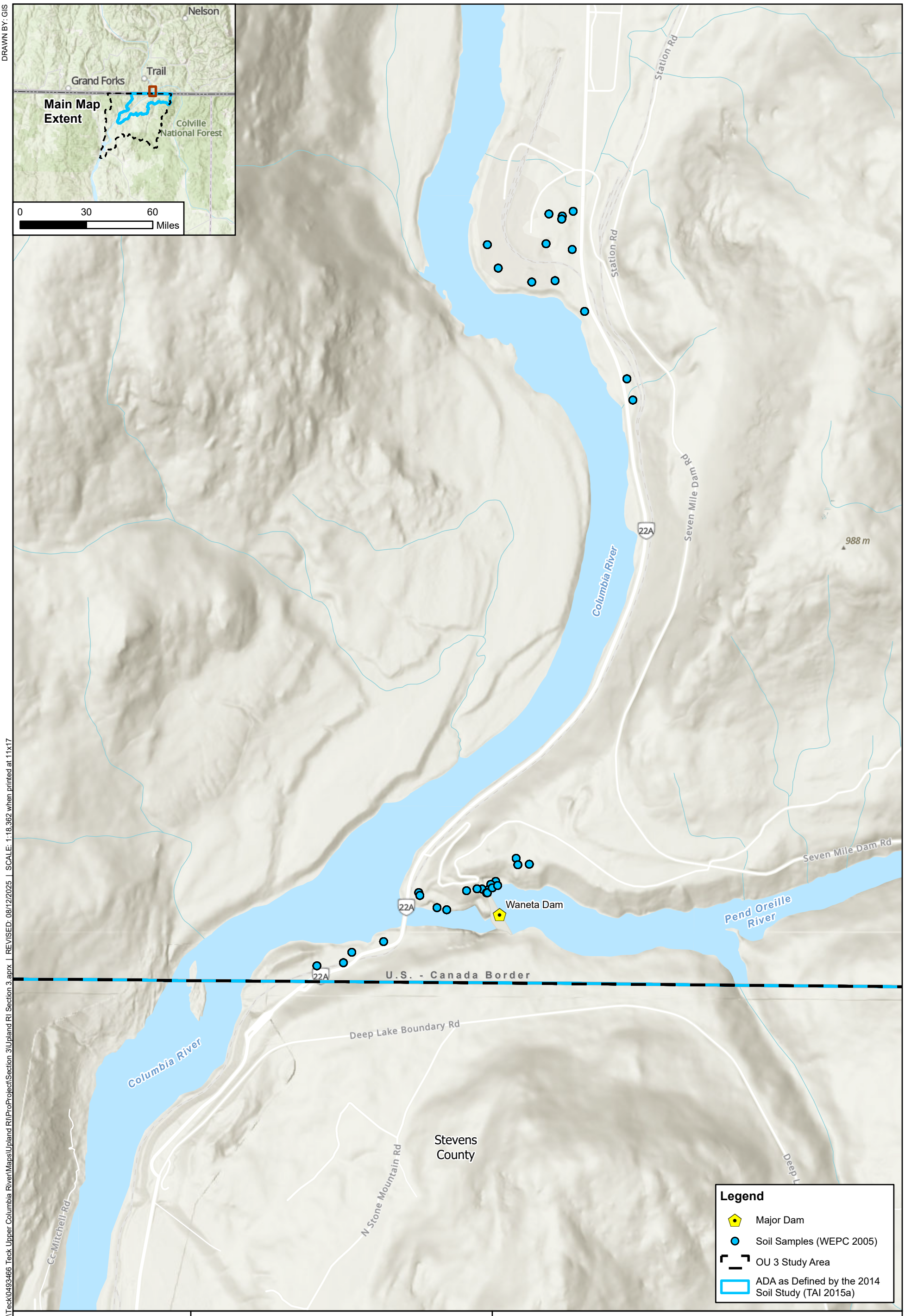
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Map 3-22. **Soil Sample Locations from the 2001 Trail Area Soil Background Assessment**
Final Upland RI Report
Upper Columbia River, Washington

Source: Esri - World Topographic Map; NAD 1983 UTM Zone 11N

DRAWN BY: GIS | REVISED: 08/20/2025 | SCALE: 1:190,114 when printed at 11x17

FILE: M:\US\Projects\S-U\Teck\0493466 Teck Upper Columbia River\Maps\Upland RI\ProProject\Section 3\Upland RI Section 3.aprx



DRAWN BY: GIS

FILE: M:\US\Projects\S-U\Teck\0493466 Teck Upper Columbia River\Maps\Upland RI\ProProject\Section 3\Upland RI Section 3.aprx | REVISED: 08/12/2025 | SCALE: 1:18,362 when printed at 11x17

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0 0.13 0.25 0.5 Miles

N

Map 3-23a. **Soil Sample Locations from the 2005 Waneta Expansion Project**
Final Upland RI Report
Upper Columbia River, Washington

Source: Esri - World Topographic Map; NAD 1983 UTM Zone 11N



LEGEND

- Sampling Site
- Highway
- Major Road
- Local Road

1,000 500 0 1,000 Meters

Scale - 1:75,000

REFERENCE

DMTI Spatial Inc.
Datum: NAD 83 Projection: UTM Zone 10

PROJECT

WANETA HYDROELECTRIC EXPANSION PROJECT
INVESTIGATIONS AND PROPOSED REMEDIATION PLANNING

TITLE

KEY PLAN FOR PROPOSED WORK SITES INVESTIGATED

Golder Associates
Burnaby, B.C.

PROJECT No. 05-1412-049			SCALE AS SHOWN	REV. 0
DESIGN	CJ	16 Jun. 2005	**FIGURE 1**	
GIS	CDB	16 Jun. 2005		
CHECK	CJ	16 Jun. 2005		
REVIEW				

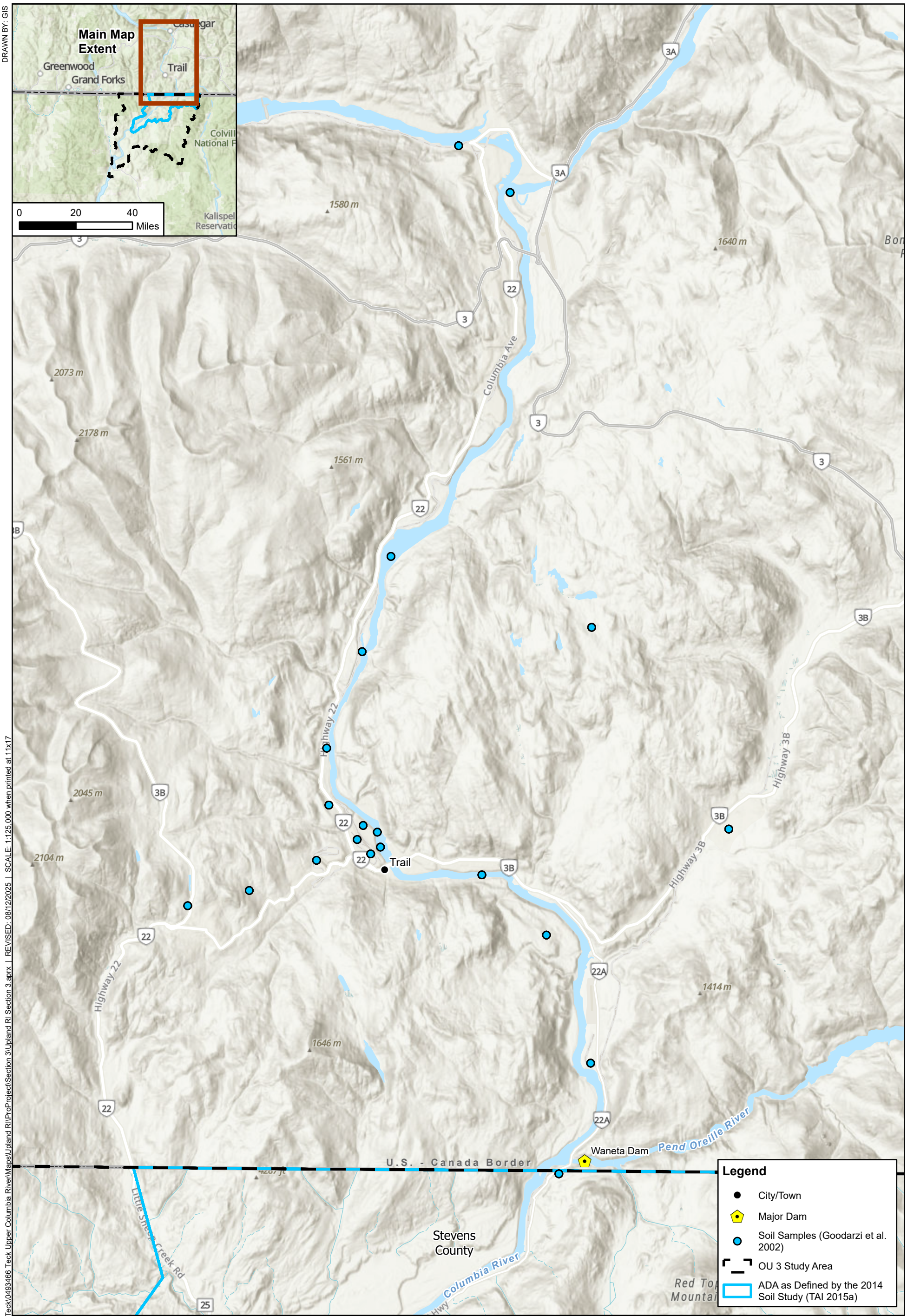
Source: WEPC (2005)

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Map 3-23b. **Sampling Sites from the 2005 Waneta Expansion Project**
Final Upland RI Report
Upper Columbia River, Washington

DRAWN BY: GIS
N:\Bur-Graphics\Projects\Key-plans\2005\aprs\05-1412-049.mxd
FILE: M:\US\Projects\S-U\Teck\0493466 Teck Upper Columbia River\Maps\Upland RI\ProProject\Section 3\Upland RI Section 3.aprx | REVISED: 08/12/2025

DRAWN BY: GIS



Legend

- City/Town
- Major Dam
- Soil Samples (Goodarzi et al. 2002)
- OU 3 Study Area
- ADA as Defined by the 2014 Soil Study (TAI 2015a)

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0 0.5 1 2 Miles

N

Map 3-24. **Soil Sample Locations from the 2001 Trail Area Moss Bag Study**
Final Upland RI Report
Upper Columbia River, Washington

Source: Esri - World Topographic Map; NAD 1983 UTM Zone 11N

FILE: M:\US\Projects\S-U\Teck\0493466 Teck Upper Columbia River\Maps\Upland RI\ProProject\Section 3\Upland RI Section 3.aprx | REVISED: 08/12/2025 | SCALE: 1:125,000 when printed at 11x17

U.S. - Canada Border
Waneta Dam
Pend Oreille River
Northport
7203 ft
Kettle River
Onion Creek
Bossburg
Evans
Marcus
Kettle Falls
Colville
Republic
7139 ft
Ferry County
Pend Oreille County
Stevens County
Columbia River
Colville River
Colville Indian Reservation
Sanpoil River
4636 ft
Coulee Dam
Grand Coulee Dam
Franklin D Roosevelt Lake
Deer Meadows
Spokane Indian Reservation
Lincoln County
5886 ft
Selkirk Mountains
97
17
155
21
25
231
20
31
2
395
90

Main Map Extent
Spokane
ashington

0 75 150 Miles

Legend

- City/Town
- Major Dam
- Sample Locations (TAI 2020a)
- OU 3 Study Area
- ADA as Defined by the 2014 Soil Study (TAI 2015a)
- Tribal Reservation
- County Boundaries

N

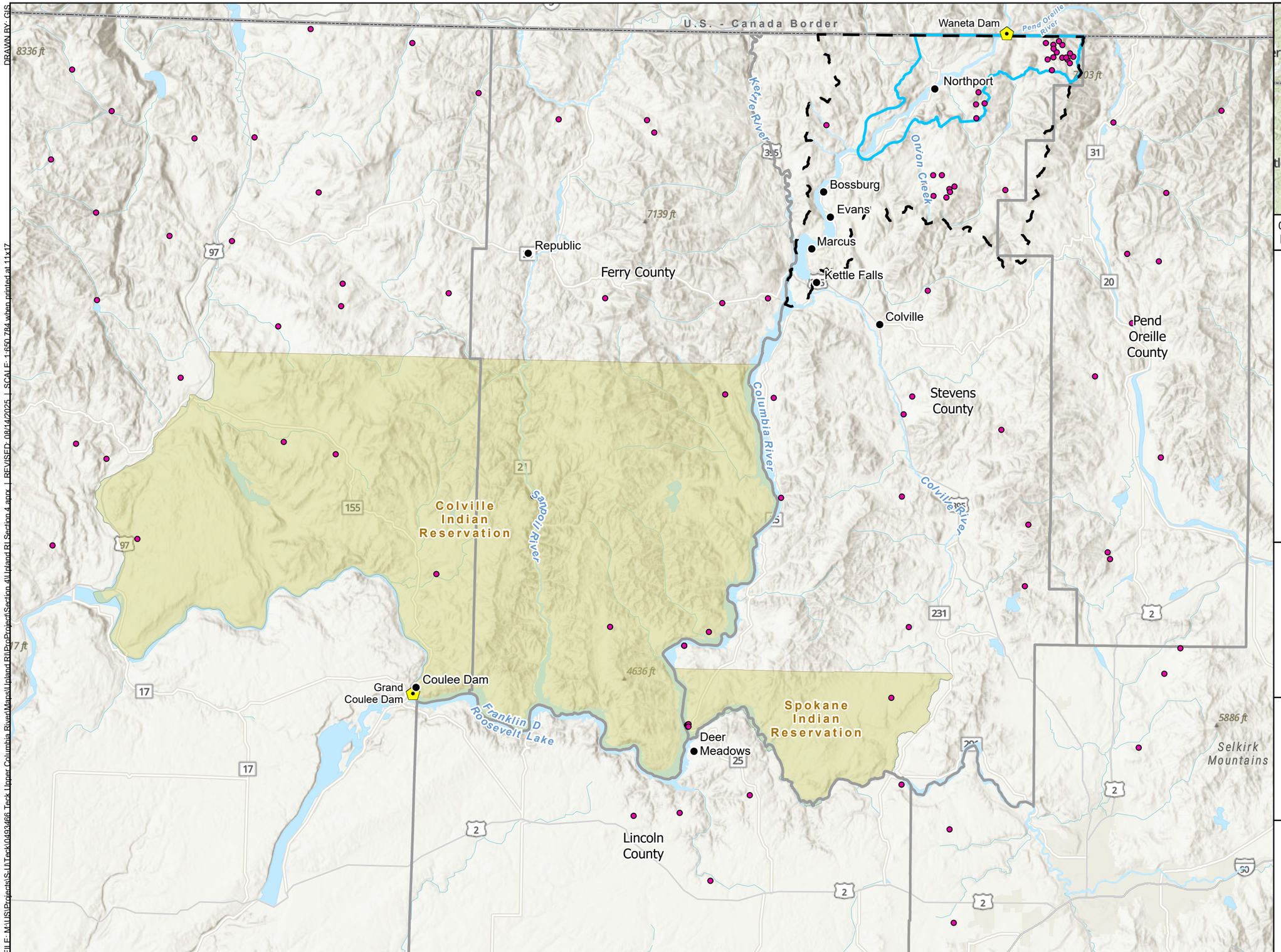
0 4 8 16 Miles

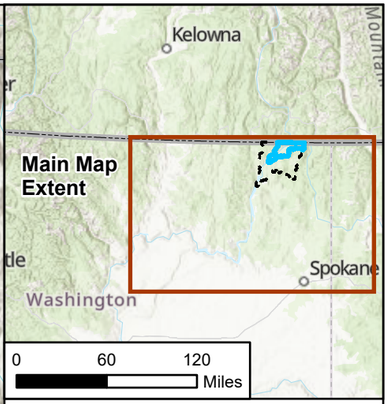
Map 4-1. **Locations of Background Samples Used to Calculate Partial Digestion BTVs**
Final Upland RI Report
Upper Columbia River, Washington

ERM
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www.erm.com

Source: Esri - World Topographic Map; NAD 1983 UTM Zone 11N

DRAWN BY: GIS
FILE: M:\US\Projects\SJ\TeckWA9346\Teck Upper Columbia River\Maps\Upland RI\ProjectSection 4\Upland RI Section 4.aprx | REVISED: 08/14/2025 | SCALE 1: 610,784 when printed at 11x17





Legend

- City/Town
- Major Dam
- Sample Locations (TAI 2020a)
- OU 3 Study Area
- ADA as Defined by the 2014 Soil Study (TAI 2015a)
- County Boundaries
- Tribal Reservation

N

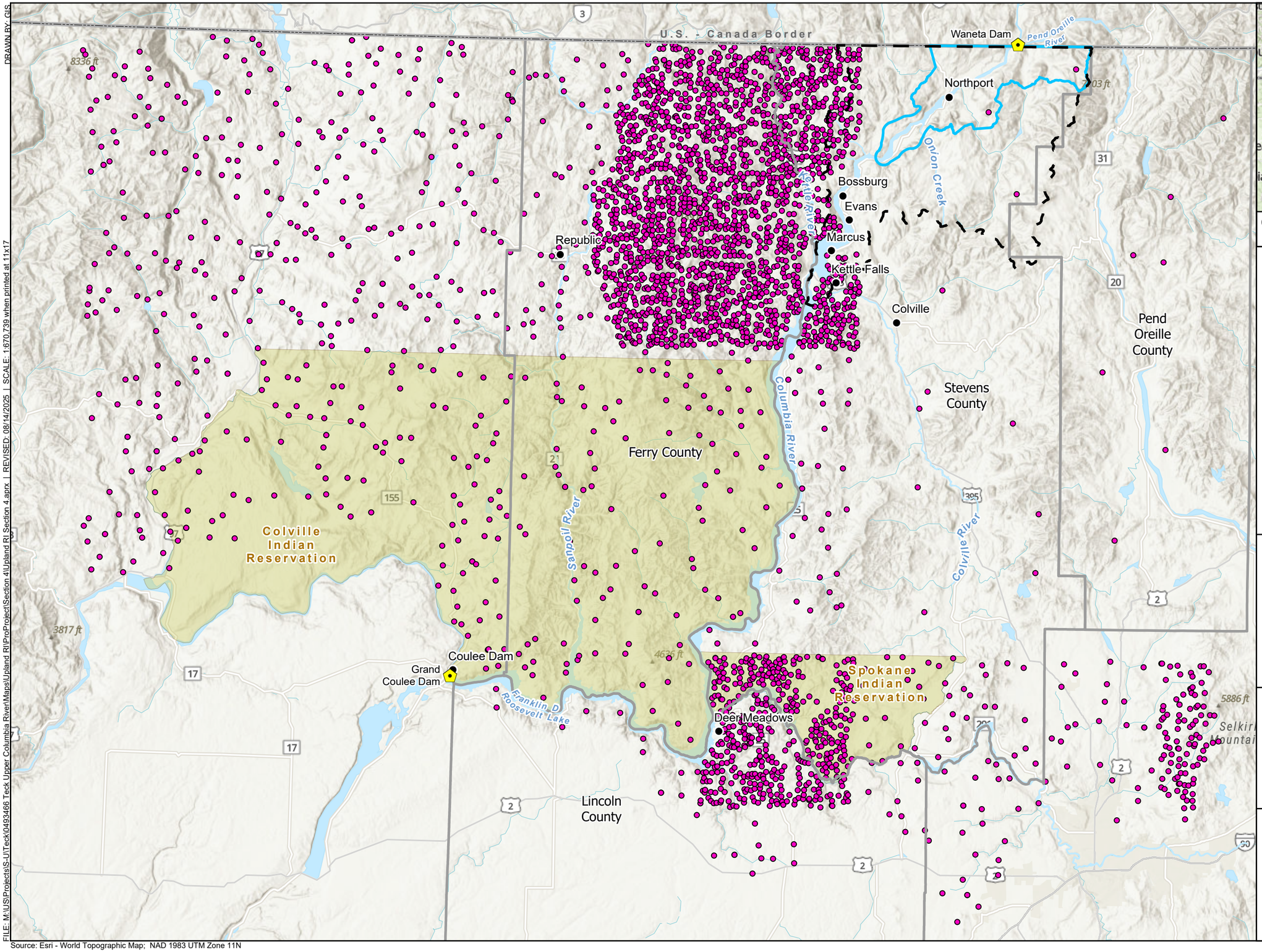
0 4.5 9 18 Miles

Map 4-2. **Locations of Background Samples Used to Calculate Mercury BTVs**
Final Upland RI Report
Upper Columbia River, Washington

ERM
Environmental Resources Management
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Source: Esri - World Topographic Map; NAD 1983 UTM Zone 11N

DRAWN BY: GIS
FILE: M:\US\Projects\SLI\Teck\0493466 Teck Upper Columbia River\Maps\Upland RI\Proj\Section 4\Upland RI Section 4.aprx | REVISED: 08/14/2025 | SCALE: 1:650,784 when printed at 11x17



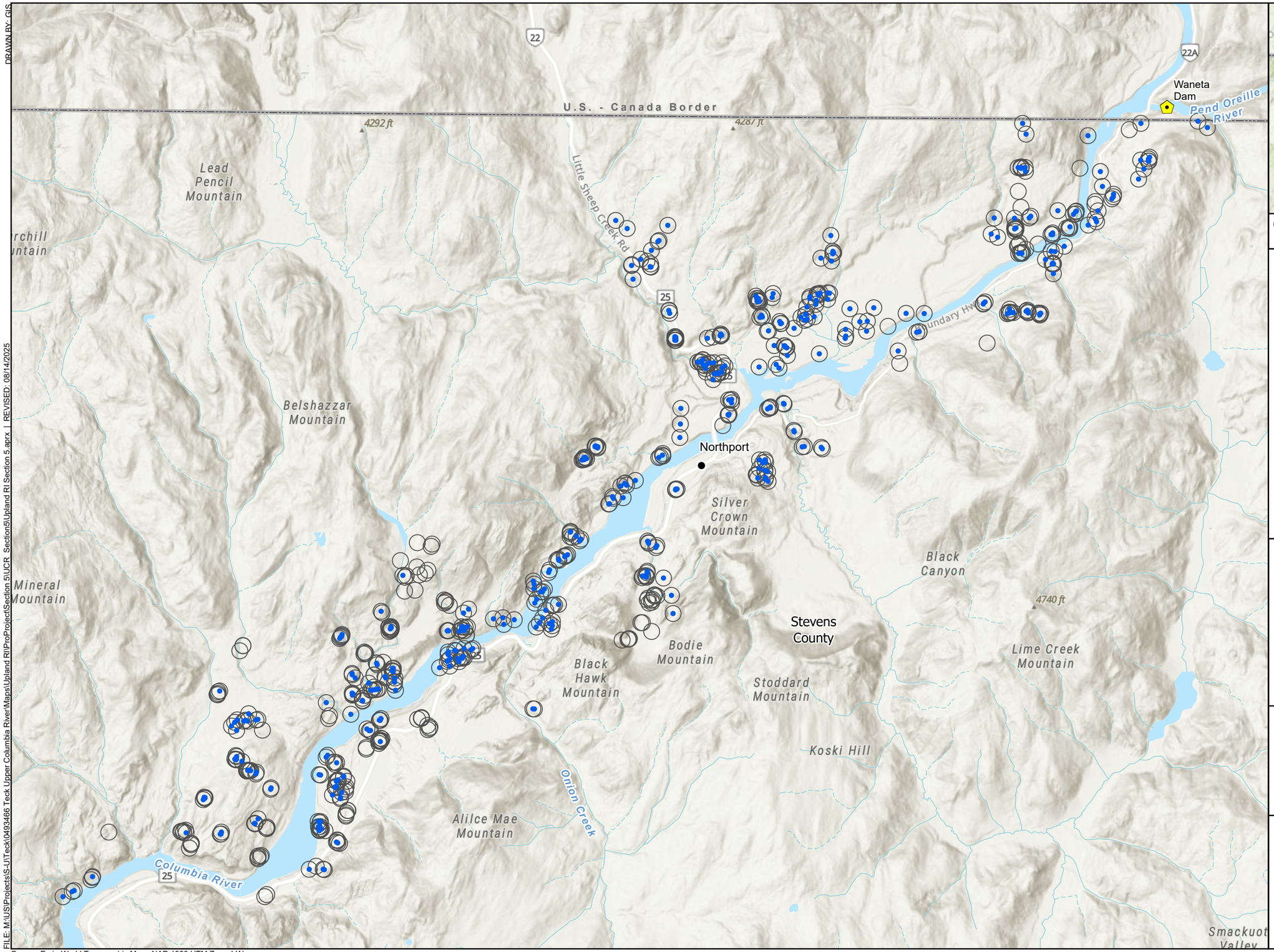
Map 4-3. **Locations of Background Samples Used to Calculate Total Digestion BTVs**
Final Upland RI Report
Upper Columbia River, Washington

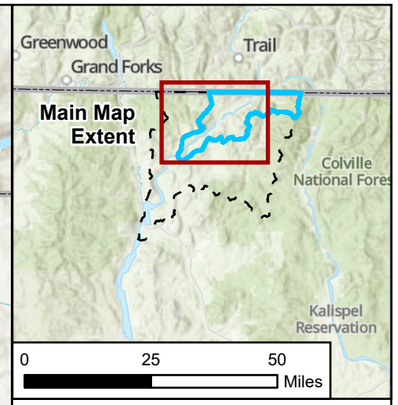
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Environmental Resources Management
www.erm.com

Source: Esri - World Topographic Map; NAD 1983 UTM Zone 11N

DRAWN BY: GIS | REVISED: 08/14/2025 | SCALE: 1:670,739 when printed at 11x17

FILE: M:\US\Projects\S-UT\eck\0493466 Teck Upper Columbia River\Maps\Upland RI\ProProject\Section 4\Upland RI Section 4.aprx | RE





Legend

- City/Town
- Major Dam
- Exceeds P3
- 2014 and 2016 RSS DUs (Excluding Beaches)
- OU 3 Study Area
- ADA as Defined by the 2014 Soil Study (TAI 2015a)

Note: Tribal allotments sampled in 2014 and 2016 are included on this map; analyses for these DUs are in Appendix 1 of the HHRA.

N

0 0.5 1 2 Miles

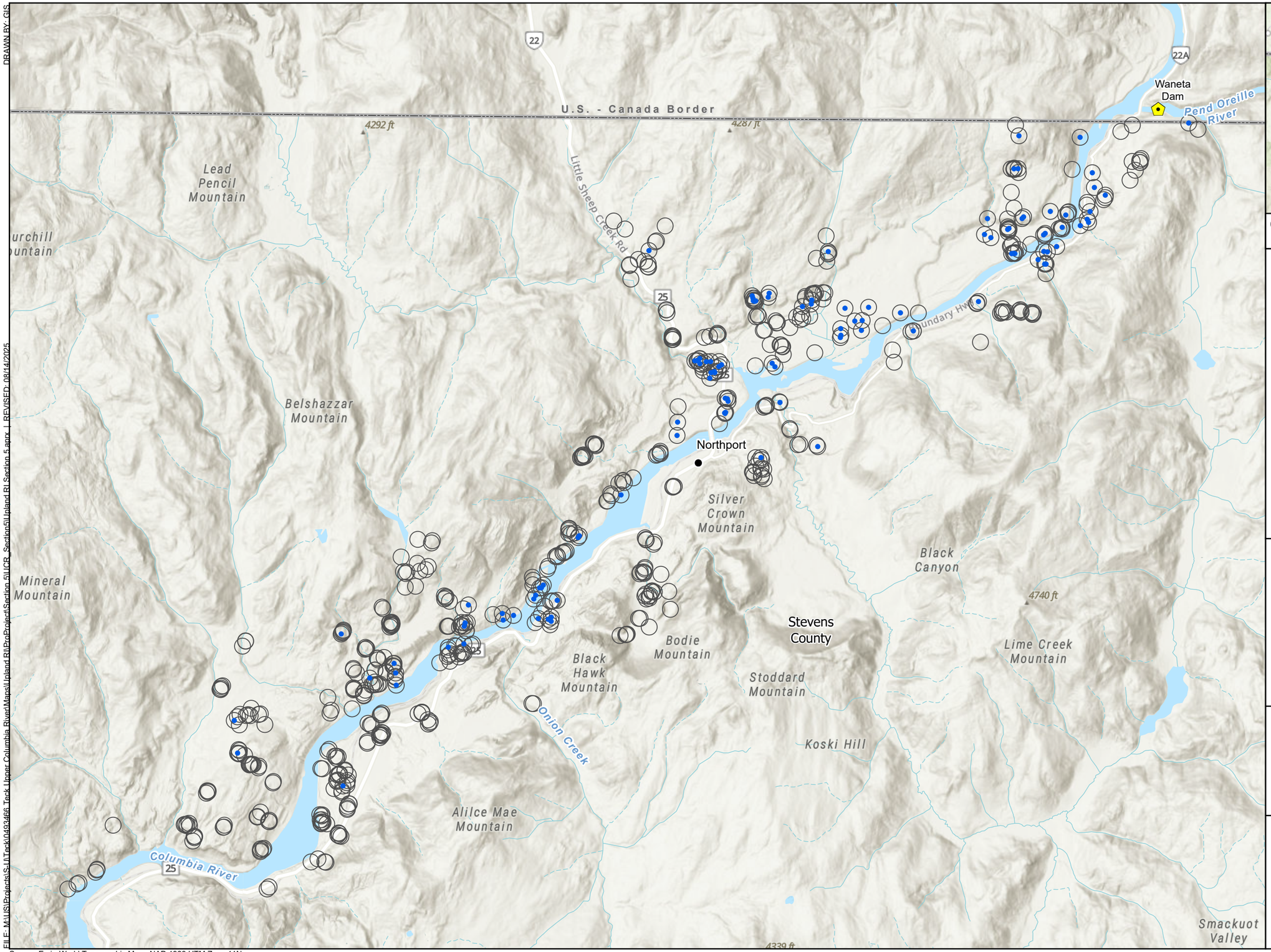
Map 5-1. **RSS DUs Where Lead Risk Exceeds P3 (Not Including Fish Consumption)**
Final Upland RI Report
Upper Columbia River, Washington

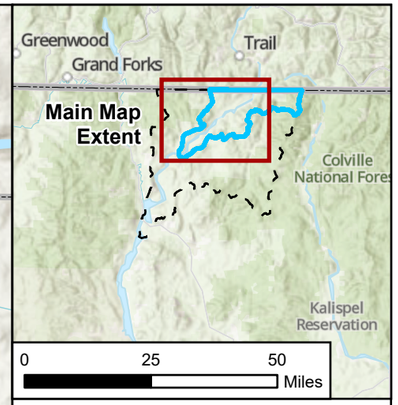
ERM
Environmental Resources Management
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Source: Esri - World Topographic Map; NAD 1983 UTM Zone 11N

DRAWN BY: GIS

FILE: M:\US\Projects\S-U\Teck\0493466 Teck Upper Columbia River\Maps\Upland RI\ProProject\Section 5\UCR_Section5\Upland RI Section 5.aprx | REVISED: 08/14/2025





Legend

- City/Town
- Major Dam
- Exceeds P5
- 2014 and 2016 RSS DUs (Excluding Beaches)
- OU 3 Study Area
- ADA as Defined by the 2014 Soil Study (TAI 2015a)

Note: Tribal allotments sampled in 2014 and 2016 are included on this map; analyses for these DUs are in Appendix 1 of the HHRA.

N

0 0.5 1 2 Miles

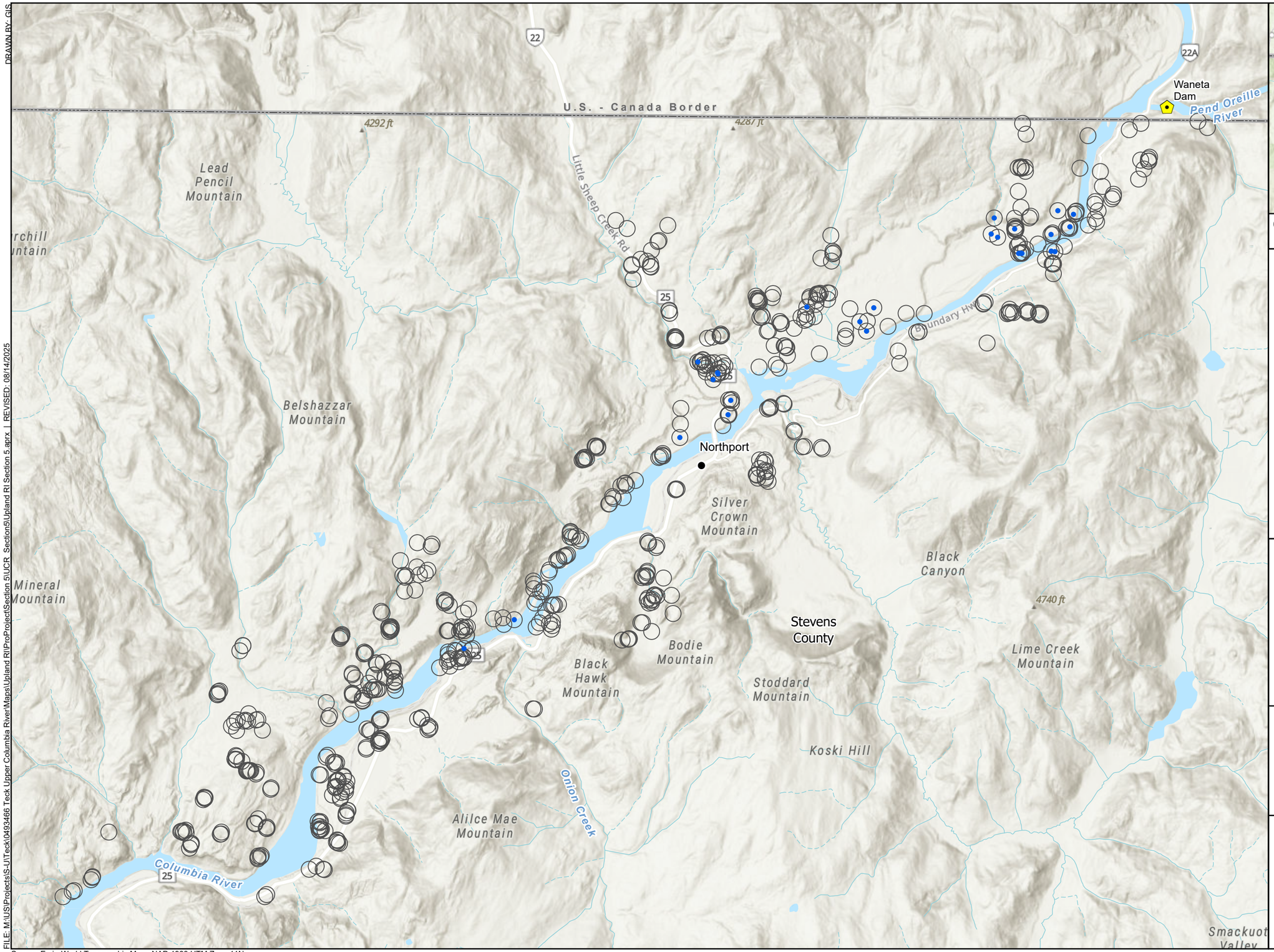
Map 5-2. **RSS DUs Where Lead Risk Exceeds P5 (Not Including Fish Consumption)**
Final Upland RI Report
Upper Columbia River, Washington

ERM
Environmental Resources Management
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Source: Esri - World Topographic Map; NAD 1983 UTM Zone 11N

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FILE: M:\US\Projects\S-U\Teck\0493466 Teck Upper Columbia River\Maps\Upland RI\ProProject\Section 5\UCR_Section5Upland RI Section 5.aprx | REVISED: 08/14/2025



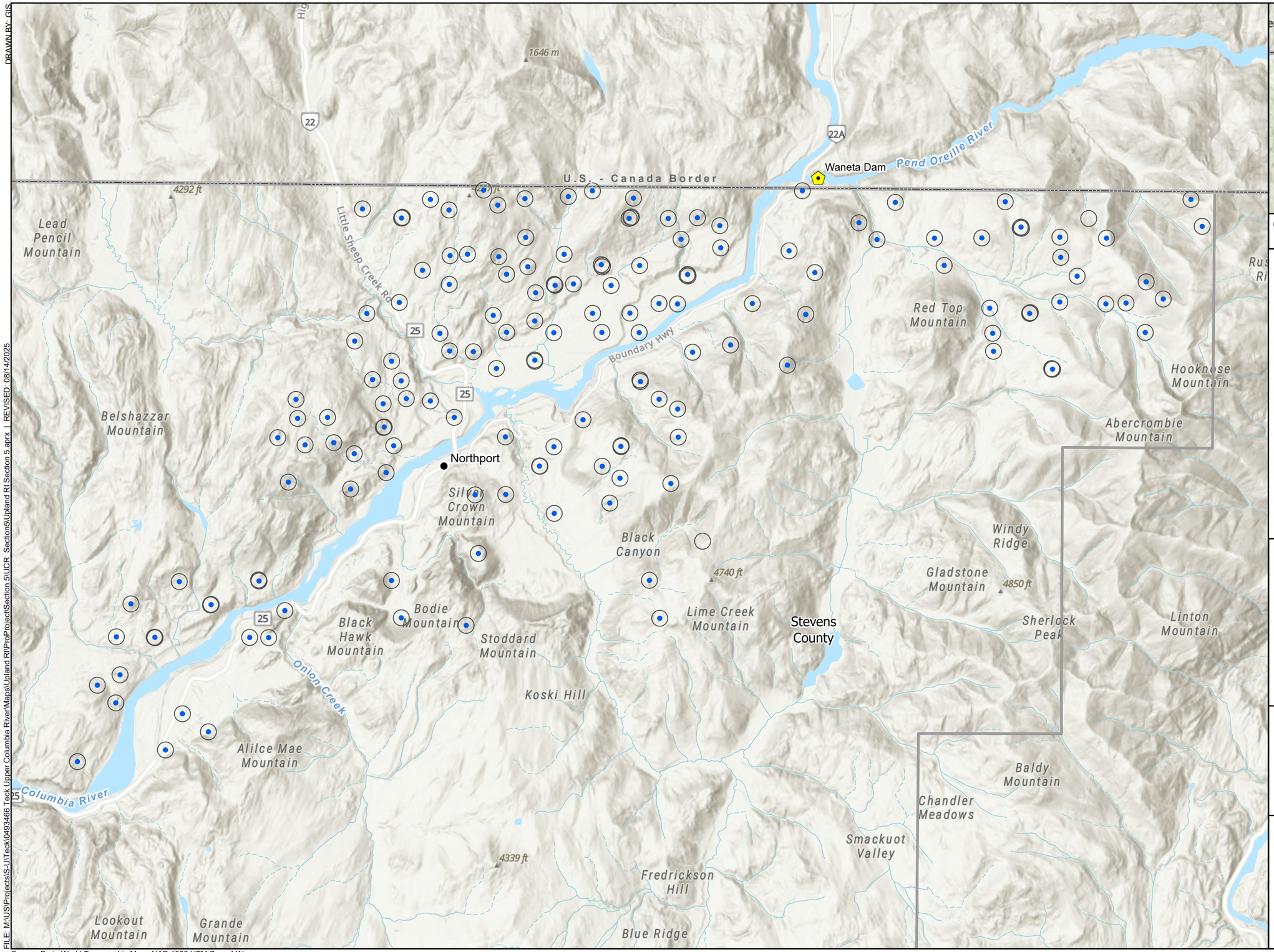
Map 5-3. **RSS DUs Where Lead Risk Exceeds P8 (Not Including Fish Consumption)**
Final Upland RI Report
Upper Columbia River, Washington

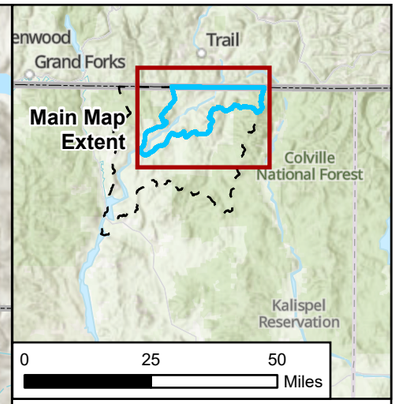
ERM
Environmental Resources Management
www.erm.com

Source: Esri - World Topographic Map; NAD 1983 UTM Zone 11N

DRAWN BY: GIS

FILE: M:\US\Projects\S-U\Teck\0493466 Teck Upper Columbia River\Maps\Upland RI\ProProject\Section 5\UCR_Section5\Upland RI Section 5.aprx | REVISED: 08/14/2025





Legend

- City/Town
- Major Dam
- Exceeds P3
- ADA DUs
- County Boundaries
- OU 3 Study Area
- ADA as Defined by the 2014 Soil Study (TAI 2015a)

Note: Tribal allotments sampled in 2014 and 2016 are included on this map; analyses for these DUs are in Appendix 1 of the HHRA.

N

0 0.5 1 2 Miles

Map 5-4. **ADA DUs Where Lead Risk Exceeds P3 (Not Including Fish Consumption)**
Final Upland RI Report
Upper Columbia River, Washington

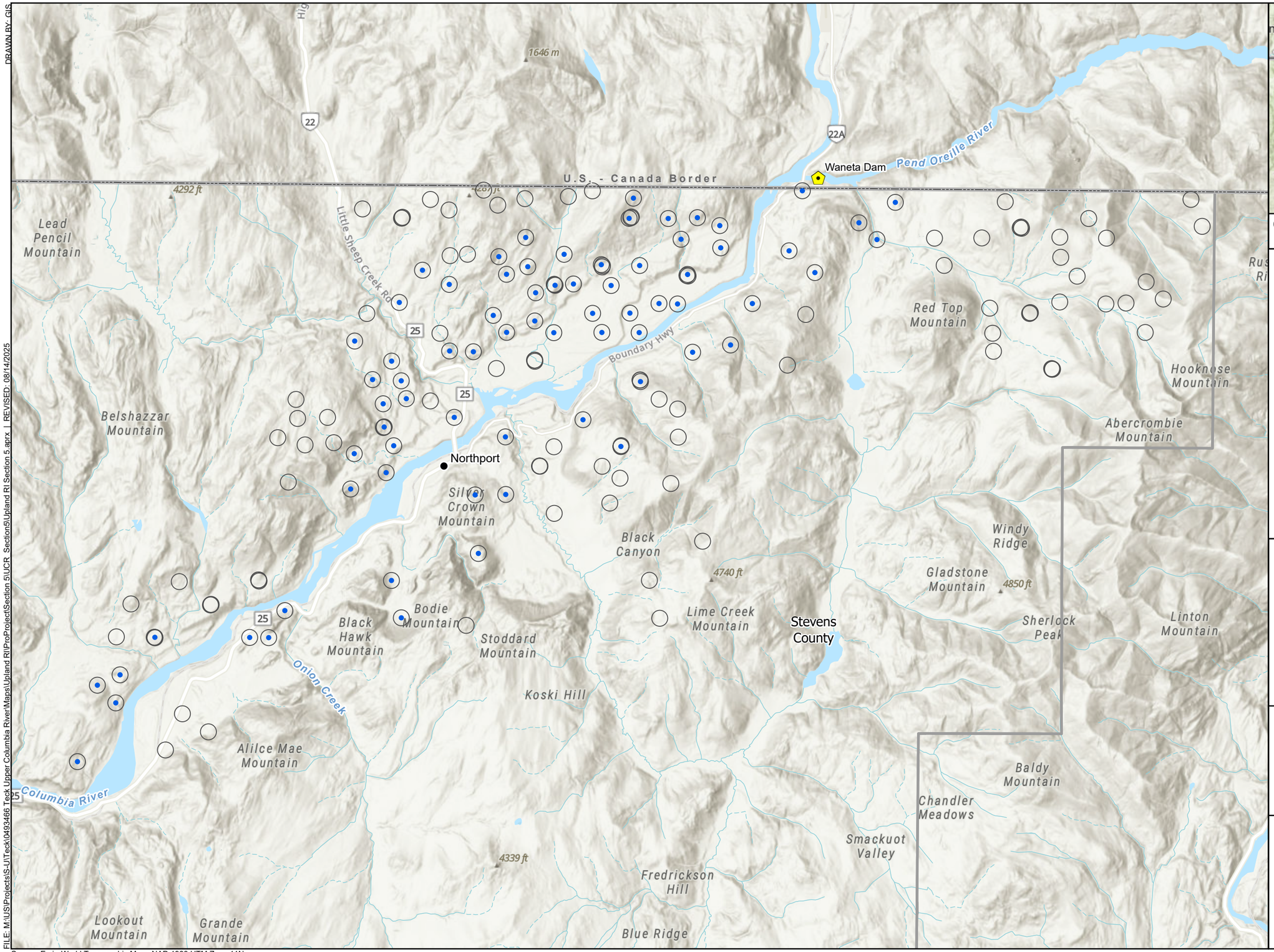
ERM
Environmental Resources Management
www.erm.com

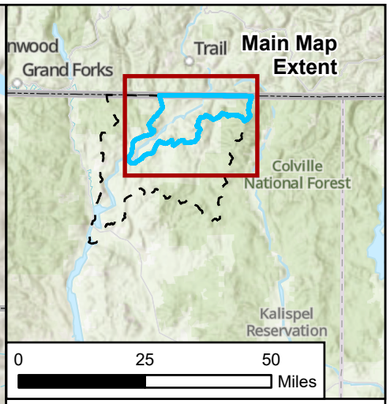
Source: Esri - World Topographic Map; NAD 1983 UTM Zone 11N

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Legend

- City/Town
- Major Dam
- Exceeds P5
- ADA DUs
- County Boundaries
- ADA as Defined by the 2014 Soil Study (TAI 2015a)
- OU 3 Study Area

Note: Tribal allotments sampled in 2014 and 2016 are included on this map; analyses for these DUs are in Appendix 1 of the HHRA.

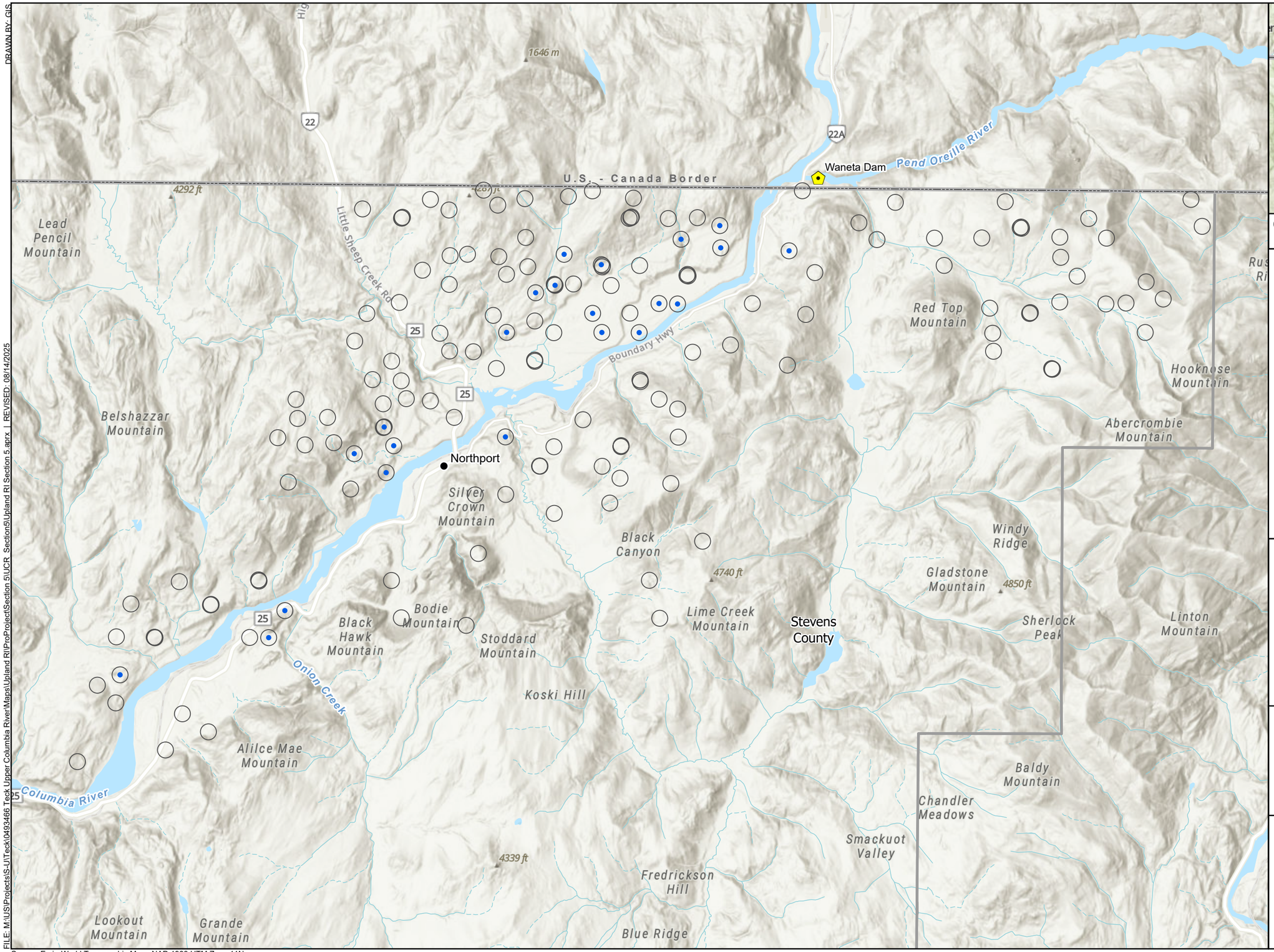
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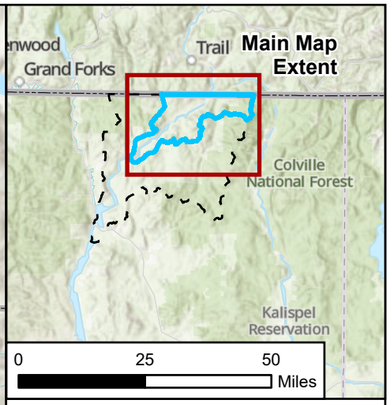
0 0.5 1 2 Miles

Map 5-5. **ADA DUs Where Lead Risk Exceeds P5 (Not Including Fish Consumption)**
Final Upland RI Report
Upper Columbia River, Washington

ERM
Environmental Resources Management
www.erm.com

Source: Esri - World Topographic Map; NAD 1983 UTM Zone 11N





Legend

- City/Town
- Major Dam
- Exceeds P8
- ADA DUs
- County Boundaries
- ADA as Defined by the 2014 Soil Study (TAI 2015a)
- OU 3 Study Area

Note: Tribal allotments sampled in 2014 and 2016 are included on this map; analyses for these DUs are in Appendix 1 of the HHRA.

N

0 0.5 1 2 Miles

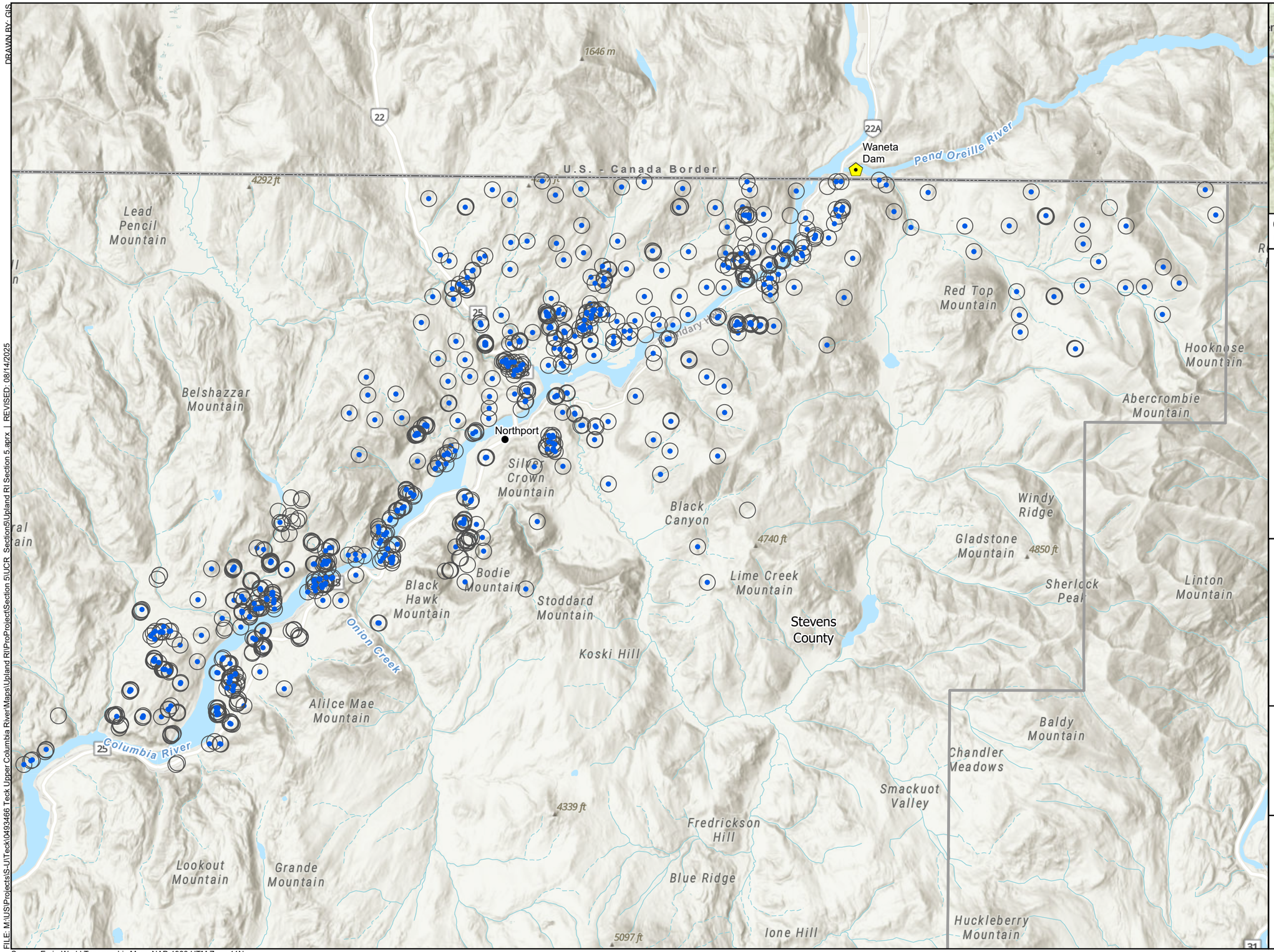
Map 5-6. **ADA DUs Where Lead Risk Exceeds P8 (Not Including Fish Consumption)**
Final Upland RI Report
Upper Columbia River, Washington

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Environmental Resources Management
www.erm.com

Source: Esri - World Topographic Map; NAD 1983 UTM Zone 11N

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FILE: M:\US\Projects\S-U\Teck\0493466 Teck Upper Columbia River\Maps\Upland RI\ProProject\Section 5\UCR_Section5\Upland RI Section 5.aprx | REVISED: 08/14/2025



Legend

- City/Town
- Major Dam
- Exceeds P3
- ADA and RSS DUs
- County Boundaries
- ADA as Defined by the 2014 Soil Study (TAI 2015a)
- OU 3 Study Area

Note: Tribal allotments sampled in 2014 and 2016 are included on this map; analyses for these DUs are in Appendix 1 of the HHRA.

N

0 0.5 1 2 Miles

Map 5-7. **ADA and RSS DUs Where Lead Risk Exceeds P3 (Not Including Fish Consumption)**

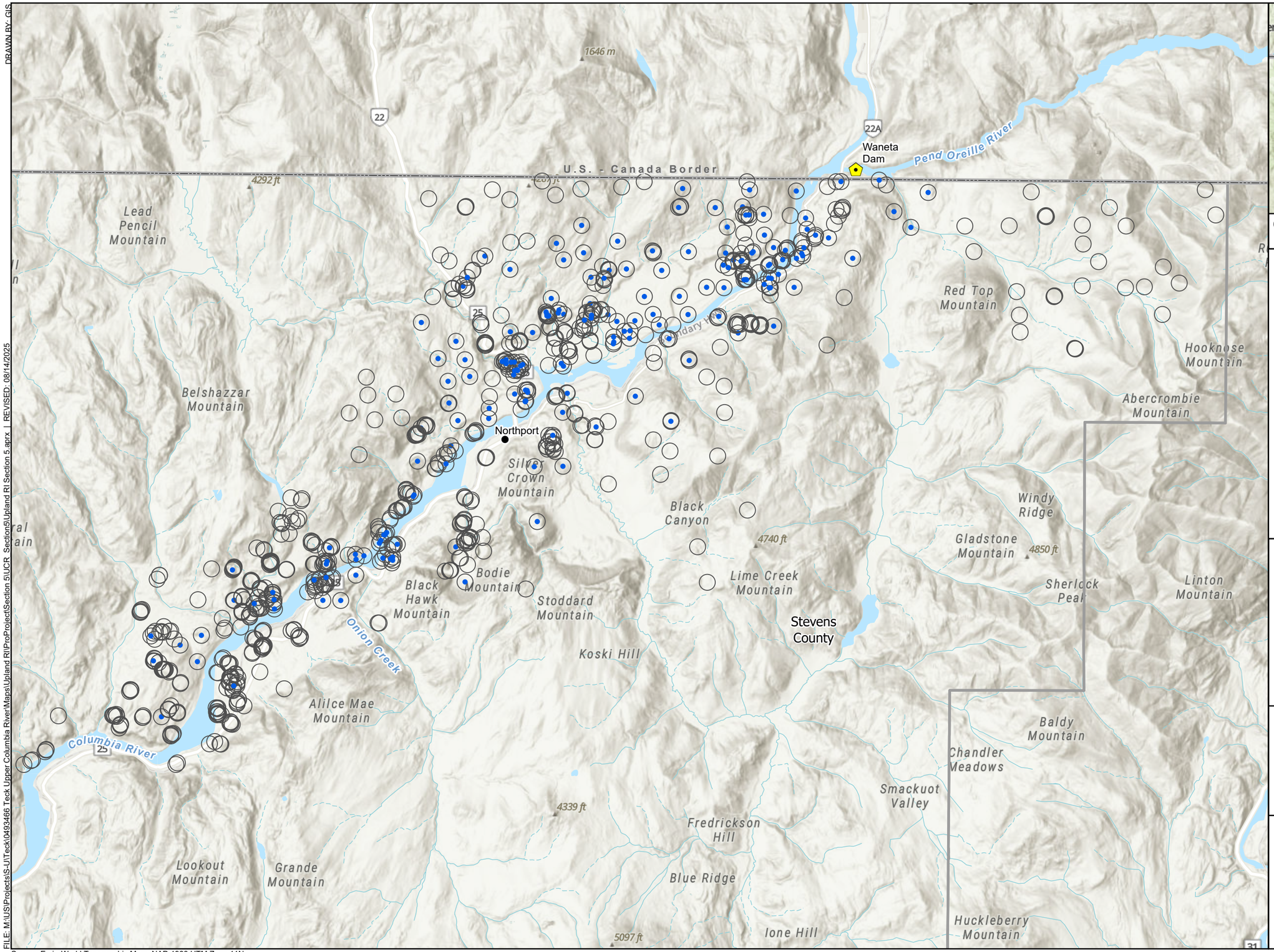
Final Upland RI Report
Upper Columbia River, Washington

ERM
Environmental Resources Management
www.erm.com

Source: Esri - World Topographic Map; NAD 1983 UTM Zone 11N

DRAWN BY: GIS

FILE: M:\US\Projects\S-U\Teck\0493466 Teck Upper Columbia River\Maps\Upland RI\ProProject\Section 5\UCR_Section5\Upland RI Section 5.aprx | REVISED: 08/14/2025



Legend

- City/Town
- Major Dam
- Exceeds P5
- ADA and RSS DUs
- County Boundaries
- ADA as Defined by the 2014 Soil Study (TAI 2015a)
- OU 3 Study Area

Note: Tribal allotments sampled in 2014 and 2016 are included on this map; analyses for these DUs are in Appendix 1 of the HHRA.

N

0 0.5 1 2 Miles

Map 5-8. **ADA and RSS DUs Where Lead Risk Exceeds P5 (Not Including Fish Consumption)**

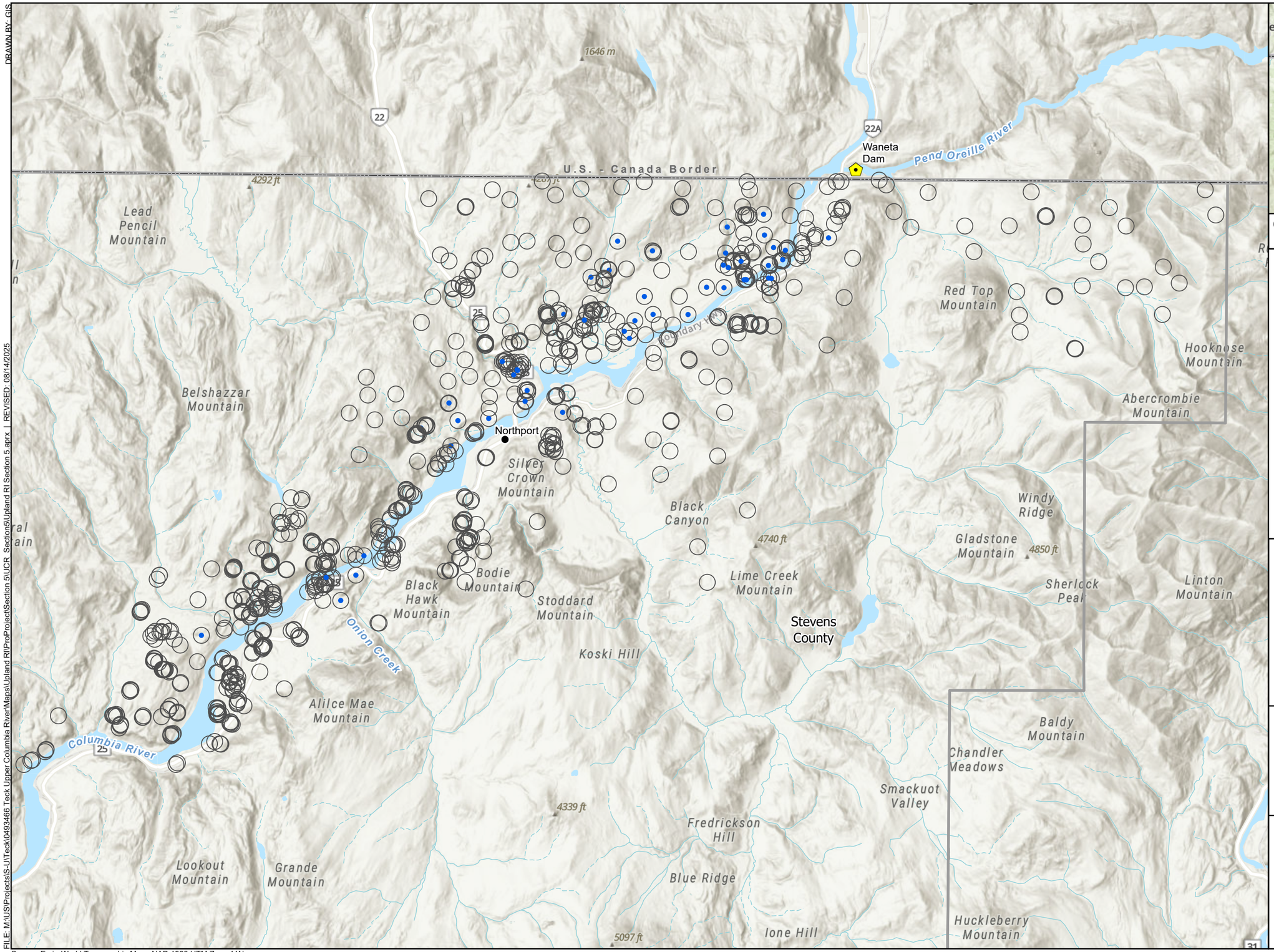
Final Upland RI Report
Upper Columbia River, Washington

ERM
Environmental Resources Management
www.erm.com

Source: Esri - World Topographic Map; NAD 1983 UTM Zone 11N

DRAWN BY: GIS

FILE: M:\US\Projects\S-U\Teck\0493466 Teck Upper Columbia River\Maps\Upland RI\ProProject\Section 5\UCR_Section5\Upland RI Section 5.aprx | REVISED: 08/14/2025



Map 5-9. **ADA and RSS DUs Where Lead Risk Exceeds P8 (Not Including Fish Consumption)**

Final Upland RI Report
Upper Columbia River, Washington

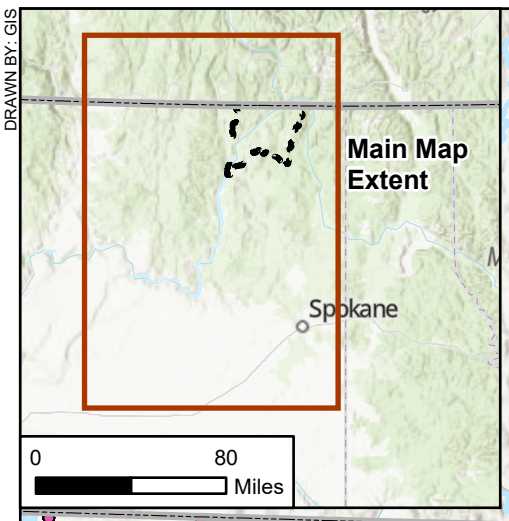
ERM
Environmental Resources Management
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Source: Esri - World Topographic Map; NAD 1983 UTM Zone 11N

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DRAWN BY: GIS



U.S. - Canada Border

Columbia River

Monashee

Christina Range

Bonnington Range

Rossland Range

Trail

Waneta Dam

Pend Oreille River

Deadman's Eddy

Northport

Marble

China Bend

Bossburg

Evans

Marcus

Kettle River

Onion Creek

Republic

Kettle Falls

Colville

Pend Oreille County

Ferry County

Colville River

Stevens County

Columbia River

Sanpoil River

4636 ft

Coulee Dam

Grand Coulee Dam

Deer Meadows

Lincoln County

3
31
20
2
155
17
231
23
291
395
90

Legend

- City/Town
- Major Dam
- OU 3 Study Area
- County Boundaries

Sample Locations

- ACMINESITE2007
- CHURC08A
- GOODA01A
- GOODA02A
- HARTC13A
- HARTC13C
- LeRoi2005
- NURE Seds
- SHANN11A
- SMITH13A
- Teck_2014_UplandSoil
- Teck_2015_Bossburg
- Teck_2016_ResSoil
- Teck_2017-18_VRA
- Teck_2017_PlantTissue
- Teck_2017_SATES_PIA
- Trail ERA
- USEPA2001Mines/Mills
- USEPA_2014_ResSoil
- WADOE_2007b
- WADOE_2007c
- WELLS15A
- Waneta2005
- geochem-fU53

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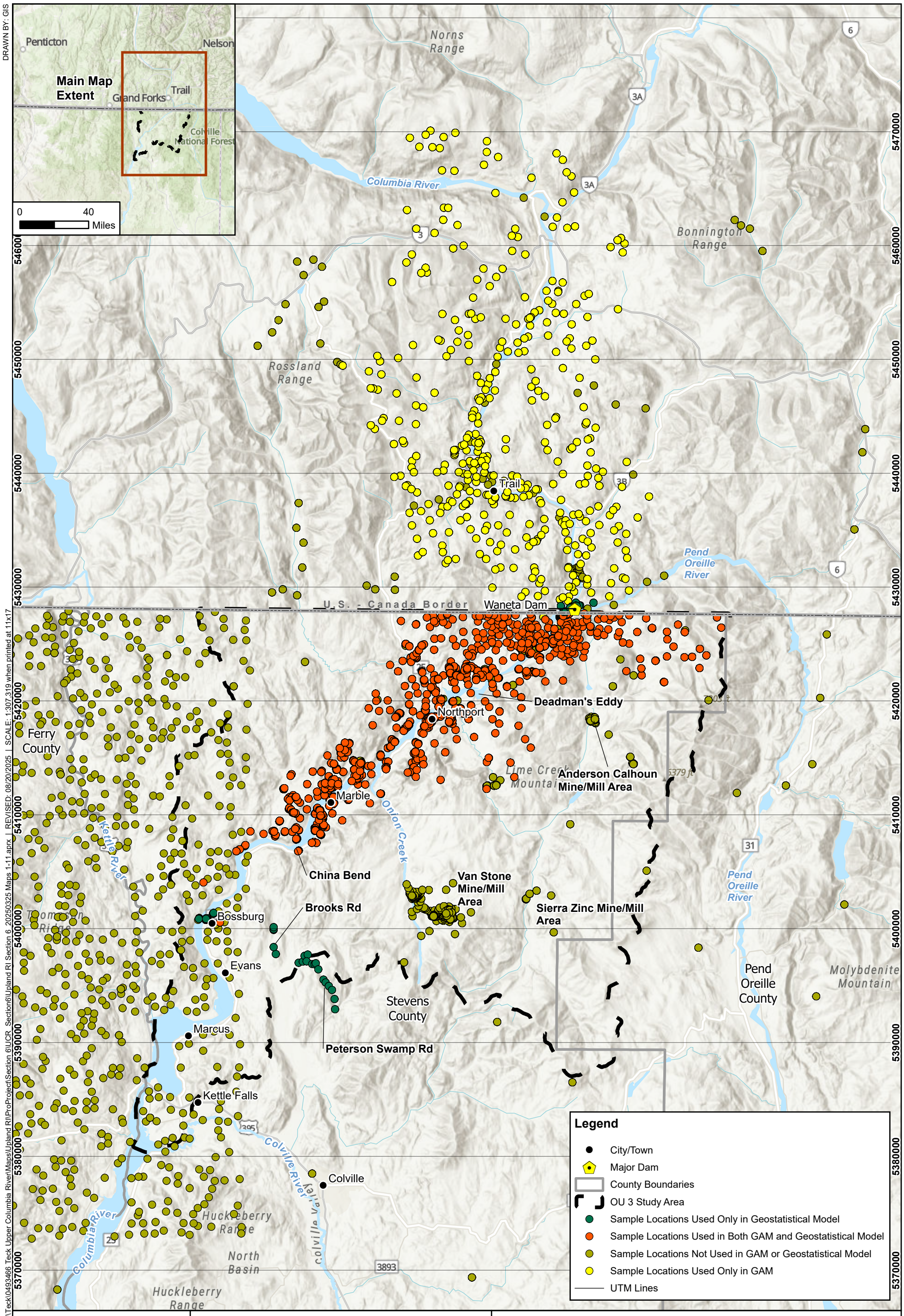
0 4 8 16 Miles

N

Map 6-1. **Soil Sample Locations in the Upland RI Data Set**
Final Upland RI Report
Upper Columbia River, Washington

Source: Esri - World Topographic Map; NAD 1983 UTM Zone 11N

FILE: M:\US\Projects\S-U\Teck\0493466 Teck Upper Columbia River\Maps\Upland RI\ProProject\Section 6\UCR_Section6\Upland RI_20250325 Maps 1-11.aprx | REVISED: 08/22/2025 | SCALE: 1:675,000 when printed at 11x17

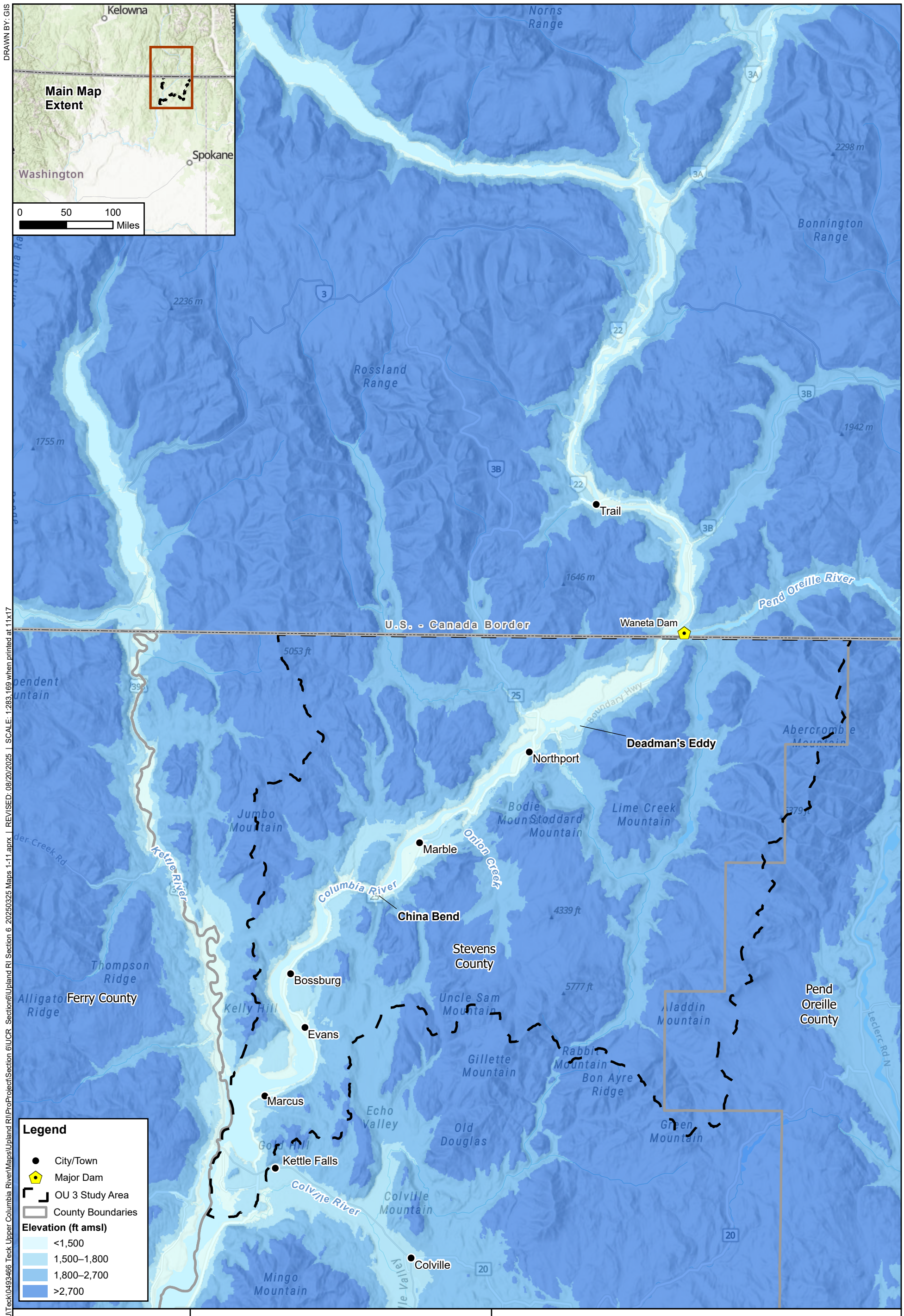


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Map 6-2. **Soil Sample Locations Used in the GAM and Geostatistical Model**
Final Upland RI Report
Upper Columbia River, Washington

Source: Esri - World Topographic Map; NAD 1983 UTM Zone 11N

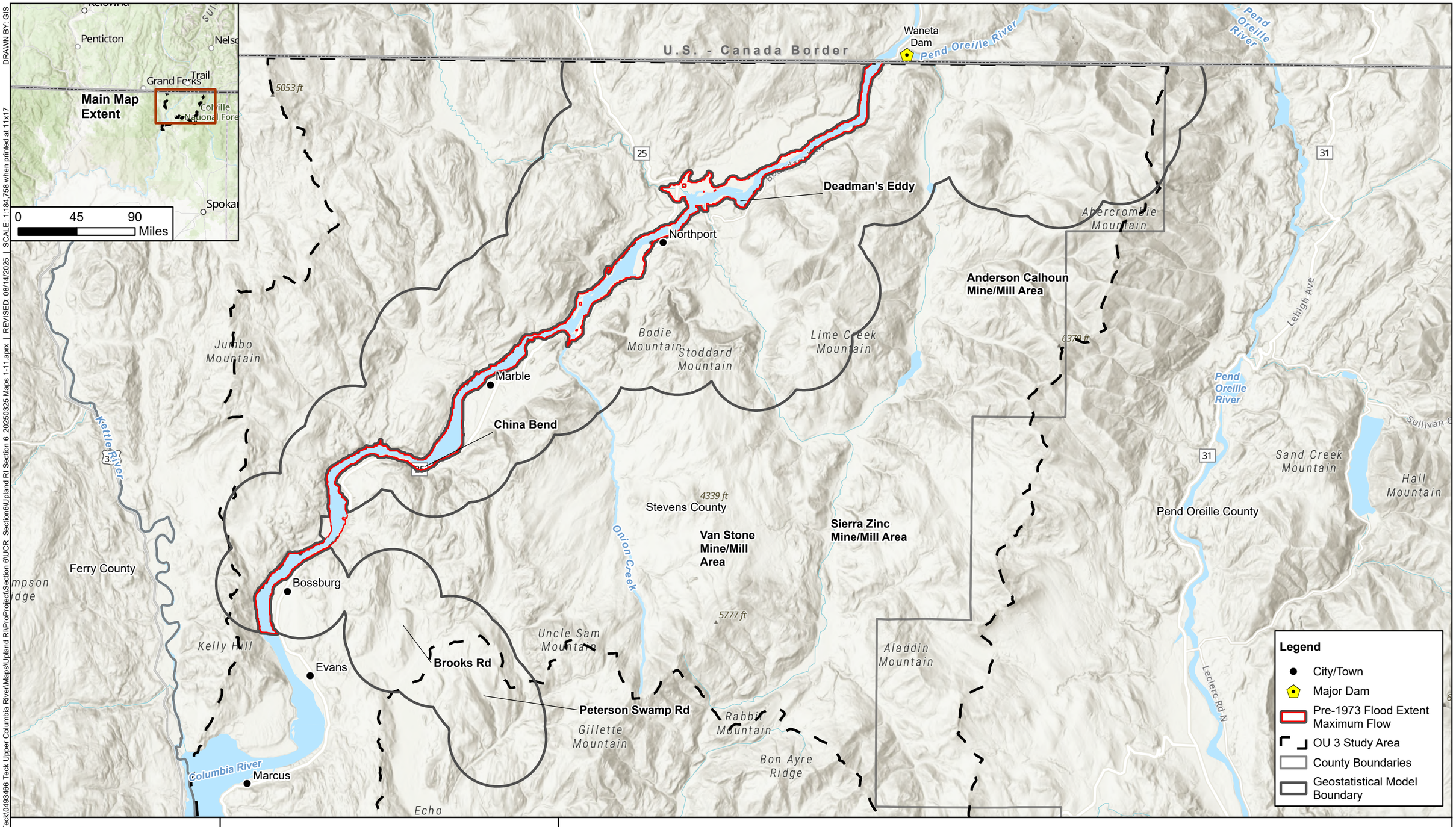
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FILE: M:\US\Projects\S-U\Teck\0493466 Teck Upper Columbia River\Maps\Upland RI\ProProject\Section 6\UCR_Section6\Upland RI Section 6_20250325 Maps 1-11.aprx | REVISED: 08/20/2025 | SCALE: 1:283,169 when printed at 11x17

Source: Esri - World Topographic Map; NAD 1983 UTM Zone 11N



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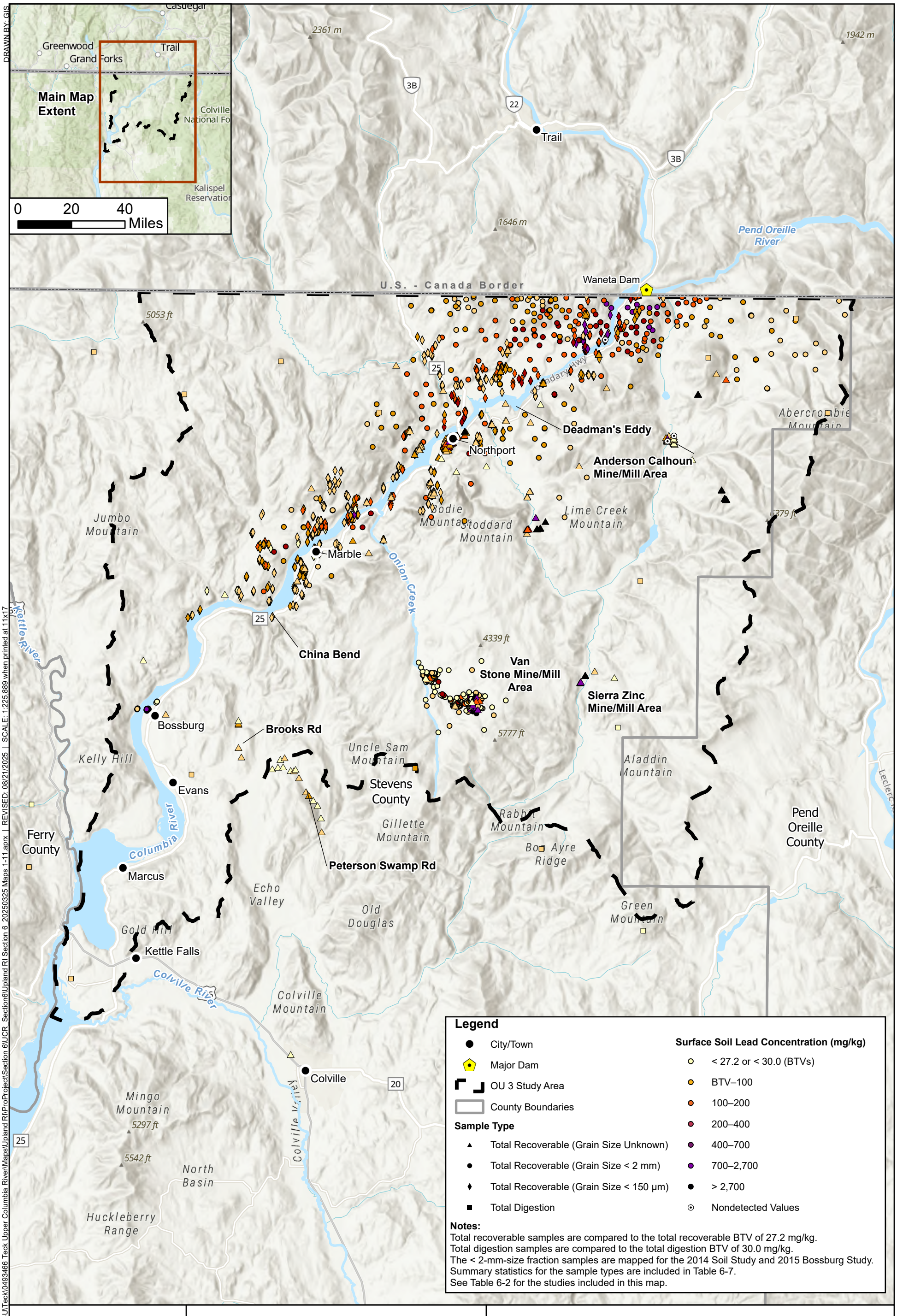
0 1.5 3 6 Miles

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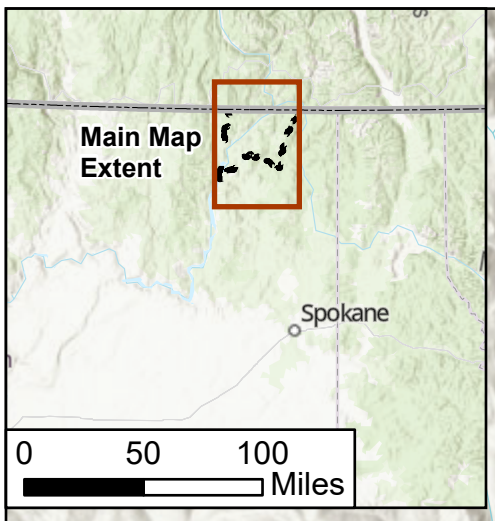
Map 6-4. **Geostatistical Model Boundary**
Final Upland RI Report
Upper Columbia River, Washington

Source: Esri - World Topographic Map; NAD 1983 UTM Zone 11N

DRAWN BY: GIS | SCALE: 1:184,758 when printed at 11x17 | REVISED: 08/14/2025 | FILE: M:\US\Projects\S-U\Teck\0493466 Teck Upper Columbia River\Maps\Upland RI\ProProject\Section 6\UCR_Section6\Upland RI Section 6_20250325 Maps 1-11.aprx


Castlegar
Greenwood
Grand Forks
Trail
Main Map Extent
Colville National Fo
Kalispel Reservation
0 20 40 Miles
2361 m
1942 m
3B
22
Trail
1646 m
Pend Oreille River
U.S. - Canada Border
Waneta Dam
5053 ft
25
Deadman's Eddy
Northport
Anderson Calhoun Mine/Mill Area
Abercrombie Mountain
Jumbo Mountain
Rodie Mountain
Stoddard Mountain
Lime Creek Mountain
Marble
Onion Creek
Kettle River
China Bend
4339 ft
Van Stone Mine/Mill Area
Sierra Zinc Mine/Mill Area
Bossburg
Brooks Rd
5777 ft
Kelly Hill
Uncle Sam Mountain
Aladdin Mountain
Evans
Stevens County
Columbia River
Ferry County
Gillette Mountain
Rabbit Mountain
Bon Ayre Ridge
Pend Oreille County
Peterson Swamp Rd
Marcus
Echo Valley
Old Douglas
Green Mountain
Gold Hill
Kettle Falls
Colville River
Colville Mountain
Colville
20
Mingo Mountain
5297 ft
5542 ft
North Basin
Huckleberry Range
Legend
City/Town
Major Dam
OU 3 Study Area
County Boundaries
Sample Type
Total Recoverable (Grain Size Unknown)
Total Recoverable (Grain Size < 2 mm)
Total Recoverable (Grain Size < 150 µm)
Total Digestion
Surface Soil Lead Concentration (mg/kg)
< 27.2 or < 30.0 (BTVs)
BTV–100
100–200
200–400
400–700
700–2,700
> 2,700
Nondetected Values
Notes:
Total recoverable samples are compared to the total recoverable BTV of 27.2 mg/kg.
Total digestion samples are compared to the total digestion BTV of 30.0 mg/kg.
The < 2-mm-size fraction samples are mapped for the 2014 Soil Study and 2015 Bossburg Study.
Summary statistics for the sample types are included in Table 6-7.
See Table 6-2 for the studies included in this map.
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0 5 10 Miles
N
Map 6-5. Lead Concentrations in Surface Soil
Final Upland RI Report
Upper Columbia River, Washington
Source: Esri - World Topographic Map; NAD 1983 UTM Zone 11N
DRAWN BY: GIS
FILE: M:\US\Projects\S-U\Teck\0493466 Teck Upper Columbia River\Maps\Upland RI\ProProject\Section 6\UCR_Section6\Upland RI Section 6_20250325 Maps 1-11.aprx | REVISED: 08/21/2025 | SCALE: 1:225,889 when printed at 11x17

DRAWN BY: GIS



2361 m
1942 m
1646 m
5053 ft
4339 ft
5777 ft
5379 ft

3B
22
25
20
395

Trail
Waneta Dam
U.S. - Canada Border
Pend Oreille River
Deadman's Eddy
Northport
Anderson Calhoun Mine/Mill Area
Abercrombie Mountain
Lime Creek Mountain
Stoddard Mountain
Sodie Mountain
Jumbo Mountain
Marble
Onion Creek
China Bend
Columbia River
Van Stone Mine/Mill Area
Sierra Zinc Mine/Mill Area
Bossburg
Brooks Rd
Kelly Hill
Kettle River
Evans
Uncle Sam Mountain
Aladdin Mountain
Gillette Mountain
Rabbit Mountain
Bon Ayre Ridge
Peterson Swamp Rd
Ferry County
Marcus
Echo Valley
Old Douglas
Stevens County
Pend Oreille County
Green Mountain
Gold Hill
Kettle Falls
Colville River
Colville Mountain
Colville
Colville Valley
Mingo Mountain
North Basin
Huckleberry Range

Legend

- City/Town
- Major Dam
- OU 3 Study Area
- County Boundaries

Study Type

- 2014 Soil Study
- 2016 Residential Soil Study
- 2014 Residential Soil Study
- 2015 Bossburg Study

RBA-Adjusted Surface Soil Lead Concentration (mg/kg)

- < 27.2 or < 30.0 (BTVs)
- BTVs–100
- 100–200
- 200–400
- 400–700
- 700–2,700
- > 2,700

Note:
Total recoverable samples are compared to the total recoverable BTV of 27.2 mg/kg.
Total digestion samples are compared to the total digestion BTV of 30.0 mg/kg.
Summary statistics for the study types are included in Table 6-7.

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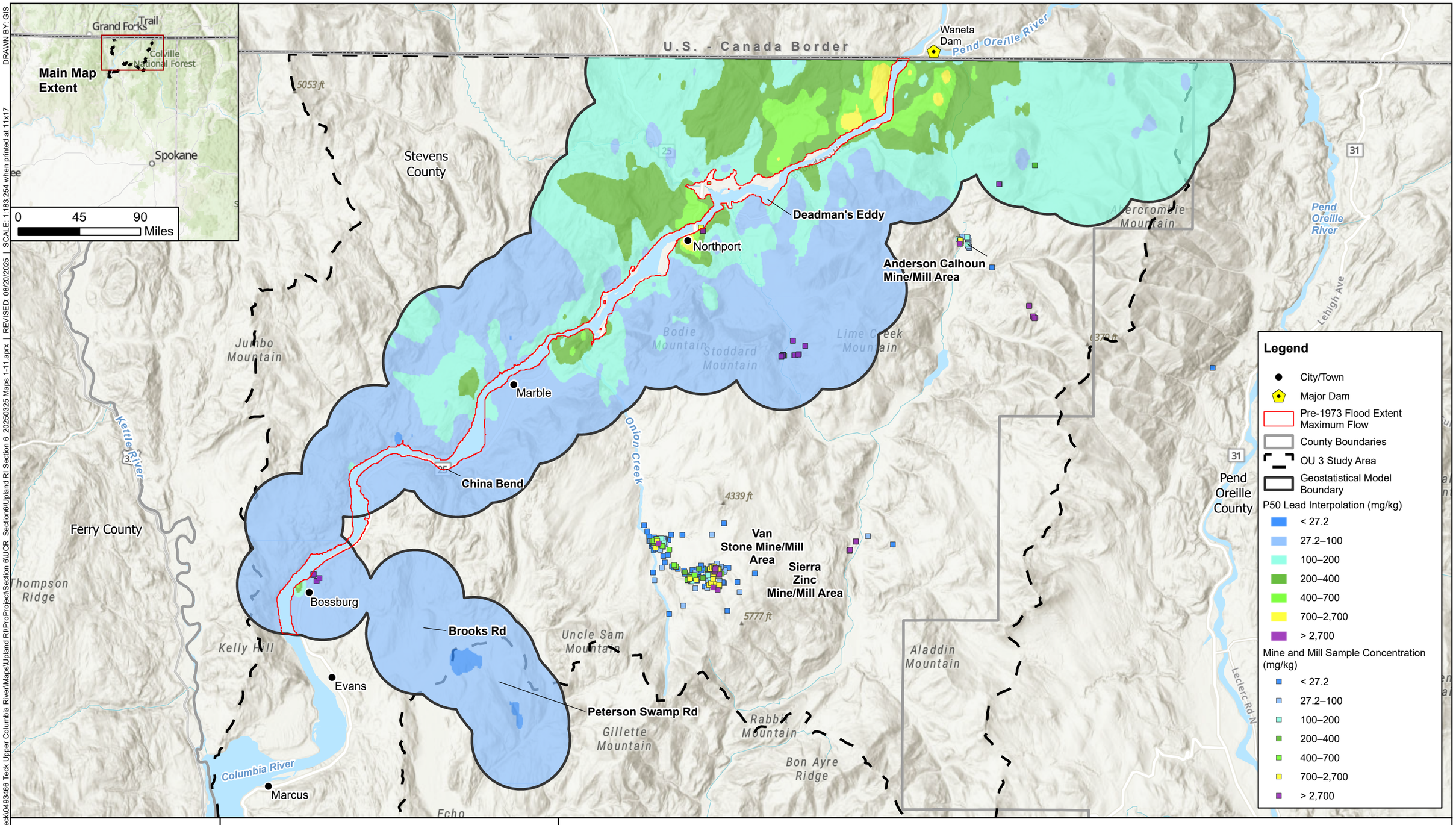
0 5 10
Miles

N

Map 6-6. **RBA-Adjusted Lead Concentrations in Surface Soil**
Final Upland RI Report
Upper Columbia River, Washington

Source: Esri - World Topographic Map; NAD 1983 UTM Zone 11N

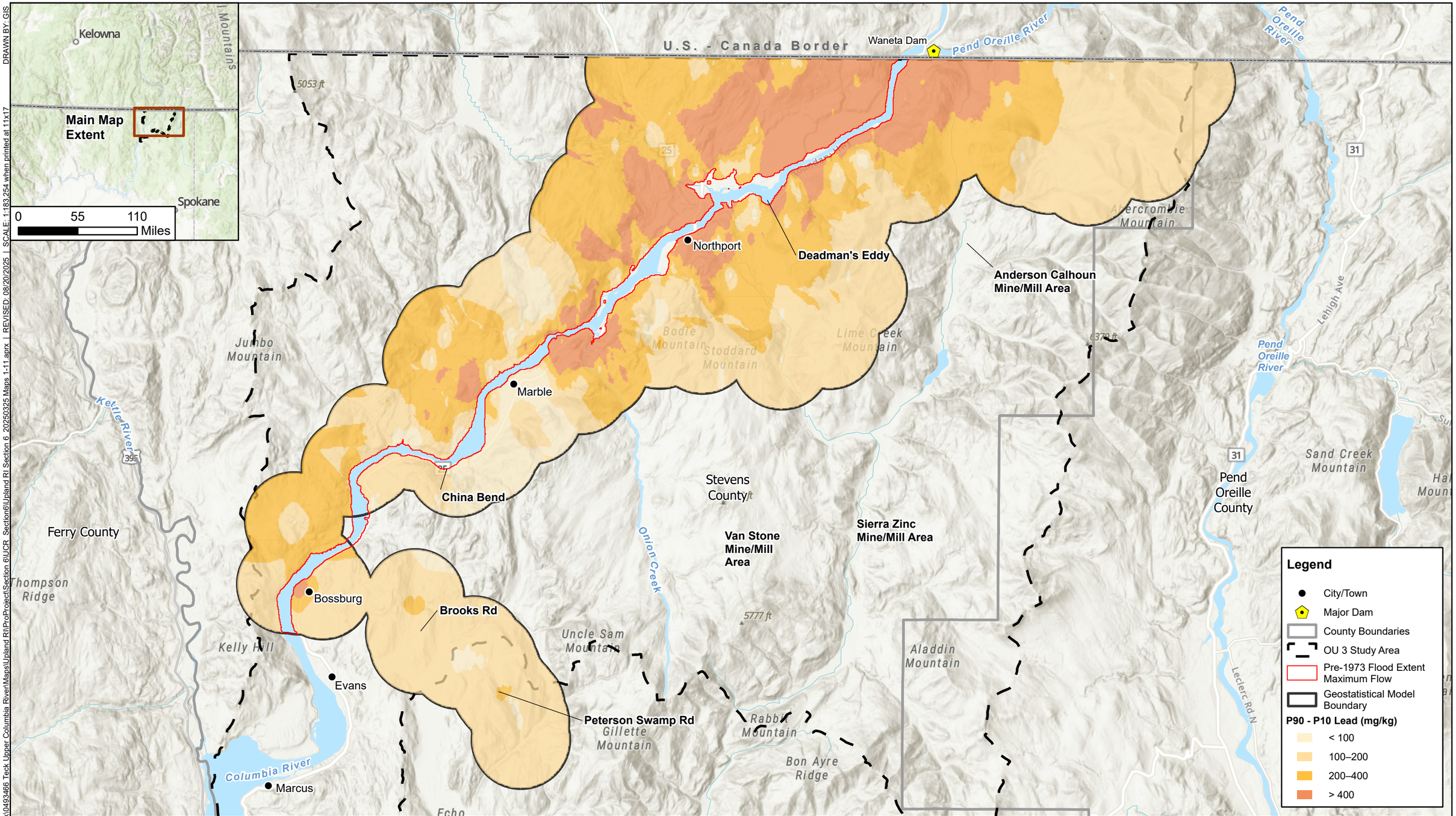
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Map 6-7. **Predicted Lead Concentrations in Surface Soil (P50 or Median Value)**
Final Upland RI Report
Upper Columbia River, Washington

Source: Esri - World Topographic Map; NAD 1983 UTM Zone 11N

DRAWN BY: GIS | SCALE: 1:183,254 when printed at 11x17 | REVISED: 08/20/2025
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0 1.25 2.5 5 Miles

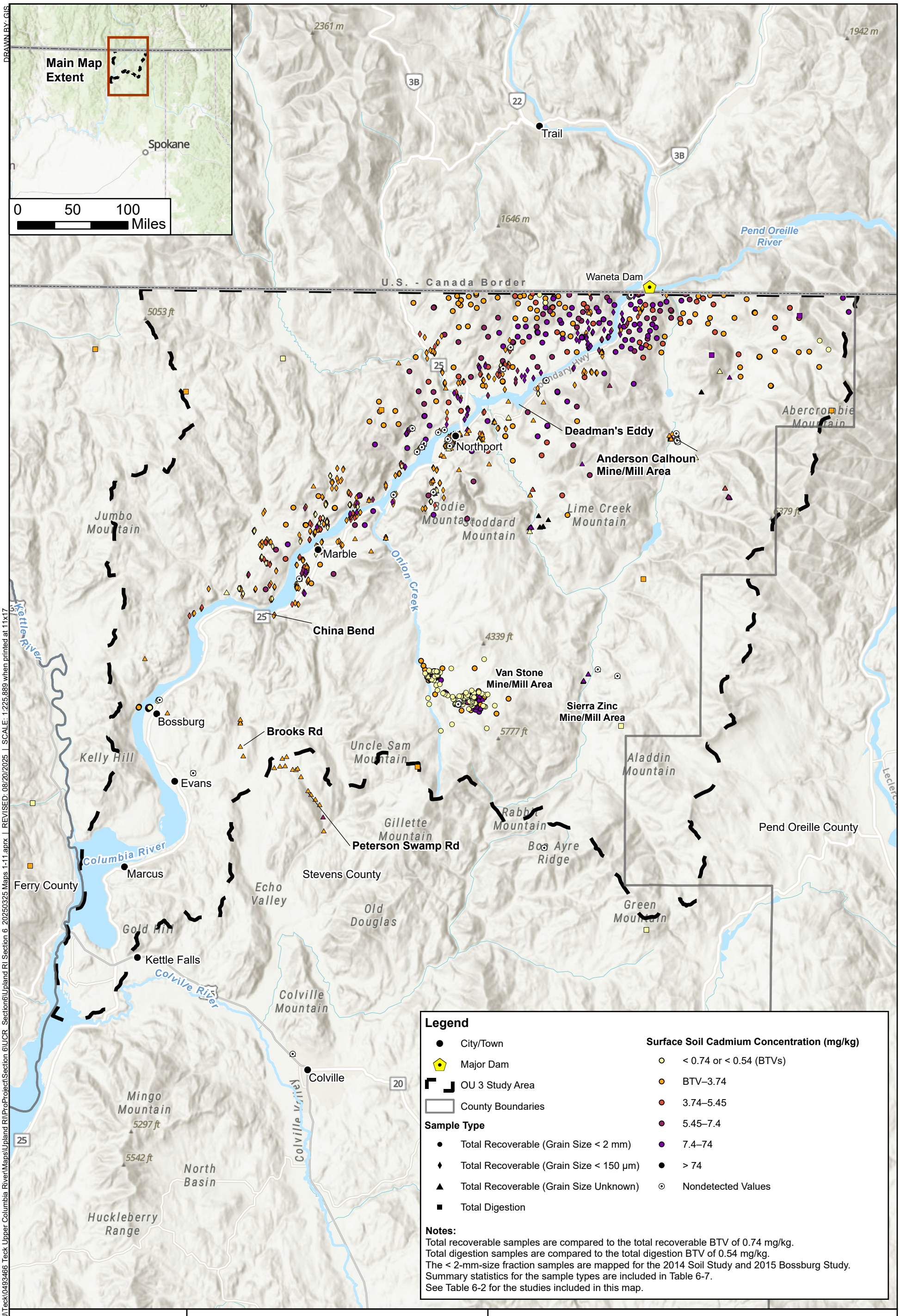
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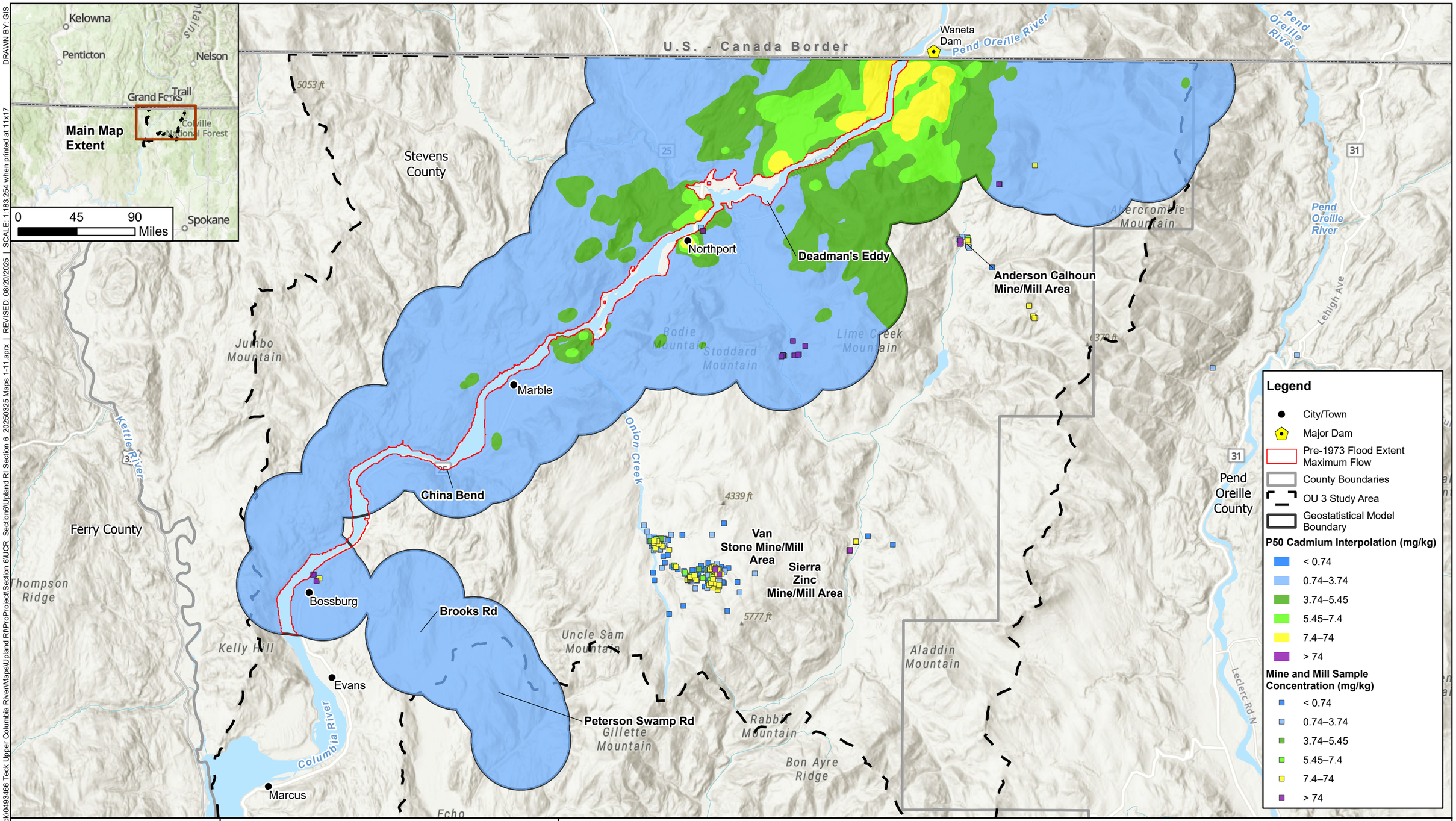
Map 6-8. **Uncertainty in Predicted Lead Concentrations in Surface Soil (P90 Minus P10)**
Final Upland RI Report
Upper Columbia River, Washington

Source: Esri - World Topographic Map; NAD 1983 UTM Zone 11N

DRAWN BY: GIS | SCALE: 1:183,254 when printed at 11x17 | REVISED: 06/20/2025

FILE: M:\US\Projects\S-U\Teck\0493466 Teck Upper Columbia River\Maps\Upland RI\ProProject\Section 6\UCR_Section6\Upland RI Section 6_20250325 Maps 1-11.aprx


Main Map Extent
Spokane
0 50 100 Miles
2361 m
1942 m
1646 m
3B
22
Trail
Pend Oreille River
U.S. - Canada Border
Waneta Dam
5053 ft
25
Boundary Hwy
Deadman's Eddy
Northport
Anderson Calhoun Mine/Mill Area
Abercrombie Mountain
Jumbo Mountain
Bodie Mountain
Stoddard Mountain
Lime Creek Mountain
Marble
Onion Creek
China Bend
4339 ft
Van Stone Mine/Mill Area
Sierra Zinc Mine/Mill Area
5777 ft
Bossburg
Brooks Rd
Kelly Hill
Uncle Sam Mountain
Aladdin Mountain
Evans
Gillette Mountain
Rabbit Mountain
Peterson Swamp Rd
Boo Ayre Ridge
Pend Oreille County
Columbia River
Marcus
Ferry County
Stevens County
Echo Valley
Old Douglas
Green Mountain
Gold Hill
Kettle Falls
Colville River
Colville Mountain
Colville
20
Mingo Mountain
5297 ft
5542 ft
North Basin
Huckleberry Range
Kettle River
Legend
City/Town
Major Dam
OU 3 Study Area
County Boundaries
Sample Type
Total Recoverable (Grain Size < 2 mm)
Total Recoverable (Grain Size < 150 µm)
Total Recoverable (Grain Size Unknown)
Total Digestion
Surface Soil Cadmium Concentration (mg/kg)
< 0.74 or < 0.54 (BTVs)
BTV–3.74
3.74–5.45
5.45–7.4
7.4–74
> 74
Nondetected Values
Notes:
Total recoverable samples are compared to the total recoverable BTV of 0.74 mg/kg.
Total digestion samples are compared to the total digestion BTV of 0.54 mg/kg.
The < 2-mm-size fraction samples are mapped for the 2014 Soil Study and 2015 Bossburg Study.
Summary statistics for the sample types are included in Table 6-7.
See Table 6-2 for the studies included in this map.
ERM
Environmental Resources Management
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0 5 10 Miles
N
Map 6-9. Cadmium Concentrations in Surface Soil
Final Upland RI Report
Upper Columbia River, Washington
Source: Esri - World Topographic Map; NAD 1983 UTM Zone 11N
DRAWN BY: GIS
FILE: M:\US\Projects\S-UTeck\0493466 Teck Upper Columbia River\Maps\Upland RI\ProProject\Section 6\UCR_Section6\Upland RI Section 6_20250325 Maps 1-11.aprx | REVISED: 08/20/2025 | SCALE: 1:225,889 when printed at 11x17



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Environmental Resources Management
www.erm.com

0 1.5 3 6 Miles

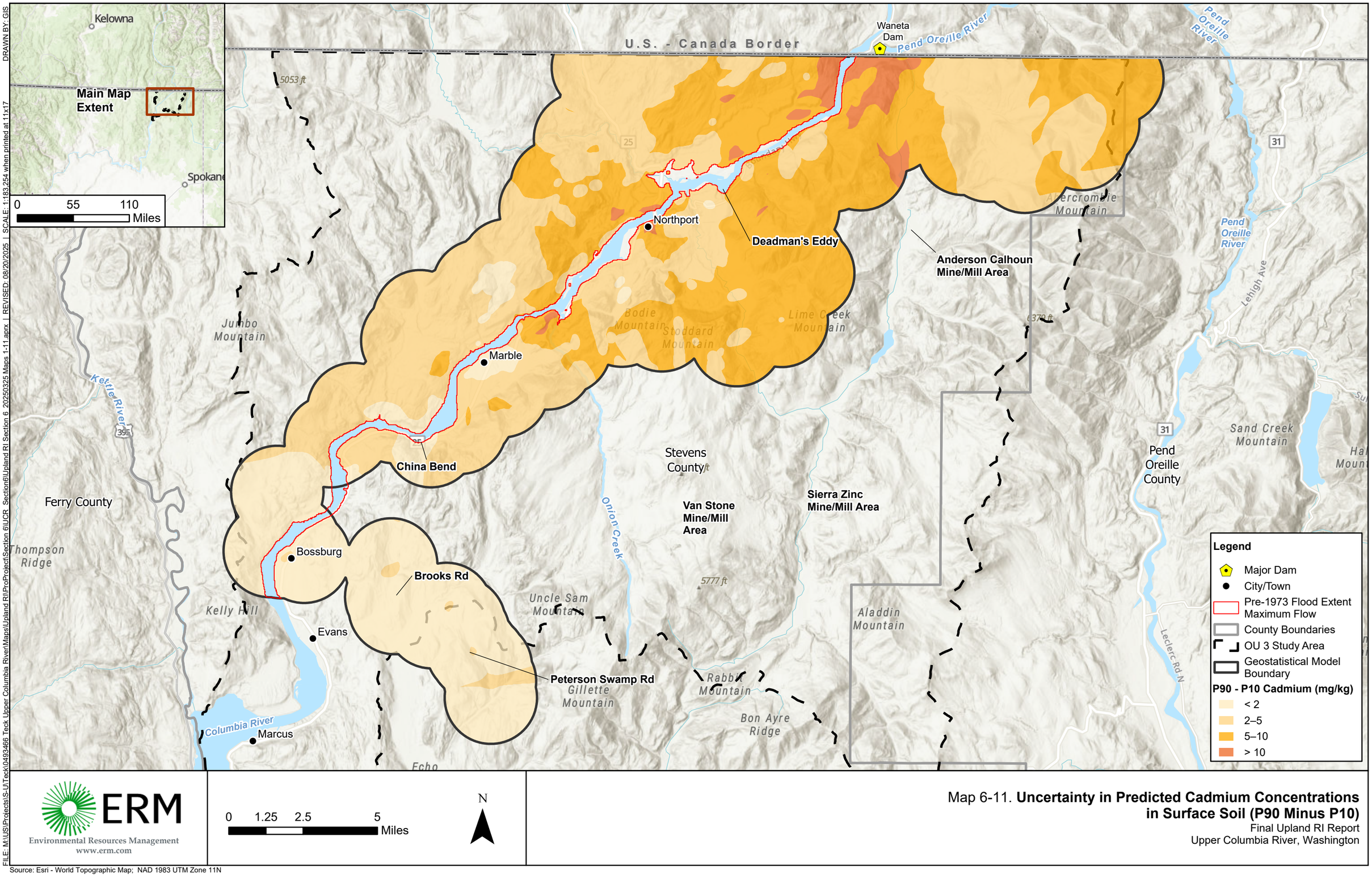
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Map 6-10. **Predicted Cadmium Concentrations in Surface Soil (P50 or Median Value)**
Final Upland RI Report
Upper Columbia River, Washington

Source: Esri - World Topographic Map; NAD 1983 UTM Zone 11N

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FILE: M:\US\Projects\S-U\Teck\0493466 Teck Upper Columbia River\Maps\Upland RI\ProProject\Section 6\UCR_Section6\Upland RI Section 6_20250325 Maps 1-11.aprx



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0 1.25 2.5 5 Miles

N

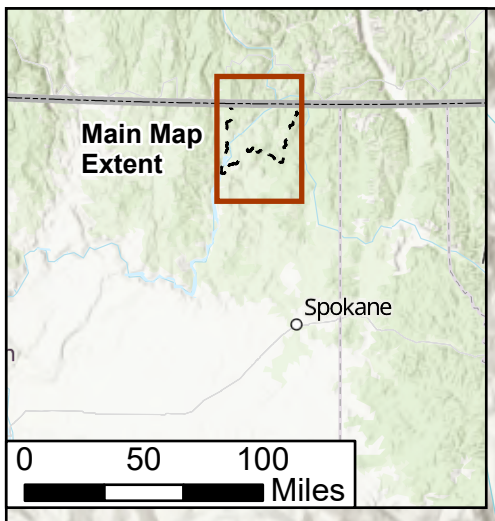
Map 6-11. **Uncertainty in Predicted Cadmium Concentrations in Surface Soil (P90 Minus P10)**
Final Upland RI Report
Upper Columbia River, Washington

Source: Esri - World Topographic Map; NAD 1983 UTM Zone 11N

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DRAWN BY: GIS



2361 m
1942 m
1646 m
5053 ft
4339 ft
5777 ft
5379 ft
3B
22
25
20
395
Trail
Columbia River
Pend Oreille River
U.S. - Canada Border
Waneta Dam
Boundary Hwy
Deadman's Eddy
Anderson Calhoun Mine/Mill Area
Abercrombie Mountain
Northport
Jumbo Mountain
Bodie Mountain
Stoddard Mountain
Lime Creek Mountain
Marble
China Bend
Van Stone Mine/Mill Area
Sierra Zinc Mine/Mill Area
Bossburg
Brooks Rd
Kelly Hill
Uncle Sam Mountain
Onion Creek
Aladdin Mountain
Pend Oreille County
Evans
Peterson Swamp Rd
Kettle River
Ferry County
Gillette Mountain
Rabbit Mountain
Bon Ayre Ridge
Marcus
Stevens County
Echo Valley
Old Douglas
Green Mountain
Gold Hill
Kettle Falls
Colville Mountain
Colville River
Colville
Colville Valley
Mingo Mountain
North Basin
Huckleberry Range

Legend

- City/Town
- Major Dam
- OU 3 Study Area
- County Boundaries

Total Recoverable (Grain Size Unknown)

- Total Recoverable (Grain Size Unknown)
- Total Recoverable (Grain Size < 2 mm)
- Total Recoverable (Grain Size < 150 µm)
- Total Digestion

Surface Soil Zinc Concentration (mg/kg)

- < 111 or 99.0 (BTVs)
- BTVs–220
- 220–378
- 378–1,110
- 1,110–11,100
- > 11,100
- Nondetected Values

Notes:
Total recoverable samples are compared to the total recoverable BTV of 111 mg/kg.
Total digestion samples are compared to the total digestion BTV of 99.0 mg/kg.
The < 2-mm-size fraction samples are mapped for the 2014 Soil Study and 2015 Bossburg Study.
Summary statistics for the sample types are included in Table 6-7.
See Table 6-2 for the studies included in this map.

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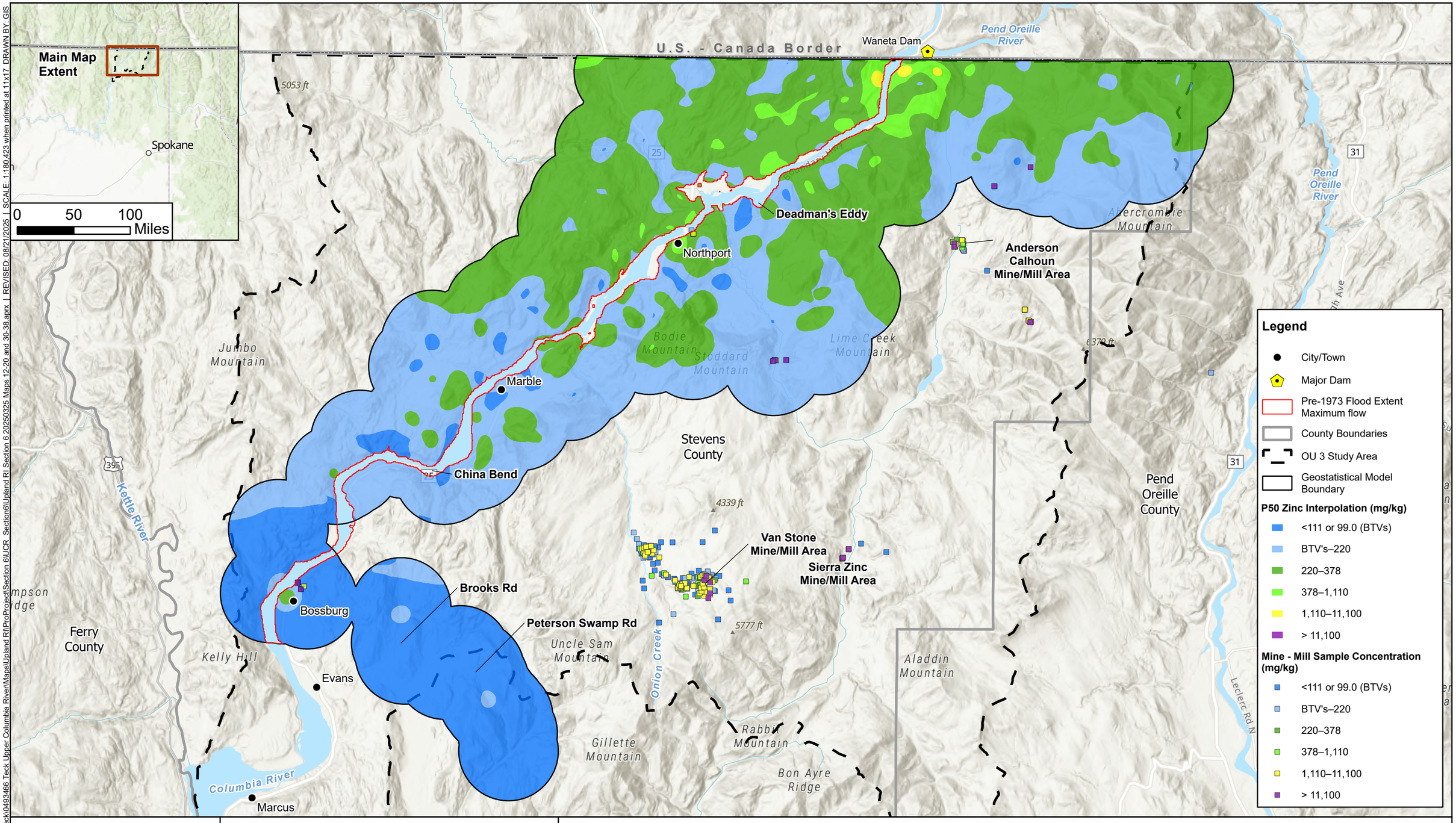
0 1.5 3 6
Miles

N

Map 6-12. **Zinc Concentrations in Surface Soil**
Final Upland RI Report
Upper Columbia River, Washington

Source: Esri - World Topographic Map; NAD 1983 UTM Zone 11N

FILE: M:\US\Projects\S-U\Teck\0493466 Teck Upper Columbia River\Maps\Upland RI\ProProject\Section 6\UCR_Section6\Upland RI Section 6 20250325 Maps 12-20 and 30-38 aprx | REVISED: 08/19/2025 | SCALE: 1:225,889 when printed at 11x17



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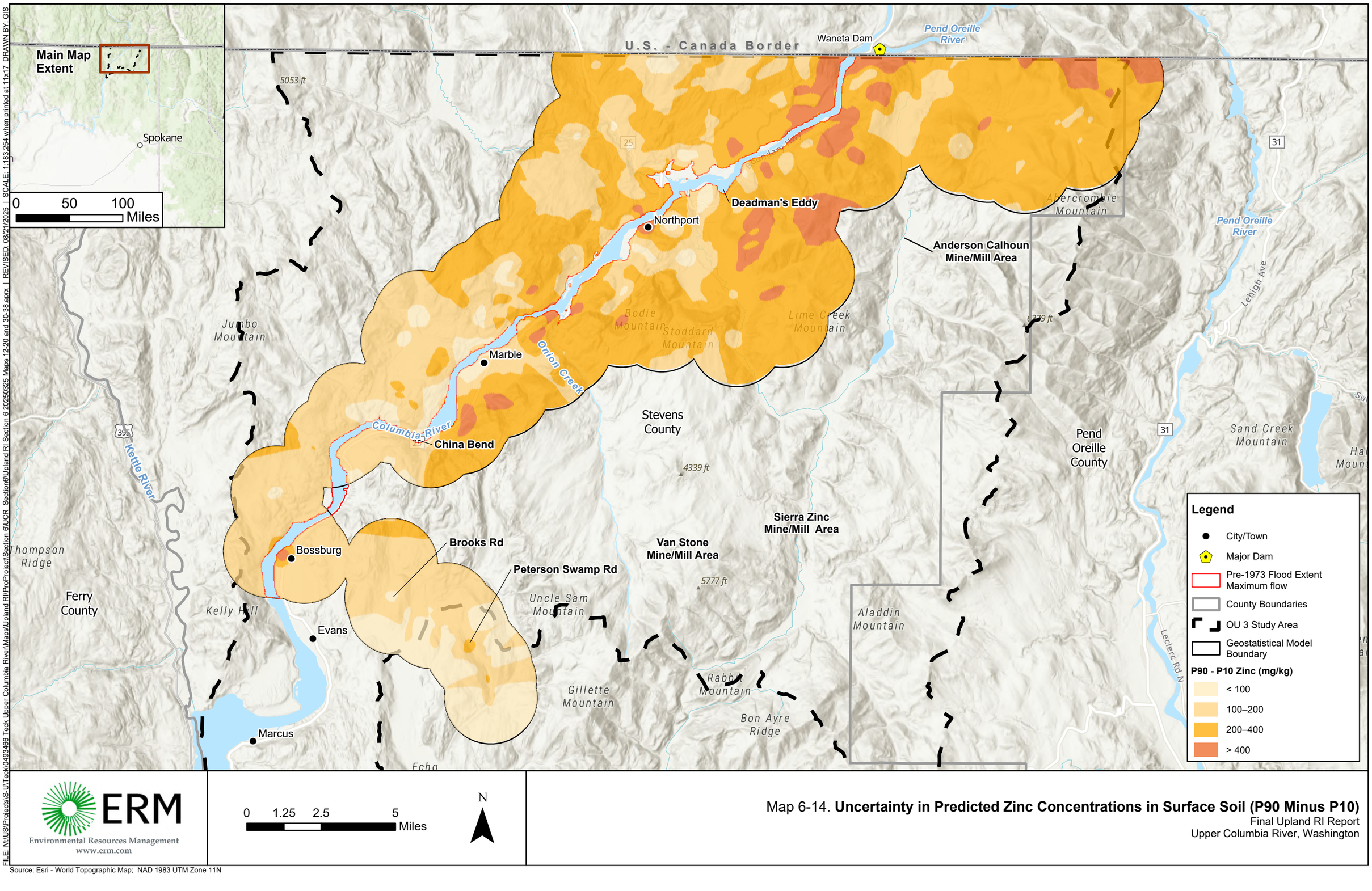
0 1.25 2.5 5 Miles

N

Map 6-13. **Predicted Zinc Concentrations in Surface Soil (P50 or Median Value)**
Final Upland RI Report
Upper Columbia River, Washington

Source: Esri - World Topographic Map; NAD 1983 UTM Zone 11N

FILE: M:\US\Projects\S-UT\eck\0493466 Teck Upper Columbia River\Maps\Upland RI\ProProject\Section 6\UCR_Section6\Upland RI Section 6 20250325 Maps 12-20 and 30-38.aprx | REVISED: 08/21/2025 | SCALE: 1:180,423 when printed at 11x17 DRAWN BY: GIS

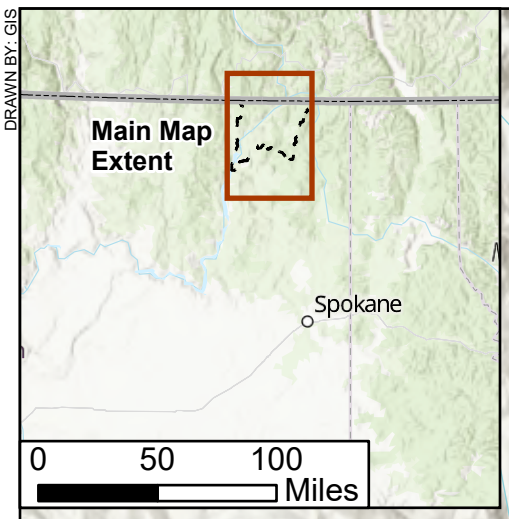


Map 6-14. **Uncertainty in Predicted Zinc Concentrations in Surface Soil (P90 Minus P10)**
Final Upland RI Report
Upper Columbia River, Washington

Source: Esri - World Topographic Map; NAD 1983 UTM Zone 11N

FILE: M:\US\Projects\S-UT\eck\0493466 Teck Upper Columbia River\Maps\Upland RI\ProProject\Section 6\UCR_Section6\Upland RI Section 6 20250325 Maps 12-20 and 30-38.aprx | REVISED: 08/21/2025 | SCALE: 1:183,254 when printed at 11x17 DRAWN BY: GIS

DRAWN BY: GIS



2361 m
1942 m
3B
22
Trail
3B
Columbia River
1646 m
Pend Oreille River
U.S. - Canada Border
Waneta Dam
5053 ft
25
Boundary Hwy
Anderson Calhoun Mine/Mill Area
Abercrombie Mountain
Deadman's Eddy
Northport
Jumbo Mountain
Bodie Mountain
Stoddard Mountain
Lime Creek Mountain
379 ft
Marble
Columbia River
Onion Creek
395
25
China Bend
4339 ft
Van Stone Mine/Mill Area
Sierra Zinc Mine/Mill Area
Bossburg
Brooks Rd
5777 ft
Uncle Sam Mountain
Aladdin Mountain
Pend Oreille County
Kelly Hill
Kettle River
Evans
Peterson Swamp Rd
Ferry County
Gillette Mountain
Rabbit Mountain
Bon Ayre Ridge
Marcus
Echo Valley
Stevens County
Old Douglas
Green Mountain
Gold Hill
Kettle Falls
395
Colville Mountain
Colville River
Colville
Colville Valley
20
Mingo Mountain
5297 ft
25
5542 ft
North Basin
Huckleberry Range

Legend

- City/Town
- Major Dam
- OU 3 Study Area
- County Boundaries

Sample Type

- Total Recoverable (Grain Size < 2 mm)
- Total Recoverable (Grain Size < 150 µm)
- Total Recoverable (Grain Size Unknown)
- Total Digestion

Surface Soil Arsenic Concentration (mg/kg)

- < 23.3 or < 12.0 (BTVs)
- BTVs–26
- 26–29
- 29–35
- 35–49
- > 49
- Nondetected Values

Notes:
Total recoverable samples are compared to the total recoverable BTV of 23.3 mg/kg.
Total digestion samples are compared to the total digestion BTV of 12.0 mg/kg.
The < 2-mm-size fraction samples are mapped for the 2014 Soil Study and 2015 Bossburg Study.
Summary statistics for the sample types are included in Table 6-7.
See Table 6-2 for the studies included in this map.

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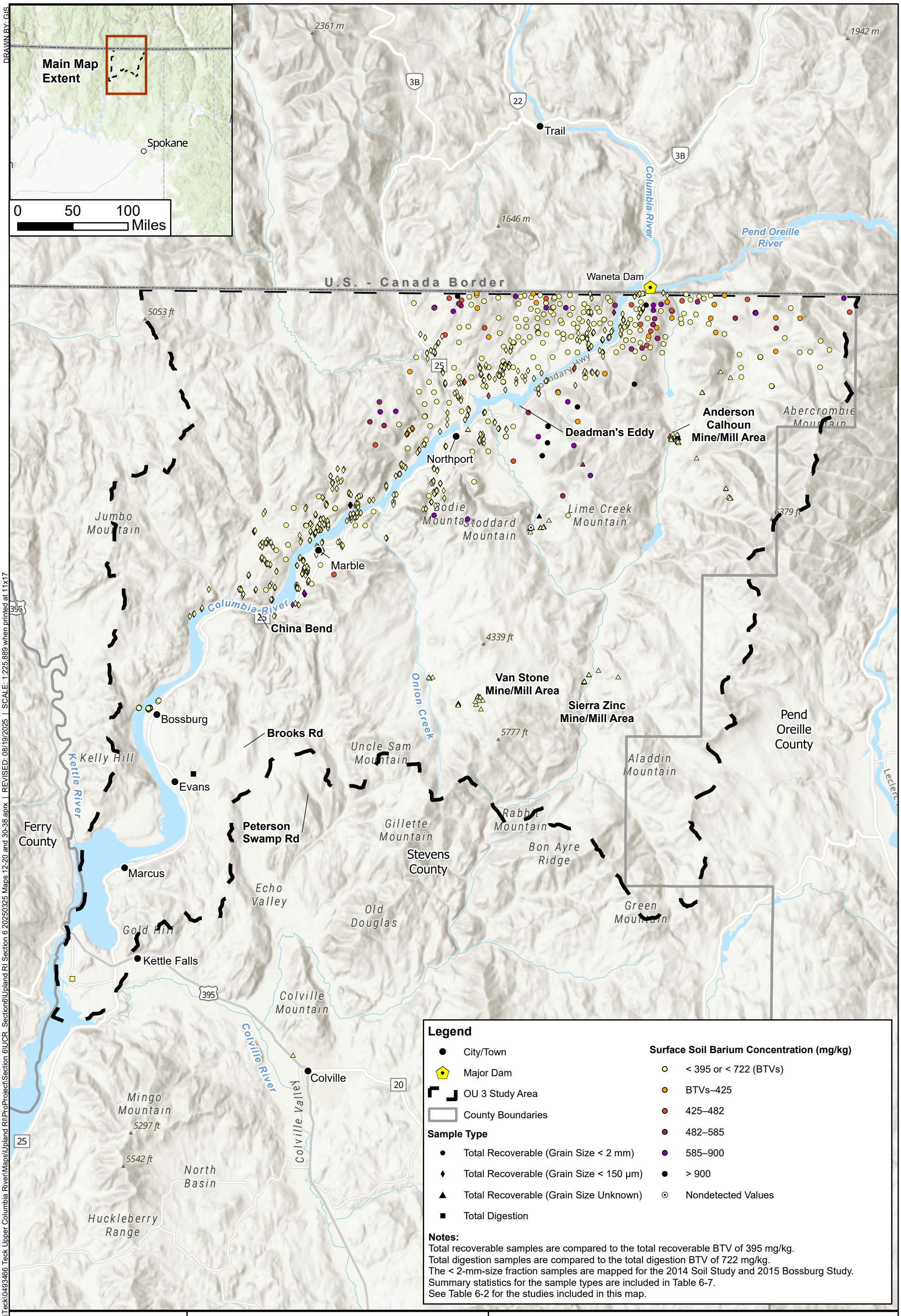
0 5 10
Miles

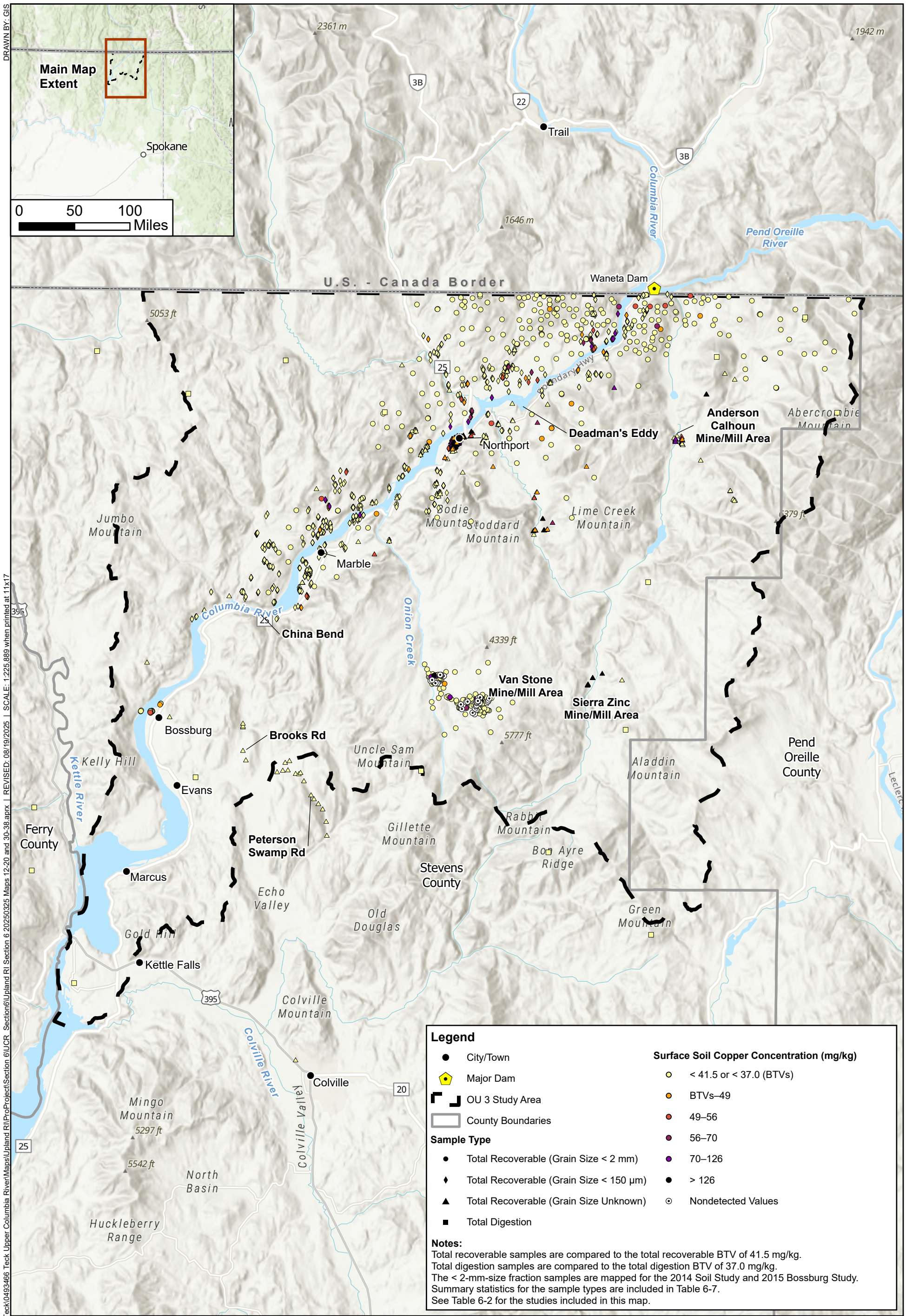
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Map 6-15. **Arsenic Concentrations in Surface Soil**
Final Upland RI Report
Upper Columbia River, Washington

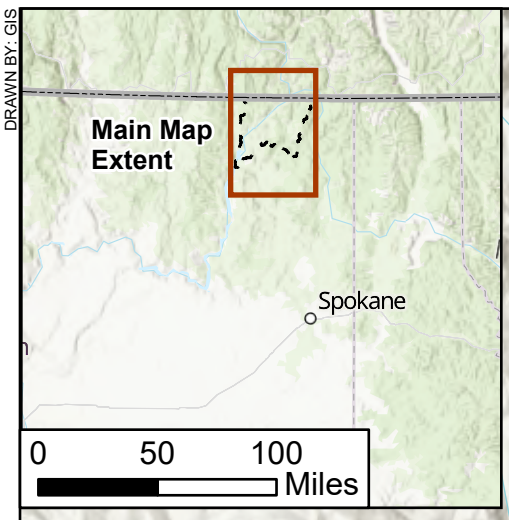
Source: Esri - World Topographic Map; NAD 1983 UTM Zone 11N

FILE: M:\US\Projects\S-U\Teck\0493466 Teck Upper Columbia River\Maps\Upland RI\ProProject\Section 6\UCR_Section6\Upland RI Section 6 20250325 Maps 12-20 and 30-38.aprx | REVISED: 06/19/2025 | SCALE: 1:225,889 when printed at 11x17


Main Map Extent
Spokane
0 50 100 Miles
2361 m
1942 m
1646 m
5053 ft
4339 ft
5777 ft
5297 ft
5542 ft
379 ft
3B
22
25
20
395
Trail
Waneta Dam
Columbia River
Pend Oreille River
U.S. - Canada Border
Boundary Hwy
Deadman's Eddy
Anderson Calhoun Mine/Mill Area
Abercrombie Mountain
Northport
Marble
China Bend
Columbia River
Jumbo Mountain
Bodie Mountain
Stoddard Mountain
Lime Creek Mountain
Van Stone Mine/Mill Area
Sierra Zinc Mine/Mill Area
Onion Creek
Bossburg
Brooks Rd
Kelly Hill
Kettle River
Evans
Peterson Swamp Rd
Uncle Sam Mountain
Aladdin Mountain
Pend Oreille County
Ferry County
Marcus
Gillette Mountain
Rabbit Mountain
Bon Ayre Ridge
Stevens County
Echo Valley
Old Douglas
Green Mountain
Gold Hill
Kettle Falls
Colville Mountain
Colville River
Colville
Colville Valley
Mingo Mountain
North Basin
Huckleberry Range
Legend
City/Town
Major Dam
OU 3 Study Area
County Boundaries
Sample Type
Total Recoverable (Grain Size < 2 mm)
Total Recoverable (Grain Size < 150 µm)
Total Recoverable (Grain Size Unknown)
Total Digestion
Surface Soil Barium Concentration (mg/kg)
< 395 or < 722 (BTVs)
BTVs–425
425–482
482–585
585–900
> 900
Nondetected Values
Notes:
Total recoverable samples are compared to the total recoverable BTV of 395 mg/kg.
Total digestion samples are compared to the total digestion BTV of 722 mg/kg.
The < 2-mm-size fraction samples are mapped for the 2014 Soil Study and 2015 Bossburg Study.
Summary statistics for the sample types are included in Table 6-7.
See Table 6-2 for the studies included in this map.
ERM
Environmental Resources Management
www.erm.com
0 5 10 Miles
N
Map 6-16. Barium Concentrations in Surface Soil
Final Upland RI Report
Upper Columbia River, Washington
Source: Esri - World Topographic Map; NAD 1983 UTM Zone 11N
DRAWN BY: GIS
FILE: M:\US\Projects\S-UTeck\0493466 Teck Upper Columbia River\Maps\Upland RI\ProProject\Section 6\UCR_Section6\Upland RI Section 6 20250325 Maps 12-20 and 30-38.aprx | REVISED: 08/19/2025 | SCALE: 1:225,889 when printed at 11x17


Main Map Extent
Spokane
0 50 100 Miles
2361 m
1942 m
1646 m
3B
22
Trail
3B
Columbia River
Pend Oreille River
U.S. - Canada Border
Waneta Dam
5053 ft
25
Boundary Hwy
Deadman's Eddy
Anderson Calhoun Mine/Mill Area
Northport
Abercrombie Mountain
Jumbo Mountain
Bodie Mountain
Stoddard Mountain
Lime Creek Mountain
379 ft
Marble
Columbia River
395
25
China Bend
Onion Creek
4339 ft
Van Stone Mine/Mill Area
Sierra Zinc Mine/Mill Area
5777 ft
Bossburg
Brooks Rd
Uncle Sam Mountain
Aladdin Mountain
Pend Oreille County
Kelly Hill
Kettle River
Evans
Ferry County
Peterson Swamp Rd
Gillette Mountain
Rabbit Mountain
Bon Ayre Ridge
Marcus
Stevens County
Echo Valley
Old Douglas
Green Mountain
Gold Hill
Kettle Falls
395
Colville Mountain
Colville River
Colville
Colville Valley
20
Mingo Mountain
5297 ft
25
5542 ft
North Basin
Huckleberry Range
Legend
City/Town
Major Dam
OU 3 Study Area
County Boundaries
Sample Type
Total Recoverable (Grain Size < 2 mm)
Total Recoverable (Grain Size < 150 µm)
Total Recoverable (Grain Size Unknown)
Total Digestion
Surface Soil Copper Concentration (mg/kg)
< 41.5 or < 37.0 (BTVs)
BTVs–49
49–56
56–70
70–126
> 126
Nondetected Values
Notes:
Total recoverable samples are compared to the total recoverable BTV of 41.5 mg/kg.
Total digestion samples are compared to the total digestion BTV of 37.0 mg/kg.
The < 2-mm-size fraction samples are mapped for the 2014 Soil Study and 2015 Bossburg Study.
Summary statistics for the sample types are included in Table 6-7.
See Table 6-2 for the studies included in this map.
ERM
Environmental Resources Management
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0 5 10 Miles
N
Map 6-17. Copper Concentrations in Surface Soil
Final Upland RI Report
Upper Columbia River, Washington
Source: Esri - World Topographic Map; NAD 1983 UTM Zone 11N
DRAWN BY: GIS
FILE: M:\US\Projects\S-U\Teck\0493466 Teck Upper Columbia River\Maps\Upland RI\ProProject\Section 6\UCR_Section6\Upland RI Section 6 20250325 Maps 12-20 and 30-38.aprx | REVISED: 06/19/2025 | SCALE: 1:225,889 when printed at 11x17

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2361 m
1942 m
3B
22
Trail
3B
Columbia River
1646 m
Pend Oreille River
U.S. - Canada Border
Waneta Dam
5053 ft
25
Boundary Hwy
Deadman's Eddy
Anderson Calhoun Mine/Mill Area
Abercrombie Mountain
Northport
Jumbo Mountain
Bodie Mountain
Stoddard Mountain
Lime Creek Mountain
5379 ft
Marble
Columbia River
Kettle River
25
China Bend
4339 ft
Van Stone Mine/Mill Area
Sierra Zinc Mine/Mill Area
Bossburg
Brooks Rd
Onion Creek
5777 ft
Uncle Sam Mountain
Aladdin Mountain
Pend Oreille County
Kelly Hill
Evans
Ferry County
Peterson Swamp Rd
Gillette Mountain
Rabbit Mountain
Bon Ayre Ridge
Marcus
Stevens County
Echo Valley
Old Douglas
Green Mountain
Kettle Falls
395
Colville Mountain
Colville River
Colville Valley
Colville
20
Mingo Mountain
2297 ft
25
5542 ft
North Basin
Huckleberry Range

Legend

- City/Town
- Major Dam
- OU 3 Study Area
- County Boundaries

Sample Type

- Total Recoverable (Grain Size < 2 mm)
- Total Recoverable (Grain Size < 150 µm)
- Total Recoverable (Grain Size Unknown)
- Total Digestion

Surface Soil Manganese Concentration (mg/kg)

- < 1,240 or < 1,380 (BTVs)
- BTVs–1,330
- 1,330–1,470
- 1,470–1,610
- 1,610–2,135
- > 2,135
- Nondetected Values

Notes:
Total recoverable samples are compared to the total recoverable BTV of 1,240 mg/kg.
Total digestion samples are compared to the total digestion BTV of 1,380 mg/kg.
The < 2-mm-size fraction samples are mapped for the 2014 Soil Study and 2015 Bossburg Study.
Summary statistics for the sample types are included in Table 6-7.
See Table 6-2 for the studies included in this map.

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0 5 10 Miles

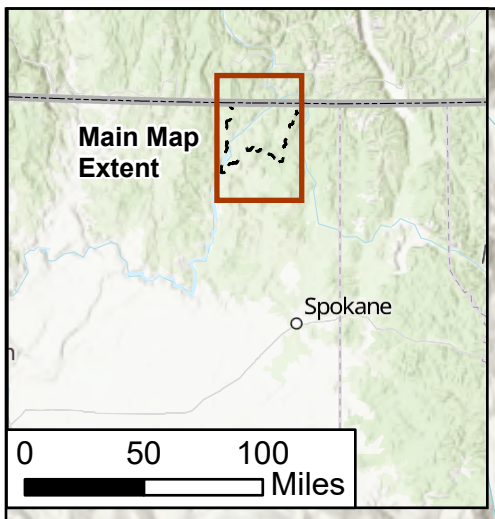
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Map 6-18. **Manganese Concentrations in Surface Soil**
Final Upland RI Report
Upper Columbia River, Washington

Source: Esri - World Topographic Map; NAD 1983 UTM Zone 11N

FILE: M:\US\Projects\S-U\Teck\0493466 Teck Upper Columbia River\Maps\Upland RI\ProProject\Section 6\UCR_Section6\Upland RI Section 6 20250325 Maps 12-20 and 30-38.aprx | REVISED: 08/19/2025 | SCALE: 1:225,889 when printed at 11x17

DRAWN BY: GIS



2361 m
1942 m
1646 m
5053 ft
4339 ft
5777 ft
5379 ft
3B
22
25
20
395
Trail
Columbia River
Pend Oreille River
U.S. - Canada Border
Waneta Dam
Boundary Hwy
Deadman's Eddy
Anderson Calhoun Mine/Mill Area
Abercrombie Mountain
Northport
Jumbo Mountain
Bodie Mountain
Stoddard Mountain
Lime Creek Mountain
Marble
Columbia River
China Bend
Onion Creek
Van Stone Mine/Mill Area
Sierra Zinc Mine/Mill Area
Bossburg
Brooks Rd
Kelly Hill
Kettle River
Evans
Peterson Swamp Rd
Uncle Sam Mountain
Aladdin Mountain
Pend Oreille County
Ferry County
Gillette Mountain
Rabbit Mountain
Bon Ayre Ridge
Marcus
Echo Valley
Stevens County
Old Douglas
Green Mountain
Gold Hill
Kettle Falls
Colville Mountain
Colville River
Colville
Colville Valley
Mingo Mountain
5297 ft
5542 ft
North Basin
Huckleberry Range

Legend

- City/Town
- Major Dam
- OU 3 Study Area
- County Boundaries

Sample Type

- Total Recoverable (Grain Size < 2 mm)
- Total Recoverable (Grain Size Unknown)
- Total Digestion

Surface Soil Mercury Concentration (mg/kg)

- < 0.12 (BTV)
- BTV–0.15
- 0.15–0.21
- 0.21–0.325
- 0.325–0.88
- > 0.88
- Nondetected Values

Notes:
Total recoverable and total digestion samples are compared to the mercury BTV of 0.12 mg/kg.
The < 2-mm-size fraction samples are mapped for the 2014 Soil Study and 2015 Bossburg Study.
Summary statistics for the sample types are included in Table 6-7.
See Table 6-2 for the studies included in this map.

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0 5 10 Miles

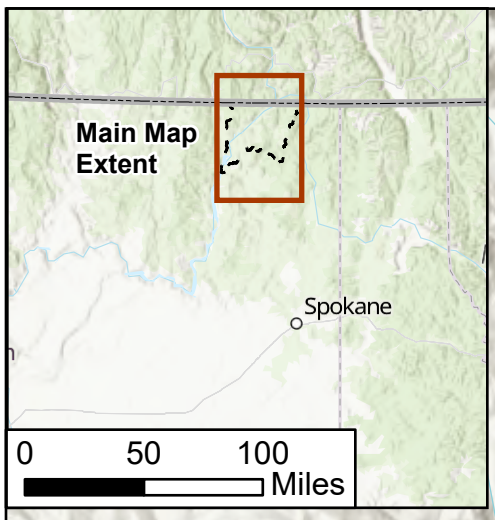
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Map 6-19. **Mercury Concentrations in Surface Soil**
Final Upland RI Report
Upper Columbia River, Washington

Source: Esri - World Topographic Map; NAD 1983 UTM Zone 11N

FILE: M:\US\Projects\S-U\Teck\0493466 Teck Upper Columbia River\Maps\Upland RI\ProProject\Section 6\UCR_Section6\Upland RI Section 6 20250325 Maps 12-20 and 30-38.aprx | REVISED: 06/19/2025 | SCALE: 1:225,889 when printed at 11x17

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2361 m
1942 m
3B
22
Trail
3B
Columbia River
1646 m
Pend Oreille River
U.S. - Canada Border
Waneta Dam
5053 ft
25
Boundary Hwy
Deadman's Eddy
Anderson Calhoun Mine/Mill Area
Abercrombie Mountain
Northport
Jumbo Mountain
Bodie Mountain
Stoddard Mountain
Lime Creek Mountain
5379 ft
Marble
Onion Creek
Columbia River
25
China Bend
4339 ft
Van Stone Mine/Mill Area
Sierra Zinc Mine/Mill Area
5777 ft
Bossburg
Brooks Rd
Kelly Hill
Uncle Sam Mountain
Aladdin Mountain
Pend Oreille County
Evans
Kettle River
Peterson Swamp Rd
Gillette Mountain
Rabbit Mountain
Bon Ayre Ridge
Ferry County
Marcus
Echo Valley
Old Douglas
Green Mountain
Gold Hill
Stevens County
Kettle Falls
395
Colville Mountain
Colville
20
Colville Valley
Mingo Mountain
5297 ft
25
5542 ft
North Basin
Colville River
Huckleberry Range

Legend

- City/Town
- Major Dam
- OU 3 Study Area
- County Boundaries

Sample Type

- Total Recoverable (Grain Size < 2 mm)
- Total Recoverable (Grain Size < 150 µm)
- Total Recoverable (Grain Size Unknown)
- Total Digestion

Surface Soil Selenium Concentration (mg/kg)

- < 0.098 or < 3.0 (BTVs)
- BTVs–0.20
- 0.20–0.27
- 0.27–0.37
- 0.37–0.503
- > 0.503
- Nondetected Values

Notes:
Total recoverable samples are compared to the total recoverable BTV of 0.098 mg/kg.
Total digestion samples are compared to the total digestion BTV of 3.0 mg/kg.
The < 2-mm-size fraction samples are mapped for the 2014 Soil Study and 2015 Bossburg Study.
Summary statistics for the sample types are included in Table 6-7.
See Table 6-2 for the studies included in this map.

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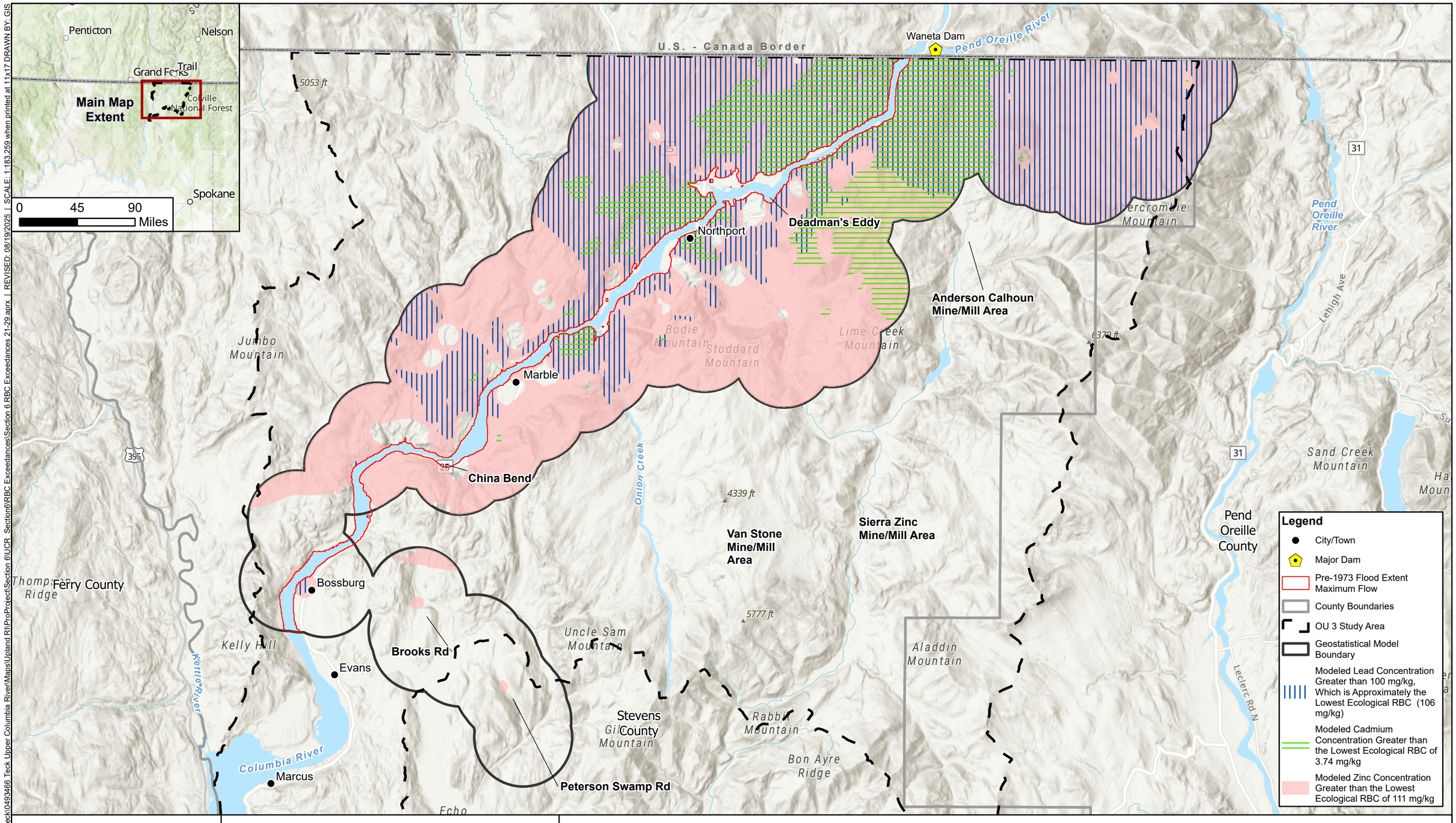
0 5 10 Miles

N

Map 6-20. **Selenium Concentrations in Surface Soil**
Final Upland RI Report
Upper Columbia River, Washington

Source: Esri - World Topographic Map; NAD 1983 UTM Zone 11N

FILE: M:\US\Projects\S-U\Teck\0493466 Teck Upper Columbia River\Maps\Upland RI\ProProject\Section 6\UCR_Section6\Upland RI Section 6 20250325 Maps 12-20 and 30-38.aprx | REVISED: 08/19/2025 | SCALE: 1:225,889 when printed at 11x17



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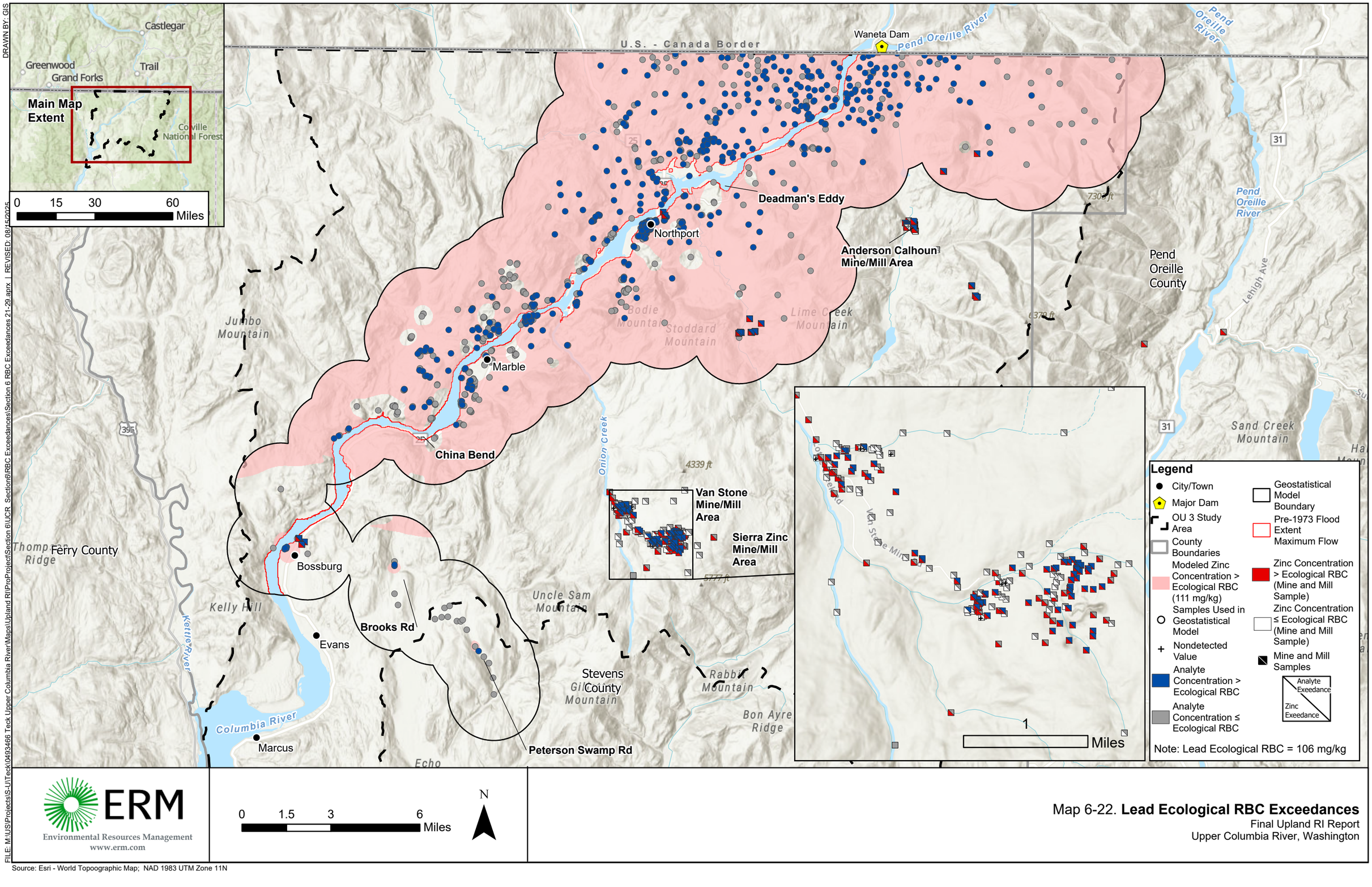
0 1.5 3 6 Miles

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Map 6-21. **Areas with Modeled Lead, Cadmium, and Zinc Ecological RBC Exceedances**
Final Upland RI Report
Upper Columbia River, Washington

FILE: M:\US\Projects\S-U\Teck\0493466 Teck Upper Columbia River\Maps\Upland RI\ProProject\Section 6\UCR_Section6\RBC Exceedances\Section 6 RBC Exceedances 21-29.aprx | REVISED: 08/19/2025 | SCALE: 1:183,259 when printed at 11x17 DRAWN BY: GIS

Source: Esri - World Topoographic Map; NAD 1983 UTM Zone 11N

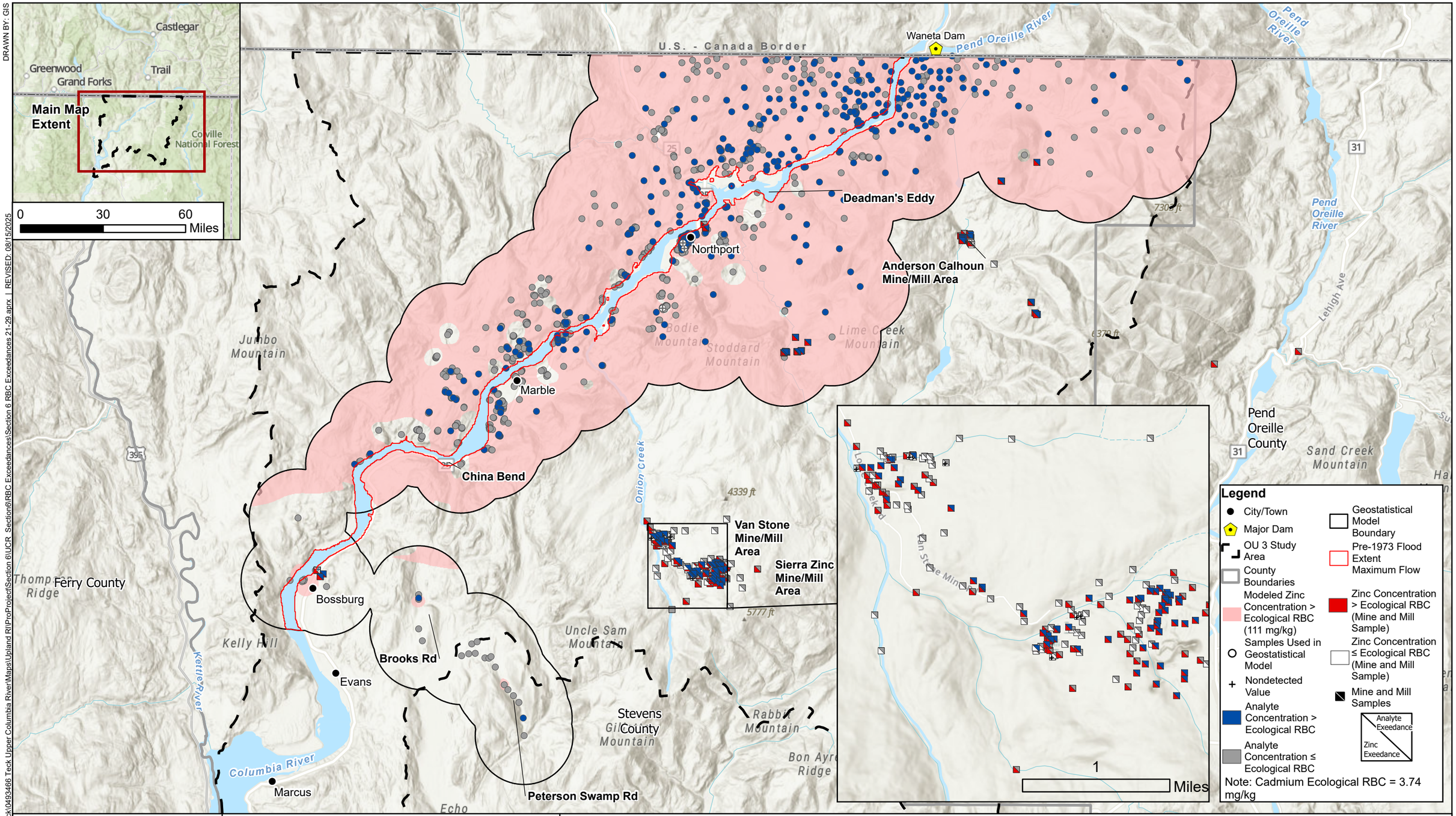


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Map 6-22. **Lead Ecological RBC Exceedances**
Final Upland RI Report
Upper Columbia River, Washington

Source: Esri - World Topoographic Map; NAD 1983 UTM Zone 11N

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FILE: M:\US\Projects\S-U\Teck\0493466 Teck Upper Columbia River\Maps\Upland RI\ProProject\Section 6\UCR_Section6\RBC Exceedances\Section 6 RBC Exceedances 21-29.aprx



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0 1.5 3 6 Miles

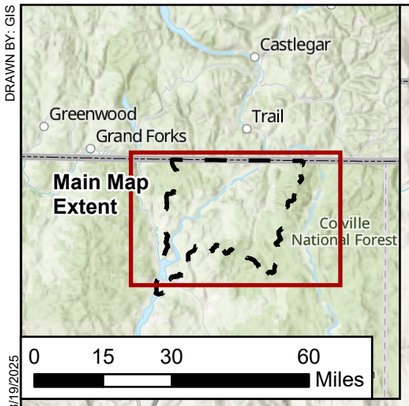
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Map 6-23. **Cadmium Ecological RBC Exceedances**
Final Upland RI Report
Upper Columbia River, Washington

Source: Esri - World Topoographic Map; NAD 1983 UTM Zone 11N

DRAWN BY: GIS | REVISED: 08/19/2025

FILE: M:\US\Projects\S-U\Teck\0493466 Teck Upper Columbia River\Maps\Upland RI\ProProject\Section 6\UCR_Section6\RBC Exceedances\Section 6 RBC Exceedances 21-29.aprx



U.S. - Canada Border

Waneta Dam

Pend Oreille River

Deadman's Eddy

Northport

Marble

China Bend

Bossburg

Evans

Brooks Rd

Marcus

Peterson Swamp Rd

Anderson Calhoun Mine/Mill Area

Van Stone Mine/Mill Area

Sierra Zinc Mine/Mill Area

Pend Oreille County

Ferry County

Stevens County

Jumbo Mountain

Bodie Mountain

Stoddard Mountain

Lime Creek Mountain

Abercrombie Mountain

Sand Creek Mountain

Kelly Hill

Uncle Sam Mountain

Gillette Mountain

Rabbit Mountain

Bon Ay Ridge

Columbia River

Kettle River

Lehigh Ave

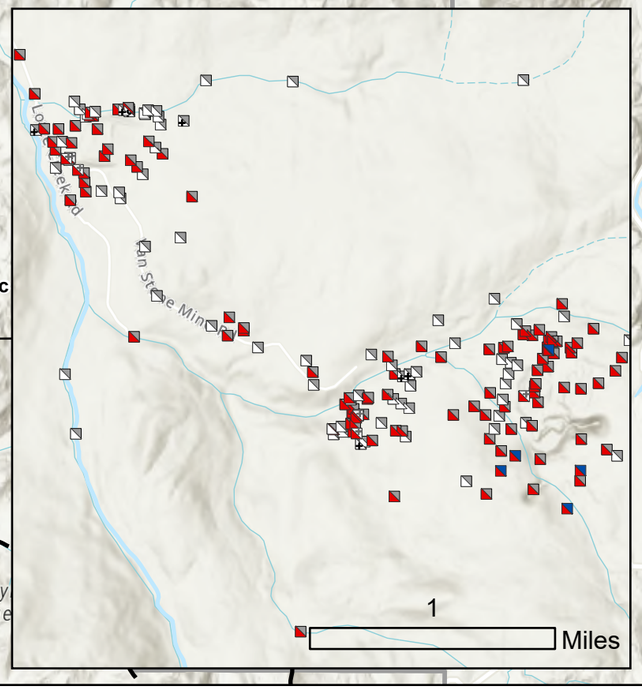
Onion Creek

5053 ft

4339 ft

5777 ft

6379 ft



Legend

- City/Town
- Major Dam
- OU 3 Study Area
- County Boundaries
- Modeled Zinc Concentration > Ecological RBC (111 mg/kg)
- Samples Used in Geostatistical Model
- Nondetected Value
- Analyte Concentration > Ecological RBC
- Analyte Concentration ≤ Ecological RBC
- Geostatistical Model Boundary
- Pre-1973 Flood Extent Maximum Flow
- Zinc Concentration > Ecological RBC (Mine and Mill Sample)
- Zinc Concentration ≤ Ecological RBC (Mine and Mill Sample)
- Mine and Mill Samples
- Analyte Exeedance / Zinc Exeedance

Note: Arsenic Ecological RBC = 23.3 mg/kg.

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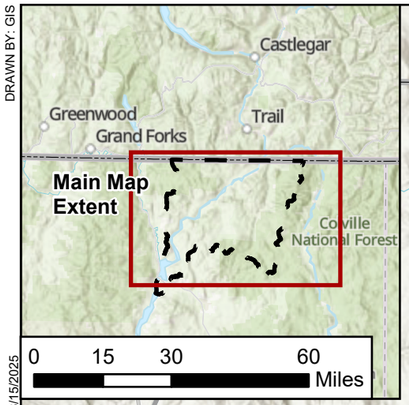
0 1.5 3 6
Miles

N

Map 6-24. **Arsenic Ecological RBC Exceedances**
Final Upland RI Report
Upper Columbia River, Washington

Source: Esri - World Topoographic Map; NAD 1983 UTM Zone 11N

DRAWN BY: GIS | REVISED: 08/15/2025 | FILE: M:\US\Projects\S-UT\Teck\0493466 Teck Upper Columbia River\Maps\Upland RI\ProProject\Section 6\UCR_Section6\RBC Exceedances\Section 6 RBC Exceedances 21-29.aprx



U.S. - Canada Border

Waneta Dam

Pend Oreille River

Deadman's Eddy

Northport

Anderson Calhoun Mine/Mill Area

Pend Oreille County

Marble

China Bend

Jumbo Mountain

Bodie Mountain

Stoddard Mountain

Lime Creek Mountain

Onion Creek

Van Stone Mine/Mill Area

Sierra Zinc Mine/Mill Area

Uncle Sam Mountain

Ferry County

Thompson Ridge

Kelly Hill

Bossburg

Brooks Rd

Evans

Kettle River

Columbia River

Marcus

Stevens County

Gillette Mountain

Rabbit Mountain

Bon Ayre Ridge

Peterson Swamp Rd

Echo

Lehigh Ave

Sand Creek Mountain

Van Stone Mine Rd

Lotze Creek Rd

NFD Road 200

4339 ft

5777 ft

7309 ft

6379 ft

3298 ft

3929 ft

1 Miles

Legend

- City/Town
- Major Dam
- OU 3 Study Area
- County Boundaries
- Modeled Zinc Concentration > Ecological RBC (111 mg/kg)
- Samples Used in Geostatistical Model
- Nondetected Value
- Analyte Concentration > Ecological RBC
- Analyte Concentration ≤ Ecological RBC
- Geostatistical Model Boundary
- Pre-1973 Flood Extent Maximum Flow
- Zinc Concentration > Ecological RBC (Mine and Mill Sample)
- Zinc Concentration ≤ Ecological RBC (Mine and Mill Sample)
- Mine and Mill Samples
- Analyte Exeedance / Zinc Exeedance

Note: Barium Ecological RBC = 395 mg/kg

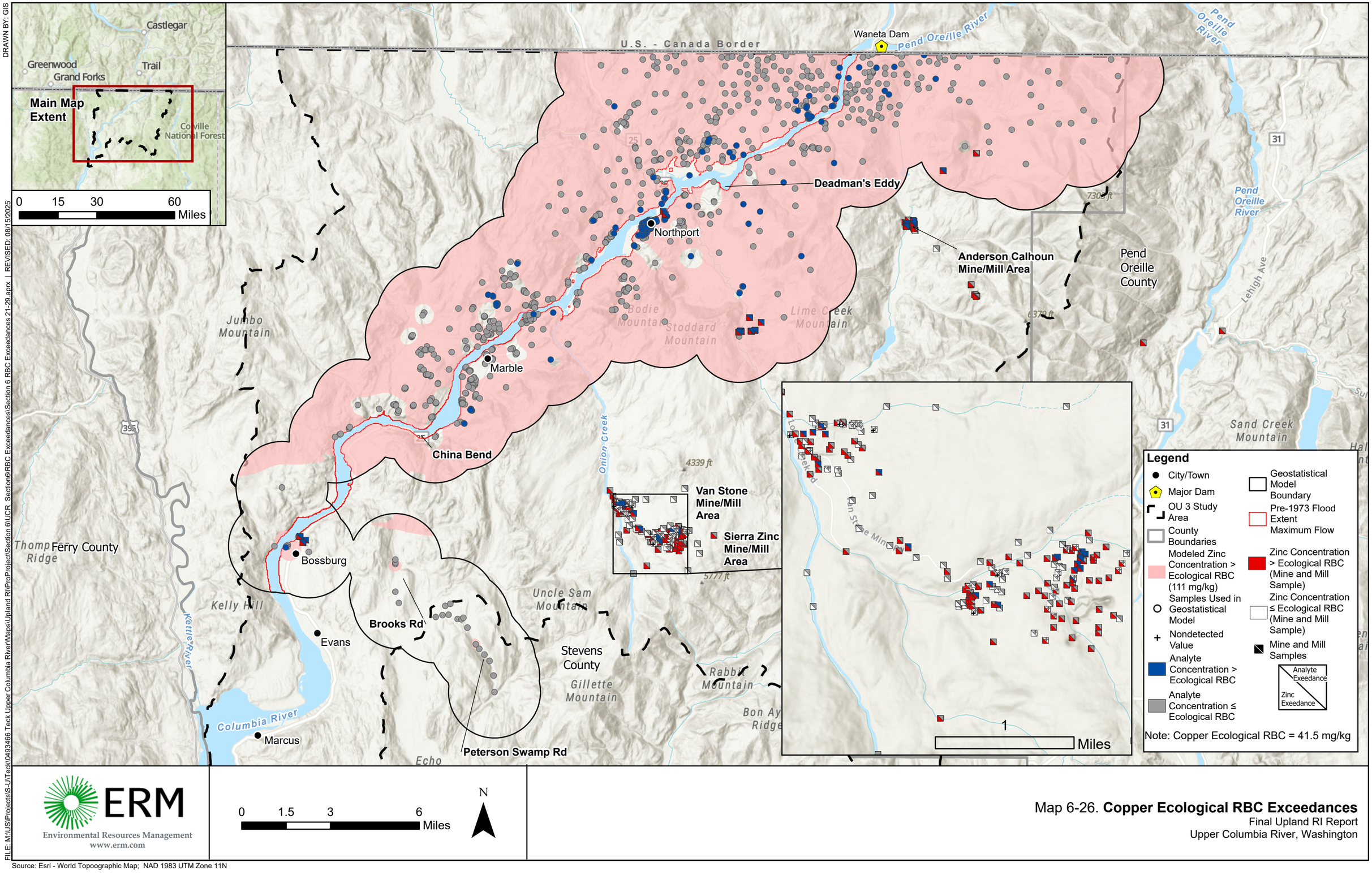
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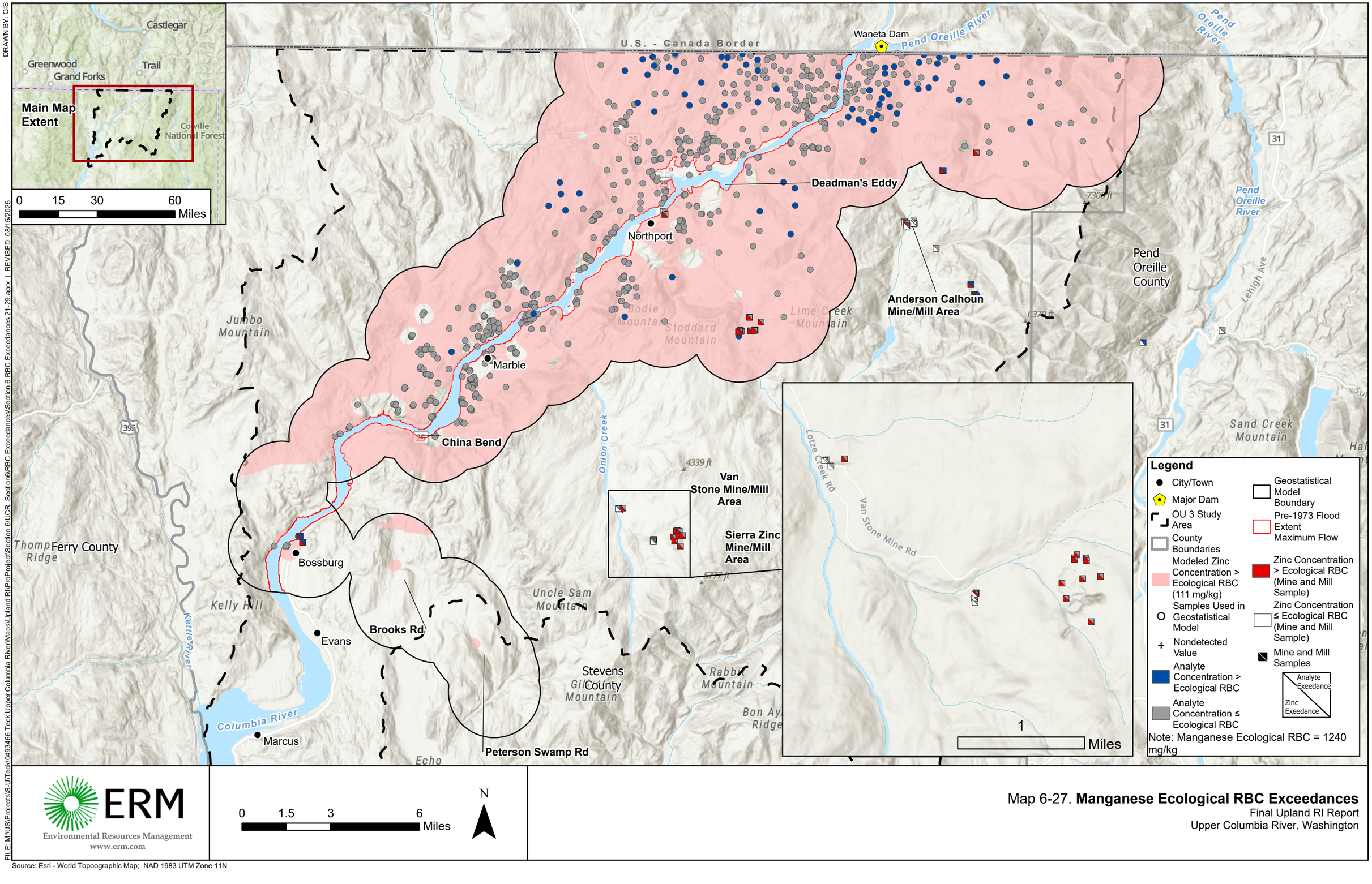
0 1.5 3 6 Miles

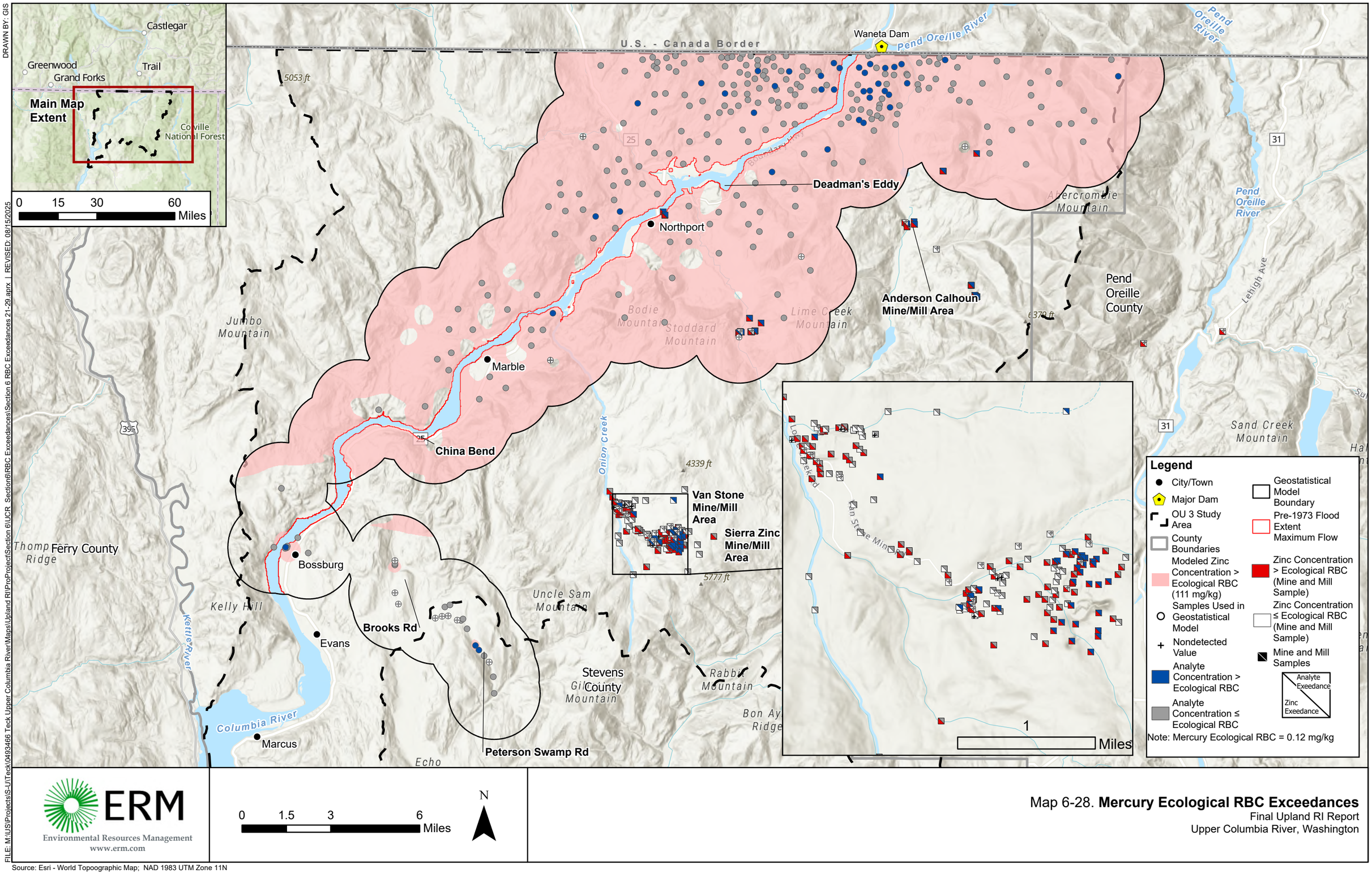
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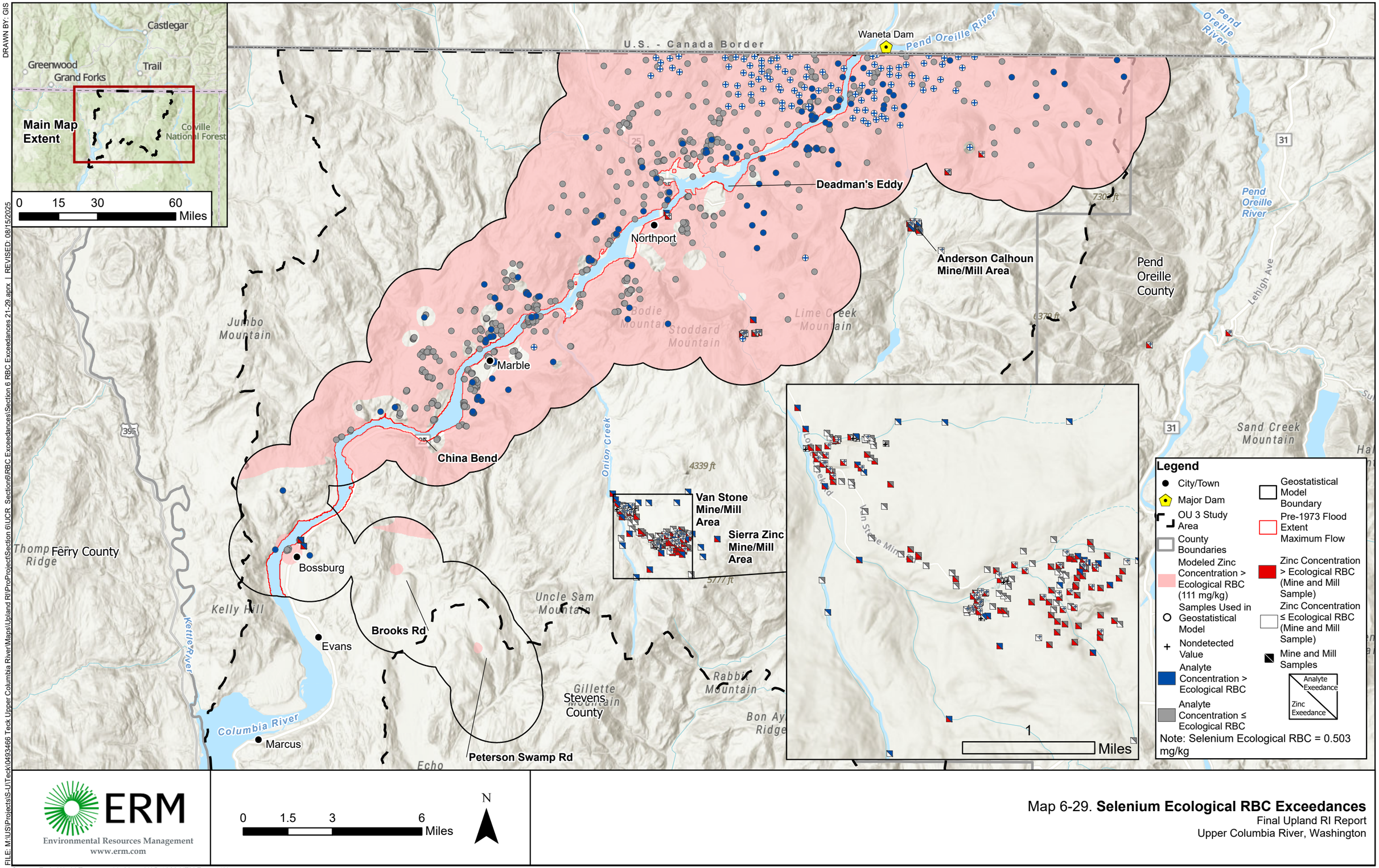
Map 6-25. **Barium Ecological RBC Exceedances**
Final Upland RI Report
Upper Columbia River, Washington

Source: Esri - World Topoographic Map; NAD 1983 UTM Zone 11N


Castlegar
Greenwood
Grand Forks
Trail
Main Map Extent
Coville National Forest
0 15 30 60 Miles
U.S. - Canada Border
Waneta Dam
Pend Oreille River
Deadman's Eddy
Northport
Anderson Calhoun Mine/Mill Area
Pend Oreille County
Jumbo Mountain
Bodie Mountain
Stoddard Mountain
Lime Creek Mountain
Marble
China Bend
Onion Creek
Van Stone Mine/Mill Area
Sierra Zinc Mine/Mill Area
Sand Creek Mountain
Thompson Ridge
Ferry County
Bossburg
Kelly Hill
Kettle River
Brooks Rd
Evans
Uncle Sam Mountain
Stevens County
Gillette Mountain
Rabbit Mountain
Columbia River
Marcus
Peterson Swamp Rd
Echo
Lehigh Ave
Sand Creek Mountain
Legend
City/Town
Major Dam
OU 3 Study Area
County Boundaries
Modeled Zinc Concentration > Ecological RBC (111 mg/kg)
Samples Used in Geostatistical Model
Nondetected Value
Analyte Concentration > Ecological RBC
Analyte Concentration ≤ Ecological RBC
Geostatistical Model Boundary
Pre-1973 Flood Extent Maximum Flow
Zinc Concentration > Ecological RBC (Mine and Mill Sample)
Zinc Concentration ≤ Ecological RBC (Mine and Mill Sample)
Mine and Mill Samples
Analyte Exeedance
Zinc Exeedance
Note: Copper Ecological RBC = 41.5 mg/kg
1 Miles
0 1.5 3 6 Miles
N
ERM
Environmental Resources Management
www.erm.com
Map 6-26. Copper Ecological RBC Exceedances
Final Upland RI Report
Upper Columbia River, Washington
Source: Esri - World Topoographic Map; NAD 1983 UTM Zone 11N
DRAWN BY: GIS
REVISED: 08/15/2025
FILE: M:\US\Projects\S-U\Teck\0493466 Teck Upper Columbia River\Maps\Upland RI\ProProject\Section 6\UCR_Section6\RBC Exceedances\Section 6


Castlegar
Greenwood
Grand Forks
Trail
Main Map Extent
Colville National Forest
0 15 30 60 Miles
U.S. - Canada Border
Waneta Dam
Pend Oreille River
Deadman's Eddy
Northport
Marble
China Bend
Bossburg
Evans
Brooks Rd
Peterson Swamp Rd
Marcus
Columbia River
Kettle River
Jumbo Mountain
Thompson Ridge
Ferry County
Kelly Hill
Bodie Mountain
Stoddard Mountain
Lime Creek Mountain
Uncle Sam Mountain
Stevens County
Gibbs Mountain
Rabbit Mountain
Bon Ay Ridge
Onion Creek
Anderson Calhoun Mine/Mill Area
Van Stone Mine/Mill Area
Sierra Zinc Mine/Mill Area
Pend Oreille County
Sand Creek Mountain
Lehigh Ave
Lozee Creek Rd
Van Stone Mine Rd
4339 ft
5777 ft
6379 ft
7309 ft
1 Miles
Legend
City/Town
Major Dam
OU 3 Study Area
County Boundaries
Modeled Zinc Concentration > Ecological RBC (111 mg/kg)
Samples Used in Geostatistical Model
Nondetected Value
Analyte Concentration > Ecological RBC
Analyte Concentration ≤ Ecological RBC
Geostatistical Model Boundary
Pre-1973 Flood Extent Maximum Flow
Zinc Concentration > Ecological RBC (Mine and Mill Sample)
Zinc Concentration ≤ Ecological RBC (Mine and Mill Sample)
Mine and Mill Samples
Analyte Exeedance
Zinc Exeedance
Note: Manganese Ecological RBC = 1240 mg/kg
ERM
Environmental Resources Management
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0 1.5 3 6 Miles
N
Map 6-27. Manganese Ecological RBC Exceedances
Final Upland RI Report
Upper Columbia River, Washington
DRAWN BY: GIS | REVISED: 08/15/2025
FILE: M:\US\Projects\S-U\Teck\0493466 Teck Upper Columbia River\Maps\Upland RI\ProProject\Section 6\UCR_Section6\RBC Exceedances\Section 6 RBC Exceedances 21-29.aprx
Source: Esri - World Topoographic Map; NAD 1983 UTM Zone 11N


Castlegar
Greenwood
Grand Forks
Trail
Main Map Extent
Coville National Forest
0 15 30 60 Miles
U.S. - Canada Border
Waneta Dam
Pend Oreille River
5053 ft
Deadman's Eddy
Northport
Aftercrombie Mountain
Pend Oreille River
Jumbo Mountain
Bodie Mountain
Stoddard Mountain
Lime Creek Mountain
Anderson Calhoun Mine/Mill Area
6379 ft
Pend Oreille County
Lehigh Ave
Marble
China Bend
Onion Creek
4339 ft
Van Stone Mine/Mill Area
Sierra Zinc Mine/Mill Area
5777 ft
Sand Creek Mountain
Thompson Ridge
Ferry County
Bossburg
Kelly Hill
Brooks Rd
Evans
Uncle Sam Mountain
Kettle River
Stevens County
Gillette Mountain
Rabbit Mountain
Bon Ay Ridge
Columbia River
Marcus
Peterson Swamp Rd
Echo
Van Stone Mine Rd
1 Miles
Legend
City/Town
Major Dam
OU 3 Study Area
County Boundaries
Modeled Zinc Concentration > Ecological RBC (111 mg/kg)
Samples Used in Geostatistical Model
Nondetected Value
Analyte Concentration > Ecological RBC
Analyte Concentration ≤ Ecological RBC
Geostatistical Model Boundary
Pre-1973 Flood Extent Maximum Flow
Zinc Concentration > Ecological RBC (Mine and Mill Sample)
Zinc Concentration ≤ Ecological RBC (Mine and Mill Sample)
Mine and Mill Samples
Analyte Exeedance
Zinc Exeedance
Note: Mercury Ecological RBC = 0.12 mg/kg
ERM
Environmental Resources Management
www.erm.com
0 1.5 3 6 Miles
N
Map 6-28. Mercury Ecological RBC Exceedances
Final Upland RI Report
Upper Columbia River, Washington
Source: Esri - World Topoographic Map; NAD 1983 UTM Zone 11N
DRAWN BY: GIS
REVISED: 08/15/2025
FILE: M:\US\Projects\S-U\Teck\0493466 Teck Upper Columbia River\Maps\Upland RI\ProProject\Section 6\UCR_Section6\RBC Exceedances\Section 6 RBC Exceedances 21-29.aprx



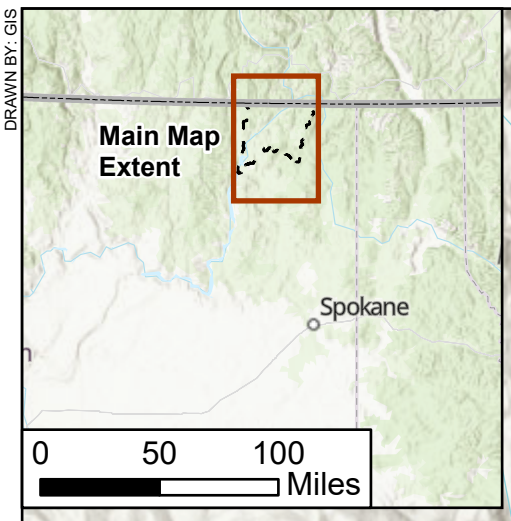
Map 6-29. **Selenium Ecological RBC Exceedances**
Final Upland RI Report
Upper Columbia River, Washington

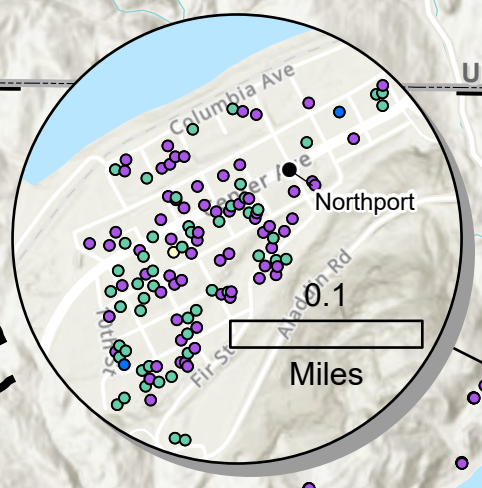
Source: Esri - World Topoographic Map; NAD 1983 UTM Zone 11N

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2361 m
1942 m
3B
22
Trail
3B
Columbia River
1646 m
Pend Oreille River
U.S. - Canada Border
Waneta Dam
5053 ft
25
Boundary Hwy
Northport
Deadman's Eddy
Anderson Calhoun Mine/Mill Area
Abercrombie Mountain
Jumbo Mountain
Bodie Mountain
Stoddard Mountain
Lime Creek Mountain
5379 ft
Marble
Columbia River
25
China Bend
4339 ft
Van Stone Mine/Mill Area
Stevens County
Bossburg
Onion Creek
Sierra Zinc Mine/Mill Area
5777 ft
Brooks Rd
Uncle Sam Mountain
Kelly Hill
Kettle River
Evans
Aladdin Mountain
Pend Oreille County
Peterson Swamp Rd
Ferry County
Gillette Mountain
Rabbit Mountain
Bon Ayre Ridge
Marcus
Echo Valley
Old Douglas
Green Mountain
Gold Hill
Kettle Falls
395
Colville Mountain
Colville River
Colville
20
20
Mingo
6009 ft
6853 ft
Cliff Ridge

Legend

- City/Town
- Major Dam
- OU 3 Study Area
- County Boundaries

Lead Surface-to-Subsurface Soil Concentration Ratio

- < 0.5
- 0.5–1.0
- 1.0–2.0
- > 2.0

Notes:
> 1 indicates the surface concentration is greater than the subsurface concentration.

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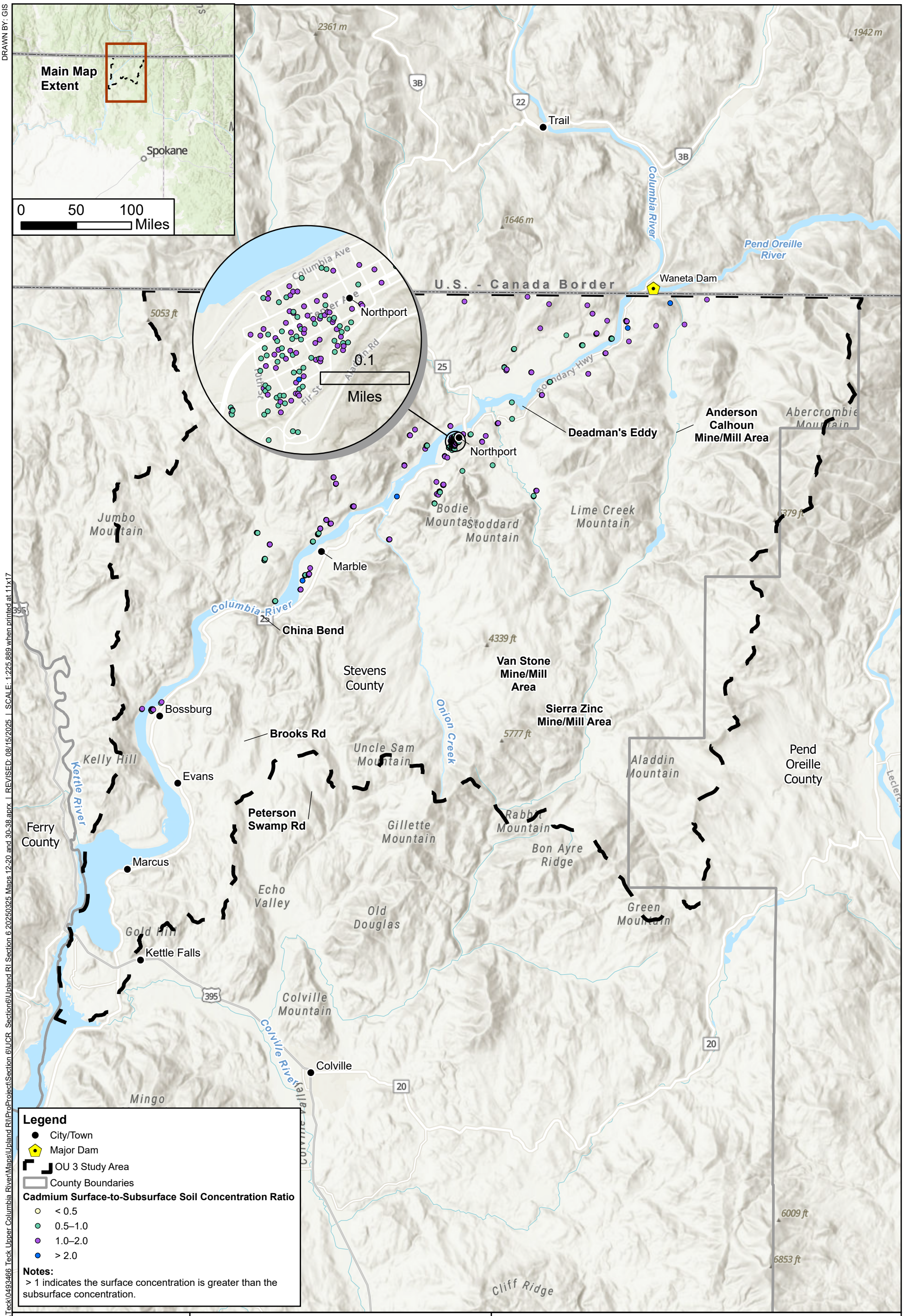
0 1.5 3 6
Miles

N

Map 6-30. **Lead Surface-to-Subsurface Soil Concentration Ratios**
Final Upland RI Report
Upper Columbia River, Washington

Source: Esri - World Topographic Map; NAD 1983 UTM Zone 11N

FILE: M:\US\Projects\S-U\Teck\0493466 Teck Upper Columbia River\Maps\Upland RI\ProProject\Section 6\UCR_Section6\Upland RI Section 6 20250325 Maps 12-20 and 30-38.aprx | REVISED: 08/15/2025 | SCALE: 1:225,889 when printed at 11x17



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0 1.5 3 6 Miles

N

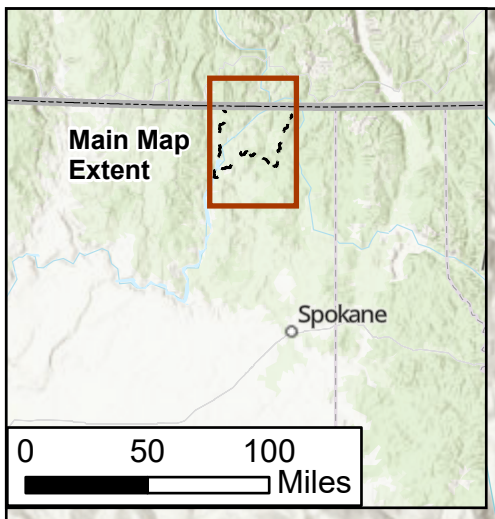
Map 6-31. **Cadmium Surface-to-Subsurface Soil Concentration Ratios**
Final Upland RI Report
Upper Columbia River, Washington

Source: Esri - World Topographic Map; NAD 1983 UTM Zone 11N

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FILE: M:\US\Projects\S-U\Teck\0493466 Teck Upper Columbia River\Maps\Upland RI\ProProject\Section 6\UCR_Section6\Upland RI Section 6 20250325 Maps 12-20 and 30-38.aprx | REVISED: 08/15/2025 | SCALE: 1:225,889 when printed at 11x17

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2361 m
1942 m
3B
22
Trail
3B
Columbia River
1646 m
Pend Oreille River
U.S. - Canada Border
Waneta Dam
5053 ft
25
Boundary Hwy
Deadman's Eddy
Anderson Calhoun Mine/Mill Area
Abercrombie Mountain
Northport
Jumbo Mountain
Bodie Mountain
Stoddard Mountain
Lime Creek Mountain
5379 ft
Marble
Columbia River
25
China Bend
4339 ft
Van Stone Mine/Mill Area
Stevens County
Bossburg
Brooks Rd
Onion Creek
Sierra Zinc Mine/Mill Area
5777 ft
Kelly Hill
Uncle Sam Mountain
Aladdin Mountain
Pend Oreille County
Kettle River
Evans
Peterson Swamp Rd
Ferry County
Gillette Mountain
Rabbit Mountain
Bon Ayre Ridge
Marcus
Echo Valley
Old Douglas
Green Mountain
Gold Hill
Kettle Falls
395
Colville Mountain
Colville River
Colville
20
20
Mingo
6009 ft
6853 ft
Cliff Ridge

Legend

- City/Town
- Major Dam
- OU 3 Study Area
- County Boundaries

Zinc Surface-to-Subsurface Soil Concentration Ratio

- < 0.5
- 0.5–1.0
- 1.0–2.0
- > 2.0

Notes:
> 1 indicates the surface concentration is greater than the subsurface concentration.

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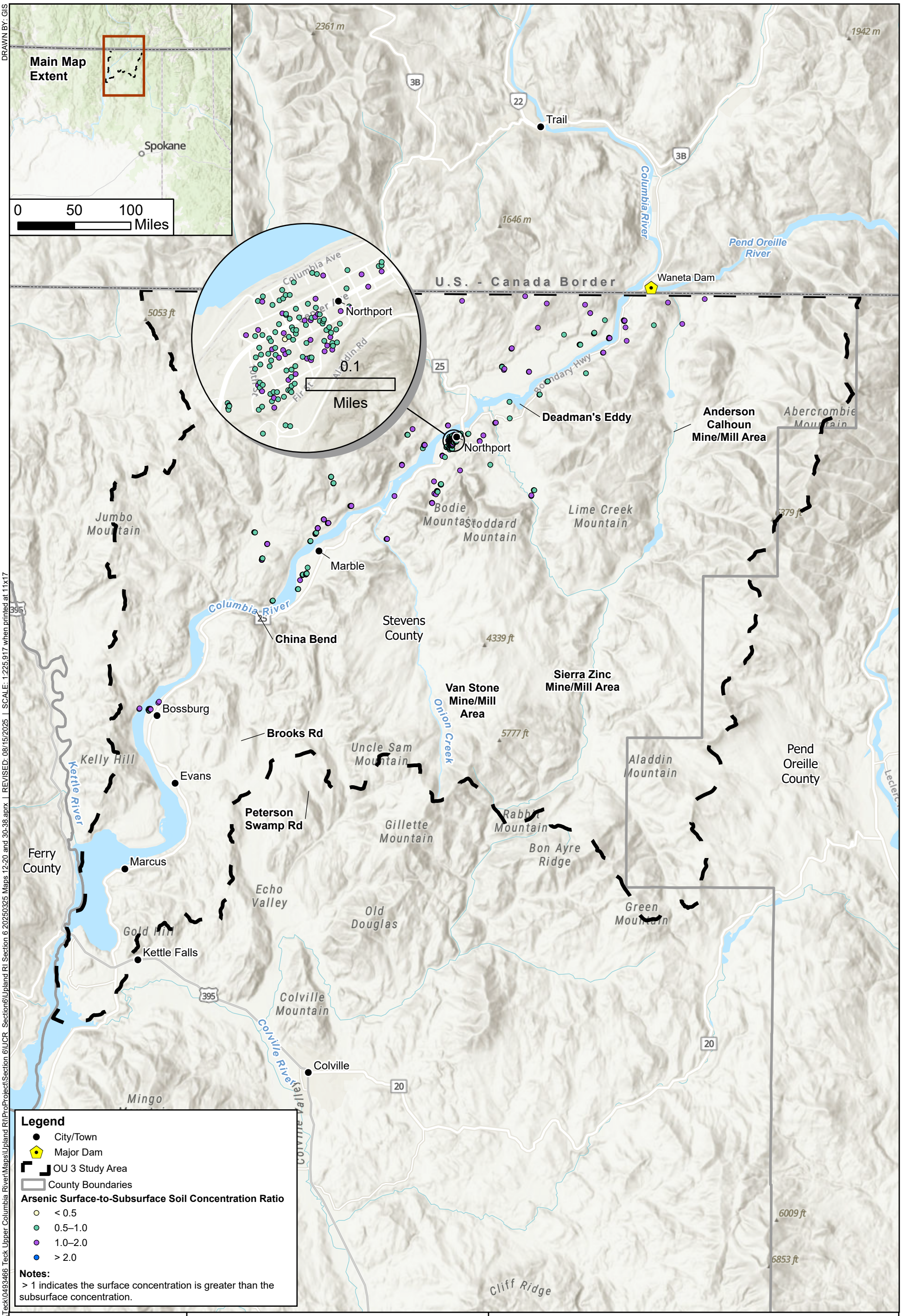
0 1.5 3 6
Miles

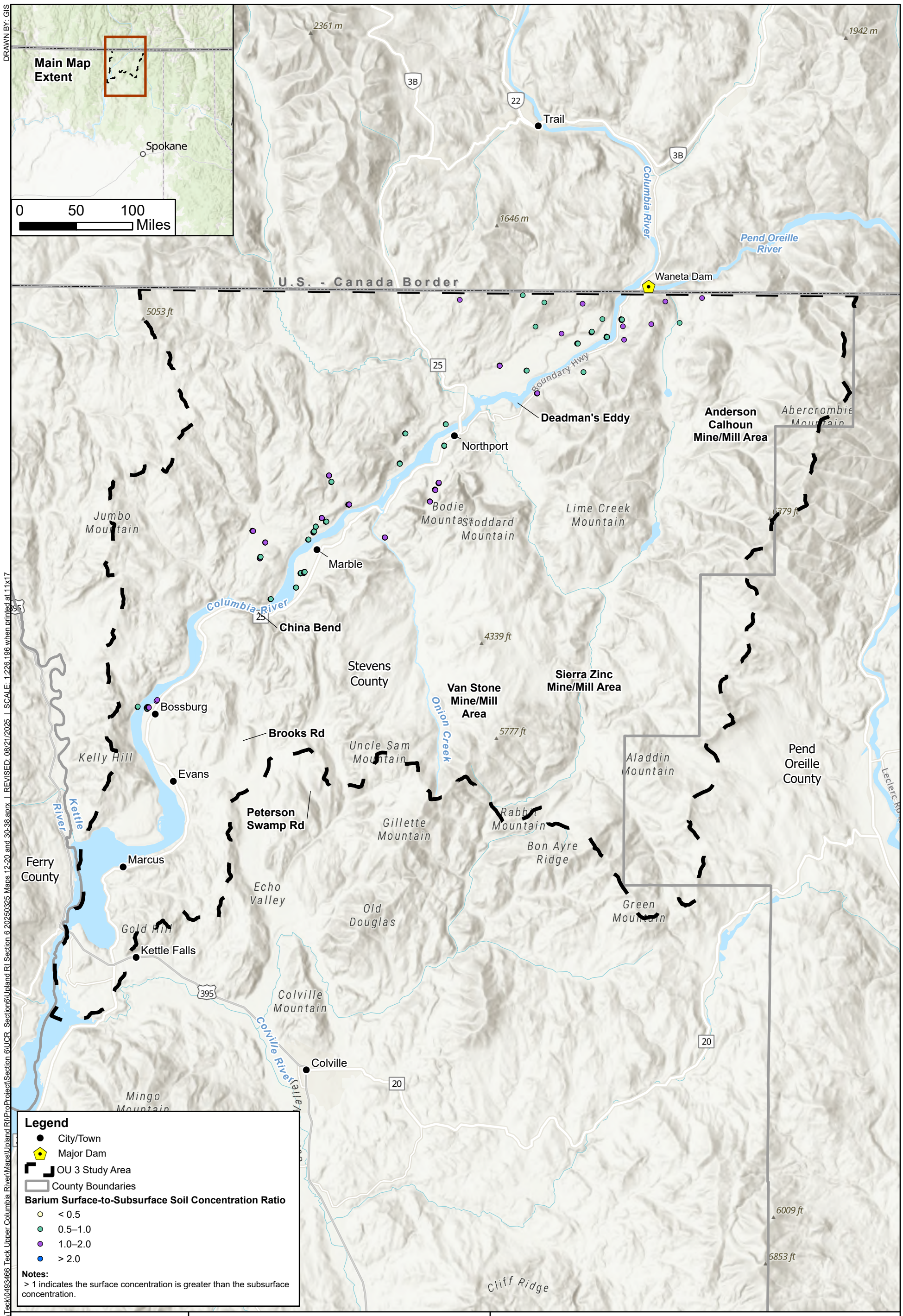
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Map 6-32. **Zinc Surface-to-Subsurface Soil Concentration Ratios**
Final Upland RI Report
Upper Columbia River, Washington

Source: Esri - World Topographic Map; NAD 1983 UTM Zone 11N

FILE: M:\US\Projects\S-U\Teck\0493466 Teck Upper Columbia River\Maps\Upland RI\ProProject\Section 6\UCR_Section6\Upland RI Section 6 20250325 Maps 12-20 and 30-38.aprx | REVISED: 08/15/2025 | SCALE: 1:226,196 when printed at 11x17


Main Map Extent
Spokane
0 50 100 Miles
Trail
3B
22
Columbia River
Pend Oreille River
U.S. - Canada Border
Waneta Dam
2361 m
1942 m
1646 m
5053 ft
Northport
Columbia Ave
Alladin Rd
First St
0.1 Miles
25
Boundary Hwy
Deadman's Eddy
Anderson Calhoun Mine/Mill Area
Abercrombie Mountain
Jumbo Mountain
Bodie Mountain
Stoddard Mountain
Lime Creek Mountain
5379 ft
Marble
Columbia River
China Bend
Stevens County
4339 ft
Sierra Zinc Mine/Mill Area
Van Stone Mine/Mill Area
Onion Creek
Bossburg
Brooks Rd
5777 ft
Uncle Sam Mountain
Aladdin Mountain
Pend Oreille County
Kelly Hill
Kettle River
Evans
Peterson Swamp Rd
Gillette Mountain
Rabbit Mountain
Bon Ayre Ridge
Ferry County
Marcus
Echo Valley
Old Douglas
Green Mountain
Gold Hill
Kettle Falls
395
Colville Mountain
Colville River
Colville
20
Mingo
6009 ft
6853 ft
Cliff Ridge
Legend
City/Town
Major Dam
OU 3 Study Area
County Boundaries
Arsenic Surface-to-Subsurface Soil Concentration Ratio
< 0.5
0.5–1.0
1.0–2.0
> 2.0
Notes:
> 1 indicates the surface concentration is greater than the subsurface concentration.
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www.erm.com
0 1.5 3 6 Miles
N
Map 6-33. Arsenic Surface-to-Subsurface Soil Concentration Ratios
Final Upland RI Report
Upper Columbia River, Washington
Source: Esri - World Topographic Map; NAD 1983 UTM Zone 11N
DRAWN BY: GIS
FILE: M:\US\Projects\S-U\Teck\0493466 Teck Upper Columbia River\Maps\Upland RI\ProProject\Section 6\UCR_Section6\Upland RI Section 6 20250325 Maps 12-20 and 30-38.aprx | REVISED: 08/15/2025 | SCALE: 1:225,917 when printed at 11x17



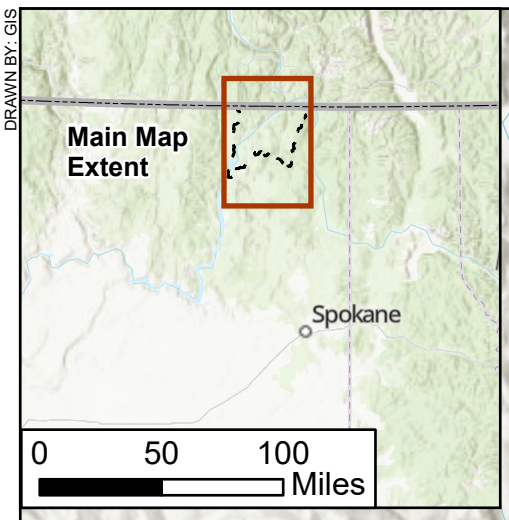
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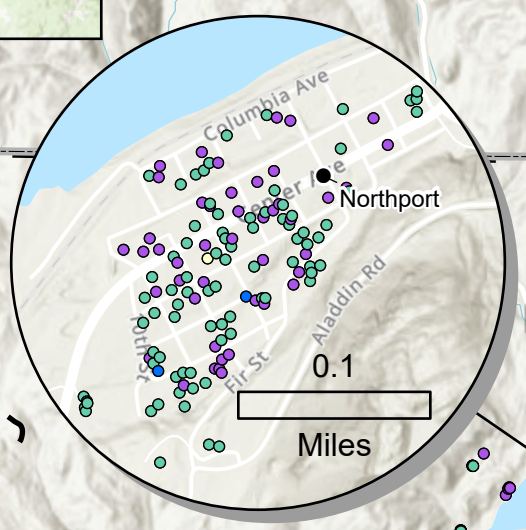
Map 6-34. **Barium Surface-to-Subsurface Soil Concentration Ratios**
Final Upland RI Report
Upper Columbia River, Washington

Source: Esri - World Topographic Map; NAD 1983 UTM Zone 11N

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FILE: M:\US\Projects\S-U\Teck\0493466 Teck Upper Columbia River\Maps\Upland RI\ProProject\Section 6\UCR_Section6\Upland RI Section 6 20250325 Maps 12-20 and 30-38.aprx | REVISED: 08/21/2025 | SCALE: 1:226,196 when printed at 11x17

DRAWN BY: GIS





2361 m
1942 m
1646 m
5053 ft
4339 ft
5777 ft
6009 ft
5853 ft
3379 ft
3B
22
25
395
20
Trail
Columbia River
Pend Oreille River
U.S. - Canada Border
Waneta Dam
Boundary Hwy
Deadman's Eddy
Anderson Calhoun Mine/Mill Area
Abercrombie Mountain
Northport
Marble
China Bend
Bossburg
Evans
Brooks Rd
Peterson Swamp Rd
Marcus
Kettle Falls
Colville
Van Stone Mine/Mill Area
Sierra Zinc Mine/Mill Area
Stevens County
Pend Oreille County
Ferry County
Jumbo Mountain
Bodie Mountain
Stoddard Mountain
Lime Creek Mountain
Kelly Hill
Uncle Sam Mountain
Onion Creek
Aladdin Mountain
Gillette Mountain
Rabbit Mountain
Bon Ayre Ridge
Echo Valley
Old Douglas
Green Mountain
Colville Mountain
Colville River
Mingo Mountain
Cliff Ridge
Kettle River
Leclerc Rd

Legend

- City/Town
- Major Dam
- OU 3 Study Area
- County Boundaries

Copper Surface-to-Subsurface Soil Concentration Ratio

- < 0.5
- 0.5–1.0
- 1.0–2.0
- > 2.0

Notes:
> 1 indicates the surface concentration is greater than the subsurface concentration.

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0 1.5 3 6 Miles

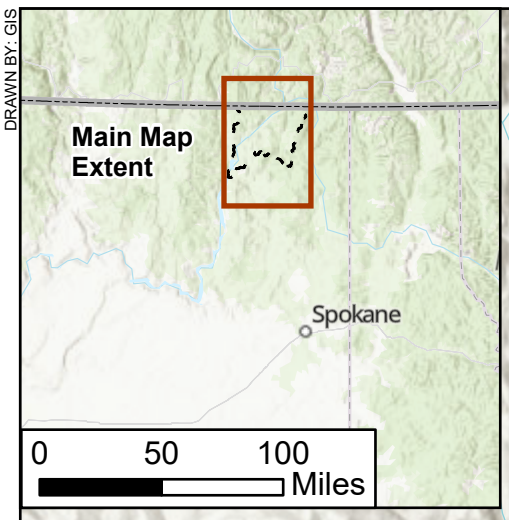
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Map 6-35. **Copper Surface-to-Subsurface Soil Concentration Ratios**
Final Upland RI Report
Upper Columbia River, Washington

Source: Esri - World Topographic Map; NAD 1983 UTM Zone 11N

FILE: M:\US\Projects\S-UT\eck\0493466 Teck Upper Columbia River\Maps\Upland RI\ProProject\Section 6\UCR_Section6\Upland RI Section 6 20250325 Maps 12-20 and 30-38.aprx | REVISED: 08/15/2025 | SCALE: 1:226,196 when printed at 11x17

DRAWN BY: GIS



2361 m
1942 m
3B
22
Trail
3B
Columbia River
1646 m
Pend Oreille River
U.S. - Canada Border
Waneta Dam
5053 ft
25
Boundary Hwy
Deadman's Eddy
Anderson Calhoun Mine/Mill Area
Abercrombie Mountain
Northport
Jumbo Mountain
Bodie Mountain
Stoddard Mountain
Lime Creek Mountain
3379 ft
Marble
Columbia River
25
China Bend
Stevens County
4339 ft
Sierra Zinc Mine/Mill Area
Van Stone Mine/Mill Area
Onion Creek
Bossburg
Brooks Rd
5777 ft
Uncle Sam Mountain
Aladdin Mountain
Pend Oreille County
Kelly Hill
Evans
Kettle River
Peterson Swamp Rd
Gillette Mountain
Rabbit Mountain
Bon Ayre Ridge
Marcus
Ferry County
Echo Valley
Old Douglas
Green Mountain
Gold Hill
Kettle Falls
395
Colville Mountain
Colville River Valley
Colville
20
20
Mingo Mountain
6009 ft
5853 ft
Cliff Ridge

Legend

- City/Town
- Major Dam
- OU 3 Study Area
- County Boundaries

Manganese Surface-to-Subsurface Soil Concentration Ratio

- < 0.5
- 0.5–1.0
- 1.0–2.0
- > 2.0

Notes:
> 1 indicates the surface concentration is greater than the subsurface concentration.

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0 1.5 3 6 Miles

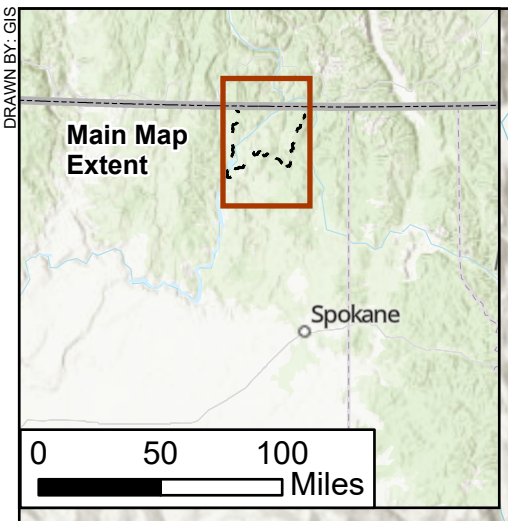
N

Map 6-36. **Manganese Surface-to-Subsurface Soil Concentration Ratios**
Final Upland RI Report
Upper Columbia River, Washington

Source: Esri - World Topographic Map; NAD 1983 UTM Zone 11N

FILE: M:\US\Projects\S-UT\eck\0493466 Teck Upper Columbia River\Maps\Upland RI\ProProject\Section 6\UCR_Section6\Upland RI Section 6 20250325 Maps 12-20 and 30-38.aprx | REVISED: 08/15/2025 | SCALE: 1:226,196 when printed at 11x17

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U.S. - Canada Border

Trail
Waneta Dam
Columbia River
Pend Oreille River
Northport
Deadman's Eddy
Anderson Calhoun Mine/Mill Area
Marble
China Bend
Bossburg
Brooks Rd
Evans
Peterson Swamp Rd
Marcus
Kettle Falls
Colville
Van Stone Mine/Mill Area
Sierra Zinc Mine/Mill Area
Stevens County
Pend Oreille County
Ferry County
Boundary Hwy
Onion Creek
Colville River
Kettle River
Columbia River

2361 m
1942 m
1646 m
5053 ft
4339 ft
5777 ft
6009 ft
5853 ft

Jumbo Mountain
Bodie Mountain
Stoddard Mountain
Lime Creek Mountain
Kelly Hill
Uncle Sam Mountain
Gillette Mountain
Rabbit Mountain
Bon Ayre Ridge
Aladdin Mountain
Abercrombie Mountain
Echo Valley
Old Douglas
Gold Hill
Green Mountain
Colville Mountain
Mingo Mountain
Cliff Ridge

3B
22
25
20
395

Legend

- City/Town
- Major Dam
- OU 3 Study Area
- County Boundaries

Mercury Surface-to-Subsurface Soil Concentration Ratio

- < 0.5
- 0.5–1.0
- 1.0–2.0
- > 2.0

Notes:
> 1 indicates the surface concentration is greater than the subsurface concentration.

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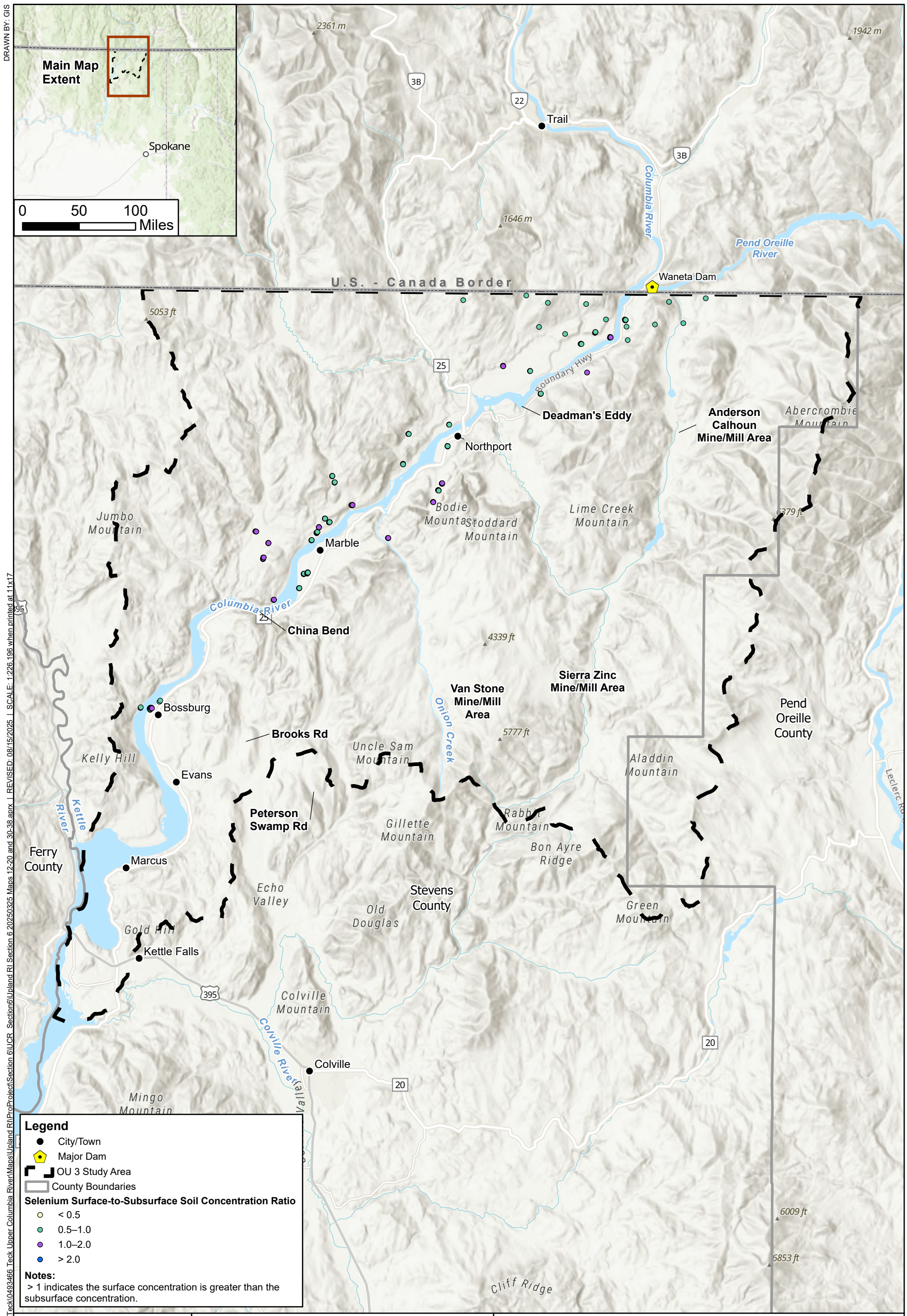
0 1.5 3 6 Miles

N

Map 6-37. **Mercury Surface-to-Subsurface Soil Concentration Ratios**
Final Upland RI Report
Upper Columbia River, Washington

Source: Esri - World Topographic Map; NAD 1983 UTM Zone 11N

FILE: M:\US\Projects\S-UT\eck\0493466 Teck Upper Columbia River\Maps\Upland RI\ProProject\Section 6\UCR_Section6\Upland RI Section 6 20250325 Maps 12-20 and 30-38.aprx | REVISED: 08/15/2025 | SCALE: 1:226,196 when printed at 11x17


Main Map Extent
Spokane
0 50 100 Miles
2361 m
1942 m
3B
22
Trail
3B
Columbia River
1646 m
Pend Oreille River
U.S. - Canada Border
Waneta Dam
5053 ft
25
Boundary Hwy
Deadman's Eddy
Anderson Calhoun Mine/Mill Area
Abercrombie Mountain
Northport
Jumbo Mountain
Bodie Mountain
Stoddard Mountain
Lime Creek Mountain
3379 ft
Marble
Columbia River
25
China Bend
4339 ft
Sierra Zinc Mine/Mill Area
Van Stone Mine/Mill Area
Onion Creek
Bossburg
Brooks Rd
5777 ft
Pend Oreille County
Uncle Sam Mountain
Aladdin Mountain
Kelly Hill
Evans
Kettle River
Peterson Swamp Rd
Gillette Mountain
Rabbit Mountain
Bon Ayre Ridge
Ferry County
Marcus
Echo Valley
Stevens County
Old Douglas
Green Mountain
Gold Hill
Kettle Falls
395
Colville Mountain
Colville River
Colville
20
20
Mingo Mountain
6009 ft
5853 ft
Cliff Ridge
Legend
City/Town
Major Dam
OU 3 Study Area
County Boundaries
Selenium Surface-to-Subsurface Soil Concentration Ratio
< 0.5
0.5–1.0
1.0–2.0
> 2.0
Notes:
> 1 indicates the surface concentration is greater than the subsurface concentration.
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www.erm.com
0 1.5 3 6 Miles
N
Map 6-38. Selenium Surface-to-Subsurface Soil Concentration Ratios
Final Upland RI Report
Upper Columbia River, Washington
Source: Esri - World Topographic Map; NAD 1983 UTM Zone 11N
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TABLES

Table 1-1. Document Titles and Abbreviated Study Names Used in the Upland RI Report

Document Title	Abbreviated Study Name for Upland RI Report	Report Citation
Upper Columbia River Final Soil Study Data Summary Report	2014 Soil Study	TAI (2015a)
Upper Columbia River Upland Soil Sampling Study, Stevens County, Washington	2012 Ecology Upland Soil Study	Ecology (2013a)
UCR Residential Soil Study Field Sampling and Data Summary Report	2014 Residential Soil Study	USEPA (2016a)
Action Memorandum for the Upper Columbia River Site Residential Properties Soil Removal near Northport, Stevens County, Washington	2015 TCRA Memorandum	USEPA (2015b)
Time-Critical Removal Action Final Completion Report	2015 TCRA	TAI (2016b)
Upper Columbia River Final Residential Soil Study Data Summary Report	2016 Residential Soil Study	TAI (2017a)
Voluntary Removal Action Final Completion Report Northport, Washington	2017–2018 VRA	TAI (2019a)
Final Soil Amendment Technology Evaluation Study Phase IA Test Plot Selection and Characterization Data Summary Report	2017 SATES Test Plot Characterization	TAI (2019b)
Upper Columbia River Final Plant Tissue Study Data Summary Report	2018 Plant Tissue Study	TAI (2019c)
Inactive and Abandoned Mine Lands (IAML) — Young America Mine, Bossburg Mining District, Stevens County, Washington	WDNR Young America Mine Site Characterization	WDNR (2008)
Young America Mine Removal Assessment Trip Report Evans, Stevens County, Washington	2011 EPA Young America Mine Removal Assessment	USEPA (2012a)
Final Bossburg Flat Beach Refined Sediment and Soil Study Data Summary Report	2015 Bossburg Study	TAI (2016c)
Preliminary Assessments and Site Inspections Report, Upper Columbia River Mines and Mills, Stevens County, Washington	2001 EPA Stevens County Mines and Mills PA/SI	USEPA (2002a)
Le Roi Smelter Removal Action Report, Northport, Stevens County, Washington	2004 EPA Le Roi Smelter Removal Action	USEPA (2005)
Van Stone Mine Remedial Investigation	2011–2012 Ecology Van Stone RI	Ecology (2013b)
Feasibility Study, Van Stone Mine, Onion Creek, Washington	2014–2015 Ecology Van Stone FS	Ecology (2017a)
Engineering Evaluation/Cost Analysis Anderson Calhoun Work Group. Anderson Calhoun Mine. Colville, Washington.	2003–2004 EPA Anderson Calhoun EE/CA	USEPA (2007a)
Soil Remediation, Boundary Land Port of Entry, Stevens County, Washington	2011 Port of Entry Soil Remediation	Shannon and Wilson (2011)
Voluntary Cleanup Report, Brooks Road/Bonanza Mine Roadbed Materials, Stevens County, Washington	2007 Brooks Road/Bonanza Mine Roadbed Voluntary Cleanup	SCDPW (2008a)
Voluntary Cleanup Report, Peterson Swamp/Bonanza Mine Roadbed Materials, Stevens County, Washington	2007 Peterson Swamp/Bonanza Mine Roadbed Voluntary Cleanup	SCDPW (2008b)
Heavy Metal Contamination in Soil and Lichen Tissue in the Colville National Forest, Washington, USA	Wells Lichen Study	Wells (2015)
Geochemical and Mineralogical Data for Soils of the Conterminous United States	2007–2010 USGS Soil Study	USGS (2013)
Natural Background Soil Metals Concentrations in Washington State	Ecology Natural Background Soil Study	Ecology (1994)
National Uranium Resource Evaluation (NURE) Hydrogeochemical and Stream Sediment Reconnaissance (HSSR) data	USGS Reformatted NURE-HSSR Program	USGS (2006)
Determination of Premining Geochemical Background and Delineation of Extent of Sediment Contamination in Blue Creek Downstream from Midnite Mine, Stevens County, Washington	USGS Midnite Mine Sediment Study	USGS (2008a)
The National Geochemical Survey—Database and Documentation: Version 5.0. USGS Open-file Report 2004-1001	USGS NURE Sample Reanalysis	USGS (2008b)
Terrestrial Ecological Risk Assessment for the Teck Metals Ltd. Smelter at Trail, BC	Trail Smelter Terrestrial ERA	Teck Metals Ltd. (2011)

Table 1-1. Document Titles and Abbreviated Study Names Used in the Upland RI Report

Document Title	Abbreviated Study Name for Upland RI Report	Report Citation
Preliminary Assessment of Background Concentrations of Elements in Soil from the Trail Area	2001 Trail Area Soil Background Assessment	Goodarzi et al. (2001)
Waneta Hydroelectric Expansion Project Investigation of Proposed Worksites for Contamination and Remedial Measures	2005 Waneta Expansion Project	WEPC (2005)
Accumulation of Trace Elements on the Surface Soil Around the Trail Smelter, British Columbia, Canada	2001 Trail Area Moss Bag Study	Goodarzi et al. (2002)
Final Human Health Risk Assessment: Upper Columbia River Site	HHRA	USEPA (2021)
Upper Columbia River Work Plan for the Remedial Investigation and Feasibility Study (RI/FS)	RI/FS Work Plan	USEPA (2008a)
Letter to Denise Mills, TAI, dated July 25, 2022, from Bonnie Arthur, EPA Remedial Project Manger, Re: Schedule Addendum to the Upper Columbia River "Workplan for the Remedial Investigation and Feasibility Study," dated December 2008	RI/FS Schedule Addendum	USEPA (2022a)
Baseline Ecological Risk Assessment for Upland Terrestrial Habitat	Upland BERA	USEPA (2023a)
Feasibility Study for OU 3	Upland FS	TAI (to be prepared)
Baseline Ecological Risk Assessment for OU 1 and OU 2	Aquatic BERA	TAI (2024b)
Draft Remedial Investigation Report for OU 1 and OU 2	Aquatic RI	TAI (to be prepared)

Notes:

BERA - Baseline Ecological Risk Assessment
Ecology - Washington State Department of Ecology
EE/CA - engineering evaluation/cost analysis
ERA - ecological risk assessment
FS - feasibility study
HHRA - Final Human Health Risk Assessment: Upper Columbia River Site (USEPA 2021)
PA/SI - preliminary assessment and site inspection
RI - remedial investigation
SATES - Soil Amendment Technology Evaluation Study
TCRA - time-critical removal action
USGS - U.S. Geological Survey
VRA - voluntary removal action
WDNR - Washington State Department of Natural Resources
WEPC - Waneta Expansion Power Corporation

Table 2-1. Demographics of Larger Localities in the UCR Region

Locality	Population	Number of Households	Number of Families	Median Age (Years)	Percent Under 18 Years Old
Colville	4,917	2,074	1,177	42.5	22.0
Northport	297	135	54	50.3	18.3
Marcus	216	76	53	53.5	17.1
Kettle Falls	1,636	740	372	44.0	23.4
Colville Reservation and Off-Reservation Trust Land	7,259	3,489	NR	41.7	19.5
Spokane Reservation and Off-Reservation Trust Land	1,884	834	NR	39.5	33.2
Ferry County	7,178	2,934	1,824	50.8	17.5
Lincoln County	10,876	4,440	3,012	47.1	22.1
Stevens County	46,445	18,222	12,370	46.7	21.5

Notes:

Demographics information is from the 2020 Decennial Census (U.S. Census Bureau 2025a) for nontribal localities and from the 2023 American Community Survey Estimates (U.S. Census Bureau 2025b) for the Colville and Spokane Reservations and Off-Reservation Trust Lands.

NR - not reported

Table 2-2. Federal- and State-Listed Species Potentially Occurring in the BERA Terrestrial Study Area

Scientific Name	Common Name	Federal Status	State Status
Mammals			
Canis lupus	gray wolf	FE delisted [a]	SE
Plants			
Pellaea gastonyi	Gastony's cliffbrake [b]	not listed	SE

Sources: TAI (2012); USFWS (2020); WDFW (2022); WDNR (2022); WNHP (2018)

Notes:

[a] The gray wolf was delisted in eastern Washington in February 2022 including throughout the UCR Site (USFWS 2023).

[b] Gastony's cliffbrake is not evaluated in the Upland BERA due to minimal exposure to soil.

FE - federal endangered

SE - state endangered

Table 2-3. Smelters in Southern British Columbia and Northeastern Washington

Smelter Location	Period of Operations	Primary Metal(s) Produced	Location of Major Suppliers of Ore [a]	Source
Trail, British Columbia	1896–1898	copper	Rossland (British Columbia)	Queneau (2010)
	1899–1915	copper, lead	Phoenix and Sullivan (British Columbia)	Queneau (2010)
	1916–1922	copper, lead, zinc	Sullivan (British Columbia)	Queneau (2010)
	1923–2025	lead, zinc	Sullivan and Pine Point (British Columbia); Red Dog (Alaska)	Queneau (2010)
Grand Forks, British Columbia	1900–1919	copper, silver, gold	Phoenix (British Columbia); Republic (Washington)	Quivik (2010)
Greenwood, British Columbia	1902–1918	copper, silver, gold	Mother Lode and Boundary Creek (British Columbia)	Quivik (2010)
Nelson, British Columbia	1895–1908	copper, silver	Silver King (British Columbia)	Lamb (2023)
Northport, Washington	1898–1909	copper	Le Roi (British Columbia)	Quivik (2010)
	1916–1921	lead	Coeur d'Alene (Idaho)	Quivik (2010)
Colville, Washington	1888–1891 (approximate)	lead, silver	Old Dominion, Daisy, Bonanza, and Young America (Washington)	Quivik (2010)

Note:

[a] Major sources of ore were used during these periods but may not have been used for the whole period.

Table 2-4. Operational History of the Trail Facility

Year	Milestone
1895 to 1896	Fritz August Heinze builds the copper smelter and founded the British Columbia Smelting & Refining Company. The initial operations rely on a heap roasting method, which involves burning wood with ore and limestone. Mechanical roasters are then used after 1 year of heap roasting. By 1896, there are four reverberatory furnaces and one blast furnace in operation at the facility and a 135-ft smokestack for the copper smelter.
1898	The facility is sold to the Canadian Pacific Railroad, which renames it the Canadian Smelting Works and begins to modernize the facility. By the end of 1898, three 600-ton-per-day blast furnaces and 48 enclosed roasters are present onsite. Fuel is typically wood, coal, and coke.
1899 to 1901	The Trail Facility begins roasting and smelting lead sulfide ores and concentrates and constructs a 175-ft smokestack for the lead smelter.
1902	The world's first electrolytic lead plant is commissioned at the Trail Facility. Prior to 1902, bullion was transported to the American Smelting and Refining Company's plant in Tacoma, Washington, for processing.
1906	Canadian Smelting Works is renamed Consolidated Mining and Smelting Company of Canada after consolidating surrounding area mines with the smelting facility.
1907	Two lead blast furnaces are in operation at the Trail Facility.
1908	Roasting is carried out in Wedge multiple-hearth furnaces, and hand-rabbled roasting furnaces have been replaced by eight circular roasters and 24 pot calciners.
1910	The first Dwight & Lloyd unit is brought online for continuous sintering of copper concentrates and displacing roasting and earlier methods of thermal agglomeration.
1914	Hot Cottrell electrostatic precipitators are installed to handle furnace off-gas and the 175-ft lead stack is replaced with a 250-ft lead stack. Prior to this, smoke from the furnaces was cooled and passed through flues and dust settling chambers that fed a chimney.
1916	The roast-leach-electrolytic zinc and electrolytic copper refineries come online, along with a 200-ft zinc stack. Two acid plants come online.
1917	Wedge roasters and pot calciners are eliminated when the Trail Facility begins using two stages of Dwight & Lloyd sintering to prepare blast furnace feed.
1922	The 135-ft copper stack is decommissioned.
1924	The 200-ft zinc stack is replaced with a 400-ft zinc stack.
1926	The 400-ft lead sinter stack is constructed and operational.
1927	Cadmium recovery efforts begin.
1929	A third acid plant comes online.
1930	Slag fuming plant is under construction, and baghouses are installed for the slag fuming process, which includes two 80-ft stacks. The copper smelting process ceases, and the construction of 65-acre fertilizer production facility begins.
1931	Three additional acid plants come online. Operations now include manufacturing of ammonium sulfate and ammonium phosphate fertilizer.
1936	Wedge multiple-hearth roasters are updated to suspension roasting method to maximize sulfuric acid output and ultimately reduce vented sulfur dioxide emissions.
1938	Two additional acid plants come online.
1930s/40s	Trail Smelter Arbitration addresses complaints from downwind American farmers.
1939	Baghouse(s) are installed at the silver refinery.

Table 2-4. Operational History of the Trail Facility

Year	Milestone
1951	Baghouse(s) are installed at the lead blast furnace smelting operation, which includes a 285-ft stack.
1955	Sinter-plant equipment is upgraded.
1962	Baghouse(s) are installed at the antimonial lead plant and zinc roasting operations, and the Trail Facility begins to add lead chloride to its sinter-plant feed.
1966	The Trail Facility operator is renamed Cominco.
1979	Major modernization of the Trail Facility begins, which includes installation of continuous drossing of the lead bullion, construction of a modern lead-smelter feed plant, modernization of the zinc plant, and upgrading of the roaster oxide leach plant. These improvements are made between 1979 and 1989.
1995	Discharge of water-granulated fumed slag to the Columbia River is discontinued.
1997	KIVCET smelter comes online, and the emissions from slag fuming furnace stacks and lead blast furnace stack significantly decline.
2000	Teck Cominco Ltd. is formed through a merger between Cominco and Teck Resources Limited. The Cominco portion of the name is removed in 2008.

Sources: Queneau (2010); Teck Resources Limited (2024); USEPA (2008a); Wilson (2023)

Note:

KIVCET - Russian acronym for flash-cyclone-oxygen-electric-smelting

Table 2-5. Trail Facility NPRI Air Release Summary

Metal or Particulate Category	NPRI Air Release Reporting Data Availability
Total particulate matter	2002–2023
Sulphur dioxide	2002–2023
Antimony (and its compounds)	1993–2023
Arsenic (and its compounds)	1993–2023
Cadmium (and its compounds)	1993–2023
Chromium (and its compounds)	2002–2023
Cobalt (and its compounds)	2002–2023
Copper (and its compounds)	1993–2023
Lead (and its compounds)	1993–2023
Manganese (and its compounds)	1993–2023
Mercury (and its compounds)	1993–2023
Selenium (and its compounds)	2009–2023
Silver (and its compounds)	1993–2023
Thallium (and its compounds)	2014–2023
Zinc (and its compounds)	1995–2023

Note:

NPRI - National Pollution Release Inventory

Table 2-6. Mines and Mills Evaluated During the 2001 EPA Stevens County Mines and Mills PA/SI

Facility Name	Dates Operated [a]	Source	Geologic Unit(s) Mined [a]	Source	Primary Commodity(ies) [a]	Source	Estimated Production Description [a]	Source	Cleanup Site ID [b]	Facility Site ID [b]	Site Status [b]
Anderson Calhoun Mine/Mill	1910 - 1980's	USEPA (2002a); USEPA (2007a); Ecology (2017b) Derkey et al. (1990); Mills (1977)	Metaline Formation	USEPA (2002a); Derkey et al. (1990); Mills (1977)	barium, lead, zinc	USEPA (2002a); Ecology (2017b); Derkey et al. (1990)	100,000 tons	USEPA (2002a); Derkey et al. (1990)	4519	8070626	No Further Action
Antelope Mine	1898–unknown	USEPA (2002a)	Rossland Group	Weaver (1920)	copper, gold	USEPA (2002a); Huntting (1956)	50 tons	USEPA (2002a); Huntting (1956); Derkey et al. (1990)	443	649154	No Further Action
Black Rock Mine/Mill	1920–1943	USEPA (2002a)	Metaline Formation	Derkey et al. (1990)	lead, zinc	USEPA (2002a); Huntting (1956)	5,280 tons in 1922–1924; 3,951 tons zinc; 70 tons lead	USEPA (2002a); Derkey et al. (1990); Mills (1977)	3939	3984735	Awaiting Cleanup
Copper King Mine	1904–1941	USEPA (2002a)	Wallace Formation, Metaline Formation	USEPA (2002a); Derkey et al. (1990)	copper, silver	USEPA (2002a)	na	na	1734	9171675	Awaiting Cleanup
Daisy Mine	1916–1935	USEPA (2002a)	Ledbetter Slate	Derkey et al. (1990); Mills (1977); Weaver (1920)	copper, gold, lead, silver	USEPA (2002a); Derkey et al. (1990)	2,000 tons prior to 1890, 1915, 1917, 1923, 1929, 1934–35 (50 tons concentrate)	Huntting (1956)	4543	2000536	Awaiting Cleanup
Deep Creek Mine	1944–1956	USEPA (2002a)	Metaline Formation	Derkey et al. (1990)	lead, silver, zinc	USEPA (2002a)	33,000 tons zinc; 7,500 tons lead; 18 tons silver; 12 tons copper	USEPA (2002a)	1969	7288890	Awaiting Cleanup
Electric Point Mine/Mill	1901–1955	USEPA (2002a); Huntting (1956)	Metaline Formation	Derkey et al. (1990); Mills (1977)	copper, lead, silver, zinc	USEPA (2002a)	15,355 tons lead; 5 tons zinc; 450 pounds silver	USEPA (2002a)	4523	8278162	Awaiting Cleanup
Farmer Mine	1937–1951	Derkey et al. (1990)	Metaline Formation	Derkey et al. (1990); Mills (1977)	lead, silver, zinc	USEPA (2002a); Huntting (1956)	19 tons	Mills (1977)	2740	8440149	No Further Action
First Thought Mine	1896–1910	USEPA (2002a)	Rossland Group	Weaver (1920)	gold, silver	USEPA (2002a); Huntting (1956); Weaver (1920)	40,000 tons	USEPA (2002a); Huntting (1956); Weaver (1920)	1531	2891707	Awaiting Cleanup
Frisco-Standard Mine	1915–1944	Derkey et al. (1990)	Ledbetter Slate	Derkey et al. (1990)	copper, lead, silver, zinc, gold	USEPA (2002a); Derkey et al. (1990); Huntting (1956)	3 tons lead; small, intermittent amounts other minerals	Mills (1977); Derkey et al. (1990)	2243	1883355	Awaiting Cleanup
Gladstone Mine/Mill	1901–1955	USEPA (2002a); Huntting (1956); Derkey et al. (1990)	Metaline Formation	Derkey et al. (1990); Mills (1977)	copper, lead, silver, zinc	USEPA (2002a); Huntting (1956)	7,792 tons lead; 22 tons zinc; 600 pounds silver; 835 pounds copper	USEPA (2002a); Huntting (1956); Mills (1977)	2714	6228568	Awaiting Cleanup
Great Western Mine	1888–1929	Mills (1977); Weaver (1920)	Metaline Formation	Derkey et al. (1990)	lead, zinc	USEPA (2002a); Huntting (1956)	468 tons zinc; 217 tons lead	USEPA (2002a); Mills (1977)	381	9476268	Awaiting Cleanup
Homestake No. 1 Mine	unknown	na	Rossland Group	Derkey et al. (1990)	copper, gold, silver	USEPA (2002a); Huntting (1956)	100 tons	Derkey et al. (1990); Weaver (1920)	1456	3646204	No Further Action
Hope and Twin Cabins Mine	unknown	na	Rossland Group	Derkey et al. (1990)	copper, gold, silver	USEPA (2002a)	100 tons	USEPA (2002a)	2025	9672131	No Further Action
Hubbard Mine	unknown	na	Flagstaff Mountain sequence	Derkey et al. (1990)	copper, gold, lead, silver, zinc	USEPA (2002a)	1 carload	Huntting (1956)	2157	1955810	No Further Action
Iroquois Mine	1917–1950	USEPA (2002a); Derkey et al. (1990)	Metaline Formation	Derkey et al. (1990); Mills (1977)	cadmium, lead, silver, zinc, gold	USEPA (2002a); Huntting (1956); Derkey et al. (1990)	amounts vary: 60 tons–600,000 tons	Huntting (1956); Derkey et al. (1990); Mills (1977)	3803	109707	Awaiting Cleanup
Jackson Mine	1928–1935	Huntting (1956)	Grass Mountain sequence	Derkey et al. (1990)	copper, lead, silver, zinc	USEPA (2002a); Huntting (1956); Derkey et al. (1990)	7 tons	USEPA (2002a)	2579	2423034	Awaiting Cleanup
Lakeview Mine	1922	Derkey et al. (1990)	Grass Mountain sequence	Derkey et al. (1990)	lead, silver	USEPA (2002a); Derkey et al. (1990)	1.2 tons lead; 48 pounds silver; 24 total tons ore	Derkey et al. (1990); Mills (1977)	4438	8897302	No Further Action
Last Chance Mine/Mill	1904–1954	USEPA (2002a); Mills (1977)	Metaline Formation	Derkey et al. (1990)	lead, silver, zinc	USEPA (2002a)	2,969 tons lead; 55 tons zinc; 9 tons silver	USEPA (2002a); Mills (1977)	2073	1855805	Awaiting Cleanup
L-Bar/Northwest Magnesite	1916–1968, 1977–1986	USEPA (2002a)	na	na	Thermax manufacturing, magnesite; then magnesium	USEPA (2002a)	700 tons per day	USEPA (2002a)	88	762	Construction Complete-Performance Monitoring
Le Roi/Northport Smelter	1897–1922	USEPA (2002a)	na	na	copper, gold, lead, silver	USEPA (2002a); Huntting (1956)	500 tons per day	USEPA (2002a)	47	767	Cleanup Complete-Active O&M/Monitoring
Lottie Mine	1898–unknown	USEPA (2002a)	Rossland Group	Mills (1977)	copper, gold, silver	USEPA (2002a); Huntting (1956)	50 tons	USEPA (2002a); Huntting (1956)	4786	6769855	No Further Action
Lucile Mine	1926–1949	USEPA (2002a); Derkey et al. (1990)	Maitlen Phyllite	Derkey et al. (1990); Mills (1977)	cadmium, lead, silver, zinc	USEPA (2002a); Huntting (1956)	21 tons lead; 12 tons zinc; 95 pounds silver; 254 tons ore	USEPA (2002a); Derkey et al. (1990); Mills (1977)	885	7562209	Awaiting Cleanup

Table 2-6. Mines and Mills Evaluated During the 2001 EPA Stevens County Mines and Mills PA/SI

Facility Name	Dates Operated [a]	Source	Geologic Unit(s) Mined [a]	Source	Primary Commodity(ies) [a]	Source	Estimated Production Description [a]	Source	Cleanup Site ID [b]	Facility Site ID [b]	Site Status [b]
Lucky Four Mine	1934	Huntting (1956); Derkey et al. (1990)	Metaline Formation	Derkey et al. (1990)	copper, gold, lead, silver	USEPA (2002a); Huntting (1956)	1 truckload to 100 tons	USEPA (2002a); Huntting (1956); Derkey et al. (1990)	188	3634437	No Further Action
Magma Mine	1927	USEPA (2002a)	Metaline Formation	Derkey et al. (1990); Mills (1977)	copper, gold, lead, silver, zinc	USEPA (2002a); Huntting (1956)	5 tons	Huntting (1956); Derkey et al. (1990)	244	3546084	No Further Action
Maki Mine	1921	Huntting (1956)	Metaline Formation	Derkey et al. (1990); Mills (1977)	cobalt, lead, zinc	USEPA (2002a); Huntting (1956)	na	Huntting (1956)	3871	195512	Awaiting Cleanup
Melrose Mine	1913–1938	USEPA (2002a)	Grass Mountain sequence	Derkey et al. (1990)	copper, lead, silver, zinc	USEPA (2002a); Huntting (1956); Derkey et al. (1990)	97 tons	USEPA (2002a); Derkey et al. (1990)	4787	6825039	Awaiting Cleanup
Myeerah Mine	1926–1942	Derkey et al. (1990)	Ledbetter Slate	Derkey et al. (1990)	gold, lead, silver, zinc	USEPA (2002a); Huntting (1956); Derkey et al. (1990)	4 tons lead; 18 pounds silver	USEPA (2002a); Derkey et al. (1990); Mills (1977)	3470	6489914	Awaiting Cleanup
Napoleon Mine/Mill	1907–1955	USEPA (2002a); Huntting (1956)	unnamed Permian-Triassic metasedimentary rocks	Mills (1977); Derkey et al. (1990)	copper, iron, gold	USEPA (2002a); Huntting (1956)	na	na	2075	3025813	Awaiting Cleanup
New Leadville Mine	unknown–1924	USEPA (2002a); Huntting (1956); Derkey et al. (1990)	Metaline Formation	Derkey et al. (1990)	lead	USEPA (2002a); Huntting (1956)	na	na	1632	7858378	Awaiting Cleanup
Northport Mill	unknown–1990s	USEPA (2002a)	na	na	barite	USEPA (2002a)	na	na	na	na	na
Northwest Alloys	1976–2001	USEPA (2002a)	na	na	magnesium, ferrosilicon	USEPA (2002a)	na	na	2494	4	Cleanup Started
R.J. Mine	1900–unknown	USEPA (2002a)	Metaline Formation	Derkey et al. (1990)	lead, silver	USEPA (2002a); Huntting (1956)	2 carloads	Huntting (1956); Derkey et al. (1990)	3342	8465344	Awaiting Cleanup
Red Top Mine	1938–1953	Huntting (1956); Derkey et al. (1990)	Maitlen Phyllite	Derkey et al. (1990); Mills (1977)	lead, silver, zinc	USEPA (2002a)	103 tons lead; 70 tons zinc; 400 pounds silver	Mills (1977)	2439	9673298	Awaiting Cleanup
Sierra Zinc Mine/Mill	1909–1956	USEPA (2002a)	Maitlen Phyllite	Derkey et al. (1990)	gold, lead, silver, zinc	USEPA (2002a); Derkey et al. (1990)	2,870 tons zinc; 460 tons lead; 1 ton silver	Derkey et al. (1990)	1838	1786484	Construction Complete-Performance Monitoring
Silver Queen Mine	1917–1941	USEPA (2002a); Derkey et al. (1990)	Metaline Formation or Stensgar Dolomite	Mills (1977); Derkey et al. (1990)	lead, silver, zinc	USEPA (2002a); Huntting (1956)	7 tons lead; 8–9 tons silver	Derkey et al. (1990); Mills (1977)	4850	6784750	Awaiting Cleanup
St. Crispin Mine	1905–1941	Weaver (1920); Huntting (1956)	dark, carbonaceous argillite	Weaver (1920)	copper, gold, lead, silver	USEPA (2002a); Huntting (1956)	na	na	1553	9267585	No Further Action
United Treasure Mine	1917–1953	USEPA (2002a); Huntting (1956); Derkey et al. (1990)	Ledbetter Slate	Derkey et al. (1990)	copper, gold, lead, silver, zinc	USEPA (2002a); Huntting (1956); Derkey et al. (1990)	84 tons	Derkey et al. (1990)	448	902477	No Further Action
Van Stone Mine/Mill	1938–1993	USEPA (2002a); Ecology (2013b); Ecology (2017a); Huntting (1956)	Metaline Formation	Derkey et al. (1990); Mills (1977)	lead, zinc	USEPA (2002a); Ecology (2013b); Ecology (2017a); Huntting (1956); Derkey et al. (1990)	2.2 million tons ore	Derkey et al. (1990)	461	1554858	Cleanup Started

Notes:

[a] This information is reproduced directly from the listed sources.

[b] This information is compiled from Ecology (2024).

na - not available

O&M - operation(s) and maintenance

PA/SI - preliminary assessment and site inspection

Table 3-1. Study Summaries

Map Number(s)	Abbreviated Study Name Used in Upland RI Report	Report Citation	UCR RI/FS Database Study ID	Sample Collection Year(s)	Discrete Grab Samples?	Composite Samples?	Core Samples?	Sample Depth(s)	Leaf Litter Removal?	Source Samples?	Sieve Size(s)
3-1	2014 Soil Study	TAI (2015a)	Teck_2014_UplandSoil	2014	no	yes	no	0–7.5 cm	yes	no	< 2 mm, < 149 µm
3-2	2012 Ecology Upland Soil Study	Ecology (2013a)	HARTC13A	2012	no	yes	yes	surface: 0–3 in.; subsurface: 3–6 in., 6–12 in., 12–24 in.	yes	no	< 2 mm
3-3a, b	2014 Residential Soil Study	USEPA (2016a)	USEPA_2014_ResSoil	2014	yes	yes	no	varies by DU type: 0–1 in., 0–3 in., 1–6 in., 0–12 in., 0–18 in.	yes	no	< 150 µm
3-3a, b and 3-4	2015 TCRA Memorandum	USEPA (2015b)	USEPA_2015_TCRASoil	2014	yes	no	no	0–6 in., 6–12 in.	yes	no	unknown
3-3a, b and 3-4	2015 TCRA	TAI (2016b)		2015	yes	no	no	2 in., 4 in., 6 in., 10 in., 12 in., and/or 24 in.	no	no	< 2 mm (per UCR database)
3-5	2016 Residential Soil Study	TAI (2017a)	Teck_2016_ResSoil	2016	yes	yes	no	varies by DU type: 0–1 in., 0–2 in., 0–2.5 in., 0–3 in., 0–3.5 in., 0–4 in., 0–4.5 in., 0–5 in., 0–5.5 in., 0–6 in., 0–6.5 in., 0–7 in., 0–7.5 in., 0–8 in., 0–9 in., 0–10 in., 0–11 in., 0–11.5 in., 0–12 in.	yes	no	< 149 µm
3-6	2017–2018 VRA	TAI (2019a)	Teck_2017-18_VRA	2017–2018	yes	yes	no	0–6 in., 0–8 in., 0–9 in., 0–12 in.	yes	no	unknown
3-3a,b and 3-7	2017 SATES Test Plot Characterization	TAI (2019b)	Teck_2017_SATES_PIA	2017	yes	yes	no	surface: 0–2 in., 0–3 in.; subsurface: 2–4 in., 4–6 in., 6–8 in., 8–10 in., 10–12 in.	yes	no	< 2 mm, < 150 µm
3-3a,b and 3-8	2018 Plant Tissue Study	TAI (2019c)	Teck_2017_PlantTissue	2018	yes	yes	no	0–3 in.	yes	no	< 150 µm
3-9	WDNR Young America Mine Site Characterization	WDNR (2008)	WADNR2008	na	yes	no	no	unknown	no	yes	unknown
3-9	2015 Bossburg Study	TAI (2016c)	Teck_2015_Bossburg	2015	yes	yes	yes	0–6 in., 6–12 in., 12–18 in.	yes	no	< 2 mm, < 150 µm
3-9	2011 EPA Young America Mine Removal Assessment	USEPA (2012a)	USEPA_2012_YAM	2011	yes	no	no	0.5–3 ft	no	yes	unknown
3-10	2001 EPA Stevens County Mines and Mills PA/SI	USEPA (2002a)	USEPA2001Mines_Mills	2001	yes	no	no	0–6 in., 0–8 in. per database; all 0–6 in. per report	yes	yes	unknown
3-11	2004 EPA Le Roi Smelter Removal Action	USEPA (2005)	LeRoi2005	2004	no	yes	no	surface: 0–1 in.; subsurface: 1–24 in. (varies)	no	no	unknown
3-12a, b	2011–2012 Ecology Van Stone RI	Ecology (2013b)	HARTC13C	2011–2012	yes	yes	no	3–6 in.	yes	yes	< 2 mm
3-12a, b	2014–2015 Ecology Van Stone FS	Ecology (2017a)	FS1554858	2014–2015	yes	no	yes	0.5–97 ft (varies)	yes	yes	< 2 mm
3-13	2003–2004 EPA Anderson Calhoun EE/CA	USEPA (2007a)	ACMINESITE2007	2003– 2004	yes	no	yes	0–2 in., 0–15 ft (varies)	no	yes	unknown
3-14	2011 Port of Entry Soil Remediation	Shannon and Wilson (2011)	SHANN11A (background database)	2011	yes	no	no	0–3 in. after removal (at least 10–20 in. below original ground surface)	yes	no	unknown
3-15	2007 Brooks Road/Bonanza Mine Roadbed Voluntary Cleanup	SCDPW (2008a)	WADOE_2007b	2007	yes	no	no	0–3 in.	yes	yes	unknown

Table 3-1. Study Summaries

Map Number(s)	Abbreviated Study Name Used in Upland RI Report	Report Citation	UCR RI/FS Database Study ID	Sample Preparation Method Type(s)	Metals Analysis Method Type(s)	Metals Analyzed in Soil Samples	Evaluated in the HHRA?	Evaluated in the Upland BERA?	Evaluated in the Upland RI?
3-1	2014 Soil Study	TAI (2015a)	Teck_2014_UplandSoil	total recoverable, partial extraction (IVBA)	ICP-MS, ICP-AES, CVAA	TAL metals plus molybdenum	yes	yes	yes
3-2	2012 Ecology Upland Soil Study	Ecology (2013a)	HARTC13A	total recoverable [b]	ICP-MS, ICP-AES, CVAA	TAL metals	no	yes	yes
3-3a, b	2014 Residential Soil Study	USEPA (2016a)	USEPA_2014_ResSoil	total recoverable, partial extraction (IVBA)	ICP-MS, ICP-AES	TAL metals (except mercury); IVBA (arsenic, lead)	yes	no	yes
3-3a, b and 3-4	2015 TCRA Memorandum	USEPA (2015b)	USEPA_2015_TCRASoil	total recoverable	ICP-MS, ICP-AES	arsenic, lead	no	no	yes
3-3a, b and 3-4	2015 TCRA	TAI (2016b)		total recoverable [b]	ICP-MS, ICP-AES	arsenic, lead	no	no	yes
3-5	2016 Residential Soil Study	TAI (2017a)	Teck_2016_ResSoil	total recoverable, partial extraction (IVBA)	ICP-MS, ICP-AES	TAL metals (except mercury); IVBA (arsenic, lead)	yes	no	yes
3-6	2017–2018 VRA	TAI (2019a)	Teck_2017-18_VRA	total recoverable	ICP-AES	arsenic, lead	no	no	yes
3-3a,b and 3-7	2017 SATES Test Plot Characterization	TAI (2019b)	Teck_2017_SATES_PIA	total recoverable, partial extraction (multiple types)	ICP-AES	TAL metals (except mercury)	no	no	yes
3-3a,b and 3-8	2018 Plant Tissue Study	TAI (2019c)	Teck_2017_PlantTissue	total recoverable	ICP-MS	TAL metals (except calcium, magnesium, potassium, sodium); mercury on a subset of samples	yes	no [c]	yes
3-9	WDNR Young America Mine Site Characterization	WDNR (2008)	WADNR2008	total recoverable [b]	ICP-MS	arsenic, cadmium, copper, lead, antimony, zinc	no	no	yes
3-9	2015 Bossburg Study	TAI (2016c)	Teck_2015_Bossburg	total recoverable, partial extraction (IVBA)	ICP-MS, ICP-AES, CVAA	TAL metals; IVBA (arsenic, lead)	yes	yes	yes
3-9	2011 EPA Young America Mine Removal Assessment	USEPA (2012a)	USEPA_2012_YAM	total recoverable	ICP-AES	antimony, arsenic, barium, beryllium, cadmium, cobalt, copper, chromium, manganese, nickel, lead, selenium, silver, thallium, vanadium, zinc	no	no	yes
3-10	2001 EPA Stevens County Mines and Mills PA/SI	USEPA (2002a)	USEPA2001Mines_Mills	total recoverable [b]	ICP-MS, CVAA	TAL metals	no	no	yes
3-11	2004 EPA Le Roi Smelter Removal Action	USEPA (2005)	LeRoi2005	total recoverable [b]	ICP-AES, ICP-MS	22 elements (including arsenic, cadmium, copper, mercury, lead, zinc)	no	no	yes
3-12a, b	2011–2012 Ecology Van Stone RI	Ecology (2013b)	HARTC13C	total recoverable [b]	ICP-MS [b], ICP-AES [b], CVAA [b]	antimony, arsenic, beryllium, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, titanium, zinc	no	no	yes
3-12a, b	2014–2015 Ecology Van Stone FS	Ecology (2017a)	FS1554858	total recoverable [b]	ICP-MS [b], ICP-AES [b], CVAA [b]	antimony, arsenic, beryllium, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, titanium, zinc; SPLP and TCLP	no	no	yes
3-13	2003–2004 EPA Anderson Calhoun EE/CA	USEPA (2007a)	ACMINESITE2007	unknown	unknown	barium, cadmium, copper, lead, selenium, zinc	no	no	yes
3-14	2011 Port of Entry Soil Remediation	Shannon and Wilson (2011)	SHANN11A (background database)	total recoverable [b]	ICP-MS	arsenic, cadmium, lead	no	no	yes
3-15	2007 Brooks Road/Bonanza Mine Roadbed Voluntary Cleanup	SCDPW (2008a)	WADOE_2007b	total recoverable [b]	ICP-MS, CVAA	arsenic, cadmium, copper, mercury, lead, zinc	no	no	yes

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Map Number(s)	Abbreviated Study Name Used in Upland RI Report	Report Citation	UCR RI/FS Database Study ID	Select Data Used for Soil Background Evaluation (Tier IIIC Data Set) [a]?
3-1	2014 Soil Study	TAI (2015a)	Teck_2014_UplandSoil	yes
3-2	2012 Ecology Upland Soil Study	Ecology (2013a)	HARTC13A	no
3-3a, b	2014 Residential Soil Study	USEPA (2016a)	USEPA_2014_ResSoil	no
3-3a, b and 3-4	2015 TCRA Memorandum	USEPA (2015b)	USEPA_2015_TCRASoil	no
3-3a, b and 3-4	2015 TCRA	TAI (2016b)		no
3-5	2016 Residential Soil Study	TAI (2017a)	Teck_2016_ResSoil	no
3-6	2017–2018 VRA	TAI (2019a)	Teck_2017-18_VRA	no
3-3a,b and 3-7	2017 SATES Test Plot Characterization	TAI (2019b)	Teck_2017_SATES_PIA	no
3-3a,b and 3-8	2018 Plant Tissue Study	TAI (2019c)	Teck_2017_PlantTissue	no
3-9	WDNR Young America Mine Site Characterization	WDNR (2008)	WADNR2008	no
3-9	2015 Bossburg Study	TAI (2016c)	Teck_2015_Bossburg	no
3-9	2011 EPA Young America Mine Removal Assessment	USEPA (2012a)	USEPA_2012_YAM	no
3-10	2001 EPA Stevens County Mines and Mills PA/SI	USEPA (2002a)	USEPA2001Mines_Mills	yes
3-11	2004 EPA Le Roi Smelter Removal Action	USEPA (2005)	LeRoi2005	no
3-12a, b	2011–2012 Ecology Van Stone RI	Ecology (2013b)	HARTC13C	yes
3-12a, b	2014–2015 Ecology Van Stone FS	Ecology (2017a)	FS1554858	no
3-13	2003–2004 EPA Anderson Calhoun EE/CA	USEPA (2007a)	ACMINESITE2007	no
3-14	2011 Port of Entry Soil Remediation	Shannon and Wilson (2011)	SHANN11A (background database)	no
3-15	2007 Brooks Road/Bonanza Mine Roadbed Voluntary Cleanup	SCDPW (2008a)	WADOE_2007b	no

Table 3-1. Study Summaries

Map Number(s)	Abbreviated Study Name Used in Upland RI Report	Report Citation	UCR RI/FS Database Study ID	Sample Collection Year(s)	Discrete Grab Samples?	Composite Samples?	Core Samples?	Sample Depth(s)	Leaf Litter Removal?	Source Samples?	Sieve Size(s)
3-16	2007 Peterson Swamp/Bonanza Mine Roadbed Voluntary Cleanup	SCDPW (2008b)	WADOE_2007c	2007	yes	no	no	0–3 in.	yes	yes	unknown
3-17	Wells Lichen Study	Wells (2015)	WELLS15A (background database)	2015	no	yes	no	0–3 in.	yes	no	< 2 mm
3-18	2007–2010 USGS Soil Study	USGS (2013)	SMITH13A (background database)	2007–2010	no	no	yes	surface: 0–6 in. (A horizon), 0–2 in. at a subset of locations; subsurface: 7–52 in. (C horizon)	yes	no	sieved to < 2 mm, crushed to < 150 µm (lab)
3-19	Ecology Natural Background Soil Study	Ecology (1994)	ECOLO94A (background database)	1987–1993	no	yes	no	surface: 0–6 in.; subsurface: 2–3 ft, 5–7 ft	no	no	< 2 mm
3-20	USGS Reformatted NURE-HSSR Program	USGS (2006)	NURE Seds Soil Only	1979	no	yes	no	unknown	no	no	< 150 µm
3-20	USGS Midnite Mine Sediment Study	USGS (2008a)	CHURC08A (background database)	1979	no	yes	no	surface: 0 in. starting depth; subsurface: 2–3 in. (per database)	no	no	< 150 µm
3-20	USGS NURE Sample Reanalysis	USGS (2008b)	geochem-fU53	1977, 1979	no	yes	no	2–3 in. (per database)	no	no	< 150 µm[h]
3-21	Trail Smelter Terrestrial ERA	Teck Metals Ltd. (2011)	Trail ERA	2001, 2002, 2004, and 2005	no	yes	no	0–6 in.	yes	no	< 2 mm (field)
3-22	2001 Trail Area Soil Background Assessment	Goodarzi et al. (2001)	GOODA01A (background database)	2001	yes	no	no	0–15 cm	yes	yes	< 2 mm (lab)
3-23a, b	2005 Waneta Expansion Project	WEPC (2005)	Waneta2005	2005	yes	no	yes	surface: 0–3 in., 0–4 in., 0–6 in.; subsurface: 32–40 in., 72–80 in.	no	no	< 2 mm
3-24	2001 Trail Area Moss Bag Study	Goodarzi et al. (2002)	GOODA02A (background database)	2001	no	yes	no	0–10 cm	no	no	< 2 mm
not mapped	Sheep Creek Air Monitoring Data[f]	Teck Metals Ltd. (1994–2009)	TNAQM	1994–2009	na	na	na	na	na	na	na
not mapped	2010 Vlassopoulos Expert Report[g]	Vlassopoulos (2010)	VLASSOPOULOS2010	na	na	na	na	na	na	na	na
not mapped	2014 Vlassopoulos Expert Report[g]	Vlassopoulos (2014)	na	na	na	na	na	na	na	na	na

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Map Number(s)	Abbreviated Study Name Used in Upland RI Report	Report Citation	UCR RI/FS Database Study ID	Sample Preparation Method Type(s)	Metals Analysis Method Type(s)	Metals Analyzed in Soil Samples	Evaluated in the HHRA?	Evaluated in the Upland BERA?	Evaluated in the Upland RI?
3-16	2007 Peterson Swamp/Bonanza Mine Roadbed Voluntary Cleanup	SCDPW (2008b)	WADOE_2007c	total recoverable [b]	ICP-MS, CVAA [d]	arsenic, cadmium, copper, mercury, lead, zinc	no	no	yes
3-17	Wells Lichen Study	Wells (2015)	WELLS15A (background database)	other (loss on ignition before total recoverable digestion)	ICP-AES	aluminum, cadmium, calcium, chromium, copper, iron, lead, magnesium, manganese, nickel, potassium, sodium, zinc	no	no	yes
3-18	2007–2010 USGS Soil Study	USGS (2013)	SMITH13A (background database)	total digestion	ICP-MS, ICP-AES, CVAA	42 elements (including arsenic, cadmium, copper, mercury, lead, zinc)	no	no	yes
3-19	Ecology Natural Background Soil Study	Ecology (1994)	ECOLO94A (background database)	total recoverable	ICP-MS, CVAA	aluminum, arsenic, beryllium, cadmium, copper, chromium, iron, mercury, magnesium, manganese, nickel, lead, zinc	no	no	yes
3-20	USGS Reformatted NURE-HSSR Program	USGS (2006)	NURE Seds Soil Only	total digestion, INAA	AAS and INAA	up to 40 elements (including arsenic, copper, lead, zinc; no cadmium or mercury); not all samples analyzed for full list of elements	no	no	yes
3-20	USGS Midnite Mine Sediment Study	USGS (2008a)	CHURC08A (background database)	total recoverable (per database)	ICP-MS (per database); INAA and ICP-MS (per report)	45 elements (including arsenic, cadmium, copper, lead, zinc; no mercury)	no	no	yes
3-20	USGS NURE Sample Reanalysis	USGS (2008b)	geochem-fU53	other [e]	ICP-MS (per database) and other	41 elements (including arsenic, cadmium, copper, mercury, lead, zinc)	no	no	yes
3-21	Trail Smelter Terrestrial ERA	Teck Metals Ltd. (2011)	Trail ERA	total recoverable	ICP-MS, CVAA	29 elements (including arsenic, cadmium, copper, mercury, lead, zinc)	no	no	yes
3-22	2001 Trail Area Soil Background Assessment	Goodarzi et al. (2001)	GOODA01A (background database)	total recoverable	ICP-MS, CVAA	report describes 27 elements: arsenic, cadmium, copper, mercury, lead, zinc, bismuth, indium, titanium, antimony, cobalt, iron, nickel, molybdenum, tin, thorium, uranium, calcium, strontium, barium, manganese, titanium, zirconium, aluminum, chromium, vanadium, selenium; UCR database includes results for 44 elements (including arsenic, cadmium, copper, mercury, lead, zinc)	no	no	yes
3-23a, b	2005 Waneta Expansion Project	WEPC (2005)	Waneta2005	total recoverable	ICP-MS, CVAA	antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, lead, mercury, molybdenum, nickel, selenium, silver, tin, vanadium, zinc, aluminum, boron, calcium, Iron, magnesium, manganese, phosphorus, potassium, sodium, strontium, titanium, zirconium	no	no	yes
3-24	2001 Trail Area Moss Bag Study	Goodarzi et al. (2002)	GOODA02A (background database)	total digestion	ICP-MS, CVAA	arsenic, cadmium, copper, mercury, lead, zinc	no	no	yes
not mapped	Sheep Creek Air Monitoring Data [f]	Teck Metals Ltd. (1994–2009)	TNAQM	na	na	na	yes	no	no
not mapped	2010 Vlassopoulos Expert Report [g]	Vlassopoulos (2010)	VLASSOPOULOS2010	na	na	na	no	no	no
not mapped	2014 Vlassopoulos Expert Report [g]	Vlassopoulos (2014)	na	na	na	na	no	no	no

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3-16	2007 Peterson Swamp/Bonanza Mine Roadbed Voluntary Cleanup	SCDPW (2008b)	WADOE_2007c	no
3-17	Wells Lichen Study	Wells (2015)	WELLS15A (background database)	yes
3-18	2007–2010 USGS Soil Study	USGS (2013)	SMITH13A (background database)	yes
3-19	Ecology Natural Background Soil Study	Ecology (1994)	ECOLO94A (background database)	yes
3-20	USGS Reformatted NURE-HSSR Program	USGS (2006)	NURE Seds Soil Only	yes
3-20	USGS Midnite Mine Sediment Study	USGS (2008a)	CHURC08A (background database)	yes
3-20	USGS NURE Sample Reanalysis	USGS (2008b)	geochem-fU53	yes
3-21	Trail Smelter Terrestrial ERA	Teck Metals Ltd. (2011)	Trail ERA	no
3-22	2001 Trail Area Soil Background Assessment	Goodarzi et al. (2001)	GOODA01A (background database)	no
3-23a, b	2005 Waneta Expansion Project	WEPC (2005)	Waneta2005	no
3-24	2001 Trail Area Moss Bag Study	Goodarzi et al. (2002)	GOODA02A (background database)	no
not mapped	Sheep Creek Air Monitoring Data [f]	Teck Metals Ltd. (1994–2009)	TNAQM	no
not mapped	2010 Vlassopoulos Expert Report [g]	Vlassopoulos (2010)	VLASSOPOULOS2010	no
not mapped	2014 Vlassopoulos Expert Report [g]	Vlassopoulos (2014)	na	no

Table 3-1. Study Summaries

Map Number(s)	Abbreviated Study Name Used in Upland RI Report	Report Citation	UCR RI/FS Database Study ID	Sample Collection Year(s)	Discrete Grab Samples?	Composite Samples?	Core Samples?	Sample Depth(s)	Leaf Litter Removal?	Source Samples?	Sieve Size(s)
not mapped	2010 Riese Expert Report [g]	Riese (2011)	RIESE2011	na	na	na	na	na	na	na	na
not mapped	2018 Child et al. Isotope Study [g]	Child et al. (2018)	na	na	na	na	na	na	na	na	na

Notes:

[a] The Tier IIIC data set included the samples that were used to calculate the July 2020 final background threshold values (BTVs) (see Appendix C).

[b] The method type is assumed.

[c] The Draft Final Upland BERA used the 2018 Plant Tissue Study for bioaccumulation models.

[d] Unable to find information to verify analysis method types shown.

[e] Other methods like instrumental neutron activation analysis (INAA), sequential atomic absorption analysis, emission spectrography, and/or fluorescence spectroscopy/mass spectrometry were used (USGS 2006).

[f] Air monitoring data from the air quality monitoring station at Sheep Creek near Northport, Washington.

[g] Lead isotope studies did not collect soil samples.

[h] The UCR database reports NURE samples with < 150 µm grainsize. The USGS does not have a specific report confirming the grainsize; however, they note that a subset of the NURE samples was sieved at < 150 µm and geochem-fU53 samples in the UCR are included in this dataset: https://mrdata.usgs.gov/geochem/doc/groups-cats.htm#nure2000

AAS - atomic absorption spectrometry
CVAA - cold vapor atomic absorption
DU - decision unit
HHRA - Final Human Health Risk Assessment: Upper Columbia River Site (USEPA 2021)
ICP-AES - inductively coupled plasma-atomic emission spectrometry
ICP-MS - inductively coupled plasma-mass spectrometry
IVBA - in vitro bioaccessibility
na - not available
SPLP - synthetic precipitation leaching procedure
TAL - target analyte list
TCLP - toxicity characteristic leaching procedure

Table 3-1. Study Summaries

Map Number(s)	Abbreviated Study Name Used in Upland RI Report	Report Citation	UCR RI/FS Database Study ID	Sample Preparation Method Type(s)	Metals Analysis Method Type(s)	Metals Analyzed in Soil Samples	Evaluated in the HHRA?	Evaluated in the Upland BERA?	Evaluated in the Upland RI?
not mapped	2010 Riese Expert Report [g]	Riese (2011)	RIESE2011	na	na	na	no	no	no
not mapped	2018 Child et al. Isotope Study [g]	Child et al. (2018)	na	na	na	na	no	no	no

Notes:
[a] The Tier IIIC data set included the samples that were used to calculate the July 2020 final background threshold values (BTVs) (see Appendix C).
[b] The method type is assumed.
[c] The Draft Final Upland BERA used the 2018 Plant Tissue Study for bioaccumulation models.
[d] Unable to find information to verify analysis method types shown.
[e] Other methods like instrumental neutron activation analysis (INAA), sequential atomic absorption analysis, emission spectrography, and/or fluorescence spectroscopy/mass spectrometry were used (USGS 2006).
[f] Air monitoring data from the air quality monitoring station at Sheep Creek near Northport, Washington.
[g] Lead isotope studies did not collect soil samples.
[h] The UCR database reports NURE samples with < 150 µm grainsize. The USGS does not have a specific report confirming the grainsize; however, they note that a subset of the NURE samples was sieved at < 150 µm and geochem-fU53 samples in the UCR are included in this dataset: https://mrdata.usgs.gov/geochem/doc/groups-cats.htm#nure2000
AAS - atomic absorption spectrometry
CVAA - cold vapor atomic absorption
DU - decision unit
HHRA - Final Human Health Risk Assessment: Upper Columbia River Site (USEPA 2021)
ICP-AES - inductively coupled plasma-atomic emission spectrometry
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Table 3-1. Study Summaries

Map Number(s)	Abbreviated Study Name Used in Upland RI Report	Report Citation	UCR RI/FS Database Study ID	Select Data Used for Soil Background Evaluation (Tier IIIC Data Set) [a]?
not mapped	2010 Riese Expert Report [g]	Riese (2011)	RIESE2011	no
not mapped	2018 Child et al. Isotope Study [g]	Child et al. (2018)	na	no

Notes:

[a] The Tier IIIC data set included the samples that were used to calculate the July 2020 final background threshold values (BTVs) (see Appendix C).

[b] The method type is assumed.

[c] The Draft Final Upland BERA used the 2018 Plant Tissue Study for bioaccumulation models.

[d] Unable to find information to verify analysis method types shown.

[e] Other methods like instrumental neutron activation analysis (INAA), sequential atomic absorption analysis, emission spectrography, and/or fluorescence spectroscopy/mass spectrometry were used (USGS 2006).

[f] Air monitoring data from the air quality monitoring station at Sheep Creek near Northport, Washington.

[g] Lead isotope studies did not collect soil samples.

[h] The UCR database reports NURE samples with < 150 µm grainsize. The USGS does not have a specific report confirming the grainsize; however, they note that a subset of the NURE samples was sieved at < 150 µm and geochem-fU53 samples in the UCR are included in this dataset: https://mrdata.usgs.gov/geochem/doc/groups-cats.htm#nure2000

AAS - atomic absorption spectrometry
CVAA - cold vapor atomic absorption
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HHRA - Final Human Health Risk Assessment: Upper Columbia River Site (USEPA 2021)
ICP-AES - inductively coupled plasma-atomic emission spectrometry
ICP-MS - inductively coupled plasma-mass spectrometry
IVBA - in vitro bioaccessibility
na - not available
SPLP - synthetic precipitation leaching procedure
TAL - target analyte list
TCLP - toxicity characteristic leaching procedure

Table 3-2. Plant Tissue Samples Collected During the 2018 Plant Tissue Study

Scientific Name	Common Name	Plant Part Collected
Bryoria fremontii	black tree lichen	entire
Camassia quamash	camas	bulb
Arctostaphylos uva-ursi	kinnikinnick	leaves
Lomatium tritermatum	lomatium	root
Claytonia lanceolata	spring beauty/Indian potato	corm
Vaccinium cespitosum	huckleberry	berry
Rosa sp.	wild rose	stems and leaves
Rosa sp.	wild rose	rose hips
Prunus virginiana	chokecherry	berry
Corylus cornuta var. *californica*	hazelnut	nut
Pinus ponderosa	ponderosa pine	nut
Amelanchier alnifolia	sarvisberry	berry
Mentha arvensis	wild mint	leaves
Schoenoplectus acutus	tule	culm
Salix exigua	willow	stems

Source: Table 2-21 in USEPA (2021)

Table 4-1. Soil Background Values Calculated for the UCR Site and Surrounding Area

Metal	Final BTVs July 2020 Based on 95/95 UTL (Appendix C)			HHRA (USEPA 2021) 95/95 UTL	Ecology (1994) Spokane Basin 90th Percentile	Ecology (2019b) 90th Percentile Range Midpoint	Ecology (2019b) Maximum 90th Percentiles											Sanei et al. (2007) Trail Site-Specific 95th Percentile
	Total Metals [a]	Partial Digestion (Total Recoverable Metals) [a,b]	Mercury [a]				WRIA 49	WRIA 51	WRIA 52	WRIA 53	WRIA 54	WRIA 55	WRIA 58	WRIA 59	WRIA 60	WRIA 61	WRIA 62	
Aluminum	73,800	40,500	NA	70,950	21,376	53,095	66,607	64,845	67,060	64,800	71,450	81,320	69,260	66,500	69,700	67,790	75,435	34,500
Antimony	3.0	0.41	NA	2.15 [c]	na	1.26	2	1.6 [d]	1.6 [d]	1.6 [d]	1.6 [d]	1.6 [d]	1.4	1.6 [d]	1.6 [d]	1.7	1.6 [d]	1.5
Arsenic	12.0 / 12.0	98.4 / 80.6 / 23.3	NA	18.3	9.34	12	49	3	6	6	10	7	9	9	9	11	9	19.7
Barium	722	395	NA	na	na	785	960	864 [d]	1137	864 [d]	594	864 [d]	820	766	999	524	861	na
Beryllium	3.0 / 3.0	2.4	NA	na	0.84	2	2	2.5	3	2.5	2.5	3.3	2.5	2.5	2.5	1.5	4	na
Cadmium	2.0 / 0.54	0.74	NA	0.61	0.72	0.44	49	0.6 [d]	0.6 [d]	0.6 [d]	0.5	0.6 [d]	0.8	0.6 [d]	0.6 [d]	2.9	0.6	1.67
Chromium	155 / 140	27.1 / 23.8	NA	145	17.8	100	60	50	103	123	80	35	70	70	151	36	46	167
Cobalt	22.0 / 22.0	20.4	NA	15	na	na	na	na	na	na	na	na	na	na	na	na	na	16.6
Copper	37.0	41.5	NA	na	21.6	33	31	20	21	17	20	17	24	24	32	32	29	51.5
Iron	52,500	31,200	NA	51,690	25,026	40,925	50,473	36,618	47,880	54,500	47,860	38,142	41,280	35,900	41,880	42,550	34,220	37,400
Lead	30.0 / 30.0	27.2	NA	35	14.9	31	25	25	25	24	22	20	34	33	24	99	35	37.9
Manganese	1,380	1,240	NA	1,182	663	1,557	1,093	972	1,100	970	1,164	1,167	1,150	1,120	1,110	1,255	1,884	1,314
Mercury	NA	NA	0.14 / 0.12	na	0.02	0.09	0.03	0.09 [d]	0.03	0.09 [d]	0.04	0.09 [d]	0.24	0.13	0.09 [d]	0.09	0.11	0.07
Molybdenum	6.0	3.5 / 1.4	NA	na	na	na	na	na	na	na	na	na	na	na	na	na	na	2.82
Nickel	46.0 / 45.0	35.0	NA	57	16.2	31	25	23	23	22	17	15	30	25	47	37	26	42
Selenium	3.0	0.098 / 0.10	NA	na	na	na	na	na	na	na	na	na	na	na	na	na	na	0.6
Silver	1.1 / 1.1	0.078	NA	na	na	0.9	0.7	0.6	0.6	0.4	0.9	1	0.7	0.9	0.8	0.6	0.8 [d]	0.39
Thallium	1.1	0.56	NA	0.68	na	0.5	0.4	0.5 [d]	0.5 [d]	0.5 [d]	0.5	0.5 [d]	0.7	0.5 [d]	0.5 [d]	0.2	0.5 [d]	0.25
Vanadium	160 / 160	47.5	NA	161	na	na	na	na	na	na	na	na	na	na	na	na	na	91
Zinc	99.0 / 101	111	NA	na	66.4	97	67	98	66	71	86	73	92	114	71	252	134	168

Notes:

All values are in mg/kg.

[a] Background threshold values (BTVs) with and without outliers are indicated with a forward slash (for example 13 / 12), respectively. Outliers were not evaluated for BTVs by individual water resource inventory area (WRIA).

[b] Samples identified for exclusion by EPA based on multivariate analyses and location (USEPA 2020b).

[c] Antimony data were not available in the Final Human Health Risk Assessment: Upper Columbia River Site (USEPA 2021) (HHRA) background data set. The background value reported in the HHRA was a 95/95 upper tolerance limit (UTL) from Ecology (2019b).

[d] WRIA-specific value shown was calculated from an all-WRIA-pooled result due to an absence of WRIA-specific outcomes resulting from small sample size (n < 10) and are provided for general comparison only.

NA - not applicable

na - not available

Table 5-1. HHRA Medium with Exposure Area

Medium		Exposure Area
Sediment	public (recreational) beach	beach
	Bossburg Flat and Evans Campground	individual SDU
	residential beach	individual DU
	subsurface	individual SDU
Surface water		UCR Reaches 1–6 combined
Fish		UCR Reaches 1–6 combined
Soil	residential soil	individual DU
	upland soil	individual ADA
	Bossburg Flat	individual UDU
	relict floodplain	individual RFDA
Outdoor air		entire Site
Indoor air		entire Site
Indoor dust		individual DU or ADA

Notes:

Adapted from Table 3-1 in the Final Human Health Risk Assessment: Upper Columbia River Site (USEPA 2021) (HHRA).

Gray shading indicates upland media.

ADA - aerial deposition area

DU - decision unit

RFDA - relict floodplain deposition area

SDU - sediment DU

UDU - upland DU

Table 5-2. Human Health COPCs Evaluated in the OU 3 Study Area by Environmental Medium

Outdoor and Indoor Air	ADA DU Soil and Indoor Dust	RSS DU Soil and Indoor Dust	Bossburg UDU Soil
arsenic	aluminum	aluminum	arsenic
cadmium	antimony	antimony	chromium
lead	arsenic	arsenic	lead
	cadmium	cadmium	
	chromium	chromium	
	cobalt	cobalt	
	iron	iron	
	lead	lead	
	manganese	manganese	
	thallium	nickel	
	vanadium	thallium	
		vanadium	

Notes:
ADA - aerial deposition area
COPC - chemical of potential concern
DU - decision unit
RSS DU - residential soil study DU
UDU - upland DU

Table 5-3. RBA Estimates for Arsenic and Lead in ADA DU and RSS DU Soils

Soil Sample Area	Number of Samples	Mean RBA (± SD) (%)
Arsenic		
ADA DUs	22	28.4 (± 6.9)
Bossburg UDUs	6	NA [c]
RSS DUs—outside [a]	32	16.4 (± 6.6)
RSS DUs—inside [b]	107	27.6 (± 7.4)
Lead		
ADA DUs	22	71.5 (± 6.4) [d]
Bossburg UDUs	6	NA [c]
RSS DUs—outside [a]	32	50.5 (± 13.6)
RSS DUs—inside [b]	107	63.9 (± 7.6)

Notes:

[a] Samples are located outside the 2014 Residential Soil Study (USEPA 2016a) boundary area. Includes tribal allotment decision units (TA DUs).

[b] Samples are located inside the 2014 Residential Soil Study (USEPA 2016a) boundary area. Includes TA DUs.

[c] Relative bioavailability (RBA) was measured at each Bossburg upland DU (UDU). RBA was not averaged across Bossburg UDUs, and UDU-specific RBA estimates were applied in the Final Human Health Risk Assessment: Upper Columbia River Site (USEPA 2021) (HHRA).

[d] The mean lead RBA applied in the HHRA for aerial deposition area (ADA) DUs was 70.6%. The mean RBA reported here was corrected to account for a laboratory reporting error in ADA-162. The corrected RBA for ADA-162 is 90.7% versus an RBA of 67.4% used in the HHRA.

NA - not applicable

RSS DU - residential soil study DU

SD - standard deviation

Table 5-4. EPA Human Health Risk Benchmarks for the UCR Site

Risk Threshold
Blood Lead Level
P3—no greater than a 5% probability of exceeding 3 µg/dL
P5—no greater than a 5% probability of exceeding 5 µg/dL
P8—no greater than a 5% probability of exceeding 8 µg/dL
Non-Cancer
HI less than or equal to 1
Cancer
Cancer risk less than or equal to 1 in 10,000 (1E-04)

Note:
HI - hazard index

Table 5-5. Lead Risks for Current Residents (RSS DUs), Potential Future Residents (ADA DUs), and Recreational Users (Bossburg UDUs)

	RSS DUs			ADA DUs [a]			Bossburg UDUs		
Lead Risk Result Type	P3	P5	P8	P3	P5	P8	P3	P5	P8
Range of probabilities of exceeding lead risk threshold across DUs (%)	1.6–99.5	< 0.1–92.8	< 0.1–67.8	4.3–98.8	0.25–87.8	< 0.1–56.6	14.6–70.9	1.6–29.6	0.1–6.2
Number (and percent) of DUs exceeding lead risk threshold	389 (66%)	87 (15%)	12 (2%)	139 (98%)	71 (50%)	16 (11%)	6 (100%)	1 (17%)	1 (17%)

Notes:

[a] Values shown incorporate updated average relative bioavailability (RBA) values for aerial deposition area (ADA) decision units (DUs), so they do not match values shown in the Final Human Health Risk Assessment: Upper Columbia River Site (USEPA 2021) (HHRA).

P3 - no greater than a 5% probability of exceeding a blood lead level of 3 µg/dL

P5 - no greater than a 5% probability of exceeding a blood lead level of 5 µg/dL

P8 - no greater than a 5% probability of exceeding a blood lead level of 8 µg/dL

RSS DU - residential soil study DU

UDU - upland DU

Table 5-6. Range of Nonlead Risks for Incidental Ingestion and Dermal Contact with Soil for RSS DUs, ADA DUs, and Bossburg UDUs

	Non-Cancer Risk			
Child/Adult	Total HI Range	Target Organ/System	HI Range	Cancer Risk (Lifetime)
RSS DUs (Current Residential Exposure)				
Child	0.8–5	cardiovascular	0.03–0.7	2E-06 to 4E-05
		developmental	0.007–0.2	
		endocrine	0.1–1	
		gastrointestinal	0.1–0.7	
		hematologic	0.005–0.4	
		nervous	0.2–1	
		skin, hair, and nails	0.2–2	
		urinary	0.003–0.6	
Adult	0.08–0.5	cardiovascular	0.004–0.07	
		developmental	0.0007–0.02	
		endocrine	0.009–0.09	
		gastrointestinal	0.01–0.06	
		hematologic	0.0005–0.04	
		nervous	0.01–0.09	
		skin, hair, and nails	0.02–0.2	
		urinary	0.0003–0.06	
ADA DUs (Future Residential Exposure)				
Child	1–4	cardiovascular	0.09–0.8	5E-06 to 4E-05
		endocrine	0.2–0.8	
		gastrointestinal	0.2–0.5	
		hematologic	0.01–0.4	
		nervous	0.2–1	
		skin, hair, and nails	0.3–2	
		urinary	0.006–0.2	
Adult	0.1–0.4	cardiovascular	0.01–0.09	
		endocrine	0.01–0.07	
		gastrointestinal	0.02–0.05	
		hematologic	0.001–0.04	
		nervous	0.02–0.1	
		skin, hair, and nails	0.03–0.2	
		urinary	0.0006–0.02	
Bossburg UDUs (Recreational Exposure)				
Child	0.008–0.2	cardiovascular	0.0005–0.02	4E-08 to 1E-06
		endocrine	NA	
		gastrointestinal	0.006–0.07	
		hematologic	0.0002–0.08	
		nervous	NA	
		skin, hair, and nails	0.0005–0.02	
		urinary	NA	
Adult	0.002–0.02	cardiovascular	0.0001–0.003	
		endocrine	NA	
		gastrointestinal	0.001–0.009	
		hematologic	0.00003–0.01	
		nervous	NA	
		skin, hair, and nails	0.0001–0.003	
		urinary	NA	

Table 5-6. Range of Nonlead Risks for Incidental Ingestion and Dermal Contact with Soil for RSS DUs, ADA DUs, and Bossburg UDUs

Child/Adult	Non-Cancer Risk			Cancer Risk (Lifetime)
	Total HI Range	Target Organ/System	HI Range	
Bossburg UDUs (Occupational Exposure)				
Adult - surface soil	0.02–0.02	cardiovascular	0.009–0.01	1E-06 to 2E-06
		endocrine	NA	
		gastrointestinal	NA	
		hematologic	NA	
		nervous	NA	
		skin, hair, and nails	0.009–0.01	
		urinary	NA	
Adult - subsurface soil	0.01–0.1	cardiovascular	0.006–0.05	9E-07 to 8E-06
		endocrine	NA	
		gastrointestinal	NA	
		hematologic	NA	
		nervous	NA	
		skin, hair, and nails	0.006–0.05	
		urinary	NA	

Notes:
ADA - aerial deposition area
DU - decision unit
HI - hazard index
NA - not applicable; no chemicals of potential concern (COPCs) affecting the target organ/system were identified in Bossburg upland DU (UDU) soil
RSS DU - residential soil study DU

Table 5-7. Range of Indoor and Outdoor Air Inhalation Risks (RME)

Air Type	Child/Adult	Non-Cancer Risk (Total HI)	Cancer Risk (Lifetime)
Resident			
Indoor	child	0.5	9E-06
	adult	0.5	
Outdoor	child	0.04	1E-06
	adult	0.07	
Recreational User—Day Trips, Boating, or Camping			
Outdoor	child	0.006–0.01	1E-07 to 5E-07
	adult	0.007–0.03	
Outdoor Worker			
Outdoor	adult	0.1	2E-06

Notes:
HI - hazard index
RME - reasonable maximum exposure

Table 5-8. Range of Nonlead Risks for Incidental Ingestion and Dermal Contact (Soil) Plus Inhalation (Air) for RSS DUs and ADA DUs

Child/Adult	Non-Cancer Risk		Cancer Risk (Lifetime) (Soil + Air)
	Target Organ/System	HI Range (Soil + Air)	
RSS DUs			
Child	nervous	0.5–1	4.5E-05
	urinary	0.2–0.8	
Adult	nervous	0.4–0.5	
	urinary	0.19–0.24	
ADA DUs			
Child	nervous	0.6–1	5.1E-05
	urinary	0.2–0.4	
Adult	nervous	0.4–0.5	
	urinary	0.19–0.21	

Notes:
Risks for Bossburg upland decision units (UDUs) are not applicable because no chemicals of potential concern (COPCs) affecting the nervous or urinary target organ/systems were identified in Bossburg UDU soil.

ADA - aerial deposition area

DU - decision unit

HI - hazard index

RSS DU - residential soil study DU

Table 5-9. Human Health COPCs Evaluated in the CHIRU Human Health Risk Assessment by Environmental Medium

Air [a]	TA DU Soil and Indoor Dust	Terrestrial Plants	Upland Birds	Upland Game
arsenic	aluminum	aluminum	arsenic	arsenic
cadmium	antimony	antimony	beryllium	beryllium
lead	arsenic	arsenic	cadmium	cadmium
	cadmium	cadmium	lead	lead
	chromium	chromium	mercury	mercury
	cobalt	cobalt	nickel	nickel
	iron	iron	selenium	selenium
	lead	lead		
	manganese	manganese		
	nickel	mercury		
	thallium	nickel		
	vanadium	thallium		
		vanadium		

Source: Appendix 1 in USEPA (2021)

Notes:

[a] Indoor and outdoor air were not evaluated separately for the Colville High Intensity Resource User (CHIRU) population

COPC - chemical of potential concern

TA DU - tribal allotment decision unit

Table 5-10. Lead Risks for Residential Exposure on TA DUs

Lead Risk Result Type	Lead Risk Threshold		
	P3	P5	P8
Range of probabilities of exceeding lead risk threshold across TA DUs (%)	1.9–96.3	0.1–75.8	< 0.1–38.2
Number (and percent) of TA DUs exceeding lead risk threshold	21 (60%)	17 (49%)	6 (17%)

Notes:

P3 - no greater than a 5% probability of exceeding a blood lead level of 3 µg/dL

P5 - no greater than a 5% probability of exceeding a blood lead level of 5 µg/dL

P8 - no greater than a 5% probability of exceeding a blood lead level of 8 µg/dL

TA DU - tribal allotment decision unit

Table 5-11. Range of Nonlead Risks for Incidental Ingestion and Dermal Contact with Soil for TA DUs

Child/Adult	Non-Cancer Risk			Cancer Risk (Lifetime)
	Total HI Range	Target Organ/System	HI Range	
Child	1–5	cardiovascular	0.05–1	3E-06 to 8E-05
		developmental	0.0004-0.05	
		endocrine	0.2–0.8	
		gastrointestinal	0.2–0.6	
		hematologic	0.01–0.5	
		nervous	0.2–1	
		skin, hair, and nails	0.2–2	
		urinary	0.008–0.3	
Adult	0.3–1	cardiovascular	0.01–0.3	
		developmental	0.00004-0.01	
		endocrine	0.05–0.2	
		gastrointestinal	0.05–0.1	
		hematologic	0.003–0.1	
		nervous	0.05–0.3	
		skin, hair, and nails	0.05–0.5	
		urinary	0.002–0.06	

Notes:
HI - hazard index
TA DU - tribal allotment decision unit

Table 5-12. CHIRU Outdoor Air Inhalation Risks (RME)

Air Type	Child/Adult	Non-Cancer Risk (Total HI)	Cancer Risk (Lifetime)
Outdoor	child	0.6	1E-05
	adult	0.6	

Notes:
CHIRU - Colville High Intensity Resource User
HI - hazard index
RME - reasonable maximum exposure

Table 5-13. Range of Nonlead Risks for Upland Media Incidental Ingestion and Dermal Contact (Soil) Plus Inhalation (Air) for CHIRU

Child/Adult	Non-Cancer Risk		Cancer Risk (Lifetime) (Soil + Air)
	Target Organ/System	HI Range (Soil + Air)	
Child	nervous	0.6–2	8.9E-05
	urinary	0.2–0.5	
Adult	nervous	0.4–0.6	
	urinary	0.2–0.3	

Notes:
CHIRU - Colville High Intensity Resource User
HI - hazard index

Table 5-14. Ecological RBCs

				American Robin					Black Capped Chickadee				Masked Shrew		
COC	BTV	Plants	Invertebrates	G	R	R-Pb	R-Hg	S	G	R	R-Pb	S	G	R	S
Arsenic	23.3	18	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Barium	395	NA	330	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Cadmium	0.74	NA	NA	4.55	5.45	NA	NA	24.5	NA	NA	NA	NA	20.5	9.92	3.74
Copper	41.5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	31.1	70	22.5
Lead	27.2	176.9	NA	1,130	139	325	NA	372	NA	NA	NA	NA	585	106	187
Manganese	1,240	220	450	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Mercury	0.12	NA	NA	6.19	0.0766	NA	0.128	0.325	NA	NA	NA	NA	NA	NA	NA
Selenium	0.098	0.52	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.503	7.63	0.931
Zinc	111	51.9	104.1	NA	NA	NA	NA	NA	378	441	NA	1,430	220	NA	NA

Notes:

Units are in mg/kg-dw.

Shade indicates the lowest ecological risk-based concentration (RBC) or background threshold value (BTV) selected to provide context to the nature and extent discussion.

Chemicals of concern (COCs) that present unacceptable risk to at least one receptor group (and for birds and mammals the most sensitive endpoint and receptor) were obtained from Table ES-1 of the Upland BERA (USEPA 2023a).

BTVs are from Table 2-8 of the Upland BERA and TAI Upland Soil Background Assessment (Appendix C).

Maximum RBA values used for calculation of bird and mammal RBCs are as follows: barium = 0.766, cadmium = 0.919, copper = 0.4, mercury = 0.095, selenium = 0.217, and zinc = 0.522.
The maximum RBA value for birds lead = 0.606 and for mammals lead = 0.742.

G - growth

NA - not applicable (either not a COC for that receptor group, or not the most sensitive species)

R - reproduction

R-Hg - reproduction for mercury; calculated using toxicity reference value (TRV) of 0.02 mg/kg bw/day from Burgess and Meyer (2008) for birds (see page 8-8 of USEPA 2023a)

R-Pb - reproduction for lead; calculated using TRV of 9.8 mg/kg bw/day from Sample et al. (2019) for birds (see page 8-8 of USEPA 2023a)

S - survival

Table 6-1a. Data Selection for the Upland RI Data Set

Selection Criterion	Selection Criteria Applied?	Rationale
Exclude nonmetals. [a]	yes	COPCs identified for upland soil are metals.
Exclude sediment, surface water, and groundwater samples.	yes [b]	Sediment, surface water, and groundwater are not media of concern.
Exclude results with units of % or mg/L.	yes	Only data reported in mg/kg are used for comparability.
Exclude results that were qualified as rejected during data validation.	yes	Rejected values are not appropriate for use in decision making.
Exclude samples without spatial coordinates. [c]	yes	Spatial coordinates are necessary for mapping and spatial analyses.
Exclude laboratory quality control samples, including laboratory replicates.	yes	These samples are not investigative samples.
Exclude samples collected below the pre-1973 flood extent maximum (i.e., floodplain samples). [d]	yes	These samples will be evaluated in the Aquatic RI report.
Exclude field-screening results obtained through XRF analysis.	yes	XRF is a screening method; only laboratory-analyzed data are used for comparability.
Exclude samples with unknown analytical methods.	yes	The data set includes multiple methods for some samples, but only results from known analytical methods are used in the analyses and only one result per sample location is used.
Exclude waste rock, soil tailings, crushed ore, and tailings.	varies	Waste rock, tailings, and crushed ore data are included in the data set but are not considered soil. Only soil samples are retained for comparability in the analyses, with the exception of the exploratory data analysis.
Exclude subsurface samples.	varies [b]	Subsurface results are evaluated separately in some analyses.
Exclude samples outside the boundaries of Stevens, Ferry, and Lincoln Counties.	varies [b]	The tri-county area represents regional conditions. Data outside the tri-county area are included in the data set but are not used in the analyses.
Exclude samples prepared using a total digestion method.	varies	Total digestion results are evaluated separately in some analyses.
Exclude samples prepared using an IVBA method.	varies	IVBA results are evaluated separately in some analyses.
Include multiple size fractions for the same sample when analyzed.	varies	Different size fractions were used for some analyses.
Include triplicate samples from the same DU when collected.	varies	Triplicate results were used for some analyses.
Include discrete and composite samples from the same DU when collected.	varies	Different sample types were used for some analyses.

Notes:

[a] Antimony, arsenic, and selenium are classified as metals/metalloids in the database and were retained.

[b] This filter was not applied to background threshold value (BTV) samples.

[c] The 2015 TCRA Memorandum samples and the pre-removal 2017–2018 VRA samples do not have spatial coordinates. These coordinates were not provided in the reports; therefore, these samples are not included in mapping or spatial analyses.

[d] This filter removes ADA-140, which was sampled during the 2014 Soil Study. This DU will be evaluated in the Aquatic RI report.

COPC - chemical of potential concern

DU - decision unit

IVBA - in vitro bioaccessibility

RI - remedial investigation

XRF - x-ray fluorescence

Table 6-1b. Study-Specific Data Selection for the Upland RI Data Set

Abbreviated Study Name	Selection Criteria	Selection Criteria Applied?	Rationale
2014 Soil Study	Exclude RFDA and WSDA samples.	yes [a]	These samples will be evaluated in the Aquatic RI report.
2016 Residential Soil Study	Exclude beach DU samples. Exclude dripline DU samples.	yes	Beach samples will be evaluated in the Aquatic RI report. Dripline samples were excluded from the HHRA.
2014 Residential Soil Study			
2017 SATES Test Plot Characterization	For replicate samples, retain only samples analyzed by ALS-Kelso.	yes	ALS-Kelso was the primary analytical laboratory for soil metals analysis.
Trail Smelter Terrestrial ERA	Retain only SALM analyses; exclude other analytical methods.	yes	This method is most consistent with U.S. analytical methods.
2001 EPA Stevens County Mines and Mills PA/SI	Exclude samples collected in Pend Oreille County.	yes	These samples were erroneously included in this study in the database.
2004 EPA Le Roi Smelter Removal Action	Exclude driveway DU samples. [b] Exclude the following locations: 092-BY, 092-DW, 092-FY, 118-DW, 118-GA, 118-PA, 138-FY, and 162-SY.	yes	Driveway DU samples likely represent non-native material. Reported sample coordinates for listed locations did not match property descriptions.

Notes:

[a] This filter was not applied to background threshold value (BTV) samples.

[b] Driveway samples had lower metals concentrations than samples from other area types (front yard, side yard, back yard, garden area, and play area). Driveway samples likely represent non-native material and therefore are not representative of local soil conditions.

DU - decision unit

HHRA - Final Human Health Risk Assessment: Upper Columbia River Site (USEPA 2021)

RFDA - relict floodplain deposition area

RI - remedial investigation

SALM - strong acid leaching method

WSDA - windblown sediment deposition area

Table 6-2. Data Used for the Statistical and Nature and Extent Evaluations

Abbreviated Study Name	UCR RI/FS Database Study ID	Grain Size(s)	Sample Preparation Method Type	Digital Data Exploration Tool [a]	Exploratory Data Analysis [a]	GAM [a,b]	Small-Scale Variability Analyses [a,b]	Post Maps [a]	RBA-Adjusted Lead Data Post Map [a,b]	Interpolated Maps [a,b] (Geostatistical Model)	Vertical Nature and Extent Surface Enrichment Ratios [b]	Vertical Nature and Extent Soil Core Profiles [b]	Vertical Nature and Extent Qualitative Assessment of Subsurface Data [b]
United States Studies													
USGS Midnite Mine Sediment Study	CHURC08A	< 150 µm (per UCR Database); < 100 µm (per report)	total recoverable (per UCR Database)	included	included	not included (spatially removed from OU 3 Study Area)	not included (study did not collect multiple samples in small-scale areas)	included	not included (no IVBA data)	not included (spatially removed from OU 3 Study Area)	not included (spatially removed from OU 3 Study Area)	not included (spatially removed from OU 3 Study Area)	not included (spatially removed from OU 3 Study Area)
Ecology Natural Background Soil Study	ECOLO94A	< 2 mm	total recoverable	not included (no surface samples)	not included (no surface samples)	not included (spatially removed from OU 3 Study Area)	not included (study did not collect multiple samples in small-scale areas)	not included (no surface samples)	not included (no IVBA data)	not included (no surface samples)	not included (no surface samples)	not included (no surface samples)	not included (no surface samples)
2012 Ecology Upland Soil Study	HARTC13A	< 2 mm	total recoverable [c]	included	included	included	included (4-point composite)	included (composites and discrete grab samples)	not included (no IVBA data)	included	included (surface composites, subsurface cores)	included (surface composites, subsurface cores)	not included (assessed quantitatively)
2014 Soil Study	Teck_2014_UplandSoil	< 2 mm, < 150 µm	total recoverable, partial extraction (IVBA)	included	included	included	included (IC)	included (ADA DUs only, < 2 mm samples only; all triplicates mapped)	included	included	not included (no subsurface samples)	not included (no subsurface samples)	not included (no subsurface samples)
2016 Residential Soil Study	Teck_2016_ResSoil	< 150 µm	total recoverable, partial extraction (IVBA)	included	included	included	included (IC and discrete grab)	included (composites and discrete samples; all triplicates mapped)	included	included	included	not included (only two depths sampled)	not included (assessed quantitatively)
2014 Residential Soil Study	USEPA_2014_ResSoil	< 150 µm	total recoverable, partial extraction (IVBA)	included	included	included	included (IC and discrete grab)	included (only composites; all triplicates mapped)	included	included	included	not included (only two depths sampled)	not included (assessed quantitatively)
2007 Brooks Road/Bonanza Mine Roadbed Voluntary Cleanup	WADOE_2007b	unknown	total recoverable [c]	included	included	not included (study design/sample type)	not included (study did not collect multiple samples in small-scale areas)	included	not included (no IVBA data)	included	not included (no subsurface samples)	not included (no subsurface samples)	not included (no subsurface samples)
2007 Peterson Swamp/Bonanza Mine Roadbed Voluntary Cleanup	WADOE_2007c	unknown	total recoverable [c]	included	included	not included (study design/sample type)	not included (study did not collect multiple samples in small-scale areas)	included	not included (no IVBA data)	included	not included (no subsurface samples)	not included (no subsurface samples)	not included (no subsurface samples)
2018 Plant Tissue Study	Teck_2017_PlantTissue	< 150 µm	total recoverable	included	included	not included (resampling of DUs from previous study[ies])	included (IC and discrete grab)	not included (resampling of DUs from previous study[ies])	not included (no IVBA data)	not included (resampling of DUs from previous study[ies])	not included (no subsurface samples)	not included (no subsurface samples)	not included (no subsurface samples)
2017 SATES Test Plot Characterization	Teck_2017_SATES_PIA	< 2 mm and < 150 µm	total recoverable, partial extraction (multiple types)	included	included	not included (resampling of DUs from previous study[ies])	included (IC and discrete grab)	not included (resampling of DUs from previous study[ies])	not included (resampling of DUs from previous study[ies])	not included (resampling of DUs from previous study[ies])	included	included	not included (assessed quantitatively)
2017–2018 VRA	Teck_2017-18_VRA	unknown	total recoverable	not included (pre-removal resampling of DUs from previous studies; post removal)	included	not included (pre-removal resampling of DUs from previous studies; post removal)	not included (sample locations)	not included (pre-removal resampling of DUs from previous studies; post removal)	not included (no IVBA data)	not included (pre-removal resampling of DUs from previous studies; post removal)	not included (pre-removal resampling of DUs from previous studies; post removal)	not included (pre-removal resampling of DUs from previous studies; post removal)	not included (pre-removal resampling of DUs from previous studies; post removal)
2015 TCRA Memorandum	USEPA_2015_TCRASoil	unknown	total recoverable	not included (pre-removal resampling of DUs from previous studies; post removal)	included	not included (pre-removal resampling of DUs from previous studies; post removal)	included (discrete grab)	not included (pre-removal resampling of DUs from previous studies; post removal)	not included (no IVBA data)	not included (pre-removal resampling of DUs from previous studies; post removal)	not included (pre-removal resampling of DUs from previous studies; post removal)	not included (pre-removal resampling of DUs from previous studies; post removal)	not included (pre-removal resampling of DUs from previous studies; post removal)
2015 TCRA		< 2 mm (per UCR Database)	total recoverable [c]										
2011 Port of Entry Soil Remediation	SHANN11A	unknown	total recoverable [c]	not included (post removal)	included	not included (post removal)	not included (study did not collect multiple samples in small-scale areas)	not included (post removal)	not included (no IVBA data)	not included (post removal)	not included (assessed qualitatively)	not included (assessed qualitatively)	included (discrete post-removal)

Table 6-2. Data Used for the Statistical and Nature and Extent Evaluations

Abbreviated Study Name	UCR RI/FS Database Study ID	Grain Size(s)	Sample Preparation Method Type	Digital Data Exploration Tool [a]	Exploratory Data Analysis [a]	GAM [a,b]	Small-Scale Variability Analyses [a,b]	Post Maps [a]	RBA-Adjusted Lead Data Post Map [a,b]	Interpolated Maps [a,b] (Geostatistical Model)	Vertical Nature and Extent Surface Enrichment Ratios [b]	Vertical Nature and Extent Soil Core Profiles [b]	Vertical Nature and Extent Qualitative Assessment of Subsurface Data [b]
United States Studies (continued)													
2003–2004 EPA Anderson Calhoun EE/CA	ACMINESITE2007	unknown	unknown	included	included	not included (non smelter source)	not included (study did not collect multiple samples in small-scale areas)	included	not included (no IVBA data)	not included [d]	not included (no subsurface samples)	not included (no subsurface samples)	not included (no subsurface samples)
2014–2015 Ecology Van Stone FS	FS1554858	< 2 mm	total recoverable [c]	not included (no surface samples)	not included (no surface samples)	not included (non smelter source)	not included (study did not collect multiple samples in small-scale areas)	not included (no surface samples)	not included (no IVBA data)	not included (no surface samples)	not included (separate cleanup action)	not included (separate cleanup action)	not included (separate cleanup action)
2011–2012 Ecology Van Stone RI	HARTC13C	< 2 mm	total recoverable [c]	included	included	not included (non smelter source)	not included (study did not collect multiple samples in small-scale areas)	included (composites and discrete grab samples)	not included (no IVBA data)	not included [d]	not included (no subsurface samples; separate cleanup action)	not included (no subsurface samples; separate cleanup action)	not included (no subsurface samples; separate cleanup action)
2004 EPA Le Roi Smelter Removal Action	LeRoi2005	unknown	total recoverable [c]	included	included	included	not included (study did not collect multiple samples in small-scale areas)	included	not included (no IVBA data)	included	included (5-point composite)	included (5-point composite)	not included (assessed quantitatively)
2015 Bossburg Study	Teck_2015_Bossburg	< 2 mm, < 150 µm	total recoverable, partial extraction (IVBA)	included	included	not included (non smelter source)	not included (study did not collect multiple samples in small-scale areas)	included (composites and discrete grab samples; < 2 mm samples only; all triplicates mapped)	included	included	included	included	not included (assessed quantitatively)
WDNR Young America Mine Site Characterization	WADNR2008	unknown	total recoverable [c]	not included (sample depths not specified)	not included (sample depths not specified)	not included (non smelter source)	not included (study did not collect multiple samples in small-scale areas)	not included (sample depths not specified)	not included (no IVBA data)	not included [d]	not included (sample depths not specified)	not included (sample depths not specified)	not included (sample depths not specified)
2011 EPA Young America Mine Removal Assessment	USEPA_2012_YAM	unknown	total recoverable	not included (sample depths not specified)	not included (sample depths not specified)	not included (non smelter source)	not included (study did not collect multiple samples in small-scale areas)	not included (sample depths not specified)	not included (no IVBA data)	not included [d]	not included (sample depths not specified)	not included (sample depths not specified)	not included (sample depths not specified)
2001 EPA Stevens County Mines and Mills PA/SI	USEPA2001Mines_Mills	unknown	total recoverable [c]	included	included	included [e]	not included (study did not collect multiple samples in small-scale areas)	included	not included (no IVBA data)	included [f]	not included (no subsurface samples)	not included (no subsurface samples)	not included (no subsurface samples)
USGS NURE Sample Reanalysis	geochem-fU53	< 150 µm (per UCR Database)	other	included	included	not included (total digestion)	not included (study did not collect multiple samples in small-scale areas)	included	not included (no IVBA data)	not included (total digestion)	not included (no subsurface samples)	not included (no subsurface samples)	not included (no subsurface samples)
USGS Reformatted NURE-HSSR Program	NURE Seds Soil Only	< 150 µm	total digestion, INAA	included	included	not included (total digestion)	not included (study did not collect multiple samples in small-scale areas)	included	not included (no IVBA data)	not included (total digestion)	not included (no subsurface samples)	not included (no subsurface samples)	not included (no subsurface samples)
2007–2010 USGS Soil Study	SMITH13A	sieved to < 2 mm, crushed to < 150 µm (lab)	total digestion	included	included	not included (total digestion)	not included (study did not collect multiple samples in small-scale areas)	included (composites and discrete grab samples)	not included (no IVBA data)	not included (total digestion)	not included (spatially removed from OU 3 Study Area)	not included (spatially removed from OU 3 Study Area)	not included (spatially removed from OU 3 Study Area)
Wells Lichen Study	WELLS15A	< 2 mm	other (loss on ignition before total recoverable digestion)	included	included	not included (total digestion)	not included (study did not collect multiple samples in small-scale areas)	included	not included (no IVBA data)	not included (total digestion)	not included (no subsurface samples)	not included (no subsurface samples)	not included (no subsurface samples)

Table 6-2. Data Used for the Statistical and Nature and Extent Evaluations

Abbreviated Study Name	UCR RI/FS Database Study ID	Grain Size(s)	Sample Preparation Method Type	Digital Data Exploration Tool [a]	Exploratory Data Analysis [a]	GAM [a,b]	Small-Scale Variability Analyses [a,b]	Post Maps [a]	RBA-Adjusted Lead Data Post Map [a,b]	Interpolated Maps [a,b] (Geostatistical Model)	Vertical Nature and Extent Surface Enrichment Ratios [b]	Vertical Nature and Extent Soil Core Profiles [b]	Vertical Nature and Extent Qualitative Assessment of Subsurface Data [b]
Canada Studies													
2001 Trail Area Soil Background Assessment	GOOD01A	< 2 mm (lab)	total recoverable	included	included	not included (spatially removed from river)	not included (in Canada)	not included (in Canada)	not included (in Canada; no IVBA data)	not included (greater than 1 km from U.S.– Canada border)	not included (in Canada)	not included (in Canada)	not included (in Canada)
2001 Trail Area Moss Bag Study	GOODA02A	< 2 mm	total digestion	included	included	not included (total digestion)	not included (in Canada)	not included (in Canada)	not included (in Canada; no IVBA data)	not included (total digestion)	not included (in Canada)	not included (in Canada)	not included (in Canada)
Trail Smelter Terrestrial ERA	Trail ERA	< 2 mm (field)	total recoverable	included	included	included	not included (in Canada)	not included (in Canada)	not included (in Canada; no IVBA data)	included [g]	not included (in Canada)	not included (in Canada)	not included (in Canada)
2005 Waneta Expansion Project	Waneta2005	< 2 mm	total recoverable	included	included	not included (study design/sample type)	not included (in Canada)	not included (in Canada)	not included (in Canada; no IVBA data)	included [g]	not included (in Canada)	not included (in Canada)	not included (in Canada)
Lead Isotope Studies [h]													
2010 Vlassopoulos Expert Report	VLASSOPOULOS2010	NA	NA	not included (sediment)	not included (sediment)	not included (sediment)	not included (sediment)	not included (sediment)	not included (sediment; no IVBA data)	not included (sediment)	not included (sediment)	not included (sediment)	not included (sediment)
2014 Vlassopoulos Expert Report	NA	NA	NA	not included (sediment)	not included (sediment)	not included (sediment)	not included (sediment)	not included (sediment)	not included (sediment; no IVBA data)	not included (sediment)	not included (sediment)	not included (sediment)	not included (sediment)
2010 Riese Expert Report	RIESE2011	NA	NA	not included (sediment)	not included (sediment)	not included (sediment)	not included (sediment)	not included (sediment)	not included (sediment; no IVBA data)	not included (sediment)	not included (sediment)	not included (sediment)	not included (sediment)
2018 Child et al. Isotope Study	NA	NA	NA	not included (sediment)	not included (sediment)	not included (sediment)	not included (sediment)	not included (sediment)	not included (sediment; no IVBA data)	not included (sediment)	not included (sediment)	not included (sediment)	not included (sediment)

Notes:
For data sets that were not included, reasons are provided in parentheses. For data sets that were included, additional information regarding what data or how the data were used is provided in parentheses.
Green shaded cells indicate the study was included in the analysis/map.
[a] Only surface samples were used (i.e., samples with upper depth of 0).
[b] Only samples prepared using a total recoverable method were included.
[c] Sample preparation method type is assumed.
[d] All or some of the samples from this study were mapped as the mines and mills data set.
[e] Only three background soil samples samples from this study were used in the model.
[f] Some samples were included in the model and others were included in the mine and mill data set.
[g] Only samples within 1 km of the U.S. - Canada border were used to inform the model.
[h] Lead isotope studies did not collect soil samples.
ADA - aerial deposition area
DU - decision unit
GAM - generalized additive model
IC - incremental composite
INAA - instrumental neutron activation analysis
IVBA - in vitro bioaccessibility
NA - not applicable
RI - remedial investigation
RBA - relative bioavailability

Table 6-3. Metals Included in the Statistical and Nature and Extent Evaluations

Metal	Human Health COC [a]	Ecological COC [b]	Digital Data Exploration Tool	Exploratory Data Analysis	GAM [d]	Small-Scale Variability Analyses	Post Maps	Interpolated Maps	Vertical Nature and Extent Analyses
Aluminum	no	no	yes	yes	no	no	no	no	no
Antimony	no	no	yes	yes	no	no	no	no	no
Arsenic	yes	yes	yes	yes	yes	no	yes	no	yes
Barium	no	yes	yes	yes	yes	no	yes	no	yes
Beryllium	no	no	yes	yes	no	no	no	no	no
Cadmium	no	yes	yes	yes	yes	yes	yes	yes	yes
Calcium	no	no	yes	yes	no	no	no	no	no
Chromium	no	no	yes	yes	no	no	no	no	no
Cobalt	no	no	yes	yes	no	no	no	no	no
Copper	no	yes	yes	yes	yes	no	yes	no	yes
Iron	no	no	yes	yes	no	no	no	no	no
Lead	yes	yes	yes	yes	yes	yes	yes	yes	yes
Magnesium	no	no	yes	yes	no	no	no	no	no
Manganese	no	yes	yes	yes	yes	no	yes	no	yes
Mercury	no	yes	yes	yes	yes	no	yes	no	yes
Molybdenum	no	no	yes	yes	no	no	no	no	no
Nickel	no	no	yes	yes	no	no	no	no	no
Potassium	no	no	yes	yes	no	no	no	no	no
Selenium	no	yes	yes	yes	yes [c]	no	yes	no	yes
Silver	no	no	yes	yes	no	no	no	no	no
Sodium	no	no	yes	yes	no	no	no	no	no
Thallium	no	no	yes	yes	no	no	no	no	no
Vanadium	no	no	yes	yes	no	no	no	no	no
Zinc	no	yes	yes	yes	yes	yes	yes	yes	yes

Notes:

[a] Human health chemicals of concern (COCs) for upland soil were identified based on the results of the HHRA and the Human Health Remedial Action Objectives for the Upper Columbia River Site (RAOs) (USEPA 2023c).

[b] Ecological COCs were identified in the Upland BERA.

[c] Low detection frequency in Canada.

[d] GAM run for the nine COCs (arsenic, barium, cadmium, copper, lead, manganese, mercury, selenium, and zinc).

Table 6-4. Spearman's Rank Correlation Coefficients for Pairwise Complete Observations Between COCs

Metal	Arsenic	Barium	Cadmium	Copper	Lead	Manganese	Mercury	Selenium	Zinc
Arsenic	1.00	0.04	0.77	0.62	0.82	0.20	0.60	0.34	0.74
Barium	0.04	1.00	0.14	0.26	-0.06	0.68	-0.19	0.36	0.09
Cadmium	0.77	0.14	1.00	0.59	0.90	0.23	0.72	0.51	0.90
Copper	0.62	0.26	0.59	1.00	0.57	0.21	0.42	0.51	0.64
Lead	0.82	-0.06	0.90	0.57	1.00	0.07	0.81	0.27	0.85
Manganese	0.20	0.68	0.23	0.21	0.07	1.00	-0.04	0.28	0.16
Mercury	0.60	-0.19	0.72	0.42	0.81	-0.04	1.00	0.29	0.67
Selenium	0.34	0.36	0.51	0.51	0.27	0.28	0.29	1.00	0.37
Zinc	0.74	0.09	0.90	0.64	0.85	0.16	0.67	0.37	1.00

Note:
COC - chemical of concern

Table 6-5. Variability in Surface Soil Metals Concentrations

Abbreviated Study Name	UCR RI/FS Database Study ID	Replicate Type	Number of DUs or Areas with ≥ 3 Samples	Metal	CV				Notes
					Minimum	Maximum	Mean	Median	
2012 Ecology Upland Soil Study	HARTC13A	composite samples	13 areas	cadmium	0.36	0.95	0.62	0.56	6 to 10 composite samples within each area
				lead	0.33	1.04	0.65	0.67	
				zinc	0.21	0.75	0.51	0.58	
2014 Residential Soil Study	USEPA_2014_ResSoil	IC triplicates and splits	114 DUs	cadmium	0.01	0.44	0.08	0.06	3 to 6 IC samples within each DU
				lead	0.01	0.61	0.10	0.08	
				zinc	0.01	0.38	0.06	0.05	
2014 Soil Study (high density)	Teck_2014_UplandSoil	IC triplicates < 150 µm	6 DUs	cadmium	0.08	0.24	0.14	0.14	
				lead	0.11	0.31	0.19	0.17	
				zinc	0.03	0.18	0.11	0.11	
		IC triplicates < 2 mm	6 DUs	cadmium	0.04	0.25	0.14	0.12	
				lead	0.07	0.35	0.21	0.20	
				zinc	0.04	0.24	0.13	0.12	
2014 Soil Study (primary area)	Teck_2014_UplandSoil	IC triplicates < 150 µm	10 DUs	cadmium	0.07	0.16	0.11	0.10	
				lead	0.05	0.14	0.09	0.10	
				zinc	0.03	0.12	0.07	0.05	
		IC triplicates < 2 mm	10 DUs	cadmium	0.02	0.14	0.09	0.10	
				lead	0.02	0.15	0.09	0.09	
				zinc	0.04	0.12	0.07	0.07	
2015 TCRA	USEPA_2015_TCRASoil	discrete grab samples	5 DUs	lead	0.21	0.67	0.34	0.22	
2016 Residential Soil Study	Teck_2016_ResSoil	IC triplicates and splits	130 DUs	cadmium	0.00	0.28	0.07	0.06	3 to 6 IC samples within each DU
				lead	0.01	0.37	0.07	0.06	
				zinc	0.00	0.26	0.06	0.05	
		discrete grab samples	28 DUs	cadmium	0.15	1.03	0.43	0.38	3 to 5 discrete grab samples within each DU
				lead	0.17	1.04	0.49	0.41	
				zinc	0.08	0.92	0.30	0.24	

Table 6-5. Variability in Surface Soil Metals Concentrations

Abbreviated Study Name	UCR RI/FS Database Study ID	Replicate Type	Number of DUs or Areas with ≥ 3 Samples	Metal	CV				Notes
					Minimum	Maximum	Mean	Median	
2017 SATES Test Plot Characterization	Teck_2017_SATES_PIA	IC samples	3 DUs	cadmium	0.24	0.53	0.40	0.42	8 to 16 IC samples within each DU
				lead	0.22	0.55	0.39	0.39	
				zinc	0.29	0.50	0.38	0.36	
		discrete grab samples	3 DUs	cadmium	0.43	0.97	0.66	0.59	103 to 304 discrete grab samples within each DU
				lead	0.55	0.86	0.74	0.81	
				zinc	0.28	0.75	0.47	0.37	
2018 Plant Tissue Study	Teck_2017_PlantTissue	composite samples	6 DUs	cadmium	0.10	0.35	0.22	0.24	3 to 11 composite samples within each DU
				lead	0.27	0.47	0.33	0.30	
				zinc	0.19	0.60	0.33	0.24	
		discrete grab samples	8 DUs	cadmium	0.34	0.71	0.51	0.51	3 to 22 discrete grab samples within each DU
				lead	0.28	0.84	0.55	0.52	
				zinc	0.23	0.68	0.43	0.41	

Notes:

CV - coefficient of variation

DU - decision unit

IC - incremental composite

Table 6-6. Variability in Surface Soil Metals Concentrations Within Residential Properties and Tribal Allotments

Abbreviated Study Name	UCR RI/FS Database Study ID	Sample Type	Number of Properties with ≥ 3 DUs	Metal	CV				Notes
					Minimum	Maximum	Mean	Median	
2014 Residential Soil Study	USEPA_2014_ResSoil	IC samples	23	cadmium	0.18	0.84	0.44	0.42	3 to 11 DUs within each residential property and tribal allotment
				lead	0.17	0.91	0.48	0.43	
				zinc	0.10	0.73	0.30	0.26	
2016 Residential Soil Study	Teck_2016_ResSoil	IC samples	70	cadmium	0.03	0.91	0.36	0.37	3 to 9 DUs within each residential property and tribal allotment
				lead	0.04	1.07	0.37	0.36	
				zinc	0.03	1.03	0.26	0.24	

Notes:

CV - coefficient of variation

DU - decision unit

IC - incremental composite

Table 6-7. Summary Statistics for the Data Used in the Areal Nature and Extent Evaluation

OU 3 Data Subset	Number of Samples	Percent of Samples with Detected Results	Soil Metal Concentration (mg/kg)					BTV	Bin 1 [a]		Bin 2		Bin 3		Bin 4		Bin 5		Bin 6		Bin 7		Concentrations Greater Than or Equal to BTV	
			Minimum	Average	Standard Deviation	Median	Maximum		Number of Samples	Percent of Samples	Number of Samples	Percent of Samples	Number of Samples	Percent of Samples	Number of Samples	Percent of Samples	Number of Samples	Percent of Samples	Number of Samples	Percent of Samples	Number of Samples	Percent of Samples	Number of Samples	Percent of Samples
Arsenic																								
Total recoverable (grain size < 2 mm)	498	100	0.5	11.7	8.26	10.8	55.5	23.3	456	92	14 [b]	3	13	3	6	1	8	2	1	0.2	NA	NA	42	8
Total recoverable (grain size < 150 µm)	1,192	100	2.25	13.6	13.1	10.2	151	23.3	1,069	90	19 [b]	2	24	2	24	2	28	2	28	2	NA	NA	123	10
Total recoverable (grain size unknown)	341	97	0.96	18.7	27.8	10.7	297	23.3	277	81	8 [b]	2	5	1	11	3	21	6	19	6	NA	NA	64	19
Total digestion	3	100	2	7.43	4.78	9.30	11	12.0	3	100	0 [b]	0	0	0	0	0	0	0	0	0	NA	NA	0	0
Barium																								
Total recoverable (grain size < 2 mm)	316	100	34.8	327	259	268	2,590	395	229	72	21 [b]	7	18	6	19	6	20	6	9	3	NA	NA	87	28
Total recoverable (grain size < 150 µm)	1,191	100	45.3	189	151	173	4,690	395	1,171	98	5 [b]	0.4	4	0.3	4	0.3	6	0.5	1	0.1	NA	NA	20	2
Total recoverable (grain size unknown)	119	99	1.4	8,310	25,900	82.5	122,000	395	95	80	0 [b]	0	2	2	2	2	2	2	18	15	NA	NA	24	20
Total digestion	2	100	260	625	516	625	990	722	1 [b]	50	0	0	0	0	0	0	0	0	1	50	NA	NA	1	50
Cadmium																								
Total recoverable (grain size < 2 mm)	498	100	0.046	6.35	13.0	3.53	180	0.74	94	19	166	33	54 [b]	11	63	13	118	24	3	0.6	NA	NA	404	81
Total recoverable (grain size < 150 µm)	1,191	100	0.263	3.70	3.98	2.55	45.6	0.74	50	4	796	67	138 [b]	12	79	7	128	11	0	0	NA	NA	1,141	96
Total recoverable (grain size unknown)	366	96	0.05	32.8	108	5.20	1,090	0.74	22	6	126	34	41 [b]	11	32	9	109	30	36	10	NA	NA	344	94
Total digestion	10	90	0.027	3.27	4.58	1.42	12.465	0.54	2	20	6	60	0 [b]	0	0	0	2	20	0	0	NA	NA	8	80
Copper																								
Total recoverable (grain size < 2 mm)	498	94	0.78	23.3	36.4	18.2	640	41.5	457	92	12 [b]	2	8	2	7	1	8	2	6	1	NA	NA	41	8
Total recoverable (grain size < 150 µm)	1,191	100	7.57	25.4	15.1	21.2	118	41.5	1,068	90	45 [b]	4	33	3	17	1	28	2	0	0	NA	NA	123	10
Total recoverable (grain size unknown)	366	100	3.5	143	822	49.4	14,700	41.5	168	46	14 [b]	4	26	7	32	9	58	16	68	19	NA	NA	198	54
Total digestion	11	100	2.09	13.7	10.4	11.0	34.6	37.0	11	100	0 [b]	0	0	0	0	0	0	0	0	0	NA	NA	0	0
Lead																								
Total recoverable (grain size < 2 mm)	498	100	2.6	474	1,960	150	26,000	27.2	98	20	88	18	102 [b]	20	115	23	54	11	29	6	12	2	400	80
Total recoverable (grain size < 150 µm)	1,192	100	8.9	173	241	98.7	1,920	27.2	51	4	554	46	325 [b]	27	160	13	54	5	48	4	0	0	1,141	96
Total recoverable (grain size unknown)	366	100	6.8	4,200	18,600	240	181,000	27.2	29	8	82	22	54 [b]	15	60	16	44	12	46	13	51	14	337	92
Total digestion	11	100	24.1	62.3	32.3	53.7	129.77	30.0	1	9	9	82	1 [b]	9	0	0	0	0	0	0	0	0	10	91
Lead (RBA-adjusted)	1,596	100	8.9	194	266	115	3,770	27.2	55	3	646	40	455 [b]	29	286	18	93	6	60	4	1	0.1	1,541	97
Manganese																								
Total recoverable (grain size < 2 mm)	316	100	43.6	987	666	860	5,920	1240	238	75	15 [b]	5	15	5	14	4	17	5	17	5	NA	NA	78	25
Total recoverable (grain size < 150 µm)	1,191	100	175	511	195	485	1,860	1240	1,181	99	4 [b]	0.3	3	0.3	1	0.1	2	0.2	0	0	NA	NA	10	1
Total recoverable (grain size unknown)	94	100	30.3	878	2,320	286	14,800	1240	84	89	0 [b]	0.0	1	1	1	1	2	2	6	6	NA	NA	10	11
Total digestion	132	99	20	905	374	810	3,107.2	1380	120 [b]	91	0	0.0	2	2	4	3	5	4	1	0.8	NA	NA	12	9
Mercury																								
Total recoverable (grain size < 2 mm)	492	98	0.0042	0.095	0.189	0.066	2.8	0.12	410	83	29 [b]	6	27	5	11	2	12	2	3	1	NA	NA	82	17
Total recoverable (grain size unknown)	110	80	0.04	1.08	3.14	0.265	26.4	0.12	39	35	5 [b]	5	5	5	11	10	23	21	27	25	NA	NA	71	65
Total digestion	1	100	0.03	0.03	NA	0.03	0.03	0.12	1	100	0 [b]	0	0	0	0	0	0	0	0	0	NA	NA	0	0
Selenium																								
Total recoverable (grain size < 2 mm)	492	71	0.1	0.432	0.358	0.380	5.2	0.098	0	0	52	11	81	16	103	21	181	37	75 [b]	15	NA	NA	492	100
Total recoverable (grain size < 150 µm)	1,191	100	0.08	0.373	0.325	0.280	5.76	0.098	3	0.3	258	22	282	24	262	22	166	14	220 [b]	18	NA	NA	1,188	99.8
Total recoverable (grain size unknown)	119	33	0.69	3.15	5.67	0.900	35	0.098	0	0	0	0	0	0	0	0	0	0	119 [b]	100	NA	NA	119	100
Total digestion	2	50	0.2	0.600	0.566	0.600	1	3.0	2 [b]	100	0	0	0	0	0	0	0	0	0	0	NA	NA	0	0
Zinc																								
Total recoverable (grain size < 2 mm)	498	98	8.1	947	3,150	238	37,000	111	102	20	125 [b]	25	122	25	87	17	57	11	5	1	NA	NA	396	80
Total recoverable (grain size < 150 µm)	1,191	100	41.1	221	174	171	1,900	111	253	21	549 [b]	46	247	21	136	11	6	1	0	0	NA	NA	938	79
Total recoverable (grain size unknown)	135	100	30.1	20,700	49,900	4,680	431,000	111	15	11	17 [b]	13	7	5	15	11	36	27	45	33	NA	NA	120	89
Total digestion	11	100	52.3	231	258	120	909.53	99.0	2	18	7 [b]	64	0	0	2	18	0	0	0	0	NA	NA	9	82

Notes:

Binning for each COC is defined in Section 6.3

Where the lowest ecological risk-based concentraion (RBC) is lower than the background threshold value (BTV), the BTV represents the lowest ecological RBC.

Percentages are rounded and may not add up to 100%.

For a geographical representation of this data see Map 6-5, Map 6-9, Map 6-12, Map 6-15 through Map 6-20.

[a] Bin 1 represents samples less than the BTV.

[b] Lowest bin with samples greater than or equal to the lowest ecological RBC.

NA - not applicable

Table 6-8. Ecological RBC Exceedances

		Samples Used in the Geostatistical Model				Mine and Mill Samples		
COC	Lowest Ecological RBC [a] (mg/kg)	Number of Samples Analyzed for Each COC	Number of Samples That Exceed the Lowest Ecological RBC	Number of Samples That Exceed the Lowest Ecological RBC Without a Modeled Zinc Ecological RBC Exceedance	Percent of Samples That Exceed the Lowest Ecological RBC Without a Modeled Zinc Ecological RBC Exceedance	Number of Samples Analyzed for Each COC	Number of Samples That Exceed the Lowest Ecological RBC	Number of Samples That Exceed the Lowest Ecological RBC Without a Measured Zinc Ecological RBC Exceedance
Arsenic	23.3	1,080	123	0	0	276	32	0
Barium	395	818	88	0	0	125	22	0
Cadmium	3.74	1,080	442	3	1	300	149	0
Copper	41.5	1,080	217	4	2	300	80	1
Lead	106	1,080	614	4	1	300	150	0
Manganese	1,240	818	72	0	0	101	14	0
Mercury	0.12	286	38	1	3	264	102	1
Selenium	0.503	829	159 [b]	13 [c]	8	282	143 [d]	18 [e]
Zinc	111	849	707	NA	NA	300	217	NA

Notes:

[a] The lowest ecological risk-based concentration (RBC) was selected from the range of relevant receptors for each ecological chemical of concern (COC) (see Table 5-14). In the case where the lowest ecological RBC was less than the backgr threshold value (BTV), the BTV was selected as the lowest ecological RBC.

[b] Eight selenium results that exceed the ecological RBC are nondetected values.

[c] One selenium result that exceeds the ecological RBC without a modeled zinc ecological RBC exceedance is a nondetected value.

[d] Seventy-eight selenium results that exceed the ecological RBC are nondetected values.

[e] Three selenium results that exceed the ecological RBC without a measured zinc ecological RBC exceedance are nondetected values.

NA - not applicable

Table 6-9. Summary Statistics for Data Used in the Surface-to-Subsurface Soil Concentration Ratio Vertical Nature and Extent Evaluation

Metal	Sampling Depth	Number of Samples	Percent of Detected Results	Soil Concentration (mg/kg)					BTV (mg/kg)	Number of Samples with Concentration > BTV	Percent of Samples with Concentration > BTV
				Minimum	Average	Standard Deviation	Median	Maximum			
Arsenic	surface	405	100	1.9	15.4	16.4	9.90	151	23.3	66	16
	subsurface	405	100	1.2	15.7	14.8	11.0	164	23.3	72	18
Barium	surface	237	100	48	200	303	168	4690	395	6	3
	subsurface	238	100	40.9	185	83.9	173	768	395	3	1
Cadmium	surface	405	99	0.25	5.16	6.06	3.10	59.3	0.74	371	92
	subsurface	405	98	0.091	4.20	4.11	2.80	21.9	0.74	350	86
Copper	surface	405	100	5.8	50.0	85.1	26.7	1,400	41.5	131	32
	subsurface	405	100	6.7	49.5	60.5	25.0	386	41.5	121	30
Lead	surface	405	100	9.03	283	362	132	1,920	27.2	376	93
	subsurface	405	100	5.1	205	264	110	2,560	27.2	357	88
Manganese	surface	237	100	177	538	421	479	5,920	1,240	5	2
	subsurface	237	100	175	543	317	482	3,590	1,240	6	3
Mercury	surface	29	100	0.013	0.120	0.160	0.062	0.708	0.12	8	28
	subsurface	29	100	0.011	0.070	0.120	0.029	0.656	0.12	4	14
Selenium	surface	237	95	0.08	0.610	0.980	0.270	5.76	0.098	235	99
	subsurface	238	95	0.08	0.580	0.890	0.280	6.84	0.098	236	99
Zinc	surface	237	100	43.1	238	204	167	1,520	111	173	73
	subsurface	238	100	36.1	187	144	144	914	111	152	64

Note:

BTV - background threshold value

Table 6-10. Surface-to-Subsurface Soil Concentration Ratios of Metals by Study

Abbreviated Study Name	Analyte	Mean Ratio (Surface: Subsurface)	95% CI on Mean Ratio	p-value [a]	Minimum Ratio	Maximum Ratio
2012 Ecology Upland Soil Study	arsenic	**1.13**	1.01 to 1.26	0.032	0.83	1.70
	barium	1.04	0.98 to 1.12	0.184	0.80	1.24
	cadmium	**1.55**	1.29 to 1.85	<0.001	0.93	2.91
	copper	1.02	0.93 to 1.12	0.611	0.80	1.45
	lead	**1.67**	1.28 to 2.17	<0.001	0.73	4.98
	manganese	**1.15**	1.04 to 1.27	0.009	0.96	1.78
	mercury	**1.33**	1.11 to 1.59	0.004	0.89	2.75
	selenium	1.00	0.99 to 1.00	0.308	0.97	1.00
	zinc	**1.27**	1.14 to 1.41	<0.001	0.97	1.79
2014 Residential Soil Study	arsenic	1.03	0.99 to 1.07	0.177	0.73	1.61
	barium	0.99	0.97 to 1.01	0.180	0.85	1.18
	cadmium	**1.20**	1.14 to 1.27	<0.001	0.58	1.77
	copper	**1.05**	1.02 to 1.08	0.003	0.85	1.46
	lead	**1.30**	1.20 to 1.40	<0.001	0.59	2.53
	manganese	1.00	0.98 to 1.03	0.894	0.75	1.17
	mercury	N/A	N/A	N/A	N/A	N/A
	selenium	**1.03**	1.00 to 1.06	0.029	0.92	1.31
	zinc	**1.13**	1.10 to 1.16	<0.001	0.78	1.42
2015 Bossburg Study	arsenic	**1.08**	1.01 to 1.17	0.030	0.88	1.62
	barium	1.01	0.97 to 1.04	0.599	0.91	1.18
	cadmium	**1.25**	1.06 to 1.46	0.009	0.95	2.91
	copper	**1.05**	1.00 to 1.10	0.037	0.96	1.36
	lead	**1.27**	1.10 to 1.47	0.003	0.93	2.13
	manganese	1.02	0.98 to 1.07	0.318	0.83	1.25
	mercury	**1.25**	1.08 to 1.44	0.005	0.86	2.32
	selenium	1.03	0.97 to 1.08	0.316	0.89	1.40
	zinc	**1.17**	1.07 to 1.27	0.002	0.97	1.72
2016 Residential Soil Study	arsenic	**0.97**	0.95 to 0.99	0.006	0.72	1.66
	barium	0.99	0.98 to 1.00	0.168	0.83	2.19
	cadmium	**1.04**	1.01 to 1.08	0.014	0.43	3.39
	copper	1.00	0.98 to 1.01	0.744	0.85	1.70
	lead	**1.06**	1.02 to 1.1.0	0.006	0.57	3.83
	manganese	**0.97**	0.95 to 0.98	<0.001	0.66	1.18
	mercury	N/A	N/A	N/A	N/A	N/A
	selenium	0.98	0.95 to 1.00	0.062	0.53	1.73
	zinc	**1.04**	1.02 to 1.07	<0.001	0.68	2.12

Table 6-10. Surface-to-Subsurface Soil Concentration Ratios of Metals by Study

Abbreviated Study Name	Analyte	Mean Ratio (Surface: Subsurface)	95% CI on Mean Ratio	p-value [a]	Minimum Ratio	Maximum Ratio
2014 Residential Soil Study, 2016 Residential Soil Study, and 2004 EPA Le Roi Smelter Removal Action combined	arsenic	**0.97**	0.95 to 0.98	<0.001	0.48	1.95
	barium	0.99	0.98 to 1.00	0.073	0.83	2.19
	cadmium	**1.06**	1.04 to 1.09	<0.001	0.43	3.39
	copper	0.99	0.98 to 1.01	0.482	0.52	2.32
	lead	**1.09**	1.06 to 1.12	<0.001	0.17	3.83
	manganese	**0.98**	0.96 to 0.99	<0.001	0.66	1.18
	mercury	N/A	N/A	N/A	N/A	N/A
	selenium	0.99	0.97 to 1.01	0.368	0.53	1.73
	zinc	**1.07**	1.05 to 1.09	<0.001	0.68	2.12
2017 SATES Test Plot Characterization	arsenic	**1.20**	1.03 to 1.40	0.022	0.69	2.36
	barium	0.98	0.93 to 1.04	0.485	0.77	1.12
	cadmium	**1.40**	1.17 to 1.67	<0.001	0.71	2.49
	copper	**1.19**	1.10 to 1.29	<0.001	0.89	1.55
	lead	**1.72**	1.32 to 2.23	<0.001	0.66	3.35
	manganese	1.03	0.97 to 1.09	0.321	0.84	1.25
	mercury	N/A	N/A	N/A	N/A	N/A
	selenium	1.06	1.00 to 1.13	0.067	0.83	1.30
	zinc	**1.15**	1.01 to 1.31	0.036	0.74	1.85
2004 EPA Le Roi Smelter Removal Action	arsenic	**0.94**	0.92 to 0.97	<0.001	0.48	1.95
	barium	N/A	N/A	N/A	N/A	N/A
	cadmium	1.04	1.00 to 1.07	0.066	0.51	2.62
	copper	0.98	0.95 to 1.00	0.100	0.52	2.32
	lead	**1.05**	1.00 to 1.10	0.032	0.17	3.14
	manganese	N/A	N/A	N/A	N/A	N/A
	mercury	N/A	N/A	N/A	N/A	N/A
	selenium	N/A	N/A	N/A	N/A	N/A
	zinc	N/A	N/A	N/A	N/A	N/A

Notes:

The null hypothesis is ratio = 1.

Ratios are calculated as the log10 surface concentration divided by log10 subsurface concentration.

Red values indicate that the surface concentration is greater than the subsurface concentration (ratio > 1).

Blue values indicate that the surface concentration is less than the subsurface concentration (ratio < 1).

Bolded values indicate that the difference between surface and subsurface concentrations is statistically significant.

A p-value < 0.05 is considered statistically significant.

[a] Probability p-values were calculated using likelihood ratio tests from linear mixed effects models to control for replication at the same location.

CI - confidence interval

N/A - not analyzed

Table 6-11. TCRA and VRA Vertical Extent Average Soil Lead Concentrations

DU	Concentration (mg/kg) Surface	Subsurface (1 to 6 in. Depth)	Subsurface (> 6 in.Depth)	Notes
Parcel Number [redacted]				
7	908	308	28	
HIC-A [a]	215	ns	16	These DUs were added during the removal action, either as decided by EPA or requested by the property owner.
HIC-B [a]	ns	ns	44	
Parcel Number [redacted]				
18	677	619	40	
20	68	ns	ns	A removal action was completed at DU 20 concurrently with the TCRA completed at DU 18.
Parcel Number [redacted]				
35	950	364	64	
35PA	1,224	200	64	
39	585	9	20	
Parcel Number [redacted]				
40	423	400	22	
Parcel Number [redacted]				
49	1,289	880	357	
Parcel Number [redacted]				
109	818	550	15	
Parcel Number [redacted]				
151	786	139	68	
Parcel Number [redacted]				
194	689	518	15	
1021	1,285	ns	28	Prior to the start of removal activities, DU 1021 was removed from the list of DUs designated for removal action at the request of the property owner.
HUB	234	ns	119	This DU was added during the removal action, either as decided by EPA or requested by the property owner.
Parcel Number [redacted]				
201G	594	409	66	

Table 6-11. TCRA and VRA Vertical Extent Average Soil Lead Concentrations

DU	Concentration (mg/kg) Surface	Subsurface (1 to 6 in. Depth)	Subsurface (> 6 in.Depth)	Notes
Parcel Number [redacted]				
203	793	326	47	
DEA-A [a]	124	62	63	These DUs were added during the removal action, either as decided by EPA or requested by the property owner.
DEA-B [a]	291	ns	7	
DEA-C [a]	329	ns	17	
Parcel Number [redacted]				
218	740	142	38	
ROY[a]	628	ns	20	This DU was added during the removal action, either as decided by EPA or requested by the property owner.
Parcel Number [redacted]				
319M	854	ns	40	
Parcel Number [redacted]				
196	1,585	287	ns	DU 196 was expanded to include KNI-A/B during the 2015 preremoval assessment.
KNI-A/B	298	160	49	
KNI-C [a]	312	ns	16	
KNI-D [a]	ns	375	283	
Parcel Number [redacted]				
412	480	ns	ns	As part of the 2015 removal site evaluation, three new DUs were identified at this property: TA-195A, TA-195B, and TA-195C.
TA-195A	222	ns	44	2015 ASAOC, Section III 8.x.: "Tribal Allotment 151-H 195" shall mean a tribal allotment described in a Workplan, but not in the Action Memorandum. Tribal Allotment 151-H 195 is also referred to as Tribal Allotment H-195. Two of the three DUs in Tribal Allotment 151-H 195 are being addressed by this removal action and are referred to as TA 195-A and TA 195-B. TAI has agreed to conduct removal actions on these DUs notwithstanding the fact that the lead levels are below the action level established by the 2015 TCRA Memorandum.
TA-195B	450	ns	88	

Table 6-11. TCRA and VRA Vertical Extent Average Soil Lead Concentrations

DU	Concentration (mg/kg) Surface	Subsurface (1 to 6 in. Depth)	Subsurface (> 6 in.Depth)	Notes
Parcel Number [redacted]				
170	1,111	172	9	Prior to the start of 2015 removal activities, DU 170 was removed from the list of DUs identified for a TCRA at the request of the property owner, but it was added back to the list of 2018 VRAs at the request of the property owner.
1030	642	ns	7	
1030-SU-A [b]	37	ns	ns	
1030-SU-B [b]	17	ns	ns	
1030-SU-C [b]	16	ns	ns	
1030-SU-D [b]	17	ns	5	
140-H1	723	ns	7	
140-O2	917	ns	10	
Parcel Number [redacted]				
180-H2	637	ns	14	
Parcel Number [redacted]				
109-H1	707	ns	11	
Parcel Number [redacted]				
203-H1	1,066	ns	45	
203-O1	1,256	424	14	
203-O3 [c]	1,480	ns	17	This DU was added during the removal action, either as decided by EPA or requested by the property owner. In 2018, per EPA approval, TAI divided DU 203-O3 into four SUs (203-O4-A, -B, -C, and -D) and performed IC sampling. Results were such that all four SUs were above the VRA action level; therefore, TAI conducted a VRA on the entire DU 203-O3.
203-O4 [c]	1,133	ns	28	This DU was added during the removal action, either as decided by EPA or requested by the property owner. In 2018, per EPA approval, TAI divided DU 203-O4 into two SUs (203-O4-A and -B) and performed IC sampling. Results were such that both SUs were above the VRA action level; therefore, TAI conducted a VRA on the entire DU 203-O4.

Table 6-11. TCRA and VRA Vertical Extent Average Soil Lead Concentrations

DU	Concentration (mg/kg) Surface	Subsurface (1 to 6 in. Depth)	Subsurface (> 6 in.Depth)	Notes
Parcel Number [redacted] (continued)				
203-O5 [c]	483	ns	ns	This DU was added during the removal action, either as decided by EPA or requested by the property owner. In 2018, per EPA approval, TAI divided DU 203-O5 into three SUs (203-O5-A, -B, and -C) and performed IC sampling. Results were such that all SUs were below the VRA action level; therefore, TAI did not conduct a VRA at DU 203-O5.
Total DUs				
	653	334	49	

Notes:

[a] Decision unit (DU) is included in this table but not included in the HHRA. TAI has informed EPA of this discrepancy.

[b] DU 1030 was divided into approximately equal-sized sampling units (SUs), 1030-SU-A, SU-B, SU-C, and SU-D, and sampled using incremental composite (IC) sampling methods. 1030-SU-A had lead concentrations above the voluntary removal action (VRA) level of 600 mg/kg and had a removal action completed. The three remaining DUs had concentrations below the action level and were not subject to VRAs. The HHRA may have reported the full DU 1030 (and associated area) as having a VRA completed, potentially omitting the remaining SUs (and associated data). TAI has informed EPA of this discrepancy.

[c] Three new DUs, 203-O3, 203-O4, and 203-O5, were added and sampled in May 2018. Two of the three DUs (203-O3 and 203-O4) had soil lead concentrations above the VRA action level of 600 mg/kg and had VRAs performed; however, DU 203-O5 results were below the VRA action level and no VRA was performed. The HHRA included DUs 203-O3 and 203-O4 but not DU 203-O5. TAI has informed EPA of this discrepancy.

ASAOC - Administrative Settlement Agreement and Order on Consent for Removal Action

ns - not sampled

TCRA - time-critical removal action