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Revision 0

Study Plan to Evaluate Radionuclide Biomobilization in Opportunistically Identified Contaminated Deep-Rooted Vegetation in the Hanford Site Central Plateau

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

P.O. Box 550
Richland, Washington 99352

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Title: *Study Plan to Evaluate Radionuclide Biomobilization in Opportunistically Identified Contaminated Deep-Rooted Vegetation in the Hanford Site Central Plateau*

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Acknowledgement

This study plan represents the efforts of dozens of individuals. Specifically, this study design was the initial idea of Dr. James A. Hansen. As the CERCLA Record of Decision Manager for the Department of Energy, Richland Operations Office, Dr. Hansen was responsible for supporting DOE leadership with key cleanup decisions. He sought ways to ensure DOE follows regulations and guidance, always on a solid scientific foundation while being efficient with tax-payer funded projects. Dr. Hansen passed away in May of 2019 and this report honors his memory and his contributions to the Hanford Site cleanup mission during his tenure with the DOE.

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Terms

ALARA	as low as reasonably achievable
BTR	buyer's technical representative
CEC	cation exchange capacity
DOE	U.S. Department of Energy
DOE-RL	U.S. Department of Energy, Richland Operations Office
DOT	U.S. Department of Transportation
DQA	data quality assessment
DQI	data quality indicator
DQO	data quality objective
DUP	laboratory sample duplicate
EB	equipment blank
ECO	environmental compliance officer
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
FS	feasibility study
FSO	field sample operations
FSP	field sampling plan
FWS	field work supervisor
GPL	geophysical logging
GPS	global positioning system
HASQARD	*Hanford Analytical Services Quality Assurance Requirements Document*
HEIS	Hanford Environmental Information System
IATA	International Air Transportation Association
IDW	investigation-derived waste
LCS	laboratory control sample
LOE	line of evidence
MB	method blank
MDA	minimum detectable activity
MS	matrix spike
MSA	Mission Support Alliance
MSD	matrix spike duplicate

MTCA	Model Toxics Control Act
OU	operable unit
PRC	Plateau Remediation Contractor
PSQ	principal study question
QA	quality assurance
QAPjP	quality assurance project plan
QC	quality control
RCO	radiological control organization
RCT	radiological control technician
SAF	sample authorization form
SMR	Sample Management and Reporting
SPLIT	field split sample
SUR	Surrogate
TOC	total organic carbon
WIDS	Waste Information Data System

1 Introduction

Radioactively contaminated vegetation is identified in Hanford Site operational areas during routine radiation surveys conducted by the Plateau Remediation Contractor (PRC) radiation control organization (RCO). Typically, contaminated vegetation is removed for disposal following identification. This Study Plan provides the quality assurance project plan (QAPjP) and field sampling requirements to characterize vertical radionuclide biomobilization[1] in several deep-rooted vegetation species and collocated soil within the shallow (0 to 4.9 m [0 to 16 ft])[2] vadose zone of Hanford Site Central Plateau operational areas. Operational areas regularly monitored by RCOs on the Central Plateau are in 200 East, 200 West, and the 600 Area (Figure 1-1).

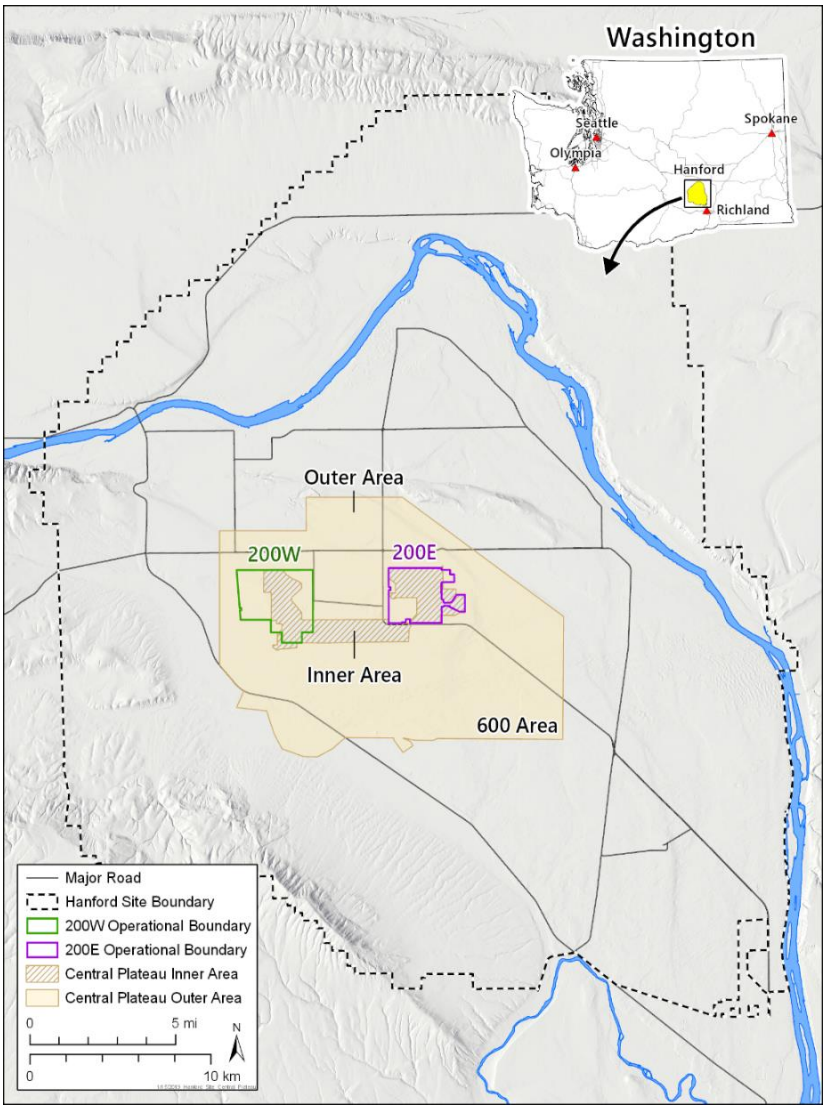

Figure 1-1. Hanford Site

[1] Vertical biomobilization is defined as radiological contaminant movement through the soil column to the soil surface via varying mechanisms that include vegetation uptake and translocation, animal burrowing, and invertebrate burrowing.

[2] The shallow Hanford Site vadose zone comprises 0 to 4.6 m (0 to 15 ft); however, in this Study Plan where soil and root sampling will occur 0.3 m (1 ft) deeper, the term shallow vadose zone is used synonymously, referring to both 0 to 4.6 m and 0 to 4.9 m.

This study represents the first of a number of complimentary biomobilization lines of evidence (LOEs) evaluating the factors associated with vertical biomobilization of soil radionuclides by key biota on the Hanford Central Plateau. Other biomobilization LOE studies will be documented in future Study Plans.

1.1 Study Scope and Need

In this study, RCOs will work closely with the biomobilization team to identify and remove characterization specimens of several targeted species of deep-rooted vegetation opportunistically[3] identified during routine monitoring and surveillance activities on the Central Plateau. Targeted deep-rooted vegetation species in this study include the annual forbs Russian thistle (*Salsola kali*) and tumble mustard (*Sisymbrium altissimum*); and the perennials sagebrush (*Artemisia tridentata*), antelope bitterbrush (*Purshia tridentata*), and gray or green rabbitbrush (*Ericameria nauseosa*, *Chrysothamnus viscidiflorus*).

Collocated depth discretized soil cores from each target deep-rooted vegetation specimen will also be collected. These characterizations will build a data foundation to support statistical evaluations of soil root depths, radionuclide contamination depths, and other physical and chemical factors that influence vertical biomobilization in vegetation. Statistical evaluations will establish the significance to the extent possible of radionuclide soil contamination depth relative to radionuclide concentration contributions in aboveground (and belowground) vegetation tissue. Soil depth specific bioaccumulation discrimination data for deep-rooted vegetation species are currently lacking in existing Hanford Site bioaccumulation literature and are also not well defined in the published scientific literature.

With future biomobilization LOEs, this study and its results will inform soil remedial alternative evaluations in future Feasibility Studies (FS) (i.e., soil biomobilization depth(s) as a consideration in evaluating soil remediation depths). The 3.05 to 4.6 m (10 to 15 ft) shallow vadose zone soil depth interval is of particular interest as it represents the boundary between a Hanford Site-specific bioactive zone depth (3.05 m; [10 ft]) (CHPRC-00651, *Evaluation of Biointrusion at the Hanford Site for Protection of Ecological Receptors*; Sample et al., 2015, "Depth of the Biologically Active Zone in Upland Habitats at the Hanford Site, Washington: Implications for Remediation and Ecological Risk Management") and the standard soil point of compliance depth of 4.6 m (15 ft) for meeting human health direct contact and ecological cleanup levels under the Model Toxics Control Act (MTCA; WAC-173-340, "Model Toxics Control Act—Cleanup"). The MTCA allows for the regulated community to petition for a conditional point of compliance soil depth for protection of ecological receptors following specified procedures (e.g., WAC-173-340-7490(4)(a), "Terrestrial Ecological Evaluation Procedures").

The opportunistic contaminated deep-rooted vegetation study was planned using the data quality objective (DQO) process as summarized in Section 1.3.

1.2 Background

This section evaluates the significance of the radionuclide biomobilization pathway for waste sites and OUs within the Central Plateau.

[3] The "opportunistic" nature of the study reflects that contaminated deep-rooted vegetation specimens are identified for evaluation in this study whenever and wherever they are located within RCO operational monitoring areas.

1.2.1 Central Plateau Habitat and Land Uses

The Central Plateau encompasses 204 km^2 (79 mi^2) and is divided into the approximately 20 km^2 (8 mi^2) Inner Area and the 184 km^2 (71 mi^2) Outer Area.[4] The Inner Area was used in the past primarily for nuclear fuel processing, waste management, and disposal activities, and it is dedicated to future long-term waste management and containment of residual contamination. The Outer Area was also used for waste management and disposal, but most of the waste sites are small and near the surface. The Outer Area will be cleaned up to enable the long-term land use of conservation/mining (DOE/RL-2009-10, *Hanford Site Cleanup Completion Framework*).

The Central Plateau is located in a semiarid climate with average precipitation of 17 cm (6.8 in.). Average monthly temperatures from 1945 through 2015 ranged from a low of –0.4°C (31.3°F) in January to a high of 24.9°C (76.9°F) in July (DOE/RL-96-32, *Hanford Site Biological Resources Management Plan*).

The habitat is predominantly shrub-steppe. The shrub overstories are often dominated by sagebrush (*Artemisia* spp.), antelope bitterbrush, and gray or green rabbitbrush, with perennial bunchgrass understories often dominated by bluebunch wheatgrass (*Pseudoroegneria spicata*), Sandberg's bluegrass (*Poa secunda*), Indian ricegrass (*Achnatherum hymenoides*), or needle-and-thread grass (*Hesperostipa comata*) (DOE/RL-96-32). Large range fires in recent years have altered the composition of the habitat, decreasing the extent of mature sagebrush stands and increasing non-native species such as tumbleweed (Russian thistle) and tumble mustard (PNNL-6415, *Hanford Site National Environmental Policy Act [NEPA] Characterization*). Within the Inner Area, which has a much higher density of waste sites than the Outer Area, much of the ground surface is intentionally kept barren to support ongoing operations. Invasive species such as Russian thistle and cheatgrass (*Bromus tectorum*) are commonly associated with disturbed soils present over waste sites (PNL-2774, *Characterization of the Hanford 300 Area Burial Grounds, Task IV – Biological Transport*). In contrast, portions of the shrub-steppe habitat in the Outer Area have been relatively undisturbed for >70 years.

Dominant soil types within the Central Plateau are Quincy sand, Burbank loamy sand, Hezel sand, and Ephrata sandy loam. The Burbank, Hezel, and Quincy soil types are excessively well drained, coarse-textured soils underlain by gravel, sand, or lacustrine material at a depth of 25.4 to 101.6 cm (10 to 40 in.) with shallow slopes, low to moderately high water-holding capacity, moderate to very rapid permeability, slight to moderate water erosion hazard, and severe wind erosion hazard (Rasmussen, 1971, *Soil Survey of Benton County Area, Washington*). Coarse soils foster diffuse recharge (PNNL-14702, *Vadose Zone Hydrogeology Data Package for Hanford Assessments*). The Ephrata sandy loam is medium-textured and is underlain by gravelly material that may have a depth of several feet; it is associated with Burbank soil (BNWL-243, *Soil Survey Hanford Project in Benton County Washington*).

The Columbia River is approximately 4.5 km (2.8 mi) north of the northern boundary of the Central Plateau. Active ponds within the Central Plateau include West Lake (a seasonal highly saline waterbody recharged naturally from groundwater) and the 200 Area Treated Effluent Disposal Facility disposal ponds (PNNL-6415). There are no streams located within the Central Plateau. Depth to groundwater within the Central Plateau varies from 54.9 to 93 m (180 to 305 ft) (DOE/RL-2011-50, *Regulatory Basis and Implementation of a Graded Approach to Evaluation of Groundwater Protection*).

[4] These areal estimates are based on geographic information system shapefiles that originated from CHPRC and INTERA for use by the U.S. Department of Energy, Richland Operations Office (2015).

1.2.2 Biomobilization at the Hanford Site

More than 80 plant and animal species known to transport radiological contamination at the Hanford Site are listed in WCH-316, *Hanford Site Biological Transport Summary*. The report describes the following species as the most significant regarding biological transport throughout the Hanford Site: tumbleweed, mulberry trees, other riparian plants, harvester ants, fruit flies, mud daubers (wasps), waterfowl, pheasants, swallows, rock doves, avian predators, and scavengers (e.g., owls, hawks, and magpies), mice, rabbits, badgers, coyotes, deer, and fish. Vegetation is continually managed on the Central Plateau using herbicides and physical removal because measured radionuclide doses are regularly found to exceed RCO thresholds (i.e., localized background concentrations). For tumbleweed (Russian thistle, tumble mustard), the entire aboveground portion of the plant becomes mobile at the end of its annual lifecycle. The stem of the tumbleweed detaches from its roots and can physically spread contamination (i.e., fragments, including seeds and litter) across large areas as the entire aboveground portion of the plant is carried by wind, hence the term "tumbleweed."

Mammals known to burrow to various depths into waste site soils (CHPRC-00651; Sample et al., 2015) are frequently found to be contaminated with radionuclides and are therefore removed from work areas (Table 1-1). Several species of ant occur at the Hanford Site, with the harvester being most common and known to excavate deeper than burrowing small mammal species (CHPRC-00651; Sample et al., 2015).

Table 1-1. Frequency of Observations of Contaminated Media, Central Plateau

Years	Number (and %) of Observations											Total
	Ants	Birds	Invertebrates (Other)	Manmade Materials	Mice	Soil and Related Materials	Tumbleweeds	Urine and Feces	Vegetation (Other)	Vertebrates (Smaller)	Vertebrates (Larger)	
1994–1998	16 (3%)	11 (2%)	26 (4%)	1 (<1%)	75 (12%)	264 (44%)	140 (23%)	34 (6%)	21 (3%)	14 (2%)	2 (<1%)	604
1999–2003	4 (1%)	2 (1%)	5 (1%)	1 (<1%)	10 (3%)	91 (26%)	212 (60%)	18 (5%)	8 (2%)	3 (1%)	1 (<1%)	355
2004–2008	4 (1%)	3 (1%)	2 (<1%)	2 (<1%)	19 (4%)	67 (14%)	323 (65%)	59 (12%)	9 (2%)	6 (1%)	0 (0)	494
2009–2013	5 (1%)	25 (6%)	0 (0)	13 (3%)	3 (1%)	86 (20%)	204 (47%)	77 (18%)	16 (4%)	1 (<1%)	0 (0)	430
2014–2016	2 (1%)	22 (7%)	0 (0)	5 (2%)	20 (6%)	55 (17%)	136 (42%)	77 (24%)	3 (1%)	1 (<1%)	0 (0)	321
Totals	**31 (1%)**	**63 (3%)**	**33 (1%)**	**22 (<1%)**	**127 (6%)**	**563 (25%)**	**1,015 (46%)**	**265 (12%)**	**57 (2%)**	**25 (1%)**	**3 (<1%)**	**2,204**

Notes: "Ants" includes the species themselves, hills, and mounds.

"Birds" includes various species, nests, and bats (though mammals, bats were lumped with birds for presentation purposes only).

"Invertebrates (other)" includes bees, caterpillars, clam shells, clams, fruit flies, mud daubers, beetles, flies, insects, and toads.

"Manmade" includes a concrete floor, caisson, asphalt, foam, boot, riser pipe cap, and a power pole.

"Mice" includes the species themselves, plus nests, carcasses, skeletons, and bait stations.

"Soil and Related" includes soil, specks, dust, gravel, stone, spots, and rocks.

"Tumbleweeds" include rooted, loose, fragments, soil, seeds, and specks. Species of tumbleweed are not specified but are assumed to include predominantly Russian thistle and some tumble mustard.

"Urine and feces" include urine and feces from birds and mammals.

"Vegetation (other)" includes vegetation, bunch grass, rabbitbrush, sagebrush, crested wheat grass, grass, dried vegetation, bunchgrass, cattail reed or fragments, shrubs, and grass root ball/sod material.

"Vertebrates (smaller)" includes rats, rabbits, snakes, gophers, and lizards.

"Vertebrates (larger)" includes a coyote jaw, deer, and feral dogs.

These biota (e.g., plants, harvester ants, and mammals) are not all equal in their relative importance to vertical biomobilization of soil radiological contamination on the Central Plateau. Vertical biomobilization by deep-rooted plants, particularly tumbleweed,[5] is most frequently reported by Mission Support Alliance (MSA) in quarterly summary reports prepared over the past 22 years (Table 1-1). Root intrusion depths of the targeted vegetation species for this study are deep: Russian thistle 2.4 m (7.9 ft), tumble mustard <2.4 m (<7.9 ft), sagebrush 2.5 m (8.2 ft), antelope bitterbrush 3 m (9.8 ft), and (gray) rabbitbrush 2.5 m (8.2 ft). These rooting depths extend deeper than the burrowing depths of both ants and mammals (CHPRC-00651; Sample et al., 2015). Deep-rooted vegetation is therefore considered the dominant (but not the only) biota responsible for vertical biomobilization of subsurface radionuclide soil contamination across the Central Plateau.

The bioaccumulation of different radionuclides by plants on the Central Plateau varies widely.[6] Uptake or concentration ratios (plant concentration/soil concentration) were <1 (from 10^{-2} to 10^{-6}) in Russian thistle for cesium-137 and the transuranics neptunium-237, plutonium-239, americium-241, and curium-244. In contrast, all concentration ratios reported in the same study for strontium-90 and technetium-99 exceeded one, indicating greater concentrations in biota tissues than soil (PNL-2253, *Ecology of the 200 Area Plateau Waste Management Environs: A Status Report*). In a later study also on the Central Plateau, concentration ratios in sagebrush ranged from 0.65 to 13.31 for technetium-99, 0.0 to 12.8 for cesium-137, and 0.02 to 145.5 for strontium-90 (WHC-EP-0771, *Comparison of Radionuclide Levels in Soil, Sagebrush, Plant Litter, Cryptogams, and Small Mammals*). PNL-2253 discusses the limitations to the concept of concentration ratios, emphasizing their site-specific nature. The wide range in concentration factors for the same radionuclide in the same plant species is attributed to differing exposure circumstances (e.g., old contaminated soil versus newly contaminated soil with airborne sources also present), soil type, and underlying soil chemical processes. In addition, research on metals indicates uptake to be a nonlinear process, with greater uptake at lower concentrations and lower uptake at higher concentrations (Efroymson et al., 2001, "Uptake of Inorganic Chemicals from Soil by Plant Leaves: Regressions of Field Data").

In a review of historical records of contaminated biota in the 200 Areas from 1965 to 1994 (WHC-MR-0418, *Historical Records of Radioactive Contamination in Biota at the 200 Areas of the Hanford Site*), tissue concentrations exceeded 10 pCi/g in 42% (1,900 out of approximately 4,500 individual cases) of observations for radionuclide uptake in or transport on biota. The 4,500 observations occurred in 45 species of wildlife (primarily small mammals including animal urine or feces) and 30 species of vegetation (most commonly Russian thistle). A total of 835 wildlife observations had concentrations >10 pCi/g of the reported analytes (cesium-137, strontium-90, plutonium-239, plutonium-240, and uranium [all isotopes]). The highest concentrations were 3,200,000 pCi/g strontium-90 in a Russian thistle in 1981 at the BC Cribs and 66,000,000,000 pCi/g strontium-90 in 1991 in a house mouse from the BX Tank Farm. The highest concentrations were most frequently from small mammals or animal feces. The report noted that reduced uptake and transport of contaminants was observed at waste sites that had been interim stabilized.

[5] Species of tumbleweed are not specified in radiological monitoring and reporting but are assumed to include predominantly Russian thistle and some tumble mustard.

[6] Uptake is a non-linear process with the greatest uptake occurring at the lowest concentrations. High uptake rates need to be considered in the context of associated soil concentrations. For example, a high degree of bioaccumulation at a low soil concentration will likely be of minimal concern, while a high degree of bioaccumulation at higher soil concentrations may be of greater interest and significance.

The frequency of contaminated media observed during routine environmental radiological surveys is an indication of more recent biomobilization patterns on the Central Plateau. Table 1-1 summarizes Central Plateau radiological survey reports from 1994 to 2016. The detection frequencies are related in part to the frequency and intensity of monitoring, which has varied over the years. In all but the first 5 years, the most frequently reported contaminated media was tumbleweeds (species unspecified but assumed to include predominantly Russian thistle with some tumble mustard), while the second most frequently reported media varied between soil, urine, and feces. For the entire reporting period, tumbleweeds accounted for 46% of all observations. For the entire reporting period, the maximum and mean activity levels in vegetation were 9,000,000 and 379,619 dpm/100 cm^2; in ant mounds, >1,000,000 and 295,065 dpm/100 cm^2; and in mammal tissue, urine and feces were 6,000,000 and 282,888 dpm/100 cm^2. (Note that for the averages, some values did not include areal units, and the missing units were assumed to be 100 cm^2.)

Biomobilization study staff accompanied radiation control technician staff over three days in July 2017 and two days in July 2018, over which time 13 specimens of radiologically contaminated (i.e., somewhat above localized background) gray rabbitbrush (nine specimens) and sagebrush (four specimens) were identified near or within the boundaries of visited site locations. Handheld sodium-iodide detectors were used to survey any target deep-rooted vegetation species (Section 3.2.1) growing in or near these waste sites (all located within the RCO surveilled operational areas), which were identified as potential locations of interest either by radiation control technicians or biomobilization staff.

1.2.3 Conceptual Site Model

Intrusion into contaminated soil by the roots of some deep-rooted vegetation species occurring at the Hanford Site may have implications to human receptor exposure and with the selection of health protective soil remedial alternatives in future FSs. Historical operations and waste management at the Hanford Site have resulted in contaminated soils (and structures) at the ground surface and at depth. As shown by Hanford data (Table 1-1), deep-rooted vegetation species can extend roots into contaminated soils and translocate contamination to the aboveground plant. Once biomobilized to the surface, radionuclides in plant tissue represent a source of radiological contamination with potential risk implications to outdoor workers. The primary human exposure pathway is external gamma exposure from biomobilized radionuclides in areas where radiologically contaminated vegetation[7] is present (Figure 1-2).

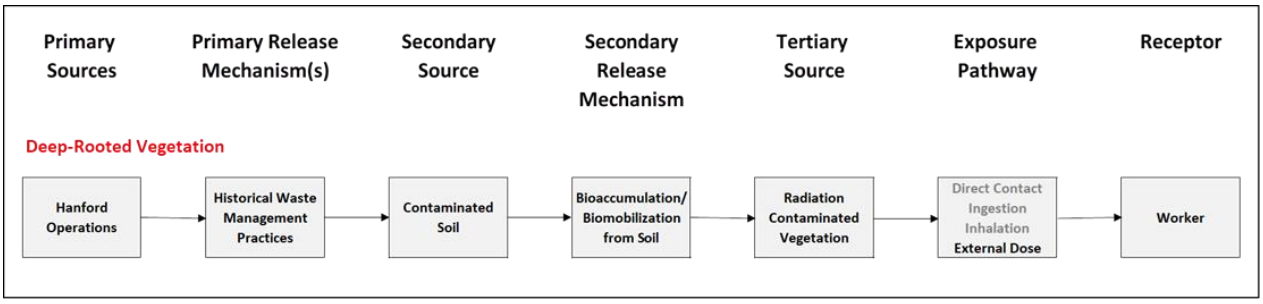

Figure 1-2. Outdoor Worker Exposure to Soil Radiological Contaminants Biomobilized by Deep-Rooted Vegetation

[7] Worker exposures to radiologically contaminated material vertically biomobilized by other biota (e.g., soil in mounds excavated by burrowing ants) can also occur and may be the subject of future sampling and analysis activities.

1.3 Data Quality Objective Summary

The DQO process is a strategic planning approach used to define the data collection design criteria to ensure that the type, quantity, and quality of data are appropriate for the intended application. Appendix A summarizes the DQO process for this study.

Empirical data from this characterization study will answer the question "what soil depth(s) (if any) most influence radionuclide bioaccumulation into aboveground plant tissue."

1.3.1 Problem Statement and Definition

Much is known about biomobilization occurrence at the Hanford Site for many biota species, including deep-rooted vegetation, as discussed in Section 1.2.2. For deep-rooted vegetation, however, the existing Hanford Site bioaccumulation data are insufficient to ascertain if a statistically significant relationship exists between discrete depths in the soil column where radioactive contamination is present and the concentrations measured in the aboveground vegetation tissue. To address this data need, the study will characterize the concentrations of radionuclides in the tissues of contaminated target vegetation species (Section 3.2.1) opportunistically identified by RCTs during routine radiation surveillance of operational locations within the Central Plateau. Data on radionuclide concentrations in collocated depth discretized (0 to 4.9 m [0 to 16 ft]) soil cores (with root tissue) beneath the plant will also be collected. The resulting data will be used to statistically assess whether (and to what degree) soil depth and other factors influence the concentrations measured in aboveground plant tissue.

The principal study question (PSQ) associated with this opportunistic sampling study of radiologically contaminated deep-rooted vegetation is as follows: "Are radionuclide concentrations in contaminated deep-rooted plant tissue significantly correlated with radionuclide soil concentrations occurring at a given soil depth interval(s)?" The key data gaps that need to be filled to address the PSQ are: (1) depth-discrete radionuclide concentrations in soil; (2) collocated radionuclide concentrations in aboveground plant tissue (and belowground roots); and (3) depth-discrete physical and chemical soil properties that can influence radionuclide uptake: total organic carbon (TOC), pH, grain size, cation exchange capacity (CEC), and concentrations of water soluble potassium (K^+) and calcium (Ca^{2+}). The soil nutrients K^+ and Ca^{2+} are related to the degree of cesium-137 and strontium-90 uptake by vegetation, respectively, via nutrient transport pathways (Romney et al., 1959, "Influence of Calcium on Plant Uptake of Sr 90 and Stable Strontium"; Zhu and Smolders, 2000, "Plant Uptake of Radiocaesium: A Review of Mechanisms, Regulation and Application").

The principal estimation statement for the study PSQ is as follows: The principal estimate to be made is the strength and significance of the relationships between the radionuclide concentrations in soil (and root tissue) at eight defined soil depth intervals, and radionuclide concentrations in collocated aboveground plant tissue. The proportion of non-detected concentrations is expected to be variable. It is also expected that the strongest and most significant relationship(s) will be observed with those radionuclides displaying the broadest concentration range in soils.

1.3.2 Hypotheses

The characterization data obtained from this study will be used to test the following hypotheses:

H_0: There is no significant correlation between radionuclide concentrations and specific physical or chemical soil characteristics (pH, CEC, TOC, grain size, and water soluble nutrients K^+ and Ca^{2+}) in soil at specific depth intervals, and radionuclide concentrations in plant tissues (aboveground, belowground).

H_a: There is a significant correlation between radionuclide concentrations and physical or chemical soil parameters (pH, CEC, TOC, grain size, and water soluble nutrients K^+ and Ca^{2+}) in soil at specific depth intervals, and radionuclide concentrations in plant tissues (aboveground, belowground).

Population parameters:

- The coefficient of determination (r^2), significance level (p), and slope of the regression between radionuclide concentrations in subsurface soil at discrete depth intervals, and aboveground and belowground radionuclide concentrations in plant tissue
- The significance level (p) of a multiple linear regression to determine the influence of specific soil characteristics of pH, CEC, TOC, grain size, and water soluble nutrients (K^+ and Ca^{2+}) on the relationship between radionuclide concentrations in subsurface soil at discrete depth intervals and aboveground and belowground radionuclide concentrations in plant tissue

1.4 Target Analytes

Table 1-2 summarizes the target analytes for this study. Because radiation control technicians will opportunistically identify locations of radiologically contaminated vegetation on the Central Plateau, radionuclides in soil and plant tissue represent target analytes for this study.

Table 1-2. Target Analytes for Contaminated Deep-Rooted Vegetation Sampling

Analyte	CAS Number
General Chemical and Physical Soil Parameters	
pH (laboratory)	N/A
Cation exchange capacity	CEC
Total organic carbon	TOC
Soil particle size analysis	—
Soil percent moisture content in each soil depth composite sample	N/A
Plant tissue percent moisture content (measured separately for each aboveground targeted vegetation species tissue composite and each belowground root tissue composite)	N/A
Inorganics – Metals*	
Calcium	7440-70-2
Potassium	7440-09-7
Radionuclides	
Americium-241	14596-10-2
Carbon-14	14762-75-5
Cesium-137	10045-97-3
Cobalt-60	10198-40-0
Curium-243	15757-87-6
Curium-243/244	CM-243/244
Europium-152	14683-23-9

Table 1-2. Target Analytes for Contaminated Deep-Rooted Vegetation Sampling

Analyte	CAS Number
Europium-154	15585-10-1
Europium-155	14391-16-3
Gross alpha	12587-46-1
Gross beta	12587-47-2
Iodine-129	15046-84-1
Neptunium-237	13994-20-2
Nickel-63	13981-37-8
Plutonium-238	13981-16-3
Plutonium-239/240	PU-239/240
Plutonium-241	14119-32-5
Selenium-79	15758-45-9
Strontium-90	10098-97-2
Technetium-99	14133-76-7
Tritium (H-3)	10028-17-8
Uranium-233/234	U-233/234
Uranium-235/236	U-235/236
Uranium-238	U-238

*Water soluble extraction (only) will be used to estimate soil concentrations of calcium and potassium (cationic form), which are important plant nutrients and related to Sr-90 and Cs-137 uptake, respectively.

CAS = Chemical Abstracts Service
CEC = cation exchange capacity
N/A = not applicable
TOC = total organic carbon

Additionally, specific geochemical, chemical, and physical soil characteristics that can influence the degree of radionuclide uptake into plant tissue from soil depth intervals (e.g., CEC, TOC, pH, soil grain size, and water soluble nutrients K^+ and Ca^{2+}) are also identified as target analytes (Table 1-2).

1.5 Project Schedule

The study design does not lend itself to a specific schedule because it is based on "opportunistic" identification of contaminated deep-rooted vegetation by RCTs conducting routine radiation surveys within Central Plateau operational areas. The study duration is estimated to be approximately 3 years or until a statistically derived sampling goal of plant specimens for each targeted vegetation species (i.e., Russian thistle, tumble mustard, sagebrush, antelope bitterbrush, rabbitbrush) has been achieved, whichever occurs first. Study activities (discussed in greater detail in Chapter 3) with generalized study time frames are summarized in Table 1-3.

Table 1-3. Study Activities and General Completion Time Frames

Study Activity	General Completion Time Frame
RCT identification of contaminated deep-rooted target vegetation species following	Variable (based on a survey schedule defined annually)
RCO notifies DBTR of contaminated deep-rooted target vegetation (single and multiple specimens).	Immediate (same day as identified)
RCO installs temporary fencing to isolate each identified, contaminated target vegetation specimen	As soon as possible after identification
DBTR determines whether contaminated deep-rooted vegetation specimen location(s) should be excluded from the study (Section 3.2.4)	Within a few days of RCO notification (or as soon as possible thereafter). If specimen must be excluded, DBTR confirms with RCO that the specimen(s) may be removed and disposed of.
NCOs collect aboveground portion of deep-rooted vegetation specimen(s) identified and deliver to the SPL (instead of routine disposal)	Within 2 weeks of contaminated deep-rooted vegetation identification by RCOs
NCO FWS confirms with DBTR aboveground contaminated deep-rooted vegetation removal and delivery to SPL has occurred	Immediately by NCO FWS following delivery of vegetation specimen(s) to the SPL
SPL initiates aboveground vegetation specimen(s) processing	Within 1 day of vegetation specimen delivery to SPL
SPL submits processed aboveground vegetation sample(s) to analytical laboratory	Immediately following sample processing
RCO stabilizes soils from former aboveground vegetation specimen location in accordance with existing energy control procedures (as required)	As soon as possible following aboveground vegetation specimen removal
DBTR pursues required clearances and permits to drill collocated soil cores at contaminated vegetation specimen location	Variable
DC and GPLC mobilize for soil coring, geophysical logging	As soon as possible once all required clearances and permits are obtained (up to 4 months is possible)
NCOs deliver soil cores to SPL	Within 1 day of collection
SPL soil core (soil and root tissue) processing	Initiated within 1 day following core delivery
SPL submits processed soil core samples (soil and root tissue) to AL	Immediately following soil core (soil, root tissue) processing completion

AL = analytical laboratory
DBTR = designated biomobilization team representative
DC = drilling contractor
FWS = field work supervisor
GPLC = geophysical logging contractor
NCO = nuclear chemical operator (field samplers)
RCO = radiation control organization
RCT = radiation control technician
SPL = sample preparation laboratory

2 Quality Assurance Project Plan

This QAPjP establishes the quality requirements for environmental data collection. It includes planning, implementation, and assessment of sampling tasks, field measurements, laboratory analysis, and data review. This chapter describes the applicable environmental data collection requirements and controls based on the quality assurance (QA) elements found in the following:

- EPA/240/B-01/003, *EPA Requirements for Quality Assurance Project Plans* (EPA QA/R-5)
- DOE/RL-96-68, *Hanford Analytical Services Quality Assurance Requirements Document* (HASQARD)
- DoD/DOE, 2013, *Department of Defense (DoD) Department of Energy (DOE) Consolidated Quality Systems Manual (QSM) for Environmental Laboratories*

This QAPjP also describes applicable requirements and controls based on guidance in Ecology Publication No. 04-03-030, *Guidelines for Preparing Quality Assurance Project Plans for Environmental Studies*, and EPA/240/R-02/009, *Guidance for Quality Assurance Project Plans*. This QAPjP supplements the contractor's environmental QA program plan.

The QAPjP includes the following sections that describe the quality requirements and controls applicable to Hanford Site OU sampling activities:

- Section 2.1, Project Management
- Section 2.2, Data Generation and Acquisition
- Section 2.3, Assessment and Oversight
- Section 2.4, Data Review and Usability

2.1 Project Management

This section identifies the project goals, planned management approaches, and planned output documentation for the opportunistic contaminated vegetation sampling study.

2.1.1 Project/Task Organization

The U.S. Department of Energy (DOE), Richland Operations Office (DOE-RL) is the lead agency for the opportunistic contaminated deep-rooted vegetation sampling study presented in this Study Plan. Implementation of the Study Plan is performed via direction from DOE-RL to the PRC or another contractor that is responsible for planning, coordinating, collecting, preparing, packaging, and shipping samples to the laboratory. Sampling activities for this study are independent of sampling and site characterization activities planned for existing Central Plateau OUs. The project organization for the contaminated deep-rooted vegetation sampling study is described in the following sections and shown in Figure 2-1.

2.1.1.1 U.S. Department of Energy, Richland Operations Office Project Lead

The DOE-RL project lead is responsible for providing day-to-day oversight of the contractor's performance of the work scope, working with the contractor and the regulatory agencies to identify and work through issues, and providing technical input to DOE-RL management.

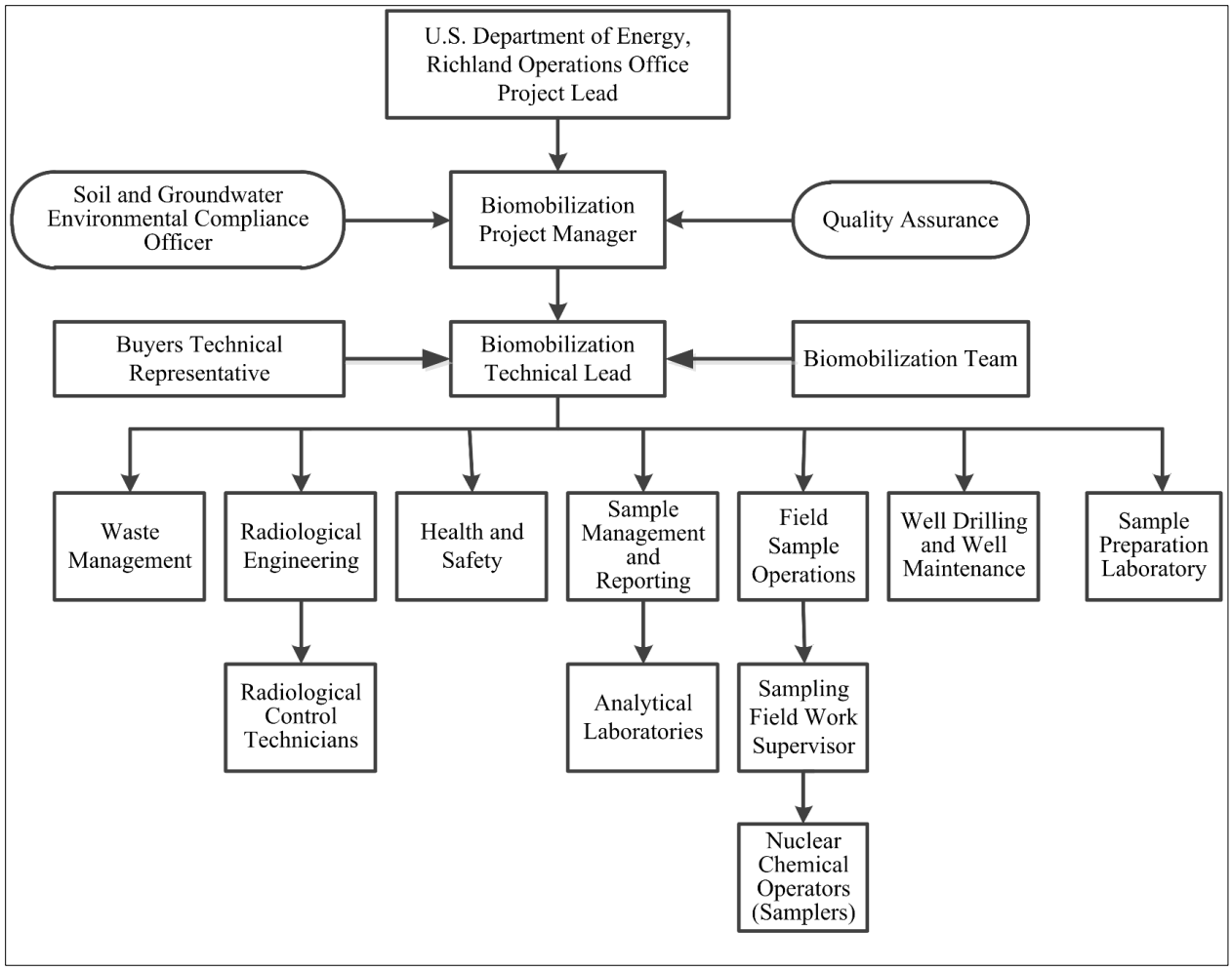

Figure 2-1. Project Organization

2.1.1.2 Biomobilization Project Manager

The PRC biomobilization project manager is responsible and accountable for the contaminated deep-rooted vegetation sampling study activities, including coordinating with DOE-RL, the regulatory agencies, and contractor management to support sampling and reporting activities, and to ensure that work is performed safely and cost effectively. In addition, the biomobilization project manager (or designee) is also responsible for managing sampling documents and requirements, field activities, and subcontracted tasks, and for ensuring that the project file is properly maintained.

2.1.1.3 Biomobilization Technical Lead

The biomobilization technical lead is the technical authority on the contaminated deep-rooted vegetation sampling study design, objectives and ensures that sampling and analysis activities (as delegated by biomobilization project manager) are carried out in accordance with the Study Plan. The biomobilization technical lead (or designee) will be present during field activities to conduct field assessments documenting compliance with all Study Plan technical requirements. The biomobilization technical lead works closely with the environmental compliance officer (ECO), QA organization, Health and Safety organization, sampling field work supervisor (FWS), and Sample Management and Reporting (SMR) organization (Figure 2-1) to integrate these and other technical disciplines in planning and implementing the contaminated deep-rooted vegetation sampling study work scope.

2.1.1.4 Biomobilization Team

The biomobilization team is comprised of a PRC designated biomobilization team representative(s) and external subject matter experts with Hanford Site vegetation expertise and biointrusion and biomobilization expertise. The biomobilization team serves several roles including but not limited to the following responsibilities:

- Receiving telephone notifications from designated RCT study representative(s) on individual contaminated shrubs greater than the threshold level of 5,000 dpm / 100 cm^2
- Developing and performing regular maintenance of a contaminated deep-rooted vegetation notification database
- Communicating and coordinating regularly with the BTR who coordinates with NCOs to facilitate contaminated deep-rooted vegetation specimen(s) sampling following review of exclusion criteria
- Coordinating with PRC on initiating / tracking the clearance process for each contaminated vegetation specimen location that does not meet exclusion criteria
- Coordinating with RCTs and reviewing photographs at sites with multiple deep-rooted vegetation specimens to designate those specimens to be sampled
- Confirming with BTR when NCOs have completed contaminated vegetation sampling (removal) and delivered the shrub sample to the sample preparation laboratory
- Maintaining project files for the study
- Supporting conduct of independent Study Plan field compliance assessments as directed by the biomobilization technical lead

The PRC designated biomobilization team representative also ensures that the sampling FWS and BTR have access to the updated contaminated deep-rooted vegetation notification database to ensure mobilizations occur to the correct contaminated specimen location(s) for soil core drilling.

2.1.1.5 Buyer's Technical Representative

The buyer's technical representative (BTR) represents the PRC's technical position by acting as the single point of contact and interface with project, technical, and subject matter experts to ensure that all study subcontractors adhere to their contracts. The BTR participates in the pre-award acquisition, coordinates contractor's mobilization and logistics, provides technical direction and guidance to the contractor (within scope of the contract), monitors the contractor's work to assure successful performance, and thoroughly reviews all invoicing and payment to ensure the work has been completed, accepted, and authorized. The BTR is a key point of contact between the designated biomobilization team representative and other PRC study personnel.

2.1.1.6 Sample Management and Reporting

SMR oversees offsite analytical laboratories, coordinates laboratory analytical work to ensure that laboratories conform to the requirements of this plan, and verifies that laboratories are qualified to perform Hanford Site analytical work. SMR generates field sampling documents, labels, and instructions for field sampling personnel and develops the sample authorization form (SAF), which provides information and instruction to the analytical laboratories. SMR ensures that field sampling documents are revised to reflect approved changes. SMR receives analytical data from the laboratories, ensures that the data are appropriately reviewed, performs data entry into the Hanford Environmental Information System

(HEIS) database, and arranges for data validation and recordkeeping. SMR is responsible for resolving sample documentation deficiencies or issues associated with field sample operations (FSO), laboratories, or other entities. SMR is responsible for informing the biomobilization project manager or designee of any issues reported by the analytical laboratories.

2.1.1.7 Field Sample Operations

FSO is responsible for planning and coordinating field sampling resources. For the opportunistic vegetation sampling project, the sampling FWS directs the nuclear chemical operators (NCOs), who collect contaminated aboveground target vegetation specimens and collocated soil cores in accordance with the methods and procedures documented in this Study Plan.

The sampling FWS ensures that deviations from the Study Plan field sampling requirements for aboveground vegetation sampling, soil core collection, issues, or potential problems encountered in the field are documented and communicated in accordance with the change control requirements. Under the supervision of the sampling FWS, the NCOs (field samplers) complete field logbooks, data forms, and chain-of-custody forms (including any shipping paperwork) and coordinate the delivery of aboveground vegetation samples and depth discretized soil core intervals to the radiologically licensed sample preparation laboratory for processing (Section 2.1.1.11). NCOs will be trained to perform their required activities consistent with the requirements of this Study Plan.

Pre-job briefings are conducted by FSO in accordance with work management and work release requirements to evaluate activities and associated hazards by considering the following factors:

- Objective of the activities
- Individual tasks to be performed
- Hazards associated with the planned tasks (and equipment)
- Controls applied to mitigate the hazards
- Environment in which the job will be performed
- Location where the job will be performed
- Equipment and material required

2.1.1.8 Sample Preparation Laboratory

The contracted radiologically licensed sample preparation laboratory processes contaminated deep-rooted vegetation and collocated soil cores after field collection to prepare composite samples and perform other sample characterization activities. The sample preparation laboratory has responsibility for composite samples submission to the contracted analytical laboratory.

2.1.1.9 Quality Assurance

The QA point of contact provides independent oversight and is responsible for addressing QA issues on the project as well as overseeing implementation of the project QA requirements. Responsibilities include reviewing project documents (including the QAPjP) and participating in QA assessments on sample collection and analysis activities, as appropriate.

2.1.1.10 Environmental Compliance Officer

Reporting to the biomobilization project manager (or designee [typically the biomobilization technical lead]), the ECO provides technical oversight, direction, and acceptance of project and subcontracted environmental work and also develops appropriate mitigation measures with the goal of minimizing adverse environmental impacts.

2.1.1.11 Health and Safety

The Health and Safety organization is responsible for coordinating industrial safety and health support within the project as carried out through health and safety plans, job hazard analyses, and other pertinent safety documents required by federal regulations or internal primary contractor work requirements.

2.1.1.12 Radiological Engineering

Radiological Engineering is responsible for the following:

- Providing radiological engineering and project health physics support.
- Conducting as low as reasonably achievable (ALARA) reviews, exposure and release modeling, and radiological controls optimization.
- Identifying radiological hazards and ensuring that appropriate controls are implemented to maintain worker exposures to hazards at ALARA levels.
- Interfacing with the project Health and Safety representative and other appropriate and designated personnel (as needed) to plan and direct project RCT support.

2.1.1.13 Waste Management

The waste management organization is responsible for identifying waste management sampling/ characterization requirements to ensure regulatory compliance and for interpreting data to determine waste designations and profiles. Waste management communicates policies and practices and ensures project compliance for storage, transportation, disposal, and waste tracking in a safe and cost-effective manner.

2.1.1.14 Analytical Laboratories

The analytical laboratories analyze samples in accordance with established procedures and subcontract requirements and provide necessary data packages containing results for analytical and physical measurements and QC. Laboratories provide explanations of results to support data review and in response to resolution of analytical issues. Statements of work flow include quality requirements consistent with HASQARD (DOE/RL-98-68). The laboratories are evaluated under the DOE Consolidated Audit – Accreditation Program (or successor programs) to DoD/DOE (2013) requirements and must be accredited by Ecology for the PRC performed analyses.

2.1.1.15 Drilling Operations

The drilling operations manager works closely with the BTR and is responsible for the following:

- Planning, coordinating, and executing the vegetation collocated soil coring work to meet the requirements of this Study Plan. The soil coring work will be conducted using a continuous coring method to collect “tight”, intact soil cores that can be cut into the eight required core depth intervals (Section 3.4.1).
- Coordinating with the sampling FWS to deliver (within a day of sampling) to the sample preparation laboratory the collocated depth discretized soil cores for each aboveground shrub sampling location.
- Coordinating with the sampling FWS and the biomobilization technical lead regarding field constraints, sampling questions or any proposed changes to aspects of the sampling activity that could have a significant effect on sampling design (and study outcomes).

Table 2-1. Data Quality Indicators

Data Quality Indicator (QC Element) [a]	Definition	Determination Methodologies	Corrective Actions
Precision (field duplicates, laboratory sample duplicates, and matrix spike duplicates)	Precision measures the agreement among a set of replicate measurements. Field precision is assessed through the collection and analysis of field duplicates. Field duplicates are defined in this opportunistic study as a split of a tissue or soil sample conducted by the sample preparation laboratory and are prepared only where there is sufficient soil or tissue to meet all analytical laboratory minimum sample volumes. Analytical precision is estimated by duplicate or replicate analyses, usually on laboratory control samples, spiked samples, and/or field samples. The most commonly used estimates of precision are the relative standard deviation and, when only two samples are available, the relative percent difference.	Use the same analytical instrument to make repeated analyses on the same sample. Use the same method to make repeated measurements of the same sample within a single laboratory. Acquire replicate field samples for information on sample acquisition, handling, shipping, storage, preparation, and analytical processes and measurements.	If duplicate data do not meet objectives: • Evaluate apparent cause (e.g., sample heterogeneity). • Request reanalysis or remeasurement. • Qualify the data before use.
Accuracy (e.g., laboratory control samples, matrix spikes, surrogates, carriers, and tracers)	Accuracy is the closeness of a measured result to an accepted reference value. Accuracy is usually measured as a percent recovery. QC analyses used to measure accuracy include standard recoveries, laboratory control samples, spiked samples, and surrogates.	Analyze a reference material or reanalyze a sample to which a material of known concentration or amount of pollutant has been added (a spiked sample).	If recovery does not meet objectives: • Qualify the data before use. • Request reanalysis or remeasurement.
Representativeness (field duplicates)	Sample representativeness expresses the degree to which data accurately and precisely represent a characteristic of a population, parameter variations at a sampling point, a process condition, or an environmental condition. It is dependent on the proper design of the sampling program and will be satisfied by ensuring that the approved plans were followed during sampling and analysis.	Evaluate whether measurements are made, and physical samples collected in such a manner that the resulting data appropriately reflect the environment or condition being measured or studied.	If results are not representative of the system sampled: • Identify the reason for results not being representative. • Flag for further review. • Review data for usability. • If data are unusable, qualify the data for limited use and define the portion of the system that the data represent. • If data are not usable, flag as appropriate. • Redefine sampling and measurement requirements and protocols. • Reanalyze, as appropriate.

Table 2-1. Data Quality Indicators

Data Quality Indicator (QC Element) [a]	Definition	Determination Methodologies	Corrective Actions
Comparability (field duplicates, field splits; preparation laboratory sample splits; analytical laboratory control samples, matrix spikes, and matrix spike duplicates)	Comparability expresses the degree of confidence with which one data set can be compared to another. It is dependent upon the proper design of the sampling program and will be satisfied by ensuring that the approved plans are followed, and that proper sampling and analysis techniques are applied.	Use identical or similar sample collection and handling methods, sample preparation and analytical methods, holding times, and QA protocols.	If data are not comparable to other data sets: • Identify appropriate changes to data collection and/or analysis methods. • Identify quantifiable bias, if applicable. • Qualify the data as appropriate. • Reanalyze if needed. • Revise sampling/analysis protocols to ensure future comparability.
Completeness (no QC element; addressed in data verification and data usability assessment)	Completeness is a measure of the amount of valid data collected compared to the amount planned. Measurements are considered to be valid if they are unqualified or qualified as estimated (typically J qualified[b]) data during validation. Field completeness is a measure of the number of samples collected versus the number of samples planned. Laboratory completeness is a measure of the number of valid measurements compared to the total number of measurements planned.	Compare the number of valid measurements completed (samples collected, or samples analyzed) with those established by the project's quality criteria (data quality objectives or performance and acceptance criteria).	If data set does not meet the completeness objective: • Identify appropriate changes to data collection and analysis methods, as appropriate. • Identify quantifiable bias, if applicable. Reanalyze, if needed • Revise sampling and analysis protocols to ensure future completeness.
Bias (equipment blanks, full trip blanks, laboratory control samples, matrix spikes, and method blanks) [c]	Bias is the systematic or persistent distortion of a measurement process that causes error in one direction (e.g., the sample measurement is consistently lower than the sample's true value). Bias can be introduced during sampling, analysis, and data evaluation. Analytical bias refers to deviation in one direction (i.e., high, low, or unknown) of the measured value from a known spiked amount.	Sampling bias may be revealed by analysis of replicate samples. Analytical bias may be assessed by comparing a measured value in a sample of known concentration to an accepted reference value or by determining the recovery of a known amount of contaminant spiked into a sample (matrix spike).	For sampling bias: • Properly select and use sampling tools. • Institute correct sampling and subsampling practices to limit preferential selection or loss of sample media. • Use sample handling practices, including proper sample preservation, that limit the loss or gain of constituents to the sample media. • Analytical data that are known to be affected by either sampling or analytical bias are flagged to indicate possible bias. • Laboratories that are known to generate biased data for a specific analyte are asked to correct their methods to remove the bias as best as practicable. Otherwise, samples are sent to other laboratories for analysis.

Table 2-1. Data Quality Indicators

Data Quality Indicator (QC Element) [a]	Definition	Determination Methodologies	Corrective Actions
Sensitivity (method detection limit, practical quantitation limit, and relative percent difference)	Sensitivity is an instrument's or method's minimum concentration that can be reliably measured (i.e., instrument detection limit or limit of quantitation).	Determine the minimum concentration or attribute to be measured by an instrument (instrument detection limit) or by a laboratory (limit of quantitation). The lower limit of quantitation [d] is the lowest level that can be routinely quantified and reported by a laboratory.	If detection limits do not meet objective: • Request reanalysis or re-measurement using methods or analytical conditions that will meet required detection or limit of quantitation. • Qualify/reject the data before use.

Reference: SW-846, *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods, Third Edition; Final Update V*, as amended.

a. Acceptance criteria for QC elements are provided in Table 2-5.

b. A validation J qualifier is not applicable to radionuclides, which are the focus of this study.

c. Field transfer blanks are not required for this study because volatile organic compounds are not an analyte of interest.

d. For purposes of this Study Plan, the lower limit of quantitation is interchangeable with the practical quantitation limit.

QA = quality assurance QC = quality control

2.1.2 Quality Objectives and Criteria

The QA objective of this plan is to ensure that analytical data of known and appropriate quality are generated, that are acceptable and useful to meet the evaluation requirements stated in the Study Plan. Data descriptors known as data quality indicators (DQIs) help determine the acceptability and usefulness of data to the user. The principal DQIs (precision, accuracy, representativeness, comparability, completeness, bias, and sensitivity) are defined for the purposes of this Study Plan in Table 2-1.Data quality is defined by the degree of rigor in the acceptance criteria assigned to the DQIs. The applicable QC guidelines, DQI acceptance criteria, and levels of effort for assessing data quality are dictated by the intended use of the data and the requirements of the analytical method. DQIs are evaluated during the data usability assessment process (Section 2.4.3).

This Study Plan describes the sampling and analyses to be performed for contaminated deep-rooted target vegetation and collocated soil. The PSQ developed for this contaminated deep-rooted vegetation sampling study is as follows: "Are radionuclide concentrations in contaminated deep-rooted plant tissue significantly correlated with radionuclide soil concentrations occurring at a given soil depth interval(s)?"

The performance or acceptance criteria for the opportunistic contaminated vegetation sampling study PSQ is as follows:

- The consequence of incorrectly determining that there is a significant correlation between subsurface soil and tissue and aboveground tissue concentrations (when in fact there is not) could provide inappropriate inputs to risk management and FSs. The acceptable limit on uncertainty (probability) of this Type I error (rejecting H_0 when it is true) is 0.05. Because the statistical test is (by nature) a "yes/no" question, the test does not compare a derived value against any type of action level; therefore, no beta value is needed.

The acceptable limit on uncertainty in measurement error (population parameters) for the PSQ is as follows:

- A weight of evidence approach will be used to determine whether the quantitative relationships between subsurface soil or tissue and aboveground tissue contamination should be used in future decision making, including the following LOEs: (1) a coefficient of determination of at least 0.2, a significance level (p) of 0.05, and a positive slope of the regression; (2) a significance level (p) of at least 0.05 of a multiple linear regression to determine the influence of soil pH, CEC, TOC, grain size and water soluble soil nutrients (K^+, Ca^{2+}) on the relationship between subsurface and surface concentrations; (3) the magnitude of depth-discrete root tissue concentrations in comparison to the corresponding depth-discrete soil concentrations and surface tissue concentrations; and (4) best professional judgment regarding the strength, validity, and meaning of the results of all the contaminated deep-rooted vegetation sampling study statistical tests and the nature of the empirical data sets when considered as a whole.

2.1.3 Methods-Based Analysis

Laboratory testing for the analytes described in Table 2-2 may include additional constituents that are part of the analytical method (i.e., methods-based reporting). The additional constituents that are part of the method and reported by the laboratory are for informational purposes only. Analytical performance requirements will be applicable only to the analytes specific to this Study Plan. Poor QC related to nontarget analyte results would not result in any required corrective action by the laboratory, except for applying proper result qualification flags.

Table 2-2. Performance Requirements for Soil and Vegetation Sample Analysis

Constituent	CAS Number	Preliminary Action Level [a]		Hanford Site Background [e]	Analytical Method	Highest Allowable MDA or PQL for Soil (pCi/g or mg/kg) or Other Solid Material [f]
		Direct Contact WAC 173-340 Method C Industrial RBL [b]	Outdoor Worker RBL [c,d]			
General Soil Chemical Parameters (mg/kg or unitless)						
Cation exchange capacity	CEC	—	—	—	EPA Method 9081	—
Total organic carbon	TOC	—	—	—	EPA Method 415.1 or 9060	100
pH	N/A	—	—	—	EPA Method 9045	—
Inorganics – Metals (mg/kg) (Soil Only) [g]						
Calcium	7440-70-2	—	—	17,200	EPA Method 6020B	100
Potassium	7440-09-7	—	—	2,150	EPA Method 6020B	500
Radionuclides (pCi/g) (Soil, Vegetation) [h]						
Americium-241	14596-10-2	—	613	—	AEA	1
Carbon-14	14762-75-5	—	570,125	—	Liquid scintillation	5
Cobalt-60	10198-40-0	—	5.7	0.0084	GEA	0.1
Cesium-137	10045-97-3	—	10.8	1.1	GEA	0.1
Curium-243	15757-87-6	—	64	—	GEA	1
Curium-243/244	CM-243/244	—	64	—	AEA	1
Europium-152	14683-23-9	—	6.8	—	GEA	0.1
Europium-154	15585-10-1	—	8.2	0.033	GEA	0.1
Europium-155	14391-16-3	—	603	0.054	GEA	0.1
Tritium (H-3)	10028-17-8	—	12,594	—	Liquid scintillation	30
Gross alpha	12587-46-1	—	—	—	GPC	5
Gross beta	12587-47-2	—	—	—	GPC	10
Iodine-129	15046-84-1	—	1,568	—	Chemical separation low-energy photon spectroscopy	2
Nickel-63	13981-37-8	—	599,520	—	Liquid scintillation	10

Table 2-2. Performance Requirements for Soil and Vegetation Sample Analysis

Constituent	CAS Number	Preliminary Action Level [a]		Hanford Site Background [e]	Analytical Method	Highest Allowable MDA or PQL for Soil (pCi/g or mg/kg) or Other Solid Material [f]
		Direct Contact WAC 173-340 Method C Industrial RBL [b]	Outdoor Worker RBL [c,d]			
Neptunium-237	13994-20-2	—	24	—	AEA	1
Plutonium-238	13981-16-3	—	3,438	0.0038	AEA	1
Plutonium-239/240	PU-239/240	—	2,971	0.025	AEA	1
Plutonium-241	14119-32-5	—	20,317	—	Liquid scintillation	15
Selenium-79	15758-45-9	—	56,818	—	Liquid scintillation	10
Strontium-90	10098-97-2	—	1,190	0.18	GPC	2
Technetium-99	14133-76-7	—	117,055	—	Liquid scintillation	5
Uranium-233/234	U-233/234	—	2,201	1.1	AEA	1
Uranium-235/236	15117-96-1	—	36	0.11	AEA	1
Uranium-238	7440-61-1	—	170	1.1	AEA	1
Physical Properties and Measurements						
Soil grain size (sieve) analysis	—	N/A	N/A	N/A	ASTM D422-63(2007)	N/A
Soil and vegetation dry weight (all vegetation tissue types)	—	N/A	N/A	N/A	ASTM D2216-05	N/A
Soil and vegetation percent moisture	—	N/A	N/A	N/A	ASTM D2216-05	N/A

References: ASTM D422-63(2007), 2007, *Standard Test Method for Particle-Size Analysis of Soils*, American Society for Testing and Materials, West Conshohocken, Pennsylvania.

ASTM D2216-05, 2005, *Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass*, American Society for Testing and Materials, West Conshohocken, Pennsylvania.

a. The preliminary action level is the risk-based value used to determine appropriate analytical requirements (e.g., detection limits).

b. The direct contact risk-based level is based on an excess lifetime cancer risk of 1 in 100,000 or hazard quotient of 1.0 (ECF-HANFORD-10-0453, *Calculation of Standard Method C Direct Contact Soil Cleanup Levels for Industrial Land Use for the 100 Areas and 300 Area Remedial Investigation/Feasibility Study Reports*).

c. The outdoor worker risk-based level for nonradionuclides is used to determine analytical performance requirements based on an excess lifetime cancer risk of 1 in 1,000,000 or a hazard quotient of 0.1 (ECF-HANFORD-16-0134, *Calculation of Soil Nonradiological Preliminary Remediation Goals for the Outdoor Worker Scenario*).

d. The outdoor worker risk-based level for radionuclides is used to determine analytical performance requirements is based on an excess lifetime cancer risk of 1 in *10,000* (ECF-HANFORD-16-0133, *Calculation of Soil Radiological Preliminary Remedial Goals for the Outdoor Worker Scenario*).

e. DOE/RL-96-12, *Hanford Site Background: Part 2, Soil Background for Radionuclides*; DOE/RL-92-24, *Hanford Site Background: Part 1, Soil Background for Nonradioactive Analytes*; ECF-HANFORD-11-0038, *Soil Background for Interim Use at the Hanford Site*.

Table 2-2. Performance Requirements for Soil and Vegetation Sample Analysis

Constituent	CAS Number	Preliminary Action Level [a]		Hanford Site Background [e]	Analytical Method	Highest Allowable MDA or PQL for Soil (pCi/g or mg/kg) or Other Solid Material [f]
		Direct Contact WAC 173-340 Method C Industrial RBL [b]	Outdoor Worker RBL [c,d]			

f. Highest allowable PQLs for soils are specified in contracts with analytical laboratories. Actual PQLs vary by laboratory and may be lower. Where project-specific action levels are greater than contract-specified highest allowable PQL, the contract-specific highest allowable PQL is given. Where project-specific action levels are less than contract-specified highest allowable PQLs, a highest allowable PQL that is lower than the action level is given, provided that the lower highest allowable PQL is technically achievable under routine operating conditions by laboratories under contract to the Plateau Remediation Contractor. Method detection limits are three to five times lower than quantitation limits. For radionuclides, values in this column are the highest allowable minimum detectable concentrations in "pCi/g" for soil/other media. The PQLs/minimum detectable concentrations for vegetation will be the best achievable based on the sample size and moisture content.

g. Water extraction only of soil samples for Method 6020B. The water soluble fraction should approximate the fraction that would be available for plant root uptake of the cationic form of these two nutrient metals.

h. Radionuclides are analyzed in both soil and vegetation tissue (shrub, root) composite samples.

AEA = alpha energy analysis
CAS = Chemical Abstracts Service
CEC = cation exchange capacity
EPA = U.S. Environmental Protection Agency
GEA = gamma energy analysis
GPC = gas proportional counting
MDA = minimum detectable activity
N/A = not applicable
PQL = practical quantitation limit
RBL = risk-based level
TOC = total organic carbon

2.1.4 Analytical Priority

The required minimum sample mass required for vegetation tissue and soil to meet the sample analysis requirements for all Table 2-2 analyses will be established once an analytical laboratory is selected. If sample mass is insufficient to permit analysis for all required analyses listed in Table 2-2 for a given sampling medium (soil or vegetation tissue), the highest priority analytes critical for supporting the contaminated deep-rooted vegetation sampling study are required to be analyzed.

For any soil or vegetation tissue (aboveground, belowground) composite sample having insufficient mass to conduct all the required radionuclide analyses (Table 2-2), the analytical method-based hierarchy for conducting sample analyses will be as follows: (1) all radionuclides using GEA analytical method; (2) all radionuclides using GPC analytical method (3) physical and chemical soil parameters: pH, TOC, CEC, grain size, and the water soluble inorganic soil nutrients Ca^{2+}, K^{+}; (4)all radionuclides using AEA analytical method, and (4) all other remaining radionuclide analytical methods specified in Table 2-2.

The percent moisture will be reported on all analyzed samples (soil and vegetation). More specifically, the percent moisture will be measured separately in each depth-discrete soil composite sample, each depth-discrete root tissue composite sample, and each aboveground shrub tissue composite sample.

2.1.5 Special Training/Certification

The following subsections describe the required biological expertise and other worker training requirements necessary for conducting the opportunistic contaminated vegetation sampling study.

2.1.5.1 Required Biological Expertise

The sample preparation laboratory personnel must possess the expertise and experience to perform non-routine biological sample processing work in a radiologically licensed laboratory as defined in this Study Plan. Botanical expertise (e.g., sample preparation laboratory lead at a minimum) is required to identify accurately deep-rooted vegetation submitted for processing. Expertise with methods for the aging of perennial shrubs is also required. The Central Plateau target vegetation that is the focus of this contaminated vegetation sampling study are deep-rooted annual and perennial species: Russian thistle, tumble mustard, sagebrush, antelope bitterbrush, and gray and green rabbitbrush.

Sample preparation laboratory personnel will be required to prepare fully representative composite samples representing all the various plant tissue structures on a given target vegetation species specimen. The sample preparation laboratory lead must also be fully knowledgeable about Russian thistle and tumble mustard lifecycles to ensure that the approximate age (annual lifecycle development stage) of these specimens submitted for processing can be described and recorded. Additionally, the sample preparation laboratory lead must have expertise in identifying (keying out) Russian thistle subspecies (e.g., *Sasola kali*, *ssp. tragus*, etc.), big sagebrush subspecies (e.g., *Artemisia tridentata* ssp. *wyomengensis*, *tridentata*, and *vaseyana*) and other sagebrush species (e.g., *Artemisia rigida*) for accurate documentation of the species that are processed (and their frequency).

2.1.5.2 Other Worker Requirements

Workers receive a level of training that is commensurate with their responsibility for collecting and transporting samples and that complies with applicable DOE orders and government regulations. Line management will ensure that the special training requirements for sample preparation laboratory personnel are met for this study.

The contractor management team has instituted training and qualification programs that satisfy multiple instructional drivers imposed by applicable DOE, *Code of Federal Regulations*, and *Washington Administrative Code* requirements.

Records are maintained for each employee in an electronic training database. The contractor's training organization maintains the training records system. Line management confirms that an employee's training is appropriate and updated prior to employee performing any field work.

2.1.6 Documents and Records

The biomobilization project manager (or designee) is responsible for ensuring that the current version of this contaminated deep-rooted vegetation sampling Study Plan is being used and for providing any updates to field personnel. Version control is maintained by the administrative document control process.

Table 2-3 defines the types of changes that may impact sampling and the associated approvals, notifications, and documentation requirements. For this study, the size and dripline perimeter (diameter) of identified contaminated deep-rooted vegetation may require the need for fewer collocated dripline soil cores (Section 3.4.1). Where field judgement (driller) indicates that a reduced number of dripline cores or core barrel diameters used is required, this type of change will be considered a minor change (minor field change) in accordance with the change control requirements specified in Table 2-3 (and requires detailed documentation in the field logbook).

Logbooks and data forms are required for field and sample processing activities. The logbook must be identified with a unique project name and number. Individuals responsible for the logbooks (owners) shall be identified in the front of the logbook, and only authorized individuals approved by a listed logbook owner may make entries into the logbooks. Logbooks will be controlled in accordance with internal work requirements and processes.

The sampling FWS, SMR, and any field crew supervisor are responsible for ensuring that field instructions are maintained and aligned with any revisions or approved changes to the Study Plan. SMR will ensure that any deviations from the Study Plan are reflected in revised field sampling documents for the samplers and the analytical laboratory. The sampling FWS will ensure that deviations from the Study Plan or problems encountered in the field are documented appropriately (e.g., in the field logbook).

The biomobilization project manager (or designee), designated RCO RCT representatives, and sampling FWS are collectively responsible for communicating field corrective action requirements and ensuring that immediate corrective actions are applied to field activities. The biomobilization project manager (or designee) is also responsible for ensuring that project files are appropriately set up and maintained.

The project files will contain project records or references to their storage locations and may include the following documented information:

- Communications of a significant nature
- Operational records and logbooks
- Field data forms (hardcopy or electronic)
- Sample preparation laboratory logbooks and data forms
- Global positioning system (GPS) data (a copy will be provided to SMR)
- Photographs
- Inspection or assessment reports and corrective action reports
- Interim progress reports
- Final reports

Table 2-3. Change Control Procedures for the Opportunistic Sampling Study Plan

Type of Change [a]	Action	Documentation
Minor change: Change has no impact on the sample or field analytical result, and little or no impact on performance or cost. Further, the change does not affect the DQOs specified in the Study Plan.	The field personnel recognizing the need for a field change will consult with the sampling FWS who will contact the biomobilization project manager (or designee [typically the biomobilization technical lead]) prior to implementing the field change.	Minor field changes will be documented in the field logbook by the sampling FWS. The logbook entry will include the field change, the reason for the field change, and the names and titles of those approving the field change.
Significant change: Change has a considerable effect on performance or cost, but still allow meeting the DQOs specified in the Study Plan.	The biomobilization project manager will inform the DOE-RL project manager of the change and seek concurrence at a unit manager's meeting or comparable forum.	Documentation of this change approval would be in the unit manager meeting minutes or comparable record.
Fundamental change: Change has significant effect on the sample or the field analytical result, performance, or cost, and the change does not meet the DQO requirements specified in this Study Plan.	If it is anticipated that a fundamental change will require the approval of the applicable DOE-RL project manager, notification will be made by the biomobilization project manager or designee, who will be involved with DOE-RL in the decision prior to implementation of a fundamental change.	Revision of the sampling document.

a. Consistent with DOE/RL-96-68, *Hanford Analytical Services Quality Assurance Requirements Documents*.

DOE-RL = U.S. Department of Energy, Richland Operations Office
DQO = data quality objective
FWS = field work supervisor

The following records are managed and maintained by SMR:

- Completed field sampling logbooks
- Field drilling and analytical data
- Field audit forms
- Completed chain-of-custody forms
- Sample receipt records
- Laboratory data packages
- Analytical data verification and validation reports
- Analytical data "case file purges" (i.e., raw data purged from laboratory files) provided by the offsite analytical laboratories

In accordance with their contract, external laboratories are responsible for maintaining and having available upon request the following for a minimum of 5 years following delivery of each analytical data report:

- Analytical logbooks
- Raw data and QC sample records
- Standard reference material and/or proficiency test sample data
- Sample chain-of-custody and sample storage temperature logs
- Instrument calibration information
- Training records for employees, as they relate to analytical methods
- Laboratory state accreditation records
- Laboratory audit records

Records obtained from subcontracted laboratories may be stored in either electronic (e.g., in the managed records area of the Integrated Document Management System) or hardcopy format (e.g., DOE Records Holding Area). Documentation and records, regardless of medium or format, are controlled in accordance with internal work requirements and processes that ensure accuracy and retrievability of stored records.

2.2 Data Generation and Acquisition

This section addresses data generation and acquisition to ensure that the project's methods for sampling measurement and analysis, data collection or generation, data handling, and QC activities are appropriate and documented. Requirements for instrument calibration and maintenance, supply inspections, and data management are also addressed.

This section also includes sample processing activities required by sample preparation laboratory personnel at the radiologically licensed sample preparation laboratory. Activities include descriptions of soil cores and root depths and photographing all core depth segments (with and without the root tissue exposed). Activities also include processing vegetation tissue and soil samples into the required depth-discrete sample composites for chain-of-custody submission to the analytical laboratory.

2.2.1 Analytical Methods and Other Laboratory Requirements

Table 2-2 summarizes information regarding the analytical method requirements for the subcontracted analytical laboratory to analyze submitted composite samples for vegetation and soil.

Updated EPA methods and nationally recognized standard methods may be substituted for the analytical methods identified in Table 2-2. The new method shall achieve project DQOs as well or better than the replaced method and is required due to the nature of the sample (e.g., high radioactivity). Note that gross gamma is not specified as a specific parameter in Table 2-2 but will be determined by summing the laboratory results for gamma emitters using the gamma energy analysis method.

2.2.2 Field Analytical Methods

Field screening and survey data will be measured in accordance with HASQARD requirements (DOE/RL-96-68). Field analytical methods are performed in accordance with manufacturer's instructions. Table 2-2 provides the parameters (if any) for field measurements.

2.2.3 Quality Control

The QC requirements specified in the Study Plan must be followed in the field and analytical laboratories to ensure that reliable data are obtained. Field QC samples will be collected to evaluate the potential for cross-contamination and to provide information pertinent to sampling variability. Laboratory QC samples estimate the precision, bias, and matrix effects of the analytical data. Table 2-4 summarizes the field and laboratory QC samples, and Table 2-5 shows the acceptance criteria for field and laboratory QC. Data will be qualified and flagged in the HEIS database, as appropriate.

Table 2-4. QC Samples

Sample Type	Frequency	Characteristics Evaluated
Field QC [a]		
Field duplicates	A field duplicate is prepared from composite sample media by the sample preparation laboratory at the rate of one per sample processing day (a field duplicate is prepared by the sample preparation laboratory only if available sample mass permits)	Precision, including sampling and analytical variability

Table 2-4. QC Samples

Sample Type	Frequency	Characteristics Evaluated
Equipment blanks	These blank samples are collected at the time of tissue processing at the sample preparation laboratory. One equipment blank per sample processing day may be necessary for tissue grinding / shredding equipment in the sample preparation laboratory unless a disposable processing option is identified for use for this processing activity. High purity water will be used to prepare this equipment blank, as its purpose is to provide an indication of the overall decontamination process of the equipment. Equipment blanks for other activities related to sampling or sample processing are not required because only disposable equipment is used. [a]	Adequacy of sampling equipment decontamination
Analytical QC [b, c]		
Laboratory sample duplicates	One per analytical batch (20 samples or less of similar media)	Laboratory reproducibility and precision
Matrix spikes	One per analytical batch	Matrix effect/laboratory accuracy
Matrix spike duplicates	One per analytical batch	Laboratory accuracy and precision
Laboratory control samples	One per analytical batch	Laboratory accuracy
Method blanks	One per analytical batch	Laboratory contamination
Carriers	Added to each sample and QC sample	Recovery/yield
Tracer	Added to each sample and QC sample	Recovery/yield

a. When a new type of nondedicated equipment is used, an equipment blank will be collected every time sampling occurs (i.e., each sample processing day in the sample preparation laboratory) until it can be shown that less frequent collection of equipment blanks is adequate to monitor the decontamination methods for nondedicated equipment.

b. Not all QC is applicable to all analytical methods. Actual QC requirements and frequency are dictated by analytical methods performed.

c. Batching across projects is allowed for similar matrices (e.g., all Hanford Site groundwater).

QC = quality control

Table 2-5. Laboratory QC Elements and Acceptance Criteria for Soil and Vegetation Samples

Analyte	QC Element	Acceptance Criteria	Corrective Action
General Chemical Parameters (Soil)			
Cation exchange capacity	MB	<MDL; <5% sample concentration	Flag with "C"
	LCS	80–120% recovery	Flag with "o" [a]
	Field duplicate	See footnote [e]	Review data [a]
Total organic carbon	MB	<MDL; <5% sample concentration	Flag with "C"
	LCS	80–120% recovery	Review data [a]
	DUP [b]/MSD [b]	≤35% RPD [c]	Review data [d]
	MS/MSD	75–125% recovery	Flag with "N"
	EB, FTB	<MDL; <5% sample concentration	Flag with "Q"
	Field duplicate	See footnote [e]	Review data [d]

Table 2-5. Laboratory QC Elements and Acceptance Criteria for Soil and Vegetation Samples

Analyte	QC Element	Acceptance Criteria	Corrective Action
Inorganics – Metals (Soil)			
ICP/AES metals	MB	<MDL; <5% sample concentration	Flag with "C"
	LCS	80–120% recovery	Flag with "o" [a]
	DUP [b]/MSD [b]	≤35% RPD [c]	Review data [d]
	MS/MSD	75–125% recovery	Flag with "N"
	EB, FTB	<MDL; <5% sample concentration	Flag with "Q"
	Field duplicate	See footnote [e]	Review data [d]
ICP/MS metals	MB	<MDL; <5% sample concentration	Flag with "C"
	LCS	80–120% recovery	Flag with "o" [a]
	DUP [b]/MSD [b]	≤35% RPD [c]	Review data [d]
	MS/MSD	75–125% recovery	Flag with "N"
	EB, FTB	<MDL; <5% sample concentration	Flag with "Q"
	Field duplicate	See footnote [e]	Review data [d]
Radionuclides (Soil, Vegetation)			
AEA (uranium, plutonium, americium, neptunium, and curium isotopics)	MB	<MDC; <5% sample activity concentration	Flag with "B"
	LCS	80–120% recovery	Flag with "o" [a]
	DUP	≤30% RPD [c]	Review data [d]
	Tracer	30–105% recovery	Review data [b]
	EB, FTB	<MDC; <5% sample activity concentration	Flag with "Q"
	Field duplicate	See footnote [e]	Review data [d]
Carbon-14	MB	<MDC; <5% sample activity concentration	Flag with "B"
	LCS	80–120% recovery	Flag with "o" [a]
	DUP	≤30% RPD [c]	Review data [d]
	MS	75–125% recovery	Flag with "N"
	EB, FTB	<MDC; <5% sample activity concentration	Flag with "Q"
	Field duplicate	See footnote [e]	Review data [d]
Plutonium-241	MB	<MDC; <5% sample activity concentration	Flag with "B"
	LCS	80–120% recovery	Flag with "o" [a]
	DUP	≤30% RPD [c]	Review data [d]
	Tracer	30–105% recovery	Review data [d]
	EB, FTB	<MDC; <5% sample activity concentration	Flag with "Q"
	Field duplicate	See footnote [e]	Review data [d]

Table 2-5. Laboratory QC Elements and Acceptance Criteria for Soil and Vegetation Samples

Analyte	QC Element	Acceptance Criteria	Corrective Action
GEA	MB	<MDC; <5% sample activity concentration	Flag with "B"
	LCS	80–120% recovery	Flag with "o" [a]
	DUP	≤30% RPD [c]	Review data [d]
	EB, FTB	<MDC; <5% sample activity concentration	Flag with "Q"
	Field duplicate	See footnote [e]	Review data [d]
Iodine-129	MB	<MDC; <5% sample activity concentration	Flag with "B"
	LCS	80–120% recovery	Flag with "o" [a]
	DUP	≤30% RPD [c]	Review data [d]
	Tracer	30–105% recovery	Review data [d]
	EB, FTB	<MDC; <5% sample activity concentration	Flag with "Q"
	Field duplicate	See footnote [e]	Review data [d]
Nickel-63	MB	<MDC; <5% sample activity concentration	Flag with "B"
	LCS	80-120% recovery	Flag with "o" [a]
	DUP	≤30% RPD [c]	Review data [d]
	MS	75–125% recovery	Review data [d]
	Carrier	40–110% recovery	Review data [d]
	EB, FTB	<MDC; <5% sample activity concentration	Flag with "Q"
	Field duplicate	See footnote [e]	Review data [d]
Selenium-79	MB	<MDC; <5% sample activity concentration	Flag with "B"
	LCS	80–120% recovery	Flag with "o" [a]
	DUP	≤30% RPD [c]	Review data [d]
	Carrier	40–110% recovery	Review data [d]
	EB, FTB	<MDC; <5% sample activity concentration	Flag with "Q"
	Field duplicate	See footnote [e]	Review data [d]
Strontium-90	MB	< MDC; <5% sample activity concentration	Flag with "B"
	LCS	80–120% recovery	Flag with "o" [a]
	DUP	≤30% RPD [c]	Review data [d]
	Tracer	30–105% recovery	Review data [d]
	Carrier	40–110% recovery	Review data [d]
	EB, FTB	<MDC; <5% sample activity concentration	Flag with "Q"
	Field duplicate	See footnote [e]	Review data [d]

Table 2-5. Laboratory QC Elements and Acceptance Criteria for Soil and Vegetation Samples

Analyte	QC Element	Acceptance Criteria	Corrective Action
Technetium-99	MB	<MDC; <5% sample activity concentration	Flag with "B"
	LCS	80–120% recovery	Flag with "o" [a]
	DUP	≤30% RPD [c]	Review data [d]
	MS	75–125% recovery	Flag with "N"
	EB, FTB	<MDC; <5% sample activity concentration	Flag with "Q"
	Field duplicate	See footnote [e]	Review data [d]
Tritium	MB	<MDC; <5% sample activity concentration	Flag with "B"
	LCS	80-120% recovery	Flag with "o" [a]
	DUP	≤30% RPD [c]	Review data [d]
	Tracer	30–105% recovery	Review data [d]
	MS	75–125% recovery	Review data [b]
	EB, FTB	<MDC; <5% sample activity concentration	Flag with "Q"
	Field duplicate	See footnote [e]	Review data [d]
Gross alpha	MB	<MDC; <5% sample activity concentration	Flag with "B"
	LCS	80–120% recovery	Flag with "o" [a]
	DUP	≤30% RPD [c]	Review data [d]
	EB, FTB	<MDC; <5% sample activity concentration	Flag with "Q"
	Field duplicate	See footnote [e]	Review data [d]
Gross beta	MB	<MDC; <5% sample activity concentration	Flag with "B"
	LCS	80-120% recovery	Flag with "o" [a]
	DUP	≤30% RPD [c]	Review data [d]
	EB, FTB	<MDC; <5% sample activity concentration	Flag with "Q"
	Field duplicate	See footnote [e]	Review data [d]

Notes: The information in this table does not represent EPA requirements but is intended solely as guidance. The table is consistent with SW-846, *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods, Third Edition; Final Update V;* and DOE/RL-96-68, *Hanford Analytical Services Quality Assurance Requirements Documents*.

Specific analytes and methods for determination are available from SMR.

a. Apply with SMR concurrence.

b. Either a sample duplicate or a MSD is to be analyzed to determine measurement precision.

c. Applies when at least one result is greater than the laboratory practical quantitation limit (chemical analyses) or greater than five times the MDC (radiochemical analyses).

d. After review, corrective actions are determined on a case-by-case basis. Corrective actions may include a laboratory recheck or flagging the data as suspect ("Y" flag) or rejected ("R" flag).

e. A field duplicate RPD for soils is not recommended because of possible soil matrix heterogeneity effects.

f. Laboratory-determined, statistically derived control limits based on historical data are used here. Control limits are reported with the data.

Table 2-5. Laboratory QC Elements and Acceptance Criteria for Soil and Vegetation Samples

Analyte	QC Element	Acceptance Criteria	Corrective Action

Data flags:

B, C = possible laboratory contamination; analyte was detected in the associated method blank

N = result may be biased; associated matrix spike result was outside the acceptance limits

Q = problem with associated field QC blank; results were out of limits

AEA = atomic energy analysis
DUP = laboratory sample duplicate
EB = equipment blank
EPA = U.S. Environmental Protection Agency
FTB = full trip blank
GEA = gamma energy analysis
ICP/AES = inductively coupled plasma/atomic emission spectroscopy
ICP/MS = inductively coupled plasma/mass spectrometry
LCS = laboratory control sample
MB = method blank
MDC = minimum detectable concentration
MDL = method detection limit
MS = matrix spike
MSD = matrix spike duplicate
QC = quality control
RPD = relative percent difference
SMR = Sample Management and Reporting
SUR = surrogate

2.2.3.1 Field Quality Control Samples

Field QC samples are collected to evaluate the potential for cross-contamination and to provide information pertinent to field sampling variability and laboratory performance ensure that reliable data are obtained. Field QC samples include field duplicates. QC sample definitions and their required frequency for collection are described below.

- **Field duplicates**: Independent samples collected as close as possible to the same time and same location as the scheduled sample and intended to be identical. For this contaminated deep-rooted vegetation sampling study, two types of field duplicate samples, prepared by the sample preparation laboratory, will be collected: vegetation tissue and soil. These samples will represent a measure of precision for the analytical laboratory. Sample preparation laboratory field duplicate samples will be collected at a frequency of one per processing day for tissue (and only if the quantity of remaining tissue—i.e., after all other required tissue sample analysis masses are fulfilled—is sufficient) and one per processing day for soil (and only if the quantity of soil is sufficient to first meet all analytical requirements). Root tissue is likely to be insufficient in mass to support preparation and submission of root tissue field duplicate samples. Field duplicates are placed in separate sample containers and analyzed independently. If insufficient sample mass for tissue or soil is available, sample preparation laboratory field duplicates will not be collected to ensure that analytical priorities are met.

  Equipment blanks (EBs): High purity water is typically passed through or poured over decontaminated sampling equipment identical to the sample set collected and placed in sample containers, as identified on the SAF. For this study, one EB will be collected each tissue processing day for non-disposable tissue grinding or macerating equipment used. The EB sample bottles are placed in the storage containers to be shipped with samples from the associated sampling event and have the same required analyses as samples from the sampling event. EBs are used to evaluate decontamination process effectiveness; these samples are not required for disposable (one-time use) sampling preparation equipment that will be used in the sample preparation laboratory (i.e., with potential exception of grinding equipment unless disposable means are also identified for this processing activity).

2.2.3.2 Laboratory Quality Control Samples

Internal QA/QC programs are maintained by laboratories used by the project. Laboratory QA includes a comprehensive QC program that includes the use of laboratory control samples (LCSs), laboratory sample duplicates (DUPs), matrix spikes (MSs), matrix spike duplicates (MSDs), method blanks (MBs), surrogates (SURs), carriers, and tracers. These QC analyses are required by EPA methods (e.g., SW-846, *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods, Third Edition; Final Update V*) and will be run at the frequency specified in the respective references, unless superseded by agreement. QC checks outside of control limits are documented in analytical laboratory reports during data quality assessments (DQAs, if performed). Table 2-5 lists the laboratory QC checks and their typical frequencies and also the acceptance criteria. The various types of laboratory QC samples are as follows:

- **Laboratory control sample (LCS)**: A control matrix (e.g., reagent water) spiked with analytes representing the target analytes or certified reference material used to evaluate laboratory accuracy.
- **Laboratory sample duplicate (DUP)**: An intralaboratory replicate sample used to evaluate the precision of a method in a given sample matrix.
- **Matrix spike (MS)**: An aliquot of a sample spiked with a known concentration of target analyte(s). The MS is used to assess the bias of a method in a given sample matrix. Spiking occurs prior to sample preparation and analysis.
- **Matrix spike duplicate (MSD)**: A replicate spiked aliquot of a sample that is subject to the entire sample preparation and analytical process. MSD results are used to determine the bias and precision of a method in a given sample matrix.
- **Method blank (MB)**: An analyte-free matrix to which the same reagents are added in the same volumes or proportions as used in the sample processing. The MB is carried through the sample preparation and analytical process and is used to quantify contamination resulting from the analytical process.
- **Tracer**: A known quantity of radioactive isotope that is different from that of the isotope of interest but is expected to behave similarly and is added to an aliquot of sample. Sample results are generally corrected based on tracer recovery.

Laboratories are required to analyze samples within the holding times specified in Table 2-6. In some instances, constituents in the samples not analyzed within the holding times may be compromised by volatilization, decomposition, or by other chemical changes. Data from samples analyzed outside of the holding times are flagged in the HEIS database with an "H."

Table 2-6. Soil, Vegetation Tissue, and EB Water Holding Time Guidelines for Laboratory Analytes

Constituent/Parameter	Matrix	Preservation [a]	Holding Time [b]
General Chemistry Parameters			
Cation exchange capacity	Soil	None required	None
Total organic carbon		≤6°C	28 days
pH	Soil	None required	Immediately upon sample receipt
Percent moisture	Soil and plant tissue	None required	As soon as possible following sample receipt

Table 2-6. Soil, Vegetation Tissue, and EB Water Holding Time Guidelines for Laboratory Analytes

Constituent/Parameter	Matrix	Preservation [a]	Holding Time [b]
Inorganics – Metals			
6020B metals (Ca^{2+}, K^{+}) [c]	Soil	None required	6 months
6020B metals (Ca^{2+}, K^{+}) [c]	EB water	Nitric pH<2	
Radionuclides – Soil, Plant Tissue			
Gross alpha/beta (gas proportional counting)	Soil and plant tissue	None required	6 months
Isotopic americium, curium, neptunium, plutonium, and uranium by alpha energy analysis			
Carbon-14, iodine-129, nickel-63, and tritium			
Gamma energy analysis			
Selenium-79 and technetium-99			
Strontium-90			
Radionuclides Equipment Blank Water			
Gross alpha/beta (gas proportional counting)	EB water	Nitric, pH≤2	6 months
Isotopic americium, curium, neptunium, plutonium, and uranium by alpha energy analysis		Nitric, pH≤2	
Carbon-14, iodine-129, and tritium		None required	
Gamma energy analysis		Nitric, pH≤2	
Nickel-63, selenium-79, and technetium-99		Nitric, pH≤2	
Strontium-90		Nitric, pH≤2	

Notes: The information in this table does not represent EPA requirements but is intended solely as guidance. Selection of container, preservation techniques, and applicable holding times should be based on the stated project-specific data quality objectives.

Container type and volume (EB) or mass (solid matrices) will be identified on the chain-of-custody form.

This table applies only to laboratory analyses.

a. For preservation identified as stored at <6°C, the sample should be protected against freezing unless it is known that freezing will not impact the sample integrity.

b. EPA has not published holding time requirements for the analysis of metals or radioisotopes in plant tissue; therefore, this study defaults to the holding time requirements for soil.

c. Water extractable soil fraction is analyzed for 6020B metals.

EB = equipment blank (required for sample preparation laboratory tissue grinding equipment unless a disposable grinding equipment option is identified)

EPA = U.S. Environmental Protection Agency

2.2.4 Measurement Equipment

Each user of measuring equipment (field or laboratory) is responsible for ensuring that the equipment is functioning as expected, properly handled, and properly calibrated at required frequencies per (manufacturer) methods governing control of the equipment. Onsite environmental instrument testing, inspection, calibration, and maintenance will be recorded in accordance with approved PRC methods. Field screening instruments will be used, maintained, and calibrated in accordance with the manufacturers' specifications and other approved PRC methods.

2.2.5 Instrument and Equipment Testing, Inspection, and Maintenance

Collection, measurement, and testing equipment should meet applicable standards (e.g., ASTM International [formerly the American Society for Testing and Materials]) or have been evaluated as acceptable and valid in accordance with instrument-specific methods, requirements, and specifications. Software applications will be acceptance tested prior to use in the field.

Measurement and testing equipment used in the field or laboratory will be subject to preventive maintenance measures to minimize downtime. Laboratories must maintain and calibrate their equipment. Maintenance requirements (e.g., documentation of routine maintenance) will be included in the individual laboratory's and onsite organization's QA plan or operating protocols, as appropriate. Maintenance of laboratory instruments will be performed in a manner consistent with applicable Hanford Site requirements.

2.2.6 Instrument/Equipment Calibration and Frequency

Field equipment calibration is discussed in Section 3.8. Analytical laboratory instruments are calibrated in accordance with the laboratory's QA plan and applicable Hanford Site requirements.

2.2.7 Inspection/Acceptance of Supplies and Consumables

Consumables, supplies, and reagents will be reviewed in accordance with internal work and EPA analytical method requirements and will be appropriate for their use. Supplies and consumables used in support of sampling and analysis activities are procured in accordance with internal work requirements and processes. Responsibilities and interfaces necessary to ensure that items procured/acquired for the contractor meet the specific technical and quality requirements must be in place. The procurement system ensures that purchased items comply with applicable procurement specifications. Supplies and consumables are checked and accepted by users prior to use.

2.2.8 Nondirect Measurements

Nondirect measurements include data obtained from sources such as computer databases, programs, literature files, and historical databases. Nondirect measurements will not be evaluated as part of this activity.

2.2.9 Data Management

In coordination with the biomobilization project manager (or designee), the SMR is responsible for ensuring that analytical data for the contaminated deep-rooted vegetation sampling study are appropriately reviewed, managed, and stored in accordance with applicable programmatic requirements governing data management methods. When appropriate, electronic data access will be through a Hanford Site database (e.g., HEIS). Where electronic data are not available, hard copies will be provided.

Laboratory errors are reported to SMR through an established process that includes a sample issue resolution form initiated in accordance with applicable methods. This process is used to document analytical errors and to establish their resolution. The sample issue resolution forms become a permanent part of the analytical data package for future reference and for records management purposes.

2.3 Assessment and Oversight

Assessment and oversight activities address the effectiveness of project implementation and associated QA/QC activities. The purpose of assessment is to ensure that the QAPjP is implemented as prescribed.

2.3.1 Assessments and Response Actions

Contractor management, QA organization, and/or Health and Safety organization will determine the need for conducting random surveillances and assessments to verify compliance with the requirements outlined in this Study Plan, project field instructions, QAPjP, and methods. As primary Study Plan author, the biomobilization technical lead may choose to conduct separate field oversight and assessments to establish compliance with Study Plan technical requirements. Deficiencies identified by these assessments will be reported in accordance with existing programmatic requirements. The project line management chain coordinates the corrective actions or deficiency resolutions in accordance with the QA program, corrective action management program, and associated methods implementing these programs. When appropriate, the biomobilization project manager (or designee) will require corrective actions.

Oversight activities in the analytical laboratories, including corrective action management, are conducted in accordance with the laboratory's QA plan. SMR oversees offsite analytical laboratories and verifies that the laboratories are qualified to perform Hanford Site analytical work.

2.3.2 Reports to Management

Program and project management (as appropriate) will be made aware of deficiencies identified by internal self-assessments, corrective actions, and findings from internal QA assessments and surveillances. Issues reported by the laboratories are communicated to SMR, which initiates a sample issue resolution form. This process is used to document analytical or sample issues and to establish resolution.

These assessments represent internal assessments. If an assessment finding results in sampling issues that impact study data quality objectives, DOE will be informed.

2.4 Data Review and Usability

This section addresses QA activities that occur after data collection. These activities determine whether the data conform to the specified criteria, thus satisfying the project objectives.

2.4.1 Data Review and Verification

Data review and verification are performed to confirm that sampling, analysis, and chain-of-custody documentation are complete. This review includes linking sample numbers to specific sampling locations; and reviewing sample collection dates, sample preparation dates, and analysis dates to assess whether holding times (if any) have been exceeded. Furthermore, the QC data review is used to determine whether analyses have met the data quality requirements specified in this Study Plan.

The criteria for verification include but are not limited to review for contractual compliance (i.e., samples analyzed as requested), use of the correct analytical method, transcription errors, correct application of dilution factors, appropriate reporting of dry versus wet weight, and correct application of conversion factors. Field QA/QC results will be reviewed to ensure usability.

The biomobilization technical lead (or designee) performs data reviews to determine if observed changes reflect potential data errors, which may result in submitting a request for data review for questionable data. The laboratory may be asked to check calculations or reanalyze the sample. The results of the request for data review are used to flag data appropriately in the HEIS database and/or to add comments.

2.4.2 Data Validation

Data validation is performed at the discretion of DOE-RL and PRC project managers and under the direction of the SMR manager. It is based on the results of the QC samples and discussions with the DOE-RL and PRC technical leads. Data validation (third-party) will be performed at a frequency of a minimum of 5% per method per matrix and be based on guidelines in EPA-540-R-2017-001, *National Functional Guidelines for Inorganic Superfund Data Review*, EPA-540-R-2017-002, *National Functional Guidelines for Superfund Organic Methods Data Review*, and adjusted for use with SW-846 and HASQARD (DOE/RL-96-68). Data validation qualifiers must be compatible with the HEIS database.

Data validation will ensure that data quality goals established during the planning phase are achieved. Data validation will be in accordance with internal procedures. The criteria for data validation are based on a graded approach. The primary contractor has defined five levels of validation: Levels A through E. Level A is the lowest level and is the same as verification, and Level E is a 100% review of data (e.g., calibration data and calculations checks). Validation will be performed to contractor Level C, which is a review of the QC data. Level C validation specifically requires (1) verification of deliverables; (2) requested versus reported analyses; and (3) qualification of results based on analytical holding times, MB results, MS/MSD results, DUP sample results, and analytical MB results. Level C validation will be performed on at least 5% of the data by matrix and analyte group. Analyte group refers to categories such as radionuclides or metals. The goal is to encompass various analyte groups and matrices during validation.

When outliers or questionable results are identified, additional data validation will be performed. The additional validation will be performed for up to 5% of the statistical outliers or questionable data. Additionally, the validation will begin with Level C and may increase to Levels D and E as needed to ensure usable data. Level C validation is a review of the QC data, while Levels D and E include review of calibration data and calculations of representative samples from the data set. Data validation will be documented in data validation reports. An example of questionable data is if the positive detections are greater than the practical quantitation limit or reporting limit in soil from a site that should not have exhibited contamination. Similarly, results less than background would not be expected and could trigger a validation inquiry. The determination of data usability will be conducted and documented in a data usability assessment report. Data validation will be documented in data validation reports and will be included in the project file.

2.4.3 Reconciliation with User Requirements

The purpose of reconciliation with user requirements is to determine if quantitative data are of the correct type and adequate quality and quantity to meet project data needs. The DQA process is the scientific and statistical evaluation of previously verified and validated data to determine if information obtained from environmental data operations are of the right type, quality, and quantity to support their intended use (usability). The DQA process uses the entirety of the collected data to determine usability for decision making. If a statistical sampling design was used during field sampling activities, the DQA will be performed following guidance in EPA/240/B-06/003, *Data Quality Assessment: Statistical Methods for Practitioners*. When judgmental (focused) sampling designs are implemented in the field, DQIs such as precision, accuracy, representativeness, comparability, completeness, and sensitivity for specific data sets (individual data packages) will be evaluated in accordance with EPA/240/R-02/004, *Guidance on Environmental Data Verification and Data Validation*. Data verification and validation are integral to the statistical data and DQI evaluation processes. The biomobilization project manager (or designee) will use the DQA or DQI process results to interpret data and determine if DQOs for this activity have been met.

3 Field Sampling Plan

The objective of the field sampling plan (FSP) is to identify and define sampling and analysis activities for the contaminated deep-rooted vegetation sampling study. The field sampling plan follows the requirements for designing a field sampling program in accordance with the guidance provided in EPA/240/B-06/001, *Guidance on Systematic Planning Using the Data Quality Objectives Process*. The field sampling plan defines the sampling objectives and design, number and type of samples to be collected, sampling locations, sampling methods, field equipment needs, and field documentation.

3.1 Sampling Objective

The objective of the FSP is to identify and describe the sampling and analysis activities necessary to evaluate vertical biomobilization of radionuclides in radiologically contaminated deep-rooted annual and perennial vegetation and collocated soil cores (collected from 0 to 4.9 m [0 to 16 ft]). Contaminated deep-rooted vegetation is identified by RCO RCTs during routine radiation surveillance activities of operational areas (200 East, 200 West, and portions of the 600 Area) on the Central Plateau. Several annual and perennial vegetation species are targeted for evaluation in this study (Section 3.2.1).

3.2 Study Design

The study is designed to take advantage of radiologically contaminated (i.e., >5,000 dpm/100 cm^2) deep-rooted vegetation opportunistically identified by RCTs during their routine radiological surveillance and monitoring activities. Rather than disposing of the vegetation (as RCO RCTs routinely do), the vegetation will be measured, dripline perimeter staked, and the aboveground portion removed (sampled). The removed aboveground shrub is then safely packaged and transported to a sample preparation laboratory where a composite sample is prepared for submission to the contracted analytical laboratory. Collocated soil cores are collected at a later time (likely a number of months) to ensure that all required clearances are obtained and the surveillance location can be safely sampled. Collectively, these data are then used to evaluate statistically the relationship (if any) between aboveground vegetation tissue radionuclide concentrations and concentrations in soil of collocated cores (with root tissue).

Table 3-1 summarizes key study activities that comprise the contaminated deep-rooted vegetation sampling study and performing personnel. FSP sections are identified where the activity is discussed, whether existing (contractor) or Study Plan specified procedures govern activity conduct, and any identified training requirements.

Two fundamental assumptions underlie the conduct of this study:

1. That the sampling and analysis of radiologically contaminated aboveground vegetation is done “at risk” by DOE-RL (i.e., clearance approvals may not be granted at all sampling locations to collect collocated soil cores)., and

2. Contaminated vegetation greater than the threshold level of 5,000 dpm / 100 cm^2 is the result of vegetation uptake of radionuclides from collocated soil into plant tissues rather than a result of radionuclide deposition on the vegetation from exogenous sources (e.g., animal latrine, atmospheric deposition); the latter not being discernible from the former by RCO RCT surveillance and monitoring equipment.

Table 3-1. Key Opportunistic Sampling Study Activities, Performing Entities, and Associated Procedures

Opportunistic Sampling Study Activity	Performing Personnel	Procedure(s) and Training	Applicable Chapter or Section(s)
Health and safety procedures	AL, DC, DRCOR, PRC, GPLC, SPL	• Existing health and safety procedures and HASPs (made compliant with Study Plan, as necessary) • Training of personnel may be required for some performing entities (e.g., SPL)	Section 3.5 and Chapter 5
Identification of contaminated deep-rooted vegetation species occurring at radiation monitoring locations	DRCOR	• Existing RCO procedures • Train RCOs on existing procedure modifications to fulfill Study Plan requirements	Sections 3.2.3.1 and 3.3
Notification of contaminated deep-rooted vegetation at surveillance locations	DRCOR	• Existing RCO contaminated material notification procedures with modification • Train RCOs on DBTR notification requirements and frequency to fulfill Study Plan requirements	Section 3.2.3.2
Create and maintain contaminated deep-rooted vegetation database	DBTR	• Follows Study Plan requirements for developing and maintaining deep-rooted vegetation notification database, conducts other required notifications, and maintains updated database • Train DBTR on notification database development, notification requirements, and database maintenance	Section 3.2.3.2
Rapidly evaluate contaminated deep-rooted vegetation location against exclusion criteria (within vegetation sampling time frame) and inform BTR / NCOs whether to sample	DBTR	• Follows existing PRC evaluation procedures on site access and sampling restrictions • Train DBTR on notifying BTR (who notifies SMR and NCOs) for aboveground vegetation sampling based on PRC exclusion criteria	Section 3.2.4
Safety of samples for collection in field or for transport to laboratories	AL, DC, DRCOR, GPLC, NCO, SPL	• Follows existing PRC procedures; SPL and AL facility procedures developed to be Study Plan and PRC procedure compliant • Laboratory training of performing personnel	Sections 3.4.2, 3.5.1, and 3.8.5
Conduct intact contaminated deep-rooted vegetation measurements, staking, sampling, packaging, and transport to SPL	NCO	• Follow aboveground vegetation measurement, staking, and sampling requirements in this Study Plan (completed within 2 weeks of vegetation identification). • Train DRCORs on aboveground vegetation sampling, packaging, and SPL transport requirements	Sections 3.3 and 3.8.5
Aboveground shrub(s) composite tissue sample preparation	SPL	• Follows SPL procedures compliant with aboveground tissue processing requirements in this Study Plan • Training of SPL personnel	Sections 3.5.1 and 3.5.2.1

Table 3-1. Key Opportunistic Sampling Study Activities, Performing Entities, and Associated Procedures

Opportunistic Sampling Study Activity	Performing Personnel	Procedure(s) and Training	Applicable Chapter or Section(s)
Aboveground vegetation QC samples, and sample handling (preservation, containers, custody, and transport to AL), sample waste management	SPL	• Follows SPL procedures compliant with existing PRC QC, sample handling, waste management procedures • Training of SPL personnel	Sections 3.5.2.1, 3.8.5; Chapter 4
Initiate application and track required clearance reviews for contaminated deep-rooted vegetation location(s) for soil core drilling	DBTR	• Follow existing PRC procedures for clearance review application (cultural, health, and safety, subsidence, ecological) • DBTR training in existing and expanded requirements for clearance reviews, specific PRC contacts for initiating / tracking clearance review process	Section 3.2.3.2
Following clearance approvals, conduct collocated soil core drilling and GPL (GPL if GPL contractor can be coordinated in timely manner with core drilling)*	DC, GPLC, NCO	Follow existing PRC procedures and requirements	Section 3.4
Transport soil cores to sample preparation laboratory	NCO	Follows existing PRC soil core transport requirements and procedures	Sections 3.4 and 3.8.5
Depth discrete core root and soil data documentation, photography, and composite sample preparation (belowground root tissue and soil)	SPL	Follows SPL procedures compliant with Study Plan requirements for depth discrete belowground root tissue and soil composite sample processing	Sections 3.5.2.2 and 3.5.3
Depth discrete core root and soil core QC samples; sample handling requirements (preservation, containers, custody, and transport to AL); sample waste management	SPL	Follows existing PRC QC sample and sample handling procedures	Sections 3.5.2.2, 3.5.3, and 3.8.5; Chapter 4
AL required analyses (and reporting) for all tissue and soil composite samples	AL, SMR	Follows PRC analytical method, quality, and sample management and reporting requirements	Chapter 2
Study investigation derived waste management (SPL and AL)	AL, SPL, WM	Follows existing PRC procedures (IDW) and SPL or AL existing (and PRC contract compliant) procedures	Section 3.5; Chapter 4

Note: Highlighted rows indicate new roles or responsibilities that will be added to existing work controls and procedures.

*Collocated soil cores containing belowground root tissue are collected in a different timeframe from aboveground shrub tissue (i.e., following clearance approvals).

AL = analytical laboratory (subcontracted)
DBTR = designated biomobilization team representative
DC = drilling contractor
DRCOR = designated radiation control organization representative
GPLC = geophysical logging contractor
HASP = Health and Safety Plan
IDW = investigation-derived waste
NCO = nuclear chemical operator (vegetation and soil core field samplers)
PRC = Plateau Remediation Contractor
RCO = radiation control organization
SMR = sample management and reporting at PRC
SPL = sample preparation laboratory (radiologically licensed, subcontracted laboratory)
WM = PRC Waste Management

The remainder of this FSP details the study design and sampling elements of the opportunistic contaminated deep-rooted vegetation sampling study, including target vegetation species, statistical design, vegetation identification and notification, sampling exclusion criteria and required clearances, field mobilization, aboveground vegetation sampling methods, soil core sampling methods, and sample preparation laboratory general requirements and sample processing procedures.

3.2.1 Targeted Deep-Rooted Vegetation Species

A number of deep-rooted vegetation species with biointrusion potential occur across the Hanford Site and are summarized in recent (CHPRC-00651; Sample et al., 2015) and historical (Link et al., 1994, "Effects of Coppice Dune Topography and Vegetation on Soil Water Dynamics in a Cold-Desert Ecosystem"; Cline et al., 1980, "Loose Rock as Biobarriers in Shallow Land Burial"; PNL-5247, *Rooting Depth and Distribution of Deep-Rooted Plants in the 200 Area Control Zone of the Hanford Site*) publications. The deepest rooted vegetation species reported to occur on the Hanford Site include the species listed below.

Perennial shrubs

- Big sagebrush (*Artisima tridentata*): Maximum reported root depth 250 cm (8.2 ft) (PNL-5247; CHPRC-00651; Sample et al., 2015)
- Gray rabbitbrush (*Ericameria nauseosa*): Maximum reported root depth 250 cm (8.2 ft) (PNL-5247; CHPRC-00651; Sample et al., 2015)
- Green rabbitbrush (*Chrysothamnus viscidiflorus*): Maximum reported root depth 200 cm (6.6 ft) (PNL-5247; CHPRC-00651; Sample et al., 2015)
- Antelope bitterbrush (*Purshia tridentata*): Maximum reported root depth 300 cm (9.8 ft) (PNL-5247; CHPRC-00651; Sample et al., 2015)
- Spiny hopsage (*Atriplex [Grayia] spinosa*): Maximum reported root depth <220 cm (<7.2 ft) (Link et al., 1994; CHPRC-00651; Sample et al., 2015)

Annual forbs

- Russian thistle (*Salsola kali*): Maximum reported root depth 240 cm (7.9 ft) (Cline et al., 1980; CHPRC-00651; Sample et al., 2015)
- Tumble mustard (*Sisymbrium altissimum*): Maximum reported root depth <240 cm (7.9 ft) (CHPRC-00651; Sample et al., 2015)
- Bursage (*Ambrosia acanthicarpa*): Maximum root depth 180 cm (5.9 ft) (PNL-5247; CHPRC-00651; Sample et al., 2015)

Not all of these species will be "target" species for this study. Targeted vegetation species for the opportunistic sampling study are sagebrush, rabbitbrush (gray or green), antelope bitterbrush, Russian thistle, and tumble mustard. The focus on these particular species is based on the following factors:

- Actual occurrence of specific species within the Central Plateau (as noted from biomobilization staff accompanying RCTs during July 2017 and July 2018): rabbitbrush (gray, green), sagebrush, Russian thistle, and tumble mustard.
- Deep maximum Hanford Site rooting depths as reported in CHPRC-00651 (rabbitbrush, sagebrush, bitterbrush, Russian thistle, tumble mustard, and hopsage).

- Represents a contaminated vegetation species identified (commonly or uncommonly) by RCTs over 22 years of documented radiation surveillance activities: rabbitbrush, sagebrush, and tumbleweed (likely Russian thistle with some tumble mustard) (Table 1-1). Note: Radiologically contaminated bitterbrush has never been identified during routine radiation surveillance and monitoring on the Central Plateau but is the deepest rooted of all perennial species reported at the Hanford Site and is retained. Contaminated bursage and hopsage have also not been identified during radiation surveillance monitoring.

The target vegetation species identified have relatively strong tap root development (PNL-5247) in addition to a lateral root system.

3.2.2 Study Statistical Design

A statistical power analysis was conducted in Statistica™ to determine whether a statistically defined number of specimens per target vegetation species was realistically attainable over the defined duration of the study. The power analysis was conducted using a power level of 0.8, an α of 0.05, a β of 0.2, and an r^2 of 0.2. The resulting minimum sample size identified was n=36 individual plant specimens for each target vegetation species. The statistically based sample number per target vegetation species is considered a "goal" and not a hard sampling requirement. Existing aboveground radiation surveillance data for the Central Plateau conducted over decades indicate that the minimum sampling number would not be easily achievable for contaminated deep-rooted perennial species given their generally low frequency of identification (Table 1-1; see also the most recent and publicly available quarterly summary report: HNF-SP-0665, *Environmental Radiological Survey Summary, Calendar Year 2016, Fourth Quarter, Hanford Site 100, 200, 300, and 600 Areas*). These existing surveillance data also indicate that the statistical sampling goal is likely to be achievable only for tumbleweeds (Table 1-1).

Radiation control operations conduct routine radiation surveys throughout each year. Quarterly summary reports summarize the findings from these surveys, which are conducted either statistically (random) or on a judgmental basis; the latter typically a result of revisiting problem locations with past histories of contaminated vegetation, soil, etc.

Deep-rooted vegetation specimen tissue samples and collocated soil cores collected during the study are all necessarily considered judgmental because they are always identified as a result of exceeding a 5,000 dpm/100 cm^2 threshold level specified in existing radiation control technical procedures (i.e., cannot be considered random samples given the intent of the radiation control program: to identify and manage radiologically contaminated soil, vegetation, etc.).

3.2.3 Contaminated Deep-Rooted Vegetation Identification and Notification

A generalized summary of the RCO RCT approach to identify radioactively contaminated vegetation and the contaminated deep-rooted vegetation notification requirements for this study follows.

3.2.3.1 Radiologically Contaminated Deep-Rooted Vegetation Identification

Under existing RCO procedures, identifying radiologically contaminated materials (biotic and abiotic) during routine surveillance activities is conducted using tractor- or truck-mounted detectors. When an area of radiological contamination is identified (e.g., vegetation of any type, soil, specks, etc.), handheld sodium-iodide detectors are typically used to pinpoint exactly the location of the contaminated material and it is removed for disposal.

™ Statistica is a registered trademark of TIBCO Software, Inc., Palo Alto, California.

Existing RCO technical procedures specify how surveillance locations are identified, the requirements for identification, removal and disposal of contaminated materials, residual energy management requirements, and required notifications. Some modifications of RCO technical procedures will be necessary to support the contaminated deep-rooted vegetation study. These modifications include but may not be limited to the following:

- Contaminated vegetation identified by RCTs in support of this study will be focused only on deep-rooted target vegetation species as discussed in Section 3.2.1.
- For this study, recording and identifying contaminated deep-rooted target vegetation species specimens as those exceeding a 5,000 dpm/100 cm^2 threshold level (only).[8] Current RCO procedure utilizes exceedance of local background only as the criterion for vegetation removal and this study utilizes a higher threshold level than local background. Where multiple specimens are present at a location (common for tumbleweeds), regardless of the number, each specimen at the location will be checked individually for exceedance of the 5,000 dpm / 100 cm^2 threshold level.
- Flagging of each individual radiologically contaminated specimen with >5,000 dpm/100 cm^2 and recording the exact reading (dpm/100 cm^2) by specimen number both on attached (tied on) flagging using indelible marker (for relocating the specimen).
- Maintaining and recording information on identified contaminated specimens that are above the 5,000 dpm / 100 cm^2 threshold, including: date, site location name, RCT name, exact reading (dpm / 100 cm^2) of the specimen(s), Global Positioning System (GPS) coordinates of each contaminated specimen, and identification of each specimen (e.g., Russian thistle, tumble mustard, sagebrush, gray rabbitbrush, green rabbitbrush, Antelope bitterbrush) in a field logbook maintained expressly for this study by the designated RCO RCT study representative(s)[9].
- At locations with multiple contaminated deep-rooted specimens (common for tumbleweeds), a digital photograph showing all the contaminated specimens with the location of the flagged specimen having the highest and the lowest dpm / 100 cm^2 readings above the threshold level being clearly visible. This photograph enables identification by the designated biomobilization team representative of which two specimens should be selected for sampling based on their locations relative to each other (i.e., to avoid root comingling, if possible). All other contaminated specimens at the location will be removed and disposed of following standard RCO RCT procedures.
- Required telephone notification by the designated RCO RCT study representative(s) to the designated biomobilization team representative when target contaminated deep-rooted vegetation species are identified above the threshold level. Note: where multiple contaminated deep-rooted target species are present, notification includes electronic submission of a digital photograph[s] documenting the relative locations to each other of the single specimen with the highest and the specimen with the lowest readings above the threshold level. Electronic submission of photographic documentation will be done the same day as specimen identification and include the following information for each submitted photo.

[8] The threshold level of 5,000 dpm/100 cm^2 is specified for (1) the posting of contamination and high contamination areas in accordance with §835.603(e) and (f) and (2) identifying the need for surface contamination monitoring and control in accordance with §§835.1101 and 835.1102. as set forth in 10 CFR, Part 835, “Occupational Radiation Protection”, Appendix D, “Surface Contamination Values”.

[9] To be identified prior to initiation of the opportunistic vegetation study.

- Confirm that reported tumbleweed(s) are living (i.e., still attached to root system; only living contaminated specimens are the subject of the study). If the first hard frost (early to mid October) has not yet occurred, the tumbleweed will be considered "living" if it is confirmed to be still attached to its root system. Generally, by end of September tumbleweeds should still be attached but may or may not be bright green in color at this very late stage in their lifecycle.
- The methods that the RCO RCTs will use to safeguard the identified contaminated vegetation specimen(s) until it can be removed (sampled) by the NCOs. Safeguarding involves the installation of temporary fencing (e.g., snow fencing) and other control measures for each identified contaminated target vegetation specimen to allow sufficient time (up to two weeks post shrub identification) for sampling paperwork generation and for the NCOs to mobilize, remove, package, and arrange transport of the contaminated shrub sample to the sample preparation laboratory for processing.
- Installation by RCO RCT(s) of gravel over the soil within the shrub dripline perimeter to manage residual soil energy at the location of a contaminated deep-rooted vegetation specimen until all approved clearances are obtained to conduct later soil core drilling.

Designated RCO RCTs will be trained to these modifications of their existing RCO procedures and the new procedures that will be required for RCO RCT(s) to support the conduct of this study.

3.2.3.2 Radiologically Contaminated Deep-Rooted Vegetation Notification Documentation Requirements

This section discusses the contaminated target vegetation notification requirements and study personnel responsibilities.

RCO RCT responsibilities. Each RCO RCT will be responsible for immediately (same day as identified) notifying the designated biomobilization team representative[10] when contaminated deep-rooted vegetation species above the 5,000 dpm/100 cm^2 threshold level are identified from surveillance activities (exact vegetation readings will be recorded). This process represents an added notification in addition to those notifications that RCO RCTs already routinely provide.

The following information will be recorded in the RCO RCT study logbook and relayed by the designated RCO RCT to the biomobilization representative when contaminated deep-rooted vegetation is identified above the contamination threshold and requires notification:

- Target vegetation species exhibiting contamination (i.e., using RCTs best judgment on the species; or if unknown a digital photograph should be submitted to the designated biomobilization team representative at the time of notification)
- Number of contaminated specimens per each target vegetation species identified at a location
- The precise reading of each species specimen present at a surveillance location that exceeds the 5,000 dpm/100 cm^2 threshold level (where multiple deep-rooted vegetation specimens are present, every shrub present must be checked and this information included in the notification with a photograph[s] showing the positions of the specimens with the highest and lowest readings)
- Confirmation that contaminated tumbleweeds exceeding the threshold level are alive and still connected to their root system (the color may begin to change as the shrub matures and approaches death (first frost), though the tumbleweed should still be alive until the end of September)

[10] To be identified prior to initiation of the opportunistic vegetation study.

- Surveillance location (Waste Information Data System [WIDS] name, if known), site name (WIDS) and GPS locations for each specimen exceeding the threshold level present within the surveillance location. The GPS unit used and the coordinates recorded for each target contaminated vegetation specimen identified by the RCO RCT will utilize the following: use of NAV83 projection system (Washington State Plane in meters), Universal Transverse Mercator (UTM) coordinates specified in northing/easting, and horizontal coordinates with a precision of at least 0.1 m

RCO RCTs will be trained on the contaminated vegetation specimen logbook information recording requirements and notification requirements necessary to support this study.

Designated biomobilization team representative responsibilities. The designated biomobilization team representative will develop and maintain an electronic database of all notifications received from the RCTs of contaminated, deep-rooted vegetation above the threshold level. Information included in the deep-rooted contaminated vegetation notification database includes the notification information identified above for the RCOs and the following:

- Name of the RCT making each radiologically contaminated specimen notification.
- The identification notification date.
- Where multiple (>15) contaminated specimens are identified at a surveillance location by the RCO RCT, the designated biomobilization team representative will identify in the database the two specimens that require RCO RCT sampling: those with the highest and lowest dpm/100 cm^2 reading (i.e., considering their relative positions to each other from submitted RCO photographs). The designated biomobilization team representative is responsible for notifying the RCO RCT which two specimens were selected for sampling and direct them to temporarily fence off these two specimens for later sampling by the NCOs. Following fencing off of these specimens, the RCO will remove and dispose of remaining contaminated specimens (i.e., at multispecimen locations) following RCO standard procedures.

The database will be updated following each notification by a designated RCO RCT representative, followed by immediate review (by the designated biomobilization team representative) of sampling exclusion criteria (Section 3.2.4).

If the surveillance location vegetation does not meet the exclusion criteria (Section 3.2.4), the designated biomobilization team representative will immediately notify (within a day) the BTR, who in turn notifies SMR and the NCOs to proceed with mobilizing for sample the aboveground deep-rooted vegetation specimen(s) (Section 3.3) within a two week period following initial identification. The designated biomobilization team representative will ensure that the biomobilization technical lead is notified regularly of updates to the notification database for locations that do not meet the exclusion criteria (i.e., locations where contaminated deep-rooted vegetation sampling will occur).

The designated biomobilization team representative will initiate all required clearances to support later soil core drilling for each surveillance location(s) that does not meet the sampling exclusion criteria. These required clearance reviews will be in accordance with the established PRC procedure. Tracking of the clearance reviews over time will also be the responsibility of the designated biomobilization team representative. These communications are meant to track the approval process timing to support mobilization and sampling planning by the BTR.

The designated biomobilization team representative will be trained on development and maintenance of the contaminated deep-rooted vegetation notification database, all notification requirements, conducting the exclusion criteria reviews, and completing and tracking the required clearance review process.

3.2.4 Sampling Exclusion Criteria and Required Clearances

Exclusion criteria determine whether a surveillance location with contaminated vegetation can be sampled safely. Once an RCO identifies contaminated shrub specimen(s) and notifies the designated biomobilization team representative, the biomobilization team representative will immediately determine using the exclusion criteria whether the surveillance location containing the contaminated deep-rooted vegetation specimen(s) is safe for aboveground vegetation sampling (and potentially also for soil core sampling). If the surveillance location does not meet the sampling exclusion criteria, then the BTR is informed to proceed with informing SMR to prepare sampling paperwork and to notify the NCOs of the sampling timeframe (within 2-weeks) for the aboveground portion of the contaminated shrub. At this time, the clearance review process for collocated soil core collection is also initiated following PRC procedure by the designated biomobilization team representative.

Site exclusion criteria applied will be in accordance with existing PRC procedures. PRC criteria for exclusion of a Hanford location for sampling (i.e., vegetation and soil coring) include but are not limited to the following considerations:

- Active or inactive burial grounds
- Any locations that pose a known high risk of subsidence (all locations are checked in this regard)
- Any high risk drilling locations (e.g., worker health and safety concerns)
- Inside of or less than a few feet outside of tank farm location
- Any location with known subsurface structure(s) such as over a tank, diversion box or pipeline that could be impacted from shrub collocated soil core drilling

3.2.5 Field Mobilization

If the surveillance location of a contaminated deep-rooted vegetation specimen does not meet any of the exclusion criteria, then SMR and the NCOs are notified by the BTR to prepare sampling paperwork and mobilize to conduct sampling of the aboveground shrub within a 2-week timeframe. The NCOs follow the designated measurements and sampling procedures in this Study Plan and then packages the sampled shrub, and transports it to the sample preparation laboratory for sample processing.

Later, once it is understood that all the required clearances for approving soil coring at the contaminated deep-rooted vegetation surveillance location will be obtained and the approximate timeframe (i.e., as a result of the ongoing communications), the designated biomobilization team representative will notify the BTR that mobilization for soil coring can be initiated. The BTR coordinates with the drilling and GPL contractors to identify a date / time when both will be available to complete the assignment. If the schedules of the contractors cannot be coordinated in a timely fashion to support drilling and GPL activities then the drilling contractor schedule will take priority and GPL data will not be collected at the designated location(s).

The BTR also notifies the sample preparation laboratory lead to prepare for receiving cores and conducting soil core vegetation root tissue and soil composite sample processing once the schedule for soil coring is established.

3.2.6 Mock Field Trial of Opportunistic Study

A mock field trial of the opportunistic study will be conducted in an uncontaminated location on the Hanford Site (likely near the Fast Flux Test Facility) prior to actual opportunistic study initiation. The purpose of the mock field trial is to work through key opportunistic field and laboratory study processes as identified in this study plan and to optimize them, and ultimately the study design. Optimization for the drilling of cores for example will include addressing issues that may arise with the use of a larger (i.e., 6 in) core barrel size for drilling taproot cores. Sample preparation laboratory processes to be optimized would likely include evaluation of the most appropriate vegetation tissue grinding method to use. Overall study optimization may include addressing these specific issues in addition to the workability of certain study design elements. For example, whether or not root tissue should continue to be evaluated in the study given the potentially significant length of time between aboveground shrub removal/sampling and belowground root tissue collection and processing since root senescence and desiccation will have occurred. The field trial will directly support updating study documents (e.g., this study plan, certain PRC technical procedures, and sample preparation laboratory study procedures).

3.3 Aboveground Vegetation Field Sampling Methods

Once the designated biomobilization team representative determines that a location with contaminated vegetation does not meet the exclusion criteria, the NCOs are directed by the BTR or designated biomobilization team representative (Section 3.2.5) to remove the aboveground portion (only) of the shrub (cut the shrub stem / woody trunk as physically close to the ground surface as possible to avoid leaving any aboveground woody trunk material). No attempt will be made by NCOs to disturb or otherwise attempt to remove any vegetation structures occurring below the woody trunk / stem..

The steps for sampling the aboveground portion of a contaminated deep-rooted vegetation specimen by the NCOs are as follows:

1. Record the date, time, and location (GPS coordinates) of each shrub in the field logbook maintained for this study by the designated RCO RCTs. The date of collection also provides an indication of the lifecycle stage for the targeted annual vegetation species, Russian thistle, and tumble mustard. The GPS unit and coordinates recorded for each target contaminated vegetation specimen identified will utilize the following: use of NAV83 projection system (Washington State Plane in meters), Universal Transverse Mercator (UTM) coordinates specified in northing/easting, and horizontal coordinates with a precision of at least 0.1 m.
2. Conduct measurements of the aboveground shrub canopy length and width at their widest points using a standard aluminum tape measure. Measure twice to ensure accuracy. Record measurements of specimen length and width in the field logbook.
3. Stake all around the shrub following the vegetation canopy outline. Staking will be lengthy, sturdy, and able to be inserted deeply for stability. Staking must be sturdy to remain visible all around the shrub for up to a number of months without breaking, toppling, or otherwise being affected by wind or weather. Metal rebar may be a good choice. Stakes will be placed every 15 cm (6 in.) around the complete vegetation canopy. When complete, the staking reveals the outline of the shrub and facilitates drillers in optimizing soil core placement within the defined shrub perimeter (which may occur some months after initial perimeter staking as the clearance approval process is underway).

4. Tie flagging tightly on several of the stakes, each marked using indelible markers with the shrub species (e.g., sagebrush or Russian thistle), specimen number, and location identifiers (e.g., WIDS identifier and GPS coordinates). These identification measures ensure that the soil core drilling team that samples later knows they are drilling in the correct location and at the correct species specimen.
5. Photograph the staked, flagged shrub and note the digital camera frame numbers and photo descriptions in the field logbook.
6. The shrub will be removed by the NCOs from within the sturdily staked shrub dripline perimeter. Removal will entail carefully cutting or sawing off the entire shrub through the woody trunk as close as is possible to the ground surface using a disposable (only) hand saw blade, clipper, or other device (i.e., to minimize leaving any woody trunk material aboveground). Each shrub to be removed will utilize a disposable hand saw blade or clippers that cannot be used on any other shrub to ensure elimination of cross contamination. Once used, saws and clippers are investigation-derived waste (IDW) and disposed of following NCO established procedures.
7. The mainstem(s) point of entry into the ground will be photographed and the digital frame numbers and descriptions recorded in the field logbook.
8. The visible mainstem (regardless of size) will be covered and the cover secured (e.g. tent stakes) to the ground surface (a piece of doubled sturdy plastic [or similar] cut to appropriate size is recommended) and clearly marked as “mainstem (taproot)” with indelible marker. Only the mainstem (taproot) is covered and marked (i.e., the rest of the soil surface within the staked perimeter is not covered). Where more than one mainstem entry point into the ground is identified following shrub removal (possible with some perennial specimens), only the largest of the mainstems will be identified, covered, secured to the ground surface, and marked as the mainstem (taproot) to denote to where the drillers should center the taproot core during drilling operations (this covering provides some protection of the mainstem from weathering and from gravel that may be placed for interim energy control that may be required in accordance with existing RCO procedures).
9. Following PRC procedures, the NCOs package the shrub in compliant packaging for safe offsite local transport by the authorized shipper to the sample preparation laboratory. SMR may be consulted as necessary to establish package transport requirements. Only one vegetation specimen will be included in each package. If needed for extra large shrubs, the shrub can be cut into large pieces to facilitate packaging. The type of packaging used will be recorded in the field logbook for each specimen transported.
10. Affix a custody seal to the sample container package and initial.
11. The container will include with indelible marker the date of collection, NCO sampler name, surveillance location name (WIDS), GPS coordinates of the specimen, and vegetation identification (species).
12. Complete a chain-of-custody form, sign, and affix to the transported package for sample preparation laboratory acceptance and signature. If multiple vegetation specimens are transported, one custody form is used per specimen. A copy of the form is made for SMR. The NCO retains a copy of the signed form as well to document their relinquishment of custody.
13. Provide a scanned copy of the field logbook entry(s) for each contaminated deep-rooted vegetation specimen sampled, and digital photographs with clear descriptions of photographic content to the designated biomobilization team representative as soon as possible at the end of each sampling day for inclusion in the project files.

NCOs will be trained on aboveground contaminated shrub removal / sampling procedures, field data documentation and sample transportation requirements.

3.4 Soil Core Field Sampling Methods

This section includes information on the number, type, depth, and placement of collocated soil cores and the field methods for collection.

3.4.1 Core Number, Type, Depth and Placement

Upon arrival, the drillers and NCOs will note that the shrub dripline perimeter is clearly staked to inform drillers of the area within which coring will occur (coring outside of the marked perimeter is not permitted). A total of up to four 4.9 m (16 ft) continuous, tight[11] soil cores will be collected at each shrub location. Each of the 4.9 m (16 ft) continuous tight cores will be later cut (discretized) by the NCOs into a total of eight soil depth intervals (Table 3-2) prior to delivery to the sample preparation laboratory. The specific core sampling methods selected will ensure collection of both tight and fully intact (including root tissue) cores at each of the required eight soil depth intervals.

Table 3-2. Number and Type of Collocated Soil Cores Collected at Each Contaminated Deep-Rooted Vegetation Location

Type of Soil Core [a]	Number of Cores Drilled per Shrub Location [b]	Number of Soil Depth Intervals Per Core	Soil Core Depth Intervals (m)
Taproot core	1	8	0–0.3, 0.3–0.9, 0.9–1.5, 1.5–2.1, 2.1–2.7, 2.7–3.4, 3.4–4.0, 4.0–4.9
Dripline cores	Up to 3	8	

a. Collocated 4.9 m (16 ft) continuous soil cores.

b. One taproot core and three dripline cores. Note that the number of dripline cores may be reduced based upon the size of the shrub dripline diameter and result in less than four cores being collected (Section 3.4.1).

Placement of the (up to) four cores within the staked shrub perimeter outline will be as shown in Figure 3-1 (though the shrub will be absent having been removed for sample preparation earlier). Figure 3-1 illustrates two types of cores drilled: the center taproot core and three dripline perimeter cores.

If required to meet sampling objectives, modifications to the number of soil cores drilled at a contaminated deep-rooted vegetation location will be based on shrub size as represented by the staked dripline sampling area. Changes in the number of cores to be drilled, if required based on shrub dripline perimeter size, is determined in the field using the judgment of the driller.

[11] Tight cores are contained within a compressive sleeve as opposed to “loose” cores, which represent cores in a loose core sleeve termed a “sausage bag”.

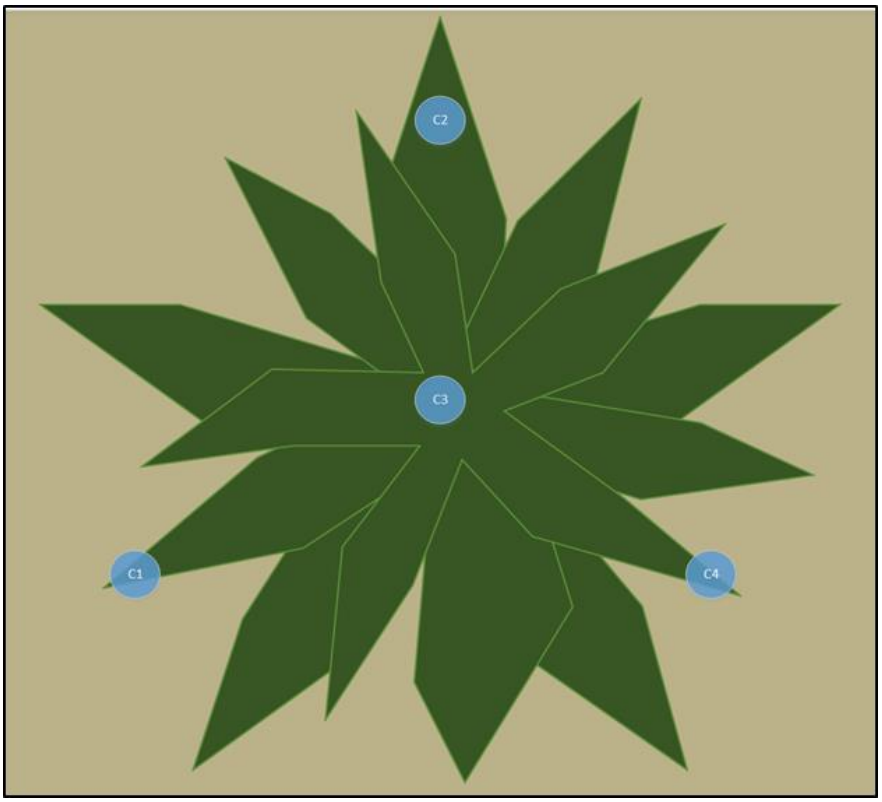

Figure 3-1. Continuous Core Placement Over Center Mainstem (Taproot) and Around Plant Specimen Dripline Perimeter

For shrubs of any size:

- One taproot core will always be collected, regardless of shrub size, using the largest possible core barrel diameter size (15 cm [6 in.] minimum is desired). GPL (i.e., spectral gamma logging system, neutron moisture logging system) data will be collected in this core and other cores if at all possible.
- Three dripline cores will be the default, unless shrub diameter (dripline perimeter size) dictates that a smaller number of dripline cores be collected. For dripline cores, a 10 cm (4 in.) minimum core barrel diameter is desired to provide the highest probability of obtaining three intact, well defined cores within the dripline perimeter.

For small sized shrubs:

- Small sized shrubs are defined as <0.61 m (<2 ft) in diameter or in canopy linear length (not all plants are round).
- The diameter of the dripline perimeter area will dictate the number of dripline cores and core barrel diameter (for dripline cores only). A lower number of dripline cores or reduced core barrel diameter will be acceptable for small shrubs if absolutely required. If collection of intact and well defined dripline cores of any number or core barrel size is not considered practical for shrubs of very small diameter (e.g., a small overall dripline perimeter size), then the collection of dripline cores (only) will be determined to be infeasible.

For moderately sized shrubs:

- Moderately sized shrubs are defined as >0.61 m to 1.2 m (>2 to 4 ft) in diameter or in canopy linear length (not all plants are round).
- The diameter of the moderately sized shrub dripline area will dictate the number and core barrel diameter for dripline cores. Three dripline cores are the default (10 cm [4 in.] minimum barrel diameter is desired). A lower number of dripline cores for moderately sized shrubs will only be acceptable if limited by the actual sampling diameter of the shrub's dripline. A minimum of two dripline cores and a maximum of three (desired) will be collected for moderately sized shrubs.

For large sized shrubs:

- Large sized shrubs are defined as >1.2 m (>4 ft) in diameter or in canopy linear length (not all shrubs are round).
- For large shrubs, three dripline cores will be collected within the perimeter of the dripline (10 cm [4 in.] minimum core barrel diameter is desired).

The largest core barrel diameter that will result in meeting the specified minimum number of tight continuous cores within each shrub size category is desired for use by the driller. Four in. (10 cm) is an acceptable barrel diameter for dripline cores but a 6 in. (15 cm) size core barrel diameter is required for the drilling of all taproot cores regardless of shrub dripline perimeter size to ensure that the growth direction and penetration depth of the taproot is evident and to support collection of significant collocated vegetation taproot tissue. A 4 in. (10 cm) diameter size should be sufficient for all dripline cores to maximize the collection of root tissue at each soil core depth interval to meet analytical objectives for the root tissue analyses and to ensure that sufficient soil fines are collected in each of eight soil core depth intervals (i.e., considering the known highly cobbled nature of shallow vadose zone Central Plateau soils).

At some vegetation sampling locations a reduced number of dripline cores than specified or a smaller core barrel diameter than desired may be necessary to complete core drilling at a contaminated deep-rooted vegetation specimen location (i.e., due to the size of the shrub dripline). When these types of changes occur, they are based on driller expert judgment and will be considered a "minor change" (minor field change) in accordance with the change control requirements discussed in Table 2-3.

Table 3-2 summarizes the number of soil cores, soil core type, and the soil core depth intervals (i.e., that will be sampled later by the sample preparation laboratory, Section 3.5) at each contaminated deep-rooted vegetation specimen location.

3.4.2 Soil Core Sampling

The drilling of soil cores and documentation methods will follow established PRC procedures for driller contractors and NCOs. Soil core depth intervals (i.e., prepared by cutting the continuous 16 ft core to the depth intervals specified in Table 3-2) are transported intact (i.e., no filling of sample jars in the field) to the sample preparation laboratory for the processing and preparation of all samples (soil, root tissue). Geophysical logging with neutron soil moisture will also be conducted, if possible, in each drilled core following established PRC GPL contractor procedures. In addition to these existing procedures, the following steps below will also be followed when drilling and collecting soil core depth intervals at each contaminated deep-rooted vegetation specimen location:

1. NCOs will have a list of the original aboveground species identified at each coring location at which collocated soil cores will be collected. This information will be used to identify the original aboveground vegetation species on soil core depth interval labels.

2. The largest size core barrel diameter (6 in. [15 cm]) will be used for the taproot core; smaller (4 in. [10 cm]) cores are acceptable for use in collecting dripline cores. Core sizes smaller than 4 in. (10 cm) are not recommended to reduce the opportunity for drilling refusal and to ensure sufficient fines are collected to meet project objectives.

   For drilling of up to three surrounding dripline cores the procedures in Section 3.4.1 will be followed when driller field judgment dictates adjustments in either dripline core number or changes from the minimum desired core barrel diameter (10 cm [4 in.]) size for these cores.

3. Upon arrival at a drilling location, a staked area denoting the removed contaminated shrub's dripline perimeter will be visible. This staked perimeter denotes the only area within which soil coring will occur.

   Perimeter area stakes may be removed if required for drilling safety. However, the complete outline of the dripline perimeter must be accurately maintained on the soil surface for visual reference (i.e., using other means by the NCOs and driller) throughout drilling to ensure all core drilling is maintained only within the designated dripline perimeter area.

4. Two types of intact depth interval cores are drilled: taproot and dripline. Coring will be conducted to collect tight, intact 16 ft continuous cores for both taproot and dripline cores.

5. The first core to be drilled is always the taproot core, placed squarely over the subsurface entry point of the shrub mainstem, which will be covered and marked for clear identification by the drilling team. This order of core drilling is required to ensure that the taproot is not damaged by subsequent dripline core drilling surrounding the taproot core. The largest core barrel diameter (15.2 cm [6 in.]) will always be used for the taproot core.

   Note that for some shrub locations (typically perennial species) more than one stem entry point to the soil is possible and may be visible. Drilling of the taproot core will only proceed through the covered, marked mainstem (previously determined to be the largest).

6. Drilling will proceed next for each of up to three dripline cores. The minimum core barrel diameter (10 cm [4 in.]) will be used for dripline cores. Refer to Section 3.4.1 regarding driller judgement-based changes that may be required to the number of dripline cores (i.e., based on the diameter of the shrub and size of the staked dripline perimeter).

7. The tight continuous 16 ft cores will be cut (in the field most likely) using a disposable knife or scissor into the eight designated soil core depth intervals as specified in Table 3-2. It is assumed that root tissue will be maintained within each core depth interval using this approach (and if somehow root tissue is pulled through during continuous coring this will be addressed using the procedures below. The following procedures will be followed and documented in the field logbook:

   A. The 16 ft continuous core will be cut at the exact bottom of each of the eight sampled depth intervals using a disposable knife or scissor (i.e., to avoid intra-core cross contamination).

      If there is a pull through of root tissue during coring, , the excess root tissue will be measured and then included with each of the core depth interval(s) from which it was pulled (i.e., based on linear length of the extending root tissue and the length of each affected core depth interval, as applicable.

   B. Root tissue so removed will be wrapped tightly along its linear length in plastic wrap to avoid the tissue drying out further. Root tissue that is wrapped will not be folded in any manner but wrapped with the root tissue's intact linear length preserved as it occurred in the depth interval.

C. The plastic wrapped intact root tissue length(s) will be marked (indelible marker) with core number, and core type (e.g., taproot or dripline core) and the depth interval. Root tissue so handled will be kept directly with the associated depth interval core segment by securing the plastic wrap containing the depth interval to the core sleeve using tape or other affixing method such as heavy rubber band). Trimming of roots, wrapping, marking and securing to core sleeves for other core depth intervals will be done similarly, as necessary, and always using a fresh disposable knife or scissor.

D. Disposable knives and scissors become IDW.

8. The field logbook will document all core drilling data, field condition issues, and other information required by standard PRC field documentation procedures. Decisions made by the driller with regard to any changes to the number of dripline cores, their placement within the staked perimeter, and core barrel diameter (i.e., other than the desired core barrel diameters) will also be recorded.

9. Field photographs will be taken to document the collection of collocated soil cores at each shrub drilling location to support data report preparation and for reference as needed by the biomobilization team. Notation of digital camera frame numbers and descriptions of each photograph (i.e., location identifier, core number (1 – 4), type of core shown (taproot core, or numbered dripline core[12]), will be entered into the field logbook with any other required core descriptions and sampling information (e.g., date, time, sampler, etc.).

10. Following standard PRC procedure each intact soil core depth interval will be labeled and prepared for transport to the sample preparation laboratory under chain-of-custody procedures. For this study, labeling will also include identification of the coring location (WIDS and GPS coordinates), core type (taproot or dripline), core number (for dripline cores only; see Step 9 above on numbering convention for dripline cores), the aboveground shrub species associated with the collocated core depth intervals at the coring location, and the core depth interval represented. The sample preparation laboratory will confirm the identification of the original aboveground shrub species specified on every soil core depth interval label as a first step in soil core depth interval processing using the sample processing data base to be developed and maintained by the sample preparation laboratory (Section 3.5). The sample preparation laboratory will make note in the laboratory notebook and data forms for soil core depth intervals processed of any differences or errors in field shrub identification from the submitted soil core depth interval labels.

3.5 Sample Preparation Laboratory

Aboveground vegetation tissue and collocated soil cores with root tissue are transported to the sample preparation laboratory to prepare composite samples that are subsequently submitted to the analytical laboratory. This section presents sample preparation laboratory general and training requirements, and specific procedures for preparing vegetation tissue and soil core composite samples.

[12] Dripline numbering example for 3 dripline cores collected: 1 of 3, 2 of 3, or 3 of 3. The number of dripline cores may vary depending on the shrub diameter.

3.5.1 Laboratory General Requirements

The contracted sample preparation laboratory will be radiologically licensed. All aspects of laboratory personnel health and safety regarding the receipt, handling, and processing of radiologically contaminated soil and vegetation will be addressed in a project specific health and safety plan that builds on existing laboratory health and safety requirements. Laboratory personnel will be trained as necessary in the safe execution of sample receipt and processing requirements following standard PRC procedures and relative to the facilities radiological license limits.

The laboratory will develop detailed Study Plan-compliant laboratory procedures for personnel to follow in preparing vegetation and soil composite samples. Developed procedures will also adhere to all established PRC sample handling requirements identified in this Study Plan: decontamination requirements (e.g., vegetation grinding equipment), sample containers, QC samples, preservation requirements, labeling, chain-of-custody form completion, and packaging for transport of all samples to the analytical laboratory. Waste management of excess sample processing materials will also be in accordance with Study Plan requirements and will be included in established laboratory procedures. Laboratory personnel will be trained by their organization in the execution of these procedures immediately following contract award. Additional training to ensure compliance with Study Plan procedures will be provided to the sample preparation laboratory personnel by PRC. The sample preparation laboratory lead will be responsible for ensuring any final updates are incorporated from this training into laboratory procedures, and that any updated personnel training (if necessary) is completed following the PRC training (late spring 2020).

The sample preparation laboratory is staffed, equipped, and "on call" to facilitate sample processing. The NCOs collect aboveground radiologically contaminated deep-rooted vegetation opportunistically (whenever and wherever found) as part of routine ongoing radiation surveillance and monitoring activities on the Hanford Site. Accordingly, contaminated deep-rooted vegetation processing will not occur on a fixed schedule. Notification of an incoming contaminated deep-rooted vegetation specimen(s) for processing will likely be only a day or two in advance of required processing.

A laboratory lead technician and contact information will be identified and included in the procedures developed, and this contact information provided to the PRC BTR and designated biomobilization team representative. The sample preparation laboratory lead will be the primary contact with the BTR for alerts regarding delivery of vegetation, or soil (on a later schedule), requiring processing.

Collocated soil cores are not submitted at the time that aboveground contaminated deep-rooted vegetation is submitted but rather at some period (up to a number of months) later once all PRC required clearance reviews for subsurface soil collection at a given contaminated vegetation specimen location have been completed. More lead time on the PRC schedule for collection and delivery of soil cores to the laboratory can be assumed.

Method compliant containers used to prepare vegetation and soil composite samples for submission to the analytical laboratory will be kept at the sample preparation laboratory for continued use. Documentation requirements for commercial precleaned containers will follow the requirements specified in Section 3.8.2.

Processing of either the aboveground contaminated deep-rooted vegetation specimen or collocated soil core depth intervals (containing root tissue) will be initiated within 1 day of receipt. Sample preparation steps follow.

Sample preparation laboratory processing activities for aboveground and belowground (root) vegetation tissue follow (Sections 3.5.2.1 and 3.5.2.2, respectively).

3.5.2 Vegetation Tissue Composite Sample Preparation

Vegetation processing activities conducted include tissue from the entire above-ground shrub and the root tissue contained within each continuous collocated soil core. Table 3-3 summarizes the number and type of vegetation tissue samples that will be processed for each contaminated vegetation specimen sampled, including root tissue included in collocated soil cores.

Table 3-3. Number and Type of Vegetation Tissue Composite Samples Prepared for Each Contaminated Vegetation Specimen

Target Vegetation Species [a]	Vegetation Sample Tissue Type	Number of Tissue Type Samples per Specimen	Sample Type
Russian thistle Tumble mustard Rabbitbrush (gray and green) Sagebrush Antelope bitterbrush	Aboveground plant tissue [b]	One	Composite [c]
		One [d]	Thin slice of mainstem or trunk segment for perennial shrub aging [d]
Russian thistle Tumble mustard Rabbitbrush (gray and green) Sagebrush Antelope bitterbrush	Belowground root tissue [c]	1–8 [e]	Composite [c, f]
Russian thistle Tumble mustard Rabbitbrush (gray and green) Sagebrush Antelope bitterbrush	Aboveground tissue or belowground root tissue	One per tissue sample processing day [g]	Equipment (decontamination) blank [h]
Russian thistle Tumble mustard Rabbitbrush (gray and green) Sagebrush Antelope bitterbrush	Aboveground tissue or belowground root tissue	One per tissue sample processing day [g]	Field duplicate [i]

a. As reported opportunistically by radiation control technicians to the biomobilization team. These five are the targeted species of the study. As discussed in Section 3.2.1, should a rare specimen of contaminated hopsage or bursage be identified, these species will also be sampled. However, in 22 years of documented radiation monitoring data collected on the Central Plateau, no radiologically contaminated specimens of these two species (or bitterbrush) have been reported (Section 1.2.2).

b. Aboveground plant tissue includes leaves, stems (green or woody), branches, flowers, seeds, prickly spines (if present), woody trunk, or main stem.

c. Compositing of aboveground and belowground vegetation tissue is completed in the radiologically licensed sample preparation laboratory prior to submission to the analytical laboratory.

d. Used by sample preparation laboratory to age each shrub specimen.

e. Root tissue composite sample number varies per vegetation specimen because root tissue may not be present in each of the eight discrete soil depth intervals in each of the soil cores drilled for a given specimen. If root tissue is present in each of the eight soil depth intervals of the collocated soil cores per vegetation species specimen, then a maximum of eight root tissue composite samples would be collected for each specimen (one root tissue composite representing each of eight soil depth intervals across the soil cores). Discrete soil depth intervals are as presented in Table 3-2.

f. Each composite sample is comprised of soil or root tissue at the same depth interval composited across all shrub soil cores (Figure 3-2).

g. Field duplicate samples are prepared in the sample preparation laboratory to evaluate laboratory precision (only) and are prepared at a frequency of one per aboveground or root tissue sample processing day, and only if enough tissue mass remains following preparation of the regular composite samples. Equipment blanks are also prepared at a frequency of one per tissue (aboveground, root) processing day.

h. Laboratory macerating or grinding equipment decontamination blank required for collection unless disposable grinding equipment is used.

i. Field duplicates are actually sample preparation laboratory sample splits.

Both types of tissue processing procedures include photographic documentation. Specific photographic requirements for aboveground or belowground (root) are identified in their respective composite tissue sample preparation subsections. General photographic requirements applicable to all photos taken in the sample preparation laboratory are as follows:

- As feasible, photographs will be taken at a consistent height and angle for image consistency.
- Special lighting is not necessary, but the light source will be consistent in each photograph and noted in reporting and documentation.
- Image resolution should be of sufficient size for small-scale features (i.e., in the cores and in documenting root tissue) to be as clearly visible as possible in the photos.
- An information card should be present in each photograph that identifies the following (as applicable to sample type):
  - Date, time, and processing company name
  - Sample type (aboveground tissue, root tissue, and soil)
  - Core type (taproot, dripline)
  - Dripline core number (up to three are possible)
  - Core depth interval,
  - Collection location (WIDS site or other descriptor)
  - Species/subspecies of the affiliated aboveground contaminated vegetation specimen
- For core depth intervals, depth marks along the side of the core in feet and inches for perspective (i.e., a tape measure or yard stick showing).
- A gray-scale card for checking brightness and contrast (as required).
- A color calibration card for checking color quality (as required).

The information shown in photographic cards will also be documented in the laboratory logbook and on lab data forms for photos taken. Digital camera frame number(s) will also be recorded in the laboratory logbook and on data forms.

All photographs will be prepared as digital files (JPG, TIFF, or similar) and placed on a hard disk or other device with more than sufficient capacity to store all of the photographic files. Given the number of photographs that can be taken each processing day (particularly for root tissue), the lead laboratory technician will audit the complete photograph log each processing day to confirm accuracy and proper documentation (and make corrections, if necessary).

Sample preparation documentation (e.g., scanned logbook pages, and data forms each processing day[13]) will also be stored electronically in an easily searchable laboratory sample processing database. All photographic documentation, sample preparation data /information, and chain-of-custody documentation will also be stored in this data base (which will be QC'd daily by the laboratory lead technician) and submitted electronically to the designated biomobilization team representative at least monthly during for maintenance in the biomobilization program study files.

[13] Electronic data forms are recommended for use by the sample preparation laboratory to support the future need of a searchable sample processing database by the biomoblization team during data analysis.

3.5.2.1 Aboveground Tissue Composite Sample Preparation Steps

Aboveground vegetation tissue sample processing will be initiated within one day following delivery of the shrub to the sample preparation laboratory.

Processing steps for aboveground contaminated shrub tissue are as follows:

1. With the exception of the tissue maceration device, all equipment used to process and prepare aboveground tissue composite samples will be disposable to eliminate the opportunity for cross contamination within processing steps. These materials become IDW that follow waste management procedures established by the laboratory and compliant with established PRC procedure. A clean pair of disposable gloves will be used for each aboveground vegetation specimen processed.

2. The sample preparation laboratory logbook and laboratory data forms will document each aboveground shrub processed. The specimen processing steps described here will be documented with digital photographs as discussed in Section 3.5.2 to illustrate procedure and for later PRC use in preparing the data report.

   Photography is not required for every aboveground specimen processed, but several specimens (including annual and perennial species) following the Section 3.5.2 procedures should have a detailed set of photographs to document procedure adherence.

   If encountered, any unusual specimen features (technician judgment) will also be photographed and similarly documented as discussed in Section 3.5.2.

3. Upon receipt, the sample preparation laboratory lead technician will confirm identification of the contaminated shrub delivered. For Russian thistle, the genus (*Sasola*), species (*kali*) and subspecies (e.g.,*tragus*, etc.) should be identified using a recognized vegetation identification key or other scientifically accepted means. Record this information in the laboratory logbook and on a data form.

4. For annual forbs (Russian thistle and tumble mustard), the specimen age (approximate) and lifecycle stage will be described based upon the shrub sampling date and physical shrub features[14]. Lifecycle stage includes describing whether the shrub is in reproductive mode (i.e., presence of flowers, seeds that are fully formed or developing).

5. For perennial shrubs, the specimen age will be determined. Using a disposable saw blade, a thin slice of the main woody trunk will be sliced off (a new saw blade is used for each contaminated perennial shrub delivered for processing to eliminate cross contamination). The age of the shrub specimen will be determined through growth rings or other scientifically accepted methods from the thin slice using a magnifying device. The age and method used will be documented in the laboratory logbook and data forms.

6. The entire shrub (including branches, stems, leaves, flowers, seeds, spines, main stem, or woody trunk) will be cut up using a disposable saw blade, clipper, or scissors into manageable size pieces and macerated or otherwise ground to shreds of a uniform size using a grinder or other specified (laboratory logbook, data forms) device.

[14]And with knowledge that in Benton County the time of the first hard frost (often early to mid-October) usually marks the death of the mature Russian thistle plant. Time of death is not equivalent to the time of shrub separation from its dead belowground roots to become a tumbleweed however, which occurs sometime later.

7. Unless disposable grinding equipment is used, the grinding equipment for aboveground shrub tissue is decontaminated thoroughly in between the preparation of each aboveground shrub composite sample. Decontamination involves manually removing any tissue observed adhering to all parts of the equipment and thoroughly rinsing the equipment (parts) with generous amounts of distilled deionized water. The effectiveness of this cleaning and decontamination is documented through the collection of an equipment (rinsate) blank prepared at the rate of one per aboveground tissue processing day.

   To prepare the blank following decontamination, the equipment is finally rinsed using high purity water of sufficient volume to meet radionuclide analysis method sample volume requirements. Container types for equipment blanks will be as required by the radionuclide analysis methods specified in Table 2-2. Each equipment blank analysis aliquot will be acidified to < pH 2 using nitric acid as a preservative. The minimum sample volume for equipment blanks for each radionuclide analysis method will be identified once an analytical laboratory is under PRC contract.

8. The tissue shreds representing the entire ground up shrub (all parts) are used to create a representative composite sample. One way to accomplish this is to place all the ground up parts of the shrub into a disposable (not reusable) bin of sufficient size, mixed well by hand for several minutes (top to bottom, side to side) and used to prepare composite sample aliquots for radionuclide, and physical (e.g., tissue moisture) analytical methods (Table 2-2). A sample aliquot meeting (or somewhat exceeding is recommended) the minimum required tissue mass required for each of these analytical methods is then collected from the bin and containerized using analytical method required containers (bottles). Minimum tissue sample masses for these analytical methods will be established once an analytical laboratory is under contract. Other composite preparation methods may be acceptable if they meet the spirit of this processing procedure and are discussed in advance with the biomobilization technical lead prior to finalizing the sample preparation laboratory's written procedures.

   It is expected that sufficient aboveground composite tissue will be available to meet all analytical method minimum tissue mass requirements. However, it is possible for small aboveground vegetation specimens that composite tissue may be insufficient.

   PROCESSING NOTE: If there is insufficient sample mass in the composited aboveground tissue composite to meet the minimum tissue requirements for radionuclide and tissue physical analysis parameters, then the sample priority scheme as presented in Section 2.1.4 is followed for prioritizing the preparation of analysis aliquots for radionuclides and physical parameters.

9. If sufficient aboveground composite tissue mass remains, a second set of sample containers will be filled with the minimum sample mass for radionuclide and physical parameter analyses, as in Step 8. These containers will constitute a field duplicate (this sample actually represents a sample preparation laboratory split). One field duplicate is prepared each tissue processing day (aboveground tissue or root tissue) and only when sufficient sample mass remains. The field duplicate is used in this study to evaluate analytical laboratory performance (only). If insufficient tissue mass remains even for conducting the prioritized radionuclide and physical parameter measures, then a field duplicate will not be collected.

10. Sample numbering and labeling of equipment blanks, regular and field duplicate aboveground tissue composite samples will be in accordance with laboratory procedures compliant with this Study Plan and PRC procedures. For this study, the following information will also be reflected in aboveground tissue sample composite identification numbering and identification: vegetation species (e.g., sagebrush, rabbitbrush, antelope bitterbrush, Russian thistle, tumble mustard; and subspecies for thistle and sagebrush), sample type (aboveground tissue composite, aboveground tissue field duplicate), and collection location (WIDS site or other descriptor of shrub collection location).

11. The equipment blank, regular and field duplicate composite sample information is then recorded in the laboratory logbook, laboratory data form and the chain-of-custody form prepared in accordance with laboratory, Study Plan and PRC compliant procedures.

12. The sample containers are placed in a compliant transport container and shipped under chain-of-custody to the analytical laboratory following laboratory, Study Plan and PRC compliant procedures (SMR is contacted directly with additional questions as necessary).

3.5.2.2 Belowground Root Tissue Composite Sample Preparation Steps

Belowground root tissue composite samples are prepared from up to four collocated 4.9 m (16 ft) continuous soil cores collected from beneath a deep-rooted contaminated vegetation specimen. Each of the up to four collocated soil cores are cut into eight soil depth intervals (Table 3-2) prior to delivery to the sample preparation laboratory. Individual processing of each core depth interval facilitates root tissue characterization (i.e., penetration depth by soil depth, tissue mass by soil depth) and composite sample preparation. Note that the number of depth discretized soil cores collocated with a contaminated deep-rooted vegetation specimen(s) may vary based on the size of the dripline of the original aboveground specimen (which can constrain core drilling area potentially resulting in fewer than four depth discretized cores per specimen).

Root tissue characterization and composite sample preparation (this section) will always proceed prior to initiating soil depth interval composite sample preparation (Section 3.5.3).

Figure 3-2 illustrates the core depth interval composite scheme to be followed for the preparation of both belowground root tissue and soil composite samples.

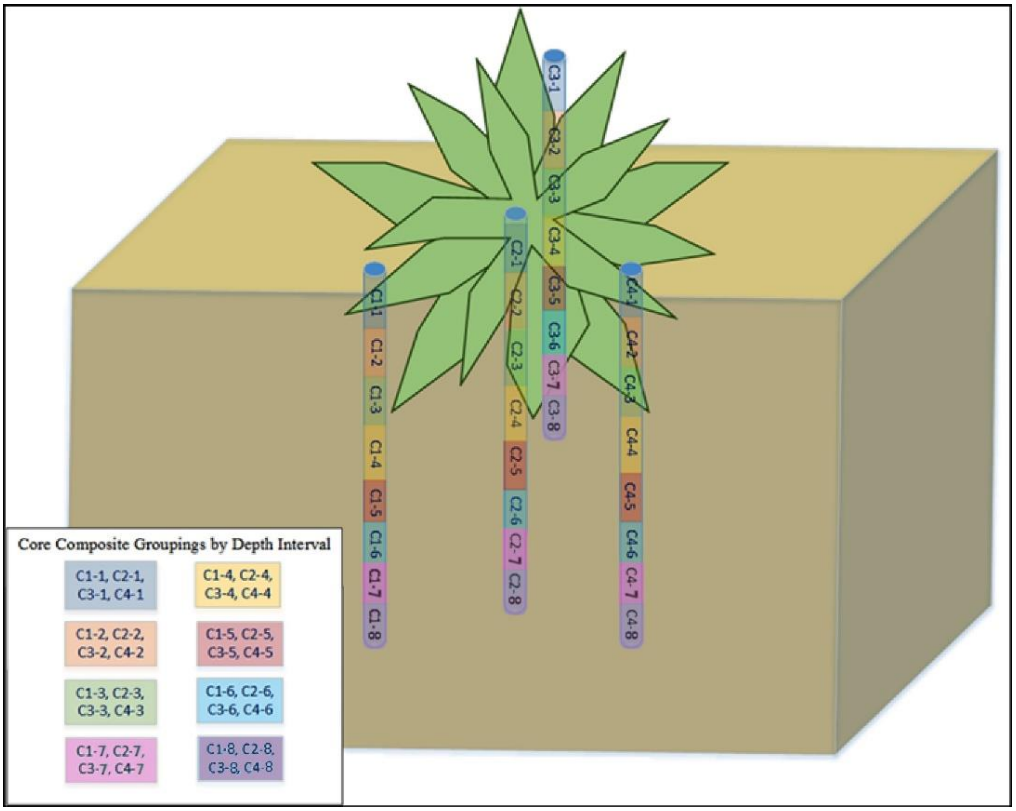

Figure 3-2. Depth Interval-Specific Sample Compositing Scheme for Root Tissue and Soil.

Root tissue composite sample preparation will be photographically documented for each core and depth interval and follow the general photographic requirements in Section 3.5.2 as well as the specific photographic requirements documented in the steps below.

Root tissue composite sample preparation and documentation steps are as follows:

1. All equipment (grinder may be an exception) used to process and prepare root tissue composite samples will be disposable to eliminate the opportunity for cross contamination within tissue processing steps. These materials become IDW that follow waste management procedures established by the laboratory, Study Plan and PRC-compliant procedures. A clean pair of disposable gloves will be used for processing soil core depth interval root tissues and also whenever collocated cores from a different aboveground vegetation specimen are processed (note: it is not necessary to use a clean pair of gloves between processing the depth interval-specific root tissue for a given aboveground specimen because the root tissues at common soil depth intervals are ultimately composited).

2. Each soil core will be delivered to the sample preparation laboratory as a series of eight tight core depth intervals corresponding to each of the eight soil depth intervals summarized in Table 3-2. Though each continuous tight soil core is cut into core depth intervals prior to delivery to the sample preparation laboratory, it is possible that some interval cores may have plastic wrapped root tissue attached (refer to Step 3 in this list). These packages, if present, include root tissue that may be pulled through during core drilling in the field and will be kept with the associated core depth interval until processed.

The first processing step is to take high resolution digital photographs following both the procedures in Section 3.5.2 and as identified in Step 3 (here) to document each of the eight core depth intervals for each of the collocated shrub cores. The purpose of these photographs is to document the intact (lightly brushed) and more fully brushed depth interval cores with root tissue exposed. This process will be repeated for each core and core depth interval until all cores and their core depth intervals are similarly described and photographed.

3. Photographic documentation requirements for root tissue in each of the core depth intervals is as follows:

   - Photograph each labeled soil core depth interval separately (label clearly visible). Due to the presence of root tissue within the depth interval segments, the core will not be divided longitudinally.

   - Intact cores for depth intervals will be photographed within their core sleeves (and showing any attached root tissue packages as applicable) as received. A core interval length scale should always be visible in the photographs.

   - Photography will then proceed after the core sleeve is gently cut away for each core depth interval and after the core surface is lightly brushed. Brushed soil is always kept with the core and depth interval being processed (for later soil composite sample preparation). Disposable brushes and metal probes are required, and a fresh brush and probe is used for each soil core and depth interval to avoid cross contamination (IDW).

   - A photograph(s) will then be taken following Section 3.5.2 photo and documentation requirements that will show the intact lightly brushed core depth segment and any visible root tissue along the core sides. Any stratigraphy present in the core depth interval soil will be described in the logbook and data forms and captured by one or more photographs (frame numbers recorded).

   - The depth interval core soil will then be gently probed to loosen any compacted soil and brushed further away to expose all (or a majority) of the root tissue within the length of the core depth interval (some root tissue may be very fine). More photographs with length scale visible are taken to document the roots and their depth in the core interval. All brushed away soil continues to be kept with the other soil from the core and depth interval being processed (to later prepare depth interval soil composite samples). Photographic and descriptive documentation for each core depth interval will include requirements in Section 3.5.2 but will also include the direction of root growth in each depth interval (i.e., for the taproot in particular in case of a change in growth direction) and any unique or unusual (technician judgment) root features observed. Some roots within the core interval soil may be fine and care will be taken to include these fine roots with appropriate resolution in photographic documentation to the degree possible.

   IMPORTANT PROCESSING NOTE: As previously indicated in Step 2, it is possible that during drilling, root tissue may be pulled out through one or more soil core depth intervals. In these instances, the NCO samplers under direction of the sampling FWS are instructed to trim the root tissue to correspond to the depth of each core interval in the field, wrap the root tissue length (without folding that could affect measuring linear length) in plastic wrap, mark, and attach it to the associated core sleeve to keep the root tissue with the core and core depth interval to which it is associated. Should this scenario occur, the root tissue will be removed from the plastic wrap, placed (back) within the brushed soil of the affiliated depth interval (with length scale visible), and

photographed (the root length should not exceed the core depth interval if properly trimmed in the field). Core depth intervals vary, and Table 3-2 should be consulted as necessary to understand root length by core depth interval. Descriptions in the laboratory logbook will clearly note all instances when root tissue was pulled free from a core interval when delivered with corresponding photograph frame numbers.

4. Record the linear length of root penetration (in meter[s]) from the top of a core depth interval to its bottom. Record the measurement on a laboratory data form and in the laboratory logbook for that core depth interval. Note also that it is possible for some core depth intervals to have root tissue present from the top to the bottom of the interval (which should be confirmed and recorded); other intervals may have root tissue present in only part of the total depth interval. For example, roots may be noted to penetrate to only 0.5 m (1.5 ft) within a specific 0.6 m (2 ft) core depth interval.

   PROCESSING NOTE: To ensure that no fine root tissue penetration depths in a soil core depth interval are missed, the disposable probe should always be used to confirm the presence or absence of smaller roots present throughout all the soil within each core depth interval. The linear root penetration depth in each core depth interval will be reflective of the deepest of the penetrating roots (coarse or fine) in that depth interval. Labeled photographs should be taken liberally (photo frames recorded in logbook) to document this situation. If root tissue of any type (coarse or fine) is not present or found within a given depth interval, record this information in the laboratory logbook and data form. All linear lengths of root penetration (or lack thereof) within each core depth interval will be recorded in the logbook and data forms.

5. Once the linear root penetration depth information has been measured, recorded, and photographed for the core depth interval being processed, gently and completely separate all the root tissue from within the discrete soil core depth interval. Brush lightly to remove as much adhered root soil as possible. Continue to retain the soil for later soil composite sample preparation for the core and depth interval being processed.

6. The extracted core depth interval root tissue is then lightly rinsed with distilled, deionized water, and blotted dry carefully with paper towels.

7. A fresh weight of the rinsed / blotted root tissue from the soil core depth interval is taken from a calibrated surface loading scale of sufficient sensitivity[15]. The wet (fresh) root weight for this core depth interval is recorded on a laboratory data form and in the laboratory logbook. Weighing sheets will be used to eliminate cross contamination of the scale loading pan during weighing of root tissue in each core depth interval.

8. Steps 1–7 are repeated for the root tissue occurring at the same soil core depth interval in each of the remaining collocated shrub soil cores until root tissue for each of eight soil depth intervals from all collocated soil cores is similarly processed.

9. The extracted root tissue of a given soil depth interval is then composited with the extracted root tissue from the same depth interval across all of the cores in a disposable bin resulting in a single depth interval specific root tissue composite sample.

   The entirety of the composited depth interval root tissue is then cut into smaller lengths for maceration / grinding to ensure consistent sized root tissue pieces (shreds or finer). The macerated

[15] The sample preparation laboratory will have weighing scales with the required sensitivity to weigh fresh root tissues, which may range in their fresh weight across core intervals (e.g., deeper soil core depth intervals may have finer roots that weigh less requiring a scale with greater sensitivity).

root tissue composite is then placed into a clean disposable bin and fully mixed (top to bottom, side to side) by hand for several minutes to ensure thorough mixing. Sample aliquots meeting the minimum tissue mass requirements for all radionuclide and tissue moisture (physical) analysis methods are collected. Containers used for preparing these aliquots will be as specified for radionuclides and vegetation tissue moisture analysis methods (Table 2-2). Minimum tissue mass requirements for radionuclides and tissue moisture will be identified once an analytical laboratory is under contract.

PROCESSING NOTE: If there is insufficient sample mass in the composited depth interval root tissue to meet the minimum tissue requirements for radionuclide and tissue moisture analyses, then the sample priority scheme as presented in Section 2.1.4 is followed for prioritizing the preparation of analysis aliquots for radionuclides and physical parameters.

10. Unless disposable equipment for grinding and macerating root tissue is used, the grinding / macerating equipment will be decontaminated thoroughly in between the preparation of each depth interval root tissue composite sample. Decontamination involves manually removing any tissue that is observed adhering to all parts of the equipment and then thoroughly rinsing the equipment (parts) with generous amounts of distilled deionized water. The effectiveness of this decontamination is documented through the collection of an equipment (rinsate) blank. An equipment blank is prepared at the rate of one per root tissue processing day.

    To prepare the equipment blank following decontamination, the equipment is rinsed slowly using high purity water. A minimum of 0.5 L will be used for the final rinse captured in a disposable container. More than 0.5 L may be necessary to meet aliquot volumes necessary for all required analytical evaluations. This rinse water will be used to fill containers required for the radionuclide methods specified in Table 2-2, with the required minimum aliquot volume. Each equipment blank analysis aliquot will be acidified to pH $\leq$2 using nitric acid as a preservative. The minimum sample volume for equipment blanks for each radionuclide analysis method will be identified once an analytical laboratory is under the PRC contract.

11. A total of up to eight depth discretized root tissue composite samples will result from across the shrub collocated soil cores. Note that fewer than eight root tissue composites may occur if none of the four cores contains any root tissue at a given soil depth interval(s). As long as at least one of the core depth composite intervals in each of the collocated shrub cores has root tissue present, a composite sample can be prepared for a soil depth interval (tissue mass may be limited for some depths, however). The total number of soil depth interval root tissue composite samples prepared from the soil cores will be recorded on laboratory data forms and in the laboratory logbook.

12. If sufficient composite root tissue mass remains from one selected core depth interval (likely to be the shallowest depth interval), a second set of analytical method compliant sample containers will be filled with the minimum required tissue sample mass for radionuclide and tissue moisture analyses. These containers will constitute a field duplicate used in this study to evaluate analytical laboratory performance (only).

    One field duplicate is prepared each root tissue processing day and only when sufficient root sample mass remains to fill all sample analysis containers with the minimum tissue mass required. Root tissue composite mass is expected to be limited. As noted in Step 9, in situations with limited tissue the priority analysis scheme may also be used for preparing the root tissue field duplicate. When insufficient root tissue mass remains from any depth interval to fill all the required analysis containers following the analysis priority scheme, then a field duplicate for root tissue will not be collected.

13. Sample numbering and labeling of equipment blanks, regular, and field duplicate composite samples will be in accordance with laboratory procedures that are Study plan and PRC compliant. For this study, the following information will be reflected in root tissue sample composite identification numbering: sample type (soil depth interval, root tissue composite), core type (taproot or dripline), dripline core number (up to three are possible), soil core depth interval represented, collection location (WIDS site or other descriptor), and target vegetation species and (as applicable) subspecies of the affiliated aboveground contaminated vegetation specimen.

14. The root tissue composite sample, equipment blank, and field duplicate (if collected) sample information are then recorded in the laboratory logbook, on laboratory data form, and on the chain-of-custody form prepared in accordance with laboratory, Study Plan and PRC compliant procedures.

The sample containers are placed in a compliant transport container and shipped under chain-of-custody to the analytical laboratory in accordance with laboratory procedures that are Study Plan and PRC compliant (SMR is contacted directly with additional questions as may be necessary).

3.5.3 Soil Core Composite Sample Preparation

As with root tissue, soil composite sample preparation follows the composite scheme illustrated in Figure 3-2. Soil core depth composite samples are prepared only after the root characterization processing steps and soil core depth interval-specific root tissue composite sample preparation steps have first been completed.

Detailed core depth interval photographs were previously taken to document intact core depth intervals with root tissue. Photographic documentation for soil composite sample preparation will document only the composite sample preparation steps (i.e., for later use in data report preparation). Photographs of soil composite sample preparation will follow the digital photography and documentation requirements presented previously (Section 3.5.2).

Core depth interval soil composite sample preparation steps are as follows:

1. As noted in the root characterization and documentation steps of Section 3.5.2, any soil stratigraphy identified in the photography of soil core depth intervals during root characterization should be cross referenced in documenting the preparation of soil core depth interval composite sample preparation.

2. All equipment used to process and prepare soil tissue composite samples will be disposable to eliminate the opportunity for cross contamination within soil processing steps. These materials become IDW that follow waste management methods established by the Study Plan and PRC-compliant waste management procedures (Chapter 4).

3. Soil from a specific core depth interval is combined with the soil from the same depth interval in the other cores. A disposable bin will be used for this purpose.

4. The soil is thoroughly mixed by hand (top to bottom and side to side) for several minutes to ensure thorough mixing.

5. A sample aliquot of the mixed composited soil is prepared for each required soil chemical, physical, inorganic and radionuclide analysis (Table 2-2) is placed in each analytical method specified container type. Sample aliquots in each container will meet the required minimum soil mass. Minimum soil mass requirements for each analysis type will be identified once an analytical laboratory is under the PRC contract.

PROCESSING NOTE: It is assumed that sufficient soil mass will be available from each core depth interval composite to meet analytical analysis needs. If soil composite mass for a depth interval is determined to be insufficient, then the priority analysis scheme in Section 2.1.4 will be followed for soil radiological, chemical, physical, and inorganic analyses.

6. If sufficient composite soil mass remains in any one of the core depth intervals, a second set of analytical method compliant sample containers will be filled with the minimum soil required mass from that interval for each required chemical, physical, inorganic and radionuclide analysis. These containers will constitute a field duplicate, which is used in this study to evaluate laboratory performance (only) and collected at a frequency of one per soil composite sample processing day.

   A soil field duplicate (laboratory split) is prepared only when sufficient soil composite sample mass at any selected depth interval remains to meet the minimum soil sample mass required. It is assumed that sufficient soil mass will be available in most depth interval composite samples. If insufficient mass remains in any soil depth interval, then a soil composite field duplicate will not be collected.

7. Sample numbering and labeling of regular and field duplicate soil composite samples will be in accordance with laboratory procedures that are Study Plan and PRC compliant. For this study, the following information will be reflected in soil sample composite identification numbering: sample type (soil composite, field duplicate), core type (taproot, dripline), dripline core number (up to three are possible), core depth interval, collection location (WIDS site or other descriptor), and species and (as applicable) subspecies of the affiliated contaminated vegetation specimen.

8. The soil composite samples and field duplicate (if collected) sample information is recorded in the laboratory logbook, laboratory data form and the chain-of-custody form prepared in accordance with laboratory and Study Plan and PRC compliant procedures.

The sample containers are placed in a compliant transport container and shipped under chain-of-custody to the analytical laboratory in accordance with laboratory procedures that are Study Plan and PRC compliant (SMR is contacted directly with additional questions as may be necessary).

3.6 Documentation of Field and Laboratory Activities

Logbooks and data forms (field and laboratory) are typically required for field sampling and sample preparation laboratory activities conducted at the Hanford Site. Field logbooks and data forms will comply with HASQARD requirements (DOE/RL-96-68).

Logbooks (field and sample preparation laboratory) must be identified with a unique project name, number, and the type of logbook (field and sample preparation laboratory). The individual(s) responsible for logbooks will be identified in the front of the logbook, and only authorized persons can make entries in the logbook. The sampling FWS or other responsible field manager will review the logbook entries documented by signature and date. Logbooks will be permanently bound, waterproof, and ruled with sequentially numbered pages. Pages will not be removed from logbooks for any reason. Entries will be made in indelible ink. Corrections will be made by marking through erroneous data with a single line, entering the correct data, and initialing and dating the changes.

Hardcopy field data forms may be used to collect field information; however, information recorded on hardcopy data forms must follow the same requirements as those for logbooks. If used, the data forms must be referenced in the logbooks. A summary of information to be recorded in logbooks or on data forms includes but is not limited to the following:

- Day and date; time task started; weather conditions; and names, titles, and organizations of personnel performing the task.
- Purpose of visit to the task area.
- Site activities in specific detail (e.g., maps and drawings) or the forms used to record such information (e.g., soil boring log). Also, details of any field tests that were conducted, and reference to any forms that were used, other data records, or methods followed while conducting activities.
- Details of any field equipment calibrations. Reference any forms that were used, other data records, and the methods followed while conducting the calibrations.
- Details of any samples collected and the preparation of duplicates, MSs, or MBs (splits are not applicable to this contaminated deep-rooted vegetation study). Reference the methods followed for collecting and preparing samples. List the locations of samples collected, sample types, each label or tag number, sample identification, sample containers and volume or mass, preservation method, packaging, chain-of-custody form number, and analytical request form number pertinent to each sample or sample set. Note the time and the name of the individual to whom sample custody was transferred.
- Time, equipment type, serial or identification number, and methods followed for decontamination (e.g., sample preparation laboratory grinding equipment) and equipment maintenance performed. Reference the page number(s) of any logbook where detailed information is recorded.
- Any equipment failures or breakdowns that occurred, with a brief description of repairs or replacements.
- Photograph frame numbers for all photographs taken.

3.6.1 Corrective Actions and Deviations for Sampling Activities

The RCOs, sampling FWS, appropriate field crew supervisors, and SMR personnel must document deviations from protocols, procedures, issues pertaining to vegetation and collocated soil core collection, chain-of-custody forms, target analytes, contaminants, sample transport, noncompliant monitoring, or other required activities. Examples of major deviations include but are not limited to the following:

- Not following the notification and communication procedures specified in this Study Plan
- RCO RCTs not flagging contaminated specimens identified
- RCO RCTs not recording actual specimen readings above 5,000 dpm/100 cm^2 on both individual specimen flagging and also in a field logbook
- Not sampling required vegetation tissue and soil cores from each radiologically contaminated target vegetation species specimen at an identified surveillance location
- Sampling an incorrect contaminated deep-rooted vegetation species specimen at a surveillance location
- Not collecting tissue or soil core samples due to “field conditions”

- Not following the sample preparation laboratory composite sample (tissue, soil) processing requirements
- Not taking prescribed photographic documentation steps (during field sampling, sample preparation laboratory sample processing)
- Not following labeling procedures (field, lab)
- Not completing required paperwork (e.g., chain-of-custody and sample analysis forms)

The biomobilization technical lead (or designee) and sampling FWS (respectively) for this study will be responsible for communicating sample preparation laboratory and field (respectively) corrective action requirements and for ensuring that respective corrective actions are applied. The sampling FWS is responsible for communicating field corrective action requirements to the soil and vegetation sampling team and for confirming that corrective actions are applied as soon as possible. The biomobilization technical lead (or designee) is responsible for communicating any identified corrective action requirements to the sample preparation laboratory as soon as possible.

Changes in any sampling activities that require notification, approval, and documentation will be performed as specified in Table 2-3.

3.7 Calibration of Field and Sample Preparation Laboratory Equipment

Field or sample preparation laboratory environmental instruments required to conduct the study are calibrated in accordance with manufacturers' operating instructions, internal work requirements and processes, and/or field instructions that provide direction for equipment calibration or verification of accuracy by analytical methods. Calibration records shall include raw calibration data, identification of the standards used, associated reports, date of analysis, and the analyst's name or initials. The results from all instrument calibration activities are recorded in accordance with HASQARD requirements (DOE/RL-96-68). Field and onsite laboratory instrumentation calibration and QA checks will be performed as follows:

- Prior to initial use of a field or sample preparation laboratory measurement system.
- At the frequency recommended by the manufacturer or methods, or as required by regulations.
- Upon failure to meet specified QC criteria.
- Calibration of radiological field instruments on the Hanford Site is performed by MSA, as specified by their calibration program.
- Daily calibration checks will be performed and documented for each instrument used. These checks will be made on standard materials sufficiently similar to the matrix under consideration for direct comparison of data. Analysis times will be sufficient to establish detection efficiency and resolution.
- Using standards for calibration that are traceable to a nationally recognized standard agency source or measurement system. The manufacturer's recommendations for storage and handling of standards (if any) will be followed.
- Equipment that does not meet these requirements will be repaired before continued use or replaced.

3.8 Sample Handling

Field sample preparation will not be undertaken in this study. A radiologically licensed sample preparation laboratory will prepare all samples submitted to the analytical laboratory. Sample handling and transfer by the sample preparation laboratory will be in accordance with established procedures to preclude loss of identity, damage, deterioration, and loss of sample material. Custody seals or custody tape will be used to verify that sample integrity has been maintained during sample transport from the field to the sample preparation laboratory and from the sample preparation laboratory to the analytical laboratory. The custody seals in each transport will be inscribed with the sampler's initials and date. During the chain-of-custody process, if it is discovered that the custody tape has been tampered with or broken on one or more of the sample aliquot bottles or the sample transport container to the analytical laboratory, the sample(s) will be analyzed but the results will include a flag to indicate that the custody tape was broken. If the sample data did not trend with other data or were not as expected, the data from the sample will be flagged accordingly.

A sampling and analytical database is used by SMR to track samples from the point of collection through the laboratory analysis process.

3.8.1 Sample Preservation

Samples will follow sample preservation requirements as shown in Table 2-6. For the vegetation tissue and soil collected in this study, no preservation requirements are necessary. For sample preparation of laboratory grinding equipment blank water samples (i.e., if disposal grinding equipment is not used), no preservation is required for carbon-14, iodine-129, and tritium. For all other radionuclides and for specified EPA Method 6020B metals (Ca^{2+} and K^{+} only), equipment blank water samples, if collected, will be preserved using nitric acid to a pH of $\leq$2.

3.8.2 Containers

For this study, vegetation and soil cores are not sampled and placed in analytical method compliant containers in the field as is common practice for the collection of soil or groundwater. The data requirements of this Study Plan necessitate the use of a radiologically licensed sample preparation laboratory for sample preparation. Field sampled materials (e.g., contaminated deep-rooted vegetation specimen tissue, and soil core depth intervals) are transported intact to the sample preparation laboratory where descriptive information and photographs are collected, followed by composite sample preparation using analytical method compliant containers. Field sampled contaminated vegetation specimens and soil cores for this study will be transported by authorized shippers to the sample preparation laboratory using safety compliant containers consistent with existing PRC procedure(s). The field sample collection record shall indicate the containers used for transport to the sample preparation laboratory. Commercially pre-cleaned container lots used in the sample preparation laboratory will be documented, including manufacturer name, lot identification, and certification. This information shall be retained for documentation. SMR can assist as needed in clarifying procedure.

Containers shall be stored in an environment within the sample preparation laboratory that minimizes the possibility of sample container contamination prior to use. Containers used to transport contaminated vegetation to the sample preparation laboratory will be prechecked (i.e., using a hand held detector) to confirm the absence of radiological contamination. If present, a replacement container will be scanned and used, and corrective actions shall be implemented to prevent reoccurrence. Contaminated sample containers cannot be used for any sample processing event. Given the specialized nature of this field study, some container sizes and types will vary for field transport to the sample preparation laboratory. Analytical method compliant containers may also vary based on laboratory-designated volume and mass

requirements for meeting analytical detection limits. Some container types needed to support this study may be nonstandard (e.g., for collecting plants from the field and for preparing composite tissue and samples, respectively). Container types and sample mass measures are identified in field and laboratory logbooks, data forms, and on chain-of-custody forms.

The radiological engineering organization will be present in the field to measure the contamination levels associated with vegetation and soil cores to determine whether exceedance of safe dose rates may occur that would affect whether the samples can be safely processed by the sample preparation and analytical laboratories. This dose rate information and other data will be used to select proper packaging, marking, labeling, and shipping paperwork and to verify that the sample can be received by the sample preparation and analytical laboratories in accordance with these laboratory's radioactivity acceptance criteria.

3.8.3 Container Labeling

Each sample is identified by affixing a standardized label or tag to the container that includes the sample identification number and other required information. The label shall identify or provide reference to associate the sample type (aboveground plant composite sample, depth-discrete belowground root tissue sample, depth-discrete soil sample) with the date, time, and location (e.g., site identifier and specific soil depth interval) of collection, preservative used (if applicable), analysis required, and NCO sampling technician or sample preparation laboratory technician's name or initials. Sample labels may be either pre-printed or handwritten in indelible/waterproof ink. The sample identification numbering scheme for the study must support the cross identification of all associated sample types for each radiologically contaminated target vegetation species specimen sampled. Each radiologically contaminated target vegetation species specimen has the following sample types associated with it: depth discretized soil sample composites (eight depth interval composite samples), one aboveground tissue composite (whole plant), and up to eight depth discretized belowground root tissue sample composite samples.

3.8.4 Sample Custody

Sample custody will be maintained in accordance with existing protocols to ensure that sample integrity is maintained throughout the analytical process. SMR Chain-of-custody protocols will be followed throughout sample collection, transfer, analysis, and disposal to ensure that sample integrity is maintained.

A chain-of-custody record will be prepared for all field collected samples transported to the radiologically licensed sample preparation laboratory. A chain-of-custody record is also prepared following completion of all tissue and soil composite preparation activities in the sample preparation laboratory and will accompany each set of samples shipped to the analytical laboratory.

Shipping requirements will determine how sample containers are prepared for shipment. The analyses requested for each sample will be indicated on the accompanying chain-of-custody form. Each time the responsibility for sample custody changes, the new and previous custodians will sign the record and note the date and time. The sampling FWS and NCOs prepare the field chain-of-custody form for transport of field collected samples to the sample preparation laboratory. In the sample preparation laboratory, the lead technician will be responsible for adherence to SMR custody procedures, including cross checking the custody form for accuracy, making a copy of the signed record before sample shipment to the analytical laboratory, and transmitting a copy to SMR.

The following minimum information is required on a completed chain-of-custody form (or as otherwise required by SMR):

- Project name
- Sample collectors' or laboratory sample processors' name(s)

- Sample composite matrix type (aboveground whole plant tissue, belowground root tissue, soil)
- Depth interval associated with each root tissue or soil composite sample
- Unique sample identification number (specific enough to reflect sample depth interval, sample matrix type (e.g., aboveground tissue, root tissue, soil), and the target vegetation specimen species (or subspecies as applicable to Russian thistle and sagebrush) with which the composite samples of aboveground vegetation, belowground root tissue and soil are associated
- Date, time, and location (or traceable reference thereto) of sample collection
- Preservatives (if any)
- Chain-of-custody information (i.e., signatures and printed names of each individual involved in the transfer of sample custody and storage locations, and dates/times of receipt and relinquishment)
- Requested analyses (or reference thereto)
- Shipping information (i.e., analytical laboratory performing the analysis)

The radiologically licensed sample preparation laboratory lead technician or analytical laboratory designated staff will note any anomalies with the samples. If anomalies are found, the laboratory will inform SMR, who will inform the biomobilization technical lead or designee (i.e., if the anomaly resolution will result in changes to study outcomes) so special direction for analysis can be provided to the laboratory, if deemed necessary.

3.8.5 Sample Transportation

Packaging and transportation instructions shall comply with applicable transportation regulations and DOE requirements. Regulations for classifying, describing, packaging, marking, labeling, and transporting hazardous materials, hazardous substances, and hazardous wastes are enforced by the U.S. Department of Transportation (DOT) as described in 49 CFR 171, "Transportation," "General Information, Regulations, and Definitions," through 177, "Carriage by Public Highway."[16] Carrier-specific requirements defined in IATA, 2019, *Dangerous Goods Regulations*, shall also be used when preparing sample shipments conveyed by air freight providers.

Samples containing hazardous constituents above regulated amounts shall be considered hazardous material in transportation and transported in accordance with DOT or International Air Transportation Association (IATA) requirements. If the sample material is known or can be identified, then it will be packaged, marked, labeled, and shipped according to the specific instructions for that material. Appropriate laboratory notifications will be made through the SMR project coordinator, if necessary.

DOT or IATA classify materials as radioactive when the isotope specific activity concentration and the exempt consignment limits described in 49 CFR 173, "Transportation," "Shippers—General Requirements for Shipments and Packagings," are exceeded. Samples shall be screened (or relevant historical data will be used) to determine if these values are exceeded. When screening or historical data indicate that samples are radioactive, the samples shall be properly classified, described, packaged, marked, labeled, and transported according to DOT or IATA requirements.

[16] Transportation regulations 49 CFR 174, "Carriage by Rail," and 49 CFR 176, "Carriage by Vessel," are not applicable, as these two transportation methods are not used.

Prior to transporting or shipping radioactive samples to the sample preparation and analytical laboratories, the organization responsible for shipping shall notify the laboratory of the approximate number samples and corresponding radiological levels. This notification is conducted through the SMR project coordinator. The laboratory (sample preparation or analytical) is responsible for ensuring that the applicable license limits are not exceeded. Prior to sample receipt, the laboratory shall provide SMR with written acceptance for samples with elevated radiological levels.

4 Management of Investigation-Derived Waste

The IDW generated by the various characterization activities documented in this contaminated deep-rooted vegetation study will be managed in accordance with the most current IDW procedures agreed upon by DOE, EPA, and Ecology. The IDW will be managed in accordance with the applicable waste control plan and the waste packing and labeling instruction sheet provided by the waste management representative.

Miscellaneous solid waste that has contacted suspect dangerous waste will be managed as dangerous waste. Decontamination fluids will be collected and managed in accordance with DOE/RL-2011-41, *Hanford Site Strategy for Management of Investigation Derived Waste*. Waste materials requiring collection will be placed in containers appropriate for the material and the receiving facility in accordance with the applicable waste management or waste control plan and applicable substantive federal and/or state requirements

Packaging and labeling during waste storage and transportation will meet the appropriate requirements of WAC 173-303, “Dangerous Waste Regulations,” and DOT. Packaging exceptions to DOT requirements may be used for onsite waste shipments if documented as such and if the packaging provides an equivalent degree of safety during transportation.

Offsite analytical laboratories are typically responsible for the disposal of unused sample quantities and wastes generated during analytical processes. On a monthly basis, the laboratory will coordinate sample disposal and status with SMR by providing a list of samples more than 90 days post-data delivery for which disposal is requested in the following month. The laboratory will also provide on a monthly basis a list of samples disposed in the preceding month that includes disposal date and method or other relevant information. Signed chain-of-custody forms indicating sample disposal will be retained in laboratory case files pending return of case files to the contractor.

Pursuant to 40 CFR 300.440, “National Oil and Hazardous Substances Pollution Contingency Plan,” “Procedures for Planning and Implementing Off-Site Response Actions,” approval from the CERCLA DOE-RL Remedial Project Manager is required before returning unused samples or waste from offsite laboratories. To document and simplify the management of returned samples, this approval is granted with the CERCLA DOE-RL Remedial Project Manager signature on this SAP, such that samples and associated sample waste may be returned to the project site and dispositioned in accordance with the same process employed for similar wastes that are not sent offsite. This approval will be communicated to affected laboratories or treatment facilities, as needed.
Field IDW includes but is not limited to disposable knives, saws (and saw blades), clippers, or scissors used in contaminated deep-rooted vegetation specimen collection, and continuous soil core depth interval cutting and cutting of hanging roots. IDW from the sample preparation laboratory includes but is not limited to disposable gloves, any disposable tissue grinding equipment, mixing bins, weighing sheets, disposable saw blades, clippers or scissors, and paper toweling.

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5 Health and Safety

All participating organizations in this contaminated vegetation sampling study will prepare, train personnel (as necessary for continued compliance), and follow organization-specific health and safety plan requirements that address the sampling and sample processing activities to be conducted in this study to ensure personnel health and safety.

DOE established the hazardous waste operations safety and health program pursuant to the *Price-Anderson Amendments Act of 1988* to ensure the safety and health of workers involved in mixed waste site activities. The program was developed to comply with the requirements of 10 CFR 851, "Worker Safety and Health Program," which incorporates the standards of 29 CFR 1910.120, "Occupational Safety and Health Standards," "Hazardous Waste Operations and Emergency Response"; 10 CFR 830, "Nuclear Safety Management"; and 10 CFR 835. The health and safety program defines the chemical, radiological, and physical hazards and specifies the controls and requirements for daily work activities on the overall Hanford Site. Personnel training; control of industrial safety and radiological hazards; personal protective equipment; stop work authority; site control and general emergency response to spills, fire, accidents, injury, site visitors, and incident reporting are governed by the health and safety program.

This study includes unique health and safety issues of which the field sampling and sample preparation laboratory processing teams must be aware in the preparation of organization specific health and safety plans:

- During field sampling activities, depending on the time of year when sampling may occur (it is opportunistic), there is a risk of insect bites or encountering aggressive wildlife (e.g., badgers). Sampling personnel will take precautions to avoid interactions with wildlife (e.g., snakes) to the extent possible and to minimize insect nuisance behaviors that may interfere with sampling activities.
- Contaminated vegetation will need to be cut or (for thick woody trunks) sawed off as close as is possible to the ground surface, cut into manageable portions and delivered to the radiologically licensed sample preparation laboratory and processed to prepare a "whole plant" tissue composite sample. Use of cutting instruments in the field or in the sample preparation laboratory can result in cuts or scrapes and the sampling personnel will need to take precautions to avoid injury.
- The sample preparation laboratory will grind the cut up vegetation tissue to prepare composite vegetation samples for submission to the analytical laboratory using either dedicated or disposable equipment. Tissue grinding equipment that is not disposable must be decontaminated between the processing of tissue samples. Grinding equipment use and decontamination (if applicable) may be a hazard to hands and fingers. Equipment use instructions should be followed carefully as required in laboratory-specific project procedures to which personnel are trained. Laboratory health and safety procedures will include steps taken to prevent atmospheric releases to the atmosphere or environment from any processing activities that may require mitigation (e.g., soil compositing dust generation could require use of a hood or water misting to suppress dust) and to ensure a safe working environment for laboratory personnel.
- Contaminated vegetation field sampling and processing in the sample preparation laboratory will include Russian thistle plants that, depending on the subspecies, can have spiny growths that can easily injure hands. Appropriate personal protective equipment will be worn during vegetation sampling and processing activities to avoid injury.

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6 References

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Appendix A

Systematic Planning Record

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Appendix A – Systematic Planning Record

Characterization Data Collection Planning Record

NOTE: In cases where the requested information is not applicable, state that, and explain why it is not applicable so that it is clear that a required field has not been forgotten.

Project Summary

Project Name: Opportunistic Contaminated Vegetation Study of the Cent. Plateau	Date: 08/06/2019
Name of Person Completing Record: Sue Robinson	Position: Principal Ecotoxicologist
Name of Responsible Manager: Alaa Aly	

Project Background:

Intrusion of biota into contaminated subsurface soil with subsequent mobilization of radionuclides to the surface is a known transport mechanism at the Hanford Site. On the Central Plateau, a general remediation approach under consideration is a "leave in place option" unless the contamination poses an unacceptable risk to human health or the environment. To support remedial soil alternative evaluations on the Central Plateau, it will be essential to determine the soil depths from which biomobilization occurs within the Central Plateau, an area of 204 km^2 (79 mi^2). The purpose of the current opportunistic study is to characterize radiologically contaminated vegetation opportunistically identified on the Central Plateau during routine radiological surveys. The study will also quantify the relationship (if any) between radionuclide concentrations occurring in the tissues of vegetation, and collocated soils collected at depth intervals of 0-0.3, 0.3-0.9, 0.9-1.5, 1.5-2.1, 2.1-2.7, 2.7-3.3, 3.3-4.0, and 4.0-4.9 m [0-1, 1-3, 3-5, 5-7, 7-9, 9-11, 11-13, and 13-16 ft]). These collocated data (e.g., soils at discrete depths, aboveground plant tissue, and belowground root tissue) will be used to answer the primary study question regarding whether a relationship is evident between specific soil depth intervals and vertical biomobilization in aboveground plant tissue.

Previous reports have qualitatively and sometimes quantitatively characterized the magnitude of biomobilization at various scales within the Central Plateau (i.e., BHI-00032, *Ecological Sampling at Four Waste Sites in the 200 Areas*; WHP-18647, *Historical Site Assessment of the Surface Radioactive Contamination of the BC Controlled Area*; WHC-EP-0771, *Comparison of Radionuclide Levels in Soil, Sagebrush, Plant Litter, Cryptogams, and Small Mammals*). However, the data that exist are insufficient to answer the primary study question.

Conceptual model: At the Hanford Site, deep-rooted vegetation are known to bring subsurface radionuclides to the surface through biological uptake with subsequent translocation of radionuclides to the aboveground portion of the plant (vertical biomobilization). At the surface, the radionuclides in plant tissue may disperse through wind and through the physical movement of some types of vegetation (e.g., tumbleweeds). The biota of concern addressed in this DQO is perennial and annual deep-rooted vegetation (e.g., Russian thistle, tumble mustard, rabbitbrush, big sagebrush, bitterbrush) that is known to vertically biomobilize (transport) radionuclides. The primary exposure pathway for humans resulting from vertical biomobilization is non-contact radiation to workers in areas with biomobilized radiological contamination present at the surface. However, other exposure pathways may contribute to risk on a site-specific basis.

Appendix A – Systematic Planning Record

Characterization Data Collection Planning Record

NOTE: In cases where the requested information is not applicable, state that, and explain why it is not applicable so that it is clear that a required field has not been forgotten.

Planning Type:

Modified External DQO Planning (includes briefing for Ecology)

Organization, Schedule, and Goal

(State the problem, requirements, schedule, PSQs, and outcomes)

State the Problem

Access to radioactively contaminated media by deep-rooted vegetation at the Hanford Site may have implications to human health risk and the selection of remedial actions. Historical operations and waste management at the Hanford Site have resulted in the presence of contaminated soils and structures at the surface and at depth. Waste sites with shallow (less than 4.6 m [15 ft] deep) subsurface radioactive contamination typically have been stabilized by adding clean cover (soil, gravel, etc.) to reduce exposure to site workers from contaminants. Plants may extend roots into contaminated soils and translocate radionuclide contamination to the surface in their tissue. Once transported to the surface, the radioactively contaminated vegetation may represent an exposure pathway and potential risk to human health (site workers). An active site-wide management program successfully reduces the frequency and magnitude of biomobilization by deep-rooted vegetation and other biota and addresses (removed) occurrences of biomobilization as they are identified. Existing data do not distinguish the relative contributions of different soil depths to the biomobilized above-ground contamination. Data from this study will support remedial soil alternative evaluations regarding the nature and significance of surface vegetation radionuclide biomobilization contributions from different soil depths within the shallow zone.

The study represents the sampling of radioactively contaminated vegetation as identified opportunistically by radiation control technicians during their routine, Central Plateau radiation surveys of contaminated abiotic and biotic media (including vegetation). Deep-rooted vegetation is the focus of this study given the high frequency of occurrence of radioactively contaminated vegetation, largely Russian thistle, by radiation control technicians.

The project lead is Sue Robinson (INTERA). Project team members include consultants Brad Sample (Ecological Risk, Inc.) and INTERA staff Kim Ralston-Hooper, Jose Lopez, and Randy Dockter. Qualified firms will conduct sampling after DOE approves the study plan. Sampling of soil cores cannot occur until an identified sampling location has received all required cultural, ecological (etc.) clearances for sampling. The decisional draft of the ~~SAP~~ is due to DOE March 2019, and a Revision 0 is due to DOE before September 30, 2019.

Appendix A – Systematic Planning Record

Characterization Data Collection Planning Record

NOTE: In cases where the requested information is not applicable, state that, and explain why it is not applicable so that it is clear that a required field has not been forgotten.

Principal Study Question	**PSQ 1**	Are radionuclide concentrations in contaminated deep-rooted plant tissue significantly correlated with subsurface radionuclide soil concentrations occurring at a given soil depth interval(s)?
Key assumptions.	**PSQ 1**	The process of determining radioactively contaminated vegetation sampling locations is based on an opportunistic sampling methodology. The radioactively contaminated vegetation to be sampled will be identified during routine radiation monitoring and surveillance activities conducted as part of the quarterly radiological control programs conducted on the Hanford Site. It is assumed that opportunistically identified radioactively contaminated vegetation >5,000 dpm/100 cm^2 in operational areas reflect subsurface soil radionuclide contamination uptake and not vegetation surficial contamination from exogenous sources (e.g., atmospheric deposition, animal latrine activities), the latter of which cannot be distinguished from soil-derived transport and uptake during radiation control surveillance.
		Risk to human health is a key consideration when determining which depths of the shallow zone soil contribute significantly to biomobilized above-ground contamination in deep-rooted vegetation. The data will be able to be transformed to obtain a normal distribution; if not, non-parametric statistics will still be able to quantify the relationships in meaningful ways.
Identify the estimation statements needed to address the PSQs.	1.	For PSQ 1, the principal estimate to be made is the strength and significance of the relationships between the radionuclide concentrations in aboveground plant tissue and soil at eight defined soil depth intervals and radionuclide concentrations in collocated plant root tissue. The proportion of non-detects is expected to be widely variable between different target analytes. It is also expected that the strongest and most significant relationship will be observed in those target analytes displaying the broadest concentration range in collocated soils.

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Characterization Data Collection Planning Record

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Data Needs

(Define the spatial and temporal boundaries of the study)

Define what constitutes a sampling unit:

The target population is all deep-rooted plants that have been opportunistically identified to exhibit radiological levels above a threshold of 5,000 dpm/100 cm^2 as identified by radiation control technicians and the collocated radioactively contaminated subsurface soil cores. Only radioactively contaminated vegetation occurring within the operational areas located on the Central Plateau will be identified to the sampling team. The sampling units are individual plant specimens of several deep-rooted vegetation species (annual, perennial) and depth discretized collocated soil cores placed through and around each plant.

What is the smallest unit upon which decisions or estimates will be made?

The quantitative relationships that this study develops will be on a Central Plateau scale (contaminated specimens, which are located anywhere on the Central Plateau within the 200 East Area, 200 West Area, and parts of the 600 Area). However, the relationships from this study, and from future proposed biomobilization studies, are expected to be applied collectively on a decision unit scale. Each operable unit at Hanford contains multiple decision units. These decision units are commonly defined by waste site boundary and depth. An individual waste site could have multiple decision units such as shallow, shallow focused, and deep. The work plans for each operable unit define the spatial extent of decision units at the scale used to design and select remedial actions.

Appendix A – Systematic Planning Record

Characterization Data Collection Planning Record

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Data Needs Summary

(Information inputs to answer PSQs: target population, characteristics of interest, spatial and temporal limits, scale of inference)

PSQ	Data Need	Media of Interest	Location	Sampling Method	Action Level	Frequency	Practical Constraints	Analytical Method	Potential Source of Data
1	• Target population: all deep-rooted plants identified with radiological levels exceeding a threshold of 5,000 dpm/100 cm^2 located within operational areas of the Central Plateau and the collocated soil cores placed through and around each identified radioactively contaminated plant. • Characteristics of interest: radionuclide concentrations and other physical and chemical parameters measured in aboveground shrub tissue, belowground depth discretized root tissue, and depth discretized soil. • Spatial limits: within operational areas but cannot be located in exclusion areas such as burial grounds, pipelines, areas of subsidence, areas with significant health and safety risk to workers, tank farms or areas with significant belowground structures (where collocated soil coring would be a problem). Sampled locations will have approved clearances for subsurface soil coring. Small shrub dripline diameters may not allow drilling of all desired cores. • Temporal limits: 36-month limit on the entire study or until a statistical goal for number of sampled plant specimens per species is attained, which ever happens first (Russian Thistle most often identified; perennials will be uncommon to rare). It is recognized that statistical sampling goals for some plant species (e.g., perennials) will likely not be achievable. • Scale of inference: Central Plateau operational areas with identified radiologically contaminated vegetation.								
1	Radionuclide concentrations in vegetation tissue composites	Plant tissue (aboveground shrub, belowground roots)	Wherever radiation control technicians identify radioactively contaminated vegetation >5,000 dpm/ 100 cm^2 within operational areas on the Central Plateau.	Composite sampling of entire aboveground shrub tissue, and composite of root tissue across eight soil depth intervals from four continuous cores	N/A	Whenever routine monitoring and surveillance activities identify a sampling unit (radioactively contaminated plant >5,000 dpm/ 100 cm^2)	RadCon safety issues. Feasibility of using direct push (continuous coring) technology through plant roots.	Radionuclides AEA (Am-241, Cm-243/244, Np-237, Pu-238, Pu-239/240, U-233/234, U-235/236, U-238); liquid scintillation (C-14, H3, Ni-63, Pu-241, Se-79, Tc-99); GEA (Cs-137, Co-60, Cm-243, Eu-152, Eu-154, Eu-155); chemical separation low-energy photo spectroscopy (I-129); GPC (gross alpha, gross beta).	This proposed study

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Characterization Data Collection Planning Record

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Data Needs Summary

(Information inputs to answer PSQs: target population, characteristics of interest, spatial and temporal limits, scale of inference)

PSQ	Data Need	Media of Interest	Location	Sampling Method	Action Level	Frequency	Practical Constraints	Analytical Method	Potential Source of Data
1	Dry weight and percent moisture in vegetation tissue	Soil and plant tissue(abovegr ound shrub tissue, belowground root tissue by depth interval)	Wherever radiation control identifies radioactively contaminated vegetation >5,000 dpm/ 100 cm^2 within Central Plateau Operational Areas.	Composite sampling of entire aboveground shrub tissue and composite of root tissue across eight soil depth intervals from up to four continuous 16 ft cores	N/A	Whenever routine monitoring and surveillance activities identify a sampling unit (radioactively contaminated plant >5,000 dpm/ 100 cm^2)	--	ASTM D2216	This proposed study
1	Shrub diameter or length/width	Aboveground portion of shrub	Wherever radiation control identifies radioactively contaminated vegetation >5,000 dpm/ 100 cm^2 within Central Plateau Operational Areas.	Measurement of shrub diameter or linear length and width dimensions	N/A	Whenever routine monitoring and surveillance activities identify a sampling unit (radioactively contaminated plant >5,000 dpm/ 100 cm^2)	--	--	This proposed study
1	Shrub age	Woody portion of shrub stem (perennials) or best estimate of annual shrub development stage	Wherever radiation control identifies radioactively contaminated vegetation >5,000 dpm/ 100 cm^2 within Central Plateau Operational Areas.	Shrub stem cross-section (perennial); annual shrub best estimate of annual shrub development stage	N/A	Whenever routine monitoring and surveillance activities identify a sampling unit (radioactively contaminated plant >5,000 dpm/ 100 cm^2)	--	--	This proposed study

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Characterization Data Collection Planning Record

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Data Needs Summary

(Information inputs to answer PSQs: target population, characteristics of interest, spatial and temporal limits, scale of inference)

PSQ	Data Need	Media of Interest	Location	Sampling Method	Action Level	Frequency	Practical Constraints	Analytical Method	Potential Source of Data
1	Rooting depth	Plant roots	Wherever radiation control identifies radioactively contaminated vegetation within Central Plateau Operational Areas >5,000 dpm/100 cm^2	Continuous core with eight discrete soil depth intervals	N/A	Whenever routine monitoring and surveillance activities identify a sampling unit (radioactively contaminated plant >5,000 dpm/ 100 cm^2)	Distinguishing fine root hairs from other organic matter in soil. Intersecting the deepest penetrating root tissue using continuous coring technique and given root desiccation & senescence occurring after aboveground shrub is removed. Future root characterization study is planned to definitively provide rooting depth for all target vegetation species.	N/A	This study if possible

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Data Needs Summary

(Information inputs to answer PSQs: target population, characteristics of interest, spatial and temporal limits, scale of inference)

PSQ	Data Need	Media of Interest	Location	Sampling Method	Action Level	Frequency	Practical Constraints	Analytical Method	Potential Source of Data
1	Depth-discrete soil composite concentrations of radionuclides	Collocated soil cores (with eight discrete soil core depth intervals)	Wherever radiation control technicians identify radioactively contaminated vegetation within operational areas on the Central Plateau >5,000 dpm/ 100 cm^2	Continuous cores with eight discrete soil depth intervals	N/A	Whenever routine monitoring and surveillance activities identify a sampling unit(radioactively contaminated plant >5,000 dpm/ 100 cm^2)	RadCon safety issues. Feasibility of using direct push (continuous coring) technology through plant roots.	Radionuclides: AEA (Am-241, Cm-243/244, Np-237, Pu-238, Pu-239/240, U-233/234, U-235/236, U-238); liquid scintillation (C-14, H3, Ni-63, Pu-241, Se-79, Tc-99); GEA (Cs-137, Co-60, Cm-243, Eu-152, Eu-154, Eu-155); chemical separation low-energy photo spectroscopy (I-129); GPC (gross alpha, gross beta).	This proposed study
1	Depth-discrete soil composite physical parameters (pH, grain size distribution, percent moisture)	Collocated soil cores (with eight discrete soil core depth intervals)	Wherever radiation control technicians identify radioactively contaminated vegetation within operational areas on the Central Plateau >5,000 dpm/ 100 cm^2	Continuous cores with eight discrete soil depth intervals	N/A	Whenever routine monitoring and surveillance activities identify a sampling unit (radioactively contaminated plant >5,000 dpm/ 100 cm^2)		EPA 9045D (soil pH); ASTM D422-63, *Particle-Size Analysis* Percent moisture in soil is a standard analytical need when conducting constituent analyses such as metals and is automatically included in lab results.	This proposed study

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Data Needs Summary

(Information inputs to answer PSQs: target population, characteristics of interest, spatial and temporal limits, scale of inference)

PSQ	Data Need	Media of Interest	Location	Sampling Method	Action Level	Frequency	Practical Constraints	Analytical Method	Potential Source of Data
1	Depth-discrete soil composite general chemical parameters(cation exchange capacity, water-soluble cations [calcium and potassium only], total organic carbon)	Collocated soil cores (at eight discrete soil core depth intervals)	Wherever radiation control technicians identify radioactively contaminated vegetation within operational areas on the Central Plateau >5,000 dpm/ 100 cm^2	Continuous cores with eight discrete soil depth intervals	N/A	Whenever routine monitoring and surveillance activities identify a sampling unit(radioactively contaminated plant)		EPA Method 9081, "Cation-Exchange Capacity of Soils (Sodium Acetate)" EPA Method 6020B, "Inductively Coupled Plasma-Mass Spectrometry," with water soluble soil extraction (only) for Ca^{2+}, K^{+} EPA Method 415.1 or 9060A, "Total Organic Carbon"	This proposed study
1	Downhole gamma-spectroscopy log and neutron moisture log	Collocated soil in taproot core (at a minimum). May also be collected in dripline cores.	Wherever radiation control technicians identify radioactively contaminated vegetation within operational areas on the Central Plateau >5,000 dpm/ 100 cm^2	Spectral gamma logging systems and neutron moisture logging systems in taproot core (minimum) and in dripline cores	N/A	Whenever routine monitoring and surveillance activities identify a sampling unit(radioactively contaminated plant) and sampling site location is appropriate for geophysical logging activities	Borehole diameter; any site access conditions or limitations. Collection of GPL data depends on timing of core drilling and availability timeframe of GPL contractor.	Down-hole multi-channel analyzer	This proposed study
1	Growing conditions compared to average years	Precipitation Air temperature	Central Plateau monitoring stations	Automated weather station	N/A	Monthly	--	Average Monthly averages, minimums and maximums	Central Plateau monitoring stations

It is anticipated that sample mass will be sufficient to analyze for all analytes in soil and for most vegetation tissue (root tissue may be limited). If a limitation to analysis based on sample mass is identified, the priority of analyses are as follows: cesium-137, strontium-90, depth discrete general soil chemical parameters (i.e., water soluble cations, total organic carbon, cation exchange capacity; soils only), depth discrete soil physical parameters (grain size, pH, percent moisture), and remaining radionuclides.

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Performance or Acceptance Criteria

(Determine the quality of data needed and analytical approach)

Specify the population parameter (e.g., mean, median, or percentile), appropriate for making decisions or estimates:

PSQ 1 (Hypotheses, Population Parameters):

Hypotheses:

H_o: There is no significant correlation between radionuclide concentrations and specific physical or chemical soil characteristics (pH, CEC, TOC, grain size, and water soluble cationic nutrients [K^+ and Ca^{2+}]) in soil at specific depth intervals, and radionuclide concentrations in plant tissues (aboveground, belowground).

H_a: There is a significant correlation between radionuclide concentrations and physical or chemical soil parameters (pH, CEC, TOC, grain size, and water soluble cationic nutrients [K^+ and Ca^{2+}]) in soil at specific depth intervals, and radionuclide concentrations in plant tissues (aboveground, belowground).

Population parameters:

(1) the coefficient of determination (r^2), significance level (p), and slope of the regression between radionuclide concentrations in subsurface soil at specific depth intervals and radionuclide concentrations in aboveground and belowground plant tissue; and

(2) the significance level (p) of a multiple linear regression to determine the influence of specific soil characteristics of soil pH, cation exchange capacity, water soluble cationic nutrients (K^+ and Ca^{2+}), total organic carbon, and grain size on the relationship between radionuclide concentrations in subsurface soil at specific depth intervals and aboveground/belowground radionuclide concentrations in plant tissue.

Estimation Problem	Develop the specification of the estimator by combining the true value of the selected population parameter with the scale of estimation and other boundaries:
	PSQ 1: The study will estimate the strength and significance of the relationship between the contaminant concentrations in soil cores (0–4.9 m [0–16 ft]; eight specific depth intervals) and that in collocated aboveground media (i.e., plant tissue) identified to have levels of radiological levels exceeding a threshold of 5,000 dpm/100 cm^2 during routine monitoring and surveillance activities within the Central Plateau.

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Estimation Problem

What are the acceptable limits on uncertainty?

PSQ 1

Uncertainty in the sampling design

The consequence of incorrectly determining that there is a significant correlation between soil at various depth intervals and plant tissue concentrations aboveground, when in fact there is not, could be inaccurate risk estimates and inappropriate inputs to risk management and feasibility studies. The acceptable limit on uncertainty (probability) of this Type I error (rejecting H_0 when it is true) is 0.05. Because the statistical test is by nature a yes or no question, the test does not compare a derived value against an action level, so a beta value is unnecessary.

Uncertainty in the measurements (population parameters)

A weight of evidence approach will be used to determine whether the quantitative relationships between soil concentrations at eight soil depth intervals and above-ground vegetation radionuclide contamination should be used in future decision making, including the following lines of evidence: (1) a coefficient of determination of at least 0.2, a significance level (p) of at least 0.05, and positive slope of the regression (after evaluating residuals to check the assumption of normality and independence and verifying that the variance of the residuals is homoscedastic*); (2) a significance level (p) of at least 0.05 of a multiple linear regression to determine the influence of soil pH, cation exchange capacity, water soluble cationic nutrients (K^+ and Ca^{2+}), total organic carbon, and grain size on the relationship between soil and vegetation radionuclide concentrations (after evaluating the variance inflation factor to diagnose multi-collinearity); (3) the magnitude of depth-discrete root tissue concentrations compared to the corresponding depth-discrete soil concentrations and surface vegetation concentrations; and (4) best professional judgment of the strength, validity, and meaning of the results of all the statistical tests and nature of the datasets when considered as a whole.

One of the challenging aspects of this study is that unlike many investigations at the Hanford Site, this study relies on predominantly biological (not physical or chemical) sciences. Biological systems are more complex, less well understood, and more difficult to quantify than systems governed only by physical or chemical relationships. While the above coefficient of determination may seem low when compared to other DQOs, comparable values have been relied on in studies used to inform CERCLA decision-making processes (such as ecological soil screening levels in OSWER Directive 9285.7-55, *Guidance for Developing Ecological Soil Screening Levels*). A broad range of contaminant concentrations in collocated (with contaminated shrub) soils will increase the likelihood of obtaining a higher r^2. Additionally, the usability of these data will be determined by weighing many factors, not just the coefficient of determination from a single relationship.

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*Homoscedastic means the variance in a sequence or vector of random variables is the same. In other words, the "noise" in the data is the same across all values of the independent variables.

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Characterization Data Collection Planning Record

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Plan for Obtaining the Data

(Specify the general plan of obtaining the needed data and explain where and how the information in this Planning Record will be formalized in a data collection plan)

Study Design

The field work for the selected study design has the following element: sampling plant tissue (entire aboveground shrub composite, root composite from eight discrete soil core depth intervals), soil (0-4.9 m [0-16 ft] in eight discrete soil depth intervals) at locations with deep-rooted plant species identified to have radiological levels exceeding a threshold of 5,000 dpm/100 cm^2. These data will be used to determine relationships between radionuclide concentrations in soil (0-0.3, 0.3-0.9, 0.9-1.5, 1.5-2.1, 2.1-2.7, 2.7-3.3, 3.3-4.0, and 4.0-4.9 m [0-1,1-3, 3-5, 5-7, 7-9, 9-11, 11-13, and 13-16 ft]) and aboveground vegetation radionuclide concentrations to understand whether a specific soil depth(s) is associated with aboveground biomobilized radionuclide contamination. A statistically based design is appropriate because the quantitative statistical relationships from this proposed study, together with other biomobilization lines of evidence (i.e., future studies to documented in future SAPs), are intended to be applied throughout the Central Plateau.

The statistically desired (goal) number of radioactively-contaminated plant specimens per species (e.g., Russian thistle, tumble mustard, rabbitbrush, sagebrush, antelope bitterbrush) for this proposed study was determined using a power analysis conducted in Statistica™, with an alpha of 0.05, beta of 0.2, and r^2 of 0.2, resulting in a desired sampling goal (n) of 36 specimens sampled opportunistically per species.

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™ Statistica is a registered trademark of TIBCO Software, Inc., Palo Alto, California.

To quantify the relationship between radionuclide concentrations in plant tissue aboveground and soil radionuclide concentrations in borings that are collocated with the plant, depth discrete soil sampling intervals were defined. A total of eight depth-discrete soil samples will be obtained from each opportunistic plant species specimen identified. These eight samples actually represent a composite across each of the eight soil depth intervals across each of four soil cores that will be collocated with each opportunistically identified contaminated plant specimen. The depth discrete soil intervals to be sampled are as follows: 0-0.3, 0.3-0.9, 0.9-1.5, 1.5-2.1, 2.1-2.7, 2.7-3.3, 3.3-4.0, and 4.0-4.9 m (0-1, 1-3, 3-5, 5-7, 7-9, 9-11, 11-13, and 13-16 ft). The last soil depth interval of 4.0-4.9 m (13–16 ft) goes 1 foot deeper than the standard soil point of compliance depth as defined in WAC-173-340, "Model Toxics Control Act—Cleanup," to understand whether roots are observed to extend beyond this depth. Soil samples from the same depth interval in each of the four soil cores will be composited after root tissue is removed. At each opportunistically identified contaminated plant location, the entire aboveground shrub (i.e., leaves, branches, flowers, spines, seeds, woody stem) will be removed (sliced off at ground surface), ground up, and a single large composite sample made for analysis. Additionally, plant root tissue belowground will also be composited for sample analysis using the same core

soil depth intervals as for soil compositing. All required clearances (cultural, etc.) will be obtained before subsurface soil core sampling can be initiated.

Radiation control organizations will "opportunistically" identify locations of radiologically contaminated vegetation to the biomobilization team as a result of their routine radiation surveillance monitoring on the Central Plateau. Accordingly, all radionuclides in soil and in plant tissue are identified as target analytes for this study. Target analytes also include physical and chemical soil parameters: cation exchange capacity, water soluble cationic nutrients (specifically K^{+}, Ca^{2+}), grain size distribution, total organic carbon, pH, and percent moisture.

Each sample will be analyzed for the constituents and parameters listed in the Data Needs Summary table (including shrub size, age). Seasonal rainfall and temperature patterns during the growing season will be compared to average conditions to assess potential climatic factors influencing maximum root depth observed during the study.

The detailed study plan is in DOE/RL-2017-14, *Study Plan for Conducting an Opportunistic Contaminated Deep-Rooted Vegetation Sampling Study in the Hanford Site Central Plateau.*

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