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Draft B

100-K West Vadose Zone In Situ Bio-Infiltration Treatability Test Plan

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

U.S. DEPARTMENT OF ENERGY

Richland Operations Office

P.O. Box 550
Richland, Washington 99352

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J. D. Aardal 08/23/2010
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Terms

100-KW	100-K West Area
ALARA	as-low-as-reasonably-achievable
ARAR	applicable or relevant and appropriate requirement
bgs	below ground surface
CERCLA	*Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
CFR	*Code of Federal Regulations*
COC	contaminant of concern
Cr(III)	trivalent chromium
Cr(VI)	hexavalent chromium
DO	dissolved oxygen
DOE	U.S. Department of Energy
DQA	data quality assessment
DQO	data quality objective
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
gpm	gallons per minute
HEIS	Hanford Environmental Information System
Mn(II)	divalent manganese
Mn(IV)	manganese
NEPA	*National Environmental Policy Act of 1969*
NPL	National Priorities List
OU	operable unit
P&T	pump-and-treat
QA	quality assurance
QC	quality control
RL	U.S. Department of Energy, Richland Operations Office
ROD	Record of Decision
RUM	Ringold Upper Mud
SAP	sampling and analysis plan
TOC	total organic compound
TTP	treatability test plan

1 Introduction

This document presents a treatability test plan (TTP) for evaluating the practicality of in situ bioremediation in the vadose zone at the 100-K West (100-KW) Area of the Hanford Site. Specifically, the test is designed to determine if chemically reducing conditions suitable for remediating hexavalent chromium (Cr(V)) contamination can be established by stimulating anaerobic microbes via infiltration of an organic nutrient solution from the ground surface.

1.1 Basis for the Treatability Test

The U.S. Department of Energy's (DOE's) Hanford Site is a 1,517 km^2 (586-mi^2) federal facility located in southeastern Washington State along the Columbia River. For administrative purposes, the Hanford Site was divided into four National Priorities List (NPL) sites[1] under *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA). The 100 Area, which is one of these NPL sites, comprises a string of former reactor sites or "areas" along the Columbia River (Figure 1). Single-pass coolant reactors were active from 1944 (B Reactor startup) to 1971, when KE reactor shut down. Those reactors were cooled with river water that had been treated with sodium dichromate to retard corrosion. Because of historical releases during operation of these reactors, Cr(VI) is the primary groundwater contaminant of concern (COC) at most of the former reactor sites within the100 Area. Some of these former reactors sites (e.g., the 100-K, 100-D, and 100-H) are the focus of intensive efforts to remediate groundwater contaminated with Cr(VI) and to mitigate the discharge of this contaminant to the river.

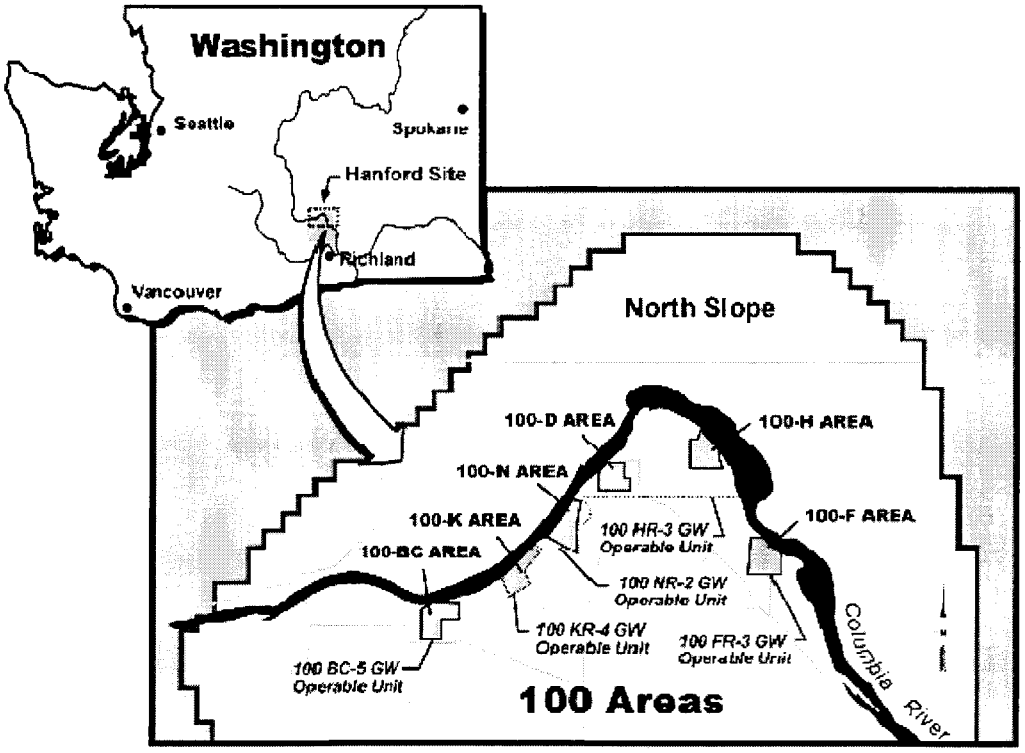


Figure 1. Location Map for the Hanford Site and the 100 Area Reactors Sites

[1] 40 Code of Federal Regulations (CFR) 300, "National Oil and Hazardous Substances Pollution Contingency Plan," Appendix B.

Ion exchange-based pump-and-treat (P&T) systems have been installed at 100-K, 100-D, and 100-H as the primary component of the interim actions implemented to address Cr(VI) groundwater contamination at these sites. The P&T systems originally implemented in these areas were inadequate to contain or remediate the Cr(VI) plumes or to protect the river. Consequently, these ion exchange treatment systems in 100-K, 100-D, and 100-H have been, or are in the process of being, substantially expanded to meet the interim remedial action objectives (U.S. Environmental Protection Agency [EPA] et al. 1996, *Declaration of the Record of Decision for the 100-HR-3 and 100-KR-4 Operable Units at the Hanford Site [Interim Remedial Actions]*) and to achieve the objectives of the 2012 and 2020 Tri-Party Agreement Milestones for river protection and groundwater remediation, respectively.

Even with the planned expansions, the P&T systems only address contamination that has reached groundwater. Given that the Cr(VI) must have passed through the vadose zone to reach groundwater and that yellow staining associated with Cr(VI) has been recently observed in vadose zone soils in 100-K, it is likely that the unsaturated soils contain residual Cr(VI) contamination. Further, it is possible that contamination within the vadose zone represents one or more active sources of Cr(VI) feeding the groundwater contaminant plumes. Therefore, the implementation of a remedial technology capable of remediating Cr(VI) within the vadose zone would be a useful complement to the P&T systems.

In situ bioremediation has been identified as a technology having the potential to reduce elevated levels of Cr(VI) rapidly and effectively in both unsaturated and saturated soils. Consequently, in situ bioremediation of the vadose zone is being evaluated as a potential action for the remediation of identified or suspected Cr(VI) contamination in the vadose zone of sites in the 100 Area (e.g., 100-D, 100-K, and 100-H).

The efficacy of in situ bioremediation has been demonstrated for remediation of Cr(VI) in groundwater at 100-D (PNNL-18784, *Hanford 100-D Area Biostimulation Test Results*). However, there are insufficient site-specific data to perform a defensible detailed analysis of bioremediation as a component of the final remedy selected for the remediation of Cr(VI) remaining in the vadose zone. CERCLA guidance recognizes that Tier II treatability testing is appropriate when insufficient data are available for remedy selection (EPA/540/R-92/071a). Consequently, a treatability test will be conducted at a 100-KW site to evaluate in situ bioremediation of the vadose zone as a potential component of the final remedy selected for the remediation of Cr(VI) in the 100 Area.

Because the vadose zone is the target for the planned test, the nutrient solutions needed to establish bioremediation (Chapter 3) will be introduced to the unsaturated soils by infiltration from the ground surface (described in Chapter 5). Hence, in the balance of this report, the method is referred to as bio-infiltration.

The primary objective of the proposed 100-KW bio-infiltration treatability test is to evaluate the performance and potential long-term effectiveness of bio-infiltration for establishing, within the vadose zone, the chemically reducing (anoxic) conditions needed for Cr(VI) remediation. If this objective is met, sufficient data will be obtained to determine if this technology represents a cost-effective alternative or a complement to removal, transport, and disposal actions for Cr(VI)-contaminated vadose zone soils. A secondary objective of the test is to obtain system operations data that will help optimize the performance of any future bio-infiltration system implemented for the remediation of Cr(VI) in the 100 Area.

1.2 Document Organization

This document constitutes the work plan for the proposed 100-KW Vadose Zone In Situ Bio-Infiltration Treatability Test. The chapters that follow describe the proposed test site, the purpose of the test, the treatment technology, the test objectives and performance criteria, and the monitoring plans. Before the

test is started, detailed instructions will be developed for the operation of the system. This document is organized as follows:

- Chapter 2 summarizes the geology and hydrology of 100-K, its groundwater geochemistry, and the nature and extent of groundwater contamination. This chapter includes the most current depiction of the 100-KW chromium plume, the upgradient end of which is the target area of the bio-infiltration test.
- Chapter 3 is a brief description of the biologic and geochemical processes that form the basis of the treatment technology.
- Chapter 4 presents the primary test objective and the criteria needed to evaluate the results of the planned testing campaign.
- Chapter 5 describes the test site and the method of nutrient infiltration. It also specifies a phased approach to testing, including pre-test activities, startup operating parameters, the logic of process adjustments, and general requirements for process control and monitoring.
- Chapter 6 lists major equipment needed for fluid handling and nutrient infiltration. In addition, it describes activities needed to prepare the test site and proposes locations for the three new monitoring wells.
- Chapter 7 lists the requirements for soil sampling and analysis during well construction, and for periodic sampling and analysis of groundwater and pore water.
- Chapters 8 and 9 discuss data management, analysis, and interpretation.
- Chapters 10 through 13 present requirements for health and safety, waste management, reporting, and environmental and regulatory compliance, respectively.
- Chapter 14 is the current project schedule.
- Chapter 15 reflects project management organization.
- Chapter 16 lists references consulted in preparing this work plan.

2 Project Description

The proposed 100-KW test site is located within 100-K approximately 46.3 km (31 mi) north-northwest of the city of Richland, Washington. The 100-K area is situated between 100-BC and 100-N in the northern section of the Hanford Site (Figure 1).

2.1 Background

The 100-KW reactor area is located on the west end of the 100-KR-4 groundwater operable unit (OU). The 100-KW P&T system is one of three P&T systems in the 100-KR-4 OU that are removing Cr(VI) from groundwater; it has been operational since January 30, 2007 and was expanded from a 6.3 to 12.6 liter per second (L/s) (100- to 200-gallons per minute [gpm]) capacity in April 2009. Figure 2 depicts the KW Cr(VI) plume map. Details regarding the 100-KW P&T system and the other 100-KR-4 OU P&T systems are available in the most recent annual groundwater summary report (DOE/RL-2010-11).

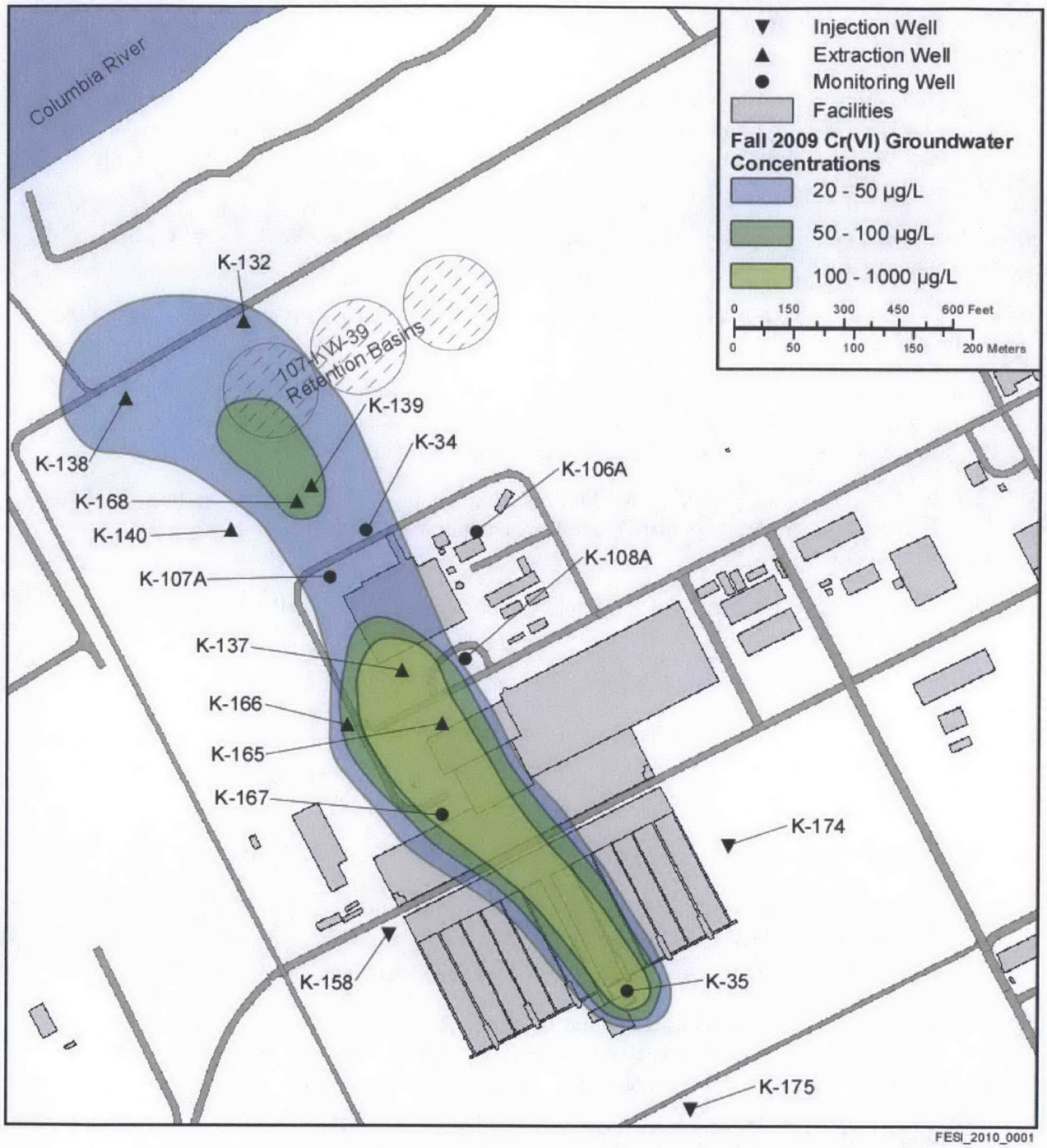


Figure 2. The 100-KW Area Cr(VI) Plume Map

During operations, billions of liters of Columbia River water were used to cool the reactor core. The river water was treated with various chemicals including sodium dichromate, which was added as an anti-corrosive to the influent in concentrations from 0.5 to 2.0 mg/L. After passing through the reactors, the coolant effluent was routed to various trenches and basins and then piped to the Columbia River or infiltrated to groundwater.

Concentrated sodium dichromate stock solution arrived south of the 100-KE Reactor in railcars, and soil staining discovered during treatment system demolition indicates that spills occurred during offloading. It is likely that some coolant water effluent and leaked concentrate remain within the vadose zone soil column as potential groundwater contamination sources.

2.2 Site Hydrogeology

The following discussion summarizes vadose zone soil descriptions from geologic logs of Wells 199-K-35 and 199-K-175, which are located near the proposed treatability test site (Figure 2 shows the well locations).

2.2.1 100-KW Area Geology

The geologic units relevant to the 100-KW Reactor area include minor surficial Holocene deposits, imported fill material, the Hanford formation, and the Ringold Formation (Figure 3). The 100-K area geologic units are discussed in detail in WHC-SD-EN-TI-155, *Geology of the 100-K Area, Hanford Site, South-Central Washington.*

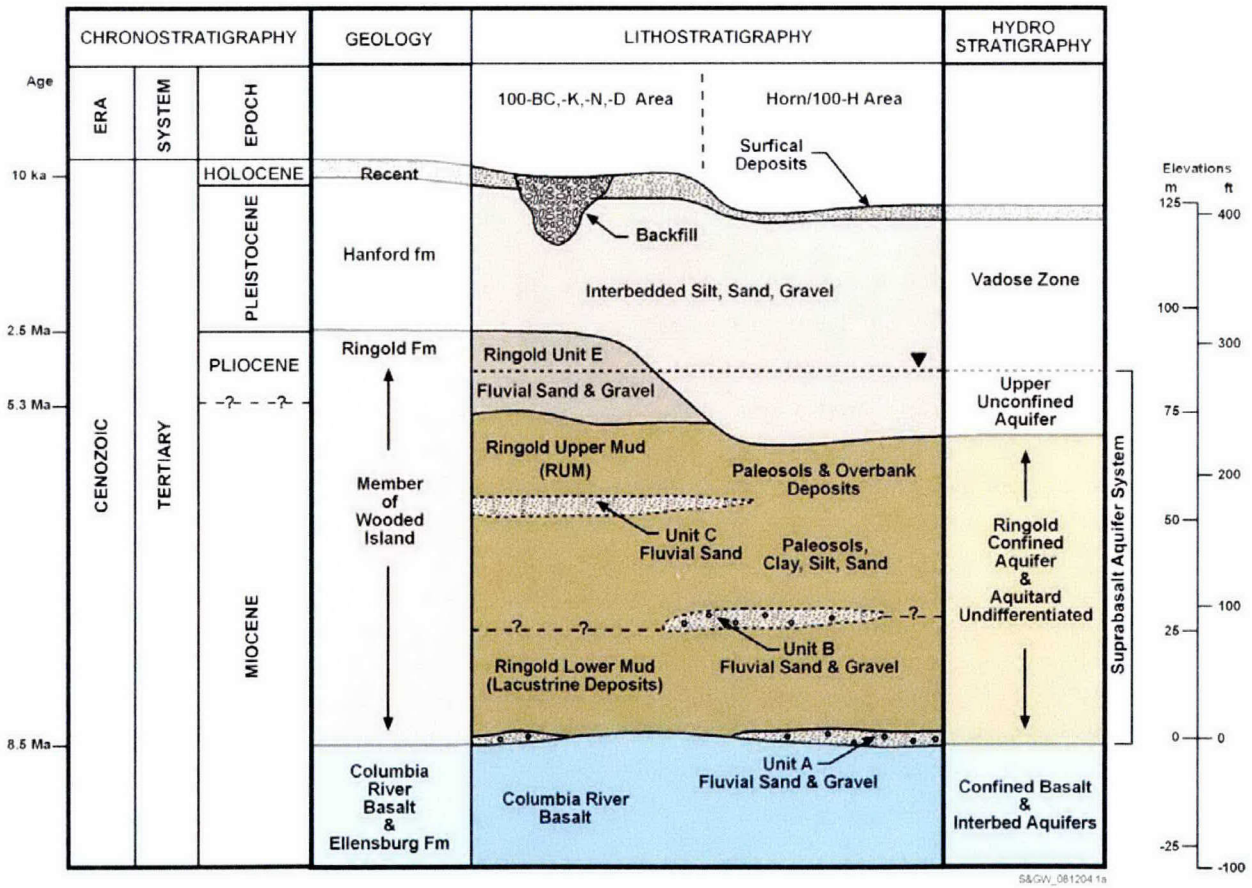


Figure 3. Generalized Hydrogeology of the 100-K Area

2.2.1.1 Imported Fill and Holocene (Recent) Deposits

The log of Well 199-K-35 drilled in 1992 indicates that the top 8.8 m (29 ft) of soil are imported fill material composed of sandy gravel similar to the underlying Hanford formation soil. Holocene aeolian sand is present at the surface in undisturbed areas. The Well 199-K-35 log also indicates that the soils were saturated from 1.8 to 7.6 m (6 to 25 ft) below ground surface (bgs) because of a leaking water line.

2.2.1.2 Hanford Formation

The Hanford formation soils beneath the 183.1 KW Head House vicinity are sandy gravel with minor silt down to the contact with the underlying Ringold Formation Unit E reached at a depth of 20.7 m (68 ft) in Well 199-K-35 and 15.2 m (50 ft) in Well 199-K-174. Well 199-K-174 is located on the east side of the former 100-KW sedimentation basins.

2.2.1.3 Ringold Formation

The Ringold Formation Unit E extends from the bottom of the Hanford formation to the top of the Ringold Upper Mud (RUM), which also is the bottom of the uppermost unconfined aquifer in 100-K. The unsaturated portion of the Ringold Unit E is composed of sandy gravels with local silty layers and is generally denser and less permeable than the overlying Hanford formation. The water table was reached at a depth of 28.2 m (92.6 ft) in Well 199-K-174 on March 16, 2009 and 30.2 m (99 ft) in Well 199-K-35 on September 25, 1992.

2.2.2 General Hydrology and Groundwater Chemistry

The uppermost unconfined aquifer in the 100-KW Reactor area is entirely within the Ringold Unit E and was about 28 m (92 ft) thick in Well 199-K-173 located outside the test area about 300 m (984 ft) northwest of the proposed location of the bio-infiltration test. This well has been included in the discussion of the Ringold Unit E because it fully penetrates the unit. The RUM, a silt-dominated aquitard, defines the bottom of the shallow unconfined aquifer.

The thickness of the unconfined aquifer (Ringold Unit E) is quite variable over 100-K as a whole (e.g., ranging from about 5.8 to 32 m [19 to 104 ft] thick). Near the 100-K west area, however, the aquifer is uniform, appearing to range between about 21.3 to 25 m (69.8 to 82 ft) in thickness. Groundwater in the 100-K west area generally flows to the northwest (downgradient) to the Columbia River. However, the direction of groundwater flow can be affected strongly on a seasonal basis by large variations in the stage of the Columbia River imposed by upstream hydroelectric dams. High river stages during the spring and summer temporarily reverse the hydraulic gradient near the river and the dominant direction of near-shore groundwater flow is away from the river during these periods. The daily and seasonal gradient reversals are thought to promote a groundwater flow component that is subparallel to the shoreline than when the river is at a low stage. During the seasonal periods of high river stage, Cr(VI) concentrations typically decline in wells located near the shore where the influx of river water inland can be substantial. Concentrations of Cr(VI) typically increase in the fall, when the river stage drops, the gradient steepens, and groundwater flow toward the river is re-established.

The general chemistry of the shallow unconfined aquifer at the 100-K west area groundwater can be described as moderately alkaline with dissolved oxygen (DO) concentrations that are at or near equilibrium with air (e.g., 8 to 10 mg/l). The major cationic species are dominated by sodium, calcium, and magnesium and the non-carbonate anionic species are dominated by sulfate and nitrate. The average specific conductance of the groundwater is 397 μS/cm and the pH typically lies between 7.5 and 8.

2.3 Nature and Extent of Contamination at the 100-KW Area

Although Cr(VI) is the primary COC in the100-KW Area, other groundwater constituents of interest include strontium-90, tritium, carbon-14, nitrate, and sulfate. With the exception of nitrate and sulfate, elevated concentrations of these constituents appear to originate from localized source areas and are generally not collocated with the chromium plume as a whole.

The 100-KW Cr(VI) plume extends from near the 183.1 KW Head House and chemical storage facility approximately 600 m (1,968 ft) downgradient to extraction Wells 199-K-132 and 199-K-138 (Figure 2). A substantial portion of the plume contains Cr(VI) above federal drinking water standards (100 μg/L). In late December 2009, elevated chromium concentrations were measured at Well 199-K-35, a former injection well near the 183.1 KW Head House that was converted to a monitoring well in November 2009. Frequent monitoring of this former injection well began in December 2009 with Cr(VI) concentrations steadily increasing from 193 to 726 μg/L by late January 2010. The concentrations of Cr(VI) decreased abruptly to about 300 μg/L in early February 2010. Between February and the middle of April 2010 (when the last available data were collected from this well), the measured concentrations generally varied slightly below or above 300 μg/L.

Concentrated sodium-dichromate released to and possibly still present within the vadose zone is considered the most likely source for chromium near the 183.1 KW Head House. Concentrated (70 percent) sodium dichromate solutions were routinely delivered to the K West site by railcar and transferred to a 158,987 liter (L) (42,000-gallon [gal]) storage tank (Site 100-KW-5) that was located adjacent to the 183.1 KW Head House (Figure 4). These concentrated feed solutions were piped from the storage tank through the 183-KW complex and to the adjacent 190-K Building (Figure 4) where the concentrated solutions were diluted and mixed with river water to produce coolant water. The *Remedial Investigation/Feasibility Study Work Plan for the 100-KR-4 Operable Unit, Hanford Site, Richland, Washington* (DOE/RL-90-21) provides detailed descriptions of these facilities and the processes used to generate, use, and discharge reactor coolant after use.

The presence of yellow-stained soils around the sodium dichromate storage tank area (Site 120-KW-5), indicates that spills and leaks occurred during transfer operations from the railcars to the storage tanks. Releases of 70 percent dichromate solutions that occurred near the storage tank likely seeped into the soils or were sluiced into a nearby French drain (Figure 5). The volume of 70 percent sodium dichromate solutions lost to the vadose zone in this area (or elsewhere near the 183.1 Head House) and the maximum depth that these spills may have penetrated into the vadose zone is unknown. However, given the acidity, high density, and extremely elevated Cr(VI) concentrations of these solutions, spills of even several gallons could introduce hundreds or thousands of mg/L of Cr(VI) several feet into the vadose zone. Larger spills would have the potential to penetrate well into the deep vadose zone where the Cr(VI) would likely act as a long-term, continuing source of groundwater contamination. The recent identification of elevated groundwater Cr(VI) concentrations (i.e., 726 μg/L) in monitoring Well 199-K-35, located near the former 120-KW-5 (Figures 2, 4, and 5), suggests the presence of one or more potentially deep residual vadose zone sources of Cr(VI) in this area.

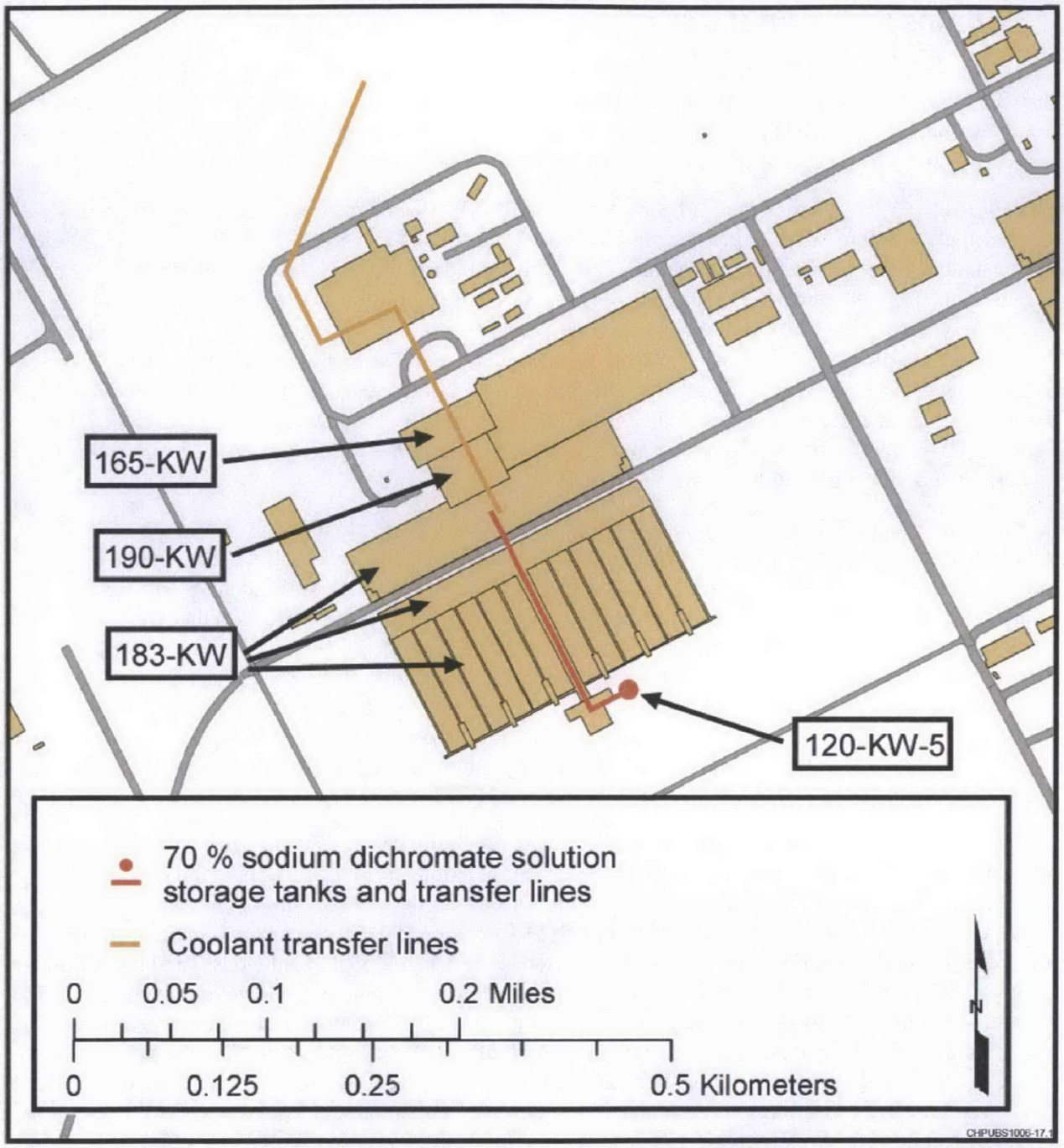


Figure 4. Facilities in the 100-KW Area that Handled High-Concentration Sodium Dichromate Solutions and the Proposed 100-KW Bio-Infiltration Test Area

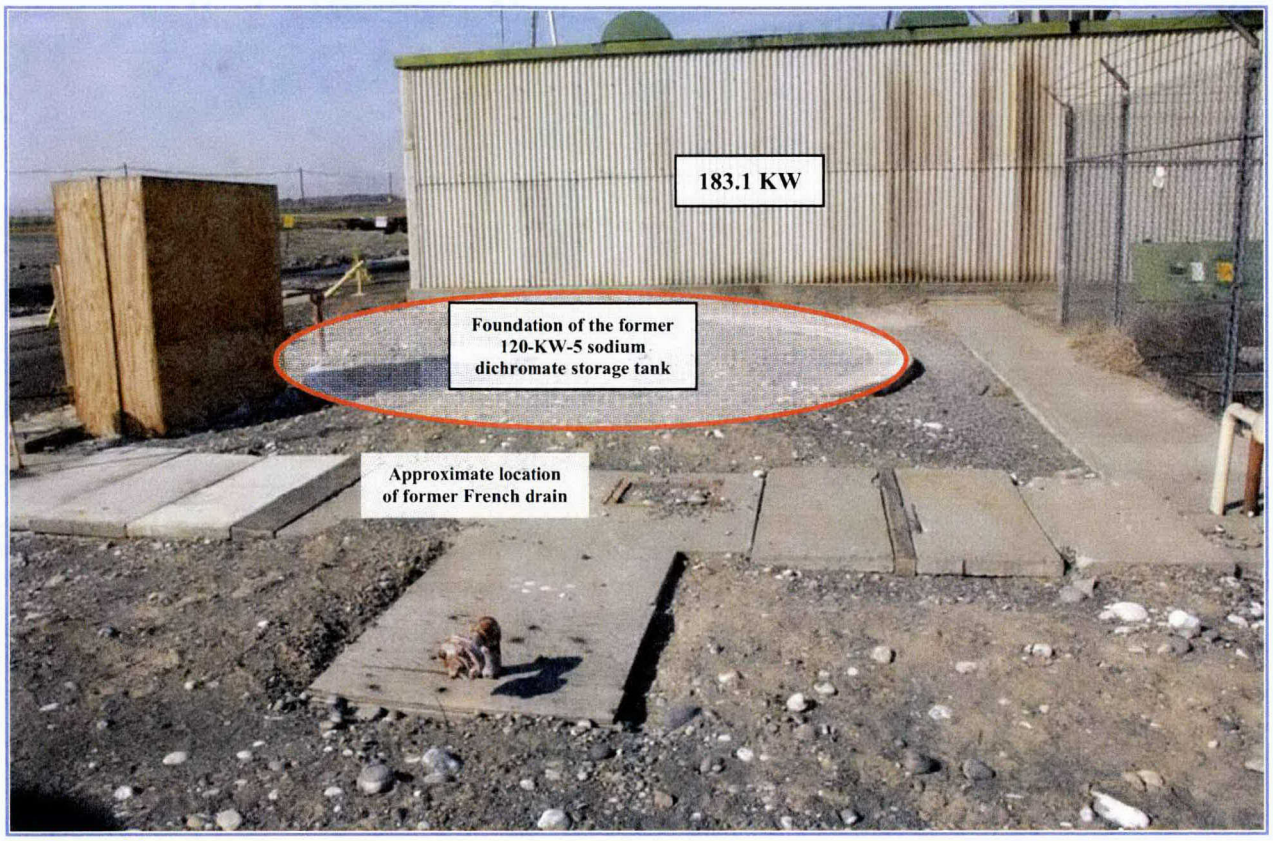


Figure 5. Photograph of the 120-KW-5 Waste Site Prior to D&D and Excavation

3 Treatment Technology Description

This chapter summarizes the technical basis for the proposed vadose zone bio-infiltration treatability test. Section 3.1 presents an overview of the microbial and geochemical processes that are necessary to lead to reductive remediation of Cr(VI) within the vadose zone. Section 3.2 briefly discusses the stability of Cr(III) phases produced by bioremediation once oxygenated conditions are re-established.

3.1 Overview of Relevant Chemical and Microbial Processes

The chromium released to the vadose zone and groundwater in the 100 Area was typically in the form of Cr(VI), a highly mobile anionic species that is stable in oxidizing natural environments. Numerous studies have demonstrated that the sufficient addition of simple organic carbon compounds (e.g., lactate or ethanol) will stimulate the rapid growth of the native microbial assemblage in an aquifer, ultimately resulting in the development of localized reducing conditions. This approach has been successfully used to bio-remediate Cr(VI) by converting it to less toxic trivalent chromium (Cr(III)). Once formed, Cr(III) will typically sorb to mineral substrates or precipitate as an insoluble solid phase such as $Cr(OH)_3$ and is therefore effectively immobile in an aquifer (Hansel, et al., 2003).

Similar microbial and related geochemical processes are known to occur in the vadose zone as well as in the saturated aquifer soils. Laboratory studies have demonstrated the processes, showing that adding water and organic nutrients to columns packed with vadose zone materials contaminated with Cr(VI) cause the effective conversion of Cr(VI) to Cr(III) (Tokunaga et al., 2003, "In-situ reduction of Cr(VI) in heavily contaminated soils through organic carbon amendment," and Oliver, 2001, *Microbial Reduction of Hexavalent Chromium Under Vadose Zone Conditions*).

The 100-KW treatability test is specifically intended to determine if infiltration of a mixture of water and the nutrient compound from the ground surface into the vadose zone is a practical approach for establishing the reducing conditions needed to convert Cr(VI) to Cr(III).

The reduction of Cr(VI) to Cr(III) because of microbial activity can be achieved by one or both of the following two general mechanisms:

- Indirect microbial conversion (chemical reduction) of Cr(VI) to Cr(III) by a reduced electron acceptor in solution or in a solid phase that was produced as a byproduct of anaerobic microbial respiration (e.g., ferrous iron or sulfide)
- Direct (enzymatic) reduction of Cr(VI) to Cr(III) by one or more members of the in situ microbial assemblage

3.1.1 Indirect Microbial Reduction (Chemical Reduction) During Bioremediation

The application of in situ bioremediation as a groundwater remediation technology for Cr(VI) uses the injection of simple organic carbon compounds (ethanol, lactate, cheese whey, sugar syrups such as molasses or corn syrup, and vegetable oils) to stimulate microbial activity within the subsurface. If a sufficient amount of an organic compound is added, the population of microbes in the subsurface will grow exponentially and the dissolved oxygen content of the groundwater will be progressively depleted by the microbial metabolism of organic carbon.

As oxygen is progressively depleted in the groundwater and anaerobic conditions develop, the microbial assemblage will shift toward those species that are able to use chemical species other than oxygen for respiration, such as nitrate, manganese, chromate, ferric iron, and sulfate.

When ferric iron (e.g., from iron hydroxides) and sulfate are used as electron acceptors, the strongly reducing byproducts ferrous iron and sulfide are produced. These chemical species, or solid phases that contain them, will rapidly reduce Cr(VI) in solution to Cr(III) (Lan et al., 2007, "Influence of Soil Minerals on Chromium(VI) Reduction by Sulfide under Anoxic Conditions").

3.1.2 Direct Microbial Reduction

Many varieties of microbes are known to directly (enzymatically) reduce Cr(VI) to Cr(III) under aerobic and anaerobic conditions using a variety of electron donors (Wiley InterScience, 2003, *Cometabolism of Cr(VI) by* Shewanella oneidensis *MR-1 Produces Cell-Associated Reduced Chromium and Inhibits Growth*). The common sulfate reducing bacteria *Desulfovibrio vulgaris*, for example, is known to reduce Cr(VI) to Cr(III) enzymatically, under anaerobic conditions (Lovely and Phillips, 1994, "Reduction of Chromate by *Desulfovibrio vulgaris* and its C3 Cytochrome"). Although some microbes are able to obtain energy using Cr(VI) as a primary electron acceptor during respiration, others (e.g., *Shewanella oneidensis*) are only able to reduce Cr(VI) to Cr(III) in the presence of another primary electron acceptor (e.g., oxygen or nitrate). The cometabolic reduction of Cr(VI) does not provide energy for the microbe but may serve as a detoxification mechanism that protects the organism from elevated levels of Cr(VI) (Wiley InterScience, 2003). In either case, the enzymatic reduction of Cr(VI) to Cr(III) by microbes is generally a much slower process than the chemical reduction of Cr(VI) to Cr(III) in the presence of ferrous iron and sulfide.

If in situ bioremediation of Cr(VI) is applied at Hanford sites, it is expected that direct microbial reduction will not contribute significantly to remediation.

3.2 Potential for Post-Treatment Re-Oxidation of Cr(III) to Cr(VI)

The oxidation of Cr(III) phases by dissolved oxygen under environmental conditions is essentially non-existent (Rai et al., 1989; Eary and Rai, 1987, "Kinetics of Chromium (III) Oxidation to Chromium (VI) by Reaction with Manganese Dioxide"). Consequently, Cr(III) compounds precipitated during bioremediation activities will not be re-oxidized to Cr(VI) by dissolved oxygen, even after fully oxygenated conditions are re-established in the aquifer or vadose zone. The stability of Cr(III) compounds under oxygenated groundwater conditions comprises the fundamental basis for the implementation of in situ bioremediation as a potentially effective remedial approach for Cr(VI).

4 Test Objectives

The primary objective of the100-KW bio-infiltration treatability test is to evaluate the performance and potential long-term effectiveness of an in situ bio-infiltration system as a remedial technology for Cr(VI) contamination in the vadose zone. The following criteria will be used to evaluate the performance of the bio-infiltration technology:

- Confirm whether Cr(VI) is present in the vadose zone of the test area and demonstrate whether the infiltration technology can produce sufficiently reducing conditions in the vadose zone to convert Cr(VI) to Cr(III) such that the observed concentrations of Cr(VI) will decline to less than 48 μg/L in the pore water of the vadose zone.
- Determine the extent that Cr(VI) is not treated (immobilized) in the vadose zone and is transported to the water table by the enhanced unsaturated flow condition produced during the test.
- If the conversion of Cr(VI) to Cr(III) in the vadose zone of the test area cannot be confirmed, demonstrate that reducing conditions known to reduce Cr(VI) to Cr(III) are established within the vadose zone.
- Determine whether (and, if so, for how long) the proposed treatment approach can produce conditions in the shallow groundwater beneath the test site that are sufficiently reducing to convert Cr(VI) from the overlying vadose zone to Cr(III).
- Provide evidence that any iron, manganese, or arsenic released into the vadose zone pore water and subsequently transported to the water table is ultimately attenuated by oxygenated conditions within the aquifer.
- Demonstrate that long-term Cr(VI)-reducing capacity has been established in the vadose zone as a result of the infiltration treatment.
- Provide evidence that Cr remaining in the vadose zone is not remobilized by the infiltration of oxygenated water after bio-infiltration has been completed.

5 Experimental Design

This chapter describes the test site, presents the method by which the nutrient solution is infiltrated from ground surface, and explains operational test design.

5.1 Test Site Description

Concentrated (70 percent) sodium dichromate solutions were routinely delivered to the 100-KW site by railcar and transferred to a 158,760 L (42,000 gal) storage tank (100-KW-5 site) that was located adjacent

to the 183.1 KW Head House (Figure 4). These concentrated feed solutions were piped from the storage tank through the 183-KW complex and the adjacent 190-K and 165-K Buildings where the concentrated solutions were diluted and mixed with river water to produce coolant water. The facilities and processes used to generate, use, and discharge reactor coolant after use are described in greater detail in DOE/RL-90-21, *Remedial Investigation/Feasibility Study Work Plan for the 100-KR-4 Operable Unit, Hanford Site, Richland, Washington.*

The presence of yellow-stained soil near the sodium dichromate storage tank indicates that spills and leaks occurred during transfer operations from the railcars to the storage tanks. Released dichromate solutions would likely have either seeped into the soils or been sluiced into a nearby French drain (Figure 5). The volume of sodium dichromate solutions lost to the vadose zone in this area and ultimately, to the underlying aquifer, is unknown.

The recent identification of elevated groundwater Cr(VI) concentrations in former injection well 199-K-35, located near the former 120-KW-5 storage tank, effectively locates the upgradient head of the 100-KW chromium plume at or near the storage tank. The increase in Cr(VI) in the well is consistent with dissipation of an essentially chromium-free groundwater mound caused by injection of treated water from the P&T plant. The post-injection source of the increased Cr(VI) in the well may be an active local vadose zone source, or the increase may be due to advective movement of contaminated groundwater toward the well.

Based on geological data collected during the installation of Wells 199-K-35 and 199-K-175, the vadose zone in this area is estimated to be 24.4 to 27.4 m (80 to 90 ft) thick near the storage tank. Most of the vadose zone in this area is composed of boulders, gravel, sand, and silt typical of the Hanford formation, although the lower vadose zone is believed to grade into the Ringold Unit E at a depth between 18.3 to 24.4 m (60 and 80 ft) bgs. The thickness of the Ringold Unit E in this area is not known. Based on data obtained from downgradient wells, it is expected to be about 30.5 m (100 ft) thick near the 183.1 KW Head House.

5.2 Nutrient Infiltration

The planned bio-infiltration test system (Figure 6) will be implemented within the excavated area of the former 183.1 KW Head House and associated facilities (Figure 7). The system will use treated effluent from the 100-KW treatment system as the primary source of water for infiltration. During the test, the treated P&T effluent will be piped to a surge (holding) tank. Some of the water will be amended with a carbon source (sodium lactate) concentrate and a fluorescent flow tracer in a separate tank. This amended solution and water from the surge tank will then be metered into a drip infiltration system for distribution into the vadose zone. The infiltration of this carbon-amended water will stimulate rapid microbial growth in the vadose zone, depleting the available oxygen, and facilitating the development of Cr(VI)-reducing conditions in the treated section of the vadose zone.

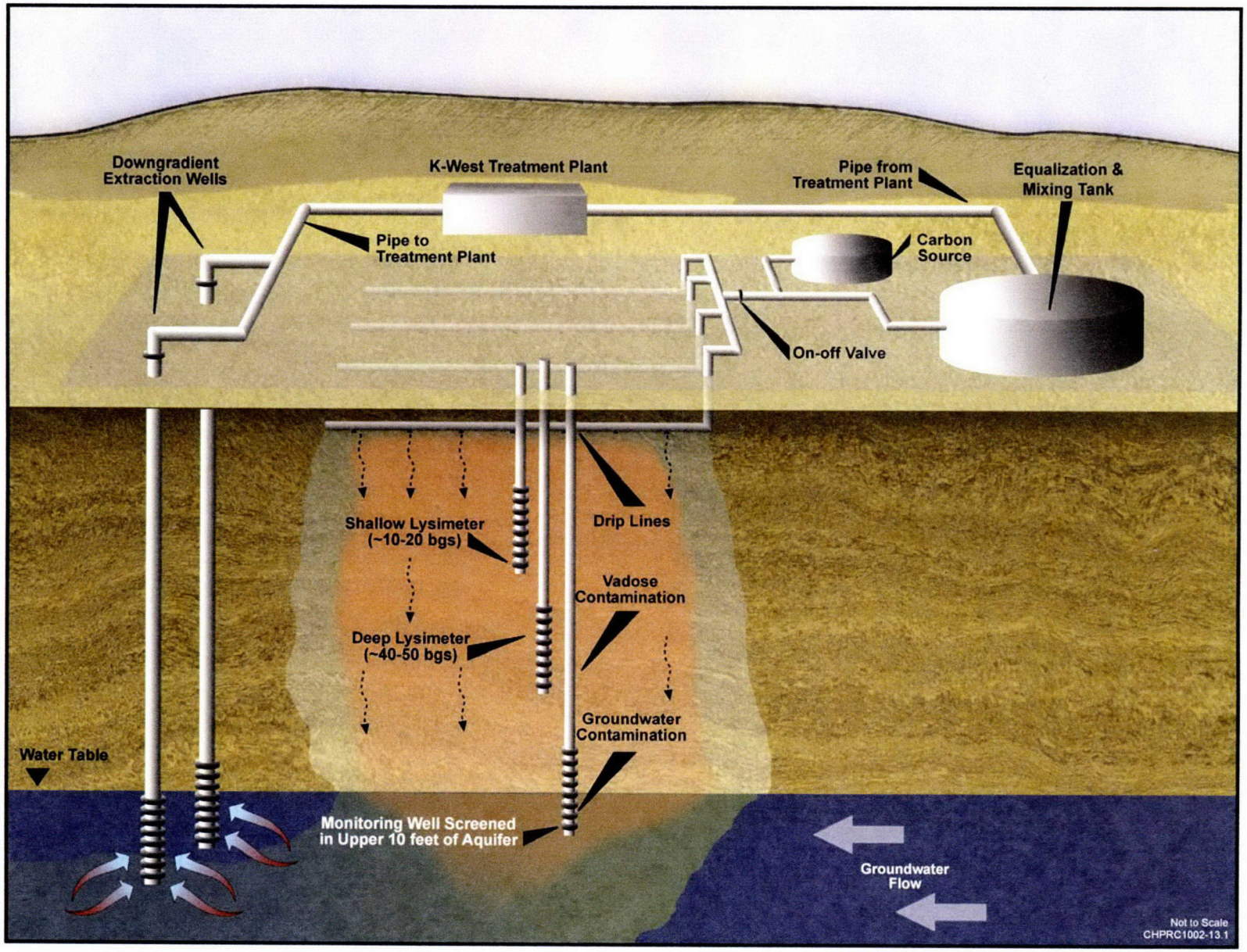


Figure 6. Functional Design of the Planned 100-KW Bio-Infiltration System

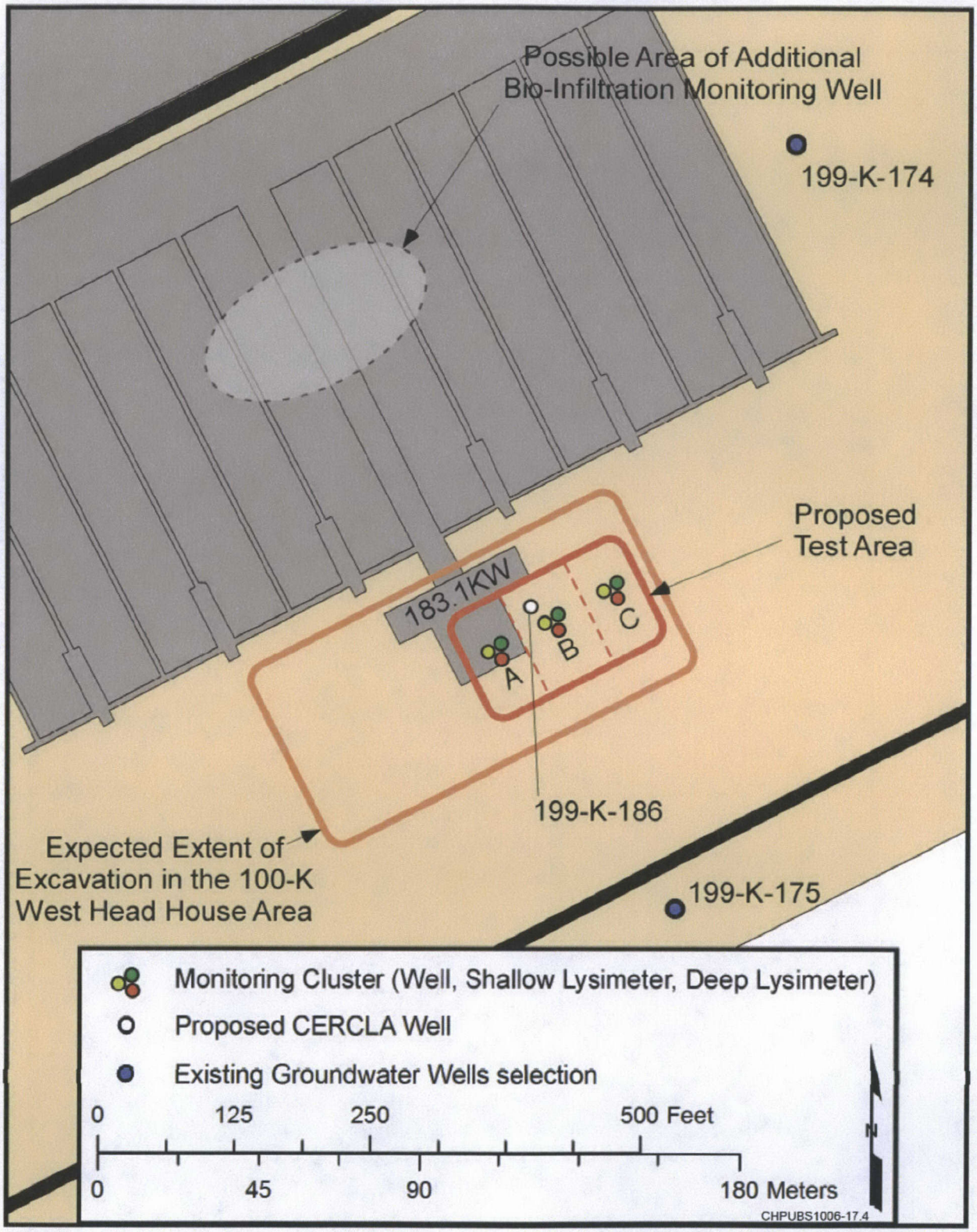


Figure 7. Expected Areas of Excavation, Proposed Bio-Infiltration Test Site, and Proposed Monitoring Well Locations

5.3 Operating Parameters

Although a simple design in concept, the field-scale bio-infiltration system planned for the vadose zone in 100-KW will face site-specific design and implementation challenges that cannot be resolved by preliminary laboratory testing or vadose zone modeling activities alone. Probable lateral and vertical variations in subsurface lithology, the hydraulic properties of the 100-KW vadose zone, and the potential for changes in infiltration pathways under different flow rates, require that the bio-infiltration treatability test system have sufficient design and operational flexibility to test a range of infiltration approaches (e.g., different combinations of infiltration rates and carbon concentrations).

5.3.1 Hydraulic, Microbial, and Geochemical Considerations

A one-dimensional vadose zone modeling sensitivity analysis was conducted to identify the probable range of water infiltration rates that will be necessary to support the treatment of a 0.2 ha (0.5-ac) test site at 100-KW under both saturated and unsaturated conditions. Values of vadose zone soil hydraulic parameters were derived from previously conducted sampling studies in the 100 Area. Travel times based on these parameter values suggest that a rate of 1.9 L/s (30 gpm) over 0.5 ac would be able to maintain partial saturation while leading to the infiltration of three pore volumes in 90 days. (Note: a pore volume is defined as the volume of water required to fill the effective porosity of the targeted vadose zone.) However, the values of saturated porosity and saturated hydraulic conductivity are lower than 'typical' values of sandy-gravel samples. Therefore, an additional simulation was conducted in which the assumed saturated porosity was doubled and the hydraulic conductivity was increased by a factor of 100.

The results of this analysis suggest that under the assumed conditions, an irrigation rate of 5.0 L/s (80 gpm) over 0.5 ac will lead to the unsaturated infiltration of three pore volumes in approximately 90 days. These modeling results provide initial guidance on the potential range of infiltration rates (5.0 to 1.9 L/s [80 to 30 gpm]) that could be implemented during the test. The actual infiltration rates initially used at the start of the test will be based on updated vadose zone modeling that will incorporate soil descriptions, grain-size analyses, and hydraulic parameters obtained from core samples collected during installation of the three monitoring wells that are proposed for the test site. The infiltration rates implemented during the test will be kept well below the values expected to result in saturated flow. The implementation of a slow infiltration rate should also reduce the extent of channeled or fingered flow that could develop in coarse sand soils if infiltration rates are too high (Yao and Hendrick, 1996, "Stability of Wetting Fronts in Dry Homogeneous Soils under Low Infiltration Rates"). Frequent monitoring of the treatment area during operations will be critical for assessing the ability of the vadose zone to receive the volume of carbon-amended water that is supplied.

Once treatment starts, the infiltration of sufficiently carbon-amended water into the vadose zone will lead to rapid microbial growth in the affected area. There will, however, be a lag period of several days or more between startup of infiltration and the expansion of, and compositional changes in, the microbial assemblage sufficient to induce strongly reducing (e.g., sulfate reducing) conditions. Consequently, if the initial volume of amended solution and the infiltration rates are too high, a non-reducing wetted front could migrate downward through the vadose zone well ahead of a much more slowly advancing reducing front. Such a rapidly advancing wetted front could solubilize and transport a substantial fraction of the Cr(VI) in the vadose zone affected prior to the arrival of the reduction front. Saturated flow-leaching tests performed on Hanford soils containing Cr(VI) suggested that as much as 95 percent of the Cr(VI) in the test soils was leached from the column during the first pore volume (PNNL-17674, *Geochemical Characterization of Chromate Contamination in the 100 Area Vadose Zone at the Hanford Site*). To prevent or greatly diminish this effect in the field, the rate of infiltration and the extent of carbon loading

will be carefully managed to maintain unsaturated conditions by maximizing the rate that reducing conditions are established in the vadose zone during infiltration.

Additional geochemical effects of infiltrating carbon-amended water into the vadose zone include the reduction of Cr(VI) to Cr(III) and the microbially mediated reductive dissolution of matrix-bound ferric iron and manganese (Mn(IV)) oxides and hydroxides in the vadose zone. Arsenic traces are associated with ferric iron and Mn(IV) oxides and hydroxides in the Hanford soils. Therefore, reductive dissolution of these phases is expected to result in the mobilization of arsenic as well as elevated levels of ferrous iron and divalent manganese (Mn(II)) into the pore water of the vadose zone. Release of arsenic was observed during the bioremediation test performed at 100-D (PNNL-18784). Consequently, the transport of detectable levels of dissolved ferrous iron, Mn(II), As (mostly as As(III)), and other reduced constituents to the water table is expected during the test. The changes in the concentrations of these constituents over time will be monitored in the vadose zone and the water table beneath the test area. However, ferrous iron, Mn(II), and As(III) that enter the water table during the treatability test are expected to be oxidized and attenuated relatively quickly once exposed to the oxygenated groundwater in the aquifer.

A description of the operational strategy that will be used for the treatability test is presented below. The primary operational factors that will be varied during operation of the system will be the concentration of carbon in the solution applied and the rate of application. Generally, the higher the carbon concentration in the solution, the farther the reducing conditions will penetrate into the vadose zone for a given volume of solution. Different flow rates will result in different infiltration properties. For example, at very high application rates, flow will occur largely through coarser grained materials, potentially bypassing fine-grain materials. At low fluid applications rates, flow will occur through all pore sizes, with a greater relative proportion of the fluid passing through finer pore throats associated with silts and fine sands. Detailed operating procedures for the proposed test will be presented in a test implementation plan that will be prepared after the design of the treatment system is finalized.

5.3.2 Pre-Test Activities

Three monitoring wells and six lysimeters will be installed prior to startup to monitor shallow groundwater and vadose zone pore water in the area for the test (Figure 7). The monitoring wells and lysimeters will be grouped into three separate monitoring clusters, each at a different location within the test area. Each of these three monitoring clusters will consist of a monitoring well, and two lysimeters (one shallow and one deep) (Figures 6 and 7). Section 6 presents additional information about the installation and design of these new monitoring wells and lysimeters.

One month prior to startup of the bio-infiltration system, the approximately 5 L/s (80 gpm) of treated effluent that are currently being re-injected by Well 199-K-175 (located just upgradient of the bio-infiltration target area) will be redistributed to other injection wells in the 100-KW system. This diversion of the upgradient re-injection activities prior to startup of the test will reduce the high flushing rate of treated effluent through the saturated zone beneath the proposed treatment system. As a result, the groundwater chemistry beneath the test site, both prior to (baseline) and during the test, will not be affected by the nearby re-injection of treated effluent. Once the treatability test starts, some or all of this 5 L/s (80 gpm) will be used as the water supply for the test.

Prior to the start of the test, a work plan will be developed and preparations will be made for a contingency action to address the possibility that unacceptably high concentrations of Cr(VI) may be flushed out of the vadose zone and into the underlying shallow water table during the test. This contingency action will consist of using one or more of the three test site monitoring wells to extract (and

contain for future treatment) the shallow groundwater beneath the site, if it receives an unacceptably high mass of Cr(VI) from the overlying vadose zone during the test.

5.3.3 Test Phase 1

During the first week of the initial stage (Phase 1) of the test, the treatment solution will be applied to the vadose zone on a daily basis as a series of small-volume batches. These batch solutions will be amended with moderate to high concentrations of lactate (e.g., 250 to 1,000 mg/L as carbon). This approach is intended to supply sufficient substrate to expand the microbial assemblage rapidly (including iron and sulfate reducing bacteria) in the shallow vadose zone, while minimizing the initial flux of water into the vadose zone. This approach is expected to promote strongly reducing conditions in the upper vadose zone without producing a significant non-reducing wetting front that might mobilize substantial amounts of Cr(VI) rapidly downward into the deeper vadose in advance of the reducing conditions.

Lysimeters installed at different depths in the treatment area (Figure 6) will be used to track the downward progress of the wetting fronts (and associated chemical changes) through the vadose zone. Throughout Phase 1, samples will be collected from the lysimeters and monitoring wells twice each week and submitted for chemical analysis. During the first week of Phase 1, pore water samples will also be collected from the lysimeters on three additional days, visually examined for evidence of a tracer compound and tested for selected field parameters (e.g., DO or conductance).

Once the monitoring data from the shallow lysimeters confirm that the wetting front and strongly reducing conditions are present in the upper vadose zone (e.g., 10 to 20 ft bgs), the volume and substrate concentrations of the successive batches of the infiltration solutions will be adjusted. The solutions will be adjusted based on field observations and lysimeter data to promote sufficient depth of penetration of carbon into the vadose zone without bio-fouling the upper few feet. This approach will promote the steady migration of the wetted zone, TOC, and strongly reducing conditions to progressively deeper sections of the vadose zone. The downward transport of reduced byproducts (e.g., ferrous iron and sulfide) produced by ferric iron and sulfate reducing bacteria is expected to help extend reducing conditions progressively deeper into the vadose zone. Continued monitoring of the samples from the lysimeters and monitoring wells will be used to confirm that the reducing front and the wetting front maintain a close spatial association with depth in the vadose zone as Phase 1 proceeds.

This step-by-step batch infiltration approach will be used until the wetting front and associated reducing front have migrated entirely through the vadose zone and have been detected in the shallow water table. This will be documented using geochemical and tracer data collected from the three monitoring wells that will be screened over the upper 3 m (10 ft) of the water table in the target area. Although this careful approach to infiltration should minimize the potential for the transport of Cr(VI) out of the vadose zone, some Cr(VI) may be transported to the water table. However, it is anticipated that most of any Cr(VI) that reaches the water table will either be converted to Cr(III) once reducing conditions are established in the shallow groundwater or captured and treated by the downgradient 100-KW P&T system.

5.3.4 Test Phase 2

Phase 2 of the test will begin once the reducing front has migrated through the entire vadose zone (Phase 1). Phase 2 infiltration will be conducted on a continuous or semi-continuous basis (e.g., 24 hours a day to 4 hours a day) as dictated by field conditions and lysimeter and monitoring well sampling (Appendix A). The infiltration rate (gpm) and lactate content will be varied as necessary to optimize overall treatment system performance. For example, the infiltration rates could be varied between high and low values periodically during Phase 2 to promote flow through suspected highly transmissive layers and through any tighter, fine-grained materials that may have been be identified by coring activities.

Phase 2 of the infiltration test will continue until monitoring well data indicate that reducing conditions have been established in the upper few feet of the water table beneath the treatment zone, or until five pore volumes of lactate-amended water has been infiltrated through the vadose zone. The geochemistry of the vadose zone and the shallow groundwater beneath the test area will be monitored throughout Phase 2 and these data will be used to help identify which operating conditions used during Phase 2 were most effective. After Phase 2 is complete, carbon infiltration activities will be terminated.

5.3.5 Test Phase 3

In Phase 3, infiltration is terminated and the last pore volume of treatment solution that was applied during Phase 2 is allowed to undergo transient drainage for a period of one month. Monitoring of the lysimeters and monitoring wells will continue on a weekly basis throughout Phase 3. If the concentrations of Cr(VI) exceed 48 μg/L in the pore water samples collected from the deep lysimeters for two consecutive sampling events, an additional pore volume of carbon-amended water may be infiltrated into the system to further increase the effectiveness of bioremediation.

Once transient drainage rates and the water content of the vadose zone have decreased substantially (e.g., based on changes in lysimeter sample volume over time), two additional boreholes will be installed through the vadose zone. Samples will be collected for visual, chemical, and mineralogical analysis (Section 7).

5.3.6 Test Phase 4

Phase 4 is the final phase of the test and virtually all the Cr(VI) originally present in the vadose zone is expected to be converted to Cr (III) during the previous phases of the test. The purpose of Phase 4 is to demonstrate that post-treatment flushing of the vadose zone with oxygenated water will not result in the solubilization and transport of Cr(VI) to the water table at concentrations above the groundwater standard of 48 μg/L. If, however, the groundwater and lysimeters monitoring data collected during the earlier phases of the test (or the post-treatment core data) indicate that substantial amounts of Cr(VI) may remain in the vadose zone after Phase 3, then Phase 4 will not be conducted.

If Phase 4 is implemented, three to five pore volumes of treated effluent from the K-West Plant (amended with 1 mg/L tracer) will be infiltrated into the vadose zone under a range of infiltration rates. Samples will be collected from the lysimeters and monitoring wells on a daily basis during the first week of Phase 4 and bi-weekly thereafter. The data from these samples will be used to ascertain the following:

- Determine the extent that residual Cr(VI) is present and mobilized from the vadose zone after treatment is complete by the infiltration of oxidizing effluent.
- Evaluate the effects of the Phase 4 infiltration on the shallow groundwater beneath the site.
- Based on the monitoring results obtained during Phase 4, estimate the potential longevity of the residual reducing (Cr(VI) treatment) capacity in the vadose zone, under natural infiltration conditions.

The shallow groundwater beneath the treatment area is expected to be sufficiently reducing to remediate any Cr(VI) that may be transported to the water table during Phase IV. Nevertheless, if the average Cr(VI) concentrations exceed 48 μg/L in the vadose zone pore water samples collected from the deep lysimeters over two consecutive sampling events, further infiltration will be placed on hold. Monitoring will continue as scheduled while the available monitoring data is reviewed. Based on this review, a decision will be made to initiate one of the following options:

- Cease all further infiltration activities and begin long-term monitoring.

- Re-institute Phase 2 bio-infiltration activities to enhance remediation.
- Continue Phase 4 activities as planned while extracting and containing for future treatment the shallow groundwater beneath the site that is impacted by elevated levels of Cr(VI) (or other COC) during Phase 4.

After the Phase 4 activities are completed, weekly sampling will continue for one additional month during transient drainage. Afterwards, quarterly monitoring of the vadose zone and groundwater beneath the treatment area will continue for one year to confirm that no adverse effects develop.

6 Equipment and Materials

This chapter presents the major surface site facilities needed to conduct bio-infiltration. The chapter includes major site preparation activities and monitoring infrastructure requirements. Flow rates, nutrient concentrations, tank volumes, and the like are subject to change during the final system design.

6.1 Major Equipment, Materials, and Process Description

Descriptions of the equipment and materials for the planned bio-infiltration system are discussed below and illustrated in Figure 6. The descriptions are preliminary and subject to change in the final process design specifications.

6.1.1 Surge Tank

A maximum of 5 L/s (80 gpm) of the estimated 12.6 L/s (200 gpm) treated effluent from the 100-KW Plant will be diverted as needed for use at the bio-infiltration treatability test. The diverted water will be piped to a 37,854 L (10,000-gal) surge tank for temporary storage. If the water supply from the 100-KW Plant is temporarily disrupted, this 37,854 L (10,000-gal) tank will be able to supply water at 5 L/s (80 gpm) for approximately two hours of operation of the treatment system.

6.1.2 Reagent Storage and Mixing System

Some water from the surge tank will be pumped to the reagent storage and mixing facility where it will be amended with 30 to 60 percent food-grade sodium lactate and a fluorescein flow tracer and mixed in the carbon source tank. This system will require one Underwriters Laboratory-listed, double-containment carbon source tank with a volume of approximately 15,140 L (4,000 gal) to store concentrated sodium lactate solutions safely. The diluted and mixed solution will be metered into the infiltration system along with additional water from the surge tank. Flow meters and totalizers will be used at the inlet and outlet of the reagent storage and mixing tank. A centrifugal booster pump will supply the necessary dynamic head to pressurize the drip system.

6.1.3 Infiltration System (Drip-Emitter System)

A drip-emitter system manufactured by Ore-Max will be used to deliver the amended solution to the vadose zone. The drip-emitter lines, which branch off a central supply line, are designed to distribute treatment solutions evenly across a large area using patented plug-resistant drip emitters.

The drip system should be deployed on the ground surface of the bottom test site, over the targeted area, and covered with six inches of pea gravel. The gravel layer will provide some physical and cold weather protection and minimize the potential for wildlife to access any surface expressions of the infiltration solution. Drip-emitter systems are well suited for this application and they are commonly used for similar processes such as chemical heap leaching of mine spoils and tailings.

6.1.4 Clean Out System

A clean out system (not shown in Figure 6) will be used as needed to prevent or remove biofouling or carbonate scaling of the drip infiltration system, which can develop over time. A separate waterline that bypasses the reagent storage and mixing system will be needed to periodically flush the drip-emitter system and supply water for the preparation of a treatment solution.

An 11,355 to 15,140 L (3,000- to 4,000-gal) polypropylene mixing tank will be needed to contain the treatment reagent and to dilute it with water to the necessary strength and volume. Once the drip system is disconnected from the water supply line, a small pump would be used to slowly transfer the solution from the mixing tank to the drip system (for up to two hours), ensuring that the solution is reaching and discharging through all the drip emitters. The clean out solution that is used should have biocidal and scale-dissolution properties. Citric acid is one commonly used option and has the advantage of being biodegradable once it is flushed into the vadose zone after the drip system has been sufficiently treated.

6.2 Test Site Preparations

The main activities associated with site preparation are removal of existing facilities, excavation of surface soils and fill, and construction of new monitoring wells and vadose zone sampling equipment.

6.2.1 Demolition and Excavation

The 183.1 KW Head House and associated facilities (Figure 7) will be demolished and the contaminated soils in the area will be excavated to an expected maximum depth of 6.1 m (20 ft) bgs, leaving an estimated 18.3 to 21.3 m (60 to 70 ft) of vadose zone in place. The treatability test site will be located within this excavated area and is expected to cover a 0.1 to 0.2 ha (0.25- to 0.5-ac) area that completely includes the former location of the 158,970 L (42,000-gal) dichromate storage tank (120-KW-5 site) and, potentially, part of the former location of the 183.1 KW Head House. Although the remaining vadose zone in the proposed test area is expected to contain elevated levels of Cr(VI), this has not yet been conclusively demonstrated. The precise location and dimensions of the test area may change, as they will be based on field observations and soil analyses conducted during and after the excavation.

6.3 Monitoring Wells and Associated Vadose Zone Lysimeters

As previously discussed, three monitoring wells and six lysimeters will be installed within the infiltration target zone to monitor the shallow groundwater and the vadose zone pore water beneath the target area, immediately before, during, and after the test (Figure 7). The monitoring wells and lysimeters will be grouped into three separate monitoring clusters, each at a different location within the test area. Each of these three monitoring clusters will consist of a monitoring well, and two lysimeters (one shallow and one deep) (Figures 6 and 7). Each monitoring well will be screened over the upper 1.5 to 3 m (5 to 10 ft) of the shallow unconfined aquifer. Two lysimeters will be installed within the vadose zone near each well. The shallow lysimeters will be installed over a depth range of between 4.6 to 6.2 m (15 to 20 ft) bgs and the deep lysimeters will be installed over a depth range of 12.2 m to 18.3 m (40 to 60 ft) bgs. These monitoring well and lysimeter clusters will provide data that will be used to estimate the depth and rate of downward migration of the substrate–amended infiltration solution and to identify changes in the vadose zone pore water chemistry over time. Design specifications for the new wells and vadose zone lysimeters will be presented in the sampling and analysis plan (SAP) for this project.

A general area within the former sedimentation basin has been identified as the possible location of a fourth monitoring well that may be installed to test for possible impacts of the treatability test on downgradient groundwater (Figure 7). The decisions of the necessity of this well, the precise surface location, and the screened interval, will be based on groundwater monitoring data collected, during

Phases 1 and 2 of the test, from the three wells described previously. Figure 7 also presents the proposed location of a monitoring well, 199-K-186, which is not part of the treatability tests and will be installed as part of the CERCLA remedial investigation of 100-K West. This well is planned for installation at the location of the former 120-KW-5 sodium dichromate storage tank and an associated French drain. Soil and water samples collected during the installation of this CERCLA well will be used to characterize the vadose zone and groundwater quality at this site. After installation, monitoring well 199-KW-186 will be used to monitor the water quality and water levels in the uppermost semi-confined water-bearing zone of the RUM, beneath the unconfined aquifer.

7 Sampling and Analysis

The types of data that will be collected as part of the investigation include the following:

- Chemical and physical properties of soil cores or cuttings collected during monitoring well installation
- Baseline groundwater and vadose zone pore water sampling to verify aquifer and vadose zone conditions prior to commencement of the treatability test
- Process control sampling to evaluate the carbon content of the substrate and substrate-amended groundwater prior to infiltration
- Vadose zone pore water and groundwater monitoring during and after the test to evaluate the effectiveness and longevity of the proposed treatment

The remainder of this section presents a brief summary of the general monitoring requirements of this treatability test. Appendix A presents a comprehensive SAP for this treatability study.

7.1 Groundwater and Vadose Pore Water Sampling and Analysis

The proposed analyte list and sampling frequency for the monitoring wells and lysimeters are presented in Appendix A. The scope and objectives of the groundwater and porewater data that will be collected during the test includes, but is not limited to, the following:

- Monitor selected field parameters, concentrations of TOC, and a fluorescent tracer compound in samples collected from the lysimeters and monitoring wells. These data will provide information on the rate that the wetting front is migrating through the vadose zone and the rate that organic carbon is being consumed by microbial reactions.
- Monitor Cr(VI) and total chromium in the lysimeters and monitoring wells to determine whether Cr(VI) is present in the vadose zone and, if so, how quickly and effectively will the Cr(VI) be converted to Cr(III) or transported to the water table during the test.
- Use the concentrations of dissolved iron, dissolved manganese, nitrate, and sulfate to monitor the timing, depth, and intensity of the reducing conditions that develop in the vadose zone and underlying shallow groundwater during the different phases of the test.
- Monitor dissolved arsenic to determine the extent that this constituent is mobilized in the vadose zone during the test and the concentrations and fate of this constituent in the underlying groundwater.

7.2 Vadose Zone Soil Sampling and Analysis

During the installation of the three monitoring wells, cores samples will be collected at intervals ranging from every 1.5 to 3.0 m (5 to 10 ft). In addition, two additional cores will be collected through the vadose zone during Phase 3 of the test. The core samples taken prior to the test and during Phase 3 will be described in the field and, based on field observations, up to 10 samples per borehole will be submitted for the analyses listed in Appendix A. If warranted by the results of visual inspection and chemical analysis, selected core samples will be collected for microbiological characterization (e.g., Phospholipid Fatty Acids) and mineralogical analysis by scanning electron microscope (SEM). These microbiological and mineralogical data will be used to help characterize the nature, extent, and magnitude of the biogeochemical changes in the vadose zone produced by the bioremediation activities.

8 Data Management

The Sample Management and Reporting Organization, in coordination with the Project Manager, is responsible for ensuring analytical data are appropriately reviewed, managed, and stored in accordance with the applicable programmatic requirements governing data management procedures. Electronic data access, when appropriate, will be via a database (e.g., Hanford Environmental Information System [HEIS] or a project specific database). Where electronic data are not available, hard copies will be provided in accordance with the *Hanford Federal Facility Agreement and Consent Order Action Plan* (Ecology et al., 1989b).

8.1 Sample Collection and Analysis

Planning for sample collection and analysis will be in accordance with the programmatic requirements governing fixed laboratory sample collection activities, as discussed in the sample team's procedures. In the event specific procedures do not exist for a particular work evolution, or it is determined additional guidance to complete certain tasks is needed, a work package will be developed to control the activities, as appropriate. Examples of the sample team's requirements include activities associated with the following tasks:

- Contaminant of concern/sample analysis requests
- Project and sample identification for sampling services
- Control of certificates of analysis
- Logbooks
- Checklists
- Sample packaging and shipping

Approved work control packages and procedures will be used to document field activities, including radiological measurements. All field activities will be recorded in the field logbook. Examples of the types of documentation for field radiological data include the following:

- Instructions regarding the minimum requirements for documenting radiological controls information as per 10 CFR 835, "Occupational Radiation Protection."
- Instructions for managing the identification, creation, review, approval, storage, transfer, and retrieval of primary contractor radiological records.
- The minimum standards and practices necessary for preparing, performing, and retaining radiological related records.

- The instruction of personnel on the development and implementation of sample plans.
- The requirements associated with preparing and transporting regulated material.
- Daily reports of radiological surveys and measurements collected during conduct of field investigation activities. Data will be cross-referenced between laboratory analytical data and radiation measurements to facilitate interpretation of the investigation results.
- Daily reports of radiological surveys and measurements collected during the field investigation activities. Data will be cross-referenced between laboratory analytical data and radiation measurements to facilitate interpreting the investigation results.

8.2 Resolution of Errors

Laboratory errors are reported to the Sample Management and Reporting Organization on a routine basis. For reported laboratory errors, the sample issue resolution process will be initiated in accordance with Contractor procedures. This process is used to document analytical errors and to establish their resolution with the Project Manager.

9 Data Analysis and Interpretation

This chapter discusses the data analysis and interpretations used to determine whether the data meet the project objectives.

9.1 Data Validation and Usability

The following sections address the quality assurance (QA) activities that occur after the data collection phase of the project is completed. Implementation of these elements determines whether data conform to the specified criteria, thus satisfying project objectives.

9.1.1 Data Review, Verification, and Validation

The criteria for verification may include review for completeness (all samples were analyzed as requested), use of the correct analytical method/procedure, review for transcription errors, correct application of dilution factors, appropriate reporting of dry weight versus wet weight, and the correct application of conversion factors. Laboratory personnel may perform data verification.

Data validation will be performed to ensure that the data quality goals established during the planning phase has been 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, A through E. Level A is the lowest level and is the same as verification. Level E is a 100 percent review of data (e.g., calibration data or calculations of representative samples from the dataset). Validation will be performed to contractor Level C, which is a review of the quality control (QC) data. Level C validation specifically requires verification of deliverables, requested versus reported analyses, and qualification of the results based on analytical holding times, method blank results, matrix spike/matrix spike duplicate, surrogate recoveries, duplicates, and analytical method blanks. Level C validation will be performed on at least 5 percent of the data by matrix and analyte group. Analyte group refers to categories, such as radionuclides, volatile and semivolatile chemicals, metals, and anions.

Relative to analytical data in sample media, physical data, and/or field screening results are of lesser importance in making inferences of risk. Data validation will not be performed for physical property data and/or field screening results.

9.1.2 Verification and Validation Methods

Validation activities will be based on EPA functional guidelines, EPA/540/R-99/008, *US EPA Contract Laboratory Program National Functional Guidelines for Organic Data Review*. Data validation may be performed by the analytical laboratory, Sample Management and Reporting, and/or by a party independent of both the data collector and the data user.

Data qualifiers assigned during data validation will be compatible with HEIS.

When outliers or questionable results are identified, additional data validation will be performed. The additional validation will be performed for up to 5 percent of the statistical outliers and/or questionable data. The additional validation will begin with Level C and may increase to Levels D and E as needed to ensure that data are usable. 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 dataset. Data validation will be documented in data validation reports. One example of questionable data is when the positive detections are greater than the practical quantitation limit or reporting limit in soil/aquifer soil from a site that should not have exhibited contamination. Similarly, results below background, which would not be expected, could trigger a validation inquiry.

9.1.3 Reconciliation with User Requirements

The data quality assessment (DQA) process compares completed field sampling activities to those proposed in corresponding sampling documents and evaluates the resulting data. The purpose of the data evaluation is to determine whether quantitative data are the correct type and of adequate quality and quantity to meet the project DQOs. The Project Manager is responsible for determining whether a DQA is necessary and ensuring that it is performed, if required. The results of the DQA will be used in interpreting the data and determining if the objectives of this activity have been met.

The DQA (if performed) with be in accordance with EPA's DQA process, EPA/240/B-06/002, *Data Quality Assessment: A Reviewer's Guide*, EPA QA/G-9R, and EPA/240/B-06/003, *Data Quality Assessment: Statistical Methods for Practitioners*, EPA QA/G-9S.

9.1.4 Corrective Actions

The responses to data quality defects identified through the DQA process will vary and may be data specific or measurement specific. Table 1 identifies some pre-identified corrective actions.

9.2 Data Interpretation

Data interpretation will be performed to assess the performance of the bio-infiltration. The primary interpretation of the data will be to assess the results of the testing program with respect to experimental objectives presented in Section 4.

10 Health and Safety

All field operations will be performed in accordance with CH2M HILL Plateau Remediation Company health and safety requirements, outlined in the latest revision of the Soil and Groundwater health and safety plan. Radiological contamination is possible during performance of the drilling and sampling activities. The sampling processes and associated activities will consider exposure reduction and contamination control techniques (e.g., as low as reasonably achievable [ALARA] and Integrated Safety Management System) that will minimize chemical exposure to the sampling team. Health and safety

Table 1. Data Quality Indicators

Data Quality Indicator	Definition	Example Determination Methodologies	Project Specific Information*	Corrective Actions Examples
Precision	The measure of agreement among repeated measurements of the same property under identical, or substantially similar, conditions, calculated either as the range or as the standard deviation. May also be expressed as a percentage of the mean of the measurements, such as relative range, relative percent difference, or relative standard deviation (coefficient of variation).	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 or have two or more laboratories analyze identical samples with the same method. Split a sample in the field and submit both samples for sample handling, preservation and storage, and analytical measurements. Collect, process, and analyze collocated samples for information on sample acquisition, handling, shipping, storage, preparation, and analytical processes and measurements.	Precision criteria shall apply: *Laboratory Analysis:* Adherence to the requirements of the current laboratory contracts. One duplicate collected for 1 in 20 water samples. *Field Measures:* Achieved by adherence to procedural SOPs.	Data interpretation or data assessment may be performed.
Accuracy	A measure of the overall agreement of a measurement to a known value; includes a combination of random error (precision) and systematic error (bias) components of both sampling and analytical operations.	Analyze a reference material or re-analyze a sample to which a material of known concentration or amount of pollutant has been added (a spiked sample); usually expressed either as percent recovery or as percent bias.	Accuracy criteria shall apply: *Laboratory Analysis:* Adherence to the requirements of the current laboratory contracts. *Field Measures:* Achieved by adherence to procedural SOPs.	Data interpretation or data assessment may be performed.
Representativeness	A qualitative term that 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 (ANSI/ASQC E4-1994).	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.	*Laboratory and Field Analysis:* Groundwater or pore water samples will be collected from each of the wells or lysimeters. The results will represent vertical progression of a chemically reducing front within the study area and track trends over time.	Data interpretation or data assessment may be performed.

Table 1. Data Quality Indicators

Data Quality Indicator	Definition	Example Determination Methodologies	Project Specific Information*	Corrective Actions Examples
Comparability	A qualitative term that expresses the measure of confidence that one data set can be compared to another and can be combined for the decision(s) to be made.	Compare sample collection and handling methods, sample preparation and analytical procedures, holding times, stability issues, and QA protocols.	*Laboratory Analysis:* The sample results need only be internally comparable. All sampling personnel will use the same sampling protocols. All samples will be submitted to the laboratory for analysis by the same methods; thus, data results will be comparable. Field splits will provide some measure of inter-laboratory comparability if sufficient sample is available.	If data are not comparable to other data sets: • Assess potential impacts in data quality assessment if performed.
Completeness	A measure of the amount of valid data needed to be obtained from a measurement system.	Compare the number of valid measurements completed (samples collected or samples analyzed) with those established by the project's quality criteria (DQOs or performance/acceptance criteria).	*Laboratory and Field Analyses:* The water samples collected from three wells and nine lysimeters shall be collected in order to meet the completeness criteria.	Evaluate the impact to the resulting data set and ability to define design criteria for the treatability test.
Sensitivity	The capability of a method or instrument to discriminate between measurement responses representing different levels of the variable of interest.	Determine the minimum concentration or attribute that can be measured by a method (method detection limit), by an instrument (instrument detection limit), or by a laboratory (quantitation limit). The practical quantitation limit is the lowest level that can be routinely quantified and reported by a laboratory.	Sensitivity criteria shall apply: *Laboratory Analysis:* Adherence to the requirements of the current laboratory contracts.	Data interpretation or data assessment may be performed.

Source:
ANSI/ASQC E4-1994, *Specifications and Guidelines for Quality Systems for Environmental Data Collection and Environmental Technology Programs.*
* Field sampling requirements are noted. Laboratories will follow contract requirements for use and interpretation of laboratory control samples. Precision, accuracy, and sensitivity requirements are satisfied by following method procedures because analyses are being performed to support treatability test design (not for regulatory decision making).

ANSI = American National Standards Institute
ASQC = American Society for Quality Control
DQO = data quality objective
QA = quality assurance
QC = quality control
SOP = standard operating procedure

personnel will use data collected during the activities addressed in this TTP as input to determine exposure levels to workers, and to conduct health and safety assessments during all field activities, in accordance with the health and safety plan.

11 Waste Management

All regulated waste generated from this treatability test plan, including sampling activities, will be managed in accordance with the waste management plan for the 100-HR-3 and 100-KR-4 OUs (DOE/RL-97-01, *Interim Action Waste Management Plan for the 100-HR-3 and 100-KR-4 Operable Units*). Disposition of purge water and miscellaneous solid waste will be conducted in accordance with DOE/RL-97-01.

Unused samples and associated laboratory waste for the analysis will be dispositioned in accordance with the laboratory contract and agreements for return to the project site. Pursuant to 40 CFR 300.440, "Procedures for Planning and Implementing Offsite Response Actions," DOE-RL Project Manager approval is required before returning unused samples or waste from offsite laboratories (as applicable).

12 Reports

Following completion of the treatability test, a final treatability test report will be prepared summarizing the results of the test. Interim reports may be produced during the implementation of the test, as determined by the project team.

13 Environmental and Regulatory Compliance

Laws and regulations pertaining to the response actions are identified through the applicable or relevant and appropriate requirements (ARAR) identification process. The ARARs identification process are based on CERCLA guidance (EPA/540/G-89/004, *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA*; EPA/540/G-89/006, *CERCLA Compliance with Other Laws Manual: Interim Final*; EPA/540/G-89/009, *CERCLA Compliance with Other Laws Manual—Part II, Clean Air Act and Other Environmental Statutes and State Requirements*). CERCLA Section 121 requires, in part, that any applicable or relevant and appropriate standard, requirement, criterion or limitation under any federal environmental law, or any more stringent state requirement pursuant to a state environmental statute, be met (or a waiver justified) for any hazardous substance, pollutant, or contaminant that will remain onsite after completion of remedial action.

This TTP is conducted under EPA/ROD/R10-99/039, *Interim Action Record of Decision for the 100-BC-1, 100-BC-2, 100-DR-1, 100-DR-2, 100-FR-1, 100-FR-2, 100-HR-1, 100-HR-2, 100-KR-1, 100-KR-2, 100-IU-2, 100-IU-6, and 200-CW-3 Operable Units, Hanford Site, Benton County, Washington* (100 Area Remaining Sites Record of Decision [ROD]). The ARARs identified in the 100 Area Remaining Site ROD apply to general response actions that could be implemented at waste sites identified within the 100-KR-2 OU. The selected interim remedial actions for the 100-KR-2 OU that will be conducted under this TTP are protective of human health and the environment, comply with ARARs, and are cost effective.

Under DOE O 451.1B, *National Environmental Policy Act Compliance Program*, Section 5.a.(13), DOE will "...incorporate NEPA values, such as analysis of cumulative, offsite, ecological, and socioeconomic impacts, to the extent practicable, in DOE documents prepared under the Comprehensive Environmental Response, Compensation, and Liability Act." These *National Environmental Policy Act of 1969* (NEPA)

values include, but are not limited to, cumulative, ecological, cultural, historical, and socioeconomic impacts, and irreversible and irretrievable commitments of resources. This treatability test occurs in a previously disturbed area within the 100-KW Reactor area and as such does not have the potential to impact NEPA values. A general discussion of NEPA values anticipated to be addressed for the 100 Area can be found in DOE/RL-2008-46, *100 Area Integrated RI/FS Work Plan*. The complete analysis will be provided in the future feasibility study.

14 Schedule

A draft project field schedule is shown in Figure 8. This working schedule may be modified as necessary.

15 Management and Staffing

CH2M HILL Plateau Remediation Company is responsible for planning and managing all project activities, ensuring that the project has defined goals, ensuring the project team understands the goals and approaches used, and ensuring the planned outputs are appropriately documented. Project management roles and responsibilities discussed in this chapter apply to the major activities covered under the TTP. The project lead maintains a list of individuals or organizations as points of contact for each functional element in Figure 9. For each functional primary contractor role, a corresponding oversight role exists within DOE Richland Operations Office (RL).

The following sections describe the project organization for the characterization borings and lysimeter installation, bio-infiltration, health and safety, and the various sampling and characterization tasks.

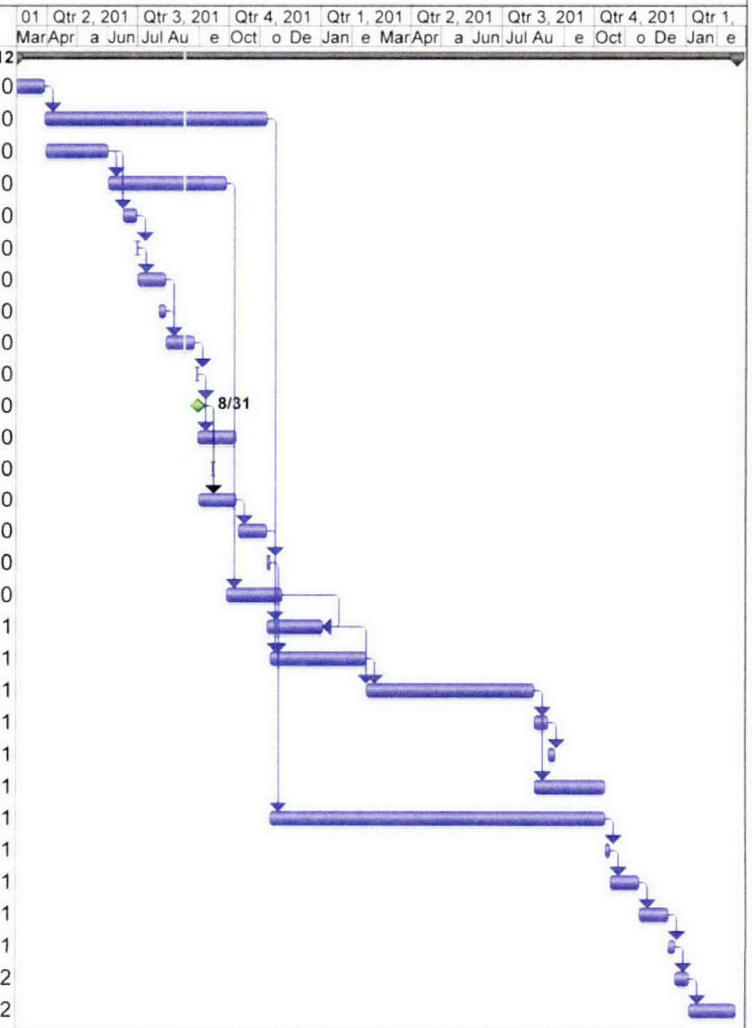
Lead Regulatory Agency Project Manager. The Lead Regulatory Agency (EPA) has assigned Project Managers responsible for overseeing the cleanup projects and activities. As the lead regulatory agency, EPA has approval authority for the work performed under this TTP. EPA will work with DOE-RL to resolve concerns regarding the work as described in this TTP in accordance with the Tri-Party Agreement (Ecology et al., 1989a).

Tri-Party Agreement Project Manager and RL Technical Lead. The Tri-Party Agreement Project Manager is responsible for authorizing remedial investigation/feasibility study activities for the 100 Area OUs. In addition, the Tri-Party Agreement Project Manager is responsible for obtaining lead regulatory agency approval of the TTP that authorizes the activities under the Tri-Party Agreement (Ecology et al., 1989a). The RL technical lead is responsible for overseeing the contractor in performing the work scope, working with the contractor and the regulatory agencies to identify and work through issues, and providing technical input to the Tri-Party Agreement Project Manager.

Project Lead. The project lead is responsible for managing field activities and subcontracted tasks, and for ensuring the project file is properly maintained. The project lead ensures that the test plan design requirements are converted into field instructions (e.g., work packages) and provides specific direction for field activities. The project lead works closely with the field engineer lead, QA, health and safety, drilling lead, and sampling lead to integrate these and other lead disciplines in planning and implementing the work scope. The project lead maintains a list of individuals or organizations filling each of the functional elements of the project organization. In addition, the project lead is responsible for version control to ensure that personnel are working to the most current job requirements. The project lead also coordinates with RL and the task leads on test plan implementation and sampling activities. The project lead supports RL in coordinating sampling activities with the regulators.

100-KW Bio-Infiltration Treatability DRAFT Test Schedule

ID	Task Name	Start	Finish
1	**KW Treability Test**	**Mon 3/1/10**	**Tue 2/21/12**
2	D4 of Surface Features	Mon 3/1/10	Mon 3/29/10
3	RTD of Existing Waste Sites	Tue 3/30/10	Mon 11/8/10
4	Write Draft Treatability Test Plan	Wed 3/31/10	Tue 6/1/10
5	TTP FDC and design	Wed 6/2/10	Tue 9/28/10
6	Draft TTP Internal Review	Thu 6/17/10	Wed 6/30/10
7	Submit Draft TTP to RL/EPA	Thu 7/1/10	Thu 7/1/10
8	RL/EPA Review of Draft TTP	Fri 7/2/10	Thu 7/29/10
9	Revise TTP per RL Comments	Fri 7/23/10	Thu 7/29/10
10	RL/EPA approval of Draft TTP	Fri 7/30/10	Fri 8/27/10
11	Submit TTP to EPA	Mon 8/30/10	Mon 8/30/10
12	M-015-116 (Propsoed 100-K TTP Milestone)	Tue 8/31/10	Tue 8/31/10
13	EPA Review of TTP	Tue 8/31/10	Fri 10/8/10
14	Conduct Workshop Review	Wed 9/15/10	Wed 9/15/10
15	Stake Holder Review	Wed 9/1/10	Fri 10/8/10
16	Revise TTP Per EPA Comments	Mon 10/11/10	Mon 11/8/10
17	Regulatory Approval of TTP	Tue 11/9/10	Thu 11/11/10
18	Procure TTP Equipment	Wed 9/29/10	Tue 11/23/10
19	Build/Construct TTP on Site	Tue 11/9/10	Mon 1/3/11
20	Drill/Install Lysimeters and Monitoring equipment	Fri 11/12/10	Wed 2/16/11
21	Operate Bioinfiltration System	Thu 2/17/11	Wed 8/3/11
22	Prepare Interim Report for FS Report	Thu 8/4/11	Wed 8/17/11
23	Issue Interim Report	Thu 8/18/11	Wed 8/24/11
24	Monitor Bioinfiltration Recovery	Thu 8/4/11	Thu 10/13/11
25	Analyze data, write TTP Report	Fri 11/12/10	Thu 10/13/11
26	Submit Draft TTP Report to RL	Fri 10/14/11	Tue 10/18/11
27	RL Review of Draft TTP Report	Wed 10/19/11	Wed 11/16/11
28	Revise Draft TTP Report	Thu 11/17/11	Thu 12/15/11
29	RL Approval of Draft TTP Report	Fri 12/16/11	Thu 12/22/11
30	Submit TTP Report to EPA	Fri 12/23/11	Thu 1/5/12
31	EPA Review of TTP Report	Fri 1/6/12	Tue 2/21/12

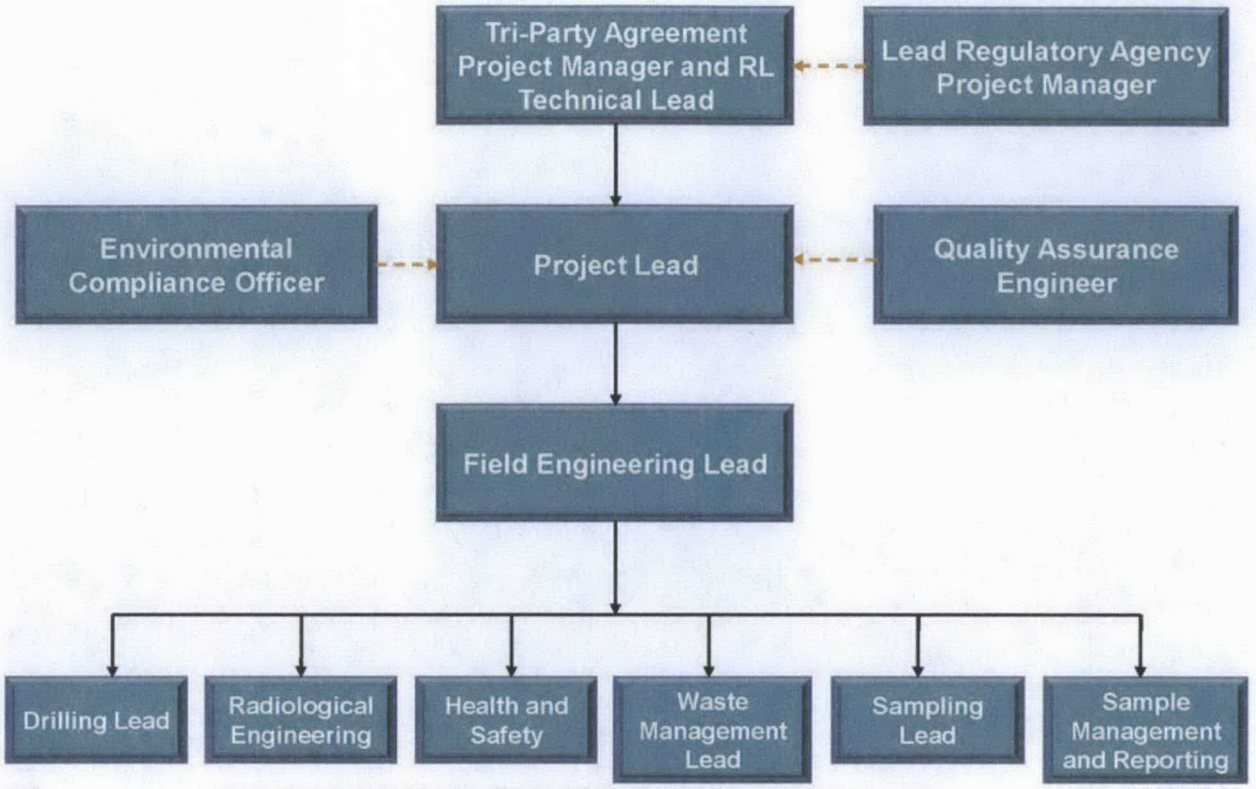


Project: K West Bioinfiltration Schedule

Task | Split | Progress | Milestone | Summary | Project Summary | External Tasks | External Milestone | Deadline

CHPUBS1006-17.7

Figure 8. Draft Field Schedule



RL = U.S. Department of Energy, Richland Operations Office
Tri-Party Agreement = Ecology et al, 1989a, *Hanford Federal Facility Agreement and Consent Order*

Figure 9. 100-KW Bio-Infiltration Treatability Test Organization

Environmental Compliance Officer. The environmental compliance officer provides technical guidance, direction, and acceptance of project and subcontracted environmental work and develops appropriate mitigation measures with a goal of minimizing adverse environmental impacts. The environmental compliance officer also reviews plans, procedures, and technical documents to ensure that environmental requirements have been addressed; identifies environmental issues affecting operations and develops cost-effective solutions; and responds to environmental and regulatory issues or concerns raised by RL or the regulatory agencies. The environmental compliance officer also may oversee project implementation for compliance with applicable internal and external environmental requirements.

Quality Assurance Engineer. The QA point of contact is matrixed to the project lead and is responsible for QA issues on the project. Responsibilities include, as appropriate, overseeing implementation of the project QA requirements; reviewing project documents, including data needs summary reports, field sampling plan, and the quality assurance project plan; and participating in QA assessments of sample collection and analysis activities. The QA point of contact must be independent of the unit generating the data.

Field Engineering Lead. The field engineering lead provides technical guidance and direction of project and subcontracted work. The field engineering lead also reviews plans, procedures, and technical documents to ensure technical requirements have been addressed, identifies potential issues affecting operations, and develops cost-effective solutions. The field engineering lead oversees implementation of subcontractor tasks such as injection boring installation and nutrient injection.

Drilling Lead. The drilling lead has overall responsibility for planning, coordinating, and executing drilling activities. Specific responsibilities include coordinating with the geological and drilling contractors. The drilling lead also communicates with the field engineering lead to identify field constraints or emergent conditions affecting sampling design or execution, and directs the procurement and installation of materials and equipment needed to support fieldwork.

Waste Management Lead (Waste Coordinator). The waste management lead communicates policies and procedures and ensures project compliance for storage, transportation, disposal, and waste tracking in a safe and cost-effective manner. In addition, Waste Management is responsible for identifying waste management sampling and characterization requirements to ensure regulatory compliance, interpreting the characterization data to generate waste designations and profiles, and preparing and maintaining other documents that confirm compliance with waste-acceptance criteria.

Sampling Lead. The sampling lead has overall responsibility for planning, coordinating, and executing sampling activities. Specific responsibilities include converting the sampling design requirements into field task instructions that provide specific direction for field activities, as well as directing training, mock-ups, and practice sessions with field personnel to ensure the sampling design is understood and can be performed as specified. The sampling lead also communicates with the field engineering lead to identify field constraints or emergent conditions affecting sampling design or execution, directs the procurement and installation of materials and equipment needed to support fieldwork, and prepares data packages. The shipping lead reports to the sampling lead for shipment authorization. No sample material will be transported on or off the Hanford Site without permission from an authorized shipper or designee.

Radiological Engineering. The radiological engineering lead is responsible for the radiological/health physics support within the project. Specific responsibilities include conducting ALARA reviews, exposure, release modeling, and radiological controls optimization for work planning. In addition, the radiological engineering lead identifies radiological hazards and implements appropriate controls to maintain worker exposures ALARA (e.g., requiring personal protective equipment). The radiological engineering lead also interfaces with the project health and safety contact, and plans and directs radiological control technician support for activities.

Sample Management and Reporting. Sample Management and Reporting coordinates laboratory analytical work, ensuring the laboratories conform to Hanford Site internal laboratory QA requirements, or their equivalent, as approved by DOE, EPA, and Washington State Department of Ecology. Sample Management and Reporting receives analytical data from the laboratories, enters data into HEIS, and arranges for data validation. Sample Management and Reporting is responsible for informing the field engineering lead of any issues reported by the analytical laboratory. Sample Management and Reporting develops and oversees implementation of the letter of instruction to the analytical laboratories, oversees data validation, and works with the project lead to prepare a characterization report on the sampling and analysis results.

Additionally, the Sample Management and Reporting organization is responsible for performing the data needs process, or equivalent. Additional related responsibilities include developing the SAP, including documenting the data needs and the sampling design, preparing associated presentations, resolving technical issues, and preparing revisions to the SAP. Samples collected in the field and released for shipping and analysis, as well as the resulting data, will be managed in accordance with applicable procedures and work plans.

Laboratories. The laboratories analyze samples in accordance with established procedures, provide necessary sample reports, and explain results in support of data validation. The laboratories must meet site-specific QA requirements and must have an approved QA plan in place.

Health and Safety. Health and Safety is responsible for coordinating industrial safety and health support for the project through health and safety plans, job hazard analyses, and other pertinent safety documents required by federal regulation or by internal primary contractor work requirements. In addition, Health and Safety assists project personnel in complying with applicable health and safety standards and requirements. Health and Safety coordinates with radiological engineering to determine personal protective clothing requirements.

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Appendix A

In Situ Bio-Infiltration Treatability Test Sampling and Analysis Plan

1

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Terms

ALARA	as low as reasonably achievable
CERCLA	*Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
Cr(III)	trivalent chromium
Cr(VI)	hexavalent chromium
DOE	U.S. Department of Energy
DQA	data quality assessment
DQO	data quality objectives
EP	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
HASQARD	Hanford Analytical Services Quality Assurance Requirements Document
HEIS	Hanford Environmental Information System
ORP	oxidation-reduction potential
OU	Operable Unit
PLFA	phospholipid fatty acid
QA	quality assurance
QAPjP	quality assurance project plan
QC	quality control
RCRA	Resource Conservation and Recovery Act of 1976
RCT	radiological control technician
RL	U.S. Department of Energy, Richland Operations Office
RPD	relative percent difference
SAP	sampling and analysis plan
SEM	scanning electron microscope
TOC	total organic carbon
TTP	treatability test plan
Tri-Party Agreement	*Hanford Federal Facility Agreement and Consent Order*

A1 Introduction

This appendix describes the process sampling and analysis requirements to monitor and evaluate the effectiveness of the in situ bio-infiltration treatability test. The objective of the bio-infiltration treatability test is to evaluate the performance and potential long-term effectiveness of an in situ bio-infiltration system as a remedial technology for hexavalent chromium contamination in the vadose zone.

A1.1 Test Data Needs and Analytes

Project-specific data needs and technology performance standards for sampling and analysis were determined during development of the treatability test plan (TTP). Refer to the TTP for a discussion of the treatability test objectives and performance criteria.

Process sampling during the test will include collection of vadose zone soil samples associated with well installation and groundwater samples during the four phases of the treatability test. Groundwater sampling will be conducted at different frequencies (weekly or quarterly) depending on the test phase.

Samples of groundwater collected as part of the treatability test will be analyzed for field and laboratory parameters as listed in Table A-1. These data will provide information on the effectiveness of the technology's performance. The analytical performance requirements for analytes, including the analytical method and required detection limits, are provided in Section A2.

Table A-1. Soil and Groundwater Sample Analytes and Field Parameters

Soil Analytes	Soil Physical Properties
Arsenic	PLFA microbial assemblage
Arsenic (TCLP)	Total organic carbon
Chromium	SEM analysis of mineralogy
Chromium (TCLP)	Grain size
Hexavalent Chromium	Moisture content
Iron	Permeability
Iron (TCLP)	
Manganese	
Groundwater Field Parameters	**Groundwater Analytes**
Dissolved oxygen (DO)	Arsenic (total and dissolved)
Oxidation-reduction potential (ORP)	Calcium (total and dissolved)
pH	Chromium (total and dissolved)
Temperature	Chromium (hexavalent)
Specific conductivity	Eosine (fluorescent tracer)
	Fluorescein (fluorescent tracer)
	Iron (total and dissolved)
	Manganese (total and dissolved)
	Nitrate (N in nitrate)
	Nitrite (N in nitrite)
	Sulfate
	Total organic carbon (TOC)

PLFA = phospholipid fatty acid
SEM = scanning electron microscope
TCLP = toxicity characteristic leaching procedure

A1.2 Project Schedule

Chapter 14 of the TTP describes the schedule for this treatability test.

A2 Quality Assurance Project Plan

The quality assurance project plan (QAPjP) establishes the quality requirements for environmental data collection, including planning, implementation, and assessment of sampling, field measurements, and laboratory analysis. This QAPjP complies with the requirements of the following:

- DOE/RL-96-68, *Hanford Analytical Services Quality Assurance Requirements Document* (HASQARD)
- DOE O 414.1C, *Quality Assurance*
- 10 CFR 830, "Nuclear Safety Management," Subpart A, "Quality Assurance Requirements"
- EPA/240/B-01/003, *EPA Requirements for Quality Assurance Project Plans*, EPA QA/R-5

Sections 6.5 and 7.8 of Ecology et al., 1989b, *Hanford Federal Facility Agreement and Consent Order Action Plan* (Tri-Party Agreement Action Plan) require that quality assurance (QA)/quality control (QC) and sampling and analysis activities specify the QA requirements for treatment, storage, and disposal units, as well as past-practice processes. Therefore, this QAPjP follows the QA elements of EPA/240/B-01/003. The QAPjP demonstrates conformance to Part B requirements of *Quality Systems for Environmental Data and Technology Programs: Requirements with Guidance for Use* (ANSI/ASQ E4-2004).

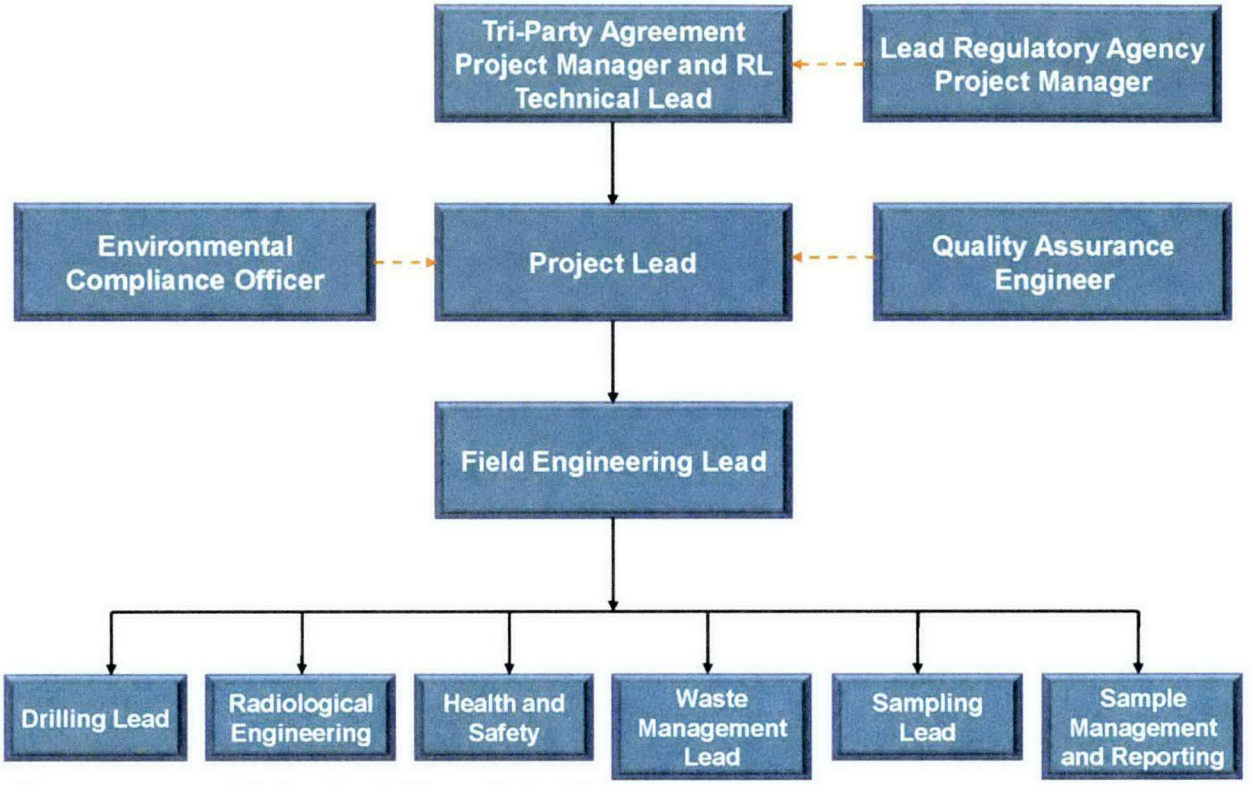
In addition to the requirements cited above, EPA-505-B-04-900A, *Intergovernmental Data Quality Task Force, Uniform Federal Policy for Quality Assurance Project Plans, Evaluating, Assessing, and Documenting Environmental Data Collection and Use Programs, Part 1: UFP-QAPP Manual* (UFP-QAPP Manual) also was used as a resource for identifying QAPjP elements. The UFP-QAPP Manual is not imposed through the Tri-Party Agreement. However, the UFP-QAPP Manual is a valuable resource and provides a comprehensive treatment of quality elements that should be addressed in any sampling and analysis plan (SAP). The UFP-QAPP Manual also was designed to be compatible with EPA/240/B-01/003, which forms the basis for this QAPjP.

A2.1 Project Management and Organization

The following subsections address project management to ensure that the project has a defined goal, the participants understand the goal and the approach to be used, and the planned outputs are appropriately documented. The project organization is shown in Figure A-1. The managing contractor will be responsible for collecting, packaging, and shipping samples to the appropriate laboratory.

A2.1.1 Management Responsibilities

Management responsibilities and inter-relationships are described in the following subsections.



RL = U.S. Department of Energy, Richland Operations Office
Tri-Party Agreement = Ecology et al, 1989a, *Hanford Federal Facility Agreement and Consent Order*

Figure A-1. Project Organization

A2.1.1.1 Regulatory Project Manager

As the Lead Regulatory Agency, the Environmental Protection Agency (EPA) has assigned Project Managers responsible for overseeing the cleanup projects and activities. As the lead regulatory agency, EPA has approval authority for the work performed under this TTP. EPA will work with DOE-RL to resolve concerns regarding the work as described in this TTP in accordance with the Tri-Party Agreement (Ecology et al., 1989a).

A2.1.1.2 Tri-Party Agreement Project Manager and RL Technical Lead

U.S. Department of Energy, Richland Operations Office (RL) is responsible for the Hanford cleanup. The Tri-Party Agreement Project Manager is responsible for authorizing the contractor to perform Hanford Site activities in accordance with the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA); the *Resource Conservation and Recovery Act of 1976* (RCRA); the *Atomic Energy Act of 1954*; and the Tri-Party Agreement. In addition, the Tri-Party Agreement Project Manager is responsible for obtaining lead regulatory agency approval of the TTP that authorizes the activities under the Tri-Party Agreement (Ecology et al., 1989a). The RL technical lead is responsible for overseeing the contractor in performing the work scope, working with the contractor and the regulatory agencies to identify and work through issues, and providing technical input to the Tri-Party Agreement Project Manager.

A2.1.1.3 Project Lead

The project lead is responsible for managing field activities and subcontracted tasks, and for ensuring the project file is properly maintained. The project lead ensures that the design requirements for the test plan

are converted into field instructions (e.g., work packages) and provide specific direction for field activities. The project lead works closely with the field engineer lead, QA, health and safety, drilling lead, and sampling lead to integrate these and other lead disciplines in planning and implementing the work scope. The project lead maintainsh a list of individuals or organizations filling each of the functional elements of the project organization (Figure A-1). In addition, the project lead is responsible for version control to ensure that personnel are working to the most current job requirements. The project lead also coordinates with RL and the task leads on test plan implementation and sampling activities. The project lead supports RL in coordinating sampling activities with the regulators.

A2.1.1.4 Quality Assurance Engineer

The QA point of contact is matrixed to the project lead and is responsible for QA issues on the project. Responsibilities include, as appropriate, overseeing implementation of the project QA requirements; reviewing project documents, including data needs summary reports and field sampling plan; and participating in QA assessments of sample collection and analysis activities. The QA point of contact must be independent of the unit generating the data.

A2.1.1.5 Waste Management Lead (Waste Coordinator)

The waste management lead communicates policies and procedures and ensures project compliance for storage, transportation, disposal, and waste tracking in a safe and cost-effective manner. In addition, Waste Management is responsible for identifying waste management sampling and characterization requirements to ensure regulatory compliance, interpreting the characterization data to generate waste designations and profiles, and preparing and maintaining other documents that confirm compliance with waste acceptance criteria.

A2.1.1.6 Environmental Compliance Officer

The environmental compliance officer provides technical guidance, direction, and acceptance of project and subcontracted environmental work and develops appropriate mitigation measures with a goal of minimizing adverse environmental impacts. The environmental compliance officer also reviews plans, procedures, and technical documents to ensure that environmental requirements have been addressed; identifies environmental issues affecting operations and develops cost-effective solutions; and responds to environmental and regulatory issues or concerns raised by RL or the regulatory agencies. The environmental compliance officer also may oversee project implementation for compliance with applicable internal and external environmental requirements.

A2.1.1.7 Field Engineering Lead

The field engineering lead provides technical guidance and direction of project and subcontracted work. The field engineering lead also reviews plans, procedures, and technical documents to ensure technical requirements have been addressed. This position also identifies potential issues affecting operations, develops cost-effective solutions, and oversees implementation of subcontractor tasks such as injection boring installation and nutrient injection.

A2.1.1.8 Sampling Lead

The sampling lead has overall responsibility for planning, coordinating, and executing sampling activities. Specific responsibilities include converting the sampling design requirements into field task instructions that provide specific direction for field activities, as well as directing training, mock-ups, and practice sessions with field personnel to ensure the sampling design is understood and can be performed as specified. The sampling lead also communicates with the field engineering lead to identify field constraints or emergent conditions affecting sampling design or execution, directs the procurement and installation of materials and equipment needed to support fieldwork, and prepares data packages. The

shipping lead reports to the sampling lead for shipment authorization. No sample material will be transported on or off the Hanford Site without permission from an authorized shipper or designee.

A2.1.1.9 Drilling Lead

The drilling lead has overall responsibility for planning, coordinating, and executing drilling activities. Specific responsibilities include coordinating with the geological and drilling contractors. The drilling lead also communicates with the field engineering lead to identify field constraints or emergent conditions affecting sampling design or execution, and directs the procurement and installation of materials and equipment needed to support fieldwork.

A2.1.1.10 Radiological Engineering

The radiological engineering lead is responsible for the radiological/health physics support within the project. Specific responsibilities include conducting as low as reasonably achievable (ALARA) reviews, exposure, release modeling, and radiological controls optimization for work planning. In addition, the radiological engineering lead identifies radiological hazards and implements appropriate controls to maintain worker exposures ALARA (e.g., requiring personal protective equipment). The radiological engineering lead also interfaces with the project health and safety contact, and plans and directs radiological control technician support for activities.

A2.1.1.11 Sample Management and Reporting

Sample Management and Reporting coordinates laboratory analytical work, ensuring the laboratories conform to Hanford Site internal laboratory QA requirements, or their equivalent, as approved by DOE, EPA, and Washington State Department of Ecology. Sample Management and Reporting receives analytical data from the laboratories, enters data into Hanford Environmental Information System (HEIS), and arranges for data validation. Sample Management and Reporting is responsible for informing the field engineering lead of any issues reported by the analytical laboratory. Sample Management and Reporting develops and oversees implementation of the letter of instruction to the analytical laboratories, oversees data validation, and works with the project lead to prepare a characterization report on the sampling and analysis results.

Additionally, the Sample Management and Reporting organization is responsible for performing the data needs process, or equivalent. Additional related responsibilities include developing the SAP, including documenting the data needs and the sampling design, preparing associated presentations, resolving technical issues, and preparing revisions to the SAP. Samples collected in the field and released for shipping and analysis, as well as the resulting data, will be managed in accordance with applicable procedures and work plans.

A2.1.1.12 Laboratories

The laboratories analyze samples in accordance with established procedures, provide necessary sample reports, and explain results in support of data validation. The laboratories must meet site-specific QA requirements and must have an approved QA plan in place.

A2.1.1.13 Health and Safety

Health and Safety is responsible for coordinating industrial safety and health support for the project through health and safety plans, job hazard analyses, and other pertinent safety documents required by federal regulation or by internal primary contractor work requirements. In addition, Health and Safety assists project personnel in complying with applicable health and safety standards and requirements. Health and Safety coordinates with radiological engineering to determine personal protective clothing requirements.

A2.1.2 Problem Definition/Background

The test system will be installed within the geographic boundary of the 100-KR-4 operable unit (OU) to test its effectiveness for reducing hexavalent chromium to trivalent chromium in vadose zone soil. Test data are required to determine the effectiveness of the technology and optimize system design and operations in order to maximize remedial action efficiency.

A2.1.3 Project/Task Description

This SAP governs sampling in support of the treatability test system. Soil samples will be collected during drilling. Groundwater monitoring will be performed weekly and quarterly, depending on the phase of testing. Samples collected will be analyzed for constituents and parameters shown in Table A-1. Chapter A3 summarizes the test work to be performed under this SAP. Additional sampling may occur based on the observation of the field engineering lead during testing. The data generated during sampling and analysis activities will be used in the development of the Treatability Test Report. In addition, these data may also be used in developing interim technical reports and presentations. Figure A-2 shows the proposed treatability test area.

A2.1.4 Quality Objectives and Criteria for Measurement Data

The QA objective of this SAP is to develop implementation guidance for providing data of known and appropriate quality. Data quality for this SAP may be assessed by five criteria: representativeness, accuracy, comparability, completeness, and precision. The applicable QC guidelines, quantitative target limits, and levels of effort for assessing data quality are dictated by the intended use of the data and the nature of the analytical methods. The applicable QC guidelines and level of effort are addressed in the following subsections and summarized in Table A-2.

A2.1.4.1 Representativeness

Representativeness is a measure of how closely analytical results reflect the actual concentration and distribution of the constituents in the matrix sampled. Sampling plan design, sampling techniques, and sample-handling protocols (e.g., storage, preservation, and transportation) are discussed in subsequent sections of this SAP. The required documentation will establish the protocols to be followed and will ensure appropriate sample identification and integrity.

A2.1.4.2 Accuracy

Accuracy is an assessment of the closeness of the measured value to the true value. Radionuclides are not target analytes for sampling but during testing could be determined to be necessary. Radionuclide measurements requiring chemical separations use this technique to measure method performance. For radionuclide measurements analyzed by gamma spectroscopy, laboratories typically compare results of blind-audit samples against known standards to establish accuracy. The validity of calibrations is evaluated by comparing results from the measurement of a standard to known values and/or by generation of in-house statistical limits based on three standard deviations (plus or minus three standard deviations). Tables A-3 and A-4 list the laboratory accuracy parameters for this SAP.

A2.1.4.3 Comparability

Comparability expresses the confidence with which one data set can be compared to another. Data comparability will be maintained by using standard procedures, uniform methods, and consistent units.

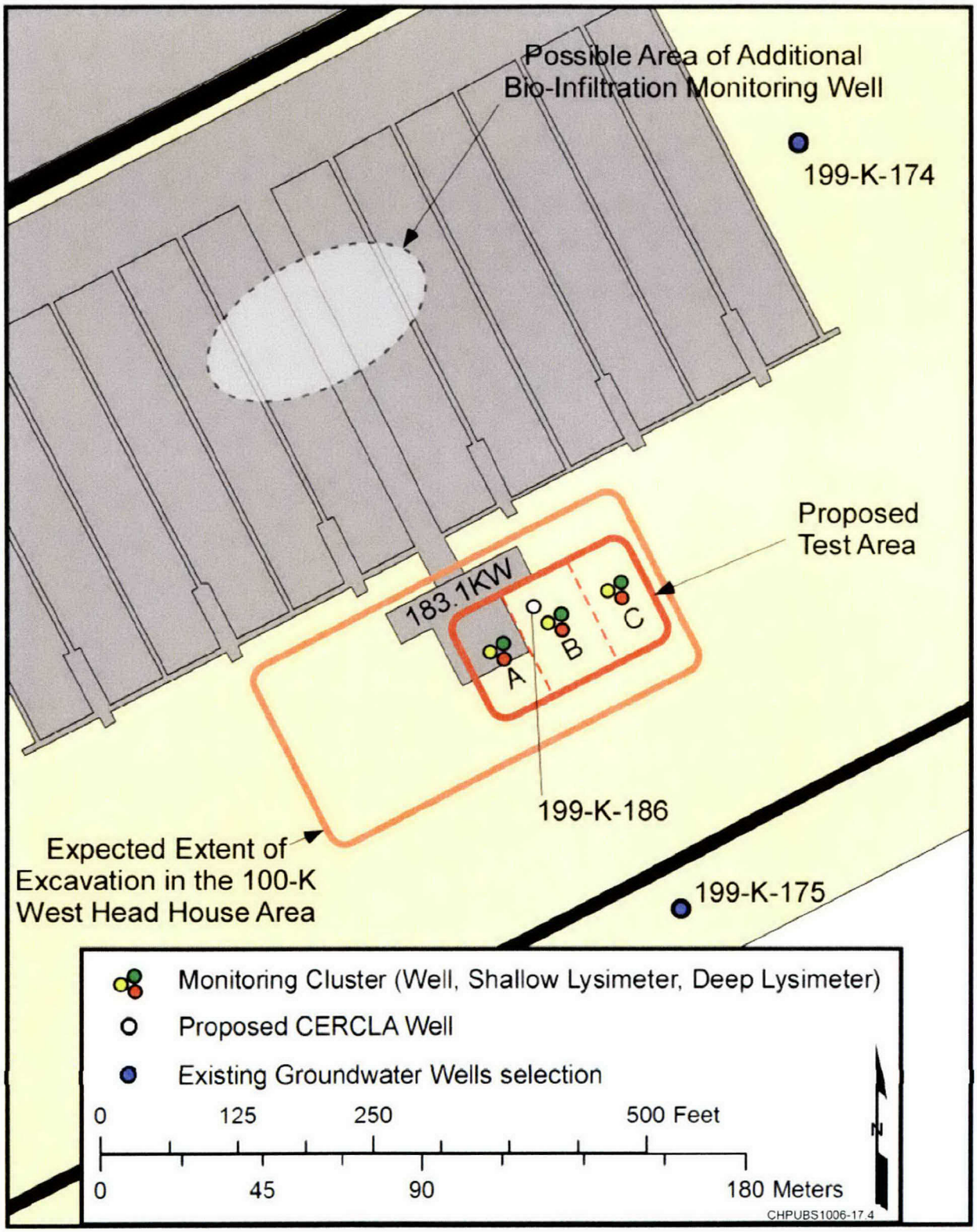


Figure A-2. Expected Areas of Excavation, Proposed Bio-Infiltration Test Site, and Proposed Monitoring Well Locations

Table A-2. Data Quality Indicators

Data Quality Indicator	Definition	Example Determination Methodologies	Project Specific Information*	Corrective Actions Examples
Precision	The measure of agreement among repeated measurements of the same property under identical, or substantially similar, conditions, calculated either as the range or as the standard deviation. May also be expressed as a percentage of the mean of the measurements, such as relative range, relative percent difference, or relative standard deviation (coefficient of variation).	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 or have two or more laboratories analyze identical samples with the same method. Collect a duplicate sample in the field and submit for sample handling, preservation and storage, and analytical measurements. Collect, process, and analyze collocated samples for information on sample acquisition, handling, shipping, storage, preparation, and analytical processes and measurements.	Precision criteria will apply: *Laboratory Analysis:* Adherence to the requirements of the current laboratory contracts. One duplicate collected for one in 20 water samples. *Field Measures:* Achieved by adherence to procedural SOPs.	Data interpretation or data assessment may be performed.
Accuracy	A measure of the overall agreement of a measurement to a known value; includes a combination of random error (precision) and systematic error (bias) components of both sampling and analytical operations.	Analyze a reference material or re-analyze a sample to which a material of known concentration or amount of pollutant has been added (a spiked sample); usually expressed either as percent recovery or as percent bias.	Accuracy criteria will apply: *Laboratory Analysis:* Adherence to the requirements of the current laboratory contracts. *Field Measures:* Achieved by adherence to procedural SOPs.	Data interpretation or data assessment may be performed.
Representativeness	A qualitative term that 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 (ANSI/ASQC E4-1994).	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.	*Laboratory and Field Analysis:* Groundwater or pore water samples will be collected from each of the wells or lysimeters. The results will represent vertical progression of a chemically reducing front within the study area and track trends over time.	Data interpretation or data assessment may be performed.

Table A-2. Data Quality Indicators

Data Quality Indicator	Definition	Example Determination Methodologies	Project Specific Information*	Corrective Actions Examples
Comparability	A qualitative term that expresses the measure of confidence that one data set can be compared to another and can be combined for the decision(s) to be made.	Compare sample collection and handling methods, sample preparation and analytical procedures, holding times, stability issues, and QA protocols.	*Laboratory Analysis:* The sample results need only be internally comparable. All sampling personnel will use the same sampling protocols. All samples will be submitted to the laboratory for analysis by the same methods; thus, data results will be comparable.	If data are not comparable to other data sets: • Assess potential impacts in data quality assessment if performed.
Completeness	A measure of the amount of valid data needed to be obtained from a measurement system.	Compare the number of valid measurements completed (samples collected or samples analyzed) with those established by the project's quality criteria (DQOs or performance/acceptance criteria).	*Laboratory and Field Analyses:* The water samples collected from three wells and six lysimeters will be collected in order to meet the completeness criteria.	Evaluate the impact to the resulting data set and ability to define treatability test design criteria.
Sensitivity	The capability of a method or instrument to discriminate between measurement responses representing different levels of the variable of interest.	Determine the minimum concentration or attribute that can be measured by a method (method detection limit), by an instrument (instrument detection limit), or by a laboratory (quantitation limit). The practical quantitation limit is the lowest level that can be routinely quantified and reported by a laboratory.	Sensitivity criteria will apply: *Laboratory Analysis:* Adherence to the requirements of the current laboratory contracts.	Data interpretation or data assessment may be performed.

Source:
ANSI/ASQC E4-1994, *Specifications and Guidelines for Quality Systems for Environmental Data Collection and Environmental Technology Programs.*
* Field sampling requirements are noted. Laboratories will follow contract requirements for use and interpretation of laboratory control samples. Precision, accuracy, and sensitivity requirements are satisfied by following method procedures because analyses are being performed to support treatability test design (not for regulatory decision making).

ANSI = American National Standards Institute
ASQC = American Society for Quality Control
DQO = data quality objectives
QA = quality assurance
QC = quality control
SOP = standard operating procedure

Table A-3. Analytical Requirements for Core Samples

Analyte	Reporting Limit	Interim Soil Remedial Action Goal Values[a]		Analytical Method	Accuracy Requirement[c] (%)	Precision Requirement[c] (%)
		Direct Exposure	Groundwater/ River Protection[b]			
Arsenic	10 mg/kg	20 mg/kg	20 mg/kg	EPA Method 6010 (ICP) or 200.8 (ICP/MS)	70-130	≤30
Chromium	1 mg/kg	120,000 mg/kg	18.5 mg/kg			
Iron	5 mg/kg	56,000 mg/kg	11,200 mg/kg			
Manganese	5 mg/kg	11,200 mg/kg	512 mg/kg			
Cr(VI)	0.5 mg/kg	2.1 mg/kg	2 mg/kg	EPA Method 7196	70-130	≤30
Total organic carbon	TBD	N/A	N/A	SW-846(a) (dry combustion with pretreatment to remove inorganic carbonates)	70-130	≤30
Analysis of mineralogy	N/A	N/A	N/A	SEM	N/A	N/A
Microbial assemblage	N/A	N/A	N/A	Phospholipid fatty acid analysis	N/A	N/A
Arsenic	0.5 mg/L	N/A	N/A	TCLP EPA Method 1311/ 6010[d]	70-130	≤30
Chromium	0.5 mg/L	N/A	N/A			
Iron	0.5 mg/L	N/A	N/A			
Grain size	N/A	N/A	N/A	ASTM A422 (sieve analysis)	N/A	N/A
Moisture content	N/A	N/A	N/A	ASTM A2216-05	N/A	N/A
Permeability	N/A	N/A	N/A	ASTM A4525-08 (air permeability test)	N/A	N/A

a. Interim soil risk assessment guidance values are specified in DOE/RL-96-17, *Remedial Design Report/Remedial Action Work Plan for the 100 Area*.

b. The more restrictive of the groundwater protection or Columbia River protection values is provided.

c. The accuracy criterion shown is the minimum for associated batch laboratory control sample percent recoveries. Laboratories must meet statistically based control, if more stringent. Additional accuracy criteria include analyte-specific evaluations preformed for matrix spike, and surrogate recoveries as appropriate to the method. The precision criterion shown is for batch laboratory replicate matrix spike analysis relative percent differences.

d. TCLP may be performed on samples selected by the project after a review of the preliminary sample results. SPLP may be performed in lieu of TCLP or in conjunction with TCLP.

N/A = not applicable
TBD = to be determined
SEM = scanning electron microscope
TCLP = toxicity characteristic leaching procedure

Table A-4. Analytical Performance Requirements for Aqueous Samples

Analyte	Analytical Method[a]	Reporting Limit[b] (µg/L)	Accuracy Requirement[c] (%)	Precision Requirement[c] (%)
Field Measurements				
pH Measurement	Multiple-Parameter Probe	0.01 pH unit	[d]	[d]
ORP		0.1 mV		
Temperature		0.1°C		
Dissolved oxygen (DO)		0 mg/L		
Specific conductivity		0.001 to 0.1 mS/cm		
Analyses				
Arsenic[e]	EPA 6010–ICP EPA 200.8-ICP/MS	10	80-120	≤20
Calcium[e]		1,000	80-120	≤20
Chromium[e]		10	80-120	≤20
Iron[e]		50	80-120	≤20
Manganese[e]		5.0	80-120	≤20
Chromium (hexavalent)	EPA 7196	10	80-120	≤20
Nitrate	EPA 300.0-IC	250	80-120	≤20
Nitrite		250	80-120	≤20
Sulfate		500	80-120	≤20
TOC	EPA 9060 or EPA 415.1	1,000	80-120	≤20
Fluorescent tracers	Spectrofluorophotometer-synchronous scan	0.05[f]	N/A	N/A

a. Analytical method selection is based on available methods by laboratories currently contracted to the Hanford Site. For the four-digit EPA methods, see SW-846, *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods, Third Edition; Final Update IV-B*. For EPA the three-digit EPA Methods, see EPA-600/4-79-020, *Methods for Analysis of Water and Wastes*. Equivalent methods may be substituted.

b. The specified reporting limits are based on current Hanford laboratory contracts.

c. The accuracy criterion shown is the minimum for associated batch laboratory control sample percent recoveries. Laboratories must meet statistically based control, if more stringent. Additional accuracy criteria include analyte-specific evaluations preformed for matrix spike, and surrogate recoveries as appropriate to the method. The precision criterion shown is for batch laboratory replicate matrix spike analysis relative percent differences.

d. Field measurements have no specific quality control requirement except to perform the manufacturer's required performance checks.

e. Groundwater samples will be analyzed for this metal as part of the 6010 Metals ICP DURA list (29). Both total and dissolved metals will be analyzed. Lysimeter samples will be analyzed for the same metals but for total metals only. Dissolved samples require filtration prior to preservation.

f. Detection limit based on literature and can be adjusted based on performing laboratory capability.

DO = dissolved oxygen
EPA = U.S. Environmental Protection Agency
IC = ion chromatography
ICP = inductively coupled plasma
MS = mass spectroscopy
N/A = not applicable
ORP = oxidation-reduction potential
TOC = total organic carbon

A2.1.4.4 Completeness

Tables A-3 and A-4 identify the test sample analytes, field parameters, and analytical performance requirements for the treatability test. The analytical data set for the sampling will be considered incomplete if these are not included. If one or more of the other analytical parameters listed in Tables A-3 and A-4 are not reported, the project lead (or designee) will determine whether the data set is complete.

The determination of analytes for waste characterization will be made in accordance with a separate DQO process, which is outside the scope of this SAP. Consequently, completeness of the analytical data set for this purpose is not a consideration for this SAP.

A2.1.4.5 Precision

Precision is a measure of the data spread when more than one measurement exists of the same sample. Precision can be expressed as the relative percent difference (RPD) for duplicate measurements, or relative standard deviation for triplicates. Tables A-3 and A-4 present analytical precision requirements for laboratory analyses.

A2.1.4.6 Special Training Requirements and Certification

The Environmental Safety and Health training program provides workers with the knowledge and skills necessary to execute assigned duties safely. Field personnel typically will have completed the following training before starting work:

- Occupational Safety and Health Administration 40-Hour Hazardous Waste Worker Training and Supervised 24-Hour Hazardous Waste Site Experience
- Eight-Hour Hazardous Waste Worker Refresher Training (as required)
- Hanford Site General Employee Training
- Radiological Worker Training (as required)

A graded approach is used to ensure that workers receive a level of training commensurate with their responsibilities in compliance with applicable DOE orders and government regulations. Specialized employee training includes pre-job briefings, on-the-job training, emergency preparedness, plan-of-the-day instructions, and facility/work site orientations.

A2.1.5 Documentation and Records

Field sampling and laboratory analytical documentation will be in accordance with contractor procedures and standard industry practices. Work products resulting from sampling and analysis may be included as documents and records, including the following:

- Sampling Records
- Laboratory data packages
- Verification and validation report

Both hardcopy and electronic versions of the record deliverables will be provided. Data files will be in an American Standard Code for Information Interchange-compatible format. The project lead is responsible for ensuring that project personnel are working to the current version of this SAP.

Data collected during field activities may be recorded electronically and/or in bound logbooks with sequentially numbered pages. Electronically recorded data will include all pertinent information necessary to uniquely identify the information, including date, time, units, and location (if relevant). When logbooks

are used, each new test day will be identified by the date at the top of the logbook page. Each new entry will be designated by a time-of-day entry and start on a new line; data of sufficient detail will be entered to describe fully the activity or data being logged. At the conclusion of each day's activities, the logger will provide his/her initials at the end of the log for that day and place a diagonal line across the remaining unused page for that day's activities. All entries will be recorded in the logbook or on data collection sheets using waterproof, non-smear ink. Calibration data for monitoring/measuring equipment will be recorded in the logbooks. Photographs/digital/video images will be taken and noted in the logbook for reference and will then be cataloged and retained for future reference. Errors will have a line drawn through them, followed by the correction, initials of the person making the change, and the date.

A2.2 Data Generation and Acquisition

The following subsections present the requirements for sampling methods, sample handling and custody, analytical methods, and field and laboratory QC. The requirements for instrument calibration and maintenance, supply inspections, and data management are also addressed. The sampling design is presented in Section A3 of this SAP.

The field engineering lead is responsible for ensuring that all field procedures are followed completely and that field-sampling personnel are adequately trained to perform sampling activities under this SAP. The field engineering lead must document all deviations from procedures or other problems pertaining to sample collection, chain of custody, sample analytes, sample transport, or noncompliant monitoring. As appropriate, such deviations or problems will be documented in the file logbook or in nonconformance report forms in accordance with internal corrective action procedures. The field engineering lead or project lead is responsible for communicating field corrective action requirements and for ensuring that immediate corrective actions are applied to field activities.

A2.2.1 Sample Preservation, Containers, and Holding Times

Suggested sample container, preservation, and holding-time requirements are specified in Table A-8 for test water samples. These requirements are in accordance with the requirements of the specific analytical method prepared for specific sample events. The final container type and volumes will be provided on the sampling authorization form and the chain-of-custody form. This SAP defines a "sample" as a filled sample bottle for starting the clock for holding-time restrictions.

A2.2.2 Sampling Methods Requirements

Sampling associated with this SAP will be performed in accordance with established sampling practices and requirements pertaining to sample collection, collection equipment, and sample handling. Procedures from the contractor (or its approved subcontractor) will be used for sampling and should be in accordance with Section A3.3 and as outlined in HASQARD QA requirements and the applicable procedures for the sampling activities listed in this SAP. Any use of non-routine hardware may require that separate written instructions supplement or replace established procedures. Section A2.2.7 provides a summary of sample and field QC sample collection requirements.

Errors during sampling activities are reported to the Sample Management and Reporting organization's project coordinator, who initiates a sample disposition record. This process documents errors and establishes resolutions with the project lead. Further details on the methods for addressing failures in the sampling and measurement system are presented in Chapter 8 of the TTP.

A2.2.3 Sampling Identification

A sample and data-tracking database will be used to track the samples from the point of collection through the laboratory analysis process. The HEIS database is the repository for laboratory analytical

results. The HEIS sample numbers will be issued to the sampling organization for this project, and the numbers are to be carried through the laboratory data-tracking system.

A2.2.4 Sample Handling, Shipping, and Custody Requirements

The processes followed for sample handling, shipping, and custody requirements will be in accordance with those presented in Section A3.4.

A2.2.5 Laboratory Sample Custody

Sample custody during laboratory analysis will be addressed in the applicable laboratory's standard operating procedures. Laboratory custody procedures will ensure that sample integrity and identification are maintained throughout the analytical process.

A2.2.6 Analytical Methods Requirements

Tables A-3 and A-4 identify the analytical methods and analytical performance requirements for groundwater sampling.

The test sample analytical performance requirements were derived from technical performance standards identified in the TTP. Analytical parameters and methods presented in Tables A-3 and A-4 were established to meet these requirements. Laboratory analysis should be conducted within allowable sample holding times for each analyte tested. Analyses for metals will be performed on both filtered and unfiltered water samples, as shown in Table A-5.

Table A-5. Field Quality Control Requirements

Sample Type	Frequency	Purpose
Field duplicate samples	Minimum of 1 sample in 20	To check the precision of the sampling and of the laboratory analyses
Equipment rinsate blank samples	Minimum of 1 sample in 20	For reusable sample equipment to check the effectiveness of the decontamination process
Full trip blank samples	Minimum of 1 sample for the process sampling	To evaluate potential sample contamination due to sample bottles, handling, preservatives, storage, and transportation

Laboratories providing analytical services in support of this test will have a corrective action program in place that addresses analytical system failures and documents the effectiveness of any corrective actions. Issues that may affect analytical results are to be resolved by the Sample Management and Reporting organization in coordination with the project lead.

Analytical errors reported by the laboratories are reported to the Sample Management and Reporting organization's project coordinator, who initiates a sample disposition record. This process documents errors and establishes resolutions with the project lead. Further details on the methods for addressing failures in the sampling and measurement system are presented in Chapter 8 of the TTP.

A2.2.7 Quality Control Requirements

Field QC samples will be collected during water sampling to evaluate the potential for cross-contamination and laboratory performance to ensure that reliable data are obtained. Particular care will be exercised to avoid the following common ways in which cross-contamination or background contamination may compromise samples:

- Improperly storing or transporting sampling equipment and sample containers

- Contaminating the equipment or sample bottles by setting the equipment/sample bottle on or near potential contamination sources (e.g., uncovered ground)
- Handling bottles or equipment with dirty hands or gloves
- Improperly decontaminating equipment before sampling or between sampling events

Table A-5 identifies the field QC samples for water sampling and the purpose of the sample. One duplicate and one trip blank will be collected for each 20 samples. This number of QC samples is based on site procedures that call for approximately one set of QC samples per 20 sampling events, with each sample representing one sampling event. Laboratory QC sample requirements will be specified in the applicable laboratory's statement of work.

A2.2.7.1 Field Duplicate Samples

Field replicates will be collected at a frequency of 1-in-20 samples. Field replicates are used to evaluate laboratory consistency and the precision of field sampling methods.

A2.2.7.2 Equipment Rinsate Blank Samples

Equipment blanks are collected from reusable sampling devices on a 1-in-20 basis. The field engineering leader may request that additional equipment blanks be taken. Equipment blanks will consist of silica sand or analyte-free water poured over the decontaminated sampling equipment and placed in containers, as identified on the project sampling authorization form. Equipment blanks are not needed for disposable sampling equipment.

A2.2.7.3 Field Trip Blank Samples

Full trip blanks, also known as trip blanks or dailies, are prepared by the sampling team before traveling to the sampling site. The preserved bottle set is either for volatile organic analysis only or identical to the set that will be collected in the field. It is filled with high-purity reagent water. The bottles are sealed and transported (unopened) to the field in the same storage containers used for samples collected that day. Full trip blanks are analyzed for the same constituents as the samples to evaluate potential contamination of the samples due to the sample bottles, preservative, handling, storage, and transportation.

A2.2.8 Measurement Equipment

Each user of the measuring equipment is responsible to ensure that the equipment is functioning as expected, properly handled, and calibrated before expiration in accordance with procedures governing control of the measuring equipment. Onsite environmental instrument testing, inspection, calibration, and maintenance will be recorded in a bound logbook. Field screening instruments will be used, maintained, and calibrated in accordance with the manufacturer's specifications and HASQARD requirements.

A2.2.8.1 Instrument/Equipment Testing, Inspection, and Maintenance Requirements

Onsite environmental instruments will be tested, inspected, and maintained. Measurement equipment must be inspected before use. Tags will be attached to field screening and onsite analytical instruments, noting the date when the instrument was last calibrated and the calibration expiration date. Maintenance requirements (e.g., parts lists and documentation of routine maintenance) will be included in the individual laboratory's and onsite organization's QA plan and/or operating procedures. Measurement and testing equipment used in the field or in the laboratory directly affecting the quality of analytical data will be subject to preventive maintenance measures to ensure that measurement system downtime is minimized.

A2.2.8.2 Instrument Calibration

Laboratories and onsite measurement organizations must maintain and calibrate equipment. Calibration of laboratory instruments will be performed in a manner consistent with SW-846, *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods, Third Edition; Final Update IV-B*, or with auditable HASQARD and contractual requirements. Radiological control technicians (RCTs) will perform calibration of radiological field instruments, if used. The data will be reported as accepted, rejected, or qualified.

Calibration is conducted with certified equipment and/or standards with a known valid relationship to nationally recognized performance standards. If no such standards exist, the basis for calibration will be documented.

A2.2.9 Inspection of Consumable Supplies

Consumables, supplies, and reagents will be reviewed in accordance with the current requirements of SW-846 and will be appropriate for use. Potential contamination is monitored by QC samples and laboratory blanks. The lot number from the manufacturer-certified, pre-cleaned sample containers will be recorded in the sampler's logbook.

A2.2.10 Nondirect Measurement

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.

A2.2.11 Data Management

The Sample Management and Reporting Organization, in coordination with the project lead, is responsible for ensuring analytical data are appropriately reviewed, managed, and stored in accordance with the applicable programmatic requirements governing data management procedures. Electronic data access, when appropriate, will be via a database (e.g., HEIS or a project specific database). Where electronic data are not available, hard copies will be provided in accordance with the *Hanford Federal Facility Agreement and Consent Order Action Plan* (Ecology et al., 1989b).

A2.2.12 Laboratory Quality Control

Laboratory duplicates will be analyzed for the waste designation samples. Laboratory method blanks and laboratory control samples/blank spikes are defined in Chapter 1 of SW-846 and will be run as specified in Chapter 1 of SW-846.

A2.2.13 Field Documentation

Field documentation will be maintained in the form of chain-of-custody/sample analysis request forms and logbook entries.

A2.3 Assessment/Oversight

Routine evaluation of data quality described for this project will be documented and filed with the data in the project file. The project lead (or designee) and/or the field engineering lead will monitor field activities for this SAP. The project lead retains overall responsibility for sampling, but may delegate specific responsibilities to the field engineering lead or other appropriate contractor staff.

The Sample and Data Management organization will select a laboratory to perform the analyses for this SAP. The Sample and Data Management organization will assess and verify that analytical data are reported by the laboratory and will then enter the verified data into the HEIS database.

A2.3.1 Assessments and Response Action

Random surveillance and assessments may be conducted to verify compliance with the requirements outlined in this SAP, project work packages, procedures, and regulatory requirements. Deficiencies identified by these assessments will be reported. The project's QA organization coordinates corrective actions/deficiencies in accordance with the contractor's QA program. When appropriate, corrective actions will be taken by the project lead (or designee). The project lead is responsible for implementing corrective actions and verifying their completeness and effectiveness.

A2.3.2 Reports to Management

Management will be made aware of deficiencies identified by self-assessments, corrective actions from environmental compliance officers, and findings from QA assessments and surveillances.

A2.4 Data Review, Verification, Validation, and Usability Requirements

The following sections address the QA activities that occur after the data collection phase of the project is completed. Implementation of these elements determines whether data conform to the specified criteria, thus satisfying project objectives.

A2.4.1 Data Review Verification and Validation

The criteria for verification may include review for completeness (all samples were analyzed as requested), use of the correct analytical method/procedure, review for transcription errors, and correct application of dilution factors. Review also includes appropriate reporting of dry weight versus wet weight, and the correct application of conversion factors. Laboratory personnel may perform data verification.

Data validation will be performed to ensure that the data quality goals established during the planning phase has been 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, A through E. Level A is the lowest level and is the same as verification. Level E is a 100 percent review of data (e.g., calibration data or calculations of representative samples from the dataset). Validation will be performed to contractor Level C, which is a review of the QC data. Level C validation specifically requires verification of deliverables, requested versus reported analyses, and qualification of the results based on analytical holding times, method blank results, matrix spike/matrix spike duplicate, surrogate recoveries, duplicates, and analytical method blanks. Level C validation will be performed on at least 5 percent of the data by matrix and analyte group. Analyte group refers to categories, such as radionuclides, volatile and semivolatile chemicals, metals, and anions.

Relative to analytical data in sample media, physical data and/or field screening results are of lesser importance in making inferences of risk. Data validation will not be performed for physical property data and/or field screening results.

A2.4.2 Verification and Validation Methods

Validation activities will be based on EPA functional guidelines, EPA/540/R-99/008, *US EPA Contract Laboratory Program National Functional Guidelines for Organic Data Review*. Data validation may be performed by the analytical laboratory, Sample Management and Reporting, and/or by a party independent of both the data collector and the data user.

Data qualifiers assigned during data validation will be compatible with HEIS.

When outliers or questionable results are identified, additional data validation will be performed. The additional validation will be performed for up to 5 percent of the statistical outliers and/or questionable data. The additional validation will begin with Level C and may increase to Levels D and E as needed to ensure that data are usable. 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 dataset. Data validation will be documented in data validation reports. One example of questionable data is when the positive detections are greater than the practical quantitation limit or reporting limit in soil/aquifer sediment from a site that should not have exhibited contamination. Similarly, results below background, which would not be expected, could trigger a validation inquiry.

A2.4.3 Reconciliation with User Requirements

The data quality assessment (DQA) process compares completed field sampling activities to those proposed in corresponding sampling documents and evaluates the resulting data. The purpose of the data evaluation is to determine whether quantitative data are the correct type and of adequate quality and quantity to meet the project DQOs. The project lead is responsible for determining whether a DQA is necessary and ensuring that it is performed, if required. The results of the DQA will be used in interpreting the data and determining if the objectives of this activity have been met.

The DQA (if performed) with be in accordance with EPA's DQA process, EPA/240/B-06/002, *Data Quality Assessment: A Reviewer's Guide*, EPA QA/G-9R, and EPA/240/B-06/003, *Data Quality Assessment: Statistical Methods for Practitioners*, EPA QA/G-9S.

A2.4.4 Corrective Actions

The responses to data quality defects identified through the DQA process will vary and may be data specific or measurement specific. Table A-2 identifies some pre-identified corrective actions.

A2.4.5 Data Interpretation

Data interpretation will be performed to assess the performance of the bio-infiltration treatability test. The primary interpretation of the data will be to assess the results of the treatability testing program with respect to experimental objectives presented in the TTP.

A3 Field Sampling Plan

This field-sampling plan identifies the activities for performance of test sampling as well as field and laboratory analysis.

A3.1 Sampling Objectives

This SAP provides for sampling to meet treatability test objectives and technology performance requirements. The primary objective of sampling is to provide sufficient analytical data to determine the effectiveness of the technology in meeting performance requirements. The data will also provide design and performance information necessary to facilitate full-scale implementation of in situ bio-infiltration. Samples will undergo analysis and testing of analytes and parameters as identified in Tables A-3 and A-4. Samples also will undergo fluorescent tracer analysis to evaluate the extent of groundwater circulation.

A3.2 Sampling Design

This section identifies the design for test sampling and identifies sample locations, sample intervals, and sampling frequencies, to be used to meet project-sampling objectives.

A3.2.1 Monitoring Wells and Associated Vadose Zone Monitoring Apparatus

Three new monitoring wells are planned for the bio-infiltration treatability test. The proposed locations for the well are included in Figure A-2. The locations were chosen such that the area represented by each well is equal. The figure also depicts a planned CERCLA remedial investigation well, 199-K-186. This well is intended to characterize the vadose zone and groundwater at the location of the French drain and the former 120-KW-5 sodium dichromate storage tank. Well 199-K-186 will monitor the uppermost semi-confined water-bearing zone of the RUM, beneath the unconfined aquifer.

The bio-infiltration treatability test monitoring wells will be designed to intercept the uppermost 1.5 to 3.0 m (5 to 10 ft) of the unconfined aquifer. In the immediate vicinity of each of the new wells, lysimeters will be installed at three depths within the vadose zone. The vadose zone monitoring apparatus will provide the means for monitoring the progressive depth of infiltrated nutrient solution and for collected pore water samples. Figures A-3 and A-4, respectively, show the general schematics for the planned monitoring wells and lysimeters.

A3.2.2 Vadose Zone Sediment Sampling and Analysis

During the installation of the three monitoring wells, cores samples will be collected continuously. The core samples will be described in the field and, based on field observations, up to 10 samples per borehole will be submitted for the analyses listed in Table A-3.

Zones of finer-grained materials may also be present locally. Site-specific lithologic and grain size distribution data for the vadose zone of the target area will be obtained from samples collected during the monitoring well installation. If warranted by the results of visual inspection and chemical analysis, selected core samples will be collected for microbiological characterization (e.g., Phospholipid Fatty Acids) and mineralogical analysis by scanning electron microscope (SEM). These microbiological and mineralogical data will be used to help characterize the nature, extent, and magnitude of the biogeochemical changes in the vadose zone produced by the bioremediation activities.

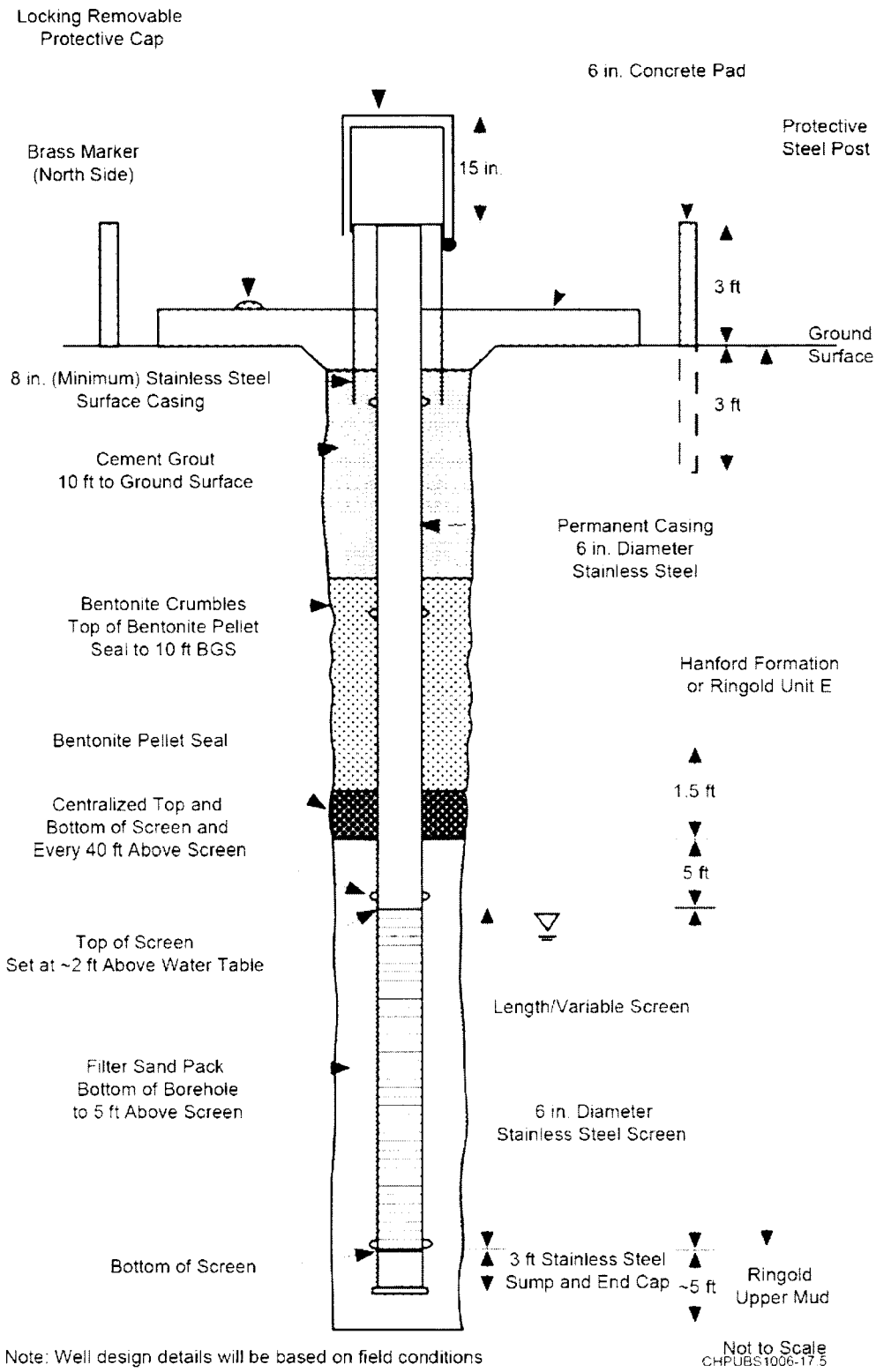
Two additional cores will be collected through the vadose zone during Phase 3 of the treatability test. These core samples will also be analyzed for the parameters listed in Table A-3.

A3.2.3 Groundwater, Pore Water, and Infiltrated Water Monitoring

Three monitoring wells and six lysimeters (with associated tensiometers) will be installed to monitor the shallow groundwater beneath the treatment area and the pore water in the vadose zone immediately before, during, and after the test. The monitoring wells and lysimeters will be grouped into three separate monitoring clusters, each at a different location within the test area. Each cluster will consist of one monitoring well, screened over the upper 1.5 to 3 m (5 to 10 ft) of the water table, and two lysimeters that will be installed between 4.6 to 6.2 m (15 to 20 ft) bgs and 12.2 m to 18.3 m (40 to 60 ft) bgs, respectively.

Table A-6 presents the proposed analyte list and sampling frequency for the monitoring wells and lysimeters. The monitoring well and lysimeter data that are collected will be used for the following purposes:

- Concentrations of total organic carbon (TOC) and the tracer compound will be monitored in samples collected from the lysimeters and monitoring wells samples. These data will provide information on the rate that the wetting front is migrating through the vadose zone and the rate that organic carbon is being consumed by microbial reactions.



Note: Well design details will be based on field conditions

Figure A-3. General Well Schematic

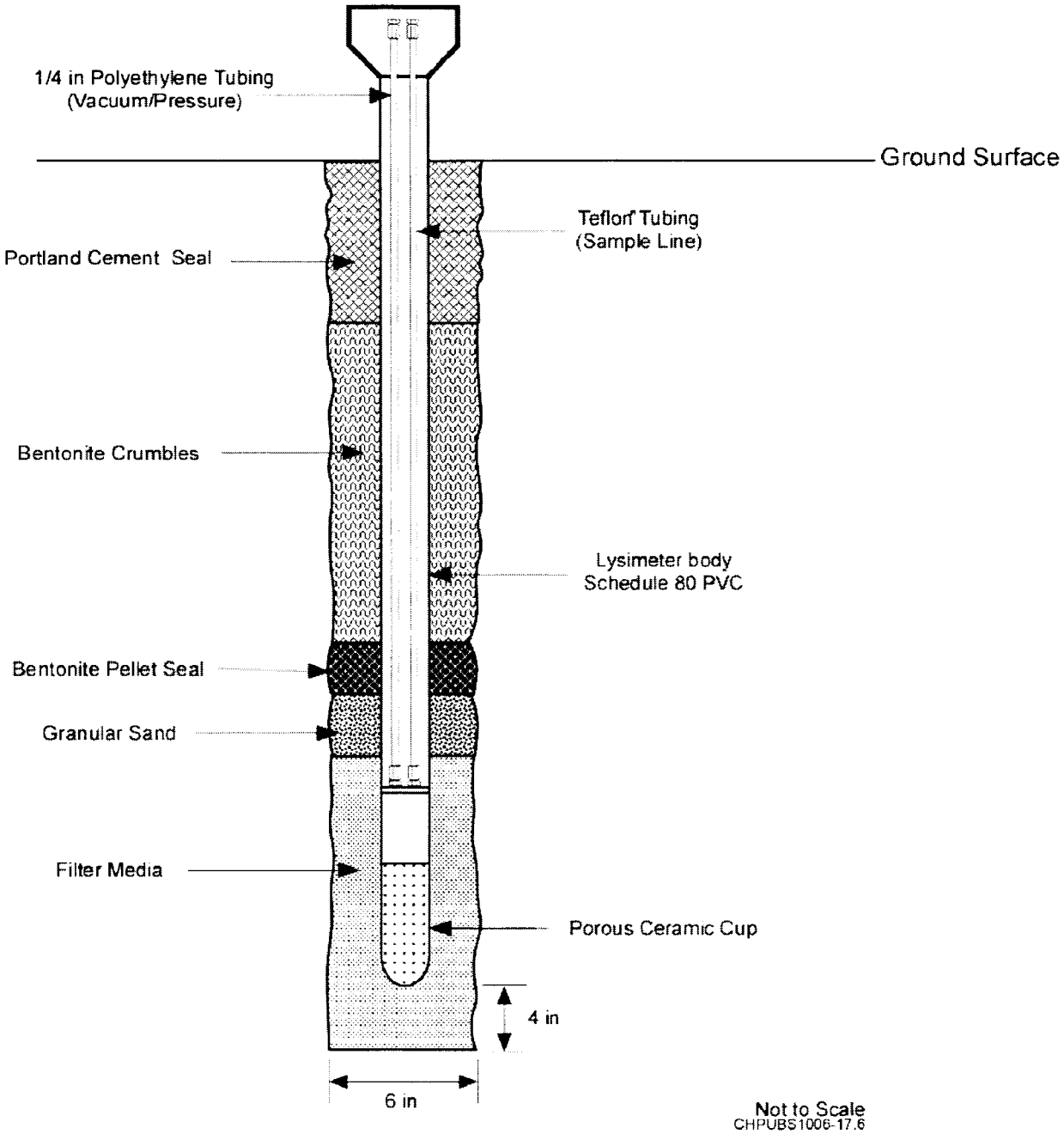


Figure A-4. General Lysimeter Schematic

Table A-6. Monitoring Well, Lysimeter, and Infiltration Solution Analytes and Sampling Frequency

Analytes[a]	TOC	Tracer	Cr(VI)	Total Metals[b]	Dissolved Metals[b]	Anions[c]
Lysimeters[d]	X	X	X	X	N/A	X
Monitoring Wells and Lysimeters[e]	X	X	X	X	X	X
Amended Treatment Water	X	X	X	X	X	X
Phase 1:	Sample twice weekly (with field parameter measurement and visual inspection daily)					
Phases 2 and 3:	Sample weekly					
Phase 4:	Sample daily during the first week and twice weekly thereafter					
Post Test Monitoring:	Sample quarterly					

a. Water levels will be measured at each monitoring well during each sampling event.

b. Total and dissolved metals analyses will include arsenic, calcium, chromium, iron, and manganese, at a minimum.

c. Analysis for anions will include nitrate, nitrite, chloride, and sulfate.

d. If sample volume requirements cannot be met, sample aliquots will be collected according to the following priority: Cr(VI), tracer, TOC, dissolved metals, and anions.

e. Groundwater samples will also be tested for pH, ORP, conductance, and DO. Lysimeter samples will be tested for pH, conductance, and DO, as sample volume allows.

Cr(VI) = hexavalent chromium
DO = dissolved oxygen
N/A = not applicable
ORP = oxygen reduction potential
TOC = total organic carbon

- Hexavalent chromium and total chromium will be monitored in the lysimeters and monitoring well to determine whether Cr(VI) is present in the vadose zone. If present, how much will be flushed to the water table and how quickly and effectively will the Cr(VI) be converted to Cr(III) during the treatability test.
- The concentrations of dissolved iron, dissolved manganese, nitrate, and sulfate will be used to monitor the timing, depth, and intensity of the reducing conditions that develop in the vadose zone and underlying shallow groundwater during the different phases of the treatability test.
- Metals including iron, manganese, arsenic, and others, will be monitored to determine the extent that these constituents are mobilized in the vadose zone during the test and the concentrations and fate of these constituents in the underlying groundwater.

A3.3 Field-Specific Collection Requirements

Treatability test sampling under this SAP will be performed in accordance with site sampling procedures using appropriate sampling equipment. Sampling handling, including container packaging, container labeling, sample custody, and sample transportation, is discussed in this section.

A3.3.1 Sample Packaging

Level I EPA pre-cleaned sample containers will be used for soil, aquifer sediment, and water samples collected for chemical analysis. Container sizes may vary depending on laboratory specific volumes and requirements for meeting analytical detection limits. Radiological Engineering will measure the contamination levels and dose rates associated with the sample containers. This information, along with 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 analytical laboratory in accordance with the laboratory's acceptance criteria. If the dose rate on the outside of a sample container or the Curie content exceeds levels acceptable by an offsite laboratory, the sampling lead, in consultation with Sample Management and Reporting, can send smaller volumes to the laboratory. Preliminary container types and volumes are identified in Tables A-7 and A-8.

Table A-7. Sample Preservation, Container, and Holding Time for Core Samples

Method	Preservation Requirement	Holding Time	Bottle Type	Minimum Sample Size* (g)
EPA 200.8	None	6 months	G/P	15
EPA 6010	Cool ~4°C (~39°F)	6 months	G/P	15
EPA 1311/6010	Cool ~4°C (~39°F)	6 months	G/P	15
EPA 300.0	Cool ~4°C (~39°F)	48 hours/28 days	G/P	50
PLFA	Cool ~4°C (~39°F)	7 days	G	50
SEM Analysis of Mineralogy	None	None	G	50
TOC	None	28 days	aG	50
ASTM A4525-08	None	None	G	1,000
ASTM A422-63	None	None	G/P	1,000

* Based on minimum quality control requirements.

48 hours/28 days = 48 hours for nitrate, nitrite, and phosphate; 28 days for others
°C = degrees Celsius
°F = degrees Fahrenheit
aG = amber glass
g = grams
G = glass
P = plastic
PLFA = phospholipid fatty acid analysis

Table A-8. Sample Preservation, Container, and Holding Time for Water Samples

Method	Preservation Requirement	Holding Time	Bottle Type	Minimum Sample Size* (mL)
EPA 200.8	HNO_3 to pH <2	6 months	G/P	300
EPA 6010	HNO_3 to pH <2	6 months	G/P	300
EPA 7196	Cool ~4°C (~39°F)	24 hours	aG	500
EPA 300.0	Cool ~4°C (~39°F)	48 hours/28 days	P	125
EPA 9060 or EPA 415.1	HCl to pH <2, Cool ~4°C (~39°F)	28 days	aGs	125
Spectrofluorophotometer synchronous analysis	None	None	G	125

* Based on minimum quality control requirements.

48 hours/28 days = 48 hours for nitrate and nitrite; others, 28 days
aG = amber glass
aGs = amber glass septum
C = Celsius
F = Fahrenheit
G = glass
HCl = hydrochloric acid
HNO_3 = nitric acid
mL = milliliter
P = plastic

A3.3.2 Sample Identification

The process samples will be uniquely numbered and the sample number and location will be documented. The sample location and frequency of process samples are summarized in Table A-6. Each sample container and chain-of-custody form must be identified by sample number and sampling authorization form number.

A sample tracking database will be used to track the samples through the collection and laboratory analysis process. The HEIS database is the repository for the laboratory analytical results. The HEIS sample numbers will be issued to the sampling organization for this project. The radiological and physical properties of each sample will be identified and labeled with a unique HEIS sample number. The sample location, depth, and corresponding HEIS numbers will be documented in the sampler's field logbook. Each sample container will be labeled with the following information, using a waterproof marker on firmly affixed, water-resistant labels:

- Sampling authorization form number
- HEIS number
- Sample collection date and time
- Analysis required
- Preservation method (if applicable)

A3.3.3 Field Sample Logbook

Information pertinent to sampling and analysis will be recorded in field checklists and logbooks in accordance with existing sample collection protocols. The sampling team will be responsible for recording relevant sampling information. Entries made in the logbook will be dated and signed by the individual making the entry. Program requirements for managing the generation, identification, transfer, protection, storage, retention, retrieval, and disposition of records will be followed.

A3.3.4 Sample Custody

Sample custody will be maintained in accordance with existing Hanford Site protocols. The custody of samples will be maintained from the time that samples are collected until ultimate disposal of the samples, as appropriate. A chain-of-custody record will be initiated in the field at the time of sampling and will accompany each set of samples shipped to the laboratory. Sample shipping procedures will be followed throughout sample shipment. Each chain-of-custody form will include the sample identification number, associated well identification number, and remediation system designation. The analyses requested for each sample will be indicated on the accompanying chain-of-custody form.

Chain-of-custody procedures will be followed throughout sample collection, storage, transfer, analysis, and disposal to ensure that sample integrity is maintained. Each time the responsibility for the custody of the sample changes, the new and previous custodians must sign the record and note the date and time. A custody seal (i.e., evidence tape) will be affixed to the lid of each sample jar. The container seal will be inscribed with the sampler's initials and the date. Sample custody during laboratory analysis will be addressed in the applicable laboratory's standard operating procedures.

A3.3.5 Sample Shipping

Samples will be transported after authorization from the Soil and Groundwater Remediation Project authorized shipper. If the wells have a medium or high risk of encountering radiological material, radiological surveys will be required. If radiological materials are not anticipated, RCT surveys may not be required if the RCT field readings show no activity above background. As applicable, the RCT will measure the contamination levels and the dose rates on the outside of each sample jar. As applicable, the RCT will also measure the radiological activity on the outside of the sample container (through the container) and will document the highest contact radiological reading in millirem per hour (mrem/h). This information, along with other data, will be used to select proper packaging, marking, labeling, and shipping paperwork in accordance with U.S. Department of Transportation regulations (49 CFR, "Transportation") and to verify that the sample can be received by the analytical laboratory in accordance with the laboratory's acceptance criteria. The sampler will send copies of the shipping documentation to Sample and Data Management within 48 hours of shipment.

As a general guideline, samples with activities less than 0.5 mrem/h can be shipped to an appropriate offsite laboratory (for example, DOE contract laboratory, or a laboratory with a U.S. Nuclear Regulatory Commission or state license for specific radionuclides). Samples with activities between 0.5 and 10 mrem/h can be shipped to an offsite laboratory, although Sample and Data Management will evaluate samples with dose rates within this range on a case-by-case basis. Samples with activities greater than 10 mrem/h will be sent to an onsite laboratory, as arranged by the Sample and Data Management organization.

A3.3.6 Management of Waste

Chapter 11 of the TTP describes waste management.

A4 Health and Safety Plan

Chapter 9 of the TTP describes project health and safety requirements.

A5 References

10 CFR 830, "Nuclear Safety Management," Subpart A, "Quality Assurance Requirements," *Code of Federal Regulations*. Available at: http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&rgn=div6&view=text&node=10:4:0.2.5.26.1&idno=10.

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40 CFR 300, "National Oil and Hazardous Substances Pollution Contingency Plan," *Code of Federal Regulations*. Available at: http://edocket.access.gpo.gov/cfr_2009/julqtr/40cfr300.App.A.htm.

300.440, "Procedures for Planning and Implementing Off-Site Response Actions."

49 CFR, "Transportation," *Code of Federal Regulations*. Available at: http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?type=simple;c=ecfr;cc=ecfr;sid=c7A238ec3D61fA4b0e97d92cbac750c;idno=49;region=DIV1;q1=49%20CFR;rgn=div5;view=text;node=49%3A1.0.1.1.2.

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