



**Department of Energy**  
Richland Operations Office  
P.O. Box 550  
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11-AMCP-0038

DEC 14 2010

Ms. J. A. Hedges, Program Manager  
Nuclear Waste Program  
State of Washington  
Department of Ecology  
3100 Port of Benton  
Richland, Washington 99354

Dear Ms. Hedges:

FIELD TEST PLAN FOR THE URANIUM SEQUESTRATION PILOT TEST,  
DOE/RL-2010-87, DRAFT A AND SAMPLING AND ANALYSIS PLAN FOR THE  
URANIUM SEQUESTRATION PILOT TEST, DOE/RL-2010-88, DRAFT A

This letter transmits the Field Test Plan for the Uranium Sequestration Pilot Test,  
DOE/RL-2010-87, Draft A and Sampling and Analysis Plan for the Uranium Sequestration Pilot  
Test, DOE/RL-2010-88, Draft A to the State of Washington Department of Ecology for review  
and comment within 45 days of receipt.

These plans support the Tri-Party Agreement Milestone M-015-110C, Submit uranium treatment  
technology field test plan as an element of the Resource Conservation and Recovery Act facility  
investigation and remedial investigation for the 200-DV-1 Operable Unit by December 31, 2010.

If you have any questions, please contact me, or your staff may contact, Briant Charboneau, of  
my staff, on (509) 373-6137.

Sincerely,

A handwritten signature in black ink, appearing to read "Richard A. Holten".

Richard A. Holten, Acting Assistant Manager  
for the Central Plateau

AMCP:RDH

Attachments

cc: See Page 2

Ms. J. A. Hedges  
11-AMCP-0038

-2-

DEC 14 2010

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N. M. Menard, Ecology  
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D. Rowland, YN (4) plus 2 CDs  
Administrative Record  
Environmental Portal

cc w/o attachs:

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# Field Test Plan for the Uranium Sequestration Pilot Test

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



Richland Operations  
Office

P.O. Box 550  
Richland, Washington 99352

**Approved for Public Release;**  
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# Field Test Plan for the Uranium Sequestration Pilot Test

Date Published  
November 2010

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



U.S. DEPARTMENT OF  
**ENERGY**

**Richland Operations  
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Richland, Washington 99352

  
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11/29/2010  
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## Approval Page

**Title**            *Field Test Plan for the Uranium Sequestration Pilot Test*

**Approval**        B. L. Charboneau  
                      U.S. Department of Energy, Richland Operations Office

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Signature

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Date

**Concurrence**    (Name of individual)  
                      Washington State Department of Ecology

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Signature

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Date

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## Terms

bgs	below ground surface
CCU	Cold Creek unit
CERCLA	<i>Comprehensive Environmental Response, Compensation, and Liability Act of 1980</i>
CHPRC	CH2M HILL Plateau Remediation Company
DOE	U.S. Department of Energy
RL	U.S. Department of Energy, Richland Operations Office
DQA	data quality assessment
DQO	data quality objective
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
ERT	electrical resistivity tomography
FS	feasibility study
FTP	field test plan
HDU	heat dissipation unit
HEIS	Hanford Environmental Information System
ORP	Office of River Protection
OU	operable unit
PNNL	Pacific Northwest National Laboratory
SAP	sampling and analysis plan
Tri-Party Agreement	<i>Hanford Federal Facility Agreement and Consent Order</i>
USPT	Uranium Sequestration Pilot Test

2



## 1 Project Description

2 In response to the Tri-Party Agreement Milestone M-015-50, the *Deep Vadose Treatability Test Plan for*  
3 *the Hanford Central Plateau* (DOE/RL-2007-56) was issued in March 2008. That plan defines tests  
4 focused on mitigating the potential of technetium-99 and uranium to contaminate groundwater. This field  
5 test plan (FTP) and its associated sampling and analysis plan (SAP) are not only an extension of the Deep  
6 Vadose Treatability Test Plan, but are necessary parts of the remedial investigation/feasibility study  
7 (RI/FS) being conducted to support a cleanup decision for the 200-UW-1 operable unit (OU). The  
8 200-UW-1 OU includes the waste site targeted for this test, which is located in the southwestern portion  
9 of the 200 Area National Priorities List site.

10 The overarching RI/FS document for the 200-UW-1 OU is the *RCRA Facility Investigation/Corrective*  
11 *Measures Study Work Plan for the 200-UP-2 Operable Unit, Hanford Site, Richland, Washington*  
12 (DOE/RL-91-19). The 216-U-8 waste site has since been moved into the 200-UW-1 OU to focus  
13 characterization and eventual remediation of similar geographically grouped waste sites. This FTP  
14 specifically defines the parameters for evaluating uranium sequestration via vadose zone ammonia  
15 injection as a potential remedy. The SAP associated with this FTP is the *Sampling and Analysis Plan for*  
16 *the Uranium Sequestration Pilot Test* (DOE/RL-2010-88).

### 17 1.1 Introduction

18 Some reactive gases and gas-advected aqueous reactants (at low water content) can induce geochemical  
19 changes in sediments that act to render contaminants such as uranium less mobile. A range of potential  
20 amendments was tested in the laboratory by the Pacific Northwest National Laboratory (PNNL) as  
21 described in *Remediation of Uranium in the Hanford Vadose Zone Using Gas-Transported Reactants:*  
22 *Laboratory-Scale Experiments* (PNNL-18879). The amendments targeted either oxidation-reduction  
23 reactions, pH manipulation, or phosphate addition to induce precipitation reactions. Based on the  
24 laboratory results, pH manipulation with ammonia gas proved to be effective in reducing uranium  
25 mobility and is amenable to application in the Hanford vadose zone (PNNL-18879 and PNNL-20004,  
26 *Uranium Sequestration in the Hanford Vadose Zone using Ammonia Gas: FY 2010 Laboratory-Scale*  
27 *Experiments*). Laboratory experiments have shown this process to be robust in many Hanford sediments.

28 Field testing is planned to further evaluate the ammonia process for application in the Hanford vadose  
29 zone to protect groundwater from uranium residing in the deep vadose zone of the Hanford Site Central  
30 Plateau. Groundwater risk mitigation is derived from reducing the fraction of uranium contamination that  
31 is mobile. Uranium sequestration via ammonia injection will be evaluated in a pilot test conducted at the  
32 200-UW-1 OU, located in the 200-West Area of the Hanford Site. The specific test site selected is  
33 adjacent the 216-U-8 Crib in this OU. Figure 1 illustrates the location of the 216-U-8 Crib relative to the  
34 U Plant (Building 221-U) located within the 200-West Area of the Hanford Site.

35 Previous characterization of the 216-U-8 Crib region indicates lateral uranium contamination spread  
36 (D&D-27783, *200-UW-1 Field Summary Report for Fiscal Years 2004 and 2005*). Nature and extent of  
37 the vadose zone plume is defined by waste stream composition, the quantity of waste discharged, and the  
38 heterogeneity of the vadose zone sediments.

39 Uranium contamination is present in two distinct regions at the 216-U-8 Crib—one relatively shallow at  
40 approximately 10.6 m (35 ft) below ground surface (bgs), and another at approximately 58 m (190 ft) bgs  
41 in the tight-grained Cold Creek unit (CCU). Following determination of suitability of one or both of these  
42 regions for the test, installation of test infrastructure will proceed to enable the field test to be conducted.

43



## 1.2 Project Activities

This FTP describes the methodologies that will be used to evaluate uranium sequestration via ammonia injection as a potential remedy for protecting groundwater from deep vadose zone contamination. The test focus is to gather information for use in subsequent FS evaluation of this technology. The test is designed to evaluate delivery of ammonia to a targeted treatment zone and decreases in uranium mobility within the treated zone. This information can be interpreted in terms of FS criteria such as short-term effectiveness, implementability, long-term effectiveness, and cost. The impact to groundwater will not be measureable over the duration of the test; therefore, information needed to conduct fate and transport modeling will be collected so that numerical models can be used to estimate how the treatment is effective for protection of groundwater.

## 2 Treatment Technology Description

The treatment technology being tested is geochemical manipulation via ammonia injection. In January 2010, PNNL reported a laboratory evaluation of gaseous technologies focused on immobilization of uranium (PNNL-18879) that recommended pursuing ammonia injection because it was best suited for field implementation. Additional information about the ammonia gas treatment process is described in PNNL-20004. Additional laboratory tests will be conducted as defined in Section 4.2.2.

As conceptually depicted in Figure 2, when ammonia gas flows into vadose zone sediments, it rapidly partitions into the pore water. A portion of the ammonia dissociates and causes the pore water pH to increase to near pH 12. Under these conditions, desorption of ions and dissolution of aluminosilicates occurs. When ammonia injection is stopped, due to buffering and the loss of ammonia over time, the pH declines and the ions in solution precipitate. These precipitates coat and bind much of the uranium contamination, rendering it less mobile. By reducing the fraction of uranium contamination that is mobile, its potential to contaminate groundwater is reduced.

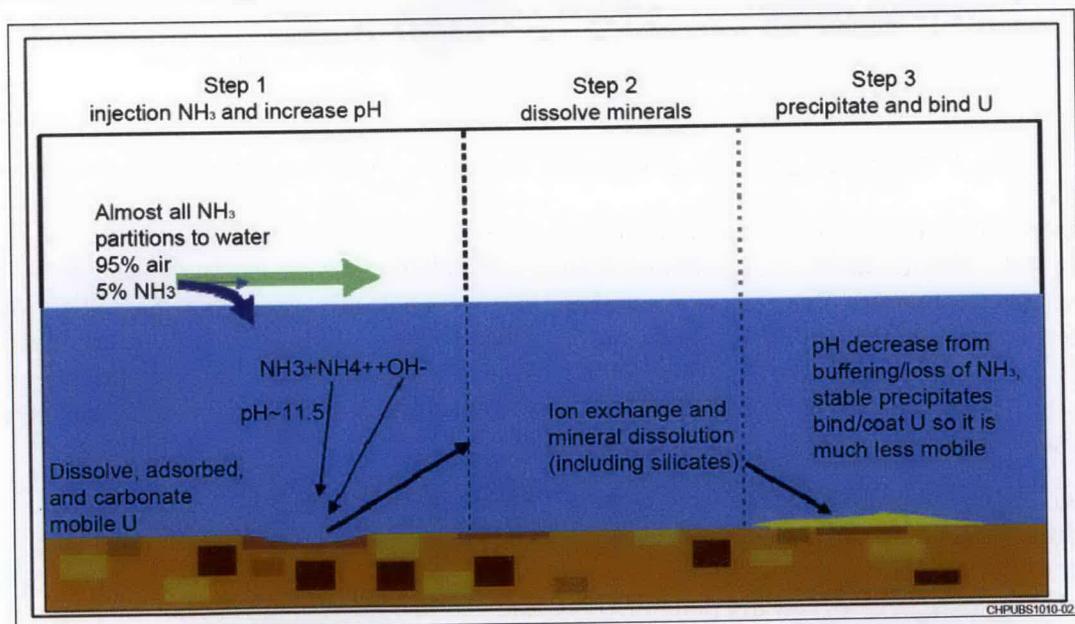
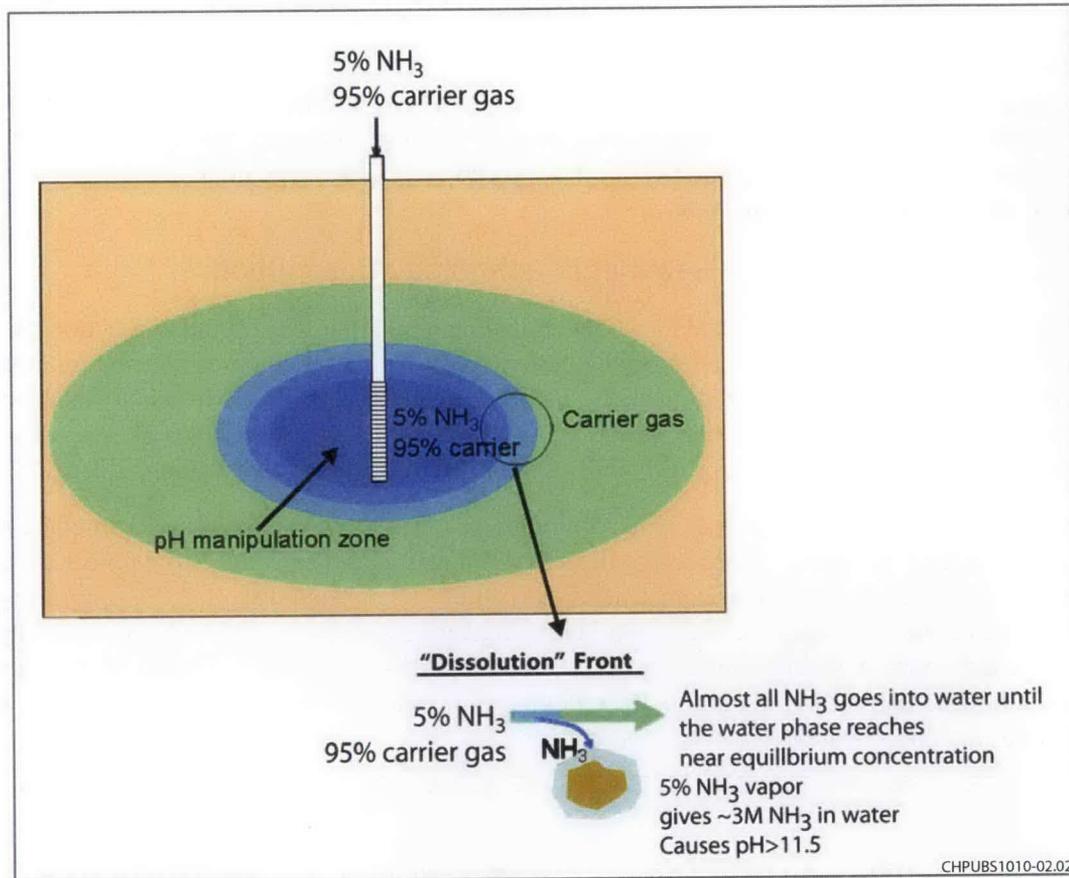


Figure 2. Conceptual Depiction of Ammonia Treatment Mechanism

Field implementation of the ammonia technology involves injection of an ammonia gas mixture into a subsurface target zone. The ammonia partitions into the pore water and approaches a pore water

1 concentration dependant on the concentration of ammonia in the gas phase according to its Henry's law  
2 coefficient. Because partitioning is very rapid and volatility is low, a sharp dissolution front is observed  
3 with near equilibrium ammonia gas and liquid concentrations behind the front and low concentrations  
4 elsewhere (Figure 3); thus, the physical properties of ammonia are favorable for controlled injection.



5  
6 **Figure 3. Conceptual Depiction of Ammonia Distribution in the Subsurface from an Injection Well**

7 Ammonia treatment results in uranium surface phases being coated with or incorporated in  
8 aluminosilicates. In this process, uranium is not chemically reduced, so oxidation state does not affect  
9 treatment effectiveness; thus, the sequestration process is not readily reversible in an oxic vadose zone.  
10 Under post-treatment neutral pH conditions, precipitates formed during ammonia treatment have low  
11 solubility and would dissolve slowly over long time periods as part of natural weathering processes.  
12 Transport of uranium that is bound or coated by precipitates will be limited, thereby reducing the flux of  
13 uranium to the groundwater.

14 As with any gas-phase technology, uniformity of distribution in the vadose zone is impacted by many  
15 factors and may be problematic, especially in low permeability zones. During the ammonia treatment  
16 process, the increase in pore water pH releases ions into solution where they will be in a mobile state until  
17 the pH returns to neutral, causing precipitation reactions. In most vadose zone conditions, movement of  
18 pore water is very slow and pH decrease will occur before any significant movement. In other words, the  
19 reaction processes are rapid compared to contaminant transport. Although this mobilization is temporary,  
20 the duration of pH return to neutral needs to be considered when assessing potential applications of the  
21 technology. The long-term fate of ammonia added to the subsurface to induce uranium treatment is  
22 a) conversion of ammonia to nitrate in the pore water, b) volatilization and upward ammonia gas

1 migration in the vadose zone, and c)  $\text{NH}_4^+$  incorporation into aluminosilicate precipitates. Laboratory data  
2 to date is incomplete with respect to this nitrogen mass balance, but it is likely that the majority of the  
3 nitrogen mass will either remain as ammonia and slowly migrate upward or be slowly converted into  
4 nitrate and a small fraction will be incorporated into precipitates (PNNL-20004).

### 5 **3 Test Objectives**

6 Overall objectives of the uranium sequestration treatability test were listed in the Deep Vadose Zone  
7 Treatability Test Plan (DOE/RL-2007-56). These objectives have been refined based on the selected  
8 reactive gas process (ammonia treatment), and the characteristics of this process identified in laboratory  
9 investigations (PNNL-18879 and PNNL-20004), described as follows:

- 10 • Determine the design parameters for applying uranium sequestration via ammonia injection,  
11 including operational parameters such as reactant flow rates and properties (e.g., gas composition),  
12 and identifying reaction targets to achieve acceptable reduction of mobile uranium content.
- 13 • Demonstrate field-scale treatment for targeted areas within the vadose zone by quantifying the  
14 – operational equipment, parameters, and instrumentation to evaluate implementability of the  
15 process on a large scale  
16 – extent of uranium mobility decrease in the field test treatment zone and comparing to decreases  
17 observed in laboratory-induced treatment of site sediments with a goal of decreasing the mobile  
18 uranium fraction in the sediment by half as determined by a decrease in the amount of uranium  
19 that can be extracted using a sequential application of groundwater, an ion exchange solution, and  
20 a mild acetic acid solution as the extracting solutions  
21 – stability of sequestered uranium in terms of dissolution rate of uranium into the pore water.
- 22 • Collect data to allow consideration of uranium sequestration via ammonia injection as a remedy in the  
23 FS process.

### 24 **4 Experimental Design and Procedures**

25 The treatability test design is intended to evaluate uranium sequestration via vadose zone ammonia  
26 injection as a potential remedy for groundwater protection. Basically, the test consists of a single well  
27 screened within an interval of the vadose zone where significant uranium contamination exists. Ammonia  
28 will be injected into the well to interact with the sediment moisture to increase its pH and render it  
29 sufficiently corrosive to dissolve a fraction of the aluminosilicate minerals that are present. After  
30 ammonia injection is stopped, sediment moisture pH will return to near-normal, resulting in precipitation  
31 of the aluminosilicate minerals and their entrainment of a significant portion of the mobile uranium. The  
32 fundamental objective is to evaluate this form of geochemical manipulation as a means of slowing  
33 contaminant transport.

#### 34 **4.1 Test Site Location and Description**

35 The Uranium Sequestration Pilot Test (USPT) will be conducted at the 216-U-8 Crib (see Figure 1),  
36 which is part of the 200-UW-1 OU. This site was selected because it is known to have mobile uranium  
37 contamination in the vadose zone, and characterization data for the vadose zone is available. Two zones  
38 of contamination suitable for this test are expected—one relatively shallow in the Hanford formation and  
39 another much deeper in the CCU silt layer.

## 4.2 Experimental Design

The experimental design for the field test is guided by the objectives outlined in Section 3.0. These objectives are targeted at collecting information to support inclusion of ammonia treatment as a technology in future *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) feasibility studies. The experimental design includes plans for a shallow and deep treatment zone field test and complementary laboratory experiments. Data from the 216-U-8 Crib area selected as the site for the field test shows uranium contamination extending outside the footprint of the crib in a shallow zone within the Hanford formation and in a deep zone within the silt portion of the CCU. For the field-testing, ammonia injection would occur in the shallow zone first. Data from the shallow test will be used to refine the approach to the deep zone test, if necessary; however, it is expected that the lateral extent of uranium in the shallow zone will be the controlling factor for selecting the test location. Uranium contamination should be more extensive in the CCU silt material such that having a deep test zone directly beneath the Hanford formation test zone will be suitable for the testing. The layout and approach in this FTP assumes that each well-monitoring location is laterally the same for both tests; however, it is expected that separate post-treatment boreholes will be installed to collect sediment samples due to the difference in timing for the shallow and deep tests.

The overall approach uses the following elements to obtain the necessary treatability information for the ammonia technology. The first element of the test is to characterize the selected test site and, if conditions are appropriate to conduct a field test, the characterization data will provide the baseline conditions for treatment. Key baseline characterization information will include pore water chemistry (e.g., pH, solute concentrations, and pore water uranium concentration), the fraction of uranium removed by increasingly harsh extraction solutions (i.e., sequential extractions similar to those conducted by PNNL [PNNL-18879]), and sediment chemistry data for uranium and precipitates/minerals found to be important to the ammonia treatment technology (e.g., PNNL-20004). Sequential extraction analysis with replicates for the untreated samples will provide information on the variability in conditions at the test site and provide a comparison basis for subsequent analysis of laboratory and field-treated sediments. The data from laboratory ammonia treatment of the collected sediments will be the primary data used to evaluate the geochemical treatment and sequestration processes. Subsequent samples collected after field treatment from within the zone of successful ammonia distribution will be analyzed to confirm that the response observed in the field is within the range of responses observed in the laboratory ammonia treatment.

Sediments collected during the test site characterization will be exposed to ammonia treatment in the laboratory. Laboratory ammonia treatment will provide the geochemical data needed to evaluate uranium sequestration under controlled conditions for the target sediments and will provide a basis for comparison with sediments exposed to ammonia treatment in the field. The laboratory data will quantify the increase in pH due to the ammonia exposure and the timescale of pH decrease and associated precipitation/sequestration processes following initial ammonia distribution. The laboratory tests will also include sediment chemistry and leaching studies in the laboratory to evaluate the long-term dissolution of sequestered uranium. The geochemical process and timescale information from the laboratory will be the primary data used to evaluate the ammonia reaction processes for the field site sediments.

A primary objective of the field testing is to evaluate ammonia distribution to treat a targeted zone of the subsurface with testing first conducted in the shallow zone where access is more cost effective. The field test installation will provide a multi-level monitoring network to evaluate three-dimensional gas tracer flow and ammonia distribution in the targeted shallow and deep treatment zones. Permeability and tracer gas testing will provide baseline information about injected gas flow in the treatment zones. Ammonia distribution during injection operations will be evaluated by monitoring for ammonia gas concentrations

1 at the gas sampling locations. Because the partitioning of ammonia is rapid, the observed ammonia gas  
2 concentrations can be used to estimate the associated pore water ammonia concentrations using Henry's  
3 law. These spatial concentration data and the injection volume will provide information to assess the  
4 success of ammonia distribution to obtain the targeted treatment conditions (e.g., pore water ammonia  
5 concentration and associated pH values) within the test zone. If shown to be feasible in laboratory  
6 evaluations, electrical resistance tomography will be applied to provide additional three-dimensional  
7 information about the ammonia distribution based on the increase in pore water conductivity that results  
8 from the dissolution reaction induced by ammonia treatment. Post-treatment sediment samples paired  
9 with pre-treatment sample locations will be collected at the end of the field test to assess whether the  
10 reaction processes and associated uranium sequestration expected, based on the laboratory tests, were  
11 induced in the field test. Post-treatment field test sediments will be analyzed using the same type of pore  
12 water chemistry, sequential extraction, and sediment chemistry/leaching studies conducted on the  
13 laboratory-treated sediments. The timeframe for collection of the post-treatment samples will be based on  
14 the observed geochemical process timeframe in the laboratory. Potentially, other in situ instruments may  
15 provide supporting data to monitor the treatment process during the field test.

16 The sections below describe the details of the planned field and laboratory testing.

#### 17 **4.2.1 Field Test**

18 The field test was designed as described below based on results of laboratory experiments conducted in  
19 fiscal years 2009 and 2010.

##### 20 **4.2.1.1 Field Test Approach**

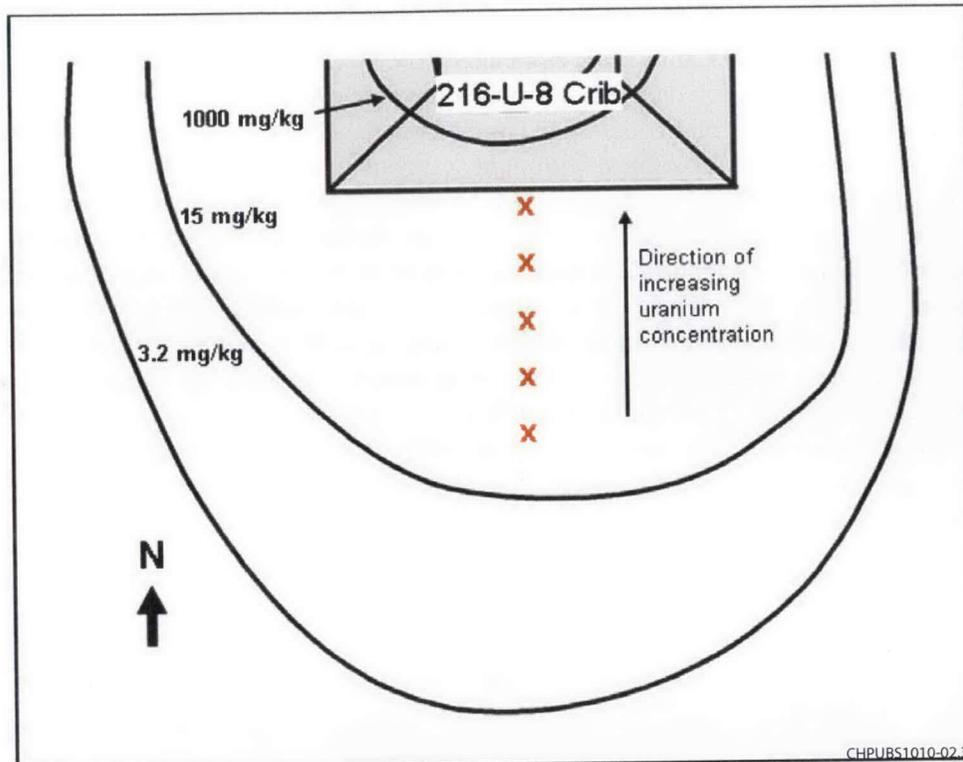
21 The conceptual design uses a single injection well configuration to distribute ammonia into a targeted  
22 treatment zone. The injection well will be located adjacent the 216-U-8 Crib where the uranium  
23 concentration and, potentially, the type of uranium compounds are expected to change with lateral  
24 distance from the crib. A 5 percent ammonia mixture in a carrier gas will be injected to induce uranium  
25 treatment. Onsite ammonia concentration is controlled to limit its hazard. A phased approach to the  
26 treatability test will be implemented as follows:

##### 27 **Phase 1. Field Site Characterization**

- 28 • Install boreholes at the site and sample/analyze in the laboratory to: (1) validate the test site selection,  
29 (2) obtain baseline information for site characterization, (3) determine effectiveness of ammonia on  
30 uranium present at this site, and (4) select target treatment zones.
- 31 • Perform laboratory evaluation of ammonia treatment on opportunistically obtained samples exhibiting  
32 mobile uranium from two wells located within and approximately 30 m (100 ft) east of the  
33 216-U-8 Crib, as follows:
  - 34 – Verify capability of ammonia treatment to statistically reduce mobile uranium content.
  - 35 – Proceed with test if ammonia treatment continues to be promising.

36 These boreholes are being installed as part of remedial investigation activities for the 216-U-8 Crib.

- 37 • Install, geophysically log, and sample five boreholes spaced at approximately 4-m (13-ft) lateral  
38 intervals beginning near the southern edge of the 216-U-8 Crib and extending southward (Figure 4,  
39 conceptual locations marked with "X"), as follows:

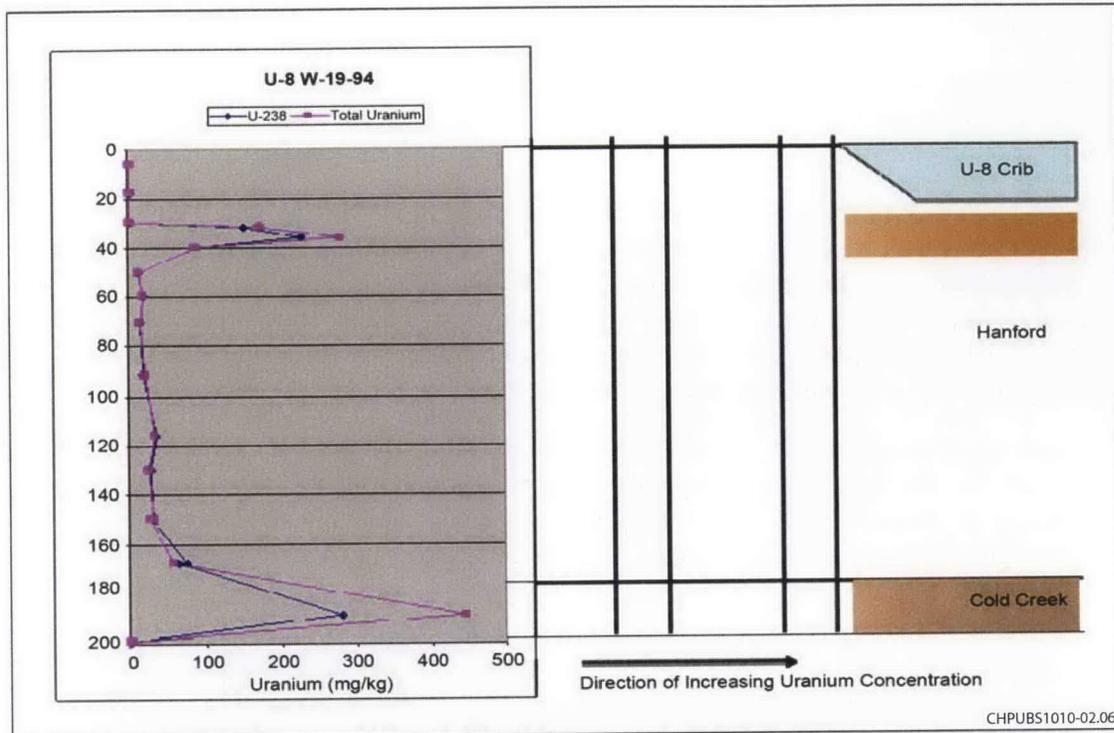


Note: Contours are the estimated uranium sediment concentrations from previous characterization in the upper 25 m of the vadose zone. Not to Scale.

**Figure 4. Conceptual Layout of Phase 1 Boreholes**

- Collect a combination of grab and continuous samples to characterize the sediment, with focus on regions anticipated to exhibit elevated uranium contamination.
- Analyze for physical and chemical properties, with emphasis on sediment pore water.
- Perform sequential extractions (PNNL-18879) to ascertain the fraction of uranium contamination that is mobile.
- Perform laboratory ammonia dosing followed by sequential extractions to evaluate treatment potential.

It is anticipated that the uranium concentration and, potentially, the type of uranium compounds, may change, moving laterally outward from the crib footprint. This concentration gradient will be considered in selecting the test site. Total depth of boreholes will be into the CCU silt zone but above the caliche layer to avoid the potential to accelerate contaminant transport toward groundwater (Figure 5). Sampling will focus on two distinct regions of uranium identified in previous characterization efforts. Details are included in the *Sampling Analysis Plan for the Uranium Sequestration Pilot Test* (DOE/RL-2010-88).



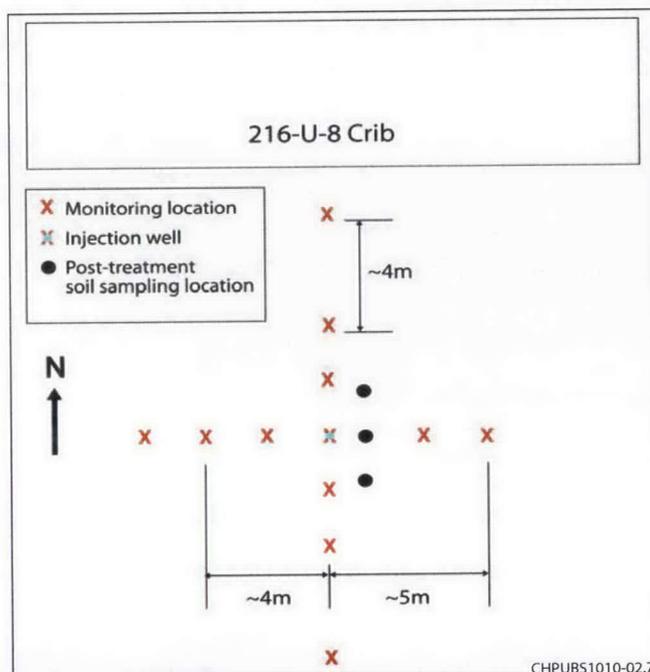
Note: Vertical lines show examples of the initial boreholes installed for Phase 1. Uranium profile is from previous characterization efforts (BHI-00034, 1995, *Borehole Summary Report for the 200-UP-2 Operable Unit, 200 West Area, Rev. 01*). Not to Scale.

**Figure 5. Conceptual Vertical Location of Potential Test Zones (Orange Zones)**

- Determine suitability of the site for field testing using the following criteria:
  - Pore water uranium concentration  $>30 \mu\text{g/L}$
  - Uranium mobile fraction (aqueous, sorbed, and rind)  $>20$  percent of total
  - Laboratory ammonia treatment decreases mobile fraction by at least 50 percent
- Select specific test location(s) (depth and distance from crib) for shallow and/or CCU zones considering the following criteria:
  - Uranium concentration and concentration gradient with preference for a test location with uranium concentrations ranging from 10 to 1,000  $\mu\text{g/g}$  within a target test zone lateral distance of 10 m (33 ft)
  - Thickness of uranium contamination to target depth intervals that can be effectively treated and monitored
  - Shallow zone configuration that enables effective testing of ammonia distribution
- Provide laboratory data for treatment effectiveness as a function of uranium concentration/phase distribution, and pore water chemistry variations observed in sediment samples. These laboratory evaluations are described in more detail in Section 4.2.2.
- Document baseline conditions for the test site.

1 **Phase 2. Field Site Test System**

- 2 • Install initial test system wells and monitoring systems with emphasis on infrastructure to conduct  
3 shallow zone ammonia test. Baseline gas flow in the shallow zone will be evaluated as input to  
4 ammonia injection design.
- 5 • Install ammonia injection well for the shallow test zone at the targeted depth interval and distance  
6 from the crib edge based on Phase 1 data. It is assumed that this location will also be used for the  
7 injection location in the deep CCU zone. Screened intervals are tentatively set at 3 m (10 ft) for a  
8 Hanford formation test and 1 m (3 ft) for a CCU test, but will be refined based on evaluation of  
9 Phase 1 data. Conceptually, the injection well will be located at one of the initial borehole locations,  
10 although the deep zone may be at a different location than for the shallow zone.
- 11 • Complete existing boreholes as instrumented monitoring locations with vertically discrete monitoring  
12 intervals for both the shallow and deep test intervals. Monitoring will focus on obtaining gas samples.  
13 Additional instruments may be installed/applied pending laboratory validation of candidate  
14 instruments. Conceptual monitoring installation details are shown on Figure 6.



Notes: Not to scale.

15  
16 **Figure 6. Conceptual Test Layout**

- 17 • Install, geophysically log, and sample additional lateral monitoring locations as shown conceptually  
18 in Section 4.2.1.2, Test Layout, and additional instructions as follows:
- 19 – Collect additional soil samples from two of the boreholes and analyze them in the laboratory to  
20 characterize lateral variation in parameters.
- 21 – Focus sample collection on the region targeted for the test that was refined by Phase 1 data.  
22 Analyses will be a subset of those performed on Phase 1 samples collected from the initial five  
23 boreholes that include attributes deemed important to the geochemical reaction processes.

1           Because these monitoring locations represent potential post-treatment sampling locations,  
2           laboratory evaluation of ammonia treatment will also be performed.

- 3   • Install a surface barrier to preclude injected gas “short-circuits” to the surface.
- 4   • Install pressure monitoring system for each gas sampling location.
- 5   • Perform borehole anemometry to evaluate the vertical distribution of soil gas flow in the well.
- 6   • Conduct an injection test using gas tracers (SF<sub>6</sub> or other gas) to determine the three-dimensional  
7    injected gas flow pattern. Pressure response will be measured during the test for use in estimating the  
8    bulk air permeability (EM 1110-1-4001).
- 9   • Conduct ammonia gas simulations using geologic data and tracer data to optimize the design of the  
10   field injection test.
- 11   • Conduct a baseline electrical resistivity tomography (ERT) analysis of the target test zones.

### 12   **Phase 3. Conduct Shallow Field Test**

- 13   • Inject sufficient ammonia such that ammonia/pore water reaction front extends approximately 5 to  
14    6 m (16 to 18 ft) from the injection well and monitor the ammonia injection with gas sampling for  
15    ammonia, oxygen, and potentially radon. Conduct ERT characterization monitoring, if feasible,  
16    pending results of laboratory evaluation of the ERT method (Section 5.2).
- 17   • Cease ammonia injection and inject flush gas, if necessary. Allow treatment zone to react over a  
18    timescale as determined in laboratory tests. If feasible, monitor the processes using in situ  
19    instruments, pending results of laboratory evaluation of the instruments (Section 5.2).
- 20   • Quantify ammonia distribution and evaluate with respect to conducting deep zone test (Phase 4).
- 21   • After a timeframe to be determined from the laboratory tests, collect post-treatment sediment samples  
22    at three lateral locations with three vertical samples per location based on ammonia distribution.  
23    Locations of post-treatment samples will be paired laterally and vertically with samples collected in  
24    boreholes prior to treatment. Samples will be collected by advancing a borehole to collect the samples  
25    within 1 m (3 ft) of the previous boreholes/monitoring locations.
- 26   • Evaluate treatment effectiveness in decreasing uranium and technetium-99 and other co-contaminant  
27    mobility through laboratory evaluation of post-treatment sediment samples using the same methods as  
28    applied to the laboratory treated samples from Phase 1.

### 29   **Phase 4. Conduct Deep Field Test**

30   Repeat operational steps defined for shallow test in the deep CCU test interval with the target treatment  
31   zone based on the results of Phases 2 and 3.

32   Soil gas sampling and analysis of borehole sediment samples will be the baseline monitoring techniques  
33   to evaluate treatment performance. The experimental design also is expected to include in situ monitoring  
34   of the ammonia/sediment pore water reaction progress during and immediately following the ammonia  
35   injection period pending laboratory validation of candidate instruments. Candidate monitoring techniques  
36   are listed in Table 1. Laboratory tests will be conducted for each of these candidate techniques to evaluate  
37   the magnitude of response that can be monitored and thereby determine their suitability for field  
38   application.

**Table 1. Candidate In Situ Monitoring Techniques**

Instrument	Function
Sediment coupons	Packet of sediment deployed in wells such that it can be removed at selected times for analysis (pH, electrical conductivity, pore water cations/anions, uranium surface phases).
Thermistor	In situ probe that measures temperature. Temperature can be a measure of when the dissolution front passes a location.
Heat Dissipation Unit (HDU)	In situ probe that collects data to calculate sediment water content or pressure. Also measures sediment temperature.
Resistivity Electrodes	Allows use of cross-borehole/surface electrical resistance tomography (two- or three-dimensional depiction of sediment resistance to electrical current). Potential to track changes in moisture content and solute concentration.
pH sensor	pH sensor capable of providing pH data at low water content or pH sensor deployed in a down-hole within a controlled moisture environment.

#### 1 **4.2.1.2 Test Layout**

2 Figure 6 shows the conceptual layout for the field test with an injection well, monitoring/initial borehole  
3 characterization locations, and post-treatment borehole locations. The layout details, including the total  
4 number of wells/monitoring locations, will be determined using data collected during Phase 1 through  
5 three characterization activities. The target radius of ammonia injection is 5 m (16 ft). Section 5 describes  
6 the anticipated above-ground equipment for the test.

#### 7 **4.2.1.3 Field Test Operations**

8 The field test is planned to have two components, a shallow zone test, and a deep CCU zone test. The  
9 shallow zone test will be conducted first. After evaluation of the ammonia distribution data from the  
10 shallow zone test, the deep zone test will be refined, if needed, and then deep zone testing will be  
11 initiated. Each field test will be operated by injecting ammonia, monitoring ammonia distribution, and  
12 collecting samples to evaluate uranium sequestration effectiveness. Potentially, in situ instruments will be  
13 used to provide additional monitoring of ammonia injection and reaction processes, pending results of  
14 laboratory evaluation (Section 5.2). The duration of injection and monitoring and the monitoring/  
15 sampling locations will be different for the shallow and deep tests; however, each test will be comprised  
16 of the same basic components described as follows. Details of timeframes and locations will be selected  
17 based on the results of Phases 1 and 2. Estimates of the timeframe and locations are provided below.

18 **Ammonia Injection.** A mixed-gas supply will be purchased to contain the 5 percent ammonia and carrier  
19 gas in cylinders that can be attached to a manifold system and regulated for injection at a specified rate.  
20 The injection lines will be installed to deliver the gas into the injection well with use of a packer or other  
21 sealing device so that the gas must exit via the well screen. The injection gas pressure will be slightly  
22 above atmospheric to support ammonia distribution in the subsurface.

23 For the shallow zone test, the gas will be injected at a nominal flow rate of 1.4 m<sup>3</sup>/min (50 ft<sup>3</sup>/min). If the  
24 flow remains relatively horizontal, injection of about 44,000 m<sup>3</sup> (1,553,845 ft<sup>3</sup>) of mixed gas will enable  
25 ammonia to reach a radius of 5 m (16 ft) in about 22 days. If flow is more spherical, injection of about  
26 89,000 m<sup>3</sup> (3,143,005 ft<sup>3</sup>) of mixed gas will enable ammonia to reach a radius of 5 m (16 ft) in about  
27 43 days.

1 Injection into the deep CCU zone may be modified after conducting Phase 1 and 2 characterization.  
2 Based on injection at a nominal flow rate of 0.3 m<sup>3</sup>/min (10 ft<sup>3</sup>/min) (this low injection rate accounts for  
3 the low permeability of the CCU silt), injection of about 110,000 m<sup>3</sup> (3,884,613 ft<sup>3</sup>) of mixed gas will  
4 enable ammonia to reach a radius of 5 m (16 ft) in about 270 days. This calculation assumes that injected  
5 gases will stay within the CCU.

6 The injection process will be monitored for operational parameters including injected volume, flow rate,  
7 temperature, ammonia content, tracer concentrations, and pressure. Subsurface monitoring will include  
8 the items discussed in the next paragraph, "Ammonia Distribution Monitoring."

9 **Ammonia Distribution Monitoring.** Primary ammonia distribution monitoring will be achieved through  
10 collection of gas samples at sampling ports located at different radial and vertical positions with respect to  
11 the injection well. Because the gas-phase and pore water phase ammonia concentrations are expected to  
12 be directly related, ammonia gas-phase concentration can be a primary monitor for ammonia distribution  
13 to the pore water. Based on laboratory experiments, the ammonia partitions rapidly to the pore water such  
14 that a sharp front will develop between the zone where ammonia has partitioned into the pore water to the  
15 target concentration (~3 M) and locations beyond this front. Within this treated zone, gas-phase ammonia  
16 concentration will be near the injected concentration. Outside the treated zone, gas-phase ammonia  
17 concentration will be low; thus, gas-phase ammonia concentration is an effective metric for defining the  
18 treatment volume (injection extent) as it progresses past a monitoring location. The frequency of soil gas  
19 sampling during injection will be finalized based on the site characterization data collected in Phases 1  
20 and 2. Additional monitoring of ammonia injection using electrical resistance, temperature, matric  
21 potential, sediment coupons, and pH may be conducted pending results of laboratory instrument testing  
22 (Section 5.2).

23 **Reaction Monitoring.** Additional flush gas (e.g., carbon dioxide/dinitrogen) may be injected to flush  
24 ammonia from the treatment zone as determined in laboratory studies. Otherwise, natural buffering will  
25 be relied upon to achieve pH reduction to near-normal levels. Results from laboratory ammonia treatment  
26 and monitoring will be used to determine the time required for uranium treatment. After this time interval,  
27 post-treatment sediment samples will be collected from at least three lateral soil sampling locations with  
28 three vertical depths per location and used to evaluate treatment effectiveness as described in Section 5.2.  
29 The sediment samples will be collected through borehole sampling. Additional monitoring of reactions  
30 using electrical resistance, matric potential, sediment coupons, and pH may be conducted pending results  
31 of laboratory instrument testing (Section 5.2).

32 **Evaluating Uranium Sequestration Effectiveness.** Laboratory evaluation of collected sediment samples  
33 will be used to assess uranium sequestration effectiveness. Sediment samples collected for the test will be  
34 used to evaluate the pore water chemistry (e.g., pH, uranium, and other ions), uranium distribution  
35 (e.g., sequential extractions, with sufficient replication for statistical analysis), uranium and precipitate  
36 dissolution (e.g., leaching experiments), sediment chemistry/mineralogy, and solid phase analysis of  
37 uranium surface phases (by electron microprobe and extended X-ray fine structure/X-ray absorption near  
38 edge structure [EXAFS/XANES]) on a limited set of samples. The samples collected in Phase 1 will be  
39 exposed to laboratory ammonia treatment and analyzed as the primary indication of geochemical  
40 processes and uranium sequestration effectiveness. Additionally, post field treatment sediment samples  
41 will be collected at locations paired with pre-treatment borehole samples and analyzed to verify that the  
42 treatment observed in the field at these locations is within the range of treatment effectiveness observed in  
43 the laboratory-treated samples. Analysis details are provided in the SAP (DOE/RL-2010-88).

#### 44 **4.2.1.4 Procedures**

45 Procedures for field operations will be prepared as field test instructions.

#### 1 **4.2.1.5 Technical Basis**

2 A series of laboratory tests were conducted and evaluated ammonia treatment of vadose zone sediments  
3 to decrease the mobility of uranium contamination. Details of these studies are reported by PNNL  
4 (PNNL-18879 and PNNL-20004). In summary, a sequential extraction procedure was used to determine  
5 the amount of uranium that could be extracted from sediment by increasingly harsh extraction solutions.  
6 These data are interpreted in terms of uranium mobility. The first three extractions are mild (groundwater,  
7 an ion exchange solution, and a weak acetic acid) and uranium extracted by these solutions would likely  
8 be relatively mobile with pore water moving through the vadose zone. The next three extractions are  
9 fairly harsh (pH 2.3 acetic acid, oxalic acid, and nitric acid) and uranium extracted by these solutions  
10 would likely be relatively immobile and only released slowly as part of sediment weathering type  
11 processes (e.g., dissolution of precipitates or minerals).

12 In recent laboratory-scale experiments, PNNL researchers applied sequential extractions to a variety of  
13 untreated sediments and to the same type of sediments that were treated with ammonia. In most  
14 sediments, the ammonia treatment resulted in a lower fraction of uranium in the first three (mobile)  
15 extractions. There was also a corresponding increase in the fraction of uranium in the harsh (immobile)  
16 extractions, with the increase in uranium fraction most notable for the most harsh (nitric acid) extraction.  
17 These changes suggest that the ammonia treatment is decreasing the mobility of uranium by binding or  
18 coating uranium with precipitates that do not readily release uranium to the pore water. These data and  
19 additional information are described in detail in PNNL reports of laboratory-scale experiments for  
20 remediation and sequestration of uranium (PNNL-18879 and PNNL-20004), which demonstrate and  
21 describe the ammonia treatment process that is the basis for the field testing.

22 The conceptual mechanism of ammonia treatment was described earlier in Section 2. Laboratory  
23 evaluation and geochemical modeling has been conducted to examine these ammonia treatment  
24 mechanisms (PNNL-20004). In summary, laboratory analysis of pore water associated with treated  
25 sediment and selected mineral components expected in Hanford sediments shows the predicted elevated  
26 pH conditions along with significant increases in solute concentrations, including those associated with  
27 aluminosilicate and other mineral dissolution and ion exchange processes. Solute concentrations then  
28 decline as precipitation occurs. Geochemical modeling confirms these processes. Additional details of  
29 these studies and sediment/precipitate analyses are provided in the uranium sequestration study  
30 (PNNL-20004).

31 The PNNL uranium remediation and sequestration studies (PNNL-18879 and PNNL-20004) also  
32 investigated factors impacting distribution of ammonia within the vadose zone. Ammonia distribution is  
33 strongly influenced by partitioning to the pore water. With a dimensionless Henry's law coefficient  
34 (equilibrium vapor concentration/aqueous concentration) of  $6.58 \times 10^{-4}$ , ammonia readily partitions to the  
35 aqueous phase. PNNL examined the partitioning process and found that rapid partitioning (in seconds)  
36 and associated rapid pore water pH increase initially occurs until pH 10. Partitioning is slower thereafter,  
37 but still relatively rapid compared to the expected gas flow rate in the subsurface.

38 By assuming equilibrium partitioning, a mass balance type calculation can be used to estimate the  
39 ammonia loading needed for a targeted region of sediment at a specified water content and ammonia gas  
40 concentration. Additionally, ammonia dissociation can be computed based on thermodynamic information  
41 so that the pH of the pore water can also be estimated. Table 2 shows the results of this analysis for a  
42 nominal Hanford formation and CCU sediment. While these estimates do not account for all of the  
43 phenomena that can occur, they capture the dominant phenomena. Laboratory testing has confirmed that  
44 these estimates are close to what is observed at the laboratory scale. These calculations will be used as a  
45 baseline estimate operational conditions and material needs for the field test. The spreadsheet calculations  
46 are also useful for comparison to subsequent numerical simulation of the injection process.

1 The spreadsheet-based analysis shown in Table 2 provides an initial basis for the injection design. During  
 2 injection, gas advection, partitioning, and diffusion processes will control the distribution of ammonia.  
 3 Partitioning causes a sharp concentration front in the ammonia gas phase and this front then moves slowly  
 4 compared to the carrier gas advection. The slow advective movement of ammonia and high concentration  
 5 gradient provide a large driving force and relatively long timeframe for diffusional processes to occur.  
 6 Laboratory intermediate-scale tests show ammonia distribution into small-scale low-permeability zones  
 7 adjacent to and embedded in high-permeability zones. The relatively slow advective movement, rapid  
 8 partitioning process, and contribution of diffusion are expected to improve the uniformity of ammonia  
 9 distribution during injection and improve the chances that use of an injection-only design will effectively  
 10 distribute ammonia to the target treatment zone. A more-detailed design associated with gas flow in the  
 11 vadose zone with an injection-only design will be tested using numerical simulations to examine a variety  
 12 of potential subsurface conditions. Unless these simulations show that an injection-only design is not  
 13 likely to function properly, field testing will proceed using an injection-only approach. The simulation  
 14 results will be used as a basis to adjust the injection design in conjunction with the field test site data  
 15 collected in Phases 1 and 2 (e.g., tracer test data).

**Table 2. Spreadsheet Calculations of Ammonia Loading and pH Impact**

Parameter <sup>a</sup>	Hanford formation	Cold Creek unit
Porosity <sup>b</sup>	0.2	0.29
Water Content <sup>b</sup> (g/g)	0.04	0.12
Water Volume Fraction (mL/mL)	0.082	0.204
Gas Volume Fraction (mL/mL)	0.118	0.086
Equilibrium NH <sub>3</sub> Concentration (M)	3.192	3.192
Calculated Equilibrium pH	11.88	11.88
Target Treatment Volume <sup>b</sup> (m <sup>3</sup> )	712	356
Total NH <sub>3</sub> Mass (kg)	3,167	3,940
NH <sub>3</sub> Mass/Pore Volume (kg)	3.0	1.093
Pore Volumes Needed	1,056	3,604
Total Gas Volume Needed (NH <sub>3</sub> + carrier) (m <sup>3</sup> )	88,660	110,280
Gas Flow Rate <sup>b</sup> (ft <sup>3</sup> /min)	50	10
Time for NH <sub>3</sub> Delivery (d)	43	270

a. Calculations are for 5% NH<sub>3</sub> gas, dimensionless Henry's law coefficient of  $6.58 \times 10^{-4}$ , 1 atm, and 17°C. The pH is determined by  $K_{\text{water}}/K_{\text{ammonia}} = [\text{OH}^-][\text{NH}_4^+]/[\text{NH}_3]$  with  $K_{\text{water}} = 1 \times 10^{-14}$  and  $K_{\text{ammonia}} = 1 \times 10^{-9.25}$ .

b. Input parameters with values selected for example calculations based on nominal Hanford formation and Cold Creek unit properties and assumed field test target and operations.

16

17 Table 3 summarizes the relationship between ammonia concentration and pH. Note that very little  
 18 ammonia is required to effect a large pH change.

**Table 3. Ammonia Gas Partitioning to Water and Resulting pH**

% NH <sub>3</sub> (g)	[NH <sub>3</sub> ](aq) <sub>total</sub>	pH
100	15.7 mol/L	12.52
30	9.2 mol/L	12.26

Table 3. Ammonia Gas Partitioning to Water and Resulting pH

% NH <sub>3</sub> (g)	[NH <sub>3</sub> ](aq) <sub>total</sub>	pH
10	6.3 mol/L	12.02
5	3.1 mol/L	11.87
1	0.63 mol/L	11.52
0.3	0.19 mol/L	11.26
0.1	$6.3 \times 10^{-2}$ mol/L	11.02
0.01	$6.3 \times 10^{-3}$ mol/L	10.51
$10^{-3}$	$6.3 \times 10^{-4}$ mol/L	9.99
$10^{-4}$	$6.3 \times 10^{-5}$ mol/L	9.41
$10^{-5}$	$6.3 \times 10^{-6}$ mol/L	8.69 (assumes no other aq. ions)
$10^{-6}$	$6.3 \times 10^{-7}$ mol/L	7.78 (assumes no other aq. ions)

#### 4.2.2 Laboratory Tests Supporting Field Testing

Field testing can provide important information about ammonia distribution and some information about reaction processes; however, laboratory testing can provide additional information about the reaction process and effectiveness that is important for evaluation of the technology at the test site and for application to other Hanford Site locations.

**Sequential Extractions.** As described in this FTP and by PNNL-18879 and PNNL-20004, sequential extractions are a baseline measurement used to evaluate the impact of treatment on uranium mobility. The sequential extraction approach in PNNL-18879 and PNNL-20004 will be modified for future laboratory tests. These modifications are to: (1) address potential long-term release of uranium from sediments (addition of long-term ion exchange extraction), (2) eliminate the oxalate extraction because it did not provide significant value for interpreting the effectiveness of ammonia treatment, and (3) provide a better comparison to methods used for evaluating sorbed uranium by others (e.g., PNNL-17031, *A Site-Wide Perspective on Uranium Geochemistry at the Hanford Site*). The revised extraction solutions are listed as follows:

- Synthetic groundwater (1 h)
- Carbonate solution for ion exchange (1 h)
- Carbonate solution for ion exchange (1,000 h)
- pH 5 sodium-acetate (1 h)
- pH 2.3 acetic acid (1 wk)
- 8 M nitric acid at 95°C (2 h)

Split sediment samples will also be subjected to microwave digestion to measure total uranium concentration.

The sequential extraction process will be applied to both untreated and treated sediments from the test site including use of three replicates per sample and a total of 47 samples collected during Phases 1 and 2.

1 **Leaching Tests.** Sequential extractions evaluate uranium mobility based on an interpretation of how the  
2 extraction relates to uranium transfer into the pore water. Saturated column leaching tests provide a  
3 measure of uranium mobility based on contact with water over time. Column tests are typically conducted  
4 with flowing water initially when uranium concentrations in the effluent are relatively high due to  
5 extraction of uranium initially present in the pore water or sorbed to the sediments. The next phase of  
6 operation uses a periodic flow condition so that uranium concentrations are allowed to build up under  
7 static conditions and then flow is induced to measure the amount of uranium that was released to the  
8 water during the stop-flow time period. Data in *Inhibition Effect of Secondary Phosphate Mineral  
9 Precipitation on Uranium Release from Contaminated Sediments* (Shi et al., 2009) provide an example of  
10 this approach for untreated sediments.

11 Leaching tests will be conducted on a subset of the samples analyzed by sequential extraction. These tests  
12 will provide uranium mobility information that can be analyzed both in terms of a comparison to the  
13 sequential extractions and to estimate uranium transport parameters; for example, the data may support  
14 use of a combined surface complexation and kinetic dissolution model of uranium release into the water.  
15 While these experiments are conducted under saturated conditions, these kinetic parameters can be  
16 translated to unsaturated flow conditions.

17 **Sediment Analysis.** Sediment analyses will be applied to help interpret uranium data and the results of  
18 ammonia treatment. Basic physical property analyses will be conducted as described in the SAP  
19 (DOE/RL-2010-88). For the ammonia treatment process, it is also important to evaluate the sediment  
20 mineralogy. In addition, uranium mineralogy will be examined for both untreated and ammonia treated  
21 samples using laser induced cryogenic fluorescence as described by the uranium sequestration study  
22 (PNNL-20004).

23 Laboratory investigation of mineral dissolution and precipitation processes along with associated  
24 geochemical modeling will also be conducted. These efforts will include some tests in saturated systems  
25 so that relatively large amounts of dissolution and precipitation can be induced to improve the ability to  
26 measure these processes. Due to the experimental nature of these investigations, the approach and  
27 methods for these tests will be developed in the laboratory and are not directly specified in the SAP  
28 (DOE/RL-2010-88).

## 29 5 Equipment and Materials

### 30 5.1 Test Equipment

31 A mixed-gas injection system is planned for the field test. By purchasing the ammonia as a mixed gas at  
32 the target injection concentration, a relatively simple gas cylinder manifold system can be used for the  
33 main injection process. Tracer gas cylinders can be connected to this system as needed. Appropriate mass  
34 flow/pressure regulators can be used to provide and maintain and measure the desired flow rate. The  
35 injection lines deliver the ammonia gas mixture to the well screen interval, which is sealed from the  
36 surface using an inflatable ammonia-resistant packer. After ammonia injection, flush gas can be added  
37 using the same system by switching to the appropriate flush gas mixture in the supply cylinders.

38 The final equipment selection and sizing will be conducted based on the results of Phase 1.

39 The soil gas sampling system will consist of a positive-displacement pump to withdraw soil gas from the  
40 in situ sample ports. An appropriate canister or bag will then be connected to a tee connection to collect  
41 the sample. The gas sampling system will also be configured for connecting an oxygen sensor at the  
42 surface to monitor oxygen as a “negative” tracer for the injected gas during initial operations.

1 In situ instrumentation may be used as described in Section 5.2.

## 2 **5.2 Evaluation of Candidate Instrumentation**

3 This section describes the candidate instruments and the testing that will be used to identify instruments  
4 for use in the field test.

5 **Heat Dissipation Unit.** A heat dissipation unit (HDU) sensor consists of a heating element and a  
6 thermocouple encased in a ceramic matrix. The ceramic relies on hydraulic continuity with the soil for  
7 water exchange. Movement of water between the ceramic and the surrounding soil will occur when a  
8 water potential gradient exists. A change in water potential will change the water content of the ceramic.  
9 At low water contents, the thermal conductivity is controlled by the water content of the ceramic. The  
10 HDU uses a constant current power source to heat the unit, causing a temperature increase that can be  
11 measured and that depends on the thermal conductivity. Sensor variability can be corrected by  
12 normalizing the temperature response using data from when the sensor is completely dry and when  
13 saturated.

$$14 \quad T_{norm} = \frac{\Delta T_{dry} - \Delta T}{\Delta T_{dry} - \Delta T_{wet}} [1]$$

15  
16 The thermal conductivity of the HDU ceramic matrix is a composite of the individual water, vapor, and  
17 solid components. The thermal conductivity of the vapor is temperature dependant and will impart  
18 temperature sensitivity to the HDU measurement. The manufacturer-recommended calibration function  
19 that relates the normalized dimensionless temperature increase to the matric potential (Bilskie et al., 2007,  
20 *Calibration of Heat Dissipation Sensors for Soil Matrix Potential*) is:

$$21 \quad \psi = \frac{(\Delta T_{corr})^{-1/\beta}}{\alpha} [2]$$

22  
23 Where  $\Delta T_{corr}$  is determined using the method outlined in *Calibration and Temperature Correction of*  
24 *Heat Dissipation Matrix Potential Sensors* (Flint et al., 2002). The HDU resolution is approximately  
25 1 kPa for matric potentials between -0.1 MPa and -5 MPa. The HDU requires a second reference  
26 temperature for the measurement. This is typically provided by a thermistor or thermocouple located on  
27 the data logger. Additional error can occur if there are significant temperature differences between the  
28 HDU and reference. Using a thermistor located at or near the HDU could remove or reduce this source of  
29 error.

30 The matric potential is expected to increase behind the dissolution front due to the dissolved ammonia and  
31 its impact on fluid volume and properties. The magnitude of matric potential increase will be tested in the  
32 laboratory using a soil column configured with an HDU sensor and then exposed to ammonia treatment.  
33 These tests will evaluate the magnitude of matric potential change as a function of initial moisture content  
34 and sediment physical properties for the targeted 5 percent ammonia treatment. If the magnitude of  
35 change is significant with respect to the sensitivity of the HDU, it may be considered as an in situ measure  
36 of ammonia content in the pore water.

37 **Thermistor.** A thermistor is a resistor that is typically made from a ceramic or polymer because its  
38 resistance depends on temperature. Thermistors generally operate over a smaller temperature range but  
39 achieve a higher precision temperature measurement. A first order approximation considers the change in  
40 resistance to be linearly dependant on the change in temperature. The slope then can be used to classify

1 thermistors into two groups, positive temperature coefficient, or negative temperature coefficient. For  
2 larger temperature ranges, a linear approximation leads to large errors in the measurement. To achieve  
3 more accurate temperature measurements over the range of interest, a more detailed description must be  
4 used. The Steinhart-Hart equation is a commonly used approximation that can provide temperature  
5 accuracies of approximately 0.02°C. Higher order polynomial approximations also can be used if properly  
6 applied. The planned temperature sensors are encapsulated negative temperature coefficient thermistors.  
7 A fifth-order polynomial will be used for determining temperature from the resistance measurement. This  
8 approach has been tested on several hundred thermistors of this type that were carefully calibrated in a  
9 precision water bath spanning the 0 to 40°C temperature range. By fitting a fifth-order polynomial to all  
10 the sensors, accuracies greater than 0.07°C for more than 99 percent of thermistors were obtained.

11 Dissolution of ammonia gas is exothermic and produces a temperature increase. Thermistors will be  
12 installed in large-scale wedge experiments to evaluate the nature of the temperature signal as the  
13 dissolution front passes the thermistor. If the signal is robust, thermistors will be considered as an  
14 inexpensive in situ instrument to monitor passage of the ammonia dissolution front.

15 **Electrical Resistivity Imaging.** Field, laboratory, and theoretical studies have reported relationships  
16 between the electrical resistivity and physical properties of variably saturated soils. Excellent correlations  
17 between soil electrical resistivity and water content have been demonstrated at laboratory scales;  
18 however, application of the method at field scales presents more challenges to successful implementation.  
19 Relationships between electrical resistivity and soil moisture depend on soil mineralogy, texture,  
20 hydraulic properties, and chemistry. Several petrophysical relationships have been developed, each with  
21 their own advantages and disadvantages. Archie's law is one such relationship that has seen widespread  
22 use relating the bulk electrical conductivity  $C_b$  (the inverse of resistivity) in terms of the porosity  $\phi$ ,  
23 degree of saturation  $S_w = \theta/\phi$ , and electrical conductivity of the saturating fluid  $C_w$  :

$$C_b = C_w \phi^m S_w^n [3]$$

24  
25 The cementation exponent,  $m$ , typically takes on values in the range 1.3 to 2.0 and depends upon the pore  
26 network. The saturation exponent,  $n$ , is related to the wettability of the soil with values normally close to  
27 2. It is assumed here that the mineral component does not significantly contribute to electrical conduction  
28 of the sample. The presence of clay minerals can invalidate this assumption, therefore requiring the use of  
29 alternative descriptions. Determining the parameters that correctly describe the site-specific electrical  
30 resistivity response to moisture changes is a crucial component for monitoring water content changes.

31 Ammonia dissolution and the resultant ion exchange and pH-induced mineral/precipitate dissolution  
32 cause an increase in pore water conductivity. Because electrical resistance imaging can be applied as a  
33 tomographic technique, it offers the potential to provide a two- or three-dimensional image of the  
34 ammonia-treated zone. It may also be able to monitor the decline in conductivity when precipitates form  
35 after pH neutralization. Laboratory soil columns will be used to evaluate the change in bulk sediment  
36 electrical resistivity caused by ammonia treatment and then after pH neutralization. These data will be  
37 evaluated to determine whether the technique can be expected to provide sufficient response in the field to  
38 image the ammonia-treated zone.

39 **pH.** The fundamental uranium sequestration driving force imposed by ammonia treatment is a temporary  
40 change in pore water pH. Measurement of pH by probes is difficult for low moisture content soils;  
41 however, the search for potential pH probes will be continued and potentially viable candidates will be  
42 tested in laboratory soil columns exposed to ammonia treatment.

1 **Sediment Coupons.** The concept of sediment coupons is to use sediment extracted during drilling to  
2 prepare packets (coupons) of sieved sediment that can be deployed within a well where it will be exposed  
3 to the ammonia gas. Coupons can be removed at selected times during the treatment process and sediment  
4 analyses applied to evaluate reaction processes. In this way, the coupon acts as a surrogate of sediment  
5 samples, but can be retrieved more readily and at more frequent intervals than obtaining standard soil  
6 samples. This concept can be tested in a large-scale wedge experiment to evaluate how well the coupons  
7 reflect the type of reactions observed in adjacent flow cell sediments. If results are favorable, a  
8 deployment mechanism for the field will be developed.

## 9 **6 Sampling and Analysis**

10 Sampling and analysis details are provided in the SAP (DOE/RL-2010-88). That document summarizes  
11 the data quality objectives process for the test and provides detailed sampling requirements.

## 12 **7 Data Management**

13 The types of data collected include the following:

- 14 • Signals from in situ instrumentation emplaced to monitor the reaction process
- 15 • Data from periodic neutron moisture logging
- 16 • Data from periodic gas sampling
- 17 • Data from above-ground gauges that measure injected gas properties and power consumption
- 18 • Chemical and physical properties of sediment samples collected during baseline data collection and  
19 following the period of ammonia reaction

20 A project-specific database will be developed and maintained to collect, organize, store, verify/validate,  
21 and manage analytical laboratory data and/or field measurements for environmental samples. The data  
22 will be stored electronically in Microsoft Excel spreadsheets and paper copies will be maintained in the  
23 project files. A project-data custodian will be designated to control and maintain the data. Figure 7  
24 provides a data management flow diagram for information derived from monitoring components and  
25 testing.

26 The Sample Management and Reporting organization, in conjunction with the Project Manager, is  
27 responsible for ensuring that the analytical data are appropriately reviewed, managed, and stored in  
28 accordance with applicable programmatic requirements governing data management procedures. Pertinent  
29 analytical data collected in the laboratory will also be recorded in the Hanford Environmental Information  
30 System (HEIS). Details of the data management plan are included in Appendix A of the SAP  
31 (DOE/RL-2010-88).

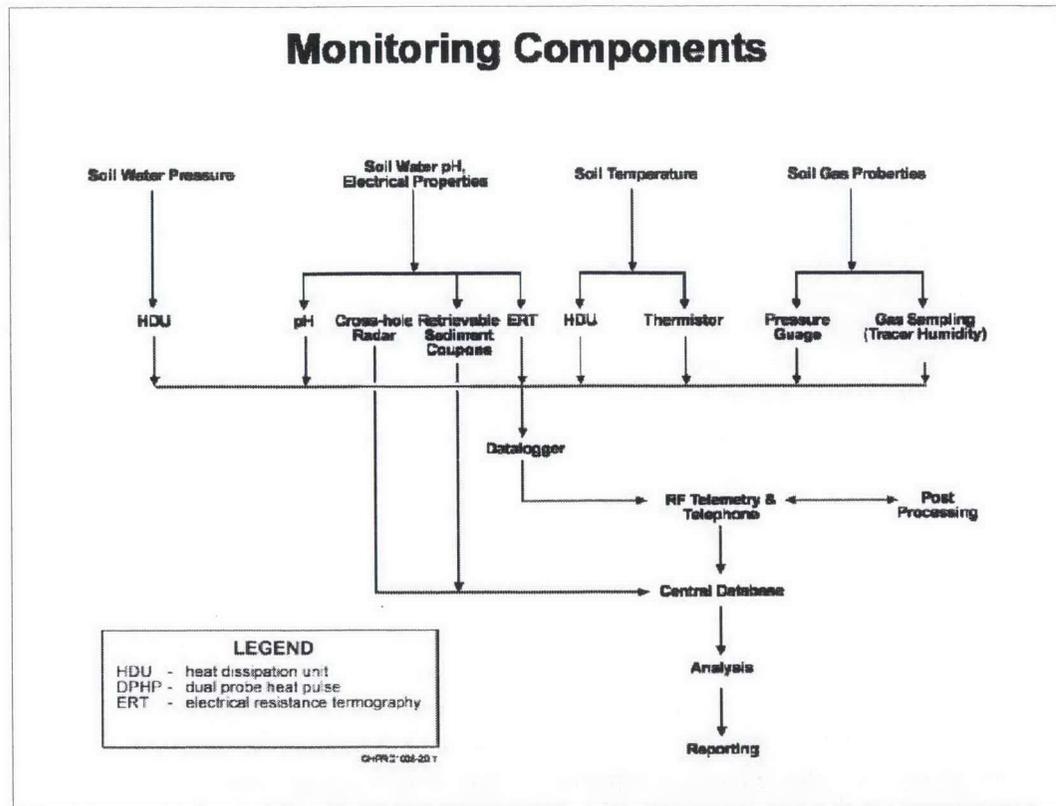


Figure 7. Vadose Zone Monitoring Components, Instrumentation, and Data-Collection Management Flow Diagram for the Uranium Sequestration Pilot Test

## 8 Data Analysis and Interpretation

Evaluation of the uranium sequestration test will include interpretation of: (1) ammonia distribution in the subsurface, (2) treatment effectiveness, (3) operational performance, and (4) results with respect to supporting evaluation of the technology using the CERCLA FS criteria. A description of these elements of the evaluation is provided below.

**Ammonia Distribution.** Ammonia concentration arrival curves at each of the radial and vertical sampling locations will be used to interpret the three-dimensional ammonia distribution at the end of the injection period. Arrival curves will also be used to evaluate the rate of ammonia transport along pathways to each sampling port, and this information will be compared and correlated to the interpreted distribution of sediment physical properties and moisture content. Ammonia arrival will be compared to arrival curves for conservative tracer to evaluate the transport attenuation due to ammonia partitioning into pore water along the flow path. Use of the ammonia as a “partitioning tracer” will provide an estimate of moisture content along the flow path.

If feasible, electrical resistivity tomography will be used to image the final ammonia distribution. Additionally, in situ instruments may be used as indicators of ammonia distribution pending laboratory evaluation (Section 5.2)

**Treatment Effectiveness.** Geochemical reactions induced by ammonia and associated sequestration of uranium will be quantified to evaluate treatment effectiveness for laboratory ammonia-treated sediment samples and then confirmed from post field treatment samples collected from zones where ammonia was

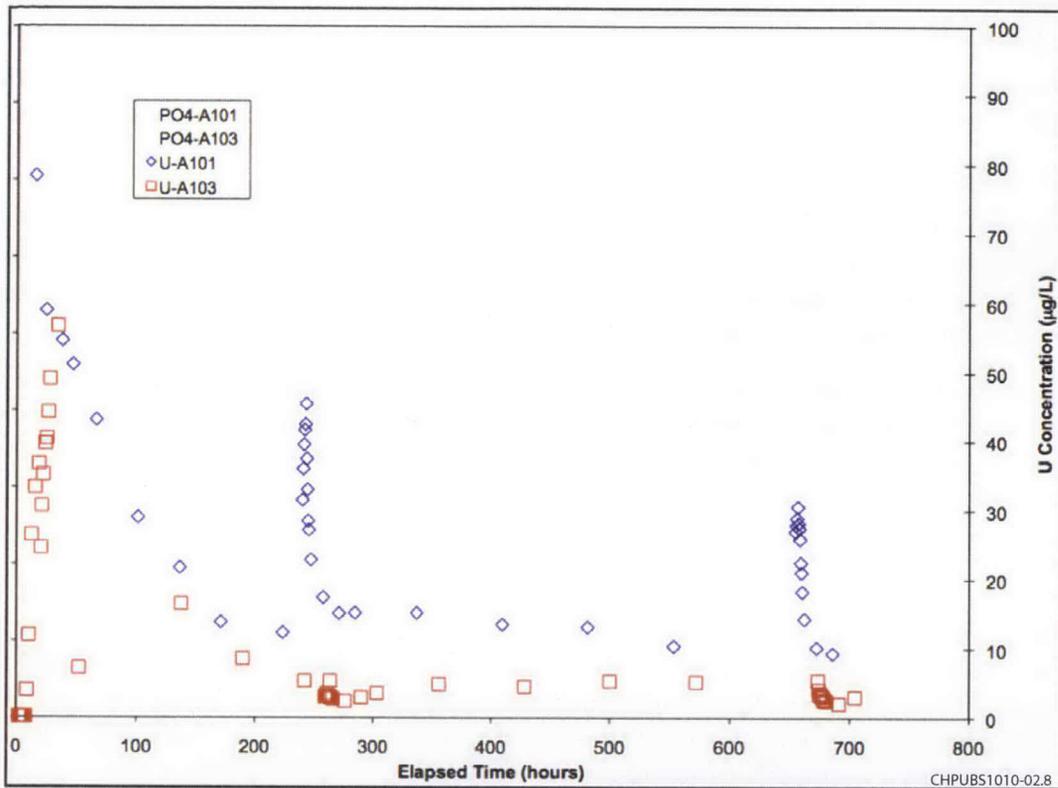
1 shown to be effectively delivered in the field test. Effectiveness will be quantified using the following  
2 methods.

3 Sequential extractions of sediments that were exposed to ammonia will be conducted for comparison to  
4 pre-treatment sediment conditions. For the Phase 1 and 2 laboratory samples, there will be approximately  
5 42 samples subjected to pre-treatment analysis and laboratory ammonia treatment for each treatment zone  
6 (shallow and deep) (five Phase 1 locations at six depths plus two additional locations at six depths). For  
7 the field tests, these analyses will be conducted on paired location pre- and post-test samples from three  
8 locations with three depths per location for a total of nine paired data points for the comparison of pre-  
9 and post-test field results. Results will be evaluated in terms of changes in the fractional quantity of  
10 uranium within each sequential extraction “bin” to evaluate whether the treatment has reduced the amount  
11 in bins associated with relatively mobile uranium and increased the amount in bins that represent  
12 relatively immobile uranium. Statistical comparison of mean concentrations in each bin will be  
13 conducted. For laboratory ammonia treatment, negative controls will be used to conduct sequential  
14 extractions on sediments that were not exposed to ammonia.

15 The stability of sequestered uranium will be evaluated using laboratory leaching experiments for  
16 14 samples selected based on Phase 1 and 2 results. These tests, similar to those conducted for related  
17 studies (Shi et al., 2009), will quantify uranium release over time when treated sediments are exposed to  
18 simulated infiltration water. Leaching methods will be conducted for sediments that were exposed to  
19 ammonia and pre-treatment sediment conditions for comparison of the cumulative mass of uranium  
20 released over time in the leaching. These tests will simulate the natural weathering that would occur over  
21 time. Uranium bound in precipitates is expected to release to the pore water due to dissolution of these  
22 precipitates. Figure 8 shows an example of a comparison of uranium leaching from untreated and  
23 phosphate-treated sediment, which can illustrate whether or not a treatment technology is effective. In this  
24 case, untreated sediment (blue circles) show 85 percent of the uranium desorbed by 200 h (50 pore  
25 volumes), but additional uranium release (and higher concentration) with 200-h stop-flow events (at 260  
26 and 670 h), from diffusion of uranium out of microfractures in sediment. Phosphate treatment of the  
27 sediment results in the 80 percent reduction in uranium release (red squares, unpublished PNNL data) and  
28 of greater significance, uranium release from stop flow events (260 h, 670 h) is extremely limited.

29 Experiments will be conducted under saturated conditions with for three to five samples selected based on  
30 Phase 1 and 2 results with sediments exposed to the pH changes expected in the field test. These  
31 sediments will be examined to evaluate the type of precipitates that are formed. Geochemical modeling  
32 and databases will be used to evaluate the expected weathering and dissolution rates from the precipitates  
33 that are formed to aid interpretation of the data collected on field-treated sediments. Geochemical  
34 information along with sediment characterization collected for the field test site will be used to estimate  
35 fate and transport parameters for pre- and post-treatment conditions.

36 **Operational Performance.** The key factor in operational performance is the ability to effectively  
37 distribute ammonia to the target treatment zone. Tracking of above-ground operational parameters will  
38 provide information on the conditions necessary to maintain injection of the ammonia gas mixture. Tracer  
39 gas distribution and ammonia gas distribution from subsurface monitoring will provide data on the ability  
40 to distribute ammonia to a targeted treatment zone. Breakthrough curves and comparison to pre-test  
41 volume and distribution estimates will be used to evaluate effectiveness. Information on required  
42 equipment and operations will be compiled to assess short-term effectiveness, implementability, and cost.



Note: Leaching of uranium from Hanford sediments with groundwater injection in one-dimensional sediment columns. Untreated sediment (blue circles) show continued release, whereas PO<sub>4</sub>-treated sediment shows 80% less uranium leaching. Stop flow events (200 h each) at 260 and 670 h result in additional uranium release from intragranular pore space.

**Figure 8. Uranium Leaching from Untreated and Phosphate-Treated Sediment**

## 9 Health and Safety

The health and safety requirements for this treatability test are contained in the health and safety plan, which will be issued separately before field work is initiated.

## 10 Waste Management

The waste management requirements for this treatability test are contained in the *Waste Control Plan for the U Plant Closure Area Waste Sites* (SGW-47799). This plan will be issued separately before field work is initiated.

## 11 Community Relations

A key goal of public involvement is to obtain stakeholder perspectives on issues affecting the Tri-Party Agreement, *Hanford Federal Facility Agreement and Consent Order* (Ecology et al., 1989), and to facilitate broad-based participation in the Hanford Site decision-making process. The Tri-Party Agreement agencies, which include the U.S. Department of Energy's Richland Operations Office (DOE-RL) and Office of River Protection (ORP), the U.S. Environmental Protection Agency (EPA), and the Washington State Department of Ecology (Ecology), believe that public involvement is essential to the success of Hanford Site cleanup.

## 11.1 Purpose

The purpose of this chapter is to provide an overview of the public involvement opportunities for this treatability test. It identifies the opportunities to inform and involve stakeholders and the public.

### 11.1.1 Definition of Stakeholders and General Public

Stakeholders are described as individuals who consider themselves affected by and/or have an interest in issues, and commit time and energy to participate in decisions. Hanford Site stakeholders include local governments, local and regional businesses, the Hanford Site workforce, local and regional environmental interests, and local and regional public health organizations.

The general public comprises those individuals who are aware of decisions, but may choose not to be involved in decision making. It is the responsibility of the agencies to provide the public with meaningful information on upcoming Hanford Site decisions so they can choose whether or not they want to participate in the decision-making process.

### 11.1.2 Availability of the Treatability Test Plan

This treatability test plan is being made available to the public by the Tri-Party Agreement agencies by including it in the Administrative Record. No public comment period is required for this test plan; therefore, no formal public review and comment period is scheduled. Tribal nations, stakeholders, and the public are encouraged to use this document and other documents produced during this study as resources for considering the Tri-Party Agreement agencies' decisions concerning the Hanford Site waste sites. Preferred alternatives for these waste sites will be selected only after the public comment period has ended for applicable proposed plans and associated feasibility studies that are supported by this treatability test, and the comments on the proposed plan have been received, reviewed, and considered.

## 11.2 Public Comments

All public comment periods on Tri-Party Agreement documents are announced in regional newspapers. As described above, public comments on this treatability test plan will be received during the formal public review period for applicable proposed plans.

## 12 Reports

Reports to management on data quality issues will be made if and when these issues are identified. These issues will be reported to the project manager by laboratory or field sampling and analysis personnel. Subsequently, standard reporting protocols (e.g., project status reports) will be used to communicate these issues to management. Because no performance or system assessments are planned as part of this treatability test, the project manager will not be providing audit or assessment reports to management unless an unanticipated request is made to conduct such an assessment.

At the end of the project, a data quality assessment (DQA) report will be prepared to evaluate whether the type, quality, and quantity of data that were collected met the intent of the data quality objective (DQO) prepared for this treatability test. After completion of the DQA report, a treatability test report summarizing the results of the test will be included as an appendix in a revision to the FS (DOE/RL-2004-66).

## 13 Schedule

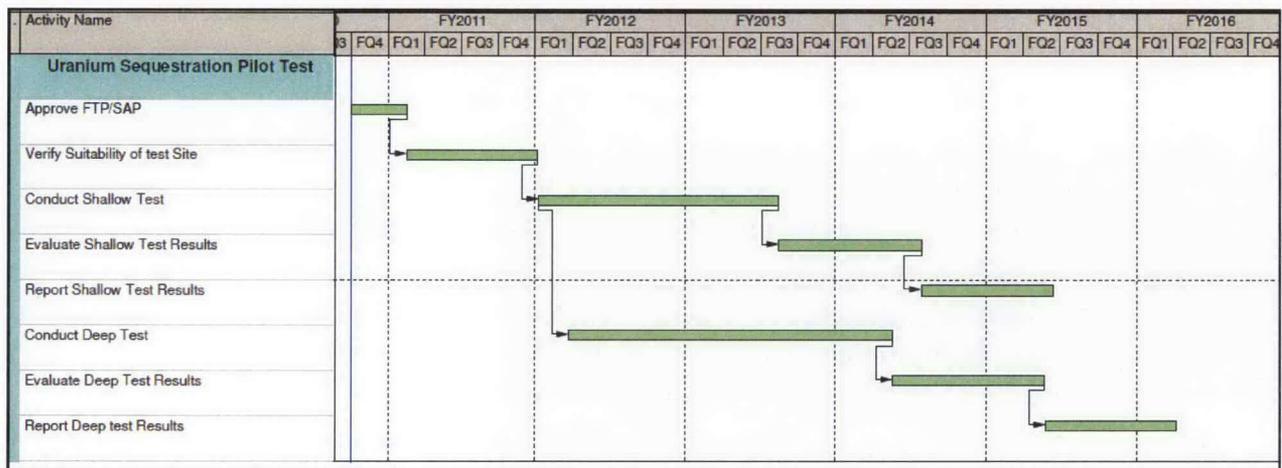
The project schedule and the schedule drivers are listed in Table 4. A more-detailed schedule is provided in Figure 9.

**Table 4. Project Schedule**

Activity	Due Date	Driver
Initiate USPT site characterization	Oct. 31, 2011	Project goal
Complete active portion of shallow test	Nov. 30, 2012	Project goal
Complete active portion of deep test	Jan. 16, 2015	Project goal
Submit RCRA Facility Investigation/Corrective Measures Study, Feasibility Study and Proposed Plan for 200-DV-1 OU to Regulator	Sept. 30, 2012	Tentative Tri-Party Agreement Milestone P-015-110A*

\* Ecology, EPA, and DOE, 2010, *Tentative Agreement on Hanford Federal Facility Agreement and Consent Order Change Forms Implementing the Central Plateau Cleanup Strategy*.

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**Figure 9. Project Schedule**

4

Data obtained from this test is anticipated to support the related tentative Tri-Party Agreement Milestone P-015-110B, which requires submittal of the corrective measures study, the FS, and the associated proposed plan for the 200-DV-1 OU to Ecology by September 30, 2015.

6

7

### 14 Management and Staffing

8

This treatability test will be conducted by the DOE-RL. The test will be managed by CH2M HILL Plateau Remediation Company (CHPRC) Soil and Groundwater Remediation Project personnel. Staffing will include personnel from CHPRC, other Hanford Site contractors, and subcontractors as specified by the CHPRC project manager. The CHPRC project manager will ensure that the personnel selected are qualified to perform all activities in accordance with the requirements specified in this test plan. Specific staffing plans are specified in work planning documents or subcontracts prepared on a task specific basis.

10

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14

### 15 Budget

15

This treatability test will be conducted by the DOE-RL. Funding for all environmental restoration conducted at the Hanford Site is distributed to DOE-RL from DOE Headquarters. Distribution of funds is

16

1 based on the allocation provided to the DOE in the President's Budget. Because of this, it is possible that  
2 not all funds requested for performance of activities are provided in a given fiscal year.

3 The CHPRC project management has prepared detailed cost estimates for the work required to complete  
4 this treatability test. Because not all activities will be completed in a single fiscal year, all that is known  
5 about the budget for completion of this project is what is available in the current fiscal year. As of  
6 publication of this test plan, the activities that will be completed in the first fiscal year of the treatability  
7 test are funded and will be performed as described.

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# Sampling and Analysis Plan for the Uranium Sequestration Pilot Test

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  
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# Sampling and Analysis Plan for the Uranium Sequestration Pilot Test

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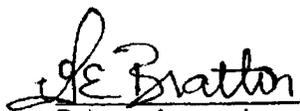
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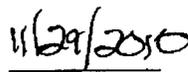


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## Approval Page

**Title**      *Sampling and Analysis Plan for the Uranium Sequestration  
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**Approval**      B.L. Charboneau  
U.S. Department of Energy, Richland Operations Office

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Signature

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Date

**Concurrence**      (Name of individual)  
Washington State Department of Ecology

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Signature

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Date



## Executive Summary

1  
2 This sampling and analysis plan (SAP) describes the field sampling activities and quality  
3 assurance processes for obtaining data of sufficient quality and quantity during conduct  
4 of the Uranium Sequestration Pilot Test (USPT) defined by the field test plan (FTP)  
5 (DOE/RL-2010-87).<sup>1</sup> The test will be located adjacent the 216-U-8 Crib located in the  
6 200-UW-1 operable unit (OU). Operation of the USPT will obtain specific information  
7 for evaluation of uranium sequestration via vadose zone ammonia injection as a treatment  
8 technology for reducing the mobility of contaminants, with emphasis on uranium, with  
9 the potential to have adverse groundwater impact. This test will provide specific  
10 information for remedy selection in the 200-UW-1 OU as well as for consideration of  
11 uranium sequestration via ammonia injection as a remedy in other OUs.

12 This SAP supports the remedial investigation/feasibility study (RI/FS) for the  
13 200-UW-1 OU. The 200-UW-1 OU includes the 216-U-8 Crib and other waste sites  
14 located in the 200-West Area of the 200 Area National Priorities List site. This SAP is an  
15 extension of the FTP (DOE/RL-2010-87), which is a necessary part of the RI/FS process  
16 as initiated by the original RI/FS work plan for these sites. The 200-UW-1 OU was  
17 created in 2004 as selected sites from the 200-IS-1, 200-LW-2, 200-PW-2, 200-PW-3,  
18 200-PW-4, 200-ST-1, 200-SW-1, 200-SW-2, and 200-UR-1 OUs were moved into the  
19 new OU (*Hanford Federal Facility Consent Order Change Control Form*,  
20 Change Number C-03-01, March 16, 2004). The original RI/FS work plan addressing the  
21 216-U-8 Crib is DOE/RL-91-19.<sup>2</sup>

22 Selection of the 216-U-8 Crib for the USPT is based on review of waste sites with  
23 significant uranium inventory with focus on availability and quality of characterization  
24 data, expectation to find mobile uranium and site accessibility. Two tests are planned—one  
25 relatively shallow test in the Hanford formation and a deep test in the silt formation  
26 associated with the Cold Creek unit. Additional characterization will be performed during  
27 the early portion of the test to validate test site selection.

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<sup>1</sup> DOE/RL-2010-87, 2010, *Field Test Plan for the Uranium Sequestration Pilot Test*, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

<sup>2</sup> DOE/RL-91-19, 1993, *RCRA Facility Investigation/Corrective Measures Study Work Plan for the 200-UP-1 Operable Unit, Hanford Site, Richland, Washington*, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: <http://www5.hanford.gov/arpir/?content=findpage&AKey=D196133323>.

1 The USPT will require the installation of approximately 15 new boreholes on the south  
2 side of the 216-U-8 Crib, one of which will serve as the ammonia injection well. The  
3 other boreholes will have instrumentation to monitor the ammonia/sediment pore water  
4 reaction process and collect data to facilitate evaluation of vadose zone ammonia  
5 injection as a potential remedy to protect groundwater from mobile contaminants.  
6 Following the period of ammonia/pore water reaction, three boreholes will be installed to  
7 ground-truth (verify) the data collected from in situ instruments and sensors and to  
8 conduct laboratory evaluation of sequestration effectiveness. The locations of the  
9 boreholes will be based on analysis of data collected during the ammonia/pore water  
10 reaction period.

11 This SAP contains four chapters covering the following topics:

- 12 • Chapter 1 summarizes the recent data quality objective process and required data for  
13 electrical resistivity evaluation.
- 14 • Chapter 2 describes the quality assurance project plan.
- 15 • Chapter 3 describes the field-sampling plan and field-related activities/plans.
- 16 • Chapter 4 provides a list of the references cited.

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18

## Terms

1-D, 3-D	one-dimensional, three-dimensional
3-SD	three-standard deviations
AE	acid extract
AEA	alpha energy analysis
ALARA	as low as reasonably achievable
ASTM	American Society for Testing and Materials
bgs	below ground surface
CCU	Cold Creek unit
CERCLA	<i>Comprehensive Environmental Response, Compensation, and Liability Act of 1980</i>
CHPRC	CH2M HILL Plateau Remediation Company
COPC	contaminant of potential concern
DOE	U.S. Department of Energy
DOE-RL	U.S. Department of Energy, Richland Operations Office
DPHP	dual-probe heat-pulse sensor
DQO	data quality objective
DR	decision rule
DS	decision statement
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
ERT	electrical resistivity tomography
FS	feasibility study
FTP	field test plan
GEA	gamma energy analysis
HDU	heat dissipation unit
HEIS	<i>Hanford Environmental Information System</i>
ICP/MS	inductively coupled plasma/mass spectrometry
LSC	liquid scintillation counting
NA	not applicable
OU	operable unit

PNNL	Pacific Northwest National Laboratory
QA	quality assurance
QAPjP	quality assurance project plan
QC	quality control
RCRA	<i>Resource Conservation and Recovery Act of 1976</i>
RI	remedial investigation
SAP	Sampling and Analysis Plan
SDPT	Soil Desiccation Pilot Test
SGLS	spectral gamma logging system
TBD	to be determined
TIC	total inorganic carbon
Tri-Party Agreement	<i>Hanford Federal Facility Agreement and Consent Order</i> (Ecology et al., 1989)
USPT	Uranium Sequestration Pilot Test
WE	water extract

## 1 Introduction

2 The *Deep Vadose Zone Treatability Test for the Hanford Central Plateau* (DOE/RL-2007-56) includes  
3 focus on uranium sequestration as a potential remedial action. This sampling and analysis plan (SAP)  
4 specifies data collection requirements associated with the *Field Test Plan for the Uranium Sequestration*  
5 *Pilot Test* (DOE/RL-2010-87). Data will be collected in association with the installation of approximately  
6 15 boreholes adjacent the 216-U-8 Crib, during the active portion of the Uranium Sequestration Pilot Test  
7 (USPT), and afterward to evaluate treatment effectiveness. Data collection requirements were identified  
8 during the data quality objectives (DQOs) process in *Data Quality Objectives Summary Report for the*  
9 *Uranium Sequestration Pilot Test* (SGW-46487). The data requirements primarily are directed at  
10 evaluating vadose zone ammonia injection as a potential groundwater protection remedy.

11 This SAP supports the remedial investigation/feasibility study (RI/FS) for the 200-UW-1 operable unit  
12 (OU). The 200-UW-1 OU includes the 216-U-8 Crib and other waste sites located in the 200-West Area  
13 of the 200 Area National Priorities List site. This SAP is an extension of the Field Test Plan (FTP)  
14 (DOE/RL-2010-87), which is a necessary part of the RI/FS process as initiated by the original RI/FS work  
15 plan for these sites. The 200-UW-1 OU was created in 2004 as selected sites from the 200-IS-1,  
16 200-LW-2, 200-PW-2, 200-PW-3, 200-PW-4, 200-ST-1, 200-SW-1, 200-SW-2, and 200-UR-1 OUs were  
17 moved into the new OU (*Hanford Federal Facility Consent Order Change Control Form*,  
18 Change Number C-03-01, March 16, 2004). The original RI/FS work plan addressing the 216-U-8 Crib is  
19 the *RCRA Facility Investigation/Corrective Measures Study Work Plan for the 200-UP-1 Operable Unit*,  
20 *Hanford Site, Richland, Washington* (DOE/RL-91-19).

### 21 1.1 Data Quality Objectives

22 The DQO process for this activity was completed (SGW-46487) consistent with the process described in  
23 *Guidance for the Data Quality Objectives Process*, EPA QA/G-4 (EPA/600/R-96/055). The DQO process  
24 is a strategic planning approach for defining data collection design criteria designed to ensure that the  
25 type, quantity, and quality of environmental data used in decision making are appropriate for the intended  
26 application. Note that EPA/600/R-96/055 was replaced by *Guidance on Systematic Planning Using the*  
27 *Data Quality Objectives Process*, EPA QA/G-4 (EPA/240/B-06/001).

28 This section presents a summary of the key outputs resulting from the DQO process. The decision  
29 statements and decision rules in Table 1 were developed during the preceding DQO process. For  
30 additional details, refer to the DQO summary report (SGW-46487).

#### 31 1.1.1 Statement of the Problem

32 The purpose of this SAP is to define data collection during conduct of the USPT. Successful test results  
33 rely on the ability to perform geochemical manipulation so that associated mobile contaminant transport  
34 is significantly slowed.

#### 35 1.1.2 Decision Statements and Decision Rules

36 Decision statements are developed during the DQO process to consolidate potential questions and  
37 alternative actions. Decision rules are generated from the decision statements. A decision rule is an  
38 "IF...THEN..." statement that incorporates the parameter of interest, unit of decision making, action  
39 level, and action(s) that would result from resolution of the decision. Table 1 presents the decision  
40 statements and decision rules identified in the DQO summary report (SGW-46487).

1 The decision rules are not explicitly quantitative because the purpose of the evaluation is to assess  
2 whether soil desiccation can effectively protect groundwater from mobile contaminants in the vadose  
3 zone. Data generated for this SAP will be appropriately applied to the decision rules in Table 1.

**Table 1. Summary of Decision Rules**

Decision Statement (DS)	Decision Rule (DR)
<b>DS No. 1</b> —Determine whether sediments from planned test interval contain sufficient mobile uranium to evaluate geochemical manipulation via ammonia injection, or if not, this test interval is rejected.	<b>DR No. 1</b> —If the average (or other value as appropriate) concentration of mobile uranium in the 216-U-8 waste site treatability test reaction zone is equivalent or greater than the concentration of mobile uranium used in the lab test, then proceed with the field test. Otherwise, perform additional site characterization to find a suitable location.
<b>DS No. 2</b> —Determine whether laboratory dosing of sediments obtained from planned test interval with ammonia results in reduced mobile uranium content or, if not, this test interval is rejected.	<b>DR No. 2</b> —If the average (or other value as appropriate) mobile uranium content of sediment samples taken from the 216-U-8 waste site treatability test reaction zone was decreased during laboratory ammonia treatment, then proceed with the 216-U-8 field test for uranium mobility reduction (DR No. 4). Otherwise, determine why the mobile uranium content was not decreased.
<b>DS No. 3</b> —Determine whether laboratory dosing of sediments obtained from planned test interval with ammonia results in reduced mobile technetium-99 content, or if not, consider determining why not.	<b>DR No. 3</b> —If the average (or other value as appropriate) mobile technetium-99 content of sediment samples taken from the 216-U-8 waste site treatability test reaction zone was decreased during laboratory ammonia treatment, then proceed with the 216-U-8 field test for technetium-99 mobility reduction (DR No. 4). Otherwise, determine why the mobile technetium-99 content was not decreased.
<b>DS No. 4</b> —Determine whether vadose zone geochemical manipulation via ammonia results in reduction of vadose zone uranium and/or technetium-99 mobility or, if not, this technology is rejected.	<b>DR No. 4</b> —If the average (or other value as appropriate) mobile uranium and/or technetium-99 content in the treatability test target zone were decreased during the treatability test, then evaluate potential future waste site treatment applications in an FS. Otherwise, do not evaluate potential future waste site treatment applications in an FS.

4 **1.1.3 Error Tolerance and Decision Consequences**

5 As explained for the decision statements and rules, evaluation of the data is based on qualitative criteria  
6 rather than quantitative statistical analyses. The borehole locations and the sediment sampling and  
7 analyses activities are based on professional judgment for acquiring information that will resolve the  
8 decision rules. Professional judgment included an evaluation of laboratory testing and modeling of the  
9 Soil Desiccation Pilot Test (SDPT) site.

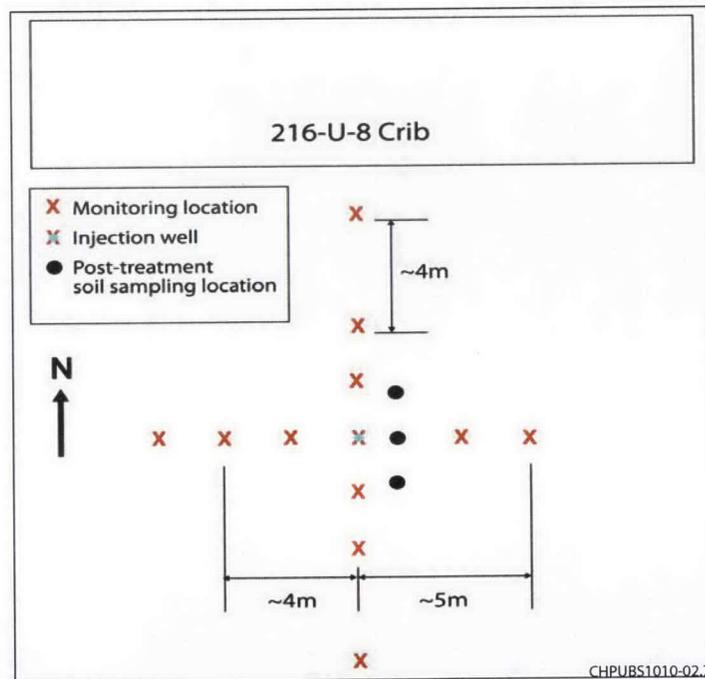
10 **1.2 Summary of Data Quality Objectives (Sampling Design)**

11 This section presents a summary of data required to address the decision statements as presented in the  
12 DQO summary report (SGW-46487).

13 Extensive baseline characterization data will be collected prior to the active portion of the test to guide  
14 final test design and provide a platform for test interpretation. Soil gas sampling will be the baseline  
15 monitoring technique to evaluate treatment processes. The experimental design is expected to include  
16 in situ monitoring of the ammonia/sediment pore water reaction progress during and immediately

1 following the ammonia injection period pending laboratory validation of candidate instruments.  
 2 Laboratory tests will be conducted for each of these candidate techniques to evaluate the magnitude of  
 3 response that can be monitored and, thereby, determine their suitability for field application. Passage of  
 4 the reaction front will be directly measured using sediment gas samples to evaluate ammonia and tracer  
 5 gas concentrations and may be inferred from sediment temperature changes that will be measured using  
 6 thermistors and/or matric potential changes as measured by heat dissipation units. Also pending favorable  
 7 laboratory evaluation, sediment electrical resistivity tomography (ERT) characterization will be  
 8 performed using electrodes emplaced in monitoring boreholes. As ammonia reacts sharply with sediment  
 9 pore water to increase its pH, dissolution of aluminosilicate material will occur, which in turn decreases  
 10 pore water resistivity. Once ammonia injection is stopped, ERT characterization will be used in  
 11 conjunction with other instrumentation to monitor pore water pH return to near-normal. It is the process  
 12 of aluminosilicate dissolution and precipitation in response to pore water pH increase and decrease that  
 13 causes partial sequestration of mobile contaminants. Most monitoring boreholes will include clusters of  
 14 monitoring sensors and/or instruments.

15 Approximately 11 monitoring boreholes and a single ammonia injection well will be installed to conduct  
 16 the USPT. Following the active portion of the test, three additional ground-truthing boreholes are planned  
 17 adjacent to monitoring locations to collect sediment samples for evaluation of sequestration effectiveness.  
 18 Approximate borehole locations are shown in Figure 1.



19

20 **Figure 1. Uranium Sequestration Pilot Test Ammonia Injection Well and Monitoring Borehole Locations**

21 Analytical results and other data obtained will be compared to the decision rules in Table 1. A detailed  
 22 sampling/data collection design is presented in Chapter 3 of this SAP.

23 Table 2 presents the selected analytical methods and performance requirements that will meet the data  
 24 needs. The analyses identified in Table 2 will be completed by an analytical laboratory and will include  
 25 the laboratory quality control (QC) requirements specified in Section 2.2.6 of this SAP.

**Table 2. Information Required to Resolve the Decision Statements**

DS No.	Required Information Category	Specific Information Needed	Field Test Methods	Analytical Methods	Sediment Quantitation Limit (mg/kg)	Pore Water Quantitation Limit (mg/L)	Precision (%)	Accuracy (%)
1	Mobile uranium concentration	Mobile uranium concentration	NA	Water extract per ASA 1996 Kinetic phosphorescence ICP/MS 6020, EPA Method 200.8	0.005	0.005	≤20	80-120
2	Treatment effectiveness	Distribution of leachable uranium	NA	Sequential extractions per PNNL-18879 Kinetic phosphorescence ICP/MS 6020, EPA Method 200.8	0.005	0.005	≤20	80-120
		Mineralogy of sequestered uranium	NA	Laser Induced Cryogenic Fluorescence (Wang et al., 2005)	NA	NA	NA	NA
		Leaching characteristics of sequestered uranium	NA	1-D column experiments that include multiple stop/flow elements	NA	0.005	≤20	80-120
3	Mobile technetium-99 concentration	Mobile technetium-99 concentration	NA	Water extract per ASA 1996 ICP/MS 6020, EPA Method 200.8, or wet chemical separation and LSC	15 pCi/g	15 pCi/L	<30	70-130

Table 2. Information Required to Resolve the Decision Statements

DS No.	Required Information Category	Specific Information Needed	Field Test Methods	Analytical Methods	Sediment Quantitation Limit (mg/kg)	Pore Water Quantitation Limit (mg/L)	Precision (%)	Accuracy (%)
4	In situ treatment effectiveness	Distribution of leachable uranium and technetium-99	NA	Sequential extractions per PNNL-18879 <u>Uranium</u> Kinetic phosphorescence ICP/MS 6020, EPA Method 200.8 <u>Technetium-99</u> ICP/MS 6020, EPA Method 200.8, or wet chemical separation and LSC	U: 0.005  <u>Technetium-99</u> : 15 pCi/g	U: 0.005  <u>Technetium-99</u> : 15 pCi/L	≤30	70-130
Other data needs	Distribution of subsurface moisture, contaminants and sediment properties	Sediment moisture content	Hanford Site-specific versions of the following methods are available from field loggers: ASTM D5753-05 (general logging guidelines) and ASTM D6727-01 (neutron logging)	ASTM D2216-05	1 vol%	NA	≤20	80-120
		Gross sediment activity	Portable field instruments	Gamma energy analysis	10 pCi/g	10 pCi/L	≤20	NA
				Total alpha/beta (WE)	100/5,000 dpm per 100 cm <sup>2</sup>	100/5,000 dpm per 100 cm <sup>2</sup>	≤50	NA
				Total alpha/beta (AE)	100/5,000 dpm per 100 cm <sup>2</sup>	100/5,000 dpm per 100 cm <sup>2</sup>	≤50	NA

5

**Table 2. Information Required to Resolve the Decision Statements**

DS No.	Required Information Category	Specific Information Needed	Field Test Methods	Analytical Methods	Sediment Quantitation Limit (mg/kg)	Pore Water Quantitation Limit (mg/L)	Precision (%)	Accuracy (%)
		Water extract: strontium-90, cesium-137, cations	NA	Water extract per ASA 1996 ASTM C1111-04 or SW-846, EPA Method 6010B	1.0	1.0	≤30	70-130
		Acid extract: strontium-90, cesium-137, cations	NA	Acid extract per ASA 1996 ASTM C1111-04 or SW-846, EPA Method 6010B	1.0	1.0	≤30	70-130
		Water extract: anions	NA	Water extract per ASA 1996 Equivalent ion-chromatography methods: ASTM D4327 or SW-846, EPA Method 9056	1.0	1.0	≤30	70-130
		Total inorganic carbon (carbonate)	NA	EPA SW-846	20	NA	≤30	70-130
		Sediment pore water pH	NA	EPA SW-846, Method 9045	NA	0.05 pH units	≤30	70-130
		Sediment pore water electrical conductivity	NA	ASTM D1125-95 or SW846, EPA Method 9050A	NA	10 μS/cm	≤20	80-120
		Sediment pore water ionic strength	NA	Calculation	NA	10	≤20	80-120

9

Table 2. Information Required to Resolve the Decision Statements

DS No.	Required Information Category	Specific Information Needed	Field Test Methods	Analytical Methods	Sediment Quantitation Limit (mg/kg)	Pore Water Quantitation Limit (mg/L)	Precision (%)	Accuracy (%)
		Uranium mobility characteristics	NA	Sequential extractions per PNNL-18879 & ICP/MS 6020, EPA Method 200.8 ICP/MS 6020, EPA Method 200.8	0.005	0.005	≤20	80-120
		Total uranium in sediment	NA	Microwave digestion and analysis for total uranium EPA SW-846 Method 3052	1.0	1.0	≤30	70-130
		Cation exchange capacity	NA	Routson et al., 1973	NA	NA	NA	NA
		Surface area	NA	ASTM C1251-95	0.001	NA	NA	NA
		Particle size distribution	NA	ASTM D422-63	NA	NA	NA	NA
		Mineralogy/ clays	NA	X-ray Diffraction	NA	NA	NA	NA
		Definition of gas flow paths	Portable field instrument(s) to determine tracer gas concentrations in situ gas samples	Dependant on gas composition	NA	NA	Dependant on gas composition	Dependant on gas composition
		Injected air properties	Field instruments (temperature, pressure, ammonia content, flow rate)	NA	NA	NA	T: ≤1.0°C. P: ≤0.2" H <sub>2</sub> O Flow rate: ≤25 cfm	Variable

7

**Table 2. Information Required to Resolve the Decision Statements**

DS No.	Required Information Category	Specific Information Needed	Field Test Methods	Analytical Methods	Sediment Quantitation Limit (mg/kg)	Pore Water Quantitation Limit (mg/L)	Precision (%)	Accuracy (%)	
8		Lithology	Geologist observations	Sediment types and depths by ASTM D2488-06	1 vol%	NA	≤20	80-120	
		Sediment air permeability	In situ pressure monitoring instruments to determine zone of pressure influence	NA	NA	NA	≤0.2	99-101	
	PneuLog® characterization		NA	NA	NA	NA	NA		
	NA		Wietsma, T.W. et al., 2009	NA	NA	NA	NA		
		Sediment hydraulic permeability	NA	Wietsma, T.W. et al., 2009	NA	NA	NA	NA	
	Monitor ammonia pore water reaction	Sediment temperature	Thermistors* (to measure temperature change associated with passage of ammonia/pore water reaction front)	NA	NA	NA	NA	≤0.1°C	99.5-100.5
		Sediment pore water matric potential	HDU* to measure matric potential of soil in contact with instrument	NA	NA	NA	NA	≤20	80-120
			Matric potential vs. saturation	ASTM D6836-02(2008)e2	NA	NA	NA	NA	NA

**Table 2. Information Required to Resolve the Decision Statements**

DS No.	Required Information Category	Specific Information Needed	Field Test Methods	Analytical Methods	Sediment Quantitation Limit (mg/kg)	Pore Water Quantitation Limit (mg/L)	Precision (%)	Accuracy (%)
		Sediment electrical conductivity	Electrical resistivity tomography*	Ulrich and Slater, 2004	NA	NA	NA	NA
			NA	ASTM G57-06	NA	NA	NA	NA
		Sediment pore water pH	pH sensor* Retrievable sediment coupon	NA	NA	NA	NA	NA
	Effect of treatment on co-contaminants	Strontium mobility change	NA	Change in total strontium is surrogate for strontium-90 Water extract per ASA 1996 Equivalent ion-chromatography methods: ASTM D4327 or SW-846, EPA Method 9056	NA	2	≤30	70-130
		Cesium-137 mobility change	NA	Water extract per ASA 1996 Gamma energy analysis	NA	15 pCi/L	≤30	70-130
		Nitrate mobility change	NA	Water extract per ASA 1996 EPA Method 9056 or Method 300.0	NA	1 to 5, depending on method	≤30	70-130

**Table 2. Information Required to Resolve the Decision Statements**

<b>DS No.</b>	<b>Required Information Category</b>	<b>Specific Information Needed</b>	<b>Field Test Methods</b>	<b>Analytical Methods</b>	<b>Sediment Quantitation Limit (mg/kg)</b>	<b>Pore Water Quantitation Limit (mg/L)</b>	<b>Precision (%)</b>	<b>Accuracy (%)</b>
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Source:

EPA Method 200.8 is found in EPA/600/R-94/111, *Methods for the Determination of Metals in Environmental Samples, Supplement 1*.

EPA Method 300.0 is found in EPA/600/4-79/020, *Methods of Chemical Analysis of Water and Wastes*.

Four-digit EPA methods are found in SW-846, *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods*, Update IV-B.

ASA, 1996, "Methods of Soil Analysis – Part 3, Chemical Methods, SSA Book Series 5," *American Society of Agronomy*.

ASTM C1111-04, *Standard Test Method for Determining Elements in Waste Streams by Inductively Coupled Plasma-Atomic Emission Spectroscopy*.

ASTM C1251-95, *Standard Test Methods for Electrical Conductivity and Resistivity of Water*.

ASTM D1125-95, *Standard Test Methods for Electrical Conductivity and Resistivity of Water*.

ASTM D2216-05, *Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass*.

ASTM D2488-06, *Standard Practice for Description and Identification of Soils (Visual-Manual Procedure)*.

ASTM D4327-03, *Standard Test Method for Anions in Water by Chemically Suppressed Ion Chromatography*.

ASTM D5753-05, *Standard Guide for Planning and Conducting Borehole Geophysical Logging*.

ASTM D6727-01, *Standard Guide for Conducting Borehole Geophysical Logging-Neutron*.

PNNL-18879, *Remediation of Uranium in the Hanford Vadose Zone Using Gas-Transported Reactants: Laboratory-Scale Experiments*.

Routson et al., 1973, "A Column Cation-Exchange-Capacity Procedure for Low-Exchange Capacity Sands."

Ulrich, C. and L.D. Slater, 2004, "Induced polarization measurements on unsaturated, unconsolidated sands."

Wang et al., 2005, "Cryogenic laser induced U(VI) fluorescence studies of a U(VI) substituted natural calcite: Implications to U(VI) speciation in contaminated Hanford sediments."

Wietsma et al., 2009, "An automated apparatus for constant flux, constant head, and falling head hydraulic conductivity measurements."

® PneuLog is a registered trademark of Praxis Environmental Technologies, Inc., Burlingame, California.

\* Precision and accuracy requirements as identified and defined in referenced EPA and procedures implemented by laboratory analysis and quality assurance procedures.

**1.3 Targeted Parameters**

The targeted parameters for evaluating treatment effectiveness include risk-based and other contaminants of potential concern (COPCs), anions and cations, and geochemical and physical sediment properties. Nonradionuclide and radionuclide lists of COPCs for the 216-U-8 Crib were evaluated in the DQO summary report (SGW-46487).

Table 3 summarizes the final set of targeted parameters identified in the DQO.

**Table 3. Targeted Parameters**

Risk-Based COPCs*	Other COPCs	Anions and Cations	Geochemical and Physical Properties
Uranium	Cesium-137	Potassium	Sediment moisture content
Technetium-99	Strontium-90	Sodium	Sediment particle size distribution
Nitrate		Calcium	Sediment pore water pH
		Magnesium	Sediment matric potential
		Total iron	Mineralogy
		Chromium	Sequestered mineral dissolution characteristics
		Copper	Specific electrical conductivity of sediment pore water
		Lead	Borehole neutron moisture and natural gamma logs
		Manganese	
		Chloride	Sediment air permeability
		Fluoride	Sediment electrical resistivity
		Sulfate	Sediment temperature
		Phosphate	Subsurface pressure & gas composition
			Lithology

\* COPCs from SGW-46487.

**2 Quality Assurance Project Plan**

The Quality Assurance Project Plan (QAPjP) establishes the quality requirements for environmental data collection, including sampling, field measurements, and laboratory analysis. This QAPjP complies with the requirements of the following:

- 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*

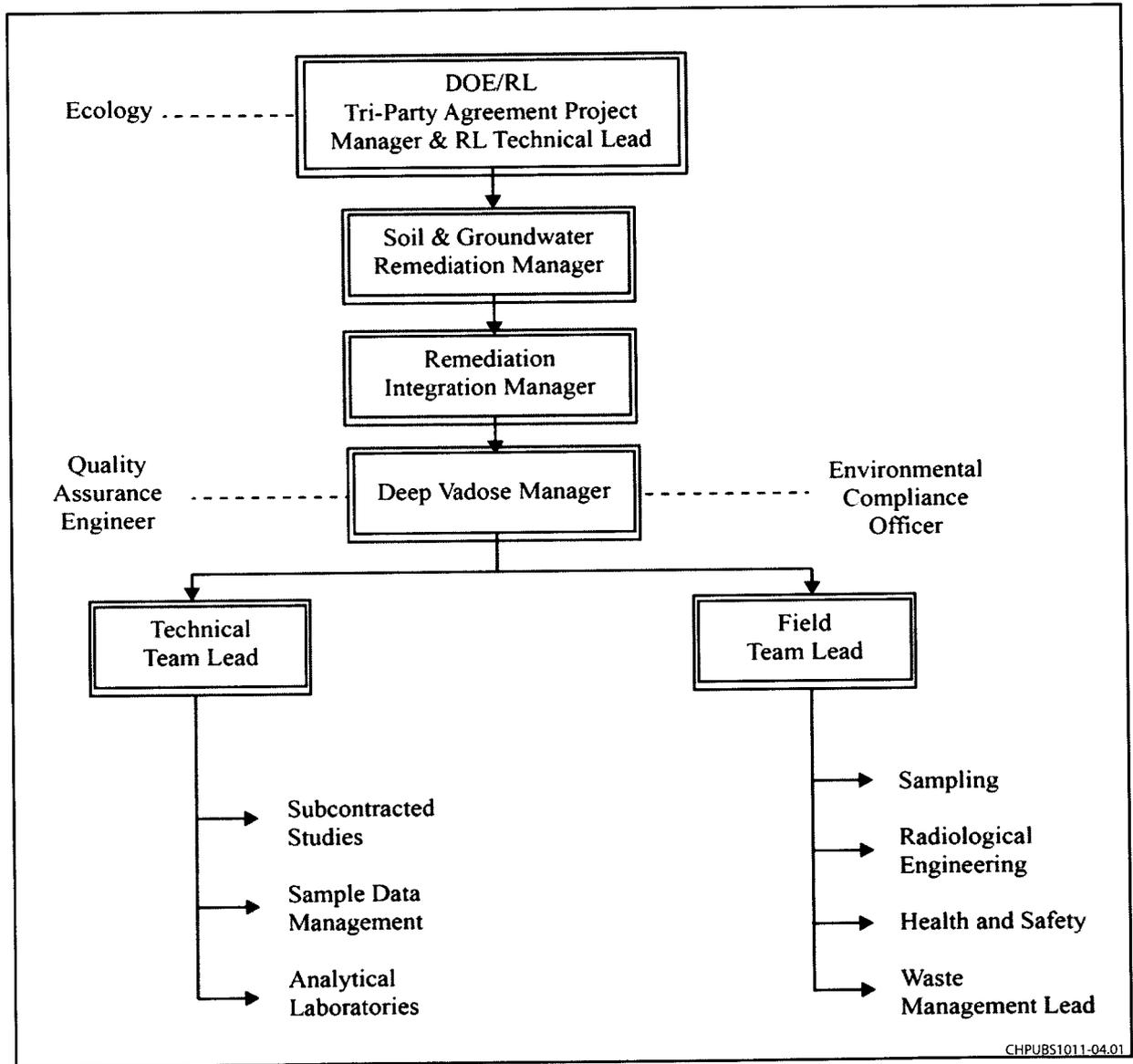
The following sections describe the quality requirements and controls applicable to this investigation.

**2.1 Project Management**

This section addresses the basic areas of project management and ensures that the project has a defined goal, that the participants understand the goal and the approach to be used, and that the planned outputs have been appropriately documented.

1 **2.1.1 Project/Task Organization**

2 CH2M HILL Plateau Remediation Company (CHPRC) or its approved subcontractor is responsible for  
 3 collecting, packaging, and shipping samples to the laboratory. CHPRC will select a laboratory to perform  
 4 the analyses; the selected laboratory must conform to Hanford Site laboratory procedures (or equivalent),  
 5 as approved by the U.S. Department of Energy, Richland Operations Office (DOE-RL), and the  
 6 U.S. Environmental Protection Agency (EPA). CHPRC is responsible for managing all interfaces among  
 7 subcontractors involved in executing the work described in this SAP. The project organization is  
 8 described in the subsections that follow and is shown in Figure 2.



9

10 **Figure 2. Project Organization Chart**

10

11 **2.1.1.1 Regulatory Project Manager**

12 As the lead regulatory agency, the Washington State Department of Ecology (Ecology) has an assigned  
 13 project manager for overseeing the cleanup projects and activities. As the lead regulatory agency, Ecology

1 has approval authority for the work performed under this FTP. Ecology will work with Department of  
2 Energy (DOE) to resolve concerns regarding the work as described in this FTP in accordance with the  
3 *Hanford Federal Facility Agreement and Consent Order* (Ecology et al., 1989), hereafter referred to as  
4 the Tri-Party Agreement.

#### 5 **2.1.1.2 Tri-Party Agreement Manager and DOE-RL Technical Lead**

6 The DOE-RL is responsible for the Hanford cleanup. The Tri-Party Agreement Project Manager is  
7 responsible for authorizing the contractor to perform Hanford Site activities in accordance with the  
8 *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA); the  
9 *Resource Conservation and Recovery Act of 1976* (RCRA); the *Atomic Energy Act of 1954*; and the  
10 Tri-Party Agreement. In addition, the Tri-Party Agreement Project Manager is responsible for obtaining  
11 lead regulatory agency approval of the FTP that authorizes the activities under the Tri-Party Agreement  
12 (Ecology et al., 1989). The DOE-RL Technical Lead is responsible for working with the contractor and  
13 the regulatory agencies to identify and work through issues, and providing technical input to the Tri-Party  
14 Agreement Project Manager.

#### 15 **2.1.1.3 Deep Vadose Zone Manager**

16 The Deep Vadose Zone Manager provides oversight for all activities and coordinates with DOE-RL, the  
17 regulators, and CHPRC management in support of sampling activities. In addition, the Deep Vadose Zone  
18 Manager provides support to the Field Team Lead to ensure that work is performed safely and cost  
19 effectively. The Deep Vadose Zone Manager maintains the approved QAPjP.

#### 20 **2.1.1.4 Field Team Lead**

21 The Field Team Lead has overall responsibility for the planning, coordination, and execution of field  
22 activities. Specific responsibilities include converting the sampling design requirements into field task  
23 instructions that provide specific direction for field activities. Responsibilities also include directing  
24 training, mock-ups, and practice sessions with field personnel to ensure that the sampling design is  
25 understood and can be performed as specified. The Field Team Lead communicates with the Technical  
26 Lead to identify field constraints that could affect the sampling design. In addition, the Field Team Lead  
27 directs the procurement and installation of materials and equipment needed to support fieldwork.

28 The Field Team Lead oversees field-sampling activities including sample collection and packaging;  
29 provision of certified clean sampling bottles/containers; documentation of sampling activities in  
30 controlled logbooks, chain-of-custody documentation, and packaging; and transportation of samples to  
31 the laboratory or shipping center.

#### 32 **2.1.1.5 Technical Lead**

33 The Technical Lead is responsible for direct management of sampling documents and requirements, and  
34 subcontracted tasks. The Technical Lead ensures that Field personnel including samplers and others  
35 responsible for implementation of the SAP and QAPjP, are provided with current copies of this document  
36 and any revisions thereto. The Technical Lead works closely with the Quality Assurance (QA) and Health  
37 and Safety organizations and the Field personnel to promulgate the SAP and QAPjP requirements with  
38 them and the other lead disciplines in planning and implementing the scope of work. The Technical Lead  
39 coordinates with and reports to DOE-RL and CHPRC management on all sampling activities. The  
40 Technical Lead has discretionary authority to make the final sampling objective determination and  
41 supports DOE-RL in coordinating sampling activities with the regulators. In the event of uncertainty,  
42 DOE-RL and EPA are contacted.

1 **2.1.1.6 Quality Assurance Engineer**

2 The QA Engineer is matrixed to the Deep Vadose Zone Manager and is responsible for QA on the  
3 project. Responsibilities include oversight of implementation of the project QA requirements; review of  
4 project documents including DQO summary reports, SAPs, and the QAPjP; and participation in QA  
5 assessments on sample collection and analysis activities, as appropriate.

6 **2.1.1.7 Environmental Compliance Officer**

7 The Environmental Compliance Officer is matrixed to the Deep Vadose Zone Manager, provides  
8 technical oversight, direction, and acceptance of project and subcontracted environmental work, and  
9 develops appropriate mitigation measures with a goal of minimizing adverse environmental impacts. The  
10 Environmental Compliance Officer also reviews plans, procedures, and technical documents to ensure  
11 that all environmental requirements are addressed; identifies environmental issues that affect operations  
12 and develops cost-effective solutions; and responds to environmental and regulatory issues or concerns  
13 raised by the DOE and/or regulatory agency staff.

14 **2.1.1.8 Waste Management Lead**

15 The Waste Management Lead communicates policies and procedures and ensures project compliance for  
16 storage, transportation, disposal, and waste tracking in a safe and cost-effective manner. Other  
17 responsibilities include identifying waste management sampling/characterization requirements to ensure  
18 regulatory compliance and interpreting the characterization data to generate waste designations, profiles,  
19 and other documents that confirm compliance with waste-acceptance criteria.

20 **2.1.1.9 Radiological Engineering**

21 The Radiological Engineering organization is responsible for the radiological engineering and health  
22 physics support for the project. Specific responsibilities include conducting as low as reasonably  
23 achievable (ALARA) reviews, exposure and release modeling, and radiological controls optimization for  
24 all work planning. In addition, radiological hazards are identified and appropriate controls are  
25 implemented to maintain worker exposures to hazards at ALARA levels. Radiological Engineering  
26 interfaces with the project Health and Safety Representative and plans and directs radiological control  
27 technician support for all activities.

28 **2.1.1.10 Sample and Data Management**

29 The Sample and Data Management organization ensures that laboratories providing analytical services for  
30 this SAP conform to Hanford Site internal laboratory QA requirements (or their equivalent), as approved  
31 by DOE-RL, the EPA, and Ecology. Sample and Data Management receives the analytical data from the  
32 laboratories, performs data entry into the *Hanford Environmental Information System* (HEIS) database,  
33 and arranges for data validation.

34 **2.1.1.11 Health and Safety**

35 The Health and Safety organization's responsibilities include coordination of industrial safety and health  
36 support within the project as carried out through health and safety plans, job hazard analyses, and other  
37 pertinent safety documents required by federal regulations or by internal CHPRC work requirements. In  
38 addition, assistance is provided to project personnel in complying with applicable health and safety  
39 standards and requirements. Personal protective equipment requirements are coordinated with  
40 Radiological Engineering.

41 **2.1.2 Problem Definition/Background**

42 The definition of the problem is provided in Section 1.1.1 of this SAP.

1 **2.1.3 Project/Task Description**

2 One borehole will be installed to inject ammonia into the vadose zone. Eleven additional boreholes will  
3 be installed to collect information during conduct of the USPT. Instrumentation associated with these  
4 holes will monitor the ammonia/sediment pore water reaction progress during the active portion of the  
5 test and pore water pH return to near-normal following shutdown of ammonia injection. Data will be used  
6 to evaluate uranium sequestration via vadose zone ammonia injection as a potential remedy to protect  
7 groundwater from mobile contaminants deep in the vadose zone. Following pH return to near-normal,  
8 three additional boreholes will be installed to ground-truth the data and evaluate treatment effectiveness.  
9 Evaluation will be in the form of a treatability test report.

10 **2.1.4 Quality Objectives and Criteria**

11 Quality objectives and criteria (including analytical methods, detection limits, and precision and accuracy  
12 requirements for each analysis to be performed) are summarized in Table 2.

13 The QA objective of this plan is to develop implementation guidance that will provide data of known and  
14 appropriate quality. Data quality is assessed by accuracy and precision, evaluation against the identified  
15 DQOs, and evaluation against the work activities identified in this SAP. The applicable QC guidelines,  
16 quantitative target limits, and levels of effort for assessing data quality are dictated by the intended use of  
17 the data and the nature of the analytical method, which are addressed in the following subsections.

18 **2.1.4.1 Representativeness**

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

24 **2.1.4.2 Accuracy**

25 Accuracy is an assessment of the closeness of the measured value to the true value. Accuracy of chemical  
26 test results is assessed by spiking samples with known standards and establishing the average recovery. A  
27 matrix spike is the addition to a sample of a known amount of a standard compound similar to the  
28 compounds being measured. Radionuclide measurements that require chemical separations use this  
29 technique to measure method performance. For radionuclide measurements analyzed by gamma  
30 spectroscopy, laboratories typically compare the results of blind audit samples against known standards to  
31 establish accuracy. Validity of calibrations is evaluated by comparing results from the measurement of a  
32 standard to known values and/or by generating in-house statistical limits based on three-standard  
33 deviations (i.e., 3-SD). Table 2 lists the accuracy requirements for fixed laboratory analyses for the  
34 project.

35 **2.1.4.3 Precision**

36 Precision is a measure of the data spread when more than one measurement has been taken using the same  
37 sample. Precision can be expressed as the relative percent difference for duplicate measurements.  
38 Analytical precision requirements for fixed laboratory analyses are listed in Table 2.

39 **2.1.4.4 Comparability**

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

1 **2.1.4.5 Completeness**

2 Uranium, technetium-99, sodium, and nitrate are the most important analytes for the technical evaluation.  
3 The analytical data set for this SAP will be considered incomplete if these analytes are not included. If  
4 one or more of the other analytical parameters in Table 2 is not reported, the Technical Lead or designee  
5 will determine whether the data set is complete for this SAP.

6 **2.1.4.6 Detection Limits**

7 Detection limits are functions of the analytical method used to provide the data and the quantity of the  
8 sample available for analyses. Detection limits identified for analyses for this project are listed in Table 2.

9 **2.1.5 Special Training Certification**

10 Typical training or certification requirements have been instituted by CHPRC to meet the training  
11 requirements imposed by such documents as the CHPRC contract (DE-AC06-08DOE-RL14788, *Contract*  
12 *Between the U.S. Department of Energy, Richland Operations Office, and CH2M Hill Plateau*  
13 *Remediation Company*), regulations, DOE orders, contractor requirements documents, American National  
14 Standards Institute/American Society of Mechanical Engineers standards, and the *Washington*  
15 *Administrative Code*. The Environmental Health and Safety Training Program provide workers with the  
16 knowledge and skills necessary to execute assigned duties safely. Field personnel typically will have  
17 completed the following training before starting work:

- 18 • Occupational Safety and Health Administration 40-Hour Hazardous Waste Worker Training
- 19 • 8-Hour Hazardous Waste Worker Refresher Training (as required)
- 20 • Radiological Worker Training
- 21 • Hanford General Employee Training

22 A graded approach is used to ensure that workers receive a level of training that is commensurate with  
23 their responsibilities and that complies with applicable DOE orders and government regulations.  
24 Specialized employee training includes pre-job briefings, on-the-job training, emergency preparedness,  
25 plan-of-the-day activities, and facility/worksites orientations. Field personnel training records will be  
26 documented and kept on file by the training organization. Training requirements for specific tasks are  
27 determined by personnel with expertise in the relevant subject area. The Field Team Lead is responsible  
28 for ensuring that training requirements are appropriately established.

29 **2.1.6 Documentation and Records**

30 The Technical Lead ensures that the Field Team Lead, samplers, and others responsible for  
31 implementation of this SAP and QAPjP are provided with current copies of this document and any  
32 revisions thereto. Documentation and records, regardless of medium or format, are controlled in  
33 accordance with internal work requirements and processes that comprise a collection of document control  
34 systems and processes that use a graded approach for the preparation, review, approval, distribution, use,  
35 revision, storage/retention, retrieval, disposition, and protection of documents and records generated or  
36 received in support of CHPRC work.

37 All information pertinent to data collection, field sampling, and analysis will be recorded in bound  
38 logbooks or other forms of media as required by applicable protocols. The sampling team will be  
39 responsible for recording all relevant sampling information in the logbooks. Entries made in the logbook  
40 will be dated and signed by the individual making the entry.

41 A treatability test report, based on the data collected, will be prepared. The report will support the  
42 development and evaluation of remedial alternatives through the feasibility study process. A

1 contractor-level document (i.e., a borehole summary report) will be produced to summarize field activities  
2 and to capture field-screening and geophysical data that are collected during installation of the boreholes  
3 used to collect in situ data. Another borehole summary report will capture similar data from those  
4 boreholes installed to collect sediment samples following the active portion of the test. The borehole  
5 summary report will be consistent with similar documents prepared for other boreholes at the  
6 Hanford Site. Project documentation and records will be prepared, approved, and maintained according to  
7 DOE-RL and contractor requirements.

## 8 **2.2 Data Generation and Acquisition**

9 This section presents the requirements for sampling methods, sample handling and custody, analytical  
10 methods, and field and laboratory QC. The requirements for instrument calibration and maintenance,  
11 supply inspections, and data management are also addressed.

### 12 **2.2.1 Sampling Process Design**

13 Professional judgment was applied to selecting monitoring locations, sediment sampling intervals,  
14 sediment samples, and condensate samples planned for laboratory analyses. Specific locations of the  
15 resulting sediment samples will be determined following the active portion of this test, based on progress  
16 of the desiccation front as indicated by in situ instrumentation and geophysical characterization. Proposed  
17 locations may be influenced by site-specific conditions (e.g., limited sample volume or inability to obtain  
18 a sample). The field team will note in the daily field sampling logbook any instance of inability to collect  
19 samples due to field conditions, and these events will be discussed in the follow-up borehole summary  
20 report. Sample locations may be adjusted based on visual or field screening methods that may indicate a  
21 better sampling location to meet the DQOs (e.g., higher concentrations at a different depth). Additional  
22 depth locations may be sampled, based on the judgment of field personnel and the Technical Lead, and  
23 based on real-time field conditions.

24 Borehole locations will be staked before the field engineer begins drilling. Minor changes in sample  
25 locations can be made and documented in the field with the approval of the Technical Lead. Changes to  
26 sample locations that could result in impacts to meeting the DQOs will require DOE-RL and EPA  
27 approval.

### 28 **2.2.2 Sampling Methods**

29 The planned borehole sampling for this SAP will be performed in accordance with established sampling  
30 practices and requirements pertaining to sample collection, collection equipment, and sample handling.  
31 The Field Team Lead is responsible for ensuring that all field procedures are followed completely and  
32 that field personnel are trained adequately. The Field Team Lead must document situations that may  
33 impair the usability of the samples and/or data in the field logbook or on nonconformance report forms in  
34 accordance with internal corrective-action procedures, as appropriate. The Field Team Lead will note any  
35 deviations from the standard procedures for sample collection, COPCs, sample transport, or monitoring  
36 that occurs. The Field Team Lead also will be responsible for coordinating all activities relating to the use  
37 of field-monitoring equipment (e.g., dosimeters and industrial-hygiene equipment). Field personnel will  
38 document in the logbook all noncompliant measurements taken during field sampling. Ultimately, the  
39 Field Team Lead will be responsible for developing, implementing, and communicating corrective-action  
40 procedures, for documenting all deviations from procedure, and for ensuring that immediate corrective  
41 actions are applied to field activities. Problems with sample collection, custody, or data acquisition that  
42 adversely impact the quality of data, or impair the ability to acquire data, or fail to follow procedure, will  
43 be documented in accordance with internal corrective-action procedures, as appropriate.

1 Sample preservation, containers, holding times, and sampling-method details for chemical and  
2 radiological analytes of interest and physical property analyses are presented in Section 3.3.1. Final  
3 sample-collection requirements will be identified on the Sampling Authorization Form.

### 4 **2.2.3 Sample Handling, Shipping, and Custody Requirements**

5 Level 1 EPA pre-cleaned sample containers will be used for samples collected for chemical analysis.  
6 Reusable containers used for sample collection (e.g., bowls and scoops) will be cleaned to Level 1 EPA  
7 protocol before each use. Container sizes may vary depending on laboratory-specific  
8 volumes/requirements for meeting analytical detection limits. Planned container types and volumes are  
9 identified in Section 3.3.1. The final types and volumes will be indicated on the Sampling Authorization  
10 Form.

11 The CHPRC sample and data-tracking database will be used to track the samples from the point of  
12 collection through the laboratory analysis process. The HEIS database is the repository for laboratory  
13 analytical results. The HEIS sample numbers will be issued to the sampling organization for this project  
14 in accordance with onsite organization procedures. Each chemical/radiological and physical properties  
15 sample will be identified and labeled with a unique HEIS sample number. The sample location, depth,  
16 and corresponding HEIS numbers will be documented in the sampler's field logbook.

17 Each sample container will be labeled with the following information using a waterproof marker on  
18 firmly affixed, water-resistant labels:

- 19 • Sampling Authorization Form
- 20 • HEIS number
- 21 • Sample collection date/time
- 22 • Name of person collecting the sample
- 23 • Analysis required
- 24 • Preservation method (if applicable)

25 A custody seal (i.e., evidence tape) will be affixed to the lid of each sample jar in a manner that will  
26 indicate potential tampering with the sample. The container seal will be inscribed with the sampler's  
27 initials and the date. For volatile organic analysis samples, the seal shall be on the outer container rather  
28 than the sample container.

29 All information pertinent to field sampling and analysis will be recorded in field checklists and bound  
30 logbooks in accordance with existing sample-collection protocols. Laboratory custody procedures will  
31 ensure the maintenance of sample integrity and identification throughout the analytical process. The  
32 sampling team will be responsible for recording all relevant sampling information. Entries made in the  
33 logbook will be dated and signed by the individual making the entry. Program requirements for managing  
34 the generation, identification, transfer, protection, storage, retention, retrieval, and disposition of records  
35 by CHPRC also will be followed.

36 Sample custody will be maintained in accordance with existing Hanford Site protocols. The custody of  
37 samples will be maintained from collection through ultimate disposal, as appropriate. A chain-of-custody  
38 record will be initiated in the field at the time of sampling and will accompany each set of samples  
39 shipped to any laboratory. Wire or laminated waterproof tape will be used to seal the coolers.  
40 Chain-of-custody procedures will be followed throughout sample collection, transfer, analysis, and  
41 disposal to ensure that sample integrity is maintained. Each time the responsibility changes for the  
42 custody of the sample, the new and previous custodians will sign the record and note the date and time.

1 The sampler will make a copy of the signed record before the sample is shipped and will transmit the  
2 copy to Sample and Data Management within 48 hours of shipping.

3 It is not necessary to indicate the planned analyses on the chain-of-custody form for every sample,  
4 because not all samples will be analyzed. Grab sediment samples are planned at 0.76 m (2.5-ft) intervals  
5 in the borehole. The sediment samples planned for analyses and the targeted analyses for the borehole are  
6 described in Table 5 of this SAP. All samples will be transported to the laboratory selected to perform the  
7 analyses. The Technical Lead, in consultation with the laboratory, may modify the samples selected for  
8 analyses and the specific targeted analyses performed on each sample. The chain-of-custody forms for  
9 sample intervals planned for analyses in each borehole will indicate the selected analyses shown in  
10 Table 5. The analyzing laboratory will screen samples with electrical-resistivity measurements and then  
11 select samples for a complete set of analyses, in consultation with the Technical Lead.

12 The radiological control technician will measure both the contamination levels on the outside of each  
13 sample jar and the dose rates on each sample jar. The radiological control technician also will measure the  
14 radiological activity on the outside of the sample container (through the container) and will document the  
15 highest contact radiological reading in millirem per hour. This information, along with other data, will be  
16 used to select proper packaging, marking, labeling, and shipping paperwork in accordance with  
17 U.S. Department of Transportation regulations (49 CFR) and to verify that the sample can be received by  
18 the analytical laboratory in accordance with the laboratory's acceptance criteria. The sampler will send  
19 copies of the shipping documentation to Sample and Data Management within 48 hours of shipping.

#### 20 **2.2.4 Analytical Methods**

21 Analytical parameters and methods are listed in Table 2. These analytical methods are controlled in  
22 accordance with the laboratory's QA plan and the requirements of this SAP.

23 Laboratories providing analytical services in support of this SAP will report errors to the CHPRC Sample  
24 Management Project Coordinator who will then initiate a Sample Disposition Record. The error reporting  
25 process is intended to document analytical errors and the resolution of those errors with the Technical  
26 Lead.

27 The corrective-action program addresses the following:

- 28 • Evaluation of impacts of laboratory QC failures on data quality
- 29 • Root-cause analysis of QC failures
- 30 • Evaluation of recurring conditions that are adverse to quality
- 31 • Trend analysis of quality-affecting problems
- 32 • Implementation of a quality-improvement process
- 33 • Control of nonconforming materials that may affect data quality

#### 34 **2.2.5 Quality Control Requirements**

35 The QC procedures must be followed in the field and laboratory to ensure that reliable data are obtained.  
36 When field sampling is performed, care will be taken to prevent the cross-contamination of sampling  
37 equipment, sample bottles, and other equipment that could compromise sample integrity.

38 Field QC samples will be collected to evaluate the potential for cross-contamination and laboratory  
39 performance. Field QC for sampling under this SAP will require the collection of field duplicates and  
40 equipment rinsate blanks. The QC samples and the required frequency for collection are described in this  
41 section. The field geologist may request that additional equipment blanks be taken. The QC samples will  
42 be collected as part of the verification and confirmatory sampling activities.

1 The collection of QC samples for onsite measurements is not applicable to the field-screening techniques  
2 described in this SAP. Field-screening instrumentation will be calibrated and controlled as discussed in  
3 Sections 2.2.7 and 2.2.8, as applicable.

4 The laboratory method blank, laboratory-control sample/blank spike, and matrix spike are defined in  
5 Chapter 1 of SW-846, *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods, Third*  
6 *Edition; Final Update IV-B*, and will be run at the frequency specified in that reference.

7 Table 4 lists the field QC  
8 requirements for sampling. If only  
9 disposable equipment is used, or  
10 equipment is dedicated to a particular  
11 borehole, then an equipment rinsate  
12 blank is not required.

**Table 4. Field Quality Control Requirements**

Sample Type	Frequency	Purpose
Duplicate	5% (1 sample in 20)	Check the precision of the laboratory analyses and field sampling
Equipment rinsate	One per 30 samples	Check the effectiveness of the decontamination process

13 **2.2.5.1 Field Duplicates**

14 Field duplicates are independent  
15 samples collected as close as possible  
16 to the same point in space and time,  
17 taken from the same source, stored in  
18 separate containers, and analyzed independently. These samples are not to be homogenized together. One  
19 field duplicate will be collected for every 20 samples collected from the borehole. The duplicate generally  
20 should be collected from an interval that is expected to have some contamination, so that valid  
21 comparisons between the samples can be made (i.e., at least some of the COPCs will be above detection  
22 limit). When sampling with a split spoon, the duplicate sample likely will be from a separate split spoon,  
23 either above or below the main sample, because of sample-volume requirements.

24 **2.2.5.2 Equipment Rinsate Blanks**

25 Equipment blanks will consist of high purity water that is washed through decontaminated sampling  
26 equipment and placed in containers, as identified on the project Sampling Authorization Form. One  
27 equipment blank will be collected for every 30 sample retrieval trips in each borehole. The field geologist  
28 may request that additional equipment blanks be taken.

29 Equipment rinsate blanks will be analyzed for the following when characterization analysis is for  
30 radionuclides only:

- 31 • Gamma emitters
- 32 • Gross alpha
- 33 • Gross beta

34 When characterization analysis is for radionuclides and chemical constituents, blanks will be analyzed for  
35 the following:

- 36 • Gamma emitters
- 37 • Gross alpha
- 38 • Gross beta
- 39 • Metals
- 40 • Anions

1 **2.2.5.3 Field Transfer Blanks**

2 No field transfer blanks are required.

3 **2.2.6 Instrument/Equipment Testing, Inspection, and Maintenance**

4 All onsite environmental instruments will be tested, inspected, and maintained in accordance with the  
5 manufacturers' operating instructions and in accordance with approved work packages. Results from  
6 testing, inspection, and maintenance activities are documented in logbooks and/or work packages.

7 Measurement and testing equipment used in the field or in the laboratory that directly affect the quality of  
8 analytical data will be subject to preventive maintenance measures to minimize the downtime of the  
9 measurement system. Laboratories and onsite measurement organizations must maintain and calibrate  
10 their equipment. Maintenance requirements (e.g., parts lists and documentation of routine maintenance)  
11 will be included in the individual laboratories' and the onsite organization's QA plans or operating  
12 procedures (as appropriate). Analytical laboratory instruments and measuring equipment are tested,  
13 inspected, and maintained in accordance with the laboratories' QA plans. Daily response checks for  
14 environmental and radiological field-survey instruments are performed in accordance with approved work  
15 packages.

16 **2.2.7 Instrument/Equipment Calibration and Frequency**

17 All onsite environmental instruments are calibrated in accordance with the manufacturers' operating  
18 instructions, internal work requirements and processes, and/or work packages that provide direction for  
19 equipment calibration or verification of accuracy by analytical methods. Calibration of laboratory  
20 instruments will be performed in a manner consistent with SW-846 or with auditable DOE Hanford  
21 Site-wide and contractual requirements. The results from all instrument calibration activities are recorded  
22 in logbooks and/or work packages.

23 Analytical laboratory instruments and measuring equipment are calibrated in accordance with  
24 laboratories' QA plans. Calibration of radiological field-survey instruments on the Hanford Site is  
25 performed under contract by Pacific Northwest National Laboratory (PNNL) staff on an annual basis, as  
26 specified in their program documentation. Field instrumentation, calibration, and QA checks will be  
27 performed in accordance with the following:

- 28 • Calibration of radiological field instruments on the Hanford Site is performed under contract by  
29 PNNL staff, as specified in their program documentation. Daily calibration checks will be performed  
30 and documented for each instrument used to characterize areas that are under investigation. These  
31 checks will be made on standard materials that are sufficiently similar to the matrix under  
32 consideration, so that direct comparison of data can be made. Analysis times will be sufficient to  
33 establish detection efficiency and resolution.
- 34 • Instrumentation used to collect test data will be calibrated and maintained in accordance with the  
35 CHPRC QA program.

36 **2.2.8 Inspection/Acceptance of Supplies and Consumables**

37 Supplies and consumables for sampling and analysis activities will be acquired according to applicable  
38 procurement specifications. Supplies and consumables will be checked and accepted by users before they  
39 are used. Supplies and consumables procured by the analytical laboratories are procured, checked, and  
40 used in accordance with the laboratories' QA plans.

1 Consumables, supplies, and reagents will be reviewed in accordance with SW-846 requirements and will  
2 be appropriate for their use. Note that contamination is monitored using the QC sample process discussed  
3 in Section 2.2.

#### 4 **2.2.9 Nondirect Measurements**

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

#### 8 **2.2.10 Data Management**

9 Data resulting from the implementation of this SAP will be managed and stored in accordance with  
10 applicable programmatic requirements governing data management procedures. At the direction of the  
11 Technical Lead, all analytical data packages will be subject to final technical review by qualified  
12 personnel (as determined by the Technical Lead) before the results are submitted to the regulatory  
13 agencies or before they are included in reports. Electronic data access, when appropriate, will be via a  
14 database (e.g., HEIS or a project-specific database). Where electronic data are not available, hard copies  
15 will be provided in accordance with Tri-Party Agreement (Ecology et al., 1989), Section 9.6.

16 Planning for sample collection and analysis will be in accordance with the programmatic requirements  
17 governing fixed laboratory sample-collection activities, as discussed in the sampling teams' procedures.  
18 In the event that specific procedures do not exist for a particular work evolution, or if additional guidance  
19 to complete certain tasks is needed, a work package will be developed for adequate control of the  
20 activities, as appropriate. Examples of the sample teams' requirements include activities associated with  
21 the following:

- 22 • Chain-of-custody/sample analysis requests
- 23 • Project and sample identification for sampling services
- 24 • Control of certificates of analysis
- 25 • Logbooks and checklists
- 26 • Sample packaging and shipping

27 Approved work-control packages and procedures will be used to document radiological measurements  
28 when this SAP is being implemented. Examples of the types of documentation for field radiological data  
29 include the following:

- 30 • Minimum requirements for documenting radiological controls information in accordance with  
31 10 CFR 835, "Occupational Radiation Protection"
- 32 • Instructions for managing the identification, creation, review, approval, storage, transfer, and retrieval  
33 of Hanford Site radiological records
- 34 • Minimum standards and practices necessary for preparing, performing, and retaining  
35 radiological-related records
- 36 • Instructional materials for indoctrination of personnel on the development and implementation of  
37 survey/sample plans
- 38 • Requirements associated with preparing and transporting regulated material

39 The sampling team and the laboratory selected to analyze sediment samples will cross-reference  
40 analytical data and radiation measurements to facilitate interpretation of the investigation results. Errors

1 reported by the laboratories are reported to the Sample Management Project Coordinator, who initiates a  
2 Sample Disposition Record. This process is used to document analytical errors and to establish resolution  
3 with the Technical Lead.

## 4 **2.3 Assessment and Oversight**

5 Assessment and oversight activities are used to evaluate the effectiveness of project implementation and  
6 associated QA and QC activities. The purpose of assessment is to ensure that the QAPjP is implemented  
7 as prescribed.

### 8 **2.3.1 Assessments and Response Action**

9 The CHPRC QA group may conduct random surveillances and assessments to verify compliance with the  
10 requirements outlined in this SAP, project work packages, the QAPjP, procedures, and regulatory  
11 requirements.

12 Deficiencies identified during these assessments will be reported in accordance with existing  
13 programmatic requirements. The CHPRC QA group coordinates deficiency reporting according to the  
14 CHPRC QA Program. When appropriate, corrective actions will be taken by the Deep Vadose Zone  
15 Manager.

16 Oversight activities in the analytical laboratories, including corrective-action management, are conducted  
17 in accordance with the laboratories' QA plans. CHPRC conducts oversight of offsite analytical  
18 laboratories to qualify them for performing Hanford Site analytical work. No laboratory assessments  
19 currently are planned for this SAP.

### 20 **2.3.2 Reports to Management**

21 Reports to management on data-quality issues will be made if and when these issues are identified. These  
22 issues will be reported by laboratory personnel to Sample and Data Management, which then will  
23 communicate the issues to the Technical Lead and Manager. Subsequently, standard reporting protocols  
24 (e.g., project status reports) will be used to communicate these issues to management. Because  
25 performance or system assessments are not planned as part of this activity, the Technical Lead will not be  
26 providing audit or assessment reports to management for this activity, unless an unanticipated request is  
27 made for such an assessment to be conducted. At the end of the project, a data-quality-assessment report  
28 will be prepared to evaluate whether the type, quality, and quantity of data collected meet the intent of the  
29 DQOs and SAP.

## 30 **2.4 Data Validation and Usability**

31 Data validation and usability activities occur after the data-collection phase of the project is completed.  
32 Implementation of these elements determines whether the data conform to the specified criteria, thus  
33 satisfying project objectives.

34 The steps in the data validation and usability process are as follows: (1) review, (2) verification,  
35 (3) validation, and (4) quality assessment.

### 36 **2.4.1 Data Review, Verification, and Validation**

37 Data that is generated by the laboratory is reviewed is by the laboratory. The laboratories under contract  
38 to CHPRC review the data and provide case narratives that describe the QC evaluation of the data set.

39 The data review is used in the subsequent data verification and validation activities, described in  
40 Section 2.4.2.

## 1 **2.4.2 Verification and Validation Methods**

2 Completed laboratory data packages will be verified by qualified Sample and Data Management  
3 personnel or by a qualified independent contractor. Verification consists of confirming that sampling and  
4 chain-of-custody documentation is complete and that sample numbers can be tied to the specific sampling  
5 locations, checking required deliverables, comparing requested versus reported analyses, and identifying  
6 transcription errors. Once the deliverables are verified, the data are validated.

7 Validation as defined in SW-846, Chapter 1, indicates that data validation is the process of evaluating the  
8 available data against project DQOs. Data validation may be performed by Sample and Data  
9 Management, or by a party independent of both the data collector and the data user. Specifically, the  
10 process of validation includes the following:

- 11 • Documenting any errors found in the data for subsequent project resolution
- 12 • Verifying compliance with the QA requirements
- 13 • Checking QC values against defined limits
- 14 • Applying qualifiers to analytical results for defining the limitations in the use of the data

15 Validation will include evaluating and qualifying the results based on holding times, method blanks,  
16 laboratory control samples, laboratory duplicates, and chemical and tracer recoveries, as appropriate. No  
17 other validation or calculation checks will be performed.

18 Level C data validation, as defined in the contractor's validation procedures based on the EPA's  
19 functional guidelines in *Laboratory Data Validation Functional Guidelines for Evaluating Inorganics*  
20 *Analyses* (Bleyler, 1988a) and *Laboratory Data Validation Functional Guidelines for Evaluating*  
21 *Organics Analyses* (Bleyler, 1988b) will be performed for a minimum of 5 percent of the  
22 laboratory-generated chemical and radiochemical data by matrix and analyte group. When outliers or  
23 questionable results are identified, additional data validation will be performed, which could involve up to  
24 5 percent of the data. The additional validation will begin with Level C and may increase to Levels D and  
25 E as needed to ensure that the data are usable. Note that Level C validation is a review of the QC data,  
26 while Levels D and E include review of calibration data and calculations of representative samples from  
27 the data set. Data validation will be documented in data validation reports, which will be provided to  
28 Sample and Data Management and in the data-quality-assessment report (see Section 2.4.3). At least one  
29 data validation package will be generated. Sample and Data Management is responsible for distributing  
30 the data validation report to the Technical Lead and to others as necessary.

## 31 **2.4.3 Reconciliation with User Requirements**

32 The determination of data usability will be documented in the data-quality-assessment report. The  
33 data-quality-assessment process is defined in *Data Quality Assessment: A Reviewers Guide*, EPA  
34 QA/G-9R (EPA/240/B-06/002). The EPA data-quality-assessment process will be used for laboratory  
35 data. The analytical data will be reviewed to determine whether precision, accuracy, and completeness  
36 objectives have been satisfied. Verified and/or validated data will be reviewed to assess their usability.  
37 The quality and quantity of the entire data set will be reviewed to determine whether DQOs have been  
38 met. The Technical Lead is responsible for ensuring that the data-quality-assessment is performed. The  
39 data-quality-assessment results will be reported to the Technical Lead.

## 40 **3 Sampling Objectives**

41 The objective of the field-sampling plan is to provide clear identification of project sampling and analysis  
42 activities and requirements. The field-sampling plan is based on the sampling design identified during the  
43 DQO process (SGW-46487) and expanded in the FTP (DOE/DOE-RL-2010-87).

### 3.1 Sampling and Data Collection Strategy

The sampling strategy uses phased implementation to support the test objectives. Primary sampling and analysis uses sediment sampling with laboratory analysis and soil gas collection and analysis. These approaches will provide the primary data to evaluate the test. The characteristics of the ammonia treatment process may also enable use of in situ sensors and geophysical techniques to provide complementary data that helps extend the temporal and spatial interpretation of the test.

### 3.2 Sampling Design

Test design aligns the primary test monitoring and data collection along an axis perpendicular with the 216-U-8 Crib to enable investigation of treatment effectiveness along the gradient in uranium concentrations expected to move outward from the crib. The design also targets individual, vertically discrete tests in Cold Creek unit (CCU) and Hanford formation strata. Based on previous characterization data, the 216-U-8 uranium contamination moved laterally away from the crib in a shallow zone near the bottom of the crib and within the much deeper CCU. The test design also relies on laboratory testing of site sediments to address some of the test objectives (e.g., evaluation of long-term treatment effectiveness) and to provide input to refine the field test design.

A phased approach, described as follows, will be implemented that minimizes risk in defining the specific test site(s) and conducting the field test:

- **Phase 1. Field Site Characterization.** Install boreholes at the site and analyze sediment samples in the laboratory to: (1) validate the test site selection, (2) obtain baseline information for site characterization, (3) determine effectiveness of ammonia on uranium present at this site, and (4) select target treatment zones. Laboratory ammonia treatment will be applied to sediment samples to verify site selection and provide detailed information quantifying ammonia treatment performance.
- **Phase 2. Field Site Test System Installation and Characterization.** Install initial test system wells and monitoring systems with emphasis on infrastructure to conduct shallow zone ammonia test. Baseline gas flow in the shallow zone will be evaluated as input to ammonia injection design. Phase 2 efforts will use analysis of additional sediment samples and soil gas sampling and analysis for tracer gases.
- **Phase 3. Conduct Shallow Field Test.** Primary sampling will be for tracers and ammonia in soil gas to evaluate ammonia distribution. Use of sensors and geophysics may also be applied. Post-treatment sediment samples will be analyzed in the laboratory to evaluate treatment effectiveness.
- **Phase 4. Conduct Deep Field Test (CCU).** The sampling design will be same as for the shallow zone test, although timeframes and monitoring/sampling locations may be different.

Soil gas sampling and analysis of borehole sediment samples will be the baseline monitoring techniques to evaluate treatment performance. The experimental design also is expected to include in situ monitoring of the ammonia/sediment pore water reaction progress during and immediately following the ammonia injection period pending laboratory validation of candidate instruments. Laboratory tests will be conducted for each candidate technique to evaluate the magnitude of response that can be monitored and, thereby, determine their suitability for field application.

1 **3.3 Sampling Locations and Frequency**

2 Table 5 lists the data collection activities to be performed prior to initiating the active portion of the test,  
3 during the active portion of the test when ammonia is being injected and during the period when pore  
4 water pH is decreasing toward neutral and post-treatment when treatment effectiveness is to be evaluated.

5 Table 5 lists sampling and data collection requirements.

**Table 5. Sampling and Data Collection Requirements**

Location	Key Features of Design	Analyses <sup>a</sup> /Measurements
<b>Phase 1: Initial Characterization, Validation of Test Site Selection, and Baseline Data Collection</b>		
Borehole closest to 216-U-8 Crib (Repeat for 4 <sup>th</sup> borehole if logging of 1 <sup>st</sup> three boreholes indicates dipping or discontinuous strata of interest)	Collect grab samples every 3 m (10 ft) from approximately 9.1 m (30 ft) below ground surface (bgs) to total depth.	Archive samples Lithology per geologist observation
Initial five boreholes per Figure 1	Collect continuous samples beginning at approximately 10.7 m (35 ft) bgs to approximately 22.8 m (75 ft) bgs, and from approximately 53.3 m (175 ft) to 59.4 m (195 ft) bgs. Depth will be guided by evaluation of data obtained from planned characterization boreholes within and near the 216-U-8 Crib.	Lithology per geologist observations Analyses will be guided by geophysical logging and indications of high moisture content and fine-grained texture: <ul style="list-style-type: none"> <li>• Moisture content</li> <li>• Water extract</li> </ul> pH Electrical conductivity Cations (Ca, Na, Al, Si, Mg, Fe, K, Ba, U, Tc, Sr, Cs) Anions (NO <sub>3</sub> , NO <sub>2</sub> , SO <sub>4</sub> , Cl, Br) carbonate by total inorganic carbon Total alpha/beta: <ul style="list-style-type: none"> <li>• Acid extract</li> </ul> Cations (Ca, Na, Al, Si, Mg, Fe, K, Ba, U, Tc, Sr, Cs) Total alpha/beta <ul style="list-style-type: none"> <li>• Microwave digestion for total U</li> <li>• Cation exchange capacity</li> <li>• Gamma energy analysis</li> <li>• U mineralogy by fluorescence</li> <li>• U sequential extractions<sup>b</sup> on untreated sediments (triplicate)</li> <li>• U sequential extractions<sup>b</sup> on NH<sub>3</sub>-treated sediments (triplicate)</li> </ul>

**Table 5. Sampling and Data Collection Requirements**

Location	Key Features of Design	Analyses <sup>a</sup> /Measurements
		<ul style="list-style-type: none"> <li>• 1-D column leaching on NH<sub>3</sub>-treated sediments (small column [50 pore volumes], then multiple stop-flow (long term) physical analyses</li> <li>Particle size distribution</li> <li>Surface area</li> <li>Sediment resistivity</li> <li>Hydraulic and air permeability</li> <li>Matric potential vs. saturation</li> <li style="padding-left: 20px;">Sediment mineralogy</li> <li>Major minerals</li> <li>Clays</li> <li>If laboratory ammonia treatment fails to decrease mobile U content by at least 50%, consider abandoning this test site</li> </ul>
Initial 5 boreholes per Figure 1	Geophysical logging (initial 5 boreholes).	SGLS logging Neutron moisture logging
<b>Phase 2: Additional Characterization and Baseline Data Collection</b>		
Additional boreholes per Figure 1	Collect continuous samples beginning at approximately 10.7 m (35 ft) bgs to approximately 22.8 m (75 ft) bgs, and from approximately 53.3 m (175 ft) to 59.4 m (195 ft) bgs. Depth will be guided by evaluation of data collected from Phase 1.	Lithology per geologist observations Analyses will be guided by geophysical logging and indications of high moisture content and fine-grained texture. <ul style="list-style-type: none"> <li>• Moisture content</li> <li>• Water extract</li> </ul> pH Electrical conductivity Cations (Ca, Na, Al, Si, Mg, Fe, K, Ba, U, Tc, Sr, Cs) Anions (NO <sub>3</sub> , NO <sub>2</sub> , SO <sub>4</sub> , Cl, Br) Carbonate by total inorganic carbon Total alpha/beta <ul style="list-style-type: none"> <li>• Acid extract</li> </ul> Cations (Ca, Na, Al, Si, Mg, Fe, K, Ba, U, Tc, Sr, Cs) Total alpha/beta <ul style="list-style-type: none"> <li>• Microwave digestion for total U</li> <li>• Cation exchange capacity</li> <li>• Gamma energy analysis</li> <li>• U mineralogy by fluorescence</li> </ul>

**Table 5. Sampling and Data Collection Requirements**

Location	Key Features of Design	Analyses <sup>a</sup> /Measurements
		<ul style="list-style-type: none"> <li>• U sequential extractions<sup>b</sup> on untreated sediments (triplicate)</li> <li>• U sequential extractions<sup>b</sup> on NH<sub>3</sub>-treated sediments (triplicate)</li> <li>• 1-D column leaching on NH<sub>3</sub>-treated sediments (small column [50 pore volumes]), then multiple stop-flow (long term)</li> <li>• Physical analyses</li> </ul> Particle size distribution Surface area Sediment resistivity Hydraulic and air permeability Matric potential vs. saturation <ul style="list-style-type: none"> <li>• Sediment mineralogy</li> </ul> Major minerals Clays If laboratory ammonia treatment fails to decrease mobile U content by at least 50%, consider abandoning this test site.
	Geophysical logging of additional boreholes.	SGLS logging Neutron moisture logging
	Sediment air permeability and gas flow path determination.	Borehole anemometry (if available)
Injection borehole		Differential pressure measurements between boreholes per US ACE EM 1110-1-4001
All boreholes		Tracer gas testing
All boreholes		Tracer gas testing
<b>Phase 3: During Ammonia Treatment Period</b>		
	Continually measure sediment temperature (to monitor NH <sub>3</sub> /pore water reaction).	Thermistors <sup>c</sup>

**Table 5. Sampling and Data Collection Requirements**

Location	Key Features of Design	Analyses <sup>a</sup> /Measurements
All subsurface monitoring locations	Periodically analyze pore water and sediment chemistry (to monitor NH <sub>3</sub> /pore water reaction).	Retrieved in-well sediment coupons <sup>c</sup> (also use coupons to periodically monitor pore water pH)
	Continually measure sediment matric potential and inferred moisture content (to monitor NH <sub>3</sub> /pore water reaction).	Heat dissipation unit <sup>c</sup>
	Continually measure sediment pore water pH.	pH sensor <sup>c</sup>
	Periodically analyze soil gas (to detect arrival of NH <sub>3</sub> and other tracer gases).	Installed collection tube; use gas chromatography for analysis
	Periodically measure bulk sediment electrical conductivity (to monitor expected increase in pore water solute concentration).	Electrical resistivity tomography <sup>c</sup>
	Continually monitor injected flow rate, pressure, gas temperature.	Common industrial instrumentation
Above-ground instruments	Continually monitor injected flow rate, pressure, gas temperature.	Common industrial instrumentation
<b>Phase 4: Post-Ammonia Treatment Period (Pore Water pH Transition to Near-Normal)</b>		
Instrumented monitoring locations focused in treatment zone	Measure pore water and sediment chemistry (to monitor pore water pH return to near-normal).	Retrievable in-well sediment coupons <sup>c</sup>
	Continually measure sediment pore water pH.	pH sensor <sup>c</sup>
	Continually measure sediment matric potential and inferred moisture content (to monitor NH <sub>3</sub> /pore water reaction).	Heat dissipation unit <sup>c</sup>
	Periodically measure bulk sediment electrical conductivity (to monitor expected decrease in pore water solute concentration).	Electrical resistivity tomography <sup>c</sup>
	Periodically measure bulk sediment electrical conductivity (to monitor expected decrease in pore water solute concentration).	Electrical resistivity tomography <sup>c</sup>

**Table 5. Sampling and Data Collection Requirements**

Location	Key Features of Design	Analyses <sup>a</sup> /Measurements
<b>Phase 5: Determination of Treatment Effectiveness (following restoration of near-normal pore water pH)</b>		
Treatment zone, including the “fringe” beyond the reaction front	Drill 3 new boreholes adjacent the injection well and 2 nearby wells. Specific depths will be determined from data collected during earlier portions of Phase 3. Collect continuous samples beginning approximately 1.5 m (5 ft) above the estimated reaction zone (to intersect the “fringe” of the reaction zone) to approximately 1.5 m (5 ft) below the estimated reaction zone (to intersect the “fringe” of the reaction zone). Do not drill/sample into or below the caliche layer of the CCU. Determine treatment effectiveness by comparing mobile fraction of contaminants with baseline data.	Lithology per geologist observations Analyses will be guided by geophysical logging and indications of high moisture content and fine-grained texture. <ul style="list-style-type: none"> <li>• Moisture content</li> <li>• Water extract</li> </ul> pH Electrical conductivity Cations (Ca, Na, Al, Si, Mg, Fe, K, Ba, U, Tc, Sr, Cs) Anions (NO <sub>3</sub> , NO <sub>2</sub> , SO <sub>4</sub> , Cl, Br) Carbonate by total inorganic carbon  Total alpha/beta <ul style="list-style-type: none"> <li>• Acid extract</li> </ul> Cations (Ca, Na, Al, Si, Mg, Fe, K, Ba, U, Tc, Sr, Cs) Total alpha/beta <ul style="list-style-type: none"> <li>• Microwave digestion for total U</li> <li>• Cation exchange capacity</li> <li>• Gamma energy analysis</li> <li>• U mineralogy by fluorescence</li> <li>• U sequential extractions<sup>b</sup> on untreated sediments (triplicate)</li> <li>• U sequential extractions<sup>b</sup> on NH<sub>3</sub>-treated sediments (triplicate)</li> <li>• 1-D column leaching on NH<sub>3</sub>-treated sediments (small column [50 pore volumes], then multiple stop-flow [long-term])</li> </ul>

Source:

EM 1110-1-4001, *Engineering and Design: Soil Vapor Extraction and Bioventing*.

a. Analyses per Table 2.

b. Sequential extractions and ammonia dosing per PNNL-18879, *Remediation of Uranium in the Hanford Vadose Zone Using Gas-Transported Reactants: Laboratory-Scale Experiments*.

c. Dependent on favorable laboratory testing.

1 **3.3.1 Sampling Preservation, Container, and Holding Times**

2 Table 6 describes sample preservation, container, and holding time requirements.

1 **3.4 Well Decommissioning/Completion**

2 Following test completion and upon EPA approval, the well and monitoring boreholes will be  
3 decommissioned by being backfilled with bentonite, or in an alternate manner in accordance with an  
4 appropriate decommissioning procedure, to meet the requirements of WAC 173-160, "Minimum  
5 Standards for Construction and Maintenance of Wells."

6 **3.5 Management of Waste**

7 Waste generated by sampling activities will be managed in accordance with an approved waste-control  
8 plan (SGW-47799, *Waste Control Plan for the U Plant Closure Area Waste Site*). The waste-control plan  
9 establishes the requirements for management and disposal of generated waste. Investigation-derived  
10 waste from these sampling activities will be handled as CERCLA waste. Unused samples will be archived  
11 for potential later analysis. Laboratory waste will be dispositioned in accordance with the laboratory  
12 contract and agreements concerning return to the Hanford Site. In accordance with 40 CFR 300.440,  
13 "National Oil and Hazardous Substances Pollution Contingency Plan," "Procedures for Planning and  
14 Implementing Off-Site Response Actions," approval from the Task Lead is required before unused  
15 samples or wastes are returned from offsite laboratories.

16 **3.6 Health and Safety**

17 Health and safety requirements will be contained in a health and safety plan specifically created for this  
18 task. Air monitoring will be conducted in accordance with the radiological-monitoring plan prepared for  
19 this study. Both the health and safety plan and air-monitoring plan will be issued separately before  
20 fieldwork is initiated.

Table 6. Sample Preservation, Container, and Holding Times for Samples

Analytes	Priority	Holding Time	Container		Volume <sup>a</sup>	Preservation	Packing Requirements
			No.	Type			
<b>Geochemical Analytical Samples</b>							
Anions <sup>b</sup> (WE)	1	28 days from leach to analysis	1	Split spoon liner	500 g	None	None
Cations (WE & AE)	1	6 months					
pH (WE)	2	14 days from extraction to analysis					
Carbonate (TIC) (WE)	2	6 months					
Total alpha/beta (WE & AE)	2	NA					
Total U (microwave digestion)	2						
Gamma energy analysis	2						
U sequential extractions (WE & AE)	1	6 months		Split spoon liner			
1-D column leaching	1	6 months		Split spoon liner			
<b>Geotechnical/Physical Analytical Samples</b>							
Moisture content	1	As soon as possible after opening container	1	Split spoon liner	500 g	None	Seal & refrigerate?
Particle size distribution	1	NA					None
Cation exchange capacity	1	NA					None
Surface area	1	NA					None

**Table 6. Sample Preservation, Container, and Holding Times for Samples**

Analytes	Priority	Holding Time	Container		Volume <sup>a</sup>	Preservation	Packing Requirements
			No.	Type			
Hydraulic permeability	2	Analyzed after resistivity and hydraulic conductivity.	1	Split spoon liner	500 g	None	Maintain liners in upright position; handle gently
Air permeability	1						
Matric potential vs. saturation	1	NA	1	Split spoon liner	500 g	None	None
U mineralogy	1	NA	1	Split spoon liner	500 g	None	None
Soil resistivity	1						
Sediment mineralogy	2						

a. Optimal volumes, which may be adjusted downward to accommodate the possibility of small sample recoveries. Minimum sample size will be defined on the Sampling Authorization Form.

b. As listed in Table 3, anions are nitrate (as nitrogen), chloride, fluoride, phosphate, and sulfate. Anions are collected in one bottle and analyzed by ion chromatography.

AE = acid extract

TIC = total inorganic carbon

WE = water extract

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