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300-FF-5 Supplemental Post-ROD Field Investigation Summary

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

Contractor for the U.S. Department of Energy
under Contract DE-AC06-08RL14788

P.O. Box 1600
Richland, Washington 99352

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CH2M HILL Plateau Remediation Company

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B Reprint of SGW-58736, Technical Memorandum (*300-FF-5 Enhanced Attenuation Area Stage A Location Selection*), Rev. 0, published April 2015 ..... B-i

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Terms

bgs	below ground surface
CSM	conceptual site model
DOE	U.S. Department of Energy
DQO	data quality objective
DUP	field duplicate
EA	enhanced attenuation
EB	equipment blank
EPA	Environmental Protection Agency
HEIS	Hanford Environmental Information System
ICP/MS	inductively coupled plasma/mass spectrometry
ID	identification
IDL	instrument detection limit
LCS	laboratory control sample
MDC	minimum detectable concentration
MDL	method detection limit
MS/MSD	matrix spike/matrix spike duplicate
N/A	not applicable
OU	operable unit
PNNL	Pacific Northwest National Laboratory
PRZ	periodically rewetted zone
PSQ	principal study question
QC	quality control
RI/FS	remedial investigation/feasibility study
RLM	Ringold Formation lower mud
ROD	record of decision
RPD	relative percent difference
Rwie	Ringold Formation member of Wooded Island – unit E
SAP	sampling and analysis plan
SI	sampling instruction

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1 Introduction

The 300 Area encompasses approximately 105 km^2 (40 mi^2) adjacent to the Columbia River in the southern portion of the Hanford Site and includes the 300 Area Industrial Complex. This complex was comprised of buildings, facilities, and process units where uranium fuel production and research and development activities took place. Much of the 300 Area has been remediated. The remediation process was accomplished within two soil operable units (OUs), 300-FF-1 and 300-FF-2, which included liquid and solid waste disposal sites. The remediation process also includes the 300-FF-5 Groundwater OU. Contaminant releases at the waste disposal sites resulted in several groundwater contaminant plumes within the underlying 300-FF-5 Groundwater OU.

Completion of the cleanup is being accomplished under the 2013 U.S. Environmental Protection Agency (EPA) and U.S. Department of Energy (DOE) record of decision (ROD), *Hanford Site 300 Area Record of Decision for 300-FF-2 and 300-FF-5, and Record of Decision Amendment for 300-FF-1* (hereafter referred to as the 300 Area ROD/ROD Amendment). Uranium is identified as a contaminant of concern in the 300 Area ROD/ROD Amendment (EPA and DOE, 2013). Part of the selected remedy for uranium contamination in groundwater is enhanced attenuation (EA) of uranium using phosphate solutions to reduce the leachability of uranium in the periodically rewetted zone (PRZ) and top of the aquifer.

The EA remedy is being implemented in two sequential stages: Stage A and Stage B. A supplemental post-ROD investigation was conducted in accordance with the Post-ROD Sampling Instruction (SI) (SGW-56993, *Sampling Instruction for the 300-FF-5 Operable Unit Supplemental Post ROD Field Investigation*). The purpose of the Post-ROD SI (SGW-56993) was to collect uranium soil concentration data to refine the Stage A enhanced attenuation (EA) area, measure the distribution and leachability of uranium within the vadose zone and PRZ in the vicinity of the proposed EA area, and refine the conceptual site model (CSM).

This report summarizes observations and measurements made during the field activities conducted as part of the supplemental post-ROD field investigation. The field activities included drilling three boreholes, construction of two monitoring wells, and soil sampling during drilling. The results of laboratory testing and analysis of the samples also are presented in this report.

Additional information regarding the sampling techniques, locations, and decision processes can be found in the Post-ROD SI (SGW-56993). Additional details regarding the drilling of three boreholes and the construction of two monitoring wells can be found in SGW-58589, *Borehole Summary Report for the Installation of 2 Wells and Drilling of 1 Borehole in the 300-FF-5 Operable Unit.*

1.1 Background

Figure 1 shows the location of the Post-ROD SI (SGW-56993) boreholes and original EA area location. The EA area is located within the influence of four major waste disposal facilities that were used in the 300 Area Industrial Complex. Although these sites have been remediated to depths ranging from 4.3 to 7.5 m (14 to 25 ft), deeper residual uranium is thought to contribute to the high uranium concentrations detected in the groundwater in this area. Historical groundwater data indicate that the high uranium concentration region is centered near Wells 399-1-17A (Borehole 1) and 399-1-55 (Borehole 2). More recent (2012) groundwater data indicate that the high uranium concentration region may be located to the north, between the remediated 316-5 Process Trenches and the remediated 316-2 Process Ponds (Borehole 3).

Figure 1. Location of Post-ROD SI (SGW-56993) Boreholes and Original EA Area

The Solid Waste Burial Ground No. 2 (Waste Site 618-2) and Dry Waste Burial Ground No. 3 (Waste Site 618-3) were located to the southwest of the proposed EA area. From 1951 through 1955, these waste sites were used to dispose of uranium-contaminated solid waste from 300 Area facilities. This included contaminated equipment and contaminated metal wastes. The sites were remediated from September 2004 through August 2006. Remediation involved excavation and removal of buried waste and contaminated soil to a maximum depth of 6.1 m (19.7 ft) below ground surface (bgs). The sites were backfilled with clean fill to grade level.

The 300 Area North Process Pond (Waste Site 316-2) was located to the northeast of the proposed EA area. This waste site consisted of several separate sections separated by dikes. From 1948 to May 1974, this site was used to dispose of cooling water and low-level liquid waste from the 300 Area fuel fabrication facilities. Lack of infiltration was a problem for the pond because it accumulated sludge containing large amounts of uranium and copper. The bottom of the pond was periodically dredged, and the sludge was deposited on the dikes. The site was remediated from May 1998 through January 1999. Remediation involved excavating and removing the contaminated soil to a maximum depth of 7.5 m (25 ft) bgs. The site was backfilled with clean fill to grade level.

The 300 Area Process Trenches (Waste Site 316-5) were located north of the proposed EA area. This site consisted of two trenches, each 468 m (1535 ft) long, operating alternately. From 1975 to 1994, the trenches were used to dispose of cooling water and low-level liquid waste from the 300 Area fuel fabrication facilities. In 1991, the site was partially remediated through an expedited response action, which removed 0.3 to 0.9 m (1 to 3 ft) of contaminated soil and sludge from the bottom and sides of the trenches, respectively. The contaminated soil and sludge were stockpiled at the north end of the trenches. Final remediation, under the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*, was conducted from July 1997 through February 1998. Remediation involved excavating and removing the contaminated soil to a maximum depth of 4.3 m (14 ft) bgs. The site was backfilled with clean fill to grade level.

Soil samples from Well 399-1-22, on the west side of the 316-2 Waste Site (Figure 1), detected elevated concentrations of uranium as deep as 6.1 m (20 ft) bgs. Soil samples from Well 399-1-55, near the south end of the 316-5 Waste Site, detected elevated concentrations of uranium as deep as 10.7 m (35 ft) bgs. In 2011 and 2012, groundwater samples from a well located near the center of the proposed EA area (399-1-17A) had high groundwater uranium concentrations (maximum of 4,030 µg/L). In 2012 and 2013, groundwater samples from a well located to the northeast of the proposed EA area (399-1-55) also had high uranium concentrations (maximum 571 µg/L). Groundwater levels in the EA area can fluctuate about 2 m (7 ft), with a depth to groundwater during high river stage of about 8 m (26 ft) bgs and a depth to groundwater during low river stage of about 10 m (33 ft) bgs.

1.2 Objectives

The data quality objectives (DQOs) process was used to develop the sampling and analytical design for the supplemental Post-ROD SI (SGW-56993). The DQO process developed two problem statements and four principal study questions (PSQs), presented in Tables 1 and 2.

Problem Statement 1 involves locating the EA area over the region of the highest uranium concentration in groundwater in order to maximize the effectiveness of the uranium sequestration. As stated in the previous section, recent groundwater data indicate a region of higher uranium concentration may be located to the northeast of the proposed EA area, based upon historical data from Well 399-1-55. Table 1 provides specific information on the PSQs to be resolved, data needs, measurements, and data use for Problem Statement 1.

Sampling to resolve PSQ 1a was performed at the three borehole locations to provide a vertical profile of uranium soil concentrations in the vadose zone and PRZ to confirm the location of higher uranium concentrations in the soil. Sampling to resolve PSQ 1b was performed to provide uranium leachability characteristics to determine the region of greater mobility of the uranium. Data collected during testing will be used to resolve these PSQs and focus the position of the EA area.

The following decision rule was used to determine if sufficient information has been collected to resolve Problem Statement 1:

> *If the new and existing total uranium soil concentration data and the new leachable uranium information do not change the current CSM (centroid of the 10 times uranium background is within the EA area boundaries), then the location of the enhanced EA area will remain as defined. Otherwise, the location of the EA area will be revised to align with the revised CSM.*

Table 1. Summary of Problem Statement 1

Problem Statement 1	The EA area (approximately 1 ha [3 ac]), as defined in the 300 Area ROD/ROD Amendment (EPA and DOE, 2013), represents a region centered on the highest concentration of uranium in the groundwater.	
PSQ 1a	Does the EA area (approximately 1 ha [3 ac]), as defined in the 300 Area ROD/ROD Amendment (EPA and DOE, 2013), represent a region centered on higher concentration of uranium in the vadose zone and PRZ?	
Discussion	Data obtained in 2011 from Well 399-1-17A indicated that the high groundwater uranium concentration, near the southern end of the 300 Area Process Trenches (Waste Site 316-5), was used to locate the EA area. More recent data from Well 399-1-55 indicate that higher groundwater uranium concentrations may be located northeast of the EA area.	
Data Need	**Measurement/Observation and Location/Frequency**	**Data Use**
Vertical profile and lateral distribution of uranium soil concentrations and lithology in the vadose zone and PRZ that correspond to regions of higher groundwater uranium	Conduct total uranium measurements and lithology observations from vertical profile samples collected in the vadose zone and PRZ at the following locations (Figure 1): • Proximity of Well 399-1-17A (borehole location 1) • Proximity of Well 399-1-55 (borehole location 2) • Region north of Well 399-1-55 (borehole location 3)	This information will be combined with existing total uranium data to refine the 3-D model of uranium soil concentrations in the study area. The total uranium data will be used to select the samples for additional analysis to resolve Problem Statement 2. The refined uranium model will also be used, in combination with data from PSQ 1b, to select the optimal location of the EA area.
PSQ 1b	Does the EA area (approximately 1 ha [3 ac]), as defined in the 300 Area ROD/ROD Amendment (EPA and DOE, 2013), represent a region of higher leachability of uranium in the vadose zone and PRZ?	
Discussion	Use uranium and lithographic profile data from PSQ 1a to determine the location and soil horizons for uranium leachability tests.	

Table 1. Summary of Problem Statement 1

Data Need	Measurement/Observation and Location/Frequency	Data Use
Leachability of uranium in the vadose zone and PRZ that corresponds to regions of higher groundwater uranium	Conduct semiselective sequential uranium leach tests on sediments collected from each borehole to determine the amount of uranium released under variable conditions. Conduct labile uranium leach tests on sediments collected from each borehole to estimate the readily leachable (labile) uranium fraction. Leach tests will be conducted on one vadose zone sample and one PRZ sample.	Confirm the region of greater leachability of uranium in the vadose zone and PRZ. Leachability of uranium will be used in combination with the 3-D model of uranium soil concentrations as refined by PSQ 1a to select the optimal location of the EA area.
	Conduct grain-size and pH analyses on samples selected for the leachability study.	Determine the physical characteristics of the substrate material that may affect leachability.

References: SGW-56993, *Sampling Instruction for the 300-FF-5 Operable Unit Supplemental Post ROD Field Investigation.*

EPA and DOE, 2013, *Hanford Site 300 Area Record of Decision for 300-FF-2 and 300-FF-5, and Record of Decision Amendment for 300-FF-1.*

EA = enhanced attenuation

PRZ = periodically rewetted zone

PSQ = principal study question

ROD = record of decision

Problem Statement 2 involves determining the leachability characteristics of samples from specific regions of the vadose zone and PRZ in order to evaluate potential phosphate infiltration and injection treatment effectiveness as a result of Stage A. Table 2 provides specific information in the PSQ to be resolved, data needs, measurements, and data use for Problem Statement 2. Two PSQs were identified to resolve Problem Statement 2.

Sampling activities performed under this field study were used to provide pretreatment uranium leachability characteristics using uranium leachability data collected to support PSQ 1b. Samples were selected to provide information on the uranium mineral composition and soil transport characteristics, which were then used to refine the CSM.

PSQ 2b involves the post-treatment leachability characteristics of uranium in the vadose zone and PRZ and will not be addressed in this document.

The following decision rule was used to determine if sufficient information has been collected to resolve PSQ 2a:

> *If the pre-treatment vadose zone and PRZ uranium leachability characteristics, predominant uranium-bearing mineral phase, and uranium travel times are consistent with the CSM used to design the EA remediation, then proceed with the remediation as designed. Otherwise, revise the EA design to align with the revised CSM.*

Table 2. Summary of Problem Statement 2

Problem Statement 2	Leachability characteristics, within the EA area, as refined by PSQs 1a and 1b, are necessary to evaluate the potential treatment effectiveness in the vadose zone and PRZ.	
PSQ 2a	What are the pretreatment leachability characteristics of the vadose zone and PRZ in the refined location of the EA area?	
Discussion	Leachability test results obtained for PSQ 1b from boreholes within the refined EA area are used to resolve PSQ 2a. Samples are available for mineral testing and flow-through column tests to support the CSM.	
Data Need	**Measurement/Observation and Location/Frequency**	**Data Use**
Leachability of uranium in the vadose zone and PRZ prior to application of phosphate in order to refine the remediation design and evaluate treatment effectiveness	Use results from semiselective sequential uranium leach tests and from labile uranium leach tests (obtained to resolve PSQ 1b) on sediments collected from each borehole within the refined EA area to determine the amount of uranium released under variable conditions, as well as to estimate the readily leachable uranium fraction.	This information will be used to refine the Stage A strategy for the phosphate injection and infiltration. The data will also be used to determine the leachability characteristics of uranium in the EA area prior to application of phosphate.
Support the CSM and refine the uranium transport model.	Perform analysis to identify primary uranium-bearing mineral phase from at least one borehole within the refined EA area. Mineral analysis will be conducted on samples selected for the leachability study. Perform two flow-through column tests using sediment samples from a borehole within the refined EA area. One flow-through column test will be conducted on field-textured sediments (by removing very large cobbles), while the other test will be performed just on the <2 mm-size fraction. Estimate the total uranium content associated with the field texture and <2 mm-size sediments.	Determine the dominant uranium-bearing mineral phase. Determine the leachability of uranium using flow-through column tests under field texture conditions and compare to conditions that represent standard laboratory collection protocol (<2 mm-size fraction). Data will be used to determine the scaling of transport parameters from the <2 mm size fraction to field-textured sediments and to estimate the total uranium content associated with the field-textured sediments as well as the <2 mm-size fraction.

Table 2. Summary of Problem Statement 2

PSQ 2b	What are the post-treatment uranium leachability characteristics of the vadose zone and PRZ in the refined EA area?	
Discussion	Stage A post-treatment data from a new borehole, co-located with a PSQ 2a borehole, will provide data to evaluate treatment effectiveness and support Stage B design.	
Data Need	**Measurement/Observation and Location/Frequency**	**Data Use**
Vertical profile and lateral distribution of uranium soil concentrations, lithology, and leachability of uranium in the vadose zone and PRZ after application of phosphate during Stage A	Conduct total uranium measurements and lithology observations on one vadose zone sample and at least one PRZ sample collected from one new borehole within the refined enhanced EA area.	Determine the leachability characteristics of uranium (relative fraction leachable compared to the total uranium) in the Stage A remediation area after application of phosphate.
	Conduct labile uranium leach tests on sediments collected from one new borehole within the refined EA area to estimate the readily leachable uranium fraction. Leach tests will be conducted on one vadose zone sample and one PRZ sample.	
	Conduct grain-size and pH analyses on samples selected for the leachability study.	Determine the physical characteristics of the substrate material that may affect leachability.
Support the CSM and refine the uranium transport model.	Perform analysis to identify primary uranium-bearing mineral phase from one borehole within the refined EA area. Mineral analysis should be conducted on samples selected for the leachability study.	Determine the extent of phosphate-phase precipitation (rind formation) on the uranium-bearing mineral phase.

Source: SGW-56993, *Sampling Instruction for the 300-FF-5 Operable Unit Supplemental Post ROD Field Investigation.*

CSM = conceptual site model

EA = enhanced attenuation

PRZ = periodically rewetted zone

PSQ = principal study question

1.3 Scope

Field activities consisted of drilling three boreholes for characterization sampling, completing two of the boreholes as monitoring wells, and analyzing the soils for leachability characteristics. During drilling operations at each of the locations, continuous split-spoon sampling was conducted from a depth of approximately 3 m (10 ft) bgs, through the vadose zone and PRZ, and into the top 0.8 m (2.5 ft) of the aquifer. Samples were collected for total uranium analysis, a semiselective sequential uranium leach test, a labile uranium leach test, pH analysis, and grain-size analysis. Additionally, selected vadose zone and PRZ samples were chosen for a flow-through column test and predominant uranium-bearing mineral-phase analysis to determine areas with the highest potential to release uranium into the groundwater.

Information regarding the semiselective leach testing can be found in PNNL-14022, *300 Area Uranium Leach and Adsorption Project*, and PNNL-21733, *Use of Polyphosphate to Decrease Uranium Leaching in Hanford 300 Area Smear Zone Sediment*. Additional details regarding the flow-through labile uranium leach testing using the extraction approach described by Kohler et al., 2004, "Methods for Estimating Adsorbed Uranium(VI) and Distribution Coefficients of Contaminated Sediments," and mineral-phase analysis by scanning electron microscope/energy dispersive x-ray spectroscopy can be found in the Post-ROD SI (SGW-56993).

2 Site Characteristics and Field Activities

2.1 Geology

The main geologic formations present in the 300 Area Industrial Complex are the loose eolian deposits, Hanford formation, and Ringold Formation. Of most concern to this project is the Hanford formation, which dominates the vadose zone, PRZ, and upper aquifer in this area. The Hanford formation is classified into three separate lithofacies: gravel dominated, sand dominated, and interbedded sand and silt dominated (DOE/RL-2002-39, *Standardized Stratigraphic Nomenclature for Post-Ringold-Formation Sediments Within the Central Pasco Basin*). Most prominent in the study area is the gravel-dominated lithofacies of the Hanford formation, consisting predominantly of angular mafic gravels and sands. Rip-up clasts of the semiconsolidated, fine-grained Ringold Formation are found in the Hanford formation. These rip-up clasts either consist of caliche or compacted mud, which was deposited during Ringold Formation-time flooding (PNNL-14834, *Sampling and Hydrogeology of The Vadose Zone Beneath the 300 Area Process Ponds*). Fine-grained silt to coarse sand from the Ringold Formation is also found to be incorporated throughout the Hanford formation gravels (WHC-EP-0500, *Geology and Hydrology of the 300 Area and Vicinity, Hanford Site, South-Central Washington*).

The vadose zone averages 10 m (33 ft) of thickness around the 300 Area Industrial Complex but can vary with the Columbia River. Rising groundwater elevations due to higher river stages saturate deeper portions of the vadose zone, while lower river stages result in dewatering of the deeper portions of the vadose zone as groundwater elevations drop. The fluctuating groundwater elevations due to seasonal changes in the Columbia River create the PRZ (DOE/RL-2014-13, *Integrated Remedial Design Report/ Remedial Action Work Plan for the 300 Area (300-FF-1, 300-FF-2 & 300-FF-5 Operable Units*).

2.1.1 Hydrogeology

Groundwater in the unconfined aquifer flows to the east and southeast and occurs in the highly permeable gravel-dominated Hanford formation and the underlying sands and gravels of the Ringold Formation. The Ringold Formation has a much lower permeability due to consolidated sediments throughout. The Ringold Formation lower mud unit is a confining layer consisting of fine-grained sediments with a very low permeability, preventing further downward migration of contamination (DOE/RL-2014-13). In the 300 Area Industrial Complex, the vadose zone, PRZ, and upper aquifer are all located within the unconsolidated sands and gravels of the Hanford formation. Groundwater flow velocities through the aquifer in this formation are rapid, up to 18 m/d (59 ft/d). The groundwater flow direction changes in response to changes in the river stage. Depending upon operations of Priest Rapids Dam, upriver from the Hanford Site, the PRZ in the 300 Area ranges from 0.32 to 2.2 m (1 to 7 ft) in thickness. Paleochannels carved into Ringold Formation sediments are filled with Hanford formation gravels and act as preferential pathways for groundwater flow and intrusion of river water during periods of high river stage (Section 4.4.4.3 of DOE/RL-2010-99, *Remedial Investigation/Feasibility Study for the 300-FF-1, 300-FF-2, and 300-FF-5 Operable Units*).

2.1.2 Borehole Geology

The geologic stratigraphy was similar in each borehole, consisting of Hanford formation sands and gravels below the drilling pad at 0.6 m (2 ft) bgs to beyond the termination depths of boreholes at approximately 12.2 m (40 ft) bgs. Borehole C8936 exhibited a layer of silty sandy gravel from 8.2 to 8.7 m (27 to 28.7 ft) bgs, which also contained a Ringold Formation mud rip-up clast. Borehole logs may be reviewed in SGW-58589. Based on the soils data gathered during drilling, the CSM has been revised to include the presence of mud-like Ringold Formation rip-up clasts in the 300 Area. Contaminants have an affiliation for fine-grained soils, which affects uranium concentrations within silty or clayey soils.

2.2 Drilling, Sampling, and Well Construction

Field activities related to drilling, sampling, and well construction are provided in the following sections.

2.2.1 Drilling

Drilling of Boreholes C8933 and monitoring wells 399-1-67 (C8936) and 399-1-68 (C8938) was initiated on December 30, 2014, and concluded on January 15, 2015. Well locations were selected based upon previous data results at Wells 399-1-17A and 399-1-55, which have previously displayed elevated uranium concentrations within groundwater. The three boreholes were drilled using a cable-tool drill rig. A split-spoon sampler was used to collect samples through the vadose zone, PRZ, and upper aquifer. The sample results will be used to refine the CSM. Additional drilling details are described in SGW-58589.

Wells 399-1-67 and 399-1-68 will be used as piezometer wells, as part of the enhanced natural attenuation requirements of Section 9.1.4 of the 300 Area ROD/ROD Amendment (EPA and DOE, 2013). Groundwater monitoring network wells will be used to collect groundwater data sufficient to monitor the effectiveness of the 300-FF-5 OU groundwater remedy in the 300 Area ROD/ROD Amendment (EPA and DOE, 2013). Table 3 summarizes drilling details for the three boreholes.

Table 3. Borehole Drilling Details

Boring ID	Well Name	Drilling Dates	Depth to Groundwater (bgs)		Date Groundwater Measured	Ground Surface Elevation (m)	Total Depth (bgs)	
			(m)	(ft)			(m)	(ft)
C8933	N/A	December 30, 2014, to January 7, 2015	9.95	32.65	January 6, 2015	115.5	12.1	39.7
C8936	399-1-67	January 13, 2015, to January 15, 2015	9.8	32.1	January 15, 2015	114.6	12.4	40.7
C8938	399-1-68	January 8, 2015, to January 12, 2015	8.6	28.2	January 12, 2015	114.3	12.6	41.3

Note: All depths are below the top of the drill pad.

bgs = below ground surface

ID = identification

N/A = not applicable

2.2.2 Sampling

Continuous split-spoon samples were collected from each borehole during drilling, beginning approximately 3 m (10 ft) below the drilling pad surface. The intention was to collect soil from the vadose zone, through the PRZ, and into the upper aquifer. Deviations from the 0.8 m (2.5 ft) sampling intervals stated in the SI were due largely to compression of sediments and sloughing of sidewall materials while drilling. Samples were collected and contained in 15.2 cm (6 in.) long by 10.2 cm (4 in.) diameter clear plastic Lexan liners labeled A through D, with A at the bottom (deep end) interval sample and D at the top (shallow end) interval. Liner sections were used for different analyses. The B liner from each split-spoon sample depth was emptied into a stainless steel bowl, homogenized, and sampled for total uranium analysis. The remainder of the homogenized material was then collected into a 1 L (33.8 fl oz) polycarbonate sample container for additional analyses, if needed. All other liners were capped, sealed, labeled, and shipped to the Pacific Northwest National Laboratory (PNNL) Environmental Sciences Laboratory, along with the samples in 1 L (33.8 fl oz) polycarbonate bottles for semiselective chemical extraction, labile uranium extraction, pH, grain-size analysis, and predominant uranium-bearing mineral-phase analysis. Split-spoon sample depths are indicated on Figure 2, which shows the depths of samples from Liner B analyzed for total uranium. Additionally, grab samples were collected from the top of the aquifer for total uranium, in the same manner as the preceding collected samples. No other material was used from this interval because the results were only compared to sediments in the vadose zone and PRZ.

Table 4 presents the SI testing requirements for boreholes.

Table 4. SI Testing Requirements

Analytes	Number of Samples	Conducting Laboratory
Total uranium (<2 mm grain-size fractions)	~ 30 (10 each borehole)	GEL Laboratories
Uranium using semiselective chemical extraction (<2 mm grain-size fractions)	6 (2 from each borehole, 1 each from vadose zone and PRZ, with mineral-phase testing from at least 1 pair of samples from 1 borehole)	PNNL
Labile uranium using sodium bicarbonate/carbonate extraction (<2 mm grain-size fractions)		
pH		
Grain size		
Predominant uranium-bearing mineral phase (<2 mm grain-size fractions)		
Field-textured sediment flow-through column test	2	PNNL
<2 mm grain-size fractions flow-through column test	2	

PNNL = Pacific Northwest National Laboratory
PRZ = periodically rewetted zone
SI = sampling instruction

2.2.3 Well Construction

Borehole C8933 was decommissioned after drilling to a total depth of 12.1 m (39.7 ft) bgs.
Wells 399-1-67 (C8936) and 399-1-68 (C8938) were constructed as monitoring wells built into the PRZ. Well casing is stainless steel, with a 20-slot stainless steel screen. Each well was constructed to place the screened interval in between the high water and low water tables, which allows for monitoring across the PRZ at both seasons.

3 Analytical Results

Sampling performed at the three boreholes was used to obtain total uranium concentrations in the vadose zone, PRZ, and top 0.8 m (2.5 ft) of the aquifer. These results were used for determination of samples chosen for further analysis (leachability characteristic tests, uranium-bearing mineral-phase analyses, and flow-through column tests). The uranium leachability characteristic data were used to document the pretreatment leachability of uranium in the vadose zone and PRZ at these locations, further refining the CSM and the location for the phosphate infiltration/injection strategy in the Stage A EA area.

Detectable amounts of total uranium ranged from 0.408 to 41.4 µg/g, with all samples collected having values above the detection limit (0.013 µg/g). Analytical results from soil grab samples taken from Liner B during drilling indicate that the highest levels of uranium in soils were found in Borehole C8936 , located just southeast of Well 399-1-55 (Figure 1). The highest concentrations were all found in this borehole location, with 11 of the total 12 samples taken having concentrations above 10 µg/g (Figure 2). At Borehole C8933, located near the center of the original EA area location, 7 of the 10 samples reported values less than 1 µg/g, with a highest value of 8.2 µg/g. Borehole C8938 reported all total uranium values above 1 µg/g, beginning at the uppermost sample and continuing the trend throughout the entire borehole. The highest levels of uranium were detected at the top sampling interval (3 to 3.8 m [10 to 12.5 ft] bgs), with concentrations of approximately 6.5 µg/g.

3.1 Total Uranium Testing

Background uranium levels in the 300 Area have been previously calculated as 3.21 µg/g (ECF-300FF5-11-0151, *Groundwater Flow and Uranium Transport Modeling in Support of the 300 Area FF-5 RI/FS*). Sample data collected during the post-ROD field investigation showed elevated uranium (above background levels) at all three of the borehole locations. Well C8936 (399-1-67), located between the 300 Area Process Trenches (Waste Site 316-5) and the footprint of the former North Process Pond (Waste Site 316-2), displayed values between 3 and 10 times the background uranium soil concentrations. Well C8938 (399-1-68) displayed the lowest values of total uranium and was consistently closer to background levels. Borehole C8933 displayed uranium values less than initially anticipated, especially given its close proximity to Well 399-1-17A, but had results more than twice background within the PRZ (Appendix B [SGW-58736, *300-FF-5 Enhanced Attenuation Area Stage A Location Selection*]).

3.2 Uranium Leachability Characteristics Testing

Based on the total uranium concentration information available from the three boreholes, soil samples were selected for studying uranium leachability characteristics. Comprehensive leachability analyses were undertaken to determine the long-term desorption characteristics, along with identification of mineral phases with which uranium may be associated. Both batch tests and flow-through column leaching tests were conducted on selected soil samples. The flow-through column tests were performed on both the field-textured sample (intact core) and the <2 mm-size samples. Grain-size analysis and pH analysis were also conducted.

3.2.1 Uranium Using Semiselective Chemical Extraction

Attempts were made to determine the mineralogical phases with which uranium is associated in the sediment by performing chemical extractions with reagents that are selective for specific phases. This semiselective extraction technique (Tessier et al., 1979, "Sequential Extraction Procedure for the Speciation of Particulate Trace Metals," with modification) was used to determine the percentage of uranium associated with carbonate solid-bearing compounds, amorphous oxides (of iron, aluminum, silica, and manganese), organic matter, and crystalline oxides and hydroxides. The semiselective chemical extraction technique is described in detail in PNNL-14022. The extractant solution is also analyzed for calcium, aluminum, iron, and manganese.

Semiselective sequential extractions were conducted at PNNL for a given soil sample in the following sequence:

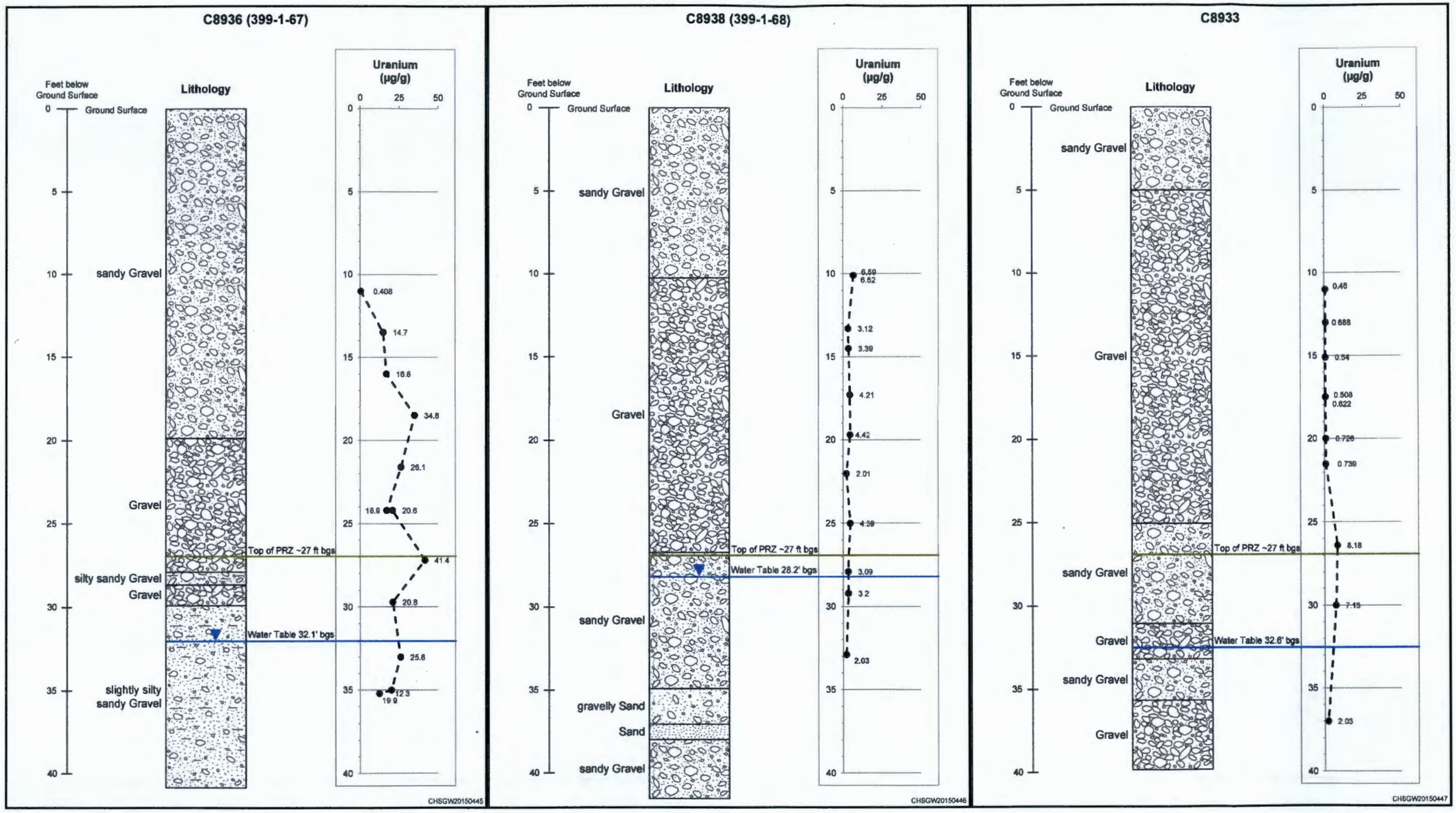
- Extraction using weak acetic acid (1 mol/L sodium acetate with final pH of 5) at a solid to solution ratio of 1 g/2 mL. The target uranium phase for this extraction is surface-adsorbed uranium and uranium associated with carbonate minerals.
- Extraction using a strong acetic acid (concentrated glacial acetic acid, pH 2.3, with 5-day contact time). The target phase for the extraction is the strongly bound (surface complexed) uranium.
- Extraction using oxalate solution (0.1 mol/L ammonium oxalate, 0.1 mol/L oxalic acid, and contact time of 1 hour). The target phases for this extraction are the amorphous iron, aluminum, manganese, and silica oxides.
- Final extraction using nitric acid (8 mol/L nitric acid at 95°C for 2 hours). The target phase for this extraction includes clays and crystalline oxides of iron, aluminum, manganese, and uranium oxides.

3.2.2 Labile Uranium Using Sodium Bicarbonate/Carbonate Extraction

The readily leachable uranium fraction (referred here as labile uranium) is estimated using the extraction approach described by Kohler et al. (2004). It uses a sodium bicarbonate (1.44×10^{-2} M) and sodium carbonate (2.8×10^{-3} M) extraction solution, at pH of 9.45 for 1 week, with periodic measurements of total dissolved uranium until a steady-state concentration is attained. This test is designed to estimate the labile uranium that is weakly adsorbed to the sediment surfaces and readily undergoes the sorption-desorption process.

3.2.3 Uranium-Bearing Mineral Phase

The predominant uranium-bearing mineral-phase identification was undertaken on selected sediment samples using Cryogenic time-resolved laser-induced U(VI) fluorescence spectroscopy. More details on this technique are presented in Appendix A.



Note: Depth to groundwater measurements were from January 2015.

Figure 2. Uranium Concentration Distribution with Borehole Geology

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3.2.4 Flow-Through Column Tests

Flow-through column leach tests are performed in order to determine the amount of uranium that can be leached from the sediment under field conditions where periodic rewetting occurs due to changes in water table elevation. Flow-through column tests are conducted on field-textured sediments (intact core) and on the <2 mm-size sediments taken from adjacent samples that were repacked by removing the gravel-size fraction. For field-textured sediment, one of the split-spoon liners is used as received (10.2 cm [4 in.] diameter by 15.2 cm [6 in.] long). For the <2 mm particle-size columns, the column size is chosen to minimize wall effects and to ensure uniform influent coverage inside the column (length of column must be greater than four times the diameter). The <2 mm particle-size columns are filled in increments and tamped as they were filled in order to minimize void space and channelized flow within the columns. The weight of the water-saturated, sediment-filled apparatus and the weight of the dry sediment placed in the columns, along with the known volume of the columns, are used to calculate the column pore volume and sediment bulk density of each column, respectively. A conservative tracer bromide anion is used to aid in determining travel times.

Column leach tests are performed by slowly percolating air-saturated upgradient simulated groundwater in an upflow direction in order to remove as much trapped air as possible, thus creating near water saturation conditions. Twice during the flow-through column tests, the flow is stopped for time periods between 48 and 72 hours and then restarted to allow release kinetics to be determined from the increased uranium concentrations found immediately after flow is resumed.

4 Observations and Discussion

The following subsections provide observations made at each borehole location during field activities as well as observations made upon review of the data gathered from the boreholes. Updates to the CSM through the use of 3-D modelling, and ultimately the refinement of the Stage A EA area, are discussed in this chapter.

4.1 C8933

The location of Borehole C8933 was determined based on historic groundwater plume maps, which exhibited elevated levels of uranium contamination south of the North Process Trench (316-5) at Well 399-1-17A. The borehole was intended to be the center of the proposed EA area. However, total uranium values detected in sandy gravel within the PRZ were less than anticipated, and results of testing have eliminated this location from the revised Stage A EA area.

4.2 C8936 (Well 399-1-67)

In the 300 Area Industrial Complex, the coarse-grained, mafic Hanford formation includes concentrated fine-grained sediment in the form of rip-up clasts as well as zones containing reworked silty Ringold sediments. Contaminants typically have an affinity for fine-grained silt and clay particles, which makes the presence of the mud-like rip-up clasts and silty gravel in C8936 (399-1-67) an important consideration for uranium mobility. Laboratory results presented in Figure 2 confirm higher concentrations of total uranium within the fine-grained soils from 8.2 to 8.7 m (27 to 28.7 ft) in Well C8936 (399-1-67). Based on these results, the center of the revised Stage A EA area has been moved to this location.

4.3 C8938 (Well 399-1-68)

Well C8938 (399-1-68) was drilled in a location exhibiting elevated uranium concentrations during groundwater sampling in 2012 at well 399-1-55. It was also located to provide lateral extent for reducing uncertainty related to residual uranium contamination in the vadose zone in the 300 Area. Testing from

the post-ROD field investigation resulted in total uranium values consistently close to background levels, eliminating this location from the revised Stage A EA area.

4.4 Refinement of 3-D Model

Leapfrog® Hydro was used to interpolate the 3-D uranium soil concentration distribution within the subsurface of the 300 Area Industrial Complex. Input data consisted of spatially referenced soil concentrations, with sample dates ranging from 1991 through 2015. Soil concentrations of uranium-238 in pCi/g to µg/g were compiled from the Hanford Environmental Information System (HEIS), which are based on the following primary reports for the 300 Area:

- DOE/RL-92-32, *Expedited Response Action Assessment for 316-5 Process Trenches*
- BHI-01164, *300 Area Process Trenches Verification Package* (Appendix D)
- Peterson, 2010, *Uranium in Sediment from FS-2 Test Pit, 618-1 Burial Ground Excavation*
- PNNL-17793, *Uranium Contamination in the 300 Area: Emergent Data and Their Impact on the Source Term Conceptual Model* (Tables 5.11, 5.22, and 5.47)
- PNNL-16435, *Limited Field Investigation Report for Uranium Contamination in the 300-FF-5 Operable Unit at the 300 Area, Hanford Site, Washington* (Table D.2)
- PNNL-22032, *Uranium in Hanford Site 300 Area: Extraction Data on Borehole Sediments*

New data from samples collected during drilling of three new boreholes in late 2014 and early 2015 (C8933, 399-1-67, and 399-1-68) and data from Peterson (2010) in the form of a letter report were also used. All soil concentrations for uranium were reported by analyzing grain size of <2 mm (by removing the gravel fraction).

Data downloaded from HEIS were selectively filtered by removing samples marked as duplicates and overburden/staging pile area measurements. Measurements from soil that was subsequently excavated after the measurements were selectively removed from the dataset. Some of the HEIS data did not come with depth-discrete measurements. Depths were assigned at 5 and 7.5 m (15 and 25 ft) for measurements classified as shallow and deep, respectively. For samples collected at the surface, the depth was set at 0.3 m (1 ft). Where a sampling depth range was given, the sampling depth was taken as the midpoint of the range. Additionally, soil sample results based on one lab method (described in HEIS as UISO_Plate_AEA) were used for consistency and comparability of data. This method detects the isotopes of uranium using alpha spectroscopy. All data for soils that were below the detectable limit were set to zero. The newest data from Boreholes C8933, 399-1-67, and 399-1-68 were received as total uranium soil concentration (µg/g). The soil concentration results for the uranium-238 isotope were used in the calculations for uranium modeling since almost all (99.3 percent) naturally occurring uranium is composed of uranium-238 (IUPAC, 1998, *Isotopic Compositions of the Elements 1997*).

Before entering the uranium concentration data into Leapfrog Hydro for plume interpolation, a base geologic model of suprabasalt sediments underlying the 300 Area Industrial Complex was constructed. Geologic model development used current datasets from the existing geologic framework model representing the entire Hanford Site south of Gable Mountain and Gable Butte (ECF-Hanford-13-0029, *Development of the Hanford South Geologic Framework Model, Hanford Site Washington*) and interpretations of recently received borehole geologic logs from the area (PNNL-22032).

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The 300 Area geologic model was constructed of two parts: a detailed Hanford formation (Hf) model, subdividing the unit into subunits based upon silt, sand, and gravel fractions; and the upper surfaces of the Ringold Formation member of Wooded Island – unit E (Rwie) and Ringold Formation lower mud (RLM) imported from the Hanford South geologic framework model (ECF-Hanford-13-0029).

The detailed Hanford formation model used the imported Rwie surface as its lower boundary and ground-proofed AeroMetric Light Detection and Ranging topography as the upper boundary. Detailed Hanford formation geologic data were interpreted from borehole geologic and geophysical logs available from HEIS, the Well Information and Document Lookup database, and Integrated Document Management System. These data were subsequently interpolated in Leapfrog Hydro using the software's radial basis function algorithm. Five distinct Hanford formation subunits were identified to be present in the 300 Area from the borehole geologic log interpretations. In order of occurrence from the ground surface down, these units were described in ECF-Hanford-13-0029 as Hf sand unit 1, Hf sandy gravel, Hf sand unit 2, Hf silty-sandy gravel, and Hf gravel.

The Ringold Formation model used the imported Rwie surface as its upper boundary and a top of basalt surface interpreted from seismic and borehole data (SGW-48478, *Interpretation and Integration of Seismic Data in the Gable Gap*) as the bottom boundary. The radial basis function algorithm also interpolated volumes from the Rwie and RLM, based on their respective imported surfaces.

After construction of the geologic framework model for the 300 Area, the uranium soil concentration data were used in 3-D uranium plume interpolation. Leapfrog Hydro uses radial basis functions for the interpolation. Control points were added to the model in order to constrain the uranium plume extents within reasonable limits as determined by analysis of the available data. Soil uranium concentrations were interpolated in the Leapfrog model volume and are shown at 30 and 90 μg/g extents (approximately 10 and 30 times the background soil uranium concentrations), to provide a better illustration of the footprint of the highest concentrations, therefore aiding in defining the area of interest.

4.5 Summary of Updates to CSM

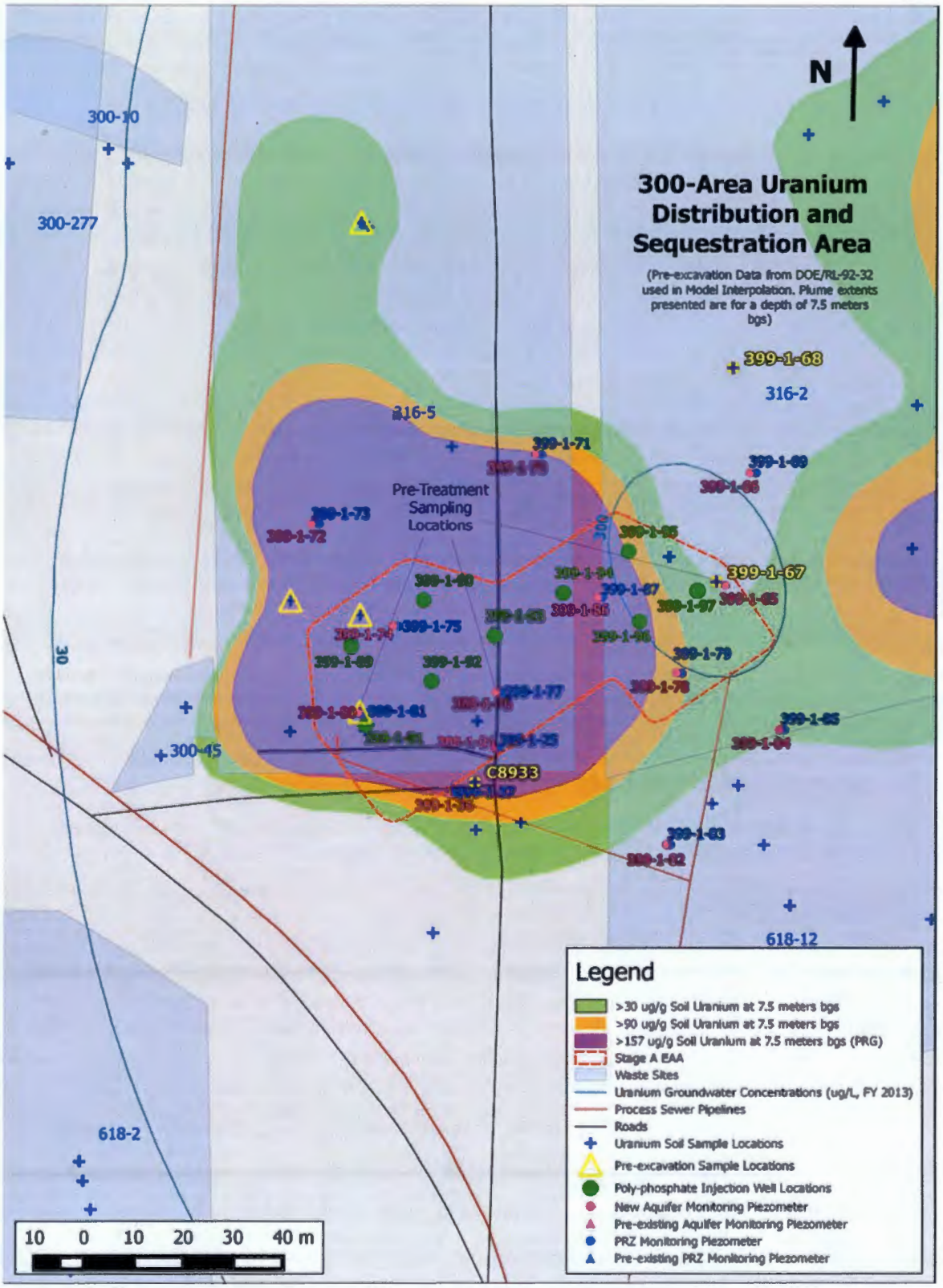
This section shows refinement of the Stage A EA area along with uranium leachability characteristic data gathered from PNNL tests and the use of that in updates to the CSM.

4.5.1 Enhanced Attenuation Area Location

The post-ROD field investigation results provided new insight into the uranium concentrations within the northern portion of the 300 Area Industrial Complex. With new soil concentration data and historical groundwater plume data, an area of highest potential uranium concentrations in the vadose zone and PRZ has been established for the Stage A EA area injection/infiltration treatment and projected Stage B location. This evaluation determined that Stage A should include the following locations. These locations were selected because they show elevated uranium levels above the natural background (Figure 3):

- Southern portion of the North Process Trenches (316-5), where high uranium soil concentrations were observed near the former outfall of the 300-15 Process Sewer
- Southwest corner of the North Process Pond (316-2), where Well 399-1-67 was recently drilled

Figure 3 also presents the locations of EA injection and monitoring wells. Additional detail regarding the use of the 3-D soil model for uranium, Stage A EA area location selection, and well location selected has been documented in a technical memorandum (SGW-58736 in Appendix B).



DOE/RL-92-32, *Expedited Response Action Assessment for 316-5 Process Trenches.*

Figure 3. Stage A EA Area and Preliminary Stage B EA Area Treatment Locations

4.5.2 Uranium Leachability Characteristics

Semiselective chemical extractions were conducted on six soil samples collected from three boreholes:

- Two samples (B304Y3 and B304Y5) were analyzed from Borehole C8933 at depths of 8.38 and 9.14 m (27.5 and 30 ft), respectively.
- Three samples (B30525, B30538, and B30546) were analyzed from Borehole C8936 (399-1-67) at approximate depths of 5.33, 7.92, and 8.69 m (17.5, 26, and 28.5 ft), respectively.
- One sample (B30589) was analyzed from Borehole C8938 (399-1-68) at an approximate depth of 7.32 m (25 ft).

The semiselective extraction was performed using weak acetic acid, strong acetic acid, ammonium oxalate, and nitric acid as described in Section 3.2.1. The results are presented in Figure 4 in terms of percent extracted uranium during each extraction along with the total extracted uranium concentration. The total extracted uranium varies from about 7 to 126 µg/g among the collected samples, with the highest concentrations observed in three samples collected from C8936 (399-1-67). In almost all samples, the weak acetic acid and nitric acid extracted the highest concentrations. The weak acetic acid extractions target the weakly adsorbed and readily soluble uranium-bearing carbonate mineral phases, while the nitric acid extraction targets the nonleachable (strongly bound) uranium associated with crystalline oxides and hydroxides and clays that remains after all other extractions have occurred. In contrast, the strong acetic acid and oxalate extractions selectively target the strongly bound (surface-complexed) uranium and that associated with amorphous oxides of iron, manganese, aluminum, and silica.

A relatively large fraction of uranium appears to be associated with the carbonate mineral phases (weak acetic acid extraction), indicating that the labile and readily leachable uranium fraction varies from 20 to 50 percent of the total uranium measured prior to extraction. For the Borehole C8936 (399-1-67) sample located at depth of 7.92 m (26 ft; sample B30538), which has the highest measured total uranium concentration of approximately 126 µg/g, the labile uranium fraction is around 43 percent. Because this sample is located within the PRZ, it is likely that the relative mobility of the labile uranium contaminates the groundwater. The increased silt content observed at this depth indicates that reduced permeability may have contributed to persistent high residual uranium concentrations within the PRZ.

The readily leachable (labile) uranium concentrations determined using the sodium bicarbonate and sodium carbonate extraction method are presented in Figure 5 (bicarbonate extraction). The amount of uranium that is weakly surface complexed and readily leachable from weak acetic acid extraction also are presented for comparison. Samples showing higher uranium concentrations from sodium bicarbonate/ carbonate extraction also tend to indicate higher concentrations from weak acetic acid extraction; however, the latter extraction leads to larger uranium concentration. This implies that most of the uranium that is potentially labile is associated with soluble carbonate mineral phases with relatively smaller amounts or uranium weakly complexed at the surface sites. Results of the fluorescence spectra, conducted on selected sediment samples (Appendix A), also indicate the presence of uranyl ion associated with calcium carbonate mineral phases (such as aragonite and calcite). Figure 6 shows the calcium concentration from the weak acetic acid sequential extraction step. Concentrations do not vary greatly among the soil samples, thereby indicating uniform distribution of calcium-bearing phases (predominantly calcium carbonate).

An interesting correlation is observed between aluminum concentrations (derived from nitric acid extraction) and the uranium concentration (from weak acetic acid extraction) as shown in Figure 7. Samples with high aluminum concentrations also tend to have high uranium concentrations associated with soluble carbonate phases. This may be a reflection of the discharged waste stream composition that

contained high concentrations of aluminum. The waste from nuclear fuel fabrication that was discharged at process ponds and trenches included basic sodium aluminate solutions along with acidic uranyl nitrate solutions.

In addition to the batch tests, two pairs of flow-through column tests were conducted on sediment samples from C8936 (399-1-67) to evaluate the leachability of uranium from field-textured sediment (intact core) and from <2 mm-size sediments (fine textured). The first pair was taken from depths of 7.9 to 8.7 m (26 to 28.5 ft) for the field-textured (B30541) and <2 mm-size (B30538) sediment column. The second pair was taken from depths of 8.7 to 9.4 m (28.5 to 31 ft) for the field-textured (B30543) and <2 mm-size (B30546) sediment column. These sampling depths were selected based on the high total uranium content observed, to collocate the sample with those where semiselective sequential extraction results were available. The flow-through column experiments were conducted by passing several pore volumes of water, whose composition was prepared at PNNL to reflect the ambient groundwater in the 300 Area. Two stop-flow events were simulated, where flow injection was stopped for 46 and 72 hours to reflect the conditions in the PRZ. Results of the experiments are presented in Figures 8 through 11.

Results of flow-through column tests conducted on the field-textured (intact core) sediments indicate initial high uranium concentration leaching out, with near exponential declines up to about 5 pore volumes (Figures 8 and 10). Initial high concentrations of uranium of >1,000 and >500 µg/L are observed that reflect flushing of uranium present in the pore waters of the sediments. The initial pore water uranium concentration may reflect equilibrated conditions over the time when the sediments were recovered from the field until column tests were conducted. After about five pore volumes, concentrations do not appear to vary much until after the stop flow event. High uranium concentrations that decline over the first few pore volumes reflect desorption from surface sorption sites where the uranium is weakly complexed (weak sites), including release from uranium-bearing carbonate mineral phases that can readily dissolve. After a few pore volumes, the desorption appears to be controlled by surface sorption sites where uranium is strongly bound (strong sites). At the resumption of flow following the two stop-flow events, uranium concentrations show a spike but then equilibrate quickly. This reflects adsorption of dissolved uranium present in the pore water on to the weak sites during the stop-flow time period, which then gets released on resumption of flow.

Results of flow through column tests, conducted on the repacked <2 mm-size (fine-fraction) sediments, are shown in Figures 9 and 11. Results indicate that uranium concentrations increase over time with increasing pore volume until reaching a near steady state. In fact, the near steady-state concentrations observed match with long-term concentrations observed for the field-textured sediments, thereby indicating that long-term concentrations for field-textured sediments are controlled by desorption from <2 mm-size (fine-fraction) sediments. This further indicates that most of the strong sites are associated with the fine-grained fraction and reflect uranium-bearing mineral phases that are not readily dissolved upon contact with water. Increasing concentrations observed over the first 10 pore volumes for the <2 mm-size sediments are consistent with this conceptual understanding, thereby reflecting slow desorption.

Additional information related to leach testing is presented in Appendix B. A detailed quantitative evaluation of the column leach test results is currently underway to determine the site-specific uranium desorption kinetics, so they can be applied to the field-scale fate and transport model to support the planned uranium sequestration remedy performance evaluation that will be presented in the Stage A Treatment Performance Report.

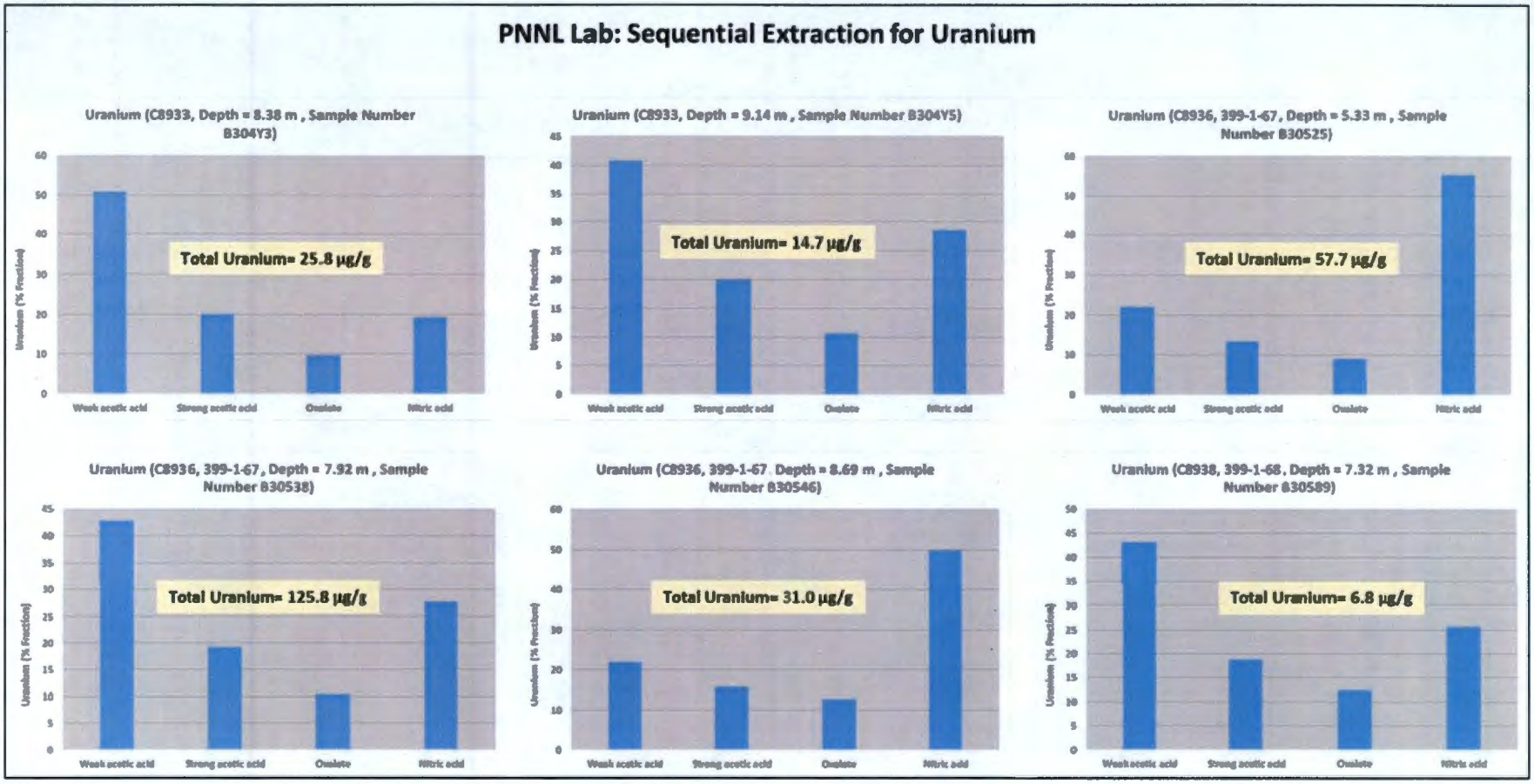


Figure 4. Results from the Semiselective Sequential Extraction Experiments to Determine Percent of Uranium Associated with Various Mineral Phases

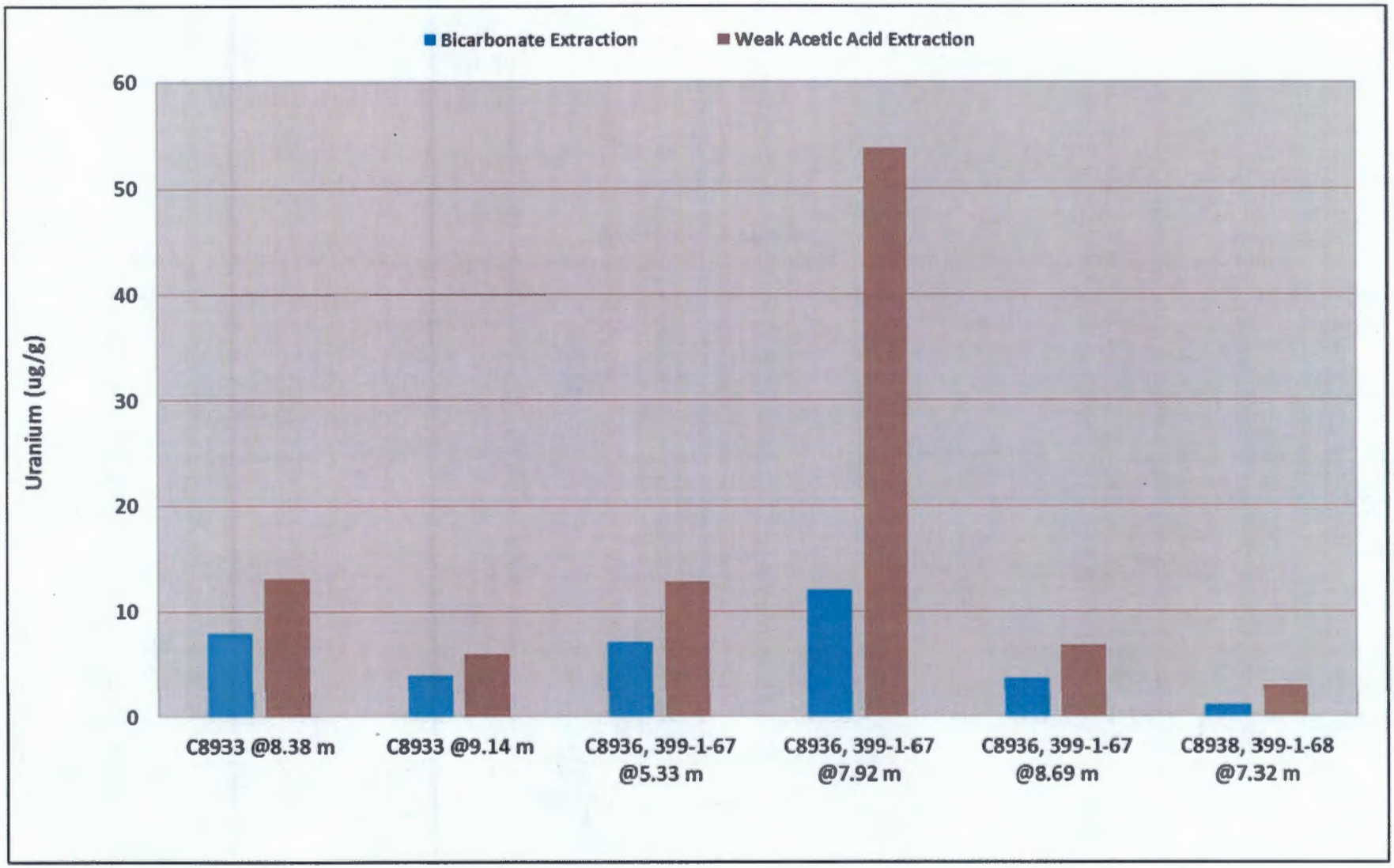


Figure 5. Uranium Concentration Using Sodium Bicarbonate/Carbonate Extraction Compared with the Uranium Concentration from Weak Acetic Acid Extraction Method

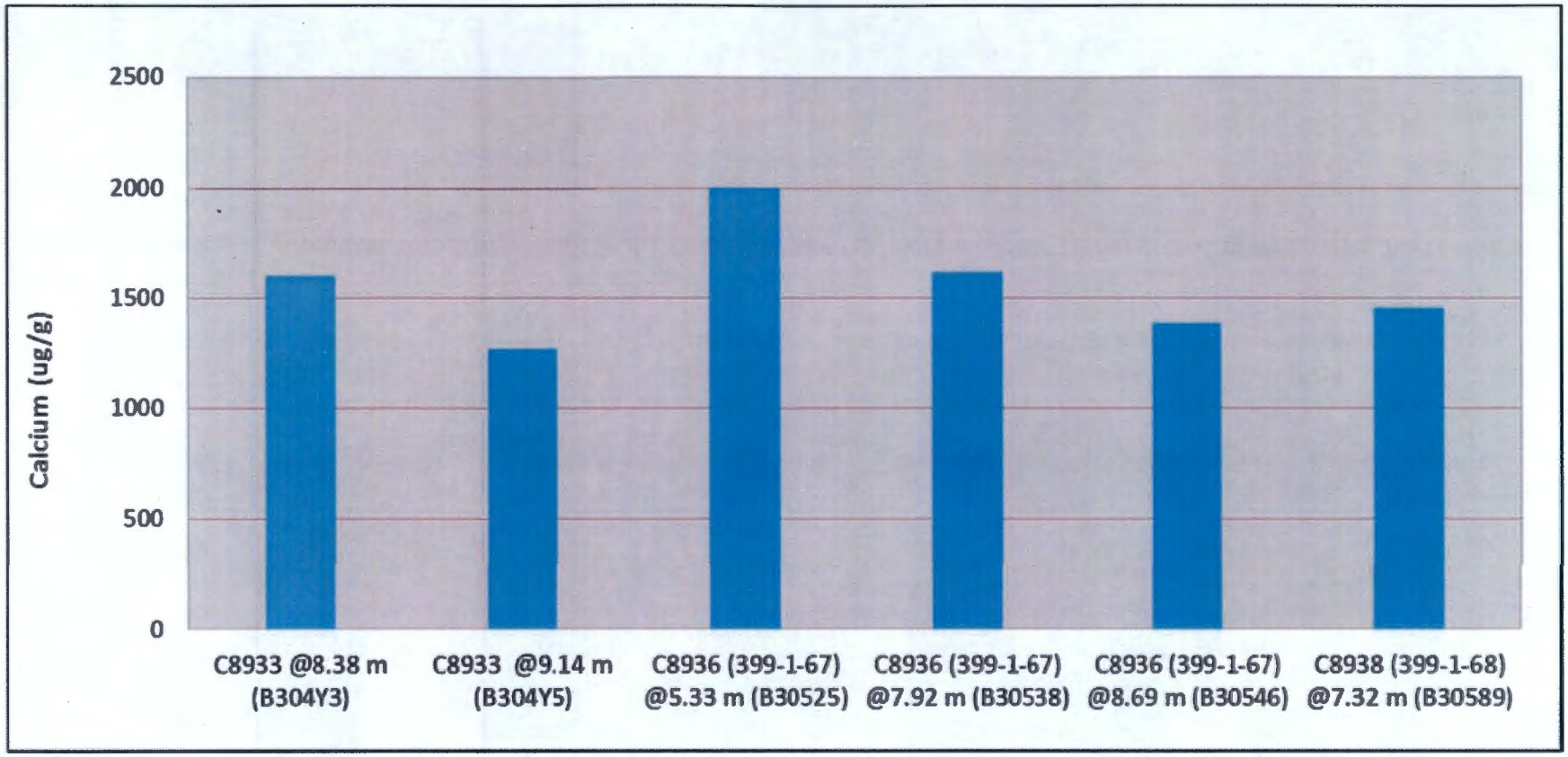


Figure 6. Observed Calcium Concentrations during the Weak Acetic Acid Sequential Extraction Step

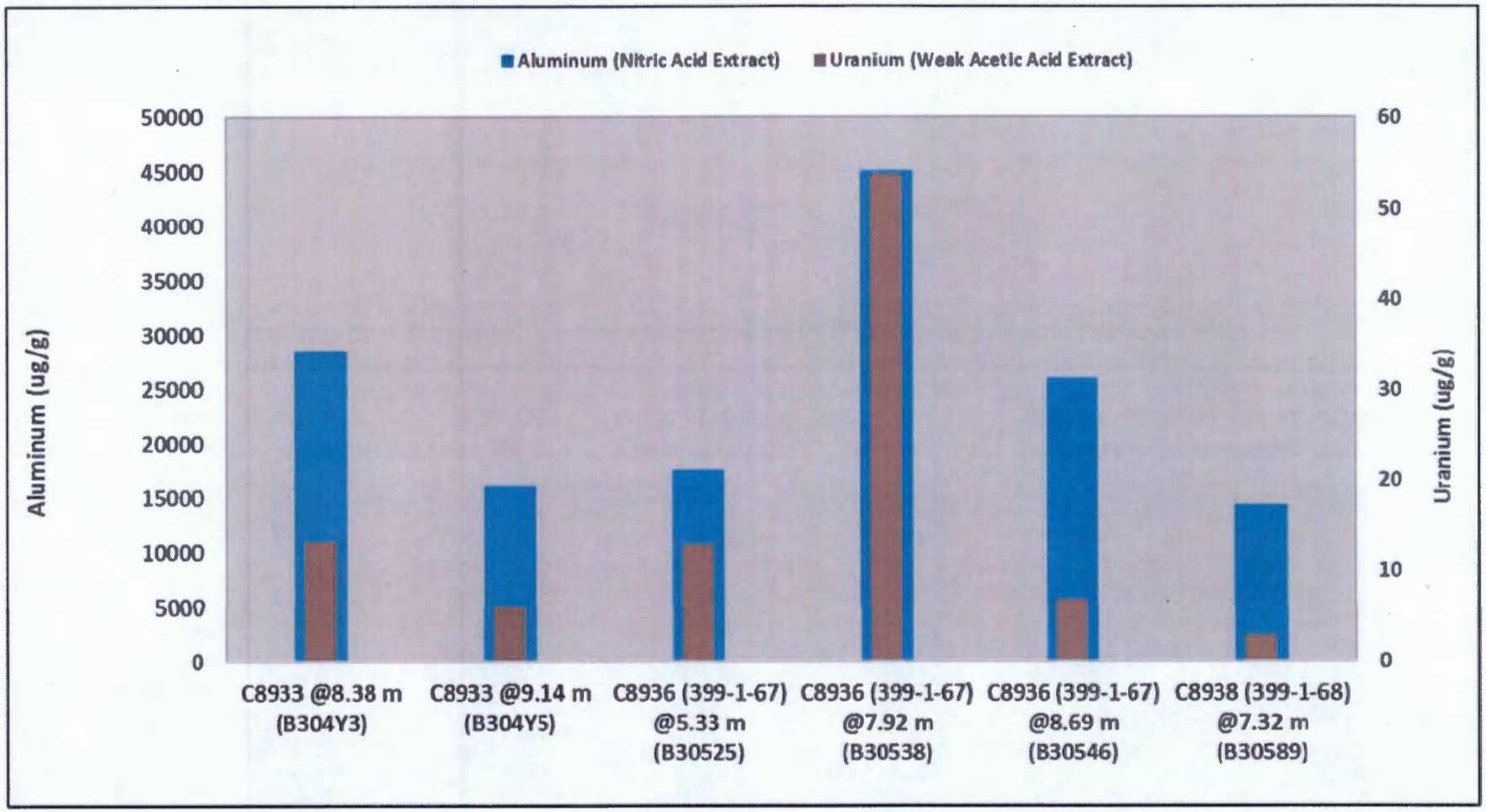
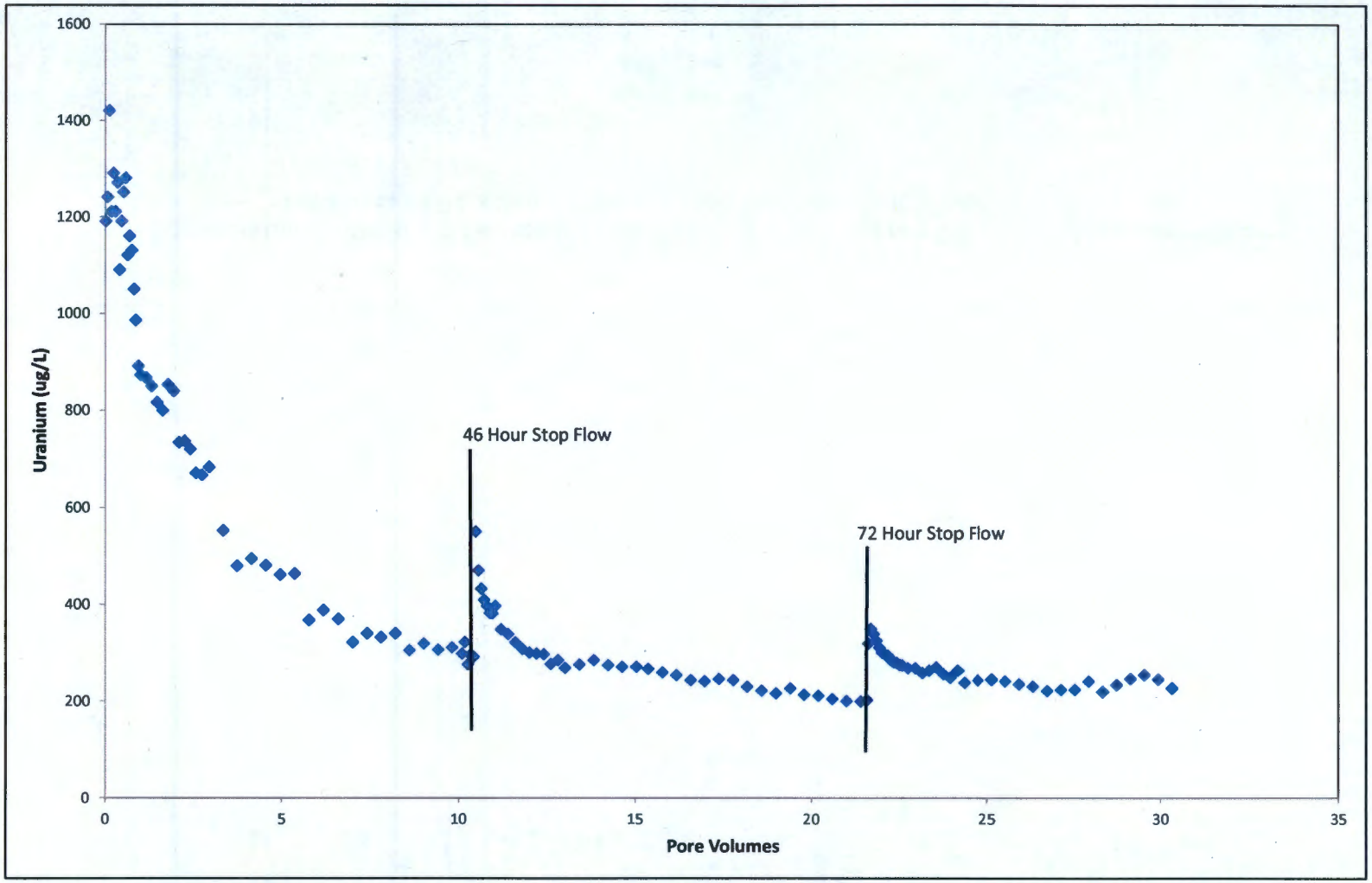
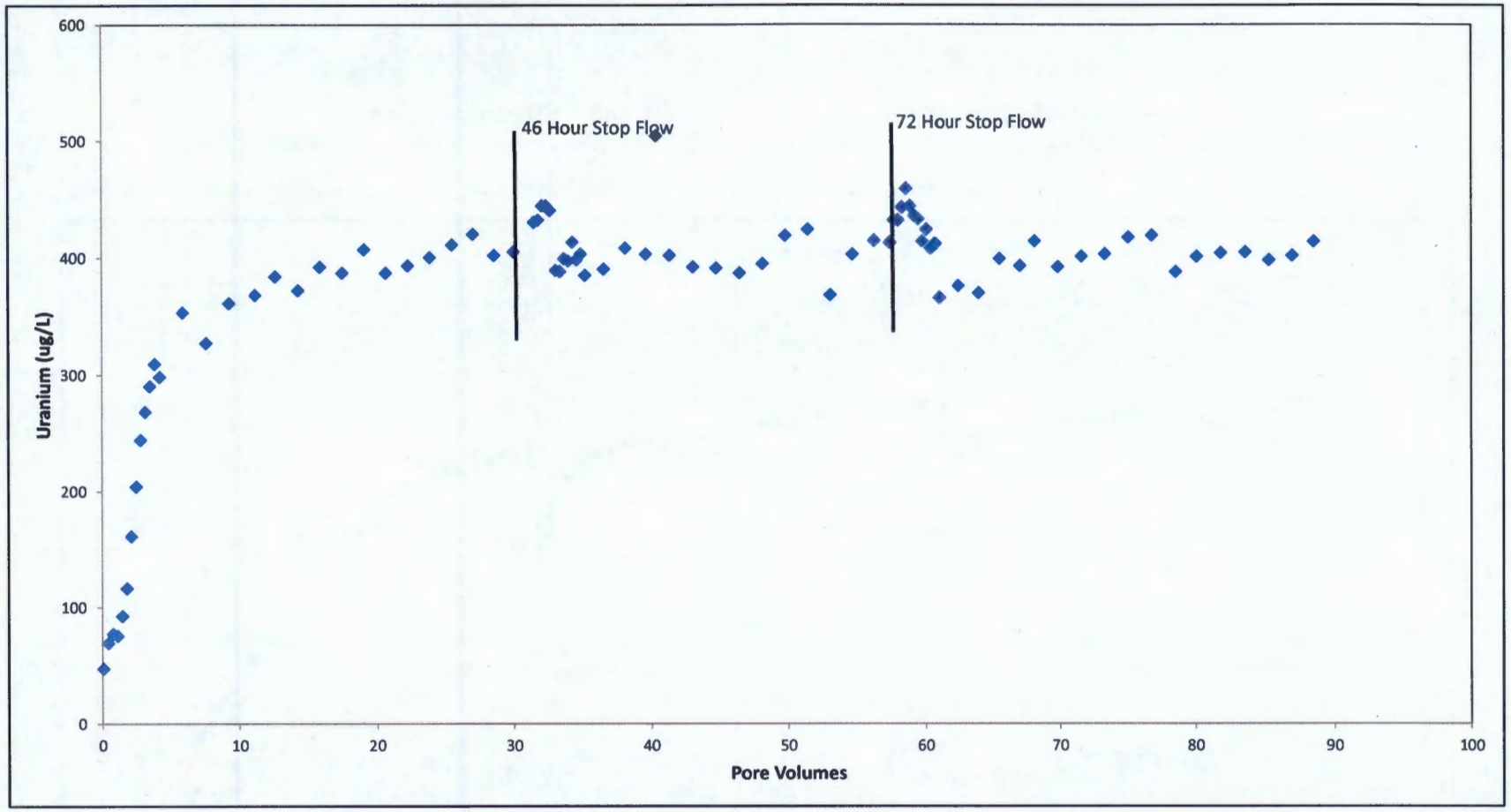


Figure 7. Aluminum Concentrations (Based on Nitric Acid Extract) Compared to Uranium Concentrations (Based on Weak Acetic Acid Extract)



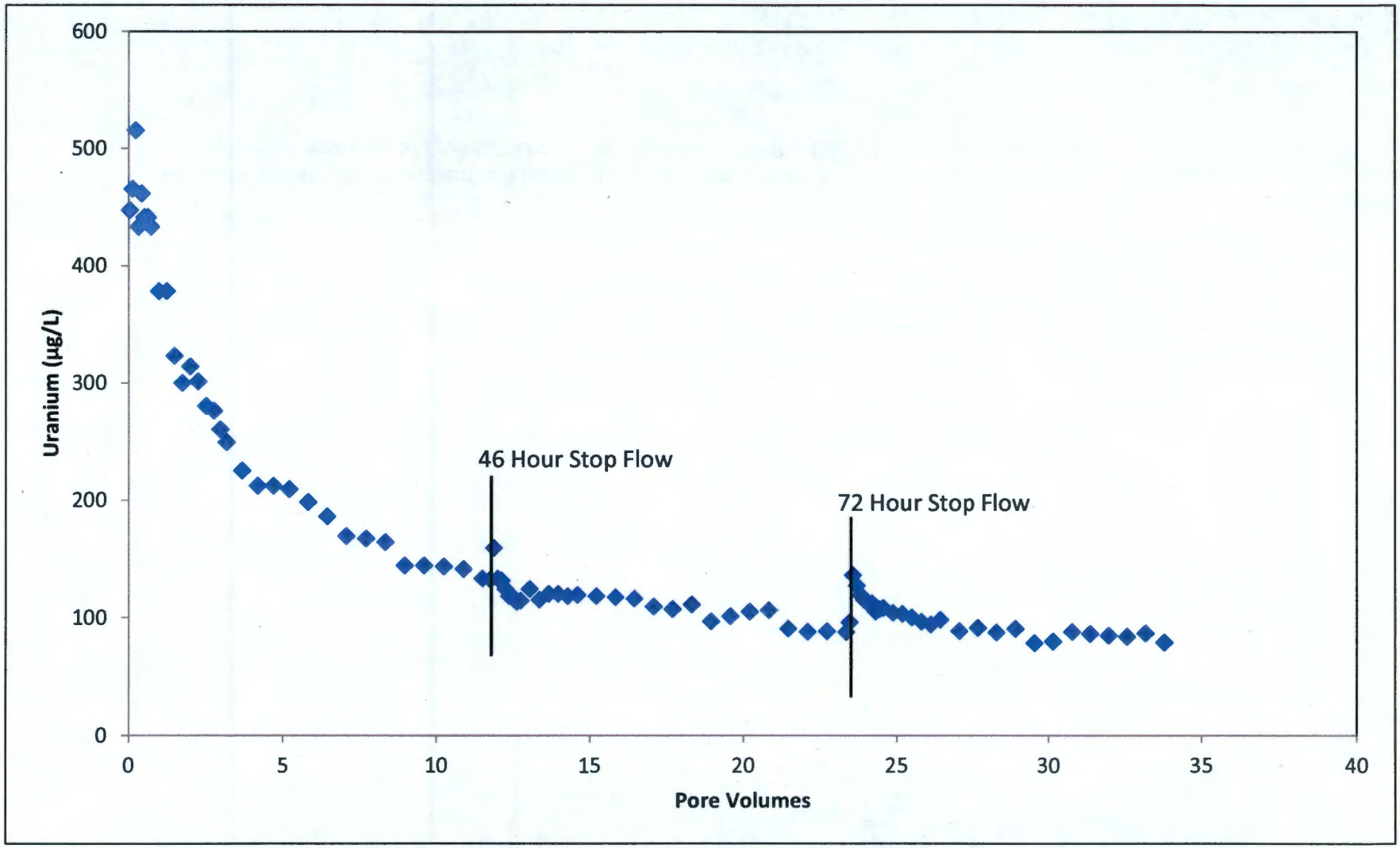
Note: Estimated pore volume is 245 mL, and approximate flow rate is 0.1519 pore volume per hour.

Figure 8. Uranium Concentration as a Function of Eluted Pore Volume for the Field-Textured Sediments (Intact Core) from C8936 (399-1-67), Located at Depth of 8.3 to 9.1 m (26 to 28.5 ft) (Sample B30541)



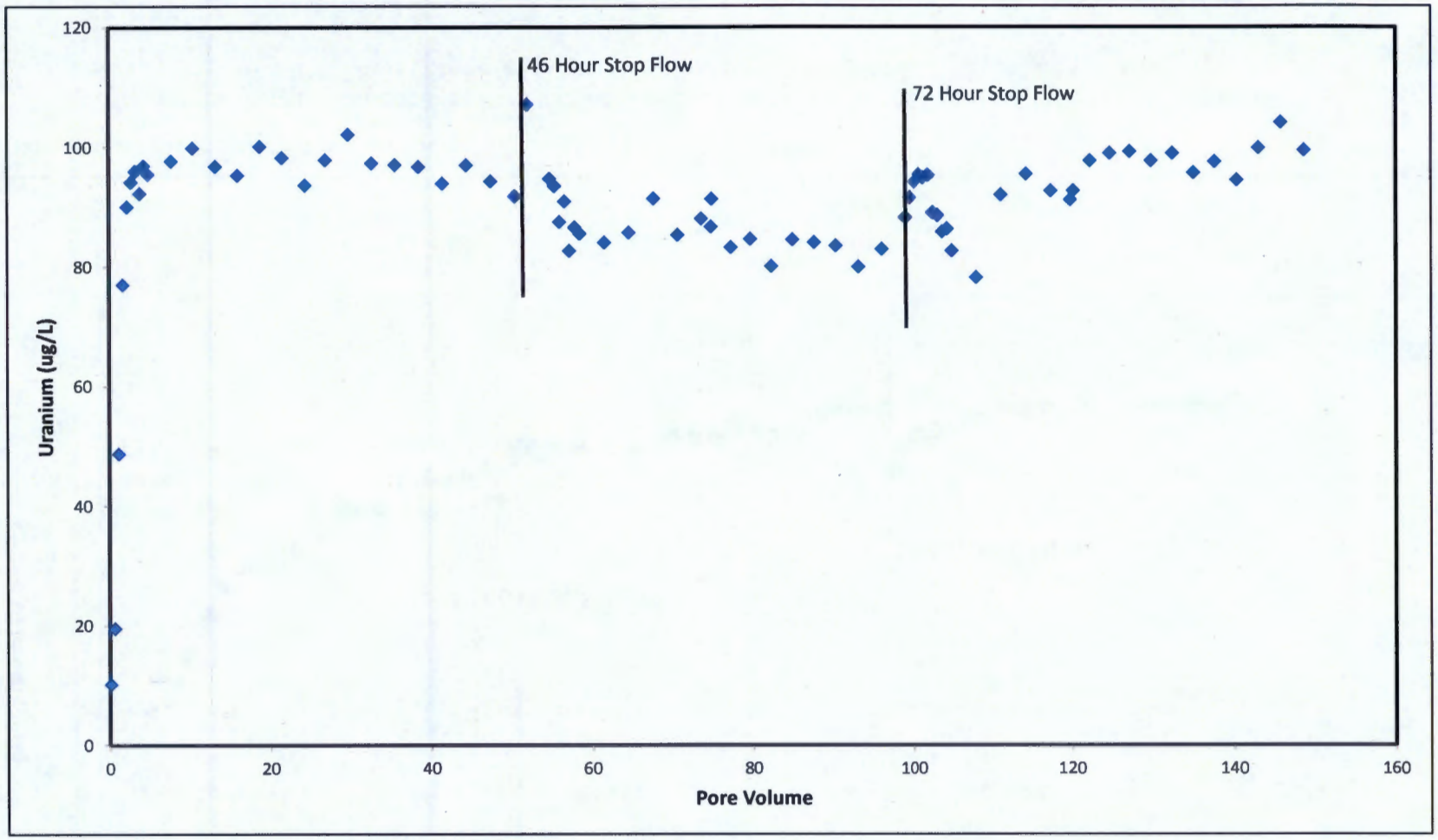
Note: Estimated pore volume is 28.65 mL, and approximate flow rate is 0.21931 pore volume per hour.

Figure 9. Uranium Concentration as a Function of Eluted Pore Volume for the <2 mm-Size (Fine-Grained) Sediments from C8936 (399-1-67) Located at Depth of 8.3 to 9.1 m (26 to 28.5 ft) (Sample B30538)



Note: Estimated pore volume is 223.5 mL, and approximate flow rate is 0.2476 pore volume per hour.

Figure 10. Uranium Concentration as a Function of Eluted Pore Volume for the Field-Textured Sediments (Intact Core) from C8936 (399-1-67), Located at Depth of 9.1 to 9.9 m (28.5 to 31 ft) (Sample B30543)



Note: Estimated pore volume is 24.5 mL, and approximate flow rate is 0.3581 pore volume per hour.

Figure 11. Uranium Concentration as a Function of Eluted Pore Volume for the <2 mm-Size (Fine-Grained) Sediments from C8936 (399-1-67), Located at Depth of 9.1 to 9.9 m (28.5 to 31 ft) (Sample B30546)

5 Data Completeness Verification and Usability

This chapter discusses the analytical results for soil samples collected in accordance with the Post-ROD SI (SGW-56993). It includes an overall verification of data for completeness and accuracy, within the sampling and analytical methods required, and an evaluation for usability in response to the DQOs of the Post-ROD SI (SGW-56993).

5.1 Completeness Evaluation

Soil samples were collected during the drilling of Borehole C8933 and Wells 399-1-67 (C8936) and 399-1-68 (C8938) in accordance with the Post-ROD SI (SGW-56993).

There were minor differences between actual sample depths and those presented in the Post-ROD SI (SGW-56993) due to conditions encountered during drilling. All samples were collected, as required by the Post-ROD SI (SGW-56993). Total uranium results were used to choose samples for further analysis (leachability characteristic tests, uranium-bearing mineral-phase analyses and flow-through column tests). Low levels of total uranium in Well 399-1-68 (C8938) did not warrant leachability testing in the PRZ, as required in the Post-ROD SI (SGW-56993). However, samples were analyzed for the constituents listed in the applicable documents, and the overall sampling design presented in the Post-ROD SI (SGW-56993) was implemented.

Table 5 summarizes the sampling design presented in the Post-ROD SI (SGW-56993) and summarizes the sampling performed to meet sampling design requirements for the borehole and new wells.

Table 5. Sample Collection Summary, Implementation, and Completion Evaluation

Location	Sampling Design Key Features	Samples Required by Design	Sampling Completed in Vadose Zone	Sampling Completed in PRZ	Percent Complete
C8933	**Total uranium soil characterization:** Soil samples within the vadose zone and the PRZ to characterize the vertical profile and lateral distribution of uranium soil concentrations	Conduct total uranium measurements.	7 Total uranium 1 Semiselective sequential uranium leach test 1 pH analysis 0 Grain-size analysis 1 Uranium-bearing mineral phase 1 Flow-through column leach test	4 Total uranium 1 Semiselective sequential uranium leach test 1 pH analysis 0 Grain-size analysis 1 Uranium-bearing mineral phase 1 Flow-through column leach test	100
399-1-67 (C8936)	**Leachability sediment characterization:** One liner of the split-spoon sample to test leachability of uranium in the vadose zone and PRZ that corresponds to regions of higher groundwater uranium	Conduct semiselective sequential uranium leach tests on sediments collected from each borehole. Conduct labile uranium flow-through leach test on sediments collected from each borehole. Conduct grain-size and pH analyses. Conduct uranium-bearing mineral phase from at least one borehole within the refined EA area.	6 Total uranium 1 Semiselective sequential uranium leach test 1 pH analysis 0 Grain-size analysis 1 Uranium-bearing mineral phase 0 Flow-through column leach test	5 Total uranium 2 Semiselective sequential uranium leach test 2 pH analysis 1 Grain-size analysis 2 Uranium-bearing mineral phase 2 Flow-through column leach test	100
399-1-68 (C8938)			7 Total uranium 1 Semiselective sequential uranium leach test 1 pH analysis 0 Grain size analysis 1 Uranium-bearing mineral phase 1 Flow-through column leach test	4 Total uranium 0 Semiselective sequential uranium leach test 0 pH analysis 1 Grain size analysis 0 Uranium-bearing mineral phase 0 Flow-through column leach test	100

bgs = below ground surface
EA = enhanced attenuation
PRZ = periodically rewetted zone

6 Verification for Field and Laboratory Quality

This chapter discusses the implementation of field and laboratory quality protocols.

6.1 Field Quality Control Sampling Requirements

The Post-ROD SI (SGW-56993) required collection of equipment blank (EB) samples and a field duplicate (DUP) sample.

Table 6 summarizes the field quality control (QC) samples required by DOE/RL-2009-45, *300 Area Remedial Investigation/Feasibility Study Sampling and Analysis Plan for the 300-FF-1, 300-FF-2 and 300-FF-5 Operable Units* (300 Area RI/FS SAP). Subsequent sections discuss each field QC sample type in further detail.

Table 6. Field QC Checks

QC Sample Type	Purpose	Frequency
EB	Verify adequacy of sampling equipment decontamination.	One EB sample per borehole
DUP	Estimate precision, including sampling and analytical variability.	One DUP sample per borehole

QC = quality control
EB = equipment blank
DUP = field duplicate

6.2 Field Quality Control Results

The following subsections discuss the field QC results as they pertain to the 300 Area RI/FS SAP (DOE/RL-2009-45).

6.2.1 Field Duplicate Results

The Post-ROD SI (SGW-56993) required one DUP sample per borehole. DUPs are independent samples generally collected from an area expected to have some contamination so valid comparisons between the samples can be made. DUPs were collected from the stainless-steel bowl of homogenized soil used for the grab samples, as required by the Post-ROD SI (SGW-56993).

DUP samples were obtained from the same sample interval using the same equipment and sampling technique as their corresponding primary field samples. In addition, DUP samples were analyzed for the same contaminants of potential concern by the same laboratory that analyzed the primary field samples. Three DUPs were taken, meeting the requirements of the Post-ROD SI (SGW-56993).

6.2.2 Equipment Blank Results

In accordance the Post-ROD SI (SGW-56993), one EB sample for every borehole was collected from any reusable sampling device. EBs were collected using silica sand and analyzed for the target analyte (total uranium). Results for these EBs were below background levels of uranium in the 300 Area, meeting the requirements of the Post-ROD SI (SGW-56993).

6.3 Laboratory Quality Control

All data were managed in accordance with the Post-ROD SI (SGW-56993). Data resulting from the implementation of the Post-ROD SI (SGW-56993) were stored in the HEIS database. Material collected from designated sample intervals was analyzed for total uranium by inductively coupled plasma/mass spectrometry (ICP/MS) using EPA solid waste method 6020 (SW-846). Sample material designated for a particular analysis by the selected laboratory was tracked with a unique HEIS database number. Requests for laboratory chemical analyses were documented on chain-of-custody forms. Analytical results provided by the laboratories were tracked and documented by sample data groups in data packages.

6.3.1 Laboratory Quality Performance

In addition to the rigorous validation performed on a selected subset of the data described in Section 6.3, a broad review of the laboratory QC results was also conducted. Laboratory QC results were stored electronically in the HEIS database and were evaluated using various database queries against the acceptance criteria (Table 7).

Table 7. Laboratory QC Acceptance Criteria

QC Sample Type	Purpose	Frequency	Acceptance Criteria
Laboratory (matrix) duplicate	Estimate analytical bias and precision.	When required by method guidance, one per batch,* 20 samples maximum, or as identified by method guidance, *per media sampled*	Laboratory duplicate samples with at least one result greater than five times the MDL or MDC must have an RPD less than or equal to 20 percent for water and 30 percent for solid matrixes to be considered acceptable.
Laboratory (method) blank	Assess response of an entire laboratory analytical system.	One per batch,* 20 samples maximum, or as identified by the method guidance, *per media sampled*	Laboratory blank limit is two times the MDL, IDL, or MDC. However, for common laboratory contaminants acetone, methylene chloride, 2-butanone, toluene, and phthalate esters, the QC limit are five times the MDL or MDC.
LCS	Assess method accuracy.	One per batch,* 20 samples maximum, or as identified by the method guidance, *per media sampled*	LCS percent recovery must be between the upper and lower control limits listed in the 300 Area RI/FS SAP (DOE/RL-2009-45).
MS or MSD	Identify analytical (preparation and analysis) bias; possible matrix effect on the analytical method used. When used, matrix spike duplicates also estimate analytical bias and precision.	When required by the method guidance, one per batch, 20 samples maximum, or as identified by the method guidance, *per media sampled*	Laboratory spikes where the sample result is less than or equal to four times the spiking concentration are evaluated by comparing the percent recovery with the upper and lower control limits provided by the laboratory. In addition, where the sample result is less than or equal to four times the spiking concentration, the MS/MSD RPD must have an RPD less than or equal to 20 percent for water and 30 percent for soil matrices.
Surrogates	Estimate recovery or yield.	When required by the method guidance, as identified by the method guidance	Surrogate percent recovery within laboratory-established statistical control limits

Table 7. Laboratory QC Acceptance Criteria

QC Sample Type	Purpose	Frequency	Acceptance Criteria

Reference: DOE/RL-2009-45, *300 Area Remedial Investigation/Feasibility Study Sampling and Analysis Plan for the 300-FF-1, 300-FF-2 and 300-FF-5 Operable Units*

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

IDL = instrument detection limit

LCS = laboratory control sample

MDC = minimum detectable concentration

MDL = method detection limit

MS/MSD = matrix spike/matrix spike duplicate

QC = quality control

RI/FS = remedial investigation/feasibility study

RPD = relative percent difference

SAP = sampling and analysis plan

The following sections outline the results of the laboratory QC evaluation.

6.3.1.1 Laboratory Control Samples

A total of five laboratory control sample (and blank spike) results were reported. Percent recoveries ranged from 92.3 to 101, all of which were within the analytical performance requirements for accuracy of 80 to 120 percent.

6.3.1.2 Laboratory Matrix Spike Recovery

The matrix spike recovery is also used as a measure of analytical accuracy. Percent recoveries ranged from 90.9 to 103, all of which were within the analytical performance requirements for accuracy of 75 to 125 percent.

6.3.1.3 Laboratory Surrogates Recovery

No surrogate recoveries were used to measure the accuracy of results related to samples submitted as part of this project.

6.3.2 Qualification Flags Applied to the Dataset

No qualification flags were assigned as a result of this data validation effort. The following qualification flags were applied by the laboratory but do not affect data quality:

- "D": all results – results are reported from a diluted aliquot of sample.
- "*": four results – duplicate analysis not within control limits

Relative percent difference values calculated on results derived from duplicate aliquots of the same samples were above the acceptable range of 20 percent. The laboratory dispositioned this exception with possible nonhomogeneity and/or matrix interference between the two analyses.

6.3.3 Holding Times and Preservation Results

Holding times are defined as the period of time from sample collection to sample analysis or extraction, and the period of time from sample extraction to sample analysis. Holding times are calculated from the date of sample collection as recorded on the chain-of-custody form to determine the validity of the results.

6.3.3.1 Inorganics

The holding time and preservation requirements for ICP/MS of metals are analysis within 180 days of sample collection for soil samples.

All samples were properly preserved and analyzed within the prescribed holding times:

6.3.3.2 Review of Laboratory Data Package Case Narratives

The case narratives of the five analytical data packages generated as a result of this project were reviewed to identify potential QC issues that would affect the usability of these data. No issues were identified that would have led to the rejection of any reported results.

7 Data Usability

This chapter discusses the overall usability of data based on the verification and effectiveness review.

7.1 Representativeness

The sampling efforts conducted during this activity were representative of the population to be sampled. No discrepancies or variances from the design were noted during field activities, and the samples collected represent a dataset that is adequate for use in evaluating the data needs described in Chapter 1.

7.2 Data Verification Considerations

Based on the review performed during this review, all required samples were collected in accordance with the Post-ROD SI (SGW-56993).

7.3 Field Quality Control

Based on the review performed during this review, all field QC samples required by the 300 Area RI/FS SAP (DOE/RL-2009-45) were collected, and the results of the analysis revealed no deficiencies to suggest that any of the data were of questionable quality.

7.4 Laboratory Quality Control

Based on the review performed during this review, all laboratory QC results associated with samples analyzed for this project were performed as required by the Post-ROD SI (SGW-56993). The results of the analyses revealed no deficiencies suggesting that any of the data were of questionable quality.

8 Data Usability Conclusions

Based on the results of this review, the sample sets and associated analytical data are of sufficient quantity and quality to meet the DQOs of the Post-ROD SI (SGW-56993). The analytical results are considered useable for their intended purposes. Samples were collected and analyzed as specified in the Post-ROD SI (SGW-56993), and results accurately indicate the presence or absence of target analyte contamination at sample locations. Laboratory and matrix accuracy and precision are within acceptable limits, and systematic or general discrepancies were not displayed. Sample results are believed to be representative of site conditions at the time of collection. Results obtained are comparable to industry standards in that collection and analytical techniques followed approved/documented procedures (except as noted in this report and reflected in qualified data points). All results are reported in industry standard units.

Detection limits, precision, accuracy, and data completeness were evaluated to determine whether any analytical data should be rejected as a result of quality assurance/QC deficiencies. The conclusions of this

data quality assessment are that the data collected during the installation of Wells 399-1-67 (C8937) and 399-1-68 (C8938) and Borehole C8933 are of the right type, quality, and quantity for their intended use as specified in the Post-ROD SI (SGW-56993).

8.1 Interpretation Uncertainties

Even though considerable effort has been undertaken to define the Stage A EA area, uncertainties remain on the 3-D geometry of the high uranium concentrations region within and around that area. This is due to lack of high-resolution depth-discrete uranium soil data availability. The interpolation techniques assume continuity of concentrations between two spatial points in three dimensions, but it is possible that residual uranium concentrations are impacted by sediment textural differences. Similarly, uncertainties exist on the leachability characteristics of the sediments. Leaching rates derived from evaluation of few soil samples may lead to predictive uncertainty in leaching characteristics at the larger domain.

9 Conclusions and Path Forward

The intent of the post-ROD field investigation was to address the PSQs developed in the Post-ROD SI (SGW-56993). Table 8 presents the main components of the DQO and conclusions drawn from data gathered.

Table 8. DQO Elements and Conclusions

Problem Statement	PSQ	Decision Rule	Conclusion
The EA area (approximately 1 ha [3 ac]), as defined in the 300 Area ROD/ROD Amendment (EPA and DOE, 2013), represents a region centered on the highest concentration of uranium in the groundwater.	PSQ 1a: Does the EA area (approximately 1 ha [3 ac]), as defined in the 300 Area ROD/ ROD Amendment (EPA and DOE, 2013), represent a region centered on a higher concentration of uranium in the vadose zone and PRZ?	If the new and existing total uranium soil concentration data and the new leachable uranium information do not change the current CSM (centroid of the 10 times uranium background is within the EA area boundaries), then the location of the enhanced EA area will remain as defined. Otherwise, the location of the EA area will be revised to align with the revised CSM.	New soil concentrations were added to the dataset used to construct the 3-D model, which led to a change in the area of highest potential uranium concentration. Considering high-concentration groundwater plume contours, a new Stage A EA area injection/infiltration treatment and projected Stage B location was established.
	PSQ 1b: Does the EA area (approximately 1 ha [3 ac]), as defined in the 300 Area ROD/ ROD Amendment (EPA and DOE, 2013), represent a region of higher leachability of uranium in the vadose zone and PRZ?		Based on the available groundwater monitoring information on uranium concentrations in the aquifer and available soil uranium concentration data in the vadose zone, it can be concluded that the new EA area represents a region of higher leachability of uranium in the vadose zone and PRZ.

Table 8. DQO Elements and Conclusions

Problem Statement	PSQ	Decision Rule	Conclusion
Leachability characteristics, within the EA area, as refined by PSQs 1a and 1b, are necessary to evaluate the potential treatment effectiveness in the vadose zone and PRZ.	PSQ 2a: What are the pretreatment leachability characteristics of the vadose zone and PRZ in the refined location of the EA area?	If the pretreatment vadose zone and PRZ uranium leachability characteristics, predominant uranium-bearing mineral phase, and uranium travel times are consistent with the CSM used to design the enhanced attenuation remediation, then proceed with the remediation as designed. Otherwise, revise the EA design to align with the revised CSM.	Due to the EA area location adjustments, two additional locations within the Stage A EA area treatment area are selected for leach studies to support the three pre- and post-treatment leachability characterization locations agreed to during the remedy implementation 300 Area RI/FS SAP (DOE/RL-2009-45) DQOs workshops.
	PSQ 2b: What are the post-treatment uranium leachability characteristics of the vadose zone and PRZ in the refined EA area?		PSQ 2b involves the post-treatment leachability characteristics of uranium in the vadose zone and PRZ and will not be addressed in this document.

References: DOE/RL-2009-45, *300 Area Remedial Investigation/Feasibility Study Sampling and Analysis Plan for the 300-FF-1, 300-FF-2 and 300-FF-5 Operable Units.*

EPA and DOE, 2013, *Hanford Site 300 Area Record of Decision for 300-FF-2 and 300-FF-5, and Record of Decision Amendment for 300-FF-1.*

CSM = conceptual site model
DQO = data quality objective
EA = enhanced attenuation
PRZ = periodically rewetted zone
PSQ = principal study question
RI/FS = remedial investigation/feasibility study
ROD = record of decision
SAP = sampling and analysis plan

Total uranium data gathered from the vadose zone and PRZ from the three boreholes was added to the data set used to generate a 3-D model of uranium concentrations in soil, which resulted in presentation of interpolated uranium concentrations in the PRZ. After evaluation of 3-D soil modelling of uranium in soil, groundwater plume data and waste site excavation data, it was determined that Stage A should include the following locations. These locations were selected because they show elevated uranium levels above the natural background (Figure 3):

- Southern portion of the North Process Trenches (316-5), where high uranium soil concentrations were observed near the former outfall of the 300-15 Process Sewer
- Southwest corner of the North Process Pond (316-2), where Well 399-1-67 was recently drilled and near the former outfall of the 300-15 Process Sewer

The refined location, along with the EA area identified in the 300 Area ROD/ROD Amendment (EPA and DOE, 2013), is presented in Figure 12.

The path forward includes three primary components described in Table 9: field mobilization for remedy implementation, sequestration injection and infiltration, and treatment performance evaluation.

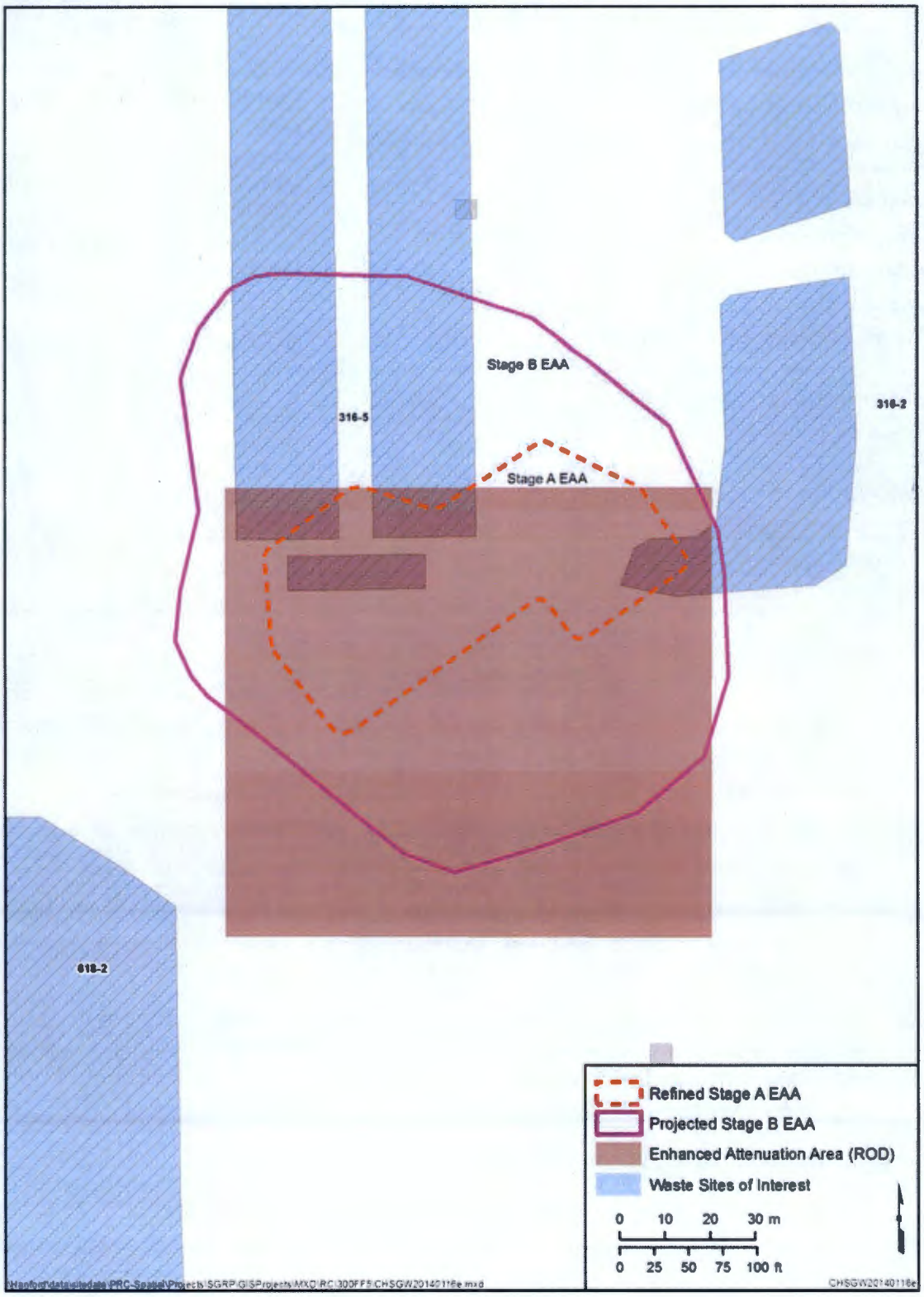


Figure 12. Refined EA Areas

Table 9. Remedy Implementation Efforts Remaining (Stage A)

Field Mobilization	Sequestration Injection/ Infiltration	Treatment Performance Monitoring
Drill and install injection wells. Drill and install monitoring wells Gather pretreatment leachability data from 2 boreholes. Install infiltration system. Test chemical mixing skids. Complete chemical delivery system design. Procure chemicals. Install chemical delivery system and mixing skids. Install injection well packers and feed pipe. Install electrical resistance tomography system. Document installations in system installation report.	Inject wells (aquifer). Infiltrate EA area. Inject wells (aquifer). Inject wells (PRZ). Obtain operational monitoring data.	Collect and analyze groundwater samples within and surrounding EA area. Drill and sample 3 post-treatment boreholes for uranium leachability characteristics. Document performance in treatment performance report.

EA = enhanced attenuation

PRZ = periodically rewetted zone

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Appendix A

Reprint of Snyder, Michelle, and K. Cantrell, "Analytical Data Report of Samples Collected for the solubility testing of wells C8933, C8936 and C8938, sample delivery group (SDG) ESL150001, SAF F15-014," Letter to Randy Hermann (CH2M Plateau Remediation Company), Pacific Northwest National Laboratory

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Pacific Northwest
NATIONAL LABORATORY
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To: Randy Hermann

From: Michelle Snyder and Kirk Cantrell

Environmental Sciences Laboratory
Energy and Environment Directorate, Pacific Northwest National Laboratory

Subject: Analytical Data Report of Samples Collected for the solubility testing of wells C8933, C8936 and C8938, sample delivery group (SDG) ESL150001, SAF F15-014.

This letter contains the following information for sample delivery group ESL150001

- Cover Sheet
- Narrative
- Analytical Results
- Quality Control

Introduction

Between January 8, 2015 and January 15, 2015 samples were received from the 300-FF5 OU for chemical analyses.

Analytical Results/Methodology

The analyses for this project were performed at the 331 building located in the 300 Area of the Hanford Site. The analyses were performed according to Pacific Northwest National Laboratory (PNNL) approved procedures and/or nationally recognized test procedures. The data sets include the sample identification numbers, analytical results, estimated quantification limits (EQL), and quality control data.

Quality Control

The preparatory and analytical quality control requirements, calibration requirements, acceptance criteria, and failure actions are defined in the on-line QA plan "Conducting Analytical Work in Support of Regulatory Programs" (CAW). This QA plan implements the Hanford Analytical Services Quality Assurance Requirements Documents (HASQARD) for PNNL.

Definitions

Dup	Duplicate
RPD	Relative Percent Difference
NR	No Recovery (percent recovery less than zero)
ND	Non-Detectable
%REC	Percent Recovery

Sample Receipt

Samples were received with a chain of custody (COC) and were analyzed according to the sample identification numbers supplied by the client. All Samples were refrigerated upon receipt until prepared for analysis.

All samples were received with custody seals intact unless noted in the Case Narrative.

Holding Times

Holding time is defined as the time from sample preparation to the time of analyses. The prescribed holding times were met for all analytes unless noted in the Case Narrative.

Analytical Results

All reported analytical results meet the requirements of the CAW or client specified SOW unless noted in the case narrative.

Case Narrative Report

Labile Uranium Selective Extraction

The labile or adsorbed uranium extraction was performed on the <2 mm, air dried sediment samples. A solution containing 0.0144 mol/L of sodium bicarbonate ($NaHCO_3$) and 0.0028 mol/L of sodium carbonate (Na_2CO_3) with a pH of approximately 9.45 was added to the sediment at a solid to solution ratio of 1 gram/2 mL, and allowed to agitate on an orbital shaker for 1 week.

Sequential Extractions

Four sequential extractions were performed on the <2mm, air dried sediment samples. The first extraction involved a weak acetic acid consisting of 1 mol/L sodium acetate with a final pH of approximately 5. The sample was agitated on an orbital shaker for 1 hour at a solid to solution ratio of 1 gram/2 mL. After 1 hour, the sample was centrifuged, the solution decanted and filtered (for ICP-MS and ICP-OES analysis), and the sample was weighed to determine the remaining residual solution prior to starting the next sequential extraction. The target uranium phase for this extraction is the adsorbed uranium and uranium associated with carbonate minerals. The second sequential extraction used a strong acetic acid (concentrated glacial acetic acid). After 5 days contact time, the same centrifuge and decanting procedure was used. The target phase for the strong acetic acid is the strongly bound uranium. The third extraction used a solution consisting of 0.1 mol/L ammonium oxalate with 0.1 mol/L oxalic acid. After 1 hour of contact time, the samples were centrifuged, decanted, filtered and weighed. The target phase for the oxalate solution are the amorphous Fe, Al, Mn and Si oxides. The final nitric acid extraction involved 8 mol/L of nitric acid. The samples were transferred to a glass beaker with a stir bar and heated at 95°C for 2 hours on a hot plate. Samples were weighed after this step so the final volume could be determined. The target phases for the nitric acid include clays, crystalline oxides, and Fe, Al, and Mn uranium oxides.

Column Leach Tests

Four column leach tests were performed on the 300FF5 sediments. The leach tests for samples B30538 and B30546 were conducted using the <2 mm size fraction that had been air dried. Glass columns were used that were 1" in diameter and 6"in length. The other 2 leach tests were performed on columns that were left intact. Samples B30541 and B30543 were fitted with end caps and fittings that would allow the lexan liners to be hooked up to pumps for the column tests. Kloehn pumps were used to push a simulated groundwater solution (recipe in the table below) through the columns in an up-flow direction. At two times during the column testing, the flow was stopped for a period of 46 hours and 72 hours and then restarted to allow release kinetics to be determined from the increased uranium concentrations found immediately after the flow in the column resumes. Column effluent was collected using a fraction collector. Samples were weighed to calculate pore volume. At the completion of testing, 50 ppm of bromide (using sodium bromide) was added to the simulated groundwater and was pumped through all four columns (at the same rate used during the leach test) to aid in determining the column porosities.

Table 1. Recipe for simulated groundwater used in column tests.

Reagent	g/L
CaCO3	0.1207
MgSO4	0.06135
NaHCO3	0.08695
KCl	0.01154
NaNO3	0.03995
**pH was adjusted to 7.3 using HCl	

Sediment Spectroscopy Analysis

Cryogenic time-resolved laser induced U(VI) fluorescence spectroscopic (TRLIFS) measurements of the uranium-bearing sediment samples were performed at near liquid helium temperature (LHeT, 6 ±2 °K) using methods described previously (Wang, Zachara et al. 2004; Wang, Zachara et al. 2005). In brief, sediment solids were placed inside a 2 mm × 4 mm x 25 mm fused quartz cuvette, sealed with a silicone stopper, further wrapped with parafilm and attached to the cold-finger of a Cryo Industries model RC-152 cryogenic workstation and cooled with helium vapors to lower the sample temperature. For spectral and lifetime measurements, the samples are excited at 415 nm using a Spectra-Physics Nd:YAG laser pumped Lasertechnik-GWU MOPO laser. The emitted light was collected at 85° to the excitation beam, dispersed through an Acton SpectroPro 300i double monochromator spectrograph, and detected with a thermoelectrically cooled Princeton Instruments PIMAX intensified CCD camera that was triggered by the delayed output of the laser pulse and controlled by the WinSpec data acquisition software. The photofluorescence decay curves were constructed by plotting the spectral intensity of a series of time-delayed fluorescence spectra as a function of the corresponding delay time. The emission spectra and decay data were analyzed using commercial software, IGOR®, from Wavematrix, Inc.

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The following analyses were performed on the following samples included in this report:

Metals Special Extract by ICP-OES

Moisture Content

pH of Waters By Electrode

U Special Extract by ICP-MS

U from Flow through column leach tests by ICP-MS

Geologic Description

Spectroscopy

SAMPLES ANALYZED IN THIS REPORT

Sample No.	Laboratory ID	Matrix	Date Collected	Date Received
B304T7	1501009-01	SOIL	12/31/14 08:35	1/8/15 09:30
B304T8	1501009-02	SOIL	12/31/14 08:35	1/8/15 09:30
B304T9	1501009-03	SOIL	12/31/14 08:35	1/8/15 09:30
B304V1	1501009-04	SOIL	12/31/14 08:35	1/8/15 09:30
B304V3	1501009-05	SOIL	12/31/14 09:11	1/8/15 09:30
B304V4	1501009-06	SOIL	12/31/14 09:11	1/8/15 09:30
B304V6	1501009-07	SOIL	12/31/14 09:11	1/8/15 09:30
B304V7	1501009-08	SOIL	12/31/14 10:40	1/8/15 09:30
B304V8	1501009-09	SOIL	12/31/14 10:40	1/8/15 09:30
B304V9	1501009-10	SOIL	12/31/14 10:40	1/8/15 09:30
B304W1	1501009-11	SOIL	12/31/14 10:40	1/8/15 09:30
B304W2	1501009-12	SOIL	12/31/14 11:40	1/8/15 09:30
B304W3	1501009-13	SOIL	12/31/14 11:40	1/8/15 09:30
B304W4	1501009-14	SOIL	12/31/14 11:40	1/8/15 09:30
B304W7	1501009-15	SOIL	12/31/14 11:40	1/8/15 09:30
B304W8	1501009-16	SOIL	12/31/14 13:00	1/8/15 09:30
B304W9	1501009-17	SOIL	12/31/14 13:00	1/8/15 09:30
B304X0	1501009-18	SOIL	12/31/14 13:00	1/8/15 09:30
B304X2	1501009-19	SOIL	12/31/14 13:00	1/8/15 09:30
B304X5	1501009-20	SOIL	12/31/14 13:40	1/8/15 09:30
B304X7	1501009-21	SOIL	12/31/14 13:40	1/8/15 09:30
B304X8	1501009-22	SOIL	1/6/15 09:05	1/8/15 09:30
B304X9	1501009-23	SOIL	1/6/15 09:05	1/8/15 09:30
B304Y0	1501009-24	SOIL	1/6/15 09:05	1/8/15 09:30
B304Y3	1501009-25	SOIL	1/6/15 09:05	1/8/15 09:30
B304Y4	1501009-26	SOIL	1/6/15 09:40	1/8/15 09:30
B304Y5	1501009-27	SOIL	1/6/15 09:40	1/8/15 09:30
B304Y6	1501009-28	SOIL	1/6/15 09:40	1/8/15 09:30
B304Y8	1501009-29	SOIL	1/6/15 09:40	1/8/15 09:30
B30505	1501009-30	SOIL	1/13/15 13:00	1/15/15 09:40
B30506	1501009-31	SOIL	1/13/15 13:00	1/15/15 09:40
B30507	1501009-32	SOIL	1/13/15 13:00	1/15/15 09:40
B30509	1501009-33	SOIL	1/13/15 13:00	1/15/15 09:40
B30510	1501009-34	SOIL	1/13/15 13:00	1/15/15 09:40
B30511	1501009-35	SOIL	1/13/15 13:30	1/15/15 09:40
B30512	1501009-36	SOIL	1/13/15 13:30	1/15/15 09:40
B30515	1501009-37	SOIL	1/13/15 13:30	1/15/15 09:40
B30516	1501009-38	SOIL	1/13/15 14:48	1/15/15 09:40
B30517	1501009-39	SOIL	1/13/15 14:48	1/15/15 09:40
B30518	1501009-40	SOIL	1/13/15 14:48	1/15/15 09:40
B30520	1501009-41	SOIL	1/13/15 14:48	1/15/15 09:40
B30521	1501009-42	SOIL	1/14/15 08:20	1/15/15 09:40
B30522	1501009-43	SOIL	1/14/15 08:20	1/15/15 09:40
B30523	1501009-44	SOIL	1/14/15 08:20	1/15/15 09:40
B30525	1501009-45	SOIL	1/14/15 08:20	1/15/15 09:40
B30526	1501009-46	SOIL	1/14/15 09:30	1/15/15 09:40

SAMPLES ANALYZED IN THIS REPORT

Sample No.	Laboratory ID	Matrix	Date Collected	Date Received
B30527	1501009-47	SOIL	1/14/15 09:30	1/15/15 09:40
B30528	1501009-48	SOIL	1/14/15 09:30	1/15/15 09:40
B30530	1501009-49	SOIL	1/14/15 09:30	1/15/15 09:40
B30531	1501009-50	SOIL	1/14/15 10:20	1/15/15 09:40
B30532	1501009-51	SOIL	1/14/15 10:20	1/15/15 09:40
B30533	1501009-52	SOIL	1/14/15 10:20	1/15/15 09:40
B30536	1501009-53	SOIL	1/14/15 10:20	1/15/15 09:40
B30537	1501009-54	SOIL	1/14/15 11:30	1/15/15 09:40
B30538	1501009-55	SOIL	1/14/15 11:30	1/15/15 09:40
B30539	1501009-56	SOIL	1/14/15 11:30	1/15/15 09:40
B30541	1501009-57	SOIL	1/14/15 11:30	1/15/15 09:40
B30542	1501009-58	SOIL	1/14/15 12:30	1/15/15 09:40
B30543	1501009-59	SOIL	1/14/15 12:30	1/15/15 09:40
B30544	1501009-60	SOIL	1/14/15 12:30	1/15/15 09:40
B30546	1501009-61	SOIL	1/14/15 12:30	1/15/15 09:40
B30547	1501009-62	SOIL	1/14/15 13:20	1/15/15 09:40
B30548	1501009-63	SOIL	1/14/15 13:20	1/15/15 09:40
B30549	1501009-64	SOIL	1/14/15 13:20	1/15/15 09:40
B30551	1501009-65	SOIL	1/14/15 13:20	1/15/15 09:40
B309C6	1501009-66	SOIL	1/14/15 14:40	1/15/15 09:40
B309C7	1501009-67	SOIL	1/14/15 14:40	1/15/15 09:40
B309C8	1501009-68	SOIL	1/14/15 14:40	1/15/15 09:40
B309D0	1501009-69	SOIL	1/14/15 14:40	1/15/15 09:40
B30555	1501009-70	SOIL	1/8/15 10:19	1/13/15 08:50
B30558	1501009-71	SOIL	1/8/15 10:19	1/13/15 08:50
B30559	1501009-72	SOIL	1/8/15 11:00	1/13/15 08:50
B30560	1501009-73	SOIL	1/8/15 11:00	1/13/15 08:50
B30561	1501009-74	SOIL	1/8/15 11:00	1/13/15 08:50
B30563	1501009-75	SOIL	1/8/15 11:00	1/13/15 08:50
B30566	1501009-76	SOIL	1/8/15 11:30	1/13/15 08:50
B30568	1501009-77	SOIL	1/8/15 11:30	1/13/15 08:50
B30569	1501009-78	SOIL	1/8/15 13:10	1/13/15 08:50
B30570	1501009-79	SOIL	1/8/15 13:10	1/13/15 08:50
B30571	1501009-80	SOIL	1/8/15 13:10	1/13/15 08:50
B30573	1501009-81	SOIL	1/8/15 13:10	1/13/15 08:50
B30574	1501009-82	SOIL	1/8/15 13:35	1/13/15 08:50
B30575	1501009-83	SOIL	1/8/15 13:35	1/13/15 08:50
B30576	1501009-84	SOIL	1/8/15 13:35	1/13/15 08:50
B30579	1501009-85	SOIL	1/8/15 13:35	1/13/15 08:50
B30580	1501009-86	SOIL	1/12/15 08:20	1/13/15 08:50
B30581	1501009-87	SOIL	1/12/15 08:20	1/13/15 08:50
B30582	1501009-88	SOIL	1/12/15 08:20	1/13/15 08:50
B30584	1501009-89	SOIL	1/12/15 08:20	1/13/15 08:50
B30587	1501009-90	SOIL	1/12/15 08:40	1/13/15 08:50
B30589	1501009-91	SOIL	1/12/15 08:40	1/13/15 08:50
B30590	1501009-92	SOIL	1/12/15 10:00	1/13/15 08:50

SAMPLES ANALYZED IN THIS REPORT

Sample No.	Laboratory ID	Matrix	Date Collected	Date Received
B30591	1501009-93	SOIL	1/12/15 10:00	1/13/15 08:50
B30592	1501009-94	SOIL	1/12/15 10:00	1/13/15 08:50
B30594	1501009-95	SOIL	1/12/15 10:00	1/13/15 08:50
B30597	1501009-96	SOIL	1/12/15 11:00	1/13/15 08:50
B30599	1501009-97	SOIL	1/12/15 11:00	1/13/15 08:50
B309F2	1501009-98	SOIL	1/12/15 12:50	1/13/15 08:50
B309F3	1501009-99	SOIL	1/12/15 12:50	1/13/15 08:50
B309F5	1501009-AA	SOIL	1/12/15 12:50	1/13/15 08:50

Wet Chemistry

Moisture Content (% by Weight) by AGG-WC-001

Lab ID	Client ID.	Results	EQL	Analyzed	Batch
1501009-25	B304Y3	5.00E0	N/A	3/13/15	5B17006
1501009-27	B304Y5	7.63E0	N/A	3/13/15	5B17006
1501009-45	B30525	8.44E0	N/A	3/13/15	5B17006
1501009-55	B30538	8.22E0	N/A	3/13/15	5B17006
1501009-61	B30546	1.47E1	N/A	3/13/15	5B17006
1501009-91	B30589	6.31E0	N/A	3/13/15	5B17006
1501009-AB	B304Y3 <2mm air dried	1.98E0	N/A	2/17/15	5B16005
1501009-AC	B304Y5 <2mm air dried	1.67E0	N/A	2/17/15	5B16005
1501009-AD	B30525 <2mm air dried	1.35E0	N/A	2/17/15	5B16005
1501009-AE	B30538 <2mm air dried	2.41E0	N/A	2/17/15	5B16005
1501009-AF	B30546 <2mm air dried	1.88E0	N/A	2/17/15	5B16005
1501009-AG	B30589 <2mm air dried	1.42E0	N/A	2/17/15	5B16005

Wet Chemistry

pH (pH Units) by AGG-pH-001

Lab ID	Client ID.	Results	EQL	Analyzed	Batch
1501009-AB	B304Y3 <2mm air dried	7.88E0	N/A	2/18/15	5B19003
1501009-AC	B304Y5 <2mm air dried	7.95E0	N/A	2/18/15	5B19003
1501009-AD	B30525 <2mm air dried	8.38E0	N/A	2/18/15	5B19003
1501009-AE	B30538 <2mm air dried	7.42E0	N/A	2/18/15	5B19003
1501009-AF	B30546 <2mm air dried	7.50E0	N/A	2/18/15	5B19003
1501009-AG	B30589 <2mm air dried	7.97E0	N/A	2/18/15	5B19003

Sequential Extraction-ICP-OES Results

LabNumber	SampleName	Analyte	final concentration	Units	EQL
1502014-01	B304Y3 weak acetic acid	Aluminum	3.14E+01	ug/g	1650
1502014-02	B304Y5 weak acetic acid	Aluminum	2.92E+01	ug/g	1650
1502014-03	B30525 weak acetic acid	Aluminum	4.42E+01	ug/g	1650
1502014-04	B30538 weak acetic acid	Aluminum	5.36E+01	ug/g	1650
1502014-05	B30546 weak acetic acid	Aluminum	4.08E+01	ug/g	1650
1502014-07	B30589 weak acetic acid	Aluminum	3.10E+01	ug/g	1650
1502014-08	B304Y3 strong acetic acid	Aluminum	1.10E+01	ug/g	1650
1502014-09	B304Y5 strong acetic acid	Aluminum	8.63E+00	ug/g	1650
1502014-10	B30525 strong acetic acid	Aluminum	1.80E+01	ug/g	1650
1502014-11	B30538 strong acetic acid	Aluminum	3.66E+01	ug/g	1650
1502014-12	B30546 strong acetic acid	Aluminum	1.69E+01	ug/g	1650
1502014-14	B30589 strong acetic acid	Aluminum	1.23E+01	ug/g	1650
1502014-15	B304Y3 oxalate	Aluminum	6.95E+02	ug/g	1650
1502014-16	B304Y5 oxalate	Aluminum	4.77E+02	ug/g	1650
1502014-17	B30525 oxalate	Aluminum	7.63E+02	ug/g	1650
1502014-18	B30538 oxalate	Aluminum	1.54E+03	ug/g	1650
1502014-19	B30546 oxalate	Aluminum	8.97E+02	ug/g	1650
1502014-21	B30589 oxalate	Aluminum	6.16E+02	ug/g	1650
1502014-22	B304Y3 nitric acid	Aluminum	2.85E+04	ug/g	16500
1502014-23	B304Y5 nitric acid	Aluminum	1.62E+04	ug/g	1650
1502014-24	B30525 nitric acid	Aluminum	1.77E+04	ug/g	1650
1502014-25	B30538 nitric acid	Aluminum	4.51E+04	ug/g	16500
1502014-26	B30546 nitric acid	Aluminum	2.59E+04	ug/g	16500
1502014-28	B30589 nitric acid	Aluminum	1.43E+04	ug/g	1650
1502014-01	B304Y3 weak acetic acid	Calcium	1.60E+03	ug/g	4900
1502014-02	B304Y5 weak acetic acid	Calcium	1.27E+03	ug/g	4900
1502014-03	B30525 weak acetic acid	Calcium	2.00E+03	ug/g	4900
1502014-04	B30538 weak acetic acid	Calcium	1.61E+03	ug/g	4900
1502014-05	B30546 weak acetic acid	Calcium	1.39E+03	ug/g	4900
1502014-07	B30589 weak acetic acid	Calcium	1.45E+03	ug/g	4900
1502014-08	B304Y3 strong acetic acid	Calcium	2.70E+02	ug/g	4900
1502014-09	B304Y5 strong acetic acid	Calcium	2.21E+02	ug/g	4900
1502014-10	B30525 strong acetic acid	Calcium	3.95E+02	ug/g	4900
1502014-11	B30538 strong acetic acid	Calcium	4.24E+02	ug/g	4900
1502014-12	B30546 strong acetic acid	Calcium	2.31E+02	ug/g	4900
1502014-14	B30589 strong acetic acid	Calcium	3.11E+02	ug/g	4900
1502014-15	B304Y3 oxalate	Calcium	n/a	ug/g	4900
1502014-16	B304Y5 oxalate	Calcium	n/a	ug/g	4900
1502014-17	B30525 oxalate	Calcium	n/a	ug/g	4900
1502014-18	B30538 oxalate	Calcium	n/a	ug/g	4900
1502014-19	B30546 oxalate	Calcium	n/a	ug/g	4900
1502014-21	B30589 oxalate	Calcium	n/a	ug/g	4900
1502014-22	B304Y3 nitric acid	Calcium	1.19E+04	ug/g	4900
1502014-23	B304Y5 nitric acid	Calcium	1.24E+04	ug/g	4900
1502014-24	B30525 nitric acid	Calcium	1.14E+04	ug/g	4900
1502014-25	B30538 nitric acid	Calcium	1.07E+04	ug/g	4900
1502014-26	B30546 nitric acid	Calcium	1.30E+04	ug/g	4900
1502014-28	B30589 nitric acid	Calcium	1.05E+04	ug/g	4900

LabNumber	SampleName	Analyte	final concentration	Units	EQL
1502014-01	B304Y3 weak acetic acid	Iron	4.10E+00	ug/g	1000
1502014-02	B304Y5 weak acetic acid	Iron	9.36E+00	ug/g	1000
1502014-03	B30525 weak acetic acid	Iron	1.47E+01	ug/g	1000
1502014-04	B30538 weak acetic acid	Iron	7.32E+00	ug/g	1000
1502014-05	B30546 weak acetic acid	Iron	9.22E+00	ug/g	1000
1502014-07	B30589 weak acetic acid	Iron	4.66E+01	ug/g	1000
1502014-08	B304Y3 strong acetic acid	Iron	n/a	ug/g	1000
1502014-09	B304Y5 strong acetic acid	Iron	n/a	ug/g	1000
1502014-10	B30525 strong acetic acid	Iron	2.05E+01	ug/g	1000
1502014-11	B30538 strong acetic acid	Iron	4.44E+01	ug/g	1000
1502014-12	B30546 strong acetic acid	Iron	5.70E+01	ug/g	1000
1502014-14	B30589 strong acetic acid	Iron	7.79E+02	ug/g	1000
1502014-15	B304Y3 oxalate	Iron	9.05E+02	ug/g	1000
1502014-16	B304Y5 oxalate	Iron	2.39E+03	ug/g	1000
1502014-17	B30525 oxalate	Iron	1.54E+03	ug/g	1000
1502014-18	B30538 oxalate	Iron	7.82E+02	ug/g	1000
1502014-19	B30546 oxalate	Iron	1.45E+03	ug/g	1000
1502014-21	B30589 oxalate	Iron	3.69E+03	ug/g	1000
1502014-22	B304Y3 nitric acid	Iron	6.32E+04	ug/g	10000
1502014-23	B304Y5 nitric acid	Iron	5.45E+04	ug/g	10000
1502014-24	B30525 nitric acid	Iron	5.34E+04	ug/g	10000
1502014-25	B30538 nitric acid	Iron	5.42E+04	ug/g	10000
1502014-26	B30546 nitric acid	Iron	6.52E+04	ug/g	10000
1502014-28	B30589 nitric acid	Iron	5.21E+04	ug/g	10000
1502014-01	B304Y3 weak acetic acid	Manganese	3.74E+00	ug/g	941
1502014-02	B304Y5 weak acetic acid	Manganese	7.34E+00	ug/g	941
1502014-03	B30525 weak acetic acid	Manganese	1.03E+01	ug/g	941
1502014-04	B30538 weak acetic acid	Manganese	9.90E+00	ug/g	941
1502014-05	B30546 weak acetic acid	Manganese	9.02E+00	ug/g	941
1502014-07	B30589 weak acetic acid	Manganese	2.70E+01	ug/g	941
1502014-08	B304Y3 strong acetic acid	Manganese	1.71E+01	ug/g	941
1502014-09	B304Y5 strong acetic acid	Manganese	2.43E+01	ug/g	941
1502014-10	B30525 strong acetic acid	Manganese	3.67E+01	ug/g	941
1502014-11	B30538 strong acetic acid	Manganese	7.30E+01	ug/g	941
1502014-12	B30546 strong acetic acid	Manganese	3.91E+01	ug/g	941
1502014-14	B30589 strong acetic acid	Manganese	6.80E+01	ug/g	941
1502014-15	B304Y3 oxalate	Manganese	1.02E+02	ug/g	941
1502014-16	B304Y5 oxalate	Manganese	5.77E+01	ug/g	941
1502014-17	B30525 oxalate	Manganese	2.94E+01	ug/g	941
1502014-18	B30538 oxalate	Manganese	4.95E+01	ug/g	941
1502014-19	B30546 oxalate	Manganese	4.10E+01	ug/g	941
1502014-21	B30589 oxalate	Manganese	3.74E+01	ug/g	941
1502014-22	B304Y3 nitric acid	Manganese	6.94E+02	ug/g	941
1502014-23	B304Y5 nitric acid	Manganese	6.22E+02	ug/g	941
1502014-24	B30525 nitric acid	Manganese	5.50E+02	ug/g	941
1502014-25	B30538 nitric acid	Manganese	6.49E+02	ug/g	941
1502014-26	B30546 nitric acid	Manganese	7.12E+02	ug/g	941
1502014-28	B30589 nitric acid	Manganese	6.38E+02	ug/g	941

Sequential Extraction-ICPMS Uranium Results

LabNumber	SampleName	Analyte	final concentration	Units	EQL
1502014-01	B304Y3 weak acetic acid	Uranium 238	1.31E+01	ug/g	10.6
1502014-02	B304Y5 weak acetic acid	Uranium 238	5.98E+00	ug/g	10.6
1502014-03	B30525 weak acetic acid	Uranium 238	1.28E+01	ug/g	10.6
1502014-04	B30538 weak acetic acid	Uranium 238	5.38E+01	ug/g	10.6
1502014-05	B30546 weak acetic acid	Uranium 238	6.78E+00	ug/g	10.6
1502014-07	B30589 weak acetic acid	Uranium 238	2.96E+00	ug/g	10.6
1502014-08	B304Y3 strong acetic acid	Uranium 238	5.19E+00	ug/g	10.6
1502014-09	B304Y5 strong acetic acid	Uranium 238	2.93E+00	ug/g	10.6
1502014-10	B30525 strong acetic acid	Uranium 238	7.74E+00	ug/g	10.6
1502014-11	B30538 strong acetic acid	Uranium 238	2.41E+01	ug/g	10.6
1502014-12	B30546 strong acetic acid	Uranium 238	4.86E+00	ug/g	10.6
1502014-14	B30589 strong acetic acid	Uranium 238	1.28E+00	ug/g	10.6
1502014-15	B304Y3 oxalate	Uranium 238	2.52E+00	ug/g	10.6
1502014-16	B304Y5 oxalate	Uranium 238	1.57E+00	ug/g	10.6
1502014-17	B30525 oxalate	Uranium 238	5.20E+00	ug/g	10.6
1502014-18	B30538 oxalate	Uranium 238	1.31E+01	ug/g	10.6
1502014-19	B30546 oxalate	Uranium 238	3.93E+00	ug/g	10.6
1502014-21	B30589 oxalate	Uranium 238	8.44E-01	ug/g	10.6
1502014-22	B304Y3 nitric acid	Uranium 238	4.99E+00	ug/g	10.6
1502014-23	B304Y5 nitric acid	Uranium 238	4.18E+00	ug/g	10.6
1502014-24	B30525 nitric acid	Uranium 238	3.19E+01	ug/g	10.6
1502014-25	B30538 nitric acid	Uranium 238	3.48E+01	ug/g	10.6
1502014-26	B30546 nitric acid	Uranium 238	1.55E+01	ug/g	10.6
1502014-28	B30589 nitric acid	Uranium 238	1.76E+00	ug/g	10.6

Total Metals by PNNL-AGG-ICP-AES/Special Extraction for Labile Uranium

CAS #	Analyte	Results	Units	EQL	Analyzed	Batch	Method
Client ID.	**B304Y3 <2mm air dried**		**Lab ID:**	**1501009-AB**			
7429-90-5	Aluminum	<6.38E-1	ug/g dry	6.38E-1	3/05/15	5C05003	PNNL-AGG-ICP-AES
7440-70-2	Calcium	4.53E1	ug/g dry	3.08E0	3/05/15	5C05003	PNNL-AGG-ICP-AES
7439-89-6	Iron	<7.14E-1	ug/g dry	7.14E-1	3/05/15	5C05003	PNNL-AGG-ICP-AES
7439-96-5	Manganese	<4.25E-1	ug/g dry	4.25E-1	3/05/15	5C05003	PNNL-AGG-ICP-AES
Client ID.	**B304Y5 <2mm air dried**		**Lab ID:**	**1501009-AC**			
7429-90-5	Aluminum	<6.35E-1	ug/g dry	6.35E-1	3/05/15	5C05003	PNNL-AGG-ICP-AES
7440-70-2	Calcium	2.84E1	ug/g dry	3.06E0	3/05/15	5C05003	PNNL-AGG-ICP-AES
7439-89-6	Iron	<7.11E-1	ug/g dry	7.11E-1	3/05/15	5C05003	PNNL-AGG-ICP-AES
7439-96-5	Manganese	<4.23E-1	ug/g dry	4.23E-1	3/05/15	5C05003	PNNL-AGG-ICP-AES
Client ID.	**B30525 <2mm air dried**		**Lab ID:**	**1501009-AD**			
7429-90-5	Aluminum	1.40E0	ug/g dry	6.33E-1	3/05/15	5C05003	PNNL-AGG-ICP-AES
7440-70-2	Calcium	8.34E0	ug/g dry	3.06E0	3/05/15	5C05003	PNNL-AGG-ICP-AES
7439-89-6	Iron	1.58E0	ug/g dry	7.09E-1	3/05/15	5C05003	PNNL-AGG-ICP-AES
7439-96-5	Manganese	<4.22E-1	ug/g dry	4.22E-1	3/05/15	5C05003	PNNL-AGG-ICP-AES
Client ID.	**B30538 <2mm air dried**		**Lab ID:**	**1501009-AE**			
7429-90-5	Aluminum	<6.40E-1	ug/g dry	6.40E-1	3/05/15	5C05003	PNNL-AGG-ICP-AES
7440-70-2	Calcium	5.91E1	ug/g dry	3.09E0	3/05/15	5C05003	PNNL-AGG-ICP-AES
7439-89-6	Iron	<7.16E-1	ug/g dry	7.16E-1	3/05/15	5C05003	PNNL-AGG-ICP-AES
7439-96-5	Manganese	<4.26E-1	ug/g dry	4.26E-1	3/05/15	5C05003	PNNL-AGG-ICP-AES
Client ID.	**B30546 <2mm air dried**		**Lab ID:**	**1501009-AF**			
7429-90-5	Aluminum	<6.37E-1	ug/g dry	6.37E-1	3/05/15	5C05003	PNNL-AGG-ICP-AES
7440-70-2	Calcium	4.31E1	ug/g dry	3.07E0	3/05/15	5C05003	PNNL-AGG-ICP-AES
7439-89-6	Iron	<7.12E-1	ug/g dry	7.12E-1	3/05/15	5C05003	PNNL-AGG-ICP-AES
7439-96-5	Manganese	<4.24E-1	ug/g dry	4.24E-1	3/05/15	5C05003	PNNL-AGG-ICP-AES
Client ID.	**B30589 <2mm air dried**		**Lab ID:**	**1501009-AG**			
7429-90-5	Aluminum	<6.34E-1	ug/g dry	6.34E-1	3/05/15	5C05003	PNNL-AGG-ICP-AES
7440-70-2	Calcium	3.19E1	ug/g dry	3.06E0	3/05/15	5C05003	PNNL-AGG-ICP-AES
7439-89-6	Iron	<7.09E-1	ug/g dry	7.09E-1	3/05/15	5C05003	PNNL-AGG-ICP-AES
7439-96-5	Manganese	<4.22E-1	ug/g dry	4.22E-1	3/05/15	5C05003	PNNL-AGG-ICP-AES

Radionuclides by ICP-MS/Special Extraction for Labile Uranium

CAS #	Analyte	Results	Units	EQL	Analyzed	Batch	Method
Client ID.	**B304Y3 <2mm air dried**		**Lab ID:**	**1501009-AB**			
U-238	Uranium 238	7.89E0	ug/g dry	3.27E-3	3/04/15	5C04003	PNNL-AGG-415
Client ID.	**B304Y5 <2mm air dried**		**Lab ID:**	**1501009-AC**			
U-238	Uranium 238	3.92E0	ug/g dry	3.25E-3	3/04/15	5C04003	PNNL-AGG-415
Client ID.	**B30525 <2mm air dried**		**Lab ID:**	**1501009-AD**			
U-238	Uranium 238	7.05E0	ug/g dry	3.24E-3	3/04/15	5C04003	PNNL-AGG-415
Client ID.	**B30538 <2mm air dried**		**Lab ID:**	**1501009-AE**			
U-238	Uranium 238	1.20E1	ug/g dry	3.28E-3	3/04/15	5C04003	PNNL-AGG-415
Client ID.	**B30546 <2mm air dried**		**Lab ID:**	**1501009-AF**			
U-238	Uranium 238	3.65E0	ug/g dry	3.26E-3	3/04/15	5C04003	PNNL-AGG-415
Client ID.	**B30589 <2mm air dried**		**Lab ID:**	**1501009-AG**			
U-238	Uranium 238	1.12E0	ug/g dry	3.25E-3	3/04/15	5C04003	PNNL-AGG-415

Particle Size Analysis

Lab ID	Client ID	% clay	% silt	% sand	% gravel
1501009-25	B304Y3	2.5	2.5	11	83
1501009-27	B304Y5	3.8	7.2	25	62
1501009-45	B30525	2.3	4.2	19	72
1501009-55	B30538	5.9	3.3	6.7	83
1501009-57	B30541	7.4	57	7.5	28
1501009-59	B30543	2.1	3.0	29	65
1501009-61	B30546	2.1	4.6	21	72
1501009-91	B30589	4.6	7.8	25	61

300-55-5 Borehole Column Leaching Experiment Data

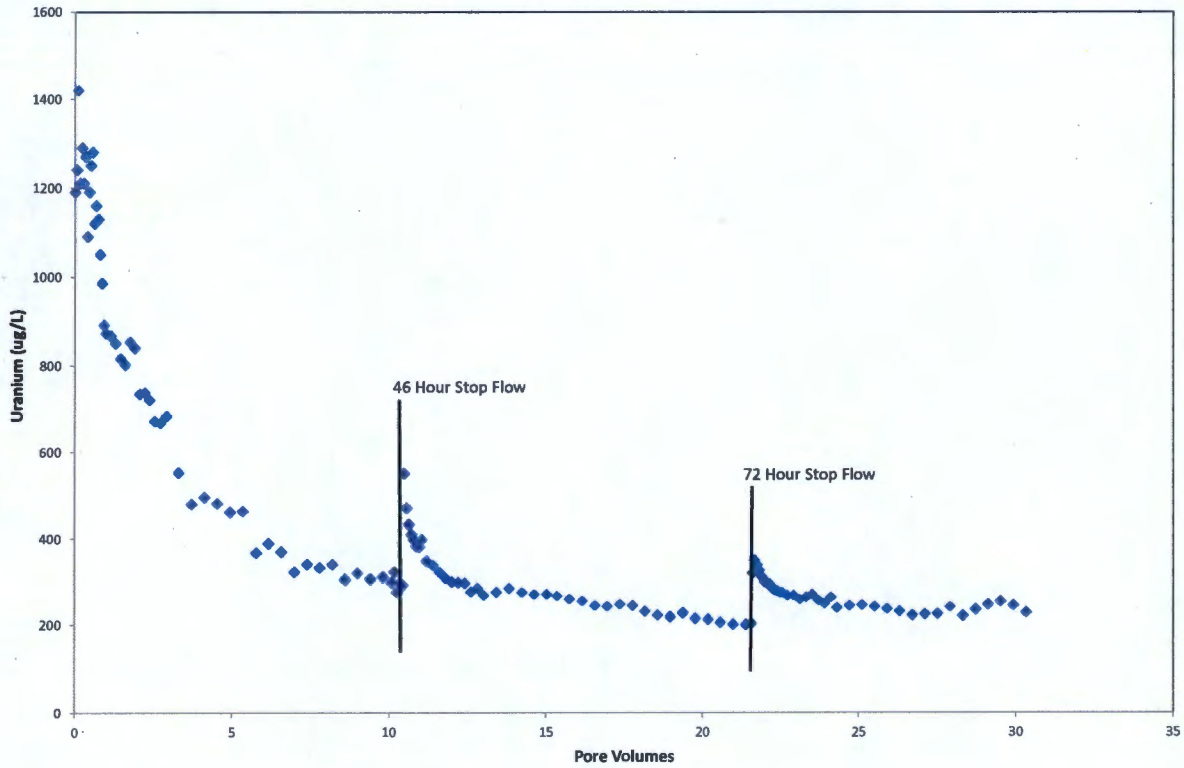

Figure 1. Uranium Concentration Versus Pore Volume and for Intact Core B30541 (estimated pore volume 345.0 mL, approximate flow rate 0.1519 pore volume per hour).

Table 2. Leachate Sample Pore and Uranium Concentration for Intact Core B30541 (estimated pore volume 345.0 mL, approximate flow rate 0.1519 pore volume per hour).

Pore Volume	Uranium (µg/L)	pH	Note
0.02	1190	8.31	
0.07	1240		
0.13	1420	8.35	
0.18	1210		
0.24	1290	8.41	
0.30	1210		
0.36	1270	8.37	
0.42	1090		
0.47	1190	8.38	
0.53	1250		
0.59	1280	8.34	
0.64	1120		
0.70	1160	8.41	
0.76	1130		

0.82	1050	8.38	
0.88	985		
0.94	891	8.32	
1.01	873		
1.16	867	8.47	
1.32	850		
1.48	816		
1.63	800		
1.79	853	8.30	
1.94	840		
2.10	734		
2.26	737		
2.42	720	8.29	
2.58	671		
2.75	667		
2.96	683		
3.35	552	8.31	
3.76	479		
4.16	494		
4.56	481		
4.97	461	8.24	
5.37	463		
5.78	367		
6.19	388		
6.60	369	8.29	
7.01	321		
7.41	340		
7.81	332		
8.21	340	8.08	
8.61	305		
9.02	319		
9.42	306		
9.82	311	8.31	
10.10	298		46 Hour Stop Flow
10.18	322	8.29	
10.26	276		
10.34	296	8.22	
10.43	292		
10.49	550	8.37	
10.56	470		
10.64	432	8.31	
10.72	409		
10.80	396	8.29	
10.88	382		
10.96	381	8.31	
11.04	397		
11.20	348	8.26	

11.40	338		
11.61	322		
11.81	308		
12.01	300	8.28	
12.22	298		
12.42	297		
12.62	277		
12.82	285	8.19	
13.03	269		
13.43	276		
13.83	285		
14.24	275	8.30	
14.64	271		
15.03	271		
15.37	267		
15.77	259	8.20	
16.17	254		
16.57	243		
16.97	241		
17.37	246	8.12	
17.78	243		
18.18	230		
18.59	221		
18.99	216	8.15	
19.39	226		
19.80	213		
20.20	211		
20.60	204	8.15	
21.00	200		
21.41	199	8.12	
21.58	202	8.00	72 Hour Stop Flow
21.62	319		
21.69	349	8.36	
21.77	339		
21.85	325	8.31	
21.93	311		
22.01	300	8.38	
22.09	297		
22.17	294	8.28	
22.25	285		
22.33	281	8.24	
22.41	279		
22.50	275	8.35	
22.58	274		
22.74	268	8.21	
22.94	268		
23.14	258		

23.34	263	
23.53	270	8.12
23.73	256	
23.93	248	
24.13	263	
24.33	238	8.13
24.73	243	
25.13	244	
25.53	241	
25.93	235	8.15
26.33	230	
26.73	221	
27.13	223	
27.53	224	8.20
27.94	241	
28.34	219	
28.74	234	
29.14	246	8.16
29.54	254	
29.94	244	
30.34	227	8.17

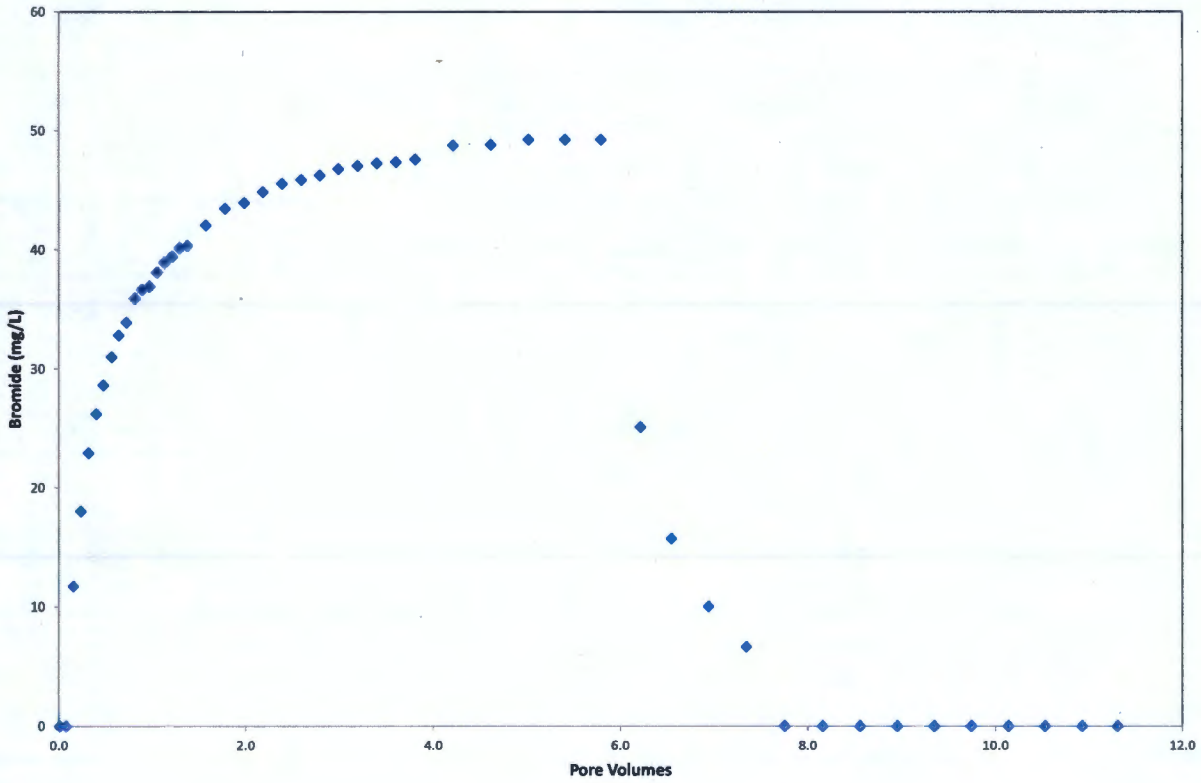

Figure 2. Bromide Concentration Versus Pore Volume and for Intact Core B30541 (estimated pore volume 345.0 mL, approximate flow rate 0.1519 pore volume per hour).

Table 3. Leachate Sample Pore Volume and Bromide Concentration for Intact Core B30541 (estimated pore volume 345.0 mL, approximate flow rate 0.1519 pore volume per hour).

Pore Volume	Bromide (mg/L)	Note
0.02	0.0	
0.08	0.0	
0.16	11.7	
0.24	18.0	
0.32	22.9	
0.41	26.2	
0.48	28.6	
0.57	31.0	
0.65	32.8	
0.73	33.9	
0.82	35.9	
0.90	36.6	
0.97	36.9	
1.05	38.1	
1.13	38.9	
1.22	39.4	
1.30	40.1	
1.38	40.3	
1.58	42.0	
1.78	43.4	
1.98	43.9	
2.19	44.8	
2.39	45.5	
2.59	45.8	
2.79	46.2	
2.99	46.7	
3.20	47.0	
3.40	47.2	
3.61	47.3	
3.81	47.5	
4.21	48.7	
4.62	48.8	
5.02	49.2	
5.41	49.2	
5.80	49.2	No Bromide
6.22	25.1	
6.55	15.7	
6.95	10.0	
7.35	6.6	
7.76	0.0	

8.17	0.0
8.56	0.0
8.96	0.0
9.35	0.0
9.75	0.0
10.14	0.0
10.53	0.0
10.93	0.0
11.31	0.0

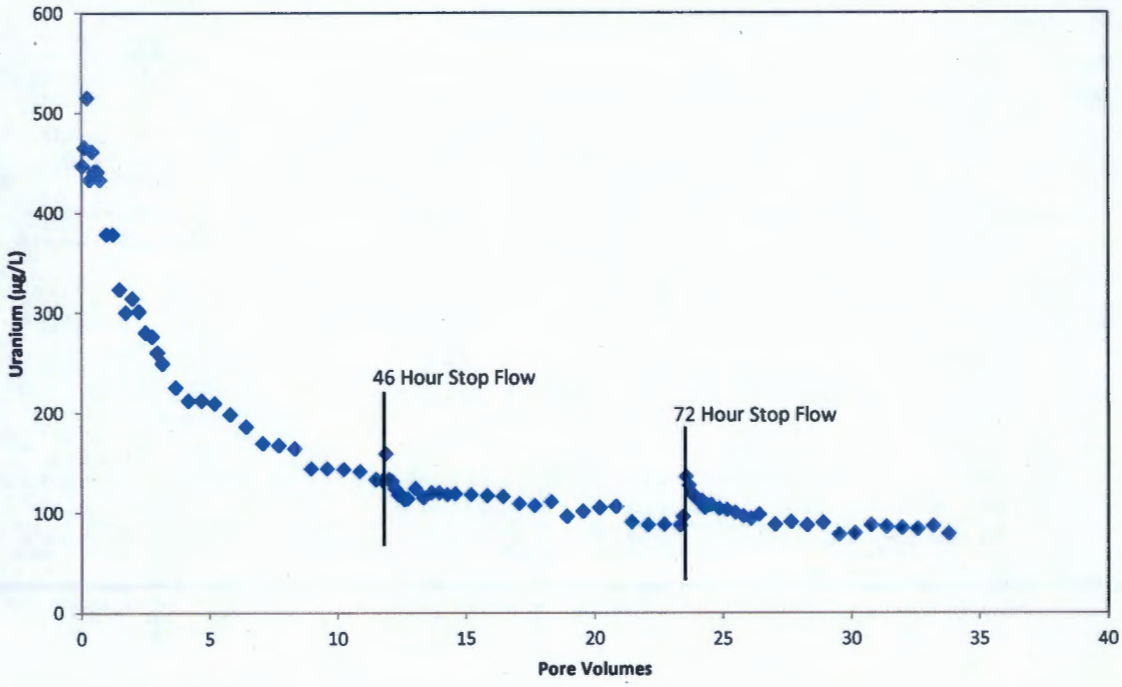

Figure 3. Uranium Concentration Versus Pore Volume and for Intact Core B30543 (estimated pore volume 223.5 mL, approximate flow rate 0.2476 pore volume per hour).

Table 4. Leachate Sample Pore Volume and Uranium Concentration for Intact Core B30543 (estimated pore volume 223.5 mL, approximate flow rate 0.2476 pore volume per hour).

Pore Volume	Uranium (µg/L)	pH	Note
0.04	447.00	8.38	
0.14	465.00		
0.23	515.00	8.33	
0.33	433.00		

0.43	461.00	8.32	
0.52	441.00		
0.63	441.00	8.17	
0.74	433.00		
0.99	378.00	8.23	
1.24	378.00		
1.50	323.00		
1.75	300.00	8.20	
2.00	314.00		
2.26	301.00		
2.51	280.00		
2.77	276.00	8.16	
2.97	260.00		
3.17	249.00		
3.68	225.00		
4.19	212.00	8.16	
4.70	212.00		
5.21	209.00		
5.82	198.00		
6.45	186.00	8.16	
7.08	169.00		
7.72	167.00		
8.34	164.00		
8.98	144.00	8.22	
9.61	144.00		
10.24	143.00		
10.88	141.00		
11.50	133.00	8.15	
11.76	132.00		46 Hour Stop Flow
11.89	159.00	8.22	
12.01	133.00		
12.13	131.00	8.19	
12.25	124.00		
12.38	118.00	8.26	
12.50	117.00		
12.62	113.00	8.29	
12.74	114.00		
13.05	124.00	8.11	
13.36	115.00		
13.67	120.00		
13.97	120.00		
14.28	118.00	8.12	
14.59	119.00		
15.21	118.00		
15.84	117.00		
16.46	116.00	8.14	
17.08	109.00		

17.70	107.00		
18.32	111.00		
18.95	96.20	8.21	
19.57	101.00		
20.21	105.00		
20.84	106.00		
21.47	90.60	8.12	
22.10	87.80		
22.73	88.20		
23.35	87.40	8.13	
23.46	95.80		72 Hour Stop Flow
23.57	136.00	8.29	
23.69	127.00		
23.82	119.00	8.23	
23.94	115.00		
24.07	112.00	8.22	
24.19	112.00		
24.31	105.00	8.24	
24.44	107.00		
24.56	108.00	8.26	
24.87	104.00	8.18	
25.18	103.00		
25.49	100.00		
25.80	96.40		
26.11	94.00	8.23	
26.42	97.90		
27.04	88.10		
27.66	90.80		
28.28	87.20	8.20	
28.91	90.00	8.14	
29.53	78.30		
30.16	79.50		
30.78	87.50		
31.38	85.90	8.13	
31.99	84.60		
32.60	83.60		
33.21	86.60		
33.81	78.70	8.19	

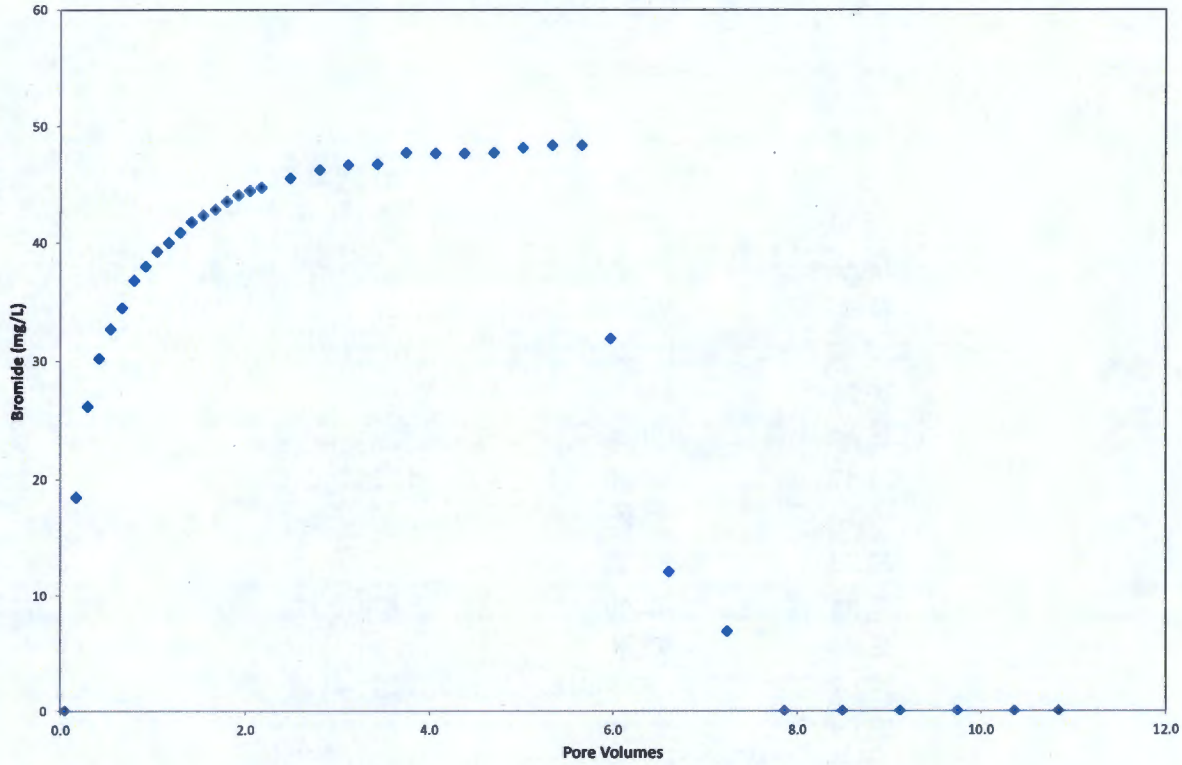

Figure 4. Bromide Concentration Versus Pore Volume and for Intact Core B30543 (estimated pore volume 223.5 mL, approximate flow rate 0.2476 pore volume per hour).

Table 5. Leachate Sample Pore Volume and Bromide Concentration for Intact Core B30543 (estimated pore volume 223.5 mL, approximate flow rate 0.2476 pore volume per hour).

Pore Volume	Bromide (mg/L)	Note
0.05	0.0	
0.17	18.5	
0.30	26.2	
0.42	30.2	
0.55	32.7	
0.67	34.5	
0.80	36.8	
0.92	38.0	
1.05	39.3	
1.17	40.0	
1.30	40.9	
1.42	41.8	
1.55	42.4	
1.67	42.9	
1.80	43.6	
1.93	44.1	
2.05	44.5	

2.18	44.8
2.49	45.6
2.80	46.3
3.12	46.7
3.43	46.8
3.75	47.8
4.07	47.7
4.39	47.7
4.71	47.8
5.02	48.2
5.34	48.4
5.66	48.4
5.97	31.9
6.61	12.0
7.24	6.9
7.87	0.0
8.50	0.0
9.12	0.0
9.75	0.0
10.37	0.0
10.85	0.0

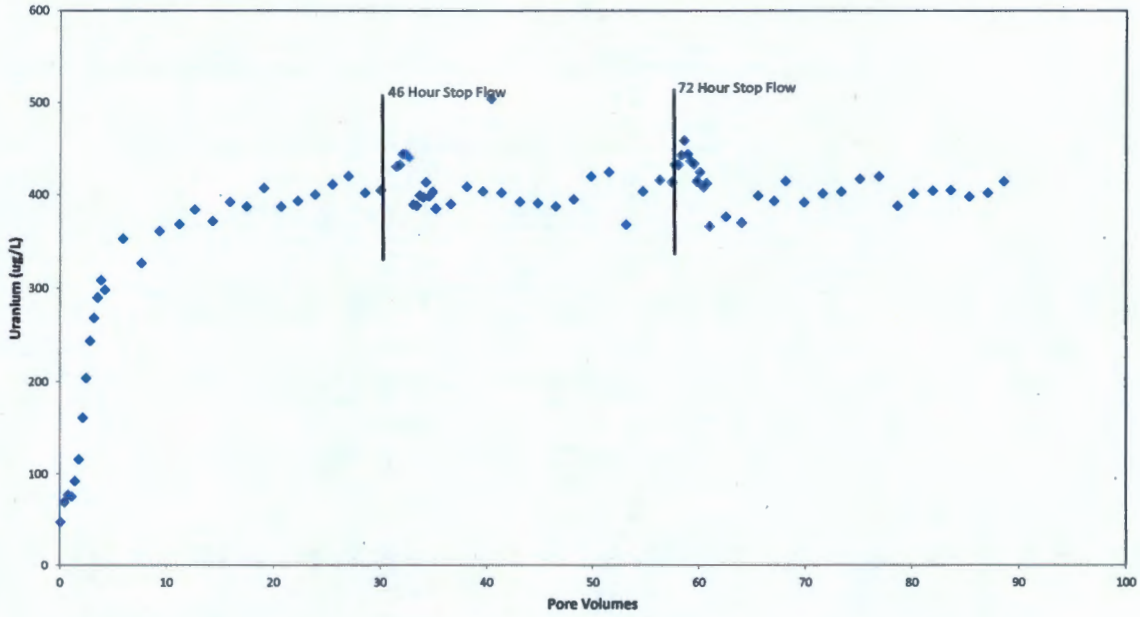

Figure 5. Uranium Concentration Versus Pore Volume and for Repacked (< 2mm) Column B30538 (estimated pore volume 28.65 mL, approximate flow rate 0.2193 pore volume per hour).

Table 6. Leachate Sample Pore and Uranium Concentration for Repacked (< 2mm) Column from Core B30538 (estimated pore volume 28.65 mL, approximate flow rate 0.2193 pore volume per hour).

Pore Volume	Uranium (µg/L)	pH	Note
0.10	47.2		
0.27		7.72	
0.44	69.1		
0.79	77.0		
0.96		7.69	
1.13	75.3		
1.47	92.3		
1.64		7.77	
1.81	116.0		
2.16	161.0		
2.33		8.00	
2.50	204.0		
2.85	244.0		
3.02		8.04	
3.19	268.0		
3.53	290.0		
3.70		8.20	
3.88	309.0		
4.22	298.0		
4.39		8.19	
5.08		8.09	

5.76		8.08
5.92	353.0	
6.43		8.04
7.11		8.02
7.62	327.0	
7.79		8.13
8.47		8.26
9.15		8.12
9.31	361.0	
9.83		8.06
10.51		8.16
11.17	368.0	8.20
11.83		8.25
12.49		8.17
12.65	384.0	
13.14		8.22
13.80		8.06
14.29	372.0	
14.46		8.27
14.62		8.21
15.10		8.23
15.90	392.0	
16.37		8.23
17.01		8.12
17.48	387.0	
17.64		8.11
18.28		7.98
18.92		8.14
19.08	407.0	
19.55		8.10
20.20		8.07
20.68	387.0	
20.84		8.07
21.48		8.07
22.12		8.06
22.28	393.0	
22.76		8.06
23.40		8.22
23.89	400.0	
24.05		8.03
24.69		8.08
25.33		8.08
25.49	411.0	
25.92		8.02
26.55		8.07
27.02	420.0	
27.18		8.01

27.80		8.10	
28.42		8.21	
28.57	402.0		
29.04		8.11	
29.66		8.01	
30.01	405.0		46 Hour Stop Flow
31.34		8.14	
31.49	430.0		
31.64		8.19	
31.78	432.0		
31.93		8.14	
32.08	444.0		
32.22		8.04	
32.37	444.0		
32.52		7.98	
32.67	440.0		
32.92		8.08	
33.07	389.0		
33.23		8.03	
33.38	388.0		
33.53		8.07	
33.68	399.0		
33.83		8.11	
33.99	397.0		
34.14		8.00	
34.29	413.0		
34.43		8.00	
34.58	398.0		
34.90	403.0		
35.04		8.24	
35.19	385.0		
35.66		8.05	
36.25		8.03	
36.56	390.0		
36.87		8.19	
37.49		8.16	
38.11	408.0	8.18	
38.71		8.20	
39.32		8.22	
39.63	403.0		
39.90		8.11	
40.19		8.16	
40.39	504.0		
40.71		8.06	
41.38	402.0	8.20	
42.06		8.07	
42.74		8.20	

43.08	392.0		
43.41		8.20	
44.09		8.23	
44.77	391.0	8.02	
45.43		8.12	
46.12		8.12	
46.46	387.0		
46.80		8.02	
47.48		8.11	
48.16	395.0	8.27	
48.33		8.22	
49.15		8.23	
49.81	419.0	8.26	
50.48		8.17	
51.14		8.17	
51.47	424.0		
51.79		8.19	
52.45		8.17	
53.10	368.0	8.11	
53.74		8.20	
54.39		8.13	
54.71	403.0		
55.03		8.11	
55.66		8.14	
56.29	415.0	8.12	
56.92		8.15	
57.42	413.0	8.05	72 Hour Stop Flow
57.72	432.0	8.04	
58.02	432.0	8.22	
58.31	443.0	8.13	
58.60	459.0	8.15	
58.90	444.0	8.26	
59.19	436.0	8.18	
59.49	433.0	8.18	
59.79	414.0	8.13	
60.09	424.0	8.22	
60.39	408.0		
60.69	412.0	8.11	
61.00	366.0		
61.30		8.23	
61.91		8.25	
62.50	376.0	8.21	
62.81		8.11	
63.11		8.17	
63.41		8.07	
63.70		8.07	
64.00	370.0	8.05	

64.31		8.11
64.62		8.14
64.92		8.15
65.22		8.10
65.54	399.0	
65.84		8.18
66.44		8.22
67.05	393.0	8.06
67.33		8.09
67.61		8.04
68.15	414.0	7.92
68.84		8.14
69.53		8.09
69.87	392.0	
70.23		8.19
70.93		8.10
71.64	401.0	8.09
72.33		8.07
73.04		8.10
73.36	403.0	
73.71		8.09
74.40		8.15
75.10	417.0	8.09
75.80		8.13
76.49		8.11
76.83	419.0	
77.18		8.22
77.89		8.12
78.59	388.0	8.19
79.26		8.22
79.78		8.20
80.12	401.0	8.11
80.81		8.14
81.50		8.08
81.85	404.0	
82.19		8.12
82.89		8.16
83.59	405.0	8.18
84.28		8.19
84.97		8.07
85.31	398.0	
85.65		8.15
86.33		8.16
87.01	402.0	8.08
87.69		8.13
88.20		8.08
88.54	414.0	
88.88		8.05

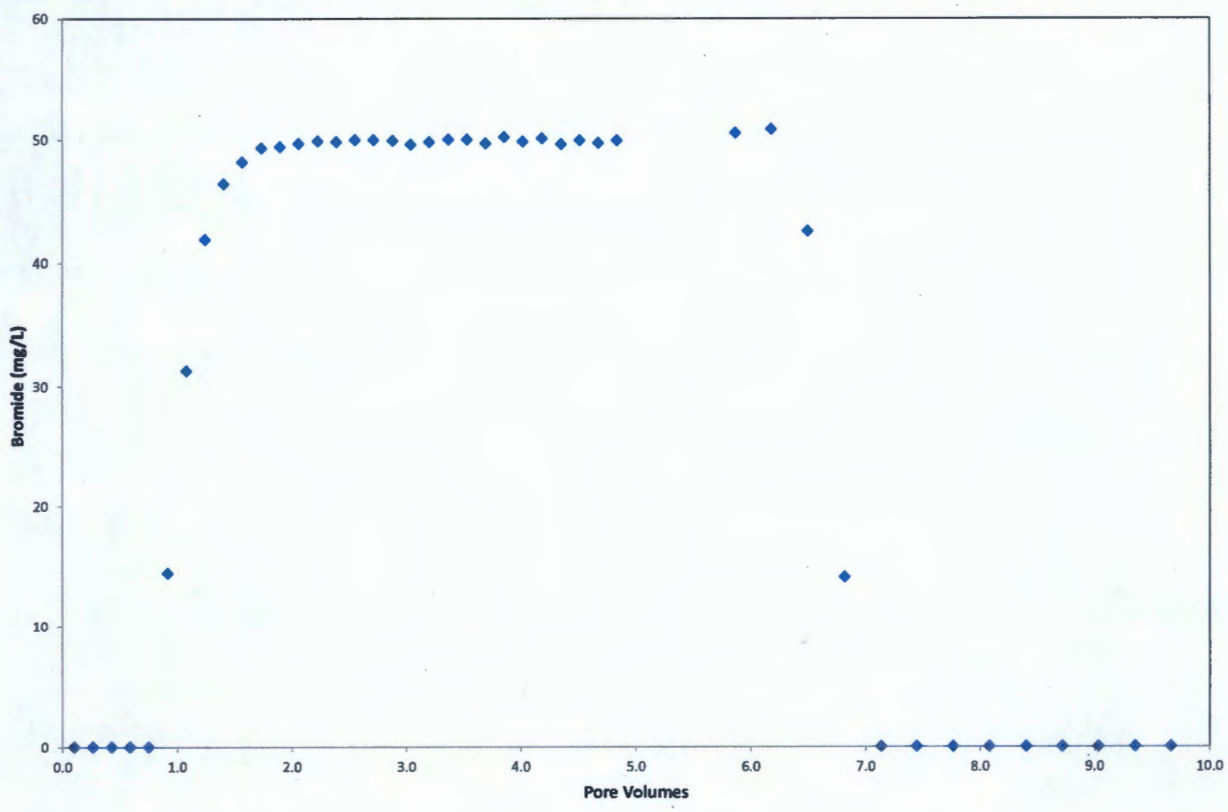

Figure 6. Bromide Concentration Versus Pore Volume and for Repacked (< 2mm) Column B30538 (estimated pore volume 28.65 mL, approximate flow rate 0.2193 pore volume per hour).

Table 7. Leachate Sample Pore and Bromide Concentration for Repacked (< 2mm) Column from Core B30538 (estimated pore volume 28.65 mL, approximate flow rate 0.2193 pore volume per hour).

Pore Volume	Bromide (mg/L)	Note
0.10	0.0	
0.27	0.0	
0.43	0.0	
0.59	0.0	
0.75	0.0	
0.92	14.4	
1.08	31.2	
1.25	41.9	
1.41	46.4	
1.57	48.2	
1.74	49.3	
1.90	49.4	
2.07	49.7	

2.23	49.9	
2.39	49.8	
2.56	50.0	
2.72	50.0	
2.89	49.9	
3.05	49.6	
3.21	49.8	
3.38	50.0	
3.54	50.0	
3.70	49.7	
3.86	50.2	
4.02	49.8	
4.19	50.1	
4.35	49.6	
4.52	49.9	
4.68	49.7	
4.84	49.9	
5.87	50.5	No Bromide
6.19	50.8	
6.50	42.6	
6.82	14.1	
7.14	0.0	
7.45	0.0	
7.77	0.0	
8.08	0.0	
8.40	0.0	
8.72	0.0	
9.03	0.0	
9.36	0.0	
9.67	0.0	
10.46	0.0	
11.24	0.0	
12.82	0.0	
14.39	0.0	

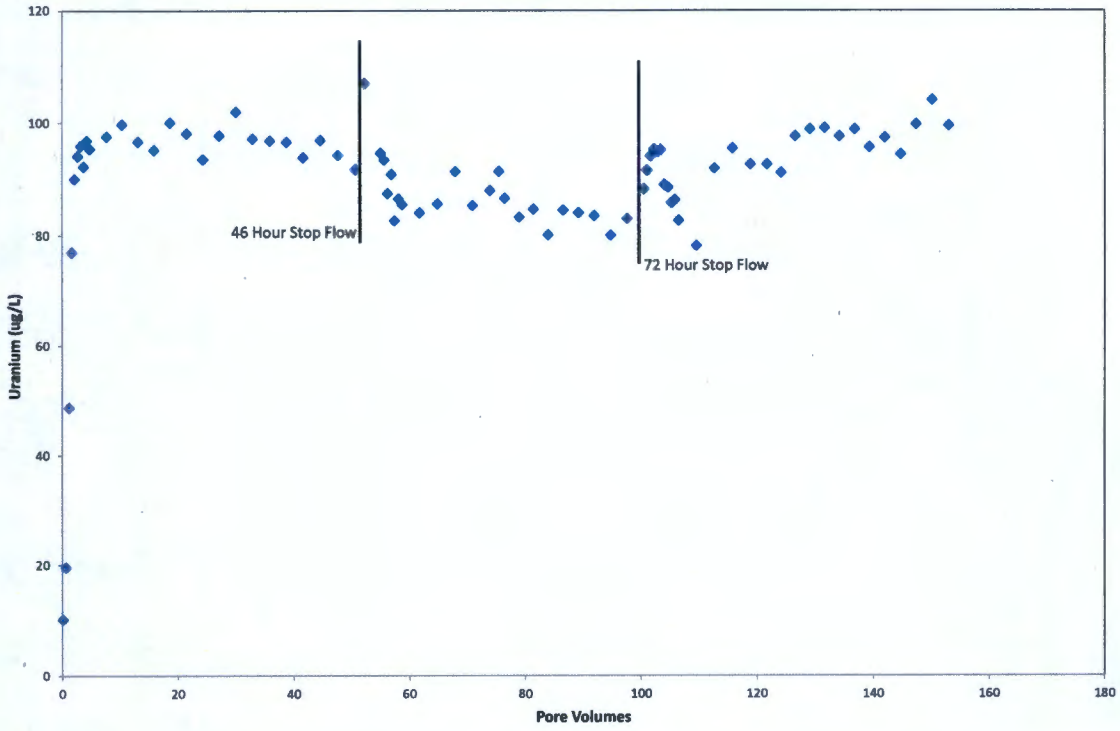

Figure 7. Uranium Concentration Versus Pore Volume and for Repacked (< 2mm) Column B30546 (estimated pore volume 24.50 mL, approximate flow rate 0.3581 pore volume per hour).

Table 8. Leachate Sample Pore and Uranium Concentration for Repacked (< 2mm) Column from Core B30546 (estimated pore volume 24.50 mL, approximate flow rate 0.3581 pore volume per hour).

Pore Volume	Uranium (µg/L)	pH	Note
0.2	10.1		
0.4		8.08	
0.7	19.5		
1.2	48.7		
1.5		8.14	
1.7	77		
2.2	90		
2.5		7.98	
2.8	94.1		
3.3	95.9		
3.5		8.23	
3.8	92.2		
4.3	96.8		
4.6		8.17	
4.9	95.4		

5.6		8.25
6.7		8.18
7.8	97.6	8.09
8.8		8.02
9.9		8.12
10.5	99.7	
11.0		8.14
12.1		8.15
13.2	96.7	8.16
14.3		8.3
15.4		8.18
16.0	95.2	
16.6		8.15
17.7		8.21
18.8	100	8.26
19.9		8.21
21.0		8.19
21.6	98.1	
22.1		8.26
23.3		8.22
24.4	93.5	8.16
25.5		8.08
26.7		8.17
27.2	97.7	
27.8		8.2
29.0		8.22
30.1	102	8.19
31.3		8.14
32.4		8.19
33.0	97.2	
33.6		8.19
34.8		8.15
35.9	96.9	8.05
37.1		8.18
38.3		8.16
38.8	96.6	
39.4		8.17
40.6		8.08
41.8	93.8	8.19
43.0		8.05
44.2		8.16
44.8	96.9	
45.4		8.16
46.6		8.16
47.8	94.2	8.19

49.0		8.17	
50.2		8.2	
50.8	91.7		
51.4		8.18	
52.3	107		46 Hour Stop Flow
54.8		8.15	
55.1	94.6		
55.4		8.25	
55.7	93.4		
56.0		8.22	
56.3	87.4		
56.7		8.18	
57.0	90.8		
57.3		8.08	
57.6	82.6		
57.9		8.18	
58.2	86.5		
58.5		8.21	
58.8	85.5		
59.1		8.17	
59.7		8.06	
60.4		8.14	
61.3		8.11	
61.9	84		
62.5		8.1	
63.7		8.16	
64.9	85.6	8.15	
66.1		8.07	
67.4		8.08	
68.0	91.3		
68.6		8.2	
69.8		8.2	
71.0	85.3	8.16	
72.2		8.14	
73.4		8.07	
74.0	88		
74.6		8.09	
75.6	91.3	8.12	
76.0		8.2	
76.5	86.6		
77.0		8.13	
78.0		8.17	
79.0	83.2	8.21	
80.0		8.18	

80.9		8.18	
81.4	84.6		
81.9		8.21	
83.0		8.15	
84.0	80.1	8.19	
84.6		8.16	
85.6		8.16	
86.7	84.5	8.15	
87.7		8.16	
88.8		8.12	
89.3	84		
89.9		8.09	
91.0		8.06	
92.1	83.5	8.15	
93.2		8.08	
94.3		8.04	
94.9	80		
95.5		8.19	
96.6		8.15	
97.8	82.9	8.08	
98.9		8.13	
100.1		8.19	
100.7	88.2		
101.2	91.5	8.14	
101.8	94.1	8.16	72 Hour Stop Flow
102.4	95.3	8.13	
103.0	94.8	8.05	
103.6	95.2	8.11	
104.2	89	8.16	
104.8	88.5	8.08	
105.4	85.8	8.08	
106.0	86.3	8.12	
106.6	82.6	8.1	
107.9		8.16	
109.1		8.19	
109.7	78.2		
110.3		8.08	
111.6		8.18	
112.8	91.9	8.06	
114.1		8.18	
115.3		8.18	
116.0	95.4		
116.6		8.12	
117.9		8.18	

119.1	92.6	8.13
120.4		8.05
121.6		8.11
121.9	92.6	
122.1		8.09
122.6		8.19
123.6		8.12
124.4	91.1	8.08
125.3		8.22
126.3		8.24
126.8	97.6	
127.3		8.2
128.3		8.15
129.3	98.8	8.19
130.3		8.16
131.3		8.13
131.8	99.1	
132.3		8.14
133.3		8.19
134.4	97.6	8.11
135.4		8.16
136.4		8.18
137.0	98.8	
137.5		8.25
138.5		8.13
139.6	95.6	8.18
140.6		8.13
141.7		8.14
142.2	97.4	
142.7		8.15
143.8		8.16
144.9	94.4	8.18
145.9		8.25
147.0		8.08
147.6	99.7	
148.1		8.14
149.2		8.2
150.3	104	8.25
151.5		8.2
152.6		8.22
153.2	99.4	
153.7		8.22
154.2		8.25

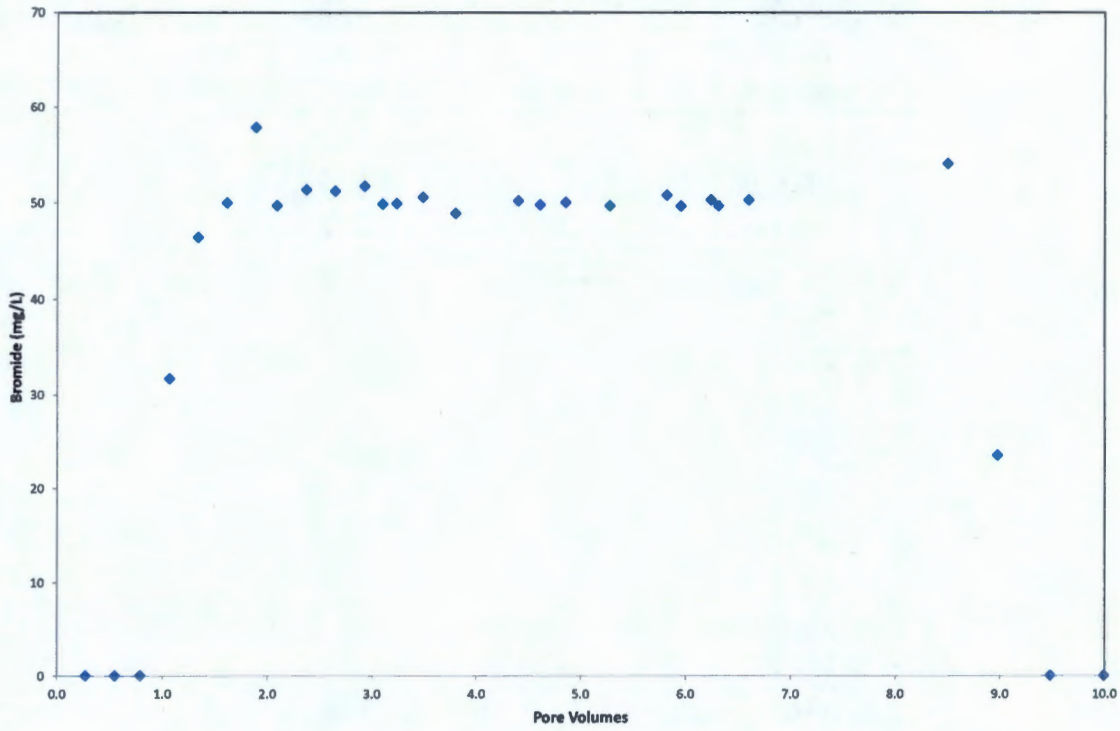

Figure 8. Bromide Concentration Versus Pore Volume and for Repacked (< 2mm) Column B30546 (estimated pore volume 24.50 mL, approximate flow rate 0.3581 pore volume per hour).

Table 9. Leachate Sample Pore and Bromide Concentration for Repacked (< 2mm) Column from Core B30546 (estimated pore volume 24.50 mL, approximate flow rate 0.3581 pore volume per hour).

Pore Volume	Bromide (mg/L)	Note
0.27	0.0	
0.55	0.0	
0.79	0.0	
1.06	31.7	
1.34	46.4	
1.62	50.0	
1.89	57.8	
2.09	49.7	
2.37	51.4	
2.65	51.2	
2.93	51.7	
3.10	49.9	
3.23	49.9	
3.49	50.6	
3.80	48.9	

4.40	50.2	
4.61	49.8	
4.86	50.0	
5.28	49.7	
5.82	50.8	
5.96	49.7	
6.24	50.3	
6.31	49.7	
6.60	50.3	
8.50	54.1	No Bromide
8.98	23.5	
9.48	0.0	
10.00	0.0	
10.50	0.0	
11.02	0.0	
11.53	0.0	
11.97	0.0	
12.49	0.0	
12.98	0.0	
14.16	0.0	
16.65	0.0	
19.26	0.0	
21.87	0.0	
23.72	0.0	

Wet Chemistry - Quality Control
Environmental Science Laboratory

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Batch 5B19003 - 1:1 Water Extract (pH_EC_Alk)										
Blank (5B19003-BLK1)				Prepared & Analyzed: 02/18/15						
pH	5.05E0	N/A	pH Units							
Duplicate (5B19003-DUP1)		**Source: 1501009-AF**		Prepared & Analyzed: 02/18/15						
pH	7.46E0	N/A	pH Units		7.50E0			0.535	35	

Total Metals by PNNL-AGG-ICP-AES/Special Extract - Quality Control
Environmental Science Laboratory

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Batch 5C05003 - Special Extract (ICP/ICPMS)										
Blank (5C05003-BLK1)				Prepared & Analyzed: 03/05/15						
Aluminum	<3.12E-1	3.12E-1	ug/g wet							
Calcium	<1.51E0	1.51E0	"							
Iron	<3.50E-1	3.50E-1	"							
Manganese	<2.08E-1	2.08E-1	"							
LCS (5C05003-BS1)				Prepared & Analyzed: 03/05/15						
Aluminum	6.64E0	3.12E-1	ug/g wet	7.50E0		88.6	80-120			
Calcium	7.25E0	1.51E0	"	7.50E0		96.7	80-120			
Iron	7.26E0	3.50E-1	"	7.50E0		96.9	80-120			
Manganese	7.36E0	2.08E-1	"	7.50E0		98.2	80-120			
Duplicate (5C05003-DUP1)		**Source: 1501009-AF**		Prepared & Analyzed: 03/05/15						
Aluminum	<6.37E-1	6.37E-1	ug/g dry		ND				35	
Calcium	4.34E1	3.07E0	"		4.31E1			0.849	35	
Iron	<7.12E-1	7.12E-1	"		ND				35	
Manganese	<4.24E-1	4.24E-1	"		ND				35	
Post Spike (5C05003-PS1)		**Source: 1501009-AG**		Prepared & Analyzed: 03/05/15						
Aluminum	4.64E2	N/A	ug/L	5.00E2	1.05E1	90.6	75-125			
Calcium	2.10E3	N/A	"	5.00E2	1.57E3	106	75-125			
Iron	5.13E2	N/A	"	5.00E2	9.95E0	101	75-125			
Manganese	2.52E2	N/A	"	2.50E2	1.92E-1	101	75-125			

Radionuclides by ICP-MS/Special Extraction - Quality Control
Environmental Science Laboratory

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Batch 5C04003 - Special Extract (ICP/ICPMS)										
Blank (5C04003-BLK1)				Prepared: 03/02/15		Analyzed: 03/04/15				
Uranium 238	<1.60E-3	1.60E-3	ug/g wet							
Duplicate (5C04003-DUP1)		**Source: 1501009-AF**		Prepared: 03/02/15		Analyzed: 03/04/15				
Uranium 238	3.56E0	3.26E-3	ug/g dry		3.65E0			2.59	35	
Post Spike (5C04003-PS1)		**Source: 1501009-AG**		Prepared & Analyzed: 03/04/15						
Uranium 238	6.38E0	N/A	ug/L	1.00E0	5.53E0	85.4	75-125			

Sequential Extractions-Quality Control

Duplicates

LabNumber	SampleName	Analyte	Result ug/g	RPD %	RPD Limit
1502014-06	B30546 DUP weak acetic acid	Aluminum	3.54E+01	14%	35
1502014-13	B30546 DUP strong acetic acid	Aluminum	1.44E+01	16%	35
1502014-20	B30546 DUP oxalate	Aluminum	9.03E+02	1%	35
1502014-27	B30546 DUP nitric acid	Aluminum	1.92E+04	40%	35
1502014-06	B30546 DUP weak acetic acid	Calcium	1.36E+03	2%	35
1502014-13	B30546 DUP strong acetic acid	Calcium	2.27E+02	2%	35
1502014-27	B30546 DUP nitric acid	Calcium	1.15E+04	23%	35
1502014-06	B30546 DUP weak acetic acid	Iron	7.54E+00	20%	35
1502014-13	B30546 DUP strong acetic acid	Iron	1.69E+01	108%	35
1502014-20	B30546 DUP oxalate	Iron	1.34E+03	8%	35
1502014-27	B30546 DUP nitric acid	Iron	5.81E+04	22%	35
1502014-06	B30546 DUP weak acetic acid	Manganese	7.54E+00	18%	35
1502014-13	B30546 DUP strong acetic acid	Manganese	3.22E+01	19%	35
1502014-20	B30546 DUP oxalate	Manganese	3.86E+01	6%	35
1502014-27	B30546 DUP nitric acid	Manganese	6.24E+02	24%	35
1502014-06	B30546 DUP weak acetic acid	Uranium 238	6.72E+00	1%	35
1502014-13	B30546 DUP strong acetic acid	Uranium 238	4.97E+00	2%	35
1502014-20	B30546 DUP oxalate	Uranium 238	3.51E+00	11%	35
1502014-27	B30546 DUP nitric acid	Uranium 238	1.28E+01	30%	35

Note: duplicate analysis failed for aluminum in nitric acid and iron in strong acetic acid.

Blank Spikes

LabNumber	SampleName	Analyte	Result ug/L	EQL	% REC	% REC Limits
1502014-29	Weak Acid BS	Aluminum	ND	1.65E+03	n/a	80-120
1502014-30	Strong Acid BS	Aluminum	6.61E+03	1.65E+03	113	80-120
1502014-31	Oxalate BS	Aluminum	4.82E+03	1.65E+03	156	80-120
1502014-32	Nitric BS	Aluminum	9.68E+03	1.65E+03	138	80-120
1502014-29	Weak Acid BS	Calcium	7.19E+03	4.90E+03	104	80-120
1502014-30	Strong Acid BS	Calcium	8.43E+03	4.90E+03	89	80-120
1502014-31	Oxalate BS	Calcium	9.02E+03	4.90E+03	83	80-120
1502014-32	Nitric BS	Calcium	1.75E+04	4.90E+03	76	80-120
1502014-29	Weak Acid BS	Iron	5.28E+03	1.00E+03	142	80-120
1502014-30	Strong Acid BS	Iron	7.35E+03	1.00E+03	102	80-120
1502014-31	Oxalate BS	Iron	7.50E+03	1.00E+03	100	80-120
1502014-32	Nitric BS	Iron	1.39E+04	1.00E+03	96	80-120
1502014-29	Weak Acid BS	Manganese	5.29E+03	9.41E+02	142	80-120
1502014-30	Strong Acid BS	Manganese	7.11E+03	9.41E+02	105	80-120
1502014-31	Oxalate BS	Manganese	7.23E+03	9.41E+02	104	80-120
1502014-32	Nitric BS	Manganese	1.11E+04	9.41E+02	120	80-120

Note: BS analysis failed for aluminum (weak acid, oxalate and nitric acid). Aluminum data may be suspect. Calcium, iron and manganese fail for the weak acid. Recoveries for these are high.

Spectroscopy Results

All sediment samples displayed similar fluorescence spectra with vibronic band positions located at 500±2 nm, 519± nm and 540±2 nm, respectively, with the exception of sample 30589 which showed a single spectral maximum at 535 nm (Figure 1 and Table 1). There is a general trend that higher spectral intensity appears to correlate with higher uranium concentration in the sediment. The vibronic band spacings ranged from 665 cm^{-1} for sample 30525 to 798 cm^{-1} for sample 30546 (Table 1). Time resolved spectra for delay times up to 1700 μs showed little change for all sample (Figure 2) except sample 30525. For the latter, a better-resolved spectral pattern emerged at longer delay times with peak positions at 482 nm, 501 nm, 521 nm, 544 nm and 568 nm, respectively, and the peak spacing increased to 810 cm^{-1} (Figure 3). In the opposite, all other samples, the spectra became even less resolved. All fluorescence decays requires two exponential functions to fit (Figure 4). It was interesting to note that while samples 30538 and 30525 possess the highest uranium concentration, their fluorescence lifetimes happened to be the shortest. Possibly, due to the shallower depth of these samples and likely association with more concentrated waste solutions, fluorescence quenchers, such as transition metal ions (e.g. Cu^{2+}), were present at higher concentrations. These quenchers were in the vicinity of the U(VI) ions, leading to more effective quenching of the U(VI) fluorescence.

Although an exact match of the fluorescence spectra of the present sediment samples with the spectra of published spectra of known crystalline U(VI) compounds could not be found, the small peak spacing values (Typically < 800 cm^{-1}; Table 1) and the red-shifted spectra maxima (sample 30589), suggested that the primary spectral component could be associated with either silicates or oxyhydroxides (Wang, Zachara et al. 2008), or as adsorbates in minerals such as calcium carbonate or quartz (Wang, Zachara et al. 2005; Wang, Zachara et al. 2011; Ilton, Wang et al. 2012). The type of red-shifted spectra are almost exclusively shown by most uranyloxyhydroxide minerals such as meta-schoepite, schoepite and becquerelite (see Figure 5 for meta-schoepite for example). As uranium concentration in sample 30589 was only 4 ppm, precipitation of uranyloxyhydroxide is unlikely. A possible explanation will be that uranyl ion was incorporated into other metal oxide minerals, resulting a U(VI) coordination environment that resembles that of typical uranyloxyhydroxide. The featureless spectra of samples 304Y3, 304Y5, 30538 and 30546 observed at longer delay times possibly had the same spectral origin as sample 30589.

Both of the evolution of the time-resolved fluorescence spectra and the presence of two fluorescence lifetime components indicated that a minimum of two U(VI) coordination. For sample 30525, the vibronic band positions of the minor spectral component seen at long delay times are consistent with those observed for uranyl ion incorporated into aragonite (Reeder, Nugent et al. 2000; Reeder, Elzinga et al. 2004; Wang, Zachara et al. 2005), a calcium carbonate mineral. This is consistent with the site mineralogy where minor fractions of calcium carbonate are present (Zachara, Brown et al. 2007). As aragonite often co-exists with calcite, it could be that the main spectral component (except sample 30589) was due to uranyl ion incorporated into calcite mineral. In fact, the stead-state fluorescence spectra resemble closely to that of uranyl incorporated into calcite (Reeder, Nugent et al. 2000; Reeder, Elzinga et al. 2004; Wang, Zachara et al. 2005) although the overall spectral positions red-shifted about 5 nm. As quartz is a major mineralogical component at the Hanford site and it is a strong uranyl ion adsorbent (Qafoku, Zachara et al. 2005; Wang, Zachara et al. 2011; Ilton, Wang et al. 2012), it could be that such red-shift of the spectra included contributions of uranyl ion adsorbed to fine quartz particles in the sediment.

Because uranium in these sediments is either incorporated into other mineral solids or adsorbed into quartz or other sediment particles, which are often present as agglomerated of finer particles, it is expected that the desorption of uranium ions will be controlled by the dissolution of the solids as well as the nature and extent of the porosity of the particle agglomerates.

Appendix B

Reprint of SGW-58736, Technical Memorandum (*300-FF-5 Enhanced Attenuation Area Stage A Location Selection*), Rev. 0, published April 2015

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TECHNICAL MEMORANDUM

300-FF-5 Enhanced Attenuation Area Stage A Location Selection

Prepared for:	300-FF-5 Operable Unit
Prepared by:	S.M. Sexton, T. Hammond, and S. Mehta
CCs:	R.E. Day, R.M. Hermann, V.J. Rohay
Date:	April 13, 2015
Doc ID	SGW-58736, Rev. 0

1. Introduction

This technical memorandum provides a brief summary of the field effort conducted during the post-record of decision (ROD) field investigation performed December 2014 through January 2015, and the proposed location of the Stage A enhanced attenuation area (EAA) for polyphosphate injection/ infiltration. The intention of the field investigation was to gather additional data concerning uranium contamination and leachability characteristics in the 300 Area to address the principal study questions of documented in SGW-56993, *Sampling Instruction for the 300-FF-5 Operable Unit Supplemental Post ROD Field Investigation.* The results from this field effort are being used to confirm the location of the EAA, as defined in the 300 Area ROD/ROD Amendment (EPA and DOE, *Hanford Site 300 Area Record of Decision for 300-FF-2 and 300-FF-5, and Record of Decision Amendment for 300-FF-1*). Due to the extensive amount of preparatory work required for the polyphosphate injection/infiltration process, this technical memo has been compiled to present a short and concise summary of the data gathered to date to support confirmation. This memo will be followed by the Supplemental Post-ROD Field Investigation Summary report defined in DOE/RL-2014-13-ADD2, *Remedial Design Report/Remedial Action Work Plan Addendum for the 300 Area Groundwater* (hereinafter the Remedial Design Report/Remedial Action Work Plan [RDR/RAWP])

Historic groundwater plume maps have pointed to elevated levels of uranium contamination near the 316-2 and 316-5 Waste Sites. Contamination levels at Wells 399-1-17A and 399-1-55 were influential in the location of the post-ROD field investigation boreholes (Figure 1). Soil samples were collected and analyzed for uranium at each of the three boreholes drilled during the post-ROD field investigation to locate the area with the highest potential for uranium leaching from the vadose zone to groundwater. Borehole locations were selected to provide lateral extents for reducing uncertainty related to residual uranium contamination in the vadose zone.

Based upon the data gathered during this post-ROD field investigation, the updated conceptual site model (CSM), and the updated three-dimensional (3D) model of uranium in soil, a finalized location for the Stage A EAA is presented in this technical memo. Well locations for Stage A, as identified in the RDR/RAWP are also presented.

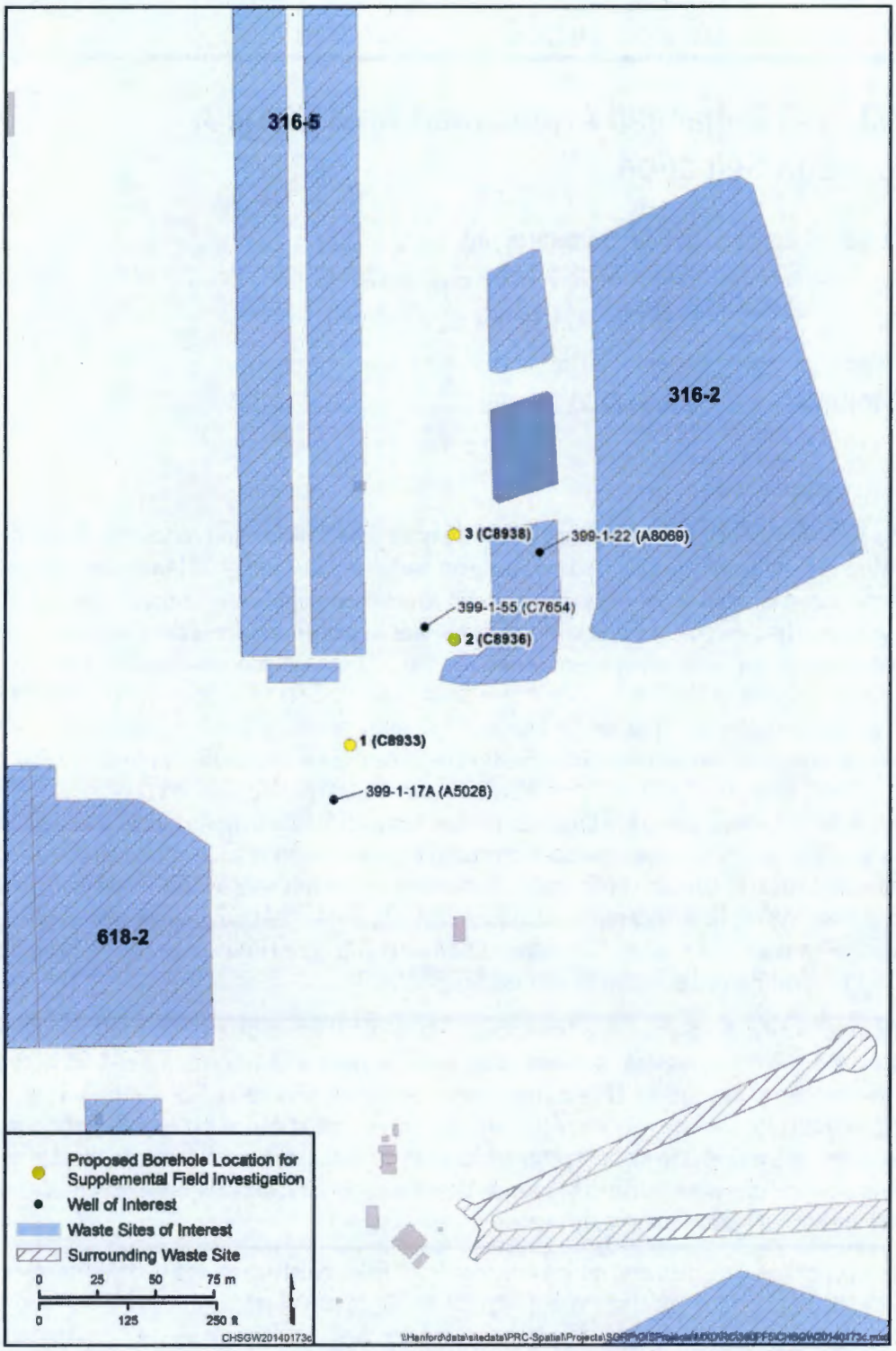

Figure 1. Post-ROD Field Investigation Well Locations

2. Initial Data Collection

Total uranium analysis of vadose zone soils through the periodically rewetted zone (PRZ) and into the upper aquifer showed varying levels of contamination between the three boreholes. Background uranium levels in the 300 Area have been previously calculated with a value of 3.21 µg/g (ECF-300FF5-11-0151, *Groundwater Flow and Uranium Transport Modeling in Support of the 300 Area FF-5 RI/FS*). The sample data collected during the post-ROD field investigation showed elevated uranium (above background levels) at all three of the borehole locations. Well C8936 (399-1-67), located between the North Process Trench (316-5) and the footprint of the former North Process Pond (Waste Site 316-2), displayed values between 3 and 10 times the background uranium soil concentrations. Well C8938 (399-1-68) displayed the lowest values of total uranium and was consistently closer to background levels. Borehole C8933, drilled near the 2006 polyphosphate injection study, displayed uranium values that were less than initially anticipated, especially given its close proximity to Well 399-1-17A, but had results more than twice the background within the PRZ. Figure 2 displays the uranium concentration results and borehole geology from soils collected during drilling operations at the three boreholes.

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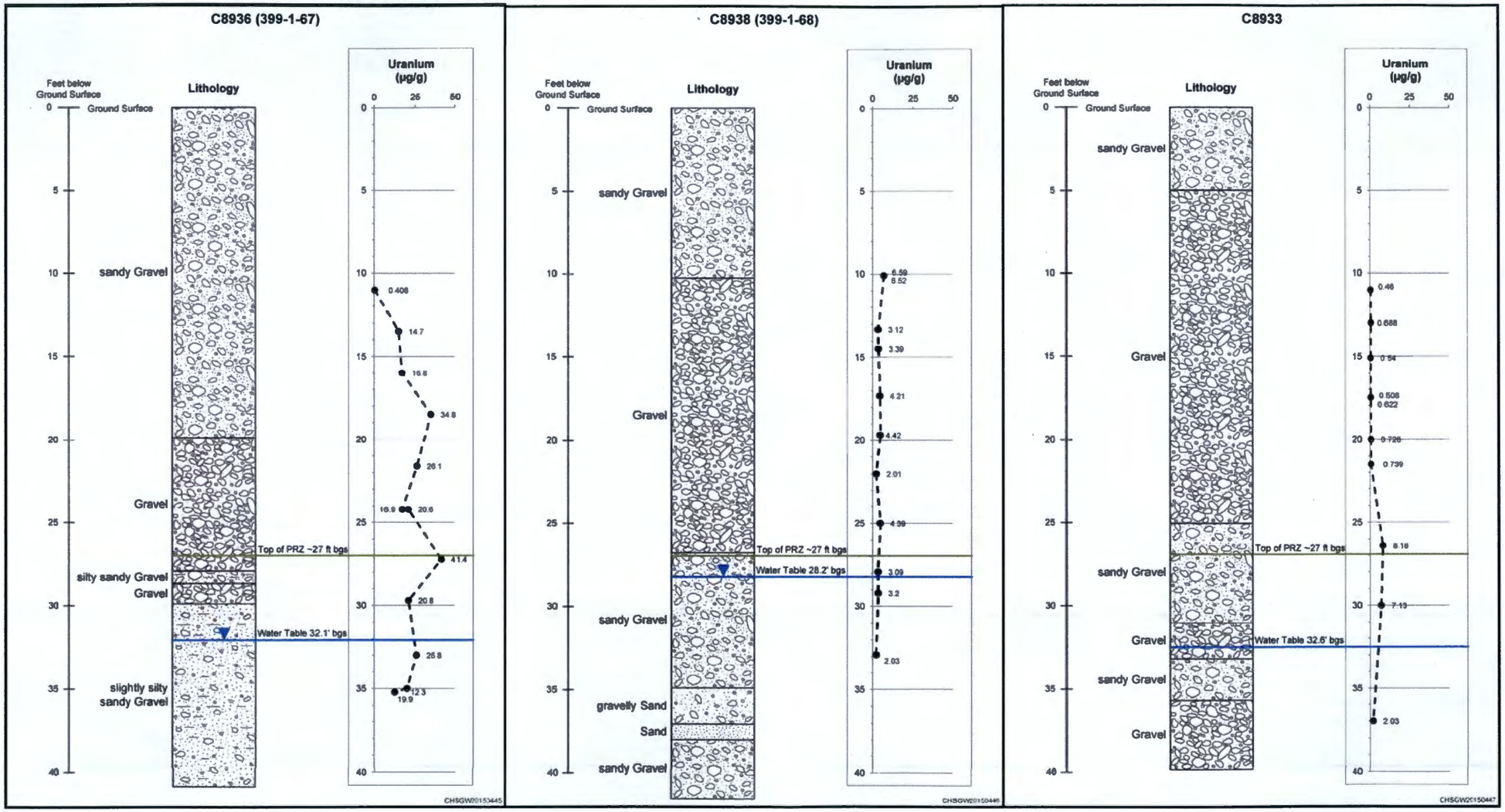

Figure 1. Uranium Concentration Distribution with Borehole Geology

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Previous efforts related to interpolation of uranium data identified data gaps, so additional data gathering was proposed to the north and east of the base of 316-5. Borehole locations were selected to provide lateral extents for reducing uncertainty related to residual uranium contamination in the vadose zone.

Data gathered during this drilling and sampling campaign are also serving to provide a more complete CSM of the 300 Area vadose zone. There have been previous attempts to complete an accurate CSM for this area, but due to the lack of data through the vadose zone, a high amount of inference is needed to complete this task. Very little data are available regarding the contamination within the 316-2 and 316-5 Waste Sites; information gathered during this study is of high importance to the cleanup goal.

Additional data collected prior to the excavation of the 316-5 Waste Site was used to construct the uranium plume model in an attempt to interpolate uranium within the PRZ in three dimensions. The results of the pre-excavation sampling, the most recent data collected during well drilling, and the historic locations of the outfall of the 300-15 Process Sewer Line within the 316-2 and 316-5 Waste Sites were crucial in selecting a final Stage A location for the sequestration effort.

Based upon the data gathered during this post-ROD field investigation and other lines of evidence presented, a finalized location for the Stage A EAA injection and monitoring wells is presented in Figure 3.

2.1 3D Soil Uranium Mass Plume Construction

Leapfrog® Hydro was used to interpolate the 3D uranium soil concentration distribution within the subsurface of the 300 Area. Input data consisted of spatially referenced soil concentrations with sample dates ranging from 1991 through 2015. Soil concentrations of uranium-238 in pCi/g or µg/g were compiled from the Hanford Environmental Information System (HEIS), and the following primary reports for the 300 Area:

- DOE/RL-92-32, *Expedited Response Action Assessment for 316-5 Process Trenches*
- BHI-01164, *300 Area Process Trenches Verification Package* (Appendix D)
- PNNL-17793, *Uranium Contamination in the 300 Area: Emergent Data and Their Impact on the Source Term Conceptual Model* (Tables 5.11, 5.22, and 5.47)
- PNNL-16435, *Limited Field Investigation Report for Uranium Contamination in the 300-FF-5 Operable Unit at the 300 Area, Hanford Site, Washington* (Table D.2)
- PNNL-22032, *Uranium in Hanford Site 300 Area: Extraction Data on Borehole Sediments*

New data from samples collected during the drilling of three new boreholes in late 2014 and early 2015 (C8933, 399-1-67 and 399-1-68) and data in the form of a letter report from Peterson, 2010, *Uranium in Sediment from FS-2 Test Pit, 618-1 Burial Ground Excavation*, were also used. All soil concentrations for uranium were reported by analyzing grain size of <2 mm (by removing the gravel fraction).

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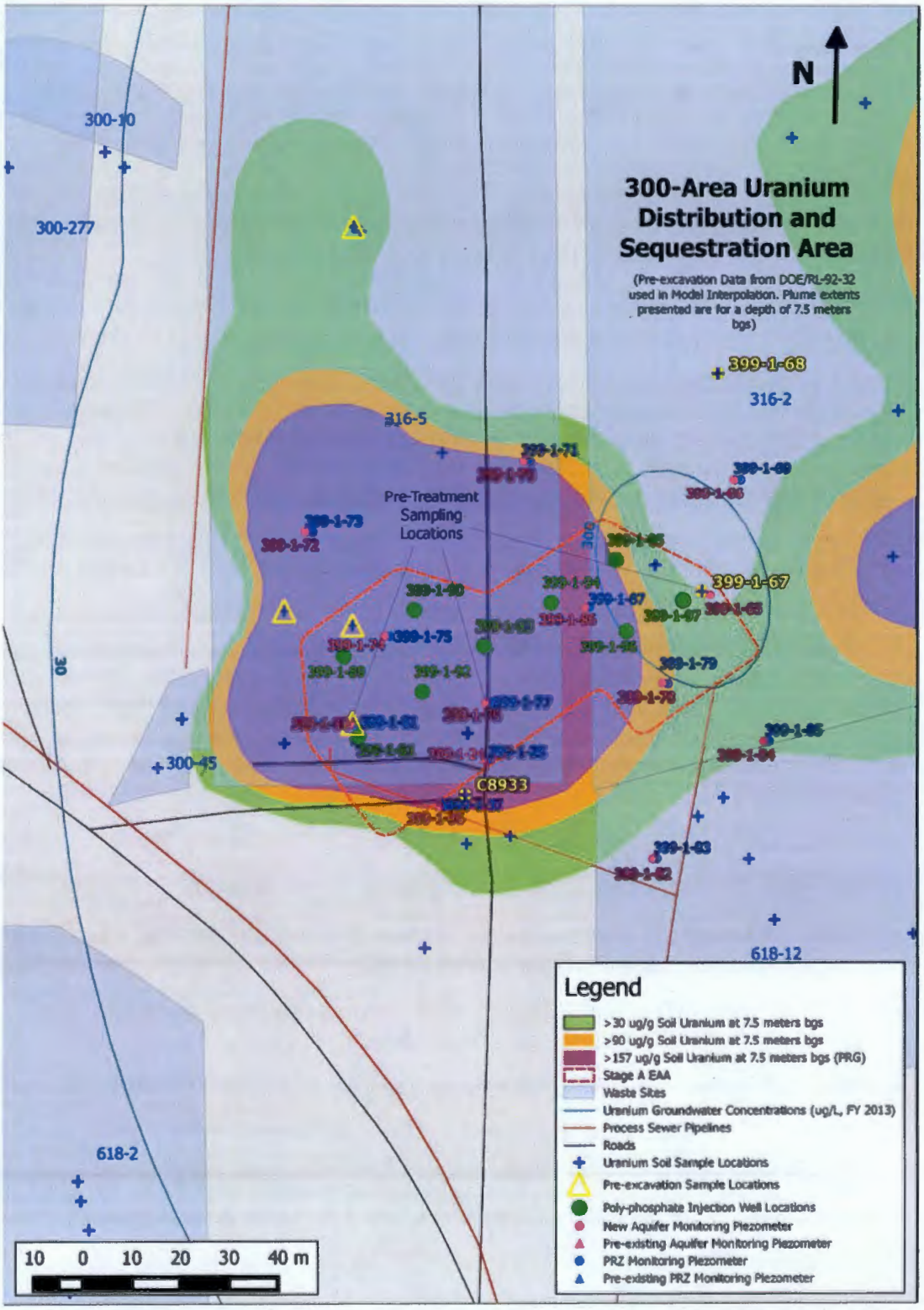

Figure 3. Uranium Concentration Distribution with Pre-excavation Sample Results Included

Data downloaded from HEIS were selectively filtered by removing samples marked as duplicates and overburden/staging pile area measurements. Measurements from soil that was subsequently excavated after measurement were also selectively removed from the data set. Some of the HEIS data did not come with depth-discrete measurements. Depths were assigned at 5 and 7.5 m (16.4 and 24.6 ft) for measurements classified as Shallow and Deep, respectively. For samples collected at the surface, the depth was set at 0.3 m (1 ft). Where a sampling depth range was given, the sampling depth was taken as the midpoint of the range. Additionally, soil sample results based on one lab method (described in HEIS as UISO_Plate_AEA) were used for consistency and comparability of data. This method detects the isotopes of uranium using alpha spectroscopy. All data for soil that were below the detectable limit were set to zero. The newest data from Boreholes C8933, 399-1-67, and 399-1-68 were received as total uranium soil concentration (µg/kg). The soil concentration results for the uranium-238 isotope were used in the calculations for uranium modeling because almost all (99.3 percent) naturally occurring uranium is composed of uranium-238 (Rosman and Taylor, 1998, *Isotopic Compositions of the Elements 1997*).

Before entering the uranium concentration data into Leapfrog Hydro for plume interpolation, a base geologic model of the suprabasalt sediments underlying the 300 Area was constructed. Geologic model development used current data sets from the existing geologic framework model representing the entire Hanford Site south of Gable Mountain and Gable Butte (ECF-HANFORD-13-0029, *Development of the Hanford South Geologic Framework Model, Hanford Site Washington*) and interpretations of recently received borehole geologic logs from the area (PNNL-22032).

The 300 Area geologic model was constructed of two parts: a detailed Hanford formation (Hf) model subdividing the unit into subunits based upon silt, sand, and gravel fractions; and importing Ringold Formation member of Wooded Island – unit E (Rwie) and Ringold Formation member of Wooded Island – lower mud unit (Rlm) surfaces extracted from the Hanford South geologic framework model (ECF-HANFORD-13-0029).

The detailed Hanford formation model utilized the extracted Rwie surface as its lower boundary and ground-proofed aerometric light detection and ranging (LiDAR) (Aerometric, 2008, *Digital Orthophotography & LiDAR Surveys Photogrammetric Report*) topography as the upper boundary. Detailed Hf geologic data were interpreted from borehole geologic and geophysical logs available from HEIS, Well Information and Document Lookup, and Integrated Document Management System. These data were subsequently interpolated in Leapfrog Hydro using the software's radial basis function algorithm. Five distinct Hf subunits were identified to be present in the 300 Area from the borehole geologic log interpretations. In order of occurrence from the ground surface down, these units were described as Hf sand unit 1, Hf sandy gravel, Hf sand unit 2, Hf silty-sandy gravel, and Hf gravel.

The model used the extracted Rwie surface as its upper boundary and a top of basalt surface interpreted from seismic and borehole data (SGW-48478, *Interpretation and Integration of Seismic Data in the Gable Gap*) as the bottom boundary. The radial basis function algorithm also interpolated volumes from Rwie and Rlm based on their respective extracted surfaces.

After construction of the geologic framework model for the 300 Area, the previously discussed uranium soil concentration data was used in 3D uranium plume interpolation. Control points were added to the model in order to maintain the uranium plume extents within reasonable limits as determined by analysis of the available data. The control points are added so that the interpolation does not extend beyond a reasonable area where concentrations are understood to be near or below background

levels. Soil uranium concentrations were interpolated in the Leapfrog Hydro model volume and are shown at 30, 90, and 157 µg/g extents (approximately 10 and 30 times the background soil uranium concentrations and industrial cleanup level for uranium in soil for protection of groundwater) to better illustrate the footprint of the highest concentrations and, therefore, aid in defining the area of interest.

2.2 EAA Definition and Lines of Evidence

Previous interpolation of soil uranium concentration data from the 2011 remedial investigation/feasibility study modeling effort (ECF-300FF5-11-0151), high-concentration uranium groundwater plume extents from 2011 and 2012 (the high river stage years), and previous waste disposal area locations served as the basis for defining the current zone of high concentration. This approach was used within the full capacity of the available data and represents a "best estimate" of the uranium concentration distribution higher than 30 µg/g (approximately 10 times the background concentration). The 30 and 90 µg/g plume extents were selected based on multiples 10 and 30 times the soil uranium background concentrations, respectively. The 157 ug/g contour shows the industrial cleanup level for uranium that is protective of groundwater.

Plume extents collected from the most recent groundwater report (DOE/RL-2014-32, *Hanford Site Groundwater Monitoring Report for 2013*) were included in Figures 2 and 3 to display the prevalent contamination plume at this area, and are shown as 30 µg/L and 300 µg/L gradients. The plume extents are affected by the groundwater flow gradient, towards the Columbia River, and reflect the dissolved and mobile uranium concentration. Successful treatment within the Stage A boundary will prevent the migration of mobile uranium to the east, resulting in the reduction or elimination of this 300 µg/L groundwater plume contour from future modelling efforts.

The EAA was determined by examining model interpolation of soil uranium distribution and available depth-discrete data and was drawn to encompass sampling locations of the highest soil uranium concentrations. The outfall area for both the 316-2 and 316-5 Waste Sites was also encompassed within the Stage A EAA. The Stage B EAA was expanded to include the highest soil uranium concentrations within Stage A EAA and the entire area of the >90 µg/g plume extent (Figure 4).

The Leapfrog Hydro plume interpolation shows the area of highest uranium soil concentrations (>90 µg/g) to be at the southern end of the 316-5 Process Trenches, extending to the southwest corner of the 316-2 North Process Pond (Figure 3). In this area, surface soil uranium concentrations were as high as 3,250 µg/g in 1991 (DOE/RL-92-32). Most uranium concentrations >90 µg/g were measured in samples from approximately 7.5 m (24.6 ft) below the surface. Plume extents depicted in Figures 3 and 4 represent the horizontal uranium contamination distribution as interpolated at 7.5 m (24.6 ft) below ground surface. Figure 3 also provides discrete sample locations used in the interpolation along with Stage A injection and monitoring well locations. The EAA is within the extents of the current interpretation of the uranium groundwater plume and covers the outfall areas of the 316-2 and 316-5 Process Sewer Pipeline.

In an effort to better constrain the area of highest soil uranium concentrations, the highest values from the data set presented in DOE/RL-92-32 were also used in plume interpolation. These high values were identified in the report as being pre-excavation samples that were collected from the bottom of the trenches prior to remediation. Post-excavation samples were also collected but were not used in the model interpolation because those values were below background levels. Because only approximately 1.2 m (4 ft) of material was removed from the bottom of the trenches, considerable uncertainty exists regarding uranium concentrations in the vadose zone and PRZ below these sampled sites as it is likely

that uranium-bearing waste infiltrated deeper. Elevations of the post-excavation samples are approximately 110.3 m (361.9 ft) above mean sea level (amsl), and the elevation of the PRZ averages between 107 and 105 m (351.1 and 344.5) amsl. The sampling sites also are within the immediate vicinity of the outfall areas of process sewer pipelines, from which considerable amounts of uranium-containing wastewater were expelled. When the model was run, excluding the pre-excavation samples, the zone of highest uranium soil concentrations was significantly diminished beyond the original extent with the pre-excavation samples in place. The diminished zone appears to be unrealistically small with respect to extents indicated by all of the previously discussed lines of evidence.

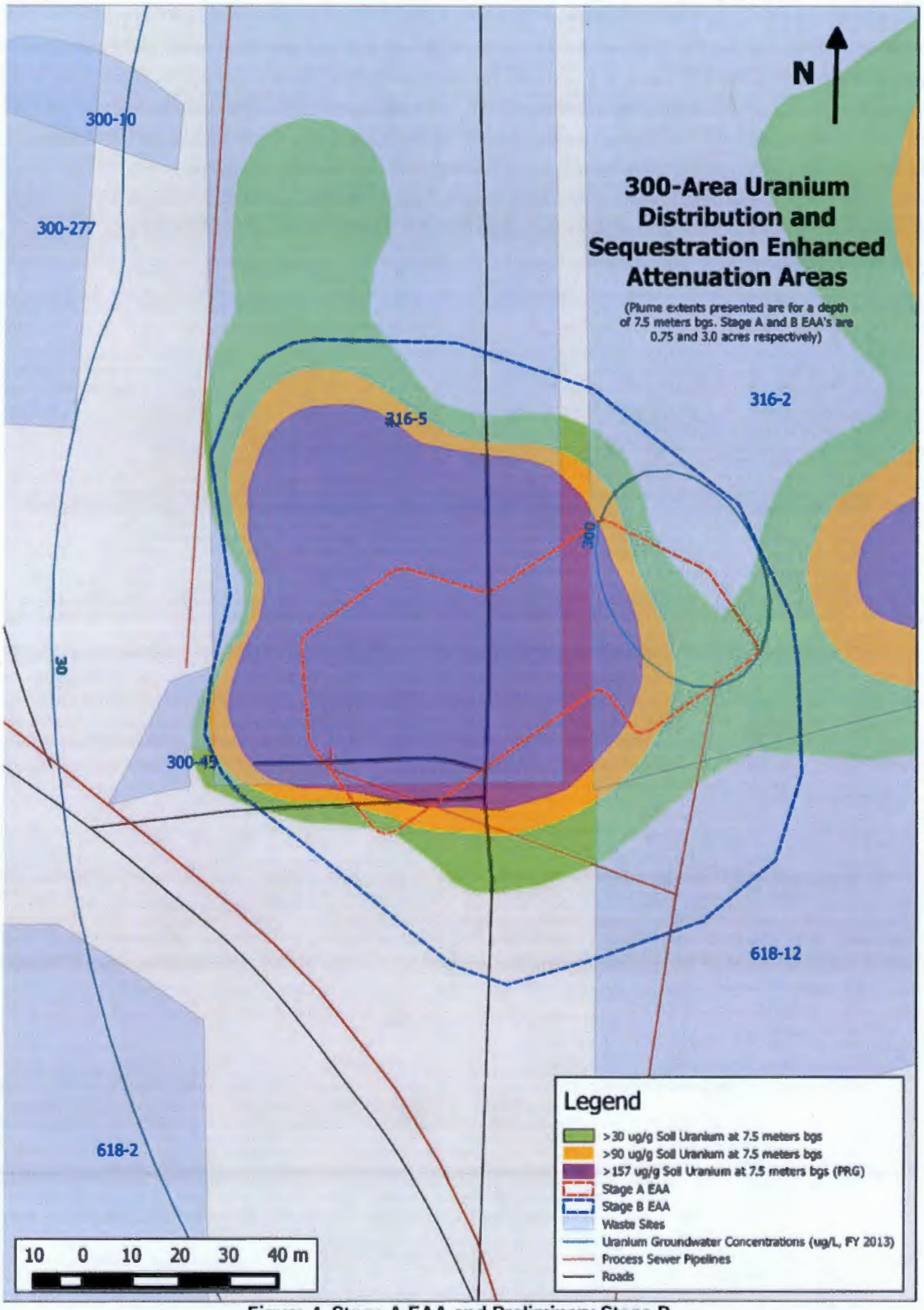

Figure 4. Stage A EAA and Preliminary Stage B EAA Treatment Locations

3. Well Location Selection

Well locations were selected based upon the criteria in Section 4.1.2.1 of the RDR/RAWP (DOE/RL-2014-13-ADD2):

> Installation of 24 mini piezometers consisting of 12 well pairs screened within the PRZ...and within the top of the aquifer... Piezometer installations will comprise three piezometer pairs upgradient of the Stage A treatment area, six piezometers pairs within the Stage A treatment area, and three piezometer pairs downgradient of the Stage A treatment area...

The nine injection wells are spaced throughout the EAA to maximize the impact of the polyphosphate injection across the infiltration system. The wells have been spaced according to the proposed radius of influence (ROI) of the injection well and were distributed as evenly as possible across the EAA. The injection well spacing was based upon injection ROIs of 7.6 m (25 ft) (DOE/RL-2014-13-ADD2), which results in a spacing of 15.2 m (50 ft) between each well. Natural groundwater flow is expected to transport the polyphosphate solution to the remaining downgradient portion of the EAA.

Pairs of wells screened within the PRZ and top of the aquifer are arranged upgradient and downgradient of the EAA and within the EAA near the injection wells. Two of the selected pairs are existing monitoring wells from previous injection tests performed by the Pacific Northwest National Laboratory (PNNL). These wells will be added to the monitoring well network for this proposed injection/infiltration treatment. Piezometer locations inside the Stage A EAA were selected to represent various distance upgradient, cross-gradient and downgradeint of injection points to provide monitoring coverage during phosphate distribution. Piezometer locations outside of the Stage A boundary were selected to represent the background groundwater concentrations. These locations represent the upgradient background concentrations at 15.2 m (50 ft), and downgradient concentrations at 15.2 m (50 ft) and 30.5 m (100 ft) from the Stage A EAA.

Additionally, one aquifer monitoring well will be drilled within close proximity to Well 399-1-67. Well 399-1-67 had the highest uranium concentrations found in soil during the post-ROD drilling activities and was constructed as a monitoring well within the PRZ. Adding an aquifer monitoring well in close proximity to 399-1-67 will provide much needed information regarding uranium sequestration at the eastern edge of the EAA.

Because the predominant groundwater flow, shown in Figure 5, is to the east and southeast (DOE/RL-2014-32), the well locations were chosen to best capture the migration of uranium. The injection/infiltration work is currently scheduled to be performed during the low water months, when uranium is most likely to be entrained in the vadose zone. By sequestering uranium before the water table rises, the monitoring network setup around the EAA will provide evidence of the ability of the polyphosphate solution to sequester sorbed uranium in the vadose zone from remobilization.

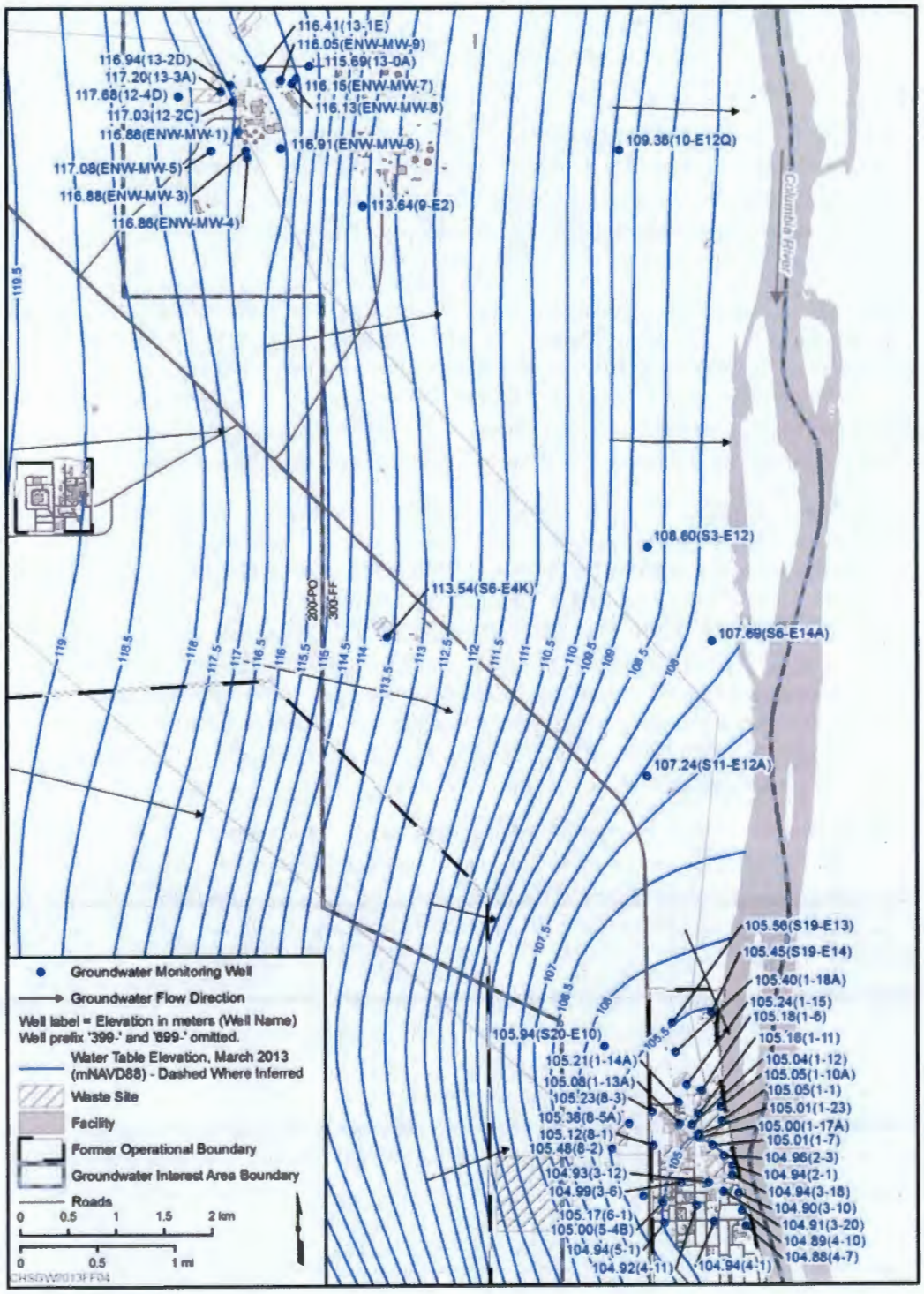

Figure 5. Groundwater Flow Across Northern 300 Area and Southeastern Hanford site

4. Conclusions and Recommendations

The intent of the post-ROD field investigation was to address the principal study questions developed in SGW-56993 presented in the following bullets.

- PSQ 1a: Does the EAA (approximately 1 ha [3 ac]), as defined in the 300 Area ROD/ROD Amendment (EPA and DOE, 2013), represent a region centered on higher concentration of uranium in the vadose zone and PRZ?
- PSQ 1b: Does the EAA (approximately 1 ha [3 ac]), as defined in the 300 Area ROD/ROD Amendment (EPA and DOE, 2013), represent a region of higher leachability of uranium in the vadose zone and PRZ?
- PSQ 2a: What are the pre-treatment leachability characteristics of the vadose zone and PRZ in the refined location of the EAA?

Total uranium data gathered from the vadose zone and PRZ from the three boreholes was added to the data set used to generate a 3D model of uranium concentrations in soil which resulted in presentation of interpolated uranium concentrations in the PRZ. Soil samples from the three boreholes continue to be analyzed for uranium leachability characteristics, identified in Table 1, which will more precisely identify the region of higher leachability uranium. The leachability characteristics along with the comprehensive data set collected from the three boreholes will be presented in the Supplemental Post-ROD Field Investigation Summary report.

Analytes	Number of Samples	Conducting Lab
Uranium using semi-selective chemical extraction (<2 mm grain-size fractions)	6 (2 from each borehole, 1 each from VZ and PRZ, with mineral phase testing from at least 1 pair of samples from 1 borehole)	PNNL
Labile uranium using sodium bicarbonate/ carbonate extraction (<2 mm grain-size fractions)		
pH		
Grain size		
Predominant uranium-bearing mineral phase (<2 mm grain-size fractions)		
Field-textured sediment flow-through column test	2	PNNL
<2 mm grain-size fractions flow-through column test	2	

Table 1. Selected Testing Requirements for EAA Sediments

The post-ROD field investigation results provided new insights into the uranium concentration within the northern 300 Area. This new information, coupled with the groundwater plume data and

information, an area of highest potential uranium concentration is established for the Stage A EAA injection/infiltration treatment and projected Stage B location. This evaluation determined that Stage A should include the following locations. These locations were selected because they show elevated uranium levels above the natural background (Figures 3 and 4).

- southern portion of the North Process Trenches (316-5), where high uranium soil concentrations were observed near the former outfall of the 300-15 Process Sewer
- southwest corner of the North Process Pond (316-2), where Well 399-1-67 was recently drilled

The refined location along with the enhanced attenuation area identified in the 300 Area ROD/ROD Amendment (EPA and DOE, 2013) is presented in Figure 6.

Due to the EAA location adjustments, two additional locations within the Stage A EAA treatment area are selected for leach studies to support the three pre- and post-treatment leachability characterization locations agreed to during the remedy implementation SAP data quality objectives workshops.

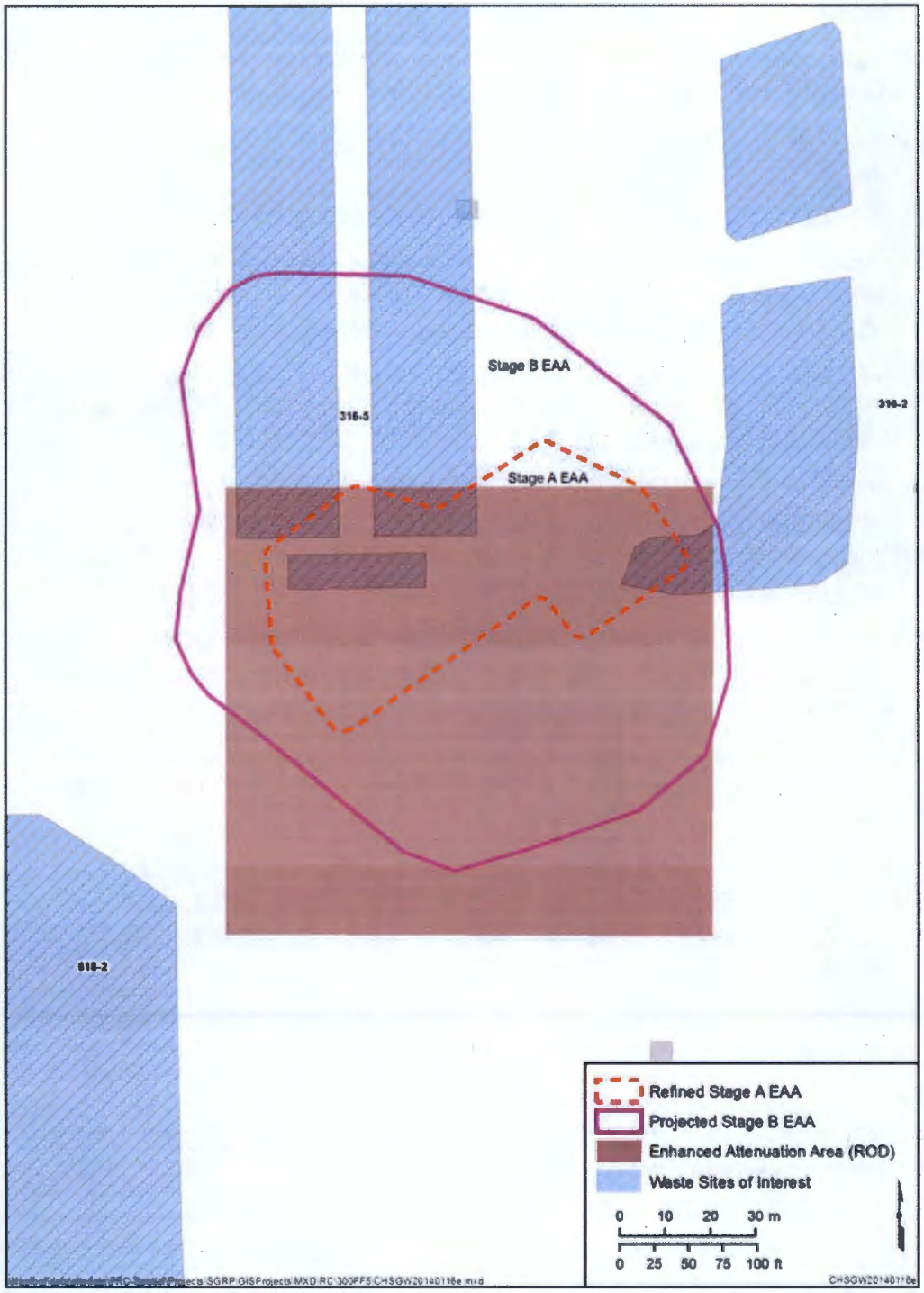

Figure 6. Refined Enhanced Attenuation Area

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