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LIST OF TERMS

COC	contaminant of concern
COTS	commercial off-the-shelf
EPA	U.S. Environmental Protection Agency
FH	Fluor Hanford, Inc.
GAC	granular activated carbon
gpm	gallons per minute
ICP/MS	inductively coupled plasma/mass spectrometry
IX	ion exchange
MCL	maximum contaminant level
OU	operable unit
P&ID	piping and instrumentation diagram
PNNL	Pacific Northwest National Laboratory
psi	pounds per square inch
SAI	sampling and analysis instruction

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METRIC CONVERSION CHART

Into Metric Units			Out of Metric Units		
If You Know	*Multiply By*	*To Get*	*If You Know*	*Multiply By*	*To Get*
Length			**Length**		
inches	25.4	millimeters	millimeters	0.039	inches
inches	2.54	centimeters	centimeters	0.394	inches
feet	0.305	meters	meters	3.281	feet
yards	0.914	meters	meters	1.094	yards
miles	1.609	kilometers	kilometers	0.621	miles
Area			**Area**		
sq. inches	6.452	sq. centimeters	sq. centimeters	0.155	sq. inches
sq. feet	0.093	sq. meters	sq. meters	10.76	sq. feet
sq. yards	0.836	sq. meters	sq. meters	1.196	sq. yards
sq. miles	2.6	sq. kilometers	sq. kilometers	0.4	sq. miles
acres	0.405	hectares	hectares	2.47	acres
Mass (weight)			**Mass (weight)**		
ounces	28.35	grams	grams	0.035	ounces
pounds	0.454	kilograms	kilograms	2.205	pounds
ton	0.907	metric ton	metric ton	1.102	ton
Volume			**Volume**		
teaspoons	5	milliliters	milliliters	0.033	fluid ounces
tablespoons	15	milliliters	liters	2.1	pints
fluid ounces	30	milliliters	liters	1.057	quarts
cups	0.24	liters	liters	0.264	gallons
pints	0.47	liters	cubic meters	35.315	cubic feet
quarts	0.95	liters	cubic meters	1.308	cubic yards
gallons	3.8	liters			
cubic feet	0.028	cubic meters			
cubic yards	0.765	cubic meters			
Temperature			**Temperature**		
Fahrenheit	subtract 32, then multiply by 5/9	Celsius	Celsius	multiply by 9/5, then add 32	Fahrenheit
Radioactivity			**Radioactivity**		
picocuries	37	millibecquerel	millibecquerels	0.027	picocuries

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1.0 INTRODUCTION

This document presents the plan for conducting a treatability test for removal of technetium-99 from groundwater extracted by the pump-and-treat system at the 200-ZP-1 Operable Unit (OU) at the Hanford Site. The testing will involve the use of an ion-exchange (IX) resin for selective removal of technetium-99. This test plan follows the U.S. Environmental Protection Agency's (EPA's) guidance and recommended outline for conducting treatability tests provided in *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (EPA 1988).

1.1 BACKGROUND INFORMATION

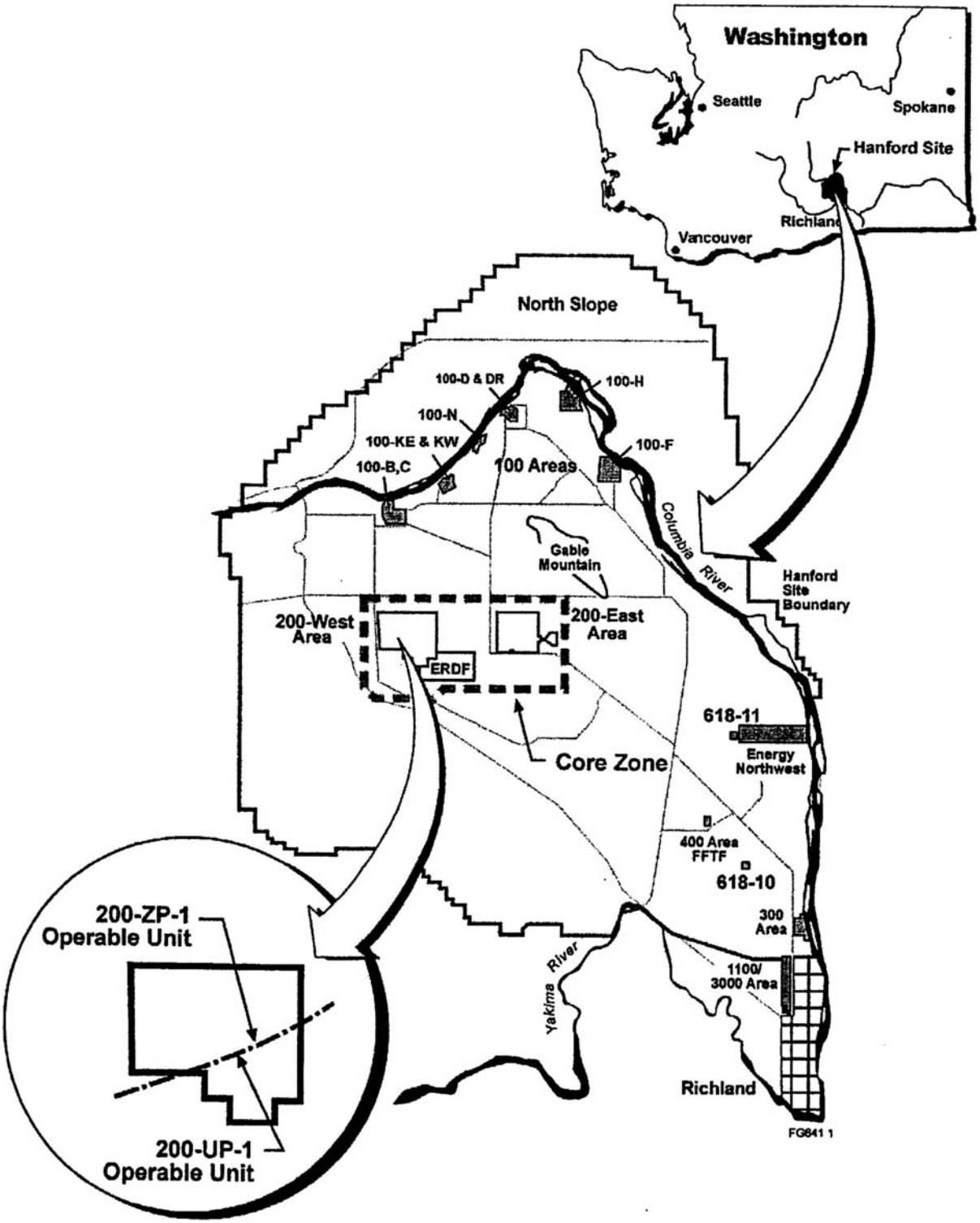
The 200-ZP-1 Groundwater OU is one of two groundwater OUs located within the 200 West groundwater aggregate areas of the Hanford Site. The location of the 200-ZP-1 OU is shown in Figure 1-1. A pump-and-treat system for the 200-ZP-1 OU was implemented in 1995 in accordance with the *Declaration of the Interim Record of Decision for the 200-ZP-1 Operable Unit* (EPA et al. 1995).

The primary contaminant of concern (COC) within the 200-ZP-1 OU is carbon tetrachloride. Additional COCs within the 200-ZP-1 OU include trichloroethene, technetium-99, nitrate, hexavalent chromium, uranium, and tritium. Carbon tetrachloride is removed from groundwater by the current pump-and-treat system, which processes water through evaporative treatment (air stripping) and polishes it by granular activated carbon (GAC) (DOE-RL 2006).

The pump-and-treat system located at the 200-ZP-1 OU was implemented in three phases. Between August 1994 and July 1996, one extraction well and one injection well were operated at a rate of 40 gallons per minute (gpm) during Phase I of operation. In August 1996, the Phase II of operations commenced in accordance with the interim Record of Decision for the 200-ZP-1 OU (EPA et al. 1995). During Phase II, a total of three extraction wells pumping at a combined rate of approximately 150 gpm were operated, along with the single injection well.

In August 1997, Phase III of operations expanded the system to bring on-line three additional extraction wells and four additional injection wells. In January 2001, one of the extraction wells in this configuration was converted to a monitoring well, with five extraction wells and five injections wells remaining in operation. In July 2005, four groundwater monitoring wells were converted to extraction wells to address a newly discovered lobe of the carbon tetrachloride plume (DOE-RL 2006). In October 2006, one additional monitoring well was converted to an extraction well, bringing the current operating total to 10 extraction wells and 5 injection wells, operating at a combined rate of approximately 300 gpm.

Figure 1-1. Location of 200 West Area and the 200-ZP-1 Operable Unit.



Groundwater from two of the newest extraction wells, 299-W15-44 and 299-W15-765 (located near the TX-TY Tank Farms and the 216-T-19 Crib), began to show increasing concentrations of technetium-99 almost immediately after groundwater extraction began. Historically, the 216-T-19 Crib received more than 120 million gal of process condensate from the 242-T evaporator between 1965 and 1980. Wastes from 221/224-T Plant were disposed to the crib between 1951 and 1956. One or more waste tanks in the TX-TY Tank Farms may have leaked, creating another potential source of contamination. Each of these waste streams contained significant amounts of technetium-99, presumably as high as 8,000 pCi/L based on an average concentration of technetium-99 detected in a monitoring well (299-W14-13) located near the 242-T evaporator.

The current groundwater treatment system does not remove technetium-99, and the increasing technetium-99 concentrations from wells 299-W15-44 and 299-W15-765 currently exceed the EPA's maximum contaminant level (MCL) for technetium-99 (900 pCi/L). The technetium-99 concentration of the mixed groundwater from all 10 of the current extraction wells is just greater than one-half of the MCL for technetium-99 but is increasing rapidly. If the water remains untreated for technetium-99, there is concern that the water reinjected into the aquifer could exceed EPA standards, technetium-99 could plate onto metal components of the current system, and/or technetium-99 could be adsorbed by the existing GAC canisters. These issues could potentially expose site employees and operators to elevated levels of beta radiation.

This test plan discusses the steps necessary to implement a treatability test to address the rising technetium-99 concentrations within the 200-ZP-1 OU, thereby ensuring that discharges to the groundwater meet EPA's standards and reduce potential employee exposure.

1.2 TECHNOLOGY SELECTION FOR TECHNETIUM-99 REMOVAL

Technetium-99 exists in groundwater at the Hanford Site in a fully oxidized form (Tc^{+7}), which exists as the pertechnetate anion (TcO_4^-). Pertechnetate is highly soluble, is kinetically inert in dilute aqueous solutions, and has a low charge and hydration energy. This anion cannot be removed using the existing treatment system at the Hanford Site, as it will not adequately be removed by adsorption or filtration by GAC. In order to prevent the discharge of unacceptable levels of technetium-99 to the groundwater after carbon tetrachloride treatment, several technologies were evaluated by Fluor Hanford, Inc. (FH) for selective removal of pertechnetate prior to carbon tetrachloride treatment.

1.2.1 Screening of Treatment Technologies

Several treatment technologies for selective treatment of technetium-99 in groundwater were reviewed, including the following: membrane separation, electrocoagulation, selective adsorbents, zero-valent iron, and IX. The review compared (1) the technologies' selectivity for technetium-99, (2) whether the technology was commercially available, and (3) the relative cost. Of the technologies evaluated, only IX was highly selective for technetium-99 and is commercially available. In addition, IX has a relatively low cost of implementation compared to the other technologies evaluated. Therefore, IX was selected for further evaluation and use in this treatability test.

The IX resins tend to indiscriminately absorb most anions, including nitrate, sulfate, bicarbonate, and chloride. Therefore, a nonselective resin would be ineffective at adsorbing technetium-99, as high concentrations of these other anions are also present in groundwater at the 200-ZP-1 OU. However, strong-base, anion-specific resins have been shown to be effective in selectively removing pertechnetate. Through research funded by the U.S. Department of Energy, newly developed resins have been shown to concentrate technetium-99 in the presence of competing anions at concentrations 4 to 6 orders of magnitude higher than technetium-99 concentrations in the groundwater. The resin selected for this treatability test is commercially available from Purolite® under the designation of "A530E" as a macroporous, strong-base, anion-exchange resin for the selective removal of perchlorate and pertechnetate oxy anions. The subsection below discusses the properties that make this the preferred resin for the treatability test and summarizes the proposed testing process.

1.2.2 Ion Exchange Using Purolite A530 Resin

Purolite A530E is a specially designed, macroporous, strong-base anion resin that has been cross-linked with divinylbenzene, allowing the resin to selectively remove hydrophobic anions. The resin is recommended for removal of perchlorate and pertechnetate oxy anions, even in the presence of higher concentrations of competing anions (as described above). At the Hanford Site, elevated concentrations of nitrate and sulfate are present in the groundwater. The primary reason for choosing the Purolite A530E resin for this treatability test is the resin's selective nature to absorb technetium-99 in the presence of these anions.

The treatability test will be conducted at the well heads of extraction wells 299-W15-44 and 299-W15-765. The reason for conducting the treatability study at these two locations is to assess the resin's effectiveness for groundwater with both relatively high and low concentrations of technetium-99 and nitrates. Well 299-W15-765 contains groundwater with concentrations of technetium-99 (measured at 3,400 pCi/L in October 2006) and nitrate (previously measured in the range of 202 to 439 mg/L), while lower concentrations of technetium-99 (1,500 pCi/L measured in October 2006) and nitrate (previously measured in the range of 113 to 185 mg/L) are present at well 299-W15-44. Performing the treatability test with these two conditions will allow confirmation of vendor-supplied data for treatment bed volumes, which are highly dependent upon anion concentrations.

A small IX column will be installed at both of the well heads for evaluation. The columns will be sized to achieve 50% breakthrough in approximately 60 days. The data collected from the study will be used to evaluate the effectiveness of the Purolite A530E resin for selective removal of technetium-99 and to assess operational costs and design considerations for full-scale application.

Purolite® is a registered trademark of The Purolite Company, Bala Cynwood, Pennsylvania.

2.0 TEST OBJECTIVES

The objectives of the treatability test for the 200-ZP-1 OU are as follows:

- Verify that Purolite A530E resin adequately removes technetium-99 from Hanford Site groundwater and determine the site-specific Purolite A530E resin usage rate (i.e., verify other treatment studies and vendor-provided data indicating treatment of 55,000 bed volumes at a concentration of up to 10,000 pCi/L for low competing anion concentrations and 15,000 bed volumes for elevated anions).
- Verify that Purolite A530E IX resin is selective for technetium-99 and does not adsorb other contaminants (e.g., carbon tetrachloride) present in Hanford Site groundwater.
- Verify that competing anions present in high concentrations (e.g., nitrate, sulfate, chloride, and bicarbonate) do not adversely reduce the resin's efficiency to the point that the technology is no longer viable.
- Verify that the resin is not adversely impacted by scaling or precipitates due to groundwater geochemistry.
- Determine operational parameters (e.g., pressure drop through the resin bed over time, need for backwashing, formation of scale on test equipment materials, plating of pertechnetate on metal components, and breakthrough times) to allow full-scale design of an IX system for technetium-99 removal.

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3.0 TEST IMPLEMENTATION

Treatability testing of the IX resin will consist of both bench-scale and pilot-scale testing. The bench-scale testing will be performed using a surrogate for technetium-99 and a range of concentrations of anions to test the influence of competing anion concentration on the ability of the resin to remove technetium-99.

The pilot-scale treatability tests will be conducted onsite using groundwater from operating extraction wells. Technetium-99 is currently only present at levels of concern in two extraction wells (299-W15-44 and 299-W15-765) and is not expected to be of concern at the majority of the 200-ZP-1 extraction wells. Therefore, it is desirable to minimize the size and cost of a technetium-99 pre-treatment system by employing the system only at the impacted wells rather than treating the full combined and diluted technetium-99 concentration at the air-stripper influent. Even though the conveyance pipes from extraction wells 299-W15-44 and 299-W15-765 are routed independently to the treatment system building, the IX treatability test will be employed directly at the well heads (i.e., still ex situ). This decision was made to avoid possible space constraints within the treatment system building, to take advantage of better accessibility of existing piping at the well heads, and to minimize pressure differentials and potential impacts to the current treatment system.

The following sections describe the details of the treatability testing equipment, equipment operation during the test, data to be collected during the test, and procedures for sample collection/ analysis.

3.1 BENCH-SCALE TESTING

Bench-scale testing of the IX resin will be performed using a surrogate for technetium-99 (either rhenium in the perrhenate form [ReO4-] or perchlorate [ClO4-]). The characteristics of the resin will be examined as they pertain to the groundwater composition in wells 299-W15-44 and 299-W15-765. The resin is commercially made by Purolite (product name A530E), which was originally developed at Oak Ridge National Laboratory for technetium removal and is now marketed as a perchlorate removal resin. The bench-scale testing will determine the impact of varying concentrations of competing anions on technetium-99 loading. Currently, nitrate concentrations are rapidly climbing in well 299-W15-765, which may have future impact on a technetium-99 removal system design. Additionally, technetium-99 concentrations are rising in both of the extraction wells, and the impact of this on loading needs to be determined to accurately predict future system behavior or to port the design to future wells (should they begin to show increasing technetium-99 levels).

3.2 ONSITE PILOT-SCALE TREATABILITY TESTING

Two treatability test systems will be designed and built for treatment of water from wells 299-W15-765 and 299-W15-44. The systems will be able to process at least 10 gpm at existing concentrations of technetium-99 for approximately 60 days. The units will be intended to discern the real-world loading capacity of technetium-99 (in the presence of competing ions) associated with the existing flow from the groundwater wells. The systems will be designed to achieve 50% breakthrough in 60 days. Test systems will be manufactured with simplicity in mind using commercial off-the-shelf (COTS) material (i.e., polyvinyl chloride materials,

hand-valving, etc.). It is not intended that these systems provide long-term solutions, and they will be constructed as such; instead, the systems will be designed as short-term treatability systems to achieve rapid schedule and low-cost requirements using COTS material. Descriptions of the IX test columns and related equipment to be used for the tests at extraction wells 299-W15-765 and 299-W15-44 are provided in the following subsections.

3.2.1 Testing at Extraction Well 299-W15-765

Based on the expected water quality at well 299-W15-765, the resin manufacturer's testing data suggest that 50% breakthrough will occur after processing 20,000 resin bed volumes of groundwater. The column is designed to achieve 50% breakthrough in approximately 60 days.

It was determined that an IX test flow rate of 30 gpm from this well and a resin bed volume of 17.3 cubic feet would achieve the 50% breakthrough in the desired 60-day timeframe. These calculations are provided in Appendix A.

A 30-in.-diameter, fiberglass-reinforced plastic test vessel will be used. The vessel will have a length (i.e., height) of approximately 72 in. to accommodate the 17.3 cubic feet of resin, plus an additional 40% excess volume to allow for resin expansion.

Piping and instrumentation diagrams (P&IDs) have been prepared for the testing equipment (see Appendix B). The IX test vessel can be piped in at the well head as a parallel slipstream, as shown on the P&IDs in Appendix B. Alternatively, if the technetium-99 concentration is high enough that untreated bypass is to be avoided, then the IX test vessel can be piped directly in-line with the existing well head piping to have all extracted groundwater from this well flow through the IX resin. A particulate filter (either bag or cartridge type) will be installed upstream to help prevent clogging of the resin bed. A nominal 20-micron filter bag or cartridge (or smaller particle capture size) will be used in the filter, based on the resin manufacturer's recommendation.

3.2.2 Testing at Extraction Well 299-W15-44

Based on the expected water quality at well 299-W15-44, the resin manufacturer's testing data suggest that 50% breakthrough will occur after processing 71,000 resin bed volumes of groundwater. The recently observed flow capacity of extraction well 299-W15-44 is approximately 8 gpm. In addition, it is desired to perform the IX test at hydraulic flow conditions that are within the range of typical full-scale conditions.

At well 299-W15-44's current operating flow rate of 8 gpm, it was determined that a resin bed volume of 1.3 cubic feet would achieve the 50% breakthrough in the desired 60-day timeframe. A 10-in.-diameter, fiberglass-reinforced plastic test vessel will be used for the test column for well 299-W15-44. The vessel will have a length (i.e., height) of approximately 54 in. to accommodate the 1.3 cubic feet of resin, plus an additional 40% excess volume to allow for resin expansion. The test column would be designed to be capable of processing a flow rate of up to 10 gpm.

3.2.3 Piping, Valves, and Instrumentation

As identified in the P&IDs (Appendix B), adequate valves will be installed to control the flow rate through the test vessel. The valves can be installed in a manner to allow continued flow of groundwater from the well to the air-stripper treatment system in the event that the testing equipment needs to be isolated and repaired.

Insulation or heat tracing of the testing equipment and piping may be required to protect the system from extreme heat and cold conditions. During active groundwater pumping through the testing equipment, the water will act to moderate extreme temperatures. However, there would be special concern if the testing system was idle during periods when ambient temperature was below freezing due to possible pipe bursting. Necessary safeguards to protect against extreme temperatures or other potential causes of leaks will be considered if necessary and incorporated into the test system during final test system design.

Sample ports will be installed to allow for the collection of influent and effluent samples from the resin column. One pressure-indicating gauge and approximately three differential pressure gauges will be installed within the testing equipment to monitor system pressure and to help identify possible issues (e.g., plugging of the filter or the IX resin bed). A turbine flow meter and totalizer (or alternate type of meter that is rated over the flow range of 2 to 50 gpm) will be used, and the manufacturer's recommendation will be followed for the minimum distance of straight-run pipe into and out of the meter. A thermo well and temperature gauge will be installed at the influent of the test system to allow for temperature monitoring during the test.

Based on discussions with Purolite, it does not appear likely that the beads of IX resin would become clogged and require backflushing, especially because the testing is planned over a period of only 2 months. Therefore, no mechanism for backflushing the vessels is incorporated into the design.

If the technetium-99 concentration increases to such a degree that it is desirable to prevent untreated groundwater (i.e., post-breakthrough groundwater) from being pumped to the carbon tetrachloride air-stripper treatment system, then a secondary IX column can be added in series behind the primary test column. The secondary resin column can be used solely for technetium-99 containment and treatment purposes, and the effluent of the secondary column would not necessarily need to be analyzed at the same frequency as the primary test column.

3.3 TEST SYSTEM MONITORING AND OPERATION

Normal operation and maintenance procedures for the existing pump-and-treat system include daily examination of the groundwater extraction well field and piping. As part of this daily routine, the operator will examine the test systems and record relevant operational data during the testing period. Operational parameters to be recorded during the treatability test include pressure, temperature, and flow rate. An example test operation log form has been prepared for recording relevant data (see Appendix C).

The frequency of test system observation by an operator is expected to be daily throughout the duration of the test to identify potential leaks or malfunctioning equipment. An operation log form is anticipated to be completed daily for the first week of testing. If no significant potential concerns are identified during the first week of testing, it is anticipated that the frequency of completion of the operation log can then be reduced to three times per week for the remainder of the testing period. The frequency of data collection may need to be adjusted based upon conditions encountered during testing.

Operational parameters that will be evaluated during the course of the testing include pressure drop across the particle filter and across the IX resin bed. For the particle filter, the manufacturer's recommendations will be followed, but filter cartridges or bags should typically be replaced before the pressure drop across the filter exceeds 15 psi. For the IX column, the manufacturer's literature suggests that for the column size and flow rate to be used during this

test, the pressure drop should be slightly under 10 psi. If the pressure drop increases to above 20 psi, the manufacturer suggests that plugging of the resin is occurring and backflushing of the resin bed may be necessary.

3.4 SAMPLING AND ANALYSIS

A preliminary listing of the sampling locations, sample collection frequency, and parameters for laboratory analysis is provided in Table 3-1. This section will also refer to the sampling and analysis instruction (SAI), which is included as Appendix D. The SAI discusses sampling methods, containers, preservative, labeling, handling, holding times, etc. A laboratory of FH's preference will be used for sample analysis.

3.5 CRITERIA FOR TERMINATION OF TESTING

The IX treatability testing will continue until 50% breakthrough of technetium-99 has been measured at the effluent of the resin bed and the analytical result of a second sample confirms the breakthrough. The 50% breakthrough is defined as the point at which the effluent concentration equals one-half of the influent concentration:

$$C_{Eff} / C_{In} = 0.5$$

If for some reason 50% breakthrough is found to occur well in advance of the time expected (i.e., 20,000 bed volumes for well 299-W15-765 and 71,000 bed volumes for well 299-W15-44), then the test should be extended for the full 60 days. If 50% breakthrough does not occur by the end of 60 days, then the test duration should be extended until the 50% breakthrough is achieved.

Table 3-1. Preliminary Sampling Parameters and Frequency.

	Anions (EPA Method 300.0) [c]				Alkalinity (EPA Method 310.1)[c]	Technetium-99 (ICP/MS)[c,d]	Carbon Tetrachloride (SW-846 Method 8260B) [c]	pH (Water Quality Meter)
	Nitrate	Sulfate	Chloride	Phosphate				
Baseline								
299-W15-765	X	X	X	X	X	X	X	X[a]
299-W15-44	X	X	X	X	X	X	X	X[a]
299-W15-765								
Influent (two times per week)[b]	X					X		
Effluent (two times per week)[b]	X					X		
Influent (weekly)		X	X	X	X			X
Effluent (weekly)		X	X	X	X			X
299-W15-44								
Influent (two times per week)[b]	X					X		
Effluent (two times per week)[b]	X					X		
Influent (weekly)		X	X	X	X		X	X
Effluent (weekly)		X	X	X	X		X	X
A530E resin post-study samples[e]	X	X	X	X	X	X	X	

NOTE: PNNL will act as the primary laboratory for analyses.

[a] For baseline pH conditions, analysis should be performed both in the field using a dedicated water quality instrument and by an analytical laboratory using EPA Method 150.1.

[b] It is initially estimated that collection of samples two times per week will be adequate. Of these two samples, one sample can be analyzed using field screening on a 48-hour turnaround time for nitrate and technetium-99. If the effluent sample is detected with technetium-99, then the second samples collected during that week can be analyzed by field screening as well, holding times permitting. If technetium-99 is not detected in the effluent sample by field screening, only one of the samples collected each week should be run by the fixed laboratory (using a standard 45-day turnaround time) using the ICP/MS methods and EPA Method 300.0. Otherwise, both samples collected each week could be run by the fixed laboratory (using a standard 45-day turnaround time).

[c] All fixed laboratory analyses should be run using a standard 45-day turnaround time.

[d] Technetium-99 analysis for groundwater samples is conducted in accordance with Procedure PNNL-AGG-415, *Inductively Coupled Plasma Mass Spectrometric (ICP-MS) Analysis* (PNNL 1998).

[e] If premature breakthrough of the IX resin is found to occur during the test, it may be advisable to perform a post-test analysis of the resin to determine the mass adsorption of technetium-99, other competing anions, and possible fouling agents (e.g., carbon tetrachloride) in order to determine possible causes for the poor IX resin performance. Resin may also need to be sampled for waste designation purposes.

EPA = U.S. Environmental Protection Agency
ICP/MS = inductively coupled plasma/mass spectrometry
IX = ion exchange
PNNL = Pacific Northwest National Laboratory

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4.0 DATA ANALYSIS AND INTERPRETATION

4.1 ASSESSMENT OF DATA QUALITY

Data collected during the test (as described in Section 3.3) will be validated and evaluated as discussed in the SAI (Appendix D). Adequacy of the data will be evaluated in the treatability test report.

4.2 ASSESSMENT OF RESIN PERFORMANCE

If the data quality evaluation concludes that the testing data were of adequate quality, then an assessment of the effectiveness of the resin in removal of technetium-99 will be performed.

If premature breakthrough of the IX resin (relative to the expected number of bed volumes estimated by the resin supplier) is found to have occurred during testing, it may be advisable to perform laboratory analysis of the spent resin. This laboratory analysis of the spent test resin could be performed to determine the mass of technetium-99, other competing anions, and possible fouling agents (e.g., carbon tetrachloride) that were absorbed in order to determine possible causes for the poor IX resin performance. One reason that this post-test analysis may be helpful in determining whether competing anions or carbon tetrachloride caused premature exhaustion of the IX resin is that with the relatively high concentration of these other potentially competing parameters, it may be that there is a high degree of uncertainty in the adsorption rate onto the resin based solely on the influent and effluent concentrations. For example, if a nitrate inlet sample is measured by the laboratory to be 400 mg/L and the effluent to be 395 mg/L, the question remains if the resin actually absorbed 5 mg/L of nitrate, or rather that the 5 mg/L difference is simply a function of inherent laboratory accuracy.

If it is determined that it may be useful, Oak Ridge National Laboratory has developed a method by which the spent column may be “stripped,” and an average of the accumulated concentration of technetium-99 within the resin measured. This data would be useful for future disposal of spent media.

4.3 EQUIPMENT EVALUATION AT END OF TESTING

To evaluate whether there is concern with scaling (i.e., the formation of precipitate) in the IX resin, the pressure data recorded during testing may be evaluated. A physical examination of the resin may also be conducted at the conclusion of testing to examine for the presence of scale or whether the resin beads have become cemented together.

Inspection of the IX column will be performed to assess radioactivity and to determine if the use of metal within a technetium-99 environment becomes significantly radioactive.

4.4 DESIGN AND IMPLEMENTATION OF A FULL-SCALE REMEDY

After the test results are analyzed, and if the test was successful, a decision may be made to proceed with full-scale application. Design considerations for a full-scale system may include the following:

- Location of the full-scale treatment system(s) at the well head versus at the carbon tetrachloride treatment plant

- Construction of mobile versus fixed-base treatment systems
- The need to provide for backflushing of resin beds
- Methods for disposal of spent IX media.

Following submittal of the treatability test summary report, a test plan will be developed for full-scale operations, and test procedures will be developed to implement the plan. The test procedures document will serve as the operations and maintenance manual for full-scale operations.

5.0 HEALTH AND SAFETY

All field operations will be performed in accordance with FH's, or its approved subcontractor's, health and safety plan (or equivalent) and the requirements of the most recent Waste Management Project radiological control procedures (or equivalent). Where necessary, a work-planning package will include a job hazard analysis and/or site-specific health and safety plan, as well as applicable radiological work permits, when appropriate.

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6.0 RESIDUALS MANAGEMENT

The nature of pertechnetate is such that it would be difficult to handle the regeneration effluent. Therefore, it is Purolite's recommendation that the used resin be disposed rather than regenerated. The spent IX column will be tested to determine its chemical and radiological characteristics. The spent column should be turned over to FH's Waste Management group for waste designation and disposal.

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7.0 REFERENCES

DOE-RL, 2006, *Remedial Investigation Report for 200-ZP-1 Groundwater Operable Unit*, DOE/RL-2006-24, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

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APPENDIX A

ION-EXCHANGE VESSEL SIZING CALCULATIONS

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TABLE A-1
ION EXCHANGE VESSEL SIZING CALCULATIONS FOR TEST AT EXTRACTION WELL 299-W15-765
FLUOR HANFORD
RICHLAND, WASHINGTON

Extraction Well 299-W15-765

User Entered Values for the Calculations:

12,000	Treatment Bed Volumes (estimated by Purolite based on influent concentrations below)
<5,000	Tc-99 Concentration (pCi/L)
400	Nitrate (mg/L)
<50	Sulfate (mg/L)
11	Flow Rate (gpm)
2.5	Media Efficiency (1-5 gpm/cf) = 3.0 minutes empty bed contact time
40%	Percent Expansion for Backwashing (Recommended 40-60%)

1) Calculate Media Capacity

12,000 Bed Volumes x 7.48 gal/cf = **89,760 gal/cf**

2) Calculate Volume of Media

11 gpm x $\frac{1}{2.5 \text{ gpm/cf}}$ = **4.4 cf of media**

3) Calculate Time for Breakthrough

89,760 gal/cf x $\frac{1}{2.5 \text{ gpm/cf}}$ = **35,904 min**
598.4 hr
25 days

4) Calculate Column Dimensions

Note: Minimum resin depth = 30"
Therefore, minimum column height based on **40%** expansion = **3.5 ft**

Using an 8" Diameter Column

4.40 cf x 40% expansion = 6.16 cf

Height of column = $\frac{6.16 \text{ cf}}{0.349 \text{ sf}}$ = **17.6 ft**

Flux (8 to 12 gpm/sf typical design)
32 gpm/sf

Using a 10" Diameter Column

4.40 cf x 40% expansion = 6.16 cf

Height of column = $\frac{6.16 \text{ cf}}{0.545 \text{ sf}}$ = **11.3 ft**

20 gpm/sf

Using a 12" Diameter Column

4.40 cf x 40% expansion = 6.16 cf

Height of column = $\frac{6.16 \text{ cf}}{0.785 \text{ sf}}$ = **7.8 ft**

14 gpm/sf

Using a 14" Diameter Column (16" Sch. 80 PVC = 14.3" I.D.)

4.40 cf x 40% expansion = 6.16 cf

Height of column = $\frac{6.16 \text{ cf}}{1.115 \text{ sf}}$ = **5.5 ft**

10 gpm/sf

TABLE A-2
ION EXCHANGE VESSEL SIZING CALCULATIONS FOR TEST AT EXTRACTION WELL 299-W15-44
FLUOR HANFORD
RICHLAND, WASHINGTON

Extraction Well 299-W15-44

User Entered Values for the Calculations:

55,000	Treatment Bed Volumes (estimated by Purolite based on influent concentrations below)
<5,000	Tc-99 Concentration (pCi/L)
110	Nitrate (mg/L)
<50	Sulfate (mg/L)
8.5	Flow rate (gpm)
2.5	Media Efficiency (1-5 gpm/cf) = 3.0 minutes empty bed contact time
40%	Percent Expansion for Backwashing (Recommended 40-60%)

1) Calculate Media Capacity

55,000 Bed Volumes x 7.48 gal/cf = **411,400 gal/cf**

2) Calculate Volume of Media

8.5 gpm x $\frac{1}{2.5 \text{ gpm/cf}}$ = **3.4 cf of media**

3) Calculate Time for Breakthrough

411,400 gal/cf x $\frac{1}{2.5 \text{ gpm/cf}}$ = **164,560 min**
2743 hr
114 days

4) Calculate Column Dimensions

Note: Minimum resin depth = 30"
Therefore, minimum column height based on **40%** expansion = **3.5 ft**

Using an 8" Diameter Column

3.40 cf x 40% expansion = 4.76 cf

Height of column = $\frac{4.76 \text{ cf}}{0.349 \text{ sf}}$ = **13.6 ft**

Flux (8 to 12 gpm/sf typical design)
24 gpm/sf

Using a 10" Diameter Column

3.40 cf x 40% expansion = 4.76 cf

Height of column = $\frac{4.76 \text{ cf}}{0.545 \text{ sf}}$ = **8.7 ft**

16 gpm/sf

Using a 12" Diameter Column

3.40 cf x 40% expansion = 4.76 cf

Height of column = $\frac{4.76 \text{ cf}}{0.785 \text{ sf}}$ = **6.1 ft**

11 gpm/sf

Using a 14" Diameter Column (16" Sch. 80 PVC = 14.3" I.D.)

3.40 cf x 40% expansion = 4.76 cf

Height of column = $\frac{4.76 \text{ cf}}{1.115 \text{ sf}}$ = **4.3 ft**

8 gpm/sf

APPENDIX B

ION-EXCHANGE TREATABILITY TEST -- PIPING AND INSTRUMENTATION DIAGRAMS

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Figure B-1. Piping and Instrumentation Diagram for Well 299-W15-765.

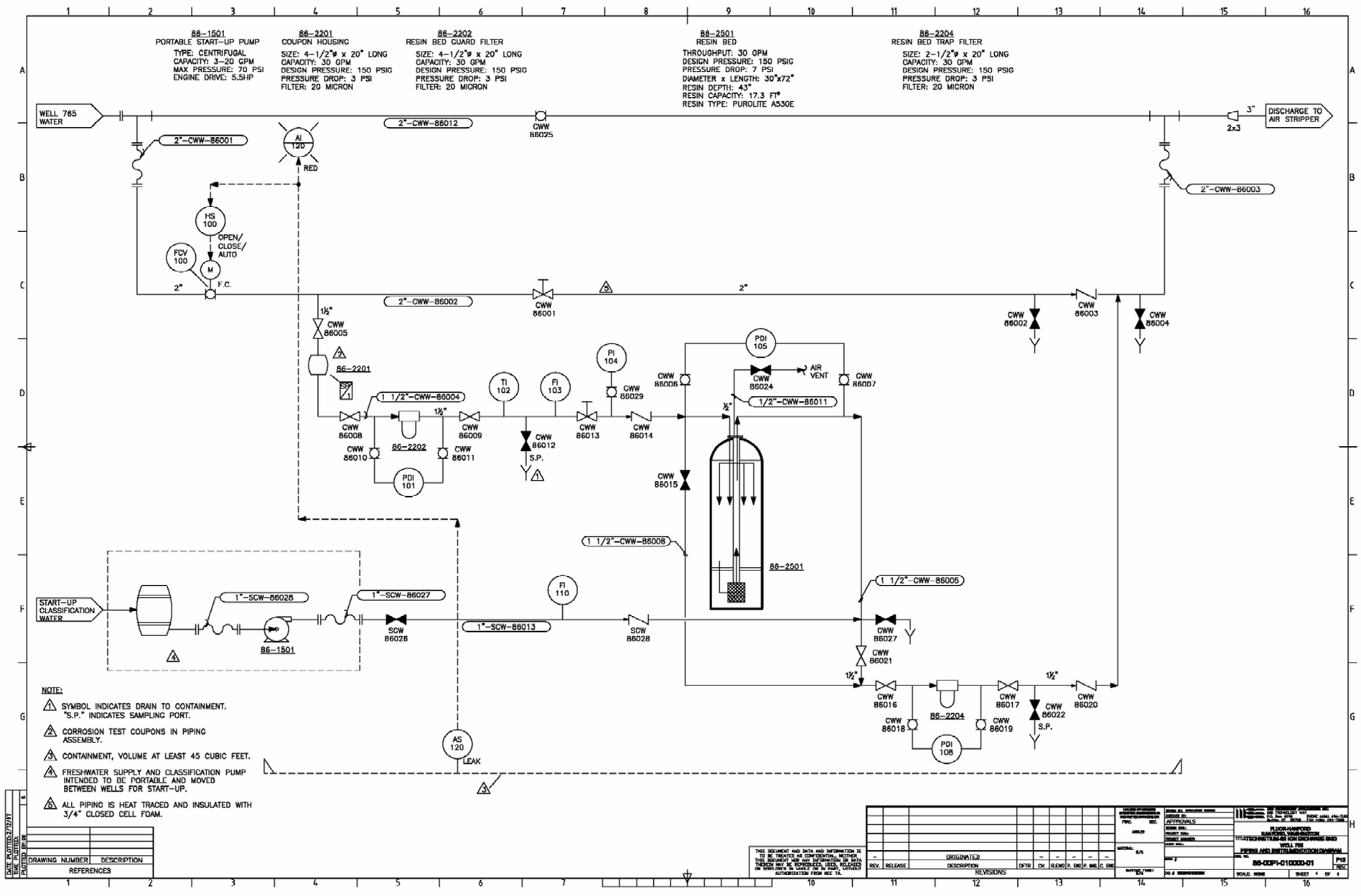
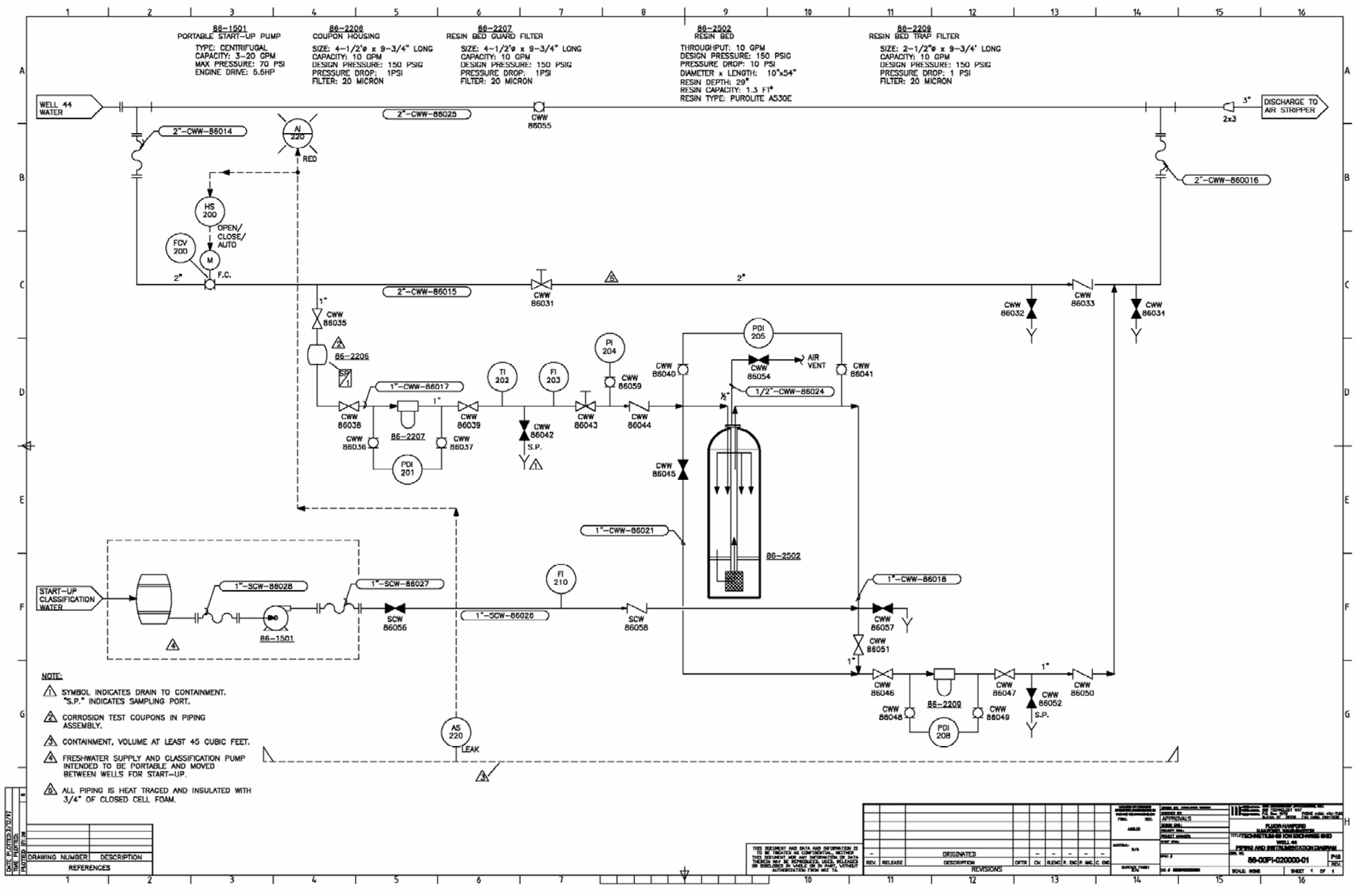


Figure B-2. Piping and Instrumentation Diagram for Well 299-W15-44.



APPENDIX C

TREATABILITY TEST OPERATION LOG

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TREATABILITY TEST OPERATION LOG
FLUOR HANFORD
RICHLAND, WASHINGTON

Operator Name: _____ **Date:** _____

299-W15-765

Time of Reading	
System Influent Pressure Gauge, PI-101 (psi)	
Inlet Temperature, TI-101 (°F)	
Particulate Filter Inlet Pressure Gauge, PI-102 (psi)	
Particulate Filter Outlet/Resin Column Inlet Pressure Gauge, PI-103 (psi)	
Treatment System Flow Rate (gpm)	
Totalized Discharge Volume (gal)	
Resin Column Outlet Pressure Gauge, PI-104 (psi)	
Water Leaks from system?	Yes / No

Water Quality Samples Collected Today? Yes / No
If yes, sample locations: _____
Samples were submitted for: _____
Immediate Analysis (48 hr TAT)
Hold for Analysis

Comments: _____

299-W15-44

Time of Reading	
System Influent Pressure Gauge, PI-101 (psi)	
Inlet Temperature, TI-101 (°F)	
Particulate Filter Inlet Pressure Gauge, PI-102 (psi)	
Particulate Filter Outlet/Resin Column Inlet Pressure Gauge, PI-103 (psi)	
Treatment System Flow Rate (gpm)	
Totalized Discharge Volume (gal)	
Resin Column Outlet Pressure Gauge, PI-104 (psi)	
Water Leaks from system?	Yes / No

Water Quality Samples Collected Today? Yes / No
If yes, sample locations: _____
Samples were submitted for: _____
Immediate Analysis (48 hr TAT)
Hold for Analysis

Comments: _____

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APPENDIX D

SAMPLING AND ANALYSIS INSTRUCTION TO SUPPORT TREATABILITY TESTING OF PUROLITE RESIN A530E FOR REMOVING TECHNETIUM-99 FROM 200-ZP-1 GROUNDWATER

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APPENDIX D

SAMPLING AND ANALYSIS INSTRUCTION TO SUPPORT TREATABILITY TESTING OF PUROLITE RESIN A530E FOR REMOVING TECHNETIUM-99 FROM 200-ZP-1 GROUNDWATER

D1.0 INTRODUCTION

This sampling and analysis instruction (SAI) was prepared to support treatability testing of the Purolite® A530E resin for removing technetium-99 from groundwater at the 200-ZP-1 Operable Unit (OU). The current 200-ZP-1 groundwater treatment system does not remove technetium-99, and the increasing technetium-99 concentrations from wells 299-W15-44 and 299-W15-765 currently exceed the U.S. Environmental Protection Agency's (EPA's) maximum contaminant level (MCL) for technetium-99 (900 pCi/L). The technetium-99 concentration of the mixed groundwater from all 10 of the current extraction wells is just greater than one-half of the MCL for technetium-99 but is increasing rapidly. If the water continues to remain untreated for technetium-99, there is a concern that the water reinjected into the aquifer could exceed EPA standards, technetium-99 could plate onto metal components of the current system, and/or technetium-99 could be adsorbed by the existing granular activated carbon canisters. These issues could potentially expose site employees and operators to elevated levels of beta radiation.

This SAI presents details on the sampling and analyses that will be performed to support this treatability testing.

D1.1 CONTAMINANTS OF CONCERN

The contaminants of concern (COCs) related to this study include technetium-99, carbon tetrachloride, nitrate, sulfate, chloride, phosphate. Other parameters of interest for testing include alkalinity and pH.

D1.2 SAMPLING AND ANALYSES TO SUPPORT TREATABILITY TESTING

Groundwater samples shall be collected from the influent and effluent of treatability test filters placed in line with the extraction water from wells 299-W15-44 and 299-W15-765. The samples shall be collected at the frequency and analyzed for the parameters that are specified in Table 3-1 in the main text of the treatability test plan. The purpose of this sampling is to evaluate the effectiveness of the Purolite A530E resin at removing technetium-99 from 200-ZP-1 groundwater and the affect that various anions (e.g., nitrate), alkalinity, and carbon tetrachloride have on the performance of the resin.

A post-study sample of the A530E resin may also be collected and analyzed for the parameters specified in Table 3-1 (see main text of treatability test plan) if premature breakthrough of the ion-exchange (IX) resin occurs during the test. It may be advisable to perform a post-test analysis of the resin to determine the mass adsorption of technetium-99 and the presence of other

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competing anions or possible fouling agents (e.g., carbon tetrachloride) in order to determine possible causes for the poor IX resin performance.

D2.0 QUALITY ASSURANCE PROJECT PLAN

This section identifies the individuals or organizations participating in the project and discusses specific roles and responsibilities. The quality objectives for measurement data and the special training requirements for staff performing the work are also documented.

D2.1 PROJECT MANAGEMENT

The following subsections address the basic areas of project management and will ensure that the project has a defined goal, the participants understand the goal and the approach to be used, and the planned outputs have been appropriately documented.

D2.1.1 Project/Task Organization

Fluor Hanford, Inc. (FH), or its approved subcontractor, will be responsible for collecting, packaging, and shipping groundwater samples to the laboratory. FH will select a laboratory to perform the analyses; the laboratory selected must conform to Hanford Site laboratory procedures (or their equivalent), as approved by the U.S. Department of Energy, Richland Operations Office; EPA; and the Washington State Department of Ecology. FH is responsible for managing all interfaces among subcontractors involved in executing the work described in the treatability test plan and SAI.

D2.1.2 Quality Objectives and Criteria for Measurement Data

The detection limits and the precision and accuracy requirements for each analysis to be performed are summarized Table D2-1.

Procedures from either FH or its approved subcontractor will be used. This applies to all FH or approved subcontractor procedures identified in this SAI.

D2.1.3 Special Training Requirements and Certification

Training or certification requirements for sampling personnel shall be in accordance with the requirements specified in the *Hanford Analytical Services Quality Assurance Requirements Document* (HASQARD), Vol. 1, “Administrative Requirements” (DOE-RL 1998).

Field personnel will typically have completed the following training before starting work:

- Occupational Safety and Health Administration 40-Hour Hazardous Waste Worker Training
- 8-Hour Hazardous Waste Worker Refresher Training (as required)
- Radiation Worker II Training
- Hanford General Employee Training.

Table D2-1. Analytical Performance Requirements for Contaminant of Concern Analysis. (3 sheets)

Type of COC	COCs	Survey or Analytical Method[a]	CRDL[b] µg/L	Precision Required	Accuracy Required
Nonradiological COCs					
Volatile organics	Carbon tetrachloride	SW-846, Method 8260[b]	3	[c]	[c]
Non-metals	Nitrate	300.0[d]	75	[c]	[c]
	Sulfate	300.0[d]	500	[c]	[c]
	Chloride	300.0[d]	200	[c]	[c]
	Phosphorus and phosphate (must digest to include organo-phosphates)	365.1, 365.2, or 365.3	50	[c]	[c]
	Alkalinity	310.1	5,000	[c]	[c]
Radiological COCs					
Beta emitters	Tc-99	Liquid scintillation	20 pCi/L	±30%	70-130%

[a] Analytical method selection is based on available methods by laboratories currently contracted to the Hanford Site. Equivalent methods may be substituted in future sampling and analysis instructions or other documents. Four-digit methods are from EPA's SW-846 (EPA 1997); other methods referenced to source.
[b] Typical CRDL or minimum detectable concentrations are based on current Hanford laboratory contracts. Detection limits in subsequent documents may differ depending on method selection and the contract laboratory. Units are "µg/L" for nonradiological COCs and "pCi/L" for radiological COCs (unless otherwise noted).
[c] Precision and accuracy in accordance with cited procedure.
[d] Method from *Standard Methods for Examination of Water and Wastewater* (Eaton et al. 1995).
COC = contaminant of concern
CRDL = contract-required detection limit

D2.1.4 Documentation and Records

Field sampling and laboratory analytical documentation will be in accordance with FH internal work processes and requirements (or flow-down requirements to FH subcontractors).

D2.2 DATA/MEASUREMENT ACQUISITION

The following subsections present the requirements for sampling methods, sample handling and custody, analytical methods, and field and laboratory quality control (QC). The requirements for instrument calibration and maintenance, supply inspections, and data management are also addressed.

D2.2.1 Sampling Methods Requirements

The sampling procedures to be implemented in the field should be in accordance with those outlined in FH internal work processes and requirements (or flow-down requirements to FH subcontractors).

D2.2.2 Sampling Identification

A sample and data-tracking database will be used to track the samples from the point of collection through the laboratory analysis process. The Hanford Environmental Information System (HEIS) database is the repository for laboratory analytical results. The HEIS sample numbers will be issued to the sampling organization for this project. The HEIS numbers are to be carried through the laboratory data-tracking system.

D2.2.3 Sample Handling, Shipping, and Custody Requirements

All sample handling, shipping, and custody requirements will be in accordance with FH internal work processes and requirements (or flow-down requirements to FH subcontractors).

D2.2.4 Analytical Methods Requirements

Analytical parameters and methods are listed in Table D2-1. Laboratory-specific standard operating procedures for analytical methods are described in FH internal work processes and requirements (or flow-down requirements to FH subcontractors).

D2.2.5 Quality Control Requirements

The QC procedures described in FH internal work processes and requirements (or flow-down requirements to FH subcontractors) will be followed in the field and laboratory to ensure that reliable data are obtained. When performing this field sampling effort, care should be taken to prevent the cross-contamination of sampling equipment, sample bottles, and other equipment that could compromise sample integrity.

Table D2-2 lists the field QC requirements for sampling. If only disposable equipment is used or equipment is dedicated to a particular well, then an equipment rinsate blank is not required. If volatile organic compound samples are not collected, then a field transfer blank is not required.

Laboratory QC sample requirements are specified in FH internal work processes and requirements (or flow-down requirements to FH subcontractors).

Table D2-2 Field Quality Control Requirements.

Sample Type	Frequency	Purpose
Duplicate	5% (1 sample in 20)	To check the precision of the laboratory analyses.
Equipment rinsate	One per 10 well trips	To check the effectiveness of the decontamination process.
Field transfer blank	One per day when volatile organics are sampled	To check for contamination during transport.

D2.2.6 Instrument/Equipment Testing, Inspection, and Maintenance Requirements

All onsite environmental instruments shall be tested, inspected, and maintained in accordance with FH internal work processes and requirements (or flow-down requirements to FH subcontractors). The results from all testing, inspection, and maintenance activities shall be recorded in a bound logbook in accordance with procedures outlined in FH internal work processes and requirements (or flow-down requirements to FH subcontractors).

D2.2.7 Instrument Calibration and Frequency

All onsite environmental instruments shall be calibrated in accordance with FH internal work processes and requirements (or flow-down requirements to FH subcontractors). The results from all instrument calibration activities shall be recorded in a bound logbook in accordance with procedures outlined in FH internal work processes and requirements (or flow-down requirements to FH subcontractors). Tags will be attached to all field screening and onsite analytical instruments, noting the date when the instrument was last calibrated and the calibration expiration date.

D2.2.8 Inspection/Acceptance Requirements for Supplies and Consumables

All subject activities shall meet requirements of FH internal work processes and requirements (or flow-down requirements to FH subcontractors). The lot number from the manufacturer-certified, pre-cleaned sample containers shall be recorded in the sampler's logbook.

D2.2.9 Data Management

Data resulting from the implementation of this SAI will be stored in the HEIS database. All reports and supporting analytical data packages will be subject to final technical review by qualified reviewers before submittal to the regulatory agencies or inclusion in reports or technical memoranda. Electronic data access, when appropriate, shall be through computerized databases (e.g., HEIS). Where electronic data are not available, hard copies will be provided in accordance with Section 9.6 of the *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement) (Ecology et. al. 2003).

D2.2.10 Sample Preservation, Containers, and Holding Times

Sample preservation, container, and holding time requirements will be prepared for specific sample events as specified on the sampling authorization forms and chain-of-custody forms in accordance with the requirements specified in FH internal work processes and requirements (or flow-down requirements to FH subcontractors) and the specific analytical method.

D2.2.11 Field Documentation

Field documentation shall be kept in accordance with FH internal work processes and requirements (or flow-down requirements to FH subcontractors).

D2.3 ASSESSMENT/OVERSIGHT

D2.3.1 Assessments and Response Action

The FH Compliance and Quality Programs group may conduct random surveillance and assessments to verify compliance with the requirements outlined in this SAI, project work packages, the project quality management plan, procedures, and regulatory requirements.

Deficiencies identified during these assessments shall be reported to the FH 200-ZP-1 Task Lead. When appropriate, corrective actions will be taken by the Task Lead in accordance with FH internal work processes and requirements (or flow-down requirements to FH subcontractors) to minimize recurrence.

D2.3.2 Reports to Management

Management shall be made aware of all deficiencies identified by self-assessments. Identified deficiencies shall be reported to the FH 200 Area Task Lead.

D2.4 DATA REVIEW, VERIFICATION, VALIDATION, AND USABILITY REQUIREMENTS

D2.4.1 Data Verification and Usability Methods

Data review and verification are performed by the laboratory to confirm that sampling and chain-of-custody documentation are complete. Documentation includes tying sample numbers to specific sampling location, reviewing sample collection, indicating the preparation and analysis dates to assess meeting required holding times, and reviewing QC to determine whether analyses met the data quality requirements specified in this SAI.

All data verification and usability assessments shall be performed in accordance with FH internal work processes and requirements (or flow-down requirements to FH subcontractors).

D2.4.2 Data Validation

Data validation is performed either by an independent third party not involved in sampling, analysis, or assessment; or by the Waste Disposal/Groundwater Remediation Projects; or by Pacific Northwest National Laboratory using FH internal work processes and requirements (or flow-down requirements to FH subcontractors). Five percent of the results will undergo validation.

D2.4.3 Data Quality Assessment

Data quality may be assessed based on trends of concentration in wells over time. As appropriate, the data quality assessment may include the statistical approaches identified in *Washington Administrative Code* (WAC) 173-340-720(4) for groundwater monitoring.

D3.0 FIELD SAMPLING PLAN

D3.1 SAMPLING OBJECTIVES

The objective of the field sampling plan is to clearly identify project sampling and analysis activities. The field sampling plan uses figures and tables whenever possible to identify sampling locations, the total number of samples to be collected, sampling procedures to be implemented, analyses to be performed, and sample bottle requirements.

D3.2 SAMPLING LOCATIONS AND FREQUENCY

Groundwater samples shall be collected from the influent and effluent of treatability test filters placed in line with the extraction water from wells 299-W15-44 and 299-W15-765. These samples shall be collected at the frequency and analyzed for the parameters specified in Table 3-1 in the main text of this treatability test plan. The purpose of this sampling is to evaluate the effectiveness of the A530E resin at removing technetium-99 from 200-ZP-1 groundwater and the affects that various anions (e.g., nitrate), alkalinity, and carbon tetrachloride have on the performance of the resin.

A post-study sample of the A530E resin may also be collected and analyzed for the parameters specified in Table 3-1 (main text of this treatability test plan) if premature breakthrough of the IX resin is occurs during the test. It may be advisable to perform a post-test analysis of the resin to determine the mass adsorption of technetium-99 and the presence of other competing anions or possible fouling agents (e.g., carbon tetrachloride) in order to determine possible causes for the poor IX resin performance.

D3.3 WELL DRILLING PROCEDURES

Well drilling will be performed in accordance with FH internal work processes and requirements (or flow-down requirements to FH subcontractors) and WAC 173-160, “Minimum Standards for Construction and Maintenance of Wells.”

D3.4 SAMPLING PROCEDURES

The procedures to be implemented in the field for sampling and purgewater management should be in accordance with those outlined in FH internal work processes and requirements (or flow-down requirements to FH subcontractors).

D3.5 SAMPLE MANAGEMENT

Sample and data management activities will be performed in accordance with FH internal work processes and requirements (or flow-down requirements to FH subcontractors).

Sample preservation, container, and holding-time requirements will be specified on sampling authorization forms and chain-of-custody forms in accordance with the requirements specified in FH internal work processes and requirements (or flow-down requirements to FH subcontractors) and the specific analytical method.

D3.5.1 Sample Custody

All samples obtained during the project will be controlled from the point of origin to the analytical laboratory, as required by FH internal work processes and requirements (or flow-down requirements to FH subcontractors).

D3.5.2 Sample Packaging and Shipping

Sample custody during laboratory analysis will be addressed in the applicable laboratory's standard operating procedures.

D3.5.3 Field Documentation

Sample preservation and container details will be addressed on the sampling authorization form and chain-of-custody form in accordance with the requirements specified in FH internal work processes and requirements (or flow-down requirements to FH subcontractors); and analytical method requirements.

D3.6 MANAGEMENT OF WASTE

FH internal work processes and requirements (or flow-down requirements to FH subcontractors) will be used to address the management of waste.

Waste generated by sampling activities will be managed in accordance with an established waste management plan and the requirements of FH internal work processes and requirements (or flow-down requirements to FH subcontractors). Investigation-derived wasted from these sampling activities will be handled as *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* waste. Unused samples and associated laboratory waste for the analysis will be dispositioned in accordance with the laboratory contract and agreements for return to the Hanford Site. In accordance with 40 *Code of Federal Regulations* (CFR) 300.440, Remedial Project Manager approval is required before returning unused samples or waste from offsite laboratories.

A waste management plan (DOE-RL 2000) has been prepared for the 200-ZP-1 OU. The waste management plan establishes the requirements for management and disposal of waste generated from groundwater wells that are used to monitor the 200-ZP-1 OU, as required by the *Declaration of the Interim Record of Decision for the 200-ZP-1 Operable Unit* (EPA et. al. 1995).

D4.0 HEALTH AND SAFETY

All field operations will be performed in accordance with FH's, or its approved subcontractor's, health and safety plan (or equivalent) and the requirements of the most recent Waste Management Project radiological control procedures (or equivalent). Where necessary, a work planning package will include a job hazard analysis and/or site-specific health and safety plan, and applicable radiological work permits, as appropriate. The job hazard analysis has been and may continue to be used for ongoing sampling activities that are already underway. However, with more extensive work performed (e.g., drilling), a site-specific plan is currently being written.

D5.0 REFERENCES

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