SGW-47614
Revision 0

Field Test Instruction 100-NR-2 Operable Unit Design Optimization Study for Sequestration of SR-90 Saturated Zone Apatite Permeable Reactive Barrier Extension

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

CH2MHILL
Plateau Remediation Company

P.O. Box 1600
Richland, Washington 99352

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Terms

ACS	American Chemical Society
bgs	below ground surface
CHPRC	CH2M HILL Plateau Remediation Company
DO	dissolved oxygen
DOS	*Design Optimization Study*
FW	formula weight
IC	ion chromatography
ICP	inductively coupled plasma
kPa	kilopascal
NIST	National Institute of Standards and Technology
ORP	oxidation-reduction potential
PRB	permeable reactive barrier
PVC	polyvinyl chloride
RL	Richland Operations Office
SpC	specific conductance

1 Introduction

1.1 Purpose

The objective of this field test instruction is to provide technical guidance for aqueous injection emplacement of an extension apatite permeable reactive barrier (PRB) for the sequestration of strontium-90 (Sr-90) using a high concentration amendment formulation. These field activities will be conducted according to the guidelines established in DOE/RL-2010-29, *100-NR-2 Design Optimization Study*, hereafter referred to as the DOS. The DOS supports the *Federal Facility Agreement Consent Order* (EPA et al., 1989), Milestone M-16-06-01, and "Complete Construction of a Permeable Reactive Barrier at 100-N." Injections of apatite precursor chemicals will occur at an equal distance intervals on each end of the existing PRB to extend the PRB from the existing 91 m (300 ft) to at least 274 m (900 ft).

1.2 Objectives

The objectives of this injection of apatite precursor chemicals are to:

1. Further refine application of the high-concentration calcium-citrate-phosphate solution over a larger scale
2. Test the effectiveness of high-concentration calcium-citrate-phosphate injection in previously untested sediment to compare with areas that received sequential injections of low- then high-concentration calcium-citrate-phosphate injections
3. Test the new well design installed under DOE/RL-2009-32 to evaluate the adequacy of injection solution delivery to the target zone
4. Test and optimize operation of the new injection system to verify that the system can deliver the designed injection solution flow volume at multiple well locations
5. Determine whether the new well design and injection system can complete chemical injections at various river stages, thereby eliminating the need for injections during specific river levels
6. Determine whether PRB can achieve up to 90 percent reduction in Sr-90 flux to the river
7. Evaluate the impact the high-concentration calcium-citrate-phosphate solution has on the release of Sr-90 and other metals from previously untreated sediments to groundwater

1.3 Summary

Field testing at the 100-N Area Apatite Treatability Test Site, as depicted on Figure 1, shows that the barrier is categorized by two general hydrologic conceptual models based on overall well capacity and contrast between the Hanford and Ringold hydraulic conductivities. The upstream portion of the original barrier, shown on Figure 1, is characterized by relatively low overall well specific capacity. This is estimated from well development data and a lower contrast in hydraulic conductivity between the Hanford formation and Ringold Formations. Comparison of test results from these two locations indicate that permeability contrast between the Hanford formation and Ringold Formation is significantly less over the upstream one-third of the barrier. The estimated hydraulic conductivity for the Hanford formation and Ringold Formation over the upstream portion of the barrier based on observations during emplacement of the existing 91 m (300 ft) PRB is approximately 12 and 10 m/day (39 and 32 ft/day), respectively (PNNL-17429). However, these estimates should be used as a rough guideline only, as significant variability in hydraulic conductivity is likely to be observed in the barrier extension wells, particularly those in the Ringold formation.

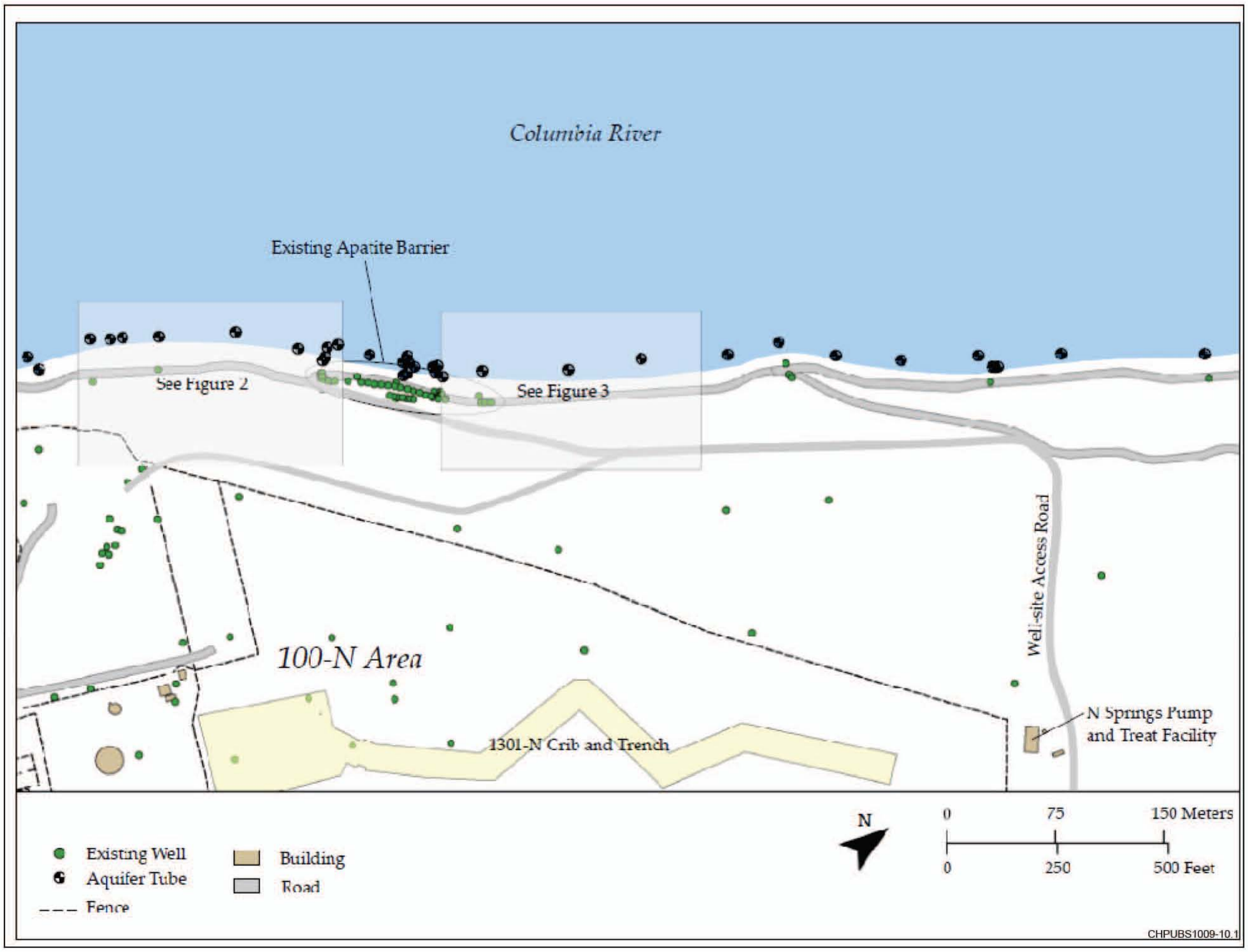


Figure 1. Injection Well Location Area Relative to Existing PRB

The downstream portion of the original barrier, shown on Figure 1, is characterized by generally higher well specific capacity and a larger hydraulic conductivity contrast between the Hanford formation and Ringold Formation. Hydraulic conductivity rates for the Hanford formation and Ringold Formation over the downstream portion of the barrier were estimated at 29 and 9 m/day (95 and 29 ft/day), respectively (with the Hanford formation hydraulic conductivity being greater in the downstream portion than the upstream portion). Once again, it should be noted that the actual conductivities may vary significantly, and the values state above should only be used as a rough initial estimates. Optimum apatite emplacement has been shown to occur when injections targeting the Hanford formation and the Ringold Formation are performed separately.

The remainder of this test instruction provides details for conducting these formation-targeted injections.

2 Injection Specification

Injection wells were constructed using 15.24 cm (6-in.) diameter polyvinyl chloride (PVC) screen and casing, and are completed at a depth of approximately 4.6 m (15 ft) below ground surface (bgs) for the shallow multi-purpose wells (Hanford formation) and 7.6 m (25 ft) bgs for the deep multi-purpose wells (Ringold Formation).Well locations upstream and downstream of the existing barrier are shown on Figures 2 and 3, respectively.

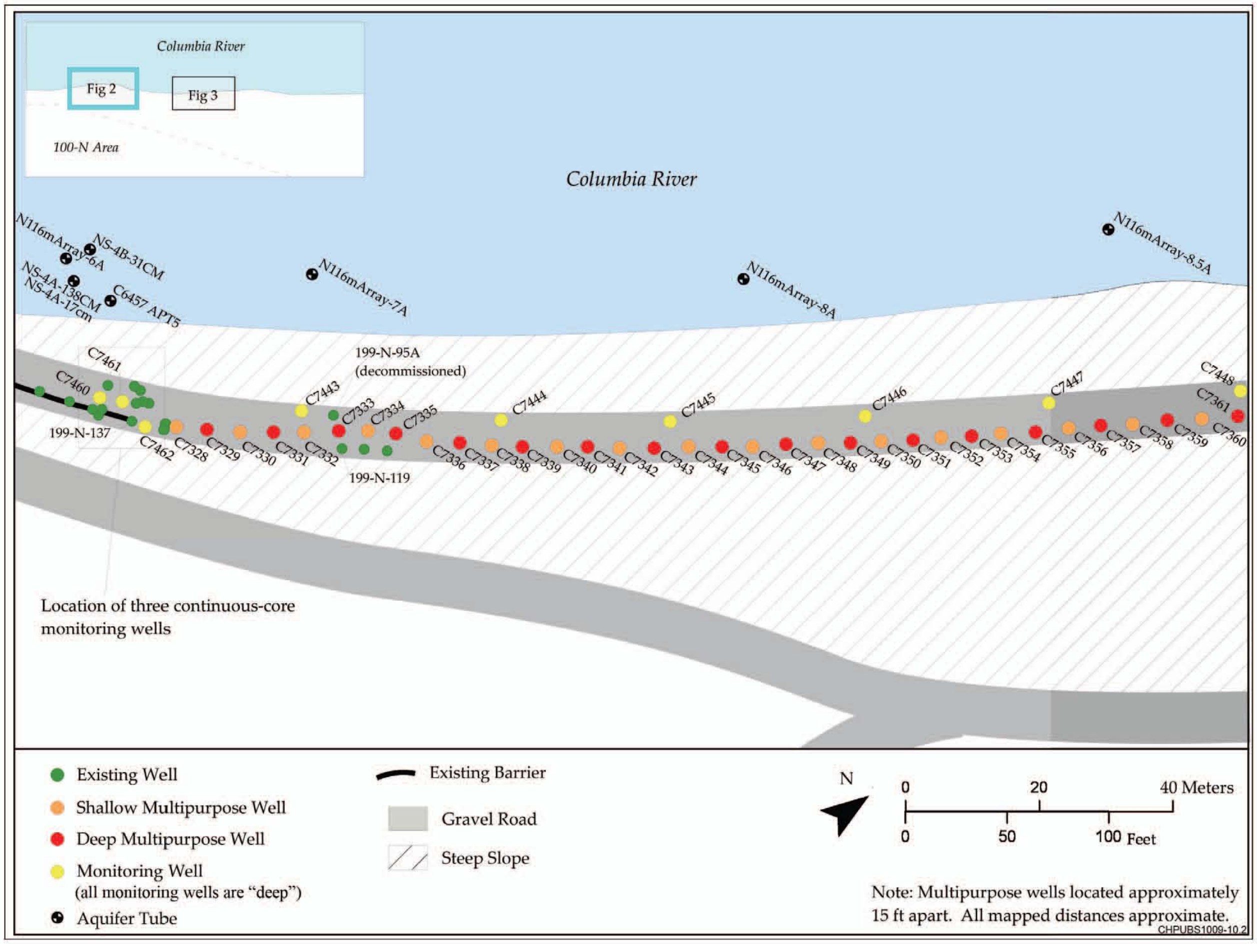
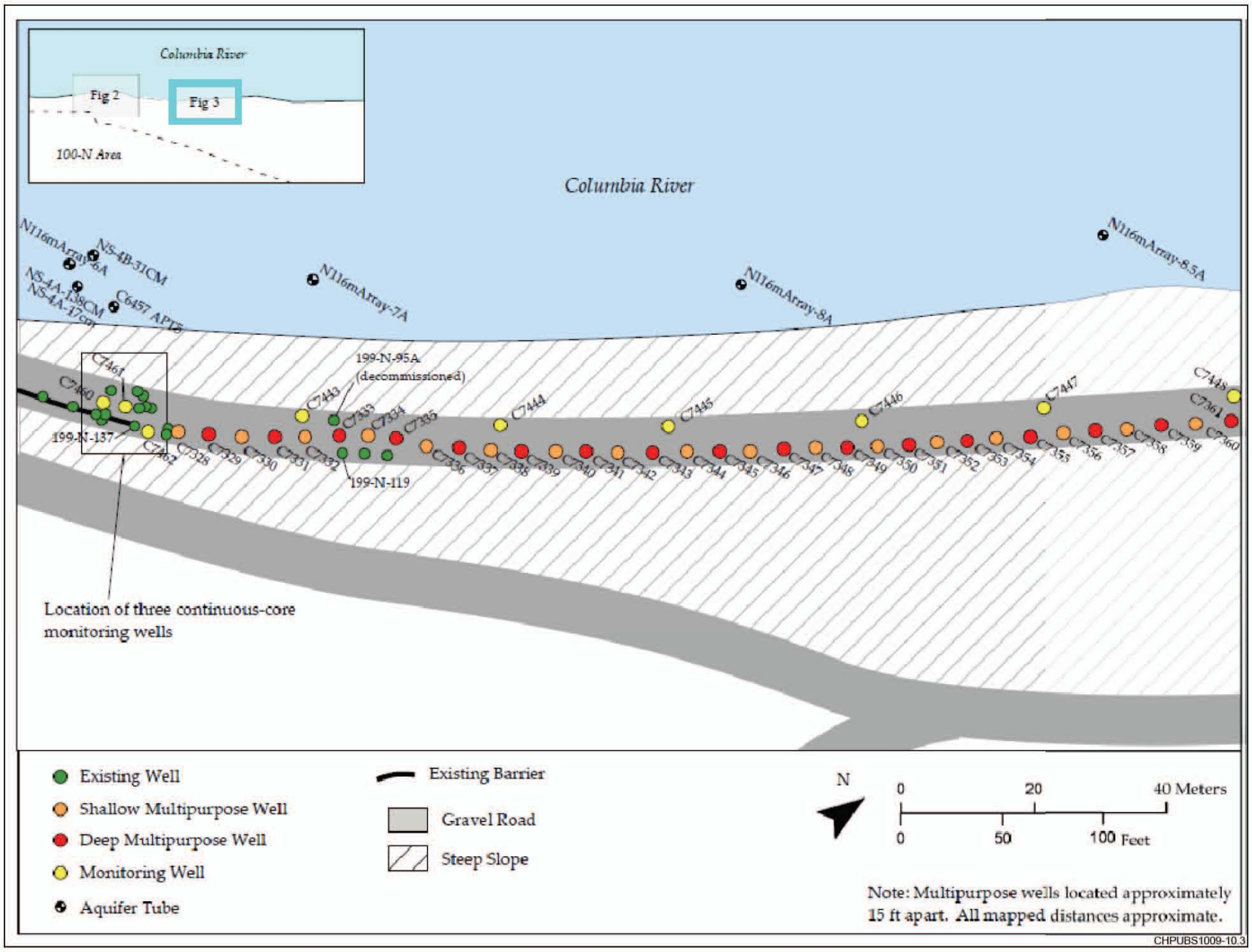


Figure 2. Well Locations Upstream of Existing Permeable Reactive Barrier

Based on chemical arrival responses observed during previous barrier treatment operations and injection design analysis conducted to date, an injection volume between 227,000 liters (L) (60,000 gallons) and 454,000 L (120,000 gallons) of high concentration calcium-citrate-phosphate solution will be used for each well. This volume of amendment is calculated to provide sufficient volume to meet injection design criteria at the targeted radial extent of 6.1 m (20 ft).

Based on injection well hydraulic performance observed during previous barrier treatment operations, an initial injection rate of 76 L/minute (20 gallons per minute [gpm]) is specified for treatment of the Hanford formation- and Ringold Formation-specific multipurpose wells both upstream and downstream of the existing barrier. At these flow rates, injection of the full 454,250 L (120,000-gallon) maximum target volume at each multi-purpose well will take approximately 100 hours to complete. The injection rate can be adjusted (within the range of 76 to 190 L/minute [20 to 50 gpm]) based on hydraulic performance observed during injection . Because of the time required to inject each well, optimizing injection rates to the upper end of the injection range is desired to minimize the amount of time required to emplace the apatite solution over the full barrier length. Optimization of injection rates will be done in the field under the direction of the project lead.

During treatment at each well location, aqueous monitoring will be performed in adjacent injection wells and available monitoring wells, as specified below. In addition, pressure buildup during treatment will be monitored as described in Section 6. The wellhead shall be routinely evaluated for any evidence that a seal has been compromised.



Note: Multipurpose wells located approximately 15 ft apart. All mapped distances approximate.

Figure 3. Well Locations Downstream of Existing Permeable Reactive Barrier

Based on the chemical delivery specification provided below, 16 tanker trucks will be required to deliver the required chemicals for each 12-well set of injections (8 truckloads of Ca-citrate solution, 8 truckloads of phosphate solution). These concentrated solutions will be subjected to a 12:1 dilution onsite to achieve the desired injection concentration. This dilution will be done using adjustable frequency drive pumps to adjust the ratio of makeup water and feed solutions. Injection will continue until the entire target injection volume has been injected into each of the targeted test wells.

3 Chemical Formulation

Solution composition, chemical delivery, and solubility concerns are described in the sections below.

3.1 Solution Composition

Laboratory and field treatability tests conducted to date found the most favorable formulation for field-scale deployment of high concentration calcium-citrate-phosphate formulation is a solution consisting of 3.6 mM calcium, 9 mM citrate, and 40 mM phosphate. This is the specified solution to be used for the work covered under these test instructions. The formula for the high concentration apatite injection solution used in previous treatability tests is as follows:

- 9.0 mM trisodium citrate $[\mathrm{HOC(COONa)(CH_2COONa)2*2H_2O}]$ formula weight (FW) 294.1 g/mol:

  - Also called sodium citrate dihydrate, American Chemical Society (ACS) registry 6132-04-3.
  - Granular form is more soluble than powdered.
  - Reagent grade (quality) or equivalent for the citrate: United States Pharmacopeia/Food Chemicals Codex (USP/FCC). (Lower grades contain up to 5 ppm heavy metals.)
- 3.6 mM calcium chloride, [$CaCl_2$], FW 110.98 g/mol:
  - Reagent grade (quality) or equivalent: certified ACS, ACS registry 10043-52-4. (Lower grades can contain 20 ppm lead.)
- 32.4 mM disodium hydrogenphosphate [Na_2HPO_4], FW 141.96 g/mol:
  - Also called disodium phosphate, anhydrous.
  - Reagent grade (quality) or equivalent: certified ACS, ACS registry 7558-79-4. (Lower grades can contain extra sodium hydroxide [NaOH], which may affect pH and ionic strength.)
- 5.6 mM sodium dihydrogenphosphate [NaH_2PO_4], FW 119.98 g/mol:
  - Also called monosodium phosphate, anhydrous.
  - Reagent grade or equivalent: certified ACS grade, ACS registry 7558-80-7. (Lower grades can contain 8 ppm arsenic and 10 ppm heavy metals.)
- 2.0 mM diammonium hydrogenphosphate [$(NH_4)_2HPO_4$], FW 132.1 g/mol:
  - Also called diammonium phosphate.
  - Granular is more soluble than powdered.
  - Reagent grade (quality) or equivalent: certified ACS, ACS registry 7783-28-0.

Other chemical formulations and mixing methods may be used as long as the resulting injection concentrations are the same.

3.2 Chemical Delivery Specification

The chemicals will be delivered to the site at the following concentrations:

- Mix 1: (Calcium citrate solution)
  - 108 mM calcium citrate
  - 323 mM sodium hydroxide
  - 48.3 mM calcium chloride
- Mix 2: (Phosphate solution)
  - 490 mM phosphoric acid
  - 844.8 mM sodium hydroxide
  - 48 mM ammonium hydroxide

Each chemical feed solution (Mix 1 and Mix 2) will be diluted 12:1 with Columbia River water prior to injection to achieve the injection concentrations specified in Section 3.1.

Because injection of the calcium-citrate-phosphate solution relies on microbial degradation of the citrate for apatite formation to occur, make-up water for these solutions should not contain residual chlorine or any other form of bactericide. Onsite make-up water will be pumped from the Columbia River immediately upstream of the injection site to achieve specified concentrations for injection.

Two new injection skids have been designed and are being constructed to inject an aqueous solution of chemical and river water through injection wells to expand the existing 100-NR-2 apatite barrier. The skids are designed to inject up to six wells simultaneously. A photo of the injection skid is shown on Figure 4 and a schematic of the injection skid is shown on Figure 5.

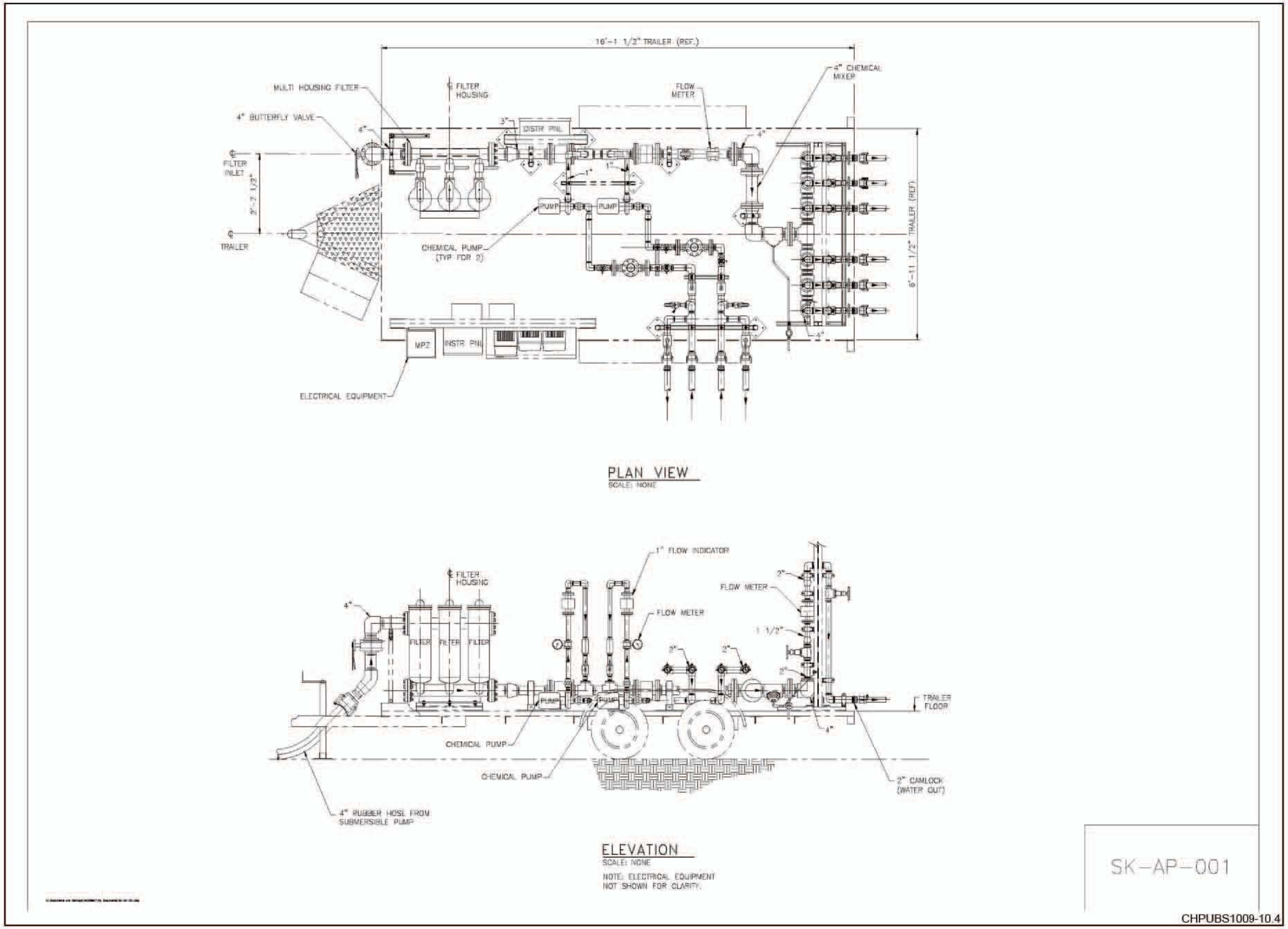
Following completion of an injection cycle, the injection systems will be flushed with river water and the systems will be prepared for storage. The injection systems will be stored in a protected area, under cover between injection cycles.

Figure 4. Injection Skid

3.3 Solution Stability Concerns

The chemical solutions have potential solubility limit issues. Minimum delivery volumes of 37,854 L (10,000-gallon) shall be maintained to avoid chemical precipitation during transport.

Another stability concern is the potential for biodegradation of the citrate solution during transport. Potential mitigation approaches may include, but are not limited to, steam cleaning or some other sterilization approach for dissolving/mixing equipment, using deionized make-up water and chilling the solution for transport. The approach should follow industry standards for citrate solution transport that ensures the citrate solution will not be appreciably degraded during transport or during the time required to inject the solution



CHPUBS1009-10.4

Figure 5. Generalized Schematic of Injection System

4 Timing and Order of Treatment

The initial barrier expansion milestone is to expand the PRB by a minimum of 91.4 m (300 ft) on either side of the existing apatite barrier, resulting in a total barrier length of 274 m (900 ft). Additional wells adjacent to the proposed extent of the barrier expansion may be added to utilize full capacity of the injection skids. Barrier emplacement will be accomplished via the use of the two injection skids that can each inject six wells simultaneously. One skid will be placed on either end of the existing barrier so that barrier expansion on both the upstream and downstream ends of the existing barrier can be conducted simultaneously. Barrier expansion to 91.4 m (approximately 30 ft) on either side of the existing barrier will occur in multiple phases. Each of the treatment phases, which will be separated by a minimum 2-week reaction period, will consist of treatment at 6 to 12 locations per injection cycle, depending on whether one or two injection skids are used (Table 1).

Table 1. Treatment Schedule and Operational Parameters

Injection Number	Wells Treated	Anticipated Flow Rate to Each Well (gal/min)	Maximum Injection Volume per Well (gallons)
1	C7294, C7298, C7302, C7306, C7310, C7314	20-50	120,000
2	C7329, C7333, C7337, C7341, C7345, C7349	20-50	120,000
3	C7296, C7300, C7304, C7308, C7312, C7316	20-50	120,000
4	C7331, C7335, C7339, C7343, C7347, C7351	20-50	120,000
5	C7293, C7297, C7301, C7305, C7309, C7313	20-50	120,000
6	C7328, C7332, C7336, C7340, C7344, C7348	20-50	120,000
7	C7295, C7299, C7303, C7307, C7311, C7315	20-50	120,000
8	C7330, C7334, C7338, C7342, C7346, C7350	20-50	120,000

Minimize impacts from adjacent injection operations, as listed in Table 1, along with relative injection flow rates, and injection volume for each treatment. The order of treatment was developed so that all Ringold Formation-targeted wells (deep multipurpose wells) will be treated together and all Hanford formation-targeted wells (shallow multipurpose wells) will be treated together. Injections 1 through 4 target the Ringold Formation and will begin in fall 2010 after finalization of the DOS. Injections 5 through 8 target the Hanford formation and are anticipated to begin in spring 2011.

5 Materials and Equipment

The minimum requirements for equipment and materials and additional sampling related materials and equipment are listed below:

- Power supply

- Portable light plants (for night work)
- Pumps
- Water and chemical supply lines
- Chemical mixing/dilution/control system (skid)
- Distribution manifolds
- Dilution water source (river water)
- Purge water containment tank(s)
- Apatite solution delivered to site in tanker trucks
- Monitoring equipment (QED MicroPurge® or equivalent for well monitoring, Myron L Company Ultrameter or equivalent for skid monitoring)
- Calibration standards
- Pressure gauges
- Flow meters
- Sampling equipment (pumps, tubing, sampling manifold[s], bottles, data sheets, flow through cell for measuring pH, oxidation-reduction potential [ORP], dissolved oxygen [DO] and specific conductance [SpC], sampling forms, etc.)
- Coolers and refrigerators for sample storage
- Personnel safety equipment and materials (gloves, eye wear, eye wash, etc.)
- Portable sanitation facility
- Conex or other storage location
- Project support trailer(s)

6 Test Monitoring

The chemical delivery system (skid) will be monitored on a regular basis to ensure appropriate flow rates are maintained. Measurements of system readings (flow rate and pressure) will be made on an hourly basis and field parameters (SpC, temperature, pH, and ORP) will be measured every 4 hours. An example record sheet is included as Appendix A.

- Samples will be collected from the injection stream at the start of the test (once rates have stabilized) and approximately every 12 hours thereafter (five samples total over the injection duration).
  - Aqueous samples will be collected and submitted for ion chromatography (IC) for anions and inductively coupled plasma(ICP) for major cations analysis.

® QED MicroPurge is a registered product of QED Environmental Systems, Inc., Ann Arbor, Michigan.

Formation pressure will be maintained at a level where the packers remain sealed in the wells. Minimal pressure differential should exist between the injection well and the injection skid, so pressure monitoring will be conducted at the skid. Routine visual inspection of the injection well surface seal will be performed throughout the test to minimize solution ponding if the well seal is compromised.

Determination of apatite solution arrival/distribution during the injection test will be done through aqueous monitoring.

- All specified monitoring wells (as indicated in Table 2) will be monitored for field parameters (SpC, temperature, pH, ORP, and DO) once every 4 hours. Aquifer tube sampling is not required during this phase of testing.
- Aqueous samples will be collected from specified monitoring wells and aquifer tubes immediately prior to injection start and once prior to the end of the injection (within approximately 6 hours). One sample of river water will be collected prior to mixing with the chemicals.
  - Aqueous samples will be collected and submitted for IC (anions) and ICP (major cations) analysis.

Primary performance monitoring will be through the collection of aqueous samples from monitoring wells and aquifer tubes as outlined in Table 2.

- Field parameters (SpC, temperature, pH, ORP, and DO) will be measured for each sample collected.
- Samples will be collected from specified wells/aquifer tubes daily for the first week, every other day for the second week, and then weekly for the first month following injection.
- Aqueous samples will be submitted for the following analysis:
  - IC – anions
  - ICP – major cations/metals
  - Gross Beta
  - Sr-90
- Depending on results of performance monitoring, core samples may be collected to determine apatite content and Sr-90 concentrations in sediment.

Table 2. Sampling Locations for Injection Arrival and Post-Injection Performance Monitoring

Injection Number	Wells Treated	Monitoring Wells and Aquifer Tubes
1	C7294, C7298, C7302, C7306, C7310, C7314 (Ringold)	C7439, C7440, C7441, N116mArray-1A, N116mArray-2A, N116mArray-3A
2	C7329, C7333, C7337, C7341, C7345, C7349 (Ringold)	C7443, C7444, C7445, C7446 N116mArray-7A and/or APT-5, N116mArray-8A
3	C7296, C7300, C7304, C7308, C7312, C7316 (Ringold)	C7439, C7440, C7441, 199-N-96A, N116mArray-1A, N116mArray-2A

Table 2. Sampling Locations for Injection Arrival and Post-Injection Performance Monitoring

Injection Number	Wells Treated	Monitoring Wells and Aquifer Tubes
4	C7331, C7335, C7339, C7343, C7347, C7351 (Ringold)	C7443, C7444, C7445, C7446, N116mArray-7A (or APT-5), N116mArray-8A
5	C7293, C7297, C7301, C7305, C7309, C7313 (Hanford)	C7439, C7440, C7441, N116mArray-1A, N116mArray-2A
6	C7328, C7332, C7336, C7340, C7344, C7348 (Hanford)	C7443, C7444, C7445, N116mArray-7A or APT-5, N116mArray-8A
7	C7295, C7299, C7303, C7307, C7311, C7315 (Hanford)	C7439, C7440, C7441, C6136, N116mArray-1A, N116mArray-2A
8	C7330, C7334, C7338, C7342, C7346, C7350 (Hanford)	C7443, C7444, C7445, C7446, N116mArray-7A, (or APT-5) N116mArray-8A

7 Sampling and Analysis

Water will be pumped from the wells at a rate of 1 to 4 L/minute, using a peristaltic pump. Based on previous experience at the site, approximately 2 to 5 minutes of purge time should be sufficient time for parameter stabilization.

Once field parameters (pH, SpC, DO, ORP, and temperature) have stabilized, indicating that representative groundwater samples can be collected, parameter values will be recorded manually on data sheets provided by the 100-N science technical lead. The original data sheets shall be provided to the 100-N science technical lead to be placed into a bound (CH2M HILL Plateau Remediation Company [CHPRC] controlled) field notebook maintained for the Apatite PRB project at the earliest convenience following the test. Calibration of field probes is performed quarterly by CHPRC instrument technicians. Only equipment that is in calibration shall be used to perform field measurements. Field personnel using this equipment will check the equipment against National Institute of Standards and Technology (NIST) traceable standards once a day at a minimum. Results of these checks must be documented on forms provided by and returned to the 100-N science technical lead. A final performance check is done at the conclusion of the injection test sampling. Calibration solutions will be provided by CHPRC. All field instrument check form originals shall also be returned to the 100-N science technical lead for placement in the project field notebook.

The sample stream will be discharged to a purge water containment tank(s). Routine purge water collection and disposal will be required throughout these planned field activities. Sample collection and analysis for the planned apatite injections will be performed according to the guidelines set forth in Tables 3 through 5. This test instruction applies to samples collected during injection and for the first month following treatment.

During injections, aquifer tubes (as outlined in Table 2) will be sampled and monitored for Sr-90, calcium, and phosphate, as described in Tables 3 and 5. Aquifer tube samples are collected in accordance with the requirements for the Apatite PRB project sampling protocols.

If groundwater and aquifer tube monitoring data show that the flux of Sr-90 has been significantly reduced as a result of apatite barrier expansion, continuous soil cores will be collected. If no considerable reduction in Sr-90 flux is seen, soil cores will not be collected. Collection of soil cores will be performed by collecting continuous core samples from ground surface to total depth (7.6 m [25 ft]). These cores will be submitted for analysis of parameters as outlined in Table 3. Sediment-core depths for Sr-90 and phosphate analysis will be at 0.6 to 0.9 m (2 to 3 ft) intervals to provide a vertical profile in each core of these constituents. A minimum of one random sample per core will be evaluated by electron microbe for identification of mineral phase apatite.

Table 3. Design Optimization Study Sampling Requirements

Parameter	Media/ Matrix	Sampling Frequency	Volume/ Container	Preservation	Holding Time
Major Cations/Metals:					
Al, As, Ba, Ca, Co, Cr, Fe, K, Mg, Mn, Ni, Zn, P, Sr, Na, Sb	Water	See Table 4	250-mL poly bottle	Filtered (0.45 μm), HNO_3 to pH <2	6 months
Anions:					
F-, Cl-, SO42-	Water	See Table 4	120-mL poly bottle	Cool 4°C	28 days
PO43-, NO2-, NO3-	Water	See Table 4	120-mL poly bottle	Cool 4°C	48 hours
Sr-90	Water	See Table 4	1-L poly bottle	Filtered (0.45 μm), HNO3 to pH <2	60 days
Gross Beta	Water	See Table 4	500-mL poly bottle	Filtered (0.45 μm), HNO3 to pH <2	60 days
Field Parameters (pH, Specific Conductance, Dissolved Oxygen[a], Oxidation-Reduction Potential[a], Temperature)	Water	With every water sample, and as deemed necessary during injection, see Table 4	Field Measurement	Raw unfiltered water, tested immediately after withdrawal from well	N/A
Apatite	Sediment	[b]	1-L/liner	Cool	N/A
Sr-90 (Gross Beta)	Sediment	[b]	1-L/liner	Cool	N/A
Phosphate	Sediment	[b]	1-L/liner	Cool	N/A

a. Dissolved oxygen and ORP measured in monitoring wells only. Not required for measurements of injection stream.

b. Sediment core sampling contingent on barrier performance.

N/A = Not Applicable

Table 4. Sampling Locations and Frequencies

Sample Purpose	Sampling Locations	Approximate Sampling Frequency	Analytes
Pre-Injection Monitoring	Specified monitoring locations (see Table 2) and one river make-up water sample.	1 time immediately prior to injection.	Cations, anions, Sr-90, gross beta, field parameters.
Injection Monitoring	Injection stream.	Field parameters every 4 hours, aqueous samples every 12 hours.	Cations, anions, field parameters.
Injection Arrival Monitoring	Specified monitoring locations (see Table 2).	Field parameters every 4 hours, aqueous samples near end of injection.	Cations, anions, field parameters.
Performance Monitoring	Specified monitoring locations (see Table 2).	Daily for 1st week, every other day for 2nd week, 1 time per week for one month. Ongoing performance monitoring.	Cations, anions, gross beta, periodic splits for Sr-90, field parameters.

Table 5. Analytical Requirements

Parameter	Analysis Method	Detection Limit or (Range)	Accuracy Requirement (% Recovery)[a]	Precision Requirement (Relative Percent Difference)[a]	QC Requirements
Major Cations/Metals: Al, Fe, Mg, Ni, K, Ag, Na, Sb, Ba, Cd, Cr, Co, Cu, V, Zn, Ca, As, Pb, Mo, Sr	ICP, EPA Method 6010B (TAL) and 6010B (add-On) for As, Pb, Mo, Sr	1 mg/L 0.1 mg/L	80-120%	≤20%	Daily calibration; blanks and duplicates and matrix spikes at 5% level per batch of 20.
Anions: F-, Cl-, SO42-, PO43-, NO2-, NO3-	Ion Chromatography, EPA Method 300.0	1 mg/L	80-120%	≤20%	Daily calibration; blanks and duplicates at 5% level per batch of 20.
Sr-90	SRTOT_SEP_PRECIP_GPC	2 pCi/L	70-130%	≤20%	Daily calibration; blanks and duplicates at 5% level per batch of 20.
Gross Beta	BETA_GPC	4 pCi/L	70-130%	≤20%	Daily calibration.
pH	pH electrode	0.1 pH unit	[b]	[b]	User calibrate, follow manufacturer recommendations.

Table 5. Analytical Requirements

Parameter	Analysis Method	Detection Limit or (Range)	Accuracy Requirement (% Recovery)[a]	Precision Requirement (Relative Percent Difference)[a]	QC Requirements
Specific Conductance	Electrode	0.1 µS/cm	[b]	[b]	User calibrate, follow manufacturer recommendations.
Dissolved Oxygen	Membrane electrode	0.1 mg/L	[b]	[b]	User calibrate, follow manufacturer recommendations.
Oxidation-Reduction Potential	Electrode	±1 mV	[b]	[b]	User calibrate, follow manufacturer recommendations.
Temperature	Thermocouple	0.1°C	[b]	[b]	Factory calibration.

a. Accuracy criteria for associated batch matrix spike percent recoveries. Evaluation based on statistical control of laboratory control samples is also performed. Precision criteria for batch laboratory replicate matrix spike analyses or replicate sample analyses.

b. This method has no quantitative requirements beyond adherence to the field measurement methodology.

8 Data Management

All operational, monitoring, and field parameter probe field standards check data will be recorded manually on data sheets which will be provided by the 100-N science technical lead for distribution to CHPRC personnel. The original data sheets will be placed into a bound (CHPRC controlled) field notebook by the 100-N science technical lead at the earliest convenience following the test. All samples submitted to analytical laboratories will be accompanied by an appropriately filled out chain of custody form.

9 Health and Safety

All work performed on site will be conducted in accordance with the *Soil and Groundwater Remediation Project Site Specific Health and Safety Plan (HASP)* (Fluor Hanford, 2008) and any applicable task specific Job Safety Analysis (CHPRC developed documents). Gloves and eye protection are needed while handling chemicals and during sample collection. A portable eye wash station will be present on site during injections. Sampling vehicles and or equipment includes hand-held portable eyewashes. All waste sampling materials (tubing, gloves, wipes, used filters, etc.), including any materials used to clean up spills or drops of sample media/injection fluid will be absorbed on wipes or other absorbent material and disposed of as waste in accordance with DOE/RL-2000-41, *Interim Action Waste Management Plan for the 100-NR-2 Operable Unit.*

10 Residuals Management

All regulated waste generated during this injection activity, including sampling activities, will be managed in accordance with DOE/RL-2000-41, I*nterim Action Waste Management Plan for the*

100-NR-2 Operable Unit. Disposition of purge water and miscellaneous solid waste will be conducted in accordance with DOE/RL-2000-41.

Unused samples and associated laboratory waste for the analysis will be dispositioned in accordance with the laboratory contract and agreements for return to the project site. Pursuant to 40 CFR 300.440, "Procedures for Planning and Implementing Off-Site Response Actions," U.S. Department of Energy, Richland Operations Office (RL) project manager approval is required before returning unused samples or waste from offsite laboratories (as applicable).

11 Summary of Test Instructions

1. Collect pre-injection samples prior to chemical injection.
   a. Field parameters and aqueous samples
2. Begin chemical injection.
3. Measure field parameters on skid every hour, sample every 12 hours.
4. Measure field parameters in specified wells every 4 hours.
5. Collect aqueous samples from specified wells and aquifer tubes near end of injection.
6. Conduct post-injection performance monitoring (as specified in Table 4).

12 References

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Appendix A

Skid Monitoring Record Sheet

Appendix A. Skid Monitoring Record Sheet

Skid ID: ______________________________

Operator: ______________________________

		Skid Parameters		Field Parameters - Injection Solution			
Date	Time	Injection Flow Rate (gpm)	Pressure (psi)	Specific Conductance (µS/cm)	Temperature (°C)	pH	Oxidation- Reduction Potential (mV)

(a) Skid Parameters will be measured and recorded hourly.

(b) Field parameters will be measured and recorded once every 4 hours.