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Revision 0

Groundwater Monitoring Plan for Solid Waste Landfill

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

U.S. DEPARTMENT OF ENERGY Richland Operations Office

P.O. Box 550
Richland, Washington 99352

Approved for Public Release;
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Executive Summary

This document presents a revision to the Solid Waste Landfill (SWL) groundwater monitoring plan (PNNL-13014[1]) issued in 2000. This revised plan addresses the applicable groundwater monitoring requirements for landfills in WAC 173-350-500.[2] The U.S. Department of Energy, Richland Operations Office has undertaken revision of this groundwater monitoring plan to comply with the applicable requirements under WAC 173-350-500 and to ensure that the plan contains the most current Hanford groundwater monitoring information for SWL (changes to the monitoring network). This groundwater monitoring plan is the principal controlling document for conducting groundwater monitoring at SWL.

SWL, also known as the Central Landfill, is a non-operating, solid waste landfill in the 200-SW-1 Operable Unit (OU). The uppermost aquifer underlying SWL is part of the 200-PO-1 Groundwater OU. SWL is located adjacent to the Nonradioactive Dangerous Waste Landfill (a *Resource Conservation and Recovery Act of 1976*[3] treatment, storage, and disposal facility) and is southeast of the 200 East Area. SWL is approximately 26 ha (65 ac) in size and divided into five units consisting of parallel trenches. SWL operated from 1973 to 1996 and received sanitary paper waste and construction and demolition debris, sewage, asbestos, and catch tank liquid waste. SWL trenches were backfilled with soil as they were filled to form an operational cover. Operation of SWL ceased in March 1996, and an interim cover was placed over the trenches.

A detection level groundwater monitoring program in accordance with WAC 173-304-490[4] was implemented at SWL in 1987. The monitoring program continued under WAC 173-304-490 through the most recent monitoring plan (PNNL-13014). Since PNNL-13014 was issued in 2000, the landfill requirements under

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[1] PNNL-13014, 2000, *Groundwater Monitoring Plan for the Solid Waste Landfill*, Pacific Northwest National Laboratory, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=D1662904.

[2] WAC 173-350-500, "Solid Waste Handling Standards," "Groundwater Monitoring," *Washington Administrative Code*, Olympia, Washington. Available at: http://apps.leg.wa.gov/WAC/default.aspx?cite=173-350-500.

[3] *Resource Conservation and Recovery Act of 1976*, 42 USC 6901, et seq. Available at: http://www.epw.senate.gov/rcra.pdf.

[4] WAC 173-304-490, "Minimum Functional Standards for Solid Waste Handling," "Groundwater Monitoring Requirements," *Washington Administrative Code*, Olympia, Washington. Available at: http://app.leg.wa.gov/WAC/default.aspx?cite=173-304-490.

WAC 173-304-490 have been superseded by the requirements for a landfill under RCW 70.95[5], that are implemented through WAC 173-350-500. Many requirements in WAC 173-350-500 relate to proposed landfills and identify information to be included in the landfill permit application, such as site characterization and design of the groundwater monitoring system. Landfill operations at SWL ceased in 1996 and the site is in the closure process.[6] Therefore, this plan addresses the WAC 173-350-500 requirements that are applicable to groundwater monitoring at a post-operational landfill with an existing monitoring well network.

This revised groundwater monitoring plan presents an update for monitoring of the uppermost aquifer beneath SWL under WAC 173-350-500. This plan addresses the following:

- Number, locations, and depths of wells in the SWL groundwater monitoring network
- Sampling and analytical methods of parameters required for groundwater contamination monitoring
- Methods for evaluating groundwater quality information
- Schedule for groundwater monitoring at SWL

This revised plan uses an updated version of the groundwater monitoring well network in the previous groundwater monitoring plan, PNNL-13014. Since 2000, three downgradient wells (699-23-34A, 699-24-34C, and 699-25-34C) became dry due to the subsiding water table and are removed from the monitoring network. Two other downgradient wells (699-24-34A and 699-24-34B) are going dry and are removed from the monitoring network. One new well (699-25-34E) was installed as a replacement in 2014, and two other new wells (699-24-34D and 699-24-34E) were installed in 2015 to replace 699-24-34A and 699-24-34B. Well 699-26-35A, previously used for upgradient data, is removed from the network because it is not directly upgradient in the groundwater flow path. However, a new upgradient well (699-24-36) was installed upgradient of SWL and is included in the network.

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[5] RCW 70.95, "Public Health and Safety," "Solid Waste Management – Reduction and Recycling," *Revised Code of Washington*, Olympia, Washington. Available at: http://apps.leg.wa.gov/rcw/default.aspx?cite=70.95.

[6] DOE/RL-90-38, 1996, *Hanford Site Solid Waste Landfill Interim Closure Plan*, Rev. 1, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=D196128768.

Groundwater flow direction determinations indicate a southeast groundwater flow exists beneath SWL. Groundwater in SWL monitoring wells will be sampled and analyzed semiannually for field parameters (pH, specific conductance, and temperature) and geochemical indicator parameters (alkalinity, bicarbonate, calcium, chloride, iron, magnesium, manganese, nitrate, sodium, and sulfate). During the first year, sampling for field parameters and geochemical indicator parameters at replacement wells 699-24-34D and 699-24-34E and the new upgradient well 699-24-36 will be quarterly. Due to known past contamination with chlorinated hydrocarbons, volatile organic compounds (VOCs) including 1,1-dichloroethane, 1,2-dichloroethane, 1,4-dichlorobenzene, 1,1,1-trichlorethane, carbon tetrachloride, tetrachloroethene, and trichloroethene are retained as site-specific constituents. Chloroform is added as a site-specific VOC based on leachate and past groundwater detections. Arsenic and 1,4-dioxane are also included as site-specific constituents because they were detected in the leachate collection system. Total coliform was a required groundwater monitoring parameter under WAC 173-304-490 and is retained as a site-specific constituent in this plan due to previous sewage disposal within SWL. All site-specific constituents are sampled semiannually. Water level measurements will be taken each time a sample is collected.

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Contents

1 Introduction 1-1

2 Background 2-1

2.1 Facility Description and Operational History 2-1
2.2 Regulatory Basis 2-3
2.3 Waste Characteristics 2-5
2.3.1 Solid and Liquid Waste Disposal 2-5
2.3.2 Soil Gas Surveys and Monitoring 2-6
2.3.3 Leachate Monitoring 2-8
2.4 Geology and Hydrogeology 2-9
2.4.1 Stratigraphy 2-10
2.4.2 Hydrogeology 2-16
2.4.3 Groundwater Flow Interpretation 2-16
2.5 Summary of Previous Groundwater Monitoring 2-19
2.6 Conceptual Site Model 2-22
2.6.1 Contaminant Characteristics 2-23
2.6.2 Contaminant Movement and Distribution 2-24
2.6.3 Carbon Dioxide and Specific Conductance 2-27
2.7 Monitoring Objectives 2-32

3 Groundwater Monitoring Program 3-1

3.1 Constituents List and Sampling Frequency 3-1
3.2 Monitoring Well Network 3-4
3.3 Differences Between This Plan and Previous Plan 3-7
3.4 Sampling and Analysis Protocol 3-7

4 Data Evaluation and Reporting 4-1

4.1 Data Review 4-1
4.2 Statistical Evaluation 4-1
4.3 Interpretation 4-2
4.4 Annual Determination of Monitoring Network 4-3
4.5 Reporting 4-3

5 References 5-1

Appendices

A Quality Assurance Project Plan ..... A-i

B Sampling Protocol ..... B-i

C Well Construction ..... C-i

Figures

Figure 1-1. Location Map for SWL 1-3
Figure 2-1. Schematic of Disposal Trench Configurations for SWL and Adjacent NRDWL 2-2
Figure 2-2. SWL Soil Gas Monitoring Stations 2-7
Figure 2-3. Generalized Stratigraphy at the Hanford Site and Area-Specific Lithology in the Vicinity of SWL and NRDWL 2-11
Figure 2-4. Monitoring Wells in the Vicinity of SWL and NRDWL 2-13
Figure 2-5. West-East Cross-Section Looking North Showing Stratigraphy Underlying SWL 2-14
Figure 2-6. North-South Cross-Section Looking East Showing Stratigraphy Underlying SWL and NRDWL 2-15
Figure 2-7. 2014 Low Gradient Water Table Monitoring Network Results at SWL and NRDWL 2-17
Figure 2-8. Changes in Water Table Elevation Between April 2008 and April 2015 for Three SWL Groundwater Monitoring Wells 2-18
Figure 2-9. Time Series Plots Showing the Trending of Alkalinity, Calcium, Magnesium, Specific Conductance, Sulfate and Nitrate for SWL Upgradient and Downgradient Wells 2-29
Figure 2-10. Conceptualization of Vapor Plume Dissemination and Measured 1,1,1-Trichloroethane and Tetrachloroethene Concentrations in Groundwater Underlying SWL and NRDWL 2-30
Figure 3-1. SWL Groundwater Monitoring Wells 3-5

Tables

Table 2-1. Previous Monitoring Plans 2-19
Table 2-2. Summary of Volatile Organic Compounds in SWL Monitoring Wells Detected at Least One Time (2000 to 2013) 2-21
Table 2-3. Physical Properties of the Primary Volatile Organic Compounds at SWL 2-25
Table 2-4. Pertinent Solid Waste Handling Standards Groundwater Monitoring Requirements 2-32
Table 2-5. Additional Monitoring Objectives 2-35
Table 3-1. Monitoring Well Network for SWL 3-2
Table 3-2. Attributes for Wells in the SWL Groundwater Monitoring Network 3-6
Table 3-3. Main Differences between this Plan and Previous Plan 3-8

Terms

BTV	background threshold value
CCU	Cold Creek unit
CSM	conceptual site model
DNAPL	dense nonaqueous phase liquid
DOE	U.S. Department of Energy
DOE-RL	DOE Richland Operations Office
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
FWS	Field Work Supervisor
GWQC	groundwater quality criteria
HSU	hydrostratigraphy unit
MSA	Mission Support Alliance
NAD83	*North American Datum of 1983*
NAVD88	*North American Vertical Datum of 1988*
N/A	not applicable
NRDWL	Nonradioactive Dangerous Waste Landfill
OU	operable unit
ppm	parts per million
ppmv	parts per million by volume
QAPjP	quality assurance project plan
RCRA	*Resource Conservation and Recovery Act of 1976*
ROS	regression on order statistics
SWL	Solid Waste Landfill
TOC	total organic carbon
TOX	total organic halides

Tri-Party Agreement	*Hanford Federal Facility Agreement and Consent Order* (Ecology et al., 1989a)
UTL	upper tolerance limit
VOC	volatile organic compound

1 Introduction

This document presents the revised groundwater monitoring plan for the Solid Waste Landfill (SWL) and supersedes the previous plan (PNNL-13014, *Groundwater Monitoring Plan for the Solid Waste Landfill*). The U.S. Department of Energy (DOE), Richland Operations Office (DOE-RL) is revising this groundwater monitoring plan to comply with the applicable requirements for a landfill under RCW 70.95, "Solid Waste Management – Reduction and Recycling," and to ensure that the plan contains the most current Hanford groundwater monitoring information for SWL (changes to the monitoring network). Monitoring under RCW 70.95 is implemented through WAC 173-350-500, "Solid Waste Handling Standards," "Groundwater Monitoring." This plan monitors parameters in groundwater samples that are used to determine whether waste or waste constituents from SWL have entered the groundwater.

SWL is a non-operating landfill as defined in WAC 173-350-100, "Definitions." Groundwater monitoring at SWL began in 1987 under WAC 173-304-490 "Minimal Functional Standards for Solid Waste Handling," "Groundwater Monitoring Requirements." WAC 173-304-490 has since been superseded by requirements in WAC 173-350-500. This plan satisfies the groundwater monitoring requirements of WAC 173-350-500 that are applicable to groundwater monitoring at a post-operational landfill with an existing monitoring well network. SWL is a landfill in the 200-SW-1 Source Operable Unit (OU). Groundwater cleanup will be addressed under the 200-PO-1 Groundwater OU decision documents.

SWL is located adjacent to the Nonradioactive Dangerous Waste Landfill (NRDWL), southeast of the 200 East Area (Figure 1-1). Operating records indicate that SWL began operations in 1973 to receive sanitary paper waste, construction and demolition debris, and asbestos from Hanford Site operations. SWL received sewage from 1973 to 1987 and catch tank liquid (containing chlorinated organic compounds) from the 1100 Area heavy equipment garage and bus shop from 1985 to 1987. Operation of SWL ceased in March 1996, and the site underwent interim stabilization measures in 1996.

The purpose of this plan, while intending to satisfy the applicable groundwater monitoring requirements of WAC 173-350-500, is to determine whether SWL has contaminated groundwater beneath the site. This determination will be accomplished by semiannual monitoring for specified field parameters and geochemical indicator parameters (WAC 173-350-500(4)(h)(i) and (ii)) and site-specific constituents (WAC 173-350-500(4)(i)). The monitoring network comprises two upgradient and six downgradient wells. Two new downgradient wells installed in calendar year 2015 are added to the monitoring network to replace two previous network wells that were sample dry. One new upgradient well installed in 2014 is added in this plan. During the first year, sampling for field parameters and geochemical indicator parameters at the two downgradient replacement wells (699-24-34D and 699-24-34E) and the new upgradient well (699-24-36) will be quarterly. Water level measurements are required each time a sample is collected to satisfy WAC 173-350-500(4)(d). The requirements for soil gas and leachate monitoring at SWL identified in DOE/RL-90-38, Rev. 1, *Hanford Site Solid Waste Landfill Interim Closure Plan* (issued in 1996) are not included in this plan. This monitoring plan is the principal controlling document for conducting groundwater monitoring at SWL.

This groundwater monitoring plan addresses the operational history, current hydrogeology, and conceptual site model (CSM) for the site and incorporates knowledge about the potential for contamination originating from SWL and includes the following chapters and appendices:

- Chapter 2 of this plan summarizes background information. It also describes SWL, including the regulatory basis, types of waste present, the pertinent geology and hydrogeology beneath SWL, and provides a brief history of groundwater monitoring. All of this information is summarized as a CSM to aid in development of the groundwater monitoring program.

- Chapter 3 describes the groundwater monitoring program, including the wells in the monitoring network, constituents analyzed, sampling frequency, and sampling protocols.
- Chapter 4 describes the data evaluation and reporting.
- Chapter 5 contains the references cited in this plan.
- Appendix A provides the quality assurance project plan (QAPjP).
- Appendix B contains sampling protocols.
- Appendix C provides information for the wells within the groundwater monitoring network.

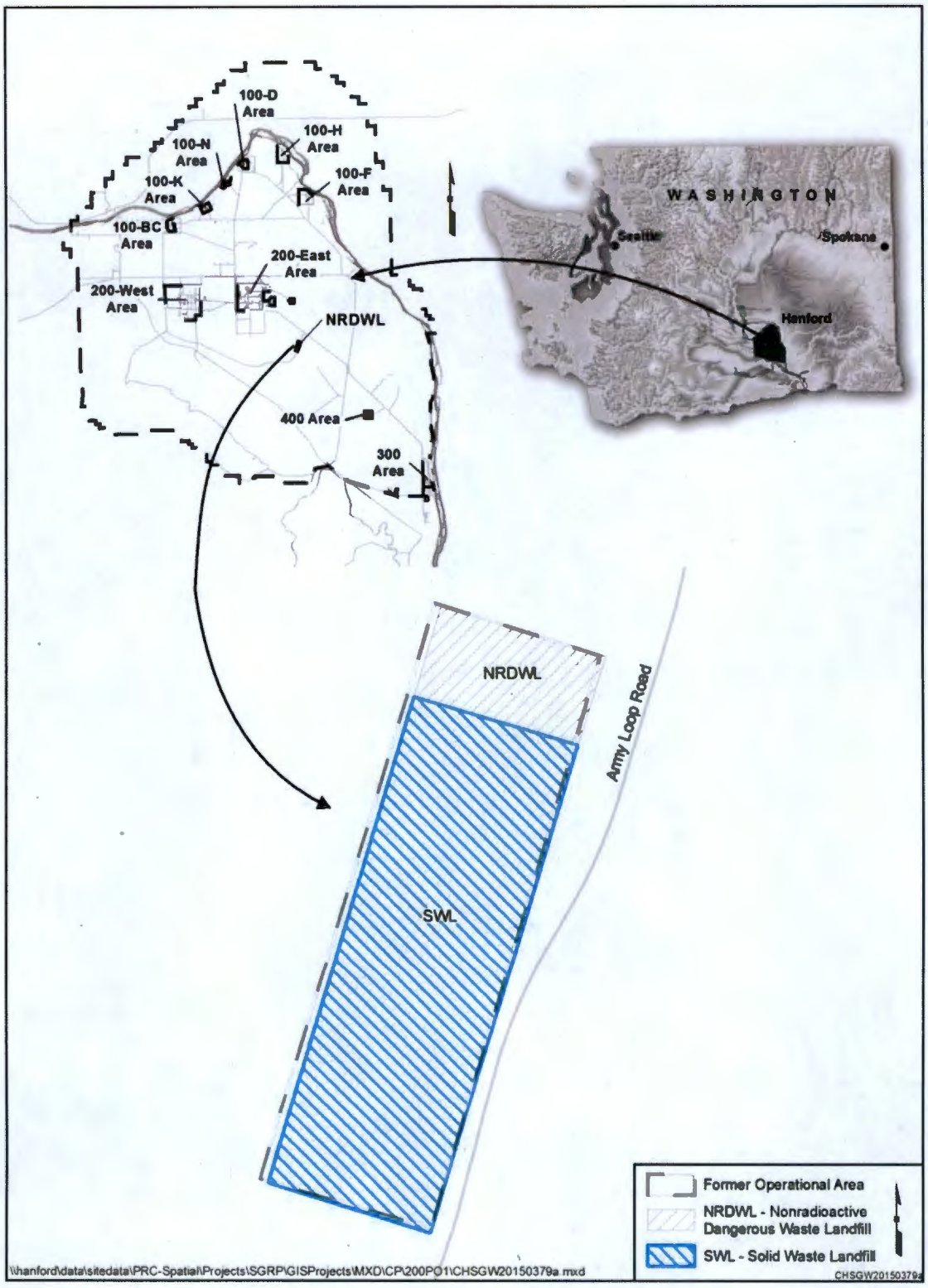

Figure 1-1. Location Map for SWL

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2 Background

This chapter describes SWL and its operating history, regulatory basis, wastes and waste characteristics associated with SWL, local subsurface geology and hydrogeology, a summary of previous groundwater monitoring, and the CSM for SWL. Site-specific constituents are also discussed in this chapter.

The information contained in this chapter was obtained from several sources, including previous groundwater monitoring plans listed in Section 2.5 and the following documents:

- DOE/RL-90-17, *Nonradioactive Dangerous Waste Landfill/Solid Waste Landfill Closure/Postclosure Plan*
- DOE/RL-90-38, Rev. 0, *Hanford Site Solid Waste Landfill Permit Application* (1991)
- DOE/RL-90-38, Rev. 1, *Hanford Site Solid Waste Landfill Permit Application* (1993)
- DOE/RL-90-38, Rev. 1, *Hanford Site Solid Waste Landfill Interim Closure Plan* (1996)
- DOE/RL-2014-32, *Hanford Site Groundwater Monitoring Report for 2013*
- DOE/RL-2015-07, *Hanford Site Groundwater Monitoring Report for 2014*
- DOE/RL-2015-21, *Hanford Site Solid Waste Landfill Annual Monitoring Report*
- DYN-SWL-LWCP-397, *Liquid Waste Certification Plan for the Solid Waste Landfill Leachate*
- HNF-7173, *Hanford Solid Waste Landfill Closure Plan*
- PNL-6823, *Interim Site Characterization Report and Ground-Water Monitoring Program for the Hanford Site Solid Waste Landfill*
- PNL-7147, *Final Report: Soil-Gas Survey at the Solid Waste Landfill*
- PNNL-11709, *Borehole Completion Data Package for Solid Waste Landfill Facility Wells 699-22-35 and 699-23-34B*
- WHC-EP-0021, *Interim Hydrogeologic Characterization Report and Groundwater Monitoring System for the Nonradioactive Dangerous Waste Landfill, Hanford Site, Washington*

2.1 Facility Description and Operational History

SWL is located about 5.6 km (3.5 mi) southeast of the 200 East Area (Figure 1-1) and occupies approximately 26 ha (65 ac). It consists of a series of parallel trenches that vary in length from 168 to 200 m (551 to 656 ft), are 5 m (16 ft) wide at the base (single width) to 16 m (52 ft) wide at the base (double width), and are 6 m (20 ft) deep (Figure 2-1). The general method of landfilling used at SWL was the trench method, where waste was placed in the trenches and covered with soil. Asbestos debris was segregated from general sanitary waste and placed in the single-wide trenches. Sanitary waste usually went into double-wide trenches. At the end of a typical day of operation, a portion of the spoil pile was pushed over the refuse to form the daily cover, which was typically 15 to 30 cm (6 to 12 in.) thick. After a trench was filled, the remaining spoil pile was bulldozed over the trench to form an operational cover.

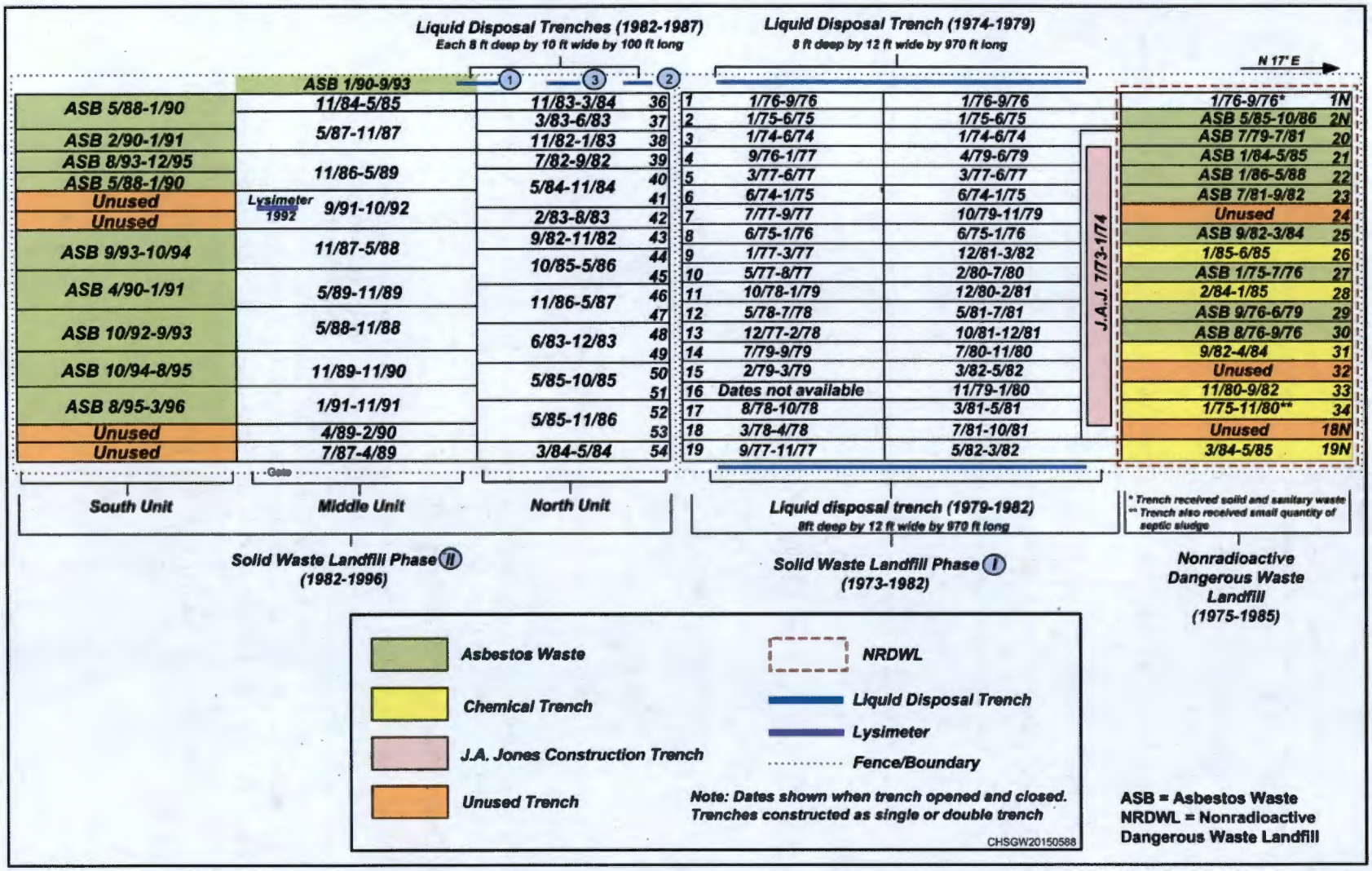


Figure 2-1. Schematic of Disposal Trench Configurations for SWL and Adjacent NRDWL

The site was originally designated as the Central Landfill. The Central Landfill began operation in 1973 to receive sanitary waste, asbestos, and construction and demolition debris from Hanford Site operations. The landfill also received sewage and liquid waste (including washwater waste from the bus garage) beginning in 1974. The Central Landfill, with an original area 154,000 m^2 (1,658,000 ft^2), was subdivided into two units for operational purposes in 1975. The northern-most unit, consisting of 40,000 m^2 (431,000 ft^2) of the Central Landfill, was isolated to dispose of asbestos waste material and nonradioactive chemical waste. This northern unit was designated formally as NRDWL because of the presence of regulated dangerous waste. NRDWL is currently regulated as a *Resource Conservation and Recovery Act of 1976* (RCRA) land disposal facility and has a separate groundwater monitoring program.
The remainder of the Central Landfill was designated as SWL and comprised 114,000 m^2 (1,227,000 ft^2). In 1982, SWL was expanded 154,000 m^2 (1,658,000 ft^2) to the south. This was designated the Phase II Area, and the former area then became the Phase I Area. The total area of SWL is 268,000 m^2 (2,885,000 ft^2).

After operation of SWL ceased in March 1996, an interim cover (which was the operational cover during operation of SWL) was placed over the SWL trenches. The cover consists of native, well-graded sand with a very low percentage of fines (DOE/RL-90-38, Rev. 1, 1996). The soil was distributed evenly and leveled in order to minimize topographic lows, which could collect precipitation and runoff. Natural vegetation typical of the area is returning to the site, with the older trenches having a thick vegetation cover, while some of the newer trenches are essentially bare (DOE/RL-2015-21). Leachate collected from natural infiltration by the leachate collection system currently averages approximately 5.7 L (1.5 gal)/day (DOE/RL-2015-21).

2.2 Regulatory Basis

In 1985, the Washington State Department of Ecology (Ecology) adopted WAC 173-304. In 1986, a detection level groundwater monitoring program was developed for SWL to address the requirements in WAC 173-304-490 (PNL-6930, *Compliance Ground-Water Monitoring Plan for the Hanford Site Solid Waste Landfill*). In April 1987, six groundwater monitoring wells at SWL were completed and groundwater monitoring commenced (PNL-6823). Monitoring results in 1987 indicated that several volatile organic compounds (VOCs) (carbon tetrachloride, trichloroethene, 1,1,1-trichloroethane, tetrachloroethene, and 1,1-dichloroethane) were present in groundwater at SWL (PNL-6823).

In 1991, a permit application (DOE/RL-90-38, Rev. 0) was submitted to continue SWL operations. At that time, SWL was regulated by WAC 173-304, and the regulatory agency was the Benton Franklin Health District. The permit application was submitted to the Benton Franklin Public Health District in January of 1991 (DOE/RL-90-38, Rev 0). The permit application was rejected because there was sufficient evidence to suggest that SWL had contaminated groundwater. As a result of subsequent negotiation between the Benton Franklin Public Health District and Ecology, Ecology accepted responsibility for regulation of SWL.

An updated monitoring plan under WAC 173-304-490 (WHC-SD-EN-AP-043, Rev. 0, *Groundwater Monitoring Plan for the Solid Waste Landfill, Hanford, Washington*) was issued in 1993 to update the well network. Also in 1993, a revised permit application (DOE/RL-90-38, Rev. 1, 1993) was submitted to Ecology (94-RPS-035, "Hanford Site Solid Waste Landfill Permit Application Revision 1"). Ecology reviewed the revised permit application and issued a letter (Ma, 1994, "Corrective Action Program Requirements, Scale Construction, Operational Plan, and Lysimeter Installation, Hanford Site Solid Waste Landfill") to the DOE-RL requesting that a corrective action program be established for SWL.

The letter (Ma, 1994) specified that a corrective action plan, meeting the requirements of WAC 173-304-490(2)(j), be submitted to Ecology by September 30, 1994. DOE-RL subsequently requested a two-month extension, which moved the due date to November 30, 1994. A corrective action

plan meeting the requirements of WAC 173-304-490(2)(j) was written (DOE/RL-94-143, *Corrective Action Plan for the Hanford Site Solid Waste Landfill*) and submitted to Ecology (95-PCA-080, "Corrective Action Plan for the Hanford Site Solid Waste Landfill"). The plan did not identify the corrective action but rather outlined a characterization approach to determine a remedial action. However, the plan was never implemented due to other site activities having higher priority.

SWL ceased operation in 1996 and an interim closure plan (DOE/RL-90-38, Rev. 1, 1996) was submitted to Ecology in July 1996 (96-EAP-198, "Transmittal of Interim Closure Work Plan for Solid Waste Landfill (DOE/RL-90-38, Rev 1)"). In November 2000, a closure plan (HNF-7173) was issued and submitted to Ecology (01-RCA-034, "Submission of Revised Hanford Solid Waste Landfill (SWL) Closure Plan"). The closure plan described the actions for closure and post-closure care in accordance with WAC 173-304-407, "General Closure and Post-Closure Requirements," and WAC 173-304-460, "Landfilling Standards." The closure plan (HNF-7173) was not approved by Ecology because Ecology had agreed to delay approval of the closure plan until a revised plan (incorporating a decision to defer placement of a final engineered cover until 2010) could be submitted to coincide with the remedial action for NRDWL (01-RCA-034).

In October 2000, an updated monitoring plan for SWL (PNNL-13014) was issued. The plan continued monitoring under WAC 173-304, proposed two new deeper downgradient wells, modified the statistical evaluation tests, and modified the data evaluation method for VOCs. In November 2009, Draft A of DOE/RL-2008-54, *Hanford Site Solid Waste Landfill Closure Plan*, was submitted to Ecology (10-AMCP-0009, "Hanford Site Solid Waste Landfill Closure Plan, DOE/RL-2008-54, Draft A, and *Nonradioactive Dangerous Waste Landfill Closure/Postclosure Plan*, DOE/RL-90-17, Revision 1"). This draft was not reviewed by Ecology pending discussions with DOE/RL on deferring closure of SWL to WAC 173-303-645, "Dangerous Waste Regulations," "Releases from Regulated Units," the regulation under which NRDWL will be closed. The deferral was granted by Ecology (Skinnarland, 2010, "Regulatory Path Forward for Final Closure of Solid Waste Landfill (SWL)"). In 2010, a groundwater monitoring plan (DOE/RL-2010-28, *Groundwater Monitoring Plan for the Nonradioactive Dangerous Waste Landfill and Solid Waste Landfill*) combining SWL and NRDWL monitoring activities was issued in anticipation of approval of DOE/RL-90-17, Rev. 2, which would have combined SWL and NRDWL into one RCRA unit to be regulated under WAC 173-303-645. Pending approval of DOE/RL-90-17, Rev. 2, the combined NRDWL and SWL groundwater monitoring plan (DOE/RL-2010-28) was to be implemented during the closure and post-closure period for SWL and NRDWL. Because approval of the closure plan has not occurred, the monitoring program under WAC 173-304-490 provided in PNNL-13014 has remained the principal controlling document for conducting groundwater monitoring at SWL.

Since issuance of the previous plan (PNNL-13014) in 2000, a new solid waste management rule (WAC 173-350) has taken effect. Requirements in WAC 173-350-500 include site characterization and groundwater monitoring system design, which are then submitted in the permit application for a proposed landfill. Landfill operations at SWL ceased in 1996 and the site has since been in the closure process (DOE/RL-90-38, Rev. 1, 1996). Therefore, many of the requirements in WAC 173-350-500 are not applicable to SWL. This update to the SWL monitoring plan incorporates the applicable requirements for groundwater monitoring of a post-operational landfill with an existing monitoring network included in WAC 173-350-500(3), "Groundwater Monitoring – System Design," WAC 173-350-500(4), "Groundwater Monitoring – Sampling and Analysis Plan," and WAC 173-350-500(5), "Groundwater Monitoring – Data Analysis, Notification, and Reporting."

2.3 Waste Characteristics

Solid and liquid waste disposal at SWL is discussed in this section, along with a discussion of soil gas and leachate monitoring.

2.3.1 Solid and Liquid Waste Disposal

Both solid and liquid wastes were disposed at SWL. The types of wastes disposed at SWL included office waste, construction/demolition debris, asbestos material, bulky items, and miscellaneous waste based on waste receipts (DOE/RL-90-38, Rev. 1, 1996):

- Office waste comprises approximately 40 percent of the total volume of waste disposed at SWL, and most of the office waste was paper products.
- Construction/demolition debris, approximately 30 percent of the total waste, originated from construction activities and renovation of buildings and included waste wood products such as pallets.
- Asbestos material (nonradioactive or nonhazardous asbestos or material containing asbestos) accounts for approximately 10 percent by volume of all waste disposed at SWL. Most of this material resulted from demolition or renovation activities at Hanford Site buildings.
- Bulky items include large items of refuse, such as appliances and office furniture, that were too large to fit into solid waste collection containers. Approximately 10 percent of the total waste volume at SWL included material in the bulky items category.
- Miscellaneous waste at SWL included garbage from Hanford Site personnel lunches, industrial waste such as packing and empty containers, medical waste from first aid stations, and various inert materials. The estimated volume of the miscellaneous waste is 10 percent.

From 1973 to 1987, liquid waste including sewage and 1100 Area catch tank liquid was discharged to SWL in separate shallow trenches. The sewage originated from portable toilets and septic tanks. Catch tank liquid from the 1100 Area heavy equipment garage and bus shop also was disposed in these trenches from 1985 to 1987. Chemical analysis of the 1100 Area catch tank liquid detected the following constituents (DOE/RL-90-38, Rev. 1, 1996):

- Carbon tetrachloride
- 1,1,1-trichloroethane
- Trichloroethene
- Tetrachloroethene

It is possible, but unlikely, that these organic compounds were in the form of dense nonaqueous phase liquids (DNAPLs). The organic compounds were most likely in a dissolved phase in the catch tank liquid waste. Sewage and other liquids were not accepted at SWL after 1987. Disposal of radioactive and dangerous waste (other than the catch tank liquid waste) was prohibited at SWL.

Based on waste receipts, SWL received approximately 400,266 m^3 (14,135,000 ft^2) of solid waste and 14,496 m^3 (511,921 ft^3) of asbestos waste from 1973 to 1995. An estimated 3,800,000 L (1,000,000 gal) to 5,700,000 L (1,500,000 gal) of sewage were discharged to the liquid trenches from 1975 to April 1987. The estimated total volume of catch tank liquid waste disposed to SWL from 1985 to 1987 is 380,000 L (100,000 gal) (DOE/RL-90-38, Rev. 1, 1996).

2.3.2 Soil Gas Surveys and Monitoring

A soil gas survey was conducted at SWL from June 1988 to February 1989 to determine the areal extent of chlorinated hydrocarbons (PNL-7147). Soil gas samples were collected from probes emplaced at depths of 1.2 to 1.8 m (4 to 6 ft) at locations 30 m (98 ft) apart. Probes were more closely spaced near the three short disposal trenches used for disposal of the 1100 Area catch tank liquid to more adequately define the spatial distribution of contaminants at their presumed sources. The survey found detectable concentrations of 1,1,1-trichloroethane, trichloroethene, tetrachloroethene, 1,1-dichloroethane, carbon tetrachloride, carbon dioxide (higher than ambient concentrations), and methane. 1,1,1-trichloroethane, trichloroethene, and tetrachloroethene were detected as far as 130 m (427 ft) west and 115 m (377 ft) east of SWL.

Downhole gas samples were collected while drilling groundwater monitoring wells (699-22-35 and 699-23-34B) at the southeast corner of SWL (PNNL-11709). The soil gas samples were collected using a membrane system that allows sampling at discrete intervals within the borehole. Samples were collected at approximately every 6 m (20 ft) in each borehole. The only VOC detected in the borehole samples was carbon tetrachloride. All 11 borehole samples contained detectable quantities of carbon tetrachloride in concentrations ranging from 0.1 to 1.4 parts per million by volume (ppmv).

Sixteen soil gas probes were installed at eight locations around the perimeter of SWL in 1993 to monitor concentrations of landfill gases (methane, carbon dioxide, and oxygen), in accordance with WAC 173-304, and to sample (field screening analysis) for chlorinated hydrocarbons. Two dedicated soil gas probes were installed at each monitoring location, one at a depth of approximately 2.7 m (8.9 ft) (labeled with an A) and a second at a depth of 4.6 m (15 ft) (labeled with a B). Soil gas is analyzed for several key VOCs (i.e., methylene chloride, 1,1-dichloroethane, chloroform, 1,1,1-trichloroethane, carbon tetrachloride, trichloroethene, 1,1,2-trichloroethane, and tetrachloroethene). Figure 2-2 shows the locations of soil gas monitoring stations. Soil gas monitoring station DE-1 is no longer used due to fire damage. In addition to the eight monitoring stations in the SWL soil gas monitoring network, soil gas monitoring station DW-2 (located along the border with NRDWL) is sampled routinely (Figure 2-2).

During four separate field screening events for chlorinated hydrocarbons between 1993 and 1997, the primary contaminant detected was 1,1,1-trichloroethane. The highest concentrations were consistently detected on the southern and eastern sides of SWL. Low levels of tetrachloroethene (0.02 to 0.19 ppmv) were detected in 1993 at seven probes but were not detected subsequently. During the same year, trichloroethene was detected at concentrations ranging from 0.010 to 0.045 ppmv at three probes; during 1997, trichloroethene was detected at trace levels at four of the probes.

Soil gas monitoring continues at SWL under the interim closure plan (DOE/RL-90-38, Rev. 1) issued in 1996, and quarterly sampling results are reported annually. The 2014 results, reported in DOE/RL-2015-21, showed that concentrations for most of the VOCs were generally below detection limits. Trichloroethene, 1,1,2-trichloroethane, and methylene chloride had local detections. Tetrachloroethene was detected in one shallow probe (SWL-02A), and 1,1,1-trichloroethane was not detected at any monitoring station. Carbon dioxide concentrations were also at low levels (below atmospheric levels of 400 parts per million [ppm]) in most of the soil gas monitoring sites. However, at the one monitoring station (SWL-04B) located between NRDWL and SWL, carbon dioxide concentrations reached 8,676 ppm.

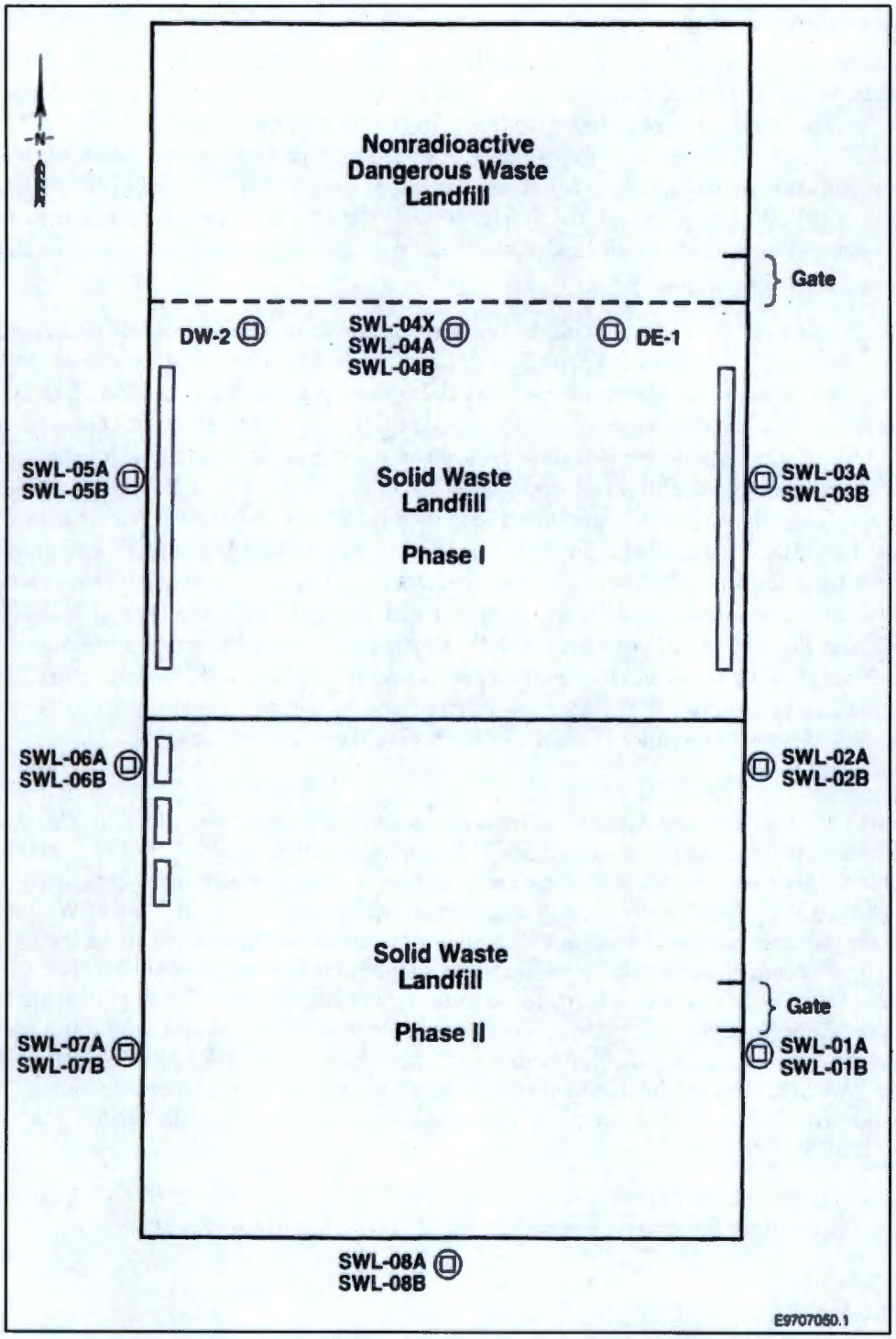


Figure 2-2. SWL Soil Gas Monitoring Stations

2.3.3 Leachate Monitoring

In 1992, a basin lysimeter was installed beneath the Phase II area middle unit at the southern end of double trench 41 and 42 (Figure 2-1). This trench was filled from north to south and was closed in October 1992. The lysimeter is 21 m (69 ft) long, 4.6 m (15 ft) wide on one end and 3.9 m (13 ft) on the other end, with a collection area of 88 m^2 (947 ft^2). A discharge pipe continuously drains the leachate by gravity flow from the basin to a nearby collection sump. The lysimeter is designed to collect leachate generated by water infiltrating through the overlying waste trench and to drain the leachate to a collection system. The leachate quality and quantity are analyzed to evaluate the impact that leachate might have on groundwater quality.

Starting in 1996, the sump associated with the lysimeter began accumulating leachate (indicating a four-year lag time between the occurrence of precipitation at the surface and the appearance of that same water as leachate). Initially, the collection rate was 19 L (5 gal) per day, but it reached 38 L (10 gal) per day by 1997. Leachate samples were analyzed for the indicator parameters (specific conductance, pH, chloride, nitrate, nitrite, ammonium ion, sulfate, chemical oxygen demand, and total organic carbon [TOC]) as specified in the landfill permit application (DOE/RL-90-38, Rev. 1, 1993). In addition, the samples were also analyzed for the constituents identified in WAC 173-351-990, "Criteria for Municipal Solid Waste Landfills," "Appendices," Appendices I and II, and for four VOCs (1,1,1-trichloroethane, 1,1-dichloroethane, tetrachloroethene, and trichloroethene) that had been detected in groundwater beneath the landfill. After these initial rounds of sampling and analysis in 1996, a sampling and analysis plan for leachate was developed that was consistent with the provisions of the SWL permit application (DOE/RL-90-38, Rev. 1, 1993) and the interim closure plan (DOE/RL-90-38, Rev. 1, 1996). In 1997, the plan was modified to monitor specific analytes quarterly and to include all analytes annually (per WAC 173-351-990, Appendices I and II) to verify no change in other analytes (DYN-SWL-LWCP-397).

Detection of 1,1,1-trichloethane, 1,1-dichloroethane, tetrachloroethene, *cis*-1,2-dichloroethene, and trichloroethene were reported in the early rounds of sampling in 1996 and 1997. Both 1,1-dichloroethane and tetrachloroethene concentrations in these early analyses exceeded the groundwater quality criteria (GWQC) of WAC 173-200, "Water Quality Standards for Groundwaters of the State of Washington." Several of the indicator parameters, some VOCs, and some metals continue to be above the GWQC and/or maximum contaminant levels for public water supplies established in WAC 246-290, "Group A Public Water Supplies." However, 1,1-dichloroethane and tetrachloroethene (primary contaminants of concern in the earlier analyses) are no longer detected in the leachate. Total dissolved solids, arsenic, manganese, 1,4-dioxane, and 1,4-dichlorobenzene are equal to or exceed the GWQC. Conductivity, manganese, and nickel exceed the maximum contaminant levels. The primary contaminants (1,1,1-trichloroethane and 1,1-dichloroethane) were below detection limits in the second quarter of fiscal year 2014 (DOE/RL-2015-21).

From the last quarter of 2013 to the third quarter of 2014 (fiscal year 2014), the following constituents (listed with highest result for the year) were detected in the leachate (DOE/RL-2015-21):

- Ammonia, 835 µg/L
- Dissolved iron, 6,970 µg/L
- Dissolved manganese, 2,040 µg/L
- Dissolved zinc, 433 µg/L
- Arsenic, 24.7 µg/L
- Barium, 472 µg/L
- Cadmium, 0.128 µg/L

- Chloride, 169,000 μg/L
- Copper, 42.0 μg/L
- Fluoride, 328 μg/L
- Nickel, 97 μg/L
- Selenium, 1.5 μg/L
- Sulfate, 64,200 μg/L
- Tetrachloroethene, 2.0 μg/L

The constituents that exceeded drinking water standards included dissolved iron (300 μg/L), dissolved manganese (50 μg/L), arsenic (10 μg/L), and chloride (25,000 μg/L). Three of these same four constituents exceeded the WAC 173-200 GWQC. These include dissolved iron (300 μg/L), dissolved manganese (50 μg/L), and arsenic (0.05 μg/L).

2.4 Geology and Hydrogeology

The geology and hydrogeology of the southwestern portion of the 200-PO-1 OU, including the SWL region, are described in detail in the following documents:

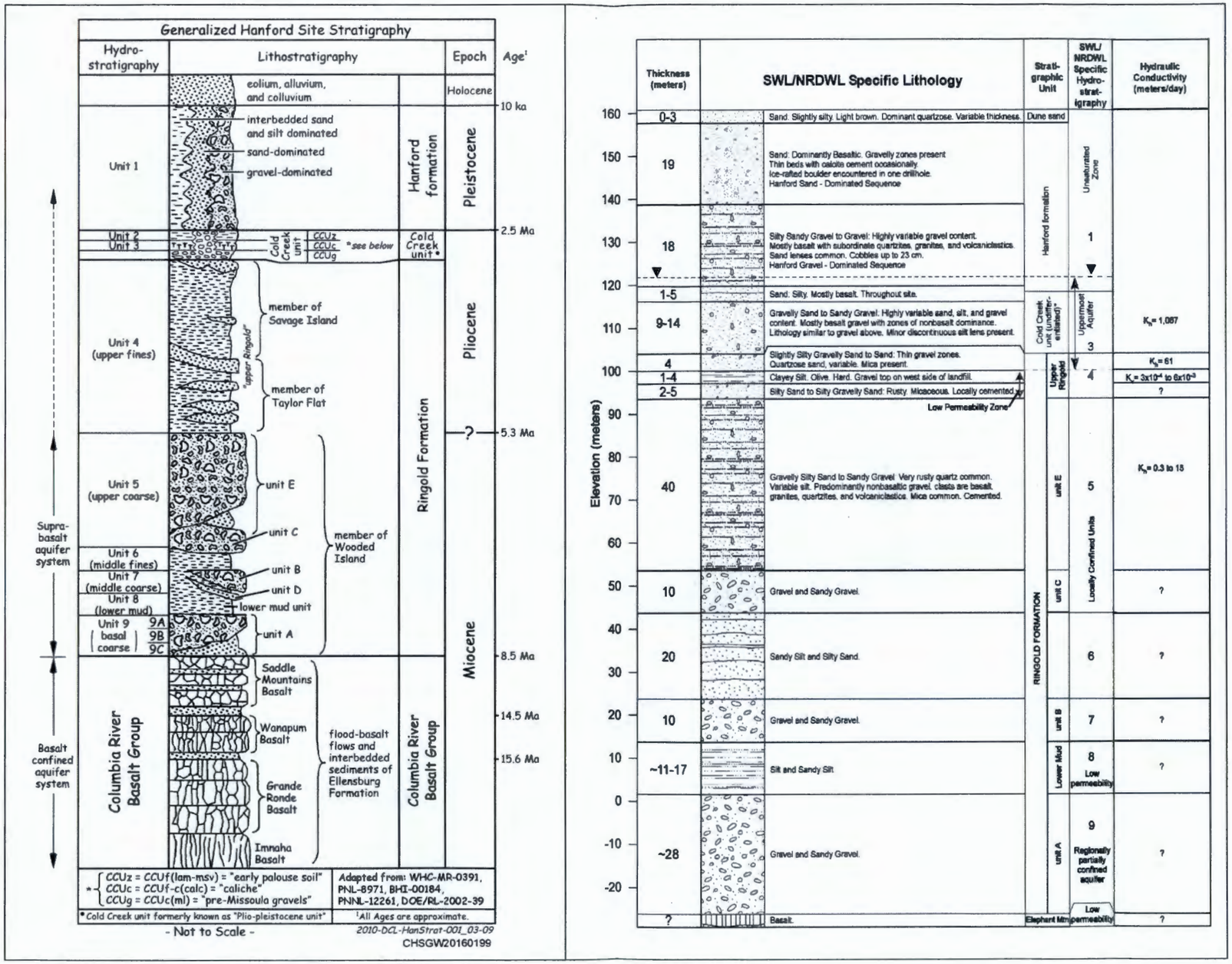
- CP-57037, *Model Package Report: Plateau to River Groundwater Transport Model Version 7.1*
- DOE/RL-90-17, *Nonradioactive Dangerous Waste Landfill/Solid Waste Landfill Closure/Postclosure Plan*
- DOE/RL-2009-85, *Remedial Investigation Report for the 200-PO-1 Groundwater Operable Unit*
- DOE/RL-2011-01, *Hanford Site Groundwater Monitoring Report for 2010* (Chapter 2, "Overview of Hanford Hydrogeology and Geochemistry")
- DOE/RL-2014-32, *Hanford Site Groundwater Monitoring Report for 2013*
- ECF-Hanford-13-0029, *Development of the Hanford South Geologic Framework Model, Hanford Site Washington*
- PNL-8971, *Three-Dimensional Conceptual Model for the Hanford Site Unconfined Aquifer System, FY 1993 Status Report*
- PNNL-12086, *Hanford Site Groundwater Monitoring for Fiscal Year 1998*
- PNNL-12261, *Revised Hydrogeology for the Suprabasalt Aquifer System, 200-East Area and Vicinity, Hanford Site, Washington*
- SGW-54165, *Evaluation of the Unconfined Aquifer Hydraulic Gradient Beneath the 200 East Area, Hanford Site*
- WHC-EP-0021, *Interim Hydrogeologic Characterization Report and Groundwater Monitoring System for the Nonradioactive Dangerous Waste Landfill, Hanford Site, Washington*

The discussion of geology and hydrogeology includes NRDWL because of its adjacent location to SWL. NRDWL wells were included as an additional source of geologic and hydrogeologic data, especially information from the deeper wells (699-26-35C and 699-25-33A).

2.4.1 Stratigraphy

A generalized stratigraphic column for the Hanford Site and an area-specific lithologic section for SWL and NRDWL are presented in Figure 2-3. The stratigraphic descriptions are based, in part, on additional data from more distant wells, as well as data from the SWL and NRDWL well network (Figure 2-4). Stratigraphy within the vicinity of SWL and NRDWL include the following (listed in order from upper to lower) (DOE/RL-2009-85):

- A discontinuous veneer of Holocene eolian silty sand or backfill mixtures of sand and gravel.
- Hanford formation (Pleistocene Age) – cataclysmic flood deposits equivalent to hydrostratigraphy unit (HSU) 1. The Hanford formation consists of three facies subunits (silt-dominated, sand-dominated, and gravel-dominated) which grade into one another both vertically and laterally. The gravel-dominated and sand-dominated facies predominate beneath SWL.
- Cold Creek unit (CCU) (Pliocene Age) – equivalent to HSUs 2 and 3; however, only HSU 3 is present beneath SWL. Unit 3 includes CCU pre-Missoula gravels. The character of this unit beneath SWL is similar to its occurrence beneath the 200 East Area where the Cold Creek is characterized as a quartzo feldspathic sandy gravel (unit G) above the Ringold and below the more basaltic Hanford formation.
- Upper Ringold (Miocene to Pliocene Aged) – equivalent to HSU 4. Fluvial deposits consisting of slightly silty gravelly sand; to sand, clayey silt, and silty sands; to silty gravelly sand. Extent beyond the NRDWL/SWL area is unknown. A fine-grained layer (containing silt and clay-called the low-permeability unit) at the base of the upper Ringold is an aquitard that forms the base of the unconfined aquifer.
- Ringold Formation Unit E (Miocene to Pliocene Aged) – equivalent to HSU 5. Fluvial deposits with thick layers of silty sandy gravel (conglomerate), intercalated with thinner beds of overbank silts and fine-grained paleosols. Beneath SWL, it is undifferentiated from Ringold Formation unit C (another coarse-grained Ringold Formation unit) that may be present beneath unit E.
- Ringold Formation, lower mud unit (Miocene Aged) – equivalent to HSU 8. This unit is composed of a sequence of fluvial overbank, paleosol, and lacustrine silt and clay, with minor sand and gravel. The local presence of this unit is indicated based on projected stratigraphic contacts established from other wells that have been completed deeper in the 200-PO-1 OU (CP-57037). Well 699-23-33, completed east of SWL, was drilled to a depth of 210 m (690 ft) below ground surface, passing though the lower mud unit and unit A and encountering basalt at a depth of 201 m (660 ft). The lower mud unit is an aquaclude (at least locally), creating confining conditions, and isolating the Ringold Formation Unit E from the underlying Ringold Formation Unit A.
- Ringold Formation, Unit A (Miocene Aged) – equivalent to HSU 9, which can be further subdivided into three subunits based on markedly different lithology and hydraulic properties. Subunits 9A and 9C are characterized by sand and gravel that have higher permeability than the middle subunit 9B that has much lower permeability and consists of silt and clay deposits. Unit A is thicker to the south and east of SWL and is pinching out beneath SWL (Figures 2-5 and 2-6). At well 699-23-33 (east of SWL), unit A is approximately 20 m (65 ft) thick and is predominately sandy gravels and gravelly sands (subunits 9A and C). The fine-grained subunit 9B is approximately 2 m (5 ft) thick at well 699-23-33.
- Bedrock, Columbia River Basalt Group – basalt flows dip gently to the south toward the axis of the Cold Creek syncline. The two uppermost flows are within the Elephant Mountain Member of the Saddle Mountains Basalt.



Note: Complete reference citations are provided in Chapter 5.

Figure 2-3. Generalized Stratigraphy at the Hanford Site and Area-Specific Lithology in the Vicinity of SWL and NRDWL

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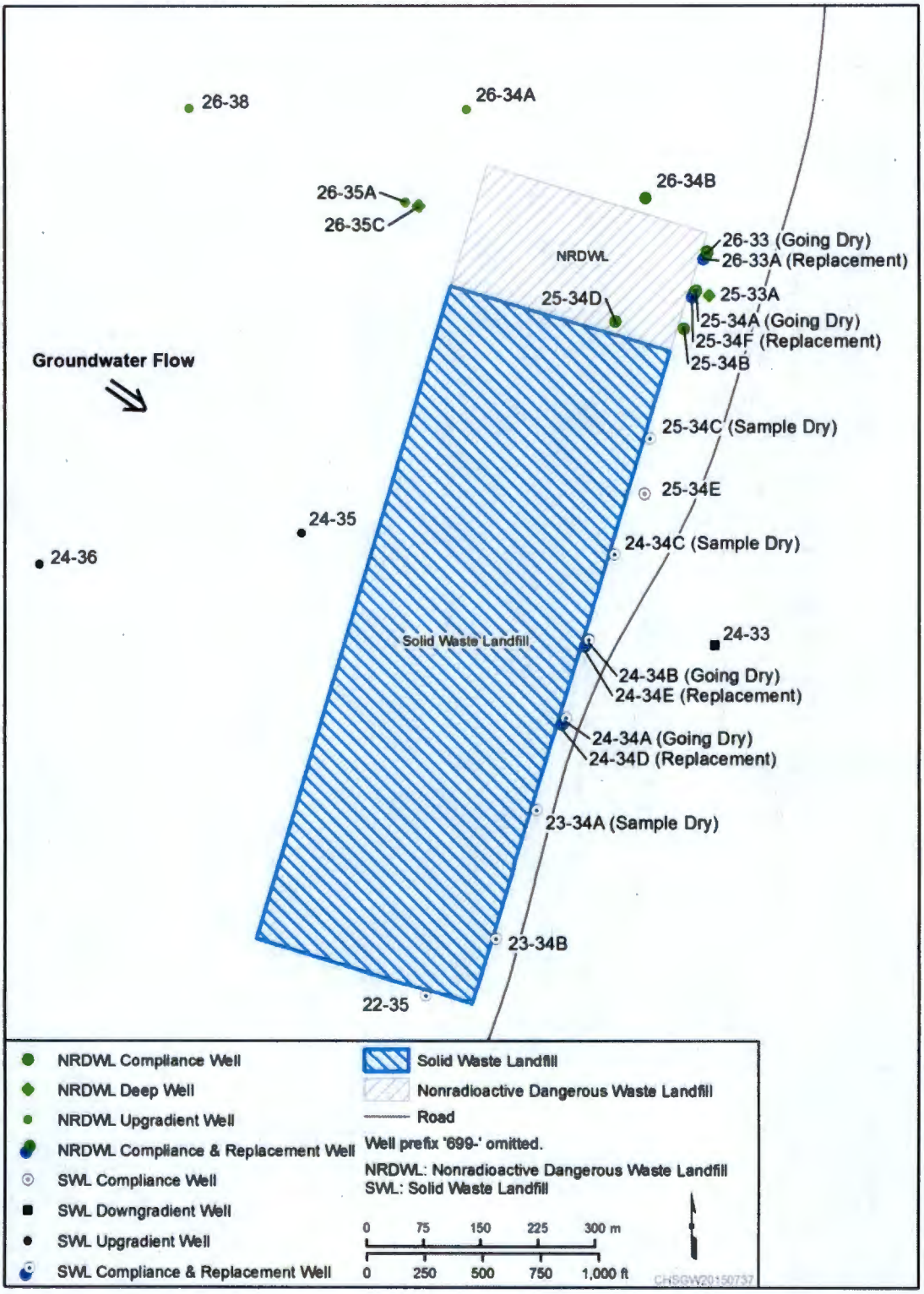

Figure 2-4. Monitoring Wells in the Vicinity of SWL and NRDWL

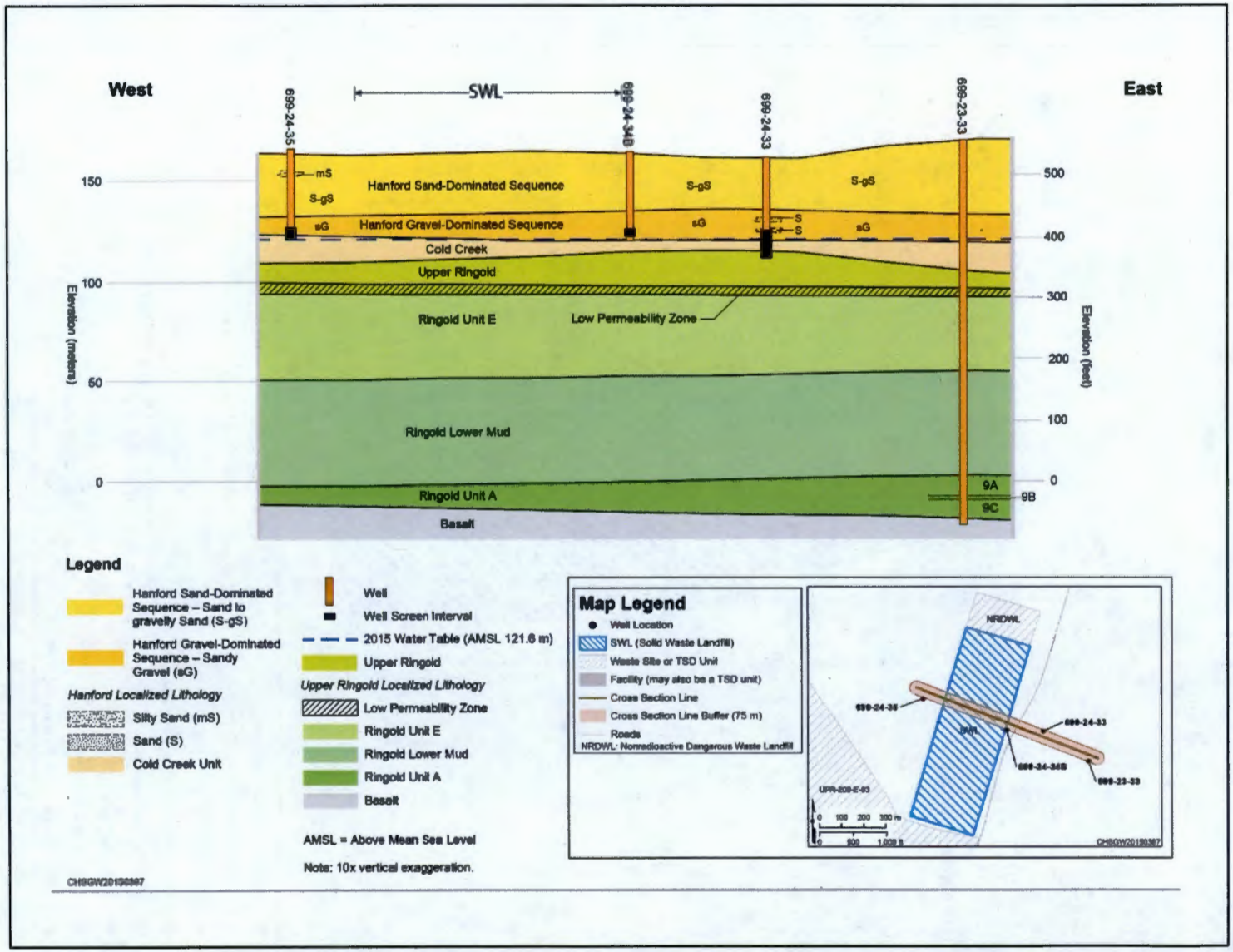

Figure 2-5. West-East Cross-Section Looking North Showing Stratigraphy Underlying SWL

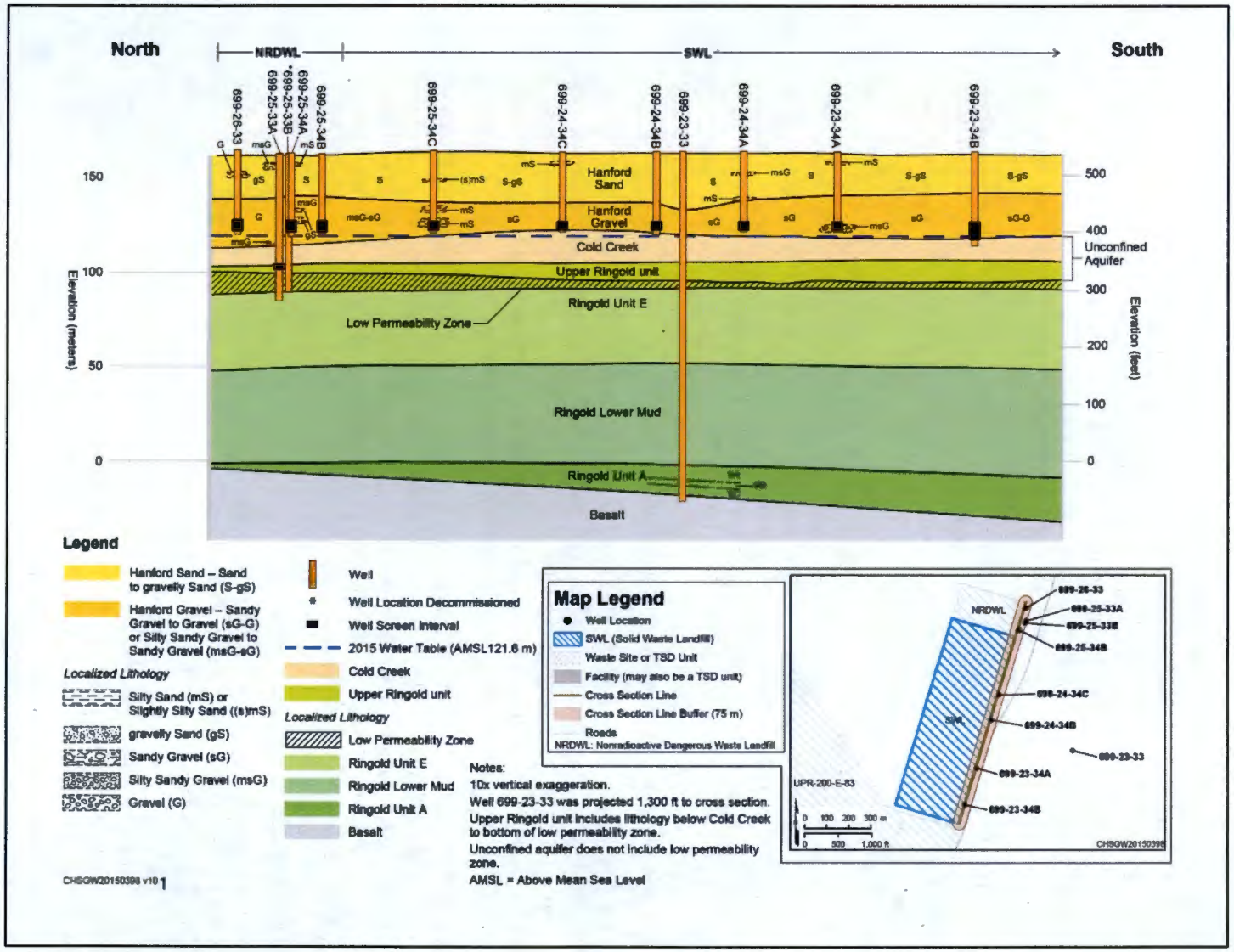

Figure 2-6. North-South Cross-Section Looking East Showing Stratigraphy Underlying SWL and NRDWL

Geologic cross-sections that include selected wells near SWL and NRDWL show the stratigraphy underlying and adjacent to the landfill (Figures 2-5 and 2-6).

2.4.2 Hydrogeology

Groundwater in the unconfined aquifer beneath SWL, as well as groundwater below a local confining unit (the lower permeability unit), is discussed in this section.

The water table beneath SWL is near the top of a silty sand unit in the lower portion of the Hanford formation or in the upper portion of the CCU (Figures 2-3, 2-5, and 2-6). The uppermost aquifer is unconfined and comprises saturated Hanford sediments and the CCU. The saturated Hanford and CCU sediments are gravelly sand to sandy gravel, approximately 18 m (59 ft) thick. The upper Ringold underlying the Hanford sediments is slightly silty gravelly sand to sand, approximately 4 m (13 ft) to 12 m (39 ft) thick. The average hydraulic conductivity of the uppermost unconfined aquifer is a composite of both of these units and is estimated at 520 to 1,500 m/day (1,706 to 4,921 ft/day) (WHC-EP-0021). A low-permeability unit in the upper Ringold locally forms the base of the uppermost aquifer because its hydraulic conductivity is orders of magnitude lower than the overlying sediments. It consists of hard, clayey silt and cemented gravels, which are approximately 12 m (39 ft) thick on the east side of NRDWL and approximately 4 m (16 ft) thick on the west side of NRDWL (DOE/RL-2015-32, *RCRA Interim Status Groundwater Monitoring Plan for the Nonradioactive Dangerous Waste Landfill*). The vertical hydraulic conductivity is estimated to range from 0.00009 to 0.0006 m/day (0.0003 to 0.002 ft/day) (WHC-EP-0021) based on laboratory analysis. The low-permeability unit is believed to be continuous across the NRDWL and SWL area because it is apparent in deep wells 699-25-33A and 699-26-35D at NRDWL (DOE/RL-2015-32) and is approximately 3 m (10 ft) thick to the east side of SWL as indicated in well 699-23-33 (Figure 2-5). However, no wells have been drilled deep enough to verify its presence immediately west of SWL.

Silty sand to sandy gravel of the Ringold Unit E underlies the low-permeability unit (HSU 4), has a hydraulic conductivity of approximately 0.3 to 15 m/day (1 to 49 ft/day), and acts as a locally confined aquifer (Figure 2-3). The Ringold lower mud unit is below the Ringold Unit E throughout much of the Hanford Site. Columbia River Basalt Group underlies the Ringold Formation. Aquifers in the basalt and below are generally confined by the dense interiors of the basalt flows.

Two wells (699-26-35C and 699-25-33A) at NRDWL (Figure 2-4) sample the bottom of the uppermost aquifer, just above the low-permeability interval. Hydraulic heads in these wells are virtually the same as found in adjacent wells completed at the top of the aquifer, indicating very low to no vertical gradient. Because of the proximity of these two wells to SWL, the vertical gradient throughout the unconfined aquifer at SWL is assumed to be similar.

2.4.3 Groundwater Flow Interpretation

Recent efforts to improve the accuracy of the water level measurements and resulting estimates of groundwater gradient near SWL included resurveys of well casings, gyroscope surveys of the wellbores, high resolution water level measurements, and consideration of barometric effects (DOE/RL-2014-32). The results of this evaluation indicated the average hydraulic gradient from January 2011 to March 2013 was 3.3×10^{-5} m/m (10×10^{-5} ft/ft), and the flow direction was 101 degrees azimuth (east-southeast). In 2014, the flow direction was determined to have an azimuth of 125 degrees (southeast) with a hydraulic gradient of 2.4×10^{-5} m/m (7.9×10^{-5} ft/ft). The flow direction determined at SWL and NRDWL (Figure 2-7) is consistent with the southeastward flow direction indicated by historical and recent tritium and iodine-129 plume migration in the 200-PO-1 far field area (DOE/RL-2015-07).

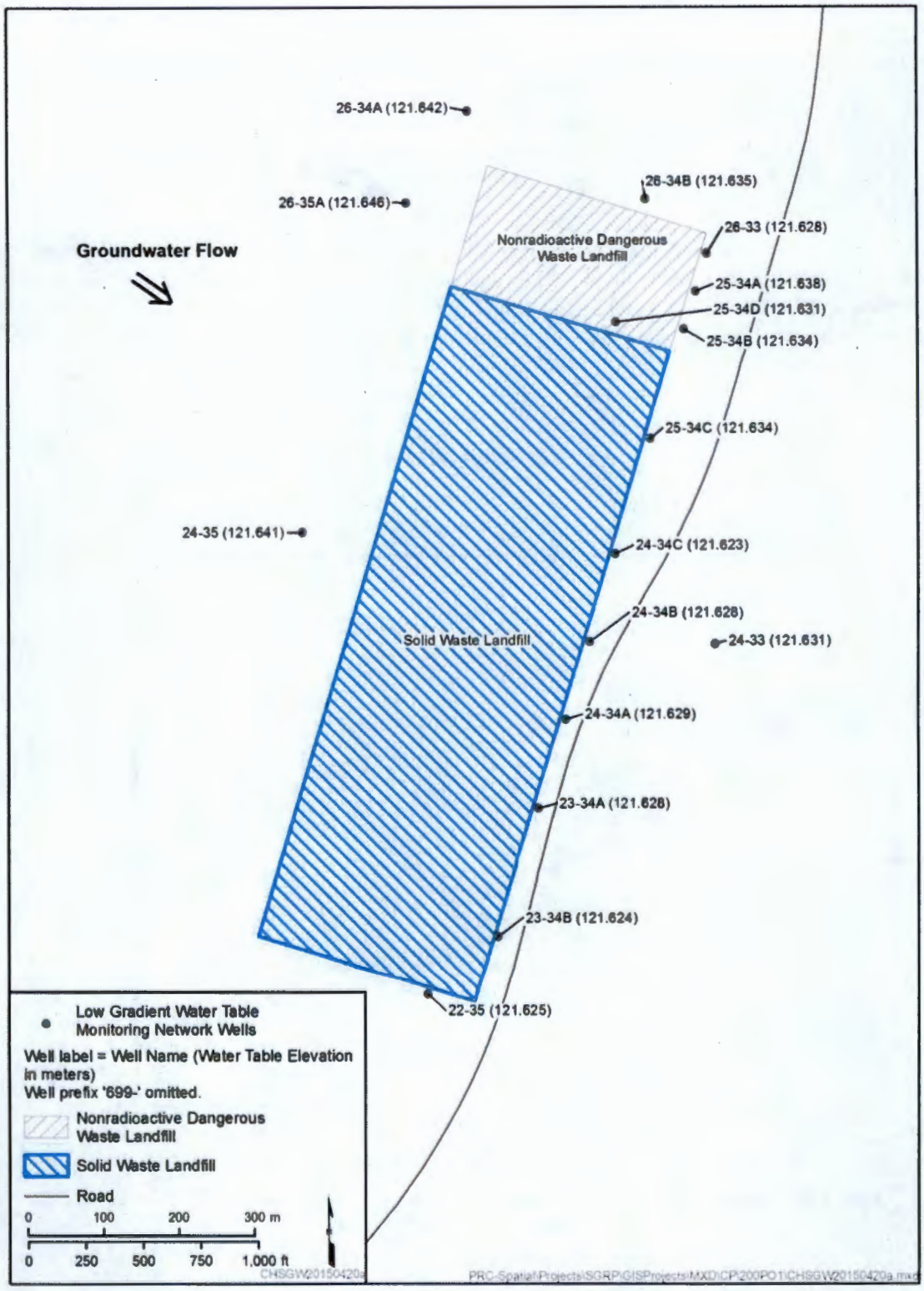

Figure 2-7. 2014 Low Gradient Water Table Monitoring Network Results at SWL and NRDWL

Using the standard Darcy equation, the groundwater flow rate beneath SWL is calculated to range from 0.12 to 0.37 m/day (0.39 to 1.21 ft/day), based on a hydraulic conductivity range of 518 to 1,524 m/day (1,699 to 5,000 ft/day) and an assumed effective porosity of 0.1. The average water level elevation at the landfill in March 2014 was 121.63 m (398.95 ft; NAVD88, *North American Vertical Datum of 1988*), which is 0.12 m (0.39 ft) less than the elevation measured in the southern portion of the 200 East Area (121.75 m [399.34 ft] NAVD88 for March 2014), over a distance of approximately 6.4 km (4 mi). This yields a regional hydraulic gradient of 1.88×10^{-5} m/m (1.88×10^{-5} ft/ft) between the 200 East Area and SWL.

The water table directly beneath the NRDWL and SWL area is relatively flat, with an elevation head ranging between 121.624 and 121.646 m (399.05 and 399.12 ft). The rate of water level decline near SWL and NRDWL has decreased in the last 5 years (Figure 2-8). Between April 2010 and April 2015, water table elevations within SWL and NRDWL network wells have shown a decrease of only about 0.13 m (0.43 ft).

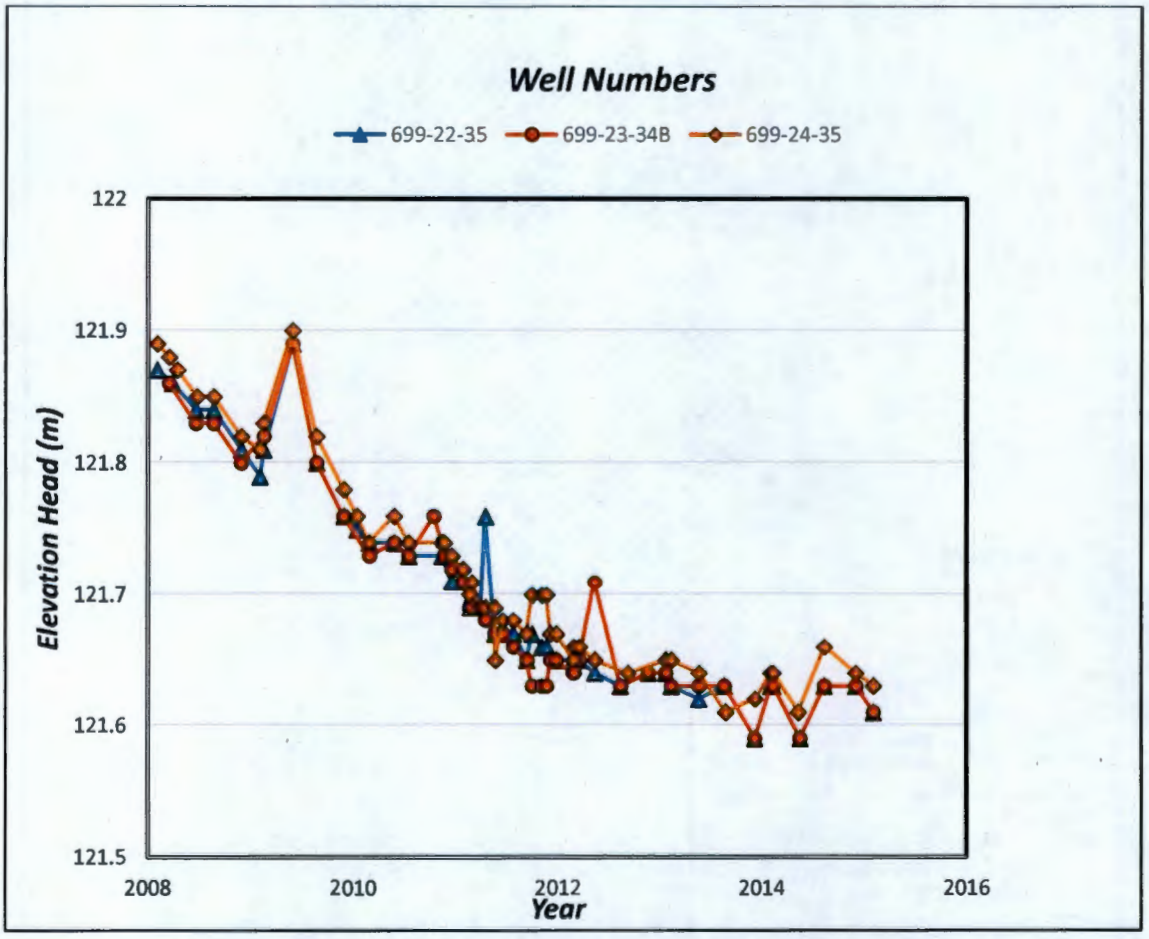

Figure 2-8. Changes in Water Table Elevation Between April 2008 and April 2015 for Three SWL Groundwater Monitoring Wells

2.5 Summary of Previous Groundwater Monitoring

Table 2-1 lists the previous groundwater monitoring plans implemented at SWL.

Table 2-1. Previous Monitoring Plans

Document	Date Issued	Monitoring Program*
PNL-6930, *Compliance Ground-Water Monitoring Plan for the Hanford Site Solid Waste Landfill*	1986	Groundwater Monitoring – Sampling and Analysis
WHC-SD-EN-AP-043, *Groundwater Monitoring Plan for the Solid Waste Landfill, Hanford, Washington*	1993 (Rev. 0) 1996 (Rev. 0A)	Groundwater Monitoring – Sampling and Analysis
PNNL-13014, *Groundwater Monitoring Plan for the Solid Waste Landfill*	2000	Groundwater Monitoring – Sampling and Analysis

* The groundwater monitoring program at Solid Waste Landfill satisfied the monitoring requirement under WAC 173-304-490 "Minimum Functional Standards for Solid Waste Handling," "Groundwater Monitoring Requirements."

Groundwater monitoring was initiated at SWL in 1987 in accordance with PNL-6930. This detection level monitoring plan included quarterly sampling at six new wells. Five downgradient wells (699-23-34A, 366-24-34A, 699-24-34B, 699-24-34C, and 699-25-34C) and one upgradient well (699-24-35) were completed by April 1987. Constituents required by WAC 173-304-490 (temperature, conductivity, pH, chloride, nitrate, nitrite, ammonia as nitrate, sulfate, dissolved iron, dissolved manganese, dissolved zinc, chemical oxygen demand, TOC, and total coliform) and additional site-specific total organic halides (TOX) and chlorinated hydrocarbons analyses were included for analysis.

Characterization and groundwater monitoring results obtained from the new wells and initial monitoring were reported in the 1989 (PNL-6823). Monitoring results from May 1987 indicated that carbon tetrachloride, trichloroethene, 1,1,1-trichloroethane, tetrachloroethene, and 1,1-dichloroethane were present in SWL groundwater (PNL-6823). Resampling confirmed the detections. The report recommended additional wells in the unconfined aquifer.

In 1993, an updated monitoring plan (WHC-SD-EN-AP-043, Rev. 0), issued as a revision to PNL-6930, proposed two new downgradient monitoring wells and a new deep monitoring well extending to the top of the basalt. The plan also included upgradient well 699-26-35A, which monitored NRDWL, in the SWL network. Downgradient well 699-24-33 is not a WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells," compliant well; drilled in 1948, it was included for informational purposes only. Constituents for analysis included the WAC 173-304-490 constituents and site-specific constituents (TOX, 1,1,1-trichloroethane, and trichloroethene). Downgradient wells 699-22-35 and 699-23-34B were drilled in 1993. In 1996, WHC-SD-EN-AP-043, Rev. 0A modified WHC-SD-EN-AP-043 to reflect the installation of two wells (the third proposed deep well was not installed). With these two new wells, the SWL monitoring network included eight downgradient wells (699-22-35, 699-23-34B, 699-23-34A, 699-24-33, 699-24-34A, 699-24-34B, 699-24-34C, and 699-25-34C) and two upgradient wells (699-24-35 and 699-26-35A).

The SWL monitoring plan was again revised in 2000 with PNNL-13014. The plan proposed increasing the monitoring network by adding a deeper upgradient existing well (699-26-35C) and two new, deeper downgradient wells for a total of three upgradient and ten downgradient wells. However, the proposed wells were not added to the network and the monitoring network remained unchanged.

The constituents in PNNL-13014 included those required in WAC 173-304-490 and site-specific constituents (arsenic and specified VOCs) previously detected in groundwater or leachate samples (1,1-dichloroethane, 1,2-dichloroethane, 1,1,1-trichlorethane, 1,4-dichlorobenzene, 1,4-dioxane, carbon tetrachloride, trichloroethene, and tetrachloroethene). Analysis for TOX was discontinued because site-specific analysis for volatile organics that were likely to have been disposed at SWL was already included. Arsenic was added as a site-specific constituent because it had been detected in leachate above the WAC 173-200 GWQC. The sampling frequency remained quarterly. Since 2000, PNNL-13014 has remained the controlling document for SWL groundwater monitoring.

In 2014, the SWL monitoring well network consisted of two upgradient wells (699-24-35 and 699-26-35A) and five downgradient wells (699-22-35, 699-23-34B, 699-24-33, 699-24-34A, and 699-24-34B). A sixth downgradient well (699-25-34E) was completed and sampled in 2014 (DOE/RL-2015-07). Wells 699-24-34C and 699-25-34C became sample dry prior to 2013 and 699-23-34A became dry in October 2013. Well 699-24-36 was installed in 2014 to expand the monitoring network farther upgradient. The well location was selected to detect the effect on groundwater caused by the possible presence (or absence) of vadose zone vapors, that appear to have impacted groundwater monitored by upgradient well 699-24-35.

In 2012 and 2013, detections of filtered arsenic at SWL monitoring wells ranged from 1.74 to 5.93 µg/L (DOE/RL-2013-22, *Hanford Site Groundwater Monitoring Report for 2012*) and 0.63 to 3.97 µg/L (DOE/RL-2014-32), respectively. In 2014, filtered arsenic detections ranged from 1.54 to 7.61 µg/L (DOE/RL-2015-07). The highest result in 2014 was measured in downgradient well 699-24-34A. The Hanford Site groundwater background value for arsenic is 11.8 µg/L (DOE/RL-96-61, *Hanford Site Background: Part 3, Groundwater Background*).

In 2013, chemical oxygen demand, coliform bacteria, pH, specific conductance, temperature, TOC, nitrate, and sulfate were measured at concentrations above background threshold values (BTVs) (DOE/RL-2014-32). Of these, coliform bacteria and TOC levels were elevated in both upgradient and downgradient wells. DOE/RL-2015-07 reports chemical oxygen demand, chloride, coliform bacteria, specific conductance, sulfate, temperature, and TOC levels above BTVs in 2014. Of these, coliform bacteria were above BTVs in both upgradient and downgradient wells.

As reported in DOE/RL-2014-32, twenty VOCs have been detected in samples collected from the SWL monitoring network since 2000 (DOE/RL-2014-32, Table PO.2). Five of the VOCs (1,1,1-trichloroethane, 1,1-dichloroethane, chloroform, tetrachloroethene, and trichloroethene) have been detected (or qualified as estimated) most frequently since 2000. 1,1,1-trichloroethane and tetrachloroethene had the greatest number of detections during the period (Table 2-2). VOCs have generally decreased in concentration since 2000 (DOE/RL-2014-32). In 2014, these five VOCs were detected at low concentrations that were qualified as estimated values (DOE/RL-2015-07).

Table 2-2. Summary of Volatile Organic Compounds in SWL Monitoring Wells Detected at Least One Time (2000 to 2013)

Constituent	Number of Detections	Number of Detections Qualified as Estimated*	Number of Nondetects
1,1,1-Trichloroethane	327	148	203
1,1,2,2-Tetrafluoropropane	1	0	0
1,1-Dichloroethane	248	231	282
1,1-Dichloroethene	20	20	326
1,2-Dichloroethane	3	3	527
1,4-Dichlorobenzene	21	19	512
1,4-Dioxane	1	1	253
2-Butanone	1	1	480
4-Methyl-2-pentanone	1	1	480
Acetone	72	60	409
Benzene	1	1	550
Carbon Tetrachloride	17	16	513
Chloroform	125	124	405
cis-1,2-Dichloroethylene	1	1	529
Ethylbenzene	1	1	471
Methylene Chloride	59	47	460
Tetrachloroethene	347	209	183
Toluene	23	23	528
Trichloroethene	301	289	229
Xylenes (Total)	2	2	479

Source: DOE/RL-2014-32, *Hanford Site Groundwater Monitoring Report for 2013* (Table PO.2)

* Flagged J (greater than method detection limit but less than practical quantitation limit).

SWL groundwater monitoring activities under this plan sample from a network of two upgradient wells (699-24-35 and 699-26-36) and six downgradient wells (699-22-35, 699-23-34B, 699-24-33, 699-24-34A, 699-24-34B, and 699-25-34E). Results from well 699-24-33 will be used for supporting information only. Samples are analyzed semiannually for geochemical indicator parameters, field parameters, and site-specific constituents. Water level measurements are collected each time a sample is obtained from a network well. The network wells are also included in the annual comprehensive March water level measurement campaign (SGW-38815, *Water-Level Monitoring Plan for the Hanford Site Soil and Groundwater Remediation Project*). Groundwater monitoring results are summarized annually for SWL in the annual Hanford Site groundwater monitoring report (e.g., DOE/RL-2015-07).

2.6 Conceptual Site Model

This section describes the SWL CSM to guide future groundwater monitoring. The CSM describes the current understanding of contaminant release and transport mechanisms at SWL. Data and analyses presented in several previous studies associated with SWL and adjacent NRDWL were used for the CSM presented here. The following documents were reviewed and drawn upon:

- 05-AMRC-0130, "Hanford Solid Waste Landfill Annual Monitoring Report"
- 09-AMCP-0010, "Solid Waste Landfill Annual Monitoring Report, July 2007 through June 2008"
- 10-AMCP-0106, "Hanford Site Solid Waste Landfill Annual Monitoring Report, July 2008 through September 2009"
- 12-AMCP-0079, "Hanford Site Solid Waste Landfill Annual Monitoring Report, October 2010 through September 2011"
- BHI-01063, *Conceptual Site Models for Solid Waste Landfill*
- BHI-01115, *Evaluation of the Soil-Gas Survey at the Nonradioactive Dangerous Waste Landfill*
- DOE/RL-90-38, Rev. 1, *Hanford Site Solid Waste Landfill Interim Closure Plan*
- DOE/RL-93-88, *Annual Report for RCRA Groundwater Monitoring Projects at Hanford Site Facilities for 1993*
- DOE/RL-96-81, *Waste Site Grouping for 200 Area Soil Investigations*
- DOE/RL-2010-28, *Groundwater Monitoring Plan for the Nonradioactive Dangerous Waste Landfill and Solid Waste Landfill*
- FH-0502966, "PHMC Section C.4.2 – Submittal of Solid Waste Landfill Annual Monitoring Report"
- Maher et al., 2003, "Vadose zone infiltration rate at Hanford, Washington inferred from Sr isotope measurements"
- Pankow and Cherry, 1996, *Dense Chlorinated Solvents and other DNAPLs in Groundwater: History, Behavior, and Remediation*
- PNL-5377, *Moisture and Textural Variations in Unsaturated Soils/Sediments Near the Hanford Wye Barricade*
- PNL-7147, *Final Report: Soil-Gas Survey at the Solid Waste Landfill*
- WHC-SD-EN-TI-199, *Nonradioactive Dangerous Waste Landfill Soil-Gas Survey: Final Data Report*

The vadose zone beneath SWL was impacted by sewage from chemical toilets and 1100 Area catch tank liquid (washwater containing VOCs from vehicles) that were discharged to the SWL liquid waste trenches (DOE/RL-2010-28). From 1973 to 1987, liquids (including sewage and 1100 Area catch tank liquids) were discharged to SWL in separate, shallow trenches dedicated for this purpose. The sewage originated from portable toilets and septic tanks.

An estimated 3,800,000 to 5,700,000 L (1,003,850 to 1,505,780 gal) of sewage were discharged to the liquid trenches from 1975 to April 1987 (Figure 2-1). Nondangerous catch tank liquid from the 1100 Area heavy equipment garage and bus shop was also disposed in these trenches from 1985 to 1987. For the two years that nondangerous catch tank waste liquid was disposed at SWL, the estimated total volume of catch tank waste liquid disposed was 380,000 L (100,385 gal) (DOE/RL-90-38, Rev. 1).

The available chemical analysis of the 1100 Area nondangerous catch liquid detected the following VOCs (DOE/RL-90-38, Rev. 1, 1993, Appendix 4E):

- **Carbon tetrachloride:** Heavy equipment garage, 5.5 and 18 μg/L; bus shop, 31 and <60 μg/L
- **1,1,1-Trichloroethane:** Heavy equipment garage, 208 μg/L; bus shop, 87 μg/L
- **Trichloroethene:** Heavy equipment garage, <10 μg/L; bus shop <40 μg/L
- **Tetrachloroethene:** Heavy equipment garage, 26 μg/L; bus shop <60 μg/L

The volume of pore space beneath the SWL trenches (to the water table) is approximately 26,380 m^3 (6,968,859 gal), assuming 25 percent pore space in the vadose zone sediment (2,638 m^2 [28,395 ft^2] for the area of the liquid waste trenches and 40 m (131 ft) to the water table). The volume of waste is approximately 6,000 m^3 (1,585,032 gal). With the total volume of wastewater less than one-fourth of the available pore volume beneath the SWL liquid waste trenches, it is unlikely that liquid waste discharges migrated to the water table as saturated flow. Considering the relatively large pore volume beneath SWL compared to the liquid volume disposed, the impact to groundwater from waste disposed within SWL facilities is likely limited to that which can be transported by soil vapor.

In 1997, a detailed evaluation of the available soil gas and SWL groundwater data was conducted in order to prepare a conceptual model (BHI-01063). The purpose for developing the 1997 conceptual model was to assess the nature and extent of VOC contamination in support of a plan for SWL closure. Key elements of the evaluation conducted and the conceptual model that was developed included an analysis of contaminant characteristics as well as contaminant movement and distribution. The content provided in BHI-01063 study is summarized in the following sections.

2.6.1 Contaminant Characteristics

The primary contaminants of concern at SWL in 1997, based on their detection in downgradient groundwater wells, were 1,1,1-trichloroethane, 1,1-dichloroethane, trichloroethene, tetrachloroethene, carbon tetrachloride, and chloroform. As organic liquids, these compounds are referred to as DNAPLs because they are denser than water and exhibit low absolute solubility in water. In general, chlorinated solvents have relatively high vapor pressures, so they can readily partition to a vapor phase and migrate great distances in the vadose zone. Chlorinated solvents have high solubilities relative to drinking water limits. As a result, a groundwater plume exceeding drinking water limits can be caused by a small amount of contaminant (Pankow and Cherry, 1996). Although chlorinated hydrocarbons have low absolute solubilities, the groundwater contamination will typically be in excess of the GWQC set forth in WAC 173-200, and even relatively small quantities of these compounds in the subsurface can result in groundwater contamination problems (Pankow and Cherry, 1996).

If a contaminant tends to partition from the aqueous phase to the solid phase (e.g., by sorption onto the surface of a soil particle), its mobility in the subsurface is reduced. For chlorinated solvents, sorption is generally low except in soils with high organic carbon content. Because Hanford Site soils have low inorganic carbon content, chlorinated solvents are not highly sorbed and tend to have a high mobility. In general, the more soluble compounds in water (e.g., chloroform) are less likely to adhere to soils, while the less soluble compounds (e.g., tetrachloroethene) will sorb more strongly to soils (DOE/RL-96-81).

Contaminants can partition from the vapor phase to the solid phase only if the unsaturated zone is very dry; otherwise, the soil grains are completely covered with a thin film of water, and sorption only occurs from the aqueous phase to the solid phase. Very dry soils rarely exist to any significant depth in the unsaturated zone, and the vapor solid partitioning is generally not important (Pankow and Cherry, 1996).

The persistence of chlorinated solvents is affected by biodegradation and volatility. Biodegradation of water soluble organics is more rapid under the oxidizing conditions found in Hanford Site soils, whereas the rate of biodegradation of the less soluble organics tends to be very slow. Increased volatility generally decreases the persistence of chlorinated solvents (DOE/RL-96-81).

2.6.2 Contaminant Movement and Distribution

In the vapor phase, a contaminant can be transported in the vadose zone through diffusion or through advective flow driven by pressure gradients caused by fluctuations in barometric pressure ("barometric pumping"). The vapor can migrate out of the vadose zone across the soil atmosphere and soil groundwater interfaces and can migrate within the vadose zone in all directions, including upgradient relative to groundwater flow. The vapor can dissolve into soil moisture, migrating waste liquids and precipitation, and/or groundwater. In the aqueous phase within the vadose zone, contaminants migrate downward to groundwater with potential lateral spreading caused by permeability differences between soil layers. In the aqueous phase within the saturated zone, the contaminants migrate downgradient with groundwater flow.

DNAPLs in the vadose zone can volatilize to the vapor phase or dissolve into the soil moisture (aqueous phase), and generally leave residual contamination in zones through which they have migrated. Soil that is saturated with a pure liquid DNAPL will have an associated equilibrium vapor concentration, as indicated in Table 2-3 (saturated vapor concentration). The low vapor concentrations observed during soil gas surveys and perimeter monitoring (less than $1/100^{th}$ of the equilibrium value) suggest that pure phase DNAPLs are not present (although the presence of this phase cannot be conclusively ruled out). VOCs will partition between the aqueous and vapor phases in proportions that depend on their individual aqueous solubilities and vapor pressures. In the absence of forced advection (e.g., soil vapor extraction), the assumption of equilibrium partitioning between the gaseous and aqueous phase appears to be valid for chlorinated solvent compounds in the unsaturated zone (Pankow and Cherry, 1996).

DOE/RL-93-88 (Section 5.3) considered the following evidence for and against several possible sources of contaminants at SWL:

- Chlorinated hydrocarbons dissolved in bus and heavy equipment washwater
- Undocumented disposal of chlorinated hydrocarbons in solid waste trenches
- Chlorinated hydrocarbons included in sewage sludge
- Chlorinated hydrocarbons migrating from NRDWL

Table 2-3. Physical Properties of the Primary Volatile Organic Compounds at SWL

Property (at 25°C)	Units	1,1,1-Trichloroethane	Trichloroethene	Tetrachloroethene	Carbon Tetrachloride	Chloroform	1,1- Dichloroethane
Molecular Weight	N/A	133.4	131.5	165.8	153.8	119.4	99
Liquid Density	g/cm^3	1.35	1.46	1.63	1.59	1.49	1.17
Vapor Pressure	mm Mercury	124.6	75	18.9	109	194	221
Saturated Vapor Concentration	ppmv	160,000	100,000	20,000	140,000	260,000	290,000
Relative Vapor Density	N/A	1.59	1.35	1.12	1.62	1.80	1.70
Henry's Law Constant	Atmosphere m^3/mol	0.0167	0.00937	0.0174	0.0298	0.00358	0.00543
Solubility	mg/L	1,309.6	1,384.9	236.96	740.21	8,513.5	5,301.7
1 ppmv*	mg/m^3 (20°C)	5.55	5.46	6.89	6.39	4.96	4.12
DNAPL	N/A	Y	Y	Y	Y	Y	Y

Source: Adapted from BHI-01063, *Conceptual Site Models for Solid Waste Landfill*, Table 4-1 (with data from Pankow and Cherry, 1996, *Dense Chlorinated Solvents and other DNAPLs in Groundwater: History, Behavior, and Remediation*, unless otherwise noted.)

* NIOSH Publication 2005-149, *NIOSH Pocket Guide to Chemical Hazards*.

DNAPL = dense nonaqueous phase liquid
N/A = not applicable
ppmv = part per million by volume
Y = chemical is a DNAPL at 25°C (77°F)

DOE/RL-93-88 (Section 5.3) concluded that the catch tank water is, at most, a minor contributor to the groundwater contamination, there is strong evidence of one or more undocumented sources of chlorinated hydrocarbons beneath SWL, and NRDWL is probably not the source of contaminants observed at SWL. The spatial correspondence between high concentrations of chlorinated hydrocarbons and carbon dioxide in soil gas may indicate that the chlorinated hydrocarbons are dissolved in an aqueous sewage phase that is migrating within the vadose zone. In this case, the chlorinated hydrocarbon waste could have been discharged to the soil column along with the sewage waste or could have mixed with it after disposal (DOE/RL-93-88, Section 5.3).

Since liquid waste disposal ceased in 1987, the driving force for liquid waste migration to groundwater has decreased. The liquid waste discharged to the soil column will continue to move downward slowly under the force of gravity and be retained in the vadose zone at residual saturations. The residual liquid can volatilize contaminants to the vapor phase, and either the vapor phase or aqueous phase can mix with precipitation migrating downward. Contaminants dissolved in the liquid phase may be sorbed onto soil particle surfaces. As indicated by the lysimeter leachate data, precipitation is a continuing source of infiltrating water that moves downward through the SWL trenches toward groundwater.

As reported in WHC-EP-0021, predictions for travel time to groundwater were made in the 1985. The travel time calculated was 46 years based on a conservative assumption for recharge of 5.6 cm/yr (2.2 in./yr). A recharge rate between less than 0.5 cm/yr and 5.6 cm/yr (0.2 in./yr and 2.2 in./yr) has been estimated from lysimeter studies at the Hanford Site (WHC-EP-0021). PNL-5377 estimated travel times from soil surface to the water table of between 93 and 886 years at a location about 3.2 km (2 m) southeast of the SWL/NRDWL site. Site-specific hydraulic characteristics for the unsaturated zone and recharge rates of 0.5 cm/yr and 5.0 cm/yr (0.2 in./yr and 2.0 in./yr) were used for the calculations. More recent estimates of infiltration rates at the Hanford Site based on lysimeter, mass balance or isotopic data indicate a range from 0.01 mm/yr to 90 mm/yr (0.0004 in./yr to 3.6 in./yr). Models suggest that the infiltration flux for the site is 7 ± 3 mm/yr (0.3 ± 0.1 in./yr) (Maher, et al., 2003).

Comparison of the measured soil gas concentrations to the maximum theoretical soil gas that could be volatilizing from an aqueous phase suggests that (1) the observed soil gas concentrations could not be produced by volatilization from the groundwater, but soil gas could be a transport mechanism for contaminants to groundwater and (2) soil gas could be a transport mechanism for contaminants from leachate. Vapor remaining in the vadose zone, from either a vapor source or volatilizing from residual soil moisture, will continue to migrate due to diffusion and barometric pumping. In fact, barometric pumping through well 699-24-33, a downgradient well and the only well at site until 1986, may have helped draw soil vapor in the downgradient direction. As reported in BHI-01063, barometric pumping also enhances the vapor phase molecular diffusion process. Chlorinated hydrocarbon contaminants in groundwater in upgradient wells probably resulted from vadose zone vapor migration (BHI-01063).

Subsequent to the BHI-01063 study, two possibilities for the source and transport mechanism of the chlorinated hydrocarbon contamination in groundwater beneath SWL and NRDWL were identified in DOE/RL-2010-28. The source was thought most likely to be SWL trenches that were known to have received chlorinated hydrocarbon wastes. The contaminants may have had a liquid source from the SWL trenches, traveling through the vadose zone laterally and vertically until reaching the groundwater. Secondly, these VOC contaminants would exist in the vadose zone as relatively dense vapors and would have likely traveled laterally through the vadose zone and then vertically to groundwater.

The first soil vapor survey was conducted at SWL from June 1988 through February 1989 to determine the areal extent of chlorinated hydrocarbons (PNL-7147). The survey found detectable concentrations of 1,1,1-trichlorethane, trichloroethene, tetrachloroethene, 1,1-dichloroethane, carbon tetrachloride, carbon dioxide, and methane. Concentrations of 1,1,1-trichlorethane, tetrachloroethene, and trichloroethene were detected as far as 130 m (427 ft) west and 115 m (377 ft) east of the SWL trenches. This further supports the hypothesis regarding lateral transport of contaminants by vapor migration. Low levels of these same VOCs were discovered in groundwater samples, including samples from upgradient wells. However, the vadose zone soil vapor survey results showed that the areas of relatively high soil vapor concentrations generally did not necessarily coincide with the locations of the known liquid disposal trenches (DOE/RL-2010-28). Significant movement of the contamination in the aquifer to upgradient wells cannot occur under groundwater advection alone, so lateral spreading in the vadose zone by vapor migration appears as the likely predominant transport mechanism to account for the presence of contaminants in upgradient wells. Soil vapor entering the vadose zone, near the base of the SWL trenches, could travel through the vadose zone and partition into groundwater at the water table interface (DOE/RL-2010-28).

As also noted in DOE/RL-2010-28, groundwater contaminant levels support the assertion that SWL is a likely source of contamination beneath SWL and NRDWL.

2.6.3 Carbon Dioxide and Specific Conductance

Specific conductance at SWL was steadily increasing between 1990 and 2004, but has stabilized or shown a slightly decreasing trend from 2005 to 2014. Historical concentration trends for alkalinity, calcium, magnesium, and specific conductance are similar for both adjacent upgradient and downgradient wells (Figure 2-9). Time series plots for sulfate and nitrate do not mimic the trends noted between alkalinity, calcium, magnesium, and specific conductance (Figure 2-9).

The elevated levels of alkalinity and specific conductance at SWL appear to be the result of increased levels of carbonate or bicarbonate in the groundwater (01-GWVZ-025, "Results of Assessment at the Non-Radioactive Dangerous Waste Landfill (NRDWL)"; DOE/RL-2010-28). The increased carbonate concentration is the result of high carbon dioxide levels in the vadose zone as initially observed in PNL-7147 and WHC-SD-EN-TI-199. The elevated carbon dioxide levels in the vadose zone apparently are the result from the breakdown of sewage beneath SWL under oxidizing conditions. Carbon dioxide typically comprises 40 to 60 percent of landfill gases. Carbon dioxide lowers groundwater pH and affects anion/cation balance (i.e., raise calcium and magnesium concentrations), which in turn, raises specific conductance. A lower pH results in enhanced dissolution of certain minerals such as calcium carbonate, that are typically abundant in arid environments, thereby raising the concentrations of cations. The major effect of this process is an increase in the hardness of the groundwater (e.g., calcium carbonate [DOE/RL-94-143]), which is also responsible for raising the specific conductance (DOE/RL-93-88 [Section 5.3], PNL-7147, and WHC-SD-EN-TI-199). The source of high specific conductance appears to primarily be attributable to calcium, magnesium, and bicarbonate. The specific conductance levels measured at SWL may also be somewhat effected by the local sulfate and nitrate concentrations. All of these constituents are nonhazardous.

Dissemination of carbon dioxide is suspected to be occurring in patterns similar to VOCs, with higher levels found under SWL and concentrations decreasing to the north underlying NRDWL (Figure 2-10). With respect to generation of soil gases, SWL appears to have stabilized, based on initially collected data in 1988 and 1989, and data collected at the eight existing soil gas monitoring stations since 1993.

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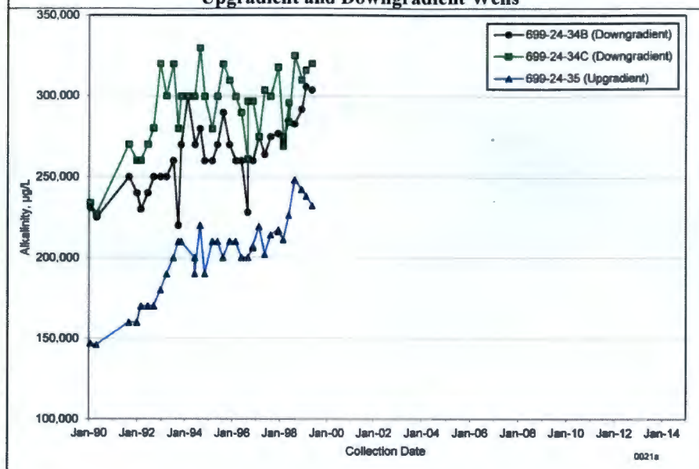
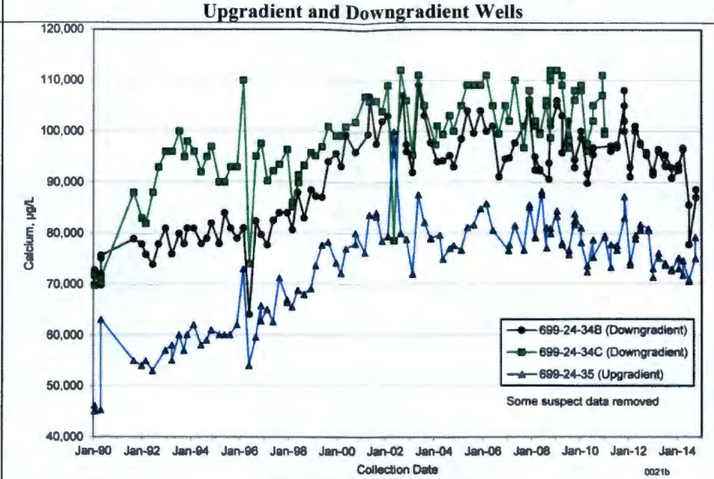
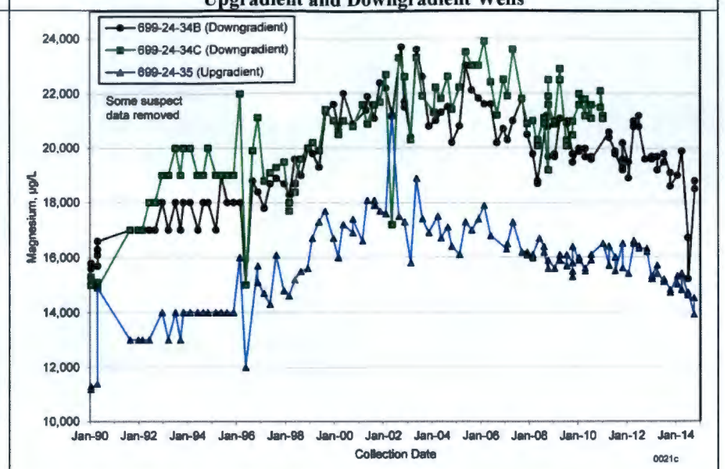
Alkalinity Concentration Trending from 1990 to 2008 for Adjacent SWL Upgradient and Downgradient Wells



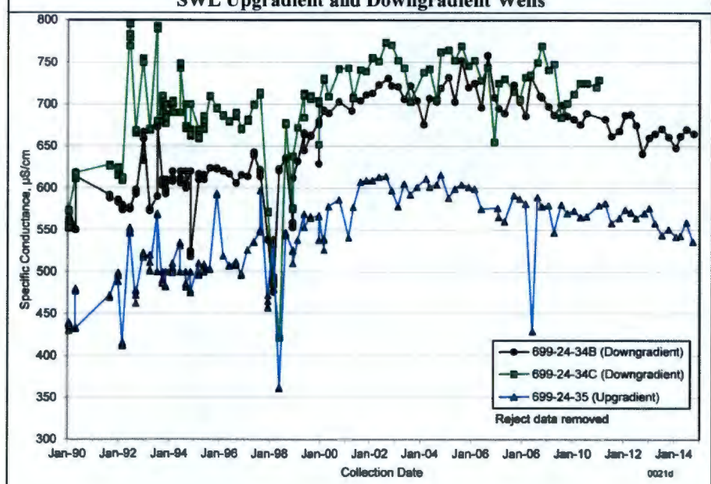
Calcium Concentration Trending from 1990 to 2014 for Adjacent SWL Upgradient and Downgradient Wells



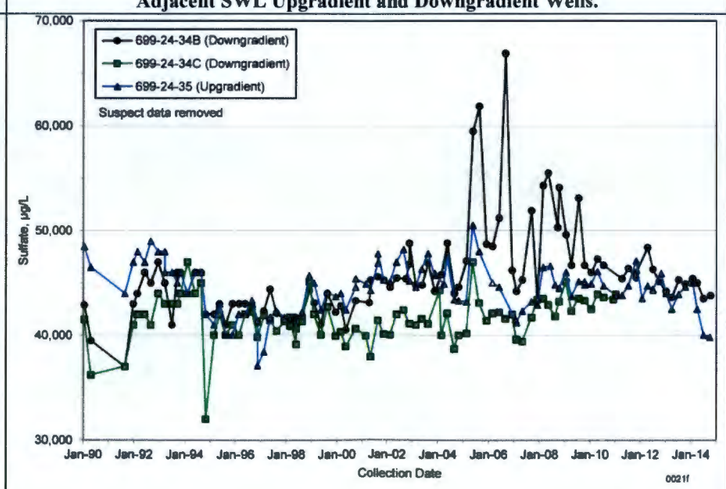
Magnesium Concentration Trending from 1990 to 2014 for Adjacent SWL Upgradient and Downgradient Wells



Specific Conductance Concentration Trending from 1990 to 2014 for Adjacent SWL Upgradient and Downgradient Wells



Sulfate Concentration Trending from 1990 to 2014 for Adjacent SWL Upgradient and Downgradient Wells.



Nitrate Concentration Trending from 1990 to 2014 for Adjacent SWL Upgradient and Downgradient Wells

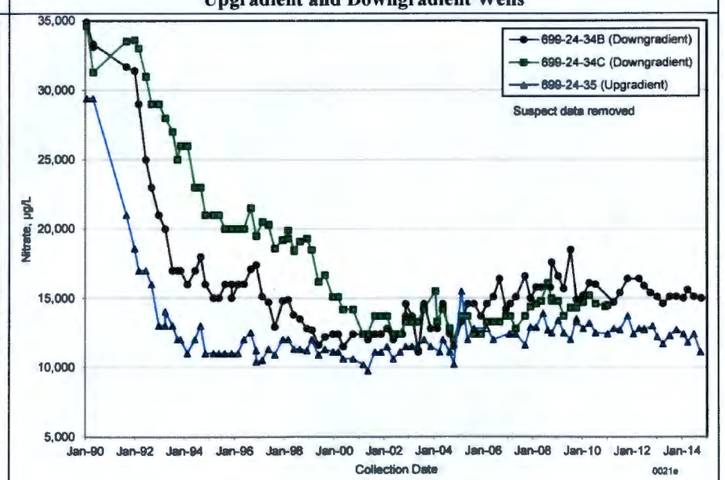


Figure 2-9. Time Series Plots Showing the Trending of Alkalinity, Calcium, Magnesium, Specific Conductance, Sulfate and Nitrate for SWL Upgradient and Downgradient Wells

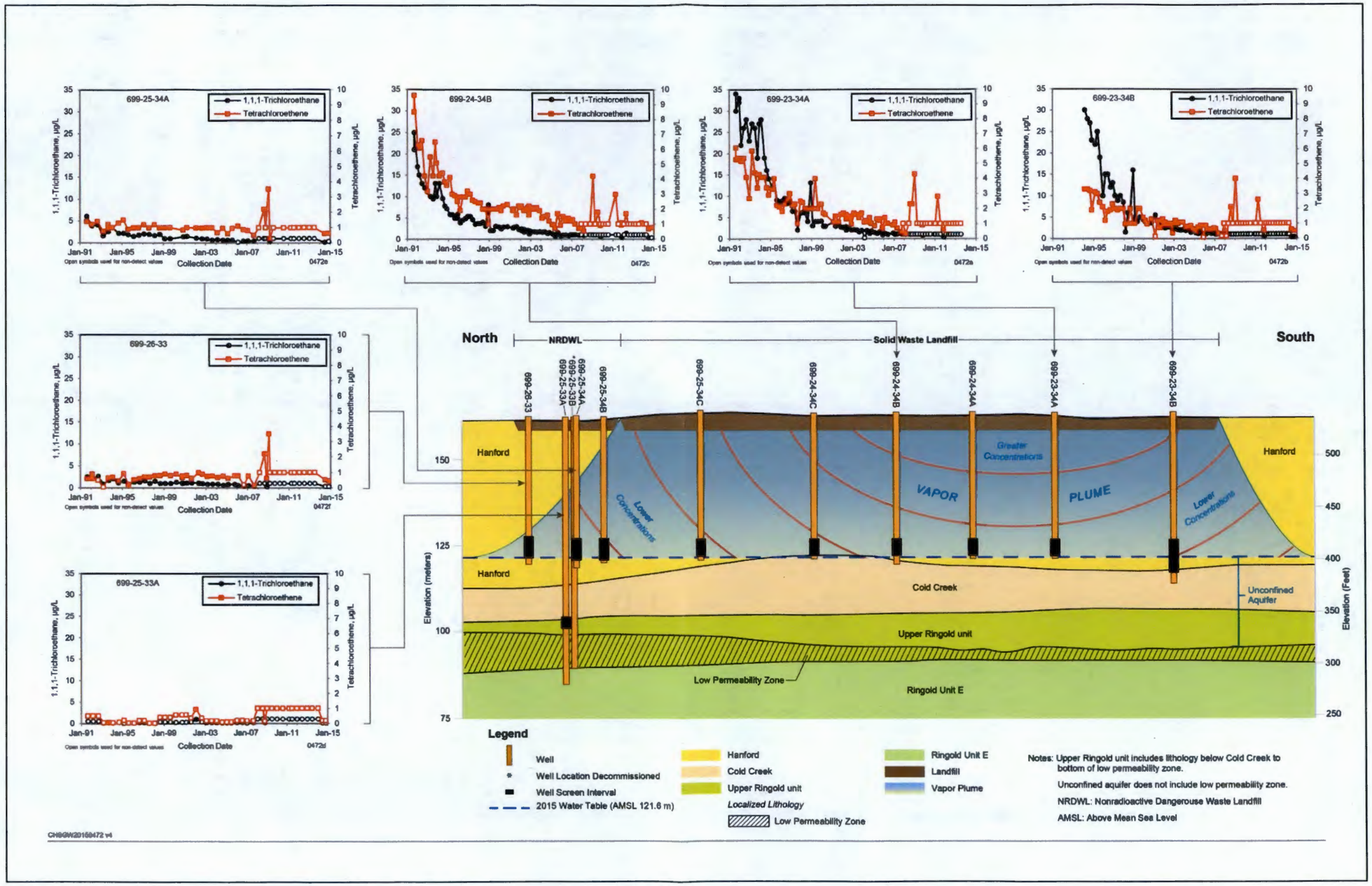


Figure 2-10. Conceptualization of Vapor Plume Dissemination and Measured 1,1,1-Trichloroethane and Tetrachloroethene Concentrations in Groundwater Underlying SWL and NRDWL

The CSM for SWL includes the following known site characteristics and assumptions pertinent to future groundwater monitoring activities:

- Sediments of the Hanford formation and CCU are relatively permeable and readily allow transport of both vadose zone soil gas and groundwater.
- The unconfined aquifer occurs in the Hanford formation, CCU, and Ringold Formation above the low permeability unit in upper Ringold. The water table is within the lower portion of the Hanford formation or CCU.
- Regionally, groundwater flows toward the southeast. The flow directly beneath the landfill is also southeast. The hydraulic gradient in the immediate vicinity of SWL is extremely low, calculated at 2.4×10^{-5} m/m using the low gradient monitoring network and trend surface analysis.
- The same chlorinated hydrocarbons detected in soil gas samples in the vadose zone are also detected in groundwater. VOCs and other soil gases (e.g., carbon dioxide) from liquid sources in the SWL disposal trenches move within the vadose zone via vapor transport. Upon reaching the vadose zone/groundwater interface, soil gases partition from vapor to liquid state and mix with groundwater (Figure 2-10).
- Trend plots for tetrachloroethene and 1,1,1-trichlorethane show the declining trends of the two most consistently detected VOCs in SWL wells (Figure 2-10). Comparison of 1,1,1-trichlorethane and tetrachloroethene concentrations in SWL wells 699-23-34A and 699-24-34B and NRDWL wells 699-25-34A and 699-26-33 (Figure 2-10) demonstrated the differences in downgradient environment for SWL and NRDWL wells. The 1,1,1-trichlorethane and tetrachloroethene levels in downgradient SWL wells have historically been much higher than levels in NRDWL downgradient wells. Higher historical groundwater concentrations at SWL appear to be attributable to proximity to higher concentration portions of the VOC vapor plume.
- Constituents continue to be detected in the upper portion of the unconfined aquifer. Currently, chlorinated hydrocarbon levels measured in soil gas and groundwater are at low concentrations or below method detection limits and will probably continue this trend.
- VOCs are not detected in the two deeper wells (699-26-35C and 699-25-33A) at NRDWL that are screened at the base of the unconfined aquifer just above the low permeability zone. The vertical distribution of contaminants at SWL is assumed to be similar.
- Elevated specific conductance and alkalinity in groundwater appears to be related to carbon dioxide levels in the vadose zone. Elevated carbon dioxide concentrations in the vadose zone apparently are the result from the breakdown of sewage beneath SWL under oxidizing conditions. When reaching groundwater carbon dioxide affects pH and anion/cation balance in the aquifer, partitioning of carbon dioxide into groundwater results in a decrease in pH, promoting dissolution of minerals and thereby increasing the cation concentrations (predominantly calcium and magnesium) The increase in cations results in elevated specific conductance levels (Figure 2-9). Impact of carbon dioxide at depth has diminished in recent years as indicated by stabile or decreasing specific conductance levels.
- Potential contaminants remain in the landfill; therefore, contaminant migration from the landfill has the potential to affect groundwater.

2.7 Monitoring Objectives

The groundwater monitoring program at SWL is conducted with the objectives of determining the facility's impact, if any, on the quality of the underlying groundwater and complying with applicable requirements for a post-operational landfill. The regulatory requirements applicable to this groundwater monitoring plan are found in WAC 173-350-500, which includes requirements for proposed landfills such as site characterization and groundwater monitoring system design. Landfill operations at SWL ceased in 1996 and the site has been in the closure process since 1996 (DOE/RL-90-38, Rev. 1, 1996). Therefore, many of the requirements in WAC 173-350-500 are not applicable to SWL. The applicable requirements for groundwater monitoring of a post-operational landfill with an existing monitoring network are included in WAC 173-350-500(3), WAC 173-350-500(4), and WAC 173-350-500(5).

Table 2-4 identifies where each groundwater monitoring element of the pertinent applicable regulations is addressed within this plan. Site-specific constituents and additional monitoring objectives are also included in this plan (Table 2-5). Leachate and soil gas monitoring at SWL are conducted separately by Mission Support Alliance (MSA) (or equivalent contractor) and are not included in this plan.

Table 2-4. Pertinent Solid Waste Handling Standards Groundwater Monitoring Requirements

Groundwater Monitoring Element	Pertinent Requirement[a]	Section Where Requirement is Addressed in Monitoring Plan
Number and Location of Wells	WAC 173-350-500(3) "Groundwater Monitoring – System design": (a) The groundwater monitoring system design and report shall be submitted with the permit application and shall meet the following criteria: (i) A sufficient number of monitoring wells shall be installed at appropriate locations and depths to yield representative groundwater samples from those hydrostratigraphic units which have been identified in the site characterization as the earliest potential contaminant flowpaths; (ii) Represent the quality of groundwater at the point of compliance. (b) Upgradient monitoring wells (background wells) shall meet the following performance criteria: (i) Shall be installed in groundwater that has not been affected by leakage from a landfill unit c) Downgradient monitoring wells (compliance wells) shall meet the following performance criteria: (i) Represent the quality of groundwater at the point of compliance; (ii) Be installed as close as practical to the point of compliance.	Section 3.2
Well Configuration	WAC 173-350-500(3) "Groundwater Monitoring – System design": (d) All monitoring wells shall be constructed in accordance with chapter 173-160 WAC, Minimum standards for construction and maintenance of wells.	Section 3.2 and Appendix C

Table 2-4. Pertinent Solid Waste Handling Standards Groundwater Monitoring Requirements

Groundwater Monitoring Element	Pertinent Requirement[a]	Section Where Requirement is Addressed in Monitoring Plan
Parameters to be Sampled Frequency of Sampling Water Level Measurements	WAC 173-350-500(4) "Groundwater Monitoring – Sampling and Analysis Plan d) Groundwater elevations shall be measured in each monitoring well immediately prior to purging, each time groundwater is sampled. The owner or operator shall determine the rate and direction of groundwater flow each time groundwater is sampled. All groundwater elevations shall be determined by a method that ensures measurement to the one hundredth of a foot (3 mm) relative to the top of the well casing. (g) Groundwater quality shall be determined at each monitoring well at least quarterly during the active life of the solid waste facility, including closure and the postclosure period. The owner or operator may propose an alternate groundwater monitoring frequency. Groundwater monitoring frequency must be no less than semiannually. (h) All facilities shall test for the following parameters: (i) Field parameters: (A) pH; (B) Specific conductance; (C) Temperature; (D) Static water level; (ii) Geochemical indicator parameters: (A) Alkalinity (as Ca CO_3); (B) Bicarbonate (HCO_3); (C) Calcium (Ca); (D) Chloride (Cl); (E) Iron (Fe); (F) Magnesium (Mg); (G) Manganese (Mn); (H) Nitrate (NO_3); (I) Sodium (Na); (J) Sulfate (SO_4); (i) Based upon the site-specific waste profile and also the leachate characteristics for lined facilities, the owner or operator shall propose additional constituents to include in the monitoring program.	Section 3.1 and Appendix B, Section B2.2

Table 2-4. Pertinent Solid Waste Handling Standards Groundwater Monitoring Requirements

Groundwater Monitoring Element	Pertinent Requirement[a]	Section Where Requirement is Addressed in Monitoring Plan
Methods Used to Evaluate the Collected Data and Responses	WAC 173-350-500(5) "Groundwater Monitoring - Data Analysis, Notification and Reporting": (a) The results of monitoring well sample analyses as required by subsection (4)(h) and (i) of this section shall be evaluated using an appropriate statistical procedure(s), as approved by the jurisdictional health department during the permitting process, to determine if a significant increase over background has occurred. (b) If statistical analyses determine a significant increase over background: (i) The owner or operator shall: (A) Notify the jurisdictional health department and the department of this finding within thirty days of receipt of the sampling data. The notification shall indicate what parameters or constituents have shown statistically significant increases; (B) Immediately resample the groundwater for the parameter(s) showing statistically significant increase in the monitoring well(s) where the statistically significant increase has occurred; (C) Establish a groundwater protection standard using the groundwater quality criteria of 173-200 WAC, "Water Quality Standards for Groundwaters of the State of Washington."	Section 4.1, 4.2, 4.5 and Appendix A
Recordkeeping and Reporting	WAC 173-350-500(5) "Groundwater Monitoring - Data Analysis, Notification and Reporting": (c) The owner or operator shall submit a copy of an annual report to the jurisdictional health department and the department by April 1st of each year. The annual report shall summarize and interpret the following information: (i) All groundwater monitoring data, including laboratory and field data for the sampling periods; (ii) Statistical results and/or any statistical trends including any findings of any statistical increases for the year and time/concentration series plots; (iii) A summary of concentrations above the maximum contaminant levels of WAC 173-200; (iv) Static water level readings for each monitoring well for each sampling event.	Section 4.5 Appendix A, Section A2.6

Note: The references cited in this table are listed in the reference section (Chapter 5) of this plan.

WAC = *Washington Administrative Code*

Table 2-5. Additional Monitoring Objectives

Monitoring Objective	Site-Specific Constituent
Monitoring of VOCs is conducted as chlorinated hydrocarbons have been previously detected in the groundwater. 1,4-dioxane and chloroform have been previously detected in the landfill leachate.	Including: 1,1-dichloroethane, 1,2-dichloroethane, 1,4-dichlorobenzene, 1,1,1-trichlorethane, 1,4-dioxane, carbon tetrachloride, chloroform tetrachloroethene, and trichloroethene
Monitoring for arsenic is conducted because arsenic is detected above the WAC 173-200 groundwater quality criteria in leachate.	Arsenic
Monitoring for total coliform is conducted due to previous disposal of sewage.	Total coliform

Reference: WAC 173-200, "Water Quality Standards for Groundwaters of the State of Washington."

VOC = volatile organic compound

WAC = *Washington Administrative Code*

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3 Groundwater Monitoring Program

This chapter describes the groundwater monitoring program for SWL consisting of a monitoring well network, parameters used as indicators of groundwater contamination, and sampling and analysis protocols. The monitoring program presented herein has been revised from that presented in the previous plan (PNNL-13014).

3.1 Constituents List and Sampling Frequency

Table 3-1 presents the wells in the groundwater monitoring network, parameters required for solid waste landfill groundwater monitoring, and sampling frequency for monitoring of SWL. Field parameters (pH, specific conductance, temperature, and water level) and geochemical indicator parameters (alkalinity, bicarbonate, calcium, chloride, iron, magnesium, manganese, nitrate, sodium, and sulfate) will be sampled and analyzed semiannually. Although quarterly sampling is identified for these parameters in WAC 173-350-500(4)(h)(i) and (ii), a semiannual frequency is appropriate given site operation ceased in 1996 and concentrations of these parameters are stable. Semiannual sampling will also align with the sample frequency for the site-specific constituents. During the first year, sampling for field parameters and geochemical indicator parameters at the replacement wells (699-24-34D and 699-24-34E) and the new upgradient well (699-24-36) will be quarterly.

Site-specific constituents monitored at SWL are VOCs (1,1-dichloroethane, 1,2-dichloroethane, 1,4-dichlorobenzene, 1,1,1-trichlorethane, 1,4-dioxane, carbon tetrachloride, chloroform, tetrachloroethene, and trichloroethene), arsenic, and total coliform. Chloroform is added as a site-specific VOC based on leachate and past groundwater detections. Samples for site-specific constituents are collected semiannually.

Monitoring for total coliform was performed in the previous plan as a required groundwater parameter under WAC 173-304-490. Total coliform is retained for semiannual analysis as a site-specific constituent due to previous disposal of sewage at SWL.

Well maintenance (e.g., pump repairs, periodic well cleaning and redevelopment) and sampling logistics resulting from multiple factors including environmental (i.e., inclement weather) and access restrictions (i.e., heightened fire danger, area access restriction due to work by other Hanford contractors such as in the tank farms) sometimes delay scheduled sampling events. Sampling events are scheduled by month. The Field Work Supervisor (FWS) determines the specific times within a given month that a well will be sampled. If a well cannot be sampled at the times determined by the FWS, then the FWS and Sampling Management and Reporting group, along with the project scientist, will consult on how best to recover or reschedule the sampling event as close to the original sampling date as possible. If it is observed during the pre-sampling walkdown that one or more network wells cannot be sampled, then sampling of the well network will not begin and management will be notified. Depending on the situation, the network sampling will be rescheduled within a short time frame (such as 3 to 4 weeks). In some cases, it may not be obvious that sampling cannot be performed until a well is accessed (e.g., an issue with a pump).

Missed sampling events that are not rescheduled within the same month are given top priority when rescheduling sampling for the following month. In the event that a sampling delay has occurred and the representativeness of the samples is in question, DOE-RL and Ecology may agree to resampling wells. DOE-RL will provide informal notification to Ecology if sampling of the network is expected to be delayed for longer than 4 weeks. Ecology may provide input in a timely fashion to DOE-RL on how to proceed. Missed or cancelled sampling events are reported to DOE-RL and are documented in the annual Hanford Site groundwater monitoring report (e.g., DOE/RL-2015-07).

Table 3-1. Monitoring Well Network for SWL

Well Name	WAC Compliant	Required Parameters[a]														Site-Specific Constituents		
		Geochemical Indicator Parameters										Field Parameters						
		Alkalinity (as $CaCO_3$)	Bicarbonate[b]	Calcium[c]	Chloride	Iron[c]	Magnesium[c]	Manganese[c]	Nitrate	Sodium[c]	Sulfate	Water Level	pH	Specific Conductance	Temperature	VOCs[d]	Arsenic[c, e]	Total Coliform
699-22-35	Y	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
699-23-34B	Y	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
699-24-34D[f]	Y	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q[i]
699-24-34D[g]	Y	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
699-24-34E[f]	Y	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q[i]
699-24-34E[g]	Y	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
699-24-33[h]	N	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
699-25-34E	Y	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
699-24-35	Y	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
699-24-36[f]	Y	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q[i]
699-24-36[g]	Y	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S

Table 3-1. Monitoring Well Network for SWL

Well Name	WAC Compliant	Required Parameters[a]														Site-Specific Constituents		
		Geochemical Indicator Parameters										Field Parameters						
		Alkalinity (as $CaCO_3$)	Bicarbonate[b]	Calcium[c]	Chloride	Iron[c]	Magnesium[c]	Manganese[c]	Nitrate	Sodium[c]	Sulfate	Water Level	pH	Specific Conductance	Temperature	VOCs[d]	Arsenic[c, e]	Total Coliform

Note: Well numbers in **bold** are upgradient wells.

a. Parameters are required by WAC 173-350-500(4)(h) and (4)(i), "Groundwater Monitoring" "Groundwater Monitoring – Sampling and Analysis Plan."

b. Bicarbonate is calculated from alkalinity.

c. Unfiltered samples will be collected in conjunction with filtered samples for select analysis to determine if metal constituents being monitored occur as both suspended and dissolved phases, or in only one state. The evaluation of suspended and dissolved metals provide supporting information for groundwater geochemical characteristics, as well as indication of well integrity such as the presence of dislodged well encrustation, well corrosion products, or failure of the well screen filter pack.

d. VOCs, at a minimum include: 1,1-dichloroethane, 1,2-dichloroethane, 1,4-dichlorobenzene, 1,1,1-trichlorethane, 1,4-dioxane, carbon tetrachloride, chloroform, tetrachloroethene, and trichloroethene.

e. Site-specific metals include arsenic at a minimum.

f. Constituents and sampling frequency for the first year of monitoring.

g. Constituents and sampling frequency after the first year of monitoring.

h. Results from well 699-24-33 are used for supporting information only.

i. First year quarterly sampling of total coliform will begin in October 2016.

N = well is not constructed as a resource protection well (WAC 173-160, "Minimum Standard for Construction and Maintenance of Wells")

Q = to be sampled quarterly

S = to be sampled semiannually

VOC = volatile organic compound

WAC = *Washington Administrative Code*

Y = well is constructed as a resource protection well (WAC 173-160)

3.2 Monitoring Well Network

The SWL monitoring network consists of two upgradient and six downgradient wells. Figure 3-1 shows the groundwater monitoring network, and information for the wells is summarized in Table 3-2.

The following criteria were used to select wells for monitoring of SWL:

- Location of the downgradient wells with respect to the landfill boundary and groundwater flow path (wells closest to the landfill boundary were prioritized for use because they would provide the most immediate indication of a release)
- Well screen position with respect to the water table (wells constructed with screens positioned closest to the vadose zone/water table interface were preferred for detecting contaminant presence in groundwater resulting from a nearby waste site/treatment, storage, and disposal unit release)
- Suitable well construction such that the sampling data provided is comparable with other network wells
- Compliance with WAC 173-160

Wells in this updated plan include six downgradient wells (699-22-35, 699-23-34B, 699-24-33, 699-25-34E, 699-24-34D [replaces 699-24-34A], and 699-24-34E [replaces 699-24-34B]) and two upgradient wells (699-24-35 and 699-24-36). Well 699-26-35A is removed from use in upgradient monitoring as it is utilized by NRDWL and is not necessary for SWL (Figure 2-4). Well 699-24-36, installed in 2014, is added to the network to expand monitoring farther upgradient to detect the groundwater effects caused by the possible presence (or absence) of vadose zone vapors that are encountered by the closer upgradient well 699-24-35. Wells 699-24-34A and 699-24-34B are going sample dry and are removed from the monitoring network and replaced by wells 699-24-34D and 699-24-34E. Installation of the replacement wells was completed in 2015. These new wells were constructed similar to well 699-24-36. Sampling of the new wells will be conducted under this plan.

Downgradient well 699-24-33 is not compliant with WAC 173-160. The well, which was constructed in 1948, consists of 20 cm (8 in.) inside diameter carbon steel casing that is perforated below the water table. As in the previous plan, results from well 699-24-33 will be used for supporting information only and are not included in upgradient versus downgradient comparisons.

The point of compliance for SWL is the row of wells along the east and south sides of the perimeter fence (Figure 3-1) and includes wells 699-22-35, 699-23-34B, 699-24-34D, 699-24-34E, and 699-25-34E. Groundwater quality at the point of compliance is determined using these downgradient wells identified in the monitoring network.

All wells are compliant with WAC 173-160 as a resource protection well, with the exception of well 699-24-33. Per agreement between DOE and Ecology, noncompliant wells are identified and placed on the prioritized drilling schedule for replacement consistent with site-wide cleanup priorities as described in Milestone M-024-58 which is contained in the Ecology et al., 1989b, *Hanford Federal Facility Agreement and Consent Order Action Plan* (Tri-Party Agreement Action Plan), as revised. This well has been included in the milestone for future replacement.

Water levels will be taken during each sampling event at a well. More detailed measurements obtained from the full well network over a several hour period will be obtained once a year. These high resolution water level measurements will be acquired to determine groundwater flow direction and hydraulic gradient.

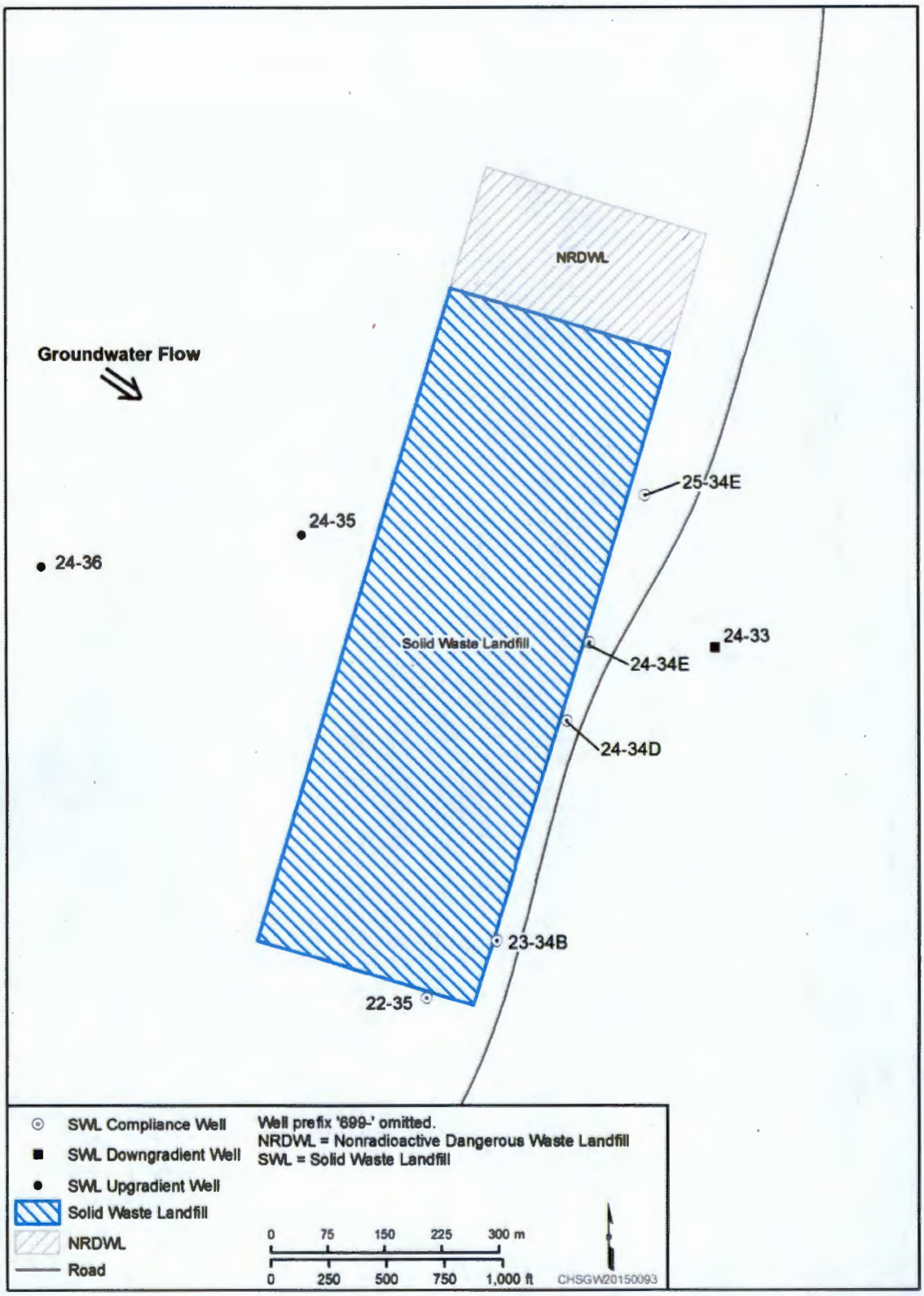

Figure 3-1. SWL Groundwater Monitoring Wells

Table 3-2. Attributes for Wells in the SWL Groundwater Monitoring Network

Well Name	Completion Date	Easting[a] (m)	Northing[a] (m)	Screen Top m (ft) bgs	Screen Bottom m (ft) bgs	Water Depth m (ft) bgs	Water Remaining m (ft)	Water Level Date
699-22-35	1993	579340.58	130309.02	37.33 (122.40)	48.01 (157.40)	41.29 (135.37)	6.72 (22.03)	4/11/16
699-23-34B	1993	579433.03	130384.70	37.36 (122.50)	46.51 (152.50)	41.21 (135.12)	5.30 (17.38)	4/11/16
699-24-33	1948	579720.07	130768.37	35.38 (116.00)	48.50 (159.00)	38.69 (126.86)	9.80 (32.13)	5/05/16
699-24-34D	2015	579524.7	130672.74	40.01 (131.19)	49.17 (161.22)	41.22 (135.81)	7.75 (24.41)	4/12/16
699-24-34E	2015	579555	130775.05	41.05 (134.58)	50.21 (164.61)	41.42 (135.79)	8.75 (28.82)	4/12/16
699-24-35[b]	1987	578833.70	130874.73	39.04 (128.00)	43.62 (143.00)	42.98 (140.92)	0.63 (2.07)	4/12/16
699-24-36[b]	2014	579627.83	130965.83	43.40 (142.31)	52.55 (172.31)	44.76 (146.79)	7.79 (25.54)	4/12/16
699-25-34E	2014	579176.84	130914.96	40.90 (134.09)	50.05 (164.09)	42.34 (138.82)	7.71 (25.28)	4/12/16

a. Coordinates are in NAD83, *North American Datum of 1983*.

b. Indicates upgradient well.

bgs = below ground surface

If a well is within approximately 2 years of going dry, a replacement well will be proposed; such wells are negotiated annually by Ecology, DOE, and the U.S. Environmental Protection Agency (EPA) under Tri-Party Agreement (Ecology et al., 1989a, *Hanford Federal Facility Agreement and Consent Order*) Milestone M-24-00.

Construction details and pertinent information for the wells are provided in Appendix C. Some wells are co-sampled with other monitoring programs (e.g., monitored to meet *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* requirements). Monitoring requirements for those other monitoring programs are described in separate plans. The reported data from those other monitoring programs are supplementary to information gathered under this plan.

3.3 Differences Between This Plan and Previous Plan

Table 3-3 identifies the main differences between this plan and the previous groundwater monitoring plan.

Previous groundwater monitoring plans for SWL have addressed monitoring requirements under WAC 173-304-490. This updated monitoring plan addresses the groundwater monitoring requirements of WAC 173-350-500. Constituents required by WAC 173-304-490 included temperature, specific conductance, pH, chloride, nitrate, nitrite, ammonia as nitrogen, sulfate, dissolved iron, dissolved manganese, dissolved zinc, chemical oxygen demand, TOC, and total coliform. The previous plan (PNNL-13014) included the required WAC 173-304-490 constituents and site-specific constituents (arsenic and VOCs that had been detected in groundwater or leachate samples). Primary VOCs of concern from the previous plan (including, but not limited to 1,1-dichloroethane, 1,2-dichloroethane, 1,1,1-trichlorethane, 1,4-dichlorobenzene, 1,4-dioxane, carbon tetrachloride, trichloroethene, and tetrachloroethene) are retained in this plan. Chloroform is added as a site-specific VOC based on leachate and past groundwater detections.

WAC 173-350-500(4)(h)(i) and (ii) includes field parameters (pH, specific conductance, temperature, and water level for groundwater monitoring) and geochemical indicator parameters (alkalinity, bicarbonate, calcium, chloride, iron, magnesium, manganese, nitrate, sodium, and sulfate). Therefore, nitrite, ammonia as nitrogen, zinc (dissolved), chemical oxygen demand, and TOC are removed as constituents, and alkalinity, bicarbonate, calcium, sodium, and magnesium are added as constituents in this plan. Although not required under WAC 173-350-500, total coliform is a site-specific constituent due to previous sewage disposal within SWL.

Several wells included in the previous plan (PNNL-13014) are removed from the monitoring network, and other wells have been added. Downgradient wells 699-23-34A, 699-24-34C, and 699-25-34C are now sample dry and are removed from the network. Existing downgradient well 699-25-34E is added to the network. Downgradient wells 699-24-34A and 699-24-34B are nearly dry and are replaced by wells 699-24-34D and 699-24-34E (drilled in 2015). Upgradient well 699-26-35A was included in PNNL-13014 but is removed from the network because it is upgradient of NRDWL. Well 699-24-36, which is directly upgradient of SWL, is added to the network.

3.4 Sampling and Analysis Protocol

The groundwater protection regulations of WAC 173-350-500(4)(a) dictate the groundwater sampling and analysis requirements applicable to solid waste handling facilities and activities. The QAPjP outlining the project management structure, data generation and acquisition, analytical procedures, and quality control is provided in Appendix A. Appendix B provides the sampling protocols (e.g., sampling methods, sample handling and custody, management of waste, and health and safety considerations).

Table 3-3. Main Differences between this Plan and Previous Plan

Type of Change	Previous Plan*	Current Plan	Justification Summary
Constituents	WAC 173-304-490 constituents and site-specific constituents	WAC 173-350-500(4)(h)(i) and (ii) constituents and site-specific constituents	Constituents updated to requirements in WAC 173-350-500 Total coliform is retained as a site-specific constituent due to previous sewage disposal at SWL. Chloroform is added as a site-specific constituent based on past leachate and groundwater detections.
Sampling Frequency	Quarterly for WAC 173-304-490 required parameters and site-specific parameters	Semiannually for WAC 173-350-500 required parameters and site-specific parameters	Semiannual sampling frequency for required parameters is appropriate as landfill operations ceased in 1996 and parameter concentrations are relatively stable. Site-specific VOC concentrations have decreased over time and are now stable at nondetect or low concentrations.
Well Network	Eight downgradient and two upgradient wells	Six downgradient and two upgradient wells	Wells 699-23-34A, 699-24-34C, and 699-25-34C are sample dry and are removed from the network; new downgradient well is 699-25-34E added to the network Upgradient well 699-26-35A monitors NRDWL and is removed from the network; well 699-24-36 directly upgradient of SWL is added to the network Downgradient wells 699-24-34A and 699-24-34B are going dry and are replaced by 699-24-34D and 699-24-34E
Groundwater Flow Direction	Southeast	No change	N/A
Type of Groundwater Monitoring Program	Detection level	No change	N/A
Background Summary Statistics	Tolerance Intervals	No change	N/A

References: PNNL-13014, *Groundwater Monitoring Plan for the Solid Waste Landfill*.

WAC 173-304-490, "Minimum Functional Standards for Solid Waste Handling," "Groundwater Monitoring Requirements," WAC 173-350-500(5), "Solid Waste Handling Standards," "Groundwater Monitoring."

N/A = not applicable
NRDWL = Nonradioactive Dangerous Waste Landfill
SWL = Solid Waste Landfill
WAC = *Washington Administrative Code*

4 Data Evaluation and Reporting

This chapter discusses the evaluation and interpretation of data.

4.1 Data Review

The data review and verification tasks are discussed in the QAPjP (Appendix A).

4.2 Statistical Evaluation

The statistical evaluation consists of the required comparison between data from downgradient compliance point wells with data from upgradient background wells to determine whether a statistically significant increase over background has occurred for the constituents and parameters listed in WAC 173-350-500(4)(h)(i) and (ii) (hereafter called listed constituents). The term background data, as used in WAC 173-350-500(5)(a), is interpreted here as data representing the quality of groundwater beneath the site prior to emplacement of waste in the facility.

Historically, background summary statistics were calculated under the WAC 173-350-490(2)(d) using data from upgradient wells 699-24-35 and 699-26-35A. Since 699-26-35A is removed from the SWL monitoring network and 699-24-36 is now added, summary statistics will be calculated using wells 699-24-35 and 699-24-36.

There is known groundwater contamination at SWL, but ambient background conditions were not calculated at any of the wells prior to the landfill going into use. To this end, intra-well background comparisons are not possible at the downgradient wells. Instead, interwell comparisons between upgradient and downgradient wells are used with the assumption that upgradient wells are representative of ambient groundwater conditions. Routine calculation of summary statistics in upgradient wells can be used as an indicator of trends that may be moving downstream and affect downgradient compliance point wells. If there is a statistically significant increase (or pH decrease) in concentration of a listed constituent over the calculated background concentration, then it must be determined whether the groundwater protection standard was exceeded using the GWQC of WAC 173-200.

Background will be calculated annually using a 5-year rolling data set. Summary statistics will be calculated initially for the listed constituents using the most recent five years of quarterly monitoring data from upgradient well 699-24-35. The summary statistics will be updated annually by adding new data for the last monitoring year and removing the data older than 5 years. As monitoring results for new well 699-24-36 are collected, they will be pooled with data from 699-24-35 to create a 5-year data set that will be updated annually. The following summary statistics will be calculated:

- Mean
- Median
- Standard deviation
- Coefficient of variation
- N (the number of data results)
- Number of samples greater than the method detection limit
- Number of samples less than the method detection limit
- Minimum data result
- Maximum data result

After conducting a data quality assessment of the background data sets, BTV calculations will be performed using data deemed valid. These BTVs, used for comparison to individual monitoring concentrations, will be the 95 percent upper confidence limit of the 95th percentile, known as a 95/95 upper tolerance limit (UTL). These 95/95 UTLs, which form the upper end of a one-sided tolerance interval, will be calculated with ProUCL, Version 5.0.00 (EPA, 2013) using either a nonparametric (no distributional assumption) approach when evidence for a particular distribution is not available or using a distributional assumption (when deemed appropriate for the approved background data). Nondetect values will be handled in accordance with ProUCL methodology (EPA, 2013). Revised versions of ProUCL will be used as they become available.

The distribution possibilities include those computed by the EPA ProUCL software: normal, gamma, and lognormal distributions (EPA, 2013). When more than one distribution is found to offer a reasonable fit, the distribution with the least skewness will be chosen (i.e., a normal distribution will be chosen over a gamma distribution, and a gamma distribution will be chosen over a lognormal distribution).
When nondetects are included for a given constituent (censored data) but at least 50 percent of the results are detected, regression on order statistics (ROS) techniques (when available) will be applied to calculate the UTL. The ROS functionality is not offered in the latest ProUCL software (Version 5.0.00) for the normal distribution. When fewer than 50 percent detections were available or ROS functionality is not available (e.g., normal distributions), the Kaplan-Meier approach will applied.

UTLs will be calculated whenever at least four detected values are available. When fewer than four detections are available, the practical quantitation limit will be considered the BTV.

For constituents (e.g., pH) where either an unusually elevated or a low concentration may be of interest, two-sided tolerance intervals may be defined (both an upper and lower tolerance limit calculated).

4.3 Interpretation

Data are used to interpret groundwater conditions at SWL. Interpretive techniques include the following:

- **Hydrographs:** Graph water levels versus time to determine decreases and increases and seasonal or manmade fluctuations in groundwater levels.
- **Water table maps:** Use water table elevations from multiple wells to construct contour maps and estimate flow directions. Groundwater flow is assumed to be perpendicular to the equal potential lines on the maps.
- **Trend plots:** Graph concentrations of constituents versus time to determine increases, decreases, and fluctuations. May be used in tandem with hydrographs and/or water table maps to determine if concentrations relate to changes in water level or groundwater flow directions.
- **Plume maps:** Map distributions of chemical constituent concentrations in the aquifer to determine the extent of contamination. Changes in plume distribution over time assist in determining plume movement and direction of groundwater flow.
- **Contaminant ratios:** Illustrate the relative abundances of contaminants from previously characterized Hanford Site-related processes and sources. Comparison of these ratios in groundwater can sometimes be used to distinguish among different sources of contamination (e.g., a specific process and its associated facility). Ratios may provide evidence of continuing source contamination, thereby linking contamination with a specific facility under monitoring. Evaluation of contaminant ratios in concentration trends may be used to demonstrate when facility-specific contamination no longer affects underlying groundwater.

4.4 Annual Determination of Monitoring Network

The monitoring well network will be examined annually to determine if it remains adequate to monitor the facility's impact, if any, on the quality of the groundwater in the uppermost aquifer underlying the facility.

The current groundwater monitoring network will continue to be re-evaluated to ensure that it is adequate to monitor any changing hydrogeologic conditions beneath the unit. If flow changes are observed, the SWL CSM and geochemical trends will be re-evaluated to determine network efficiency and any necessary modifications required for the network.

Water-level measurements will continue to be collected during each sampling event. An additional and more comprehensive set of water level measurements is made annually for selected wells on the Hanford Site and the data are presented in the annual Hanford Site groundwater monitoring reports (e.g., DOE/RL-2015-07).

4.5 Reporting

Monitoring results are reported annually in accordance with the requirements of WAC 173-350-500(5)(c). Groundwater results are presented in the Hanford Site annual groundwater monitoring reports (e.g., DOE/RL-2015-07). A separate annual report for SWL that summarizes and evaluates groundwater, leachate, and soil gas results is prepared annually by MSA (or equivalent contractor).

Evaluation of SWL groundwater monitoring results under WAC 173-350-500 is performed using the same process described in the previous plan. Results of field parameters and geochemical indicator parameters are evaluated and compared to the BTVs. When downgradient results exceed BTVs, the results will be compared with the groundwater protection standards using the GWQC of WAC 173-200. Results of site-specific constituents will be compared to the GWQC of WAC 173-200. The comparisons to WAC 173-200 GWQC are presented in the annual SWL report.

WAC 173-350-500(5)(b)(i)(A) and (B) requires notification to the jurisdictional health department (in the case of SWL, Ecology is the jurisdictional agency) within 30 days if statistical analysis of monitoring results determines that there is a significant increase over background and to immediately resample the groundwater for the parameter(s) showing the statistically significant increase in the well where the increase occurred. However, several groundwater parameters and site-specific constituents at SWL (e.g., arsenic, chemical oxygen demand, coliform bacteria, nitrate, sulfate, pH, specific conductance, temperature, tetrachloroethene, and TOC) historically and routinely exceed BTVs or GWQC (WAC 173-200). Notification will not occur for parameters or constituents that have historically exceeded BTVs and GWQC. Notification will be limited to new exceedances.

The Hanford Site annual groundwater monitoring report identifies constituents that exceed BTVs and the wells in which the exceedances occurred. The annual groundwater report also evaluates results of the site-specific constituents. Groundwater flow direction and flow rates are reported in the annual groundwater monitoring report (e.g., DOE/RL-2015-07) and the SWL annual report.

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5 References

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Appendix A

Quality Assurance Project Plan

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Contents

A1 Introduction **A-1**

A2 Project Management **A-1**

A2.1 Project/Task Organization A-1

A2.1.1 DOE-RL Manager A-1

A2.1.2 DOE-RL Project Lead A-1

A2.1.3 Soil and Groundwater Remediation Project Remedy Selection and Implementation Director A-2

A2.1.4 Project Delivery Manager for Groundwater Science A-3

A2.1.5 Sample Management and Reporting Group A-3

A2.1.6 Field Sample Operations A-3

A2.1.7 Quality Assurance A-4

A2.1.8 Environmental Compliance Officer A-4

A2.1.9 Health and Safety A-4

A2.1.10 Waste Management A-4

A2.1.11 Analytical Laboratories A-4

A2.2 Problem Definition/Background A-4

A2.3 Project/Task Description A-4

A2.4 Quality Assurance Objectives and Criteria A-5

A2.5 Special Training/Certification A-5

A2.6 Documents and Records A-5

A3 Data Generation and Acquisition **A-11**

A3.1 Analytical Method Requirements A-11

A3.2 Field Analytical Methods A-13

A3.3 Quality Control A-13

A3.3.1 Field Quality Control Samples A-16

A3.3.2 Laboratory Quality Control Samples A-16

A3.4 Measurement Equipment A-18

A3.5 Instrument and Equipment Testing, Inspection, and Maintenance A-18

A3.6 Instrument/Equipment Calibration and Frequency A-19

A3.7 Inspection/Acceptance of Supplies and Consumables A-19

A3.8 Nondirect Measurements A-19

A3.9 Data Management A-19

A4 Assessment and Oversight **A-19**

A4.1 Assessments and Response Actions A-19

A4.2 Reports to Management A-20

A5 Data Review and Usability A-20

A5.1 Data Review and Verification A-20

A5.2 Data Validation A-20

A5.3 Reconciliation with User Requirements A-21

A6 References A-21

Tables

Table A-1. Data Quality Indicators A-6

Table A-2. Change Control for Monitoring Plans A-9

Table A-3. Analytical Requirements for Groundwater Analysis A-11

Table A-4. QC Samples A-13

Table A-5. Laboratory Quality Control and Acceptance Criteria A-14

Table A-6. Preservation and Holding Time Guidelines for Laboratory Analyses A-17

Figure

Figure A-1. Project Organization A-2

Terms

DOE	U.S. Department of Energy
DOE-RL	U.S. Department of Energy, Richland Operations Office
DQA	data quality assessment
DQI	data quality indicator
DUP	duplicate (laboratory)
EB	equipment blank
ECO	Environmental Compliance Officer
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
FSO	Field Sample Operations
FTB	full trip blank
FWS	Field Work Supervisor
FXR	field transfer blank
GC/MS	gas chromatography/mass spectrometry
HASQARD	*Hanford Analytical Services Quality Assurance Requirements Document* (DOE/RL-96-68)
HEIS	Hanford Environmental Information System
LCS	laboratory control sample
MB	method blank
MDL	method detection limit
MS	matrix spike
MSD	matrix spike duplicate
N/A	not applicable
PQL	practical quantitation limit
QA	quality assurance
QAPjP	quality assurance project plan
QC	quality control
S&GRP	Soil and Groundwater Remediation Project
SAF	Sampling Authorization Form

SMR	Sample Management and Reporting
SPLIT	field split
SUR	surrogate
SWL	Solid Waste Landfill
Tri-Party Agreement	*Hanford Federal Facility Agreement and Consent Order* (Ecology et al., 1989a)
VOC	volatile organic compound
WAC	*Washington Administrative Code*

A1 Introduction

A quality assurance project plan (QAPjP) establishes the quality requirements for environmental data collection. It includes planning, implementation, and assessment of sampling tasks, field measurements, laboratory analysis, and data review. This chapter describes the applicable environmental data collection requirements and controls based on the quality assurance (QA) elements found in EPA/240/B-01/003, *EPA Requirements for Quality Assurance Project Plans* (EPA QA/R-5) and DOE/RL-96-68, *Hanford Analytical Services Quality Assurance Requirements Document* (HASQARD). Sections 6.5 and 7.8 of the Ecology et al., 1989b, *Hanford Federal Facility Agreement and Consent Order Action Plan* (Tri-Party Agreement Action Plan) require the QA/quality control (QC) and sampling and analysis activities to specify QA requirements for a solid waste management unit. This QAPjP also describes the applicable requirements and controls based on guidance provided in Ecology Publication No. 04-03-030, *Guidelines for Preparing Quality Assurance Project Plans for Environmental Studies*, and EPA/240/R-02/009, *Guidance for Quality Assurance Project Plans* (EPA QA/G-5). This QAPjP is intended to supplement the contractor's environmental QA program plan.

This QAPjP is divided into the following five chapters, which describe the quality requirements and controls applicable to the Solid Waste Landfill (SWL) groundwater monitoring activities:

- Chapter A2, Project Management
- Chapter A3, Data Generation and Acquisition
- Chapter A4, Assessment and Oversight
- Chapter A5, Data Review and Usability
- Chapter A6, References

A2 Project Management

This chapter addresses the management approaches planned, project goals, and planned output documentation.

A2.1 Project/Task Organization

Project organization (regarding routine groundwater monitoring) is described in the following subsections and illustrated in Figure A-1.

A2.1.1 DOE-RL Manager

Hanford Site cleanup is the responsibility of U.S. Department of Energy (DOE)-Richland Operations Office (RL). The DOE-RL Manager is responsible for authorizing the contractor to perform activities under various environmental regulations for the Hanford Site.

A2.1.2 DOE-RL Project Lead

The DOE-RL Project Lead is responsible for providing day-to-day oversight of the contractor's performance of the work scope, working with the contractor to identify and work through issues, and providing technical input to the DOE-RL management.

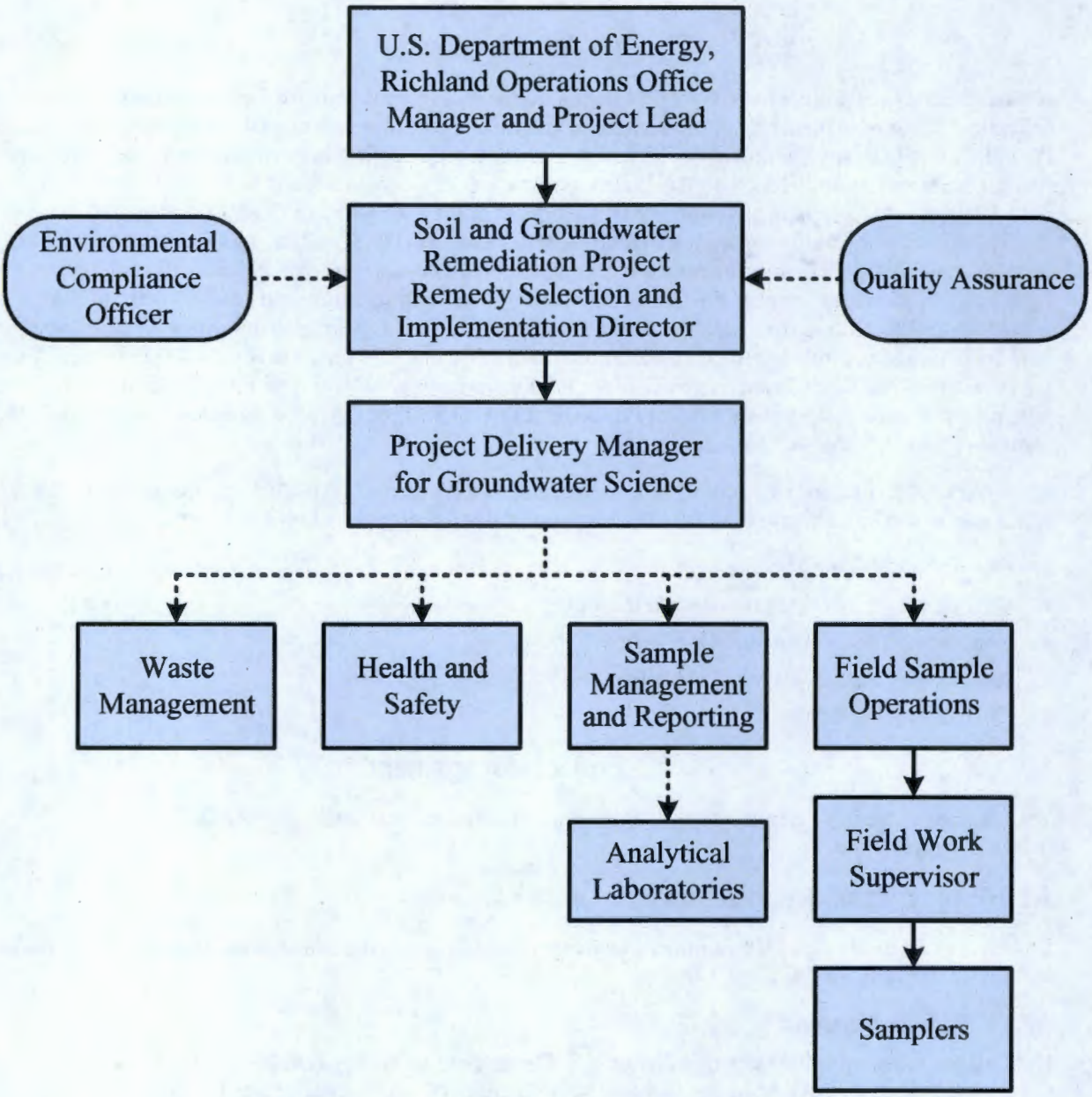

Figure A-1. Project Organization

A2.1.3 Soil and Groundwater Remediation Project Remedy Selection and Implementation Director

The Soil and Groundwater Remediation Project (S&GRP) Remedy Selection and Implementation Director provides oversight and coordinates with DOE-RL and primary contractor management in support of sampling and reporting activities. The Remedy Selection and Implementation Director also provides support to the Project Delivery Manager for Groundwater Science to ensure that work is performed safely and cost effectively.

A2.1.4 Project Delivery Manager for Groundwater Science

The Project Delivery Manager for Groundwater Science is responsible for direct management of activities performed to meet groundwater monitoring requirements. The Project Delivery Manager for Groundwater Science coordinates with, and reports to, DOE-RL and primary contractor management regarding groundwater monitoring requirements. The Project Delivery Manager for Groundwater Science (or designee) works closely with the Environmental Compliance Officer (ECO), QA, Health and Safety, and Sample Management and Reporting (SMR) group to integrate these and other technical disciplines in planning and implementing the work scope. The Project Delivery Manager for Groundwater Science assigns scientists to provide technical expertise.

A2.1.5 Sample Management and Reporting Group

The SMR group oversees offsite analytical laboratories, coordinates laboratory analytical work to ensure that laboratories conform to the requirements of this plan, and verifies that laboratories are qualified for performing Hanford Site analytical work. The SMR group generates field sampling documents, labels, and instructions for field sampling personnel and develops the Sampling Authorization Form (SAF), which provides information and instruction to the analytical laboratories. The SMR group ensures that field sampling documents are revised to reflect approved changes. The SMR group receives analytical data from the laboratories, ensures it is appropriately reviewed, performs data entry into the Hanford Environmental Information System (HEIS) database, and arranges for data validation and recordkeeping. The SMR group is responsible for resolving sample documentation deficiencies or issues associated with Field Sample Operations (FSO), laboratories, or other entities. The SMR group is responsible for informing the Project Delivery Manager for Groundwater Science of any issues reported by the analytical laboratories.

A2.1.6 Field Sample Operations

The Field Sample Operations (FSO) is responsible for planning and coordinating field sampling resources and provides the Field Work Supervisor (FWS) for routine groundwater sampling operations. The FWS directs the nuclear chemical operators (samplers), who collect groundwater samples in accordance with this groundwater monitoring plan and corresponding standard procedures and work packages. The FWS ensures that deviations from field sampling documents or issues encountered in the field are documented appropriately (e.g., in the field logbook). The FWS ensures that samplers are appropriately trained and available. Samplers collect samples in accordance with sampling documentation. The samplers also complete field logbooks, data forms, and chain-of-custody forms, including any shipping paperwork, and enable delivery of the samples to the analytical laboratory.

Pre-job briefings are conducted by FSO, in accordance with work management and work release requirements, to evaluate activities and associated hazards by considering the following factors:

- Objective of the activities
- Individual tasks to be performed
- Hazards associated with the planned tasks
- Controls applied to mitigate the hazards
- Environment in which the job will be performed
- Facility where the job will be performed
- Equipment and material required

A2.1.7 Quality Assurance

The QA point of contact provides independent oversight and is responsible for addressing QA issues on the project and overseeing implementation of the project QA requirements. Responsibilities include reviewing project documents, including the QAPjP, and participating in QA assessments on sample collection and analysis activities, as appropriate.

A2.1.8 Environmental Compliance Officer

The ECO provides technical oversight, direction, and acceptance of project and subcontracted environmental work and also develops appropriate mitigation measures with the goal of minimizing adverse environmental impacts.

A2.1.9 Health and Safety

The Health and Safety organization is responsible for coordinating industrial safety and health support within the project as carried out through health and safety plans, job hazard analyses, and other pertinent safety documents required by federal regulations or internal primary contractor work requirements.

A2.1.10 Waste Management

Waste Management is responsible for identifying waste management sampling/characterization requirements, to ensure regulatory compliance and for interpreting data to determine waste designations and profiles. Waste Management communicates policies and procedures and ensures project compliance for storage, transportation, disposal, and waste tracking in a safe and cost-effective manner.

A2.1.11 Analytical Laboratories

The analytical laboratories analyze samples in accordance with established procedures and the requirements of this plan, and provide necessary data packages containing analytical and QC results. Laboratories provide explanations of results to support data review and in response to resolution of analytical issues. Statements of work flow down quality requirements consistent with the HASQARD (DOE/RL-98-68). The laboratories are evaluated under the DOE Consolidated Audit Program and must be accredited by the Washington State Department of Ecology (Ecology) for the analyses performed for S&GRP.

A2.2 Problem Definition/Background

The purpose of this groundwater monitoring plan is to satisfy *Washington Administrative Code* (WAC) 173-350-500, "Solid Waste Handling Standards," "Groundwater Monitoring." More specific information on the activities to satisfy these requirements is provided in the main text of this monitoring plan in Chapters 1 and 3, and Sections 2.7, 4.2, 4.3, 4.4, and 4.5. Background information on monitoring is also provided in the main text (Sections 2.2, 2.5, and 3.3).

A2.3 Project/Task Description

The project description is provided in Chapters 2, 3, and 4 of this monitoring plan and includes the geochemical indicator parameters and field parameters as required by WAC 173-350-500 for establishing groundwater quality and groundwater contamination detection, evaluation of the monitoring network, interpretation of analytical results, and reporting. The parameters to be monitored, along with the monitoring wells and frequency of sampling, are provided in the main text (Chapter 3). Information on the collection and analyses of groundwater from the monitoring network is provided in this appendix and in Appendix B. In addition to the required parameters of WAC 173-350-500, site-specific constituents to be monitored are included in Chapter 3.

A2.4 Quality Assurance Objectives and Criteria

The QA objective of this plan is to ensure that the generation of analytical data of known and appropriate quality is acceptable and useful in order to meet the evaluation requirements stated in the monitoring plan. In support of this objective, data descriptors known as data quality indicators (DQIs) are used to help determine the acceptability and usefulness of the data to the user. Principal DQIs are precision, accuracy, representativeness, comparability, completeness, bias, and sensitivity. These DQIs are defined for the purposes of this document in Table A-1.

Data quality is defined by the degree of rigor in the acceptance criteria assigned to the DQIs. The applicable QC guidelines, DQI acceptance criteria, and levels of effort for assessing data quality are dictated by the intended use of the data and the requirements of the analytical method. DQIs are evaluated during the data quality assessment (DQA) process (Section A5.3).

A2.5 Special Training/Certification

Workers receive a level of training that is commensurate with their responsibility for collecting and transporting groundwater samples according to the training plan. This training is commensurate with that needed to collect and transport groundwater samples for the SWL. The FWS, in coordination with line management, will ensure that special training requirements for field personnel are met.

Training has been instituted by the contractor management team to meet training and qualification programs that satisfy multiple training drivers. For example, the environmental, safety, and health training program provides workers with the knowledge and skills necessary to execute assigned duties safely.

Training records are maintained for each employee in an electronic training record database. The contractor's training organization maintains the training records system. Line management confirms that an employee's training is appropriate and up-to-date prior to performing any fieldwork.

A2.6 Documents and Records

The Project Delivery Manager for Groundwater Science (or designee) is responsible for ensuring that the current version of the groundwater monitoring plan is used and providing any updates to field personnel. Version control is maintained by the administrative document control process. Table A-2 defines the types of changes that may impact the groundwater monitoring plan and the associated approvals, notifications, and documentation requirements. Elements of the monitoring plan that are required by WAC 173-350-500(4)(d), (g), and (h) cannot be changed.

Logbooks and data forms are required for field activities. The logbook must be identified with a unique project name and number. Individuals responsible for the logbooks shall be identified in the front of the logbook, and only authorized individuals may make entries into the logbooks. Logbooks will be controlled in accordance with internal work requirements and processes.

The FWS, SMR group, and any field crew supervisors are responsible for ensuring that field instructions are maintained and aligned with any revisions or approved changes to the groundwater monitoring plan. The SMR group will ensure that any deviations from the plan are reflected in revised field sampling documents for the samplers and analytical laboratory. The FWS or appropriate field crew supervisors will ensure that deviations from the plan or problems encountered in the field are documented appropriately (e.g., in the field logbook).

Table A-1. Data Quality Indicators

Data Quality Indicator (QC Element)[a]	Definition	Determination Methodologies	Corrective Actions
Precision (field duplicates, laboratory sample duplicates, and matrix spike duplicates)	Precision measures the agreement among a set of replicate measurements. Field precision is assessed through the collection and analysis of field duplicates. Analytical precision is estimated by duplicate/replicate analyses, usually on laboratory control samples, spiked samples, and/or field samples. The most commonly used estimates of precision are the relative standard deviation and, when only two samples are available, the relative percent difference.	Use the same analytical instrument to make repeated analyses on the same sample. Use the same method to make repeated measurements of the same sample within a single laboratory. Acquire replicate field samples for information on sample acquisition, handling, shipping, storage, preparation, and analytical processes and measurements.	If duplicate data do not meet objective: • Evaluate apparent cause (e.g., sample heterogeneity). • Request reanalysis or re-measurement. • Qualify the data before use.
Accuracy (laboratory control samples, matrix spikes, and surrogates)	Accuracy is the closeness of a measured result to an accepted reference value. Accuracy is usually measured as a percent recovery. QC analyses used to measure accuracy include standard recoveries, laboratory control samples, spiked samples, and surrogates.	Analyze a reference material or reanalyze a sample to which a material of known concentration or amount of pollutant has been added (a spiked sample).	If recovery does not meet objective: • Qualify the data before use. • Request reanalysis or re-measurement.
Representativeness (field duplicates)	Sample representativeness expresses the degree to which data accurately and precisely represent a characteristic of a population, parameter variations at a sampling point, a process condition, or an environmental condition. It is dependent on the proper design of the sampling program and will be satisfied by ensuring that the approved plans were followed during sampling and analysis.	Evaluate whether measurements are made and physical samples collected in such a manner that the resulting data appropriately reflect the environment or condition being measured or studied.	If results are not representative of the system sampled: • Identify the reason for results not being representative. • Flag for further review. • Review data for usability. • If data are usable, qualify the data for limited use and define the portion of the system that the data represent. • If data are not usable, flag as appropriate. • Redefine sampling and measurement requirements and protocols. • Resample and reanalyze, as appropriate.

Table A-1. Data Quality Indicators

Data Quality Indicator (QC Element)[a]	Definition	Determination Methodologies	Corrective Actions
Comparability (field duplicate, field splits, laboratory control samples, matrix spikes, and matrix spike duplicates)	Comparability expresses the degree of confidence with which one data set can be compared to another. It is dependent upon the proper design of the sampling program and will be satisfied by ensuring that the approved plans are followed and that proper sampling and analysis techniques are applied.	Use identical or similar sample collection and handling methods, sample preparation and analytical methods, holding times, and quality assurance protocols.	If data are not comparable to other data sets: • Identify appropriate changes to data collection and/or analysis methods. • Identify quantifiable bias, if applicable. • Qualify the data as appropriate. • Resample and/or reanalyze if needed. • Revise sampling/analysis protocols to ensure future comparability.
Completeness (no QC element; addressed in data quality assessment)	Completeness is a measure of the amount of valid data collected compared to the amount of data planned. Measurements are considered to be valid if they are unqualified or qualified as estimated data during validation. Field completeness is a measure of the number of samples collected versus the number of samples planned. Laboratory completeness is a measure of the number of valid measurements compared to the total number of measurements planned.	Compare the number of valid measurements completed (samples collected or samples analyzed) with those established by the project's quality criteria (data quality objectives or performance/ acceptance criteria).	If data set does not meet the completeness objective: • Identify appropriate changes to data collection and/or analysis methods. • Identify quantifiable bias, if applicable. • Resample and/or reanalyze if needed. • Revise sampling/analysis protocols to ensure future completeness.

Table A-1. Data Quality Indicators

Data Quality Indicator (QC Element)[a]	Definition	Determination Methodologies	Corrective Actions
Bias (equipment blanks, field transfer blanks, full trip blanks, laboratory control samples, matrix spikes, and method blanks)	Bias is the systematic or persistent distortion of a measurement process that causes error in one direction (e.g., the sample measurement is consistently lower than the sample's true value). Bias can be introduced during sampling, analysis, and data evaluation. Analytical bias refers to deviation in one direction (i.e., high, low, or unknown) of the measured value from a known spiked amount.	Sampling bias may be revealed by analysis of replicate samples. Analytical bias may be assessed by comparing a measured value in a sample of known concentration to an accepted reference value or by determining the recovery of a known amount of contaminant spiked into a sample (matrix spike).	For sampling bias: • Properly select and use sampling tools. • Institute correct sampling and subsampling procedures to limit preferential selection or loss of sample media. • Use sample handling procedures, including proper sample preservation, that limit the loss or gain of constituents to the sample media. • Analytical data that are known to be affected by either sampling or analytical bias are flagged to indicate possible bias. • Laboratories that are known to generate biased data for a specific analyte are asked to correct their methods to remove the bias as best as practicable. Otherwise, samples are sent to other laboratories for analysis.
Sensitivity (method detection limit, practical quantitation limit, and relative percent difference)	Sensitivity is an instrument's or method's minimum concentration that can be reliably measured (i.e., instrument detection limit or limit of quantitation).	Determine the minimum concentration or attribute to be measured by an instrument (instrument detection limit) or by a laboratory (limit of quantitation). The lower limit of quantitation[b] is the lowest level that can be routinely quantified and reported by a laboratory.	If detection limits do not meet objective: • Request reanalysis or re-measurement using methods or analytical conditions that will meet required detection or limit of quantitation. • Qualify/reject the data before use.

Source: SW-846, *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods, Third Edition; Final Update V*, as amended.

a. Acceptance criteria for QC elements are provided in Table A-5

b. For purposes of this groundwater monitoring plan, the lower limit of quantitation is interchangeable with the practical quantitation limit.

QC = quality control

Table A-2. Change Control for Monitoring Plans

Type of Change*	Action	Documentation
Temporary addition of wells or site-specific constituents, or increased sampling frequency that does not impact the requirements of WAC 173-350-500(4).	Project Delivery Manager for Groundwater Science approves temporary change; provides informal notification to DOE-RL.	SMR group's integrated groundwater monitoring schedule.
Unintentional impact to groundwater monitoring plan that impacts the monitoring program requirements of WAC 173-350-500(4), including one-time missed well sampling due to operational constraints, delayed sample collection, broken pump, lost bottle set, missed sampling of indicator parameters, or loss of samples in transit.	Project Delivery Manager for Groundwater Science provides electronic notification to DOE-RL. DOE-RL provides informal notification to Ecology as appropriate.	Annual Hanford Site groundwater monitoring report.
Planned change to groundwater monitoring activities, including addition or deletion of site-specific constituents, change of sampling frequency for site-specific constituents, or changes to well network.	Project Delivery Manager for Groundwater Science obtains DOE-RL approval; revise monitoring plan as appropriate.	Revised groundwater monitoring plan as appropriate.
Anticipated unavoidable changes.	Project Delivery Manager for Groundwater Science provides informal notification to DOE-RL; revise monitoring plan as appropriate.	Annual groundwater monitoring report and revised groundwater monitoring plan as appropriate.

Note: WAC 173-350-500(5), "Solid Waste Handling Standards," "Groundwater Monitoring," contains additional sampling and notification requirements should results demonstrate a significant increase (or pH decrease).

* "Site-specific constituents" are any constituents that may be included in this monitoring plan as additional analytes that are not required by WAC 173-350-500(4)(h) and (i).

DOE-RL = U.S. Department of Energy, Richland Operations Office

Ecology = Washington State Department of Ecology

SMR = Sample Management and Reporting

WAC = *Washington Administrative Code*

The Project Delivery Manager for Groundwater Science, FWS, or designee is responsible for communicating field corrective action requirements and ensuring that immediate corrective actions are applied to field activities. The Project Delivery Manager for Groundwater Science is also responsible for ensuring that project files are setup, as appropriate, and/or maintained. The project files will contain project records or references to their storage locations. Project files generally include, as appropriate, the following information:

- Operational records and logbooks
- Data forms
- Global positioning system data (a copy will be provided to the SMR group)
- Inspection or assessment reports and corrective action reports
- Field summary reports
- Interim progress reports
- Final reports
- Forms required by WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells," and the master drilling contract

The following records are managed and maintained by SMR personnel:

- Completed field sampling logbooks
- Groundwater sample reports and field sample reports
- Completed chain-of-custody forms
- Sample receipt records
- Laboratory data packages
- Analytical data verification and validation reports
- Analytical data case file purges (i.e., raw data purged from laboratory files) provided by offsite analytical laboratories

The laboratory is responsible for maintaining, and having available upon request, the following items:

- Analytical logbooks
- Raw data and QC sample records
- Standard reference material and/or proficiency test sample data
- Instrument calibration information
- Training records for employees, as they relate to analytical methods.
- Laboratory state accreditation records
- Laboratory audit records

Convenience copies of laboratory analytical results are maintained in the HEIS database. Records may be stored in either electronic (e.g., in the managed records area of the Integrated Document Management System) or hard copy format (e.g., DOE Records Holding Area). Documentation and records, regardless

of medium or format, are controlled in accordance with internal work requirements and processes that ensure accuracy and retrievability of stored records. Records required by the Tri-Party Agreement (Ecology et al., 1989a) will be managed in accordance with the requirements therein.

The results of groundwater monitoring are reported annually in accordance with the requirements of WAC 173-350-500(5). Reporting will be made in the annual Hanford Site groundwater monitoring report (e.g., DOE/RL-2015-07, *Hanford Site Groundwater Monitoring Report for 2014*).

A3 Data Generation and Acquisition

This chapter addresses data generation and acquisition to ensure that the project's methods for sampling, measurement and analysis, data collection or generation, data handling, and QC activities are appropriate and documented. Requirements for instrument calibration and maintenance, supply inspections, and data management are also addressed.

A3.1 Analytical Method Requirements

Analytical method requirements for samples collected are presented in Table A-3. Updated U.S. Environmental Protection Agency (EPA) methods may be substituted for the analytical methods identified in Table A-3.

Table A-3. Analytical Requirements for Groundwater Analysis

Constituent	Analytical Method[a]	Highest Allowable Practical Quantitation Limit[b] (µg/L)
Geochemical Indicator Parameters (WAC 173-350-500(4)(h))		
Alkalinity (as $CaCO_3$)	EPA/600 Method 310.1 or Standard Method 2320	5,000
Bicarbonate (HCO_3)		c
Chloride	EPA/600 Method 300.0	400
Nitrate (NO_3)		250
Sulfate		550
Calcium	SW-846 Method 6010B/C	1,000
Iron		100
Magnesium		1,000
Manganese		15
Sodium		1,000
Field Parameters (WAC 173-350-500(4)(h))		
pH	Field measurement Instrument/meter	N/A
Specific Conductance		N/A
Temperature		N/A

Table A-3. Analytical Requirements for Groundwater Analysis

Constituent	Analytical Method[a]	Highest Allowable Practical Quantitation Limit[b] (µg/L)
Site-Specific Constituents		
Coliform Bacteria	Standard Method 9223	N/A
Arsenic	SW-846 Method 6010B/C	10
1,1-Dichloroethane	SW-846 Method EPA 8260	1
1,2-Dichloroethane		1
1,4-Dichlorobenzene		4
1,4-Dioxane		5
1,1,1-Trichlorethane		5
Carbon tetrachloride		1
Chloroform		1.4
Tetrachloroethene		1
Trichloroethene		1

Reference: WAC 173-350-500(4), "Solid Waste Handling Standards," "Groundwater Monitoring."

Note: The information in this table does not represent EPA requirements but is intended solely as guidance.

a. For EPA Method 300.0, see EPA/600/R-93/100, *Methods for the Determination of Inorganic Substances in Environmental Samples*. For four-digit EPA methods, see SW-846, *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods, Third Edition; Final Update V*. Equivalent methods may be substituted.

b. For purposes of this groundwater monitoring plan, the highest allowable PQL is interchangeable with the lower limit of quantitation, which is the lowest level that can be routinely quantified and reported by a laboratory. The highest allowable practical quantitation limits are not to be exceeded and are specified in contracts with analytical laboratories. Actual quantitation limits vary by laboratory and may be lower than required contractually. Method detection limits are three to five times lower than quantitation limits.

c. Constituent concentration is calculated from alkalinity and does not have an individual PQL.

EPA = U.S. Environmental Protection Agency

N/A = not applicable

PQL = practical quantitation limit

A3.2 Field Analytical Methods

Field screening and survey data will be measured in accordance with HASQARD (DOE/RL-96-68) requirements (as applicable). Field analytical methods may also be performed in accordance with manufacturer manuals. Table A-3 provides the parameters (if any) identified for field measurements. Appendix B provides further discussion on field measurements.

A3.3 Quality Control

QC requirements specified in the plan must be followed in the field and analytical laboratory to ensure that reliable data are obtained. Field QC samples will be collected to evaluate the potential for cross-contamination and to provide information pertinent to sampling variability. Laboratory QC samples estimate the precision, bias, and matrix effects of the analytical data. Field and laboratory QC samples are summarized in Table A-4. Acceptance criteria for field and laboratory QC are shown in Table A-5. Data will be qualified and flagged in HEIS, as appropriate.

Table A-4. QC Samples

Sample Type	Frequency	Characteristics Evaluated
Field Quality Control		
Field Duplicates	One in 20 well trips	Precision, including sampling and analytical variability
Field Splits	As needed When needed, the minimum is one for every analytical method, for analyses performed.	Precision, including sampling, analytical, and interlaboratory
Full Trip Blanks	One in 20 well trips	Cross-contamination from containers or transportation
Field Transfer Blanks	One each day that volatile organic compounds are sampled	Contamination from sampling site
Equipment Blanks	As needed If only disposable equipment is used or equipment is dedicated to a particular well, then an equipment blank is not required; otherwise, one for every 20 samples[a]	Adequacy of sampling equipment decontamination and contamination from nondedicated equipment
Analytical Quality Control[b]		
Laboratory Duplicates	One per analytical batch[c]	Laboratory reproducibility and precision
Matrix Spikes	One per analytical batch[c]	Matrix effect/laboratory accuracy
Post Digestion Spike	One per analytical batch[c]	Matrix effect/laboratory accuracy
Post-Digestion Spike Duplicates	One per analytical batch[c]	Laboratory accuracy and precision
Matrix Spike Duplicates	One per analytical batch[c]	Laboratory accuracy and precision
Laboratory Control Samples	One per analytical batch[c]	Laboratory accuracy
Method Blanks	One per analytical batch[c]	Laboratory contamination

Table A-4. QC Samples

Sample Type	Frequency	Characteristics Evaluated
Surrogates	Added to each sample and QC sample[c]	Recovery/yield

Note: The information in this table does not represent EPA requirements but is intended solely as guidance.

a. For portable pumps, equipment blanks are collected one for every 10 well trips. Whenever a new type of nondedicated equipment is used, an equipment blank will be collected every time sampling occurs until it can be shown that less frequent collection of equipment blanks is adequate to monitor the decontamination methods for the nondedicated equipment.

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

c. Unless not required by, or different frequency is called out in, laboratory analysis methods.

EPA = U.S. Environmental Protection Agency

QC = quality control

Table A-5. Laboratory Quality Control and Acceptance Criteria

Analyte	Quality Control	Acceptance Criteria	Corrective Action
Anions			
Alkalinity (Measurement includes bicarbonate alkalinity)	MB	<MDL <5% Sample concentration	Flag with "C"
	LCS	80–120% recovery	Review Data[a]
	DUP[b]/MSD[b]	≤20% RPD[c]	Review Data[a]
	MS/MSD	75–125% recovery	Flag with "N"
	EB, FTB	<2 times MDL	Flag with "Q"
	Field Duplicate/SPLIT	≤20% RPD[c]	Review Data[a]
Coliform	MB	Pass/Fail[d]	Flag with "C"
	LCS	Pass/Fail[d]	Review Data[a]
	DUP	Pass/Fail[d]	Review Data[a]
Anions by IC (chloride, sulfate, nitrate)	MB	<MDL <5% sample concentration	Flag with "C"
	LCS	80–120% recovery	Review Data[a]
	DUP[b]/MSD[b]	≤20% RPD[c]	Review Data[a]
	MS/MSD	75–125% recovery	Flag with "N"
	EB, FTB	<2 times MDL	Flag with "Q"
	Field Duplicate/SPLIT	≤20% RPD[c]	Flag with "Q"
Metals			
ICP-AES Metals (arsenic, calcium, iron, magnesium, manganese, sodium)	MB	<MDL <5% Sample concentration	Flag with "C"
	LCS	80–120% recovery	Review Data[a]

Table A-5. Laboratory Quality Control and Acceptance Criteria

Analyte	Quality Control	Acceptance Criteria	Corrective Action
	DUP[b]/MSD[b]	≤20% RPD[c]	Review Data[a]
	MS/MSD	75–125% recovery	Flag with "N"
	EB, FTB	<2 times MDL	Flag with "Q"
	Field Duplicate/SPLIT	≤20% RPD[c]	Flag with "Q"
Volatile Organic Compounds			
Volatiles by GC/MS (1,1-dichloroethane, 1,2-dichloroethane, 1,4-dichlorobenzene, 1,1,1-trichlorethane, 1,4-dioxane, carbon tetrachloride, chloroform, tetrachloroethene, trichloroethene)	MB	<MDL[e] <5% Sample concentration	Flag with "B"
	LCS	70 to 130% Recovery	Review Data[a]
	DUP[b]/MSD[b]	≤20% RPD[c]	Review Data[a]
	MS/MSD	70 to 130% Recovery	Flag with "T"
	SUR	70 to 130% Recovery	Review Data[a]
	EB, FTB, FXR	<2 times MDL[e]	Flag with "Q"
	Field Duplicate/SPLIT	≤20% RPD[c]	Flag with "Q"

Notes: The information in this table does not represent EPA requirements but is intended solely as guidance.

This table only applies to laboratory analyses. Specific conductance, pH, and temperature are not listed as they are measured in the field.

a. After review, corrective actions are determined on a case-by-case basis. Corrective actions may include a laboratory recheck or flagging the data as suspect (Y flag), failed field QC (Q flag), or rejected (R flag).

b. Either a DUP or a MSD is to be analyzed to determine measurement precision.

c. Applies when at least one result is greater than the laboratory PQL.

d. Passing QC; MB = no colonies detected, LCS = appropriate colonies detected, DUP = colonies detected/undetected are consistent with sample.

e. For common laboratory contaminants such as acetone, methylene chloride, 2-butanone, toluene, and phthalate esters, the acceptance criteria is < 5 times the MDL.

EB = equipment blank
EPA = U.S. Environmental Protection Agency
FTB = full trip blank
FXR = field transfer blank
GC/MS = gas chromatography/mass spectrometry
IC = ion chromatography
ICP-AES = inductively coupled plasma-atomic emission spectroscopy
LCS = laboratory control sample
MB = method blank
MDL = method detection limit
MS = matrix spike
MSD = matrix spike duplicate
PQL = practical quantitation limit
QC = quality control
RPD = relative percent difference
SPLIT = field split
SUR = surrogate

Data Flags:

B (organics) = analyte was detected in both the associated QC blank and the sample
C (inorganics/wetchem) = analyte was detected in both the sample and the associated QC blank and the blank value exceeds 5% of the measured concentration present in the associated sample
N = all except GC/MS – matrix spike outlier
T = volatile organic analysis and semivolatile organic analysis GC/MS – matrix spike outlier
Q = associated QC sample is out of limits

A3.3.1 Field Quality Control Samples

Field QC samples are collected to evaluate the potential for cross-contamination and provide information pertinent to field sampling variability and laboratory performance to help ensure that reliable data are obtained. Field QC samples include field duplicates, field split (SPLIT) samples, and three types of field blanks (full trip blanks [FTBs], field transfer blanks [FXRs], and equipment blanks [EBs]). Field blanks are typically prepared using high-purity reagent water. QC sample definitions and their required frequency for collection are described below:

Field duplicates: independent samples collected as close as possible to the same time and same location as the scheduled sample, and intended to be identical. Field duplicates are placed in separate sample containers and analyzed independently. Field duplicates are used to determine precision for both sampling and laboratory measurements.

Field splits (SPLITs): two samples collected as close as possible to the same time and same location and are intended to be identical. SPLITs will be stored in separate containers and analyzed by different laboratories for the same analytes. SPLITs are interlaboratory comparison samples used to evaluate comparability between laboratories.

Full trip blanks (FTBs): bottles prepared by the sampling team before travel to the sampling site. The preserved bottle set is either for volatile organic analysis only or identical to the set that will be collected in the field. It is filled with high-purity reagent water[1], and the bottles are sealed and transported (unopened) to the field in the same storage containers used for samples collected that day. Collected FTBs are typically analyzed for the same constituents as the samples from the associated sampling event. FTBs are used to evaluate potential contamination of the samples attributable to the sample bottles, preservative, handling, storage, and transportation.

Field transfer blanks (FXRs): preserved volatile organic analysis sample vials filled with high-purity reagent water at the sample collection site where volatile organic compounds (VOCs) are collected. Samples will be prepared during sampling to evaluate potential contamination attributable to field conditions. After collection FXR sample vials will be sealed and placed in the same storage containers with samples collected the same day for the associated sampling event. FXR samples will be analyzed for VOCs only.

Equipment blanks (EBs): Reagent water passed through or poured over the decontaminated sampling equipment identical to the sample set collected and placed in sample containers, as identified on the SAF. EB sample bottles are placed in the same storage containers with samples from the associated sampling event. EB samples will be analyzed for the same constituents as samples from the associated sampling event. EBs are used to evaluate the effectiveness of the decontamination process and those samples are not required for disposable sampling equipment.

A3.3.2 Laboratory Quality Control Samples

Internal QA/QC programs are maintained by laboratories used by the project. Laboratory QA includes a comprehensive QC program that includes the use of laboratory sample duplicates (DUPs), matrix spikes (MSs), matrix spike duplicates (MSDs), laboratory control samples (LCSs), method blanks (MBs), and surrogates (SURs). These QC analyses are required by EPA methods (e.g., those in SW-846, *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods, Third Edition; Final Update V*), and

[1] High-purity water that is generally defined as water that has been distilled, deionized, or any combination of distillation, deionization, reverse osmosis, activated carbon filtration, ion exchange, particulate filtration, or other polishing techniques (DOE/RL-96-68).

will be run at the frequency specified in the respective references unless superseded by agreement. QC checks outside of control limits are documented in analytical laboratory reports during DQAs, if performed. Laboratory QC checks and their typical frequencies are listed in Table A-4. Acceptance criteria are shown in Table A-5. Descriptions of the various types of laboratory QC samples are as follows:

Laboratory sample duplicate (DUP): an intralaboratory replicate sample that is used to evaluate the precision of a method in a given sample matrix.

Matrix spike (MS): an aliquot of a sample spiked with a known concentration of target analyte(s). MS is used to assess the bias of a method in a given sample matrix. Spiking occurs prior to sample preparation and analysis.

Matrix spike duplicate (MSD): a replicate spiked aliquot of a sample that is subjected to the entire sample preparation and analytical process. MSD results are used to determine the bias and precision of a method in a given sample matrix.

Laboratory control sample (LCS): a control matrix (e.g., reagent water) spiked with analytes representative of the target analytes or a certified reference material that is used to evaluate laboratory accuracy.

Method blank (MB): an analyte-free matrix to which the same reagents are added in the same volumes or proportions as used in the sample processing. The MB is carried through the complete sample preparations and analytical procedure and is used to quantify contamination resulting from the analytical process.

Surrogate (SUR): a compound added to every sample in the analysis batch (field samples and QC samples) prior to preparation. SURs are typically similar in chemical composition to the analyte being determined, but they are not normally encountered. SURs are expected to respond to the preparation and measurement systems in a manner similar to the analytes of interest. Because SURs are added to every standard, sample, and QC sample, they are used to evaluate overall method performance in a given matrix. SURs are used only in organic analyses.

Laboratories are required to analyze samples within the holding times specified in Table A-6. In some instances, constituents in the samples not analyzed within the holding times may be compromised by volatilization, decomposition, or other chemical changes. Data from samples analyzed outside of the holding times are flagged in the HEIS database with an "H."

Table A-6. Preservation and Holding Time Guidelines for Laboratory Analyses

Constituent/Parameter	Preservation*	Holding Time
Alkalinity (includes bicarbonate alkalinity)	Store ≤6°C	14 days
Coliform	Store ≤6°C	6 hours
Anions by ion chromatography (chloride, sulfate, nitrate)	Store ≤6°C	48 hours

Table A-6. Preservation and Holding Time Guidelines for Laboratory Analyses

Constituent/Parameter	Preservation*	Holding Time
Inductively coupled plasma metals (arsenic, calcium, iron, magnesium, manganese, sodium)	Adjust pH to <2 with nitric acid	6 months
Volatiles by GC/MS (1,1-dichloroethane, 1,2-dichloroethane, 1,4-dichlorobenzene, 1,1,1-trichlorethane, 1,4-dioxane, carbon tetrachloride, chloroform, tetrachloroethene, and trichloroethene)	Store ≤6°C, Adjust pH to <2 with sulfuric acid or hydrochloric acid	14 days maximum preserved

Notes: The container type for a sample is available on the chain-of-custody.

The information in this table does not represent EPA requirements but is intended solely as guidance.

This table only applies to laboratory analyses. Specific conductance, pH, and temperature are not listed as they are measured in the field.

* For preservation identified as stored at ≤6°C, the sample should be protected against freezing unless it is known that freezing will not impact the sample integrity.

EPA = U.S. Environmental Protection Agency

GC/MS = gas chromatography/mass spectrometry

A3.4 Measurement Equipment

Each user of the measuring equipment is responsible to ensure that equipment is functioning as expected, properly handled, and properly calibrated at required frequencies in accordance with methods governing control of the measuring equipment. Onsite environmental instrument testing, inspection, calibration, and maintenance will be recorded in accordance with approved methods. Field screening instruments will be used, maintained, and calibrated in accordance with manufacturer specifications and other approved methods.

A3.5 Instrument and Equipment Testing, Inspection, and Maintenance

Collection, measurement, and testing equipment will meet applicable standards (e.g., ASTM International, formerly the American Society for Testing and Materials) or will have been evaluated as acceptable and valid in accordance with instrument-specific methods, requirements, and specifications. Software applications will be acceptance tested prior to use in the field.

Measurement and testing equipment used in the field or in the laboratory will be subject to preventive maintenance measures to ensure minimization of downtime. Laboratories must maintain and calibrate their equipment. Maintenance requirements (e.g., documentation of routine maintenance) will be included in the individual laboratory and onsite organization's QA plan or operating protocols, as appropriate. Maintenance of laboratory instruments will be performed in a manner consistent with applicable Hanford Site requirements.

A3.6 Instrument/Equipment Calibration and Frequency

Field equipment calibration is discussed in Appendix B. Analytical laboratory instruments are calibrated in accordance with the laboratory's QA plan and applicable Hanford Site requirements.

A3.7 Inspection/Acceptance of Supplies and Consumables

Consumables, supplies, and reagents will be reviewed in accordance with test methods in SW-846 and will be appropriate for their use. Supplies and consumables used in support of sampling and analysis activities are procured in accordance with internal work requirements and processes. Responsibilities and interfaces necessary to ensure that items procured/acquired for the contractor meet the specific technical and quality requirements must be in place. The procurement system ensures that purchased items comply with applicable procurement specifications. Supplies and consumables are checked and accepted by users prior to use.

A3.8 Nondirect Measurements

Data obtained from sources, such as computer databases, programs, literature files, and historical databases, will be technically reviewed to the same extent as data generated as part of any sampling and analysis QA/QC effort. Data used in evaluations will be identified by source.

A3.9 Data Management

The SMR group, in coordination with the Project Delivery Manager for Groundwater Science, is responsible for ensuring that analytical data are appropriately reviewed, managed, and stored in accordance with applicable programmatic requirements governing data management methods.

Electronic data access, when appropriate, will be through a Hanford Site database (e.g., HEIS). Where electronic data are not available, hard copies will be provided in accordance with Section 9.6 of the Tri-Party Agreement Action Plan (Ecology et al., 1989b).

Laboratory errors are reported to the SMR group through an established process. For reported laboratory errors, a sample issue resolution form will be initiated in accordance with applicable methods. This process is used to document analytical errors and establish their resolution with the Project Delivery Manager for Groundwater Science. The sample issue resolution forms become a permanent part of the analytical data package for future reference and records management.

A4 Assessment and Oversight

Assessment and oversight activities address the effectiveness of project implementation and associated QA/QC activities. The purpose of assessment is to ensure that the QAPjP is implemented as prescribed.

A4.1 Assessments and Response Actions

Random surveillances and assessments verify compliance with the requirements outlined in this plan, project field instructions, the QAPjP, methods, and regulatory requirements. Deficiencies identified by these assessments will be reported in accordance with existing programmatic requirements. The project line management chain coordinates the corrective actions/deficiency resolutions in accordance with the QA program, corrective action management program, and associated methods implementing these programs. When appropriate, corrective actions will be taken by the Project Delivery Manager for Groundwater Science.

Oversight activities in the analytical laboratories, including corrective action management, are conducted in accordance with laboratory QA plans. The SMR group oversees offsite analytical laboratories and verifies that laboratories are qualified to perform Hanford Site analytical work.

A4.2 Reports to Management

Program and project management (as appropriate) will be made aware of deficiencies identified by self-assessments, corrective actions from ECOs, and findings from QA assessments and surveillances. Issues reported by the laboratories are communicated to the SMR group, which then initiates a sample issue resolution form. This process is used to document analytical or sample issues and establish resolution with the Project Delivery Manager for Groundwater Science.

These assessments are internal assessments and are not subject to RCRA regulation. If an assessment finding results in sampling issues that impact a regulatory requirement, DOE would be informed and the matter discussed with Ecology at the appropriate level and time.

A5 Data Review and Usability

This chapter addresses QA activities that occur after data collection. Implementation of these activities determines whether the data conform to the specified criteria, thus satisfying the project objectives.

A5.1 Data Review and Verification

Data review and verification are performed to confirm that sampling and chain-of-custody documentation are complete. This review includes linking sample numbers to specific sampling locations, and reviewing sample collection dates and sample preparation and analysis dates to assess whether holding times, if any, have been met. Furthermore, a review of QC data is used to determine whether analyses have met the data quality requirements specified in this plan.

The criteria for verification include, but are not limited to, review for contractual compliance (samples were analyzed as requested), use of the correct analytical method, transcription errors, correct application of dilution factors, appropriate reporting of dry weight versus wet weight, and correct application of conversion factors. Field QA/QC results also will be reviewed to ensure that they are usable.

The project scientist, assigned by the Project Delivery Manager for Groundwater Science, will perform a data review to help determine if observed changes reflect improved/degraded groundwater quality or potential data errors, which may result in submittal of a request for data review on questionable data. The laboratory may be asked to check calculations or re-analyze the sample, or the well may be resampled. Results of the request for data review process are used to flag the data appropriately in the HEIS database and/or to add comments.

A5.2 Data Validation

Data validation is performed at the discretion of the Project Delivery Manager for Groundwater Science and under the direction of the SMR group. It is based on the results of the QC samples for an individual network, discussions with the project scientist, and discussions with the laboratory services manager. If defined as appropriate, data validation (third party) will be performed at a minimum frequency of 5 percent and be based on EPA functional guidelines.

A5.3 Reconciliation with User Requirements

The DQA process compares completed field sampling activities to those proposed in corresponding sampling documents and provides an evaluation of the resulting data. The purpose of the DQA is to determine whether quantitative data are of the correct type and are of adequate quality and quantity to meet the project data quality needs. For routine groundwater monitoring performed through this groundwater monitoring plan, the DQA is captured in the DQA appendix associated with the annual Hanford Site groundwater report (e.g., DOE/RL-2015-07), which evaluates field and laboratory QC and the usability of data. Further DQAs will be performed at the discretion of the Project Delivery Manager for Groundwater Science and documented in a report overseen by the SMR group.

A6 References

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WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells," *Washington Administrative Code*, Olympia, Washington. Available at: http://apps.leg.wa.gov/WAC/default.aspx?cite=173-160.

WAC 173-350-500, "Solid Waste Handling Standards," "Groundwater Monitoring," *Washington Administrative Code*, Olympia, Washington. Available at: http://app.leg.wa.gov/WAC/default.aspx?cite=173-350-500.

Appendix B

Sampling Protocol

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Contents

B1 Introduction **B-1**

B2 Sampling Methods **B-1**

B2.1 Decontamination of Sampling Equipment B-3

B2.2 Water Levels B-4

B3 Documentation of Field Activities **B-4**

B3.1 Corrective Actions and Deviations for Sampling Activities B-5

B4 Calibration of Field Equipment **B-5**

B5 Sample Handling **B-5**

B5.1 Containers B-6

B5.2 Container Labeling B-6

B5.3 Sample Custody B-6

B5.4 Sample Transportation B-7

B6 Management of Waste **B-7**

B7 Health and Safety **B-8**

B8 References **B-8**

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Terms

DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
FWS	Field Work Supervisor
gpm	gallons per minute
HASQARD	*Hanford Analytical Services Quality Assurance Requirements Document* (DOE/RL-96-68)
IATA	International Air Transport Association
NTU	nephelometric turbidity unit
QA	quality assurance
QC	quality control
SMR	Sample Management and Reporting

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B1 Introduction

Groundwater monitoring at the Hanford Site has been conducted since the mid-1980's. Hanford Site groundwater sampling methods contain extensive requirements for sampling precautions to be taken; equipment and its use; cleaning and decontamination; records and documentation; and sample collection, management, and control activities. Together, Appendices A and B provide the sampling and analysis essentials necessary for the groundwater monitoring plan: sample collection, sample preservation and holding times, chain-of-custody control, analytical procedures, and field and laboratory quality assurance (QA)/quality control (QC).

This appendix provides more specific elements of the sampling protocols and techniques used for the groundwater monitoring plan. Chapter 3 of the groundwater monitoring plan identifies the monitoring wells that will be sampled, the constituents to be analyzed, and sampling frequency for the groundwater monitoring at the Solid Waste Landfill.

B2 Sampling Methods

Sampling may include, but is not limited to, the following methods:

- Field screening measurements
- Groundwater sampling
- Water level measurements

Groundwater samples will be collected in accordance with the current revision of applicable operating methods. Groundwater samples are collected after field measurements of purged groundwater have stabilized:

- pH – two consecutive measurements agree within 0.2 pH units
- Temperature – two consecutive measurements agree within 0.2°C (32.3°F)
- Conductivity – two consecutive measurements agree within 10 percent of each other
- Turbidity – less than 5 nephelometric turbidity units (NTUs) prior to sampling (or project scientist's recommendation)

Unless special requirements are requested from project scientists, wells are typically purged using the equivalent volume as that of three borehole diameters multiplied by the length of the saturated portion of the well screen. Stable field readings are also required as specified above. The default pumping rate is 7.6 to 45.4 L/min (2 to 12 gallons per minute [gpm]) depending on the pump, although this is not practical at every well. On occasions where the purge volume is extraordinarily large, wells are purged for a minimum of 1 hour and are then sampled once stable field readings are obtained.

Field measurements (except for turbidity) are obtained using a flow-through cell. Groundwater is pumped directly from the well to the flow-through cell. At the beginning of the sample event, field crews attach a clean, stainless-steel sampling manifold to the riser discharge. The manifold has two valves and two ports: one port is used only for purgewater, and the other port is used to supply water to the flow-through cell. Probes are inserted into the flow through cell to measure pH, temperature, and conductivity. Turbidity is measured by inserting a sample vial into a turbidimeter. The purgewater is then discharged to the purgewater truck.

Once field measurements have stabilized, the hose supplying water to the flow-through cell is disconnected and a clean, stainless-steel drop leg is attached for sampling. The flow rate is reduced during sampling to minimize loss of volatiles (if any) and prevent over filling the bottles. Sample bottles are filled in a sequence designed to minimize loss of volatiles, if any. Filtered samples are collected after collection of the unfiltered samples. For some constituents (e.g., metals) both filtered and unfiltered samples are collected. If additional samples require filtration (e.g., at turbidity greater than 5 NTUs), an inline, disposable 0.45 μm filter is used.

Typically, three traditional types (i.e., Grundfos[1], Hydrostar[2], and submersible electrical pumps) of environmental-grade sampling pumps are used for groundwater sampling at Hanford Site monitoring wells. In addition, low-purge-volume, adjustable-rate bladder pumps may be used. Individual pumps are selected based on the unique characteristics of the well and the sampling requirements.

A small number of wells will not support pumping of samples because of low yield or the physical characteristics of the well. In these cases, a grab sample may be obtained. In cases where there is not sufficient yield, purgewater activities are not performed.

Low-purge-volume sampling methodology for the collection of groundwater samples is also being implemented at the Hanford Site. Low-flow purging and sampling uses a low-purge-volume, adjustable-rate bladder pump with flow rates typically on the order of 0.1 to 0.5 L/min (0.26 to 0.13 gpm). This methodology is intended to minimize excessive movement of water from the soil formation into the well. The objective is to pump in a manner that minimizes stress (drawdown) to the system. Purge volumes for wells using low-purge bladder pumps are determined on a well-specific basis based on drawdown, pumping rate, pump and sample line volume, and volume required to obtain stable field conditions prior to collecting samples.

For certain types of samples, preservatives are required. Preservatives, based on the analytical methods used, are added to the collection bottles before their use in the field. Samples may require filtering in the field, as noted on the chain-of-custody form.

To ensure sample and data usability, sampling associated with this groundwater monitoring plan will be performed in accordance with the requirements of DOE/RL-96-68, *Hanford Analytical Services Quality Assurance Requirements Document* (HASQARD), pertaining to sample collection, collection equipment, and sample handling.

Sample preservation and holding-time requirements are specified for groundwater samples in Appendix A, Table A-6. These requirements are in accordance with the analytical method specified in Appendix A, Table A-3. The container types, preservatives, and volumes will be identified on the chain-of-custody form. This groundwater monitoring plan defines a sample as a filled sample bottle for purposes of starting the clock for holding-time restrictions.

Holding time is the maximum allowable period between sample collection and analysis. Exceeding required holding times could result in changes in constituent concentrations due to volatilization, decomposition, or other chemical alterations. Required holding times depend on the constituent and are listed in analytical method compilations such as APHA/AWWA/WEF, 2012, *Standard Methods for the Examination of Water and Wastewater*, and SW-846, *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, Third Edition; Final Update V*. Recommended holding times are also provided in HASQARD (DOE/RL-96-68) and in applicable laboratory contracts.

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[1] Grundfos® is a registered trademark of Grundfos Holding A/S Corporation, Bjerringbro, Denmark.

[2] Hydrostar® is a registered trademark of KYB Corporation, Tokyo, Japan.

B2.1 Decontamination of Sampling Equipment

Sampling equipment will be decontaminated in accordance with sampling equipment decontamination methods. To prevent potential contamination of the samples, care should be taken to use decontaminated equipment for each specific sampling activity.

Special care should be taken to avoid the following common ways in which cross-contamination or background contamination may compromise the samples:

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

Decontamination of sampling equipment and pumps is performed using high-purity water[3] in each step. In general, three rinse cycles are performed to decontaminate sampling equipment: a detergent rinse, an acid rinse, and a water rinse. During the detergent rinse, the equipment is washed in a phosphate-free detergent solution, followed by rinsing with water in three sequential containers. After the third water rinse, equipment that is stainless-steel or glass is rinsed in a 1M nitric acid solution (pH less than 2). Equipment is then rinsed with water in three sequential containers (the water rinses following the acid rinse are conducted in separate water containers that are not used for detergent rinse). Following the final water rinse, equipment is rinsed in hexane and then placed on a rack to dry. Dry equipment is loaded into a drying oven. The oven is set at 50°C (122°F) for items that are not metal or glass or at 100°C (212°F) for metal or glass. Once reaching temperature, equipment is baked for 20 minutes and then cooled. The equipment is then removed from the oven, and the equipment is enclosed in clean, unused aluminum foil using surgeon's gloves. The wrapped equipment is stored in a custody-locked, controlled-access area.

To decontaminate sampling pumps that are not permanently installed, the pump cowling is first removed, washed (if needed) in phosphate-free detergent solution, and then reinstalled on the pump. The pump is then submerged in phosphate-free detergent solution, and 11.4 L (3 gal) of solution is pumped through the unit and disposed. Detergent solution is then circulated through the submerged pump for 5 minutes. The pump is removed from solution and rinsed with water. The pump is submerged in water and 30.3 L (8 gal) of water is pumped through the unit and disposed. The pump is removed from the water and the intake and housing are covered with plastic sleeving. The cleaning is documented on a tag that is affixed to the pump, and the tag will include the following information:

- Date pump cleaned
- Pump identification
- Comments
- Signature of person performing decontamination

[3] High-purity water that is generally defined as water that has been distilled, deionized, or any combination of distillation, deionization, reverse osmosis, activated carbon filtration, ion exchange, particulate filtration, or other polishing techniques (DOE/RL-96-68).

B2.2 Water Levels

Each time a sample is obtained, measurement of the ground water surface elevation at each monitoring well is required by WAC 173-350-500(4)(d), "Solid Waste Handling Standards," "Groundwater Monitoring." Using a calibrated depth measurement tape, the depth to water is recorded in each well prior to purging, using calibrated depth measurement tapes that ensures measurement to 3 mm (0.11 in.) relative to the top of the casing. When two consecutive measurements are taken that agree within 6 mm (0.24 in.); the final determined measurement is recorded, along with the date and time for the specific event. The depth to groundwater is subtracted from the elevation of a reference point (usually the top of the casing) to obtain the water-level elevation. The top of the casing is a known elevation reference point because it has been surveyed to local reference data.

B3 Documentation of Field Activities

Logbooks or data forms are required for field activities and will be used in accordance with HASQARD (DOE/RL-96-68) requirements. A logbook must be identified with a unique project name and number. The individual(s) responsible for logbooks will be identified in the front of the logbook, and only authorized persons may make entries in logbooks. Logbook entries will be reviewed by the sampling Field Work Supervisor (FWS), cognizant scientist/engineer, or other responsible manager; the review will be documented with a signature and date. Logbooks will be permanently bound, waterproof, and ruled with sequentially numbered pages. Pages will not be removed from logbooks for any reason. Entries will be made in indelible ink. Corrections will be made by marking through the erroneous data with a single line, entering the correct data, and initialing and dating the changes.

Data forms may be used to collect field information; however, information recorded on data forms must follow the same requirements as those for logbooks. The data forms must be referenced in the logbooks.

A summary of information to be recorded in logbooks or on data forms is as follows:

- Day and date; time task started; weather conditions; and names, titles, and organizations of personnel performing the task.
- Purpose of visit to the task area.
- Site activities in specific detail (e.g., maps and drawings) or the forms used to record such information (e.g., soil boring log or well completion log). Also, details of any field tests that were conducted; reference to any forms that were used, other data records, and methods followed in conducting the activity.
- Details of any field calibrations and surveys that were conducted. Reference any forms that were used, other data records, and the methods followed in conducting the calibrations and surveys.
- Details of any samples collected and the preparation (if any) of splits, duplicates, matrix spikes, or blanks. Reference the methods followed in sample collection or preparation; list location of sample collected, sample type, each label or tag numbers, sample identification, sample containers and volume, preservation method, packaging, chain-of-custody form number, and analytical request form number pertinent to each sample or sample set; and note the time and the name of the individual to whom custody of samples was transferred.
- Time, equipment type, serial or identification number, and methods followed for decontaminations and equipment maintenance performed. Reference the page number(s) of any logbook where detailed information is recorded.

- Any equipment failures or breakdowns that occurred, with a brief description of repairs or replacements.

B3.1 Corrective Actions and Deviations for Sampling Activities

The Project Delivery Manager for Groundwater Science, FWS, appropriate field crew supervisors, and Sample Management and Reporting (SMR) personnel must document deviations from protocols, issues pertaining to sample collection, chain-of-custody forms, target analytes, contaminants, sample transport, or noncompliant monitoring. Examples of deviations include samples not collected due to field conditions.

As appropriate, such deviations or issues will be documented (e.g., in the field logbook) in accordance with internal corrective action methods. The Project Delivery Manager for Groundwater Science, FWS, field crew supervisors, or SMR personnel will be responsible for communicating field corrective action requirements and ensuring that immediate corrective actions are applied to field activities.

Changes in sample activities that require notification, approval, and documentation will be performed as specified in Appendix A, Table A-2.

B4 Calibration of Field Equipment

Onsite environmental instruments are calibrated in accordance with the manufacturer's operating instructions, internal work requirements and processes, and/or field instructions that provide direction for equipment calibration or verification of accuracy by analytical methods. Calibration records shall include the raw calibration data, identification of the standards used, associated reports, date of analysis, and analyst's name or initials. The results from all instrument calibration activities are recorded in accordance with the HASQARD requirements (DOE/RL-96-68).

Field instrumentation, calibration, and QA checks will be performed as follows:

- Prior to initial use of a field analytical measurement system.
- At the frequency recommended by the manufacturer or methods, or as required by regulations.
- Upon failure to meet specified QC criteria.
- Daily calibration checks will be performed and documented for each instrument used. These checks will be made on standard materials sufficiently like the matrix under consideration for direct comparison of data. Analysis times will be sufficient to establish detection efficiency and resolution.
- Using standards for calibration that are traceable to a nationally recognized standard agency source or measurement system. Manufacturer's recommendations for storage and handling of standards (if any) will be followed.

B5 Sample Handling

Sample handling and transfer will be in accordance with established methods to preclude loss of identity, damage, deterioration, and loss of sample. Custody seals or custody tape will be used to verify that sample integrity has been maintained during sample transport. The custody seal will be inscribed with the sampler's initials and date.

A sampling and analytical database is used to track samples from the point of collection through the laboratory analysis process.

B5.1 Containers

Samples shall be collected, where and when appropriate, in break-resistant containers. The field sample collection record shall indicate the laboratory lot number of the bottles used in sample collection. When commercially pre-cleaned containers are used in the field, the name of the manufacturer, lot identification, and certification shall be retained for documentation.

Containers shall be capped and stored in an environment that minimizes the possibility of sample container contamination. If contamination of the stored sample containers occurs, corrective actions shall be implemented to prevent reoccurrences. Contaminated sample containers cannot be used for a sampling event. Container sizes may vary depending on laboratory-specific volumes/requirements for meeting analytical detection limits. Container types and sample amounts/volumes are identified on the chain-of-custody form.

B5.2 Container Labeling

Each sample is identified by affixing a standardized label or tag to the container. This label or tag shall contain the sample identification number. The label shall identify or provide reference to associate the sample with the date and time of collection, preservative used (if applicable), analysis required, and collector's name or initials. Sample labels may be either preprinted or handwritten in indelible or waterproof ink.

B5.3 Sample Custody

Sample custody will be maintained in accordance with existing protocols to ensure that sample integrity is maintained throughout the analytical process. Chain-of-custody protocols will be followed throughout sample collection, transfer, analysis, and disposal to ensure that sample integrity is maintained. A chain-of-custody record will be initiated in the field at the time of sampling and will accompany each set of samples shipped to any laboratory.

Shipping requirements will determine how sample shipping containers are prepared for shipment. The analyses requested for each sample will be indicated on the accompanying chain-of-custody form. Each time the responsibility for custody of the sample changes, new and previous custodians will sign the record and note the date and time. The field sampling team will make a copy of the signed record before sample shipment and transmit the copy to the SMR group.

The following minimum information is required on a completed chain-of-custody form:

- Project name
- Collectors' names
- Unique sample number
- Date and time of collection
- Matrix
- Preservatives
- Chain of possession information (i.e., signatures and printed names of each individual involved in the transfer of sample custody and storage locations, and dates/times of receipt and relinquishment)
- Requested analyses (or reference thereto)

- Shipped-to information (i.e., analytical laboratory performing the analysis)

Samplers should note any anomalies with the samples. If anomalies are found, samplers should inform the SMR group; so special direction for analysis can be provided to the laboratory if deemed necessary.

B5.4 Sample Transportation

Packaging and transportation instructions shall comply with applicable transportation regulations and U.S. Department of Energy (DOE) requirements. Regulations for classifying, describing, packaging, marking, labeling, and transporting hazardous materials, hazardous substances, and hazardous wastes are enforced by the U.S. Department of Transportation (DOT) as described in 49 CFR 171, "Transportation," "General Information, Regulations, and Definitions," through 49 CFR 177, "Carriage by Public Highway."[4] Carrier-specific requirements defined in the current edition of International Air Transport Association (IATA) *Dangerous Goods Regulations*, shall also be used when preparing sample shipments conveyed by air freight providers.

Samples containing hazardous constituents shall be considered hazardous material in transportation and transported according to DOT/IATA requirements. If the sample material is known or can be identified, then it will be classified, described, packaged, marked, labeled, and shipped according to the specific instructions for that material. Appropriate laboratory notifications will be made, if necessary, through the SMR project coordinator.

B6 Management of Waste

Waste materials are generated during sample collection, processing, and subsampling activities. Waste will be managed in accordance with DOE/RL-2004-18, *Waste Control Plan for the 200-PO-1 Groundwater Operable Unit*. For waste designation purposes, wells listed in Table 3-2 in the main text of the monitoring plan may be surveyed in the Hanford Environmental Information System and the maximum concentration for each analyte within the most recent 5 years will be evaluated for use to create a waste profile, if required.

Miscellaneous solid waste that has contacted suspect dangerous waste will be managed as dangerous waste. Purgewater and decontamination fluids will be collected and managed in accordance with DOE/RL-2011-41, *Hanford Site Strategy for Management of Investigation Derived Waste*; and DOE/RL-2009-80, *Investigation Derived Waste Purgewater Management Work Plan*. Waste materials requiring collection will be placed in containers appropriate for the material and the receiving facility in accordance with the applicable waste management or waste control plan and applicable substantive federal and/or state requirements.

Packaging and labeling during waste storage and transportation will meet WAC 173-303 and DOT requirements, as appropriate. Packaging exceptions to DOT requirements may be used for onsite waste shipments if documented as such and if the packaging provides an equivalent degree of safety during transportation.

Offsite analytical laboratories are responsible for the disposal of unused sample quantities.

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[4] Transportation regulations 49 CFR 174, "Carriage by Rail," and 49 CFR 176, "Carriage by Vessel," are not applicable, as these two transportation methods are not used.

B7 Health and Safety

DOE established the hazardous waste operations safety and health program pursuant to the *Price-Anderson Amendments Act of 1988* to ensure the safety and health of workers involved in mixed-waste site activities. The program was developed to comply with the requirements of 10 CFR 851, "Worker Safety and Health Program," which incorporates the standards of 29 CFR 1910.120, "Occupational Safety and Health Standards," "Hazardous Waste Operations and Emergency Response" 10 CFR 830, "Nuclear Safety Management," and 10 CFR 835, "Occupational Radiation Protection." The health and safety program defines the chemical, radiological, and physical hazards and specifies the controls and requirements for daily work activities on the overall Hanford Site. Personnel training; control of industrial safety and radiological hazards; personal protective equipment; site control; and general emergency response to spills, fire, accidents, injury, site visitors, and incident reporting are governed by the health and safety program.

B8 References

10 CFR 830, "Nuclear Safety Management," *Code of Federal Regulations*. Available at: http://www.ecfr.gov/cgi-bin/text-idx?SID=47e3de0454360a17406cb89ade0c966d&mc=true&node=pt10.4.830&rgn=div5.

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Appendix C

Well Construction

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Contents

C1 Introduction **C-1**

C2 Reference **C-14**

Figures

Figure C-1. Well 699-22-35 Construction and Completion Summary C-2
Figure C-2. Well 699-23-34B Construction and Completion Summary C-3
Figure C-3. Well 699-24-33 Construction and Completion Summary C-4
Figure C-4. Well 699-24-34D Construction and Completion Summary C-5
Figure C-5. Well 699-24-34E Construction and Completion Summary C-7
Figure C-6. Well 699-24-35 Construction and Completion Summary C-9
Figure C-7. Well 699-24-36 Construction and Completion Summary C-10
Figure C-8. Well 699-25-34E Construction and Completion Summary C-12

Tables

Table C-1. Hydrogeologic Monitoring Unit Classification Scheme C-1
Table C-2. Sampling Interval Information for Wells within the Solid Waste Landfill Network C-1

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C1 Introduction

This appendix provides the following information for the Solid Waste Landfill groundwater monitoring wells:

- Well name
- Hydrogeologic unit to be monitored (the portion of the aquifer that is located at the well screen or perforated casing) (Table C-1)
- The following sampling interval information, as shown in Table C-2:
  - Elevation at top of the screen or perforated interval
  - Elevation at the bottom of the screen or perforated interval
  - Open interval length (i.e., difference between elevations of top and bottom of the screen or perforated interval)

Figures C-1 through C-8 provide the well construction and completion summaries for wells 699-22-35, 699-23-34B, 699-24-33, 699-24-34D, 699-24-34E, 699-24-35, 699-24-36, and 699-25-34E.

Table C-1. Hydrogeologic Monitoring Unit Classification Scheme

Unit	Description
TU	**Top of Unconfined.** Screened across the water table or the top of the open interval is within 1.5 m (5 ft) of the water table, and the bottom of the open interval is no more than 10.7 m (35 ft) below the water table.

Table C-2. Sampling Interval Information for Wells within the Solid Waste Landfill Network

Well Name	Hydrogeologic Unit Monitored	Elevation Top of Open Interval (m [ft] NAVD88)	Elevation Bottom of Open Interval (m [ft] NAVD88)	Open Interval Length (m [ft])
699-22-35	TU	125.52 (411.52)	114.84 (376.52)	10.68 (35.00)
699-23-34B	TU	125.41 (411.18)	116.26 (381.18)	9.15 (30.00)
699-24-33	TU	124.90 (409.51)	111.78 (366.49)	13.12 (43.00)
699-24-34D	TU	122.98 (403.22)	113.82 (373.19)	9.16 (30.03)
699-24-34E	TU	121.94 (399.81)	112.78 (369.78)	9.16 (30.03)
699-24-35	TU	125.50 (411.48)	120.93 (396.49)	4.58 (15.00)
699-24-36	TU	122.95 (403.10)	113.80 (373.10)	9.15 (30.00)
699-25-34E	TU	123.01 (403.31)	113.86 (373.32)	9.15 (30.00)

Reference: NAVD88, *North American Vertical Datum of 1988.*

Note: See Table 3-2 in main text for depth of remaining water column.

TU = Top of Unconfined, as described in Table C-1

0502850

WELL CONSTRUCTION AND COMPLETION SUMMARY

Drilling Method:	Air Rotary	Sample Method:	Grab/Split Spoon	WELL NUMBER: 699-22-35 A8443	TEMPORARY WELL NO: None
Drilling Fluid Used:	Air	Additives Used:	None	Coordinates: N Not documented	
Driller's Name:	D. Kettle	WA State Lic Nr:	Not Available	Coordinates: E Not documented	
Drilling Company:	PC Drilling Co.	Company Location:	Richland, WA	Start Card #: Not Available	
Date Started:	20Dec93	Date Completed:	11Jan94	Elevation Ground Surface:	

Depth to Water: 124.9 ft 05Jan94
(Ground surface)

GENERALIZED STRATIGRAPHY Geologist's Log

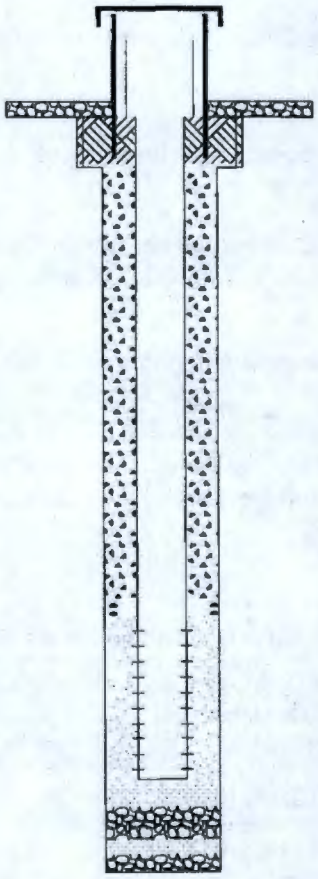
0 - 2 ft : Sand
2 - 2.4 ft : Sand and Carbonate
2.4 - 30 ft : Sand
30 - 35 ft : Gravelly Sand
35 - 56 ft : Sand
56 - 67.6 ft : Gravelly Sand
67.5 - 71 ft : Sandy Gravel
71 - 86 ft : Sand
86 - 110 ft : Sandy Gravel
110 - 124 ft : Silty Sandy Gravel
124 - 136 ft : Gravel
136 - 150 ft : Gravelly Sand
150 - 180.25 ft : Sandy Gravel

Elevation of Reference Point: m

Height of Reference Point Above Ground Surface:

Depth of Surface Seal: 11 ft.

Type of Surface Seal: 4x4 Concrete Pad



180.25 ft : Borehole drilled depth

0 - 12 ft : 13-in. 12-3/4" CS Temp. Casing
12 - 180.25 ft : 9-in. 8-5/8" CS Temp. Casing

Fill	*Casing*	*Screen*
0 - 11 ft : 13-inch hole Cement 11 - 12 ft : 13-inch hole Bentonite Crumbles	0 - 12 ft : 13 inch 12-3/4" CS Temp. Casing 0 - 122.4 ft : 4 inch 4" Perm. Casing 12 - 180.25 ft : 9 inch 8-5/8" CS Temp. Casing	
12 - 115.1 ft : 9-inch hole Bentonite Crumbles		
115.1 - 117 ft : 9-inch hole 3/8" Bentonite Pellets 117 - 119 ft : 9-inch hole 1/4" Bentonite Pellets 119 - 157.7 ft : 9-inch hole 20-40 Silica Sand 157.7 - 158 ft : 9-inch hole 20-40 Silica Sand 158 - 158.6 ft : 9-inch hole 10-20 Silica Sand 158.6 - 164.4 ft : 9-inch hole Hole Plug 164.4 - 172.4 ft : 9-inch hole Slough 172.4 - 175.9 ft : 9-inch hole Hole Plug 175.9 - 180.25 ft : 9-inch hole Slough	157.4 - 157.7 ft : 4 inch End Cap	122.4 - 157.4 ft : 4 inch 4" .010 SS Wire Wrap Pipe Size

Drawing By: DLF
Reference: Hanford Wells
Revision: 0
Revision Date: 14Jan98
Print Date: 14Jan98

Report Form: WELLS Project File: WELLS.GPJ

BECHTEL

Figure C-1. Well 699-22-35 Construction and Completion Summary

0500344

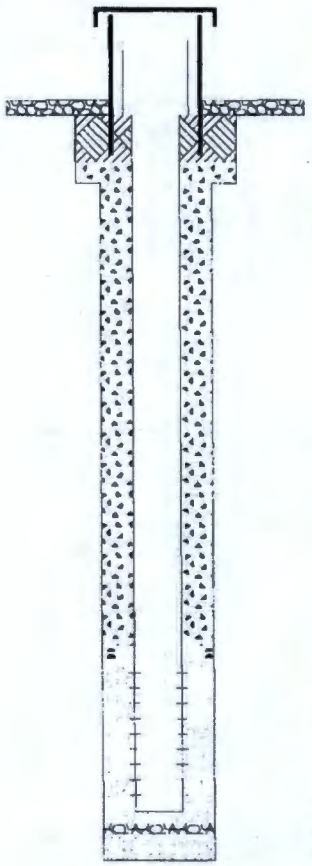
WELL CONSTRUCTION AND COMPLETION SUMMARY

Drilling Method:	Cable Tool	Sample Method:	Grab/Split Spoon	WELL NUMBER	699-23-34B A8450	TEMPORARY WELL NO:	None
Drilling Fluid Used:	NA	Additives Used:	None	Coordinates: N	Not documented		
Driller's Name:	C. Shields	WA State Lic Nr:	Not Available	Coordinates: E	Not documented		
Drilling Company:	KEH Constr. Forces	Company Location:	Hanford	Start Card #:	Not Available		
Date Started:	04Nov93	Date Completed:	07Jan94	Elevation Ground Surface:			

Depth to Water: 125.23 ft 10Jan94
(Ground surface)

GENERALIZED STRATIGRAPHY Geologist's Log

0 - 5 ft : Sand
5 - 12 ft : Sand
12 - 14 ft : Sand
14 - 34 ft : Sand
34 - 40 ft : Sandy Gravel
40 - 60 ft : Sand
60 - 65 ft : Gravelly Sand
65 - 79 ft : Sandy Gravel
79 - 85 ft : Gravel
85 - 92 ft : Gravel
92 - 94 ft : Sandy Gravel
94 - 101 ft : Gravel
101 - 112 ft : Sandy Gravel
112 - 121 ft : Sandy Gravel
121 - 130 ft : Sandy Gravel
130 - 138 ft : Silty Sandy Gravel
138 - 150 ft : Silty Sandy Gravel
150 - 163.5 ft : Gravel



163.5 ft : Borehole drilled depth

0 - 15 ft : 13-in. 12-3/4" Carbon Steel Temp. Casing
15 - 163.5 ft : 9-in. 8-5/8" Carbon Steel Temp. Casing

Elevation of Reference Point: m

Height of Reference Point Above Ground Surface:

Depth of Surface Seal: 10.3 ft.

Type of Surface Seal: 4x4 Concrete Pad

Fill	*Casing*	*Screen*
0 - 10.3 ft : 13-inch hole Cement 10.3 - 15 ft : 13-inch hole 20-40 Bentonite Crumbles	0 - 15 ft : 13 inch 12-3/4" CS Temp. Welded Csg. 0 - 122.5 ft : 4 inch 4" Casing 15 - 163.5 ft : 9 inch 10-3/4" CS Temp. Welded Csg.	
15 - 116.3 ft : 9-inch hole 20-40 Bentonite Crumbles		
116.3 - 117.6 ft : 9-inch hole 1/2" Bentonite Pellets 117.6 - 119.2 ft : 9-inch hole 1/4" Bentonite Pellets 119.2 - 152.8 ft : 9-inch hole 20-40 Silica Sand 152.8 - 154.6 ft : 9-inch hole 20-40 Silica Sand 154.6 - 155.6 ft : 9-inch hole 10-20 Silica Sand 155.6 - 157.7 ft : 9-inch hole Slough 157.7 - 163.1 ft : 9-inch hole Bentonite Hole Plug 163.1 - 163.5 ft : 9-inch hole Slough	152.5 - 152.8 ft : 4 inch	122.5 - 152.5 ft : 4 inch 4" .010 SS Wire Wrap Pipe Size

Drawing By: DLF
Reference: Hanford Wells
Revision: 0
Revision Date: 19Dec97
Print Date: 19Dec97

Report Form: WELLS Project File: WELLS.GPJ

Figure C-2. Well 699-23-34B Construction and Completion Summary

WELL CONSTRUCTION AND COMPLETION SUMMARY AS-BUILT

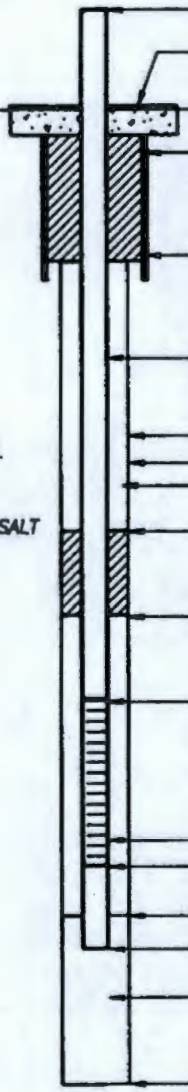
Drilling Method: Cable Tool	Sample Method: Dart Bailer	WELL NUMBER: 699-24-33	TEMPORARY WELL NO.: 25-35
Drilling Fluid Used: Water	Additives Used:	Hanford Coordinates: N/S	E/W
Driller's Name: Rumley	WA State Lic. No.:	State Coordinates: N	E
Drilling Company:	Company Location:	Start Card #: T R S	
Date Started: 7/30/48	Date Complete: 8/12/48	Elevation Ground Surface (ft):	

Depth to water: 141.0

Data source: Driller's Log

GENERALIZED STRATIGRAPHY

5–20: Fine SAND
20–27: BASALT SAND & TR. GRAVEL
27–30: Fine SAND & BASALT
30–75: Fine SAND & SILT
75–77: Coarse SAND & GRAVEL
77–80: Coarse SAND & ROCKS
80–88: ROCKS
88–92: BASALT, GRANITE & ROCKS
92–97: Fine SAND
97–111: BASALT, GRANITE & ROCKS
111–114: Fine SAND
114–118: Fine SAND, BASALT & GRAVEL
118–120: SAND, ROCK & BOULDERS
120–122: SAND, ROCK, BOULDERS & GRAVEL
122–127: SAND, ROCK & GRAVEL
127–133: SAND, ROCK, GRAVEL & BASALT
133–135: GRANITE, ROCKS, BOULDERS & BASALT
135–140: SAND, SILT & ROCKS
140–144: SAND & SILT
144–145: SAND & GRAVEL
145–153: SAND
153–158: SAND & ROCKS
158–160: SAND, ROCKS & BASALT
160–164.5: SAND & ROCK
164.5–164.5 SAND & GRAVEL



Elevation of casing:	524.21
Elevation of reference point:	INF
Concrete pad dimensions:	INF
Depth of surface seal:	INF
Type of surface seal: INF	
I.D. of surface casing (if present):	N/A
Type of surface casing: N/A	
Depth of surface casing:	N/A
I.D. of riser pipe:	8-in.
Type of riser pipe: INF	
Diameter of borehole:	8-in.
Diameter of perforated borehole casing:	8-in.
Type of filter: INF	
Elevation/depth of top of seal:	INF
Type of seal: INF	
Elevation/depth of top of gravel pack:	N/A
Type of gravel pack: N/A	
Elevation/depth of top of screen perforation:	116.0
Description of screen/perforation: Perforated /5 holes/foot 2 holes / foot (129.0–144.0)	
I.D. of screen section:	N/A
Elevation/depth of bottom of screen/perforation:	164.0
Elevation/depth of bottom of gravel pack:	N/A
Elevation/depth of bottom of plugged blank section:	
Type of filter below plugged section: Cement plug (159–164.5)	
Elevation/depth of bottom of borehole:	164.0
Elevation/depth of remediated borehole:	N/A

NOTES: N/A: Not Applicable
INF: Insufficient Data

8831752\14931

Figure C-3. Well 699-24-33 Construction and Completion Summary

WELL SUMMARY SHEET		Start Date: 8/11/2015 Finish Date: 9/10/2015	Page 1 of 2
Well ID: C9406		Well Name: 699-24-34D	
Location: 5 m East of SWL		Project: Installation of 4 Wells at NRDWL & SWL	
Prepared By: Tracy Mallgren	Date: 9/15/15	Reviewed By: D. MEHRER	Date: 9-30-15
Signature:		Signature:	

CONSTRUCTION DATA

Description

Concrete Pad: 0.50 ft above ground surface (ags)

6-in Protective Casing: 2.85 ft ags - 2.15 ft below ground surface (bgs)

Type I/II Portland Cement Grout: 0.00 - 9.90 ft bgs

3/8-in Cetco Medium Bentonite Chips: 9.90 - 123.8 ft bgs

4-in I.D. Schedule 10, Type 304/304L, Stainless Steel Blank Casing: 1.85 ft ags - 131.19 ft bgs

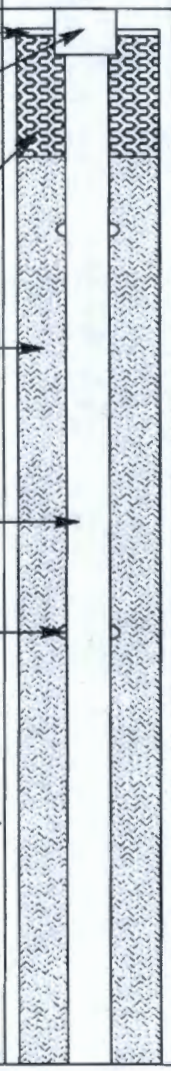
Stainless steel centralizer

Depths are in ft below ground surface.

Borehole drilled with: 9 1/4-in O.D. casing from 0.00 - 80.50 ft bgs and 8-in O.D. casing from 80.50- 169.60 ft bgs.

All temporary drill casing was removed from the ground.

Diagram



GEOLOGIC/HYDROLOGIC DATA

Depth in Feet: 0, 10, 20, 30, 40, 50, 60, 70, 80

Graphic Log

Lithologic Description (ft bgs)

0 - 10 Silty Sand (mS)

10 - 20 Sand (S)

20 - 25 Slightly Silty Sand ((m)S)

25 - 30 Sand (S)

30 - 35 Slightly Silty Sand ((m)S)

35 - 55 Sand (S)

55 - 60 Gravelly Sand (gS)

60 - 75 Sand (S)

75 - 85 Gravel (G)

85 - 130 Sandy Gravel (sG)

A-6003-643 (REV 1)

Figure C-4. Well 699-24-34D Construction and Completion Summary (page 1 of 2)

WELL SUMMARY SHEET		Start Date: 8/11/2015 Finish Date: 9/10/2015	Page 2 of 2
Well ID: C9406		Well Name: 699-24-34D	
Location: 5 m East of SWL		Project: Installation of 4 Wells at NRDWL & SWL	
Prepared By: Tracy Mallgren	Date: 9/15/15	Reviewed By: J.D. MEURER	Date: 9-30-15
Signature:		Signature:	

CONSTRUCTION DATA

Stainless steel centralizer

3/8-in Cetco Medium Bentonite Chips: 9.90 - 123.80 ft bgs

4-in I.D. Schedule 10, Type 304/304L, Stainless Steel Blank Casing: 1.85 ft ags - 131.19 ft bgs

3/8-in Cetco Coated Bentonite Pellet Seal: 123.80 - 126.80 ft bgs

8-16 mesh Premier Colorado Silica Filter Pack Sand: 126.80 - 167.20 ft bgs

4-in I.D. Schedule 10, Type 304/304L, 40-slot (0.040 in.) Stainless Steel Screen: 131.19 - 161.22 ft bgs

Depths are in ft below ground surface.

Borehole drilled with:
9 1/4-in O.D. casing
from 0.00 - 80.50 ft bgs
and
8-in O.D. casing
from 80.50 - 169.60 ft bgs.

All temporary drill casing was removed from the ground.

4-in I.D. Schedule 10, Type 304/304L, Stainless Steel Sump: 161.22 - 164.22 ft bgs

GEOLOGIC/HYDROLOGIC DATA

Depth in Feet: 90, 100, 110, 120, 130, 140, 150, 160, 170

Graphic Log

Lithologic Description (ft bgs)

85 - 130 Sandy Gravel (sG)

130 - 135 Silty Gravel

135 - 155 Silty Sandy Gravel (msG)

Static Water Level: 135.6 ft bgs (8/26/15)

155 - 169 Sandy Gravel (sG)

Total Depth: 167.5 ft bgs (8/20/2015)

Straightness Test: Passed 8/24/2015

A-6003-643 (REV 1)

Figure C-4. Well 699-24-34D Construction and Completion Summary (page 2 of 2)

WELL SUMMARY SHEET		Start Date: 8/20 /2015 Finish Date: 9/09/2015	Page 1 of 2
Well ID: C9407		Well Name: 699-24-34E	
Location: 5 m E of SWL North		Project: Installation of 4 Wells at NRDWL & SWL	
Prepared By: Tracy Mallgren	Date: 9/15/15	Reviewed By: J.D. MEHRER	Date: 9-30-15
Signature:		Signature:	

CONSTRUCTION DATA

Description

Concrete Pad: 0.50 ft above ground surface (ags)

6-in Protective Casing: 2.56 ft ags - 2.44 ft below ground surface (bgs)

Type I/II Portland Cement Grout: 0.00 - 10.80 ft bgs

3/8 in Cetco Medium Bentonite Chips: 10.80 - 127.40 ft bgs

4-in I.D. Schedule 10, Type 304/304L, Stainless Steel Blank Casing: 1.59 ft ags - 134.58 ft bgs

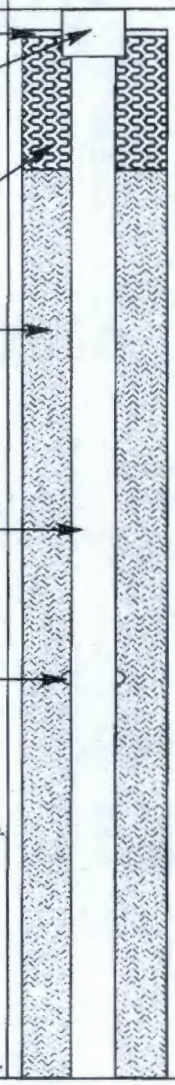
Stainless steel centralizer

Depths are in ft below ground surface.

Borehole drilled with:
9 1/4-in O.D. casing
from 0.00 - 99.50 ft bgs
and
8-in O.D. casing
from 99.50 - 169.50 ft bgs.

All temporary drill casing was removed from the ground.

Diagram



GEOLOGIC/HYDROLOGIC DATA

Depth in Feet: 0, 10, 20, 30, 40, 50, 60, 70, 80

Graphic Log

Lithologic Description (ft bgs)

0 - 15 Sand (S)

15 - 20 Slightly Silty Sand ((m)S)

20 - 35 Sand (S)

35 - 45 Gravelly Sand (gS)

45 - 46 Slightly Silty Sand ((m)S)

46 - 50 Sand (S)

50 - 60 Gravelly Sand (gS)

60 - 95 Sand (S)

A-6003-643 (REV 1)

Figure C-5. Well 699-24-34E Construction and Completion Summary(page 1 of 2)

WELL SUMMARY SHEET	Start Date: 8/20/2015 Finish Date: 9/09/2015	Page 2 of 2
Well ID: C9407	Well Name: 699-24-34E	
Location: 5 m East of SWL North	Project: Installation of 4 Wells at NRDWL & SWL	
Prepared By: Tracy Mallgren — Date: 9/15/15	Reviewed By: J.D. MEHRER — Date: 9-30-15	
Signature:	Signature:	

CONSTRUCTION DATA

Description

Stainless steel centralizer

3/8-in Cetco Medium Bentonite Chips: 10.80 - 127.40 ft bgs

4-in I.D. Schedule 10, Type 304/304L, Stainless Steel Blank Casing: 1.59 ft ags - 134.58 ft bgs

3/8-in Cetco Coated Bentonite Pellet Seal: 127.40 - 130.00 ft bgs

8-16 mesh Premier Colorado Silica Filter Pack Sand: 130.00 - 169.00 ft bgs

4-in I.D. Schedule 10, Type 304/304L, 40-slot (0.040 in.) Stainless Steel Screen: 134.58 - 164.61 ft bgs

Depths are in ft below ground surface.

Borehole drilled with:
9 1/4-in O.D. casing
from 0.00 - 99.50 ft bgs
and
8-in O.D. casing
from 99.50 - 169.50 ft bgs

All temporary drill casing was removed from the ground.

4-in I.D. Schedule 10, Type 304/304L, Stainless Steel Sump: 164.61 - 167.61 ft bgs

Diagram

GEOLOGIC/HYDROLOGIC DATA

Depth in Feet: 90, 100, 110, 120, 130, 140, 150, 160, 170

Graphic Log

Lithologic Description (ft bgs)

60 - 95 Sand (S)

95 - 120 Sandy Gravel (sG)

120 - 125 Gravel (G)

125 - 135 Silty Sandy Gravel (msG)

135 - 140 Gravel (G)

Static Water Level: 137.4 ft bgs (8/27/15)

140 - 169 Sandy Gravel (sG)

Total Depth: 169.5 ft bgs (8/27/2015)

Straightness Test: Pass 8/31/2015

A-6003-643 (REV 1)

Figure C-5. Well 699-24-34E Construction and Completion Summary (page 2 of 2)

WELL CONSTRUCTION AND COMPLETION SUMMARY AS-BUILT

Drilling Method: Cable Tool	Sample Method:	WELL NUMBER: 699-24-35	TEMPORARY WELL NO.:
Drilling Fluid Used: SM-2 Well Water	Additives Used:	Hanford Coordinates: N/S N24351	E/W W35203
Driller's Name: Buttena, Ludtke	WA State Lic. No.: 0066, 1333	State Coordinates: N	E
Drilling Company: Onwego Drilling	Company Location: Kennewick	Start Card #:	T R S
Date Started: 2/3/87	Date Complete: 3/2/87	Elevation Ground Surface (ft): INF.	

Depth to water: 132.2

Data source: Geologist's Log

GENERALIZED STRATIGRAPHY

5–8: Fine SAND
8–10: GRAVELLY SAND
10–11: SAND
11–12: SILTY SAND
12–31: SAND
31–32.5: SILTY SAND
32.5–40: SAND
40–52.5: PEBBLY SAND
52.5–60: GRAVELLY SAND
60–75: SAND
75–105: GRAVELLY SAND
105–140: SANDY GRAVEL
140–143: SAND
143–145: SANDY GRAVEL

Elevation of casing:	538.81
Elevation of reference point:	INF
Concrete pad dimensions:	4x4x4
Depth of surface seal:	0–5.0
Type of surface seal: Portland Cement	
I.D. of surface casing (if present):	N/A
Type of surface casing: N/A	
Depth of surface casing:	N/A
I.D. of riser pipe:	6-in.
Type of riser pipe: Stainless Steel	
Diameter of borehole:	10-in.; 14-in./10.0
Diameter of perforated borehole casing:	N/A
Type of filler: Volclay Grout	
Elevation/depth of top of seal:	119.0
Type of seal: Volclay pellets	
Elevation/depth of top of gravel pack:	124.0
Type of gravel pack: 10–20 & 8–12 Silica Sand	
Elevation/depth of top of screen perforation:	127.5
Description of screen/perforation: S.S. 10 in./40-slot/S.S. Telescoping (132.5–142.5) 6-in./30-slot	
I.D. of screen section:	10-in., 6-in.
Elevation/depth of bottom of screen/perforation:	142.5
Elevation/depth of bottom of gravel pack:	145.5
Elevation/depth of bottom of plugged blank section:	N/A
Type of filler below plugged section: N/A	
Elevation/depth of bottom of borehole:	145.5
Elevation/depth of remediated borehole:	N/A

NOTES: N/A: Not Applicable
INF: Insufficient Data

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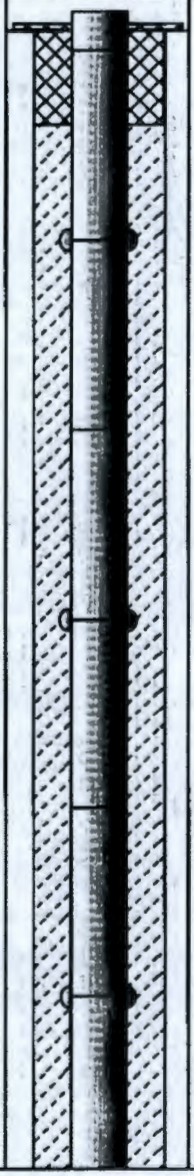
Figure C-6. Well 699-24-35 Construction and Completion Summary

WELL SUMMARY SHEET		Start Date: 1/7/2014 Finish Date: 2/25/2014	Page 1 of 2
Well ID: C8772		Well Name: 699-24-36	
Location: W. of Central Landfill		Project: 3 Wells – M-24 Project	
Prepared by: Julie Johanson	Date: 3/3/2014	Reviewed by: J.D. MEHREF	Date: 4-2-14
Signature: Julie Johanson		Signature: JDM	

CONSTRUCTION DATA

Description	Diagram
Surface Completion: 4'x4'x6" Concrete Pad w/brass survey marker and 6 5/8" protective monument (2.98' bgs) Well Completion material: High Strength Cement 0.0' bgs - 1.5' bgs Type I/II Portland Cement 1.5' bgs - 10.1ft bgs Medium Bentonite Chips 10.1' bgs - 135.1' bgs 3/8" Bentonite Pellets 135.1' bgs - 137.1' bgs 10x20 Colorado Silica Sand 137.1' bgs - 176.0' bgs Natural Fill 176.0' bgs - 177.25' bgs Permanent Well: 4 1/2" OD Stainless Steel Blank 2.02' ags - 142.31' bgs 4 1/2" OD Stainless Steel 0.040 Slot Screen 142.31' bgs - 172.31' bgs 4 1/2" OD Stainless Steel Sump 172.31' bgs - 175.31' bgs All temporary casing completley removed from ground on 2/4/14 bgs = below ground surface ags = above ground surface	

GEOLOGIC/HYDROLOGIC DATA

Depth in Feet	Graphic Log	Lithologic Description
0		0 - 0.5: Drill Pad
		0.5 - 70: Sand (S)
20		
40		
60		
		70 - 75: Gravelly Sand (gS)
		75 - 85: Slightly Silty Gravelly Sand ((m)gS)
80		
		85 - 90: Sand (S)
		90 - 100: Gravelly Sand (gS)
100		
		100 -105: Sandy Gravel (sG)
		105 - 110: Silty Sandy Gravel (msG)
		110 - 115: Sandy Gravel (sG)
		115 - 118: Silty Sandy Gravel (msG)
		118 -121: Slightly Silty Gravelly Sand ((m)gS)

A-6003-843 (03/03)

Figure C-7. Well 699-24-36 Construction and Completion Summary (page 1 of 2)

WELL SUMMARY SHEET		Start Date: 1/7/2014 Finish Date: 2/25/2014	Page 2 of 2
Well ID: C8772		Well Name: 699-24-36	
Location: W. of Central Landfill		Project: 3 Wells – M-24 Project	
Prepared by: Julie Johanson	Date: 3/4/2014	Reviewed by: J.D. MEHRER	Date: 4-2-14
Signature:		Signature:	

CONSTRUCTION DATA

Description
Well Completion Material: High Strength Concrete 0.0' bgs - 1.5' bgs
Type I/II Portland Cement 1.5' bgs - 10.1' bgs
Medium Bentonite Chips 10.1' bgs - 135.1' bgs
3/8" Bentonite Pellets 135.1' bgs - 137.1' bgs
10x20 Colorado Silica Sand 137.1' bgs - 176.0' bgs
Natural Fill 176.0' bgs - 177.25' bgs
Permanent Well: 4 1/2" OD Stainless Steel Blank 2.02' ags - 142.31' bgs
4 1/2" OD Stainless Steel 0.040 Slot Screen 142.31' bgs - 172.31' bgs
4 1/2" OD Stianless Steel Sump 172.31' bgs - 175.31' bgs
All temporary casing completely removed from ground (2/4/2014).
bgs = below ground surface ags = above ground surface

Diagram

GEOLOGIC/HYDROLOGIC DATA

Depth in Feet	Graphic Log	Lithologic Description
120		115 -118: Silty Sandy Gravel (msG)
		118 - 121: Slightly Silty Gravelly Sand ((m)gS)
		121 - 140: Silty Sandy Gravel (msG)
140		140 - 144: Sand (S)
		144 - 161: Silty Sandy Gravel (msG)
		DTW: 146.31' bgs
160		161 - 162: Slightly Silty Gravelly Sand ((m)gS)
		162 - 165: Slightly Silty Sand ((m)S)
		165 - 177.25: Silty Sandy Gravel (msG)
		TD: 177.25' bgs
180		

A-6003-643 (03/03)

Figure C-7. Well 699-24-36 Construction and Completion Summary (page 2 of 2)

WELL SUMMARY SHEET		Start Date: 12/28/2013 Finish Date: 2/24/2014	Page 1 of 2
Well ID: C8200		Well Name: 699-25-34E	
Location: NNE of Central Landfill		Project: 3 Wells -- M-24 Project	
Prepared by: Julie Johanson	Date: 3/3/14	Reviewed J.D. MEHRER	Date: 4-2-14
Signature:		Signature:	

CONSTRUCTION DATA		Depth in Feet	GEOLOGIC/HYDROLOGIC DATA	
Description	Diagram		Graphic Log	Lithologic Description
Surface Completeion: 4'x4'x6" Concrete Pad w/brass survey marker and 6 5/8" protective monument 2.83' ags		0		0 - 65: Sand (S)
Well Completion Material: High Strength Concrete 0.0' bgs - 1.5' bgs		20		
Type I/II Portland Cement 1.5' bgs - 8.3' bgs				
Medium Bentonite Chips 8.3' bgs - 126.8' bgs		40		
1/4" Bentonite Pellets 126.8' bgs - 129.3' bgs				
10x20 Colorado Silica Sand 129.3' bgs - 163.0' bgs				
Natural Fill 163.0' bgs - 168.7' bgs		60		
				65 - 75: Silty Sand (mS)
Permanent Well: 4 1/2" OD Stainless Steel Blank 1.83' ags - 134.09' bgs				75 - 85: Sand (S)
		80		
4 1/2" OD Stainless Steel 0.040 Slot Screen 134.09' bgs - 164.09' bgs				85 - 95: Sandy Gravel (sG)
4 1/2" OD Stainless Steel Sump 164.09' bgs - 167.09' bgs				95 - 104: Gravelly Sand (gS)
		100		
All temporary casing completely removed from ground on 2/20/2014.				104 - 110: Silty Sand (mS)
				110 - 120: Sandy Gravel (sG)
bgs = below ground surface ags = above ground surface				

A-6003-843 (03/03)

Figure C-8. Well 699-25-34E Construction and Completion Summary(page 1 of 2)

WELL SUMMARY SHEET		Start Date: 12/28/2013 Finish Date: 2/24/2014	Page 2 of 2
Well ID: C8200		Well Name: 699-25-34E	
Location: NNE of Central Landfill		Project: 3 Wells – M-24 Project	
Prepared by: Julie Johanson	Date: 3/3/14	Reviewed by: J.D. MEHRER	Date: 4-2-14
Signature:		Signature:	

CONSTRUCTION DATA		Depth in Feet	GEOLOGIC/HYDROLOGIC DATA	
Description	Diagram		Graphic Log	Lithologic Description
Well Completion Material: High Strength Concrete 0.0' bgs - 1.5' bgs		120		110 - 120: Sandy Gravel (sG)
				120 -125: Gravelly Sand (gS)
Type I/II Portland Cement 1.5' bgs - 8.3' bgs				125 - 140: Sandy Gravel (sG)
Medium Bentonite Chips 8.3' bgs - 126.8' bgs		140		DTW: 138.54' bgs
				140 - 147: Gravel (G)
1/4" Bentonite Pellets 126.8' bgs - 129.3' bgs				147 - 160: Silty Sandy Gravel (msG)
10x20 Colorado Silica Sand 129.3' bgs - 163.0' bgs				
Natural Fill 163.0' bgs - 168.7' bgs		160		160 - 165: Silty Gravel (mG)
				165 - 168: Silty Sandy Gravel (msG)
				TD: 168.7' bgs
Permanent Well: 4 1/2" OD Stainless Steel Blank 1.83' ags - 134.09' bgs		180		
4 1/2" OD Stainless Steel 0.040 Slot Screen 134.09' bgs - 164.09' bgs				
4 1/2" OD Stainless Steel Sump 164.09' bgs - 167.09' bgs				
All temporary casing completely removed from ground on 2/20/2014.				
bgs = below ground surface ags = above ground surface				

A-6003-643 (03/03)

Figure C-8. Well 699-25-34E Construction and Completion Summary (page 2 of 2)

C2 Reference

NAVD88, 1988, *North American Vertical Datum of 1988*, National Geodetic Survey, Federal Geodetic Control Committee, Silver Spring, Maryland. Available at: http://www.ngs.noaa.gov/.