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Revision 1

Groundwater Monitoring Plan for the Nonradioactive Dangerous Waste Landfill and 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

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Executive Summary

This groundwater monitoring plan has been prepared in accordance with the groundwater protection requirements pursuant to WAC 173-303-645, "Dangerous Waste Regulations," "Releases from Regulated Units," for both the Nonradioactive Dangerous Waste Landfill (NRDWL) and the Solid Waste Landfill (SWL). The NRDWL is a treatment, storage, and disposal unit regulated under RCW 70.105, "Public Health and Safety," "Hazardous Waste Management." RCW 70.105 is implemented through WAC 173-303. The SWL is a limited-purpose landfill regulated under RCW 70.95, "Public Health and Safety," "Solid Waste Management – Reduction and Recycling." RCW 70.95 is implemented through WAC 173-350-500, "Solid Waste Handling Standards," "Ground Water Monitoring."

The SWL closure and post-closure groundwater monitoring is subject to WAC 173-350-500; however, compliance with groundwater monitoring requirements for the SWL will be achieved through deferral under WAC 173-350-710(8) ("Permit Application and Issuance") to equal or greater requirements within WAC 173-303-645. This plan has been written to meet WAC 173-350-500 requirements for the SWL and WAC 173-303-645 requirements for NRDWL under a combined monitoring program.

The combined monitoring program under this plan has been established to coordinate closure and post-closure of the NRDWL and the SWL. The new groundwater monitoring system established under this plan will be referred to as the NRDWL/SWL waste management area.

Contents

1 Introduction 1-1

2 Facility Background 2-1

2.1 Operational History 2-1
2.2 Waste Characteristics 2-1
2.2.1 Nonradioactive Dangerous Waste Landfill 2-1
2.2.2 Solid Waste Landfill 2-4

3 Hydrogeology and Groundwater – Chemistry 3-1

3.1 Physical Hydrogeology 3-1
3.2 Groundwater Hydrology 3-1
3.3 Current Well Completions and Conditions 3-6
3.4 Groundwater Chemistry 3-7
3.4.1 Background Conditions 3-7
3.4.2 NRDWL and SWL Groundwater Monitoring Results 3-9
3.4.3 Barium and Nickel at the NRDWL and SWL 3-19
3.4.4 Vadose Zone Chemistry 3-22

4 Groundwater Monitoring Program 4-1

4.1 Groundwater Monitoring Well System 4-1
4.2 Dangerous Constituents and Indicator Parameters 4-3
4.3 Detection Monitoring 4-6
4.4 Groundwater Monitoring System 4-8
4.5 Point of Compliance 4-9
4.6 Sampling and Analysis 4-9
4.6.1 Monitoring Parameters 4-10
4.6.2 Sampling Frequency 4-12
4.6.3 Sampling Procedures 4-12
4.6.4 Sample Chain-of-Custody 4-13
4.7 Decontamination of Sampling and Drilling Equipment 4-13
4.8 Analytical Procedures and Quality Assurance 4-14
4.9 Data Management 4-19
4.9.1 Loading Data 4-19
4.9.2 Data Review, Verification, Validation, and Usability 4-19
4.9.3 Data Review Corrective Actions 4-20
4.10 Statistical Analysis of Groundwater Monitoring Data 4-20
4.11 Reporting and Recordkeeping 4-22
4.12 Evaluation and Notification 4-22

5 Compliance Monitoring Program **5-1**

6 Corrective Action Program **6-1**

7 References **7-1**

Figures

Figure 2-1. Regional Map with Locations of the Hanford Site, NRDWL, and SWL 2-2
Figure 2-2. NRDWL and SWL Arrangement and Dates of Trench Operations 2-3
Figure 2-3. Current NRDWL and SWL Groundwater Monitoring Well Locations 2-4
Figure 3-1. Regional Stratigraphy in the Vicinity of the NRDWL/SWL 3-2
Figure 3-2. Cross-Section Along the Downgradient Side of the NRDWL/SWL WMA 3-3
Figure 3-3. Water Table Map of the 200-PO-1 Groundwater OU, Including the NRDWL/SWL WMA, March 2009 3-5
Figure 3-4. 200-PO-1 Groundwater OU Boundary 3-8
Figure 3-5. Specific Conductance Trends in Wells 699-25-34A, 699-24-34C, and 699-25-34D 3-10
Figure 3-6. Calcium Trends in Wells 699-25-34A, 699-24-34C, and 699-25-34D 3-10
Figure 3-7. Magnesium Trends in Wells 699-25-34A, 699-24-34C, and 699-25-34D 3-11
Figure 3-8. PCE Concentrations in Wells 699-25-34B, 699-25-34D, and 699-26-33 3-12
Figure 3-9. TCE Concentrations in Wells 699-25-34B, 699-25-34D, and 699-26-33 3-12
Figure 3-10. 1,1,1-Trichloroethane Concentrations in Wells 699-25-34B, 699-25-34D, and 699-26-33 3-13
Figure 3-11. Carbon Tetrachloride Concentrations in Wells 699-25-34B, 699-25-34D, and 699-26-33 3-13
Figure 3-12. 1,1-Dichloroethane Trends in Wells 699-22-35, 699-23-34A, and 699-24-34C at the SWL 3-14
Figure 3-13. Carbon Tetrachloride Trends in Wells 699-22-35, 699-23-34A, and 699-24-34C at the SWL 3-14
Figure 3-14. PCE Trends in Wells 699-22-35, 699-23-34A, and 699-24-34C at the SWL 3-15
Figure 3-15. TCE Trend in Wells 699-22-35, 699-23-34A, and 699-24-34C at the SWL 3-15
Figure 3-16. PCE Trends in SWL Well 699-24-34C and NRDWL Wells 699-25-34B and 699-25-34D 3-16
Figure 3-17. PCE Plume at the NRDWL and SWL, August 1991 3-17
Figure 3-18. PCE Plume at the NRDWL and SWL, February 1994 3-18
Figure 3-19. PCE Plume at the NRDWL and SWL, February 2007 3-19
Figure 3-20. Barium Concentrations near the SWL 3-20
Figure 3-21. Barium at Well 699-22-35 Versus Well 699-24-35 Since 2008 3-21
Figure 3-22. Concentration Differences for Nickel in Wells 699-24-34A and 699-24-35 3-21
Figure 3-23. Nickel in Several Wells near the SWL 3-22
Figure 3-24. Location of Soil Vapor Monitoring Stations at the SWL 3-24

Figure 4-1. NRDWL/SWL WMA Groundwater Monitoring Well Locations and Purposes 4-2

Tables

Table 3-1. Information for Current NRDWL and SWL Monitoring Wells 3-6
Table 4-1. Groundwater Monitoring Constituents Identified for the NRDWL/SWL WMA and Source of Listing (Secondary Constituents) 4-3
Table 4-2. Indicators for Groundwater Contamination at the NRDWL/SWL WMA and Basis for Selection 4-6
Table 4-3. Groundwater Water Monitoring Wells and Sample Frequency for NRDWL/SWL WMA Monitoring Parameters 4-7
Table 4-4. Preservation Techniques, Analytical Methods Used, and Current Method Quantitation Limits 4-10
Table 4-5. Quality Control Samples 4-15
Table 4-6. Field and Laboratory QC Elements and Acceptance Criteria 4-16
Table 4-7. Appendix 5 Constituent Analyses 4-18
Table 4-8. Blind Standard Constituents and Schedule 4-19

Terms

ANOVA	analysis of variance
bgs	below ground surface
CERCLA	*Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
CRDL	contract-required detection limit
DOE	U.S. Department of Energy
DUP	laboratory matrix duplicate
EB	equipment blank
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
FTB	full trip blank
FXR	field transfer blank
FY	fiscal year
GC	gas chromatography
GC/MS	gas chromatography/mass spectrometry
HEIS	Hanford Environmental Information System
IC	ion chromatography
ICP	inductively coupled plasma
ICP/MS	inductively coupled plasma/mass spectrometry
LCS	laboratory control sample
MB	method blank
MDA	minimum detectable activity
MDL	method detection limit
MS	matrix spike
MSD	matrix spike duplicate
MSL	mean sea level
NA	not available
NAVD88	North American Vertical Datum of 1988
NRDWL	Nonradioactive Dangerous Waste Landfill

NTU	nephelometric turbidity units
OU	operable unit
PCB	polychlorinated biphenyl
PCE	tetrachloroethene
QC	quality control
RCRA	*Resource Conservation and Recovery Act of 1976*
RPD	relative percent difference
RSD	relative standard deviation
SUR	surrogate
SVOC	semivolatile organic compound
SWL	Solid Waste Landfill
TCE	trichloroethene
TOC	total organic carbon
TOX	total organic halides
TSD	treatment, storage, and disposal
VOC	volatile organic compound
WMA	waste management area

1 Introduction

This groundwater monitoring plan has been prepared to support the closure and post-closure activities for the Nonradioactive Dangerous Waste Landfill (NRDWL) and the Solid Waste Landfill (SWL). This groundwater monitoring plan has been prepared in accordance with the groundwater protection requirements pursuant to WAC 173-303-645, "Dangerous Waste Regulations," "Releases from Regulated Units," for the NRDWL and WAC 173-350-500, "Solid Waste Handling Standards," "Ground Water Monitoring," for the SWL. The NRDWL is a treatment, storage, and disposal (TSD) unit regulated under RCW 70.105, "Public Health and Safety," "Hazardous Waste Management." RCW 70.105 is implemented through WAC 173-303. The SWL is a limited-purpose landfill regulated under RCW 70.95, "Public Health and Safety," "Solid Waste Management – Reduction and Recycling." RCW 70.95 is implemented through WAC 173-350-500 and WAC 173-304-490, "Minimum Functional Standards for Solid Waste Handling," "Ground Water Monitoring Requirements."

The existing SWL groundwater monitoring plan is based on WAC 173-304-490; however, for closure and post-closure activities, the SWL will continue to be a limited-purpose landfill, but the requirements have changed from those listed in WAC 173-304 to those of WAC 173-350. The requirements of WAC 173-350-500 will be met by deferral to the equivalent or superior requirements of WAC 173-303-645. This deferral request was granted under WAC 173-350-710(8), "Permit Application and Issuance," by the Washington State Department of Ecology (Ecology) in 2010 and is fully detailed in the closure plan. This groundwater monitoring plan has been written to meet the requirements of WAC 173-303-645 for the NRDWL and SWL under one combined monitoring program.

The combined monitoring program under this plan has been established to coordinate closure and post-closure of the NRDWL and the SWL. The new groundwater monitoring system established under this plan will be referred to as the NRDWL/SWL waste management area (WMA).

This plan is anticipated to be approved in parallel with the closure plan for NRDWL and SWL. This plan will be implemented during the closure period and will remain effective in the post-closure period.

Chapter 2 of this groundwater monitoring plan discusses the facility, and Chapter 3 provides the groundwater hydrology and groundwater chemistry. Chapter 4 describes the groundwater monitoring program proposed for groundwater monitoring, Chapter 5 provides a brief summary of how a compliance monitoring program would be implemented (if required), and Chapter 6 is a placeholder for how a corrective action program would be established (if required) in the event that a compliance monitoring program is established.

2 Facility Background

This chapter provides an overview of the physical structures, operational history, and waste characteristics for the NRDWL and SWL prior to establishing the NRDWL/SWL WMA under this monitoring plan (Figure 2-1).

The NRDWL is located approximately 5.6 km (3.5 mi) southeast of the 200 East Area within the Hanford Site boundary. The landfill has an area of 4.0 ha (10 ac) and began operations in 1975. The NRDWL consists of 19 parallel trenches, each approximately 122 m (400 ft) long, 4.9 m (15 ft) wide at the base, and 4.6 m (15 ft) deep. The last receipt of dangerous waste was in May 1985, and the last receipt of asbestos waste occurred in May 1988.

The SWL is adjacent to the NRDWL on the south side. The SWL is approximately 907 m (2,980 ft) in length and 294 m (965 ft) in width. It is divided into five units, each consisting of a series of parallel trenches. The two oldest units of the SWL are identified as the Phase I area, covering approximately 11 ha (28 ac), and these units have been active since 1973. The Phase II area is divided into three units: north, middle, and south. Phase II was constructed in 1982 and covers approximately 15 ha (38 ac). In addition, several liquid waste disposal trenches were documented at SWL (as detailed in Section 2.2.2). The SWL received waste from 1973 through March 1996. Figure 2-2 shows the trench arrangements and dates of operation.

Figure 2-3 shows the locations of groundwater monitoring wells that have been used for monitoring the NRDWL and SWL.

2.1 Operational History

The SWL received principally solid waste including paper, construction debris, asbestos, and lunchroom waste. It also received sewage and bus garage washwater. Beginning in 1975 at the NRDWL, containerized chemical waste was disposed into six trenches, asbestos in nine trenches, non-hazardous solid waste in one trench, and three trenches were unused. At the end of each operating day, the waste containers were covered with soil.

2.2 Waste Characteristics

This section summarizes the general waste types, waste volumes, and dates of operation of the NRDWL and SWL. Additional details are available in the U.S. Department of Energy (DOE) closure/post-closure plan for the NRDWL and SWL (DOE/RL-90-17, *Nonradioactive Dangerous Waste Landfill/Solid Waste Landfill Closure/Postclosure Plan*).

2.2.1 Nonradioactive Dangerous Waste Landfill

The waste disposed at the NRDWL falls into the following categories (DOE/RL-90-17):

- Chemical waste with absorbents, including the following:
  - Small containers of laboratory chemicals
  - Bulk organic waste, solvent waste, paints, paint thinners, and waste oil
  - Empty containers
- Asbestos material
- Sanitary solid waste

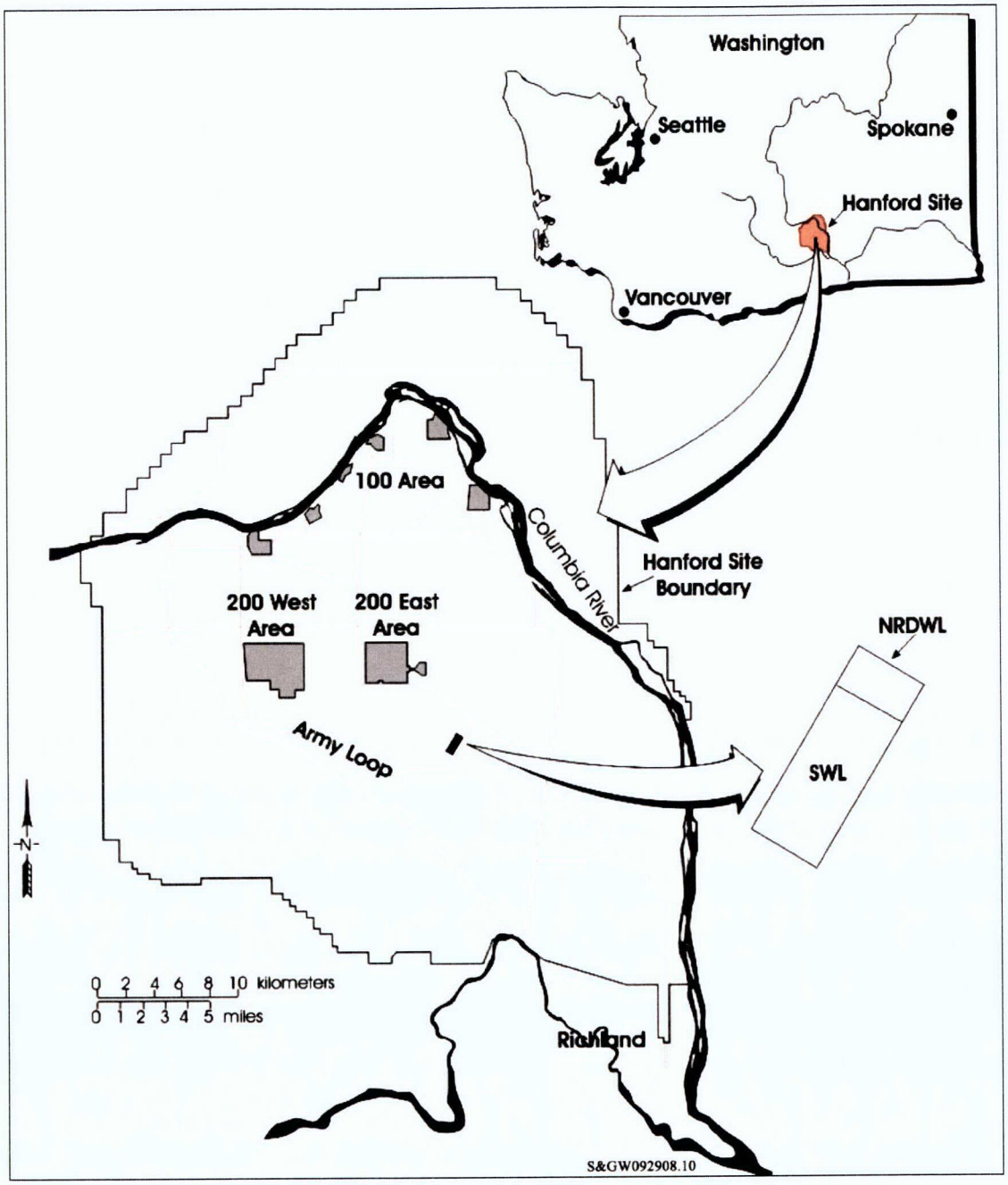


Figure 2-1. Regional Map with Locations of the Hanford Site, NRDWL, and SWL

Most of the chemical waste at the NRDWL was placed in metal drums prior to disposal. Containers of small-quantity laboratory chemicals were placed in laboratory packs and surrounded with sorbing material. Non-hazardous waste and asbestos waste were generally not placed into containers. In addition, some of the bulk organic wastes that were sorbed onto soil and other sorbents may not have been placed into containers. Additional details on the characteristics of waste disposed at the NRDWL are provided in DOE/RL-90-17.

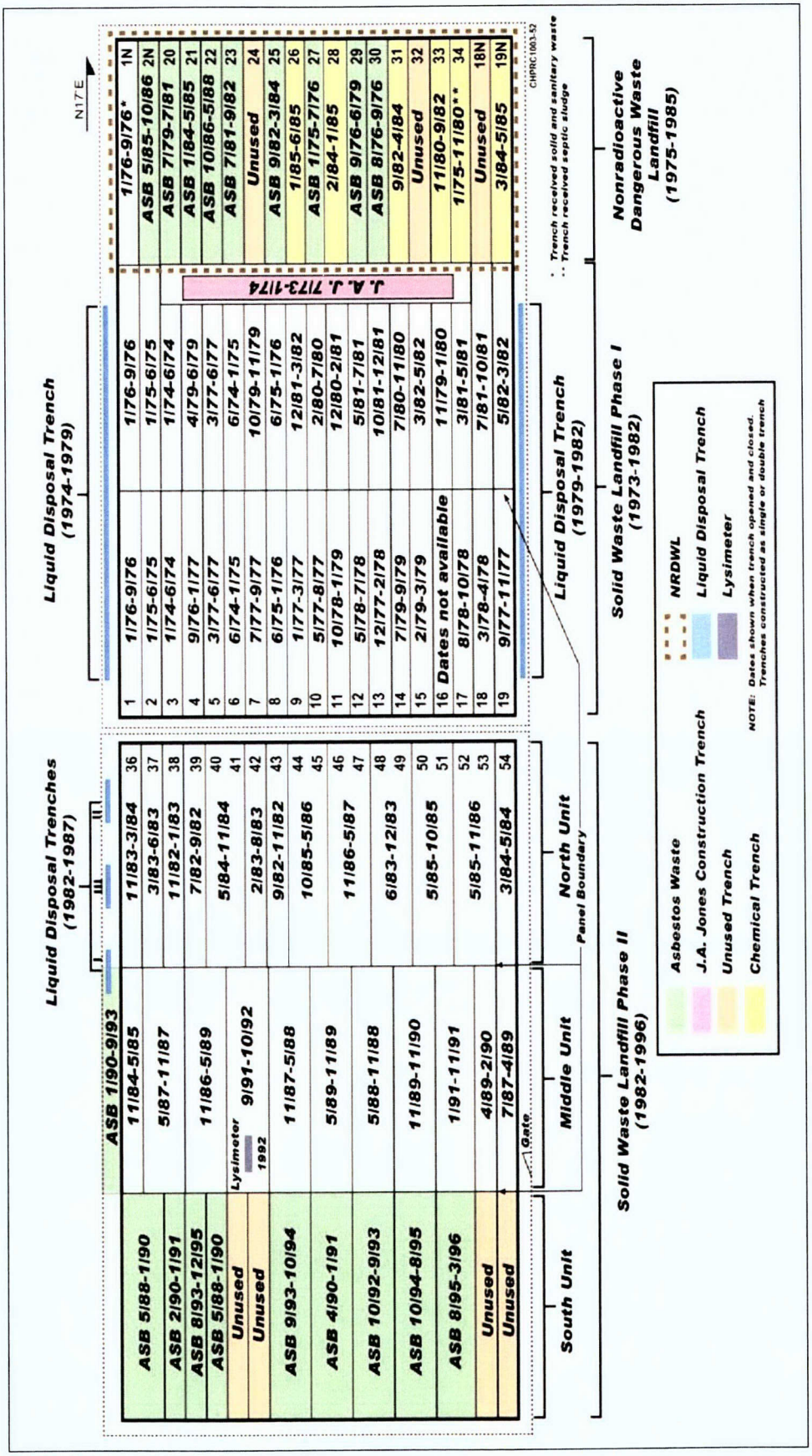


Figure 2-2. NRDWL and SWL Arrangement and Dates of Trench Operations

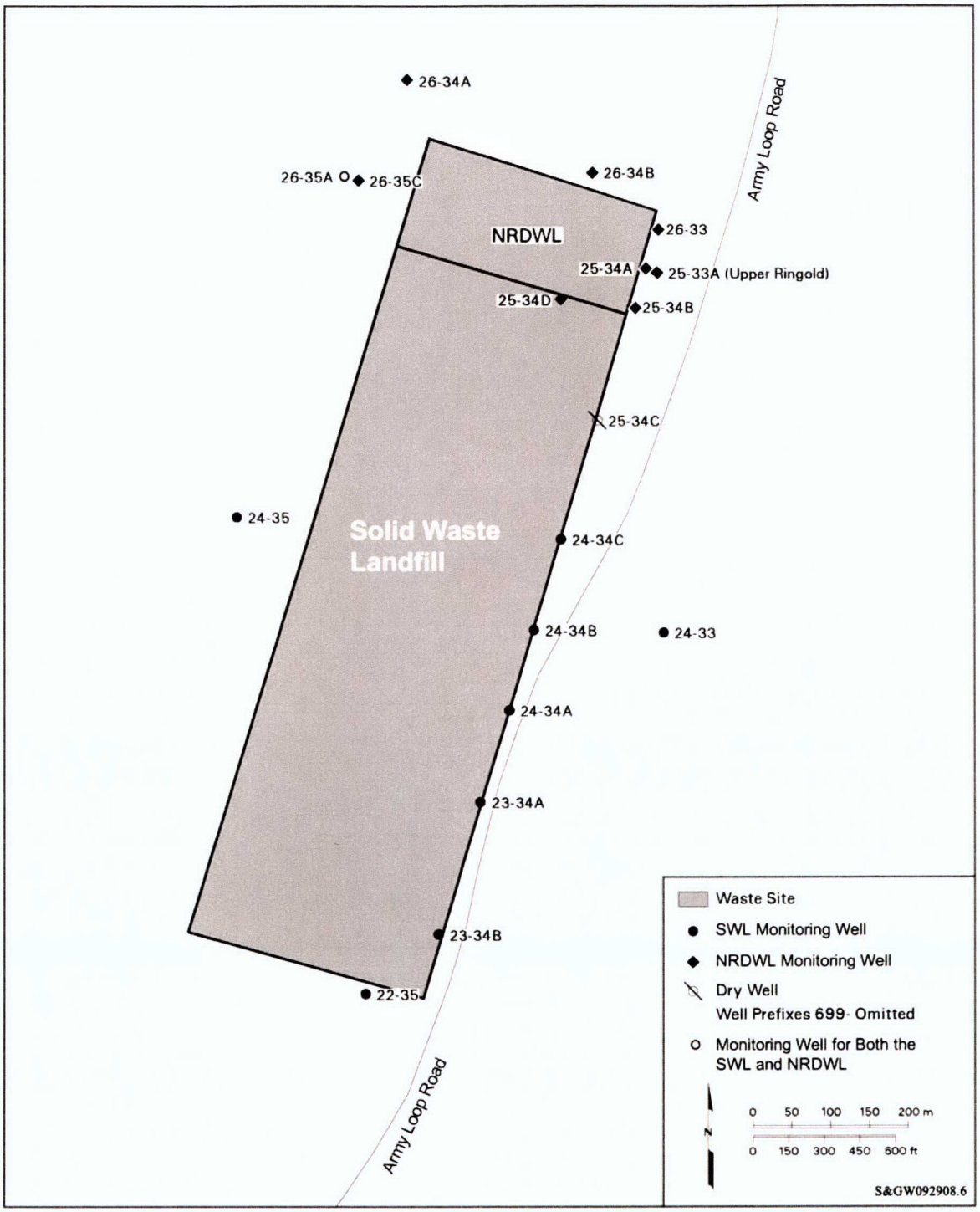


Figure 2-3. Current NRDWL and SWL Groundwater Monitoring Well Locations

2.2.2 Solid Waste Landfill

Both solid and liquid wastes were disposed at the SWL, including office waste, construction/demolition debris, asbestos material, bulky items, and miscellaneous waste (DOE/RL-2008-54, *Hanford Site Solid Waste Landfill Closure Plan*). Based on waste receipts, the SWL received approximately 400,266 m^3

(1,313,208 ft^3) of solid waste and 14,496 m^3 (47,559 ft^3) of asbestos waste from 1973 to 1995. 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.

From 1973 to 1987, liquids (including sewage and 1100 Area catch tank liquids) were discharged to the SWL in separate, shallow trenches dedicated for this purpose. The sewage originated from portable toilets and septic tanks. Non-dangerous catch tank liquid from the 1100 Area heavy equipment garage and bus shop was also disposed in these trenches from 1985 to 1987. The available chemical analysis of the 1100 Area non-dangerous catch liquid detected the following volatile organic compounds (VOCs):

- **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 (TCE):** Heavy equipment garage, <10 μg/L; bus shop <40 μg/L.
- **Tetrachloroethene (PCE):** Heavy equipment garage, 26 μg/L; bus shop <60 μg/L.

For the 2 years that non-dangerous catch tank waste liquid was disposed at the SWL, the estimated total volume of catch tank waste liquid disposed was 380,000 L (100,385 gal) (DOE/RL-90-38, *Hanford Site Solid Waste Landfill Interim Closure Plan*, Rev. 1). The waste types and volumes are discussed in more detail in DOE/RL-90-38 and DOE/RL-2008-54.

1

3 Hydrogeology and Groundwater – Chemistry

This chapter describes the geology, hydrogeology, and groundwater chemistry beneath the NRDWL/SWL WMA.

3.1 Physical Hydrogeology

The geologic units at the NRDWL/SWL WMA include the following, from top to bottom:

- Eolean deposits and recent fill
- Hanford formation
- Cold Creek unit(s)
- Ringold Formation

The Columbia River Basalt underlies the Ringold Formation. The hydrostratigraphic units, as described in *Three-Dimensional Conceptual Model for the Hanford Site Unconfined Aquifer System, FY 1993 Status Report* (PNL-8971), are roughly equivalent to the geologic units. The Hanford formation includes the entire vadose zone and the uppermost-saturated unit; pre-Hanford formation/post-Ringold Formation (Cold Creek) sediments underlie the Hanford formation. The upper portion of the Ringold Formation sediments locally includes a low-permeability unit, which apparently constitutes the local base of the unconfined aquifer beneath the NRDWL/SWL WMA. Figure 3-1 provides a generalized stratigraphic column for the NRDWL/SWL regional area; Figure 3-2 provides a cross-section along the downgradient side of the NRDWL/SWL WMA. Other cross-sections of the region are provided in the NRDWL/SWL closure/post-closure plan (DOE/RL-90-17). The low-permeability unit is a silty or clayey layer, approximately 60 m (197 ft) depth in the HSU5 hydrostratigraphic unit (undifferentiated Ringold). The HSU4 unit (the upper Ringold unit) is likely missing in the immediate vicinity of the NRDWL/SWL WMA, although it is present 4.5 km (2.8 mi) to the east and 3.5 km (2.2 mi) to the north. Wells installed at the SWL were not drilled deep enough to determine the presence of this low-permeability unit below the SWL.

The gravelly Ringold Unit E underlies the low-permeability unit of the upper Ringold. The Ringold lower mud unit is below Ringold Unit E throughout much of the Hanford Site, but the local presence of this unit cannot be verified because wells have not been installed to this depth beneath the NRDWL/SWL WMA. Aquifers in the Saddle Mountains Basalt and below are generally confined by the dense interiors of the basalt flows.

3.2 Groundwater Hydrology

Groundwater in the unconfined aquifer beneath the NRDWL/SWL WMA, as well as in the vadose zone, is discussed in this section. Aquifer characteristics are discussed first, followed by discussion of the vadose zone.

The water table beneath the NRDWL/SWL WMA is near the top of a silty sand unit in the lower portion of the Hanford formation or in the upper portion of the Cold Creek unit. The uppermost aquifer is unconfined and comprises the saturated Hanford sediments, the Cold Creek unit, and possibly the upper portion of Ringold Unit E. The saturated Hanford and Cold Creek unit sediments are gravelly sand to sandy gravel, approximately 18 m (59 ft) thick, and the upper Ringold underlying the Hanford sediments are slightly silty gravelly sand to sand, approximately 4 m (13 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, *Interim Hydrogeologic Characterization*

Report and Groundwater Monitoring System for the Nonradioactive Dangerous Waste Landfill, Hanford Site, Washington).

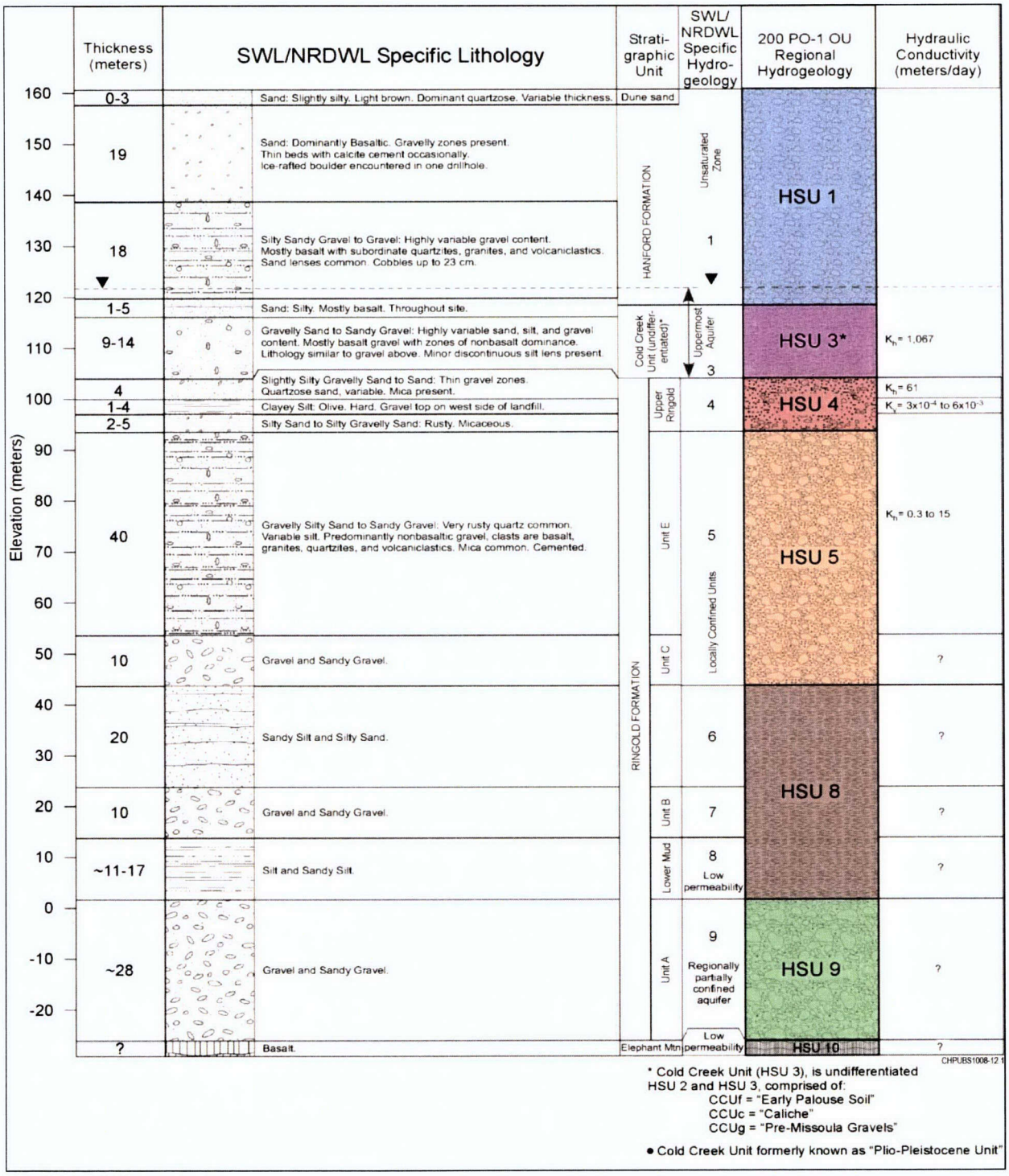


Figure 3-1. Regional Stratigraphy in the Vicinity of the NRDWL/SWL

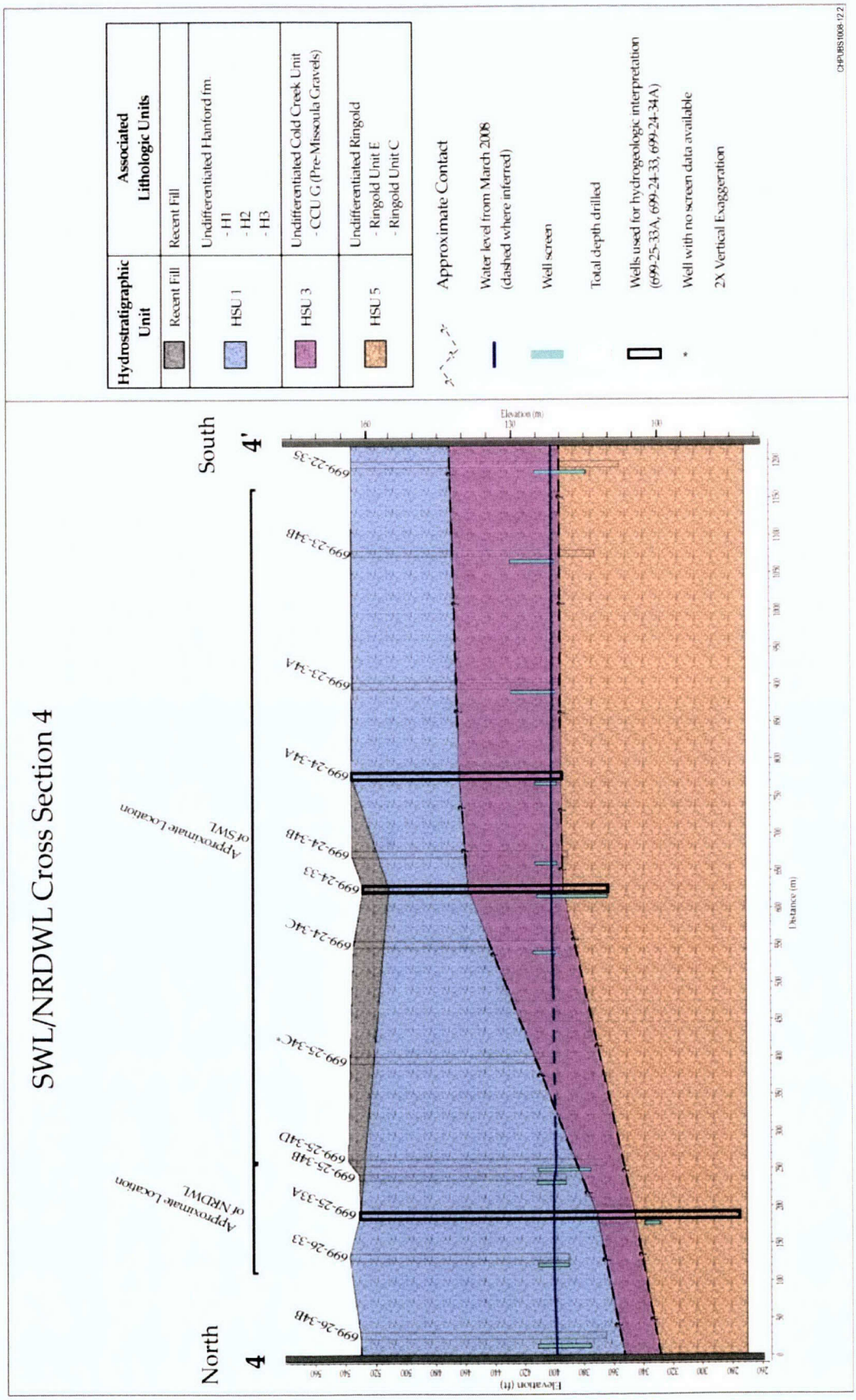


Figure 3-2. Cross-Section Along the Downgradient Side of the NRDWL/SWL WMA

A low-permeability unit in Ringold Unit E is believed to locally form 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, which is approximately 1 m (3 ft) thick on the east side of the NRDWL and approximately 4 m (13 ft) thick on the west side of the NRDWL. The vertical hydraulic conductivity is estimated to range from 0.0001 to 0.02 m/day (3 to 7 ft/day) (WHC-EP-0021) based on laboratory analysis. The low-permeability unit is believed to be continuous across the NRDWL/SWL WMA because it is continuous across the NRDWL and is approximately 3 m (10 ft) thick in well 699-23-33 (located 640 m [2,100 ft] south of well 699-25-33A). However, this unit is not present at well 699-28-40 (located 1.8 km [1.12 mi] west of the NRDWL/SWL WMA).

Silty sand to sandy gravel of the Ringold Unit E underlies the low-permeability unit, has a hydraulic conductivity of approximately 0.3 to 15 m/day (1 to 49 ft/day), and acts as a locally confined aquifer. The Ringold lower mud unit is below the Ringold Unit E throughout much of the Hanford Site, but the local presence of this unit cannot be verified because wells have not been installed to this depth beneath the NRDWL.

The 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.

The water table directly beneath the NRDWL/SWL WMA is fairly flat, between 121.8 and 122.0 m (399.6 and 400.3 ft) in elevation. The gradient is estimated at 0.00002 (DOE/RL-2008-66, *Hanford Site Groundwater Monitoring for Fiscal Year 2008*, Table B-1), and groundwater flows toward the east and southeast (Figure 3-3). Although the gradient is too low to measure with a high degree of certainty, historical water table maps from 1944, 1989, and 1995 (DOE/RL-96-61, *Hanford Site Background: Part 3, Groundwater Background*) and groundwater contaminant plumes from the 200 East Area corroborate groundwater flow toward the east and southeast (DOE/RL-2008-66). In addition, groundwater is inferred to flow southeast within the region between the 200 East Area and the NRDWL/SWL WMA because the average water-level elevation at the landfill (121.88 m [400 ft] North American Vertical Datum of 1988 [NAVD88] for March 2008) is 0.14 m (0.46 ft) less than the average elevation in the 200 East Area (122.02 m NAVD88 for March 2008) over a distance of approximately 8 km (5 mi). This yields a regional hydraulic gradient of 1.8×10^{-5} (DOE/RL-2008-66).

The groundwater flow rate beneath the NRDWL/SWL WMA is calculated to range from 0.03 to 0.27 m/day (0.10 to 0.89 ft) based on a hydraulic conductivity range of 500 to 1,500 m/day (1,640 to 4,921 ft/day), an effective porosity range of 0.1 to 0.3, and using the standard Darcy equation (DOE/RL-2008-66, Table B-1).

Two wells at the NRDWL (699-25-35C and 699-25-33A) sample the bottom of the uppermost aquifer, just above the low-permeability unit. Heads in these wells are virtually the same as in adjacent wells completed at the top of the aquifer, indicating no significant vertical gradient (PNNL-12086, *Hanford Site Groundwater Monitoring for Fiscal Year 1998*, Section 3.7).

The vadose zone is approximately 40 m (131 ft) thick, including sand, silty sandy gravel, and gravel. Because of the relatively thick vadose zone and low moisture content of the vadose zone sediments, travel time for unsaturated flow through the vadose may be longer than the time since the landfills were put into service.

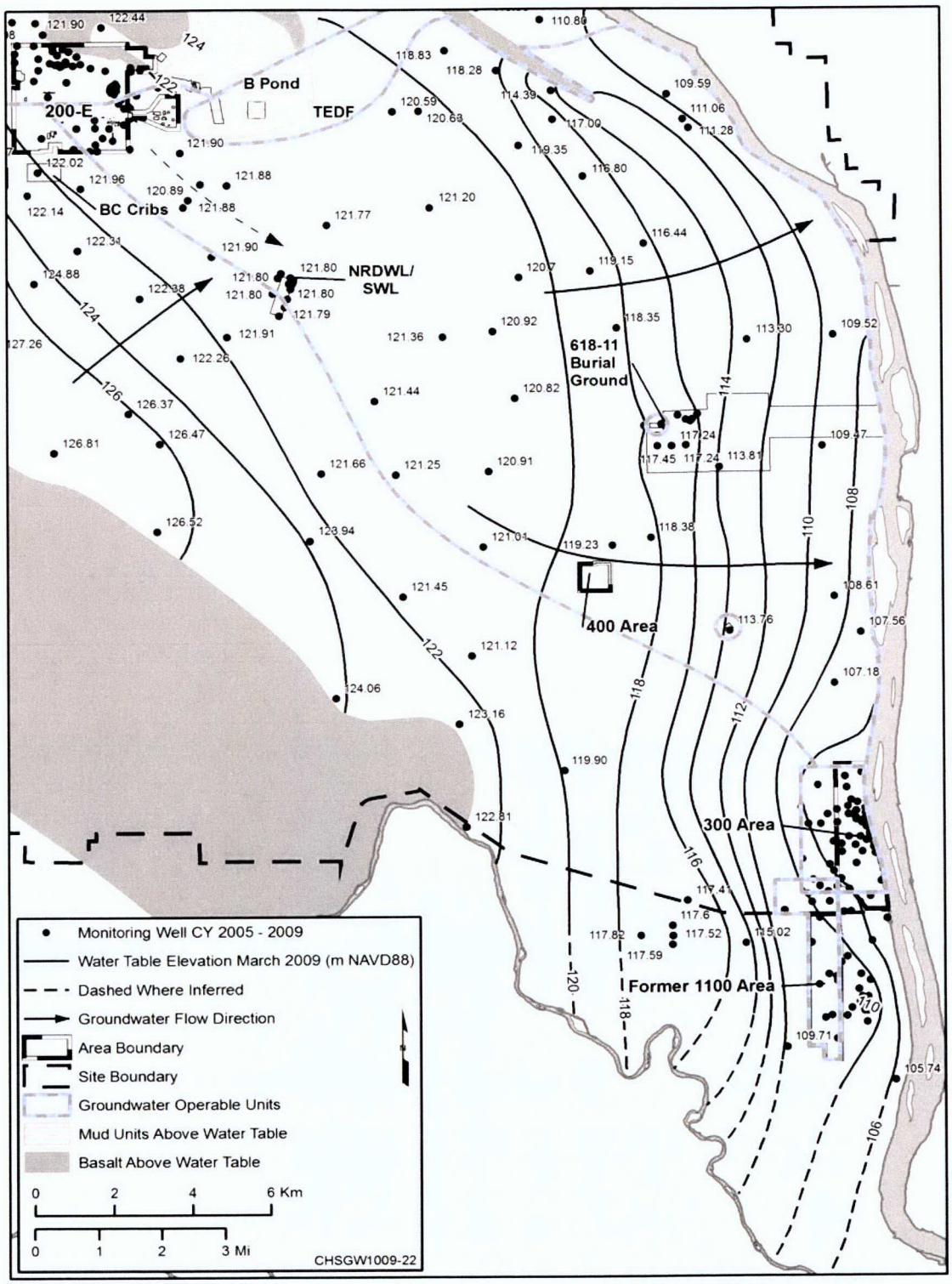


Figure 3-3. Water Table Map of the 200-PO-1 Groundwater OU, Including the NRDWL/SWL WMA, March 2009

3.3 Current Well Completions and Conditions

Basic well information is summarized in Table 3-1 for the NRDWL/SWL WMA. The existing groundwater monitoring system at NRDWL includes nine wells (three upgradient and six downgradient) (Figure 2-3). All nine wells meet Washington State standards for resource protections wells in accordance with WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells" (construction details of the wells are provided in PNNL-12227, *Groundwater Monitoring Plan for the Nonradioactive Dangerous Waste Landfill*). The six downgradient wells are arranged around the east and southeast sides of the landfill in order to detect groundwater constituents moving in the southeastward groundwater flow direction, typical of the uppermost unconfined aquifer in this area. Conversely, the three upgradient wells are located on the western and northwestern sides to sample upgradient (background) groundwater. Two of the nine wells at NRDWL are screened just above the low-permeability unit in the upper portion of the Ringold Formation. These wells (699-26-35C is upgradient, and 699-25-33A is downgradient) were completed in this lower unit in order to sample groundwater at the local base of the unconfined aquifer to assess whether constituents derived from the NRDWL are transported to the lower portions of the aquifer. The remaining seven wells are screened at the top of the uppermost aquifer.

Figure 2-3 shows the wells at the SWL, and Table 3-1 provides additional information for these wells. The existing well system includes nine wells, two of which are upgradient; one of these wells (699-25-35A) is shared with the current NRDWL well system. Downgradient well 699-24-33 is the only well not constructed in accordance with WAC 173-160; this is an older well constructed prior to promulgation of the WAC 173-160 well construction requirements. The wells proposed for the groundwater monitoring system under this plan are discussed in Chapter 4.

Table 3-1. Information for Current NRDWL and SWL Monitoring Wells

Well Name	Depth to Water (ft bgs)	Water-Level Date	Water Table Elevation – MSL NAVD88 (ft)	Screen Top (ft bgs)	Screen Bottom (ft bgs)	Measured Water Column (ft) (Date Measured)
NRDWL Monitoring Wells						
699-25-33A	130	7/20/2009	400	191	201	10[c]
699-25-34A	132	7/20/2009	400	118	138	2.6 (3/2010)
699-25-34B	131	8/21/2009	400	118	138	7.6 (2006)
699-25-34D	138	8/21/2009	400	127	162	24[c]
699-26-33	137	8/21/2009	400	124	144	7.2 (4/2010)
699-26-34A	130	8/21/2009	400	117	137	7.3 (2002)
699-26-34B	130	8/21/2009	400	118	154	24[c]
699-26-35C	134	8/21/2009	400	193	203	10[c]
699-26-35A[d]	134	7/20/2009	400	120	140	9 (2/2006)

Table 3-1. Information for Current NRDWL and SWL Monitoring Wells

Well Name	Depth to Water (ft bgs)	Water-Level Date	Water Table Elevation – MSL NAVD88 (ft)	Screen Top (ft bgs)	Screen Bottom (ft bgs)	Measured Water Column (ft) (Date Measured)
SWL Monitoring Wells						
699-22-35	~134	7/20/2009	400	122	157	23[c]
699-23-34A	134	7/20/2009	400	121	136	2.4 (6/2008)
699-23-34B	~134	7/20/2009	400	105	136	2[c]
699-24-33[b]	126	7/20/2009	400	116[a]	164[a]	38[c]
699-24-34A	135	7/20/2009	400	123	137	2.1 (5/2007)
699-24-34B	135	7/20/2009	400	122	137	2.3 (8/2008)
699-24-34C	134	7/20/2009	400	121	136	3.2 (12/2003)
699-24-35	140	7/20/2009	400	128	143	2.9 (5/2008)

a. No screen; perforated casing. Depth to top and bottom of casing perforations.

b. Not compliant with WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells."

c. Calculated from well construction records and water table levels.

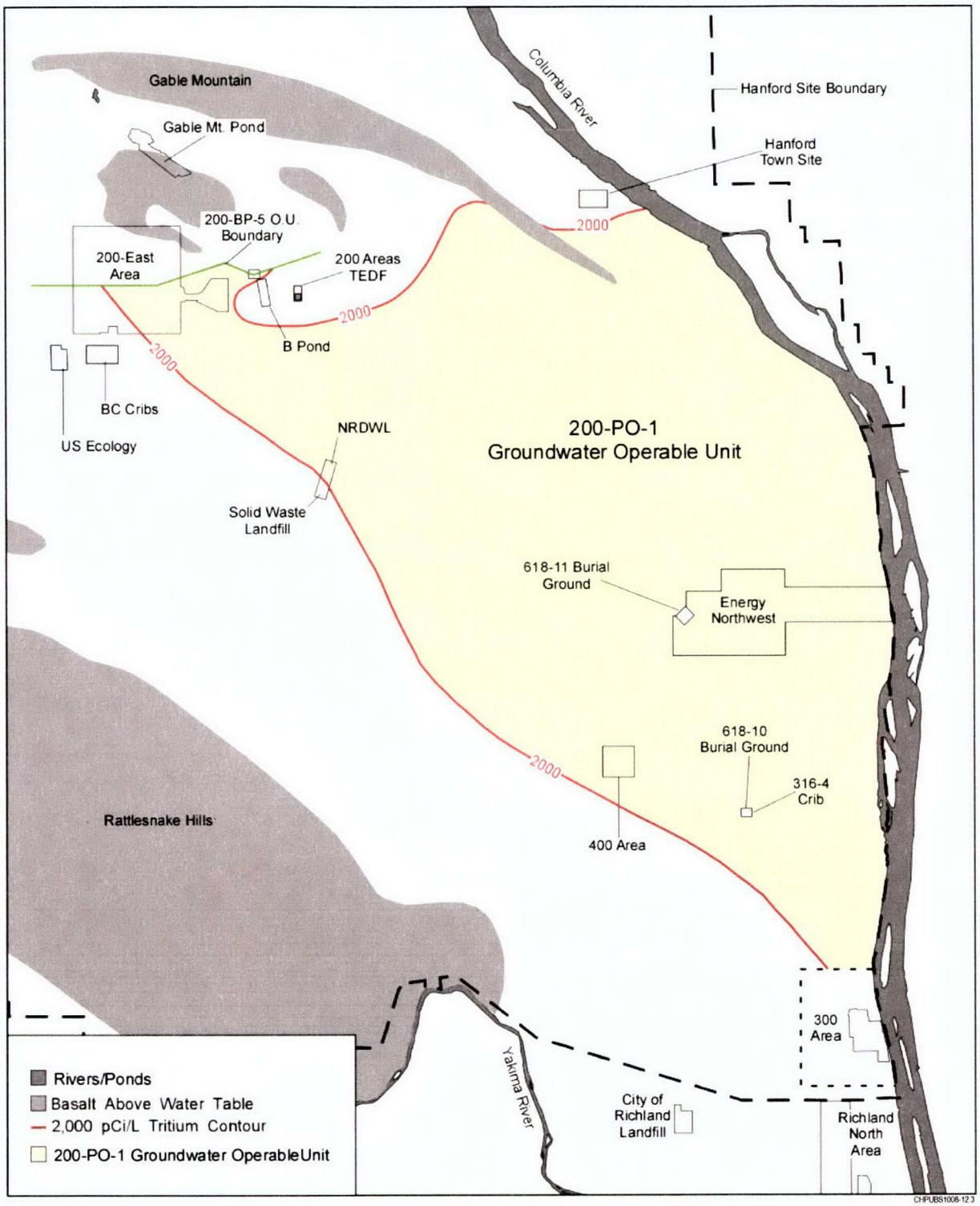
d. Well is shared by NRDWL and SWL in current monitoring plans.

3.4 Groundwater Chemistry

Groundwater monitoring results from the 200-PO-1 Groundwater Operable Unit (OU) and the current NRDWL and SWL monitoring programs are discussed in the following subsections.

3.4.1 Background Conditions

Regional groundwater contaminant sources are identified through the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) remedial investigation activities at the 200-PO-1 Groundwater OU. The 200-PO-1 OU comprises the groundwater beneath a large area in the southeastern portion of the Hanford Site (Figure 3-4). Monitoring results for the 200-PO-1 OU have shown that groundwater upgradient of the NRDWL/SWL WMA has been contaminated from sources in the 200 East Area. The principal contaminant plume from the 200 East Area is a nitrate plume. As this nitrate plume reaches the NRDWL/SWL area, the plume's concentration is approximately 20 mg/L (DOE/RL-2008-66). The drinking water standard (DWS) for nitrate is 45 mg/L (or 10 mg/L nitrogen in nitrate). Other potential groundwater contaminants from the 200 East Area are either not detected beneath the NRDWL/SWL WMA or are similar to background concentrations.



Source: DOE/RL-2008-01, *Hanford Site Groundwater Monitoring Report for FY 2007*.

Figure 3-4. 200-PO-1 Groundwater OU Boundary

3.4.2 NRDWL and SWL Groundwater Monitoring Results

Groundwater monitoring of the NRDWL previously focused on interim status monitoring requirements of the *Resource Conservation and Recovery Act of 1976* (RCRA). The NRDWL facility and closure plan will be incorporated into final status under the Hanford Site RCRA Permit (WA7890008967). Under interim status, the indicator parameters include pH, specific conductance, total organic carbon (TOC), and total organic halides (TOX) (PNNL-12227). Statistical comparisons are made between upgradient and downgradient concentrations. Critical means are calculated from upgradient wells. When downgradient concentrations exceed a critical mean, sampling and analyses are repeated for verification purposes. If verified, monitoring would advance to a groundwater quality assessment program.

The VOCs are monitored because they are contaminants of concern associated with the NRDWL. Nitrate is present in groundwater and has a source in the 200 East Area. The groundwater quality parameters (chloride, iron, manganese, phenols, sodium, and sulfate) are required analytes under the interim status groundwater monitoring program of WAC 173-303-400(3) ("Interim Status Facility Standards") but are either not detected (i.e., phenols) or are detected in concentrations below their respective DWSs (DOE/RL-2008-66).

Two of the four indicator parameters (specific conductance and TOC) have exceeded their critical means in NRDWL downgradient wells in the past, but none currently exceed a critical mean. Specific conductance increased in NRDWL wells and, in fiscal year (FY) 2001, surpassed the previously established critical mean (600.7 µS/cm in FY 2001) at wells 699-25-34A and 699-25-34B. An evaluation of the results indicated that the exceedance was caused by increases in the concentrations of non-dangerous constituents potentially from the adjacent SWL, where these constituents were higher than at the NRDWL. The exceedance of the critical mean for specific conductance did not indicate that the NRDWL had contaminated groundwater with dangerous constituents. The DOE submitted "Results of Assessment at the Non-Radioactive Dangerous Waste Landfill (NRDWL)" (0101-GWVZ-025), which served as both the assessment plan and the assessment report. Indicator evaluation monitoring status resumed in FY 2001. From 2002 to 2009, there were no significant exceedances of the three other indicator parameters.

The critical mean value for TOC was exceeded in samples collected in August 2008 from downgradient wells 699-25-34A and 699-25-34B, and the *Groundwater Quality Assessment Plan for the Non-Radioactive Dangerous Waste Landfill* (SGW-40274) was then prepared and implemented. The results, which are reported in *Groundwater Quality Assessment Report for the Nonradioactive Dangerous Waste Landfill* (SGW-41904), did not indicate dangerous constituents in groundwater associated with the elevated TOC. Indicator evaluation monitoring resumed in FY 2009 and continues to the present.

During FY 2009, specific conductance remained elevated at both the NRDWL and SWL, still due to elevated levels of calcium and magnesium. Concentration trends of specific conductance, calcium, and magnesium (Figures 3-5 through and 3-7) in well 699-24-34C at the SWL and wells 699-25-34A and 699-25-34D at the NRDWL are similar, but concentrations remain higher at the SWL than at the NRDWL.

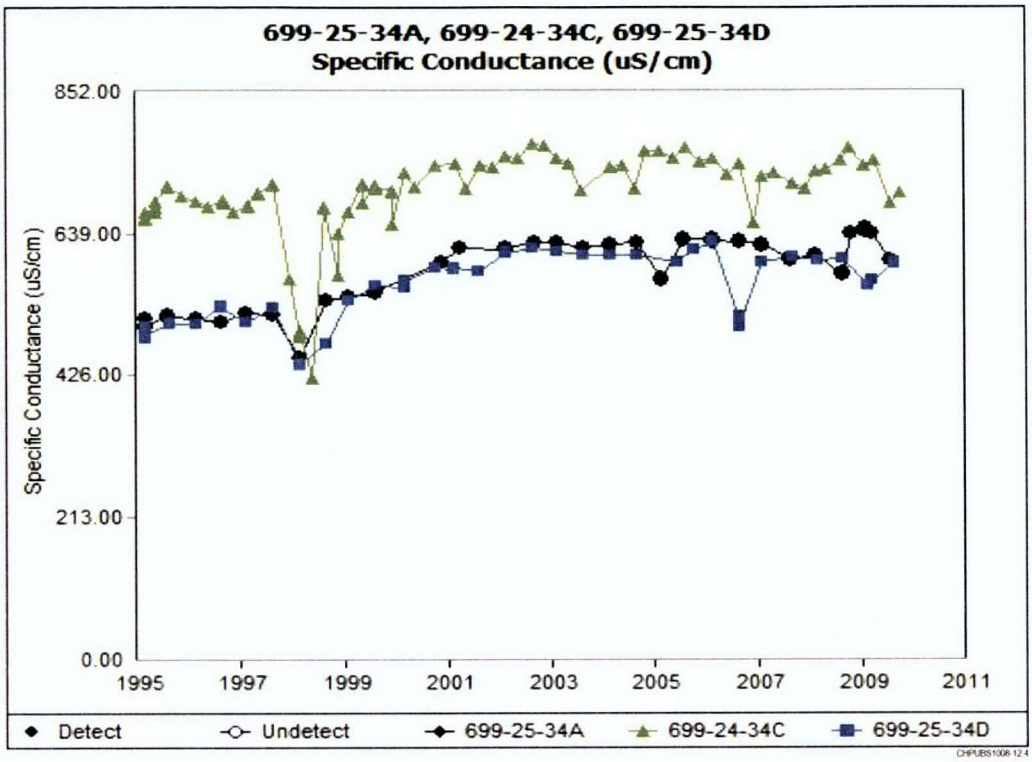


Figure 3-5. Specific Conductance Trends in Wells 699-25-34A, 699-24-34C, and 699-25-34D

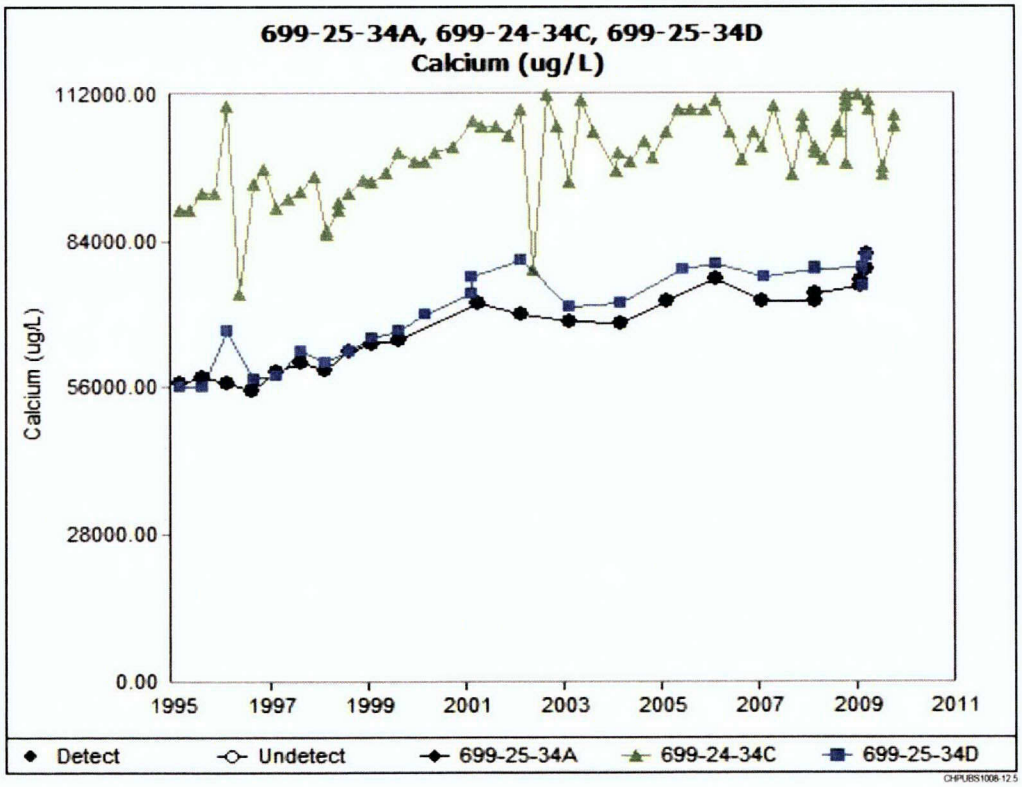


Figure 3-6. Calcium Trends in Wells 699-25-34A, 699-24-34C, and 699-25-34D

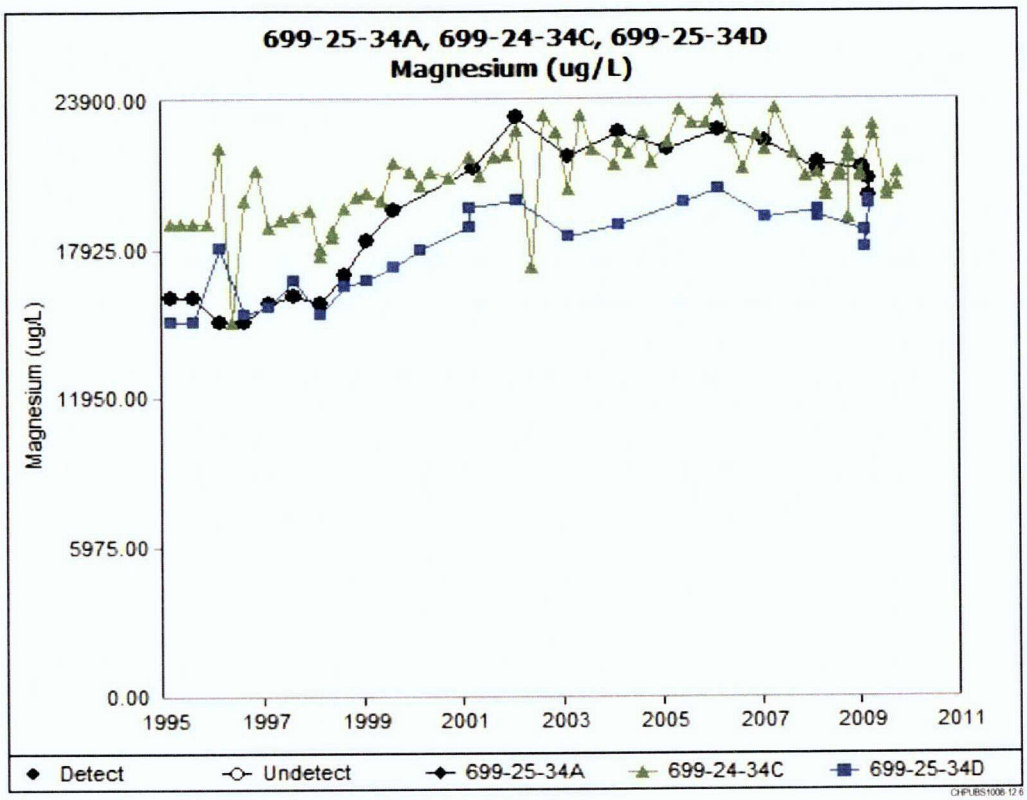


Figure 3-7. Magnesium Trends in Wells 699-25-34A, 699-24-34C, and 699-25-34D

Beginning in 1987, various VOCs were detected in NRDWL and SWL wells (Figures 3-8 through 3-16). Concentrations were already elevated at the time the wells were installed, and concentrations have steadily decreased over time. Six chlorinated hydrocarbons were detected in groundwater during FY 2007 in wells 699-24-33, 699-24-34A, 699-24-34B, 699-24-34C, 699-24-35, 699-25-34A, 699-25-34B, 699-25-34A, 699-26-33, 699-26-34A, 699-26-34B, and 699-26-35A. The detected chlorinated hydrocarbons included PCE, TCE, 1,1,1-trichloroethane, 1,1-dichloroethane, carbon tetrachloride, and chloroform. Most of these results were qualified as estimated values, and none were detected at concentrations above their respective federal DWSs, although concentrations of PCE, carbon tetrachloride, 1,1-dichloroethane, and TCE have exceeded the respective Washington State water quality standards for groundwater (WAC 173-200-040, "Water Quality Standards for Ground Waters of the State of Washington," "Criteria"), as noted in Figure 3-8 and Figures 3-11 through 3-16. Several detections of these same chlorinated hydrocarbons were also reported in FY 2008 and FY 2009 at levels near their respective laboratory method detection limits (MDLs).

Figure 3-8 illustrates that PCE has been below 3 µg/L for a long period, as shown in three selected wells (699-25-34B, 699-25-34D, and 699-26-33), but a short-duration increase was observed in late 2008 and early 2009 (Figure 3-8), which subsequently decreased in late 2009. The TCE in these wells has been stable and below 1 µg/L since 1993 (Figure 3-9). A long-term declining trend is also observed for 1,1,1-trichloroethane, and concentrations have been below 1 µg/L since 2003 (Figure 3-10). Carbon tetrachloride (DWS of 5 µg/L; water quality standard of 0.3 µg/L) in these wells has been below 1 µg/L since FY 1994 (Figure 3-11), with the exception of a reported value of 2 µg/L in early 2009. Subsequently, carbon tetrachloride concentrations returned to non-detect levels. The current MDL for these constituents is 1 µg/L.

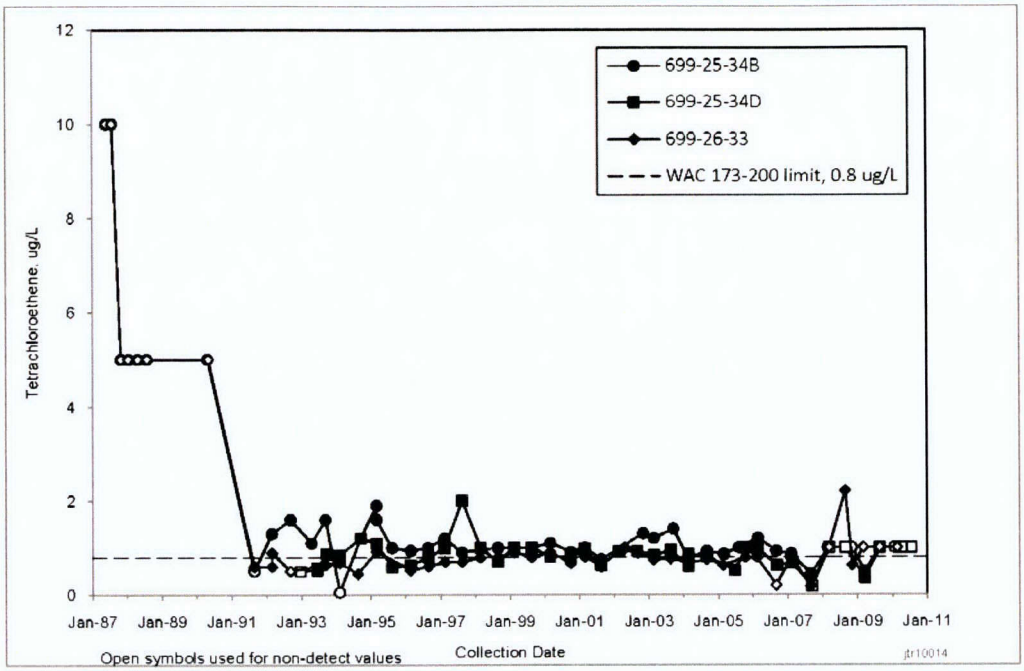


Figure 3-8. PCE Concentrations in Wells 699-25-34B, 699-25-34D, and 699-26-33

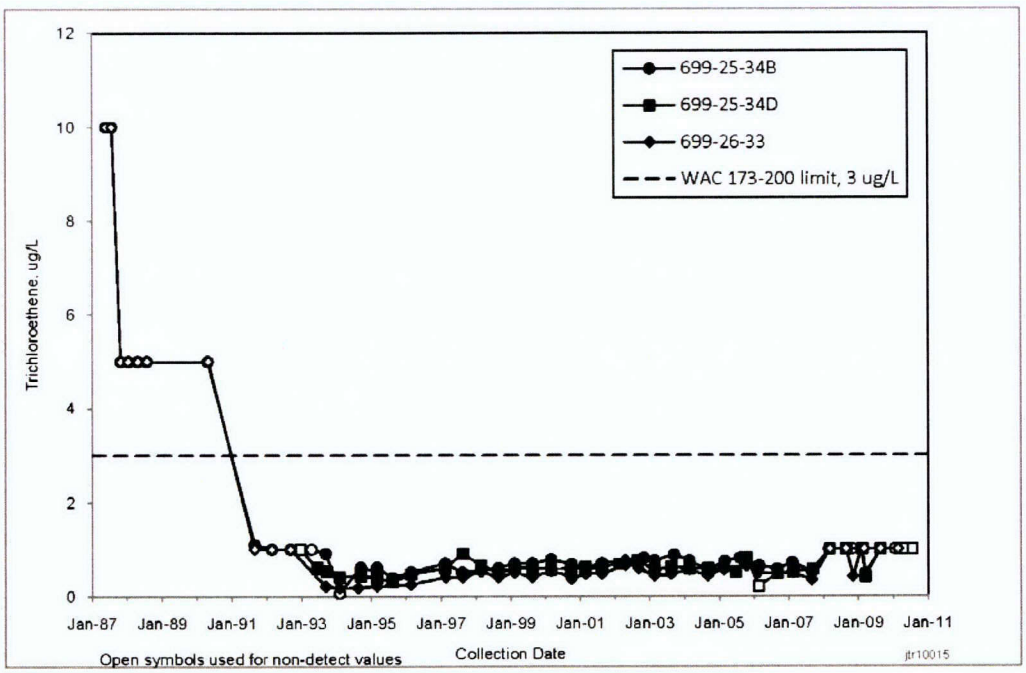


Figure 3-9. TCE Concentrations in Wells 699-25-34B, 699-25-34D, and 699-26-33

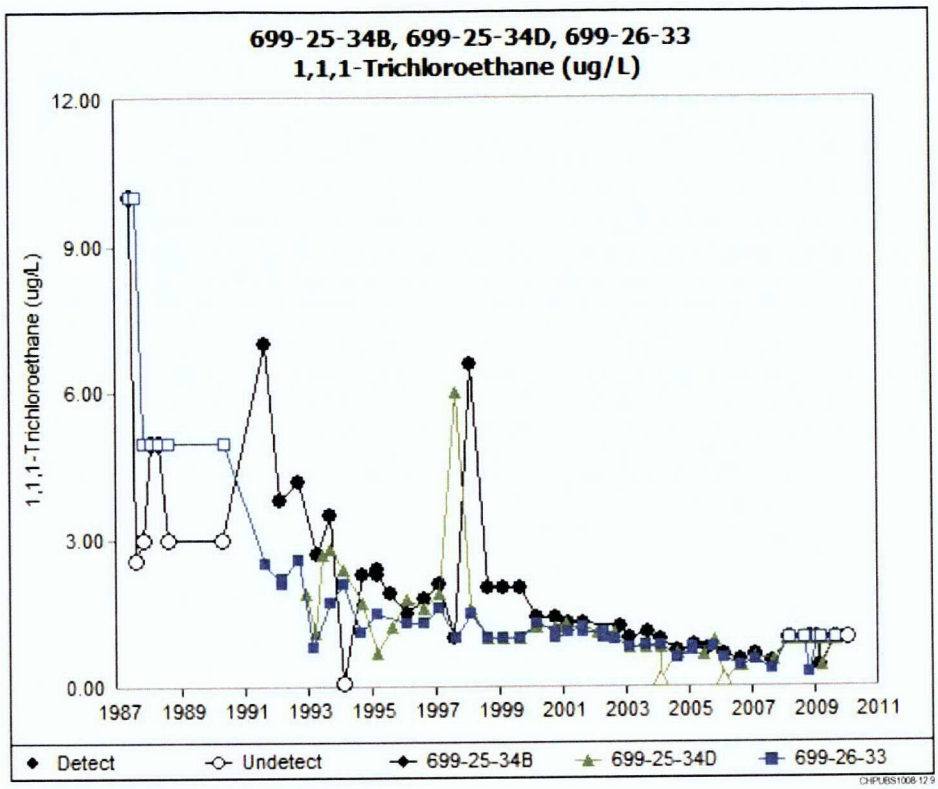


Figure 3-10. 1,1,1-Trichloroethane Concentrations in Wells 699-25-34B, 699-25-34D, and 699-26-33

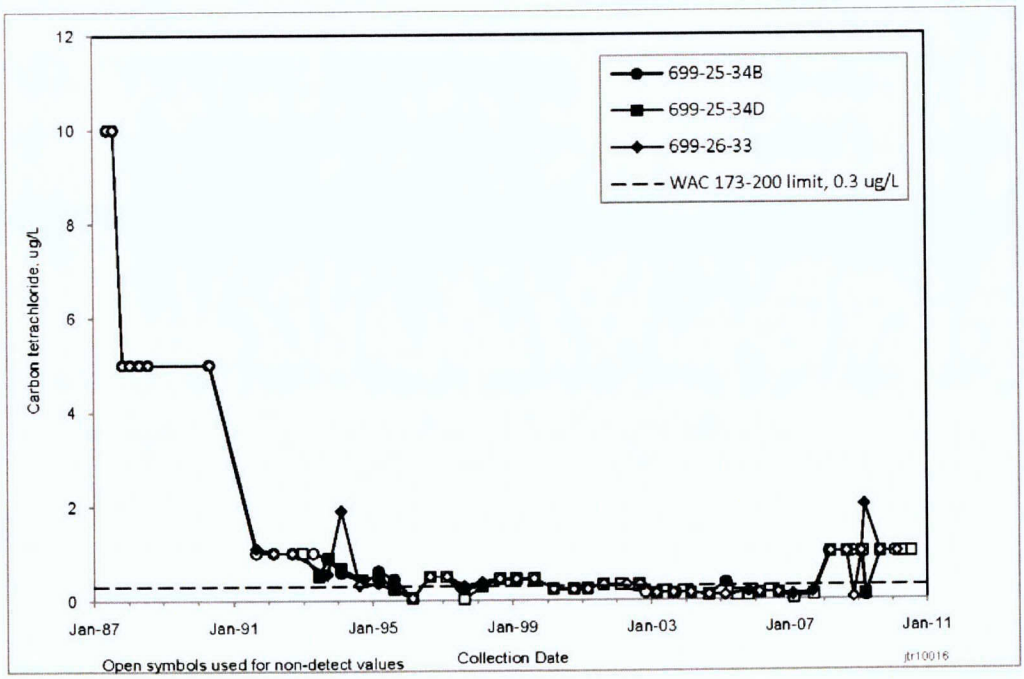


Figure 3-11. Carbon Tetrachloride Concentrations in Wells 699-25-34B, 699-25-34D, and 699-26-33

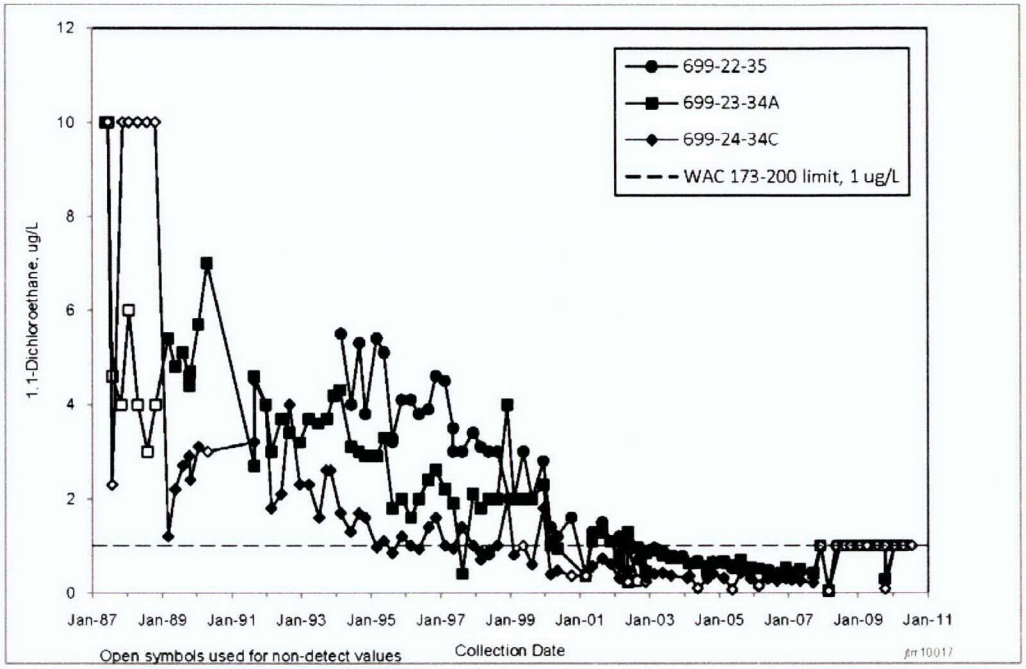


Figure 3-12. 1,1-Dichloroethane Trends in Wells 699-22-35, 699-23-34A, and 699-24-34C at the SWL

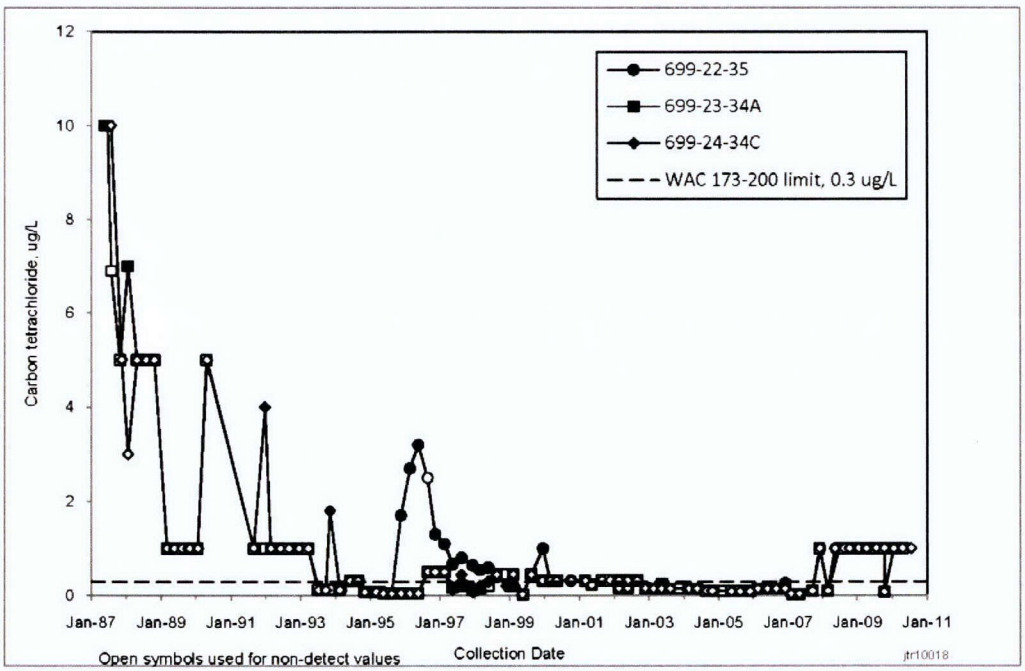


Figure 3-13. Carbon Tetrachloride Trends in Wells 699-22-35, 699-23-34A, and 699-24-34C at the SWL

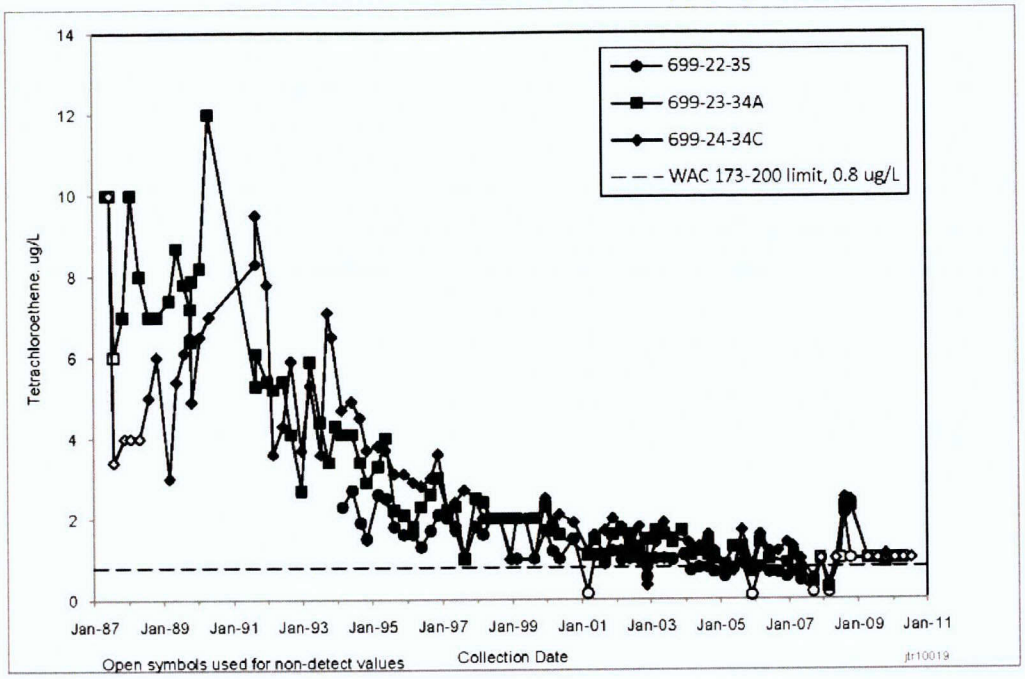


Figure 3-14. PCE Trends in Wells 699-22-35, 699-23-34A, and 699-24-34C at the SWL

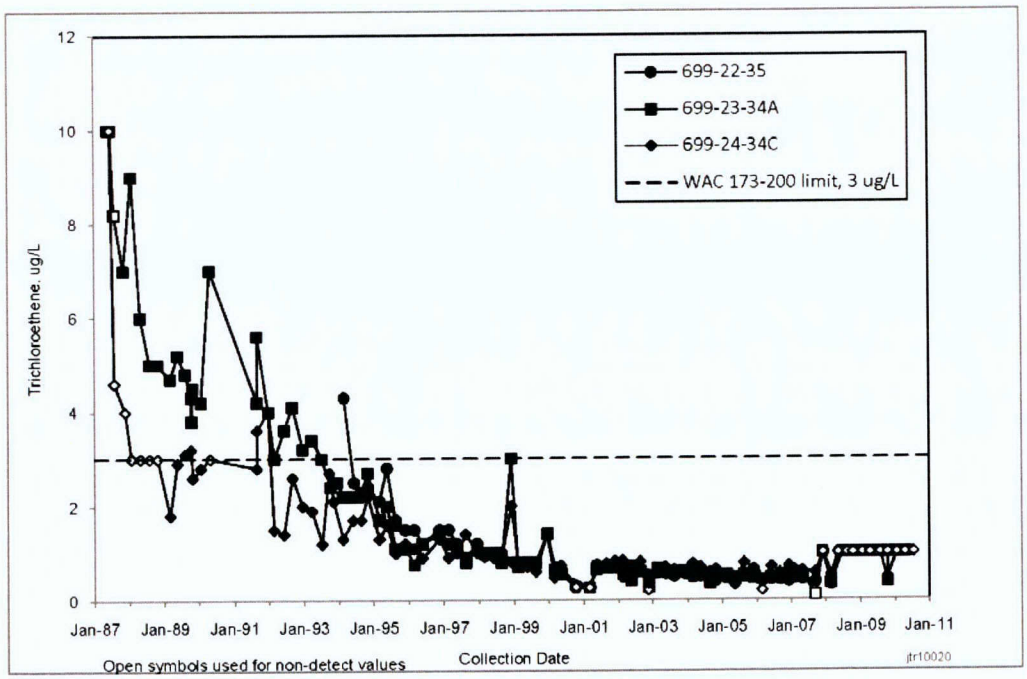


Figure 3-15. TCE Trend in Wells 699-22-35, 699-23-34A, and 699-24-34C at the SWL

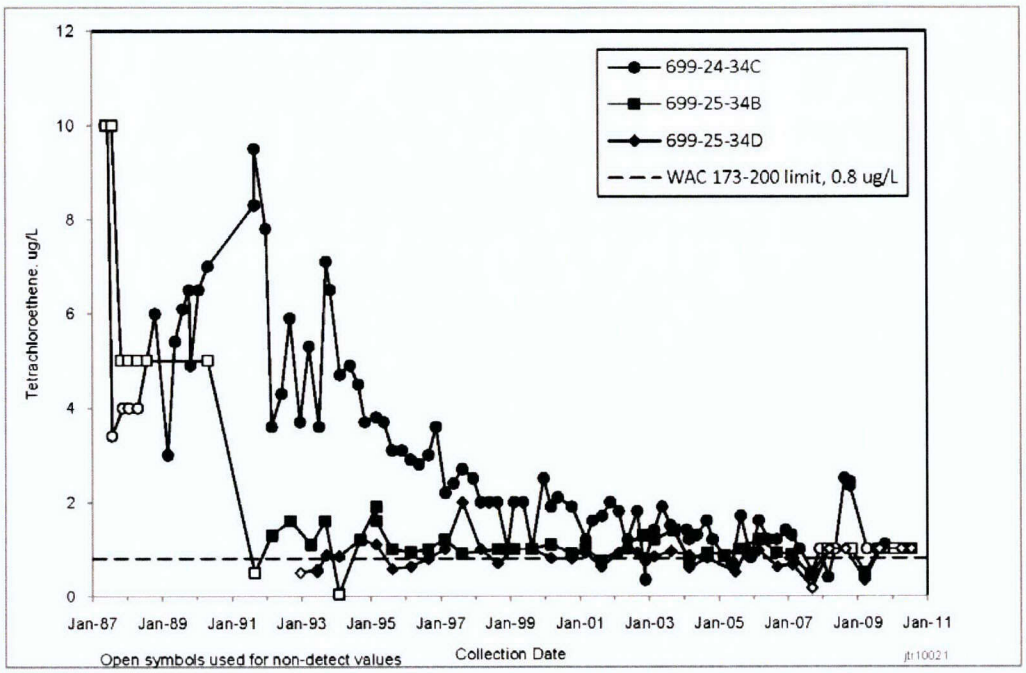


Figure 3-16. PCE Trends in SWL Well 699-24-34C and NRDWL Wells 699-25-34B and 699-25-34D

Two leading possibilities are postulated as the source and transport mechanisms of the chlorinated hydrocarbon contamination in groundwater beneath the NRDWL/SWL WMA. The source is most likely the trenches within the SWL 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 contaminants exist in the vadose zone as vapors and possibly traveled laterally through the vadose zone and then vertically to groundwater. Significant movement of the contamination in the aquifer to the upgradient wells cannot occur under groundwater advection alone, so lateral spreading in the vadose zone by vapor migration is a likely predominant transport mechanism.

Groundwater contaminant levels support the assertion that the SWL is a likely source of contamination beneath the NRDWL/SWL WMA. Trend plots for 1,1-dichloroethane, carbon tetrachloride, PCE, and TCE for SWL wells 699-22-35, 699-23-34A, and 699-24-34C are provided in Figures 3-12 through 3-15 to demonstrate the previously elevated levels and the declining trends of these contaminants in SWL wells. The PCE concentrations for SWL well 699-24-34C and NRDWL wells 699-25-34B and 699-25-34D (Figure 3-16) demonstrate the relationship between the contamination in downgradient SWL and NRDWL wells. The PCE levels in SWL wells have historically been higher than levels in NRDWL wells; this is also demonstrated by PCE distributions in groundwater for August 1991, February 1994, and February 2007, as shown in Figures 3-17 through 3-19. These figures also further illustrate the declining trends in PCE concentrations.

The increase in PCE in late 2008 and early 2009 to levels as high as 4.5 µg/L cannot be explained; however, the results were flagged with a "J" qualifier, which indicates results greater than the laboratory MDL but less than the contract-required detection limit. In addition, the increase occurred in 12 wells nearly simultaneously; results were reported between 3.3 and 4.5 µg/L for samples collected between January 19 and February 10, 2009. The results for samples collected after March 2010 have returned to <1 µg/L or non-detect. Furthermore, results from six wells in the 200 West Area between December 2008

and January 2009 indicated similar increases, with subsequent results returning to non-detects. The elevated results have been flagged as suspect in the database.

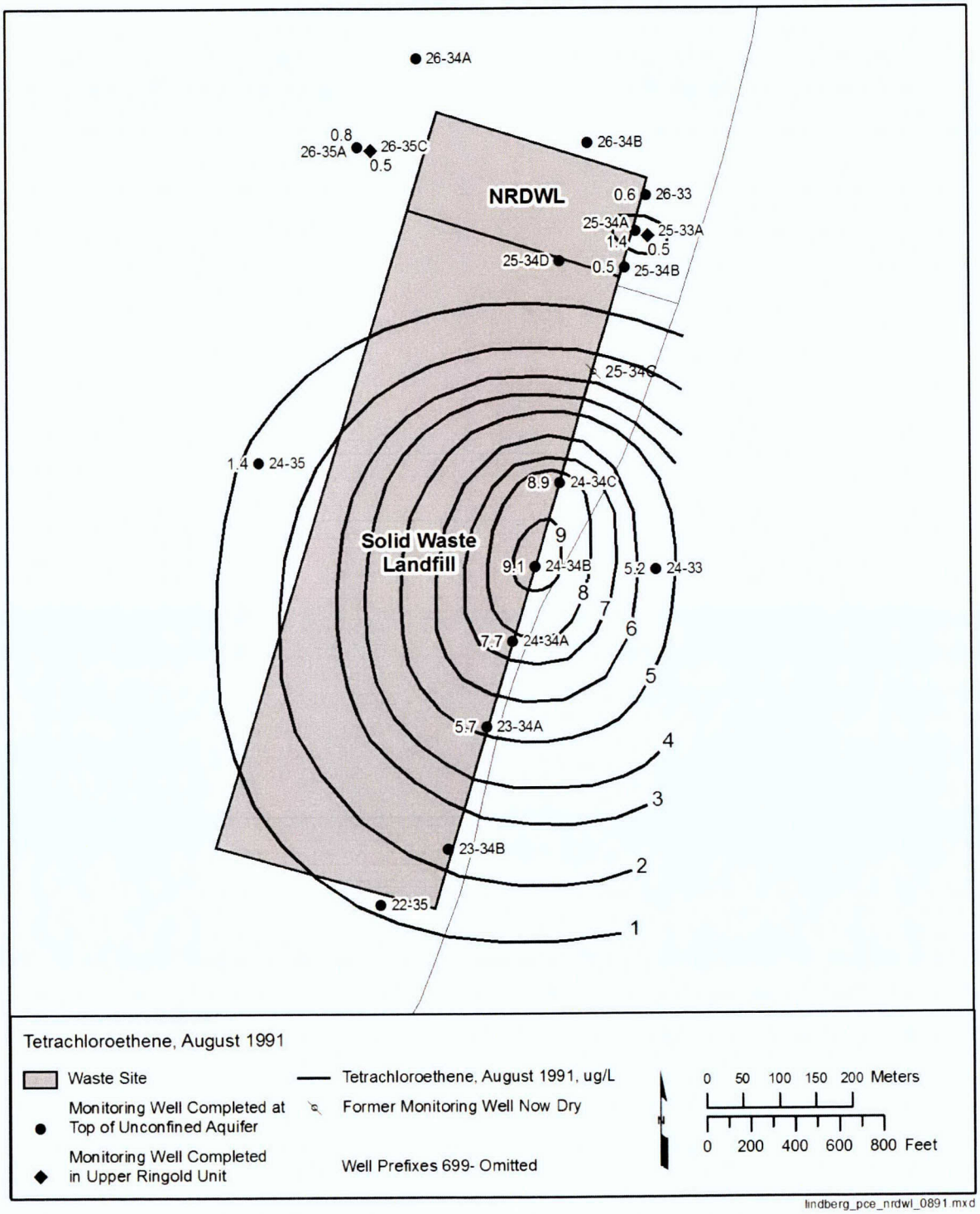


Figure 3-17. PCE Plume at the NRDWL and SWL, August 1991

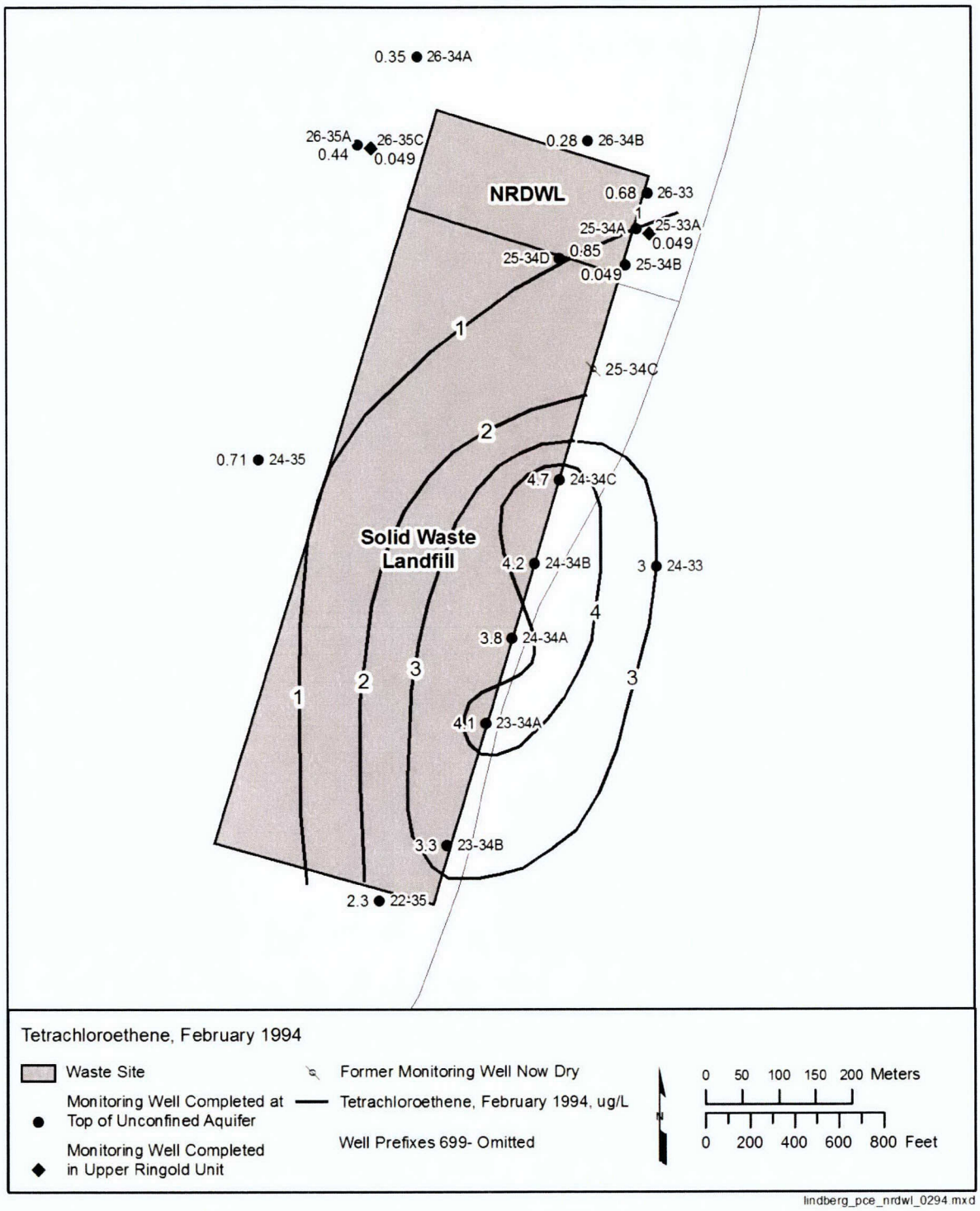


Figure 3-18. PCE Plume at the NRDWL and SWL, February 1994

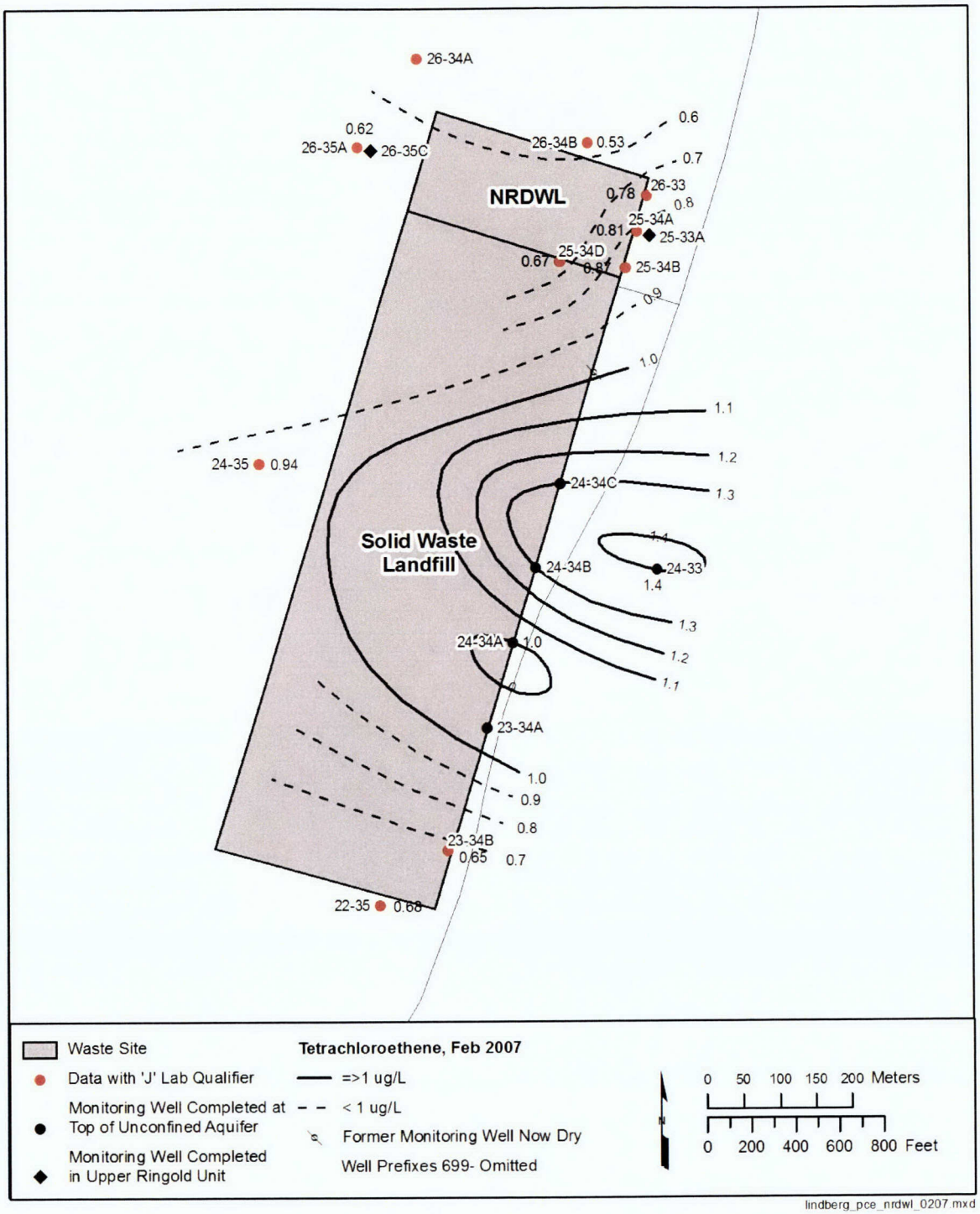


Figure 3-19. PCE Plume at the NRDWL and SWL, February 2007

3.4.3 Barium and Nickel at the NRDWL and SWL

Since 1986, the SWL was monitored as a solid waste managed unit under WAC 173-304, not as a TSD unit under WAC 173-303. According to the approved groundwater monitoring plan, specific parameters were evaluated and reported, which did not include barium and nickel. However, for qualitative

characterization in support of development of the revised groundwater monitoring plan for final closure and post-closure activities, detections of all available analytical constituents at the SWL were compared to Appendix 5 of Ecology Publication 97-407, *Chemical Test Methods for Designating Dangerous Waste: WAC 173-303-090 and -100*. As a result of the analysis, two constituents on that list, barium and nickel, were measured at concentrations elevated relative to upgradient measurements at a limited number of wells at the SWL, and they were not found at elevated levels at the NRDWL. The following subsections provide a more detailed discussion of these findings.

3.4.3.1 Barium

Figure 3-20 shows barium concentrations measured near the SWL. The maximum concentration limit for barium is 1,000 µg/L (WAC 173-303-645, Table 1). Barium concentrations are highest at well 699-22-35, near the southern border of the SWL, but concentrations well below the maximum contaminant level. Barium levels decrease northward but are consistently higher than concentrations near upgradient well 699-24-35. Well 699-32-43 is a far-field well (>2,000 m [6,562 ft]) upgradient and shows low levels of barium, indicating that barium may not be originating from upgradient sources in the 200 East Area.

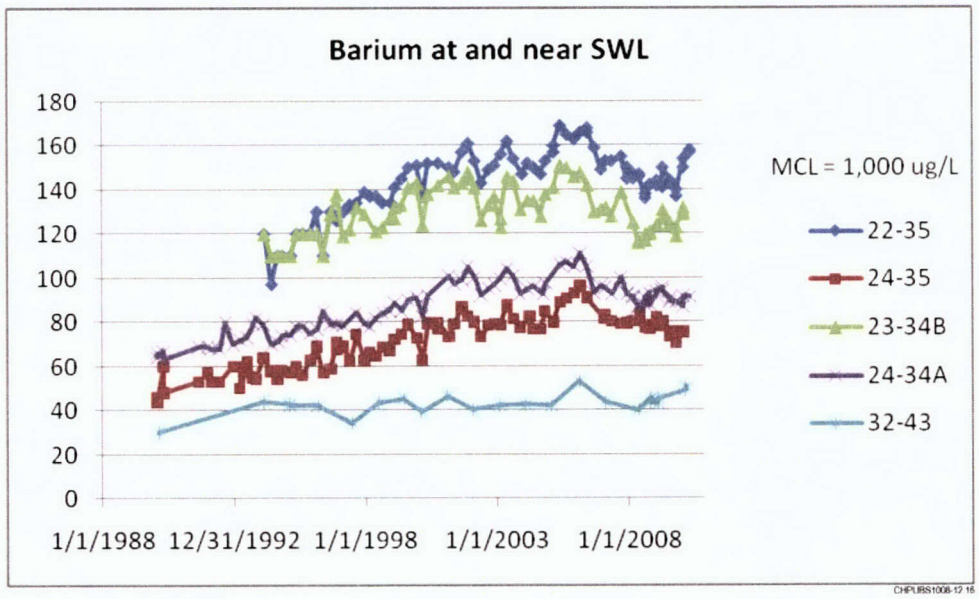


Figure 3-20. Barium Concentrations near the SWL

Figure 3-21 shows the elevated barium concentrations from 2008 to present at downgradient well 699-22-35 relative to upgradient well 699-24-35. The information in this section provides qualitative information that barium concentrations are elevated relative to other wells, including upgradient wells. Statistical analysis performed in accordance with this plan will provide a quantitative analysis whether barium concentrations in some downgradient wells are statistically significant relative to barium concentrations in upgradient wells.

3.4.3.2 Nickel

Figure 3-22 shows nickel concentrations for wells 699-24-34A and 699-24-35 measured from 2005 to April 2010. Nickel appears to be consistently higher in downgradient well 699-24-34A than in upgradient well 699-24-35.

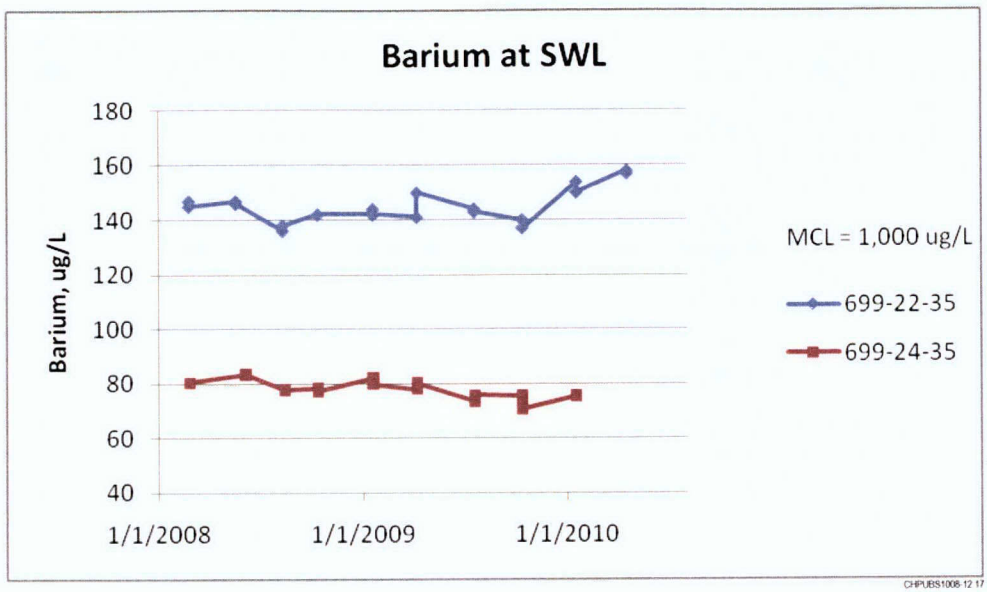


Figure 3-21. Barium at Well 699-22-35 Versus Well 699-24-35 Since 2008

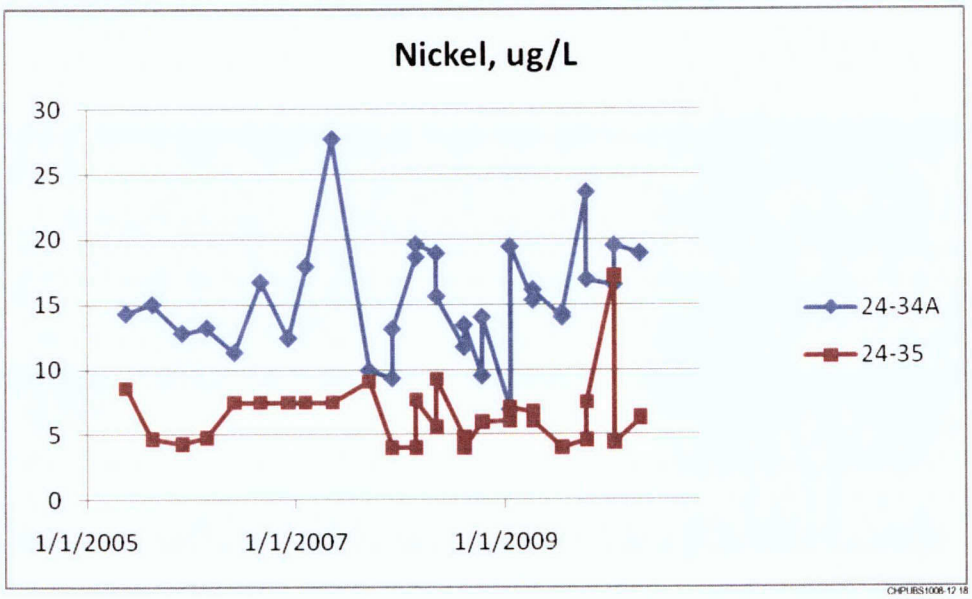


Figure 3-22. Concentration Differences for Nickel in Wells 699-24-34A and 699-24-35

Figure 3-23 shows nickel concentrations for additional wells 699-24-34B and 699-22-35 over the same period. Well 699-22-35 exhibited high concentrations of barium but not high nickel concentrations. Nickel measurements in these wells exhibited significant variability; however, well 699-24-34A appears to have consistently higher nickel measurements than the other SWL wells.

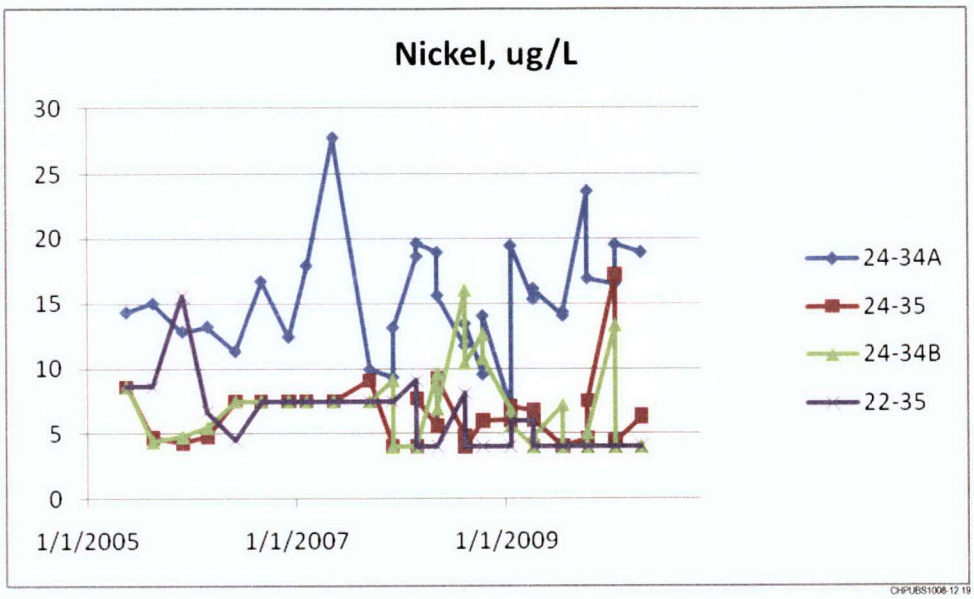


Figure 3-23. Nickel in Several Wells near the SWL

The results discussed above cannot be used to determine whether the WMA has impacted groundwater quality because the results are only qualitative comparisons using concentration trend plots. To make decisions regarding whether downgradient wells have higher concentrations than upgradient wells, the use of one or more statistical treatments is required in accordance with WAC 173-303-645. Future sampling, analysis, and evaluation under this plan, and in accordance with the requirements of WAC 173-303-645, will allow for such a determination.

3.4.4 Vadose Zone Chemistry

The vadose zone beneath the NRDWL/SWL site was impacted by sewage and 1100 Area catch tank liquid that were discharged to the liquid waste trenches at the SWL, as well as potentially small quantities of liquid waste in drums or laboratory packs with surrounding absorbing material. The total quantity of liquid waste discharged to the liquid waste trenches was 4.18 to 6.08 million L (4,180 to 6,080 m^3, or 1.1 to 1.6 million gal) over a 12-year period from 1975 to 1987 (see Section 2.2.2). The volume of the pore space beneath the 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). Thus, the volume of waste is approximately 6,000 m^3 (1,585,032 gal), and the available pore space is approximately 26,000 m^3 (6,868,473 gal). With the total volume of wastewater less than one-fourth of the available pore volume beneath the liquid waste trenches, it is unlikely that liquid waste discharges migrated to the water table as saturated flow.

The impact to the groundwater from the waste disposed within the NRDWL/SWL facility is likely limited to that which can be transported by soil vapor, such as pH and anion/cation changes due to carbon dioxide increases from the sewage, and VOCs from soil vapor discharged from the 1100 Area catch tank liquid. It is also helpful to explain the radial pattern to the PCE plume maps shown in Figures 3-17, 3-18, and 3-19 and the impact to upgradient wells that would (under normal advection in the aquifer) remain unaffected by PCE transport in liquid form. The remainder of this section provides a discussion of the results from soil vapor surveys (Section 3.4.4.1) and the leachate collection system (Section 3.4.4.2).

3.4.4.1 Soil Vapor Survey

The first soil vapor survey was conducted at the SWL from June 1988 through February 1989 to determine the areal extent of chlorinated hydrocarbons (PNL-7147, *Final Report: Soil Gas Survey at the Solid Waste Landfill*). The survey found detectable concentrations of 1,1,1-trichloroethane, TCE, PCE, 1,1-dichloroethane, carbon tetrachloride, carbon dioxide, and methane. Concentrations of 1,1,1-trichloroethane, PCE, and TCE were detected as far as 130 m (427 ft) west and 115 m (426 ft) east of the SWL trenches. This further supports the hypothesis provided earlier regarding lateral transport of contaminants by vapor migration. This lateral transport of VOC vapors also likely affects underlying groundwater. Low levels of these same VOCs were discovered in groundwater samples, including samples from upgradient wells. However, the vadose zone soil vapor survey results show that the areas of relatively high soil vapor concentrations generally do not necessarily coincide with locations of the known liquid disposal trenches.

In situ soil vapor samples were collected during the drilling of groundwater monitoring well 699-22-35 and 699-23-34B at the southeast corner of the SWL in FY 1993 and FY 1994 (PNNL-11709, *Borehole Completion Data Package for Solid Waste Landfill Facility Wells 699-22-35 and 699-23-34B*). Samples were collected approximately every 6 m (20 ft) at each borehole. The only target analyte detected in the borehole samples was carbon tetrachloride. Each of the 11 borehole samples contained detectable quantities of carbon tetrachloride in concentrations, ranging from 0.1 to 1.4 parts per million by volume.

Sixteen soil vapor probes were permanently installed at eight locations around the perimeter of the SWL (Figure 3-24) in September 1993 to monitor concentrations of landfill gases (methane, carbon dioxide, and oxygen) in accordance with WAC 173-304; they were also sampled and analyzed using field-screening methods for chlorinated hydrocarbons. Regular monitoring has continued from 1996 to present. The only VOC analyte noted in the 1996 sampling was 1,1,1-trichloroethane, which quickly decreased from a high of 2.44 μg/L in November 1996 to non-detectable starting in January 1999. The VOCs were no longer detected after 2006. These results are summarized in DOE/RL-2008-54.

3.4.4.2 Leachate Collection System

In 1992, a basin lysimeter was installed beneath the southern end of double Trench 41 and 42 (Figure 2-2), which was closed in October 1992. The lysimeter has a collection area of 88 m^2 (289 ft^2). A discharge pipe drains the leachate from the lysimeter basin to a sump where leachate generated by water infiltrating through the overlying waste trench is collected. The leachate quality and quantity are analyzed to evaluate the impact that leachate may potentially have on groundwater quality. The leachate lysimeter monitoring system is discussed further in DOE/RL-2008-54.

Leachate samples were initially analyzed for parameters specified in the SWL permit application (DOE/RL-90-38, *Hanford Site Solid Waste Landfill Permit Application*, Rev. 0). A sampling and analysis plan for leachate was developed that is consistent with the provisions of the SWL interim closure plan and the permit application (DOE/RL-90-38, Rev. 1). Several organic contaminants, including 1,4-dioxane, were detected in the early rounds of sampling in 1996 and 1997; however, levels have since dropped for most organic contaminants. Results from 2006 and 2007 indicated the continued presence of low levels of 1,4-dichlorobenzene. Total dissolved solids, arsenic, iron, manganese, and nickel exceeded their respective primary or secondary DWSs at least once in the 2006 and 2007 leachate samples (DOE/RL-2008-54). This leachate is collected just below the waste, approximately 35 m (115 ft) above the groundwater. The leachate results are useful for selecting indicator parameters for detection monitoring.

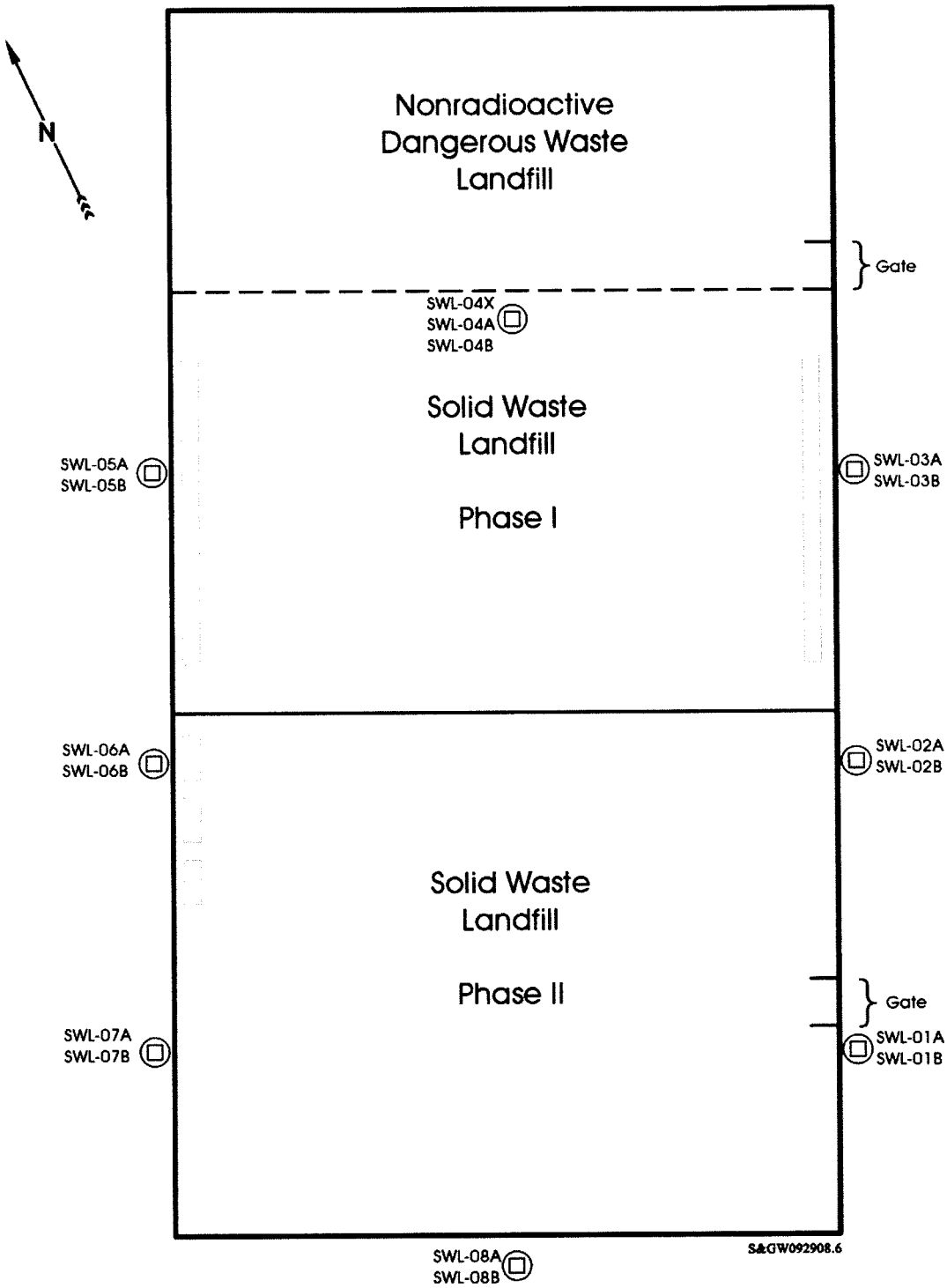


Figure 3-24. Location of Soil Vapor Monitoring Stations at the SWL

4 Groundwater Monitoring Program

Figure 4-1 shows the groundwater monitoring wells to be monitored at the NRDWL/SWL WMA under this monitoring plan. This well system is capable of yielding groundwater samples from the uppermost aquifer that provide the following:

- Represent the quality of background water that has not been affected by leakage from the NRDWL/SWL WMA
- Represent the quality of groundwater passing the point of compliance
- Allow for the detection of contamination when constituents have migrated from the NRDWL/SWL WMA to the uppermost aquifer

This groundwater monitoring program is designed to determine whether statistically significant evidence exists of contamination in the uppermost aquifer attributable to the NRDWL/SWL WMA and to provide the process and schedule for actions, notification, and permit modification, if necessary. The detection monitoring system provides a new groundwater monitoring system that includes upgradient wells, compliance wells, a far-field well, and deep wells. The wells are discussed in Section 4.3.

The leachate collection and soil vapor monitoring systems have been useful in the past to provide information about the presence of liquid waste beneath the trenches and contaminants as soil vapor in the vadose zone at the SWL. These systems also provide an indication of moisture infiltration from the surface. Because these systems provide information to complement the groundwater monitoring well system, the systems will continue to be operational during the closure and post-closure periods.

4.1 Groundwater Monitoring Well System

Groundwater monitoring will be conducted under a detection monitoring program in accordance with WAC 173-303-645(9). Although the dangerous constituents barium and nickel appear to be elevated relative to upgradient wells, those results were not obtained in accordance with a monitoring system implemented under requirements of WAC 173-303-645. The monitoring well system will include the following changes to the existing well system:

- A new well along the point of compliance to replace dry well 699-25-34C (new compliance well; Figure 4-1).
- Two new upgradient wells (proposed upgradient wells 1 and 2; Figure 4-1) will be installed at distances far enough upgradient (approximately 500 m [1,640 ft]) to minimize the effects of VOCs from soil vapor in the vadose zone. Sections 3.2 and 3.4.4 discuss the presence of VOCs in upgradient wells by soil vapor transport in the vadose zone from the NRDWL/SWL WMA.
- Up to four additional far-field downgradient well(s) (proposed downgradient wells 1 through 4; Figure 4-1) beyond the line of compliance at the request of Ecology. The purpose for these wells is to determine if dangerous waste constituents released earlier from the facility may be present downgradient of the current well monitoring system.

The new groundwater monitoring wells will be installed in a phased, or stepped, approach. The first phase will include installation of the well in 2011 at the point of compliance where existing well 699-25-34C went dry in 2003, followed by the two new upgradient wells in 2012 to establish and begin implementing a detection monitoring system in accordance with WAC 173-303-645(9). The far-field downgradient wells will be identified in an installation schedule that would include joint DOE/Ecology decisions.

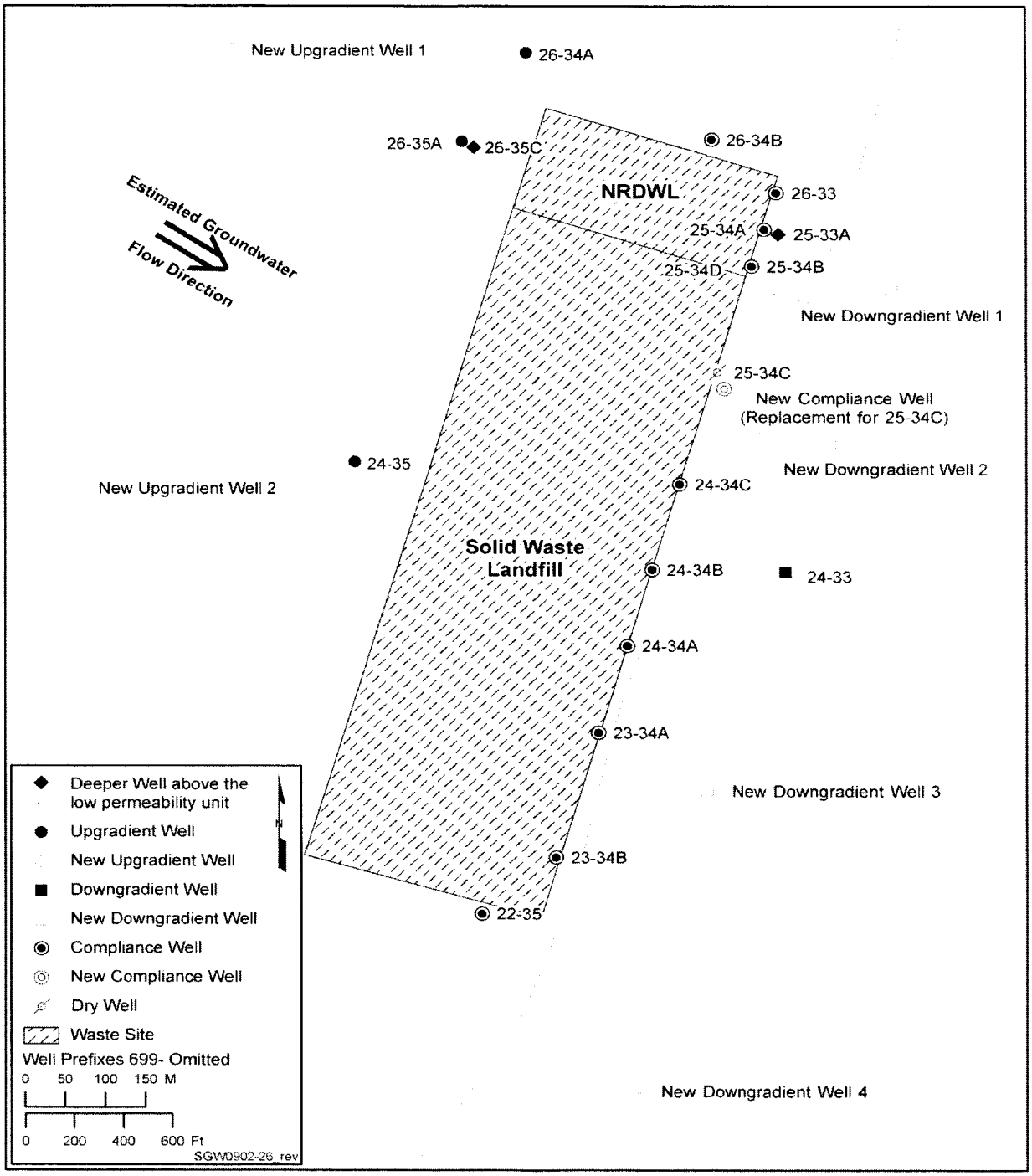


Figure 4-1. NRDWL/SWL WMA Groundwater Monitoring Well Locations and Purposes

The second phase will include installation of far-field downgradient well 3 in 2012 (downgradient of existing well 699-23-34A; Figure 4-1) and will begin sampling and analysis for the indicator parameters. This well is proposed as the first far-field downgradient well because its location is the most likely position to detect far-field contamination (if it exists) from the downgradient extension of known contaminant plumes (Figures 3-17 through 3-19). Once data from two sampling events have been

collected at far-field downgradient well 3, DOE will meet with Ecology to determine whether any of the additional far-field downgradient wells are needed based on the results from the first well. Until the two new upgradient wells are installed (when the first phase is complete), the NRDWL and SWL will continue to be monitored under their current groundwater monitoring plans (PNNL-12227, *Groundwater Monitoring Plan for the Nonradioactive Dangerous Waste Landfill*; and PNNL-13014, *Groundwater Monitoring Plan for the Solid Waste Landfill*, respectively) or similar plans implementing the same regulations.

4.2 Dangerous Constituents and Indicator Parameters

Dangerous constituents to which the groundwater protection standard applies are identified in accordance with WAC 173-303-645(4)(a). Also in accordance with WAC 173-303-645(4)(a) and WAC 173-303-645(9)(a), indicator parameters are then selected to provide a reliable indication of the presence of dangerous constituents in the groundwater.

Groundwater monitoring constituents relevant to monitoring at the NRDWL/SWL WMA are provided in Table 4-1. These constituents are included in Appendix 5 of Ecology Publication 97-407, as provided in WAC 173-303-110(7), "Sampling, Testing Methods and Analytes." These constituents have been, or may have been, disposed at the NRDWL based on the Dangerous Waste Permit Application, Part A (WA7890008967) and DOE/RL-90-17, Appendix B. Additionally, the constituents identified in Table 4-1 are based on SWL lysimeter leachate monitoring and testing results of the non-dangerous catch tank liquid. Table 4-1 also includes the sources of information for the chemical constituents identified therein.

Table 4-1. Groundwater Monitoring Constituents Identified for the NRDWL/SWL WMA and Source of Listing (Secondary Constituents)

Chemical Constituent	Source
1,2-Dichloroethane	1, 2
1,4-Dichlorobenzene	1, 3
1,4-Dioxane	2, 3
2,4-Dinitrophenol	1
Acetone	1, 3
Acetonitrile	1, 2
Acrylonitrile	1
Aniline	1
Arsenic	1, 2, 3
Barium	2, 3
Benzene	1, 2
Benzo(a)pyrene	1
Cadmium	2
Carbon disulfide	1
Carbon tetrachloride	1, 2, 4

Table 4-1. Groundwater Monitoring Constituents Identified for the NRDWL/SWL WMA and Source of Listing (Secondary Constituents)

Chemical Constituent	Source
Chlorobenzene	1
Chloroform	1, 2
Chromium	2
Copper	2
Cresol-m	1
Cresol-o	1
Cresol-p	1
Cresol-mixed isomers (cresylic acid) (sum of o-, m-, and p-cresol)	1
Cyanides (total)	1
Dibromomethane	1
1,1-Dichloroethane	2
Di-n-octyl phthalate	1
Ethyl benzene	1
Isobutyl alcohol	1
Kepone	1
Lead	1, 2
Mercury	1, 2
Methanol	1
Methyl ethyl ketone	1
Methyl isobutyl ketone	1
Methylene chloride	1, 2
Naphthalene	1
Nickel	2, 3
Nitrobenzene	1
p-Dimethylaminoazobenzene	1
Pentachlorophenol	1
Phenanthrene	1
Phenol	1

Table 4-1. Groundwater Monitoring Constituents Identified for the NRDWL/SWL WMA and Source of Listing (Secondary Constituents)

Chemical Constituent	Source
Pyrene	1
Pyridine	1
Selenium	2
Silver	2
PCE	1, 2, 4
Toluene	1
1,1,1-Trichloroethane	1, 2, 4
1,1,2-Trichloroethane	1
TCE	1, 2, 4
Trichlorofluoromethane	1
Xylenes-mixed isomers (sum of o-, m-, and p-xylene)	1
Zinc	2

Notes: The sources cited by number in this table correspond to the following references:

1. WA7890008967, Dangerous Waste Permit Application, Part A.
2. DOE/RL-90-17, *Nonradioactive Dangerous Waste Landfill/Solid Waste Landfill Closure/ Postclosure Plan*, Rev. 2.
3. DOE/RL-2008-54, *Hanford Site Solid Waste Landfill Closure Plan*; SWL lysimeter leachate sample analyses.
4. Chemical analysis of the 1100 Area non-dangerous catch liquid discharged to the SWL.

The groundwater monitoring constituents were evaluated to select dangerous waste indicator parameters that will be monitored in the compliance wells and that are subject to statistical evaluation. The evaluation was based on WAC 173-303-645(9)(a), which provides for identifying the constituents to be monitored after considering the types, quantities, and concentrations of wastes managed in the unit, as well as the mobility, stability, and persistence of waste constituents or their reaction products.

Constituents detected in the SWL lysimeter leachate collection system and the non-dangerous catch tank liquid were also considered in dangerous constituent indicator parameter selection. Dangerous constituents that have been frequently detected in lysimeter leachate above background and/or maximum contaminant levels include arsenic, barium, nickel, 1,4-dichlorobenzene, and acetone.

An optimal set of dangerous constituent indicator parameters is selected based on those that will provide reliable indication of contamination to groundwater and will also limit excessive analysis and statistical evaluation. The dangerous constituents selected as dangerous waste indicator parameters are listed in Table 4-2. Further discussion on monitoring and evaluation of the dangerous waste indicator parameters is provided in Sections 4.6 through 4.10.

Table 4-2. Indicators for Groundwater Contamination at the NRDWL/SWL WMA and Basis for Selection

Constituent	Basis for Selection
Acetone	Quantity, mobility, reported in leachate
TCE	Quantity, mobility, reported in groundwater
PCE	Quantity, mobility, reported in groundwater
Carbon tetrachloride	Quantity, mobility, reported in groundwater
1,1-Dichloroethane	Mobility, reported in groundwater
1,1,1-Trichloroethane	Mobility, reported in groundwater
Barium	Quantity, mobility, reported in leachate
Cadmium	Quantity
Mercury	Quantity
Nickel	Quantity, mobility, reported in leachate
Arsenic	Reported in leachate
TOX	Indicator of halogenated organics

Notes: The basis of selection definitions are as follows:

- "Quantity" pertains to waste volume.
- "Mobility" relates to solubility and transport.
- "Reported in leachate" refers to whether the constituent was detected in the SWL lysimeter leachate.
- "Reported in groundwater" refers to previous detection in groundwater under the NRDWL/SWL WMA.

After installation of the two proposed new upgradient wells, replacement for dry well 699-25-34C, and installation of the first far-field downgradient well (see Section 4.4), groundwater samples will be collected from the new upgradient wells, wells at the point of compliance, and the first new far-field well in the NRDWL/SWL groundwater monitoring system. These samples will be analyzed for the list of constituents in Appendix 5 of Ecology Publication 97-407.

Secondary constituents are those dangerous constituents identified in Table 4-1 that are not selected as dangerous waste indicator parameters, as well as major anions, cations, and alkalinity. These constituents are discussed further in Section 4.6.1 and in Table 4-3.

4.3 Detection Monitoring

After determining upgradient concentrations of the indicator parameters during eight sampling events, downgradient concentrations of indicator parameters at the wells along the facility boundary (point of compliance) will be compared statistically to the upgradient concentrations. If statistically significant evidence exists that concentrations of indicator parameters at downgradient wells exceed concentrations at upgradient wells (see Section 4.10), as required in WAC 173-303-645(9)(f), groundwater protection standards and concentration limits will subsequently be established in accordance with WAC 173-303-645(9)(g)(iv)(D). Section 4.12 of this plan provides the process and schedule for actions, notification, and permit modification, if necessary.

Table 4-3. Groundwater Water Monitoring Wells and Sample Frequency for NRDWL/SWL WMA Monitoring Parameters

Well	Dangerous Constituent Indicator Parameters	Secondary Constituents (Table 4-1)	Appendix 5 Analytes[a]
699-25-33A (deep)	Annually	A	1
699-25-34A	Quarterly	A	1
699-25-34B	Quarterly	A	1
699-26-33	Quarterly	A	1
699-26-34A	Annually	A	1
699-26-34B	Quarterly	A	1
699-26-35C (deep)	Annually	A	1
699-26-35A	Annually	A	1
699-22-35	Quarterly	A	1
699-23-34A	Quarterly	A	1
699-23-34B	Quarterly	A	1
699-24-33	Annually	A	1
699-24-34A	Quarterly	A	1
699-24-34B	Quarterly	A	1
699-24-34C	Quarterly	A	1
699-24-35	Annually	A	1
New downgradient 1	Semiannually[b]	A	1
New downgradient 2	Semiannually[b]	A	1
New downgradient 3	Semiannually[b]	A	1
New downgradient 4	Semiannually[b]	A	1
New upgradient 1	Annually	A	1
New upgradient 2	Quarterly	A	1
Replacement for 699-25-34C	Quarterly	A	1

Notes: Wells in bold are compliance wells; wells in italics are upgradient wells.

a. Appendix 5 of Ecology Publication 97-407, *Chemical Test Methods for Designating Dangerous Waste: WAC 173-303-090 and -100.*

b. Semiannually the first year and annually thereafter.

If a comparison value is exceeded at a statistically significant level, additional measurements shall be collected to verify that a detection event has occurred. If the detection of a dangerous constituent is verified (as discussed in Section 4.10), compliance monitoring will be implemented in accordance with WAC 173-303-645(10).

4.4 Groundwater Monitoring System

The groundwater monitoring system proposed for the NRDWL/SWL WMA will consist of 20 to 23 wells. The wells include 5 upgradient wells, 11 compliance wells, 2 to 5 far-field downgradient wells, and 2 deep wells, which are described below:

- Upgradient wells will be used to determine upgradient concentrations of detected groundwater constituents quarterly. These wells include the following:
  - Proposed upgradient well 1
  - Proposed upgradient well 2
  - Existing wells 699-24-35, 699-26-35A, and 699-26-34A will be only sampled annually and the data used for information purposes only (not for statistical comparisons)

- Compliance (point-of-compliance) wells will be monitored quarterly to determine if releases from the NRDWL/SWL WMA impact groundwater quality. Statistical analysis will be performed for these wells:
  - 699-22-35
  - 699-23-34B
  - 699-23-34A
  - 699-24-34A
  - 699-24-34B
  - 699-24-34C
  - 699-25-34B
  - 699-25-34A
  - 699-26-33
  - 699-26-34B
  - Proposed replacement for dry well 699-25-34C

  Several existing compliance wells may require replacement if the fringe of the barrier extends beyond the wells. These wells will be replaced with wells, as necessary, located just beyond the edge of the barrier. In addition, any compliance well going dry will be replaced. Well 699-25-34D, due to its current location between NRDWL and SWL, is anticipated to constrain closure construction and may be problematic for routine access during post-closure care. The well will be decommissioned and no longer used as part of the monitoring well network.

- Two to five far-field well will be monitored at least annually to evaluate whether contamination exists downgradient at distances up to 200 m (656 ft) from the NRDWL/SWL WMA. These wells will include the following:
  - Existing well 699-24-33
  - Proposed new far-field downgradient well 3
  - Proposed downgradient wells 1, 2, and 4 (if installed)

These one to four new far-field wells will be initially drilled to a depth of up to 35 m (115 ft) below the water table to determine whether the low-permeability unit is present beneath the SWL portion of the NRDWL/SWL WMA, and also to determine whether contamination is present at depths up to 35 m (115 ft) below the water table. Some of these wells may be completed at some depth below the water table if contamination is discovered in samples collected during drilling.

- Existing deep monitoring wells monitor the bottom of the uppermost aquifer under the NRDWL portion of the NRDWL/SWL WMA. These wells include the following:
  - 699-25-33A
  - 699-26-35C

  These wells will be sampled annually, and the data will be used for information purposes only (not for statistical comparisons).

Figure 4-1 shows the locations of the new wells. Two new upgradient wells (proposed upgradient wells 1 and 2) will be installed approximately 720 m (2,361 ft) upgradient of the line of wells along the point of compliance, on the east side of the NRDWL and SWL. The locations of the two proposed wells are planned to be distant enough upgradient of the landfill to avoid groundwater contamination by VOCs from the vadose zone at the landfill. The distance upgradient of these two well locations is based on the small amount of VOCs detected at the existing upgradient well 699-26-34A and its distance from the most concentrated portion of the PCE plume in 1991 (near well 699-24-34B).

A new compliance well will be installed to replace well 699-25-34C, which is dry.

One new far-field downgradient well (proposed downgradient well 3) will be installed approximately 190 m (623 ft) downgradient (east-southeast) of the SWL. This well will be used to detect potential contaminant plumes that may have moved beyond the point of compliance. After the well has been installed and sampled twice, DOE will meet with Ecology to discuss the concentration results, future sampling frequency, and whether the other three far-field wells (new far-field downgradient wells 1, 2, and 4) are needed. Soil samples will be collected from each of the new far-field downgradient wells approximately every 1.5 m (5 ft) (or less, depending on visual observation during drilling). Groundwater samples will be collected during drilling and will be analyzed on a rapid-turnaround basis to evaluate the presence and/or depth distribution of organic contaminants. The wells will be completed so the well screen is in an interval where the highest levels of contaminants are detected (above MDLs). If a well is completed deeper than at the water table, an adjacent well will be installed at the water table. Detailed borehole sampling and analysis plan, characterization and well completion criteria will be provided in a separate plan to be maintained in the Hanford Facility Operating Record. After the wells are installed, this monitoring plan will be modified to include the details on the new wells.

4.5 Point of Compliance

Wells will be monitored in accordance with the requirements provided in this monitoring plan. The point of compliance for the NRDWL/SWL WMA groundwater monitoring plan will be represented by the vertical surface between the 11 downgradient compliance monitoring wells along the northern, eastern, and southern facility boundary, and it extends down into the uppermost aquifer underlying the WMA, based on the requirements of WAC 173-303-645(6)(a).

4.6 Sampling and Analysis

The integrated groundwater monitoring system for the NRDWL/SWL WMA will consist of 20 to 23 wells; 6 wells will be upgradient, and 14 to17 wells will be downgradient (after all 4 of the new wells are installed). The 11 compliance wells will be sampled and analyzed for statistical evaluation. The wells

will be monitored in accordance with the requirements outlined in this section, which includes a description of the sampling and analysis program for the regulated unit (monitoring parameters, analytical methods, monitoring frequency, and sampling protocols).

4.6.1 Monitoring Parameters

Monitoring parameters include the dangerous waste indicator parameters (subject to statistical evaluation), secondary dangerous waste constituents, geochemical evaluation parameters, and field parameters. Water-level measurements are collected from each well every time the well is sampled.

Indicator parameters were derived from evaluating the dangerous constituents and are provided in Table 4-2 and discussed in Section 4.1. Indicator parameters were selected to provide a reliable indication of the presence of dangerous constituents in the groundwater; the indicator parameters were derived from Table 4-1 based on the rationale provided in Table 4-2. The constituents were retained as indicator parameters based on quantity, solubility, mobility, persistence, and/or detectability. These indicator parameters are subject to statistical evaluation (see Section 4.10). Additional dangerous waste constituent results are received from the laboratory as provided by the analytical method, but statistical analysis is not performed on these additional constituents; several of these are considered part of the secondary constituent list.

Geochemical parameters include major cations, anions, and alkalinity. These parameters will be used to evaluate the charge balance of the chemical analyses, as well as to evaluate general groundwater chemistry conditions. Field parameters are collected to determine that the sample collected (as well as is practicable) is representative of groundwater conditions. Both field and geochemical parameters are listed in Table 4-4.

Table 4-4. Preservation Techniques, Analytical Methods Used, and Current Method Quantitation Limits

Constituent	Collection and Preservation[a]	Analysis Methods[b]	Required Detection Limit (µg/L)
Metals Analyzed by Inductively Coupled Plasma Method – Unfiltered/Filtered (secondary constituents)			
Calcium	P, HNO_3 to pH <2	SW-846[c] Method 6010B/C, SW-846 Method 6020[d], or EPA/600 Method 200.8[d]	1,000
Sodium			500
Manganese			5
Potassium			4,000
Iron			50
Magnesium			750
Trace Metals – Unfiltered/Filtered (indicator parameters except chromium, which is a secondary constituent)			
Arsenic	P, HNO_3 to pH <2	SW-846 Method 6020 or EPA/600 Method 200.8	2
Barium			5
Cadmium			2
Chromium (total)			2
Mercury	G, HNO_3 to pH <2	SW-846 Method 7470A, EPA/600 Method 200.8	0.5

Table 4-4. Preservation Techniques, Analytical Methods Used, and Current Method Quantitation Limits

Constituent	Collection and Preservation[a]	Analysis Methods[b]	Required Detection Limit (µg/L)
Nickel	P, HNO_3 to pH <2	SW-846 Method 6020 or EPA/600 Method 200.8	40
Anions by Ion Chromatography (secondary constituents)			
Bromide	P	EPA/600 Method 300.0[c]	250
Chloride			200
Fluoride			500
Nitrate			250
Nitrite			250
Phosphate			500
Sulfate			500
Volatile Organic Analyses (indicator parameters)			
Acetone (by volatile organic analysis)	G, no headspace	SW-846 Method 8260C	20
Carbon tetrachloride			5
1,1,1-Trichloroethane			5
1,1-Dichloroethane			10
TCE			5
PCE			5
Semivolatile Organic Analyses (secondary constituents)			
Phenol	Amber glass	SW-846 Method 8270D	10
Toxaphene			20
1,4-Dioxane			500
2,4-Dinitrophenol			25
2,4,6-Trichlorophenol			10
Other (TOX is an indicator parameter; all others are secondary constituents)			
TOX	G, H_2SO_4 to pH <2, no head space	SW-846[c] Method 9020	10
TOC	G/P, HCL to pH <2	SW-846[c] Method 9060	1,000
Alkalinity	G/P	Standard Method[f] 2320, EPA/600 Method 310.1, EPA/600 Method 310.2	5,000
Conductivity, laboratory	P	Instrument/meter	1 µohm

Table 4-4. Preservation Techniques, Analytical Methods Used, and Current Method Quantitation Limits

Constituent	Collection and Preservation[a]	Analysis Methods[b]	Required Detection Limit (µg/L)
Conductivity, field	Field measurement	Instrument/meter	1 µohm
Dissolved oxygen, field	Field measurement	Instrument/meter	NA
pH, laboratory measurement	P	Instrument/meter	0.1
pH, field measurement	Field measurement	Instrument/meter	0.1
Temperature	Field measurement	Instrument/meter	NA
Total dissolved solids	P	EPA/600 Method 160.1	10,000
Turbidity, field measurement	Field measurement	Instrument/meter	0.1 NTU

a. All samples will be collected in plastic (P), glass (G), or amber glass containers and will be cooled to 4°C upon collection.

b. Constituents grouped together are analyzed by the same method, unless otherwise indicated.

c. SW-846, *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods, Third Edition; Final Update IV-B.*

d. SW-846 Method 6010 is the preferred method; however, EPA Method 6020 or EPA/600 Method 200.8 may be used, as long as the method quantitation limit listed is met.

e. Analytical method adapted from *Method 300.0, Test Methods for Determination of Inorganic Anions in Water by Ion Chromatography* (EPA-600/4-84-017).

f. *Standard Methods for the Examination of Water and Wastewater*, 21st edition (AWWA et al., 2005).

4.6.2 Sampling Frequency

Table 4-3 provides the wells and constituent groups to be analyzed and the frequency of sampling. Samples will be collected quarterly for 2 years from upgradient and compliance wells to establish background conditions for the dangerous constituents identified in Section 4.5.1. After background data are obtained, samples will continue to be collected quarterly from the upgradient and compliance wells, and the data will be evaluated in accordance with the statistical methods presented in Section 4.10.

During the period when the barrier is constructed over the NRDWL and SWL, some wells may not be amenable for sampling. When this occurs, the missed sampling event will be documented in the Hanford Facility Operating Record and will be reported in the annual groundwater monitoring report.

4.6.3 Sampling Procedures

Groundwater sampling procedures, sample collection documentation, sample preservation and shipment, and chain-of-custody requirements are described in this subsection. For SWL lysimeter sampling and soil vapor monitoring, all current data quality objectives, methods, and parameter reporting will be maintained as documented in the respective reporting programs.

Samplers are required to fill out groundwater sample report forms as they purge and sample each well. Field personnel measure water levels in each well before sampling and then purge stagnant water from the well. Field personnel also record the time during which the sampling occurs. Water levels are typically measured with laminated-steel electrical sounding tapes with a precision of 2 mm (0.08 in.). Procedures require sample collection after three casing volumes of water have been purged from the well and after field parameters (pH, temperature, specific conductance, and turbidity) have stabilized. Field parameters are measured in a flow-through chamber. Unfiltered samples are collected for volatile

organic analysis; filtered and unfiltered samples are collected for trace metals analyses. Only the filtered analysis results are used for statistical analysis of trace metals data.

Sample preservation techniques will follow generally accepted practices (e.g., U.S. Environmental Protection Agency [EPA]-approved guidelines such as SW-846, *Test Methods for Evaluating Solid Wastes, Physical/Chemical Methods, Third Edition; Final Update IV-B*, Table 11-1 [or equivalent]) and will be documented on sample authorization forms that are generated for each sampling event. If samples require preservatives, the preservatives are added to collection bottles before use in the field. A chemical preservative label is affixed to the sample container that lists the specific preservative used. The preservative's brand name, lot number, concentration, and date opened are recorded.

4.6.4 Sample Chain-of-Custody

Groundwater samplers use chain-of-custody forms to maintain and document the integrity of groundwater samples from the time of collection through data reporting. The forms are generated during scheduling and are managed through a documented procedure. Required information recorded on the chain-of-custody forms includes the following:

- Sampler's name
- Destination and method of shipment
- Collection date and time
- Sample identification number(s)
- Analysis method(s)
- Preservation method(s)

Samples are labeled and sealed with evidence tape, wrapped with bubble wrap, and placed in a U.S. Department of Transportation-approved container with ice, as appropriate. The packaging parameters for samples are determined by associated hazards. Samples for offsite laboratories are shipped in accordance with U.S. Department of Transportation regulations. A chain-of-custody form accompanies all samples. When samples are transferred from one custodian to another (e.g., from sampler to shipper, or from shipper to analytical laboratory), the receiving custodian inspects the chain-of-custody form and the samples, noting any deficiencies. Each transfer of custody is documented by the printed names and signatures of the custodian relinquishing the samples and the custodian receiving the samples, as well as the time and date of transfer. Commercial shippers do not sign chain-of-custody forms, but the forms are signed by the receiving laboratory, and sample integrity is verified by inspecting the bottle seals.

4.7 Decontamination of Sampling and Drilling Equipment

Monitoring wells for the NRDWL/SWL WMA shall be equipped with dedicated sampling pumps. Sample pumps are placed at approximately mid-depth within the screen interval. Water-level measuring tapes are cleaned with potable or deionized water and a clean towel. Single-use sample manifolds used at the wellhead require decontamination as follows:

1. Wash with a phosphate-free detergent.
2. Rinse three times in high-purity water.
3. Rinse in a 1M solution of nitric acid.
4. Rinse three more times in high-purity water, then rinse in hexane.
5. Dry in the drying chamber.

The decontamination process for sampling and drilling equipment is performed in accordance with established procedures.

The following information is included relative to well drilling equipment when the new wells are installed at the NRDWL/SWL WMA. Well drilling equipment is decontaminated using high-temperature pressure washing. The equipment is then rinsed with clean water.

The equipment used to collect soil samples during drilling for later chemical analysis is decontaminated as follows:

1. Wash with phosphate-free detergent, rinse three times with deionized water.
2. Rinse once with nitric acid (glass or stainless-steel equipment only).
3. Rinse three more times with deionized water, then rinse with hexane.
4. After heat drying, equipment is wrapped in unused aluminum foil and sealed with tape until needed. The tape shall not come into contact with the equipment to avoid any contamination from the materials on the tape.

4.8 Analytical Procedures and Quality Assurance

Instruments for field measurements (e.g., pH, specific conductance, temperature, and turbidity) are calibrated using standard solutions before use, including the following:

- For pH 4, 7, and 10, buffer/standard solutions
- For specific conductance, 445 μS/cm and 1,413 μS/cm solutions
- For turbidity, Gelex®[1] standards 0 to 10, 0 to 100, and 0 to 1,000 nephelometric turbidity units (NTU)

Instruments are operated in accordance with the manufacturer's instructions. Each instrument is assigned a unique number that is tracked via field and verification documentation.

Laboratory analytical methods are specified in Table 4-4 and are reflected in laboratory contracts. The laboratory analytical methods are standard methods from EPA SW-846 (2008, as revised); EPA-600/4-79-020, *Methods for Chemical Analysis of Water and Wastes* (as revised); and *Standard Methods for the Examination of Water and Wastewater,* 20th edition (AWWA et al., 1998). Table 4-4 identifies the analytes, analytical methods, and required maximum practical quantitation limits.

The quality control (QC) program is designed to assess and enhance the reliability and validity of groundwater data, and to document whether the resulting data are of the quantity and quality necessary for the intended decision-making purpose.

In groundwater detection monitoring, the primary decision-making purpose is to determine whether a statistically significant increase in a dangerous constituent concentration is observed in groundwater downgradient from the permitted site. Consequently, data quality is monitored by evaluating the results of QC samples, conducting audits, validating groundwater data, and comparing these results to data quality requirements established in this groundwater monitoring plan (Section 4.9.2). Accuracy, precision, and detection are the primary parameters used to assess data quality. Data for these parameters are obtained from two categories of QC samples: (1) those that provide checks on field and laboratory activities (field QC), and (2) those that monitor laboratory performance (laboratory QC). Table 4-5 summarizes the types of samples in each category and the sample frequencies and characteristics evaluated.

[1] Gelex® is a registered trademark of Hach Company, Loveland, Colorado.

Table 4-5. Quality Control Samples

Sample Type	Primary Characteristics Evaluated	Frequency
Field QC		
Full trip blank	Contamination from containers or transportation	One per 20 well trips
Field transfer blank	Airborne contamination from the sampling site	One each day VOCs samples are collected
Equipment blank	Contamination from non-dedicated sampling equipment	As needed[a]
Duplicate samples	Reproducibility	One per 20 well trips
Laboratory QC		
Method blank	Laboratory contamination	One per batch[c]
Laboratory duplicates	Laboratory reproducibility	[b]
Matrix spike	Matrix effects and laboratory accuracy	[b]
Matrix spike duplicate	Laboratory reproducibility and accuracy	[b]
Surrogates	Recovery/yield	[b]
Laboratory control sample	Method accuracy	One per batch

a. For portable Grundfos® (registered trademark of Grundfos Pumps Corporation, Colorado Springs, Colorado) pumps, equipment blanks are collected one per 10 well trips. Whenever a new type of non-dedicated equipment is used, an equipment blank is collected every time sampling occurs until it can be shown that less-frequent collection of equipment blanks is adequate to monitor the decontamination procedure for the non-dedicated equipment.

b. As defined in the laboratory contract or quality assurance plan and/or analysis procedures.

c. A "batch" is a number (25 to 75) of like analyses that are analyzed as a group for efficiency purposes.

The QC data are evaluated based on acceptance criteria for each QC sample type, as summarized by constituent identified in Table 4-6. These criteria limits are intended to provide confidence that the analytical and field methods are in control and provide reliable data. For field and method blanks, the acceptance limit is two times the instrument detection limit (metals) or MDL (other chemical parameters), except for the common laboratory contaminants acetone, methylene chloride, 2-butanone, and phthalate esters where the limit is five times the MDL. Groundwater samples that are associated (i.e., collected on the same date and analyzed by the same method) with out-of-limit field blanks shall be flagged with a "Q" in the Hanford Environmental Information System (HEIS) database to indicate a potential problem, and then recorded in the Hanford Facility Operating Record.

Field duplicates must agree within 20 percent (as measured by relative percent difference) to be acceptable. Only those field duplicates with at least one result greater than five times the appropriate detection limit shall be evaluated. In the case where one result is a non-detect, the detection limit is used to calculate the relative percent difference. Unacceptable field duplicate results are flagged with a "Q" in the database and recorded in the Hanford Facility Operating Record.

Table 4-6. Field and Laboratory QC Elements and Acceptance Criteria

Method[a]	QC Element	Acceptance Criteria	Corrective Action
General Chemical Parameters			
Alkalinity Chemical oxygen demand Conductivity pH Total dissolved solids TOC TOX	MB[b]	<MDL	Flagged with "C"
	LCS	80-120% recovery[c]	Data reviewed[d]
	DUP	≤20% RPD[c]	Data reviewed[d]
	MS[e]	75-125% recovery[c]	Flagged with "N"
	EB, FTB	<2 times MDL	Flagged with "Q"
	Field duplicate	≤20% RPD[f]	Flagged with "Q"
Ammonia and Anions			
Anions by IC	MB	<MDL	Flagged with "C"
	LCS	80-120% recovery[c]	Data reviewed[d]
	DUP	≤20% RPD[c]	Data reviewed[d]
	MS	75-125% recovery[c]	Flagged with "N"
	EB, FTB	<2 times MDL	Flagged with "Q"
	Field duplicate	≤20% RPD[f]	Flagged with "Q"
Metals			
Arsenic Cadmium Chromium Mercury ICP metals ICP/MS metals	MB	<CRDL	Flagged with "C"
	LCS	80-120% recovery[c]	Data reviewed[d]
	MS	75-125% recovery[c]	Flagged with "N"
	MSD	≤20% RPD[c]	Data reviewed[d]
	EB, FTB	<2 times MDL	Flagged with "Q"
	Field duplicate	≤20% RPD[f]	Flagged with "Q"
VOCs			
Volatiles by GC/MS	MB	<MDL	Flagged with "B"
	LCS	Statistically derived[g]	Data reviewed
	MS	Statistically derived[g]	Flagged with "N"
	MSD	Statistically derived[g]	Data reviewed[d]
	SUR	Statistically derived[g]	Data reviewed[d]
	EB, FTB, FXR	<2 times MDL[h]	Flagged with "Q"
	Field duplicate	≤20% RPD[f]	Flagged with "Q"

Table 4-6. Field and Laboratory QC Elements and Acceptance Criteria

Method[a]	QC Element	Acceptance Criteria	Corrective Action
SVOCs			
Phenols by GC Semivolatiles by GC/MS	MB	<2 times MDL	Flagged with "B"
	LCS	Statistically derived[g]	Data reviewed[d]
	MS	Statistically derived[g]	Flagged with "N"
	MSD	Statistically derived[g]	Data reviewed[d]
	SUR	Statistically derived[g]	Data reviewed[d]
	EB, FTB	<2 times MDL[h]	Flagged with "Q"
	Field duplicate	≤20% RPD[f]	Flagged with "Q"

a. Refer to Table 4-4 for specific analytical methods.

b. Does not apply to pH.

c. Laboratory-determined, statistically derived control limits may also be used. Such limits are reported with the data.

d. 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) or rejected ("R" flag).

e. Applies to TOC and TOX only.

f. Applies only in cases where one or both results are greater than five times the detection limit.

g. Determined by the laboratory based on historical data. Control limits are reported with the data.

h. For common laboratory contaminants such as acetone, methylene chloride, 2-butanone, toluene, and phthalate esters, the acceptance criteria is less than five times the MDL.

Data flags:

B, C = possible laboratory contamination (analyte was detected in the associated method blank)

N = result may be biased (associated matrix spike result was outside the acceptance limits)

Q = problem with associated field QC sample (blank and/or duplicate results were out of limits)

The acceptance criteria for laboratory duplicates, matrix spikes, matrix spike duplicates, surrogates, and laboratory control samples are defined in Table 4-6 and are in accordance with EPA SW-846. The acceptance criteria for the associated parameter data shall be analyzed and recorded in accordance with Section 4.9.2.

Table 4-7 lists the analyses methods for Appendix 5 of Ecology Publication 97-407. This list is also Appendix IX (40 CFR 264, "Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities"). These methods will be required once for each well in the NRDWL/SWL well system. The table provides the method number, collection and preservation requirements, and the required precision and accuracy for each method.

Table 4-7. Appendix 5 Constituent Analyses

Method Name	Method Number	Collection and Preservation	Precision	Accuracy
Semivolatile organic analyses	SW-846 Method 8270	Glass, no headspace	≤20%	±20%
Volatile organic analyses	SW-846 Method 8260	Amber glass	≤20%	±20%
Phenolics	SW-846 Method 8041	Amber glass	≤20%	±20%
Pesticides and PCBs	SW-846 Method 8081	Amber glass	≤20%	±20%
Herbicides	SW-846 Method 8150	Amber glass	≤20%	±20%
Dioxins	SW-846 Method 8280	Amber glass	≤20%	±20%
Metals	SW-846 Method 6010, 6020, or 200.8	Plastic, HNO_3 to pH <2	≤20%	±20%
Cyanide	SW-846 Method 9012 or 335.2	Glass or plastic, NaOH pH >12	≤20%	±20%
Sulfide	SW-846 Method 9030	Plastic, ZnAc+NaOH to pH >9	≤20%	±20%

Notes:

1. The constituents in this table are from 40 CFR 264, Appendix IX, "Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities," "Ground-Water Monitoring List." (Also Appendix 5 of Ecology Publication 97-407, *Chemical Test Methods for Designating Waste: WAC 173-303-090 and -100].*)

2. SW-846, *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods, Third Edition; Final Update IV-B.*

Table 4-8 lists the acceptable accuracy for the double-blind standards for carbon tetrachloride and TCE. These samples are prepared by spiking Hanford Site background well water (wells 699-19-88 and 699-49-100C) with known concentrations of constituents of interest. Spiking concentrations range from the detection limit to the upper limit of concentration determined in groundwater on the Hanford Site. Investigations shall be conducted for double-blind standards that are outside of acceptance limits in accordance with Section 4.9.2. The results from these standards shall be used to determine acceptability of the associated parameter data.

Recommended holding times depend on the analytical method, as specified in EPA SW-846 or EPA-600/4-79-020. The holding times shall be specified in laboratory contracts pursuant to Permit requirements. Data associated with missed holding times are flagged with an "H" in the HEIS database and noted in the Hanford Facility Operating Record. Data exceeding holding times shall be maintained but potentially may not be used in statistical analyses in accordance with Section 4.10.

Additional QC measures include laboratory audits and participation in nationally based performance evaluation studies. Audit results are used to improve performance. Summaries of audit results and performance evaluation studies shall be incorporated into the Hanford Facility Operating Record, as appropriate to substantiate data quality objectives and data acceptance criteria.

Table 4-8. Blind Standard Constituents and Schedule

Constituents	Frequency	Accuracy (%)	Precision (% RSD)[a]
Carbon tetrachloride	Quarterly	±25%	≤25%
Chloroform	Quarterly	±25%	≤25%
TCE	Quarterly	±25%	≤25%
Fluoride	Quarterly	±25%	≤25%
Nitrate	Quarterly	±25%	≤25%
Cyanide	Quarterly	±25%	≤25%
Chromium	Annually	±20%	≤25%
TOC[b]	Quarterly	Varies according to spiking compound	Varies according to spiking compound
TOX[c]	Quarterly	Varies according to spiking compound	Varies according to spiking compound

a. If the results are less than five times the required detection limit, then the criterion is that the difference of the results of the replicates is less than the required detection limit.

b. The spiking compound generally used for TOC is potassium phthalate. Other spiking compounds may also be used.

c. Two sets of spikes for TOX will be used. The spiking compound for one set should be 2,4,5-trichlorophenol. The spiking compound for the second set should include the constituents used for the VOCs sample (carbon tetrachloride, chloroform, and TCE).

4.9 Data Management

This section describes data management practices, including data loading; data review, verification, validation, and usability; and data review corrective actions.

4.9.1 Loading Data

The contract laboratories report analytical results electronically and in hardcopy. The electronic results shall be loaded into the HEIS database as they are received from the laboratories. The appropriate sections of the HEIS shall be incorporated by reference into the Hanford Facility Operating Record. Field data (e.g., specific conductance, pH, temperature, turbidity, and depth to water) are recorded on field records (e.g., groundwater sample report forms). Data management staff enter this information into the HEIS database manually through data entry screens and verify each value against the hardcopy. When an electronic field data collection system is implemented, it will replace the manual field data collection and data entry process.

Data not available electronically may include well logbooks, borehole videos, geologic descriptions, field screening data, or other information.

4.9.2 Data Review, Verification, Validation, and Usability

A final data review shall determine whether data meet the following specific criteria. All work activities shall follow documented procedures and processes for data verification and validation, summarized as follows. Verification involves assessing data accuracy, completeness, consistency, availability, and internal control practices to determine overall reliability of the data collected. Other data quality

objectives that shall be met include the proper chain-of-custody, sample handling, use of proper analytical techniques for each constituent, and the quality and acceptability of the laboratory analyses conducted.

Groundwater monitoring staff perform checks on laboratory electronic data files for formatting, outlier values, data flagging (qualifiers), and completeness. Hardcopy results are verified to check for (1) completeness, (2) notes on condition of samples upon receipt by the laboratory, (3) notes on problems that arose during the analysis of the samples, and (4) correctly reporting results. If data are incomplete or deficient, staff will work with the laboratory to correct the problem discovered.

Validation of groundwater data involves assessing whether the data collected and measured truly reflect aquifer conditions. The data validation process provides the requirements and guidance for validating groundwater data that are routinely collected. Validation is a systematic process of reviewing verified data against a set of criteria (Table 4-6) to determine whether the data are acceptable for their intended use.

The results of laboratory and field QC evaluations, double-blind sample results, laboratory performance evaluation samples, and holding-time criteria are considered when determining data usability. Staff review the data to identify whether observed changes reflect changes in groundwater quality or potential data errors, and they may request data reviews of laboratory, field, or water-level data for usability purposes. The laboratory may be requested to check calculations or re-analyze the sample, or the well may be resampled. Results of the data reviews are used to flag the data appropriately in the HEIS database (e.g., "R" for reject, "Y" for suspect, or "G" for good) and/or to add comments.

Upon final data acceptance, both the raw data and the accepted/validated data shall be incorporated into the Hanford Facility Operating Record.

4.9.3 Data Review Corrective Actions

The responses to data quality defects are identified through the verification/validation process. Table 4-6 identifies the corrective actions.

4.10 Statistical Analysis of Groundwater Monitoring Data

This section summarizes the method of statistical evaluation and the statistical procedures to indicate whether dangerous waste or dangerous waste constituents from the NRDWL/SWL WMA might have entered the groundwater in the uppermost aquifer. To establish baseline conditions, eight samples will be collected during the first 2 years (i.e., quarterly sampling frequency) after the WMA is subject to the conditions of the Permit. After the baseline has been established, sample collection and analysis will continue on a quarterly basis. See Section 4.5.2 for discussion of the circumstances when closure activities could prevent sampling events. More details on specific statistical criteria will be available after the background data set is available and evaluated. Statistical evaluations will be made as soon as practicable after validation of the full data set from each quarterly sampling event.

Table 4-1 lists the dangerous constituents that have been identified for the NRDWL/SWL WMA. Table 4-2 identifies the dangerous constituents and indicator parameters used to indicate the presence of contamination (WAC 173-303-645[9][a]) and that are subject to statistical evaluation for the NRDWL/SWL WMA.

The monitoring program will periodically re-evaluate the statistical tests being used. The methods described will be reviewed during and after baseline data are collected to ensure that the methods are the most appropriate, considering site conditions.

The goal of a RCRA final status detection monitoring program (WAC 173-303-645[9]) is to monitor for indicator parameters that provide a reliable indication of the presence of dangerous constituents identified at a facility in groundwater in the uppermost aquifer beneath the site. This is accomplished by testing for statistically significant changes in concentrations of selected indicator parameters in downgradient wells relative to baseline values.

The statistical method of analysis of variance (ANOVA) is proposed for the detection monitoring program of the NRDWL/SWL WMA. The proposed statistical method is consistent with *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities Unified Guidance* (EPA 530-R-09-007) and WAC 173-303-645.

The ANOVA determines whether there are any statistically significant differences in mean concentrations among a set of wells. Applied to the NRDWL/SWL WMA, an ANOVA will detect differences between compliance wells and upgradient wells, as well as differences between upgradient wells and differences between compliance wells. The primary concern in groundwater monitoring is a change in any compliance well relative to upgradient wells, but the ANOVA will detect changes in any of the wells relative to the other wells, which will inform the analyst of changing upgradient conditions, as well as detecting any changes in downgradient conditions at the point of compliance.

The ANOVA applied at the NRDWL/SWL WMA consists of two analyses steps. The first step involves an F-test to determine any significant difference between the wells. If the F-test determines a significant difference between wells, the second step is performed, which is a series of T-tests to determine which wells are significantly different from others.

The F-test is a ratio of the differences between wells to the differences within wells. If there is a greater difference between wells than within wells, then there is statistically significant evidence of concentration differences between wells. If concentration variability within wells is large relative to differences between wells, then there is not significant evidence of differences between wells. This test will be used to determine whether there are any significant differences between wells, whether upgradient or downgradient. Testing at the NRDWL/SWL WMA will be performed at the 5 percent level, meaning that statistical evidence of differences between upgradient and downgradient conditions will be assumed if there is less than a 5 percent chance of the measured value occurring if upgradient and downgradient conditions are actually the same. This realizes a test-wise, false-positive rate of 5 percent in accordance with EPA 530-R-09-007.

The series of T-tests compares wells pair-wise. In the usual application of an ANOVA for groundwater monitoring, each downgradient well is compared to the mean of the upgradient wells. For the NRDWL/SWL WMA, this will be performed at an individual significance level of 0.01 in accordance with EPA 530-R-09-007. The approach compares all well pairs to determine which wells statistically group together, which provides a more comprehensive analysis. If upgradient wells differ significantly from one another, this analysis will detect that difference and determine which downgradient wells differ significantly from all upgradient wells, as well as which downgradient wells differ from which individual upgradient wells. A more comprehensive view of variability among all the wells of the system is provided compared to a simpler upgradient/downgradient comparison.

If any downgradient wells are found to statistically differ from upgradient wells, those wells will be immediately resampled and re-analyzed for the constituents. If the constituents are confirmed to be elevated, all downgradient wells will be resampled and analyzed for the constituents listed in Table 4-1 (WAC 173-303-645[9][g][ii]). If the elevated levels are not confirmed, detection monitoring will continue.

If it is thought that the data are not normally distributed, a non-parametric ANOVA (Kruskal-Wallis) technique can be applied. The Kruskal-Wallis procedure is an ANOVA applied to the ranks of the data rather than the actual measurements. This does not rely on the assumption that the underlying data are normally distributed.

If all measurements (both upgradient and downgradient) are non-detects, an ANOVA will not be applied since no differences will be found. In that case, evidence of detectable quantities in downgradient wells without corresponding detections in upgradient wells will be considered evidence of potential facility impact to groundwater.

4.11 Reporting and Recordkeeping

Reporting of monitoring results and statistical evaluations for the NRDWL/SWL WMA will be through the annual groundwater monitoring report (e.g., DOE/RL-2008-66).

Pertinent information for groundwater monitoring and electronic files for groundwater data shall be maintained in the Hanford Facility Operating Record. Records may be stored in either electronic or hardcopy format. The Hanford Facility Operating Record will also include groundwater sample reports, chain-of-custody forms, and sample receipt records.

4.12 Evaluation and Notification

Groundwater flow rate and direction in the uppermost aquifer will be evaluated and reported annually. After 2 years of background data collection, groundwater chemistry data collected under this monitoring plan will be analyzed semiannually to determine whether there is statistically significant evidence of contamination (in accordance with WAC 173-303-645[9][f]) using the statistical method provided in Section 4.10. The groundwater chemistry and statistical results will also be reported annually and maintained in the project file (WAC 173-303-645[9][c]).

If statistically significant evidence of contamination is determined for one or more of the dangerous constituents or indicator parameters at any monitoring well at the compliance point, the owner or operator may resample (for verification purposes) within one month and repeat the analysis for the compounds with elevated concentrations. If resampling confirms statistically significant evidence of contamination, the following will be performed in accordance with WAC 173-303-645(9)(g):

- Notify Ecology in writing within 7 days of the finding, indicating which chemical parameters have shown statistically significant evidence of contamination.
- Sample the groundwater in all monitoring wells and determine if the constituents identified in Table 4-1 are present, and if so, at what concentration. For any of these compounds detected, the owner or operator may resample within one month of receiving the results and repeat the analysis for those compounds detected in accordance with WAC 173-303-645(9)(g)(ii). If the constituents are detected in the second analysis, the constituents will form the basis for compliance monitoring.
- If dangerous constituent(s) are detected, submit an application for a Permit modification to Ecology within 90 days to establish a compliance monitoring program in accordance with WAC 173-303-645(9)(g)(iv).
- If dangerous constituents are not detected, continue to monitor in accordance with this detection monitoring program.

- In the case that a source other than the NRDWL/SWL WMA caused the contamination or the detection is an artifact caused by an error in sampling, analysis, or statistical evaluation or natural variation in groundwater (as allowed by WAC 173-303-645[9][g][vi]), the following will apply:
  - Notify Ecology in writing within 7 days of the finding, and indicate the intent to make a demonstration to this effect.
  - Submit a report to Ecology within 90 days. The report should demonstrate that a source other than the regulated unit caused the contamination, or that the contamination resulted from an error in sampling, analysis, statistical evaluation, or is a natural variation in groundwater chemistry.
  - Continue monitoring in accordance with this detection monitoring program.
  - If it is determined, in accordance with WAC 173-303-645(9)(h), that this detection monitoring program no longer satisfies the requirements of WAC 173-303-645(9), an application will be submitted to Ecology for a Permit modification within 90 days to make any appropriate changes to the program.

As part of the Permit, the groundwater monitoring system will be evaluated at a minimum every 5 years to determine if the number and locations of wells, analytical constituents, sampling frequency, and statistical evaluation methods are appropriate, especially for post-closure monitoring. Changes to the monitoring plan will be proposed through the Permit modification process.

5 Compliance Monitoring Program

A compliance monitoring program that satisfies requirements set forth in WAC 173-303-645(10) will be established for the NRDWL/SWL WMA if detection-level monitoring reveals statistically significant evidence of dangerous waste/dangerous waste constituents from sources within the regulated unit. If compliance monitoring is required, DOE will submit a revised monitoring plan to Ecology specifying dangerous constituents to be monitored, sampling and analysis protocols, statistical evaluation methods, and so forth. In the compliance monitoring program, the dangerous constituents or parameters will be compared to concentration limits specified in the facility permit, as specified in WAC 173-303-645(5), during the compliance period.

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6 Corrective Action Program

When a compliance monitoring program is established as specified in Chapter 5, Chapter 6 will be updated to indicate how a compliance monitoring program would transition into a corrective action monitoring program in accordance with WAC 173-303-645(11).

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1

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