PNNL-13283

Second ILAW Site Borehole Characterization Plan

S. P. Reidel

August 2000

Prepared for the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830

PACIFIC NORTHWEST NATIONAL LABORATORY
operated by
BATTELLE
for the
UNITED STATES DEPARTMENT OF ENERGY
under Contract DE-AC06-76RLO 1830

Printed in the United States of America

Available to DOE and DOE contractors from the
Office of Scientific and Technical Information, P.O. Box 62, Oak Ridge, TN 37831;
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Available to the public from the National Technical Information Service,
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(9/97)

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Pacific Northwest National Laboratory
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Summary

The U.S. Department of Energy's Hanford Site has the most diverse and largest amounts of radioactive tank waste in the United States. High-level radioactive waste has been stored at Hanford since 1944. Approximately 209,000 m^3 (54 Mgal) of waste are currently stored in 177 tanks. Vitrification and onsite disposal of low-activity tank waste (LAW) are embodied in the strategy described in the Tri-Party Agreement. The tank waste is to be retrieved, separated into low- and high-level fractions, and then immobilized. The low-activity vitrified waste will be disposed of in the 200 East Area of the Hanford Site.

This report is a plan to drill and characterize the second borehole for the Performance Assessment. The first characterization borehole was drilled in 1998. The plan describes data collection activities for determining physical and chemical properties of the vadose zone and saturated zone on the northeast side of the proposed disposal site. These data will then be used in the 2005 Performance Assessment.

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1.0 Introduction

The U.S. Department of Energy's (DOE) Hanford Site has the most diverse and largest amounts of radioactive tank waste in the United States. High-level radioactive waste (HLW) has been stored in large underground tanks since 1944. Approximately 209,000 m^3 (54 Mgal) of waste are currently stored in 177 tanks (Hanlon 2000). These caustic wastes consist of many different chemicals and radionuclides, including liquids, slurries, salt cakes, and sludges. The wastes are stored in 149 single-shell tanks (SST) and 28 double-shell tanks (DST).

The Office of River Protection (ORP) now focuses on resolving tank safety issues, planning for waste retrieval, developing waste pretreatment and treatment facilities, and evaluating waste storage and disposal needs. Vitrification and onsite disposal of low-activity waste (LAW) are embodied in the strategy described in the Tri-Party Agreement.

Low-activity waste will be disposed of in the Immobilized Low-Activity Waste (ILAW) Site, which will be located in 200 East Area (Figure 1.1). A characterization plan was written for that complex following the Data Quality Objectives (DQO) process (Reidel et al. 1995). The deep borehole portion of that plan was revised to provide a characterization plan, sampling and analysis plan, and quality assurance plan for the first ILAW Site borehole (Reidel and Reynolds 1998). This first ILAW Site borehole (299-E17-21) was drilled in April 1998. The geologic data, geophysical logging, hydrologic tests, and groundwater analyses were reported in Reidel et al. (1998).

Reidel and Horton (1999) issued a geologic data package that integrated the first ILAW Site borehole with the existing geologic information on the ILAW Site. Their interpretation of the site showed that the ILAW Site is on the southwest margin of an ancestral channel of the Columbia River that was later used by floodwaters from the Missoula floods during the Pleistocene Epoch.

A DQO meeting was held in February 2000 to discuss the need for a second ILAW Site borehole. The ILAW Site Performance Assessment team and other interested parties concluded that a second borehole was needed near the northeast corner of the site to further evaluate the hydrologic and physical properties of the sediments found in the channel. This report documents the results of that meeting and the plan to drill the borehole and obtain samples. The data obtained from this borehole will support the current and future ILAW Site performance assessments.

1.1 Scope

This report presents a plan to drill the second characterization borehole and collect data at the ILAW Site. In addition, it updates and revises the deep borehole portion of the characterization plan by Reidel et al. (1995), but it is not intended to revise or modify other parts of the original plan. Any other modifications or changes to the original plan will be addressed elsewhere.

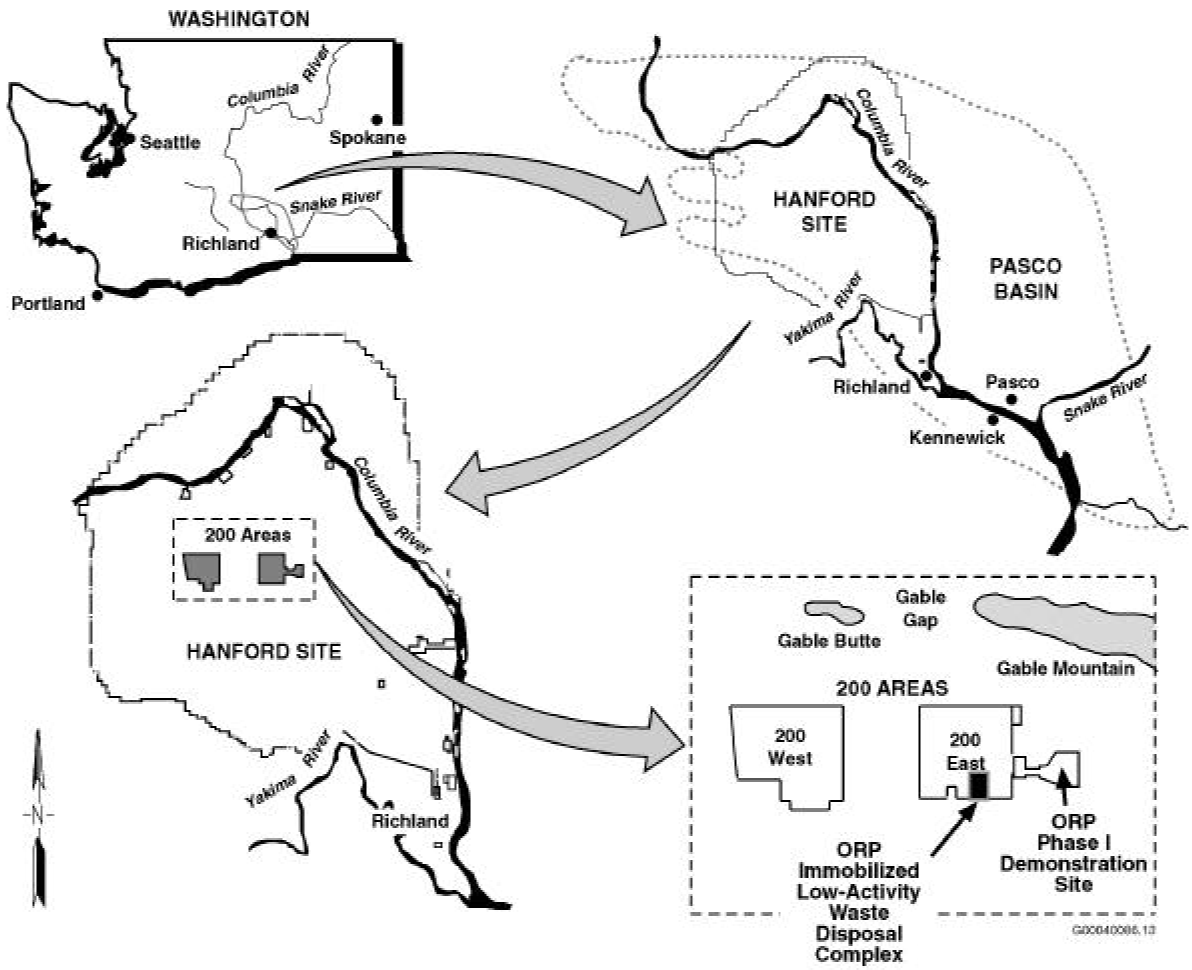


Figure 1.1. Location of the Office of River Protection Privatization Areas and Immobilized Low-Activity Waste Site

1.2 Purpose and Objective

This document provides a plan for data collection to determine the physical and chemical properties of the vadose zone and the saturated zone at and in the immediate vicinity of the proposed ILAW Site in support of the Hanford ILAW Site Performance Assessment (Reidel et al. 1995).

The objective of the vadose and saturated zone characterization is to provide data to develop a conceptual geohydrologic model of the ILAW Site for use in the Hanford ILAW Performance Assessment. This model will include geologic, hydraulic, and hydrochemical parameters as defined by the DQO process (EPA 1993) and developed by Reidel et al. (1995) for this project. The conceptual model will be used in the performance assessment to model the movement of moisture and contaminants through the vadose zone. The characteristics of the saturated zones, as well as results of in situ testing, will be used in groundwater modeling.

2.0 Background Information

2.1 Geology

2.1.1 Hanford Site Stratigraphy

The ILAW Site is in a sequence of sediments (Figure 2.1) that overlie the Columbia River Basalt Group on the north limb of the Cold Creek syncline. These sediments include the upper Miocene to Pliocene Ringold Formation, the Plio-Pleistocene unit, Pleistocene cataclysmic flood gravels and sands and silt of the Hanford formation, and Holocene eolian deposits.

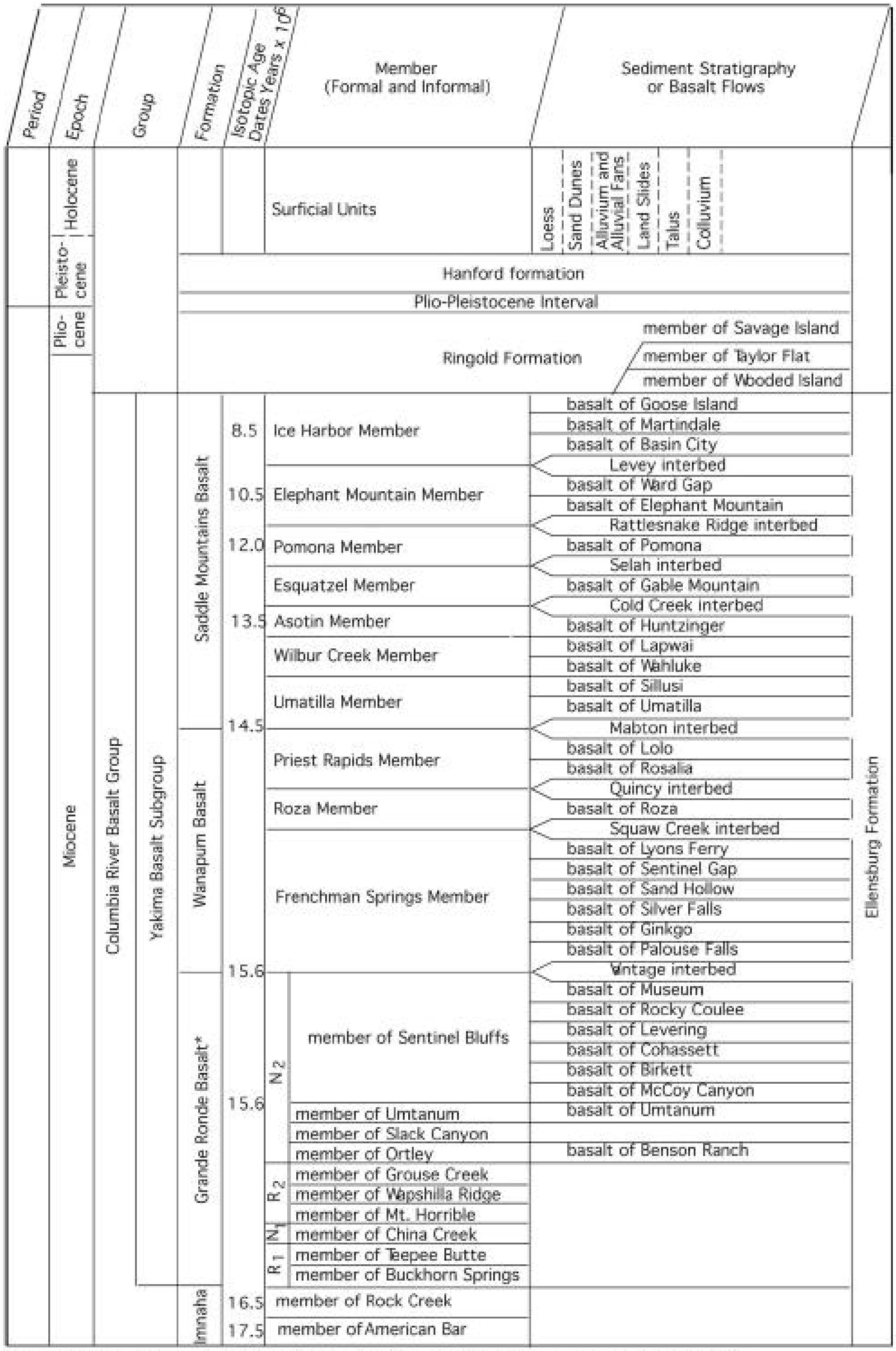
In summary, the geology of the 200 East Area consists of the Elephant Mountain Member of the Saddle Mountains Basalt, Columbia River Basalt Group overlain by the Ringold Formation, and the Hanford formation.

The Ringold Formation consists of fluvial and lacustrine sediments deposited by the ancestral Columbia and Clearwater-Salmon river systems between about 3.4 and 8.5 Ma. Lindsey (1996) described the Ringold Formation in terms of three informal members: 1) the member of Wooded Island, 2) the member of Taylor Flat, and 3) the member of Savage Island. Of these, only the member of Wooded Island is present beneath the 200 East Area.

The member of Wooded Island consists of five separate units dominated by fluvial gravels. The gravels are designated (from bottom to top) as units A, D, B, C, and E. The gravel units are separated by fine-grained deposits typical of overbank and lacustrine environments. The lowermost of the fine-grained sequences is designated the lower mud unit. Only gravel units A and E are present beneath the 200 East Area, and the Ringold Formation is entirely absent beneath the north and northeast parts of the 200 East Area (Lindsey et al. 1992).

The Ringold Formation gravels are clast- and matrix-supported, pebble-to-cobble gravels with a fine to coarse sand matrix (DOE 1988; Lindsey 1996). The most common lithologies are basalt, quartzite, and intermediate to felsic volcanics. Interbedded lenses of silt and sand are common. Cemented zones within the gravels are discontinuous and of variable thickness. In outcrop, the gravels are massive, planer bedded, or cross-bedded. Lying above the Ringold gravels are silts and sands of the upper Ringold.

The Hanford formation overlies the Ringold Formation. The Hanford formation consists of glacio-fluvial sediments deposited by cataclysmic floods from Glacial Lake Missoula, Pluvial Lake Bonneville, and ice-margin lakes (DOE 1988). The Hanford formation sediments resulted from at least four major glacial events and were deposited between about 1 Ma and 13 Ka. The Hanford formation consists of pebble- to boulder-gravel, fine- to coarse-grained sand, and silt- to clayey-silt. These deposits are divided into three facies: 1) gravel-dominated facies, 2) sand-dominated facies, and 3) silt-dominated facies, as



*The Grande Ronde Basalt consists of at least 120 major basalt flows comprising 17 members. N_2, R_2, N_1, and R_1 are magnetostratigraphic units.

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Figure 2.1. Generalized Stratigraphy of the Hanford Site

described below. These same facies are referred to as coarse-grained deposits, plane-laminated sand facies, and rhythmite facies, respectively in Bjornstad et al. (1987). The Hanford formation is present throughout the Hanford Site and is up to 65 m thick (Delaney et al. 1991).

- Gravel-dominated facies - This facies generally consists of coarse-grained basaltic sand and granule-to-boulder gravel. These deposits display an open framework texture, massive bedding, plane to low-angle bedding, and large-scale planar cross bedding in outcrop. The gravel-dominated facies was deposited by high-energy floodwaters in or immediately adjacent to the main cataclysmic flood channel ways.

- Sand-dominated facies - This facies consists of fine- to coarse-grained sand and granule gravel. The sands typically have a high basalt content and are commonly referred to as black, gray, or salt-and-pepper sands. They may contain small pebbles and rip-up clasts, pebble-gravel interbeds, and silty interbeds less than 1 m (3 ft) thick. The silt content of the sands is variable, but where it is low, a well-sorted and open framework texture is common. The sand facies was deposited adjacent to main flood channel ways during the waning stages of flooding. The facies is transitional between the gravel-dominated facies and the silt-dominated facies.

- Silt-dominated facies - This facies consists of thin bedded, plane-laminated, and ripple cross-laminated silt, and fine- to coarse-grained sand. Beds are typically a few centimeters to several tens of centimeters thick and commonly display normally graded-bedding (Myers et al. 1979; Bjornstad et al. 1987; DOE 1988). Local clay-rich beds occur in the silt-dominated facies. Sediments of this facies were deposited under slack water conditions and in back-flooded areas (DOE 1988).

2.2 ILAW Disposal Site Geology

2.2.1 ILAW Site Stratigraphy

The stratigraphy at the ILAW disposal site consists of the Hanford formation and Ringold Formation overlying the Columbia River Basalt Group. Surficial sediments are mainly eolian deposits consisting of reworked Hanford sands and silts.

The stratigraphy and the stratigraphic model developed for this study is summarized in Figure 2.2 and Table 2.1. The location of Figure 2.2 is shown in Figure 2.3 and is based on more detailed cross-sections given in Reidel and Horton (1999).

The stratigraphy of the ILAW disposal site is divided from youngest to oldest into the following units:

- Eolian Deposits
- Hanford formation, sandy unit
  - Layer 3 (extends into upper gravelly unit)
  - Layer 2
  - Layer 1

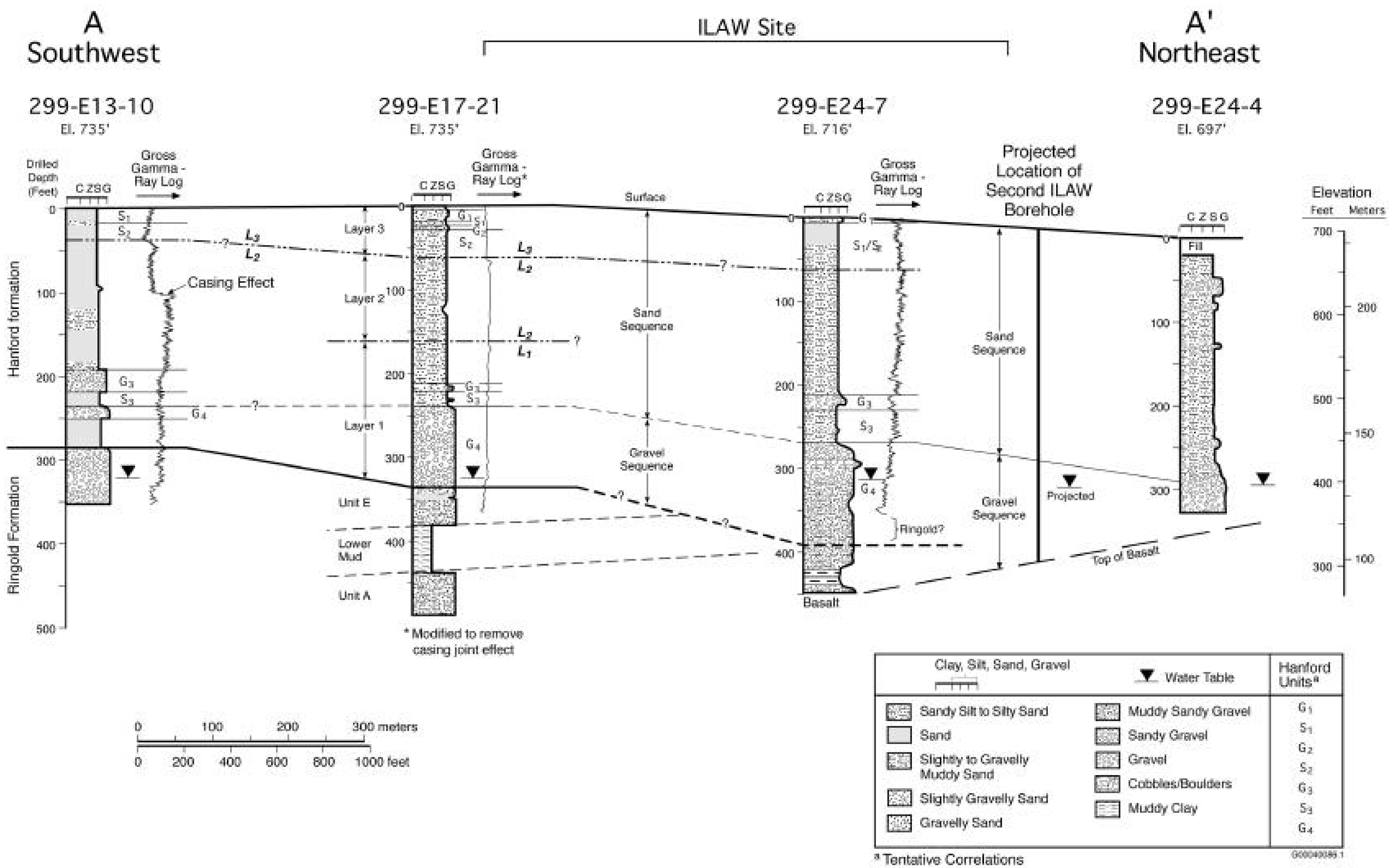

Figure 2.2. Cross Section Through the ILAW Disposal Site and Vicinity. See Figure 2.3 for location of cross section.

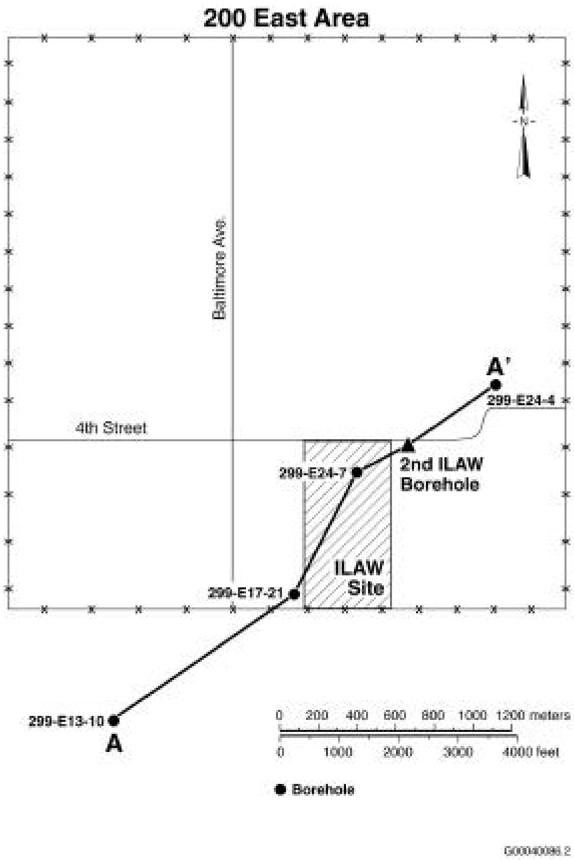

Figure 2.3. Location Map for Figure 2.2 and Second ILAW Site Borehole

- Hanford formation, basal gravel units
- Ringold Formation
  - Upper Ringold
  - Unit E
  - Lower Mud
  - Unit A
- Columbia River Basalt Group.

The sequences of sandy gravels to gravelly sands (G1, G2, G3, G4) and sandy to silty sandy units (S, S1, S2, S3) can be recognized locally in the Hanford formation layers (Table 2.1). These units are not formally defined but are tentatively correlated across the site. Additional work will be necessary to verify these correlations. They are shown in Reidel and Horton (1999) and in Table 2.1.

2.2.2 Columbia River Basalt Group

Previous studies (Reidel and Fecht 1994a) have shown that the youngest lava flows of the Columbia River Basalt Group at the 200 East Area are those of the 10.5 million-year-old Elephant Mountain Member. This member underlies the entire 200 East Area and surrounding area and forms the base of the

Table 2.1. Stratigraphic Information from Boreholes in and Adjacent to the New ILAW Disposal Site[a]

Borehole[b]	Back-fill	Surface Sand (S)	Top of Layer 3 (L3)	Top of Layer 2 (L2)	Top of Layer 1 (L1)	Top of Sandy Gravel 1 (G1)	Surface Elevation [brass cap or casing (C)]	Top of Sand 1 (S1)	Top of Sandy Gravel 2 (G2)	Top of Sand to Silty Gravelly Sand 2 (S2)	Top of Gravel 3 (G3)	Top of Sand to Silty Sand 3 (S3)	Top of Gravel 4 (G4)	Thickness of Hanford Forma-tion	Top of Ringold	Top of Unit E	Silt	Top of Lower Mud	Thickness of Ringold	Top of Unit A	Basalt	Water Table Eleva-tion	Date of Water Level Measurement
E13-10	N	733	ND	ND	ND	NP	733(C)	733	713	705	537	514	494	239	449	494	NP	NP	ND	NP	NP	399.74	Mar-99
E17-12	N	719	669	647	564	704	719 (C)	694	NP	694	497	479	NP	290	429	429	NP	NP	ND	NP	NP	399.17	Mar-99
E17-13	31	NP	ND	647	ND	ND	719 (C)	689	NP	689	494	469	NP	265	424	424	NP	NP	ND	NP	NP	399.56	Mar-98
E17-17	N	716	ND	651	ND	716	717	702	NP	702	NP	546	492	299	417	492	442	NP	ND	NP	NP	399.8	Oct-98
E17-18	N	717	ND	648	ND	713	718	693	626	616	NP	546	483	291	426	483	434	NP	ND	NP	NP	399.27	Mar-99
E17-20	N	716	ND	646	ND	706	717	696	676	671	566	556	NP	ND	NP	491	436	NP	ND	NP	NP	400.55	Apr-97
E17-21	N	735	730	677	567	730	735	720	715	705	523	505	447	238	497	400	NP	357	ND	296	NP	403	Apr-98
E18-1	N	NA	ND	ND	ND	720	716	700	675	660	545	535	NP	215	505	505	NP	NP	ND	NP	NP	399.44	Mar-99
E18-3	N	718	ND	656	ND	715	718	703	ND	656	546	542	NP	235	483	483	NP	NP	ND	NP	NP	401.1	Jun-96
E18-4	N	718	ND	ND	ND	715	718	699	668	658	ND	568	NP	232	486	486	NP	NP	ND	NP	NP	401.17	Jun-96
E19-1	N	736	ND	ND	ND	735	736 (C)	716	686	672	520	506	NP	250	486	486	NP	346	285	306	201	ND	ND
E23-1	N	0 to 5	ND	665	ND	704	710 (C)	NP	689	665	489	477	454	ND	NP	454	417	NP	ND	NP	NP	399.63	Mar-99
E23-2	0	720	ND	628	ND	NP	721 (C)	720	NP	605	520	500	484	290	430	430	ND	NP	166	ND	264	401.59	Dec-94
E24-4	20	696	ND	646	ND	NP	697 (C)	696	NP	ND	ND	ND	431	270	426	466	ND	NP	ND	NP	NP	399.53	Aug-98
E24-7	N	0	ND	652	ND	716	716 (C)	708	NP	708	500	486	448	380	336	336	296	ND	70	ND	266	400.52	Jun-97
E24-16	N	715	ND	656	ND	714	715	706	626	616	526	496	NP	ND	NP	460	426	NP	ND	NP	NP	399.41	Mar-99
E24-17	N	716	ND	659	ND	711	716	706	NP	706	536	524	491	295	421	421	NP	NP	ND	NP	NP	399.59	Apr-97
E24-18	N	716	ND	664	ND	715	716	699	NP	699	506	481	456	325	391	391	NP	NP	ND	NP	NP	399.3	Mar-99
E37-47A	N	716	ND	ND	ND	NP	715	716	NP	716	526	NP	474	284	432	412	NP	350	231	304	201	405	Oct-96

N = Not present. Letter number designations in table headings refer to cross section units (Figures 4.14, 4.15, 4.16, and 4.17).
NA =
ND = Not determined.
NP = Not penetrated.
(a) Values for tops of all units are elevations in feet above mean sea level. Thickness values are given in feet.
(b) All borehole numbers prefixed with 299-.

unconfined aquifer. No erosional windows are known or suspected to occur in the ILAW disposal site area. Figure 2.2 shows the elevation of the top of the Columbia River Basalt Group under the 200 East Area and vicinity.

2.2.3 Ringold Formation

Because few boreholes penetrate much of the Ringold Formation at the ILAW disposal site, data are limited. The Ringold Formation reaches a maximum thickness of 95 m (285 ft) on the west side of the ILAW disposal site and thins eastward. It consists of three units of the Lindsey (1996) Member of Wooded Island and the Member of Taylor Flats. The deepest unit encountered is the lower gravel, Unit A. Lying above Unit A is the Lower Mud and overlying the Lower Mud is an upper gravel, Unit E. The upper Ringold (sand and silt of the Member of Taylor Flat) is not present at the ILAW disposal site but is present east of the site. Unit A and Unit E are equivalent to mapping unit PLMcg, Pliocene-Miocene continental conglomerates of Reidel and Fecht (1994a,b). The Lower Mud is equivalent the mapping unit PLMc, Pliocene-Miocene continental sand, silt, and clay beds of Reidel and Fecht (1994a,b).

2.2.3.1 Unit A

Only three boreholes penetrated Unit A in the study area (Table 2.1). Unit A is 19 m (61 ft) thick on the west side of the ILAW Site but thins and pinches out to the northeast. Unit A is sandy gravel consisting of both felsic and basaltic rocks. There are occasional yellow to white interbedded sand and silt with silt and clay lenses. Green-colored, reduced-iron stain is present on some grains and pebbles. Although the entire unit appears to be partially cemented, the zone produced abundant water in borehole 299-E17-21.

2.2.3.2 Lower Mud

Nineteen meters (61 ft) of the Lower Mud was encountered at the ILAW Site. The upper most part (about 1 m [4 ft]) consists of a yellow sandy to silty mud. The silty mud grades downward into about 10 m (34 ft) of blue mud with zones of silt to slightly silty mud. The blue mud, in turn, grades down into 7 m (23 ft) of brown silty mud with organic rich zones and occasional wood fragments. The Lower Mud is absent in the center and northern parts of the ILAW Site (Reidel and Horton 1999).

2.2.3.3 Unit E

Unit E is as much as 15 m (50 ft) of sandy gravel to gravelly sand with scattered large pebbles and cobbles up to 25 cm (10 in.) in size. The gravel consists of both felsic and basaltic clasts that are well rounded with a sand matrix supporting the cobbles and pebbles. Cementation of this unit ranges between slight and moderate. The upper contact of Unit E is not easily identified at the new ILAW Site. In the western part of the study area, unconsolidated gravels of the Hanford formation directly overly the Ringold Unit E gravels, making exact placement of the contact difficult. The dominance of basalt in the Hanford formation and the absence of any cementation are the key criteria used for distinguishing them here (Reidel et al. 1998). In the central and northeast part of the study area, Unit E is interpreted to have been completely eroded (Reidel and Horton 1999). Unconsolidated gravels and sands typical of the Hanford formation replace them.

2.2.4 Upper Ringold

The upper Ringold is not present at the ILAW disposal site but has been identified in the southeast corner of 200 East Area in borehole 299-E37-47A (Lindberg et al. 1997). These sediments apparently pinchout before reaching the ILAW disposal site.

2.2.5 Unconformity at Top of Ringold Formation

The surface of the Ringold Formation is irregular in the ILAW disposal site area (Reidel and Horton 1999). A northwest-southeast trending erosional channel or trough is centered along the northeast portion of the site (Figure 2.2). The deepest portion near borehole 299-E24-7 in the northern portion of the ILAW disposal site. This trough is interpreted to be a smaller part of a much larger trough under the 200 East Area resulting from scouring by the Missoula floods or post-Ringold fluvial incision prior to the Missoula floods.

2.2.6 Hanford Formation

The Hanford formation is as much as 116 m (380 ft) thick in and around the ILAW disposal site (Figure 2.2). It thickens in the erosional channel cut into the Ringold Formation and thins to the southwest along the margin of the trough. It may thin to the northeast of the trough, but this is based on only one data point.

The Hanford formation consists of poorly sorted pebble-to-boulder gravel and fine- to coarse-grained sand, with lesser amounts of interstitial and interbedded silt and clay. In previous studies of the ILAW disposal site (Reidel and Reynolds 1997), the Hanford formation was described as consisting of three units: an upper and lower gravelly facies and a sandy facies between the two gravelly units. The upper gravelly facies appears to be thin or absent in the ILAW Site disposal area. The silt-dominated, slack-water facies (Touchet Beds) is not present. In Table 2.1, the elevations are given for the tops of several of the more distinct and tentatively correlated units of the Hanford formation.

2.2.6.1 Basal Gravel Sequence

The lowermost 27 m (88 ft) of the Hanford formation encountered in borehole 299-E17-21 consists of the gravel-dominated facies. Drill core and cuttings from this borehole indicate that the unit is clast-supported pebble-to-cobble gravel with minor amounts of sand in the matrix. The cobbles and pebbles are almost exclusively basalt with no cementation. In outcroppings, these deposits display massive bedding, plane to low-angle bedding, and large-scale planar forset cross-bedding, but such features typically cannot be observed in borehole core. This unit either pinches out west of the ILAW disposal site or becomes more sand rich. It thickens to the northeast. The gravel is interpreted to be Missoula flood gravels deposited in the erosional channel carved into the underlying Ringold Formation.

This basal gravel sequence is equivalent to mapping unit Qfg1, Missoula Outburst flood gravel deposits of Reidel and Fecht (1994a,b). Those units are 720 Ka and have a reversed magnetic polarity. Further analysis will be required to determine whether this is the correct mapping unit.

2.2.6.2 Sandy Sequence

The upper portion of the Hanford formation consists of at least 73 m (240 ft) of fine- to coarse-grained sand with minor amounts of silt and clay and some gravelly sands. This sequence is equivalent to the following mapping units of Reidel and Fecht (1994a,b): Qfs1, Qfs2, and Qfs3, Missoula Outburst Flood Deposits consisting of sand, silt, and clay.

Three paleosols (soils) were identified in core and drill cuttings from borehole 299-E17-21 (Reidel et al. 1998). Paleosol Horizon 1 occurs at 50 m (163 ft) drilled depth (Figure 2.2), paleosol Horizon 2 at 18 m (58 ft) drilled depth, and paleosol Horizon 3 at 1.5 m (5 ft) drilled depth. These three horizons represent time intervals when soil development took place and are interpreted to separate and distinguish three periods of Missoula flood deposition. Reidel et al. (1998) called the layers defined by the paleosols: Layer 1 as that part of the Hanford formation extending from the paleosol horizon at 50 m (163 ft) to the top of the basalt gravel at 75 m (247 ft). Layer 2 extends from the top of the second paleosol horizon 18 m (58 ft) to the top of the first paleosol at 50 m (163 ft). Layer 3 extends from the top of the third paleosol horizon at 1.5 m (5 ft) depth to the second paleosol horizon at 18 m (58 ft) drilled depth.

Layer 1. Layer 1 is 26 m (84 ft) thick in borehole 299-E17-21. A zone of sand and silt cemented by $CaCO_3$ forms a poorly developed caliche layer in the paleosol. Only the upper several inches are cemented, but $CaCO_3$ extend to a depth of about 3 m (10 ft) below the top. $CaCO_3$ fragments or as grain coatings were found to a depth of at least 66 m (218 ft).

The lower 6 m (20 ft) of Layer 1 consists of interbedded sands and gravels. The basal gravel sequence underlying Layer 1 appears to grade upward into a sequence of interbedded sands and gravels. At least three upward fining zones of gravels to sands were recognized in Layer 1.

Planar-laminar sands with minor silt lenses dominate the upper 16 m (54 ft) of Layer 1. This sequence consists of fining upward sands, well-compacted, slightly $CaCO_3$-cemented sands, and well-laminated sands. As noted above, $CaCO_3$ associated with development of the paleosol extends well down into this layer.

Layer 1 is equivalent to mapping unit Qfs1 of Reidel and Fecht (1994a,b). Mapping unit Qfs1 is a Missoula Outburst Flood Deposits consisting of sand, silt, and clay that is 720 Ka and has a reversed magnetic polarity (Baker et al. 1991). Layer 1 has only been identified in borehole 299-E17-21. Either data from surrounding boreholes is of too poor of quality to identify this layer, or the layer might only be local.

Layer 2. The upper 27 m (90 ft) of Layer 2 is principally fine- to medium-grained sand with minor amounts of interstitial silt. Throughout the sands are disseminated flakes of $CaCO_3$ and $CaCO_3$-cemented sand grains. Several fining upward zones were recognized as well as well-compacted zones of sand and silt with faint laminations. Layer 2 was correlated to other boreholes based on an examination of geologists' logs and archived chip samples. In addition, the paleosol that forms the top of this layer appears to responsible for zones of lateral spreading of contaminants under waste disposal sites immediately east of the ILAW disposal site.

Layer 2 may be equivalent to mapping unit Qfs2 of Reidel and Fecht (1994a,b). The mapping unit is a Missoula Outburst Flood Deposits consisting of sand, silt and clay that is older than 13 Ka and younger than 720 Ka. Mapping unit Qfs2 has a normal magnetic polarity.

Layer 3. Layer 3 is 16 m (53 ft) thick in borehole 299-E17-21. The paleosol is a 3-m (1.1-ft) thick, oxidized and leached zone of fine-grained sand and silt with some pebbles with a 10-cm (4-in.) caliche zone (sand and silt cemented by $CaCO_3$). Several distinct gravelly sands are present within a meter of the paleosol at the top of this layer. This forms the surface of much of the ILAW disposal site north of the eolian deposits.

The lower 8 to 10 m (25 to 30 ft) of Layer 3 consists principally of sand with interstitial silt and minor silt lenses. Several minor silt lenses are locally present but are discontinuous. Gravelly sand marks a transition to finer-grained sand with more silt at a drilled depth of approximately 8 m (25 ft).

Layer 3 is interpreted to consist of the upper gravelly sequence and the upper part of the sandy sequence defined in previous studies. It is part of mapping unit Qfs3 of Reidel and Fecht (1994a,b), Outburst Flood Deposits, consisting of sand, silt, and clay that is about 13 Ka. An ash from the 13 Ka eruption of Mt. St. Helens (Set S Ash) is typically found near the top of this unit in many places throughout the Pasco Basin. The ash was not recognized in any of the boreholes near the ILAW disposal site.

2.2.7 Eolian Unit

Eolian deposits cover the southern part of the ILAW disposal site. Borehole 299-E17-21 was sited on a stabilized sand dune. The eolian unit is composed of fine- to coarse-grained sands with abundant silt, as layers and as material mixed with the sand. Calcium-carbonate coating found on the bottom of pebbles and cobbles in drill core through this unit is typical of Holocene caliche development in the Columbia Basin. This unit is equivalent to mapping unit Qd, Holocene Dune Sand, of Reidel and Fecht (1994a,b).

2.3 Hydrology

Hanford Site hydrogeology is discussed in many studies (DOE 1988, Vol. 2, Chapter 3; Gephart et al. 1979; Graham et al. 1981; Graham et al. 1984; and Delaney et al. 1991) and has been summarized for the ILAW Site in Reidel et al. (1995). The following sections summarize that information relevant to the ILAW Site.

The hydrogeology of the Pasco Basin and Hanford Site is a multiaquifer system that consists of four hydrogeologic units corresponding to the upper three formations of the Columbia River Basalt Group and the sediments overlying the basalts. Confined zones in the basalt aquifers are present in the sedimentary interbeds and/or interflow zones that occur between dense basalt flows. The main water-bearing portions of the interflow zones are networks of interconnecting vesicles and fractures of the flow tops and flow bottoms (DOE 1988). The aquifer above the basalt is a regionally unconfined and locally semi-confined aquifer and is contained largely within the sediments of the Ringold Formation and Hanford formation.

2.3.1 Hydrology of the ILAW Site

The uppermost aquifer in the vicinity of the ILAW Site is dominated by the fluvial gravels of the Ringold Formation and flood deposits of the Hanford formation. The saturated thickness of these units ranges from 230 ft (70 m) at the southwest end of the site to 30 m (100 ft) under the northeast site. The Elephant Mountain Member of the Columbia River Basalt Group forms the base of the unconfined aquifer at the ILAW Site.

The unsaturated zone beneath the land surface at the ILAW Site is approximately 100 m (300 ft) thick and consists of the Hanford formation. Borehole 299-E24-7 in the northeast part of the ILAW Site (Figure 2.3) indicates that the water table is at an elevation of approximately 120 m (400 ft) in the lower gravel sequence of the Hanford formation. This lies within the Columbia River/Missoula flood channel. The water table is relatively flat across the ILAW Site.

2.4 Groundwater Quality

2.4.1 Contaminant Plumes at the ILAW Site

Plume maps for the major groundwater contaminants in the 200 West and 200 East Areas and the ILAW Site were discussed by Reidel et al. (1995). The most recent update of this information is by Hartman et al. (2000) in the 1999 annual groundwater monitoring report (PNNL-13116). In summary, the only contaminants beneath the ILAW Site are tritium, iodine-129, and nitrate, and they are confined to the northern part of the ILAW Site (Figure 2.4).

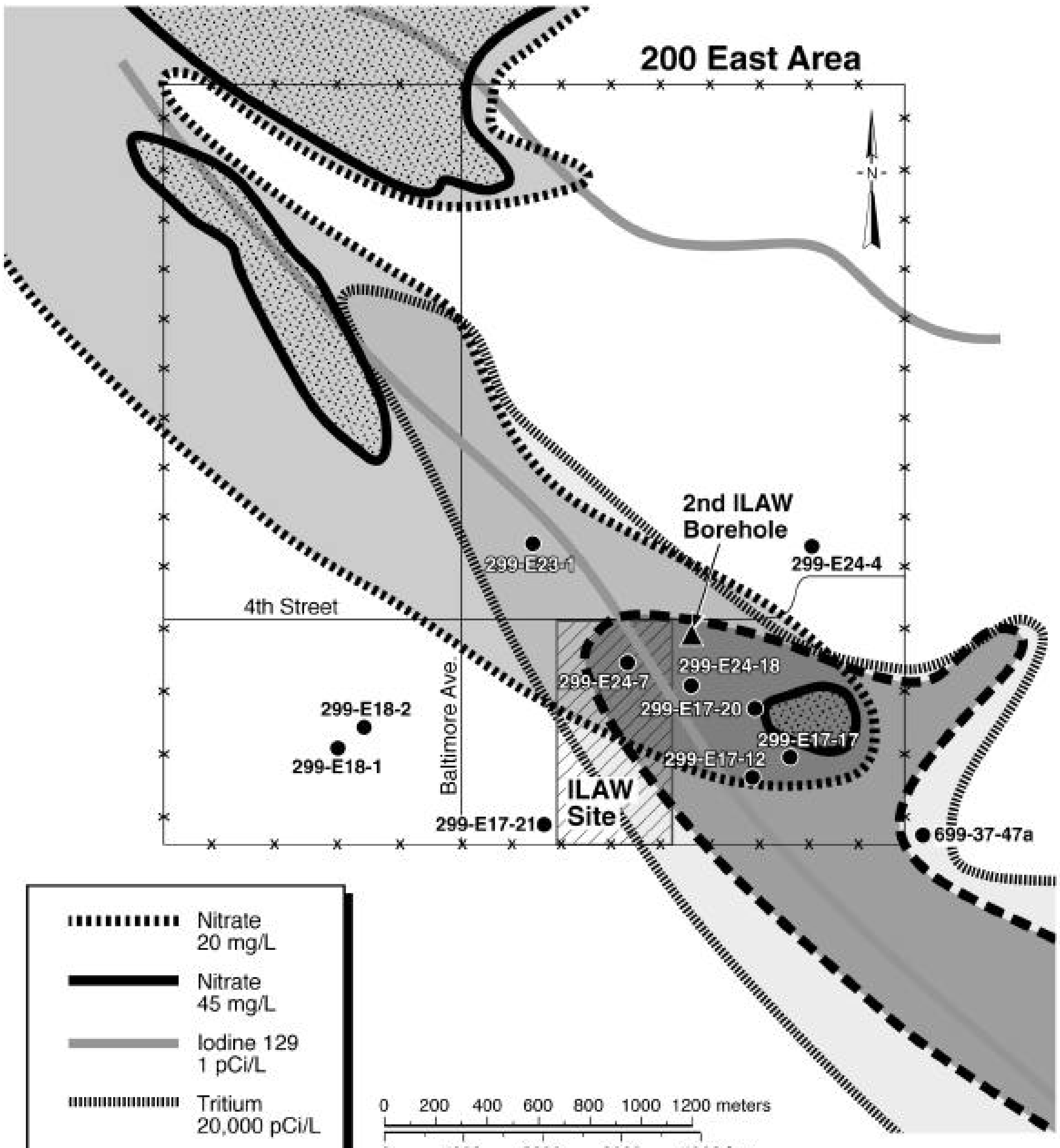

Figure 2.4. Contaminant Plume Map for the 200 East Area

3.0 Data Quality Objectives Process

In 1995, a DQO meeting was held to define the characterization requirements for the ILAW Site. This DQO meeting established the activities and data needs that the ILAW Site Performance Assessment team determined were necessary to complete a performance assessment of the ILAW disposal site. A characterization plan was written (Reidel et al. 1995) to describe the tasks needed to supply the necessary information for the performance assessment and to meet environmental monitoring requirements as specified by the then-applicable DOE Order (DOE 5820. 2A) and other applicable requirements (NRC 10 CFR 61). The characterization plan also included appendixes covering sampling and analysis plans and quality assurance.

In 1998, a portion of the plan was revised and updated in preparation for drilling the first ILAW Site performance assessment characterization borehole (Reidel and Reynolds 1998). The first borehole (299-E17-21) was subsequently drilled in spring 1998 on the southwest corner of the site. The borehole drilling and geologic studies were documented by Reidel et al. (1998) and integrated into the ILAW Site geologic database (Reidel and Horton 1999).

On February 28, 2000, a DQO meeting was held to discuss the need for a second characterization borehole for the ILAW Site performance assessment. Three questions were addressed:

- Is there a need for a second borehole?
- If there is a need, where should it be located?
- What are the data needs to be obtained from samples taken from the borehole?

The following section is divided into two parts. The first part is the original DQO discussion from Reidel et al. (1995). It is included for completeness and to provide the background for ILAW Site performance assessment data collection. The second part is a summary of the February 2000 DQO meeting, which provides the justification for the second ILAW Site borehole.

3.1 1995 Data Quality Objectives Process

3.1.1 Description of Data Quality Objectives Process and Limitations

Data Quality Objectives ensure that the type, quantity, and quality of environmental data used in the decision-making process are appropriate for their intended applications. The process for developing DQOs involves seven general or primary steps:

- Statement of problem (Section 3.1.3)
- Decision and expected action (Section 3.1.4)
- Decision inputs (Section 3.1.5)
- Study boundaries (Section 3.1.6)
- Decision rule (Section 3.1.7)

- Limits on decision errors (Section 3.1.8)
- Optimize sampling design (Section 3.1.9).

The DQO process has both a quantitative and a qualitative aspect. The quantitative aspect seeks to use statistics to design the most efficient field investigation that controls the possibility of making an incorrect decision. The qualitative aspect seeks to encourage good planning for field investigations and complements the statistical design. The DQO process is flexible and iterative.

The site characterization plan will specify the type, quantity, and quality of subsurface data needed to support decisions related to the suitability of the site for long-term disposal of LAW. A more preliminary and qualitative application of the DQO process has been chosen as the most appropriate and cost-effective approach to meet the project needs. As more details and decisions about the site develop (e.g., the site characterization criteria are met), a more thorough and quantitative application of the DQO process (i.e., a statistically based sampling design) can be developed. A phased DQO approach, where knowledge gained in the early phase assists the determination of future data needs and quality desired, is preferred over other types of site characterization efforts (e.g., simultaneous acquisition of data). However, the latter approach may have to be adopted to accommodate changes in the available resources due to the possibility of accelerated funding levels early in the project life cycle.

3.1.2 Data Requirements and Regulatory Drivers

There are two primary regulatory or (related) drivers for the types of site characterization data addressed in this plan:

- characterization guidelines for compliance with 10 CFR 61 (commercial LAW sites)
- site-specific characterization needs for the performance assessment (DOE Order 5820.2A).

Although the ILAW Site is not a commercial site, the guidance documents (e.g., DOE 1990a) for complying with 10 CFR 61 provide a logical and prudent set of guidelines. Much of the information suggested in the subject documents has already been acquired for the Hanford Site. This information has been published in numerous sources, the most recent and complete being DOE (1988). Site-specific data are the principal data required by 10 CFR 61.

The following principal factors govern the proposed sampling strategy: 1) provide the site data needs for the performance assessment modeling[1], 2) acquire information on the nature and presence of man-made objects and materials on or near the surface, and 3) conduct site characterization activities in a cost-effective manner through careful planning and integration of sampling efforts where possible. For example, the data needs specified in 2) are not related to the performance assessment issues but are included in this plan to avoid duplication of efforts.

The following sections discuss each of the steps used in the DQO process for this plan.

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[1] The data needs for a performance assessment are a subset of the data needs specified in 10 CFR 61.

3.1.3 Statement of Problem

To develop the DQOs that adequately address subsurface characterization data needs at the ILAW Site, the overall performance objective or goal must be identified. One objective of a performance assessment for the ILAW Site is to demonstrate that potential radiological impacts for each of the human exposure pathways will not exceed applicable standards. This involves determining potential pathways and specific receptor locations for human exposure to radionuclides, developing appropriate scenarios, selecting computer codes, and documentation.

Piepho et al. (1995) provided a preliminary assessment of the near-field and far-field transport parameters for a Low-Level Waste (now LAW) performance assessment. The near field includes the waste package and vault and the far field in beyond. Their scoping study used as a performance measure the maximum or peak drinking water dose during the first 10,000 years after disposal realized by an individual drinking water from a well located 328 ft (100 m) downgradient from the waste source. This is the scenario chosen by Kincaid et al. (1993) and Piepho (1994) for the grout performance assessment.

This scenario addresses the ability of the site and/or the waste package to contain or control the contaminant release rate. Commercial LLW sites are required to ensure that a hypothetical member of the public is not exposed to a total dose from all sources of more than 25 mrem/yr (or 4 mrem/yr for the drinking water pathway) at any time during the 10,000-year postclosure period (NRC 1988). Kincaid et al. (1993), Piepho (1994), and Piepho et al. (1995) use a drinking water well 328 ft (100 m) downgradient from the site to assess the maximum or peak doses during the first 10,000 years.

3.1.3.1 Conceptual Model Considerations

The first step in the DQO process is the development of a conceptual model of the processes to ensure that the type, quantity, and quality of subsurface characterization data to be collected are appropriate for the intended use. For this plan, the conceptual model and processes as discussed by Piepho et al. (1995) have been adopted and are described in the following paragraphs. Other waste forms and disposal options are being considered. Should another option be chosen, the conceptual model will be revised and necessary changes made in a revision to this plan.

The conceptual model chosen for the Piepho et al. (1995) analysis was similar to that used in the Grout performance assessment (Kincaid et al. 1993; Piepho 1994). Differences between models include the following:

- A concrete vault is already highly cracked (1-mm crack for every 1 m of concrete)
- Glass cullet, which has a total release time of 25,000 years with the highest rate at early times, is placed in a sandy-soil matrix (backfill soil)
- No clay cap exists above the gravel wedge.

This analysis used only one glass release rate (10^{-5} cm/yr or $7.1X^{-4}$ g/day-m^2 with a glass cullet diameter of 0.5 cm). The chemistry in the near field focused on the contaminant species, not on glass corrosion, by simply using distribution coefficients (K_ds). Even though this conceptual model, especially the size of the vault, will not be the one chosen for the LLW-Glass Interim performance assessment, it still represents a degraded long-term waste disposal facility. The transport parameters determined in the ILAW Site-Glass Interim performance assessment will be ranked in order of importance; the rankings will probably be very similar to the importance ranking determined later. Two recharge scenarios were analyzed: a low recharge value of 0.1 cm/yr and a high recharge value of 5 cm/yr. Parameters were ranked for each scenario. Section 3.1.5.1 describes the importance of each of the transport parameters included in Piepho et al. (1995).

3.1.3.2 Resource Constraints

At this time, only one borehole will be drilled.

3.1.4 Decision and Expected Action

The second step in the DQO process is to identify the key decision for the current phase of the project and identify alternative actions that may be taken based on the findings of the field investigation (i.e., site characterization). Thus, the relevant decision regarding which subsurface characterization data are needed is:

> *Within a reasonable degree of uncertainty, will the individual drinking water dose of 4 mrem/yr (25 mrem/yr all pathways) be exceeded at any time during the 10,000-year postclosure period due to the groundwater exposure pathway?*

Although this is not the only factor used in evaluating the acceptability of the site, a positive answer could lead to a decision to reject the proposed location, especially if there were any other negative aspects or uncertainties (see Section 3.1.7.3).

3.1.5 Decision Inputs

Piepho et al. (1995) used performance assessment models to predict the long-term concentrations in the soil column and groundwater and the resulting dose to a hypothetical member of the public. The input parameters for this scenario fall under four general areas:

1. Release rate from the waste form and/or package
2. Moisture migration rate or travel time to groundwater
3. Contaminant mass input rate or flux to groundwater
4. Soil column and aquifer properties for solute transport calculations.

This plan addresses the latter three areas. These data will support one major aspect of the decision-making process concerning the acceptability of the proposed ILAW Site project at Hanford for long-term disposal of LAW.

The importance of each of the transport parameters included in Piepho et al. (1995) and Mann et al. (1998) is summarized below. Some transport parameters and other parameters not included in that study are discussed in terms of importance based on the experienced opinions of the study's authors.

3.1.5.1 Far-Field Transport Parameter Needs

The following discussion defines far field as beyond the waste package and vault. Low recharge is comparable to natural conditions today, and high recharge is comparable to irrigation.

Based on the preliminary modeling summarized above, the following site-related parameter needs (or *decisional inputs*) to determine compliance with regulatory criteria or with the overall performance objective were identified:

1. **K_d of Tc-99 in vadose zone -** Most important parameter for low recharges but not important for high recharges.

2. **K_d of uranium isotopes and Se-79 in vadose zone -** Very important for low recharges but not important for high recharges.

3. **K_d of Np-237 in vadose zone -** Most important parameter for high recharges but not important for low recharges.

4. **K_d of I-129 in vadose zone -** More important for low recharges but not important for high recharges.

5. **Hydraulic parameters -** Some importance for low recharges but not important for high recharges. Porosity importance implies that the moisture-retention properties and saturated conductivities of the soils are more important for low recharges than for high recharges but are not that important overall. Piepho et al. (1995) implied that only the hydraulic properties of the engineered features (e.g., the gravel wedge, vault barrier, etc.) are important. For the vadose zone, the porosity of the sandy sequence of the Hanford formation was more important than the gravel sequence, which was more important than the backfill soil porosity, and the porosity of the Ringold Formation was the least important parameter of entire set of parameters.

6. **Bulk densities -** Can be important for low recharge rates and for transport of sorbing contaminants. Bulk density can be estimated from porosity and particle density if these parameters are somehow known (which is generally not the case).

7. **Dispersivities -** Potentially important for high recharges but not important for low recharges.

3.1.5.2 Near-Field Transport Parameters

Although not a *driver* for this plan, the near-field transport parameters identified in the scoping calculations, or modeling are summarized here for comparison purposes and to enhance integration of the overall performance assessment data collection effort.

1. **K_d of uranium isotopes in waste matrix -** Very important for both low recharges and high recharges.

2. **K_d of Np-237 in waste matrix -** Very important for high recharges and important for low recharges.

3. **K_d of Tc-99 in waste matrix -** Important for high recharges but not important for low recharges.

4. **K_d of I-129 in waste matrix and vadose zone -** Important for low recharges but not important for high recharges.

5. **Dispersivities -** Important for high recharges but not important for low recharges.

3.1.5.3 Other Parameters

Based on the experience of Piepho et al. (1995) and issues raised by others (e.g., Blush and Heitman 1995), other potentially important parameters have been identified. These parameters are summarized as follows:

1. **Diffusion coefficients -** Diffusion dominates dispersion or advection or both in the near-field vadose zone. Diffusion is important if the advection into the waste matrix is very small.

2. **Solubilities -** Not important in far-field but can be important in the transition zone between the near-field and far-field. Solubility is an important parameter in the near-field.

3. **Darcy velocities** - These are determined primarily by the recharge and hydraulic parameters of all porous media, in particular for Piepho et al. (1995), the gravel wedge, waste vault, and surrounding soil. They are variables, not parameters, calculated by modeling. The most important velocity for transport purposes is the pore velocity, which is the Darcy velocity divided by the moisture content.

4. **Recharge -** Recharge is very important if the waste matrix and vault are very porous or cracked. The Richards barrier at the surface is also very important in reducing the recharge. Because recharge is known to depend on climate, vegetation, and soil properties and because future recharge will still depend on climate and vegetation, Piepho et al. (1995) suggest that perhaps recharge is best handled by looking at recharge scenarios (e.g., low and high recharge scenarios).

5. **Retardation coefficients -** These are calculated from the particle density, porosity, and K_d values. There still is an open issue as to whether the retardation is a function of moisture content or not and whether the K_d parameter itself is a function of moisture content. Because retardation effects in the vadose zone are extremely important, these issues must be given priority. The vadose zone is a large *physical-chemical* filter already in place, and its effectiveness needs to be understood so the engineered disposal facility is neither under- nor over-engineered.

6. **Aquifer parameters -** These parameters were excluded from the Piepho et al. (1995) analysis but can be important for not only dilution effects, but also for overlapping plumes from previous operations.

7. **Colloidal mass transport -** Colloidal phases of transuranics and other radionuclides leached from the waste form may travel more rapidly through the vadose zone than previously thought, based on K_d measurements. This type of transport has been identified at other DOE sites, and laboratory studies have shown that the major fraction of plutonium leached from vitrified glass is colloidal (Blush and Heitman 1995). Although no laboratory or field evidence exists for the Hanford Site to support this claim, it cannot be ruled out and is therefore included in this performance assessment data needs exercise.

3.1.5.4 Summary of Subsurface or Far-Field Characterization Data Needs

The critical question for subsurface or far-field characterization as it applies to performance assessment parameter needs (Sections 3.1.5.1, 3.1.5.2, and 3.1.5.3) is as follows:

> *How do the properties of the vadose zone and saturated zone affect the performance measure as defined by Piepho et al. (1995)?*

Site-specific data are not available to adequately address this question. The following paragraphs outline data and inputs still needed to address the key conclusions of the Piepho et al. (1995) study.

Physical Discontinuities. The conceptual model assumes no preferential pathways for moisture migration to groundwater and laterally continuous sediments. Clastic dikes are known to exist across the Hanford Site and in the 200 East Area. These structures could act as conduits for moisture and mobile contaminant migration. Because of the emplacement mechanisms of cataclysmic flood deposits, horizontal continuity of sediments varies; the edges of sedimentary units may provide vertical connections between more conductive units. Thus, subsurface characterization is needed to determine if the character and extent of clastic dikes or other vertical discontinuities are present in the proposed waste site location. Surface mapping and geophysical surveys should be performed over the entire proposed area for the burial ground. The mapping and surveys should address the possibility of near-surface clastic dikes. The spacing for such a survey depends on the method used but should be close enough to provide full or continuous coverage.

Sorption Parameters. The importance of sorption parameters to estimate contaminant migration rates is one of the most important factors for assessing performance of the site (Piepho et al. 1995). Characterization studies need to place a high priority on obtaining K_d values for sediments from the site for the key radionuclides. The behavior of colloidal phases (retention by Hanford sediments, etc.) is a related issue that may need experimental input. The ability of the sedimentary strata (fine sediment layering) to “filter” colloidal phases is also potentially important for which delineation of the fine structure in the soil or sediment column could be important. (The latter is more related to the vadose zone properties discussed above.) The potential role that colloids may have in the transport of key radionuclides will be evaluated, particularly the ability of colloids to move through unsaturated environments. Recent studies indicate that colloids in low ionic strength solutions can move through coarse textured, unsaturated sands. Additional work needs to be conducted to determine if colloid movement is possible in the high ionic strength solutions and finer textured sediments existing in laboratory column and potentially field experiments.

Infiltration Rate and Spatial Variability. The preliminary performance assessment modeling has demonstrated the importance of the net infiltration rate for assessing mass movement and travel times. Work performed to date on the 200 Area Plateau using the chloride mass balance method of estimating long-term net infiltration rates suggests chloride is restricted to the upper 5 to 10 m. A test was completed in spring 1995 to obtain better recharge estimates for a 10,000-year timeframe. The importance of this information to addressing performance assessment issues and the very high uncertainty in present values dictates the need for obtaining additional high-quality recharge data.

Vadose Zone Parameters. The Piepho et al. (1995) study demonstrated the importance of vadose zone hydraulic parameters, particularly in the far-field scenarios. The basic data needed to address the vadose zone moisture movement issue are hydraulic conductivity, porosity, moisture content, chloride and chlorine-36 and/or iodine-129 profiles for infiltration rates, evidence of physical discontinuities, sorption parameters, anisotropy, K_ds, etc.

Aquifer Properties. Although the aquifer properties were not included in the preliminary performance modeling of Piepho et al. (1995), it was concluded that they are important considerations since they provide the parameters to assess radionuclide transport or movement away from the site.

3.1.6 Study Boundaries

Section 3.1.6 identifies the spatial and temporal domain boundaries and types of additional data needed to address the primary decisional questions stated in Sections 3.1.4 and 3.1.5.4. This step in the DQO process defines the set of circumstances covered by the decision(s) being addressed. This includes:

- spatial boundaries that define what should be studied and from where the samples should be taken

- temporal boundaries that describe when the samples should be taken and what timeframe the study should represent.

3.1.6.1 Spatial Boundaries

The principal spatial scale of interest is the area occupied by the disposal trenches of the ILAW Site and out to the 100-m compliance boundary.

Geographic Domain. The area within which the primary decisional question (Section 3.1.4) will be addressed for the ILAW Site is within the physical boundary of the disposal facility plus 100 m; i.e., the distance to the hypothetical downgradient drinking water well. The proposed disposal trenches will be contained within the designated area for the disposal facility. Because the disposal trenches could occupy all available space within the designated area, representative soil column or vadose zone data over this area are needed. The maximum lateral distance to the hypothetical drinking water well (100 m downgradient from the nearest waste source) is the compliance boundary line.

Generalized Well Locations. Based on the resource constraints for characterization, approximately three deep borings (at least 5 m [16 ft] into the saturated zone), completed as multi-purpose characterization and monitoring wells (i.e., one upgradient and two downgradient locations) are deemed adequate. Considering lateral or spatial “gaps” in stratigraphic information in the proposed area (Chapter 2.0) and groundwater characterization and monitoring needs, the optimum locations for three new or supplemental test borings/wells would be one upgradient location along the northwest corner and two downgradient locations. This configuration would provide hydrochemical characterization data as well as potential monitoring wells for preoperational and operational groundwater monitoring (if required). Using existing stratigraphic and soil property data from adjacent wells will require only a limited number of new characterization wells.

Sample Population(s) of Interest. The statistical term “population” refers to the total collection of objects or medium to be studied and from which a sample is to be drawn. Because physical properties within the vadose zone occur in distinct intervals or layers, it is appropriate to subdivide the population of geologic media to be sampled into strata that have homogeneous properties. This can be accomplished for several of the parameters of interest by using stratigraphic cross sections in the vicinity of the study area (Chapter 2.0). Based on existing knowledge and professional judgment, the stratigraphic column can be subdivided into four subpopulations based on “macro” textural characteristics and the division between saturated and unsaturated conditions. In general terms, these are the 1) upper gravel sequence, 2) middle sands, 3) lower gravels, and 4) saturated zone of the lower gravels (Figure 2.2).

3.1.6.2 Temporal Domain Boundaries

The temporal domain boundaries of interest are set by two principal recharge scenarios: 1) low recharge (<0.1 cm/yr) natural conditions, and 2) high recharge or irrigation scenario (>5 cm/yr).

Low Discharge Scenario. The formal time frame to which the study data will apply for the *natural conditions* or low recharge scenario is 10,000 years. Model predictions, however, will be extended to the time at which the peak downgradient drinking water pathway dose rate (in mrem/yr) actually occurs. The performance objective in this generic model prediction is not exceeded within the 10,000-year period of interest. However, the peak concentrations of long-lived, mobile radioactive waste constituents, which do not occur until approximately 60,000 years postclosure, exceed the performance objective. For this plan, the time period of interest over which the study data will be applied is 10,000 years. However, it should be recognized that an underlying assumption in performance model calculations for the natural or undisturbed scenario is that conditions over the last several thousand years will be the same as the next 10,000 years. Extending beyond 10,000 years involves entering the next glacial period (a cycle occurs approximately every 100,000-plus years). Dramatic climatic changes (glacial floodwaters over the site, wetter and or drier conditions, etc.) will be highly likely occur. Thus, even though the model predictions may extend far beyond the 10,000-year temporal boundary, the computation assumes that climatic conditions are constant for the entire period.

High Discharge. At a recharge or deep drainage rate of >5 cm/yr, as would occur if irrigation water were applied to the disposal site, the moisture migration rate to groundwater would be on the order of only a few hundred years (or less at higher drainage rates). Although travel time to groundwater is much shorter, the calculated concentrations of leachate could be lower than the low recharge scenario. The primary difference in these two cases is that input data requirements are less for the high discharge case than for the low discharge case; i.e., the high discharge or irrigation scenario does not require determination of natural recharge rates. However, all other parameters are common to both cases.

3.1.7 Decision Rule

As described in the DQO guidance manuals, this step integrates previous steps into a statement that describes the logical basis for choosing among alternate actions. This involves specifying 1) the parameters of interest, 2) an action level, and 3) alternative actions. These elements are then combined into **"if-then"** statements. This step is best applied to deciding the degree of contamination at a waste site and the action taken if standards are exceeded (e.g., remediation).

3.1.7.1 Statistical Parameters of Interest

Table 3.1 outlines the statistical parameters of interest needed to support the overall performance measure (primary parameter). The parameters are listed in order of relative importance.

Table 3.1. Parameters of Interest

Task	Properties/Parameters	Constituents of Interest	Sampled Population	Statistical Parameters
Geochemical retardation	K_d	^{99}Tc Uranium isotopes ^{79}Se ^{129}I ^{237}Np	3 subpop. in the vadose zone 1 subpop. in the sat. zone	Central tendency and dispersion
Recharge measurement	Recharge rates (long-term)	NA	1/borehole (deep)	Central tendency
	Recharge rates (contemporary)	NA	1/borehole (shallow)	Central tendency
Hydrogeological investigation	Hydraulic cond. Porosity Bulk density Moisture	NA	3 subpop. in the vadose zone 1 subpop. in the sat. zone	Central tendency
NA = Not applicable.				

3.1.7.2 Action Level or Measurement Threshold

This element is generally taken as a cleanup standard or other regulatory standard. The closest "standard" that applies to the performance assessment is the maximum dose rate of 4 mrem/yr for the drinking water pathway. All the above parameters of interest derived from subsurface characterization are input parameters to the model computations, which yield the performance measure or standard (mrem/yr). The action involved if the primary parameter exceeds the "performance standard" would be to first reexamine input assumptions, use alternative model(s), refine dose calculations, and/or assess conservatism of all assumptions used in model predictions.

3.1.7.3 Alternative Actions

Exceedance of the performance standard alone would not necessarily rule out the proposed disposal location. Ultimately, however, it could contribute to rejection of the site. The consequences of this action would be that considerable expense would be involved in locating an alternative site or disposal option. A tentative “If-then” statement is:

> *If the siting criteria (e.g., performance standard for drinking water pathway) are not met after all input parameters are checked and refined, then the proposed waste disposal site will be considered to pose an unacceptable risk to a hypothetical human intruder and alternative locations and or designs may have to be considered.*

This type of decision would involve several levels of review (e.g., by regulatory bodies). If the proposed location were rejected, a location with more favorable lithology may be needed. Other alternative actions could be to revise the waste stream flow sheet and or primary and secondary barrier designs. Surplus facilities such as the chemical processing “canyons” in 200 West Area could also be considered as an option. The latter would potentially reduce the costs for vault construction and take advantage of more favorable subsurface characteristics at the same time. Disadvantages would involve the loss in efficiencies gained by centralizing ILAW Site/glass processing and handling activities in the 200 East Area.

3.1.8 Limits on Decision Errors

This step of the DQO process specifies the limits on decision errors that are deemed tolerable. Errors related to input data acquisition consist of both sampling and measurement components. The combination of these errors is the total study error, which is directly related to the decision error.

A decision error occurs when the data lead the decision maker(s) to believe the null hypothesis is false when it is true (a false positive) or that the null hypothesis is true when it is not (a false negative). To reduce such errors, an adequate estimate of key population parameters is needed. Reducing such error generally involves greater cost (i.e., more samples, more replicate analyses, etc.). However, reducing decision error at a greater cost may not be the most desirable approach to take, especially at earlier stage of the site characterization effort.

For site characterization purposes, the statistical parameter of concern is the average concentration. Therefore, from a statistical view point, the major objective is to collect sufficient samples to obtain an estimate ($\bar{x}$) of the population average value (μ) with some prescribed accuracy for a parameter of interest. To determine the needed sample size, the following three items have to be specified:

- Level of confidence, $100(1 - \alpha)\%$
- Variability presented in the population, σ^2
- Magnitude of error that can be tolerated, $d = \left|\bar{x} - \grave{\imath}\right|$.

The sample size needed is $n = (z_{1-\alpha/2} \frac{\sigma}{d})^2$

where $z_{1-\alpha/2}$ is the $100(1-\alpha/2)\%^{th}$ quantile of the standard normal distribution (Gilbert 1987). When a reliable value for σ^2 is not available, but the relative standard deviation (the coefficient of variation = σ/μ) is known, the needed sample size becomes:

$$n = (z_{1-\alpha/2} \frac{\sigma/\mu}{d/\mu})^2$$

If the data are approximately normally distributed, but σ^2 (or σ/μ) is not known, then the *t* distribution is used instead of the standard normal distribution. That is $t_{1-\alpha/2,\, n-1}$ is used in place of $z_{1-\alpha/2}$, where $t_{1-\alpha/2,\, n-1}$ is the $100(1-\alpha/2)\%^{th}$ quantile of the *t* distribution with n-1 degrees of freedom. Because $t_{1-\alpha/2,\, n-1}$ depends on n, an iterative procedure is used to determine the sample size, n. First, an initial value of n (n') is computed using one of the above equations. Values from the *t*-table with (n'-1) degrees freedom are then substituted in the above formula to compute a new value of n. The new value of n-1 would be used to obtain the *t* value from the *t*-table and compute an updated value of n. This process continues until no further changes in “n” occur. Based on guidance in DOE (1990b), the level of confidence $(1-\alpha)\%$ is to be 95% and the margin of error (half width of the confidence band) on the estimate of the population mean is to be 10%.

In addition to specifying the limits of decision errors (i.e., $(1-\alpha)\%$ = 95% and a 10% margin of error), estimates of the population variability for the parameters of interest are needed to apply the statistical methods. At the present time, these estimates (site-specific) are not available. Hence, the most cost-effective approach is to conduct the site characterization efforts in phases. In the first phase, estimates of central tendency (mean or median) and variability will be obtained based on limited amounts of data. For example, the first phase could involve analysis of sample media collected from analog sites and/or samples from one borehole drilled at the ILAW Site.

Uncertainty Due to Choice of Performance Assessment Model. The consensus among the performance assessment model experts on the DQO scoping team was that computed results could range considerably, simply because of the computer code and/or mathematical model used for the calculation of pathway doses. Although the modeling uncertainty is recognized, uncertainties attributable to subsurface characteristics of the site are considered separately for this plan. Regardless of which modeling approach is used, the input parameters derived from site characterization data should be the same. The best approach to deal with the effect of modeling uncertainty may be to use more than one model in addition to the different exposure scenarios and develop a matrix of predicted values. Relative weight can then be assigned based on professional judgment, consensus, or expert panel opinion.

3.1.9 Optimize Sampling Design

This final step in the DQO process is intended to develop alternative environmental sampling designs and evaluate their efficiency at providing the data for meeting the overall performance objective. The purpose is to identify the most resource-effective sampling design. Application or implementation of the DQO process described in this and previous sections and additional operational details are described in Reidel et al. (1995) and Chapter 4.0 and the respective sampling and analysis plans (SAPs) of Reidel et al. (1995) and Appendix A1 of this report.

As indicated, the primary focus of the DQO process has been on the input parameters for the performance assessment. However, other site-related information is required to satisfy construction (geotechnical) and regulatory requirements. Some of these tasks can be integrated with the performance assessment subsurface data acquisition activities. Accordingly, these additional data and information needs are included in Sections 3.1.9.1, 3.1.9.2, and 3.1.9.3 to facilitate development of an integrated or optimum sampling design for subsurface characterization of the proposed disposal site.

3.1.9.1 Information Categories

1. Estimates of population and/or subpopulation means of key parameters used for computation of drinking water dose rate. Representative samples of the respective soil column needed to establish the estimates of central tendency and population variance across the designated area for the disposal trenches.

2. Site geophysical survey using 100% coverage in critical areas (disposal trenches) to assess or confirm the absence of vulnerable geology (e.g., clastic dikes, evidence of faulting).

3. Baseline or preoperational survey; surface soil, biota, air, groundwater (DOE 1990b; DOE Order 5820.2A, Chapter III). The subsurface portion of this requirement will use characterization data collected during the surface and near-surface portion of vadose zone characterization.

3.1.9.2 Strategy Elements

Phased Approach.

1. Fatal flaws reconnaissance: buried materials, subsurface geologic features; soil contamination survey.

2. Use analog sites such as the submarine pit, U.S. Ecology pit, or shallow boreholes drilled at the ILAW Site to estimate population variability for key parameters (e.g., K_ds) before drilling commences. This is especially important if all deep boreholes must be drilled in the first year.

3. Iterate DQO process. Analyze initial results before committing all remaining resources (avoid fatal flaw).

Composite (where possible). Composites, if shown to yield acceptable estimates of key parameters, should be used to reduce the number of samples analyzed and provide more rapid or “early” information for competing demands for core.

Use Field Screening and Interpolation Methods to Minimize Laboratory Analyses.

1. Unsaturated/saturated hydraulic conductivity over range of porosities, and use sediment properties to interpolate for full column.

2. Determine K_ds for sand zones only, and use grain size data to estimate K_d for gravel zone, (1 - %Gravel) * K_d.

3. Use aerial radiation survey, near-surface geophysical surveys, and hand-held radiation survey instruments to limit number of near-surface soil samples.

Prioritize Parameters and Data Collection Tasks. Do the most important tasks first, and archive samples where possible.

Emphasize Realistic and Credible Scenarios for Performance Assessment Input. Do not use population extremes for the median or mean values of key input parameters.

3.1.9.3 Sampling Considerations

1. Use sampling methods most appropriate for the parameters of interest (e.g., use discrete samples for recharge estimates, use composite samples for sorption parameters and other related physical properties, etc.).

2. Coordinate sample handling to avoid potential conflicts (e.g., recharge-related parameters require sealed sample media while stratigraphic detail must be physically examined).

3. Conduct data acquisition efforts in a logical manner to accomplish multipurpose sampling from each core.

3.2 2000 Data Quality Objectives Meeting

In February 2000, the ILAW Site team and representatives of other programs held a DQO meeting to determine whether a second borehole was necessary, where it should be located, the data needs that should be obtained from the borehole, and drilling requirements to meet the data needs. This section documents the data needs and requirements for drilling the second borehole to support the ILAW Site 2005 performance assessment. These needs and requirements form the basis for a characterization plan, the sampling and analysis requirements, and the quality assurance requirements for a second borehole.

3.2.1 Need for a Borehole

Based on the data available from the first ILAW Site borehole and the ILAW Site 2001 Geology Data Package (Reidel and Horton 1999), the ILAW Site Performance Assessment team determined that a second borehole is necessary. The principal justifications for the second borehole are as follow:

- The ILAW Site Geology Data Package for the 2001 performance assessment identified a major erosional channel in the subsurface that cuts across the ILAW Site. The first ILAW Site borehole (299-E17-21) penetrated the edge of the channel, and a subsequent reinterpretation of older boreholes around the site indicated that sediments comprising the vadose zone and saturated zone have been eroded progressively deeper to the northeast by Pleistocene-age floods. The erosional channel represents an unconformity at the ILAW Site where some of the deeper sediment layers were truncated, and younger Hanford formation sands and gravels were deposited in their place. Sediments with potentially different physical and hydrologic properties are now juxtaposed along the unconformity. A second ILAW Site borehole is required to better define the stratigraphy and determine the physical and hydrologic properties of the sediments that fill the channel along the north and east portion of the ILAW Site. This information is needed to better define the sediment layers and their properties that will be used in the 2005 ILAW Site performance assessment.

- The first ILAW Site borehole penetrated three paleosol horizons. The lowest paleosol is at the surface of the pre-770,000-year-old flood deposits. This was confirmed in 1999 using paleomagnetic data (Appendix B, Reidel and Horton 1999). This is significant to the ILAW Site performance assessment because it indicates that younger Pleistocene-age floods crossing the 200 East Area did not completely erode all deposits from the earlier floods as previously thought. Thus, the ILAW Site stratigraphy consists of layers of different ages. The middle paleosol appears to be a geologic layer that caused lateral spreading of contaminants from cribs east of the ILAW Site (e.g., 216-A-10 crib). Layers that can cause lateral spreading of downward migrating moisture can have great significance to the ILAW Site performance assessment and will have to be evaluated in the 2005 performance assessment modeling. The performance assessment team determined that there is a need to verify the presence (or absence) of these horizons across the ILAW Site and obtain samples for physical and hydraulic properties for evaluation in the 2005 performance assessment.

- It has been shown that boreholes can provide preferential pathways to the water table. The ILAW Site performance assessment team does not want any borehole drilled inside the site boundaries that could potentially compromise the site. However, the performance assessment team still requires geologic information from across the site. Noninvasive geophysical methods such as seismic and ground penetrating radar offer an alternative to drilling, but these methods must be constrained by boreholes to ensure the data are accurate. A second ILAW Site borehole on the northeast side of the site provides a necessary control point for future, noninvasive geophysical tests that will be performed across the site to verify the presence of laterally extensive units without drilling confirmation boreholes in the site.

- Although the vadose zone is the principal target for the performance assessment, groundwater information is needed to define groundwater flow paths and background constituent levels at the ILAW Site. A second characterization borehole is needed to provide this information on the east side of the site. A second borehole will also support groundwater monitoring for the site.

3.2.2 Borehole Location

The performance assessment team concluded that locating the second ILAW Site borehole on the northeast side of the ILAW Site would meet all the data requirements identified above to support the 2005 performance assessment. The best location would be south of 4th Avenue and along the east side of the site. The exact borehole location will be determined for the characterization plan.

3.2.3 Borehole Depth

The 2005 performance assessment will require data to be collected from the borehole through the entire vadose zone. The first borehole was drilled to the Ringold Formation, Unit A so that the Groundwater Program could obtain water samples from both above and below the partially confining Ringold Formation Lower Mud Unit. Water samples contained little, if any, contaminants. The second well is expected to penetrate the 200 East Area tritium plume. Because of the need for groundwater background values on the east side of the ILAW Site and the cost effectiveness of completing the borehole as a groundwater monitoring well, the performance assessment team concluded that the borehole should be drilled to the water table and completed as a groundwater monitoring well. If the Groundwater/Vadose Zone Integration Program or the Groundwater Monitoring program requires information from a deeper well, the ILAW Site team will make the borehole available to them.

3.2.4 Sample Requirements

Appendix A provides the parameters for the 2005 performance assessment that will be obtained from samples acquired from the second ILAW Site borehole. The ILAW Site performance assessment team compiled this table at the February 2000 planning meeting. The performance assessment team derived this table by evaluating results of tests that were done on the first ILAW Site borehole samples and the importance of the results to the performance assessment.

Once the table of parameters and tests was derived, the performance assessment team determined the type and amount of sample that was necessary to perform the tests. Some tests can be performed on samples obtained by standard Hanford cable tool drilling but most of the tests, including the most important ones for the performance assessment, required continuous, intact, and undisturbed core samples.

The performance assessment team concluded that because of the sampling requirements, a drilling method similar to the Becker Hammer method, which was used on the first borehole, would be required to obtain continuous and undisturbed samples.

4.0 Characterization Tasks

Subsurface characterization data are required both to determine the site suitability and to meet the performance assessment needs. The characterization tasks were grouped by Reidel et al. (1995) into two major areas:

- geohydrological model development
- site monitoring.

The geohydrological model development study consists of three parts, based on location in the geologic column (reproduced from Reidel et al. 1995, Table 4-1): surface and near-surface characterization, vadose zone geohydrological characterization, and unconfined aquifer characterization. The site monitoring study includes near-surface (preoperational) baseline, vadose zone monitoring, and groundwater monitoring. Site monitoring is discussed in Reidel et al. (1995) and will not be considered further here.

The following activities are required to complete the studies (Reidel et al. 1995):

1. existing data assessment
2. surface geologic mapping
3. shallow (~15 m) borehole construction and sample collection
4. deep (at least ~5 m into saturated zone) borehole construction and geologic logging
5. ground-penetrating radar survey
6. electromagnetic induction survey
7. borehole geophysical logging
8. existing data integration
9. aquifer testing
10. infiltration/recharge studies
11. planning activities
12. contaminant assessment.

The characterization tasks using the samples/data collected from these activities are shown in Table 3.1 under the study part(s) that the tasks support.

4.1 Geohydrologic Model Development

The disposal option considered for the ILAW Site performance assessment and the characterization plan by Reidel et al. (1995) is that the low-level tank wastes at the Hanford Site will be processed into a glass form and disposed of in the ground. To assess the groundwater pathways portion of the waste disposal system performance, a detailed knowledge of the geohydrologic conditions of the site must

Table 4.1. Site Characterization Studies and Activities (from Reidel et al. 1995)

Studies	4.1.0 Geohydrologic Model Development			4.2.0 Monitoring		
Activities	4.1.1 Surface and Near-Surface Characterization	4.1.2 Vadose Zone Geohydrologic Characterization	4.1.3 Upper Unconfined Aquifer Characterization	4.2.1 Environmental Base-line Plan	4.2.2 Vadose Zone Plan	4.2.3 Groundwater Plan
Shallow Boreholes	• Determine textural units (stratigraphy)	• Determine stratigraphy/ textural properties • Determine petrologic/ mineralogic composition • Determine physical properties/moisture content • Measure ^{129}I, ^{36}CL, D/O 18, chloride • Determine KD/ geochemical properties • Determine radiologic and chemical contamination • Matric potential	N/A			
Deep Boreholes	N/A	• Determine stratigraphy/ textural properties • Determine petrologic/ mineralogic composition • Determine physical properties/moisture content • Measure ^{129}I, ^{36}CL, D/O 18 • Determine KD/ geochemical properties • Determine radiologic/ chemical contamination	• Determine stratigraphy/ textural properties • Determine hydraulic properties • Determine hydrochemical/ geochemical characterization	• Groundwater quality baseline (see groundwater monitoring plan)		• Provide access to groundwater • Groundwater quality baseline
Ground-Penetrating Radar	• Map textural variations/ clastic dikes and excavations • Locate shallow buried objects (pipes, drums, burial grounds)	• Map location of clastic dikes	N/A	• Locate shallow buried objects • Map textural variation (e.g., clastic dikes, excavation)		• Locate shallow buried objects • Map textural variation (e.g., clastic dikes, excavation)

Table 4.1. (contd)

Studies	4.1.0 Geohydrologic Model Development			4.2.0 Monitoring		
Activities	4.1.1 Surface and Near-Surface Characterization	4.1.2 Vadose Zone Geohydrologic Characterization	4.1.3 Upper Unconfined Aquifer Characterization	4.2.1 Environmental Base-line Plan	4.2.2 Vadose Zone Plan	4.2.3 Groundwater Plan
Existing Hydrogeology and Contaminant databases	• Assess and integrate appropriate data	• Assess and integrate existing data	• Assess and incorporate existing data	• Assess and incorporate existing data	• Assess and incorporate existing data	• Assess and incorporate existing data
Surface Geol. Mapping	• Determine surface geology, land forms and topography			• Determine surface geology, landform, and topography		
Analog Studies						
Miscellaneous Field Testing	• Characterize transfer line to B-C Cribs	• Recharge tests	• Aquifer testing to determine properties			
Planning						

be known. Because this plan is only concerned with the borehole task, only the vadose zone and saturated zone plans will be addressed here. The reader is referred to Reidel et al. (1995) for a complete discussion of the other activities.

4.1.1 Vadose Zone Geohydrologic Characterization

The geologic and hydrologic properties of the vadose zone control the flow of water and the transport of contaminants through the vadose sediments to the unconfined aquifer. This study is designed to determine and characterize the physical and geochemical properties of the vadose zone underlying the proposed ILAW Site for the Hanford ILAW Performance Assessment.

4.1.1.1 Determine the Physical and Geochemical Properties of the Vadose Zone at ILAW

Objective. This task will determine the geologic, hydrologic, and geochemical properties for the ILAW Site. These properties provide parameters for a quantitative conceptual model of the site that will be used in the performance assessment to predict flow and transport in the vadose zone. Samples collected in this study will also be used to determine the K_d values of the vadose zone sediments and to investigate infiltration rates.

Data Needs. The following data are required to determine physical and geochemical properties. The data specifically to be obtained from the borehole proposed for this plan are listed in Appendix A1, Table A1.3. These data are derived specifically from the following test plans: Kaplan (1997) and Khaleel (1997).

As part of the DQO process (Reidel et al. 1995, Chapter 3.0), it was determined that three boreholes to groundwater (deep) and, if necessary, one to nine shallow 50 ft (15 m) boreholes would be necessary to meet these data needs. This decision is based on two factors: technical judgment and resource limitations.

Deep Boreholes. The number and placement of the deep boreholes for the ILAW Site was based on 1) processes controlling deposition of vadose zone sediments, 2) the size and layout of the area, 3) usefulness for establishing a groundwater baseline and for operational and postclosure monitoring (Reidel et al. 1995), and 4) obtaining data from areas with poor control. Reidel et al. (1995) proposed one borehole be placed upgradient with respect to the depositional environment and two depositional downgradient boreholes. This placement allows a comparison of the vertical and lateral extents of textural variation in the vadose zone. It also should allow for identification of significant textural units and their lateral extent.

Placement of Deep Borehole. In preparation for drilling the first borehole for characterization of the ILAW Site, a meeting was held with all the data users of the samples from the borehole. It was decided that the first borehole (borehole 3, Reidel et al. 1995) should be at the southwest corner of the site. This location met all the original performance measures for the boreholes including groundwater monitoring. The primary objective of that borehole was not aquifer characterization but vadose zone characterization.

The second ILAW Site borehole will be on the northeast side of the ILAW Site south of 4th Avenue and along the east side of the site (Figure 2.3 and Appendix A1, Figure A1.1). That location will meet all the data needs defined in Section 3.2.2.

The second borehole is expected to penetrate the 200 East Area tritium plume. Because this borehole is emphasizing the vadose zone, it will be drilled to the water table and completed as a groundwater monitoring well. If the Groundwater/Vadose Zone Integration program or the Groundwater Monitoring program required information from a deeper well, then the borehole will be made available to them for deepening. Based on Figure 2.2, the suprabasalt sediments are approximately 130 m (425 ft) thick and the saturated zone is about 30 m (100 ft) thick.

4.1.1.2 Vadose Zone Characterization Activities

Vadose zone characterization is accomplished by drilling boreholes to obtain samples to test and/or analyze. Some analog studies also are planned to provide data on clastic dikes and infiltration/ recharge, both of which are important to the Hanford Site but are not easily assessed at the ILAW Site. The boreholes also provide access for geophysical logging of the subsurface.

Borehole. The borehole addressed in this plan will be drilled through the vadose zone and saturated zone to the water table. Continuous core will be obtained from the drilling. Samples will be taken from continuous cores and will be geologically logged and analyzed for physical properties and chemical compositions. Selected samples will be analyzed for parameters listed in Appendix A1, Kaplan 1997, Khaleel 1997, and Murphy 1997).

Geologic descriptions will include, but not be limited to, detailed field lithologic descriptions. The descriptions will include color, texture, sorting, bulk mineralogy, roundness, relative calcium carbonate reactivity, consolidation, and cementation. All drilling and well construction data will be documented.

Laboratory analyses include selected chemical characteristics, grain size distribution, physical and hydraulic properties, and mineralogy.

Geophysical Logging. The borehole will be geophysically logged. Geophysical logging will provide data for comparison with core derived data for stratigraphic interpretation, (porosity) estimation, and relative moisture content of the sediments drilled. Relative moisture is one of the most important parameters to be obtained by geophysical logging. Neutron/moisture, NaI, and radionuclides logs will be run to measure moisture, infer stratigraphy, and measure radionuclides. Geophysical tools will be used to help define hydrostratigraphic units and to correlate these units among adjacent boreholes. They will also be used to identify any possible zones that are contaminated by gamma-ray emitting radionuclides.

4.1.2 Aquifer Characterization

4.1.2.1 Purpose

This task describes geohydrologic and geochemical characterization of the unconfined aquifer at the ILAW Site that will be done as part of this borehole task. Geohydrologic characterization describes the conditions and properties that control groundwater flow directions and rates within the aquifer. The characterization borehole described in this plan will be constructed as a monitoring well. Data collection and interpretation are focused on geology, geochemistry, hydrogeology, hydrochemistry, and groundwater modeling. This borehole will provide the following:

1. geochemical/radiological baseline
2. stratigraphic data and physical properties
3. hydrologic parameters
4. monitoring and aquifer testing
5. hydrostratigraphy information about the bottom of the aquifer.

Geochemical and hydrochemical measurements will be used to evaluate the chemical behavior of key constituents in the aquifer. Mineralogic composition and sorptive properties of the aquifer solids combined with geochemical characteristics of the pore fluid (groundwater) and geochemical modeling will be used to evaluate factors that influence contaminant migration rate (e.g., redox status, sorption, solubility, chemical precipitation, and/or isotope exchange reactions). Sampling and analysis for appropriate regulatory constituents will also provide background or baseline data to meet the groundwater component of environmental monitoring requirements.

4.1.2.2 Objectives

As a result of recommendations from the optimized sampling and analysis design step of the DQO process (Reidel et al. 1995, Section 3.8), it was decided that the characterization borehole considered in this plan should also be completed as groundwater monitoring well. The decision was based on a desire to maximize the use of resources, obtain physical and geochemical data to characterize the aquifer, and develop a preoperational groundwater baseline for the Site.

The aquifer is about 30 m (100 ft) thick at the ILAW Site and is probably composed of Ringold Unit E. The Ringold lower mud is absent at this locality (Figure 2.2). Aquifer testing elsewhere on the site has shown that the unconfined aquifer can have variable properties vertically through the aquifer. It was decided that characterization should concentrate on the vadose zone and the upper portion of the aquifer because the vadose zone is the primary area of concentration in this plan.

4.1.2.3 Characterization Methods

The borehole described in this plan will be completed as a groundwater monitoring well. Data will be obtained during the drilling of borehole and following installation of the groundwater monitoring well. The number and location of samples and analyses to be preformed is described in the borehole SAP. One intact sediment core will be taken at the water table to provide representative samples for stratigraphic description, testing, analyses of physical and chemical parameters, and design of the monitoring well. The core will be archived to provide a source of readily available and representative sediment. The monitoring well will then be installed and groundwater samples taken and analyzed (see Section 4.2.3, Reidel et al. (1995) and SAP). Following well installation, depth to groundwater will be established.

Geophysical Logging. The borehole will be geophysically logged (see Appendix A1).

Aquifer Testing. The monitoring well described in this plan will be used to obtain in situ hydraulic conductivities and to refine estimates of groundwater travel time. Hydraulic testing will consist of an instantaneous slug test.

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Appendix A1

Sampling and Analysis Plan

Preface

This Sampling and Analysis Plan (SAP) pertains to borehole characterization at the Immobilized Low-Activity Waste Site (ILAW Site). The SAP consists of two principal parts: (1) a Field Sampling Plan (FSP), and (2) a Quality Assurance Project Plan (QAPjP). These two components of the SAP will be used to control the data collection activities for borehole drilling and related sampling. The data collection activities described herein are the product of the Data Quality Objective (DQO) process (EPA 1993) and the DQOs determined by Reidel et al. (1995). Because the Hanford Site now has many support contractors doing work, the procedures referenced in this plan are provided for guidance only. Equivalent approved PHMC procedures may be substituted.

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Field Sampling Plan

1.0 Introduction

This Field Sampling Plan (FSP) describes the rationale and procedures for sample selection and the analyses to be performed on sediment and groundwater samples associated with subsurface characterization borehole to be drilled at the Immobilized Low-Activity Waste site (ILAW Site). Recommended procedures for sample collection, chain of custody, sample preservation, shipment, and chemical analysis are included but equivalent, approved Project Hanford Management contractor procedures may be substituted. The media-specific discussions are provided in two separate subsections: borehole sediments and groundwater.

2.0 Borehole Drilling and Sampling

The tasks involved in borehole drilling and sampling include the following:

- activity preparation
- location and designation of the borehole
- drilling and geologic material sampling
- sample handling
- analysis of samples
- documentation
- borehole geophysics
- well completion.

2.1 Activity Preparation

Preparation activities necessary before beginning fieldwork for borehole drilling include the following:

- coordinate with team members
- coordinate with support services as addressed in the Quality Assurance Project Plan (QAPjP, Appendix A2)
- evaluate drilling techniques

- obtain support documentation
- obtain monitoring and sampling equipment.

2.2 Location and Designation of Boreholes

One deep borehole is planned for this study in the location shown in Figure A1.1. The deep borehole is designed to provide samples to 1) characterize the sediments in the vadose zone and saturated zone, and 2) characterize groundwater (both hydrologic and hydrochemical). The deep borehole will also serve as a groundwater monitoring well for preoperational baseline and/or other purposes as required. The boring will be constructed in accordance with Washington Administrative Code 173-160 requirements and other appropriate Hanford requirements or equivalent.

2.2.1 Location and Installation

The primary factor dictating the location of the borehole is its characterization function with respect to developing the geohydrologic model for the site and satisfying associated DQOs (Reidel et al. 1995, and Section 3.2, this report).

Rationale. The deep borehole will be placed on the northeast side of the ILAW Site. Existing boreholes in the area provide information on the southern portions of the site, but characterization data are not available from the northeast side. This borehole provides data on the vadose zone and saturated zone in an area previously uncharacterized.

Based on the data available from the first ILAW Site borehole and the ILAW Site 2001 Geology Data Package (Reidel and Horton 1999), the ILAW Site Performance Assessment team determined that a second borehole is necessary. The principal justifications for the second borehole are:

- The ILAW Site Geology Data Package for the 2001 performance assessment identified a major erosional channel in the subsurface that cuts across the ILAW Site. The first ILAW Site borehole (299-E17-21) penetrated the edge of the channel and a subsequent reinterpretation of older boreholes around the site indicated that sediments comprising the vadose zone and saturated zone have been eroded progressively deeper to the northeast by Pleistocene age floods. The erosional channel represents an unconformity at the ILAW Site where some of the deeper sediment layers were truncated and younger Hanford formation sands and gravels were deposited in their place. Sediments with potentially different physical and hydrologic properties are now juxtaposed along the unconformity. A second ILAW Site borehole is required to better define the stratigraphy and determine the physical and hydrologic properties of the sediments that fill the channel along the north and east portion of the ILAW Site. This information is needed to better define the sediment layers and their properties that will be used in the 2005 ILAW Site performance assessment.
- The first ILAW Site borehole penetrated three paleosol horizons. The lowest paleosol is at the surface of the pre 770,000-year-old flood deposits. This was confirmed in 1999 using paleomagnetic

data (Appendix B, Reidel and Horton 1999). This is significant to the ILAW Site performance assessment because it indicates that younger Pleistocene-age floods crossing the 200 East Area did not completely erode all deposits from the earlier floods as previously thought. Thus, the ILAW Site stratigraphy consists of layers of different ages. The middle paleosol appears to be a geologic layer that caused lateral spreading of contaminants from cribs east of the ILAW Site (e.g., 216-A-10 crib). Layers that can cause lateral spreading of downward migrating moisture can have great significance to the ILAW Site performance assessment and will have to be evaluated in the 2005 performance assessment modeling. The performance assessment team determined that there is a need to verify the presence (or absence) of these horizons across the ILAW Site and obtain samples for physical and hydraulic properties for evaluation in the 2005 performance assessment.

- It has been shown that boreholes can provide preferential pathways to the water table. The ILAW Site performance assessment team does not want any borehole drilled inside the site boundaries that could potentially compromise the site. However, the performance assessment team still requires geologic information from across the site. Noninvasive geophysical methods such as seismic and ground-penetrating radar offer an alternative to drilling, but these methods must be constrained by boreholes to ensure the data are accurate. A second ILAW Site borehole on the northeast side of the site provides a necessary control point for future, noninvasive geophysical tests that will be performed across the site to verify the presence of laterally extensive units without drilling confirmation boreholes in the site.

- Although the vadose zone is the principal target for the performance assessment, groundwater information is needed to define groundwater flow paths and background constitutes levels at the ILAW Site. A second characterization borehole is needed to provide this information on the east side of the site. A second borehole will also support groundwater monitoring that will be a regulatory requirement for the site.

2.2.2 Planned Depths and Timing

The borehole will be drilled into the saturated zone and completed as a groundwater monitoring well. The top of the water table is approximately 100 m (325 ft) below the surface. The stratigraphy encountered in this borehole can then be compared to characterization borehole 299-E21-17 at the southwest corner of the site. This well will be drilled either during fiscal year (FY) 2000 or beginning in FY 2001 during the cooler months of the year to minimize moisture losses from the core samples during the recovery and handling steps.

2.3 Characterization Borehole Designation and Core Labeling

Boreholes are given designations that relate to the area in which they are located except in the 200 Areas. A permanent borehole number will be assigned once the well is installed and surveyed. The approximate 299 coordinate and well number is listed in Table A1.1.

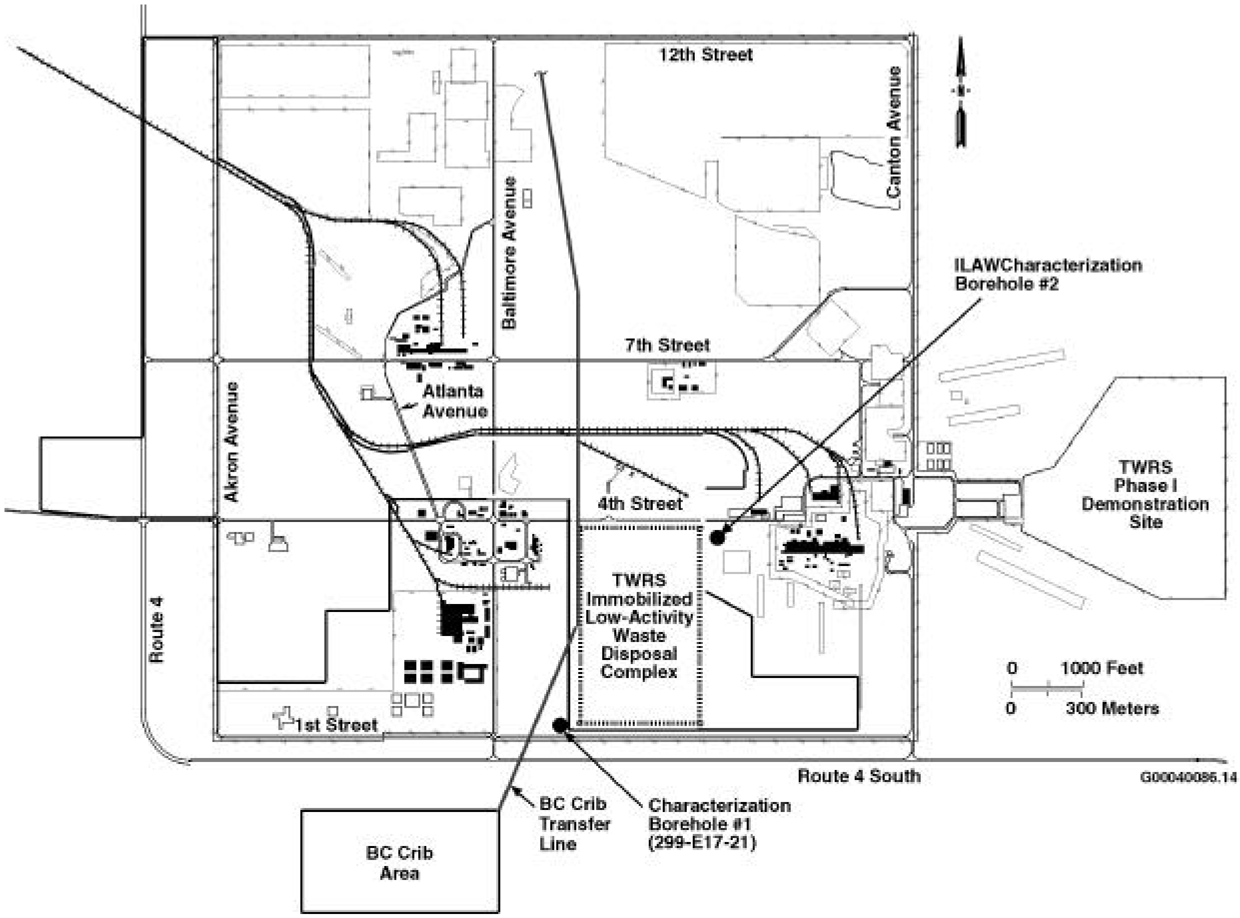

Figure A1.1. Location of Second ILAW Site Characterization/Groundwater Monitoring Well

The preliminary location in Hanford coordinates is shown in Table A1.1.

Table A1.1. Preliminary Borehole Name and Location for ILAW Borehole #2

Borehole #	West Longitude	North Latitude	Elevation	Location
C3177	119°31.524	46°33.020	216 m	Northeast corner of ILAW Site

Samples obtained from the intact coring/sampling process during the drilling process will be sealed in Lexan or other equivalent material liners and refrigerated as soon as they are retrieved from the downhole sampler. Refrigeration can be standard sample coolers with precautions to not allow moisture from the cooler to impact the sample. Sample liners will be labeled with the borehole number, depth interval of the sample, and top and bottom of sample information and arrow indicating top. The samples will be transported after a field radiation and release survey (if required) to the Pacific Northwest National Laboratory (PNNL) laboratory operated by the Applied Geology and Geochemistry Group located in the 3720 building. Samples will be refrigerated until analyzed or declared excessed.

2.4 Drilling Equipment and Coring Procedures

A continuous record of samples through the vadose zone is required for this project. Recognizing that this is a difficult task, but an important one, a drilling method will be used that will allow collection of a continuous intact soil sample(s) (i.e., core) that is representative of the entire vadose zone interval. In addition, drilling fluids will not be used because measuring the moisture content and matric potential are important. Thus, an air rotary drilling technique is preferred. Depending on borehole location and projected depth, a 6-m (20-ft) starter casing 15 to 30 cm (6 to 12 in.) in diameter will be used. Down-sizing of well casing during drilling will be done at appropriate intervals depending on drilling conditions. Proposed casing as-builts are shown in Figure A1.2; the drilling engineer will determine the final design.

2.5 Sample Types and Frequency

Samples will be taken from as continuous a record of the vadose zone sediment column as possible. Sampling activities will be administered in accordance with applicable procedures in BHI-EE-01, *Environmental Investigations Procedures*, or equivalent Hanford Site approved procedure.

The continuous core samples will be taken for tests listed in Table A1.2, which include geologic logging, physical property tests, and chemical analyses. Section 2.5.1 outlines the specific subsample schedules for the cored intervals.

2.5.1 Sample Allocation and Interval Selection

Table A1.2 shows continuous core handling and sample allocation. More detailed descriptions of the steps, related subsampling considerations, and potential constraints are discussed as follows.

2.5.1.1 Physical Description of Core

The philosophy behind the sample allocation is determined by the DQO process (EPA 1993). All sampling will be conducted in accordance with procedure *Soil and Sediment Sampling* (BHI-EE-01, Procedure 4.0 or approved PHMC procedure). A description of the borehole sediments is typically performed by the well site geologist at the time of drilling to obtain a continuous lithologic record. However, with continuous core that is to be immediately sealed in the plastic core liners, the physical description will have to be performed at a later date when the core liners are opened for processing. A sampling device that can be advanced with the casing and be efficiently retrieved to the surface will be used. The sampler will retrieve intact sample with a minimum outside diameter of 10 cm (4 in.), have the ability to advance in 3 m (10 ft) increments in downhole conditions, and will have Lexan or equivalent liners for sample retention. The sample liners should be in 0.6 m (2 ft) long, individual segments.

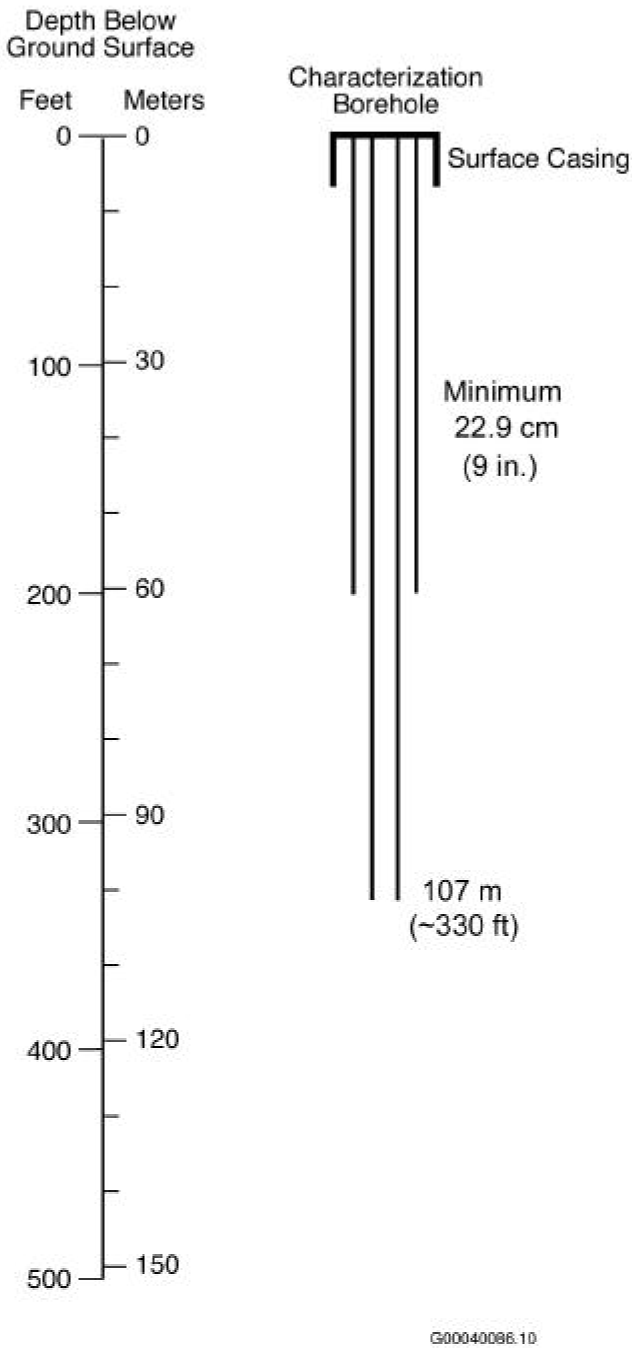

Figure A1.2. Projected Well Design

Table A1.2. Proposed Maximum Sampling Requirements Based on Test Plans (Table 4.1 and Kaplan 1997, Khaleel 1997, and Murphy 1997a and 1997b). The actual number of samples that will be analyzed will depend on the stratigraphy encountered during drilling.

Depth (in feet)	Core	Chemical Transport	Physical Properties	Recharge Tracers
0-10	Y	X		X
10-20	Y	X	X	X
20-30	Y			X
30-40	Y	X	X	X
40-50	Y			X
50-60	Y	X	X	X
60-70	Y			
70-80	Y	X	X	X
80-90	Y			
90-100	Y	X	X	X
100-110	Y			
110-120	Y	X	X	
120-130	Y			X
130-140	Y	X	X	
140-150	Y			
150-160	Y	X	X	X
160-170	Y			
170-180	Y	X	X	
180-190	Y			X
190-200	Y	X	X	
200-210	Y			
210-220	Y	X	X	
220-230	Y			X
230-240	Y	X	X	
240-250	Y			
250-260	Y	X	X	
260-270	Y			X
270-280	Y	X	X	
280-290	Y			
290-300	Y	X	X	
300-310	Y			X
310-320	Y	X	X	
320-330	Y			
330-340	Y	X	X	

(a) Approximate watertable.
(b) Core to be collected at lower mud if present.

The well site geologist will describe the samples in the field and record the descriptions on borehole logs per *Geologic Logging* (BHI-EE-01, Procedure 7.0, or equivalent, approved PHMC procedure); the field descriptions will be based on cuttings that are in excess of the core. Every sample collected will be recorded on a borehole log at the drill site because the cores will be immediately sealed. Detailed field lithologic descriptions of available material will include, if possible, color, texture, sorting, bulk mineralogy, roundness, relative calcium carbonate reactivity, consolidation, and cementation. All drilling and well construction data, sample depths, radiological and chemical survey points, etc., will be documented on the borehole logs. Actual test to be performed on the core samples (summarized in Table A1.3) will be governed by test plans written by Kaplan (1997), Khaleel (1997), and Murphy (1997a and 1997b) unless superseded by newer test plans approved by CHG.

If adequate sample volumes are not available, sample allocation of core will be made on the basis of relative importance of the parameter of interest to evaluating the site performance objective. Thus, K_ds are first priority, followed by natural recharge rate, hydraulic conductivity, and physical parameters. Every effort must be made, however, to obtain all the desired information from the available core. This may be accomplished by reusing certain sections after nondestructive testing is completed. For example, intact core required for hydraulic conductivity tests can be analyzed for mineralogy, grain size, or calcium carbonate after the hydraulic tests are completed. Likewise, intact core for moisture and chloride content (upper portion of core) can be reused for those tests not influenced by distilled water leaching (grain size, carbonate, etc.).

2.5.1.2 Sampling Rationale

The sampling scheme provided in Table A1.2 was determined by discussion with the sample users (Kaplan 1997, Khaleel 1997, Murphy 1997), and the referenced test plans document the sampling rationale, requirements, and procedures used on the tests for Chemical Transport studies, Physical Properties of the Vadose Zone, and Estimating Recharge by Environmental Tracers.

2.5.2 Hydrologic Parameters

A knowledge of hydrologic parameters contributes to identifying preferred flow paths, aquifer boundaries, the rate and direction of flow, and potential contamination zones. Parameters of interest include results from 1) physical testing of intact soil samples, 2) aquifer tests and other tests for hydraulic properties, and 3) chemical and radiological analyses of formation water samples. (Physical tests are described in Khaleel 1997.)

Table A1.3. Laboratory Analyses to be Performed on Core and Users of Analyses

Test	Chemical Transport Studies (Section 4.1.2.3.4, Reidel et al. 1995 and revised by Kaplan 1997)	Physical Properties of Vadose Zone (Section 4.1.2.1, Reidel et al. 1995 and revised by Khaleel 1997)	Estimating Recharge by Environmental Tracers (Section 4.1.2.3.3, Reidel et al. 1995 and revised by Murphy 1997b)	Aquifer Characterization (Section 4.1.3, Reidel et al. 1995)
Stratigraphy	X	X	X	X
Geophysical logging	X	X	X	X
Moisture content	X	X	X	
Matric potential		X		
pH	X			
Cation exchange capability	X			
Iron oxide concentration	X			
Mineralogy - XRD	X	X		
Cations	X			
Anions	X			
$CaCO_3$	X		X	
Kd	X			
Gravimetric moisture	X	X	X	
Bulk density	X	X	X	X
Particle density	X	X	X	
Particle size distribution	X	X	X	X
Porosity	X	X	X	X
Unsaturated hydraulic conductivity		X	X	
Saturated hydraulic conductivity		X	X	X
Moisture retention	X	X	X	

Table A1.3. (contd)

Test	Chemical Transport Studies (Section 4.1.2.3.4, Reidel et al. 1995 and revised by Kaplan 1997)	Physical Properties of Vadose Zone (Section 4.1.2.1, Reidel et al. 1995 and revised by Khaleel 1997)	Estimating Recharge by Environmental Tracers (Section 4.1.2.3.3, Reidel et al. 1995 and revised by Murphy 1997b)	Aquifer Characterization (Section 4.1.3, Reidel et al. 1995)
Pore water H^3			X	
Groundwater composition				X
Aquifer testing				X

2.6 Sample Handling

All sampling activities will be conducted in accordance with Bechtel Hanford, Inc. (BHI) procedures (BHI-EE-01), or an approved, equivalent PHMC or PNNL procedure unless specified otherwise by a test plan. Special handling requirements may be associated with the type of analysis, laboratory procedures for the analysis, or regulatory requirements BHI procedure 3.0, "Chain of Custody," and procedure 3.1, "Sample Packaging and Shipping."

A minimum of one 15 cm (6 in.) length of core (in sleeve) or one 1-pint sample jar will be set aside as archive samples for each sampling event, assuming sufficient sample material is recovered and or is available after sample allocation. The archived samples will be used for future analyses if needed, and also will support auditing activities. Archived cores will be retained in their original plastic (Lexan) liners and covered at the ends with Teflon caps. Teflon tape on plastic end caps is acceptable if Teflon caps are not available. The caps will be securely taped to the liner to achieve an airtight seal. Archive samples will be delivered with a completed chain-of-custody form to the Hanford Geological Sample Library for archival **after** temporary custody during the analysis phase when all samples have been taken from the core. All samples will receive a radiation release survey sticker prior to shipment. No drilling muds will be added to the borehole. Addition of other fluids such as water will be avoided unless absolutely necessary and approved by the well site geologist and project scientist. This is to allow for reliable determination on moisture content, make detection of moist zones or perched water zones easier, allow collection of representative moisture samples, and determine sorptive properties that are representative of actual subsurface conditions. Thus, considerable care must be take to avoid alteration of the natural state of the lithologic samples during the drilling and core recovery process. Drilling the boreholes during the cooler months of the year aids in preserving the natural moisture content of the sample.

2.6.1 Special Sampling for Projects

The foregoing sampling requirements address the needs of several special sampling efforts. However, more detailed bench instructions may be needed. These instructions will be prepared by the principal investigators involved and will be submitted to the project manager for concurrence prior to sample collection. This is to ensure that any special handling instructions are provided to the well site geologist and field staff in advance of drilling.

2.7 Borehole Geophysics

Geophysical logging provides data comparison with core-derived data for stratigraphic interpretation, density (porosity) estimation, and relative moisture content of the sediments drilled. Geophysical tools will be used to determine *in situ* moisture content, help define hydrostratigraphic units, and correlate these units among adjacent boreholes. They will also be used to identify any possible zones that are contaminated by gamma-emitting radionuclides. The boreholes will be logged in accordance with

WHC-CM-7-7, EII 11.1, "Geophysical Logging" or equivalent, approved PHMC procedure. Geophysical logging probes will include high-resolution spectral gamma probes, gamma density, neutron-epithermal-neutron, and may include gross gamma. Only proven techniques with procedures adequate to control the quality of the data will be used. After completion, each well will be re-logged with a sodium-iodide spectral gamma tool to provide a baseline for future radionuclide monitoring and tracking.

Optimal conditions for logging require that no more than one thickness of casing be present. This will require logging to be done in stages before each additional casing is telescoped into place.

2.8 Well Completion

The intent is to use the borehole as a RCRA-quality monitoring well (Sections 4.1.3 and 4.2.3 of Reidel et al. 1995). With the declining groundwater table in the area, the exact depth of the screen will have be determined. Once the water table has been reached, the project scientist, in conjunction with the RCRA project scientists, will determine the depth for the screen.

3.0 Groundwater Sample Collection Procedures

The following procedures supplement the description provided in Section 4.2.3 of the main body of this plan.

3.1 Sample Collection Field Measurement Procedures

The procedures for groundwater sample collection, chain-of-custody, water-level measurements, and field measurements include the following PNNL procedures or approved Waste Management procedures:

- PNNL Manual PNL-MA-567, Procedures for Ground-Water Investigations
- Waste Management Manual ES-SSPM-001, Rev. 5, Sampling Services Procedures Manual.

3.2 Analytical Methods

All groundwater analyses will be done under the existing contract between PNNL and Quanterra (contract number MW6-SBB-A19981). All procedures, preservation requirements and techniques, accuracy and precision, and methods will follow the contract specifications.

4.0 References

Bechtel Hanford Company. 1997. *Environmental Investigations Procedures*. Manual BHI-EE-01.

Kaplan, D. I. 1997. T*est Plan for Performing Kd Measurements on Borehole #1 Samples: Subtask 1A in Project ED8029*. Draft Letter report, Pacific Northwest National Laboratory, Richland, Washington.

Khaleel, R. 1997. *Test Plans for Measurement and Analysis of Vadose Zone Hydraulic Properties for the Tank Waste Disposal Site*. Fluor Daniel Northwest report: FDNW-ENI-98-008.

Murphy, E. M. 1997a. *Preparation of Samples for Chlorine-36 Analysis on Archived Sediments from the LLGPA Site*. Letter Report, Pacific Northwest National Laboratory, Richland, Washington.

Murphy, E. M. 1997b. *Tracer Measurements of Samples from Shallow Boreholes*. Letter Report, Pacific Northwest National Laboratory, Richland, Washington.

Reidel, S. P., and D. G. Horton. 1999. *Geologic Data Package for the 2001 Immobilized Low-Activity Waste Performance Assessment*. PNNL-12257, Pacific Northwest National Laboratory, Richland, Washington.

Reidel, S. P., A. M. Tallman, V. G. Johnson, C. J. Chou, S. M. Narbutovskih, and J. Kiesler. 1995. *Characterization Plan for the Proposed TWRS Treatment Complex*. WHC-SD-WM-PNL-109, Westinghouse Hanford Company, Richland, Washington.

U.S. Environmental Protection Agency (EPA). 1993. *Data Quality Objectives Process for Superfund - Interim Final Guidance*. EPA/540-R-93-071, Washington, D.C.

Washington Administration Code (WAC) 173-160. “Minimum Standards for Construction and Maintenance of Wells.” Olympia, Washington (as amended).

Appendix A2

Quality Assurance Project Plan - ILAW Site Borehole Number 2

Contents

Quality Assurance Project Plan

1.0 Project Description

1.1 Background Information

The subsurface activities covered by this plan are part of the overall characterization effort as described by Reidel et al. (1995). This effort will provide data for the performance assessment of the Immobilized Low-Activity Waste (ILAW) Site disposal for the Office of River Protection (ORP). The characterization borehole considered in this plan will also be completed as a groundwater monitoring well. Thus, quality control/quality assurance (QC/QA) procedures related to both core sampling and groundwater sampling and handling are addressed. It should also be noted that this Quality Assurance Project Plan (QAPjP) is intended to be used in conjunction with other associated project plans (i.e., Field Sampling Plan (FSP) (Appendix A1 and Job Safety Analysis). Implementation of these plans will ensure that the: 1) site characterization efforts are conducted in a safe and efficient manner, 2) sampling and analysis activities are carried out to achieve the specified data quality goals, and 3) quality of data gathered can be monitored and documented.

1.2 Quality Assurance Project Plan Applicability and Relationship to PHMC Quality Assurance Program

This QAPjP applies specifically to various activities performed for characterization borehole/ groundwater monitoring well discussed in the plan. The QAPjP is an element of the FSP prepared specifically for this investigation and is consistent with other environmental work (EPA 1988a) and the overall quality program requirements of the River Protection Project Contractor. It is also designed to comply with the *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement 1998, Rev. 5). Distribution and revision control of the QAPjP will comply with RPP-PRO-261.

1.3 Schedule of Activities

Individual task scopes are described in the main body of this report and the FSP (Appendix A1). Drilling activities are planned to begin in FY 2001.

2.0 Project Organization and Responsibilities

2.1 Technical Lead Responsibilities

The Applied Geology and Geochemistry Organization of PNNL has primary responsibility for overseeing this characterization activity, but the drilling will be subcontracted by Bechtel Hanford Company, and support services will be provided by other PHMC companies.

2.2 Analytical Systems Laboratories

Samples will be routed to the appropriate PNNL building for physical properties testing and PNNL laboratories for chemical and mineral analyses specified by the following test plans: Kaplan (1997) and Khaleel (1997). All activities will be conducted in accordance with 10 CFR 830.120 and, where applicable, HASQAD (DOE 1998).

2.3 Health Physics

Because the proposed drill site is not in or near contaminated areas, a Radiation Work Permit and Health Physics support will not be necessary. The drill site will be located over suspected contaminant plumes, however, which will necessitate containing purgewater.

2.4 Transportation Logistics

PNNL or BHI shall provide guidance and instruction for the transport of samples. This shall include direction concerning proper shipping paperwork, marking, labeling, and packaging requirements.

2.5 Support Contractors

Procurement of any other contracted field activities shall be in compliance with applicable procedure requirements. All work shall be performed in compliance with PNNL-approved QA plans and/or procedures and shall be subject to standard internal and external quality auditing and surveillance controls. Applicable quality requirements shall be invoked as part of the approved procurement documentation or work order.

3.0 Objectives for Measurements

This project is a characterization activity to obtain data that will be used in the mathematical models for the performance assessment of the ILAW Site (see Chapter 3.0 of the main report). This chapter summarizes the data quality requirements to meet the intended use and objectives. Data quality requirements, however, are given in the appropriate test plans. The requirements are discussed in the following sections.

3.1 General Precision and Accuracy Objectives

As an outcome of the Data Quality Objective (DQO) process (Chapter 3.0, Reidel et al. 1995; Chapter 3.0 this report), the general requirement for precision (relative standard deviation [RSD] of 25%) and accuracy (margin of error = 10%) is intended for all phases of the ORP complex site and ILAW Site characterization effort. This guidance is consistent with that specified in *Low Level Waste Management Handbook Series: Environmental Monitoring for Low Level Waste Disposal Sites* (DOE 1990). However, the individual test plans take precedence for setting the precision and accuracy of the tests being performed. The general guidance or objective may be accomplished differently for the groundwater than for characterization based on lithologic samples. For example, groundwater characterization may require repeat sampling (e.g., quarterly for 3 years) to meet the general objective and/or to satisfy other regulatory or DOE Orders (e.g., for preoperational baseline monitoring).

3.2 Borehole Geologic Investigation

Intact and representative core samples are necessary for accurate characterization of subsurface geologic conditions and development of the geohydrologic model. Accurate interpretations of the subsurface geology, in turn, form the framework for performance assessment modeling of the subsurface. Cores provide the only means by which the geologic conditions in the borehole can be directly observed and analyzed. In addition, a comparison of core to analogous rocks in adjacent boreholes and exposed at the earth's surface are fundamental to the accurate interpretation of geologic conditions throughout the site.

The proposed coring program will accommodate sample collection for stratigraphic interpretation and analysis of physical and chemical properties. Geologic loggings of intact cores are the fundamental prerequisites for the stratigraphic interpretations needed to support geochemical and hydrologic conceptual modeling. Consequently, the objective of the geologic logging is to describe the observable geologic features found in the core. Procedures for geologic logging are described in PNL-MA-567, Section *Drilling Operations*, and BHI-EE-01, Section 7.0, *Geologic and Hydrologic Data Collection, Geologic Logging.*

Sampling Intervals. Physical and chemical properties are necessary for the interpretations, development of the geohydrologic model, and performance assessment modeling that are central to this characterization plan.

The geology of the ILAW Site has been described by Reidel and Horton (1999). Most of the vadose zone is a sandy unit of the Hanford formation, which is underlain by a gravelly unit of the same formation. The principal units of the saturated zone are the Ringold Formation gravels units E and A and possibly the lower mud. The vadose zone will be the principal unit sampled; tests plans by Kaplan (1997) and Khaleel (1997) provide rationale for the sampling design.

3.3 Groundwater Investigation

Data quality requirements for this task include measurements associated with both hydrologic testing and sampling and analysis for chemical constituents.

3.3.1 Hydrologic Testing

Hydrologic test data will be used to improve estimates of the rate and direction of groundwater movement. The velocity field for the flow system is a fundamental boundary condition. This information is derived from hydraulic conductivity data and gradient (water table elevations).

3.3.1.1 Water Table Elevation

This parameter is obtained by subtracting the depth to groundwater from the well casing elevation. Well casing elevations are required to be surveyed to within ±0.3 cm (±0.01 ft). Depth to water measurement equipment standards and calibration requirements are contained within PNL-MA-567, Procedure WL-1, Water Level Measurement Procedure, or equivalent, approved BHI procedures.

3.3.1.2 Hydraulic Conductivity

Hydraulic conductivity will be estimated from a slug test. The accuracy of hydraulic conductivity estimates are constrained by such items as natural hydrogeologic variations (anisotropic and nonhomogeneous conditions), partial penetration of aquifer, lack of observation wells, hydrogeologic boundaries, and other such hydrogeologic phenomenon. For these reasons, the DQO is to provide order-of-magnitude estimates for hydraulic conductivity.

Hydrogeologic conditions cannot be manipulated to meet the DQO of order-of-magnitude accuracy. In fact, the accuracy of the estimated hydraulic conductivity is not really known because the true value cannot be determined. Only indirect methods can be used to satisfy the DQO for hydraulic conductivity. These indirect methods will include calibrating or standardizing the measurement equipment to the tolerances set in BHI-EE-01, Procedure 7.1, "Aquifer Testing," or PNL-MA-567, Aquifer Testing Procedures (AT-4, AT-5, AT-6, AT-7, and AT-8), or equivalent Hanford Site approved procedure, conducting the tests using approved procedures, and using industry accepted analysis methods to interpret the test data. Acceptable industry analysis methods include Cooper-Jacob (Cooper and Jacob 1946), Neuman (1975), Bouwer (1989), and Cooper-Jacob-Papadopulos (Cooper et al. 1967).

4.0 Sampling Procedures

4.1 Procedure Approvals and Control

All procedures required for sampling activities shall be approved and shall comply with applicable PNNL procedures. PNNL sampling procedures are those described in PNL-MA-567, "Drilling Operations Procedures." Applicable procedures include DO-1, "Collection and Documentation of Borehole Samples and Well Construction Data;" DO-2, "Split-Barrel Auger Sediment Sampling;" and DO-4, "Contaminated Sediment Sampling."

4.2 Sampling Procedures

This section describes procedures related to collecting samples for geological, hydrochemical, and other investigations.

4.2.1 Geologic Sampling

All geologic sampling shall be performed in accordance with BHI-EE-01, Procedure 4.0, "Soil and Sediment Sampling" or PNNL Procedure DO-1, "Collection and Documentation of Borehole Samples and Well Construction Data;" DO-2, "Split-Barrel Auger Sediment Sampling;" and DO-4, "Contaminated Sediment Sampling." All boreholes shall be logged in compliance with PNL-MA-567, Procedure DO-1, "Collection and Documentation of Borehole Samples and Well Construction Data," except when otherwise directed by the project scientist. Sample size, sample support, types, location, and other site-specific specifications are defined in the FSP (Appendix A1). Sample container selection shall be in accordance with PNNL-approved BHI procedure BHI-EE-01, Procedure 4.0, "Soil and Sediment Sampling."

4.2.2 Hydrochemical Sampling

Groundwater sampling will be conducted as described in the FSP (Appendix A1) and Section 4.2.3 of the main body of this characterization plan (Reidel et al. 1995).

4.3 Other Procedures

If it is determined that other procedures are required that have not already been identified in this QAPjP, they will be identified in the appropriate task plan. Documentation requirements shall be addressed within individual procedures.

4.4 Procedure Changes

Should deviations from established procedures be required to accommodate unforeseen field situations, they may be authorized by the field team coordinator and subject to the approval of the buyer's technical representative for the RPP contractor.

5.0 Sample Custody

All samples obtained during the course of this investigation shall be controlled as required by PNNL approved BHI procedure BHI-EE-01, Procedure 3.0, "Chain of Custody," or Waste Management approved procedure ES-SSPM-001 5P1-1 from the point of origin to the analytical laboratory. Laboratory chain-of-custody procedures shall be reviewed and approved as required by CHG procurement control procedures and shall ensure the maintenance of sample integrity and identification throughout the analytical process. Chain-of-custody forms shall be initiated for returned residual samples. Results of analyses shall be traceable to original samples through the unique code or identifier specified in the FSP (see Appendix A1, Section 2.6). All results of analyses shall be controlled as permanent project quality records.

6.0 Calibration Procedures

All measuring and test equipment, whether in existing inventory or purchased for this investigation, shall be calibrated in compliance with the requirements of applicable procedures. Equipment that requires user calibration or field adjustment shall be calibrated as required by standard procedures for user calibration.

All calibration of laboratories measuring and test equipment shall meet the minimum requirements of *Laboratory Data Validation Functional Guidelines for Evaluating Inorganics Analyses*, Section II (EPA 1988b); *Laboratory Data Validation Functional Guidelines for Evaluating Organics Analyses*, Section III (EPA 1988c); and *Test Methods for Evaluating Solid Waste - Physical/Chemical Methods* (EPA 1986) or equivalent approved procedures. Such requirements shall be invoked through CHG procurement control procedures. Laboratory QA plans for the PNNL shall address laboratory equipment to be calibrated and the calibration schedules.

7.0 Analytical Procedures

Analytical methods are identified in the FSP (Appendix A1) and in appropriate test plans. All analytical procedures approved for use in this investigation shall require the use of standard reporting techniques and units wherever possible to facilitate the comparability of data sets in terms of precision and accuracy. All approved procedures shall be retained in the project QA records and shall be available for review upon request by the direction of the technical lead.

8.0 Data Reduction, Validation, and Reporting

Analytical data from sampling activities will be used primarily to determine the presence and amounts of analytes of interest in the sampled locations or intervals. Analytical laboratories shall be responsible for the examination and validation of analytical results to the extent appropriate. The requirements discussed in this chapter shall be invoked, as appropriate, in procurement documentation prepared in compliance with procedures. Results from all analyses shall be summarized in a validation report and supported by recovery percentages, QC checks, equipment calibration data, chromatograms, spectrograms, or other validation data if appropriate.

All validation reports and supporting data may be subjected to a detailed technical review by a qualified reviewer designated by the technical lead. All validation reports, technical reviews, and supporting data shall be retained as permanent project QA records in compliance with referenced procedures.

Statistical evaluations of validated data shall be based on appropriate methods identified through the DQO process. Results of the statistical evaluations shall be provided to the technical lead on a timely basis so that subsequent data collection activities, if necessary, can be planned based on another iteration of the DQO process.

9.0 Internal Quality Control

All activities will be conducted in accordance with 10 CFR 830.120 and, where applicable, the Hanford Analytical Services Quality Assurance Requirements Document.

The quality of analytical samples shall be subject to in-process QC checks in the field and the laboratory. Minimum requirements are defined as follows.

Unless otherwise specified in the FSP (Appendix A1), minimum field QC checks for groundwater sampling activities shall include the following:

- Duplicate samples—a minimum of 5% of the total collected samples shall be duplicated.
- Method (equipment) blank samples—the minimum number of blank samples shall be equivalent to 5% of the total number of collected samples. Blank sampling shall be evenly distributed throughout the entire sampling period.

Internal QC checks performed by the analytical laboratories shall be in compliance with approved analytical procedure requirements.

10.0 Performance and System Audits

Acceptable performance for this project is defined as compliance with the requirements of this QAPjP, its implementing procedures and appendices, and associated plans (e.g., the FSP [Appendix A1]). All activities addressed by this QAPjP are subject to surveillances of project performance and systems adequacy. Surveillances shall be conducted in accordance with appropriate PNNL procedures and shall be scheduled at the discretion of the cognizant quality engineer or technical lead.

11.0 Preventive Maintenance

All measurement and testing equipment used in the field and laboratory that directly affect the quality of the analytical data shall be subject to preventive maintenance measures. These measure are designed to minimize measurement system downtime. For this investigation, such measures are confined to laboratory equipment, because all field measurements are related either to the measurement of the sample interval or to the determination of radiological or other health and safety hazards. Laboratories shall be responsible for performing or managing the maintenance of their analytical equipment; maintenance requirements, spare parts lists, and instructions shall be included in individual methods or in laboratory QA plans. All QA plans shall be subject to RPP contractor review and approval.

12.0 Data Assessment Procedures

As discussed in Chapter 8.0, a data validation report shall be prepared by the analytical laboratory. This report shall summarize the precision, accuracy, and completeness of the analysis. The report shall compare actual analytical results with the objectives stated in the *Hanford Analytical Services Quality Assurance Program* (DOE/RL 1995). If the stated objectives for a particular parameter are not met, the situation shall be analyzed, and limitations or restrictions on the uses of such data shall be established. The validation report shall be reviewed and approved by the technical lead, who may direct additional sampling activities if DQOs have not been met. The approved report shall be routed to the project quality records and included within the reports that will be prepared for submittal to the regulatory agencies at the completion of activities.

13.0 Corrective Action

Corrective action requests required as a result of surveillance reports shall be documented and dispositioned as required by standard PHMC corrective action procedures. Primary responsibilities for corrective action resolution are assigned to the technical lead and the Quality Engineer.

Other measurement systems, procedures, or plan corrections that may be required as a result of routine review processes shall be resolved as required by governing procedures or shall be referred to the technical lead for resolution. Copies of all surveillance documentation shall be routed to the project QA records upon completion or closure.

14.0 Quality Assurance Reports

As stated in Chapters 10.0 and 13.0, project performance shall be assessed by the surveillance process. Surveillance documentation shall be routed to the project records upon completion or closure of the activity. A report summarizing surveillance activity, as well as any associated corrective actions, shall be prepared by the QA coordinator at the completion of the project.

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