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Pacific Northwest National Laboratory

Operated by Battelle for the U.S. Department of Energy

Characterization Plan for the Immobilized Low-Activity Waste Borehole

S. P. Reidel
K. D. Reynolds

March 1998

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

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MASTER

Pacific Northwest National Laboratory
Richland, Washington 99352

Summary

The U.S. Department of Energy's (DOE'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 in large underground tanks 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 by private vendors. The U.S. Department of Energy will receive the vitrified waste from private vendors and dispose of the low-activity fraction in the Hanford Site 200 East Area. The Immobilized Low-Activity Waste Disposal Complex (ILAWDC) is part of the disposal complex.

This report is a plan to drill the first characterization borehole and collect data at the ILAWDC. This plan updates and revises the deep borehole portion of the characterization plan for the ILAWDC by Reidel and others (1995). It describes data collection activities for determining the physical and chemical properties of the vadose zone and the saturated zone at and in the immediate vicinity of the proposed ILAWDC. These properties then will be used to develop a conceptual geohydrologic model of the ILAWDC site in support of the Hanford ILAW Performance Assessment.

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1.0 Introduction

The U.S. Department of Energy's (DOE's) 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 1997). These caustic wastes consist of many different chemicals and radionuclides, in the forms of liquids, slurries, salt cakes, and sludges.

The radioactive wastes came from various sources: 1) plutonium and uranium recovery processing of approximately 100,000 Mtu of irradiated fuel, 2) radionuclides recovery processing of tank waste, and 3) miscellaneous sources (e.g., laboratories and reactor decontamination solutions). The neutralized wastes contain sodium nitrate, sodium hydroxide, sodium aluminate, sodium phosphate, large amounts of organic materials in soluble solids, and approximately 260 MCi of radioactivity. The wastes are stored in 149 single-shell tanks (SSTs) and 28 double-shell tanks (DSTs).

The TWRS Program 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. The pretreatment and immobilization operations for both LAW and HLW will be privatized. After the request for proposal (RFP) for pretreatment and immobilization was issued (Wagoner 1996), contracts were awarded to two teams for the demonstration phase of tank waste immobilization.

Low-activity waste will be disposed of in the Immobilized Low-Activity Waste Disposal Complex (ILAWDC) which will be located in 200 East Area (Figure 1.1). A characterization plan was written for that complex following the Data Quality Objectives Process (Reidel et al. 1995). This plan is a revision to that original plan and provides information on the location of the first borehole to be drilled in support of the ILAWDC and the data to be collected from that borehole. This plan is cross referenced to the original plan of Reidel and other (1995) to provide background information and data. The data obtained from this borehole will support the final performance assessment (PA) of the ILAWDC and to characterize the subsurface.

1.1 Scope

This characterization plan presents a plan to drill the first characterization borehole and collect data at the ILAWDC. 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 any other portion of the original plan. Any other modifications or changes to the original plan will need to be addressed elsewhere.

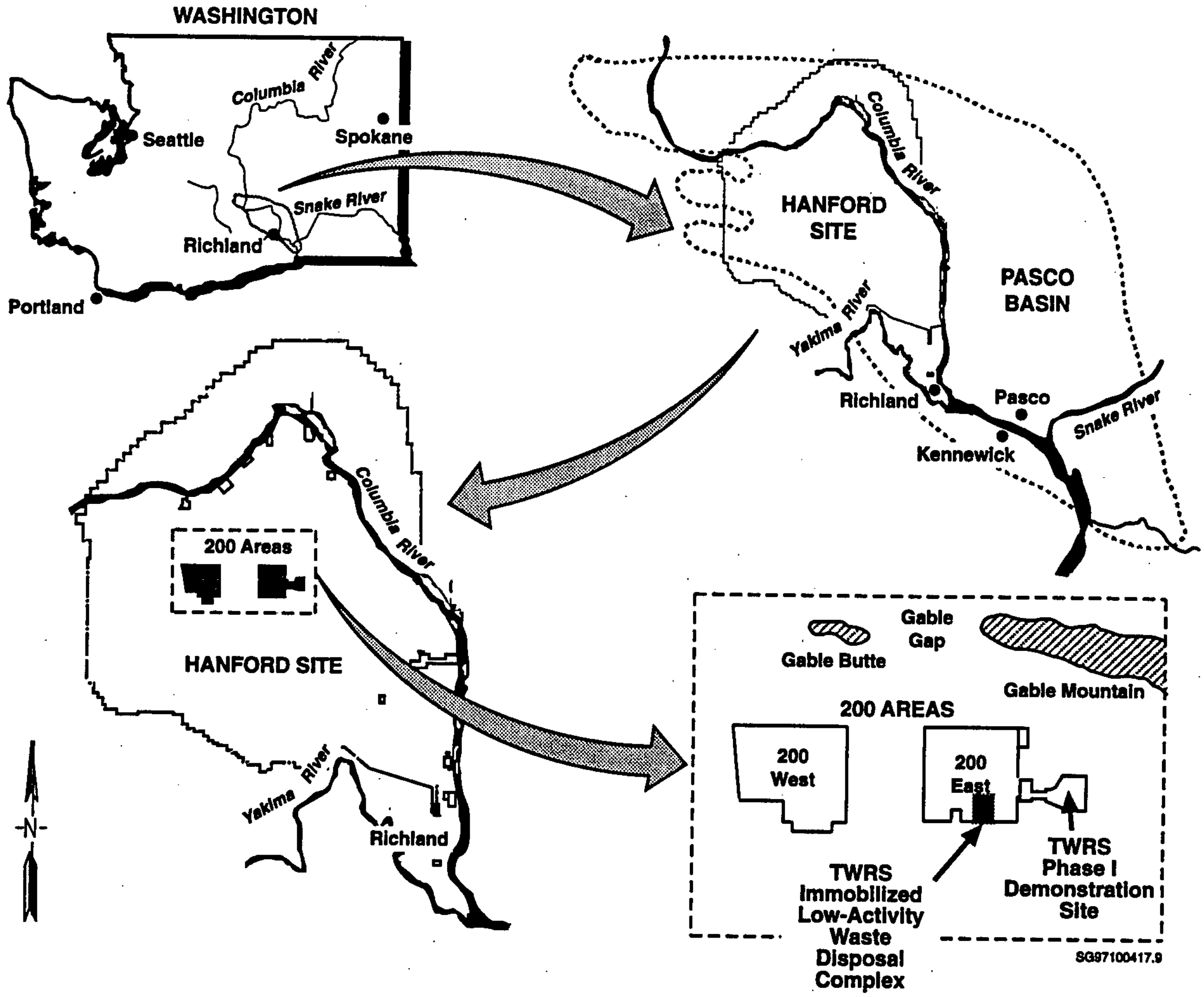

Figure 1.1. Locations of the Pasco Basin, Hanford Site, and the TWRS Privatization Areas in the 200 East Area

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 ILAWDC in support of the Hanford ILAW Performance Assessment.

The objective of the vadose and saturated zone characterization is to provide data to develop a conceptual geohydrologic model of the ILAWDC for use in the Hanford Immobilized Low-Activity Tank Waste Performance Assessment. This model will include geologic, hydraulic, and hydrochemical parameters as defined by the data quality objectives (DQO) process (EPA 1993) and developed by Reidel et al. (1995) for this project. The conceptual model will be used in the final PA 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.

1.3 Project Background

1.3.1 Phased Privatization Concept for Treatment of Tank Waste

The DOE is in the process of privatizing the treatment of most of the radioactive hazardous waste contained in the underground waste storage tanks on the Hanford Site. Privatization is defined as vendors, under contract with DOE, using private funding to design, permit, construct, operate, and deactivate their own equipment and facilities to treat radioactive hazardous tank waste. Payment for these services takes the form of fixed price per unit of product meeting DOE specifications.

Privatization activities have been divided into two phases. Phase I is a "proof of concept" phase to demonstrate the capabilities of privatization through the treatment of up to 13% of the tank waste at Hanford. Once demonstrated, privatization will be expanded to include the treatment of the remainder of the tank waste.

During Phase I, readily retrievable and well-characterized selected DST waste would be retrieved and processed in up to two separate demonstration facilities. The waste processed during Phase I could also include selected SST waste. Compositions of the LAW to be processed in Phase I are given in waste composition Envelopes A, B, and C in the RFP (Wagoner 1996), whereas HLW compositions are given in Envelope D. Both of the facilities would process liquid waste to produce immobilized LAW, whereas one facility would produce both immobilized LAW and HLW. The facility for LAW will be constructed separately from that processing HLW but both could be on the same site.

Phase I activities will be conducted in two parts. Phase IA will last 20 months with 16 months for planning and conceptual design by the private contractor followed by 4 months for DOE review. Phase IB will consist of plant construction and operation to process about 2800 MT of sodium waste as LAW. A possible extension of the Phase IB contract would produce an additional 2300 MT of sodium wastes as LAW. Phase IB is expected to last about 10 to 14 years with a 5- to 9-year process period. Up to 13% of the Hanford waste will be processed in Phase IB, which will conclude with the completion of facility deactivation.

The immobilized LAW (ILAW) would be sealed in packages at treatment facilities and then transported to an interim onsite storage facility, where it would be stored for eventual disposal. Between 13,000 and 18,000 ILAW waste packages, based on RFP specification, are expected to be produced during Phase IB. The four remaining grout vaults are now designated as a storage facility for approximately the first 5,000 ILAW packages (Project W-465, Immobilized LAW Interim Storage), with the remainder to be stored in the ILAWDC in the 200 East Area. The 200 East Area disposal site, previously called Low-Level Tank Waste Disposal Site, has been designated as Project W-520, LAW Disposal Complex. The LAW treatment facility would operate for a 10-year period.

Phase II of privatization would be implemented as a separate contract following successful implementation of Phase IB. Implementation of Phase II could involve continued operation of Phase IB facilities plus construction of a full-scale separations and LAW vitrification facility and a full-scale HLW vitrification facility. Phase II would include the retrieval and treatment of the remaining DST and SST waste, as well as the waste contained in miscellaneous underground storage tanks.

1.3.2 Location of Facilities

The two Phase I facilities will be located on the east side of the 200 East Area within the TWRS Phase I Demonstration Site (see Figure 1.1). This site originally was to be the Grout Treatment Facility (GTF) but the GFT project was canceled. The ILAWDC is planned for the south-central part of the 200 East Area (see Figure 1.1) (Shord 1995).

2.0 Background Information

The Hanford Site was established in 1944 as a U.S. Government nuclear materials production facility. During its history, Site missions have included nuclear reactor operation, storage and reprocessing of spent nuclear fuel, and management of radioactive and hazardous wastes. Present activities primarily involve management of radioactive, dangerous, and extremely dangerous waste. The inactive fuel reprocessing facilities and the radioactive waste management facilities are in the 200 East and 200 West Areas (Separations Area) and are owned by the DOE. These facilities are currently operated by the Project Hanford Management Contractor (PHMC). Fifty years of operations in these areas have resulted in the storage, disposal, and release of radioactive and/or hazardous wastes.

2.1 Geology

2.1.1 Geologic Setting of the Hanford Site

The Hanford Site lies within the Columbia Plateau, which is formed from a thick sequence of tholeiitic basalt flows called the Columbia River Basalt Group (CRBG). These flows have been folded and faulted over the past 17 million years, creating broad structural and topographic basins separated by asymmetric anticlinal ridges. Sediments up to 518 m (1,700 ft) in thickness have accumulated in some of these basins. Basalt flows of the CRBG are exposed along the anticlinal ridges, where they have been uplifted as much as 1,097 m (3,600 ft) above the surrounding area. Overlying the CRBG in the synclinal basins are sediments of the late Miocene, Pliocene, and Pleistocene ages. The Hanford Site lies within one of the larger basins, the Pasco Basin. The Pasco Basin is bounded on the north by the Saddle Mountains and on the south by Rattlesnake Mountain and the Rattlesnake Hills (Figures 2.1 and 2.2). Yakima Ridge and Umtanum Ridge trend into the basin and subdivide it into a series of smaller anticlinal ridges and synclinal basins. The largest syncline, the Cold Creek syncline, lies between Umtanum Ridge and Yakima Ridge and is the principal structure within the DOE waste management areas. The geology of the Hanford Site is described in detail in DOE (1988, Vol. 1).

2.1.2 Geology of the ILAWDC

The ILAWDC site is located in the 200 East Area (see Figure 1.1). The geology and hydrology of the 200 East Area has been the subject of much study and many reports over the past few decades (Myers et al. 1979; Myers and Price 1981; Gephart et al. 1979; Tallman et al. 1979; Graham et al. 1981; Routson and Johnson 1990; Lindsey et al. 1992). The principal source of geologic, hydrologic, hydraulic, and geochemical information in the area is from boreholes. Numerous boreholes have been drilled throughout the 200 East Area for groundwater monitoring and waste management studies. However, data are limited within the TWRS ILAWDC.

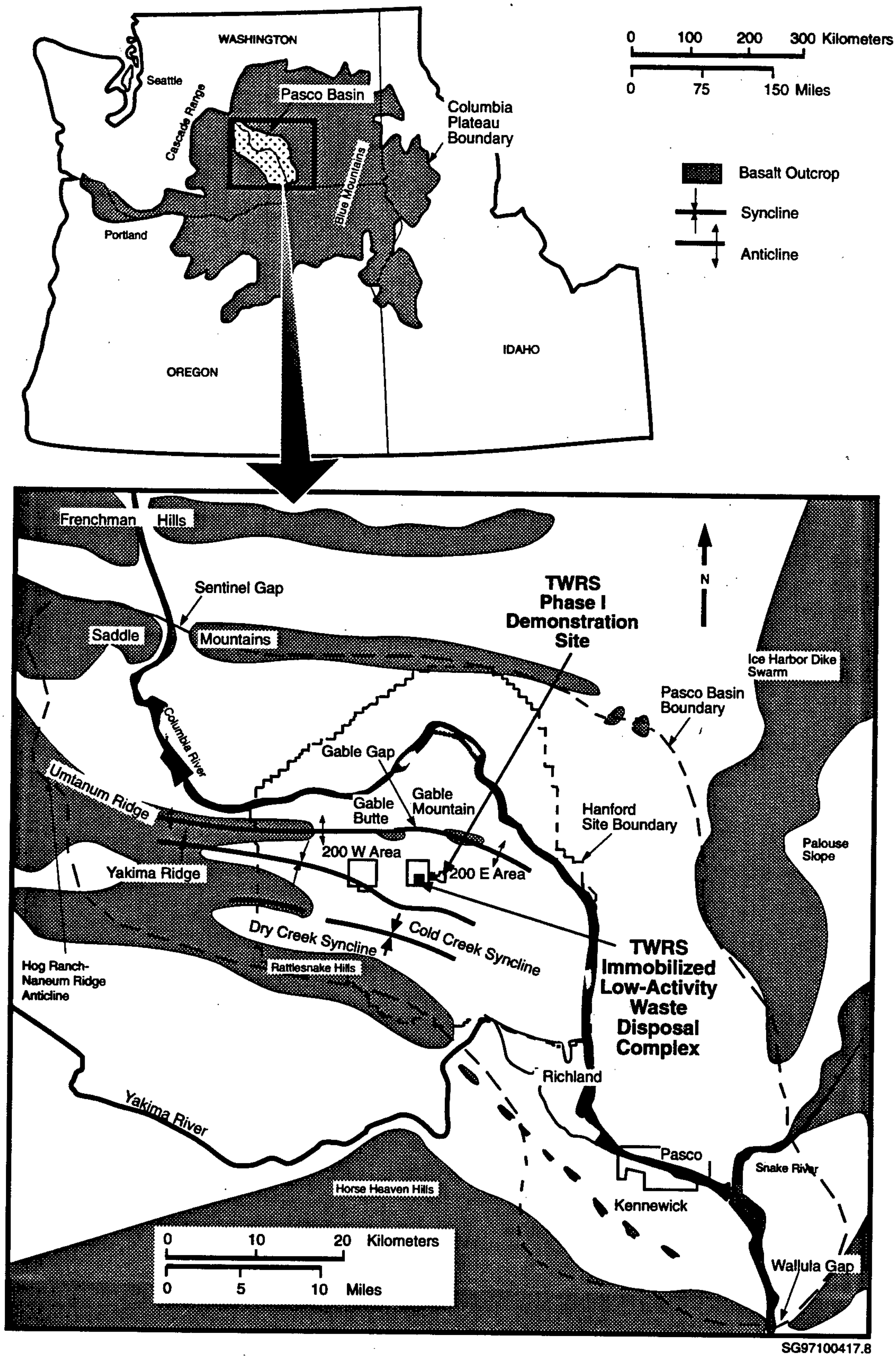

Figure 2.1. Geologic Structures Within and Adjacent to the Pasco Basin

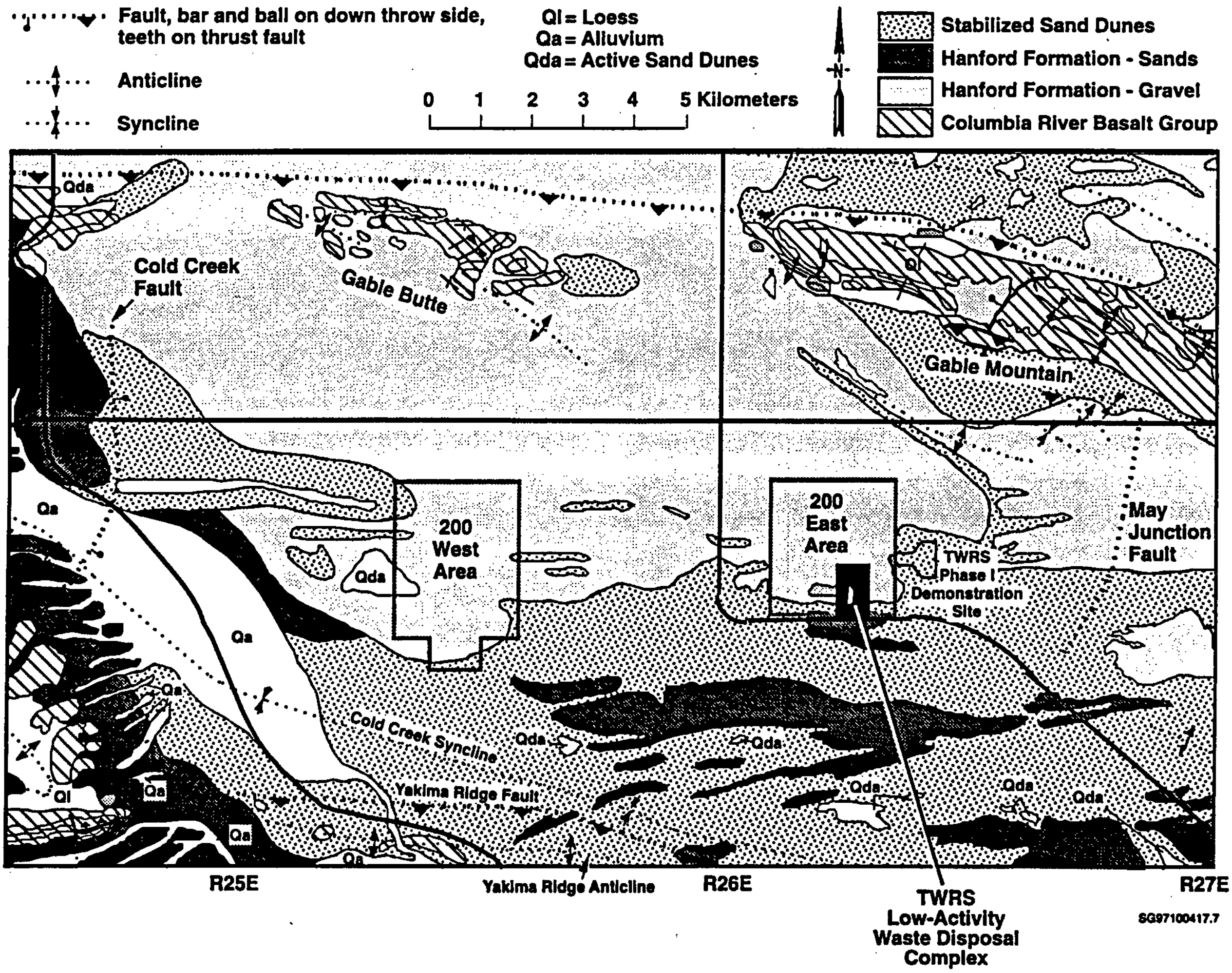

Figure 2.2. Geologic Map of the 200 Areas and Vicinity

The ILAWDC lies on the Cold Creek bar, a geomorphic remnant of the cataclysmic floods of the Pleistocene epoch. As the flood water raced across the lowlands of the Pasco Basin and Hanford Site, the flood waters lost energy and began leaving behind deposits of gravels.

The ILAWDC lies about 3 km (2 mi) north of the axis of the Cold Creek Syncline, which controls the structural grain of the basalt bedrock and Ringold Formation (see Figures 2.1 and 2.2). The basalt surface and Ringold Formation trend roughly southeast-northwest parallel to the major geologic structures of the site. As a result, the Ringold Formation and the underlying CRBG gently dip to the south off the Umtanum Ridge anticline into the Cold Creek syncline.

Geologic mapping at the Hanford Site has not identified any faults in the vicinity of the ILAWDC (see Figure 2.2) (DOE 1987, 1988). The closest faults are along the Umtanum Ridge-Gable Mountain structure north of the site and the May Junction fault east of the site.

The stratigraphy of the ILAWDC consists of the Columbia River Basalt Group overlain by the Ringold Formation, the Hanford formation and Holocene eolian deposits. The following discussion of the ILAWDC stratigraphy is based on information from the logs of boreholes 299-E24-7 and 299-E24-18 (Figure 2.3). Information from additional nearby boreholes was used to construct the interpretive cross-sections in Figures 2.4 and 2.5.

2.1.2.1 Ringold Formation

The Ringold Formation is a heterogeneous mix of variably cemented and compacted gravel, sand, silt, and clay. These strata record a history of alluvial-lacustrine sedimentation and pedogenic activity associated with the ancestral Columbia River system between 8 and 3 million years ago. The depositional system was a braided stream channel. Ringold Formation deposits in the Hanford Site represent an eastward shift of the Columbia River from the west side of the Hanford Site to the east side. The river eventually shifted to a course that took it through Gable Gap and south across the present 200 East Area and ILAWDC.

The Ringold Formation is 30 to 35 m (100 to 125 ft) thick at the ILAWDC and is dominated by gravels (see Figures 2.4 and 2.5). The Ringold Formation begins at about 100 m (330 ft) depth and continues to the top of the CRBG at about 137 m (450 ft) depth. The Ringold Formation consists primarily of gravel units A and E. Ringold Unit A is probably the predominant unit. Both units are consolidated sandy gravel to muddy sandy gravel.

Studies in the 200 East Area (e.g., Tallman et al. 1979) show that the lower mud pinches out somewhere between the eastern boundary of 200 East Area and the ILAWDC. It is interpreted to pinch out to the east of the ILAWDC or just under it; the lower mud is absent in borehole 299-E24-7 but probably is present farther south under the site. Where the lower mud unit is absent, gravel unit E directly overlies gravel unit A, and it impossible to differentiate the two units.

2.1.2.2 Hanford Formation

The Hanford formation is an informal name that represents all the deposits of the cataclysmic floods of the Pleistocene epoch (2 Ma to 13 ka) (see Figures 2.4 and 2.5). The floods came from glacial Lake Missoula which formed in the Clark Fork River valley behind continental glaciers that spread south as far as the present Columbia Plateau. The lake may have given way as many as 40 times, allowing impounded water to spread across eastern Washington and form the Channeled Scablands. These flood waters collected in the Pasco Basin and formed Lake Lewis, which slowly drained through the small water gap in the Horse Heaven Hills called Wallula Gap.

Three principal types of deposits were left behind by the Lake Missoula floods: 1) high-energy deposits consisting of gravel; 2) low-energy, slackwater deposits consisting of rhythmically bedded silt and sand, known as the Touchet Beds; and 3) coarse to fine sand deposits representing an energy transition environment. The Hanford formation typically has been divided into a variety of sediment types, facies, or lithologic packages. Recent reports dealing with the Hanford formation (i.e., Delaney et al. 1991; Reidel et al. 1992), have recognized three basic facies: 1) gravel-dominated, 2) sand-dominated,

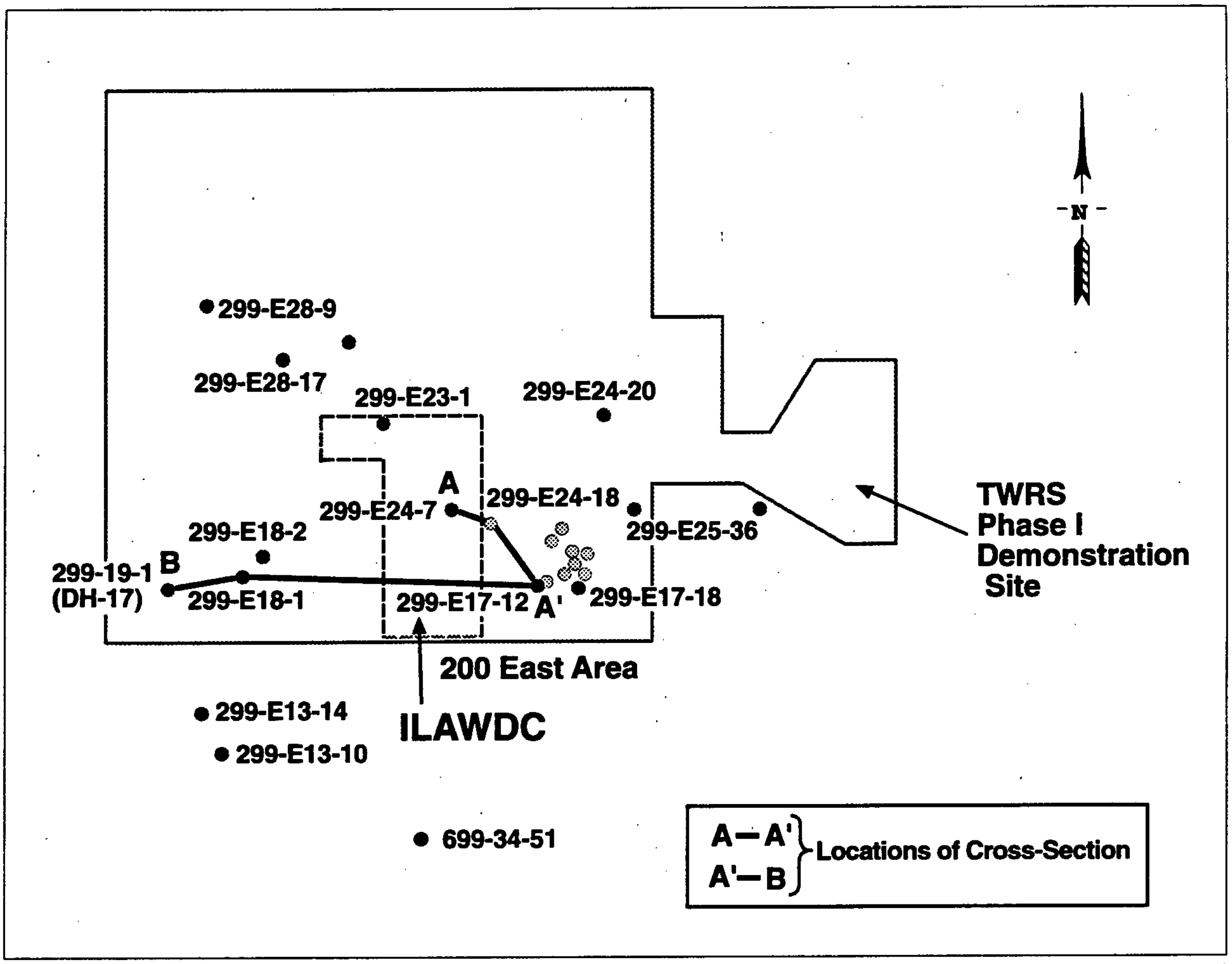

Figure 2.3. Boreholes Near the ILAWDC

and 3) silt-dominated. These facies generally correspond to the coarse gravels, laminated sands, and graded rhythmites, respectively (DOE 1988; Baker et al. 1991; and Delaney et al. 1991).

Gravel-dominated strata consist of coarse-grained sand and granule to boulder size gravel that display massive bedding, plane to low-angle bedding, and large-scale cross-bedding in outcrop. Matrix commonly is lacking from the gravels, giving them an open-framework appearance. The sand-dominated facies consists of fine- to coarse-grained sand and granules that display plane lamination and bedding and, less commonly, plane and trough cross-bedding. Small pebbles and pebbly interbeds (<20 cm [8 in.] thick) may be encountered in the sand dominated facies. The silt content of these sands varies, although where it is low, an open-framework texture may occur. The silt-dominated facies consists of silt and fine- to coarse-grained sand forming normally graded rhythmites. Plane lamination and ripple cross-lamination is common in outcrop.

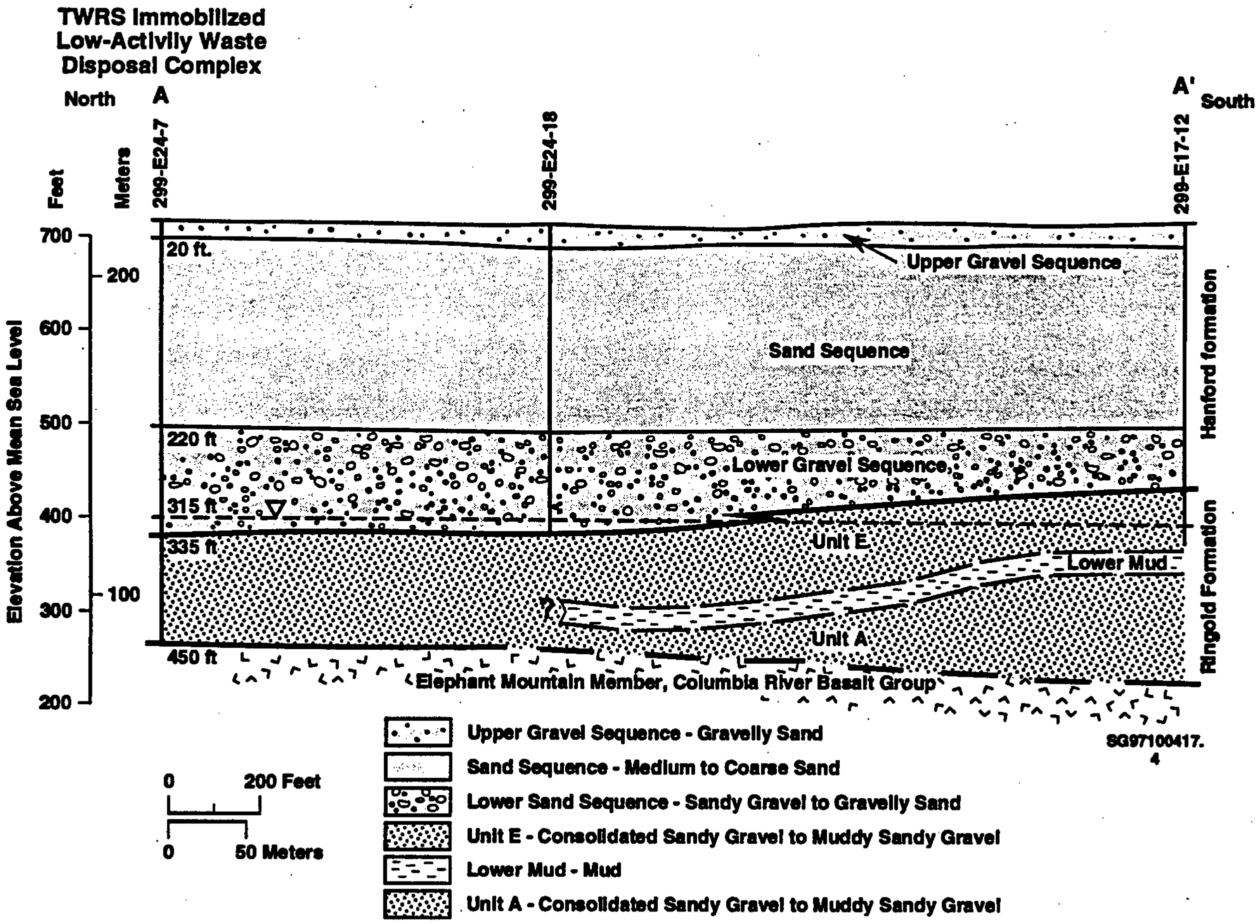

Figure 2.4. Geologic Cross Section A-A' at the ILAWDC

The Hanford formation is about 90 m (300 ft) thick at the ILAWDC and consists predominantly of sands and gravelly sands. The sandy sequence is interpreted to lie between a slightly gravelly sand and a lower sandy gravel to gravelly sand (see Figures 2.4 and 2.5). The Hanford formation thickens both to the north and south of the ILAWDC site. The lower gravel to gravelly sand is about 35 m (115 ft) thick and probably thins to the east on an irregular Ringold surface. The water table is probably in this lower gravel sequence. The Hanford formation sandy sequence is about 60 m (200 ft) thick and is the dominant facies in the ILAWDC area. The upper 6 m (20 ft) is composed of an irregularly distributed gravelly sand sequence.

2.1.2.3 Holocene Deposits

Holocene surficial deposits consisting of silt, sand, and gravel form a thin (<5 m [16 ft]) veneer across much of the Hanford Site. The southern 200 m (656 ft) of the ILAWDC are covered with a stabilized dune sand that is as much as 8 m (26 ft) high. "Old growth" sagebrush is present over much of the ILAWDC and in particular the sand dunes, indicating that the dune field has been stable since before the Hanford Site was established in the 1940s.

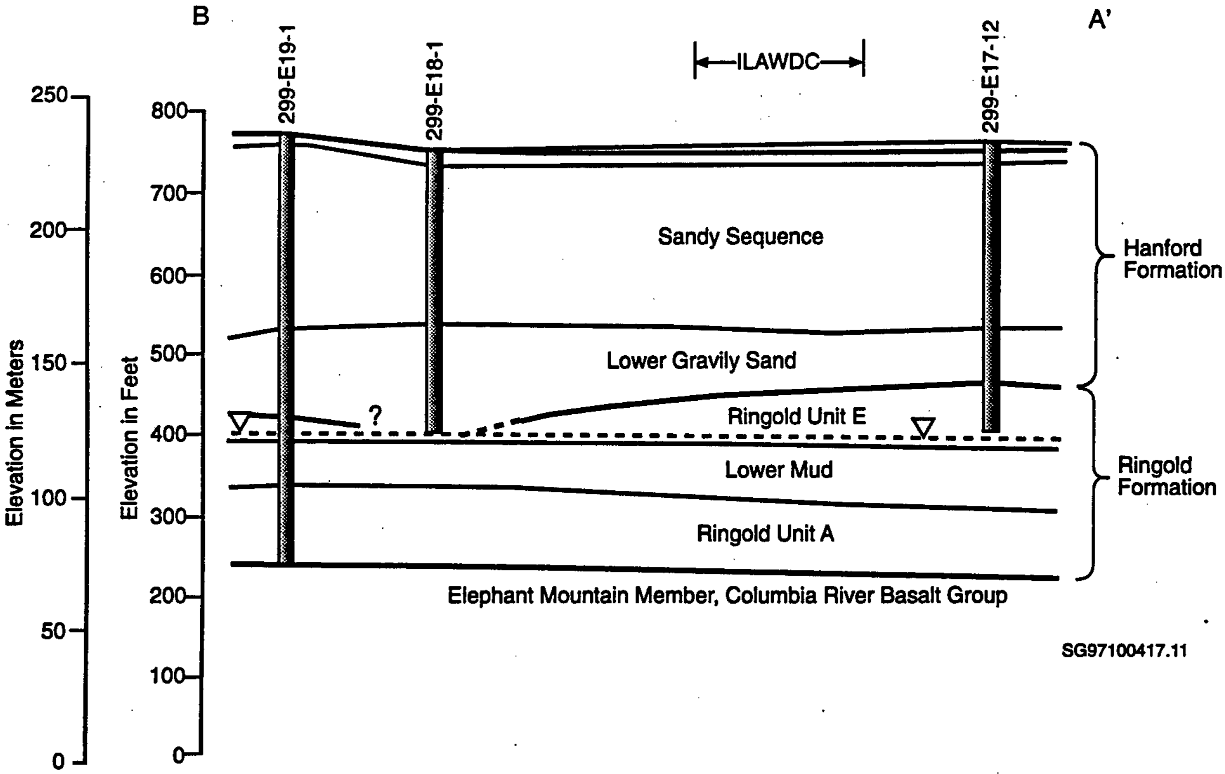

Figure 2.5. Geologic Cross Section B-B' at the ILAWDC

2.2 Hydrology

Hanford Site hydrogeology is discussed in several studies (DOE 1988, Vol. 2, Chapter 3; Gephart et al. 1979; Graham et al. 1981; Graham et al. 1984; and Delaney et al. 1991). The following sections summarize the Hanford Site and the ILAWDC site hydrology.

2.2.1 Hanford Hydrologic Setting

The Hanford Site has a semiarid climate and receives an average of 16 cm (6.25 in.) of precipitation per year. Mean annual runoff is estimated to be approximately 3% of the total precipitation. The remaining precipitation is assumed to be lost through evapotranspiration with a small component recharging the groundwater system (DOE 1988).

Primary surface-water features associated with the Hanford Site are the Columbia River and its major tributaries (the Yakima, Snake, and Walla Walla Rivers). West Lake, about 4 ha (10 acres) in size and less than 1 m (3 ft) deep, is the only natural lake within the Hanford Site (DOE 1988). Wastewater ponds, cribs, and ditches associated with nuclear fuel processing and waste disposal activities are also present on the Hanford Site.

Natural recharge rates are suggested to range from near 0 to more than 10 cm/yr (4 in./yr), depending on surface conditions (Gee 1987; Routson and Johnson 1990; Fayer 1997). Low recharge rates occur in fine-textured sediments where deep-rooted plants occur. Greater recharge is interpreted to occur in areas having a coarse gravelly surface and no vegetative cover (e.g., disturbed areas such as around the tank farms).

Approximately one-third of the Hanford Site is drained by the Yakima River system. Cold Creek and its tributary, Dry Creek, are ephemeral streams within the Yakima River drainage system. Both streams drain areas along the western part of the Hanford Site. Surface flow, which may occur during spring runoff or after heavier-than-normal precipitation, infiltrates and disappears into the surface sediments.

The hydrogeology of the Pasco Basin is characterized by a multiaquifer system that consists of four hydrogeologic units corresponding to the upper three formations of the CRBG and the sediments overlying the basalts. The basalt aquifers consist of the CRBG flood basalts and relatively minor amounts of intercalated fluvial and volcaniclastic sediments of the Ellensburg Formation. 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.

2.2.2 Uppermost Aquifer System

The uppermost aquifer system is generally unconfined regionally beneath the Hanford Site and lies at depths ranging from less than 0.3 m (1 ft) below ground surface near West Lake and the Columbia and Yakima Rivers to greater than 107 m (350 ft) in the central portion of the Cold Creek syncline. Groundwater in the aquifer system occurs within the glaciofluvial sands and gravels of the Hanford formation and the fluvial/lacustrine sediments of the Ringold Formation.

A water table map of the uppermost aquifer under the Hanford Site is shown in Figure 2.6. The position of the water table in the western portion of the Hanford Site is generally within Ringold Unit E gravels. The water table in the eastern portion of the Hanford Site is generally within the Hanford formation. Hydraulic conductivities for the Hanford formation (601 to 3,048 m/d [2,000 to 10,000 ft/d]) are much greater than those of the gravel facies of the Ringold Formation (186 to 930 m/d [610 to 3,050 ft/d]) (Graham et al. 1981). The main body of the unconfined aquifer generally occurs within the Ringold Formation.

The base of the uppermost aquifer system is defined as the top of the uppermost basalt flow. However, fine-grained overbank and lacustrine deposits in the Ringold Formation locally form confining or semi-confining layers for Ringold fluvial gravels underlying gravel unit A. The uppermost aquifer system is bounded laterally by anticlinal basalt ridges and is approximately 152 m (500 ft) thick near the center of the Pasco Basin.

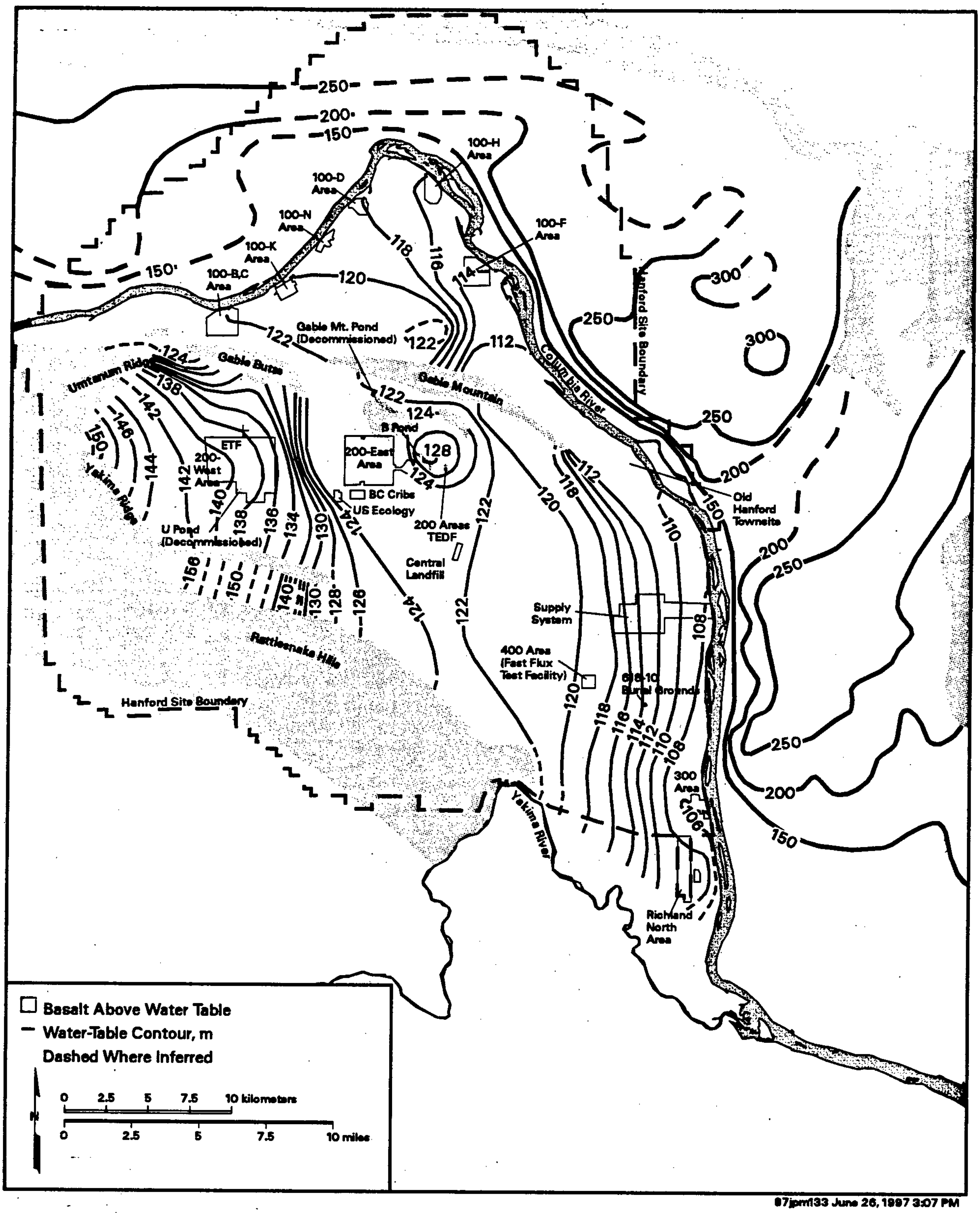

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Figure 2.6. Water Table Map for the Central Plateau

Sources of natural recharge to the uppermost aquifer system are rainfall and runoff from the higher bordering elevations, water infiltrating from small ephemeral streams, and river water along reaches of the Yakima and Columbia rivers. Discharge from the uppermost aquifer is primarily to the Columbia River (Graham et al. 1981; DOE 1987).

Artificial recharge to the uppermost aquifer occurs principally from Hanford Site wastewater disposal practices at surface ponds, ditches, and various cribs within the 200 West and 200 East Areas. Two of the largest recharge mounds have developed beneath the 200 East and 200 West Areas at B Pond and U Pond, respectively. Beneath U Pond, which was decommissioned in 1985, the water table had risen in excess of 26 m (85 ft) since the start of disposal operations. The mound under B Pond has risen more than 9 m (30 ft) (Graham et al. 1981). These facilities are associated with wastewater disposal from fuel and waste processing activities and receive or have received liquid effluents of varying chemical characteristics. With decreasing discharges to the groundwater, the elevation of the water table at these artificial mounds is decreasing.

Although the general groundwater flow direction in the vicinity of the 200 East Area is from west to east, artificial recharge due to the B-Pond system perturbs this general trend. For example, the resulting groundwater mound creates flow directions in the vicinity of the TWRS Phase I Demonstration Site that are currently opposite the natural west-to-east flow directions. The inferred flow direction at the ILAWDC is flat or can not be reliably estimated based on current water table elevations. As the influence of the groundwater mound diminishes with distance, the general west-to-east flow may prevail. In addition, as effluent stream discharge volumes continue to decline in the future, the perturbations in the groundwater flow direction discussed above will subside.

2.2.3 Hydrology of the ILAWDC

The uppermost aquifer in the vicinity of the ILAWDC is dominated by the fluvial gravel units A and E of the Ringold Formation. Because unit E directly overlies unit A in the northern part of the ILAWDC (see Figure 2.4), the two units cannot be differentiated there. The saturated thickness of units A and E, combined with the saturated portion of the Hanford formation, is approximately 40 m (135 ft) under the site and overlies the Elephant Mountain Member of the Columbia River Basalt Group.

The unsaturated zone, or vadose zone, beneath the land surface at the ILAWDC is approximately 96 m (315 ft) thick. The vadose zone consists of the Hanford formation. Borehole 299-E24-7 in the northeast corner of the ILAWDC (see Figure 2.4) indicates that the water table is at an elevation of approximately 120 m (400 ft) in the lower gravel sequence of the Hanford formation. The contact between the Hanford and Ringold formations is 6 m (20 ft) lower than the water table.

2.3 Groundwater Quality

2.3.1 Contaminant Plumes at the ILAWDC

Plume maps for the major groundwater contaminants in the 200 West and 200 East Areas and the ILAWDC were discussed by Reidel et al. (1995). The most recent update of this information is by Hartman and Dressel (1997) in the annual groundwater monitoring report for fiscal year 1996. In summary, the only contaminant beneath the ILAWDC borehole site is tritium.

3.0 Data Quality Objectives Process

Chapter 3.0 addresses the relevant components of the general data quality objectives (DQO) process as they apply to the subsurface characterization data needs to support the ILAWDC performance assessment. This section is derived from Reidel et al. (1995) and is included for completeness.

3.1 Description of Data Quality Objective 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 3.3)
- decision and expected action (Section 3.4)
- decision inputs (Section 3.5)
- study boundaries (Section 3.6)
- decision rule (Section 3.7)
- limits on decision errors (Section 3.8)
- optimize sampling design (Section 3.9).

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 minimizes 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 data quality, 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.

3.2 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, Licensing Requirements for Land Disposal of Radioactive Wastes (commercial LAW sites)

- site-specific characterization needs for the performance assessment (DOE Order 5820.2A).

Although the ILAWDC is not a commercial site, the guidance documents (e.g., DOE 1990b) 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 PA modeling[1]; 2) acquire information on the nature and presence of manmade 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 PA 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.

3.3 Statement of Problem

To develop the DQOs that adequately address subsurface characterization data needs at the ILAWDC, the overall performance objective or goal must be identified. One objective of the PA for the ILAWDC 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) PA. The near field includes the waste package and vault and the far field extends beyond the vault. The scoping study of Piepho et al. (1995) 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 100 m (328 ft) downgradient from the waste source. This is the scenario chosen by Kincaid et al. (1993) and Piepho (1994) for the grout PA.

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

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 100 m (328 ft) downgradient from the site to assess the maximum or peak doses during the first 10,000 years.

3.3.1 Conceptual Model Considerations

Part of 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 Peipho et al. (1995) analysis was similar to that used in the Grout PA (Kincaid et al. 1993; Piepho 1994). Differences between the two models include

- a concrete vault is already highly cracked (1-mm crack for every 1 m of concrete) (Kincaid et al. 1993)

- 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) (Piepho 1994)

- no clay cap exists above the gravel wedge (Kincaid et al.).

The Piepho (1994) analysis used only one glass release rate (10^{-5} cm/yr or $7.1X^{-4}$ g/d-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 PA, it still represents a degraded long-term waste disposal facility. The transport parameters determined in the ILAWDC-Glass Interim PA 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 3.5.1 describes the importance of each of the transport parameters included in Peipho et al. (1995).

3.3.2 Resource Constraints

At this time, only one borehole will be drilled.

3.4 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?**

While 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 3.7.3).

3.5 Decision Inputs

Piepho et al. (1995) used PA 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 ILAWDC project at Hanford for long-term disposal of LAW.

The importance of each of the transport parameters included in Peipho et al. (1995) 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.

3.5.1 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 parameters are needed to determine compliance with regulatory criteria or with the overall performance objective:

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

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

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

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

5. **Hydraulic parameters** - Hydraulic parameters have some importance for low recharges but are 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. The porosity of the Ringold Formation was the least important parameter of the entire set of parameters.

6. **Bulk densities** - Bulk densities can be important for low recharges but bulk densities are better modeled by the product of the solid particle density and (1 - porosity), because the porosity has to be determined anyway and the solid particle density is fairly constant (around 2.75 g/cm^3).

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

3.5.2 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** - These K_ds are very important for both low recharges and high recharges.

2. **K_d of Np-237 in waste matrix** - The K_d of Np-237 is very important for both high recharges and low recharges.

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

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

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

3.5.3 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** - Solubilities are not important in the 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 current and future recharge depend on climate, vegetation, and soil properties 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 retardation is a function of moisture content or not and whether the K_d parameter itself is a function of moisture content or not. Since 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 that the 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** - Based on K_d measurements, colloidal phases of transuranics and other radionuclides leached from the waste form may travel more rapidly through the vadose zone than previously thought. 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). While no laboratory or field evidence exists at the Hanford Site to support this claim, it cannot be ruled out and is therefore included in this PA data needs exercise.

3.5.4 Summary of Subsurface or Far-Field Characterization Data Needs

The critical question for subsurface or far-field characterization as it applies to PA parameter needs (Sections 3.5.1, 3.5.2, and 3.5.3) is as follows:

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

3.5.4.1 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.

3.5.4.2 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 retention of colloidal phases in the Hanford and Ringold sediments 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.

3.5.4.3 Infiltration Rate and Spatial Variability

The preliminary PA 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 the spring of 1995 to obtain better recharge estimates for a 10,000 year timeframe. The importance of this information to addressing PA issues and the very high uncertainty in present infiltration values dictates the need for obtaining additional high-quality recharge data.

3.5.4.4 Vadose Zone Hydraulic Parameters

The Peipho 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, and K_ds (see Table 4.1).

3.5.4.5 Aquifer Properties

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

3.6 Study Boundaries

Section 3.6 identifies the spatial and temporal domain boundaries and types of additional data needed to address the primary decisional questions stated in Sections 3.4 and 3.5.4. 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.

3.6.1 Spatial Boundaries

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

3.6.1.1 Geographic Domain

The area within which the primary decisional question (Section 3.4) will be addressed for the ILAWDC is within the physical boundary of the disposal facility (see Figure 1.1) plus a 100-m wide compliance area surrounding the ILAWDC. The 100-m distance is 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, penetrating at least 5 m into the saturated zone and completed as multi-purpose characterization and monitoring wells, 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 of the ILAWDC and two down gradient locations. This configuration would provide hydrochemical characterization data as well as potential monitoring wells for preoperational and operational groundwater monitoring if such monitoring required. The use of existing stratigraphic and soil property data from adjacent wells will require only a limited number of new characterization wells.

3.6.1.2 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 1) the upper gravel sequence, 2) the middle sands, 3) the lower gravels, and 4) the saturated zone of the lower gravels (see Figures 2.4 and 2.5).

3.6.2 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).

3.6.2.1 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-yr 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 flood waters over the site, wetter and/or drier conditions, etc.) will be very likely to occur. Thus, even though the model predictions may extend far beyond the 10,000-yr temporal boundary, the computation assumes that climatic conditions are constant for the entire period.

3.6.2.2 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). While 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 the low discharge case, in that the high discharge or irrigation scenario does not require determination of natural recharge rates. However, all other parameters are common to both cases.

3.7 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).

3.7.1 Statistical Parameters of Interest

Table 3.1 shows the parameters of interest and the statistical parameters needed to support the overall performance measure. The parameters are listed in order of relative importance.

3.7.2 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 PA is the maximum dose rate of 4 mrem/yr for the drinking water pathway. All of 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

Table 3.1. Parameters of Interest

Task	Properties/Parameters	Sampled Population	Statistical Parameters
Geochemical retardation	K_d for Tc-99, Uranium isotopes, Se-79, I-129, and Np-237	3 subpopulations in the vadose zone and 1 subpopulation in the saturated zone	Central tendency and dispersion
Recharge measurement	Recharge rates (long-term)	1/borehole (deep)	Central tendency
	Recharge rates (contemporary)	1/borehole (shallow)	Central tendency
Hydro-geological investigation	Hydraulic conductivity, porosity, bulk density, moisture	3 subpopulations in the vadose zone and 1 subpopulation in the saturated zone	Central tendency

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.

3.7.3 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., 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 TWRS/glass processing and handling activities in the 200 East Area.

3.8 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 <u>total study error</u>, which is directly related to the decision error.

A decision error occurs when the data lead the decision maker(s) to believe 1) the null hypothesis is false when it is actually true (a false positive) or 2) the null hypothesis is true when it is actually false (a false negative). To reduce such errors, an adequate estimate of key population parameters is needed. Reducing such error generally involves greater cost for sample collection and analysis. However, reducing decision error at an increased cost may or may not be the most desirable approach to take, especially at early stages 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 for a parameter of interest (μ) with some prescribed accuracy. In order 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, $d = |\bar{x} - \mu|$

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

where $z_{1-\alpha/2}$ is the $100(1-\alpha/2)\%^{th}$ quartile 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:

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

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 $100(1-\alpha/2)\%^{th}$ quartile 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 the number of needed samples (n) occur. Based on guidance in DOE (1990a), the level of confidence ($100[1-\alpha]\%$) 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., $100[1-\alpha]\% = 95\%$ 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 site-specific estimates 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 ILAWDC.

Uncertainty Due to Choice of PA Model. The consensus among the PA model experts on the DQO scoping team was that computed results could range considerably, simply due to the computer code and/or mathematical model used for the calculation of pathway doses. While 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 for all models. 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.

3.9 Optimizing 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), Chapter 4.0 of this report, 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 PA. However, other site-related information is required to satisfy construction and regulatory requirements. Some of these tasks can be integrated with the PA subsurface data acquisition activities. Accordingly, these additional data and information needs are included in Sections 3.9.1, 3.9.2, and 3.9.3 to facilitate development of an integrated or optimum sampling design for subsurface characterization of the proposed disposal site.

3.9.1 Information Categories

1. Estimates of population mean and/or subpopulation mean for 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 such as 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 1990a; 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.

3.9.2 Strategy Elements

3.9.2.1 Phased Approach

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

2. Use analog sites such as the submarine pit, US Ecology pit, or shallow boreholes drilled at the ILAWDC 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).

3.9.2.2 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 drill core.

3.9.2.3 Use Field Screening and Interpolation Methods to Minimize Laboratory Analyses

1. Measure unsaturated/saturated hydraulic conductivity over a 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.

3.9.2.4 Prioritize Parameters and Data Collection Tasks

Do the most important tasks first and archive samples for later analyses where possible.

3.9.2.5 Emphasize Realistic and Credible Scenarios for PA Input

Do not use population extremes for the median or mean values of key input parameters.

3.9.3 Sampling Considerations

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

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

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

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 Upper Unconfined Aquifer Characterization. The Site Monitoring study includes Environmental 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 (about 15 m) borehole construction and sample collection
4. Deep (at least about 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 4.1 under the study part(s) that the tasks support.

4.1 Geohydrologic Model Development

The disposal option considered for the ILAWDC PA 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 that will be disposed of in the ground. In order to assess the groundwater pathways portion of the waste disposal system performance, a detailed knowledge of the geohydrologic conditions of the site must be known.

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 Baseline 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 I-129, Cl-36, 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 I-129, Cl-36, 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 man made intrusions • 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, excavations)		• Locate shallow buried objects • Map textural variation (e.g., clastic dikes, excavations)
Electromagnetic induction		• Map clastic dikes to greater depth • Map vertical extent of textural units				
Borehole geophysics		• Determine physical properties - stratigraphy - hydrologic • Determine radionuclides present	• Determine physical properties - stratigraphy - hydrologic • Determine radionuclides present	• Determine radionuclides present	• Determine radionuclides present	• Determine radionuclides present

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 Baseline Plan	4.2.2 Vadose Zone Plan	4.2.3 Groundwater Plan
Existing hydrogeology and WIDS 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 geology mapping	• Determine surface geology, land forms and topography			• Determine surface geology, landform, and topography		
Analog studies		• Analog clastic dikes				
Miscellaneous field testing	• Characterize transfer line to B-C Cribs	• Recharge tests	• Aquifer testing to determine properties			

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 ILAWDC for the Hanford Immobilized Low-Activity Tank Waste Performance Assessment.

4.1.1.1 Determine the Physical and Geochemical Properties of the Vadose Zone

Objective. This task will determine the geologic, hydrologic, and geochemical properties for the ILAWDC. These properties provide parameters for a quantitative conceptual model of the site that will be used in the PA 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 Table 4.2. These data are derived specifically from the following test plans: Kaplan (1997), Khaleel (1997), and Murphy (1997a and 1997b).

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

Deep Boreholes. The number and placement of the deep boreholes for the ILAWDC is 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 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 ILAWDC site, a meeting was held with all the data users of the samples from the borehole. It was decided to move the location of the first borehole (borehole 3, Reidel et al. 1995) to the southwest corner of the site (Figure 4.1). This new location meets all the original performance measures for the boreholes except as a monitoring well it may no longer be directly downgradient of the site because of the flatness of the water table and changing site groundwater conditions. The primary objective of this borehole is not aquifer characterization but vadose zone characterization. Borehole number 2, however, still remains downgradient and can serve as a downgradient well. The advantage of locating the borehole at the

Table 4.2. Tests to be Performed on Borehole Samples and Data Uses

Test \ Use	Chemical Transport Studies[(a)]	Physical properties of Vadose Zone[(b)]	Estimating Recharge by Environmental Tracers[(c)]	Aquifer Characterization[(d)]
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	
Gravimetric moisture	X	X	X	
Bulk density	X	X	X	X
Particle density	X	X	X	
Particle size	X	X	X	X
Initial Porosity		X	X	X
Porosity		X		X
Unsaturated hydraulic conductivity		X	X	
Saturated hydraulic conductivity		X	X	X
Moisture retention	X	X	X	
Chloride			X	
Pore water extraction for H^3			X	
Groundwater Composition				X
Aquifer Testing				X

(a) Reidel et al. (1995), Section 4.1.2.3.4 as revised by Kaplan (1997).
(b) Reidel et al. (1995), Section 4.1.2.1 as revised by Khaleel (1997).
(c) Reidel et al. (1995), Section 4.1.2.3.3 as revised by Murphy (1997b).
(d) Reidel et al. (1995), Section 4.1.3.

southwest corner is that the closest vadose zone characterization borehole on the west side of the ILAWDC is near the southwest corner of the 200-East Area, 1.4 km from this site (see Figure 2.3). The new location provides important vadose zone and saturated zone characterization data in a part of the 200-East Area where data are lacking.

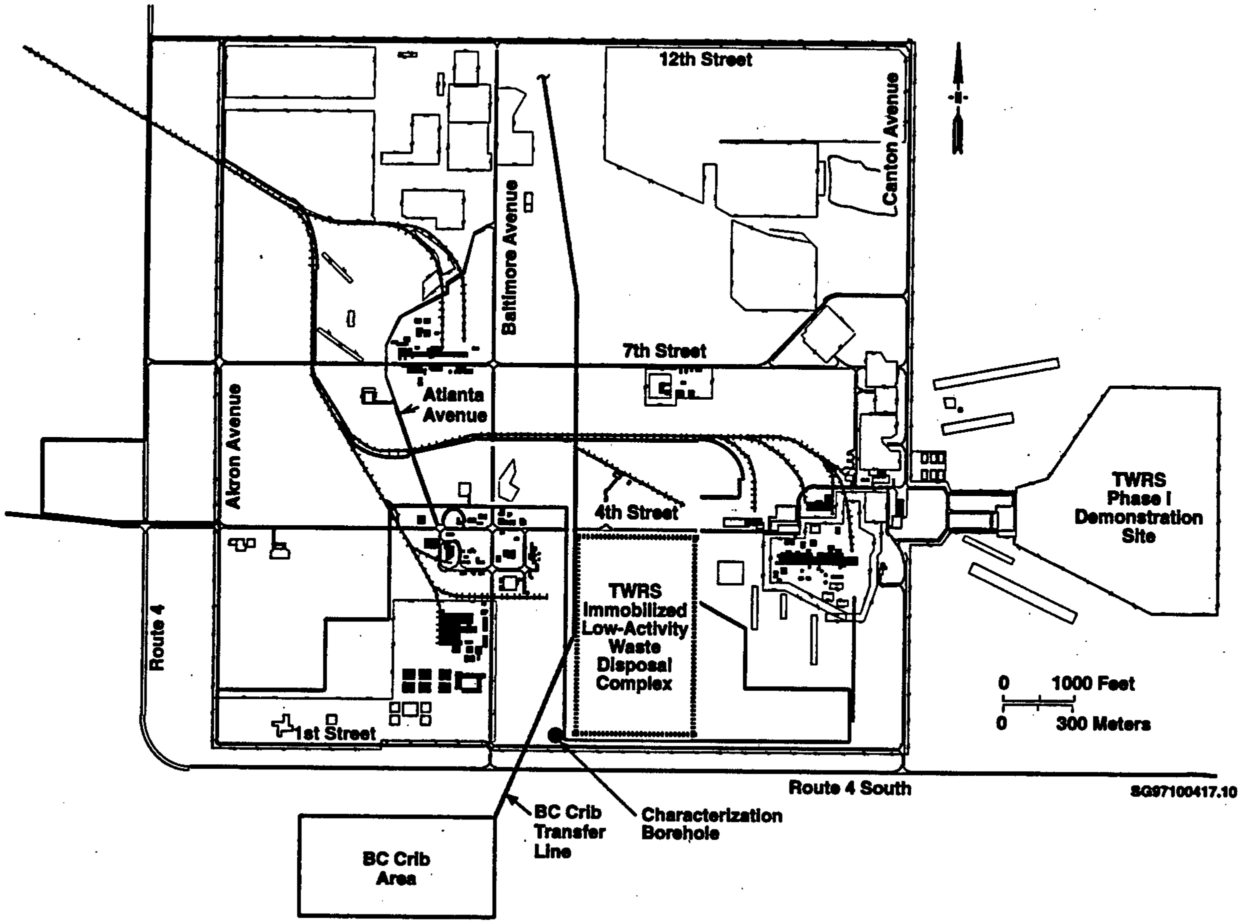

Figure 4.1. Location of ILAWDC Characterization Borehole

Shallow Boreholes. Shallow boreholes are required to support infiltration studies. The number, justification, and requirements of these boreholes are described by Murphy (1997a and 1997b). Murphy (1997b) states that at least two of the shallow boreholes will be located near the deep borehole considered in this plan.

4.1.1.2 Vadose Zone Characterization Activities

Vadose zone characterization is accomplished by constructing 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 ILAWDC. The boreholes also provide access for geophysical logging of the subsurface.

Boreholes.

Deep Borehole. The borehole addressed in this plan will be drilled through the vadose zone and saturated zone into the top of the uppermost Columbia River Basalt group flow. 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 Table 4.2 (also see Appendix A, Kaplan [1997], Khaleel [1997], and Murphy [1997b]).

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.

Shallow Boreholes. The shallow boreholes will be constructed after completion of the deep borehole on the southwest corner of the site. The samples from these boreholes will be used to measure the presence of specific isotopes related to climatic trends of the Pleistocene and fallout from the 1940s. In addition, the boreholes will be logged and samples collected to support model development of the vadose zone following the same procedures as the deep boreholes.

Geophysical Logging. All boreholes (deep and shallow) will be geophysically logged. Geophysical logging will provide data comparison with core derived data for stratigraphic interpretation, density (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 ILAWDC 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 such as redox status, sorption, solubility, chemical precipitation, and/or isotope exchange reactions that influence contaminant migration rate. 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 this report), it was decided that the characterization borehole considered in this plan should be completed as a 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 unconfined aquifer is about 50 m (155 ft) thick at the ILAWDC and is probably within the Ringold Units A and E and possibly also the lower mud. Aquifer testing elsewhere on the site (WHC 1992) has shown that the unconfined aquifer can have variable properties vertically through the aquifer. At some localities at the Hanford Site it has been argued that hydraulic conductivities of the aquifer are higher at greater drilled depths.

It was decided that characterization should focus on the upper portion of the aquifer because the vadose zone is the primary area of concern in this plan but that characterization should include the deep aquifer as well. Therefore, this borehole will be drilled to the lower portion of the aquifer but will be completed as a groundwater monitoring well in the upper part of the aquifer. This will allow one deep borehole at the northern end of the site, existing borehole 299-E24-7, and one at the southwest end, the new borehole. The stratigraphy encountered in the new borehole can be compared to that encountered in borehole 299-E24-7 to determine if the lower mud sequence of the Ringold Formation is present at the south end of the ILAWDC and if there are any variations in the Ringold Formation across the site.

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 drilling of the 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. Two intact sediment cores will be taken to provide representative samples for stratigraphic description, testing, analyses of physical and chemical parameters, and design of the monitoring well. Cores 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 Appendix A1). 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. When the other two, new wells are completed a constant rate discharge test can be run. A separate test plan will be written for the two well aquifer testing after installation of this borehole and prior to the installation of the other two wells.

5.0 References

10 CFR 61, Code of Federal Regulations, Title 10, Part 61. *Licensing Requirements for Land Disposal of Radioactive Waste.*

Baker, V. R., R. N. Bjornstad, A. J. Busacca, K. R. Fecht, E. P. Kiver, U. L. Moody, J. G. Rigby, D. F. Stradling, and A. M. Tallman. 1991. "Quaternary Geology of the Columbia Plateau." *The Geology of North America*, Vol. K-2, Quaternary Nonglacial Geology, Conterminous U.S.

Blush, S. M., and T. H. Heitman. 1995. "Train Wreck Along the River of Money." *An Evaluation of the Hanford Cleanup*, Report for the U.S. Senate Committee on Energy and Natural Resources.

Delaney, C. D., K. A. Lindsey, and S. P. Reidel. 1991. *Geology and Hydrology of the Hanford Site: A Standardized Text for Use in Westinghouse Hanford Company Documents and Reports.* WHC-SD-ER-TI-0003, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

DOE Order 5820.2. *Radioactive Waste Management.* U. S. Department of Energy, Washington, D.C.

Fayer, M. J.. 1997. *Estimated Recharge Rates at the Existing Disposal Site*. Letter Report: Task 6. S1W03495.

Gee, G. W. 1987. *Recharge at the Hanford Site: Status Report.* PNL-6403, Pacific Northwest Laboratory, Richland, Washington.

Gephart, R. E., R. C. Arnett, R. G. Baca, L. S. Leonhart, and F. A. Spane, Jr. 1979. *Hydrologic Studies Within the Columbia Plateau, Washington: An Integration of Current Knowledge.* RHO-BWI-ST-5, Rockwell Hanford Operations, Richland, Washington.

Gilbert, R. O. 1987. *Statistical Methods for Environmental Pollution Monitoring.* Van Nostrand Reinhold Company, New York, New York, pp. 30-42.

Graham, M. J., M. D. Hall, S. R. Strait, and W. R. Brown. 1981. *Hydrology of the Separations Area.* RHO-ST-42, Rockwell Hanford Operations, Richland, Washington.

Graham, M. J., G. V. Last, and K. R. Fecht. 1984. *An Assessment of Aquifer Intercommunication in the B-Pond - Gable Mountain Area.* RHO-RE-ST-12P, Rockwell Hanford Operations, Richland, Washington.

Hartman, M. J., and P. E. Dresel (eds.). 1997. *Hanford Site Groundwater Monitoring for FY 1996.* PNNL-11470, Pacific Northwest National Laboratory, Richland Washington.

Hanlon, B. M. 1997. *Waste Tank Summary Report for Month ending August 31, 1997.* HNF-EP-0182-113, Lockheed Martin Hanford Company, Richland, Washington.

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

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

Kincaid, C. T., J. A. Voogd, J. W. Shade, J. H. Westsik, Jr., G. A. Whyatt, M. D. Freshley, M. G. Piepho, K. A. Blanchard, K. Rhoads, and B. G. Lauzon. 1993. *Performance Assessment of Grouted Double Shell Tank Waste Disposal at Hanford.* WHC-SD-WM-EE-004, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Lindsey, K. A., B. N. Bjornstad, J. W. Lindberg, and K. M. Hoffman. 1992. *Geologic Setting of the 200 East Area: An Update.* WHC-SD-EN-TI-012, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Myers, C. W., and S. M. Price (eds.). 1981. *Subsurface Geology of the Cold Creek Syncline*, "Bedrock Structure of the Cold Creek Syncline Area." RHO-BWI-ST-14, Rockwell Hanford Operations, Richland, Washington.

Murphy, E. M. 1997a. *Preparation of Samples for Chlorine-36 Analyses 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.

Myers, C. W., S. M. Price, J. A. Caggiano, M. P. Cochran, W. H. Czimer, N. J. Davidson, R. C. Edwards, K. R. Fecht, G. E. Holmes, M. G. Jones, J. R. Kunk, R. D. Landon, R. K. Ledgerwood, J. T. Lillie, P. E. Long, T. H. Mitchell, E. H. Price, S. P. Reidel, and A. M. Tallman. 1979. *Geologic Studies of the Columbia Plateau: A Status Report.* RHO-BWI-ST-4, Rockwell Hanford Operations, Richland, Washington.

Piepho, M. G. 1994. *Grout Performance Assessment Results of Benchmark, Base, and Sensitivity Cases.* WHC-SD-WM-TI-561, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Piepho, M. G., R. J. Serne, D. I. Kaplan, and D. W. Langford. 1995. *Importance Ranking of Near- and Far-Field Transport Parameters from a LLW Glass Performance Assessment.* WHC-8H210-MGP-18, Westinghouse Hanford Company, Richland, Washington.

Reidel, S. P., K. A. Lindsey, and K. R. Fecht. 1992. *Field Trip Guide to the Hanford Site.* WHC-MR-0391, Westinghouse Hanford Company, Richland, Washington.

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

Routson, R. C., and V. G. Johnson. 1990. "Recharge Estimates for the Hanford Site 200 Areas Plateau." *Northwest Science*, Vol. 74, pp. 150-158.

Shord, A. L. 1995. *Tank Waste Remediation System Complex Site Evaluation Report.* WHC-SD-WM-SE-021, Westinghouse Hanford Company, Richland, Washington.

Tallman, A. M., K. R. Fecht, M. C. Marratt, and G. V. Last. 1979. *Geology of the Separation Areas Hanford Site, South Central Washington*. RHO-ST-23, Rockwell Hanford Operations, Richland, Washington.

U.S. Department of Energy. 1987. *Disposal of Hanford Defense High-Level, Transuranic and Tank Wastes, Final Environmental Impact Statement.* DOE/EIS-0113, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

U.S. Department of Energy. 1988. *Consultation Draft, Site Characterization Plan, Reference Repository Location, Hanford Site, Washington.* DOE/RW-0164, Vols. 1-9, Office of Civilian Radioactive Waste Management, U.S. Department of Energy, Washington, D.C.

U.S. Department of Energy. 1990a. *Low Level Waste Management Handbook Series: Environmental Monitoring for Low Level Waste Disposal Sites*. DOE-LLW-13Tg, Rev. 2, U.S. Department of Energy, Washington, D.C.

U.S. Department of Energy. 1990b. *Site Characterization Handbook for Low-Level Radioactive Waste Disposal Facilities*. DOE/LLW-67T, U.S. Department of Energy, Washington, D.C.

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

U.S. Nuclear Regulatory Commission. 1988. *Licensing Requirements for Land Disposal of Radioactive Wastes*. 10 Code of Federal Regulations Part 61, U.S. Nuclear Regulatory Commission, Washington, D.C.

Wagoner, J. D. 1996. "Letter to Prospective Offerers" (Feb. 20, 1996; Letter number 96-RTI-029 for RFP DE-RP06-96RL13308).

Appendix A1

Sampling and Analysis Plan

Preface

This Sampling and Analysis Plan (SAP) pertains to borehole characterization at the Immobilized Low-Activity Waste Disposal Complex (ILAWDC). 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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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 Disposal Complex (ILAWDC). Recommended procedures for sample collection, chain of custody, sample preservation, shipment, and chemical analysis are included but equivalent, approved PHMC procedures may be substituted. Procedures given here are superseded by procedures referenced in the test plans of Kaplan (1997), Khaleel (1997), and Murphy (1997a and 1997b). 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:

- 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 field work 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 and possibly four shallow (50 ft) boreholes (depending on resources) of the originally planned 9 boreholes are planned for this study in the locations 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). Both deep and shallow boreholes will be used to estimate recharge by evaluating environmental tracers. The deep borehole can also serve as a groundwater monitoring well for preoperational baseline and/or other purposes as required. All borings will be constructed in accordance with Washington Administrative Code 173-160 requirements and other appropriate Hanford requirements (e.g., WHC-S-014, Rev. 7 [WHC 1992]) or equivalent.

2.2.1 Location and Installation

The primary factor dictating the locations of the boreholes is their characterization function with respect to developing the geohydrologic model for the site and satisfying associated DQOs (Reidel et al. 1995). Installation of one deep borehole to characterize subsurface conditions beneath the ILAWDC and up to four shallow boreholes to support the ongoing natural recharge/infiltration study will be done as part of this plan.

Rationale. The deep borehole will be placed on the southwest side of the TWRS ILAWDC. Existing boreholes in the area provide information on the northeast side of the site but no information is available from the southwest side. This borehole provides data on the vadose zone and saturated zone in an area previously uncharacterized.

2.2.2 Planned Depths and Timing

The borehole will be drilled to the top of basalt. The stratigraphy encountered in this borehole can then be compared to borehole 299-E24-7 in the northeast corner of the site. This well will be drilled beginning in 1998 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. The borehole number assigned is 299-E17-21 and the coordinates for the well are listed in Table A1.1.

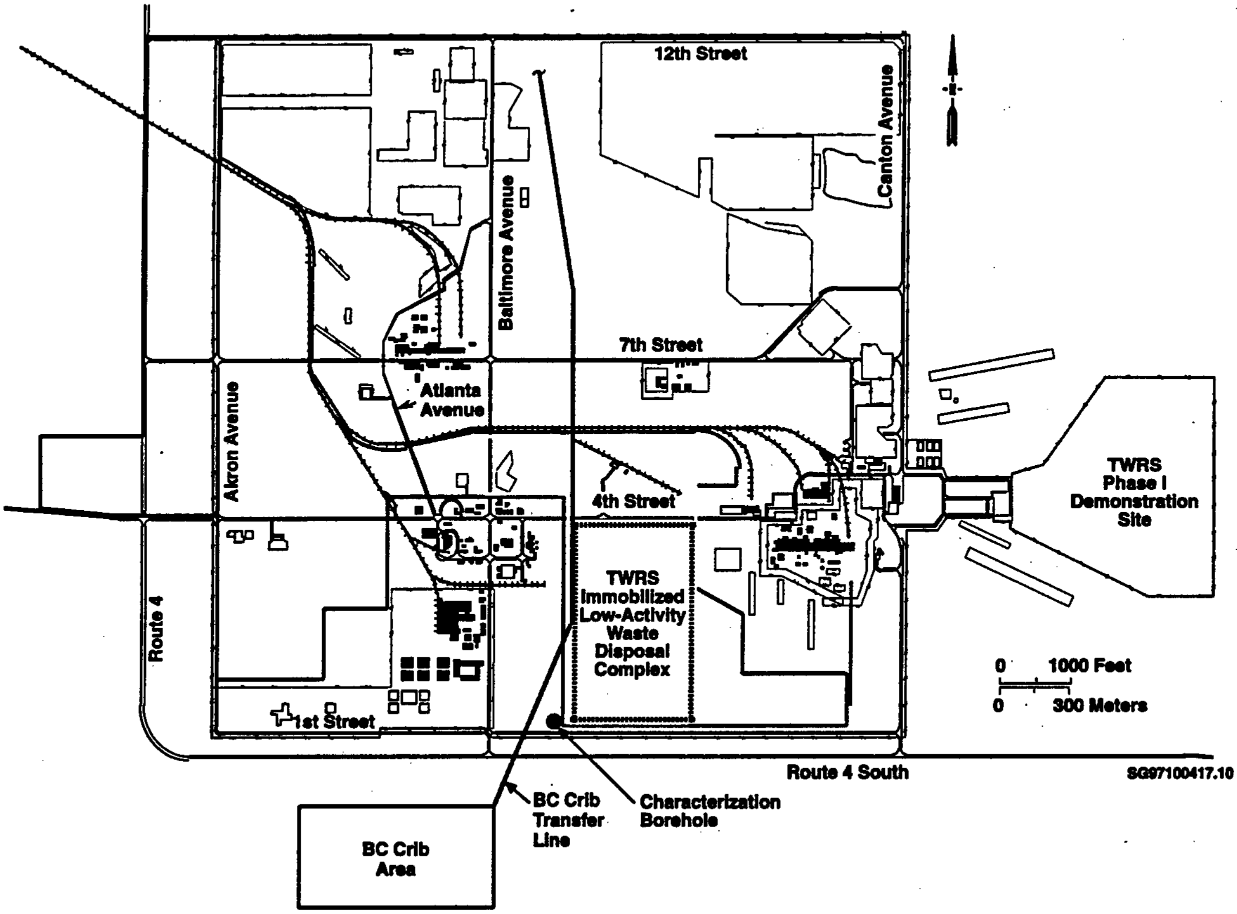

Figure A1.1. Location of Characterization/Groundwater Monitoring Well

Table A1.1. Preliminary Borehole Name and Location

Borehole #	West	North	Location
299-E17-21	E57107.017	N134894.209	Southwest corner of ILAWDC

Samples obtained from the intact coring/sampling process during 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. The samples will be transported after a field radiation and release survey (if required) to the PNNL laboratory operated by Dr. Ellyn Murphy in the RTL building. Samples will be stored in refrigeration until analyzed.

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 technique utilizing an intact long length core barrel in conjunction with temporary casing advance (e.g., "Becker Hammer" type methodology) will be used to obtain as continuous a record of sediment from each borehole as possible. In addition, drilling fluids will not be used because the moisture content and matric potential are important parameters of interest. 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. Downsizing of well casing during drilling will be done at appropriate intervals depending on well 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 *Environmental Investigations Procedures* (Bechtel Hanford, Inc. 1997) or *Environmental Investigations and Site Characterization Manual* (WHC-CM-7-7) 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 the allocation of drill core samples. 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; WHC-CM-7-7, EII 5.2; or equivalent, approved PHMC procedure). A description of the borehole sediments is typically performed by the well site geologist at the time of drilling in order 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 which 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 4 in., have the ability to advance in 10 ft increments in downhole conditions, and will have lexan or equivalent liners for sample retention. The sample liners should be in 2 ft long, individual segments.

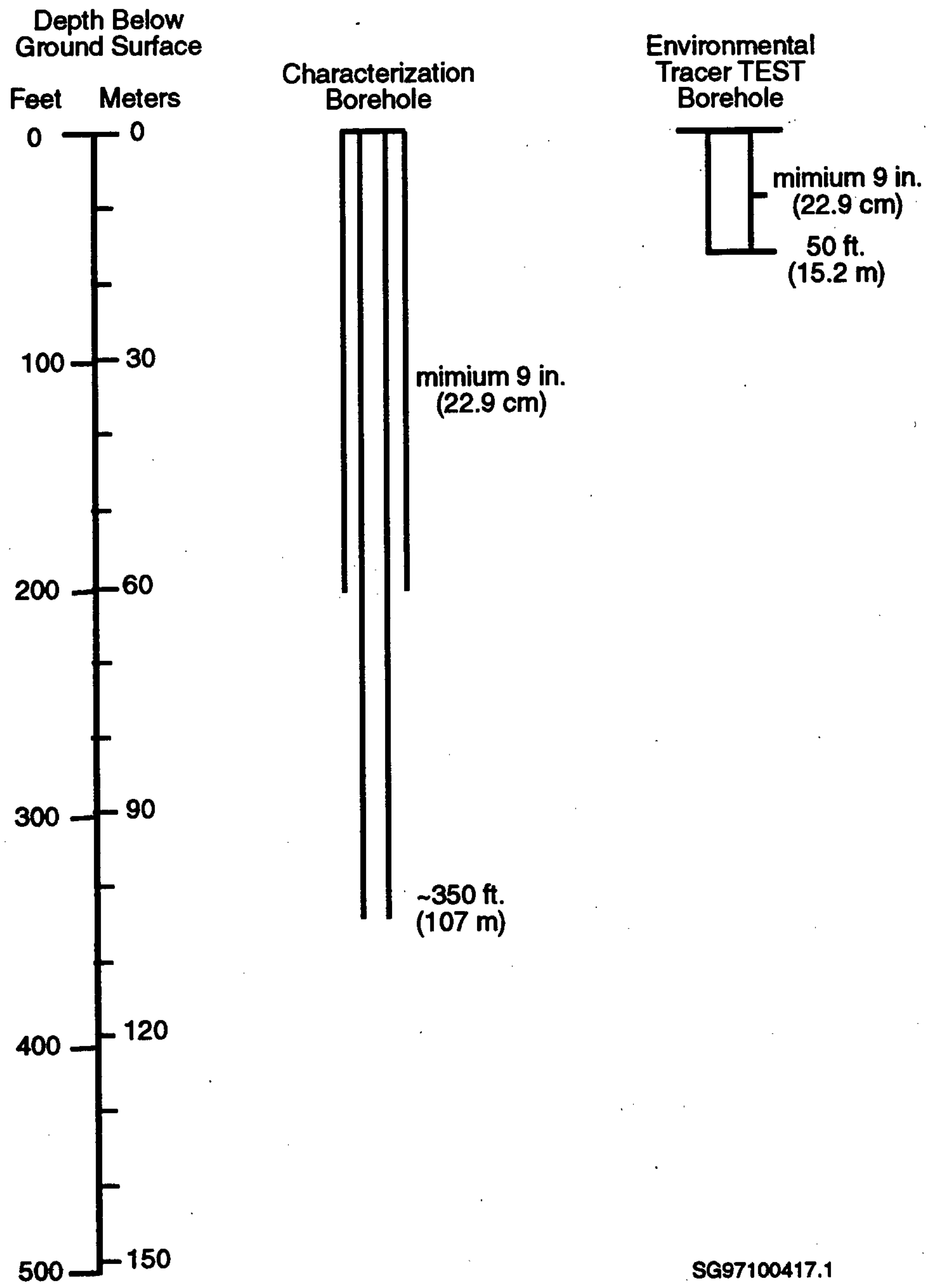

Figure A1.2. Projected Well Designs

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; WHC-CM-7-7, EII 9.1; 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,

Table A1.2. Sampling Requirements Based on Test Plans (Table 4-1 and Kaplan 1997, Khaleel 1997, and Murphy 1997a and 1997b)

Depth (in ft)	Core	Chemical Transport	Physical Properties	Recharge Tracers	Aquifer Study
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				

Table A1.2. (contd)

Depth (in ft)	Core	Chemical Transport	Physical Properties	Recharge Tracers	Aquifer Study
330-340	Y	X	X		
340-350	Y				
350-360[(a)]	Y	X	X	X	
360-370	Y	X	X		
370-380	N				
380-390	N				
390-400	N				
400-410	N				
410-420	N				
420-430[(b)]	Y	X	X		X
430-440	N				
440-450	N				

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

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, 1997b).

If adequate sample volumes are not available, 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 will 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.

Table A1.3. Analyses to be Preformed on Core and Data Uses

Test	Chemical Transport Studies[a]	Physical Properties of Vadose Zone[b]	Estimating Recharge by Environmental Tracers[c]	Aquifer Characterization[d]
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	
Gravimetric moisture	X	X	X	
Bulk density	X	X	X	X
Particle density	X	X	X	
Particle size	X	X	X	X
Initial porosity		X	X	X
Porosity				
Unsaturated hydraulic conductivity		X	X	
Saturated hydraulic conductivity		X	X	X
Moisture retention	X	X	X	
Chloride		X	X	
Pore water extraction for H^3			X	
Groundwater composition				X
Aquifer testing				X

(a) Section 4.1.2.3.4, Reidel et al. (1995) and revised by Kaplan (1997).
(b) Section 4.1.2.1, Reidel et al. (1995) and revised by Khaleel (1997).
(c) Section 4.1.2.3.3, Reidel et al. (1995) and revised by Murphy (1997b).
(d) Section 4.1.3, Reidel et al. (1995).

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).

2.6 Sample Handling

All sampling activities will be conducted in accordance with BHI or WHC procedures (BHI-EE-01, WHC-CM-7-7, and WHC-CM-7-8) or an approved, equivalent PHMC or PNNL procedures 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" will apply.

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 (Lexon) liners and covered at the ends with Teflon[1] 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.

[1] Teflon is a trademark of E. I. du Pont de Nemours & Company.

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 to correlate those units among adjacent boreholes. Geophysical logging 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 and neutron-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 utilize 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 been determined after groundwater is encountered. 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 the main body of this plan.

3.1 Sample Collection and Field Measurement Procedures

The procedures for groundwater sample collection, water-level measurements, and field measurements include the following or equivalent, approved PHMC (Procedures SML-EP-001) or PNNL procedure:

- BHI-EE-01, Procedure 4.1
- WHC-CM-7-8, 6.1
- WHC-CM-7-8, 5.1
- WHC-CM-7-8, 5.2
- WHC-CM-7-7, EII 10.2

- WHC-CM-7-7, EII 1.2, 1.4
- BHI-EE-01, Procedure 3.0
- BHI-EE-01, Procedure 4.0.

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, Inc. 1997. *Environmental Investigations Procedures*. Manual BHI-EE-01.

Kaplan, D. I. 1997. *Test 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*. FDNW-ENI-98-008, Fluor Daniel Northwest, Inc., Richland, Washington.

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.

Pacific Northwest Laboratory. 1989. *Procedures for Ground-Water Investigations*. PNL-6894, Pacific Northwest 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. 1984. *Test Method for Determination of Inorganic Anions in Water by Ion Chromatography*. EPA-600/4-84-017, Environmental Monitoring and Support Laboratory, U.S. Environmental Protection Agency, Cincinnati, Ohio.

U.S. Environmental Protection Agency. 1986. *Test Methods for Evaluating Solid Waste Physical/ Chemical Methods*. EPA SW-846, 3rd ed., U.S. Environmental Protection Agency, Washington, D.C.

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

WAC 173-160, *Minimum Standards for Construction and Maintenance of Wells*, Washington State Administrative Code, Olympia, Washington (as amended).

Westinghouse Hanford Company. *Westinghouse Hanford Environmental Investigations and Site Characterization Manual*. WHC-CM-7-7, Westinghouse Hanford Company, Richland, Washington. (current version)

Westinghouse Hanford Company. *Westinghouse Hanford Environmental Engineering and Technology*. WHC-CM-7-8, Westinghouse Hanford Company, Richland, Washington. (current version)

Westinghouse Hanford Company. 1992. *Generic Specification -- Groundwater Monitoring Wells*. WHC-S-014, Rev. 7, Westinghouse Hanford Company, Richland, Washington.

Appendix A2

Quality Assurance Project Plan - ILAWDC Borehole

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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 (PA) of the Immobilized Low Activity Waste Disposal Complex (ILAWDC) for the Tank Waste Remediation System (TWRS) complex site. 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: 1) the site characterization efforts are conducted in a safe and efficient manner, 2) the sampling and analysis activities are carried out to achieve the specified data quality goals, and 3) the 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 Project Hanford Management Contractor (PHMC). It is also designed to comply with the *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement) (Ecology et al. 1994). Distribution and revision control of the QAPjP will comply with standard PHMC procedures in WHC-CM-4-2, *Quality Assurance Manual* or equivalent, approved PHMC or PNNL procedures.

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 1998.

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, Inc. 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), Khaleel (1997), and Murphy (1997). All analyses shall be performed in compliance with PNNL-, PHMC-reviewed and/or approved laboratory QA plans and analytical procedures.

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.

2.4 Transportation Logistics

PNNL or a selected PHMC contractor 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- and/or PHMC-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 PA of the ILAWDC (see Chapter 3.0 of the main report). This chapter summarizes the data quality requirements to meet the intended use and objectives. Detailed discussion of the 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 of the main report; Reidel et al. 1995), the general requirement for precision (relative standard deviation [RSD] of 25%) and accuracy (margin of error = 10%) is intended for all phases of the TWRS complex site and ILAWDC 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 preformed. The general guidance or objective may be accomplished differently for groundwater than for vadose 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 regulatory requirements or DOE Orders 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 PA 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, comparisons 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 BHI-EE-01, Procedure 7.0 and in WHC-CM-7-7, *Environmental Investigations and Site Characterization Manual*, Environmental Investigation Instructions (EII) 9.1, REV 3, "Geologic Logging," or any approved Hanford Site contractor procedure. Additional geologic logging requirements are described in the test plans of Murphy (1997).

Sampling Intervals. Physical and chemical properties are necessary for interpretation of the physical and chemical environments, development of the geohydrologic model, and PA modeling that are central to this characterization plan.

The conceptual model for the ILAWDC indicates that there are three principal lithologic units that comprise the vadose zone and one that comprises the saturated zone. This model is based on borehole 299-E24-7, located on the northeast corner of the ILAWDC. The bulk of the vadose zone is the sandy Hanford unit, which is overlain and underlain by a gravelly sand unit. The principal unit of the saturated zone is the Ringold gravels units E and A and possibly also the lower mud. These units will be the principal units sampled; tests plans by Kaplan (1997), Khaleel (1997), and Murphy (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 (in feet) above mean sea level. Well casing elevations are required to be surveyed to within ±0.01 ft (±0.3 cm). Depth to water measurement equipment standards and calibration requirements are contained within WHC-CM-7-7, EII 10.2, "Measurement of Groundwater Levels" or equivalent, approved PHMC or PNNL 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 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 BHI, PNNL, or PHMC procedures. Where WHC-CM-7-7, EIIs are referenced, the latest approved PHMC version shall be used.

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." All boreholes shall be logged in compliance with procedure 7.0, "Geologic Logging," 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 procedure 4.0, "Soil and Sediment Sampling."

4.2.2 Hydrochemical Sampling

Groundwater sampling for regulatory constituents will be conducted as described in the FSP (Appendix A1) and Section 4.2.3 of the main body of this characterization plan.

4.3 Other Procedures

If it is determined that other procedures are required that have not already 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 in accordance with the requirements of WHC-CM-7-7, EII 1.4, "Deviation from Environmental Investigations Instructions" or equivalent PHMC procedure. This EII defines the documentation, review, and disposition of instruction change authorization forms. Other types of procedure change requests shall be documented as required by PHMC procedures governing their preparation.

5.0 Sample Custody

All samples obtained during the course of this investigation shall be controlled as required by BHI-EE-01, procedure 3.0, "Chain of Custody," from the point of origin to the analytical laboratory. Laboratory chain-of-custody procedures shall be reviewed and approved as required by PHMC 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 as required by standard PHMC procedures.

6.0 Calibration Procedures

All PHMC, PNNL or BHI 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 laboratory 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 PHMC approved procedures. Such requirements shall be invoked through PHMC procurement control procedures. Laboratory QA plans for both the Pacific Northwest National Laboratory and PHMC 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 standard PHMC 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

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, the associated field sampling plans (Appendix A1), and other applicable PHMC QA program plans. All activities addressed by this QAPjP are subject to surveillances of project performance and systems adequacy. Surveillances shall be conducted in accordance with appropriate PHMC, BHI, or 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 affects the quality of the analytical data shall be subject to preventive maintenance measures. These measures 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 PHMC review and approval.

12.0 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.

13.0 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.

14.0 References

Bechtel Hanford, Inc. 1977. *Environmental Investigations Procedures*. Manual BHI-EE-01.

Bouwer, H. 1989. "The Bouwer and Rice Slug Test - An Update." *Groundwater*, 27(3):304-309.

Cooper, H. H. Jr., and C. E. Jacob. 1946. "A Generalized Graphical Method for Evaluating Formation Constants and Summarizing Well-Field History." *Am. Geophys. Union Trans.*, 27(4):526-534.

Cooper, H. H. Jr., C. E. Jacob, and I. S. Papadopulos. 1967. "Response of a Finite-Diameter Well to an Instantaneous Charge of Water." *Water Resources Research*, 3(1):263-269.

Kaplan, D. I. 1997. *Test 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*. FDNW-ENI-98-008, Fluor Daniel Northwest, Inc., Richland, Washington.

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

Neuman, S. P. 1975. "Analysis of Pumping Test Data from Anisotropic Unconfined Aquifers Considering Delayed Yield Gravity Response." *Water Resources Research*, Vol. 10, p. 303-312.

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

U.S. Department of Energy. 1990. *Low Level Waste Management Handbook Series: Environmental Monitoring for Low Level Waste Disposal Sites*. DOE-LLW-13Tg, Rev. 2, U.S. Department of Energy, Washington, D.C.

U.S. Department of Energy. 1995. *Hanford Analytical Services Quality Assurance Plan*. DOE/RL-94-95, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

U.S. Environmental Protection Agency. 1986. *Test Methods for Evaluating Solid Waste - Physical/ Chemical Methods*, SW-846 (3rd. Edition), Office of Solid Waste and Energy Response, U.S. Environmental Protection Agency, Washington, D.C.

U.S. Environmental Protection Agency. 1988a. *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA*. OSWER Directive 9335.3-01, Draft, Office of Solid Waste and Emergency Response, U.S. Environmental Protection Agency, Washington, D.C.

U.S. Environmental Protection Agency. 1988b. *Laboratory Data Validation Functional Guidelines for Evaluating Inorganics Analyses*. Hazardous Site Evaluation Division, U.S. Environmental Protection Agency, Washington, D.C.

U.S. Environmental Protection Agency. 1988c. *Laboratory Data Validation Functional Guidelines for Evaluating Organics Analyses*. Hazardous Site Evaluation Division, U.S. Environmental Protection Agency, Washington, D.C.

Washington State Department of Ecology, U.S. Environmental Protection Agency, and U.S. Department of Energy. 1994. *Hanford Federal Facility Agreement and Consent Order*, 2 Vols., Olympia, Washington.

Westinghouse Hanford Company. 1990. *Environmental Technology Development and Applications Manual*. WHC-IP-0635, Westinghouse Hanford Company, Richland, Washington.

Westinghouse Hanford Company. *Quality Assurance Manual*. WHC-CM-4-2, Westinghouse Hanford Company, Richland, Washington.

Westinghouse Hanford Company. *Environmental Investigations and Site Characterization Manual*. WHC-CM-7-7, Westinghouse Hanford Company, Richland, Washington.

Appendix B

Description of Work Drilling Requirements
Well Construction Data Sheet

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1.0 Description of Work

1.1 Introduction

This appendix describes 1) the drilling, sampling, and construction of a shallow groundwater well and 2) drilling, sampling, and decommissioning of two vadose borings in support of the Characterization Plan for the Immobilized Low-Activity Waste Disposal Complex (ILAWDC). It provides the requirements for the drilling and sampling methodologies, and the locations for placement of the well and vadose characterization borings. The specific sample collection and drilling criteria required during drilling of these borings is based on the DQO process documented in Reidel et al. (1995), on activities and goals presented in Section 3.0, Data Quality Objectives Process, and Appendix A1, Sampling and Analysis Plan (SAP) of this report.

The single groundwater well constructed for this project will be drilled into the top of basalt for deep aquifer characterization and for geologic sampling, geochemical characterization, and correlation to well 299-E4-7. The boring will be completed as a Resource Conservation Recovery Act (RCRA) compliant shallow groundwater well for monitoring purposes. At the conclusion of the groundwater well construction and development, an instantaneous slug injection test will be performed. Subsequent to the drilling and completion of the groundwater monitoring well, two 50 ft vadose borings will be constructed for geologic interpretation, sample collection, and analysis of physical and geochemical parameters. After sampling and field testing, the vadose borings will be abandoned as per Washington Administrative Code 173-160 requirements. The geochemical samples collected in both the vadose and deep borings will be used to estimate groundwater recharge by evaluating environmental tracers as outlined in the Characterization Plan and the site-specific SAP.

The drilling and sampling methodology has been specified by the principal investigators for this project to meet the project specific defined DQO and Quality Assurance and Project Plan goals.

1.2 Background

The Immobilized Low-Activity Waste Complex designated as Project W-520, is a portion of the Phase II Privatization activities. The Phase II "proof of concept" activities are being undertaken to demonstrate the effectiveness of privatized designs to dispose of both low activity and high level radioactive and mixed waste inventory retrieved from underground tanks on the 200 Area plateau. In conjunction with the Phase II Privatization activities for construction and testing of a vitrification process facility, a disposal complex for the low-activity waste treated by the vitrification process is being planned. The drilling and characterization efforts described in this appendix are to provide characterization support for the planned storage complex for the vitrified low-activity waste as described in the body of this report.

1.3 Site Geology

A detailed description of the general Hanford geologic and hydrologic settings, and a detailed discussion of the expected site specific hydro-geologic conditions are found in Section 2.0 of this report.

For the purposes of the drilling specification the following description of the expected geologic conditions will serve as a formation prognosis. The prognosis is Hanford Formation 0 m to 101m (0 to 335 ft) below land surface (BLS), Ringold Formation 101 to 137 m (335 to 450 ft) BLS, and the Columbia River Basalt Group (CRBG) at approximately 137 m (450 ft) BLS. See Figures 2.3, 2.4, and 2.5 in the body of the main report for an area map, geologic cross sections, and formation contact projections at the ILAWDC.

1.3.1 Hanford Section

The section from 0 to 6 m (0 to 20 ft) BLS is predominately gravelly sand with a sharp lower contact with a sand dominated section. The sand section is approximately 60 m (200 ft) thick extending from 6 to 66 m (20 to 220 ft) BLS. Underlying the sandy section is a gravel to gravelly sand facies expected to be approximately 35 m (115 ft) thick and extend from 66 to 100 m (220 to 335 ft) BLS. The top of the unconfined aquifer in this area is at approximately 96 to 97 m (315 to 320 ft) BLS in the lower portion of the Hanford gravelly sand facies.

1.3.2 Ringold Section

Gravelly sands to sandy gravels of the Ringold Formation are projected at 100 to 101 m (330 to 335 ft) BLS. This section is an undifferentiated Ringold "E" and "A" section. The Ringold Formation "A" and "E" facies may be separated by the Lower Mud facies at approximately 134 to 137 m (420 to 430 ft) BLS. Ringold "E" and "A" facies are predominately sandy gravels grading to gravelly sands with minor to major sand intervals. In some cases the sandy gravel sections may be locally cemented. Discovery and sampling of the Lower Mud is, if present, a part of the deliverable for meeting the drilling data quality objectives. The contact of CRB and Ringold "A" sediments is expected at approximately 137 m (450 ft) BLS.

2.0 Drilling and Sampling Requirements

This section delineates the specific requirements for drilling methodologies, well construction and temporary casing designs, and soil and hydrologic sampling, sample handling, and analysis that have been determined to meet the project DQOs.

2.1 Drilling and Sampling Method

An air bailing technique is required that will advance casing while providing an efficient method of obtaining extended length intact samples by use of a driven 2 to 10 ft long split spoon device. The sampling device in the vadose zone will have a minimum outside diameter of 5 1/2 in. and an inside diameter of 4 7/8 in. to meet laboratory analysis equipment parameters. The sampling device will have removable liners of lexan or equivalent type material. These liners will be in 1 or 2 ft lengths and will have sealable end caps. The preferred drilling method must have the ability to advance and retrieve the intact samples with both a rigid advance and wireline system. Choice of which system is used will be based on the ability to advance the boring in the geologic conditions encountered. The required drilling system will advance a minimum 9 in. outside diameter (OD) temporary casing to the bottom of the projected screen interval (approximately 103 to 107 m [340 to 350 ft] BLS). Below the screened portion of the well, the system must be capable of advancing temporary casing of a minimum diameter of 5 in. with a rotary air bailing technique that will under-ream the drilled hole as the casing is advanced. The circulated cuttings for both the vadose and saturated portion of the well will be contained at the surface by use of a cyclone separation system. Cuttings containment requirements and purge water control/containment procedures will be established by the drilling contracting organization as per the following Section 3.0 of this appendix. A representative continuous sample of bailed/air lifted cuttings will be retained and available for geologic interpretation.

2.2 Sediment Sampling Requirements

All reasonable effort will be expended to retrieve a continuous set of soil samples, as per the Sample and Analysis Plan (SAP, Appendix A1), from surface to approximately 103 to 107 m (340 to 350 ft) BLS. These samples will be collected by the above described split spoon method and will be labeled and transported as per the SAP. Particular attention will be given to sampling the Lower Mud, if present. Any samples of the Lower Mud will be obtained with the split spoon device. Additionally, the capillary fringe and sediments at the water table will be obtained. If present, the Lower Mud is expected at approximately 137 to 140 m (420 to 430 ft) BLS. A decision regarding any attempt to sample the interval will be made by the principal investigator and well site geologist based on cuttings observations and drilling information. WMNW samplers will provide labor support necessary to document, label, and transport the collected samples as per the SAP.

2.3 Groundwater Sampling, Testing, and Geophysics

2.3.1 Groundwater

The SAP goals of providing information on observed hydrologic conditions will require that field personnel have access to the well head on a regular basis during penetration of the saturated interval. This access is necessary to record water levels and recovery times for characterization of the unconfined aquifer conditions. In addition to hydrologic data, additional geochemical data will be collected by retrieving a groundwater sample at the total depth of the well. This sample will be collected by use of an inflatable packer, pressure transducer, data logger and pump system for the purpose of isolating and collecting a sample at approximately 137 m (450 ft) BLS.

After drilling to total depth, the well will be pre-developed by air circulation to remove excess fines from the sample zone. The temporary casing will be withdrawn approximately 1.5 m (5 ft) from it's total advance point and the packer and pump system will be placed in contact with the exposed formation, the packer will be inflated and a groundwater sample will be collected. During sample collection, WMNW sampling personnel will track the below listed groundwater parameters to indicate that the sample collected is representative of formation conditions. Additionally, the turbidity of the sample will be as low as reasonably achievable before a sample is taken (preferably <5 NTU).

Hydrochemical parameters tested will include, but not be restricted to:

- pH
- Specific conductance (conductivity)
- Eh (oxidation-reduction potential)
- Nitrate/nitrite
- Chloride.

The sample will be transported to a PNNL designated facility for analysis as per the SAP.

2.3.2 Hydrologic Testing

The hydraulic properties of the upper unconfined aquifer will be investigated at the conclusion of the monitoring well construction by conducting an instantaneous slug injection test. An appropriate BHI/ PHMC or PNNL procedure will be used for this test. The selected procedure to be used will be documented in the Field Activity Reports or other similar record and concurred with by the principal investigator.

2.3.3 Geophysical Data

To satisfy the requirements of the DQO process and the subsequent SAP, two types of geophysical tools will be utilized for characterization of the borings drilled for this project. These tools are a high purity germanium (spectral) tool and a neutron-neutron (moisture) tool. Logging runs will be conducted in the two vadose borings after reaching total depth and before the boreholes are abandoned. The deep borehole will be logged with both tools at the casing downsize point, approximately 103 to 107 m (340 to 350 ft) BLS, and at the total depth of the borehole prior to the groundwater sampling event described in Section 2.3.1.

3.0 Drilling Data Sheet

3.1 Description/Location

A total of three borings will be drilled to support the ILAWDC project activities in the 200 East Area (Figure B.1). Two borings (Well ID #B8501 and #B8502) will be for vadose characterization purposes and will be drilled and sampled to approximately 15 m (50 ft) BLS and subsequently abandoned. The third boring (Well ID #B8500, Well Name 299-E17-21) will be drilled and sampled to the top of basalt and plugged back to within 9 m (30 ft) of the top of water and a RCRA compliant groundwater monitoring well will be constructed and developed for sampling. The groundwater monitoring well will be constructed with a 4 in. diameter, 30 ft long, continuous wire wrapped 20 slot stainless steel screen and matching stainless steel riser to surface. The approved materials include stainless steel ASTM A778 or ASTM A312 type 304, 316, 304L, or 316L, minimum Sch. 5 or equivalent. The riser pipe will be fitted with, or have welded centralizers of the same type of stainless steel as the well casings at 40 ft intervals. The exact placement of the screen relative to the top of the groundwater will be determined by the well site geologist with the concurrence of the principal investigator. The borings will be drilled and constructed/abandoned in accordance with the following estimated parameters.

Prognosis for the expected geology to be encountered during drilling is provided in Section 2.1 of the Characterization Plan and in Section 1.3 of this appendix. Figures 2.4 and 2.5 provide a graphical representation of the projected geologic conditions.

3.2 Schedule

The drilling and completion/abandonment of these borings is required to be completed by March 31, 1998. Scheduling of the start of drilling activities should be conducted to meet the above deadline.

Table B.1. Well Construction Parameters

Well ID/ Well Number	Estimated Total Depth (ft/m)	Depth to Water/Depth of Screen	Screen Length	Primary Filter Pack	Secondary Filter Pack	Bent.Seal Interval/Cement Seals(C)
B8500/ 299-E17-21	450/137	320 ft/97 m 350 ft/107 m	30 ft (350-320)	350-318 (32)	318-315 (3)	430-450 360-420 310-0/ 420-430(C) 355-360(C) 310-315(C)
B8501	50/15	NA	NA	NA	NA	50-0
B8502	50/15	NA	NA	NA	NA	50-0

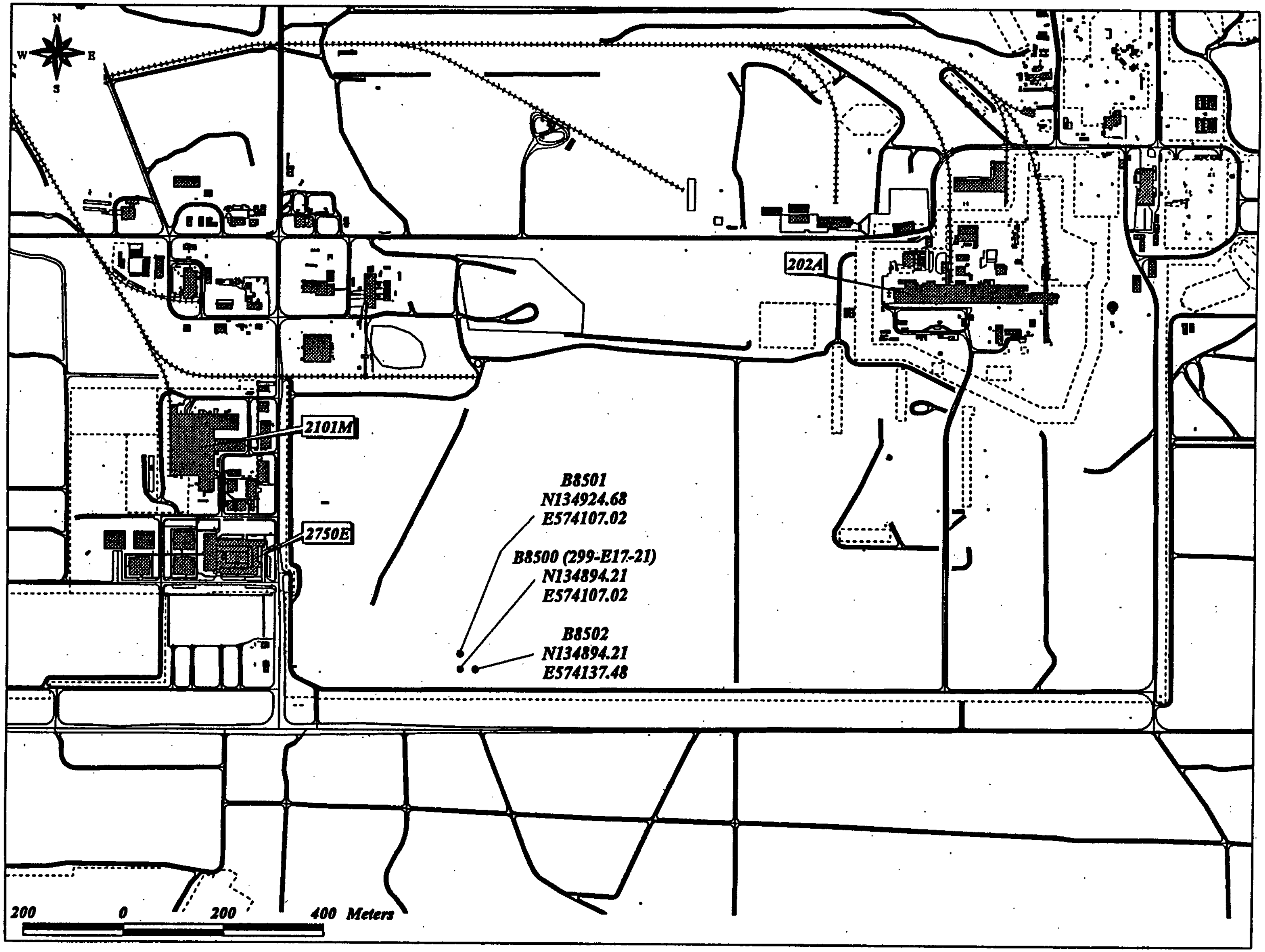

Figure B.1. Location Map for the ILAWDC Boreholes

3.3 Location

The three borehole locations have been staked by PNNL personnel and the coordinates of the locations are presented in Table B.2.

Table B.2. Borehole Identification Numbers and Coordinates

Well Identification Number	Well Number	Northing	Easting
B8500	299-E17-21	N134894.209	E574107.017
B8501	NA	N134924.68	E574107.02
B8502	NA	N134894.21	E574137.48
NOTE: See Figure B-1 for a map of the well locations.			

3.4 Sequence of Drilling

Borehole #B8500 (299-E17-21) will be drilled and completed prior to drilling the two vadose characterization borings. The access road to B8500 will be used for egress to the B8501 and B8502 locations. A separate road can be used for access to B8502, if necessary. There is no specific order for completion of the two vadose borings.

3.5 Drilling Method

As described in Section 2.0, Drilling and Sampling Requirements, the designated drilling method for the vadose zone and top 30 ft of the saturated zone is an air bailing, dual wall, percussion technique. Because of the specific criteria and laboratory analysis being applied to the soil samples recovered, sonic or sonic assisted rotary methods of sample collection and drilling are not allowed. At the casing downsize point, below the screen construction depth, an air rotary under reaming system that will advance casing with the drilling assembly is required. A minimum calculated up-hole velocity of 5,000 ft/min is required for this portion of the drilling to provide adequate hole cleaning to facilitate the geologic characterization requirements.

3.6 Approximate Well Depths

Well No./Well ID	Drl. Dia. (in.)	Well Dia. (in.)	Estimated Depth (ft/m)	Estimated Depth to Water (ft/m)
299-E17-21/B8500	9 X 6 Dual	4	450/137	320/97
NA/B8501	9 X 6 Dual	NA	50/15	NA
NA/B8502	9 X 6 Dual	NA	50/15	NA
NOTE: Depths are estimated and are below ground surface numbers.				

3.7 Construction

See diagram (Figure A1.2) for the general well configuration. The completed groundwater monitoring well will be constructed in compliance with standard RCRA requirements with the additional feature of a 30 ft screened interval. The bentonite sealed portions of the monitoring well and vadose borings will be sealed with a medium or coarse grained "chunk" type bentonite.

If the Lower Mud is present, a cement seal will be placed across the interval during abandonment of the lower drilled section of the well (e.g., the possible seal section would be approximately 128 to 131 m (420 to 430 ft) BLS. This seal will be placed by use of a tremmie pipe from surface to the bottom of the sealed section. The need for this seal and the exact depths of placement will be determined by the well site geologist with the concurrence of the principal investigator and will be based on the determined presence/absence of the Lower Mud unit of the Ringold Formation. Two additional approximate 5-ft lifts of cement will be required immediately below and immediately above the screened interval at approximately 355 to 360 ft and 310 to 315 ft BLS.

Filter pack placement across the screened interval of the well will require extensive surging to insure proper packing of the filter material. A dual surge plate surge block will be employed to maximize proper filter pack development.

The two vadose characterization wells will be drilled and sampled, geophysically logged, and decommissioned by filling the borings with chunk type bentonite and extracting the temporary casing.

3.8 Well Development

As directed above in Section 3.7, Construction, the screen interval will be pre-developed for proper filter pack placement and maximization by use of a surge block device. Secondary development will consist of pumping at a volume determined by the well site geologist/hydrologist to be necessary to complete the filter pack development using a submersible pump placed near the bottom of the screened interval. Completion of the development process may require movement of the development pump to higher portions of the screened interval and varying of the pumping rate. Pumping will continue until the project hydrologist or site geologist determines that development is complete, and the well produces water with a maximum turbidity of 5 NTU.

3.9 Soil Sampling

Retrieval of a continuous set of split spoon samples from surface to approximately 20 ft into the saturated zone at 107 m (350 ft) depth will be attempted by use of either a rigid or wire-line type of split spoon device as described in Section 2.1, Drilling and Sampling Method, and in Section 2.2, Sediment Sampling Requirements. For vadose zone samples, the sampler will have an outside diameter of 5 1/2 in.

and an inside diameter of 4 7/8 in., and will have lexan or equivalent removable liners for sample containment. The liners will have rubber, plastic, or equivalent type material end caps for sealing purposes.

The required samples from the Lower Mud interval (137 to 140 m [420 to 430 ft] BLS) will be retrieved with a 3 1/2 in. OD sampler with a 2 7/8 in. inside diameter. This sampler will also be equipped with lexan or equivalent type liners and end caps.

A table outlining the projected laboratory analysis to be performed for each sample interval is available in the SAP (see Table A1.2).

3.10 Groundwater Sampling

As described in Section 2.3.1 of Appendix B, a groundwater sample will be retrieved from the Ringold A sediments before the lower portion of the deep borehole is abandoned. This will be accomplished by backpulling the temporary casing approximately 5 to 10 ft and placing an inflatable packer, pump, and transducer system below the bottom of the temporary casing. The transducer will be calibrated and a recording type data logger will be used to monitor hydrologic conditions during sampling. A WMNW sampler will be present to operate the data logging system, collect samples, and track groundwater information to verify adherence to the sample collection parameters set forth in Section 2.3.1. It is estimated that 1 to 2 field days will be required to complete this scope of work.

3.11 Hydrologic Testing

At the conclusion of the well development phase of well construction, an instantaneous slug injection test will be conducted as per approved procedures as outlined in the SAP. The aquifer test requires concurrence of the principal investigator.

3.12 Services Requested from Bechtel Hanford Inc. (BHI)

Following is a list of services and documentation that BHI is requested to supply as part of the above outlined work scope:

- Placement and oversight of the drilling services contract to meet the drilling, sampling, and well construction requirements contained in this appendix.

- A Waste Disposal Plan which outlines the drilling cuttings, purge water containment, drumming, and disposal requirements that the drilling subcontractor will be required to comply with in the performance of the above scope of work.

- Disposal, if necessary, of all drilling and purge water waste generated during performance of the above outlined work scope.

- BHI will provide all of the required pre-drilling documentation necessary for drilling and construction activities. This documentation will include, but not be limited to: Excavation Permits, Site Specific Health and Safety Plans, any Quality Assurance required by BHI procedures for the BHI portion of the drilling activities.

- Construction of all required access roads and drilling pads.

- A biweekly report to the project manager and/or principal investigator of all costs incurred by each activity; including drilling support and materials costs, oversight, contracting, and management expenses.

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