PNNL-11620
UC-402, 502, 630

Pacific Northwest National Laboratory

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

Liquid Effluent Retention Facility Final-Status Groundwater Monitoring Plan

M. D. Sweeney
C. J. Chou
B. N. Bjornstad

September 1997

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

PNNL-11620

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

Printed in the United States of America

**Available to DOE and DOE contractors from the
Office of Scientific and Technical Information, P.O. Box 62, Oak Ridge, TN 37831;
prices available from (615) 576-8401.**

**Available to the public from the National Technical Information Service,
U.S. Department of Commerce, 5285 Port Royal Rd., Springfield, VA 22161**

The document was printed on recycled paper.

PNNL-11620
UC-402, 502, 630

Liquid Effluent Retention Facility Final-Status Groundwater Monitoring Plan

M. D. Sweeney
C. J. Chou
B. N. Bjornstad

September 1997

Prepared by
Pacific Northwest National Laboratory[a]
for the U.S. Department of Energy under
Contract DE-AC06-76RLO 1830

(a) Also prepared by Rust Federal Services Hanford.

Contents

Figures

Tables

1.0 Introduction

The following sections describe the groundwater-monitoring program for the Liquid Effluent Retention Facility (LERF). The LERF is regulated under the Resource Conservation and Recovery Act of 1976 (RCRA). The LERF is included in the "Dangerous Waste Portion of the Resource Conservation and Recovery Act Permit for the Treatment, Storage, and Disposal of Dangerous Waste, Permit WA890008967", (referred to herein as the Permit) (Ecology 1994) and is subject to final-status requirements for groundwater monitoring (WAC 173-303-645).

This document describes a RCRA/WAC groundwater detection-monitoring program for groundwater in the uppermost aquifer system at the LERF. This plan describes the LERF monitoring network, constituent list, sampling schedule, statistical methods, and sampling and analysis protocols that will be employed for the LERF. This plan will be used to meet the groundwater monitoring requirements from the time the LERF becomes part of the Permit and through the post-closure care period, until certification of final closure.

1.1 History of Groundwater Monitoring at the LERF

A groundwater-monitoring network was installed at the LERF in 1990 before final construction of the facility. Samples were collected quarterly from the four wells (one upgradient and three downgradient from the LERF) and interim-status evaluation of indicator parameters began before waste was transferred to the basins. Constituents analyzed during the first year of sampling included the analytes listed in 40 CFR 265 Appendix IX, groundwater-quality parameters, and several site-specific constituents. Data for these analytes are in the Hanford Environmental Information System (HEIS) database. The selection of site-specific constituents was based on waste-stream analysis of the primary generating facility, the 242-A Evaporator. Total organic carbon, total organic halogen, pH and specific conductivity, collectively known as indicator parameters, were also evaluated during the first year; the critical means specific to this facility were calculated for these parameters. Once the critical means were established, groundwater sampling was changed to a semiannual schedule.

1.2 Changes from Interim-Status Groundwater Monitoring

The LERF will enter final status in detection-level monitoring, a program similar to indicator-evaluation monitoring conducted under interim status. The two programs differ substantially, however, in sampling requirements and in statistical analysis. Interim-status regulations require the collection of multiple samples (replicates) in one sampling event. The default procedure under final-status regulations require independent samples, which involve waiting periods between samples. The proposed sampling method is described in Section 4.0. Statistical methods proposed in this document are also different than those used under interim-status, and the proposed method represents a preferred alternative to the default procedure as described in WAC 173-303-645 (h). The proposed program also relies on a shorter constituent list than did the previous program.

The "assessment" program under interim status is equivalent to a "compliance" program in final status. In compliance monitoring, specific constituents are chosen and compared to concentration limits. If these limits are exceeded, then the site enters a corrective-action phase.

The radioactive portion of mixed waste is interpreted by DOE to be regulated under the Atomic Energy Act of 1954; the non-radioactive hazardous portion of the mixed waste is interpreted to be regulated under RCRA and WAC 173-303. It is the position of DOE that any procedures, methods, data, or information associated with this monitoring program that relate solely to the radioactive constituent of mixed wastes is outside the scope of the Hanford Facility RCRA Permit but are included for the sake of completeness. It is the position of Ecology that the radioactive portion influences safe storage of the waste and, therefore, information about radioactive constituents is necessary to ensure compliance with WAC 173-303 and the RCRA permit. Both agencies acknowledge the other's position, but to avoid a conflict on the issue, DOE has agreed to provide information on the radioactive constituents without agreeing with Ecology's position and Ecology has agreed to accept the information in this context without giving up its position.

2.0 Facility Description

This section provides an overview of the physical structures, operational history, and waste characteristics for the LERF. More detail is provided in the *Conceptual Design Report 242-A Evaporation and PUREX Interim Retention Basin* (Rieck 1990).

2.1 Physical Structure

The LERF is located in the central portion of the Hanford Site on the eastern boundary of the 200 East Area (Figure 2.1). Construction of the LERF was completed in 1991. This facility, originally classified as a surface impoundment for mixed waste storage, will be permitted as a RCRA Treatment, Storage, and Disposal (TSD) Facility. The LERF received a surface impoundment-treatment exemption from land disposal restrictions (40 CFR 268.4) in 1995 and is now regulated as a treatment facility.

The facility originally was designed with four basins arranged side by side on a 16-hectacre site. Four excavations were made; only three of the four excavations are lined and are currently scheduled for use. The dimensions of the basins at the anchor wall are 103 m by 85 m at the top, with a design capacity of 2.5E07 L. The are basins constructed with primary and secondary liners, consisting of 1.5-mm membranes over low-permeability soil composites (DOE 1991).

The leachate detection, collection, and removal system is designed, constructed, and operated to detect, collect, and remove liquids that could permeate the primary liner. System components include a layer of drainage gravel sloped to a lined sump, high-density polyethylene (HDPE) drainage net on the basin sidewalls, a perforated leachate riser extending down between the two liners, a dedicated submersible leachate pump installed in the riser, piping, and associated instrumentation. The total estimated capacity of the drainage layer to store leachate is approximately 1.8E05 L. The pumping system is designed to remove that quantity of fluids, and the removal system is designed to start at 10% of the layer capacity. Based on these design parameters, it is unlikely that the drainage layer would ever fill to capacity (DOE 1991).

An interim-status detection-level groundwater-monitoring network was installed around the LERF in 1990 in accordance with the interim-status groundwater-monitoring plan for the 200 East Area Liquid Effluent Retention Facility (Schmid 1990).

2.2 Operational History

The LERF originally was constructed to provide interim storage of 242-A Evaporator process-condensate effluent containing listed and dangerous waste constituents (Rieck 1990). From 1977 until 1989, process condensate from the 242-A Evaporator was disposed to the 216-A-37-1 Crib via the 207-A

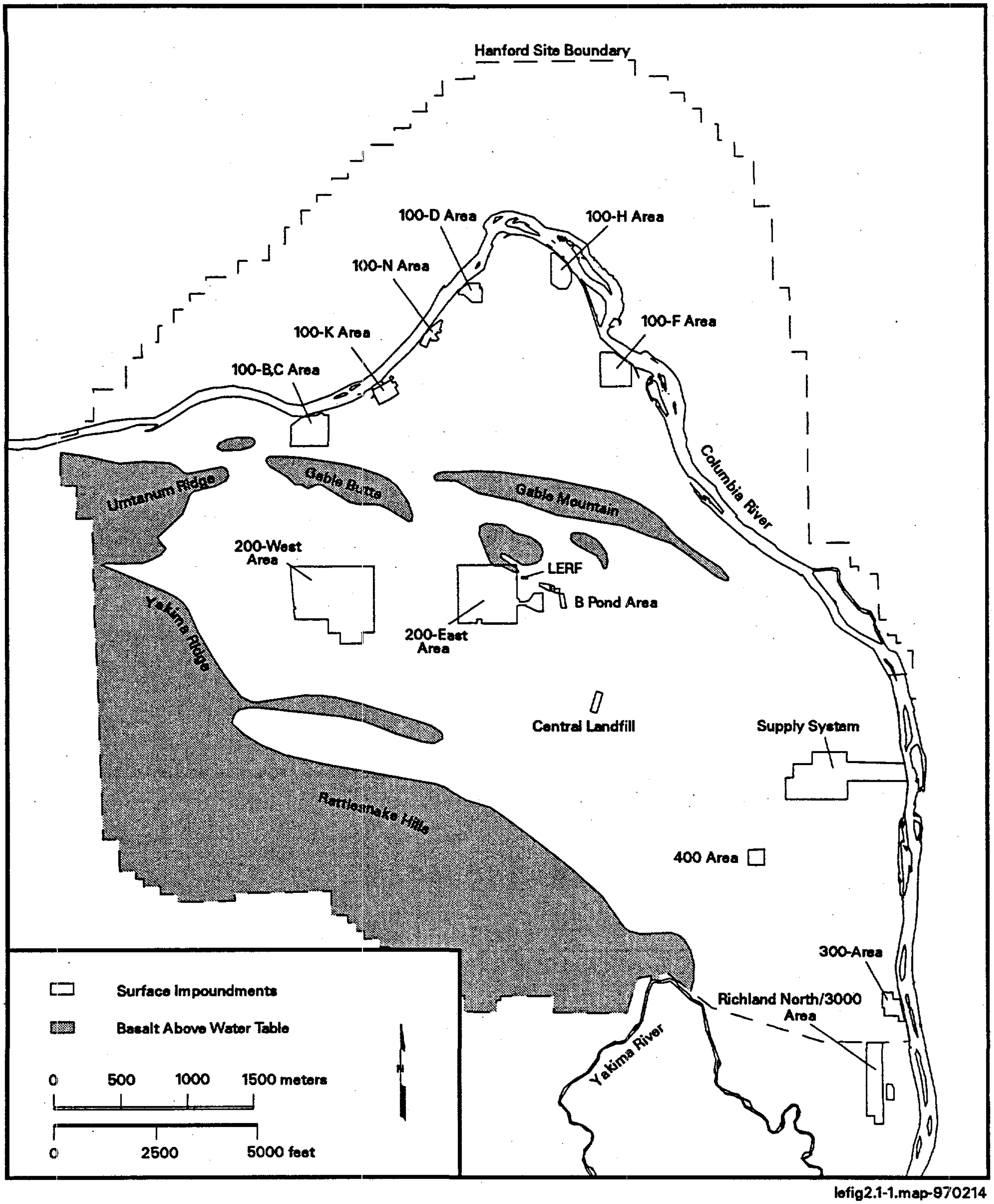


Figure 2.1. Hanford Site Location Map

Retention Basins (Smith and Kasper 1983). The 242-A Evaporator was shut down in 1989 and was placed on temporary-standby status pending construction of a waste-disposal alternative to supplant use of the soil-column crib (Schmid 1991a).

Construction of the LERF began in February 1990 with a geotechnical investigation of the site. The facility was completed in November 1993 and was ready to begin receiving waste from the 242-A Evaporator. The evaporator upgrades necessary for the re-start were not completed until 1993, and the first waste-reduction campaign did not begin until April of 1994. The effluent from 242-A Evaporator is the result of evaporative-condensation campaigns of liquids held in the double-shell tanks (DSTs). Figure 2.2 details the configuration of the LERF, along with the location of nearby wells and the facility boundaries.

The 242-A Evaporator and the LERF are part of a volume-reduction process for high-level radioactive wastes stored in underground-storage tanks at the Hanford Site. As part of a Tri-Party Agreement (Ecology et al. 1989) milestone, the volume of high-level waste in tanks at Hanford have been reduced by 2.13E07 L after treatment with the 242-A Evaporator system (Guthrie 1994; 1995). This volume reduction has relieved the shortage of adequate DST space, allowing other Hanford Site operations to continue. Since the completion of the 200 Area Effluent Treatment Facility (ETF), the LERF has been incorporated into the treatment process and will continue to provide storage for operations at the ETF throughout its entire life cycle.

The LERF also is linked to Tri-Party Agreement milestones that involve treatment or elimination of selected effluent streams, some of which were previously discharged to cribs, ponds, or ditches. LERF basins have been identified as storage capacity for other Hanford Site projects involving contaminated waste streams. Future waste streams are identified as generators for LERF as cleanup activities at the site progress.

2.3 Waste Characteristics

The ETF was intended and designed to treat a variety of radioactive and/or aqueous mixed wastes. During the initial phases of developing the dangerous waste permit application for the LERF and ETF, however, process condensate from the 242-A Evaporator was the only mixed waste identified for storage and treatment in the LERF and the ETF. As cleanup activities at Hanford progress, many of the aqueous wastes generated from site remediation and waste-management activities will be sent to the ETF and LERF for treatment and storage.

Contaminants in the process condensate are expected to consist chiefly of volatile organics that boil off with the water, and radionuclides that are entrained in the vapors, and may include acetone, methyl ethyl ketone, methyl isobutyl ketone waste, and tritium. Other aqueous wastes that will be treated and stored at the ETF and LERF include, but are not limited to the following Hanford wastes: contaminated groundwater from pump-and-treat remediation activities such as groundwater from the 200-UP-1 Operable Unit; water from deactivation activities such as water from the spent-fuel-storage basins at deactivated reactors (e.g., N Reactor); laboratory aqueous waste from unused samples and sample analyses; and leachate from landfills, such as the Environmental Restoration Disposal Facility.

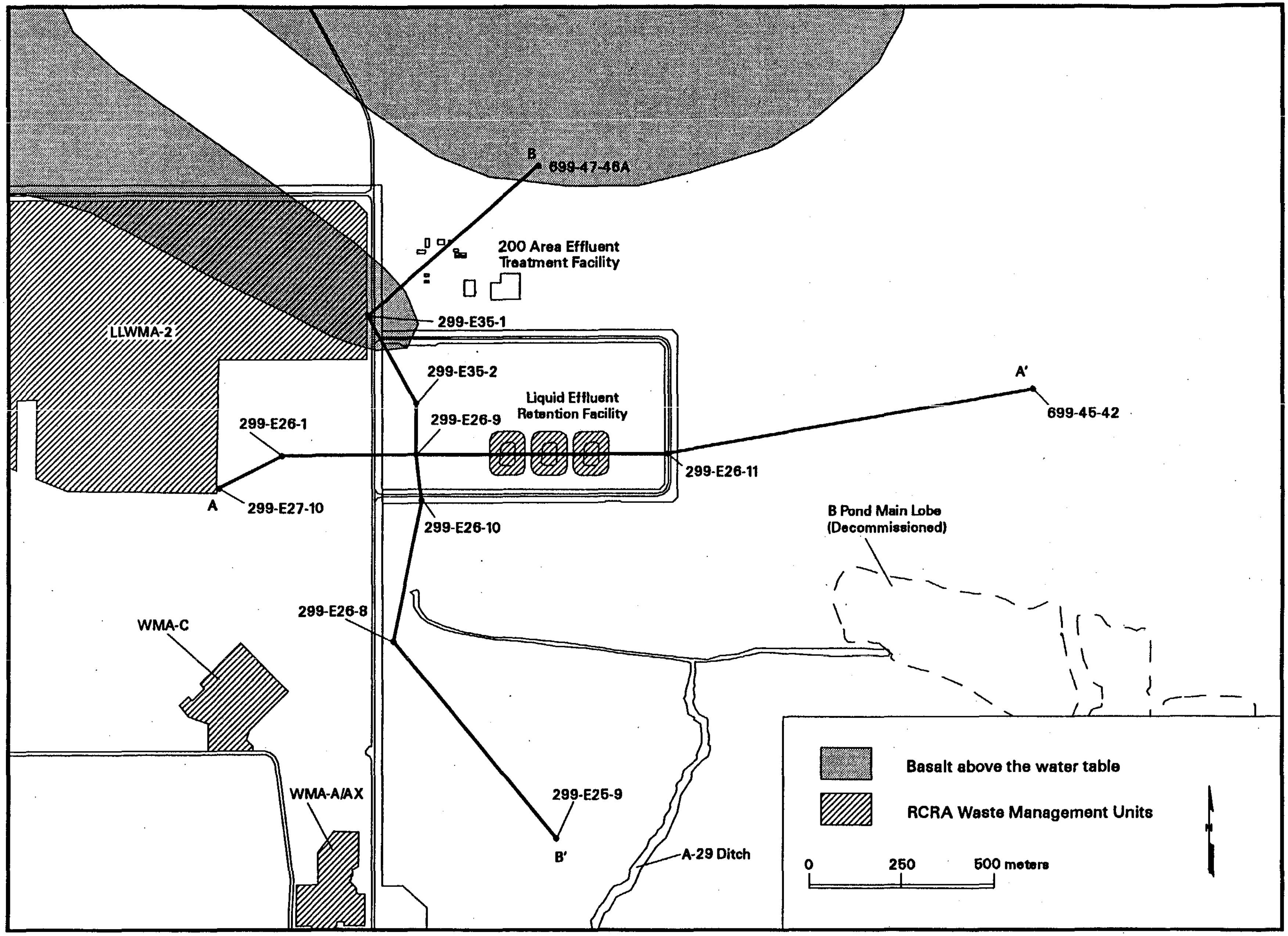


Figure 2.2. LERF Location Map

3.0 Hydrogeology and Groundwater-Monitoring Results

This section describes the stratigraphy, physical hydrology, and groundwater chemistry beneath the LERF Area.

3.1 Geology

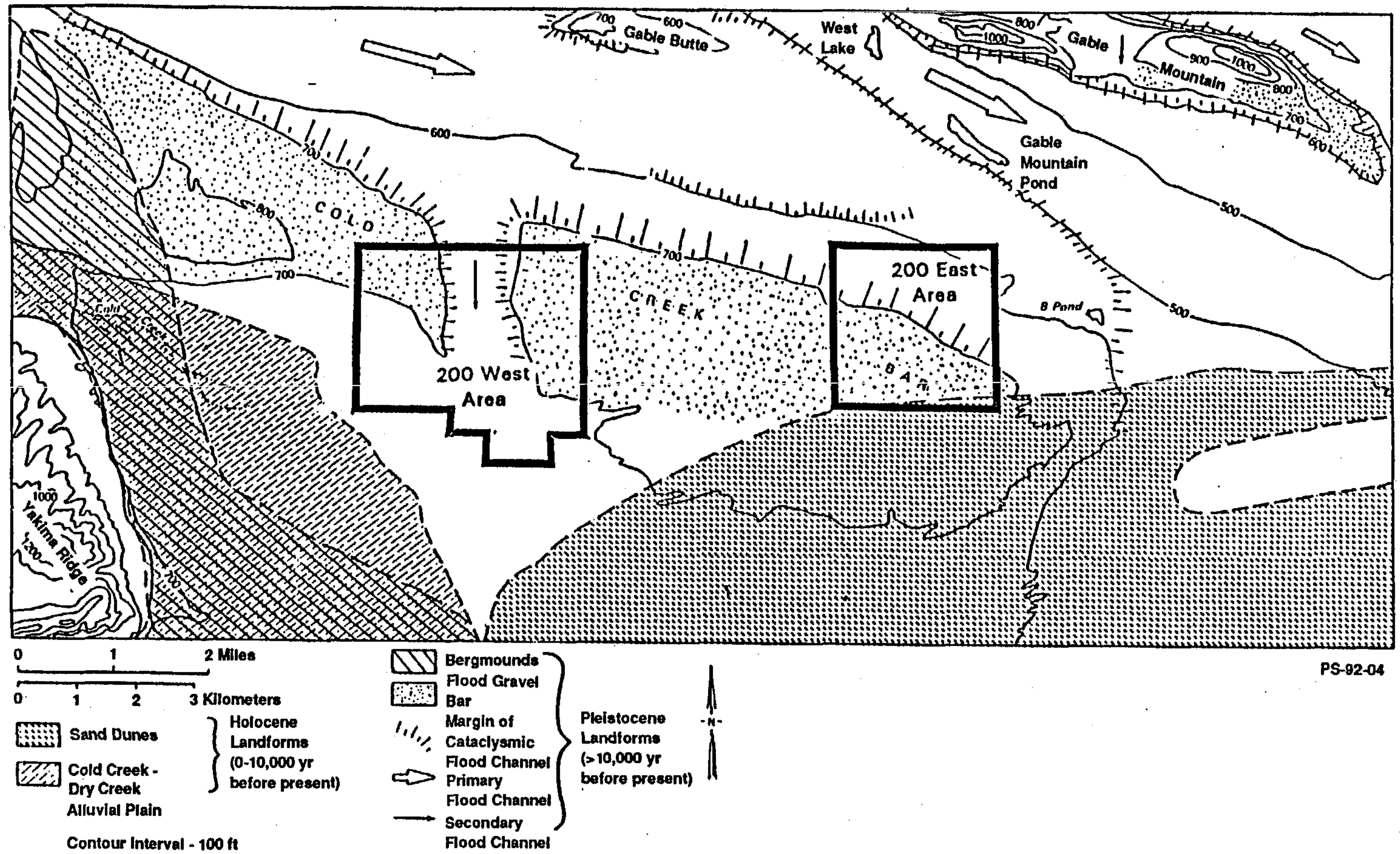
This section summarizes the geology in the vicinity of the LERF. More detailed discussions are found in Delaney et al. (1991), Lindsey et al. (1992), and Sweeney et al. (1994). The terrain surrounding the LERF is relatively flat and the average elevation is about 195 m above msl. The prevailing wind is from the northwest, although strong winds are from the southwest. Sagebrush and cheatgrass cover the area except for access roads and the site itself.

The LERF lies in the Pasco Basin, northeast of the Cold Creek Bar (Figure 3.1) between the axis of the Umtanum-Gable Mountain anticlinal ridge and the axis of the Cold Creek syncline (Figure 3.2). The site is situated on the north flank of the syncline and on the south flank of a principal anticlinal flexture (Figure 3.2).

The stratigraphy beneath the LERF Area has been interpreted principally from the four boreholes drilled to construct the groundwater-monitoring network for the facility (Sweeney et al. 1994). Other correlations were made with sediment data from the 200 East Low-Level Burial Ground Waste-Management Area 2 (LLBG WMA 2) and the 216-B-3 Pond (B Pond). Stratigraphic correlations are presented in Figure 3.3. This figure compares the general stratigraphy of Lindsey (1995) with the conceptual hydrostratigraphic units of Thorne et al. (1993). The thickness of the super-basalt sediments beneath the LERF Area is about 61 m.

Geologic cross sections (Figures 3.4 and 3.5) show the distribution and characteristics of geologic units within the LERF Area. The following sections discuss the geologic units beneath the LERF Area in more detail. Locations of this cross section, along with the locations of all boreholes used in this study, are shown in Figure 2.2.

Three principal stratigraphic units are present near the LERF: the Hanford formation, the Ringold Formation, and the Columbia River basalt. The Hanford formation consists of mostly uncemented gravel, sand, and silt deposited by glacial-outburst cataclysmic floods, which occurred periodically throughout the Pleistocene (Fecht et al. 1987; Baker et al. 1991). The Hanford formation is up to 75 m thick in the vicinity of LERF. The Hanford formation has been divided into three lithofacies that grade and transition from one to the other. The three facies are referred to a gravel-, sand-, and silt-dominated facies by Lindsey et al. (1992) and gravel, plane-laminated sand, and graded rhythmite facies by Baker et al. (1991). The gravel facies is the predominant lithofacies in proximity to high-energy cataclysmic flood channels, such as at the LERF. Sand- and silt-dominated facies are more common southward, away from the axes of the main flood channels. More detailed discussions of the Hanford formation are presented in DOE (1988), Baker et al. (1991), Lindsey et al. (1992; 1994), and Connelly et al. (1992).



*** Keyed features are specifically selected and do not encompass all features.**

Figure 3.1. Geomorphic Features of the 200 Areas

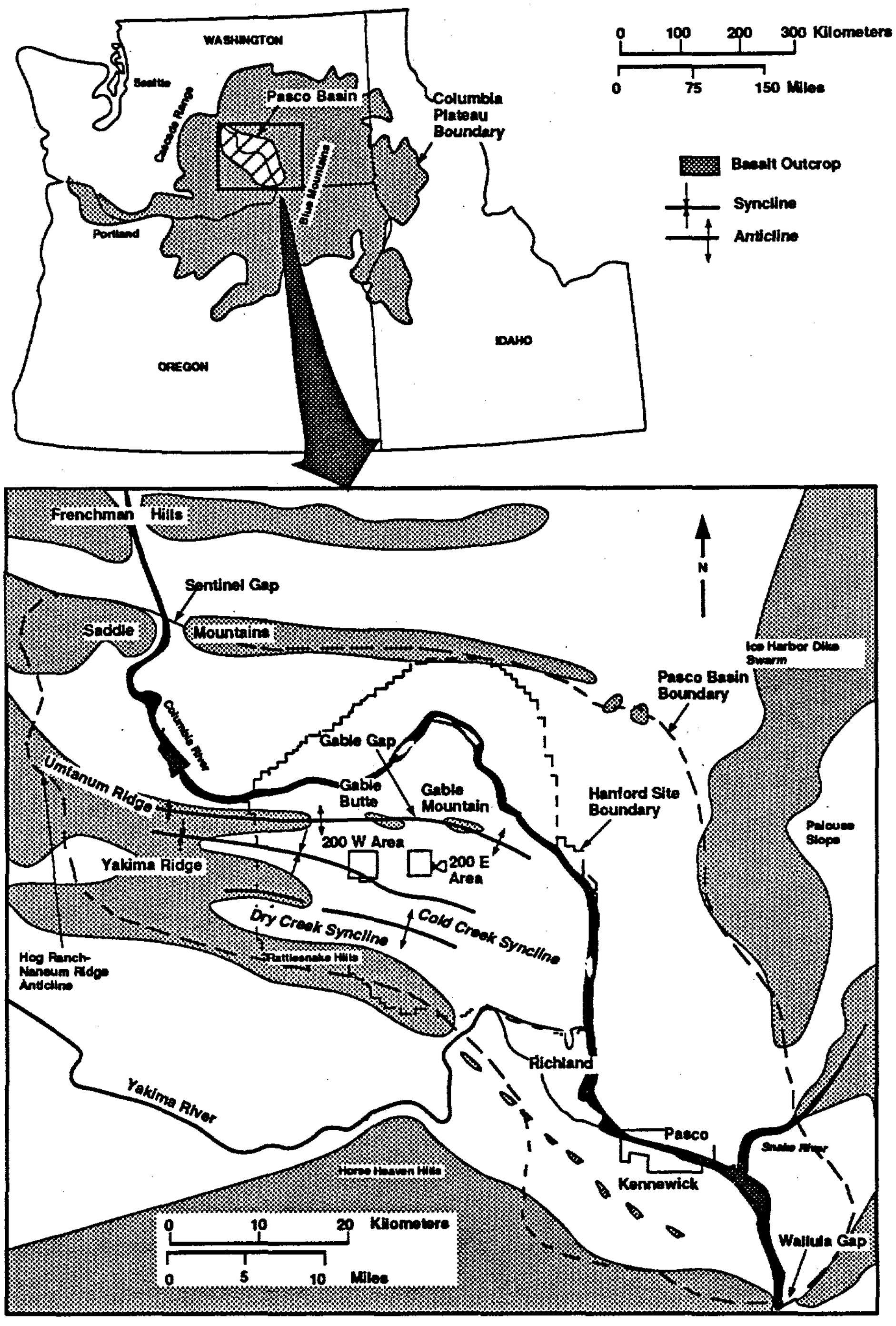


Figure 3.2. Generalized Structural Features of the Pasco Basin, Washington

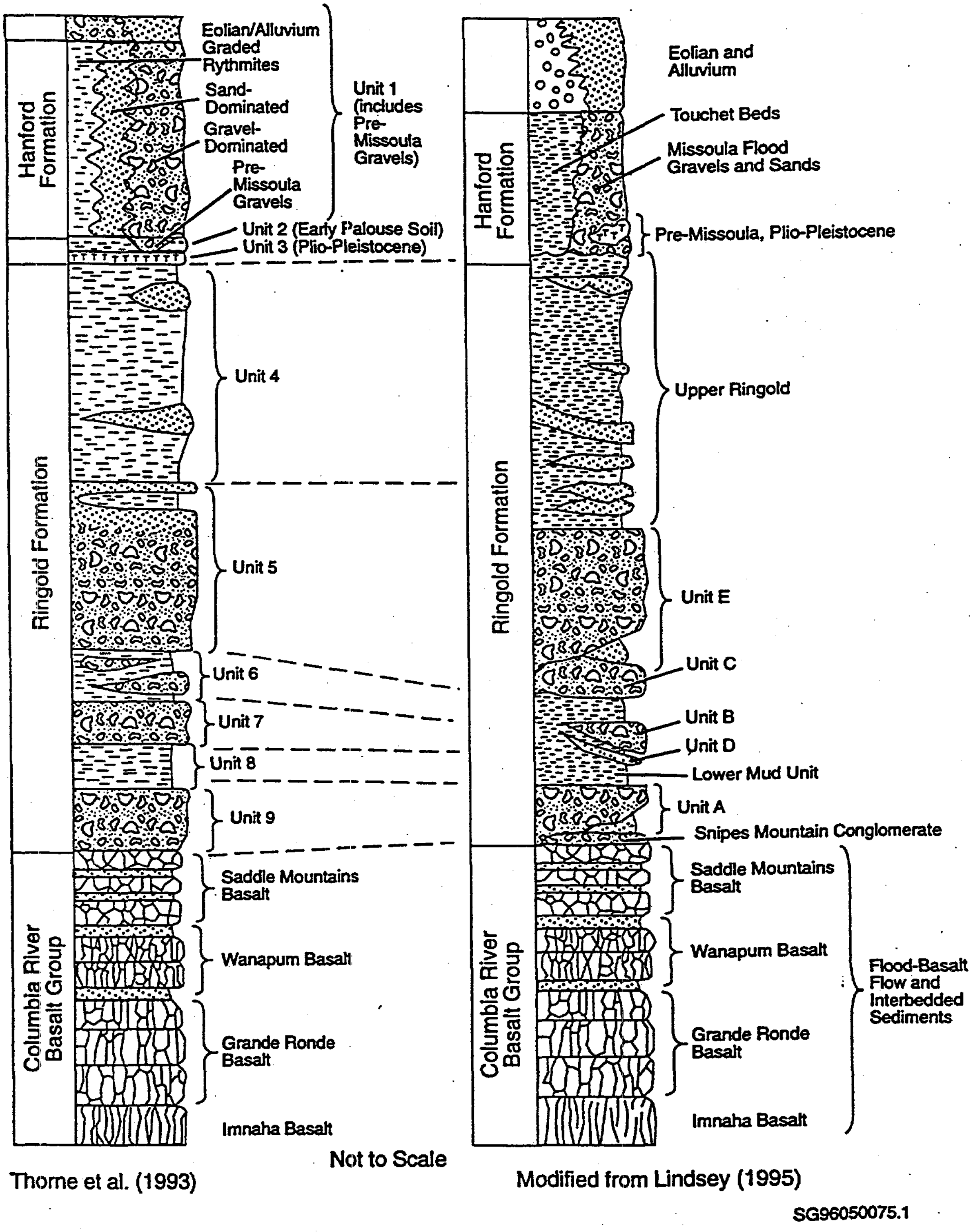
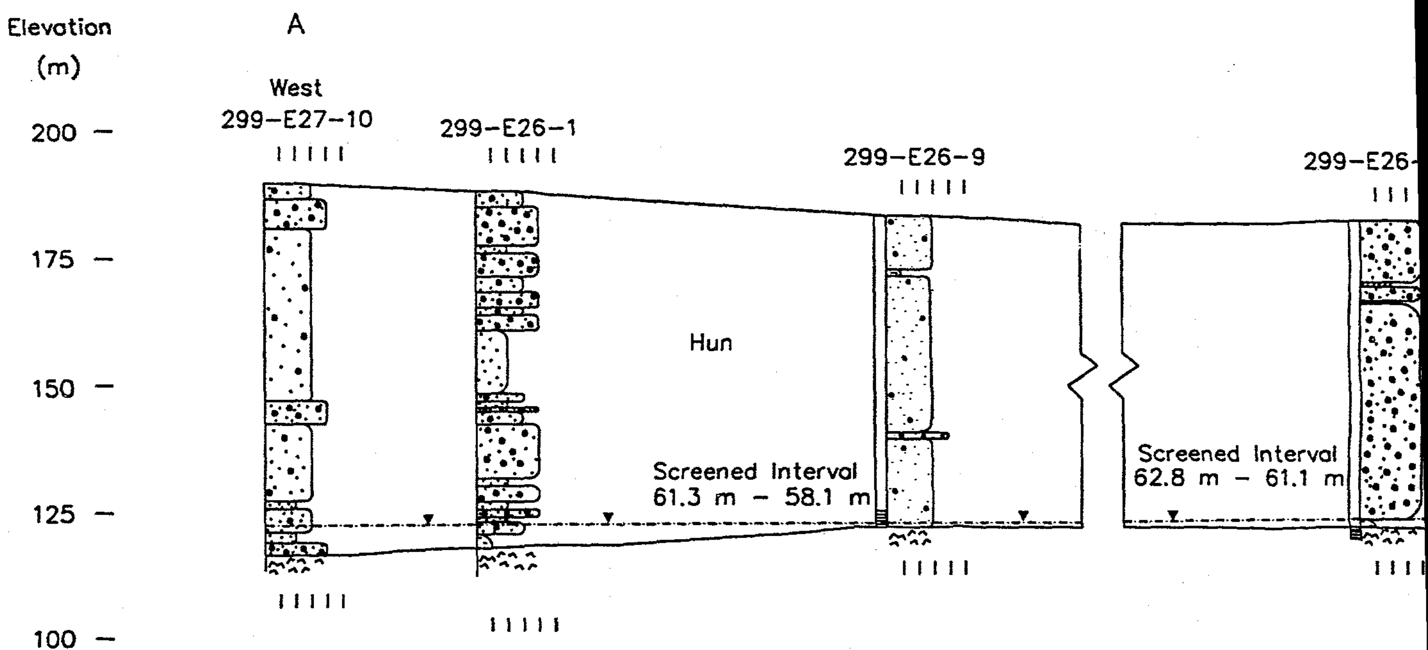


Figure 3.3. Comparison of Generalized Geology and Hydrogeologic Stratigraphic Columns



Explanation

Dominant grain size scale

S P
C/Z GS C/B

C/Z - Clay and Silt
S - Sand
GS - Gravelly Sand
P - Pebble Gravel
C/B - Cobble & Boulder Gravel

Lithologic Symbols

G Gravel
SG Sandy Gravel
GS Gravelly Sand
S Sand
MS Muddy Sand
SM Sandy Mud
M Mud
Basalt

Stratigrap

Hanford for

Hug - u
Hs - s
Hlg - lo
Hun - u

Ringold For

RA - u

Saddle Mou

EM - E

Forma
Facies
Water

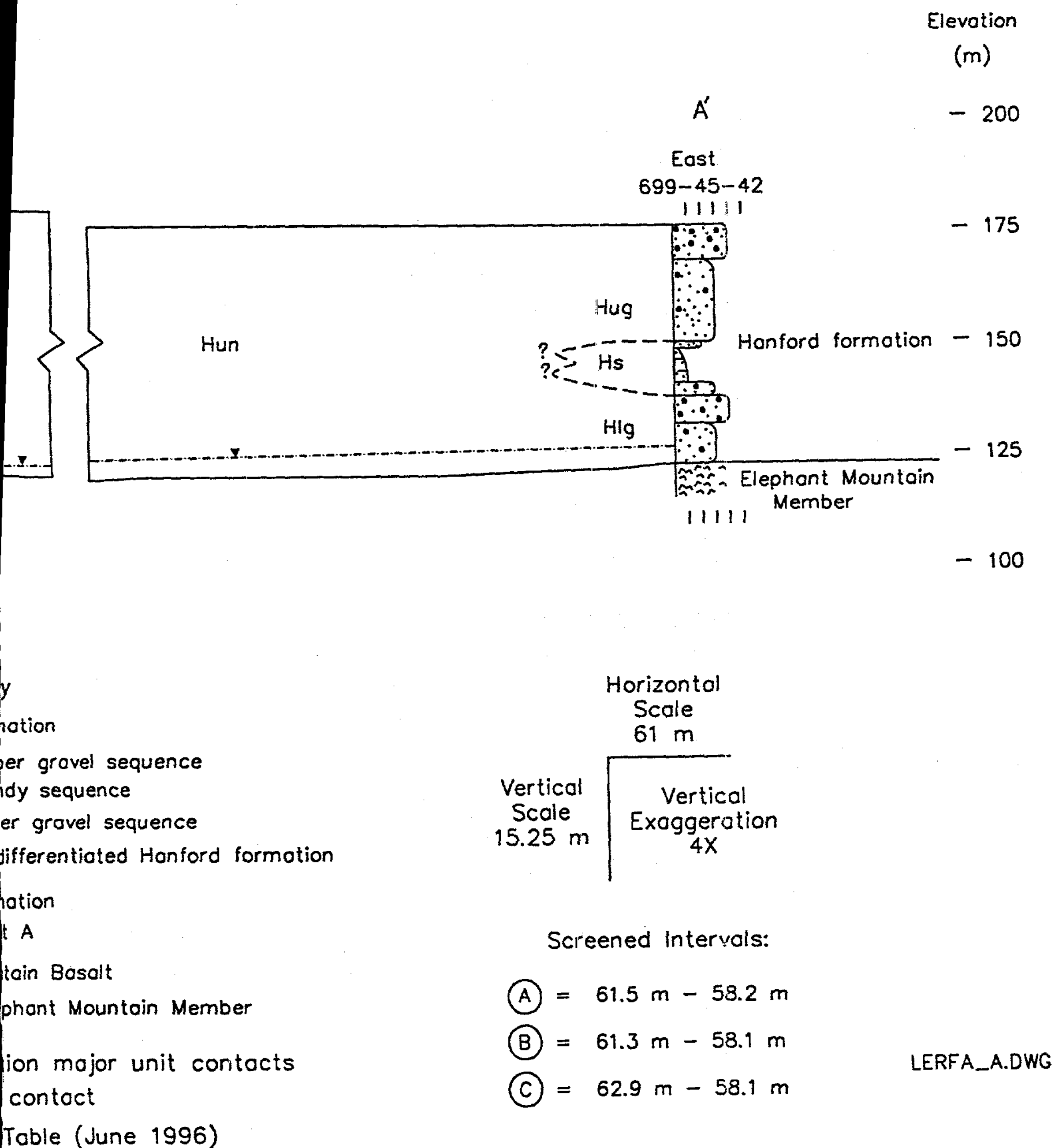
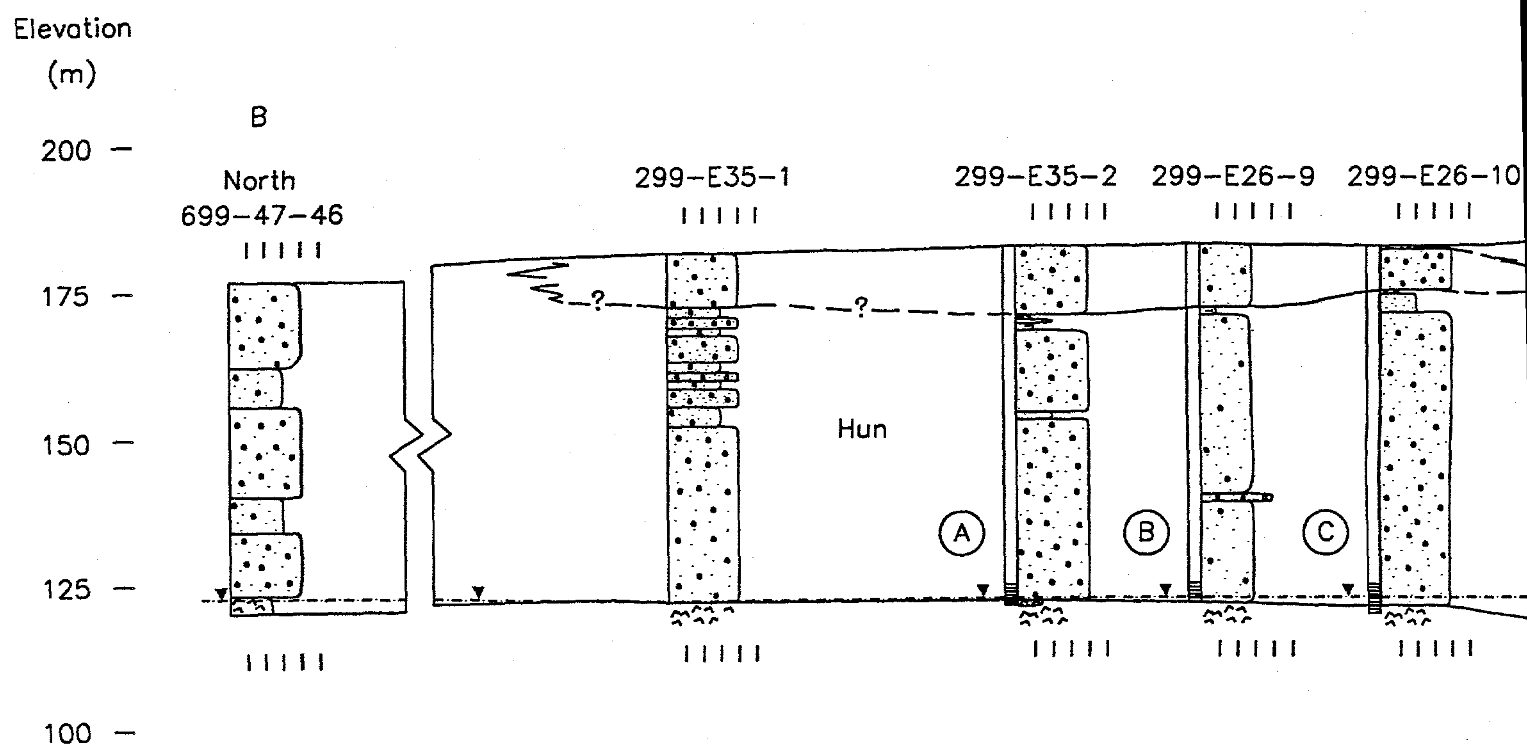


Figure 3.4. West to East Cross Section Through the LERF Area (A-A')



Explanation

Dominant grain size scale

S P
C/Z GS C/B

C/Z – Clay and Silt
S – Sand
GS – Gravelly Sand
P – Pebble Gravel
C/B – Cobble & Boulder Gravel

Lithologic Symbols

G Gravel
SG Sandy Gravel
GS Gravelly Sand
S Sand
MS Muddy Sand
SM Sandy Mud
M Mud
Basalt

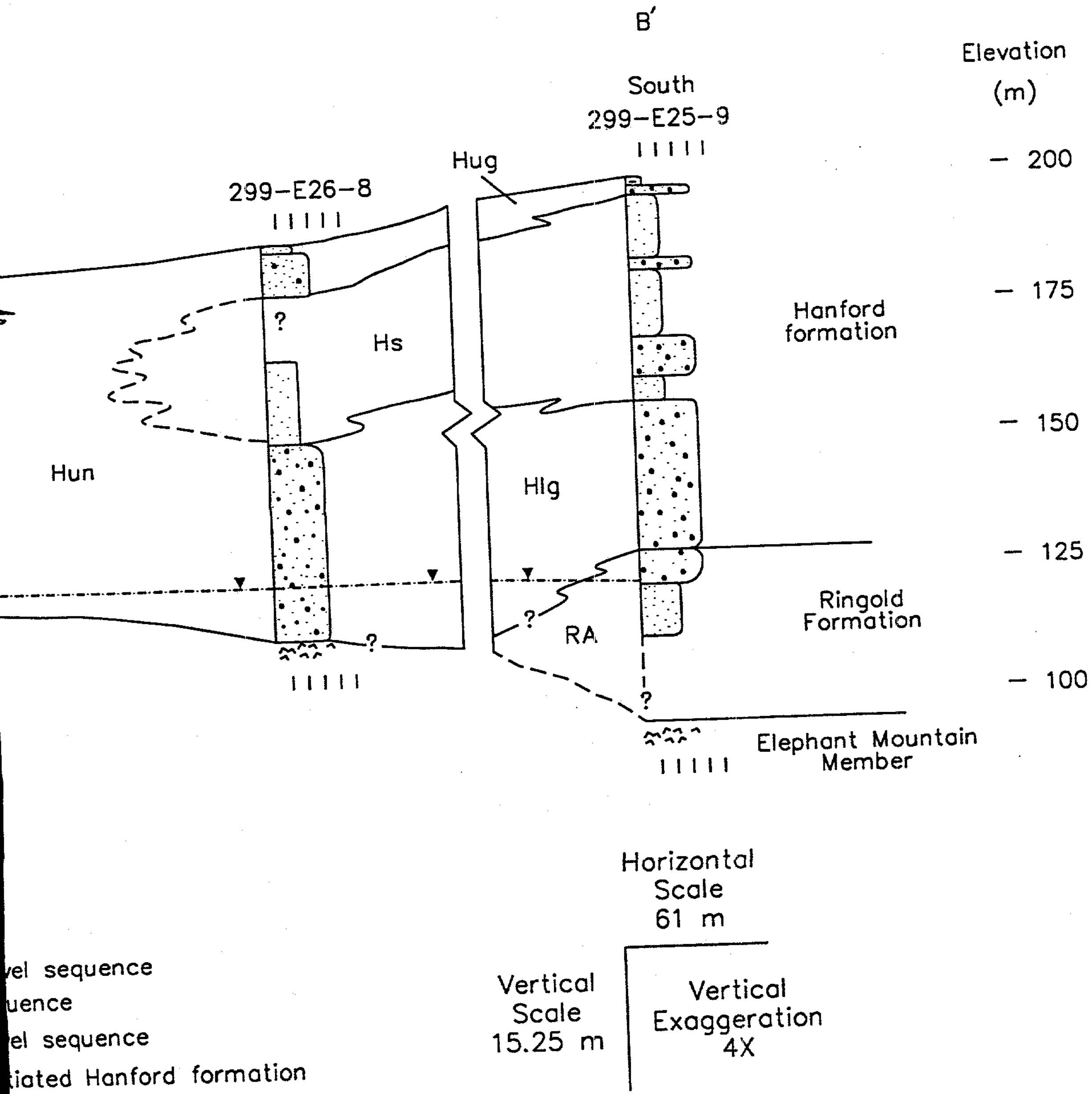
Stratigraphy

Hanford formation
Hug – upper gr
Hs – sandy se
Hlg – lower gr
Hun – undifferen

Ringold Formation
RA – unit A

Saddle Mountain B
EM – Elephant

Formation n
Facies cont
Water Table



vel sequence
uence
el sequence
tiated Hanford formation

salt
Mountain Member
ajor unit contacts
ct
(June 1996)

Screened Intervals:

(A) = 61.5 m – 58.2 m

(B) = 61.3 m – 58.1 m

(C) = 62.9 m – 58.1 m

LERFB_B.DWG

Figure 3.5. North to South Cross Section Through the LERF Area (B-B')

3.1.1 Hanford Formation

The Hanford formation in the vicinity of the LERF consists predominantly of a loose, sandy, pebble-cobble gravel, and a gravelly sand, with occasional layers of sand and/or muddy sand. Sometimes a sequence of the sand-dominated facies occurs between sequences of gravel-dominated facies (Connelly et al. 1992; Lindberg et al. 1993), especially to the south and west of the LERF site. Where this occurs, the Hanford formation is subdivided into an upper gravel sequence (Hug), a sandy sequence (Hs), and a lower gravel sequence (Hlg) (Figures 3.4 and 3.5). The sandy sequence only is present locally within a few of the wells beneath the LERF. Where the sandy sequence is missing, the single sequence of gravel-dominated facies exists, designated as undifferentiated (Hun) on the cross sections (Figures 3.4 and 3.5).

The LERF is located along the southern flank of a major WNW-ESE trending cataclysmic flood channel. Because of multiple flood events, and the turbulence and extremely high-energy associated with these floods, it is difficult to impossible to correlate individual strata within flood sequences; correlations must be done with extreme caution. In outcrops of the Hanford formation elsewhere in the Pasco Basin, for example, it is not uncommon to see gravel-dominated facies grade into and juxtaposed against sand- and silt-dominated facies over a distance of a few tens of meters.

3.1.2 Ringold Formation

The Ringold Formation represents ancient fluvial and lacustrine deposits associated with the ancestral Columbia River, which accumulated sediments in the Pasco Basin between ~3.0-8.5 Ma. Characteristics of the Ringold Formation include a higher degree of consolidation and weathering, compared to the Hanford formation. Isolated, erosional remnants of the Ringold Formation exist locally between the Hanford formation and basalt bedrock beneath the LERF. Thin (few meters or less) pockets of Ringold Formation occur to the south (well 299-E25-9) (Figure 3.5). The Ringold sediments preserved are from the older unit (Unit A), identified in Lindsey et al (1992, 1994), Lindberg et al. (1993), and Connelly et al. (1992).

3.1.3 Elephant Mountain Member

Basalt was encountered in all four of the boreholes drilled around the LERF Area. Samples of the basalt from three of the wells were sent to Washington State University for X-ray fluorescence (XRF) analysis. The results of the XRF analysis indicate that all three basalt samples were of the Elephant Mountain Member chemical type (Sweeney et al. 1994). This tholeiitic basalt member has been dated at 10.5 Ma (McKee et al. 1977). The Elephant Mountain Member has been described as having medium- to fine-grained texture with abundant microphenocrysts of plagioclase, transitional to normal magnetic polarity, is one of the youngest members of the Saddle Mountains Basalt, and is the uppermost member expected in this area (Reidel and Fecht 1981; DOE 1988; Graham et al. 1984; Tallman et al. 1979).

The top of the basalt forms the base of the unconfined aquifer in the LERF Area. All four wells in the LERF-monitoring network reached total depth at the top of the Elephant Mountain Member and are screened across the entire saturated zone in the Hanford formation. These monitoring wells will generally lose their capability to produce representative samples in relation to their position on the top of basalt surface of the Elephant Mountain Member. The top of basalt for the Elephant Mountain Member dips gently to the south with a gradient of 2.0E-02 across most of the 200 East Area (Figure 3.6).

3.2 Groundwater Hydrology

The uppermost aquifer in the LERF Area generally resides in the gravels of the Hanford formation. Figure 3.7 shows the water table in the LERF Area in June 1996. The thickness of the saturated zone varies throughout the LERF groundwater-monitoring network. A regional groundwater elevation decline has occurred since the monitoring network was installed (Figure 3.8). This has resulted in a saturated thickness of 0.6 to 1 m at the northwest portion of the network, 2.5 m in the southwest, and 4.0 m in the east. This constant decline eventually will lead to a saturated thickness of 0 m under most of the LERF (Figure 3.9).

Hydrologic testing was performed at the LERF in 1990 after the installation of the monitoring well network. The purpose of the testing was to provide estimates of transmissivity and hydraulic conductivity of the screened interval.

Slug tests were performed in the unconfined aquifer of the Hanford formation in all four wells. Transmissivity was estimated by the Bouwer and Rice (1976) and Cooper et al. (1967) methods. Values ranged from 11 to 232.5 m^2/d for well 299-E26-9. This produces an equivalent hydraulic conductivity of approximately 6 to 122 m/d, assuming an aquifer thickness of 1.8 to 1.9 m. Substantially lower transmissivity and conductivity data were obtained from wells 299-E26-11 and 299-E35-2. The transmissivity and conductivity for these wells are 6 m^2/d and 11 m/d for 299-E26-11 and 6 m^2/d and 40 m/d for 299-E35-2. The results for the three wells that were reported are indicative of the range of values that can be obtained in the 200 East Area. Data were not obtained for well 299-E26-10 (Sweeney et al. 1994).

Regional groundwater flow is from west to east, but impacted by groundwater mounding resulting from waste-water discharges. Groundwater generally flows from east to west in the uppermost aquifer beneath the LERF Area. The direction of groundwater flow is dominated by residual hydraulic mounding at the 216-B-3 Pond System (Figure 3.7). Decades of effluent discharges to this facility continue to affect groundwater flow, both inside and to the east of the 200 East Area. As discharges in effluent disposal have declined, the mound beneath B Pond either has changed its shape or its position as evidenced by the water level measurements surrounding the facility (Figure 3.10). Groundwater elevations are predicted to reach their pre-production levels in this area as the mound beneath the 216-B-3 Pond System dissipates.

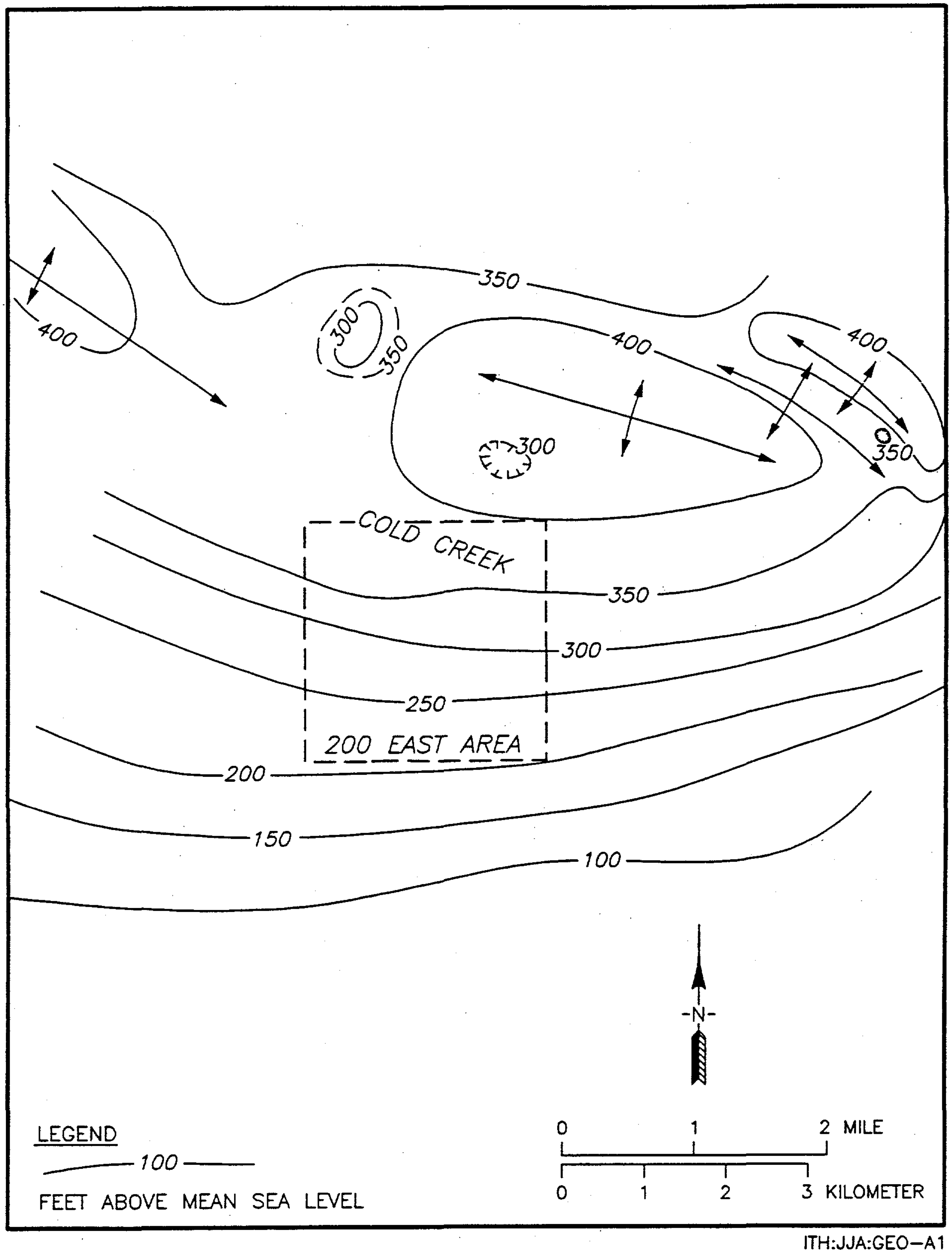
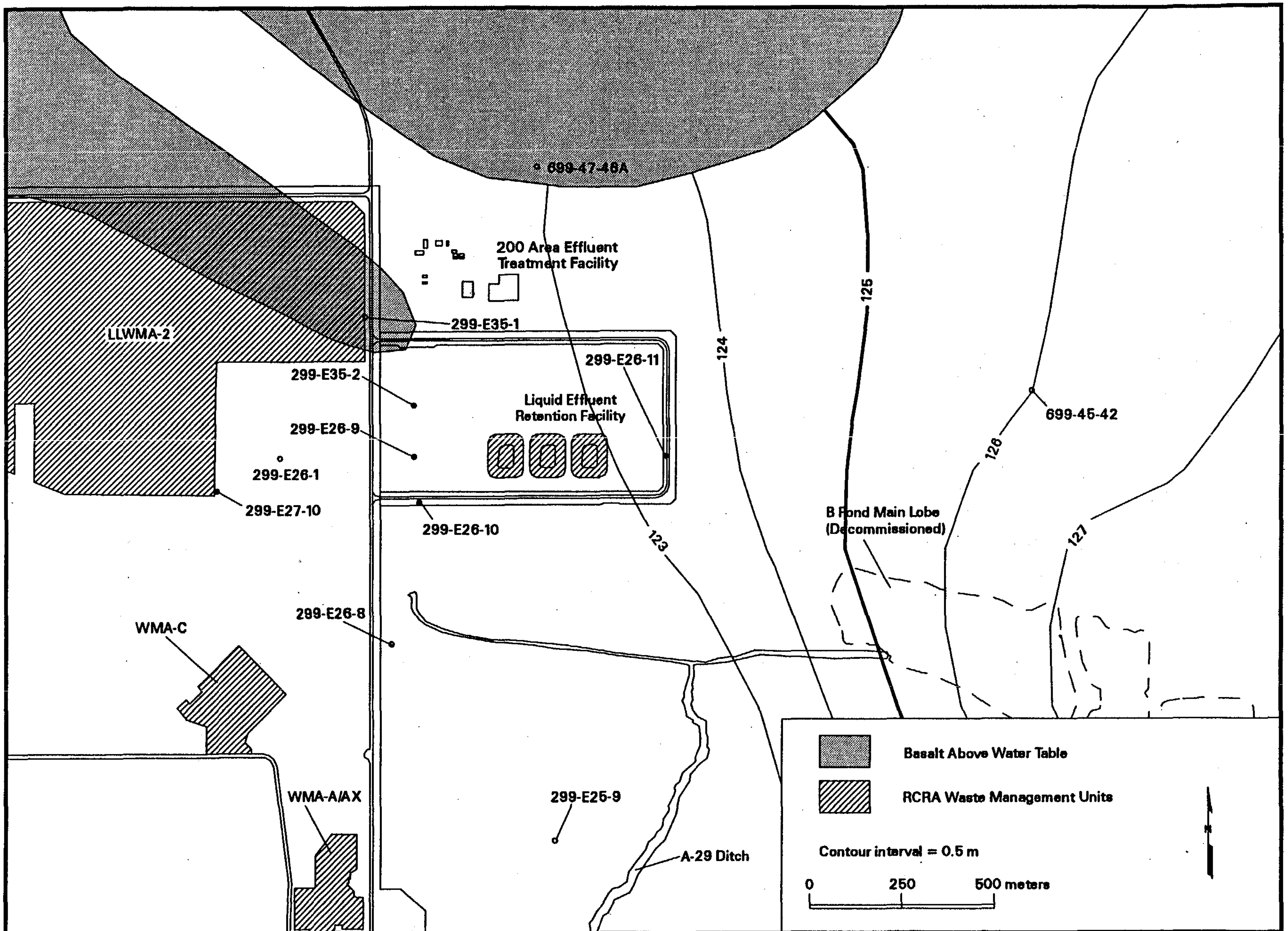


Figure 3.6. Top of Basalt Structure Contour Map (after Fecht, Reidel, and Chamness)



lerfig3.2-1.map-970514

Figure 3.7. Water Table Map of the LERF Area, June 1996

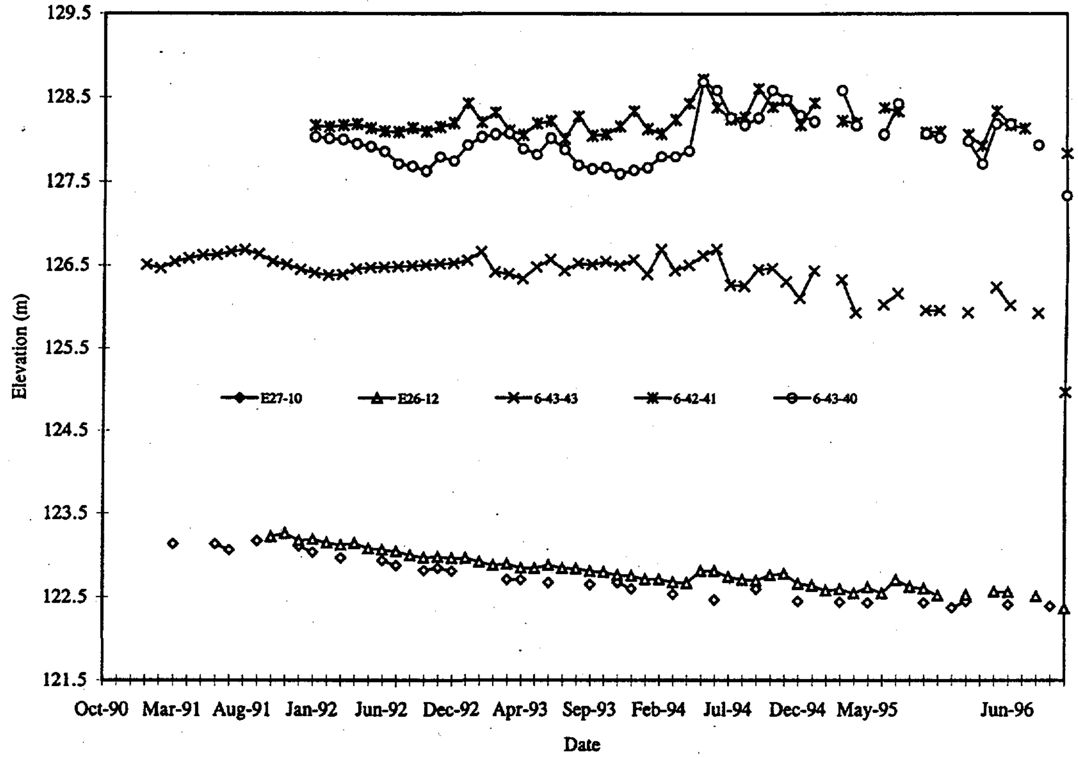


Figure 3.8. Hydrograph of Ground-Water Monitoring Wells Near the LERF Area

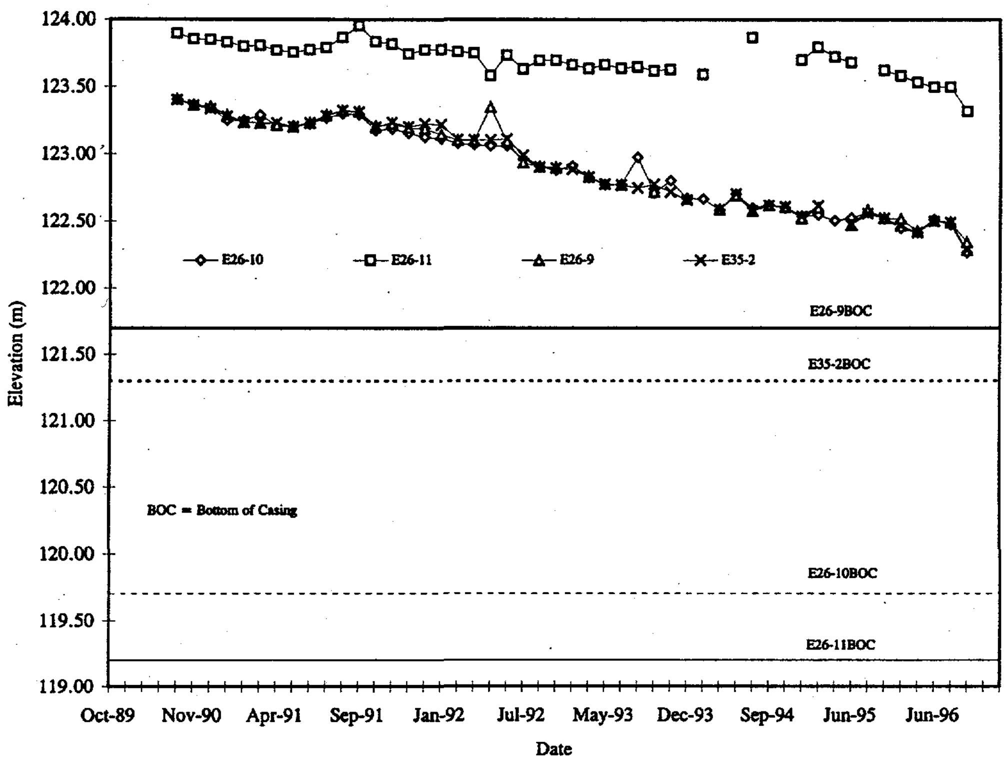
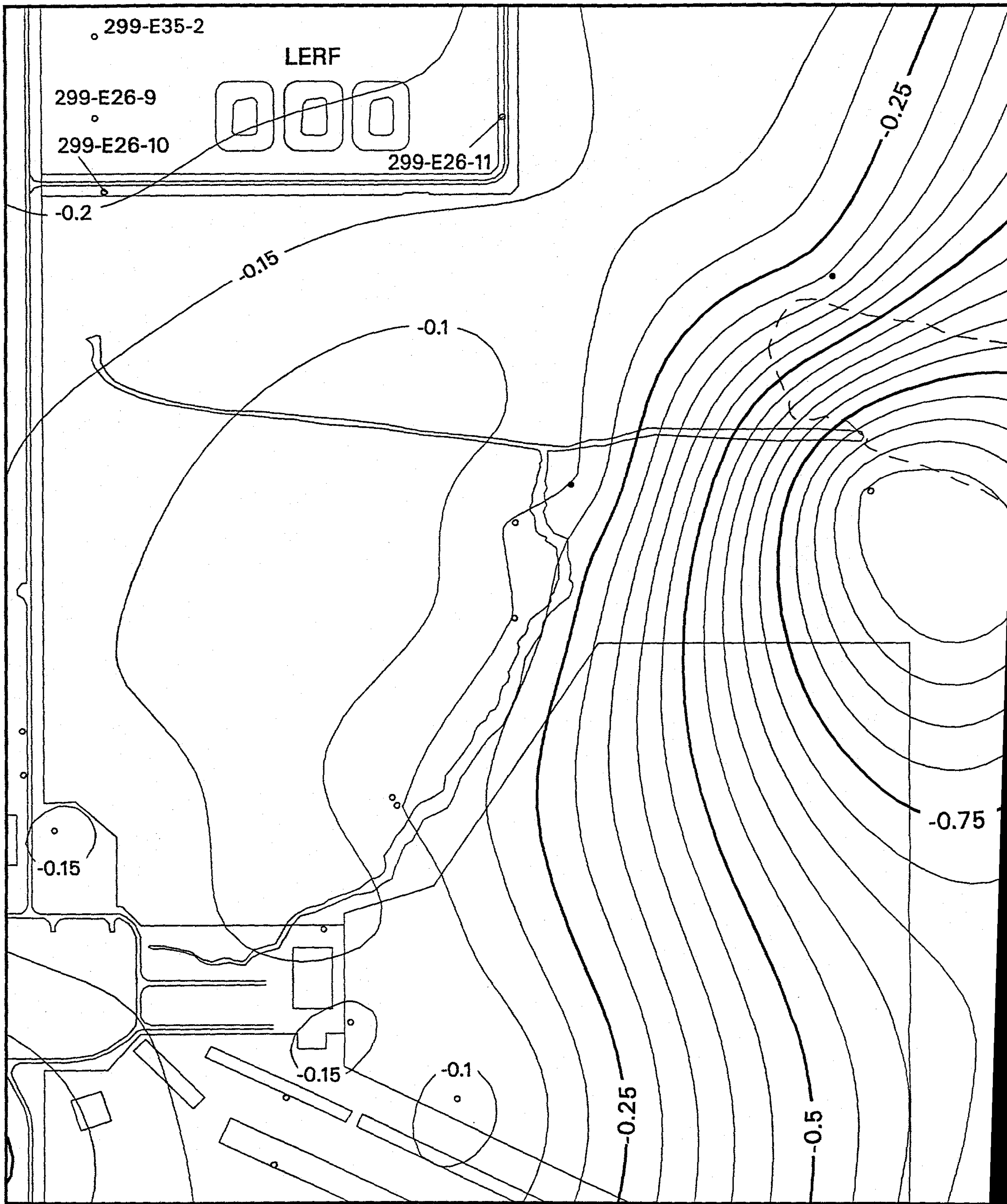
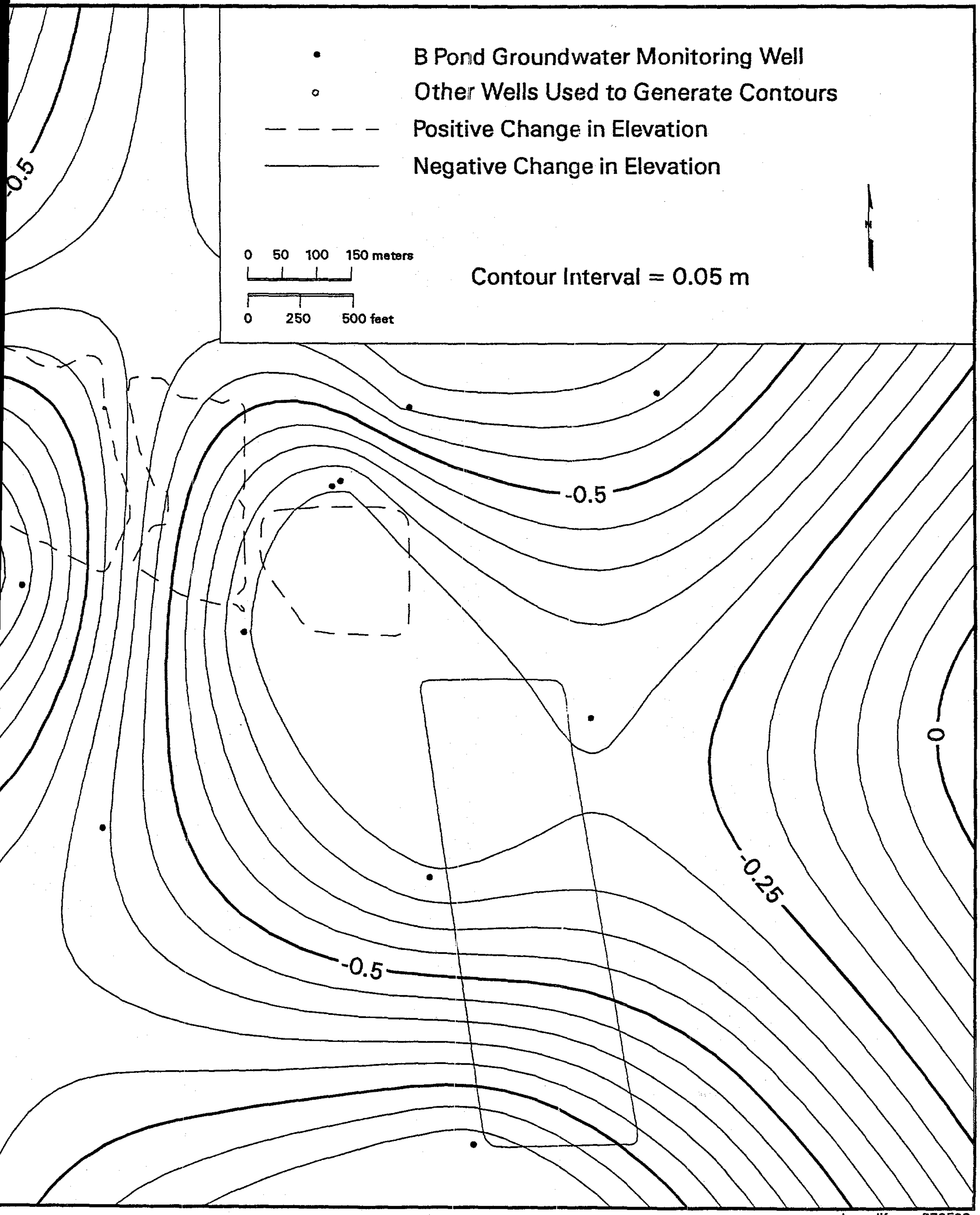


Figure 3.9. Hydrograph of LERF Ground-Water Monitoring Wells



299-E35-2
LERF
299-E26-9
299-E26-10
299-E26-11
-0.2
-0.15
-0.1
-0.25
-0.75
-0.15
-0.15
-0.1
-0.25
-0.5



bpondif.map-970509

Figure 3.10. Ground-Water Elevation Differential, June 1996 to January 1997

3.3 Groundwater Chemistry

Groundwater chemistry in the uppermost aquifer beneath the LERF has been affected by liquid waste discharged at the 216-B-3 Pond System. No specific pattern of chemical contamination has been identified, but groundwater has been significantly diluted because of the large volume of river water with lower dissolved solids than ambient groundwater (Reidel et al. 1995). Concentrations of arsenic (Johnson 1993) and elevated total organic halides (TOX) have been identified in groundwater beneath the 216-B-3 Pond System. The presence of arsenic has been proposed to be an artifact of discharges to other facilities (e.g., the 216-A-29 Ditch and the 216-A-37 or 216-A-30 Cribs [Reidel et al. 1995]). Arsenic, as well as uranium, was detected in the lower portion of well 699-37-47A. This well was drilled for the PUREX Plant Cribs in 1996 (Lindberg et al. 1997). The constituent identified as contributing to the elevated TOX is tris-2-chloroethyl phosphate (Hartman and Dresel 1997). The source of this constituent currently is being investigated. Neither of these constituents are increasing in concentration and are not considered to impact groundwater significantly in the LERF Area. No exceedences of interim-status groundwater-monitoring parameters have been found.

4.0 Groundwater-Monitoring Program

This section proposes a final-status RCRA detection-level groundwater-monitoring program for the LERF. The groundwater-monitoring program is designed to achieve the following goals in a technically sound and cost-effective manner:

- protect human health and the environment
- comply with the intent of final-status groundwater-monitoring requirements of WAC 173-303-645 and 40 CFR 264 Subpart F
- provide information for groundwater investigation and/or remediation.

This section presents a monitoring network design consisting of the existing wells; methods for sampling and analysis, and a statistical approach for data evaluation.

The elements of this monitoring program were developed through a data quality objectives (DQO) process (EPA 1993). The primary purpose of the DQO process is to ensure that the type, quantity, and quality of data used in monitoring are appropriate for their intended purposes.

4.1 Objectives of RCRA Monitoring

Three stages of groundwater monitoring programs are defined in WAC 173-303-645 with three separate objectives. The detection monitoring program [173-303-645(9)] is designed to determine whether a RCRA-regulated unit has adversely affected the groundwater quality in the uppermost aquifer beneath the regulated unit (i.e., whether a release has occurred). This is accomplished by comparing downgradient concentrations of constituents of concern to values indicative of background concentrations. If a statistically significant increase (or pH decrease) over background occurs in any downgradient well, then a compliance-monitoring program is initiated. In compliance monitoring, downgradient groundwater concentrations of constituents of concern are compared to the concentration limits set in the facility's permit. Concentration limits could be those specified in WAC 173-303-645 5(a)(ii) or alternative concentration limits established by Ecology. If concentration limits are exceeded, the regulated unit must implement a corrective action program. The objective of corrective-action is to protect human health and the environment by removing the dangerous waste constituents and parameters or treating them in place.

Results of the interim-status groundwater-monitoring program indicate that the LERF has not impacted the groundwater quality beneath the site. Thus, a detection-monitoring program is deemed appropriate for the site.

4.2 Chemical Parameters and Dangerous Constituents

Nitrate, TOX, total organic carbon (TOC), tritium, gross alpha- and gross beta-emitting isotopes were selected as the constituents of concern. The following factors were considered in deriving a constituent list for the LERF: 242-A Evaporator campaign analysis, history of detection in the site groundwater, and other potential source streams that have been identified for storage in the LERF. Because the likelihood is small that any release has occurred during LERF operational activities, the selection of the constituents of concern was not driven by patterns of groundwater contamination. A broad analytical approach was selected due to the inherent uncertainties associated with predicting long-term use of the LERF for effluent treatment. Although waste treatment campaigns of DST wastes have produced a relatively narrow range of effluent variability, future treatment campaigns may produce elevated levels of constituents that cannot be predicted. Also, cleanup efforts throughout the site will produce source streams beyond the narrowly defined chemical makeup of effluents generated by the 242-A Evaporator.

Nitrate was selected for groundwater analysis due to concentrations of ammonia in 242-A Evaporator process condensate. The TOX and TOC analyses were selected to detect a wide variety of organic constituents from various sources. These analytical methods will detect the presence of acetone, 1-butanol, 2-butanone, methyl isobutyl keytone, and pyridine in groundwater samples. As a group, these constituents represent the current process knowledge for organic contaminants in the 242-A Evaporator process condensate. Radiological contaminants entrained in the process condensate necessitated the use of screening techniques to identify gross activities for both beta- and alpha-emitting isotopes. Tritium was also identified in the process condensate and will be an early indication of contaminant transport to groundwater.

4.3 Concentration Limits

This section proposes the concentration limits for the LERF constituents of concern. These concentration limits serve as the compliance standards in case the regulated unit is found to impact the quality of groundwater and the facility enters into compliance-monitoring status. At that time, concentration limits for additional constituents of concern will be proposed and a revised groundwater-monitoring plan will be prepared. These concentration limits would be applied during compliance monitoring to determine whether corrective action might be necessary. It should be noted that concentration limits are not proposed for the general contamination-indicator parameters (i.e., TOC, TOX, gross alpha, and gross beta). These indicator species can only provide an indication of the presence of dangerous constituents in the groundwater. They cannot identify the specific constituent(s) that cause the degradation in groundwater quality.

- Nitrate: 45,000 ppb (as NO_3); based on final maximum contaminant level (MCL), 56 FR, January 30 1991

- Tritium: 80,000 pCi/L[(a)] (Eckerman et al.).

(a) Concentration assumed to yield an effective dose equivalent of 4 mrem/yr from a drinking-water pathway.

4.4 Groundwater-Monitoring Network and Point of Compliance

The proposed groundwater-monitoring network for the LERF contains four wells. Upgradient monitoring is accomplished with well 299-E26-11. The downgradient wells drilled for this facility include 299-E26-9, 299-E26-10, and 299-E35-2 (Figure 2.1). All wells were drilled to fulfill the requirements for well network monitoring for RCRA sites (WAC 173-160). The well construction and completion summaries, including schematics, for the four wells can be found in Appendix A. Specifically, the objective was to select well locations that would monitor the uppermost aquifer for waste constituents of concern. In the instance of the LERF, the constituents of concern include TOX, TOC, nitrate, tritium, gross beta, and gross alpha. None of these constituents has been detected in significant quantities from LERF wells. The three downgradient wells are west of the LERF to intercept any groundwater contaminants emanating from the LERF and flowing with the groundwater in directions consistent with the operational history of the facility.

Based on the Monitoring Efficiency Model (Wilson et al. 1992), the proposed downgradient wells should provide a monitoring efficiency of approximately 95.5%, assuming a groundwater-flow direction to the west. The location of 299-E26-11 was selected to provide upgradient groundwater conditions for the facility while attempting to minimize the influences of the 216-B-3 Pond System. The capability of the monitoring network to provide representative samples will decline as groundwater reverts to the pre-weapons production easterly flow direction. This reversal will have less impact than the overall decline of water table elevation. The declines eventually will leave two downgradient wells without enough groundwater to provide representative samples.

The point of compliance (POC) is defined in 40 CFR 264.95 and WAC 173-303-645 (6) as a "vertical surface" located at the hydraulically downgradient limit of the waste management area that extends down into the uppermost aquifer underlying the regulated unit. For the LERF, the POC should be the three downgradient monitoring wells as described above (i.e., 299-E26-9, 299-E26-10, and 299-E35-2; Figure 2.1).

4.5 Compliance Period

The compliance period is the number of years equal to the active life of the unit (including any waste-management activity before permitting and the closure period). Typically, groundwater monitoring is required for a period of 30 years following completion of closure activities, although this period may be shortened or extended by the regulatory authority. If the regulated unit undergoes corrective action, then the compliance period will be extended until it can be demonstrated that the applicable limit has not been exceeded for a period of three consecutive years.

4.6 Sampling and Analysis

This section describes the sampling and analysis program for the regulated unit, including monitoring parameters, analytical methods, monitoring frequency, and sampling protocols.

4.6.1 Monitoring Parameters

Table 4.1 lists constituents to be analyzed for the regulated unit. This list includes the following:

- the indicator constituents identified in Section 4.2 (Only the constituents of concern to the LERF will be used to determine whether statistically significant evidence of contamination has occurred)
- additional constituents to aid data interpretation (alkalinity, anions, and inductively coupled plasma (ICP) metals)
- field parameters routinely acquired at the well head (pH, turbidity, specific conductance, and temperature).

4.6.2 Sampling Frequency

The hazardous-waste regulations under RCRA require owners and operators of hazardous-waste facilities to use design features and control features that prevent the release of hazardous waste into groundwater. Regulated units are also subject to the groundwater-monitoring and corrective-action standards of 40 CFR Part 264, Subpart F and WAC 173-303-645. These regulations require that a statistical method and sampling procedure approved by the regulator(s) be used to determine whether there are releases from regulated units into groundwater. Default statistical methods and sampling procedures are specified in these regulations; however, alternatives are available as discussed below.

Historically, the default statistical method for detecting release from the regulated unit is *the tests on mean concentrations* between upgradient (background) and downgradient wells. For facilities regulated under the interim-status regulations, for example, a t-test is required to make this determination [40 CFR 265.93(b)]. For facilities regulated under the final status regulations, the recommended approach at the time of promulgation was analysis of variance (ANOVA) (EPA 1989, page 4-1 and page 5-3) where the

Table 4.1. Constituent List for the 200 Areas LERF

Constituent List		
Indicator Constituents	Field Parameters	Other
TOC TOX Nitrate Tritium Gross Alpha Gross Beta	pH Turbidity Temperature Specific Conductance	Alkalinity Anions Metals (filtered) by ICP[a] Method
(a) ICP = Inductively Coupled Plasma.		

means of different groups of observations are compared to determine whether there are any significant differences among the groups (e.g., background wells and compliance wells). If so, then contrast procedures may be used to determine where the differences lie.

The owner and operator has the latitude within the interim-status regulations to choose a t-test that will accommodate the data collected, however. There is much less choice with regard to the data collection requirement. Four replicate measurements (analyzed on the same sample) must be collected for the general contamination-indicator parameters during each sampling event.

Under final status regulations, two sampling procedures are allowed: (1) a sequence of at least four samples taken at an interval that ensures, to the greatest extent technically feasible, that an independent sample is obtained (i.e., the default sampling procedure); and (2) an alternate sampling procedure proposed by the owner or operator and approved by the regulator(s) that is to be protective of human health and the environment [40 CFR 264.97(g)(1) and (2), WAC 173-303-645 (8)(g)(i) and (ii)]. Under the default sampling procedure, the minimum number of samples that are to be collected each testing period is *four*. This minimum number was selected by the EPA to maintain consistency with the prior requirements (i.e., interim-status requirements using a t-test on means) that specified that the owner or operator collect one sample from each well and divide it into four replicate samples for laboratory analysis (53FR, 39725). Hence, EPA contended that requiring four samples to be collected from each well for laboratory analysis should not impose an increase in the number of analyses but recognized that there may be an increase in the field sampling costs associated with this sampling procedure. The requirement of four independent samples, therefore, reflected EPA's position (in 1989) of being consistent with interim-status requirements to collect four replicate samples and to use a test on mean concentrations as a default statistical method.

The most far-reaching change is the extension of groundwater-monitoring requirements to solid waste facilities, mandated in the 40 CFR Part 258, Subtitle D regulations. In particular, the solid waste Final Rule of 1991 dropped the four independent samples per monitoring period requirement (only one measurement is required per monitoring event).

Another major change included the issuance of an Addendum (EPA 1992) to *Interim Final Guidance on Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities* (EPA 1989). This Addendum reflects more current thinking within the statistics profession and offers a series of currently recommended techniques and updated advice concerning the Interim Final Guidance document (EPA 1992, page 1). One of the revisions is the recommendation of using a two-phased testing strategy (EPA 1992, pages 67-74) that evaluates each sample *individually* rather than relying on a test of the mean concentrations of several independent samples (i.e., the ANOVA procedure). This revision is prompted because the ANOVA method is to be avoided in the groundwater-monitoring applications for the following reasons (see Gibbons 1994, page 260 and EPA 1992, page 67): (1) the ANOVA procedure may have lower power for detecting a narrow plume of contamination that affects only one or two wells in a much larger network (approximately twenty or more comparisons); (2) a significant ANOVA test result will not indicate which well or wells is potentially contaminated without further post-hoc comparisons (i.e., comparisons that are found to be of interest after the data were collected); (3) because the one-way ANOVA procedure is not designed to test multiple constituents simultaneously, the overall false positive rate will be approximately 5% *per constituent*, leading to a potentially high overall network-wide false-positive rate if many constituents need to be tested (It should be noted that a site such as LERF with six indicator constituents will have a 26% = 1 - $(0.95)^6$ overall false positive rate); and (4) collection of four independent samples at a given well may necessitate a several-month wait if the natural groundwater velocity at that well is low.

In summary, the reason for the requirement of four independent samples during each monitoring event for facilities regulated under final status is that the one-way ANOVA can be performed (Davis and McNichols 1994). This requirement was dropped in the solid waste Final Rule of 1991. The EPA 1992 Addendum acknowledges that the one-way ANOVA procedures (parametric and nonparametric) are less attractive. It is desirable to seek alternative strategies (e.g., tolerance limits, prediction limits, or both) that allow statistical testing for each new groundwater sample individually as it is collected and analyzed. Furthermore, because each compliance well is compared with the interval limits separately, a narrow plume of contamination can be identified more efficiently than with an ANOVA procedure. That is, no post-hoc comparisons are necessary to find the contaminated wells, and the two-phased testing method has more power against the "needle-in-a-haystack" contamination hypothesis. The alternative strategy, set out below, is consistent with the Addendum to the Interim Final Guidance but does not require the collection of four independent samples during each monitoring event.

The regulations allow the use of an alternate sampling procedure [40 CFR 264.97(g) (2) and WAC 173-303-645 (8)(g)(ii)] and statistical method, provided they meet the performance standards as specified in 40 CFR 264.97(i) and in WAC 173-303-645(8)(ii). It also should be noted that in referring to "statistical methods" EPA endorsed a system approach to groundwater monitoring that evaluates the choice of a level of significance, the choice of a statistical test, the sampling requirement, the number of samples, and the frequency of sampling in their entirety, not by individual components (EPA 1989, page 2-4).

Based on justifications provided above, an alternate sampling procedure that is endorsed by EPA as being protective of human health and the environment is described briefly below. The compliance wells and background wells will be sampled for indicator constituents (see column 1 of Table 4.1) at least semiannually during the compliance period. Other constituents will be sampled in all monitoring wells on an annual basis. A two-staged testing strategy as recommended by EPA (1992) is proposed (see Section 4.7 for detail). During each semiannual sampling event, one sample will be collected from each well and individually compared to the background values established for the regulated unit (i.e., the first stage). The second stage is applicable to instance(s) where an initial exceedance(s) has occurred. In this stage, an upper prediction limit (using background data) will be calculated and compared to results of verification samples (i.e., confirmation sampling). Specifically, two verification resamples are to be obtained sequentially (from each well which exceeds the tolerance limit) and analyzed for the constituent in question. A statistical exceedance is declared if both verification resamples exceed the prediction limit. The use of upgradient-monitoring data to establish the upper tolerance limits as background values (i.e., the first stage) is described in Section 4.7.2. The proposed resampling scheme (i.e., the second stage) is discussed in Section 4.7.3. Temporal variabilities caused by seasonal effects are not expected in groundwater at the LERF.

4.6.3 Sampling Procedures

Groundwater-sampling procedures, sample-collection documentation, sample preservation and shipment, and chain-of-custody requirements are described in Environmental Investigation Instructions (EII) (WHC 1992), or superseding equivalent contractor procedures, and in the *Quality Assurance Project Plan for RCRA Groundwater Monitoring Activities* (WHC 1993) (or in superseding equivalent PNNL project quality assurance plan, in preparation). Work by subcontractors shall be conducted to their equivalent approved standard operating procedures.

All field-sampling activities will be recorded in the proper field logbook as specified in EII 1.5, or superseding procedures, and subsequent revisions. Before sampling each well, the static water level will be measured and recorded as specified in EII 10.2, or superseding procedures. Based on the measured water level and well construction details, the volume of water in the well will be calculated and documented on the well sampling form or field notebook. Each well will be purged until the approved criteria are met, as specified in EII 5.8, or superseding procedures. Purge water will be managed according to EII 10.3, or superseding procedures. If a well pumps dry because of very slow recharge or low water levels, then samples will be collected after recharge.

Quality assurance requirements are defined in the PNL-MA-70, *Quality Assurance Manual* (PNNL 1997) and Article 31 of the *Hanford Federal Facility Agreement and Consent Order* (Ecology and EPA 1996). The RCRA sampling and analysis program is supported by WHC (1993) or equivalent PNNL documents. Sample-preservation and chain-of-custody procedures are described in EII 5.1 (WHC-CM-7-7), or superseding procedures.

4.6.4 Analytical Procedures

Procedures for field measurements (pH, specific conductance, temperature, and turbidity) are specified in the user's manual for the meters used. The laboratory approved for the groundwater-monitoring program will operate under the requirements of current laboratory contracts and will use standard laboratory procedures as listed in the SW-846 (EPA 1986) or an alternate equivalent. Alternative procedures, when used, will meet the guidelines of SW-846, Chapter 10. Analytical methods and quality control for the RCRA groundwater-monitoring activities are described in WHC (1993) (or superseding PNNL quality assurance plan, in preparation).

4.7 Statistical Methods

This section proposes statistical evaluation procedures for the LERF groundwater monitoring program. Statistical evaluation of groundwater-monitoring data will comply with requirements set forth in the WAC 173-303-645(8)(h) and (i) final status regulations. Acceptable statistical methods for a final-status detection-monitoring program includes ANOVA, tolerance intervals, prediction intervals, control charts, test of proportions, or other statistical methods approved by Ecology [WAC 173-303-645(8)(h)]. The type of monitoring, the nature of the data, the proportions of nondetects, spatial and temporal variations are important factors to consider when selecting appropriate statistical methods. Procedures outlined in the following EPA technical guidance documents will be followed:

- *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities - Interim Final Guidance* (EPA 1989)

- *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities - Draft Addendum to Interim Final Guidance* (EPA 1992).

The concentrations of constituents of concern in POC wells will be compared with data from background wells semiannually to determine whether there is a statistically significant increase over background concentrations.

4.7.1 Approach

The goals of statistical evaluation methods proposed for the LERF are:

- The network-wide false-positive rate (across all constituents and wells being tested) should be kept at an acceptable low level. (Note that the false-positive rate [or Type I error rate] is the probability that the test will indicate contamination falsely although no contamination has occurred); and

- The test strategy should have adequate statistical power to detect real contamination when it occurs.

When the number of upgradient/downgradient comparisons is moderate to large (approximately twenty or more), the false-positive rate associated with the testing network as a whole can be quite high. If the test network consists of twenty separate comparisons (e.g., four wells multiplied by five constituents) and a false-positive rate for each individual well comparison is set at 1%, for example, then one would expect an overall network-wide (i.e., facility-wide) false positive rate of over 18% [note that $18\% - 1 - (0.99)^{20}$]. This means there is nearly one chance in five that one or more comparisons will register potential contamination falsely even if none has occurred, adding additional sampling and analysis expense to verify the false-positive results. To lower the network-wide false-positive rate, the number of tested constituents should be limited to the most useful indicators (EPA 1992, page 62; Gibbons 1994, page 16); therefore, only the constituents of concern will be subject to statistical evaluations for the LERF. Another strategy to lower the overall false-positive rate is to perform verification sampling to determine whether the statistically significant difference between background and compliance-point wells is an artifact caused by an error in sampling, analysis, statistical evaluation, or natural variation in groundwater chemistry.

Another goal of the statistical method is to maintain adequate statistical power for detecting contamination. The power of a test depends on several factors, including the background sample size, the type of test proposed, and the number of comparisons (i.e., the false-positive rate). Other things being equal, the larger the sample size (number of background samples), the larger the statistical power; therefore, the proposed statistical method should use historical groundwater-monitoring data (collected under the interim-status) to the greatest extent possible. The ANOVA procedures (either the parametric method or the Kruskal-Wallis test) are not proposed because they may have less power for detecting a narrow plume of contamination. Furthermore, a significant ANOVA test result will not indicate which well or wells is potentially contaminated without further evaluation (see Section 4.6.2).

After careful evaluation of statistical methods (that are acceptable for a final-status detection monitoring), a two-phase testing strategy that is recommended by EPA (1992, pages 67-75) is proposed for the LERF. In the first stage, an upper tolerance limit (for each constituent of concern) with pre-specified average coverage will be calculated based on background (upgradient well) data and will be compared to individual compliance-point (downgradient well) samples. The second stage is applicable to instance(s) where an initial exceedance(s) occurred. In this stage, an upper prediction limit (using background data) will be calculated and compared to results of verification samples (i.e., confirmation sampling). Specifically, two verification resamples are to be obtained sequentially (from each well which exceeds the tolerance limit) and analyzed for the constituent in question. A statistical exceedance is declared if both verification re-samples exceed the prediction limit.

The use of an upper tolerance limit as an initial screening tool is more powerful than the use of an upper prediction limit. An upper tolerance limit is designed to cover a certain specified percentage of all future measurements from the background distribution with $(1 - \alpha)\%$ confidence. By contrast, an upper prediction limit is designed to cover 100% of the future k measurements. If the number of future comparisons (e.g., the product of the number of monitoring wells and the number of constituents) is moderate to large (e.g., ≥twenty), the tolerance limits will be smaller than prediction limits. The proposed screening approach results in a statistical comparison that is more conservative in detecting small releases, and is therefore more protective of human health and the environment. Once an initial exceedance is observed, however, an upper prediction limit should be used for the verification resampling to control the overall false positive rate; an artifact of the built-in failure rate associated the upper tolerance limit (i.e., incomplete well coverage). The use of upgradient monitoring data to establish the upper tolerance limits (i.e., the first stage) is described in Section 4.7.2. The proposed re-sampling scheme (i.e., the second stage) is discussed in Section 4.7.3.

4.7.2 Background Values

Certain assumptions concerning the statistical model or methods are required to determine and interpret background groundwater characteristics properly at the regulated unit. These assumptions and/or justifications are stated below.

- Groundwater-monitoring data are representative of actual groundwater conditions in the uppermost aquifer beneath the site. Representativeness is best satisfied by following prescribed sampling and analysis procedures and collecting a sufficient number of samples.

- Seasonal or temporal variations are insignificant. As discussed earlier, temporal variabilities caused by seasonal effects are not expected at the LERF.

- Groundwater-chemistry data are typically log-normally distributed. The use of a log-normal distribution as a default statistical model is justified because: (1) most groundwater-monitoring data are positively skewed and are restricted to positive values; (2) all of the available statistical tests for distribution assumptions are inadequate when the sample size is small (approximately less than twenty observations); (3) EPA's experience with contaminant concentration data, and groundwater-monitoring data in particular, suggests that a log-normal distribution generally is more appropriate as a default statistical model than normal distribution (EPA 1992, page 2); and (4) pollutant sources are randomly diluted in a multiplicative fashion through repeated dilution and mixing with uncontaminated water, which can lead mathematically to a log-normal distribution (Ott 1990).

Background values (area) are defined as the levels of chemical, physical, biological, and radiological constituents or parameters upgradient of a unit, practice, or activity that have not been affected by that unit, practice, or activity. Background groundwater concentration, for a particular constituent of concern, is defined statistically as the 95% ("the coverage") upper tolerance limit with a 95% confidence ("the tolerance coefficient") (Ecology 1996a, page 65). The use of a coverage of 95% and a tolerance coefficient of 95% is also recommended by EPA (1989 and 1992). These recommendations are consistent with methods for defining background concentrations as required under the "Model Toxics Control Act Cleanup Regulation," WAC 173-340 (Ecology 1996b amended). One-sided upper tolerance limit for normally distributed data is of the form:

$$\bar{x} + ks \quad (1)$$

where $\bar{x}$ is the sample mean; k is a multiplier based on the coverage, the confidence level, and sample size; and s is the sample standard deviation. Values of k can be obtained from Natrella (1966) and Gilbert (1987, Table A.3). The upper tolerance limit for log-normally distributed data can be estimated by (1) transforming the raw data using $\log_{10}$ (common logarithm) or $\log_e$ (natural logarithm); (2) calculating the upper tolerance limit using the log-transformed data and Equation (1); and (3) back-transforming (antilog) to the original unit.

Before using these parametric limits that depend heavily on the normality (or log-normality) assumption, the adequacy of normal (or log-normal) distribution as a model will be assessed by probability plots and/or statistical goodness-of-fit tests, such as the Shapiro-Wilk test or the Lilliefors test of normality (Gilbert 1987; Conover 1980).

When the normal or log-normal distribution cannot be justified, the use of nonparametric tolerance intervals may be considered. The upper tolerance limit is usually the largest observed value in a random sample. The nonparametric tolerance intervals, however, require a large number of samples to provide a reasonable coverage and tolerance coefficient. The number of samples needed for a minimum coverage of P% and a tolerance coefficient of (1 - α)% is (Gumbel 1958, page 68):

$$n = \frac{\log_{10} \alpha}{\log_{10} P} \tag{2}$$

To have a minimum coverage of 95% and 95% confidence, 59 background samples are needed. Due to the large background sample size requirement, a non-parametric tolerance limit (with a minimum coverage of 95% and a 95% confidence) may not be practical in groundwater-detection monitoring. If one can use an average coverage of 95% (not the minimum as discussed above), however, then at least nineteen background samples are needed to achieve 95% coverage on the average. [Note: When the maximum sample value is chosen as the upper tolerance limit, then it can be shown that the expected coverage is equal to n/(n+1)]. If background samples are less than nineteen, then a lower average coverage and/or a lower confidence level would result.

Analytical results were reviewed under the aegis of the RCRA quality-control (QC) program. The QC program that supports the sampling and analysis of groundwater from the LERF is described in the PNNL comprehensive groundwater-monitoring report (Hartman and Dresel 1997). For the LERF, verified and validated groundwater-monitoring data (from upgradient well 299-E26-11) except for TOC and TOX, were used to establish the background value for each dangerous constituent of concern using Equation (1).

The reasonableness of the assumed log-normal (or normal) distributions was tested using the Lilliefors test for normality of data. The test results indicated that all of the dangerous constituents of concern can be reasonably approximated by log-normal (or normal) distributions, except for nitrate. On further evaluation there appear to be two concentration groups. Concentrations of earlier nitrate data (collected from June 1991 to April 1992, four data points) range from 4,900 μg/L to 6,100 μg/L. The range of the recent data (from July 1992 to January 1996, six data points) is from 7,400 μg/L to 8,200 μg/L. Because the earlier nitrate data are not representative of the current conditions, they are not used in the background value derivation. A statistical goodness-of-fit test is not performed for nitrate data because of insufficient data (six data points); however, upper tolerance limits (for a log-normal, normal, and non-parametric distribution) were calculated and evaluated. These limits (normal = 8,700 μg/L, log-normal = 8,800 μg/L, and non-parametric = 8,200 μg/L) are fairly comparable. Hence, an upper-tolerance limit based on a log-normal distribution is proposed as the background value for nitrate. As more monitoring data are collected, this value will be re-evaluated.

TOX data analyzed during the period from January 1992 through October 1993 were flagged with "Y" (suspect) because of audit concerns. These data were eliminated from further statistical evaluation because the validity of such data is in doubt. In addition, the majority of the TOC and TOX data (from upgradient well) were essentially nondetects. These data were either reported with a "U" qualifier, indicating that data were below the method detection limit (MDL), or reported with a "L" qualifier, indicating that data were between the MDL and the contractually required detection limit. Furthermore, analytical laboratories and the MDLs have changed several times over time (from June 1991 to January 1997). It is not appropriate to use these essentially not-detected TOC and TOX data to calculate the background values using Equation (1) because the lack of estimates of background variability precludes the determination of the upper-tolerance limits.

To overcome this problem, the limit of quantitation (LOQ) will be used as a surrogate background value for TOC and similarly for TOX. The LOQ is defined as the level above which quantitative results may be obtained with a specified degree of confidence (Keith 1991). It is determined by using field-blanks data. Note that the field blanks are QC samples that are introduced into a process to monitor the performance of the system. The use of field blanks to calculate LOQ is preferred over the use of laboratory blanks because field blanks provide a measure of the errors in the entire sampling and analysis system. Methods to calculate LOQ are described in detail in Schmid et al. (1991b).

Based on above discussions, the following background values are proposed for the LERF and are presented in Table 4.2. The necessary summary statistics and k values are also provided. It should be noted that the means and standard deviations shown in Table 4.2 are expressed in respective log unit of measurement (common logarithm).

Background values (i.e., upper tolerance limits) will be compared with individual sample results obtained from downgradient compliance wells semiannually. If an initial exceedance(s) occurs, then an upper prediction limit calculated from background data (see Section 4.7.3) will be calculated and compared to re-samples from well(s) which exceed the tolerance limit (i.e., confirmation sampling). In addition, background values will also be used to track the encroachment of upgradient sources of contaminant plumes. In order to assure that the background database contains independent and representative measurements, new data will be added that are determined to belong to the same background population. Background values (listed in Table 4.2) and the statistical approach will be evaluated and updated periodically to reflect these additions. If changes in groundwater flow directions result in changes in definition of upgradient well(s) or changes in site conditions, then background values will be re-established. If statistical evaluation methods are no longer effective to achieve its goals (see discussions in Section 4.7.1) caused by changing site conditions, then a new statistical approach will be proposed.

4.7.3 Confirmation Sampling

Tolerance limits have a built-in failure rate of (1 - P)%; for example, one would expect 1 in every 20 samples to be outside of the upper 95% tolerance limit just by chance. Verification re-sampling is necessary to decrease the chance of a false-positive decision because of either the built-in failure rate or the effects of gross errors in sampling or analysis. This is the best currently available approach to balance false-positive and false-negative decisions in groundwater-monitoring applications (Gibbons 1994, page 15). In case of an initial exceedance, a verification sampling is needed to determine if the exceedance is an artifact caused by an error in sampling, analysis, or statistical evaluation or natural variation in the groundwater. Recent EPA guidance (1992) encourages the use of re-sampling as a means to reduce the facility-wide false-positive rate.

Table 4.2. Proposed Background Values[a] for the LERF

Constituent of Concern	Number of Background Samples	Transformed Mean	Transformed Standard Deviation	Multiplier (K)	Upper Tolerance Limit
Tritium	14	3.267	0.0746	2.614	2,900 pCi/L
Nitrate[b]	6	3.8796	0.0174	3.711	8,800 µg/L
Gross Alpha	12	0.333	0.162	2.736	5.97 pCi/L
Gross Beta	12	0.7431	0.1324	2.736	12.74 pCi/L
TOC[c]	NA	NA	NA	NA	LOQ
TOX[c]	NA	NA	NA	NA	LOQ

(a) Background values are defined as the upper 95% tolerance limit with 95% confidence.
(b) Nitrate data collected from 1/21/92 to 1/3/96 were used. Earlier nitrate data were not unrepresentative of current conditions.
(c) Most recently calculated LOQ will be the surrogate background value.

As described in Section 4.7.1, a two-phase testing strategy is proposed for the LERF. The second-stage confirmation sampling is applicable to instance(s) where an initial exceedance(s) occurred. Each well that triggers the upper tolerance limit is re-sampled for only those constituents that triggered the limit and is retested using an upper prediction limit established from background (upgradient) data.

A prediction interval is a statistical interval constructed to include a specified number of future observations (or the average of several future observations) from a population or distribution with a specified probability. That is, after sampling background well(s) for some time and measuring the concentration of an analyte, the data can be used to construct an interval that will contain the next analyte sample or samples (assuming the distribution has not changed). If concentrations of future observation(s) (or their mean) at a compliance-point well are above the upper prediction limit, then evidence of contamination is indicated. The formula to calculate an upper parametric-prediction limit for a single future observation (appropriate for a normal distribution) is provided in EPA (1989, pp. 5-24 to 5-28) and is stated below:

$$\bar{x} + t_{(n-1,k,1-\alpha)} * s * \sqrt{1 + \frac{1}{n}} \qquad (3)$$

where $\bar{x}$ and s are the mean and standard deviation for the background well data; n is the number of observations in the background data; k is the number of future comparisons (e.g., the product of the number of monitoring wells and the number of constituents); and $t_{(n-1, k, 1-\alpha)}$ is the Bonferroni t-value, which is equivalent to the usual t-value at the $(1 - \alpha/k)$ level with $(n - 1)$ degrees of freedom. If data can be approximated by a log-normal distribution, then one should:

- Transform the original data into log units;
- Obtain estimates of mean and standard deviation of the log-transformed variable;
- Calculate the upper prediction limit using Equation (3); and
- Back-transform (anti-log) the calculated upper prediction limit into original unit.

When the parametric assumptions of a normal-based (or a log normal-based) prediction limit cannot be justified, then a non-parametric prediction interval may be considered. A non-parametric upper prediction limit typically is constructed by estimating the limit to be the maximum observed value of the set of background samples. If there are too few background measurements to achieve an adequate site-wide false positive rate using the non-parametric approach, Poisson prediction limits are a suitable replacement. The formula used to compute the Poisson prediction limit can be found in EPA (1992, pages 35-38) and in ASTM (1996, page 11).

Note that Equation (3) assumes that the future multiple comparisons (i.e., verification-sampling events) are independent. This is not true in the context of upgradient versus downgradient comparisons where each new monitoring measurement is compared to the same upgradient background limit. If background-sample sizes of $n = 20$ or more, then a prediction limit based on Bonferroni-adjusted t-value yields similar results to those obtained by the multivariate t-statistic that accounts for the correlation among repeated comparisons (Gibbons 1994, page 25).

The use of Bonferroni t-value to control the overall site-wide false-positive rate is not recommended when the number of future comparisons is large. In such an instance, it does so at the expense of the false-negative rate (i.e., failure to detect contamination when present). This is not acceptable. Conversely, control of the false-negative rate at the expense of the false-positive rate is also unacceptable. The best currently available approach to balancing false positive- and false-negative rates in groundwater-monitoring applications is the use of verification re-sampling (Gibbons 1994, page 15).

Confirmation retesting can be accomplished by taking a specific number of additional, independent samples from well(s) where a specific constituent triggers the initial exceedance. Because more independent data are added to the overall testing procedure, retesting of additional samples, in general, will make the statistical test more powerful and result in a more reliable determination of possible contamination. The objectives for the verification sampling, therefore, are to ensure: (1) quick identification and confirmation of contamination exceeding the background value, if any, and (2) the statistical independence of successive resamples from any well where initial exceedance has occurred. The performance of the statistical retesting strategy depends substantially on obtaining independent verification samples from the triggering well. These re-samples, therefore, must be separated enough by time so that the well could be recharged and restabilized.

Based on the results of simulation study described by Gibbons (1994, pages 18-32), it is proposed to accomplish confirmation retesting by adopting a plan in which both of two resamples must exceed the prediction limit for a statistically significant increase (over background) to be declared. Specifically, the verification sampling will be conducted as follows. If the initial sample result exceeds the upper tolerance limit (i.e., the first stage), then a re-sample is obtained from each of the triggering well(s) and analyzed for the constituent in question. If that measurement is less than the prediction limit (e.g., calculated using appropriate table from Gibbons) or less than the maximum observed background value, then no further sampling is necessary. A statistically significant result will be declared only if both re-sample results are larger than the upper prediction limit.

For constituents of concern, upper prediction limits cannot be calculated at the present time because the number of future comparisons (k) and the number of observations in the background database (n) at that time cannot be specified in advance. Recommended confidence levels $(1-\alpha)\%$ for the two-staged retesting strategies are provided in EPA (1992, page 70). A 90% confidence level for the upper prediction limit and a 95% coverage for the tolerance limit is deemed appropriate for the LERF at the present time. One should refer to the table that provides parametric retest strategies (see EPA 1992, page 70), however, or refer to the appropriate tables provided in Gibbons (1994, pages 24- 31), or to the formulas provided in ASTM (1996, pages 10-11), to find the best combination of confidence level and coverage ratio at the time when actual exceedance has occurred because the number of background samples would be different than that was used in Table 4.2.

4.7.4 Non-Detects

Non-detects will be handled using the recommendations stated in the EPA guidance documents (1989 and 1992). In general, non-detects will be less of a problem in using a nonparametric method to evaluate compliance data. If a parametric statistical method is used, then the handling of non-detects will depend on the percentage of detected values. Basically, a substitution method (use two of the detection limits to replace non-detects) will be used if less than 15% of all samples are non-detects. If the percent of non-detects is between 15% to 50%, then either Cohen's method (requires either normal or log-normal data) or Aitchison's adjustments will be used. Detailed descriptions of these methods can be found in EPA (1989 and 1992). When more than 50% of the sample values are non-detects, then the Poisson model may be used to derive a Poisson tolerance limit and a Poisson prediction limit (EPA 1992, pp. 35 - 40). If background data are essentially non-detects, then most recent LOQ will be used as the upper tolerance limit and upper prediction limit.

4.7.5 Outliers

An "outlier" is an observation that does not conform to the pattern established by other observations in the data set. Possible reasons for its occurrence include contaminated sampling equipment, inconsistent sampling or analytical procedure, data transcribing error, and true but extreme measurements. Statistical methods such as Grubbs' method (Grubbs 1969) for testing of outliers and/or the box-and-whisker plot (Ostle and Malone 1988) may be used. Once an observation is found to be an outlier, then the following action can be taken:

- If the error can be identified and the correct value can be recovered through the data review process (see Section 5.1), then replace the outlier value with the corrected value.
- If the error can be documented but the correct value cannot be recovered, then the outlier should be deleted. Describe this deletion in the statistical report.
- If no error can be documented, then assume that the value is a valid measurement; however, obtain another sample to confirm the high value, if necessary.

4.8 Determining the Rate and Direction of Groundwater Flow

Depth to water will be measured in the four LERF groundwater-monitoring wells during sampling and as part of the site-wide water-table elevation model. Maps produced from the site-wide model will be used to interpret the direction of groundwater flow and to derive the water-table gradient for the LERF. The gradient, in turn, will be used with estimated values of hydraulic conductivity and effective porosity to calculate flow rate using the Darcy equation.

4.9 Continuation of Monitoring Compliance at the LERF

The general groundwater-flow direction is from west to east in the vicinity of the 200 East Area; artificial recharge due to the B Pond system perturbs the general trend. The resulting groundwater mound creates flow direction in the vicinity of the LERF that is currently opposite the general west-to-east flow directions. The inferred flow is from east to west beneath the LERF. As the influence of the groundwater mound diminishes with distance, the general west-to-east flow prevails. As discharge volumes continue to decline in the future, the perturbation in groundwater-flow direction discussed above will subside. In addition, the water table continues to decline beneath the facility in response to a decline in the groundwater mound beneath B-Pond.

Because groundwater elevations in the Central Plateau were not well documented before nuclear process operations at the Hanford Site, it is generally unknown at what elevation groundwater will stabilize. It is possible that the uppermost aquifer beneath the LERF will not reside in the Hanford formation or in remnants of the Ringold Formation. The next water-bearing interval occurs in the sediments of the Rattlesnake Ridge Interbed. This aquifer system exists under confined conditions between the Elephant Mountain and Pomona Members of the Saddle Mountain Basalt Formation.

The Hanford formation eventually will yield only negligible quantities of groundwater for representative samples. The LERF groundwater-monitoring network will then cease to fulfill its intended function. A replacement or alternate monitoring system will have to consider the changing hydrogeologic conditions beneath the facility. Monitoring efficiency studies will also address an expected groundwater flow reversal that may precede the effective loss of water in the groundwater-monitoring network. Activities that will take place to obtain the necessary information to maintain compliance include:

- semi-annual groundwater elevation measurements from the LERF network and from wells in the vicinity of the facility

- monitoring efficiency modeling for the current network based on current flow conditions

- modeling of groundwater flow throughout the 200 East Area to predict possible future flow conditions

- combining modeling results to determine network efficiency and modification requirements for the network

It would not be prudent, therefore, to recommend specific countermeasures to correct the monitoring network because it is fully functional at this time. Projections of when the groundwater elevation beneath the LERF will reach a level where the network cannot fulfill regulatory requirements are not exact. The effective life-span of the network has exceeded earlier projections of water-level decline in LERF monitoring network wells (Wurstner and Freshley 1994) (Figure 3.9). There is a strong probability that the network will lose one well by 2000. Two wells out of the network might not provide representative samples in six years.

Because the methodology available for monitoring compliance at this facility at some arbitrary future time cannot be assumed, it is more reasonable to recommend a monitoring system close to the time when the groundwater network is no longer compliant.

5.0 Data Management and Reporting

This section describes data-management practices and reporting requirements for the regulated unit.

5.1 Data Storage and Retrieval

All contract analytical laboratory results are submitted by the laboratory in electronic form and are loaded into the HEIS database. Parameters measured in the field either are entered into HEIS manually or through electronic transfer. Data from the HEIS database may be downloaded to smaller databases, such as the Geosciences Data Analysis Toolkit (GeoDAT) for data validation, data reduction, and trend analysis.

Record copies of data are stored at the laboratory until the contract is terminated, then sent to PNNL for storage. Field records are stored at PNNL.

5.2 Data Verification and Validation

Verification and validation of groundwater chemistry and water-level data is or will be performed according to WHC-CM-7-8, Section 2.6 (WHC 1992) or an equivalent PNNL procedure. Data are flagged if quality control is suspect. Data are also screened for completeness and representativeness by a project scientist assigned to the regulated unit. Data are compared to historical and spatial trends. Suspect data are investigated through the data-review process and are flagged in the database.

5.3 Reporting

The results of the statistical evaluation will be submitted to Ecology in the form of RCRA quarterly reports and the groundwater annual monitoring report. The statistical results might include a list of groundwater parameters analyzed, detection and/or quantitation limits, and background values. If a statistically significant increase (after the confirmation resampling evaluation process) in one or more of the constituents of concern is determined, then the following steps will be taken:

- Notify Ecology in writing within 7 days of the finding with a report indicating which chemical parameters or dangerous-waste constituents have shown statistically significant increases over the background values, and which points of compliance (wells) are involved.

- Submit an application for a permit modification to establish a compliance-monitoring program to Ecology in 90 days.

In case of a false positive claim, the following procedures will be taken:

- Notify Ecology in writing within 7 days of the finding (i.e., exceedance) that a false-positive claim will be made.

- Submit a report to Ecology within 90 days. This report should demonstrate that a source other than the LERF caused the contamination or that the detection resulted from an error in sampling, analysis, or evaluation or natural variation in groundwater.

- Submit an application for a permit modification, if necessary, to make appropriate changes to the detection-monitoring program within 90 days.

- Continue to monitor in accordance with the detection-monitoring program.

6.0 Compliance-Monitoring Program

A compliance-monitoring program that satisfies requirements set forth in WAC 173-303-645 (10) will be established for the LEFF if groundwater sampling during detection-level monitoring reveals statistically significant increases (or pH decreases) over background concentrations for groundwater. If compliance monitoring is required, then the DQO process will be used to guide the selection of constituents of concern, sampling and analysis, statistical methods, etc. If other groundwater constituents indicative of migrating waste products are identified, then the list of groundwater parameters will be revised to include such constituents. In the compliance monitoring programs, the constituents of concern will be compared to concentration limits [maximum contaminant levels (MCLs)]. A revised groundwater-monitoring plan will be prepared and submitted to Ecology for approval.

7.0 Corrective-Action Program

If, at a point of compliance (a well), dangerous constituents of concern are measured in the groundwater at concentrations that exceed the applicable groundwater-concentration limit, Ecology must be notified in 7 days, and an application to modify the permit to include a corrective-action plan must be sent to Ecology within 90 days. After concurrence from Ecology, a corrective-action level-monitoring program will be established. The development of a corrective-action level-monitoring program will be initiated by integration of RCRA/CERCLA programs. A description of the groundwater-monitoring plan that will be used to assess the effectiveness of the corrective/remedial action measures will be prepared and submitted to Ecology when the need for corrective action is first identified.

8.0 References

Public Laws

Resource Conservation and Recovery Act of 1976, as amended, Public Law 94-580, 90 Stat. 2795, 42 USC 6901 et seq.

Code of Federal Regulations

40 CFR 258, Code of Federal Regulations, Title 40, Part 258. *Solid Waste Facility Criteria.*

40 CFR 264, Code of Federal Regulations, Title 40, Part 264. *Standards for Owners of Hazardous Waste Treatment, Storage, and Disposal Facilities.*

40 CFR 265, Code of Federal Regulations, Title 40, Part 265. *Interim Status Standards for Owners of Hazardous Waste Treatment, Storage, and Disposal Facilities.*

40 CFR 268, Code of Federal Regulations, Title 40, Part 268. *Land Disposal Restrictions.*

Federal Register

53 FR 39725. October 11, 1988. "Statistical Methods for Evaluating Ground-Water Monitoring Data from Hazardous Waste Facilities." *Federal Register.*

Washington Administrative Code

WAC 173-303-645, Washington Administrative Code. *Releases from Regulated Units.* Olympia, Washington.

American Society for Testing and Materials (ASTM). 1996. "PS 64-96, Provisional Standard Guide for Developing Appropriate Statistical Approaches for Ground-Water Detection Monitoring Programs." *Annual Book of ASTM Standards.* Philadelphia, Pennsylvania.

Baker, V. R., B. 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*, in Quaternary Nonglacial Geology; Conterminous United States, RB Morrison (editor), Geological Society of America, The Geology of North America, v. K-2, Boulder, Colorado.

Bouwer, H., and R. C. Rice. 1976. "A Slug Test for Determining Hydraulic Conductivity of Unconfined Aquifers with Completely or Partially Penetrating Wells." *Water Resources Research* 12(3):423-428.

Connelly, M. P., J. V. Borghese, C. D. Delaney, B. H. Ford, J. W. Lindberg, and S. J. Trent. 1992. *Hydrologic Model for the 200 East Groundwater Aggregate Area.* WHC-SD-EN-TI-019, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Conover, W. J. 1980. *Practical Nonparametric Statistics.* Second Edition, John Wiley and Sons, Inc., New York, New York, pp. 357-367.

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

Davis, C. B., and R. J. McNichols. 1994. "Groundwater Monitoring Statistics Update: Part I: Progress Since 1988." *Groundwater Monitoring Review*, pp. 148-158.

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-EN-TI-003, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Eckerman, K. F., A. B. Wolbarst, and C. B. Richardson. 1988. *Federal Guidance Report No. 11, Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion, Derived Guides for Control of Occupational Exposure and Exposure-to-Dose Conversion Factors for General Application, Based on the 1987 Federal Radiation Protection Guidance.* EPA-520/1-88-020, prepared by Oak Ridge National Laboratory for Office of Radiation Programs, U.S. Environmental Protection Agency, Washington, D.C.

Fecht, K. R., S. P. Reidel, and A. M. Tallman. 1987. "Paleodrainage of the Columbia River System on the Columbia Plateau of Washington State--a Summary." In Schuster, JE, ed., *Selected Papers on the Geology of Washington.* Washington State Division of Geology and Earth Resources, Bulletin 77, p. 219-248.

Gibbons, R. D. 1994. *Statistical Methods for Groundwater Monitoring.* John Wiley and Sons, Inc., New York, New York, p. 15-16, 84-93.

Gilbert, R. O. 1987. *Statistical Methods for Environmental Pollution Monitoring.* Van Nostrand Reinhold Company, New York, New York, pp. 157-163.

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

Grubbs, F. E. 1969. "Procedures for Detecting Outlying Observations in Samples." *Technometrics* 11:1-21.

Gumbel, E. J. 1958. *Statistics of Extremes.* Columbia University Press, New York, New York, pp. 68.

Guthrie, M. D. 1994. *242-A Campaign 94-1 Post Run Document.* WHC-SD-WM-BE-053, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Guthrie, M. D. 1995. *242-A Campaign 94-2 Post Run Document.* WHC-SD-WM-BE-054, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

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

Johnson, V. G. 1993. *Westinghouse Hanford Company Operational Groundwater Status Report*, 1990-1992. WHC-EP-0595, Westinghouse Hanford Company, Richland, Washington.

Keith, L. H. 1991. *Environmental Sampling and Analysis: A Practical Guide.* Lewis Publishers, CRC Press, Inc., Boca Raton, Florida, pp. 93-115.

Lindberg, J. W., J. V. Borghese, B. N. Bjornstad, and M. P. Connelly. 1993. *Geology and Aquifer Characteristics of the Grout Treatment Facility.* WHC-SD-EN-TI-071, Westinghouse Hanford Company, Richland, Washington.

Lindberg, J. W., B. A. Williams, and F. A. Spane, Jr. 1997. *Borehole Data Package for Well 699-37-47A, PUREX Plant Cribs, CY 1996.* PNNL-11515, Pacific Northwest National Laboratory, Richland, Washington.

Lindsey, K. A. 1995. *Miocene- to Pliocene-Aged Suprabasalt Sediments of the Hanford Site, South Central Washington.* BHI-00184, Rev. 0, Bechtel Hanford Inc., 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.

Lindsey, K. A., J. L. Slate, G. K. Jaeger, K. J. Swett, and R. B. Mercer. 1994. *Geologic Setting of the Low-Level Burial Grounds.* WHC-SD-EN-TI-290, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

McKee, E. H., D. A. Swanson, and T. L. Wright. 1977. *Duration and volume of Columbia River basalt volcanism, Washington, Oregon and Idaho,* in Geologic Society of America Abstracts with Programs, v. 9, no. 4.

Natrella, M. G. 1966. *Experimental Statistics.* National Bureau of Standards Handbook 91, John Wiley and Sons, Inc., New York, New York, Tables A-6 and A-7.

Ostle, B., and L. C. Malone. 1988. *Statistics in Research: Basic Concepts and Techniques for Research Workers, Fourth Edition.* Iowa State University Press, Ames, Iowa, pp. 66-67.

Ott, W. R. 1990. "A Physical Explanation of the Lognormality of Pollutant Concentrations." *Journal of Air Waste Management Association* 40:1378-83.

Pacific Northwest National Laboratory (PNNL). 1997. *Pacific Northwest National Laboratory Quality Assurance Manual.* PNL-MA-70, Pacific Northwest National Laboratory, Richland, Washington.

Rieck, C. A. 1990. *Conceptual Design Report 242-A Evaporation and PUREX Interim Retention Basin.* WHC-SD-W105-CDR-001, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Reidel, S. P., and K. R. Fecht. 1981. *Wanapum and Saddle Mountains Basalt in the Cold Creek Syncline Area, in Subsurface Geology of the Cold Creek Syncline.* RHO-BWI-ST-14, Rockwell Hanford Operations, Richland, Washington.

Reidel, S. P., V. G. Johnson, A. G. Law, S. D. Evelo, D. B. Barnett, and M. D. Sweeney. 1995. *Groundwater Impact Assessment Report for the 216-B-3 Pond System.* WHC-EP-0813, Westinghouse Hanford Company, Richland, Washington.

Schmid, J. S. 1990. *Interim Status Ground Water Monitoring Plan for the 200 East Area Liquid Effluent Treatment Facility.* WHC-SD-EN-AP-024, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Schmid, J. S. 1991a. *Interim Status Ground Water Monitoring Plan for the 200 East Area Liquid Effluent Treatment Facility.* WHC-SD-EN-AP-024, Rev. 1, Westinghouse Hanford Company, Richland, Washington.

Schmid, J. S, P. B. Freeman, and M. H. Edrington. 1991b. "1.0 Introduction." In *Annual Report for RCRA Groundwater Monitoring Projects at Hanford Site Facilities for 1990.* DOE/RL-91-03, prepared by Geosciences Group, Westinghouse Hanford Company, Environmental Division for U.S. Department of Energy, Richland Operations Office, Richland, Washington.

Smith, R. M., and R. B. Kasper. 1983. *Serviceability of Cribs Affected by PUREX Startup.* RHO-HS-EV-18, Rockwell Hanford Operations, Richland, Washington.

State of Washington Department of Ecology (Ecology). 1994. *Hanford Facility RCRA Permit.* Permit WA890008967, effective September 28, 1994, Olympia, Washington.

State of Washington Department of Ecology (Ecology). 1996a. *Implementation Guidance for the Groundwater Quality Standards.* Publication #96-02, Washington State Department of Ecology, Olympia, Washington.

State of Washington Department of Ecology (Ecology). 1996b. *The Model Toxics Control Act Cleanup Regulation, Chapter 173-340 WAC,* as amended. Publication No. 94-06, Washington State Department of Ecology, Olympia, Washington, pp. 55-56.

State of Washington Department of Ecology (Ecology), and U.S. Environmental Protection Agency (EPA). 1996. *Hanford Federal Facility Agreement and Consent Order.* Ecology No. DE 86-133, Olympia and Seattle, Washington.

State of Washington Department of Ecology (Ecology), U.S. Environmental Protection Agency (EPA), and U.S. Department of Energy (DOE). 1989. *Hanford Federal Facility Agreement and Consent Order Between the U.S. Environmental Protection Agency, the U.S. Department of Energy, and the State of Washington Department of Ecology*, May 15, 1989, as amended. Olympia, Seattle, and Richland, Washington.

Sweeney, M. D., K. A. Lindsey, J. S. Schmid, and J. V. Borghese. 1994. *Site Characterization Report for the Liquid Effluent Retention Facility.* WHC-SD-EN-EV-024, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

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

Thorne, P. D., M. A. Chamness, F. A. Spane, Jr., V. R. Vermeul, and W. D. Webber. 1993. *Three-Dimensional Conceptual Model for the Hanford Site Unconfined Aquifer System, FY 93 Status Report.* PNL-8971, Pacific Northwest Laboratory, Richland, Washington.

U.S. Department of Energy (DOE). 1988. *Consultation Draft Site Characterization Plan.* 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 (DOE). 1991. *Liquid Effluent Retention Facility Dangerous Waste Permit Application.* DOE/RL-90-43, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

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

U.S. Environmental Protection Agency (EPA). 1989. *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities - Interim Final Guidance.* PB89-151047, U.S. Environmental Protection Agency, Washington, D.C.

U.S. Environmental Protection Agency (EPA). 1992. *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities - Draft Addendum to Interim Final Guidance.* EPA/530-R-93-003, U.S. Environmental Protection Agency, Washington, D.C.

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

Westinghouse Hanford Company (WHC). 1993. *Quality Assurance Project Plan for RCRA Groundwater Monitoring Activities*. WHC-SD-EN-QAPP-001, Rev. 1, Westinghouse Hanford Company, Richland, Washington.

Westinghouse Hanford Company (WHC). 1992. *Validation and Verification of RCRA Monitoring Data.* WHC-CM-7-8, Westinghouse Hanford Company, Richland, Washington.

Wilson, C. R., C. M. Einberger, R. L. Jackson, and R. B. Mercer. 1992. "Design of Groundwater Monitoring Networks using the Monitoring Efficiency Model (MEMO)." *Groundwater* (30)6:965-970.

Wurstner, S. K., and M. D. Freshley. 1994. *Predicted Impacts of Future Water Level Decline on Monitoring Wells Using a Groundwater Model of the Hanford Site*. PNL-10196, Pacific Northwest Laboratory, Richland, Washington.

Appendix A

Well Construction Diagrams for the LERF Groundwater-Monitoring Network

WELL CONSTRUCTION AND COMPLETION SUMMARY

Drilling Method: Cable tool
Drilling Fluid Used: 200E Potable water
Driller's Name: M Thorenson
Drilling Company: Kaiser Engineers
Date Started: 09Jul90

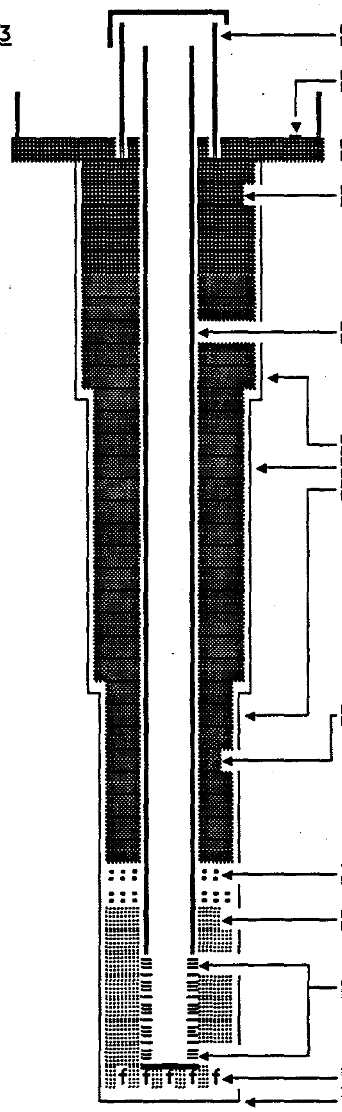
Sample Method: Drive barrel Hard tool
Additives Used: None
WA State Lic Nr: Not documented
Company Location: Hanford
Date Complete: 10Aug90

WELL NUMBER: 299-E26-9
TEMPORARY WELL NO: LF-2
Hanford Coordinates: N/S N 44,779.9 E/W W 46,960.4
State NAD83 N 137,133.40m E 575,576.37m
Coordinates: N 449,961 E 2,248,250
Start Card #: Not documented T___ R___ S___
Elevation Ground surface: 599.89 (Brass cap)

Depth to water: 195.2-ft Aug90
(Ground surface) 197.4-ft 14Jun93

GENERALIZED STRATIGRAPHY
Geologist's Log
Sl=slightly

0↔10: Sandy GRAVEL
10↔25: Muddy sandy GRAVEL
25↔35: Sandy GRAVEL
35↔40: Gravelly SAND
40↔42: Muddy SAND
42↔45: Gravelly SAND
45↔50: Sandy GRAVEL
50↔55: Muddy sandy GRAVEL
55↔70: Sandy GRAVEL
70↔75: Muddy sandy GRAVEL
75↔100: Sandy GRAVEL
100↔105: Muddy sandy GRAVEL
105↔115: Sandy GRAVEL
115↔120: Muddy sandy GRAVEL
120↔125: Gravelly SAND
125↔145: Sandy GRAVEL
145↔150: Muddy sandy GRAVEL
150↔155: Sandy GRAVEL
155↔180: Muddy sandy GRAVEL
180↔201: Sandy GRAVEL
201↔202.5: BASALT



Elevation of reference point: (top of casing) [602.89-ft]
Height of reference point above ground surface [3.00-ft]
Depth of surface seal [0.0↔18.6-ft]
Type of surface seal:
Cement grout, 3.2↔18.6-ft
4-ftx4-ftx6-in concrete pad extends 3.2-ft into annulus

4-in ID stainless steel casing, ‾+1.0↔190.3-ft

Hole diameter,
0.0↔59.8-ft, 13-in nominal
59.8↔157.5-ft, 11-in nominal
157.5↔202.5-ft, 9-in nominal

Bentonite crumbles, 18.6↔182.9-ft, 8↔20-mesh

¼-in bentonite pellets, 182.9↔186.5-ft

Silica sand pack, 186.5↔201.0-ft, 20↔40-mesh

4-in ID T304 stainless steel screen, w/channel pack 190.3↔200.9-ft, #10-slot

Fill, 201.0↔202.5-ft
Borehole drilled depth: [202.5-ft]

Drawing By: RKL/2E26-09.ASB
Date : 17Sep93
Reference : ______

SUMMARY OF CONSTRUCTION DATA AND FIELD OBSERVATIONS
RESOURCE PROTECTION WELL - 299-E26-9

WELL DESIGNATION	:	299-E26-9
CERCLA UNIT	:	200 Aggregate Area Management Study
RCRA FACILITY	:	LERF
HANFORD COORDINATES	:	N 44,779.9 W 46,960.4 [200E-18Sep90]
LAMBERT COORDINATES	:	N 449,961 E 2,248,250 [HANCONV] N 137,133.40m E 575,576.37m [NAD83-18Sep90]
DATE DRILLED	:	Aug90
DEPTH DRILLED (GS)	:	202.5-ft
MEASURED DEPTH (GS)	:	201.6-ft, 25Jan93
DEPTH TO WATER (GS)	:	195.2-ft, 01Aug90; 197.4-ft, 14Jun93
CASING DIAMETER	:	4-in stainless steel, ~+1.0↔190.3-ft; 6-in stainless steel, +3.0↔~0.5-ft
ELEV TOP CASING	:	602.89-ft, [200E-18Sep90]
ELEV GROUND SURFACE	:	599.89-ft, Brass cap [200E-18Sep90]
PERFORATED INTERVAL	:	Not applicable
SCREENED INTERVAL	:	190.3↔200.9-ft, 4-in #10-slot stainless steel; with channel pack
COMMENTS	:	FIELD INSPECTION, 25Jan93; 6-in stainless steel casing. 4-ft by 4-ft concrete pad, 4 posts, 1 removable capped and locked, brass cap in pad with well ID. Not in radiation zone. DTW=200.3-ft, DTB=204.6-ft (TOC) OTHER:
AVAILABLE LOGS	:	Geologist
TV SCAN COMMENTS	:	Not applicable
DATE EVALUATED	:	Not applicable
EVAL RECOMMENDATION	:	Not applicable
LISTED USE	:	LERF quarterly water level measurement, 01Feb91↔14Jun93;
CURRENT USER	:	WHC ES&M w/l monitoring and RCRA sampling, PNL sitewide sampling 93
PUMP TYPE	:	Hydrostar, intake @ 199.2-ft (GS)
MAINTENANCE	:	

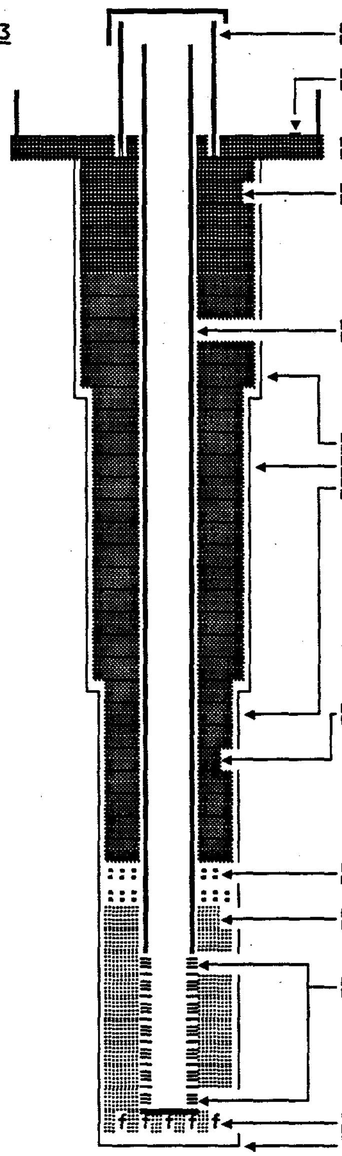
WELL CONSTRUCTION AND COMPLETION SUMMARY

Drilling Method: Cable tool	Sample Method: Not documented	WELL NUMBER: 299-E26-10 TEMPORARY WELL NO: LERF-3
Drilling 200E Fluid Used: Potable water	Additives Used: None	Hanford Coordinates: N/S N 44,420.1 E/W W 46,919.3
Driller's Name: L Watkins	WA State Lic Nr: Not documented	State NAD83 N 137,023.76m E 575,589.23m Coordinates: N 449,602 E 2,248,292
Drilling Company: Kaiser Engineers	Company Location: Hanford	Start Card #: Not documented T___ R___ S___
Date Started: 20Jul90	Date Complete: 28Aug90	Elevation Ground surface: 598.49-ft (Brass cap)

Depth to water: 193.3-ft Sep90
(Ground surface) 196.0-ft 14Jun93

GENERALIZED STRATIGRAPHY   Geologist's Log
Sl=slightly

0↔5: Graveely muddy SAND
5↔24: Sandy GRAVEL
24↔30: Sl gravelly SAND
30↔35: Gravelly SAND
35↔100: Muddy sandy GRAVEL
100↔105: GRAVEL
105↔110: Muddy sandy GRAVEL
110↔130: Sandy GRAVEL
130↔135: Muddy sandy GRAVEL
135↔145: Sandy GRAVEL
145↔150: Muddy sandy GRAVEL
150↔155: Sandy GRAVEL
155↔160: Muddy sandy GRAVEL
160↔165: Sandy GRAVEL
165↔204.3: Muddy sandy GRAVEL
204.3↔206.6: BASALT



Drawing By: RKL/2E26-10.ASB
Date : 17Sep93
Reference :

SUMMARY OF CONSTRUCTION DATA AND FIELD OBSERVATIONS
RESOURCE PROTECTION WELL - 299-E26-10

WELL DESIGNATION	:	299-E26-10
CERCLA UNIT	:	200 Aggregate Area Management Study
RCRA FACILITY	:	LERF
HANFORD COORDINATES	:	N 44,420.1 W 46,919.3 [200E-18Sep90]
LAMBERT COORDINATES	:	N 449,602 E 2,248,292 [HANCONV] N 137,023.76m E 575,589.23m [NAD83-18Sep90]
DATE DRILLED	:	Aug90
DEPTH DRILLED (GS)	:	206.6-ft
MEASURED DEPTH (GS)	:	206.7-ft, 27Aug93
DEPTH TO WATER (GS)	:	193.3-ft, 04Sep90; 196.0-ft, 14Jun93
CASING DIAMETER	:	4-in stainless steel, ~+1.0↔190.5-ft; 6-in stainless steel, +3.0↔~0.5-ft
ELEV TOP CASING	:	601.47-ft, [200E-18Sep90]
ELEV GROUND SURFACE	:	598.49-ft, Brass cap [200E-18Sep90]
PERFORATED INTERVAL	:	Not applicable
SCREENED INTERVAL	:	190.5↔206.1-ft, 4-in #10-slot stainless steel; with channel pack
COMMENTS	:	FIELD INSPECTION, 27Aug93; 4 and 6-in stainless steel casing. 4-ft by 4-ft concrete pad, 4 posts, 1 removable. Capped and locked, brass cap in pad with well ID. Not in radiation zone. OTHER:
AVAILABLE LOGS	:	Geologist
TV SCAN COMMENTS	:	Not applicable
DATE EVALUATED	:	Not applicable
EVAL RECOMMENDATION	:	Not applicable
LISTED USE	:	LERF quarterly water level measurement, 01Feb91↔14Jun93;
CURRENT USER	:	WHC ES&M w/l monitoring and RCRA sampling, PNL sitewide sampling 93
PUMP TYPE	:	Hydrostar, intake @ 201.2-ft (GS)
MAINTENANCE	:	

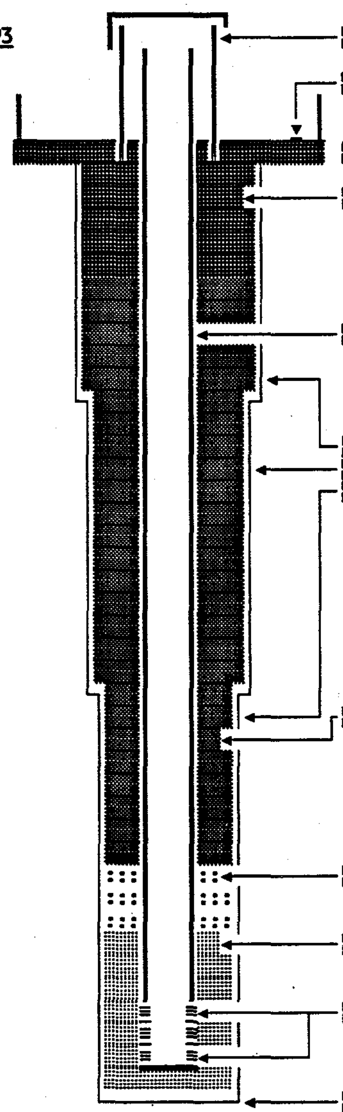
WELL CONSTRUCTION AND COMPLETION SUMMARY

Drilling Method: Cable tool	Sample Method: Drive barrel Hard tool	WELL NUMBER: 299-E26-11
Drilling Fluid Used: 200E Potable water	Additives Used: None	TEMPORARY WELL NO: LF-4
Driller's Name: L Watkins	WA State Lic Nr: Not documented	Hanford Coordinates: N/S N 44,779.2 E/W W 44,979.2
Drilling Company: Kaiser Engineers	Company Location: Hanford	State NAD83 N 137,134.88m E 576,180.17m
Date Started: 21Jun90	Date Complete: 20Aug90	Coordinates: N 449,966 E 2,250,231
		Start Card #: Not documented T____ R____ S______
		Elevation Ground surface: 596.72-ft (Brass cap)

Depth to water: 189.9-ft Aug90
(Ground surface) 191.3-ft 14Jun93

GENERALIZED Geologist's
STRATIGRAPHY Log
Sl=slightly

0↔24: Sandy GRAVEL
24↔40: GRAVEL
40↔53: Sandy GRAVEL
53↔54: Muddy SAND
54↔55: Gravelly SAND
55↔60: Gravelly SAND
60↔65: Sandy GRAVEL
65↔70: Muddy sandy GRAVEL
70↔80: Sandy GRAVEL
80↔85: Muddy sandy GRAVEL
85↔90: Sandy GRAVEL
90↔100: Muddy sandy GRAVEL
100↔105: Sandy GRAVEL
105↔110: GRAVEL
110↔135: Sandy GRAVEL
135↔140: GRAVEL
140↔145: Sandy GRAVEL
145↔155: GRAVEL
155↔160: Muddy sandy GRAVEL
160↔165: Sandy GRAVEL
165↔193: Muddy sandy GRAVEL
193↔198: Sl gravelly sandy MUD
198↔206.2: BASALT



Elevation of reference point: [599.68-ft]
(top of casing)

Height of reference point above [2.96-ft]
ground surface

Depth of surface seal [3.0↔15.8-ft]
Type of surface seal:
Cement grout 3.0↔15.8-ft,
4x4-ft x 6-in concrete pad
extending 3.0-ft into annulus

4-in ID stainless steel casing,
¯+1.0↔200.2-ft

Hole diameter,
0.0↔61.5-ft, 13-in nominal
61.5↔166.6-ft, 11-in nominal
166.7↔206.2-ft, 9-in nominal

Bentonite crumbles,
15.8↔188.0-ft, 8↔20-mesh

%-in bentonite hole plug,
188↔195.9-ft

Silica sand pack,
195.9↔197.0-ft, 40↔60-mesh
197.0↔206.0-ft, 20↔40-mesh

4-in T304, stainless steel screen
w/channel pack
200.2↔205.8-ft

Borehole drilled depth: [206.2-ft]

Drawing By: RKL/2E26-11.ASB
Date : 17Sep93
Reference : ____

SUMMARY OF CONSTRUCTION DATA AND FIELD OBSERVATIONS
RESOURCE PROTECTION WELL - 299-E26-11

WELL DESIGNATION	:	299-E26-11
CERCLA UNIT	:	200 Aggregate Area Management Study
RCRA FACILITY	:	LERF
HANFORD COORDINATES	:	N 44,779.2 W 44,979.2 [200E-18Sep90]
LAMBERT COORDINATES	:	N 449,966 E 2,250,231 [HANCONV] N 137,134.88m E 576,180.17m [NAD83-18Sep90]
DATE DRILLED	:	Aug90
DEPTH DRILLED (GS)	:	206.2-ft
MEASURED DEPTH (GS)	:	206.2-ft, 27Aug93
DEPTH TO WATER (GS)	:	189.9-ft, 13Aug90; 191.3-ft, 14Jun93
CASING DIAMETER	:	4-in stainless steel, ~+1.0↔200.2-ft; 6-in stainless steel, +3.0↔~0.5-ft
ELEV TOP CASING	:	599.68-ft, [200E-18Sep90]
ELEV GROUND SURFACE	:	596.72-ft, Brass cap [200E-18Sep90]
PERFORATED INTERVAL	:	Not applicable
SCREENED INTERVAL	:	200.2↔205.8-ft, 4-in #10-slot stainless steel; with channel pack
COMMENTS	:	FIELD INSPECTION, 27Aug93; 4 and 6-in stainless steel casing. 4-ft by 4-ft concrete pad, 4 posts, 1 removable. Capped and locked, brass cap in pad with well ID. Not in radiation zone. OTHER:
AVAILABLE LOGS	:	Geologist
TV SCAN COMMENTS	:	Not applicable
DATE EVALUATED	:	Not applicable
EVAL RECOMMENDATION	:	Not applicable
LISTED USE	:	LERF quarterly water level measurement, 01Feb91↔14Jun93;
CURRENT USER	:	WHC ES&M w/l monitoring and RCRA sampling, PNL sitewide sampling 93
PUMP TYPE	:	Hydrostar, intake @ 203.2-ft (GS)
MAINTENANCE	:	

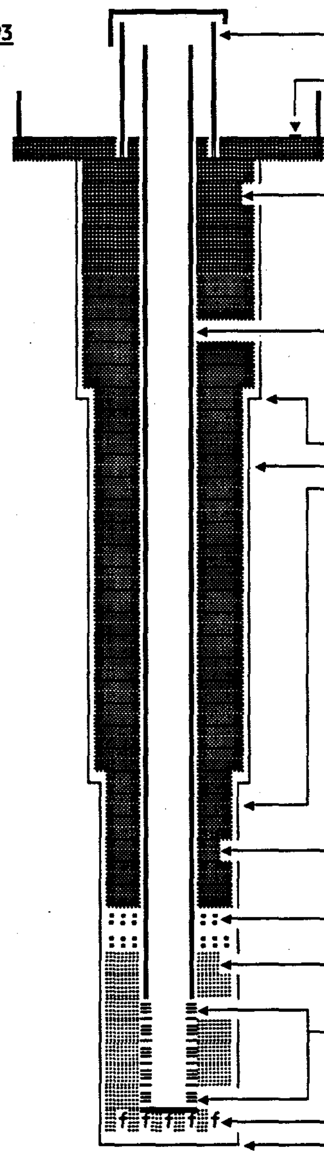
WELL CONSTRUCTION AND COMPLETION SUMMARY

Drilling Method: Cable tool	Sample Method: Drive barrel Hard tool	WELL NUMBER: 299-E35-2 TEMPORARY WELL NO: LF-1
Drilling Fluid Used: 200E Potable water	Additives Used: None	Hanford Coordinates: N/S N 45,179.9 E/W W 46,959.4
Driller's Name: D Garcia	WA State Lic Nr: Not documented	State NAD83 Coordinates: N 137,255.30m E 575,576.34m; N 450,361 E 2,248,250
Drilling Company: Kaiser Engineers	Company Location: Hanford	Start Card #: Not documented T___ R___ S___
Date Started: 21Jun90	Date Complete: 01Aug90	Elevation Ground surface: 599.15-ft (Brass cap)

Depth to water: 193.9-ft Aug90
(Ground surface) 196.6-ft 14Jun93

GENERALIZED STRATIGRAPHY Geologist's Log
Sl=slightly

0↔10: Muddy sandy GRAVEL
10↔15: Sandy GRAVEL
15↔20: GRAVEL
25↔39: Sandy GRAVEL
39↔44: Sandy MUD<>muddy SAND
44↔60: Sandy GRAVEL
60↔65: GRAVEL
65↔94: Muddy sandy GRAVEL
94↔96: Sl muddy gravelly SAND
96↔105: Sandy GRAVEL
105↔198: Muddy sandy GRAVEL
198↔200.1: Gravelly sandy MUD
200.1↔202.3: BASALT



Elevation of reference point: [602.10-ft]
(top of casing)
Height of reference point above ground surface [2.95-ft]
Depth of surface seal [0.0↔19.6-ft]
Type of surface seal:
Cement grout to 19.6-ft, has 4x4-ftx6-in concrete pad extending 2.5-ft into annulus
4-in ID stainless steel casing, ~+1.0↔190.9-ft
Hole diameter,
0.0↔67.3-ft, 13-in nominal
67.3↔150.6-ft, 11-in nominal
150.6↔202.3-ft, 9-in nominal
Bentonite crumbles, 19.6↔183.8-ft, 8↔20-mesh
¼-in bentonite tablets, 183.8↔186.9-ft
Silica sand pack, 186.9↔201.5-ft, 20↔40-mesh
4-in T304 stainless steel screen, 190.9↔201.5-ft, #10-slot w/channel pack
Fill, 201.5↔202.3-ft
Borehole drilled depth: [202.3-ft]

Drawing By: RKL/2E35-02.ASB
Date : 13Sep93
Reference : WHC-MR-0235

SUMMARY OF CONSTRUCTION DATA AND FIELD OBSERVATIONS
RESOURCE PROTECTION WELL - 299-E35-2

WELL DESIGNATION	:	299-E35-2
CERCLA UNIT	:	200 Aggregate Area Management Study
RCRA FACILITY	:	LERF
HANFORD COORDINATES	:	N 45,179.9 W 46,959.4 [200E-18Sep90]
LAMBERT COORDINATES	:	N 450,361 E 2,248,250 [HANCONV] N 137,255.30m E 575,576.34m [NAD83-18Sep90]
DATE DRILLED	:	Aug90
DEPTH DRILLED (GS)	:	202.3-ft
MEASURED DEPTH (GS)	:	Not documented
DEPTH TO WATER (GS)	:	193.9-ft, 02Aug90; 196.6-ft, 14Jun93
CASING DIAMETER	:	4-in stainless steel, ~+1.0↔190.9-ft; 6-in stainless steel, +3.0↔~0.5-ft
ELEV TOP CASING	:	602.10-ft, [200E-18Sep90]
ELEV GROUND SURFACE	:	599.15-ft, Brass cap [200E-18Sep90]
PERFORATED INTERVAL	:	Not applicable
SCREENED INTERVAL	:	190.9↔201.5-ft, 4-in #10-slot stainless steel; with channel pack
COMMENTS	:	FIELD INSPECTION, OTHER:
AVAILABLE LOGS	:	Geologist
TV SCAN COMMENTS	:	Not applicable
DATE EVALUATED	:	Not applicable
EVAL RECOMMENDATION	:	Not applicable
LISTED USE	:	LERF quarterly water level measurement, 01Feb91↔14Jun93;
CURRENT USER	:	WHC ES&M w/l monitoring and RCRA sampling
PUMP TYPE	:	Hydrostar, intake @ 202.6-ft (TOC)
MAINTENANCE	:	

Distribution

No. of Copies

OFFSITE

Stan Leja
Washington State Department of Ecology
1315 4th Avenue
Kennewick, WA 99336

ONSITE

2 **DOE Richland Operations Office**

M. J. Furman	H0-12
A. C. McKarns	A5-15

CH2M Hill

L. C. Swanson	H0-02

3 **Fluor Daniel Northwest**

A. G. Miskho	H6-23
S. M. Price	H6-23
F. A. Ruck III	H6-23

No. of Copies

4 **Waste Management Services of Hanford**

N. A. Ballantyne	S6-72
R. C. Bowman	H6-24
J. G. Coenenberg	H6-24
R. H. Engelmann	H6-26

28 **Pacific Northwest National Laboratory**

B. N. Bjornstad	K6-81
C. J. Chou (6)	K6-81
P. E. Dresel	K6-96
M. J. Hartman	K6-96
S. P. Luttrell	K6-96
R. M. Smith	K6-96
M. D. Sweeney (10)	K6-81
B. A. Williams	K6-81
Information Release Office (7)	K1-06