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ADDENDUM D
GROUNDWATER MONITORING

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ADDENDUM D
GROUNDWATER MONITORING

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D GROUNDWATER MONITORING

The IDF will be a RCRA compliant landfill (i.e., a double lined trench with leachate collection system). This Addendum describes the groundwater monitoring plan for the IDF and addresses the requirements of RCRA, as described in [40 CFR 264, Subpart F](#), by reference of [WAC 173-303-645\(3\)](#). Figure D.1 shows the location of the IDF and surrounding groundwater wells in the 200 East Area. This Addendum is designed to meet final status detection-level groundwater monitoring requirements for the IDF. This groundwater monitoring plan is based on the application of a modified data quality objectives (EPA QA/G-4) process to a conceptual model, and the most recent evaluations of groundwater hydrology and chemistry at the site.

This plan describes the characteristics of the waste to be disposed in the IDF and the site geology and hydrology used to design and operate the monitoring well network and to interpret the groundwater data. The historic groundwater chemistry from wells near the IDF site is provided. Much of the information pertaining to waste characterization is taken from [HNF-4921](#) and that pertaining to hydrogeology from [PNNL-11957](#), [PNNL-12257](#), [PNNL-13652](#), and [PNNL-14029](#).

The plan includes a description of network well locations, well construction, sample constituents, and sampling frequency for detection-level groundwater monitoring. Procedures for determination of compliance point groundwater quality also are included. Finally, this plan provides the basis for rapid development of a compliance monitoring plan if a validated exceedance of an indicator parameter is found. This plan controls initial baseline monitoring and subsequent detection level monitoring only for the IDF.

Source, special nuclear, and byproduct materials as defined by the [Atomic Energy Act of 1954](#), as amended, are regulated at DOE facilities exclusively by DOE acting pursuant to its AEA authority. These materials are not subject to regulation by the State of Washington. All information contained herein and related to, or describing AEA-regulated materials and processes in any manner may not be used to create conditions or other restrictions set forth in any permit, license, order, or any other enforceable instrument. DOE asserts that pursuant to the AEA, it has sole and exclusive responsibility and authority to regulate source, special nuclear and by-product materials at DOE-owned nuclear facilities. Information contained herein on radionuclides is provided for process description purposes only.

D.1 Exemption from Groundwater Protection Requirement

An exemption is not requested.

D.2 Interim Status Period Groundwater Monitoring Data

The IDF will be a new facility constructed in the 200 East Area. Interim status groundwater monitoring is not applicable.

D.3 Aquifer Identification

The following sections discuss geology and hydrology.

D.3.1 Geology of the IDF Site

The 200 East Area lies on the Cold Creek bar, a geomorphic remnant of the cataclysmic, glacial related floods of the Pleistocene Epoch. As the floodwaters raced across the lowlands of the Pasco Basin and Hanford Site, floodwaters lost energy and began to deposit sand and gravel. The 200 Area Plateau is one of the most prominent deposits. The 200 Area Plateau lies just southwest of one of the major flood channels across the Hanford Site that forms the topographic lowland south of Gable Mountain.

Borehole data provide the principal source of geologic, hydrologic, and groundwater information for the 200 East Area and the IDF site. Numerous boreholes (both vadose zone boreholes and groundwater monitoring wells) have been drilled in the 200 East Area for groundwater monitoring and waste management studies (Figure D.1 shows the location of groundwater wells near the IDF site.) However, data are limited within the IDF site primarily because no previous construction or waste disposal activities

1 have occurred in this part of the Hanford Facility. Most boreholes in the 200 East Area have been drilled
2 using the cable tool method and either a hard tool or drive barrel to advance the hole. Some boreholes
3 have been drilled by rotary and wire line coring methods. More recently, boreholes in the area have been
4 drilled, and in five cases cored, by percussion hammer methods. Geologic logs are based on examination
5 of drill core, chips, and cuttings from these boreholes. Chip samples typically are taken at 1.5-meter
6 intervals and routinely archived at the Hanford Geotechnical Sample Library.

7 **D.3.1.1 Structural Framework**

8 The IDF site will be located south of the Gable Mountain segment of the Umtanum Ridge anticline and
9 about 3 kilometers north of the axis of the Cold Creek syncline, which controls the structural grain of the
10 basalt bedrock and the Ringold Formation. The basalt surface and Ringold Formation trend roughly
11 southeast-northwest parallel to the major geologic structures of the site. As a result, the Ringold
12 Formation and the underlying Columbia River Basalt Group gently dip to the south off the Umtanum
13 Ridge anticline into the Cold Creek syncline.

14 Geologic mapping on the Hanford Site and examination of drill core and borehole cuttings in the area
15 have not identified any faults in the vicinity of the IDF site (DOE/RW-0164). The closest known faults
16 are along the Umtanum Ridge-Gable Mountain structure north of the disposal site and the May Junction
17 fault east of the site (Figure D.2).

18 **D.3.1.2 Stratigraphy**

19 The basalt and post basalt stratigraphy for the IDF site is shown in Figure D.3. Approximately 137 to 167
20 meters of suprabasalt sediments overlie the basalt bedrock at the site.

21 Basalt Bedrock

22 Previous studies (RHO-BWI-ST-14; Reidel and Fecht 1994) have shown that the youngest lava flows of
23 the Columbia River Basalt Group at the 200 East Area are those of the 10.5 million year old Elephant
24 Mountain Member. This member underlies the entire 200 East Area and surrounding area and forms the
25 base of the suprabasalts aquifer. No erosional windows in the basalt are known or suspected to occur in
26 the area of the IDF site.

27 Ringold Formation

28 Few boreholes penetrate the entire Ringold Formation at the IDF site so available data are limited. The
29 Ringold Formation reaches a maximum thickness of 95 meters on the west side of the site and thins
30 eastward. The member of Wooded Island (Figure D.3) is the only member of the Ringold Formation in
31 the 200 East Area. The deepest Ringold Formation unit encountered is the lower gravel, unit A. Lying
32 above unit A is the lower mud unit and overlying the lower mud unit is upper gravel, unit E. The sand
33 and silt units of the members of Taylor Flat and Savage Island of the Ringold Formation are not present at
34 the IDF site. Unit A and unit E are equivalent to the Pliocene-Miocene continental conglomerates (Reidel
35 and Fecht 1994). The lower mud unit is equivalent to the Pliocene-Miocene continental sand, silt, and
36 clay beds (Reidel and Fecht 1994).

37 Only three boreholes have penetrated unit A in the area of the IDF site. Unit A is 19 meters thick on the
38 west side of the site and thins to the northeast. Unit A is partly to well cemented conglomerate consisting
39 of both felsic and basaltic clasts in a sandy matrix and is interpreted as a fluvial gravel facies
40 (Lindsey 1996). There are minor beds of yellow to white interbedded sand and silt. Green colored,
41 reduced iron stain is present on some grains and pebbles. Although the entire unit appears to be
42 cemented, the zone produced abundant high quality water in borehole 299-E17-21 (PNNL-11957).

43 Nineteen meters of the lower mud unit were encountered in one borehole at the IDF site (PNNL-11957).
44 The upper most 1-meter or so consists of a yellow mud to sandy mud. The yellow mud grades downward
45 into about 10 meters of blue mud. The blue mud, in turn, grades down into 7 meters of brown mud with
46 organic rich zones and occasional wood fragments. The lower mud unit is absent in the center of the site
47 (northeast of borehole 299-E24-7 on Figure D.4).

1 Unit E is described as a sandy gravel to gravelly sand. Unit E is interpreted to consist of as much as
2 15 meters of conglomerate with scattered large pebbles and cobbles up to 25 centimeters in size in a
3 sandy matrix. The gravel consists of both felsic and basaltic rocks that are well rounded with a sand
4 matrix supporting the cobbles and pebbles. Cementation of this unit ranges from slight to moderate. The
5 upper contact of unit E is not identified easily at the IDF site. In the western part of the study area,
6 unconsolidated gravels of the Hanford formation directly overly the Ringold Formation unit E gravels,
7 making exact placement of the contact difficult. The dominance of basalt and the absence of cementation
8 in the Hanford formation are the key criteria used to distinguishing these (PNNL-11957). In the central
9 and northeast part of the area, unit E has been eroded completely. Unconsolidated gravels and sands
10 typical of the Hanford formation replace unit E.

11 Unconformity at the Top of the Ringold Formation

12 The surface of the Ringold Formation is irregular in the area of the IDF site. A northwest-southeast
13 trending erosional channel or trough (the Columbia River/Missoula flood channel) is centered through the
14 northeast portion of the site. The trough is deepest near borehole 299-E24-21 in the northern part of the
15 site ([PNNL-13652](#)). This trough is interpreted as part of a larger trough under the 200 East Area resulting
16 from scouring by the Missoula floods. Borehole 299-E17-21, located at the southwest corner of the IDF
17 site, is at the west side of the channel where approximately 46 meters of Ringold Formation have been
18 removed and replaced by Hanford formation gravels. Boreholes 299-E17-25 and 299-E17-23, located
19 along the southeastern edge of the Site, are near the deepest portion of the channel where it is interpreted
20 that almost all of the Ringold Formation has been eroded. At this location, the water table in the channel
21 is interpreted to be 52 meters above the basalt, which forms the floor of the channel. The surface of basalt
22 rises to the north where the water table is approximately 27 meters above the basalt at the northeast corner
23 of the site near borehole 299-E24-21.

24 Hanford formation

25 The Hanford formation is as much as 116 meters thick in and around the IDF site. The Hanford
26 formation thickens in the erosional channel cut into the Ringold Formation and thins to the southwest
27 along the margin of the channel.

28 At the IDF site, the Hanford formation consists mainly of sand dominated facies with lesser amounts of
29 silt dominated and gravel dominated facies. The Hanford formation has been described as poorly sorted
30 pebble to boulder gravel and fine- to coarse-grained sand, with lesser amounts of interstitial and
31 interbedded silt and clay. In previous studies of the site (WHC-MR-0391), the Hanford formation was
32 described as consisting of three units: an upper and lower gravel facies and a sand facies between the two
33 gravelly units. The upper gravel dominated facies appears to be thin or absent in the immediate area of
34 the IDF site (PNNL-12257, [PNNL-13652](#), and [PNNL-14029](#)).

35 The lowermost part of the Hanford formation encountered in boreholes at the IDF site consists of the
36 gravel-dominated facies. Drill core and cuttings from boreholes 299-E17-21, 299-E17-22, 299-E17-23,
37 299-E17-25, and 299-E24-21 indicate that the unit is a clast supported pebble to cobble gravel with minor
38 amounts of sand in the matrix. The cobbles and pebbles almost are exclusively basalt with no
39 cementation. This unit pinches out west of the IDF site and thickens to the east and northeast
40 (Figure D.4). The water table beneath the IDF site is located in the lower gravel unit. The lower gravel
41 unit is interpreted to be Missoula flood gravels deposited in the erosional channel carved into the
42 underlying Ringold Formation.

43 The upper portion of the Hanford formation consists of at least 73 meters of fine- to coarse-grained sand
44 with minor amounts of silt and clay and some gravelly sands.

45 Holocene Deposits

46 Holocene, eolian deposits cover the southern part of the IDF site. Caliche coatings on the bottom of
47 pebbles and cobbles in drill cores through this unit are typical of Holocene caliche development in the
48 Columbia Basin. The southern part of the IDF site is capped by a stabilized sand dune. The eolian unit is

1 composed of fine- to coarse-grained sands with abundant silt, as layers and as material mixed with the
2 sand.

3 Clastic Dikes

4 A clastic dike was encountered in borehole C3828, adjacent to well 299-E17-25, at the IDF site. Clastic
5 dikes also have been observed in excavations surrounding the site [e.g., US Ecology, the former Grout
6 area, the 216-BC cribs, the Central Landfill, and the Environmental Restoration Disposal Facility. In
7 undisturbed areas, such as the IDF site, clastic dikes typically are not observed because these are covered
8 by windblown sediments. The occurrence of a clastic dike in borehole C3828 suggests that these
9 probably are present elsewhere in the subsurface at the disposal site. The IDF excavation will be
10 geologically mapped to document the occurrence of any clastic dikes that may exist at the site.

11 **D.3.2 Groundwater Hydrology**

12 The unconfined aquifer under the IDF site occurs in the fluvial gravels of the Ringold Formation and
13 flood deposits of the Hanford formation. The thickness of the aquifer ranges from about 70 meters at the
14 southwest corner of the site to about 30 meters under the northeast corner of the IDF site. The Elephant
15 Mountain Member of the Columbia River Basalt Group forms the base of the unconfined aquifer
16 (Figure D.4).

17 The unsaturated zone beneath the land surface at the IDF site is approximately 100 meters thick and
18 consists of the Hanford formation. The water level in boreholes in and around the site indicates that the
19 water table is in the lower gravel sequence of the Hanford formation and at an elevation of approximately
20 123 meters above sea level. The water table is nearly flat beneath the IDF site. Table D.1 gives water
21 level information from wells near the site. The locations of the wells are shown on Figure D.1. The latest
22 water table map shows less than about 0.1 meter of hydraulic head differential across the IDF site
23 (Figure D.5).

24 The Ringold Formation lower mud unit occurs within the aquifer at the southwest corner of the IDF site
25 (299-E17-21) but is absent in the central and northern parts of the site (299-E24-7 and 299-E24-21). The
26 lower mud unit is known to be a confining or partly confining layer at places under the Hanford Site
27 ([PNNL-12261](#)) and this might be the case under the southwest corner of the IDF site. Groundwater
28 samples were collected and analyzed from above and below the lower mud unit during drilling of well
29 299-E17-21. Chemical parameters (pH, electrical conductivity, and Eh) were different in the two samples
30 suggesting that the lower mud is at least partly confining in the area. No contamination was found above
31 or below the lower mud. An interpretation of the distribution and thickness of this stratum is shown in
32 Figure D.4. The surface of the lower mud unit is interpreted to dip gently to the southwest
33 ([PNNL-13652](#)).

34 Hydrographs for selected wells near the IDF site are shown in Figure D.6. Although the water table is
35 extremely flat in the area of the IDF, hydrographs suggest that groundwater flow has had an easterly
36 component throughout the 1990s and has not significantly changed due to cessation of discharges to the
37 216-B Pond system. Hydrographs for the older wells (299-E23-1, 299-E23-2, and 299-E24-7) show two
38 maxima in the water level. These coincide with the operation of the PUREX Plant, which operated
39 between 1956 and 1972 and between 1983 and 1988. All the hydrographs show a decline in the water
40 table during recent years. The rate of decline is between 0.18 and 0.22 meter per year and will take
41 between 10 and 30 years to stabilize. The reason for the decline is the cessation of effluent discharge to
42 the 216-B Pond System, which is centered northeast of 200 East Area. Based on hindcast water table
43 maps (BNWL-B-360), the water table is expected to decline another 2 to 7 meters before reaching
44 pre-Hanford Site elevations. The cessations of effluent discharge also are responsible for changes in the
45 direction of groundwater flow across much of the 200 East Area.

46 Groundwater flow beneath the IDF site recently was modeled to be southeasterly ([PNNL-13400](#)). This
47 direction differs from the easterly direction predicted by the analysis of other earlier reports. The
48 southeasterly flow direction primarily is attributable to inclusion of the highly permeable Hanford
49 formation sediments in the ancestral Columbia River/Missoula flood channel in the analysis. A

southeasterly flow direction is reflected in the geographic distribution of the regional nitrate plume and in the distribution of other constituents under the south-central 200 East Area (PNNL-14187). As stated in PNNL-13404, the water table gradient is too low to be used for determining flow direction or flow rate at the PUREX Plant cribs immediately east of the IDF site.

Hydraulic conductivity directly beneath the IDF site was estimated from data collected during four slug tests at well 299-E17-21 and five slug tests of 299-E24-21. The interval tested at 299-E17-21 was the upper 7.8 m of the unconfined aquifer from 101.3 to 109.1 m depth. That portion of the aquifer is Hanford formation gravel from 101.3 to 102.1 m depth and Ringold Formation unit E gravels from 102.1 to 109.1 m depth (PNNL-11957). The interval tested at well 299-E24-21 was entirely in the Hanford formation gravel sequence between 95.2 and 101.3 m depth. The best fit value to the data from 299-E17-21 indicated a hydraulic conductivity of about 68.6 meters per day (PNNL-11957) and from 299-E24-21 suggested a hydraulic conductivity of 75 meters per day ([PNNL-13652](#)).

D.4 Contaminant Plume Description

Although no groundwater monitoring has been done for the IDF, groundwater monitoring has been done in support of RCRA permitting activities and in support of other activities in the area. The results of that monitoring show that a regional nitrate plume exists beneath the IDF site (PNNL-14187). In the south-central 200 East Area, the plume extends in a northwest - southeast direction along the axis of the Columbia River/Missoula flood channel eroded into the Ringold Formation sediments. The channel is filled with more transmissive Hanford formation sediments.

D.4.1 Groundwater Contamination

Nitrate, associated with past-practice activities in 200 East Area, is a general groundwater chemistry parameter and is not a contaminant of concern for the IDF. However, the distribution of existing nitrate in the groundwater gives an indication of the general groundwater flow direction and the influence that adjacent sites might have on the IDF.

High nitrate concentrations found near liquid waste disposal facilities located outside the IDF site that received effluent from the PUREX Plant are decreasing steadily with time. The highest nitrate concentration found in 2002 was 170,000 $\mu\text{g/L}$ in well 299-E17-9 at the 216-A-36B crib and the crib is thought to be the source of the nitrate. The drinking water standard for nitrate is 45,000 $\mu\text{g/L}$ (nitrate ion).

Nitrate in well 299-E24-18, just inside the east boundary of the IDF site, decreased from a high of 86,300 $\mu\text{g/L}$ in 1990 to a low of 17,000 $\mu\text{g/L}$ in 1993, reflecting the cessation of PUREX Plant operations in 1988. Since 1993, nitrate has increased to 48,300 $\mu\text{g/L}$ in 2003 (Figure D.7). The reason for the increase is not understood. One possibility is related to changing groundwater flow direction. During PUREX Plant operations, flow direction was probably to the northwest because of effluent discharges to the B Pond System and PUREX Plant cribs, and nitrate contamination might have spread to the northwest during that period. Subsequently, liquid discharges to the B Pond System and PUREX Plant cribs have ceased and the flow direction in the area of the IDF site apparently has returned to the southeast direction. With that change, higher levels of nitrate contaminated groundwater might be returning to the area from the northwest.

Except for an anomalous value of 82,600 $\mu\text{g/L}$ in 1988, nitrate concentration in well 299-E24-7 was steady and ranged between 12,800 and 35,400 $\mu\text{g/L}$ between 1985 and 1996 when the well was last sampled (Figure D.7). The last two measured values from 1995 and 1996 were 26,000 $\mu\text{g/L}$. Farther southwest, nitrate detected in 1998 in well 299-E17-21 in Ringold unit E was 23,600 $\mu\text{g/L}$.

D.4.2 Vadose Zone Contamination

Very little characterization and monitoring of the soil have been done at the IDF site because no major construction or waste disposal activities have occurred in this part of the Hanford Site. A pre-operational environmental monitoring plan (RPP-6877) for the disposal facility was issued in 2000. Implementation of that plan has begun and characterization activities will occur during the next few years. The

1 pre-operational environmental monitoring plan has a strong emphasis on vadose zone characterization and
2 deferred groundwater monitoring to this groundwater monitoring plan. Vadose zone information
3 resulting from pre-operational monitoring will be included, if applicable, in updates to this groundwater
4 monitoring plan.

5 The pre-operational monitoring plan identified three areas near the IDF site that might have had an
6 influence on the vadose zone beneath the site. These are the 218-E-1 Burial Ground and an unplanned
7 release associated with the burial ground; the coal ash pile in the northwest part of the site; and a transfer
8 line along the northern part of the west boundary of the IDF site (RPP-6877). Work was outlined in the
9 pre-operational monitoring plan to determine whether these three areas had introduced contamination to
10 the site. Appropriate results from pre-operational monitoring will be incorporated into this groundwater
11 monitoring plan as results become available and as revisions are needed.

12 In addition to these facilities, the 216-A-38-1, 216-A-45, and 216-A-10 cribs and the 299-E24-111
13 injection well are located east of the IDF site. The 216-A-38-1 crib never was used ([DOE/RL-92-04](#)).
14 The 299-E24-111 injection well never received any waste ([DOE/RL-92-04](#)). The 216-A-45 and the
15 216-A 10 cribs both received large quantities of liquid waste ([DOE/RL-92-04](#)). Because these latter two
16 facilities are more than 200 meters from the IDF site, it is unlikely these facilities have affected the soil
17 beneath the IDF site. Data from the vadose zone in IDF wells drilled along the east side of the site
18 support this.

19 **D.5 Detection Monitoring Program**

20 Because the IDF has not been constructed, no contaminants have been released to the ground or to the
21 groundwater.

22 **D.5.1 Indicator Parameters, Waste Constituents, Reaction Products to be Monitored**

23 Monitoring for baseline conditions was completed for the indicator parameters in April 2006 and for the
24 complete Appendix IX list in January 2007. Semi-annual monitoring has continued since that time with
25 the collection of four independent samples each semiannual period. During the Pre-Active life, sampling
26 will continue at the IDF with the collection of one sample each year to maintain the baseline. When the
27 IDF becomes operational, sampling will revert to four independent samples collected each semiannual
28 period.

29 **D.5.1.1 Regulated Constituents**

30 The regulated constituents for this groundwater monitoring plan are the constituents identified in
31 Addendum A, IDF Part A Form.

32 **D.5.1.2 Monitoring Parameters**

33 The parameters to be routinely monitored are listed in Table D.2. These parameters include the indicator
34 parameters and supplemental parameters.

35 The indicator parameters will be used to monitor for hazardous constituents reaching the groundwater as a
36 result of IDF operations. Only the indicator parameters are subject to the statistical methods described in
37 Section D.5.4.7. Total organic carbon and total organic halides are indicator parameters selected to
38 monitor impacts of RCRA regulated organic constituents on the groundwater quality. Specific
39 conductance is selected as an indicator parameter to monitor impacts of metals and anions on
40 groundwater quality. pH is a general indicator of groundwater quality. Specific conductance and pH are
41 measured in the field at the time of sampling. Chromium is included as an indicator parameter because
42 hexavalent chromium is one of the more mobile of the regulated metals to be disposed of at the IDF and
43 should be one of the first constituents to enter groundwater if the regulated facility impacts groundwater.

44 Analyses of alkalinity, anions, and metals are to provide supplemental data on general groundwater
45 chemistry beneath the IDF. This information aids data interpretation and quality control. Supplemental
46 parameters will not be used in statistical evaluations. Turbidity is analyzed at the well just before
47 sampling and provides an indication of the groundwater condition at the time of sampling.

1 For the first year of monitoring, all parameters listed in Table D.2 will be monitored twice each quarter to
2 determine background concentrations. After the first year, indicator and supplemental parameters will be
3 monitored semi-annually. In addition, field measurements of temperature and turbidity will be made at
4 each sampling event.

5 During the first sampling event at each well for the first year of monitoring, samples will be collected for
6 analysis of the indicator parameters, the supplemental parameters, and the Appendix IX constituents
7 ([40 CFR 264](#)) included in Addendum A, IDF Part A Form. After the first sampling event, samples will
8 be collected for analysis of indicator parameters and supplemental parameters only.

9 After the first year of sampling, if an indicator parameter suggests there is an impact to groundwater,
10 additional samples will be collected to verify the initial results. If a statistically significant increase in any
11 indicator parameter is confirmed, analyses will be made for the regulated parameters in Addendum A,
12 IDF Part A Form.

13 **D.5.1.3 Dangerous Waste Characterization**

14 This section describes the waste to be disposed in the IDF and gives background information on how the
15 constituents of concern (regulated constituents) and indicator parameters were selected.

16 **D.5.1.3.1 Volume of the Waste Package**

17 The IDF will be a single, expandable disposal facility constructed to [RCRA](#) Subtitle C standards, half of
18 which is for disposal of mixed waste the other half will be for disposal of low-level waste. Initial capacity
19 for mixed waste disposal is 82,000 cubic meters of waste with an ultimate capacity of up to 450,000 cubic
20 meters of waste. Disposal capacity beyond the initial 82,000 cubic meters will require a modification to
21 the Part B Permit. The mixed waste types to be disposed in the IDF include vitrified LAW from the
22 RPP-WTP and DBVS. Additionally, mixed waste generated by IDF operations will be disposed of in
23 IDF.

24 The vitrified LAW will be mostly silicate glass monoliths. The RPP-WTP packages nominally measure
25 approximately 1.22 m diameter by 2.3 m high and the DBVS package nominally measure approximately
26 2.4 m wide by 3.1 m high by 7.3 m long. Vitrified LAW will be remote handled.

27 If other forms of immobilized LAW are considered in the future, this monitoring plan will be amended.

28 Mixed waste generated through waste operations at IDF will be packaged based on the size of the waste,
29 with the most common container being galvanized or aluminized 208 liter containers.

30 **D.5.1.3.2 Composition of the Waste Packages**

31 [HNF-4921](#) provides detailed estimates for the inventory of hazardous chemicals in the vitrified LAW feed
32 and in the vitrified LAW package. The composition of the vitrified LAW package was estimated in
33 [HNF-4921](#) based on:

- 34 1) the Tank Waste Retrieval System Characterization Program tank-by-tank Best Basis Inventories,
- 35 2) the latest U.S. Department of Energy, Office of River Protection (DOE/ORP) guidance,
- 36 3) the requirements for waste retrieval and vitrification,
- 37 4) available information from waste treatment plant contractors, and
- 38 5) proposed operating scenarios for retrieval of waste from DSTs and SSTs.

39 **D.5.1.4 Behavior of Constituents**

40 Almost all of the regulated constituents for the IDF show some degree of retardation in the vadose zone
41 and in the saturated zone. Table D.3 indicates the range of expected behaviors in the subsurface at the
42 IDF for selected regulated constituents. The constituents in Table D.3 were selected by comparing the
43 expected constituents in the vitrified LAW package (from [HNF-4921](#)) and the historical inventories of the
44 Hanford Site low-level burial grounds (from WHC-MR-0008 and WHC-SD-EN-AP-015) to [40 CFR 264](#),

1 Appendix IX (refer to Addendum A, IDF Part A Form). The mobilities and solubilities in Table D.3 give
2 an estimated range for the properties of the constituents of concern.

3 **D.5.1.5 Detectability**

4 The detection limits in groundwater for each RCRA regulated constituent and the indicator parameters are
5 given in Table D.4.

6 **D.5.2 Groundwater Monitoring Program**

7 The following sections provide a description of wells, equipment decontamination, representative
8 samples, and monitoring wells that are not upgradient.

9 **D.5.2.1 Description of Wells**

10 The groundwater monitoring well network for the IDF ultimately will have eight wells: three
11 hydraulically upgradient of the facility and five hydraulically downgradient. The downgradient wells will
12 be placed to sample groundwater passing the point of compliance. The point of compliance at the IDF
13 site is a plane connecting the groundwater monitoring wells along the southern and eastern sides of the
14 site in accordance with [WAC 173-303-645](#)(6), which states "The point of compliance is a vertical surface
15 located at the hydraulically downgradient limit of the waste management area that extends down into the
16 uppermost aquifer underlying the regulated unit". The monitoring network will consist of existing and
17 new, downgradient wells to complete the monitoring network. All wells will be [WAC 173-160](#)
18 compliant.

19 Three upgradient wells will be used for the IDF monitoring network. Two of these wells (299-E18-1 and
20 299-E24-21) are existing wells. Upgradient well 299-E24-21 was installed in March 2001 for
21 characterization of the IDF site. The well, located at the northeast corner of the site (Figure D.8), was
22 constructed to RCRA standards as per [WAC 173-160](#). Well 299-E18-1 was installed in 1988 as part of
23 the 2101-M RCRA monitoring network. The well currently has 2 to 3 meters of water above the bottom
24 of the screened interval.

25 The third upgradient well will be a new well located at the northwest corner of the IDF (Figure D.8). The
26 well will be constructed to RCRA standard as per [WAC 173-160](#) and screened at the water table.

27 Three of the downgradient wells are existing wells (299-E17-22, 299-E17-23, and 299-E17-25) that were
28 installed as [WAC 173-160](#) compliant wells in 2002. Their location is shown in Figure D.8. The
29 remaining two downgradient wells will be installed in a sequence coordinated with the IDF operations.

30 Three phases of trench construction are assumed for the purposes of this monitoring plan. Excavation for
31 the first phase is scheduled for September 2004 and a new phase is planned for every ten subsequent
32 years. Changes in the planned operations of the IDF will be reflected in changes to this groundwater
33 monitoring plan as needed.

34 The first new downgradient well will be installed along the eastern side of the facility (Figure D.8) at least
35 one year before the IDF receives waste. The second new downgradient well will be installed along the
36 southern boundary of the Site at least one year before the third phase of waste disposal becomes
37 operational. Both wells will be installed such that at least one year of background data can be obtained
38 prior to the associated operational phase becoming active. Figure D.8 shows the sequence for both
39 groundwater well construction and waste disposal. The locations of all existing and new wells in the IDF
40 monitoring network are noted on the figure.

41 The placement of the wells for the IDF monitoring network was based on professional judgment. The
42 efficiency of the resulting groundwater monitoring network was evaluated using a simple two
43 dimensional, horizontal transport model called the monitoring efficiency model (MEMO)
44 ([Wilson et al. 1992](#)). The model estimates the efficiency of a monitoring network at the point of
45 compliance. The model simulates a contaminant plume originating from a series of grid points within the
46 disposal facility using the Domenico-Robbins method (Domenico and Robbins 1985). The model
47 calculates both advective flow and dispersive flow in two dimensions and determines whether the

1 resulting plume will be detected by a monitoring well before the plume travels some selected distance
2 beyond the disposal facility boundary. The selected distance is termed the buffer zone. (A longitudinal
3 dispersivity of 95 meters and horizontal dispersivity of 9.5 meters were used to evaluate the monitoring
4 network in Figure D.8.) Outputs from the model are the monitoring efficiency and a map of the disposal
5 facility showing areas where leaks would not be detected under the given site-specific parameters
6 provided as input to the model. Monitoring efficiency is defined as the ratio of the area within a disposal
7 facility from which a release likely would be detected to the total area of the disposal facility, expressed
8 as a percentage.

9 The monitoring efficiency calculated by the MEMO model for the proposed monitoring network is 100%
10 for phase I, 98% for phase II, and 99% for phase III (Figure D.8).

11 All wells for the IDF site will be constructed to meet [WAC 173-160](#) requirements. The wells will be
12 protected at the surface with a concrete pad, protective posts, a protective outer casing, and locking cap.
13 The casing and screen will be stainless steel, an appropriate filter pack for the screen slot size will be
14 used, and an annular seal of bentonite and cement will be emplaced. All wells will be screened at the
15 water table with 10.6 meter long screens, which will accommodate the greatest possible future decrease in
16 water level. The wells will be developed and dedicated sampling pumps will be installed.

17 New wells will be surveyed with a down hole gyroscope at the time of construction to determine any
18 deviation from vertical so that corrections can be made to subsequent water level measurements.
19 Gyroscope surveys will also be conducted on existing wells in the network prior to IDF operations.

20 **D.5.2.2 Equipment Decontamination**

21 Drilling equipment will be decontaminated using high temperature and pressure [82°C (180°F) and
22 greater than 70.3 kg/cm² (1,000 psi)] washing with an approved cleaning solution. The equipment will be
23 rinsed with clean water. The procedure is specified in controlled manuals.

24 Equipment for collecting soil samples during drilling for later chemical analysis and for measuring the
25 water table will be decontaminated according to established methods. The methods call for washing
26 equipment with phosphate free detergent, rinsing three times with reverse osmosis/de-ionized water,
27 rinsing once with 1M or 10% nitric acid (glass or stainless steel equipment only), rinsing three more times
28 with reverse osmosis/de-ionized water, and a final rinse with chromatograph grade hexane. Equipment
29 will be dried for 50 minutes at 100°C (212°F). After drying, equipment will be wrapped in unused
30 aluminum foil and sealed with tape.

31 No decontamination of groundwater sampling equipment will be necessary because each well will have a
32 dedicated pump.

33 **D.5.2.3 Representative Samples**

34 No groundwater chemistry data specific to the IDF site are available. Sample representativeness will be
35 addressed after collection of the first year of background data.

36 **D.5.2.4 Locations of Background Groundwater Monitoring Wells that are not** 37 **Upgradient**

38 All background groundwater monitoring wells at the IDF are located upgradient.

39 **D.5.3 Background Values**

40 Groundwater background (baseline) has not been established for the IDF site. Background data will be
41 determined before construction of the site using the wells described previously (Section D.5.2.1) for the
42 use of upgradient vs. downgradient comparisons (Section D.5.4.7).

43 **D.5.3.1 Plan for Establishing Groundwater Quality Data**

44 Well location, sampling frequency, sampling quantity, and background values are discussed in the
45 following sections.

1 **D.5.3.1.1 Well Locations**

2 Groundwater monitoring wells in the IDF monitoring network were described in Section D.5.2.1 and their
3 locations are shown on Figure D.8.

4 **D.5.3.1.2 Sampling Frequency**

5 Eight background samples will be collected during the first year of monitoring from phase I wells. Two
6 samples will be collected quarterly for one year. For the new well needed for Phase III Operations, two
7 samples will be collected quarterly for one year before Phase III is operational. For all wells, two
8 independent samples will be collected each quarter, one per month for 2 consecutive months followed by
9 a month of non-sampling. This sequence will be repeated each quarter during the first year of monitoring.
10 Section D.5.3.1.3 provides frequency logic.

11 **D.5.3.1.3 Sampling Quantity**

12 The performance of the statistical method proposed for the IDF is evaluated by the following two goals:

- 13 • To have adequate statistical power to detect real contamination when contamination occurs
14 • To keep the network wide Type I error (across all constituents and wells being tested) at an
15 acceptably low level (approximately 5%). [Note that the Type I error in the detection monitoring
16 stage equates to the false positive rate, that is, the probability that the test will indicate contamination
17 has occurred although no contamination has truly occurred.]

18 The statistical power and the network-side false positive rate of a test depend on several factors, including
19 the background sample size, the type of proposed test, and the number of comparisons. All other factors
20 being equal, the larger the sample size is (i.e., the number of background samples), the greater the
21 statistical power is. Therefore, as recommended in EPA/530-R-93-003, at least eight independent
22 samples will be collected from each well for background purposes. This is a sufficient number of samples
23 to establish a reliable background (EPA/530-R-93-003) and meets the regulations in
24 [WAC 173-303-645\(9\)\(d\)](#).

25 **D.5.3.1.4 Background Values**

26 The default method of analysis of variance (ANOVA) will be used to detect any impact on groundwater
27 quality at the IDF where the mean of the measurements from compliance (downgradient) wells is
28 compared to the mean of the distribution of background data from the upgradient wells. The details of the
29 method are described in Section D.5.4.7.1.

30 **D.5.4 Sampling, Analysis and Statistical Procedures**

31 Sample collection, sample preservation and transfer/shipment, analytical procedures, chain of custody and
32 additional requirements for compliance point monitoring are discussed in the following sections.

33 **D.5.4.1 Sample Collection**

34 Groundwater sampling procedures, sample collection documentation, sample preservation and
35 transfer/shipment, and chain-of-custody requirements are described in subcontractor operating
36 procedures/manuals and in a quality assurance project plan for the Hanford Groundwater Performance
37 Assessment Project. Quality requirements for sampling activities, including requirements for procedures,
38 containers, transport, storage, chain of custody, and records requirements, are specified in a statement of
39 work (SOW) to subcontractors. To ensure that samples of known quality are obtained, the subcontractor
40 will be required to use contractor controlled procedures based on standard methods for groundwater
41 sampling whenever possible. The procedures will be reviewed for technical quality and consistency. In
42 addition, periodic assessments of sample collection activities will be performed to ensure further that
43 procedures are followed to maintain sample quality and integrity. The following is a brief description of
44 the sampling requirements.

45 Samples generally will be collected after three casing volumes of groundwater are withdrawn or after the
46 field parameters pH, temperature, and specific conductance have stabilized. Field parameters are

1 measured in a flow through chamber. Turbidity should be equal to or below five NTU (nephelometric
2 turbidity units) before sample collection if possible. Sample preservatives will be added to the collection
3 bottles in the laboratory before their use in the field. Samples to be analyzed for metals will be filtered in
4 the field to ensure results represent dissolved metals and do not include particulates ([40 CFR 136.3](#)).
5 Duplicates, trip blanks, and field equipment blanks will be collected as part of the general quality control
6 program.

7 Water level measurements will be made each time a well is sampled. Procedures developed in
8 accordance with the techniques described in American Society for Testing and Materials (ASTM, [1988](#)),
9 Garber and Koopman (1968), and U. S. Geological Survey (1977) will be followed to measure water
10 levels. Water levels will be measured primarily with laminated steel electrical sounding tapes, although
11 graduated steel tapes are used occasionally.

12 **D.5.4.2 Sample Preservation and Shipment**

13 Sample preservation will be done in accordance with existing procedures. A chemical preservative label
14 will be affixed to the sample container listing the specific preservative. The brand name, lot number,
15 concentration, and date opened of the preservatives will be recorded. A calibrated dispenser or pipette
16 will be used to dispense preservatives. Appropriate measures will be taken to eliminate any potential for
17 cross contamination.

18 Sample packaging and transfer/shipping will be done in accordance with subcontract procedures.
19 Samples will be labeled and sealed with evidence tape, wrapped with bubble wrap, and placed in a
20 Department of Transportation approved container with coolant (if required). Hazardous samples will
21 have packaging parameters determined by associated hazards. A chain of custody will accompany all
22 samples.

23 **D.5.4.3 Analytical Procedures**

24 The methods for analysis of chemical constituents in groundwater will conform to *Test Methods for*
25 *Evaluating Solid Wastes: Physical/Chemical Methods, 3rd Ed. (SW-846)*; *Methods for Chemical Analysis*
26 *of Water and Wastes (EPA-600/4-79-020)* or other EPA methods; and the *Annual Book of ASTM*
27 *Standards* (American Society for Testing and Materials, 1986). The methods used to obtain routine data
28 results are presented in Table D.4.

29 **D.5.4.3.1 Data Storage and Retrieval**

30 All contract analytical laboratory results will be submitted by the laboratory to be loaded into the Hanford
31 Environmental Information System (HEIS) database. Most data are received from the laboratory in
32 electronic form, and will be loaded electronically. Parameters measured in the field will be entered into
33 HEIS either manually or through electronic transfer. Hard copy data reports are received for records
34 storage. Data from the HEIS database will be retrieved for data validation, data reduction, and trend
35 analysis. Copies of supporting analytical data will be sent yearly to Pacific Northwest National
36 Laboratory (PNNL) for storage.

37 **D.5.4.3.2 Data Verification and Validation**

38 Verification of analytical data provided by the subcontracted laboratory will be performed in accordance
39 with established procedure. This procedure includes checks for: (1) completeness of hardcopy
40 deliverable, (2) condition of samples on receipt by the laboratory, (3) problems that arose during the
41 analysis of the samples, and (4) correct reporting of results. The procedure also describes the actions to
42 be taken if data are incomplete or deficient.

43 Verification and validation of groundwater chemistry data will be performed according to established
44 procedures. Data will be reviewed quarterly to assure the data are complete and representative. The
45 review will include evaluation of quality control data (e.g., field blanks, duplicates, and laboratory blanks)
46 and a technical review by a project scientist familiar with the hydrogeology of the site. The technical
47 review might include comparison of recent data to historical trends and comparison of related

1 constituents. Suspect data will be investigated through the data review process in accordance with
2 established procedures and will be flagged in the database.

3 **D.5.4.3.3 Reporting**

4 Groundwater chemistry and water level data will be reviewed after each sampling event and will be
5 available in the HEIS database. The results of the statistical evaluation and associated information, when
6 these evaluations are performed, will be submitted to Ecology annually in the Hanford Site groundwater
7 monitoring annual report.

8 If statistically, significant evidence of contamination is determined (after waste has been introduced to the
9 facility and after the confirmation resampling evaluation process) for one or more of the indicator
10 parameters at any monitoring well at the compliance point, and if the owner or operator decides not to
11 make a false positive claim, the following will be performed.

- 12 • Notify Ecology in writing within 7 days of the finding indicating which chemical parameters or
13 dangerous waste constituents have shown statistically significant evidence of contamination.
- 14 • Determine whether dangerous constituents are present and, if so, in what concentration.
- 15 • The owner or operator might re-sample within 1 month and repeat the analysis for those compounds
16 detected in the above (i.e., second bullet). The resample data will be compared with the trigger value.
- 17 • Submit an application for a permit modification, if necessary, to establish a compliance monitoring
18 program to Ecology in 90 days or within the time agreed to in writing by Ecology.

19 The dangerous constituents detected, either in the initial analysis or in the second confirmation analysis,
20 will form the basis for compliance monitoring.

21 In case of a false positive claim [as allowed by [WAC 173-303-645\(9\)\(g\)\(vi\)](#)], the following will apply.

- 22 • Notify Ecology in writing within 7 days of the finding (i.e., exceedance) and indicate that a false
23 positive claim will be made.
- 24 • Submit a report to Ecology within 90 days or within the time agreed to in writing by Ecology. This
25 report should demonstrate that a source other than the regulated unit caused the contamination or that
26 the contamination resulted from an error in sampling, analysis, evaluation, or natural variation in
27 groundwater chemistry.
- 28 • Submit an application for a permit modification, if necessary, to make any appropriate changes to the
29 detection monitoring program within 90 days or within the time agreed to in writing by Ecology.
- 30 • Continue to monitor in accordance with the detection monitoring program.
- 31 • Submit an application for a permit modification, if the detection monitoring program is determined to
32 no longer satisfy the requirements of [WAC 173-303-645\(9\)](#), to make any appropriate changes to the
33 program within 90 days or within the time agreed to in writing by Ecology.

34 **D.5.4.4 Chain of Custody**

35 The procedures used for chain-of-custody control of samples are documented in existing manuals. The
36 procedure requires that each transfer of custody shall be documented by the signatures of the custodian
37 relinquishing the samples and the custodian receiving the samples, as well as the time and date of transfer.
38 The laboratory custodian will sign and date the chain-of-custody form upon receipt of the samples at the
39 laboratory.

40 **D.5.4.5 Additional Requirements for Compliance Point Monitoring**

41 This section describes sampling frequency and determination of groundwater quality for the samples from
42 the groundwater monitoring network. Compliance data will be compared to baseline data collected from
43 the upgradient wells and a determination of impacts to groundwater will be made using the proposed
44 ANOVA method (explained in Section D.5.4.7.1).

1 **D.5.4.5.1 Sampling Frequency**

2 Under final status regulations, the default sampling procedure states that a sequence of at least four
3 samples from each well (background and compliance wells) must be collected at least semiannually
4 during detection monitoring at an interval that ensures, to the greatest extent technically feasible, that an
5 independent sample is obtained [[40 CFR 264.97\(g\)\(1\) and \(2\)](#), [WAC 173-303-645\(8\)\(g\)\(i\) and \(ii\)](#), and
6 [WAC 173-303-645\(9\)\(d\)](#)].

7 The default sampling procedures are adopted for the IDF Active life as follows: four independent
8 samples from each groundwater monitoring well will be sampled for the indicator parameters (Table D.2)
9 semiannually during the active life of the regulated unit (including the closure period), one per month for
10 four consecutive months followed by two months of non-sampling. The mean of the measurements from
11 the downgradient wells will be compared semiannually to the mean of the distribution of the background
12 data using ANOVA.

13 Semi-annual monitoring has been accomplished at the IDF since January 2007 with the collection of four
14 independent samples each semiannual period. During the Pre-Active life, sampling will continue at the
15 IDF with the collection of one sample each year to maintain the baseline. During Active life, sampling
16 will revert to four independent samples collected each semiannual period described above.

17 **D.5.4.5.2 Compliance Point Groundwater Quality Values**

18 The groundwater quality data collected from the groundwater monitoring wells will be compared to the
19 mean of the background data from upgradient wells for each constituent by ANOVA. If the mean is
20 calculated from transformed baseline data (logarithmic transformation or nonparametric approach), then
21 the monitoring data will be transformed accordingly; otherwise, the original monitoring data will be used
22 in the comparisons.

23 During detection monitoring, data verification will be applied in case of an initial exceedance. For
24 ANOVA test, if the test of hypothesis of equal means for all wells fails, *post hoc* comparisons are needed
25 to determine which compliance well(s) is (are) contaminated. This will be done by comparing
26 concentration differences (called contrasts in the ANOVA and multiple comparison framework) between
27 each compliance well with the background wells (EPA/530-SW-89-026). If the contaminated compliance
28 well(s) is (are) determined by *post hoc* comparisons, verification sampling will be implemented for the
29 constituent(s) in question. Verification sampling is needed to determine if the exceedance is an artifact
30 caused by an error in sampling, analysis, or statistical evaluation or an actual variation in groundwater
31 chemistry. A collection of at least four measurements from the re-sampled compliance well(s) is required
32 to perform ANOVA test on comparison with the mean of the background data (EPA/530-R-93-003).
33 Adequate time should elapse to ensure statistical independence between the original measurements and
34 the re-sample measurements, which is assured by the sampling frequency proposed in Section D.5.4.5.1.

35 The existing nitrate plume beneath the IDF site is described in Section D.4.1. Nitrate is not included in
36 Addendum A, IDF Part A Form and, therefore, is not a constituent of concern for the IDF. Existing
37 groundwater conditions will be monitored by the indicator parameters and supplemental constituents as
38 described in Section D.5.1. Specific conductance will respond to nitrate so that any changes in the nitrate
39 concentration will be reflected by changes in the indicator parameter specific conductance.

40 Anion analysis is one of the supplemental constituents to be monitored at the IDF site. Anion analysis
41 will determine the nitrate concentration. Therefore, through comparison of regression lines of specific
42 conductance and nitrate (Zar, 1999) and/or contaminant source analysis ([Gibbons, 1994](#)); it can be
43 determined whether any change in specific conductance is due to a change in nitrate. If a change in
44 specific conductance is due to a change in nitrate, then that specific conductance change is not attributed
45 to the IDF. If, however, a statistically significant change in specific conductance is not attributable to
46 nitrate, verification sampling will occur as described above.

1 **D.5.4.6 Annual Determination**

2 Groundwater flow rate and flow direction at the IDF site will be determined annually for the uppermost
3 aquifer. Flow rate will be determined by calculation using the groundwater gradient, and the Darcy flow
4 equation, $v_h = K_h i_h / n_e$, where v_h is the horizontal groundwater velocity, K_h is the horizontal hydraulic
5 conductivity, i_h is the horizontal hydraulic gradient, and n_e is the effective porosity. Effective porosities
6 used at Hanford Site RCRA regulated units are on the order of 0.1 to 0.3 (PNNL-14187); effective
7 porosity might be determined specifically for the IDF from hydrologic tests.

8 Hydraulic gradients will be determined from measurements of water levels.

9 **D.5.4.7 Statistical Determination**

10 This section describes the method of statistical evaluation and the statistical procedures to indicate
11 whether dangerous waste or dangerous waste constituents from the IDF might have entered the
12 groundwater in the uppermost aquifer. These evaluations will be made as soon as practicable after
13 validation of the full data set from each sampling event.

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

17 The goal of a RCRA final status detection-monitoring program [[WAC 173-303-645\(9\)](#)] is to monitor for
18 indicator parameters that provide a reliable indication of the presence of dangerous constituents in
19 groundwater in the uppermost aquifer beneath the site. This is accomplished by testing for statistically
20 significant changes in concentrations of indicators in downgradient wells relative to baseline values. The
21 default statistical method ANOVA is proposed for the detection monitoring program of the IDF. The
22 proposed statistical method is consistent with EPA/530-R-09-007, EPA/530-SW-89-026,
23 EPA/530-R-93-003, and [WAC 173-303-645](#).

24 The number of tested constituents will be limited to the indicators to maintain a sufficiently low false-
25 positive rate (EPA/530-R-93-003, pp. 62; Gibbons 1994, pp. 16). Verification sampling is an integral
26 part of the statistical design to lower the overall false-positive rate and determine whether the difference
27 between background and compliance-point data is an artifact caused by an error in sampling, analysis, or
28 statistical evaluation (Section D.5.4.5.2).

29 **D.5.4.7.1 Statistical Procedure**

30 In accordance with [WAC 173-303-645\(8\)\(h\)](#), acceptable statistical methodology includes analysis of
31 variance (ANOVA), tolerance intervals, prediction intervals, control charts, test of proportions, or other
32 statistical methods approved by Ecology. The type of monitoring, the nature of the data, the proportions
33 of non-detects, and spatial and temporal variations are some of the important factors to be considered in
34 the selection of appropriate statistical methods. The EPA default method ANOVA will be implemented
35 for the IDF site to compare the differences of means of the measurements from upgradient and
36 downgradient wells. The detailed discussions of the ANOVA test can be found in EPA/530-SW-89-026
37 and statistical textbooks, and can be executed using commercial statistical software such as SAS or
38 SYSTAT. Under [WAC 173-303-645\(8\)\(i\)\(ii\)](#), the proposed statistical method must comply with the
39 performance standard, that is, for a multiple comparisons procedure the Type I error level must be no less
40 than 0.05, and maintained at the level of no less than 0.01 for individual well comparisons. By definition,
41 Type I error is the false rejection rate of the null hypothesis (H_0) of the statistical test. In detection or
42 compliance monitoring, the statistical test is defined as H_0 : no release, i.e., the means of the distributions
43 from upgradient and downgradient wells are the same, and the alternative (H_a) evidence of release, e.g.,
44 "clean until proven contaminated" (EPA/530-R-93-003). Therefore, the proposed statistical method must
45 comply with the requirement of maintaining Type I error, which equates false positive rate in the stage of
46 detection monitoring at approximate 5% level. As described in EPA/530-SW-89-026, ANOVA
47 procedures have the advantages of combining multiple downgradient into a single statistical test, thus

1 enabling the network-wide false positive rate for any single constituent (not multiple constituents) to be
2 kept at 5%, and maintain reasonable power for detecting contamination.

3 The details of the ANOVA procedures are described as follows (EPA/530-SW-89-026):

- 4 • First, check the proportion of non-detects of the measurements from the upgradient and downgradient
5 wells. When the proportion of non-detects is less than 15%, the non-detects will be reported as one-
6 half the minimum detection limit or practical quantitation limit, and proceed with parametric
7 ANOVA analysis. When the proportion of non-detects is greater than 15%, non-parametric ANOVA
8 analysis will be used for comparing the means of downgradient and upgradient wells.
- 9 • Evaluate the distributions of the measurements from the upgradient and downgradient wells. The
10 assumptions with parametric ANOVA test are the residuals are normally distributed with equal
11 variance. The normality of the distribution the residuals can be checked using coefficient of
12 variation, plotting the data on probability plot, and/or Shapiro-Wilk's test (EPA/530-SW-89-026;
13 [Gibbons, 1994](#)). The assumption of normality usually can be met by log-transforming the data or by
14 other Box-Cox transformations. When the assumptions of normality and lognormality cannot be
15 justified, the non-parametric ANOVA method will be used for the IDF. Bartlett's test can be used in
16 checking equality, or homogeneity, of variances.
- 17 • The parametric ANOVA procedures include:
 - 18 • Assume a monitoring network with k wells, and total number of observations N. First, compute
19 well total, well mean, and well residuals (observations subtracted by well mean) for each well and
20 grand total and mean of all observations (all wells). The well residuals are used to check the
21 assumption of normality.
 - 22 • Compute the sum of squares of difference between well means and the grand mean, SS_{wells} that
23 is a measure of the variability between wells with (k-1) degrees of freedom.
 - 24 • Compute the total sum of squares of differences between all observations and the grand mean,
25 SS_{total} , which is a measure of the variability in all observations with (N-1) degrees of freedom.
 - 26 • Compute the sum of squares of differences of observations within wells from the well means,
27 SS_{error} , which is a measure of the variability within wells with (N-k) degrees of freedom
28 calculated by the following subtraction:
29
$$SS_{error} = SS_{total} - SS_{wells}$$
 - 30 • Test the hypothesis of equal means for all k wells by computing F value with the means squares
31 of differences:
32
$$F = MS_{wells} / MS_{error}$$

33 Where the means of squares are the sums of squares divided by the associated degrees of
34 freedom, that is, $MS_{wells} = SS_{wells} / (k-1)$, and $MS_{error} = SS_{error} / (N-k)$. Compare the F value to the
35 tabulated F statistics with (k-1) and (N-k) degree of freedom at the 5% significance level
36 (EPA/530-SW 89-026, Appendix B, Table 2). If the calculated F value exceeds the tabulated F
37 statistics, the null hypothesis of equal well means is rejected. Proceed with test of contrasts in the
38 next step. Otherwise, the hypothesis of equal means is accepted that there is no significant
39 difference between the concentrations at k wells (upgradient and downgradient wells), that is, no
40 evidence of contamination.
 - 41 • If the hypothesis of equal well means is rejected, contrasts (concentration differences between a
42 compliance well and background wells) will be tested for each compliance well to determine
43 which compliance well(s) is (are) contaminated. Bonferroni t-statistics will be computed to
44 determine if the significant F value is due to difference between background and compliance
45 wells. Assume that of the k wells, k_b are background (upgradient) wells, and k_c are compliance
46 (downgradient) wells (i.e., $k_b + k_c = k$). Each of the k_c compliance wells is compared to the mean
47 of the background wells as the following steps:
 - 48 • Compute the mean m_b from the k_b background wells with a total of n_b samples.

- Compute the difference D_i between the mean from the i^{th} compliance well and the mean from the background wells.

- Compute the standard error of the difference from the i^{th} compliance well with n_i observations as:

$$SE_i = [MS_{\text{error}} (1/n_b + 1/n_i)]^{1/2}$$

Where MS_{error} is computed previously as the measure of variability within wells.

- Obtain the t-statistics from Bonferroni's t-table (EPA/530-SW-89-026, Appendix B, Table 3) with a significance level of $(\alpha=0.05/k_c)$ but no less than 0.01 (for individual comparison) and $(N-k)$ degrees of freedom. The critical value for the i^{th} compliance well is defined as $C_i = SE_i \times t$.
- If the difference D_i exceeds the critical value C_i , conclude that the mean of the i^{th} compliance well is significantly higher than the mean of the background wells. Otherwise, conclude that the well is not contaminated.
- The one-way non-parametric ANOVA tests the null hypothesis that the data from each well come from the same continuous distribution and hence have the same median. The procedures, called the Kruskal-Wallis test, include the following steps:
 - Assume the monitoring network as defined previously with a total of N observations from k wells (k_b background wells and k_c compliance wells). Rank all N observations from least (1) to greatest (N). Let the background wells be group 1, and denote the compliance wells as group 2 to (k_c+1) . (One group per compliance well).
 - Compute the sum (R_i) and the average (m_i) of the ranks of the n_i observations in the i th group.
 - Compute the Kruskal-Wallis statistics (H) as

$$H = \left[\frac{12}{N(N+1)} \sum_{i=1}^{k_c+1} \frac{R_i^2}{n_i} \right] - 3(N+1)$$

- Compare the calculated H value to the tabulated chi-squared value with k_c degrees of freedom (EPA/530-SW-89-026, Appendix B, Table 1). The null hypothesis of equal medians is rejected when the calculated H value exceeds the tabulated critical value.
- When the null hypothesis of equal medians is rejected, compute the critical difference C_i for each compliance well to the background data (group 1 with n_b observations):

$$C_i = Z_{(0.05/k_c)} \left[\frac{N(N+1)}{12} \times \left(\frac{1}{n_b} + \frac{1}{n_i} \right) \right]^{1/2}$$

Where $Z_{(0.05/k_c)}$ is the upper $(0.05/k_c)$ percentile from the standard normal distribution (EPA 530-SW-89-026, Appendix B, Table 4). If there are more than five compliance wells ($k_c > 5$), use $Z_{0.01}$, the upper one-percentile from the standard normal distribution ($Z_{0.01}=2.32$) for individual comparison ([WAC 173-303-645](#)(8)(i)(ii)).

- Compute the difference ($D_i = m_i - m_1$) of average rank m_i ($i=2$ to k_c+1) for each compliance well to the background (m_1). Compare the difference D_i to the critical value C_i for each compliance well. If D_i exceeds C_i , conclude that the median of the i^{th} compliance well is significantly higher than the background median.
- As monitoring continues, the background data will be updated periodically (e.g., every year or two) to incorporate the new data from upgradient wells. This updating process will continue for the life of the monitoring program. Prior to updating older background data with more recent results, a two-sample t-test will be run to compare the older concentration levels with the concentrations of the proposed update samples. If the t-test does not show a significant difference at the 5 percent significant level, proceed to re-estimate the baseline parameters by including the more recent data. If the t-test does show a significant difference, the newer data will not be included as background unless

1 some specific factors can be, identified explaining why background levels at the IDF site have
2 naturally changed (EPA-530-R93-003).

3 Formal testing for outliers will be done when an observation of the background data seems inconsistently
4 high (by orders of magnitude) compared to the rest of the data set in order to avoid the artificial increase
5 of the mean of the background data and a corresponding increase of the false negative rate. Statistical
6 methods such as the Grubbs' method (Grubbs, 1969), the box-and-whisker plot (Ostle and Malone, 1988),
7 EPA Guidance (EPA-530-SW-89-026, pp. 11-14) and/or American Society for Testing and Materials
8 guidance (ASTM 1998) will be used for testing outliers. The outliers must be checked to determine if the
9 measurements are in error and need to be corrected or excluded from calculating the background mean. If
10 no specific error is found, the measurements must be retained in the data.

11 A statistically significant exceedance over background (baseline) levels only indicates that the new
12 measurement in a particular monitoring well for a particular constituent is inconsistent with chance
13 expectations based on the available sample of background (baseline) measurements. Any statistical result
14 must be supported by other information to determine if a waste disposal facility has impacted
15 groundwater (ASTM 1998).

16 **D.5.4.7.2 Results**

17 Sampling and analysis results are reviewed at least semiannually (i.e., after each sampling event) and are
18 available in HEIS. The DOE will submit results of statistical evaluations, when these evaluations are
19 performed, to Ecology annually in the Hanford Site groundwater monitoring annual report.

20 **D.5.5 Compliance Monitoring Program**

21 A compliance monitoring program that satisfies requirements set forth in [WAC 173-303-645](#)(10) will be
22 established for the IDF if detection-level monitoring reveals statistically significant evidence of dangerous
23 waste contamination from sources within the regulated unit. If compliance monitoring is required, DOE
24 will submit a revised monitoring plan to Ecology specifying dangerous constituents to be monitored,
25 sampling and analysis protocols, statistical evaluation methods, etc. In the compliance monitoring
26 program, the dangerous constituents or parameters will be compared to concentration limits specified in
27 the facility permit as discussed in [WAC 173-303-645](#)(5) during the compliance period.

28 The RCRA regulations [[WAC 173-303-645](#)(9)(g)] state that if a statistical exceedance occurs in a
29 downgradient well, the entire network immediately must be resampled and analyzed for the constituents
30 in Appendix IX of [40 CFR 264](#). This sampling would be conducted in parallel with a required permit
31 modification. Appendix IX is an extensive list including a wide variety of volatile and semivolatile
32 organic compounds and trace metals. It is prudent to narrow the analyte list to the specific exceedance
33 event; e.g., if the exceeding contaminant is total organic halides, the project would analyze for the
34 halogenated hydrocarbons most likely to be present in the area. Results of the resampling will form the
35 basis for returning to detection monitoring or designing a compliance monitoring program.

36 **D.5.6 Corrective Action Program**

37 If, at a point of compliance (a well), dangerous constituents of concern are measured in the groundwater
38 at concentrations that exceed the applicable groundwater concentration limit, Ecology must be notified in
39 7 days, and an application to modify the permit to include a corrective action plan must be sent to
40 Ecology within 90 days or within the time agreed to by Ecology. A description of the groundwater
41 monitoring plan, including all additional corrective actions that are appropriate for a corrective action
42 program will be prepared and submitted to Ecology when the need for corrective action first is identified.

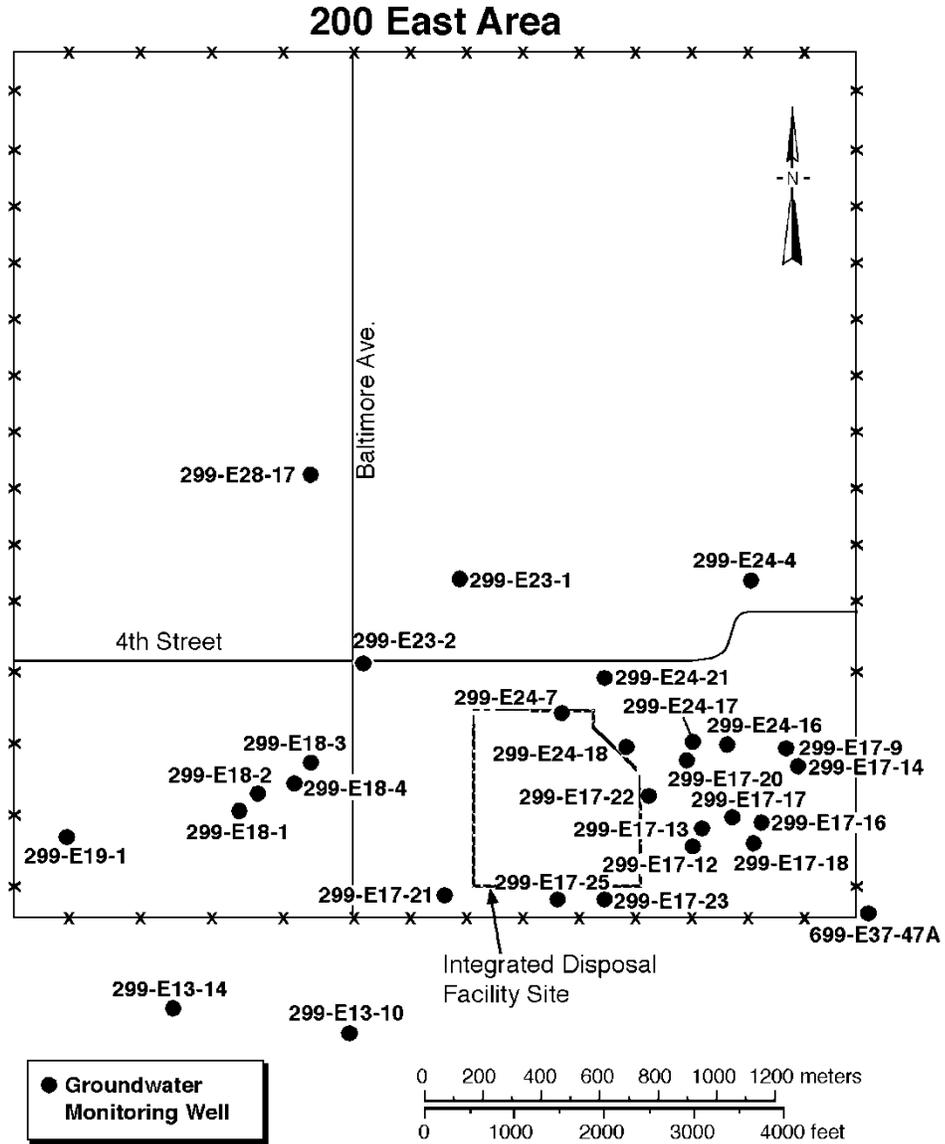
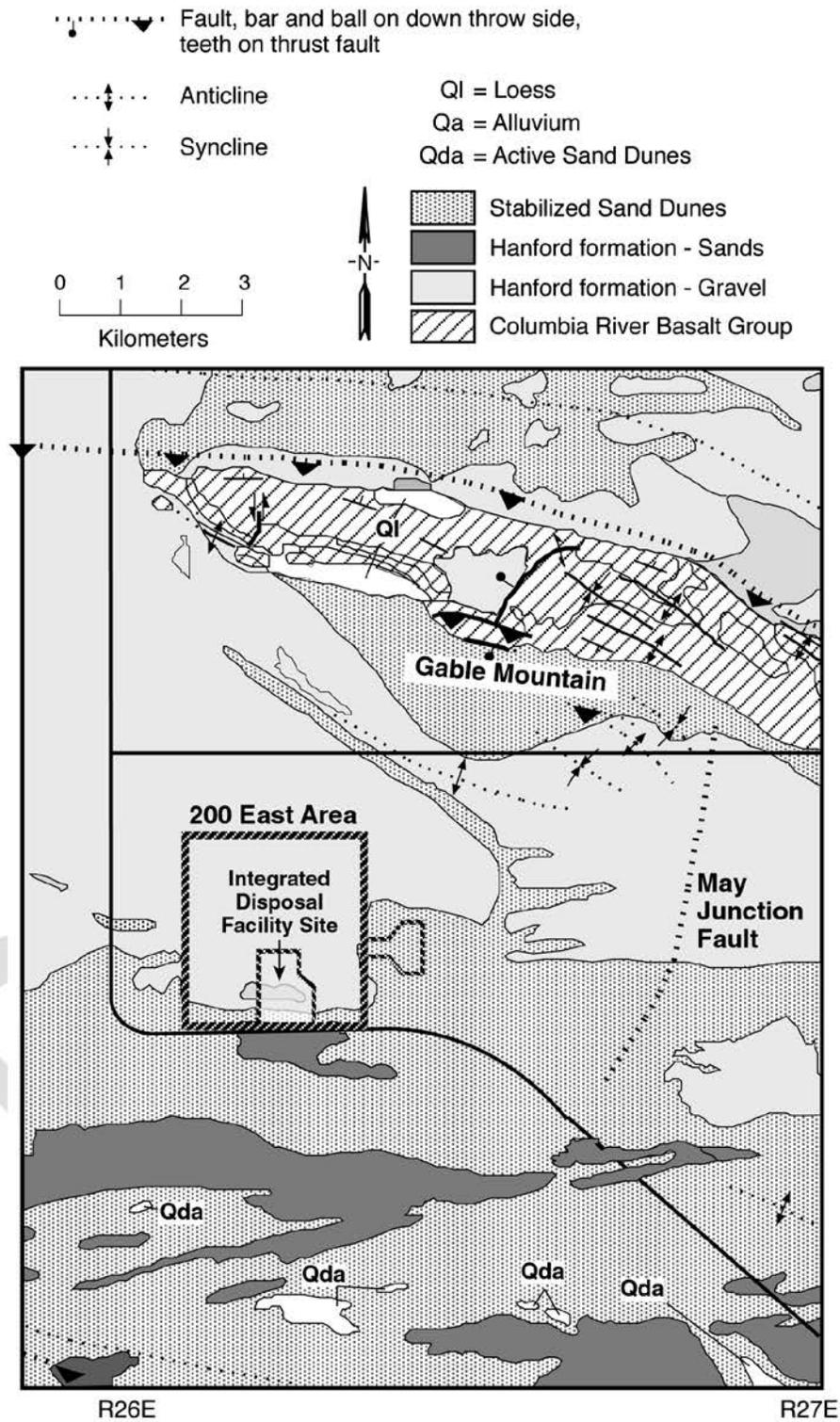


Figure D.1. Location of the IDF and Nearby Boreholes

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1 Figure D.2. Geologic Map of the 200 East and 200 West Areas and Vicinity

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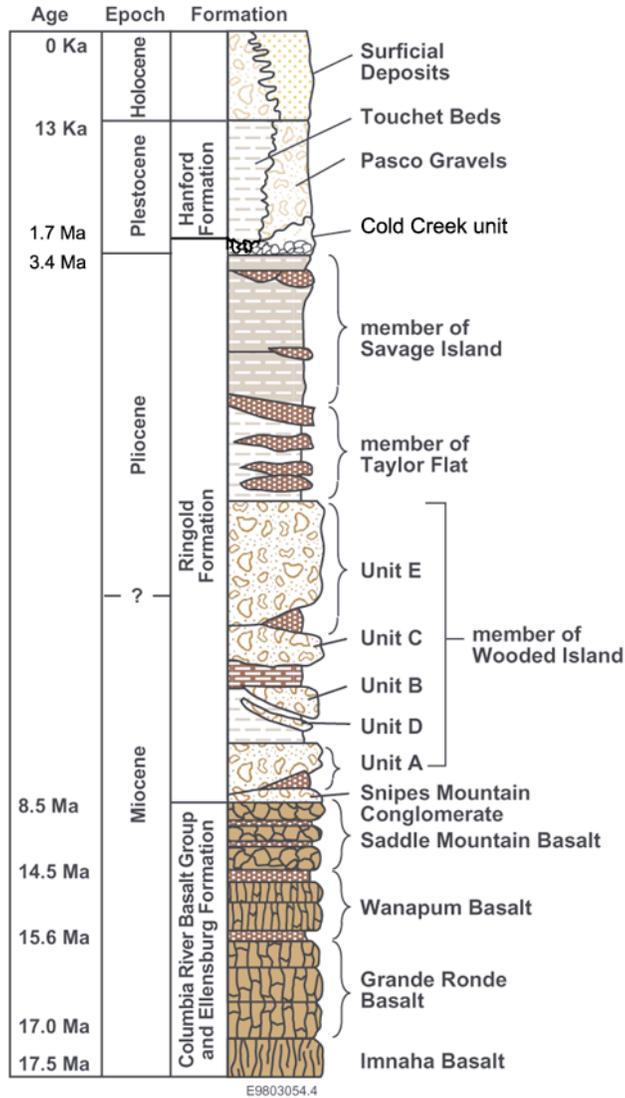


Figure D.3. Stratigraphy of the Hanford Site

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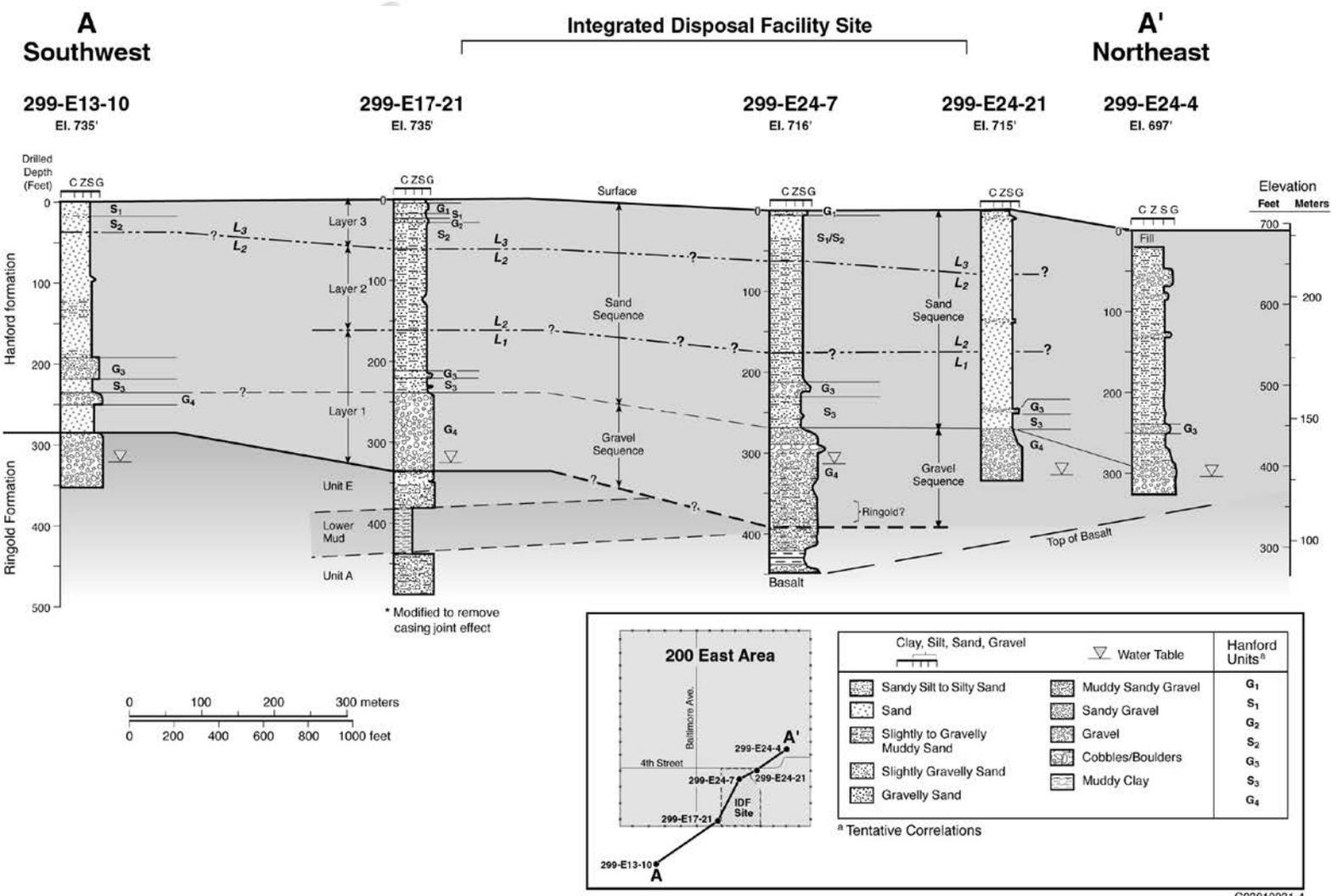


Figure D.4. Cross-Section through the IDF Site

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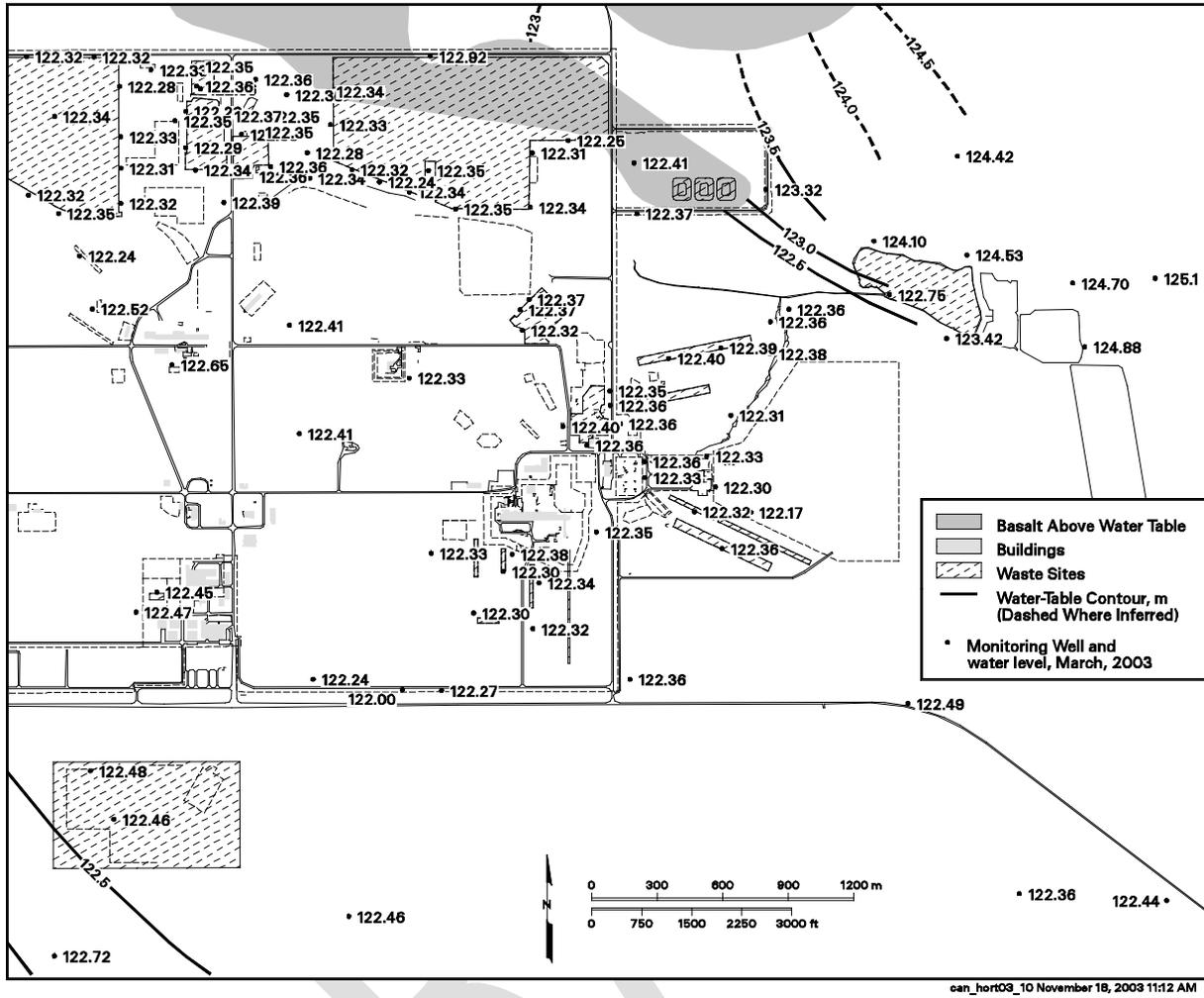


Figure D.5. Water Table Map for the Hanford Site 200 East Area

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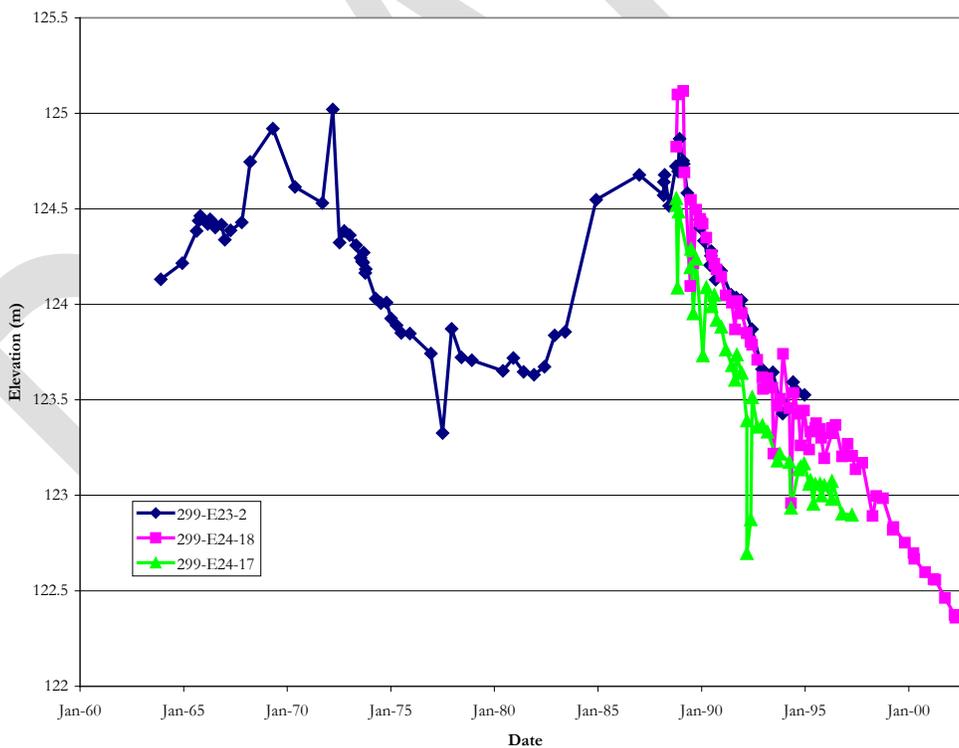
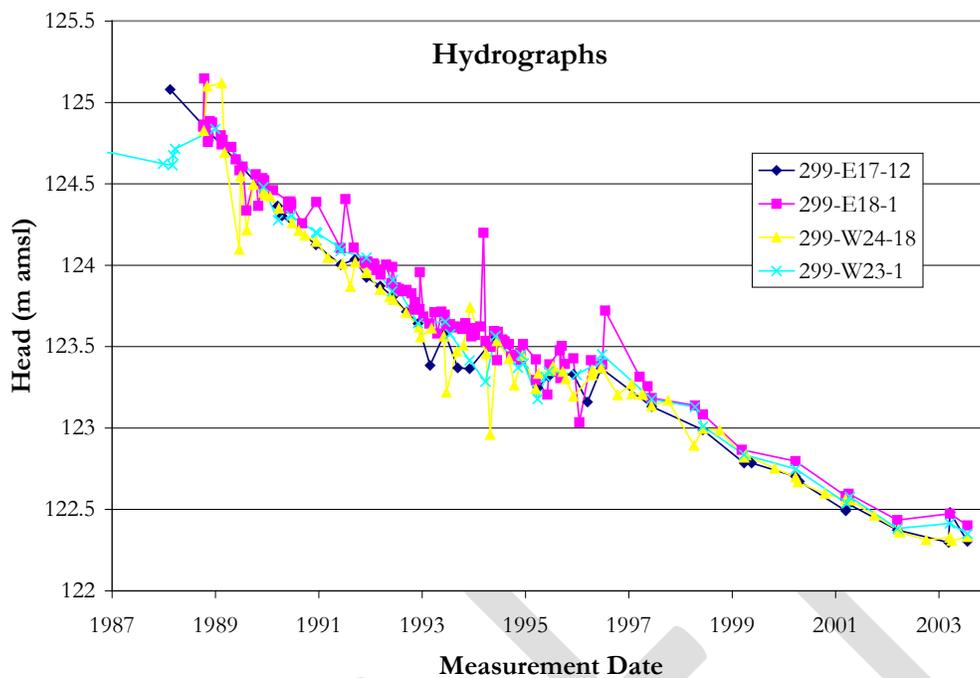
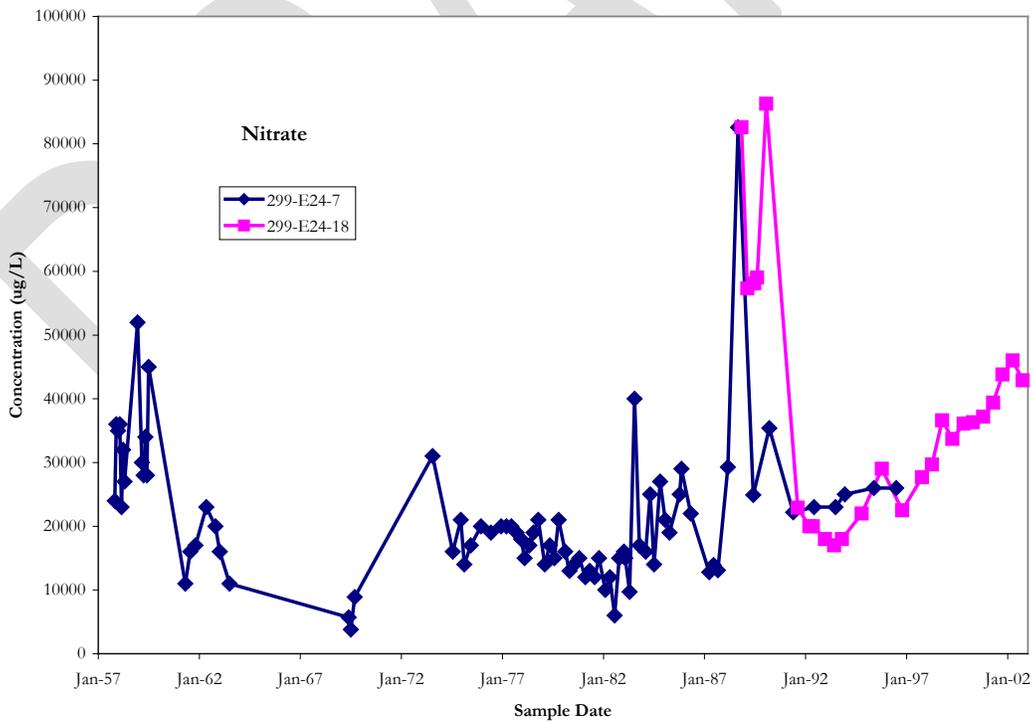
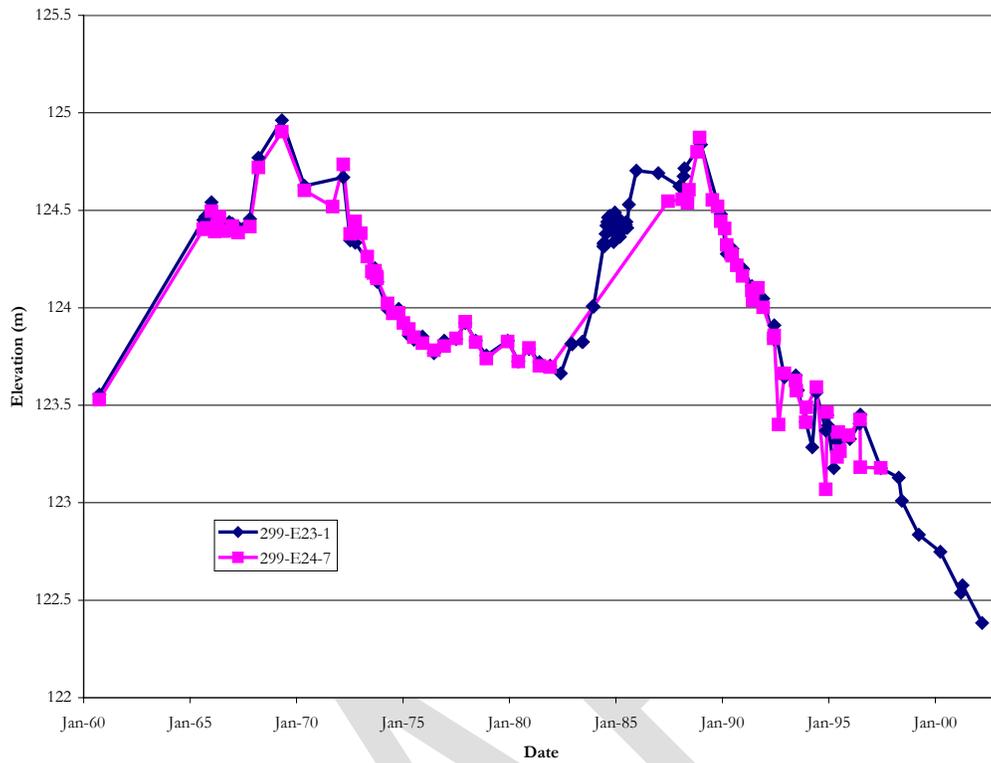
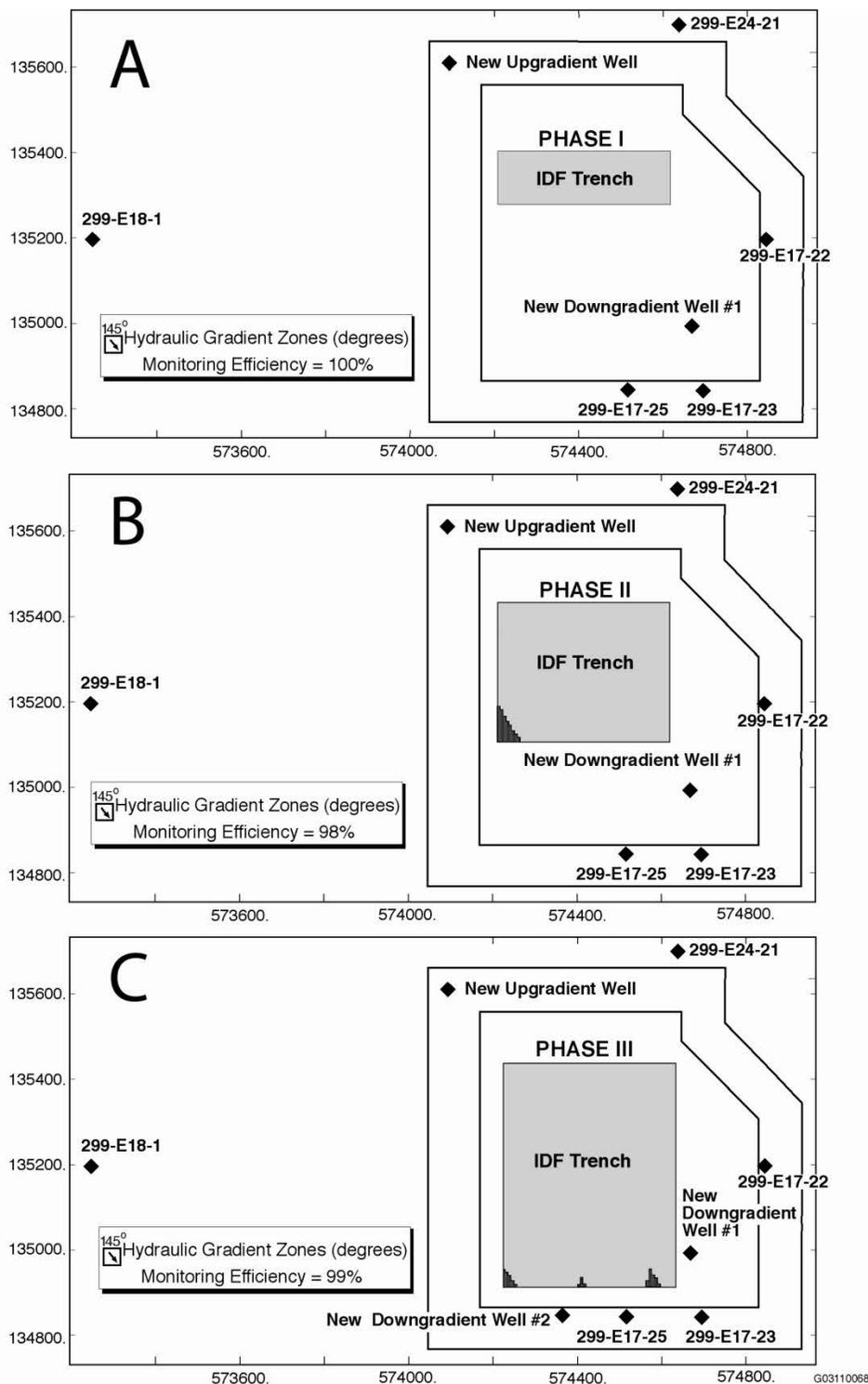


Figure D.6. Hydrographs for Wells near the IDF Site

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1 **Figure D.7. Concentration versus Time for Nitrate in Wells 299-E24-7 and 299-**
2 **E24-18**
3



1 **Figure D.8. Sequence for Installation of Downgradient Monitoring Wells at the**
 2 **IDF**
 3 Areas in black are areas from which leaks will not be detected with the array of monitoring wells shown.
 4 A. Area used for disposal and associated monitoring wells for construction phase I;
 5 B. Area used for disposal and associated monitoring wells for construction phase II;
 6 C. Area used for disposal and associated monitoring wells for construction phase III.

Table D.1. Water Levels in Groundwater Wells in the Vicinity of the IDF Site

Well	Measure date	DTW m ^a	WT elev m ^b	Ref elev m ^c
299-E13-10	03/14/02	101.7	122.5	226.31
299-E17-12	03/14/02	100.0	121.1	221.09
299-E17-13	04/12/01	97.7	122.6	220.34
299-E17-17	04/12/99	97.8	122.8	220.54
299-E17-18	10/03/02	98.5	122.3	220.76
299-E17-20	04/09/97	97.1	123.2	220.33
299-E17-21	04/23/98	100.4	122.7	224.26
299-E17-22	05/20/02	98.1	122.5	220.59
299-E17-23	05/20/02	101.6	122.2	223.84
299-E17-25	05/21/02	98.3	126.7	225.03
299-E18-1	03/14/02	98.2	122.4	220.65
299-E18-3	06/27/96	97.8	123.4	221.20
299-E18-4	06/27/96	97.7	123.4	221.05
299-E19-1	03/22/88	100.4	124.9	225.26
299-E23-1	03/14/02	96.0	122.4	218.39
299-E23-2	12/20/94	97.2	123.5	220.77
299-E24-4	08/10/98	90.6	122.9	213.47
299-E24-7	06/11/97	96.2	123.2	219.34
299-E24-16	10/04/02	97.7	122.3	220.02
299-E24-17	04/07/97	97.36	122.9	220.16
299-E24-18	10/02/02	98.0	122.3	220.35
299-E24-21	03/22/01	95.4	122.6	217.85

^a DTW = depth to water

^b WT elev = elevation of water table (meters above mean sea level)

^c Ref elev = reference elevation (meters above mean sea level, North American Vertical Datum 88 reference), generally top of well casing.

Table D.2. Monitored Constituents for the IDF

Indicator parameters	Supplemental constituents
Chromium (filtered)	Alkalinity
Specific conductance (field)	Anions
Total organic carbon	ICP metals
Total organic halides	Turbidity (field)
pH (field)	

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Table D.3. Expected Behavior of Selected Regulated Constituents/Materials for the IDF

Constituent/material	Expected charged state	Expected mobility ¹ (K_d)	Comments
Organics			
Acetonitrile	N/A	High (0.16)	Miscible with water (Howard Volume IV, 1993)
Carbon tetrachloride	N/A	High (0.60); 0.29 (DOE/RL-93-99)	Moderately soluble in water (805 mg/L) (Howard, Volume II, 1990)
Creosote ²	N/A	High (0.03 to 0.06) ³	Relatively low solubility in water. Naphthalene solubility in water (31.7 mg/L [Howard, Volume 1, 1989]). Anthracene solubility in water (0.03 to 0.5 mg/L [Mackay et al, Volume II, 1992])
Dioxane	N/A	High (0.01)	Miscible with water (Howard, Volume II, 1990)
Ethylene glycol	N/A	Unknown ⁴	Miscible with water (Howard, Volume II, 1990)
Naphthalene		Moderate (4 to 10); 1.4 (DOE/RL-93-99)	Sparingly soluble in water (31.7 mg/L [Howard, Volume I, 1989])
Polychlorinated biphenyls	N/A	Low (20 to 100); 440 to 2,300 (DOE/RL-93-99)	Low solubility in water. 0.01 to 1 mg/L as Alocors (Mackay et al. 1992); 0.27 to 1.45 mg/L (WHC-SD-EN-TI-201)
Tetrachloroethylene	N/A	High (2.1); 0.22 (DOE/RL-93-99)	Moderately soluble in water (1,503 mg/L) (Howard, Volume II, 1990)
Toluene	N/A	High (0.37 to 1.8); 0.18 (DOE/RL-93-99)	Moderately soluble in water (535 mg/L) (Howard, Volume II, 1990)
Trichloroethylene	N/A	High (1.0); 0.1 to 1.0 (WHC-SC-EN-TI-201); 0.11 (DOE/RL-93-99)	Moderately soluble in water (1,100 mg/L) (Howard, Volume II, 1990)
Vinyl chloride	N/A	High (0.004); 0.056 (DOE/RL-93-99)	Moderately soluble in water (2,763 mg/L) (Howard, Volume I, 1989)
Inorganics			
Antimony	Cation (Sb^{+3})	Moderate (0 to 40, best estimate: 20 [DOE/RL-93-99])	Moderately soluble (best estimate): 1,000 mg/L (DOE/RL-93-99)
Arsenic	Anion (AsO_4^{-5})	High, 0 (DOE/RL-93-99)	Moderately soluble (best estimate): 1,000 mg/L (DOE/RL-93-99)
Barium	Cation (Ba^{+2})	Moderate, 20 to 200, best estimate: 50 (DOE/RL-93-99)	Low solubility (best estimate): 1 mg/L (DOE/RL-93-99)
Beryllium	Cation (Be^{+2})	Moderate, 15 to 200, best estimate: 20 (DOE/RL-93-99)	Solubility unknown. Best estimate: 1 mg/L
Cadmium	Cation (Cd^{+2})	Moderate, 15 to 30, best estimate: 23 (DOE/RL-93-99)	Sparingly soluble. Best estimate: 25 mg/L (DOE/RL-93-99)
Chromium	Anion (CrO_4^{-2})	High (0.0 to 1.02 [PNNL-13895]; 0.001 (WHC-SC-EN-TI-201)	Low solubility: 0.5 to 10 mg/L (WHC-SC-EN-TI-201)
Lead	Cation (Pb^{+2})	Low (1,330 to 469,000 [PNNL-13895])	Low solubility: 287 μ g/L in Hanford Site groundwater (PNL-9791)
Mercury	Cation (Hg^{+2})	Moderate, best estimate: 30 (DOE/RL-93-99)	Solubility unknown. Best estimate: 1 mg/L (DOE/RL-93-99)

Table D.3. Expected Behavior of Selected Regulated Constituents/Materials for the IDF

Constituent/material	Expected charged state	Expected mobility ¹ (K_d)	Comments
Nickel	Cation (Ni^{+2}) $Ni(OH)_2$ $NiCO_3$	Low (48 to 337 [PNNL-13895])	Low solubility: 1.9 mg/L in Hanford Site groundwater (PNL-9791)
Selenium	Anion (SeO_4^{-6})	High (3 to 10 [PNNL-13895]) (3 to 8 PNNL-11966)	Moderately soluble. Best estimate: 1,000 mg/L (DOE/RL-93-99)
Silver	Cation (Ag^+)	Moderate, 20 to 30, best estimate: 25 (DOE/RL-93-99)	Sparingly soluble (best estimate): 25 mg/L (DOE/RL-93-99).

1 N/A = Not applicable

2 ¹ Unless cited in the column, K_d (partition coefficient) values were calculated from K_{oc} (normalized sorption
3 coefficient) values obtained from either the Handbook of Environmental Fate and Exposure Data for Organic
4 Chemicals series (Volumes I-IV) (P.H. Howard, ed) or the Illustrated Handbook of Physical-Chemical Properties
5 and Environmental Fate for Organic Chemicals series [Mackay et al. 1992a, 1992b]. For all organics (except carbon
6 tetrachloride), the calculation assumes an organic carbon content for Hanford Site soil of 1.0%. The value of
7 organic carbon assumed is conservative recognizing that the organic carbon content of most Hanford Site soil falls
8 considerably below this value. However, applying this level of conservatism also recognizes that mineral-driven
9 sorption likely plays a role in organic constituent mobility for Hanford Site soils with organic carbon content at or
10 below 0.1% ([PNNL-13560](#)). A calculation of a K_d value using acetonitrile as an example is as follows. The
11 literature estimated value of K_{oc} for acetonitrile is 16 (Howard 1993).

12 $K_d = f_{oc} \times K_{oc}$ where f_{oc} = the mass fraction of organic carbon in the soil.

13 K_d (acetonitrile) = 0.01 X 16 = 0.16.

14 ² Creosote is a coal tar distillate containing high quantities of naphthalene and anthracene.

15 ³ Because creosote is predominately a mixture of naphthalene and anthracene (footnote 2), assumed K_{oc} values for
16 naphthalene (Howard 1989) and anthracene (Mackay et al., Volume II) in calculating a K_d range for creosote.

17 ⁴ This constituent has a low octanol/water partition coefficient indicating that its adsorption to soil would be low
18 (Howard, Volume II, 1990)

19

Table D.4. Analytical Methods and Method Detection Limits for Regulated Constituents and Indicator Parameters

Class of Compounds	Analytical Methods ¹	Method Detection Limit ³ (ug/L)
Metals	<u>Trace Metals:</u> SW 846, Method 6010 or SW 846, Method 6020 or EPA/600/R-94/111, Method 200.8	0.18 - 44.8 ² 0.042-8.5 .05-50
	<u>Arsenic:</u> SW 846, Method 6010 or SW 846, Method 6020 or EPA/600/R-94/111, Method 200.8	50 2 0.40
	<u>Cadmium:</u> SW 846, Method 6010 or SW 846, Method 6020 or EPA/600/R-94/111, Method 200.8	4 0.86-2.3 0.10
	<u>Chromium:</u> SW 846, Method 6010 or SW 846, Method 6020 or EPA/600/R-94/111, Method 200.8	4 1.9-3.1 0.5
	<u>Lead:</u> SW 846, Method 6010 or SW 846, Method 6020 or EPA/600/R-94/111, Method 200.8	27 0.49 0.10
	<u>Mercury:</u> SW 846, Method 6020 or SW 846 Method 7470 or EPA/600/R-94/111, Method 200.8	.093 0.1 0.05
	<u>Selenium:</u> SW 846, Method 6010 or SW 846, Method 6020 or EPA/600/R-94/111, Method 200.8	30 1 0.30
	<u>Thallium:</u> SW 846, Method 6010 or SW 846, Method 6020 or EPA/600/R-94/111, Method 200.8	32 0.6 0.10
	Semi-Volatile Organics	SW 846, Method 8041 or SW 846, Method 8040 SW 846, Method 8270
Pesticides/Polychlorinated Biphenyls	SW 846, Method 8081 (Pesticides) SW 846, Method 8082 (PCBs)	0.0034 - 1.9 ² 0.14-0.49 ²
Herbicides	SW 846, Method 8151	.085-84 ²
Volatile Organic Compounds	SW 846, Method 8260 (VOAs)	.04-100 ²
Dioxins	SW 846, Method 8290	.00000067-.000005 ²
General Chemistry	<u>Cyanide:</u> SW 846, Method 9012 or Standard Methods 4500-CN or 600/4-79-020, Method 335.2	2.0-2.4 4 4
	<u>Sulfide:</u> SW 846, Method 9030	180-730 ²

Table D.4. Analytical Methods and Method Detection Limits for Regulated Constituents and Indicator Parameters

Class of Compounds	Analytical Methods ¹	Method Detection Limit ³ (ug/L)
Alkalinity	EPA-600/4-79-020 , Method 310.1 & 310.2, Standard Methods 2320	850 – 2500 ⁴
Anions	EPA-600/R-93-100, Method 300.0	5.1–4430 ²
pH	Company specific	Not applicable
Specific conductance	EPA-600/R-93-100, Method 120.1	Not applicable

- 1 1 Changes to the Analytical Methods require prior approval per [WAC 173-303-830](#), Appendix I, C.2.
- 2 2 Detection limit varies according to specific compound. The range of method detection limits for all compounds
3 detected by the specific analytical method is given.
- 4 3 Method detection limits are based on historical values reported by the analytical laboratories, where available.
5 MDLs may vary by laboratory and are updated periodically.
- 6 4 This MDL is based on Method 310.1, which was used previously. No technical difference is found
7 between Method 310.1 and SM 2320, except the SM covers more information on the principles of the method.

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