CHAPTER 5.0
GROUNDWATER MONITORING

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CHAPTER 5.0
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5.0 GROUNDWATER MONITORING

The IDF will be an RCRA-compliant landfill (i.e., a double lined trench with leachate collection system). This chapter 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 5.1 shows the location of the IDF and surrounding groundwater wells in the 200 East Area. This chapter 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.

5.1 Exemption from Groundwater Protection Requirement

An exemption is not requested.

5.2 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.

5.3 Aquifer Identification

The following sections discuss geology and hydrology.

5.3.1 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 5.1 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

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

5.3.1.1 Structural Framework

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

Geologic mapping on the Hanford Site and examination of drill core and borehole cuttings in the area have not identified any faults in the vicinity of the IDF site (DOE/RW-0164). The closest known faults are along the Umtanum Ridge-Gable Mountain structure north of the disposal site and the May Junction fault east of the site (Figure 5.2).

5.3.1.2 Stratigraphy

The basalt and post-basalt stratigraphy for the IDF site is shown in Figure 5.3. Approximately 137 to 167 meters of suprabasalt sediments overlie the basalt bedrock at the site.

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

Ringold Formation. Few boreholes penetrate the entire Ringold Formation at the IDF site so available data are limited. The Ringold Formation reaches a maximum thickness of 95 meters on the west side of the site and thins eastward. The member of Wooded Island (Figure 5.3) is the only member of the Ringold Formation in the 200 East Area. The deepest Ringold Formation unit encountered is the lower gravel, unit A. Lying above unit A is the lower mud unit and overlying the lower mud unit is upper gravel, unit E. The sand and silt units of the members of Taylor Flat and Savage Island of the Ringold Formation are not present at the IDF site. Unit A and unit E are equivalent to the Pliocene-Miocene continental conglomerates (Reidel and Fecht 1994). The lower mud unit is equivalent to the Pliocene-Miocene continental sand, silt, and clay beds (Reidel and Fecht 1994).

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

Nineteen meters of the lower mud unit were encountered in one borehole at the IDF site (PNNL-11957). The upper most 1-meter or so consists of a yellow mud to sandy mud. The yellow mud grades downward into about 10 meters of blue mud. The blue mud, in turn, grades down into 7 meters of brown mud with organic rich zones and occasional wood fragments. The lower mud unit is absent in the center of the site (northeast of borehole 299-E24-7 on Figure 5.4).

Unit E is described as a sandy gravel to gravelly sand. Unit E is interpreted to consist of as much as 15 meters of conglomerate with scattered large pebbles and cobbles up to 25 centimeters in size in a sandy matrix. The gravel consists of both felsic and basaltic rocks that are well rounded with a sand

matrix supporting the cobbles and pebbles. Cementation of this unit ranges from slight to moderate. The upper contact of unit E is not identified easily at the IDF site. In the western part of the study area, unconsolidated gravels of the Hanford formation directly overly the Ringold Formation unit E gravels, making exact placement of the contact difficult. The dominance of basalt and the absence of cementation in the Hanford formation are the key criteria used to distinguishing these (PNNL-11957). In the central and northeast part of the area, unit E has been eroded completely. Unconsolidated gravels and sands typical of the Hanford formation replace unit E.

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

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

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

The lowermost part of the Hanford formation encountered in boreholes at the IDF site consists of the gravel-dominated facies. Drill core and cuttings from boreholes 299-E17-21, 299-E17-22, 299-E17-23, 299-E17-25, and 299-E24-21 indicate that the unit is a clast-supported pebble- to cobble gravel with minor amounts of sand in the matrix. The cobbles and pebbles almost are exclusively basalt with no cementation. This unit pinches out west of the IDF site and thickens to the east and northeast (Figure 5.4). The water table beneath the IDF site is located in the lower gravel unit. The lower gravel unit is interpreted to be Missoula flood gravels deposited in the erosional channel carved into the underlying Ringold Formation.

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

Holocene Deposits. Holocene, eolian deposits cover the southern part of the IDF site. Caliche coatings on the bottom of pebbles and cobbles in drill cores through this unit are typical of Holocene caliche development in the Columbia Basin. The southern part of the IDF site is capped by a stabilized sand dune. The eolian unit is composed of fine- to coarse-grained sands with abundant silt, as layers and as material mixed with the sand.

Clastic Dikes. A **c**lastic dike was encountered in borehole C3828, adjacent to well 299-E17-25, at the IDF site. Clastic dikes also have been observed in excavations surrounding the site [e.g., US Ecology, the former Grout area, the 216-BC cribs, the Central Landfill, and the Environmental Restoration Disposal Facility (BHI-01103)]. In undisturbed areas, such as the IDF site, clastic dikes typically are not observed because these are covered by windblown sediments. The occurrence of a clastic dike in borehole C3828

suggests that these probably are present elsewhere in the subsurface at the disposal site. The IDF excavation will be geologically mapped to document the occurrence of any clastic dikes that may exist at the site.

5.3.2 Groundwater Hydrology

The unconfined aquifer under the IDF site occurs in the fluvial gravels of the Ringold Formation and flood deposits of the Hanford formation. The thickness of the aquifer ranges from about 70 meters at the southwest corner of the site to about 30 meters under the northeast corner of the IDF site. The Elephant Mountain Member of the Columbia River Basalt Group forms the base of the unconfined aquifer (Figure 5.4).

The unsaturated zone beneath the land surface at the IDF site is approximately 100 meters thick and consists of the Hanford formation. The water level in boreholes in and around the site indicates that the water table is in the lower gravel sequence of the Hanford formation and at an elevation of approximately 123 meters above sea level. The water table is nearly flat beneath the IDF site. Table 5.1 gives water level information from wells near the site. The locations of the wells are shown on Figure 5.1. The latest water table map shows less than about 0.1 meter of hydraulic head differential across the IDF site (Figure 5.5).

The Ringold Formation lower mud unit occurs within the aquifer at the southwest corner of the IDF site (299-E17-21) but is absent in the central and northern parts of the site (299-E24-7 and 299-E24-21). The lower mud unit is known to be a confining or partly confining layer at places under the Hanford Site (PNNL-12261) and this might be the case under the southwest corner of the IDF site. Groundwater samples were collected and analyzed from above and below the lower mud unit during drilling of well 299-E17-21. Chemical parameters (pH, electrical conductivity, and Eh) were different in the two samples suggesting that the lower mud is at least partly confining in the area. No contamination was found above or below the lower mud. An interpretation of the distribution and thickness of this stratum is shown in Figure 5.4. The surface of the lower mud unit is interpreted to dip gently to the southwest (PNNL-13652).

Hydrographs for selected wells near the IDF site are shown in Figure 5.6. Although the water table is extremely flat in the area of the IDF, hydrographs suggest that groundwater flow has had an easterly component throughout the 1990s and has not significantly changed due to cessation of discharges to the 216-B Pond system. Hydrographs for the older wells (299-E23-1, 299-E23-2, and 299-E24-7) show two maxima in the water level. These coincide with the operation of the PUREX Plant, which operated between 1956 and 1972 and between 1983 and 1988. All the hydrographs show a decline in the water table during recent years. The rate of decline is between 0.18 and 0.22 meter per year and will take between 10 and 30 years to stabilize. The reason for the decline is the cessation of effluent discharge to the 216-B Pond System, which is centered northeast of 200 East Area. Based on hindcast water table maps (BNWL-B-360), the water table is expected to decline another 2 to 7 meters before reaching pre-Hanford Site elevations. The cessations of effluent discharge also are responsible for changes in the direction of groundwater flow across much of the 200 East Area.

Groundwater flow beneath the IDF site recently was modeled to be southeasterly (PNNL-13400). This direction differs from the easterly direction predicted by the analysis of WHC-SD-WM-RPT-241 and other earlier reports. The southeasterly flow direction primarily is attributable to inclusion of the highly permeable Hanford 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, 1 of 2, 2 of 2). As stated in PNNL-13404 (1 of 2, 2 of 2), 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).

5.4 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, 1 of 2, 2 of 2). 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.

5.4.1 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 µg/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 µg/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 µg/L in 1990 to a low of 17,000 µg/L in 1993, reflecting the cessation of PUREX Plant operations in 1988. Since 1993, nitrate has increased to 48,300 µg/L in 2003 (Figure 5.7). 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 µg/L in 1988, nitrate concentration in well 299-E24-7 was steady and ranged between 12,800 and 35,400 µg/L between 1985 and 1996 when the well was last sampled (Figure 5.7). The last two measured values from 1995 and 1996 were 26,000 µg/L. Farther southwest, nitrate detected in 1998 in well 299-E17-21 in Ringold unit E was 23,600 µg/L.

5.4.2 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. Implementation of the *Integrated Disposal Facility Preoperational Monitoring Plan* (RPP-6877) has begun and characterization activities will occur during the next few years. The *Integrated Disposal Facility Preoperational Monitoring Plan* (RPP-6877) has a strong emphasis on vadose zone characterization and deferred groundwater monitoring to this groundwater monitoring plan. Vadose zone information resulting from preoperational monitoring will be included, if applicable, in updates to this groundwater monitoring plan.

The *Integrated Disposal Facility Preoperational Monitoring Plan* (RPP-6877) identified three areas near the IDF site that might have had an influence on the vadose zone beneath the site. These are the 218-E-1 Burial Ground and an unplanned release associated with the burial ground; the coal ash pile in the

northwest part of the site; and a transfer line along the northern part of the west boundary of the IDF site (RPP-6877). Work was outlined in the *Integrated Disposal Facility Preoperational Monitoring Plan* to determine whether these three areas had introduced contamination to the site. Appropriate results from preoperational monitoring will be incorporated into this groundwater monitoring plan as results become available and as revisions are needed.

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

5.5 Detection Monitoring Program

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

5.5.1 Indicator Parameters, Waste Constituents, Reaction Products to be Monitored

5.5.1.1 Regulated Constituents

The regulated constituents for this groundwater monitoring plan are the constituents identified on the IDF Part A Form.

5.5.1.2 Monitoring Parameters

The parameters to be routinely monitored are listed in Table 5.2. These parameters include the indicator parameters and supplemental parameters.

The indicator parameters will be used to monitor for hazardous constituents reaching the groundwater as a result of IDF operations. Only the indicator parameters are subject to the statistical methods described in Section 5.5.4.7. Total organic carbon and total organic halides are indicator parameters selected to monitor impacts of RCRA regulated organic constituents on the groundwater quality. Specific conductance is selected as an indicator parameter to monitor impacts of metals and anions on groundwater quality. pH is a general indicator of groundwater quality. Specific conductance and pH are measured in the field at the time of sampling. Chromium is included as an indicator parameter because hexavalent chromium is one of the more mobile of the regulated metals to be disposed of at the IDF and should be one of the first constituents to enter groundwater if the regulated facility impacts groundwater.

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

For the first year of monitoring, all parameters listed in Table 5.2 will be monitored twice each quarter to determine background concentrations. After the first year, indicator and supplemental parameters will be monitored semi-annually. In addition, field measurements of temperature and turbidity will be made at each sampling event.

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

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

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

5.5.1.3 Dangerous Waste Characterization

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

5.5.1.3.1 Volume of the Waste Package

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

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

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

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

5.5.1.3.2 Composition of the Waste Packages

HNF-4921 provides detailed estimates for the inventory of hazardous chemicals in the vitrified LAW feed and in the vitrified LAW package. The composition of the vitrified LAW package was estimated in HNF-4921 based on

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

5.5.1.4 Behavior of Constituents

Almost all of the regulated constituents for the IDF show some degree of retardation in the vadose zone and in the saturated zone. Table 5.3 indicates the range of expected behaviors in the subsurface at the IDF for selected regulated constituents. The constituents in Table 5.3 were selected by comparing the expected constituents in the vitrified LAW package (from HNF-4921) and the historical inventories of the Hanford Site low-level burial grounds (from WHC-MR-0008 and WHC-SD-EN-AP-015) to 40 CFR 264, Appendix IX (see IDF Part A Form). The mobilities and solubilities in Table 5.3 give an estimated range for the properties of the constituents of concern.

5.5.1.5 Detectability

The detection limits in groundwater for each RCRA regulated constituent and the indicator parameters are given in Table 5.4.

5.5.2 Groundwater Monitoring Program

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

5.5.2.1 Description of Wells

The groundwater monitoring well network for the IDF ultimately will have eight wells: three hydraulically upgradient of the facility and five hydraulically downgradient. The downgradient wells will be placed to sample groundwater passing the point of compliance. The point of compliance at the IDF site is a plane connecting the groundwater monitoring wells along the southern and eastern sides of the site in accordance with WAC 173-303-645(6), which states "The point of compliance is 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". The monitoring network will consist of existing and new, downgradient wells to complete the monitoring network. All wells will be WAC 173-160 compliant.

Three upgradient wells will be used for the IDF monitoring network. Two of these wells (299-E18-1 and 299-E24-21) are existing wells. Upgradient well 299-E24-21 was installed in March 2001 for characterization of the IDF site. The well, located at the northeast corner of the site (Figure 5.8), was constructed to RCRA standards as per WAC 173-160. Well 299-E18-1 was installed in 1988 as part of the 2101-M RCRA monitoring network. The well currently has 2 to 3 meters of water above the bottom of the screened interval.

The third upgradient well will be a new well located at the northwest corner of the IDF (Figure 5.8). The well will be constructed to RCRA standard as per WAC 173-160 and screened at the water table.

Three of the downgradient wells are existing wells (299-E17-22, 299-E17-23, and 299-E17-25) that were installed as WAC 173-160 compliant wells in 2002. Their location is shown in Figure 5.8. The remaining two downgradient wells will be installed in a sequence coordinated with the IDF operations.

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

The first new downgradient well will be installed along the eastern side of the facility (Figure 5.8) at least one year before the IDF receives waste. The second new downgradient well will be installed along the southern boundary of the Site at least one year before the third phase of waste disposal becomes operational. Both wells will be installed such that at least one year of background data can be obtained prior to the associated operational phase becoming active. Figure 5.8 shows the sequence for both groundwater well construction and waste disposal. The locations of all existing and new wells in the IDF monitoring network are noted on the figure.

The placement of the wells for the IDF monitoring network was based on professional judgment. The efficiency of the resulting groundwater monitoring network was evaluated using a simple two dimensional, horizontal transport model called the monitoring efficiency model (MEMO) (Wilson et al. 1992). The model estimates the efficiency of a monitoring network at the point of compliance. The model simulates a contaminant plume originating from a series of grid points within the disposal facility using the Domenico-Robbins method (Domenico and Robbins, 1985). The model calculates both advective flow and dispersive flow in two dimensions and determines whether the resulting plume will be detected by a monitoring well before the plume travels some selected distance beyond the disposal facility boundary. The selected distance is termed the buffer zone. (A longitudinal dispersivity of 95 meters and horizontal dispersivity of 9.5 meters were used to evaluate the monitoring network in Figure 5.8.) Outputs from the model are the monitoring efficiency and a map of the disposal facility showing areas where leaks would not be detected under the given site-specific parameters provided as input to the

model. Monitoring efficiency is defined as the ratio of the area within a disposal facility from which a release likely would be detected to the total area of the disposal facility, expressed as a percentage.

The monitoring efficiency calculated by the MEMO model for the proposed monitoring network is 100% for phase I, 98% for phase II, and 99% for phase III (Figure 5.8).

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

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

5.5.2.2 Equipment Decontamination

Drilling equipment will be decontaminated using high temperature and pressure [82ºC (180°F) and greater than 70.3 kg/cm^2 (1,000 psi)] washing with an approved cleaning solution. The equipment will be rinsed with clean water. The procedure is specified in controlled manuals.

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

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

5.5.2.3 Representative Samples

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

5.5.2.4 Locations of Background Groundwater Monitoring Wells that are not Upgradient

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

5.5.3 Background Values

Groundwater background (baseline) has not been established for the IDF site. Background data will be determined before construction of the site using the wells described previously (Section 5.5.2.1) for the use of upgradient vs. downgradient comparisons (Section 5.5.4.7).

5.5.3.1 Plan for Establishing Groundwater Quality Data

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

5.5.3.1.1 Well Locations

Groundwater monitoring wells in the IDF monitoring network were described in Section 5.5.2.1 and their locations are shown on Figure 5.8.

5.5.3.1.2 Sampling Frequency

Eight background samples will be collected during the first year of monitoring from phase I wells. Two samples will be collected quarterly for one year. For the new well needed for phase III operations, two samples will be collected quarterly for one year before phase III is operational. For all wells, two independent samples will be collected each quarter, one per month for 2 consecutive months followed by a month of non-sampling. This sequence will be repeated each quarter during the first year of monitoring. Section 5.5.3.1.3 provides frequency logic.

5.5.3.1.3 Sampling Quantites

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

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

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

5.5.3.1.4 Background Values

The default method of analysis of variance (ANOVA) will be used to detect any impact on groundwater quality at the IDF where the mean of the measurements from compliance (downgradient) wells is compared to the mean of the distribution of background data from the upgradient wells. The details of the method are described in Section 5.5.4.7.1.

5.5.4 Sampling, Analysis and Statistical Procedures

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

5.5.4.1 Sample Collection

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

Samples generally will be collected after three casing volumes of groundwater are withdrawn or after the field parameters pH, temperature, and specific conductance have stabilized. Field parameters are measured in a flow through chamber. Turbidity should be equal to or below 5 NTU (nephelometric turbidity units) before sample collection if possible. Sample preservatives will be added to the collection bottles in the laboratory before their use in the field. Samples to be analyzed for metals will be filtered in

the field to ensure results represent dissolved metals and do not include particulates (40 CFR 136.3). Duplicates, trip blanks, and field equipment blanks will be collected as part of the general quality control program.

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

5.5.4.2 Sample Preservation and Shipment

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

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

5.5.4.3 Analytical Procedures

The methods for analysis of chemical constituents in groundwater will conform to *Test Methods for Evaluating Solid Wastes: Physical/Chemical Methods, 3rd Ed.* (SW-846); *Methods for Chemical Analysis of Water and Wastes* (EPA-600/4-79-020) or other EPA methods; and the *Annual Book of ASTM Standards* (American Society for Testing and Materials, 1986). The methods used to obtain routine data results are presented in Table 5.4.

5.5.4.3.1 Data Storage and Retrieval

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

5.5.4.3.2 Data Verification and Validation

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

Verification and validation of groundwater chemistry data will be performed according to established procedures. Data will be reviewed quarterly to assure the data are complete and representative. The review will include evaluation of quality control data (e.g., field blanks, duplicates, and laboratory blanks) and a technical review by a project scientist familiar with the hydrogeology of the site. The technical review might include comparison of recent data to historical trends and comparison of related constituents. Suspect data will be investigated through the data review process in accordance with established procedures and will be flagged in the database.

5.5.4.3.3 Reporting

Groundwater chemistry and water level data will be reviewed after each sampling event and will be available in the HEIS database. The results of the statistical evaluation and associated information will be submitted to Ecology quarterly in Hanford Site groundwater monitoring reports.

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

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

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

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

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

5.5.4.4 Chain of Custody

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

5.5.4.5 Additional Requirements for Compliance Point Monitoring

This section describes sampling frequency and determination of groundwater quality for the samples from the groundwater monitoring network. Compliance data will be compared to baseline data collected from the upgradient wells and a determination of impacts to groundwater will be made using the proposed ANOVA method (explained in Section 5.5.4.7.1).

5.5.4.5.1 Sampling Frequency

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

The default sampling procedures are adopted for the IDF Active life as follows: four independent samples from each groundwater monitoring well will be sampled for the indicator parameters (Table 5.2) semiannually during the active life of the regulated unit (including the closure period), one per month for four consecutive months followed by two months of non-sampling. The mean of the measurements from the downgradient wells will be compared semiannually to the mean of the distribution of the background data using ANOVA.

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

5.5.4.5.2 Compliance Point Groundwater Quality Values

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

During detection monitoring, data verification will be applied in case of an initial exceedance. For ANOVA test, if the test of hypothesis of equal means for all wells fails, *post hoc* comparisons are needed to determine which compliance well(s) is (are) contaminated. This will be done by comparing concentration differences (called contrasts in the ANOVA and multiple comparison framework) between each compliance well with the background wells (EPA/530-SW-89-026). If the contaminated compliance well(s) is (are) determined by *post hoc* comparisons, verification sampling will be implemented for the constituent(s) in question. Verification sampling is needed to determine if the exceedance is an artifact caused by an error in sampling, analysis, or statistical evaluation or an actual variation in groundwater chemistry. A collection of at least four measurements from the re-sampled compliance well(s) is required to perform ANOVA test on comparison with the mean of the background data (EPA/530-R-93-003). Adequate time should elapse to ensure statistical independence between the original measurements and the re-sample measurements, which is assured by the sampling frequency proposed in Section 5.5.4.5.1.

The existing nitrate plume beneath the IDF site is described in Section 5.4.1. Nitrate is not included in IDF Part A Form and, therefore, is not a constituent of concern for the IDF. Existing groundwater conditions will be monitored by the indicator parameters and supplemental constituents as described in Section 5.5.1. Specific conductance will respond to nitrate so that any changes in the nitrate concentration will be reflected by changes in the indicator parameter specific conductance.

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

5.5.4.6 Annual Determination

Groundwater flow rate and flow direction at the IDF site will be determined annually for the uppermost aquifer. Flow rate will be determined by calculation using the groundwater gradient, and the Darcy flow equation, $v_h = K_h i_h / n_e$, where v_h is the horizontal groundwater velocity, K_h is the horizontal hydraulic conductivity, i_h is the horizontal hydraulic gradient, and n_e is the effective porosity. Effective porosities used at Hanford Site RCRA regulated units are on the order of 0.1 to 0.3 (PNNL-14187, 1 of 2, 2 of 2); effective porosity might be determined specifically for the IDF from hydrologic tests.

Hydraulic gradients will be determined from measurements of water levels.

5.5.4.7 Statistical Determination

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

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

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

The number of tested constituents will be limited to the indicators to maintain a sufficiently low false-positive rate (EPA/530-R-93-003, page 62; Gibbons 1994, page 16). Verification sampling is an integral part of the statistical design to lower the overall false-positive rate and determine whether the difference between background and compliance-point data is an artifact caused by an error in sampling, analysis, or statistical evaluation (Section 5.5.4.5.2).

5.5.4.7.1 Statistical Procedure

In accordance with WAC 173-303-645(8)(h), acceptable statistical methodology includes analysis of variance (ANOVA), tolerance intervals, prediction intervals, control charts, test of proportions, or other statistical methods approved by Ecology. The type of monitoring, the nature of the data, the proportions of non-detects, and spatial and temporal variations are some of the important factors to be considered in the selection of appropriate statistical methods. The EPA default method ANOVA will be implemented for the IDF site to compare the differences of means of the measurements from upgradient and downgradient wells. The detailed discussions of the ANOVA test can be found in EPA/530-SW-89-026 and statistical textbooks (Gilbert, 1987; Casella and Berger, 1990; Davis, 2002), and can be executed using commercial statistical software such as SAS or SYSTAT. Under WAC 173-303-645(8)(i)(ii), the proposed statistical method must comply with the performance standard, that is, for a multiple comparisons procedure the Type I error level must be no less than 0.05, and maintained at the level of no less than 0.01 for individual well comparisons. By definition, Type I error is the false rejection rate of the null hypothesis (H_0) of the statistical test. In detection or compliance monitoring, the statistical test is defined as H_0: no release, i.e., the means of the distributions from upgradient and downgradient wells are the same, and the alternative (H_a) evidence of release, e.g., "clean until proven contaminated" (EPA/530-R-93-003). Therefore, the proposed statistical method must comply with the requirement of maintaining Type I error, which equates false positive rate in the stage of detection monitoring at approximate 5% level. As described in EPA/530-SW-89-026, ANOVA procedures have the advantages of combining multiple downgradient into a single statistical test, thus enabling the network-wide false

positive rate for any single constituent (not multiple constituents) to be kept at 5 percent, and also maintain reasonable power for detecting contamination.

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

- First, check the proportion of non-detects of the measurements from the upgradient and downgradient wells. When the proportion of non-detects is less than 15%, the non-detects will be reported as one-half the minimum detection limit or practical quantitation limit, and proceed with parametric ANOVA analysis. When the proportion of non-detects is greater than 15%, non-parametric ANOVA analysis will be used for comparing the means of downgradient and upgradient wells.
- Evaluate the distributions of the measurements from the upgradient and downgradient wells. The assumptions with parametric ANOVA test are the residuals are normally distributed with equal variance. The normality of the distribution the residuals can be checked using coefficient of variation, plotting the data on probability plot, and/or Shapiro-Wilk's test (EPA/530-SW-89-026; Gibbons, 1994). The assumption of normality usually can be met by log-transforming the data or by other Box-Cox transformations. When the assumptions of normality and lognormality cannot be justified, the non-parametric ANOVA method will be used for the IDF. Bartlett's test can be used in checking equality, or homogeneity, of variances.
- The parametric ANOVA procedures include:
  - Assume a monitoring network with k wells, and total number of observations N. First, compute well total, well mean, and well residuals (observations subtracted by well mean) for each well, and grand total and mean of all observations (all wells). The well residuals are used to check the assumption of normality.
  - Compute the sum of squares of difference between well means and the grand mean, SS_{wells} that is a measure of the variability between wells with (k-1) degrees of freedom.
  - Compute the total sum of squares of differences between all observations and the grand mean, SS_{total}, which is a measure of the variability in all observations with (N-1) degrees of freedom.
  - Compute the sum of squares of differences of observations within wells from the well means, SS_{error}, which is a measure of the variability within wells with (N-k) degrees of freedom calculated by the following subtraction:

    $$SS_{error} = SS_{total} - SS_{wells}$$

  - Test the hypothesis of equal means for all k wells by computing F value with the means squares of differences:

    $$F = MS_{wells} / MS_{error}$$

    where the means of squares are the sums of squares divided by the associated degrees of freedom, that is, $MS_{wells} = SS_{wells} / (k-1)$, and $MS_{error} = SS_{error} / (N-k)$. Compare the F value to the tabulated F statistics with (k-1) and (N-k) degress of freedom at the 5% significance level (EPA/530-SW 89-026, Appendix B, Table 2). If the calculated F value exceeds the tabulated F statistics, the null hypothesis of equal well means is rejected. Proceed with test of contrasts in the next step. Otherwise, the hypothesis of equal means is accepted that there is no significant difference between the concentrations at k wells (upgradient and downgradient wells), that is, no evidence of contamination.
- If the hypothesis of equal well means is rejected, contrasts (concentration differences between a compliance well and background wells) will be tested for each compliance well to determine which compliance well(s) is (are) contaminated. Bonferroni t-statistics will be computed to determine if the significant F value is due to difference between background and compliance

wells. Assume that of the k wells, k_b are background (upgradient) wells, and k_c are compliance (downgradient) wells (i.e., $k_b + k_c = k$). Each of the k_c compliance wells is compared to the mean of the background wells as the following steps:

- 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 ith compliance well and the mean from the background wells.
- Compute the standard error of the difference from the ith compliance well with n_i observations as:

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

  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 (α=0.05/k_c) but no less than 0.01 (for individual comparison) and (N-k) degrees of freedom. The critical value for the ith 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 ith 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 (kb background wells and kc 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 (kc+1). (one group per compliance well).
  - Compute the sum (Ri) and the average (mi) of the ranks of the ni observations in the ith group.
  - Compute the Kruskal-Wallis statistics (H) as

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

- Compare the calculated H value to the tabulated chi-squared value with kc 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):

$$C_i = Z_{(0\,05/kc)} \left[\frac{N(N+1)}{12} \times \left(\frac{1}{n_b} + \frac{1}{n_i} \right) \right]^{1/2}$$

Where $Z_{(0.05/\,kc)}$ 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 ith 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 some specific factors can be, identified explaining why background levels at the IDF site have naturally changed (EPA/530-R93-003).

Formal testing for outliers will be done when an observation of the background data seems inconsistently high (by orders of magnitude) compared to the rest of the data set in order to avoid the artificial increase of the mean of the background data and a corresponding increase of the false negative rate. Statistical methods such as the Grubbs' method (Grubbs, 1969), the box-and-whisker plot (Ostle and Malone, 1988), EPA guidance (EPA/530-SW-89-026, p. 11-14) and/or American Society for Testing and Materials guidance (ASTM 1996) will be used for testing outliers. The outliers must be checked to determine if the measurements are in error and need to be corrected or excluded from calculating the background mean. If no specific error is found, the measurements must be retained in the data.

A statistically significant exceedance over background (baseline) levels only indicates that the new measurement in a particular monitoring well for a particular constituent is inconsistent with chance expectations based on the available sample of background (baseline) measurements. Any statistical result must be supported by other information to determine if a waste disposal facility has impacted groundwater (ASTM 1996).

5.5.4.7.2 Results

Sampling and analysis results are reviewed at least semiannually (i.e., after each sampling event) and are available in HEIS. The DOE will submit results of statistical evaluations to Ecology.

5.5.5 Compliance Monitoring Program

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

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

5.5.6 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 or within the time agreed to by Ecology. A description of the groundwater monitoring plan, including all additional corrective actions that are appropriate for a corrective action program will be prepared and submitted to Ecology when the need for corrective action first is identified.

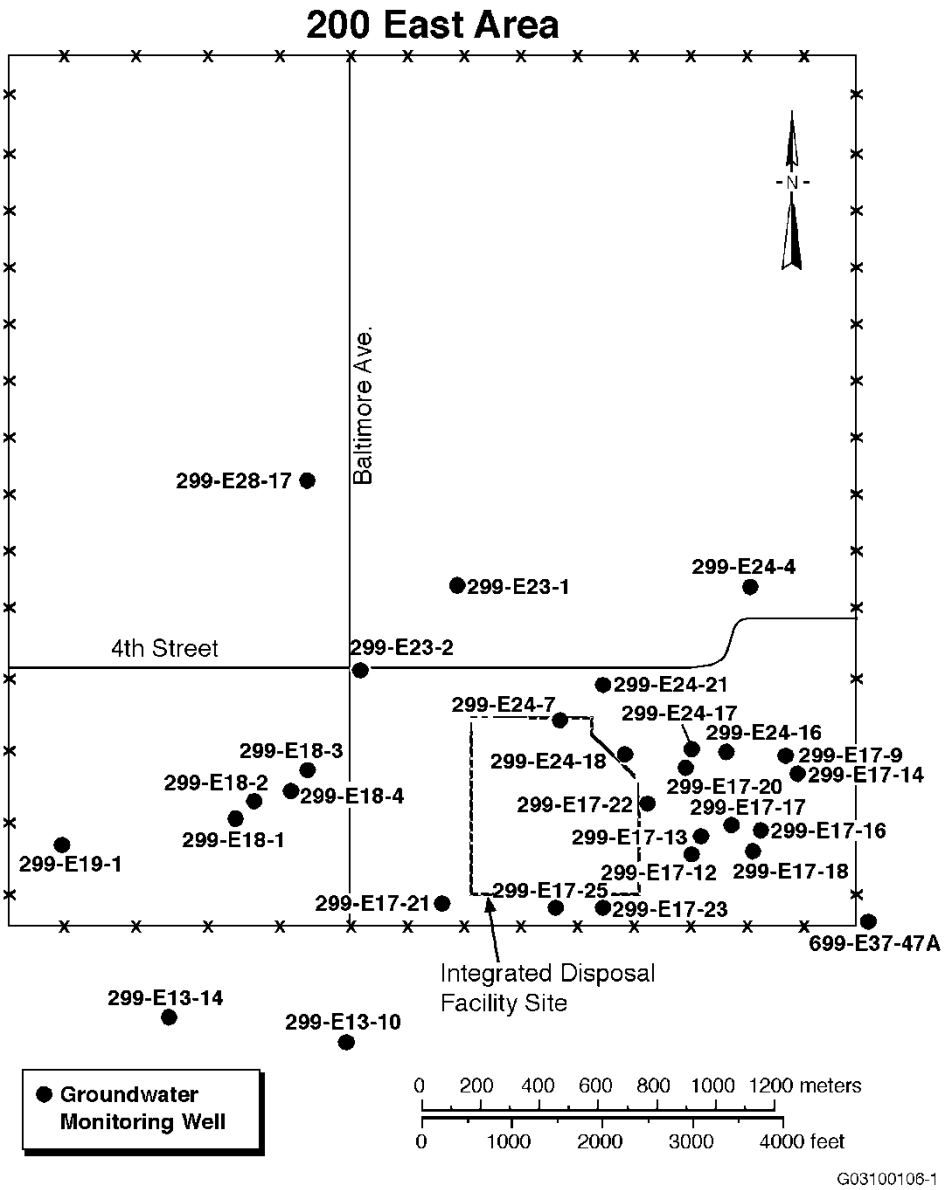


Figure 5.1. Location of the IDF and Nearby Boreholes

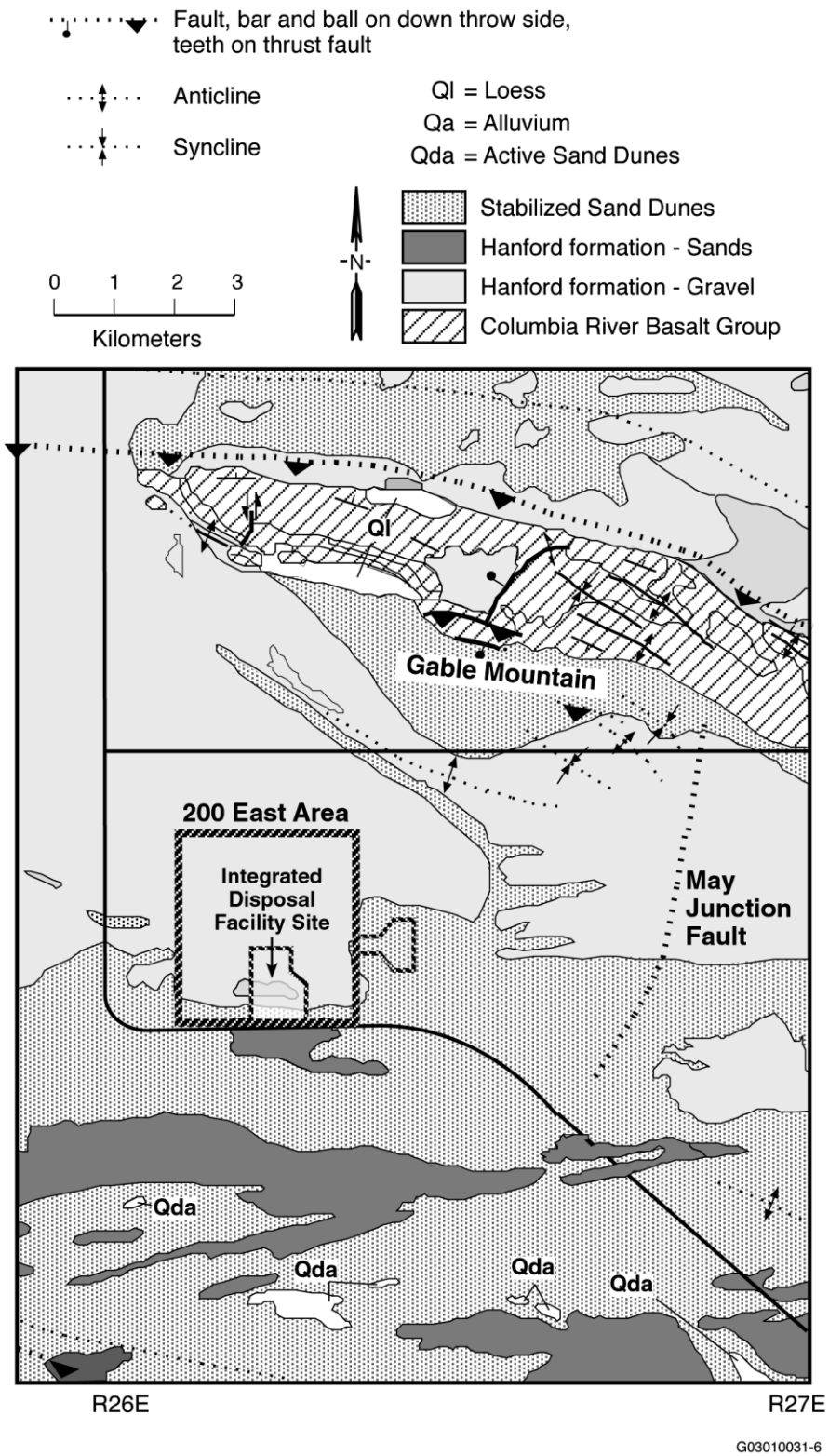


Figure 5.2. Geologic Map of the 200 East and 200 West Areas and Vicinity

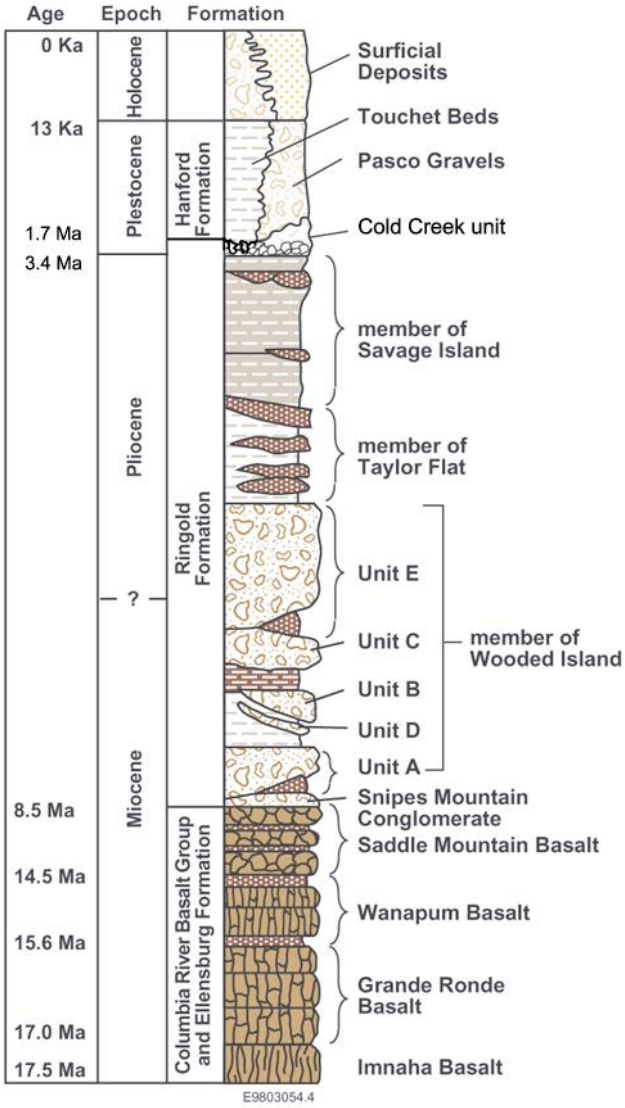


Figure 5.3. Stratigraphy of the Hanford Site

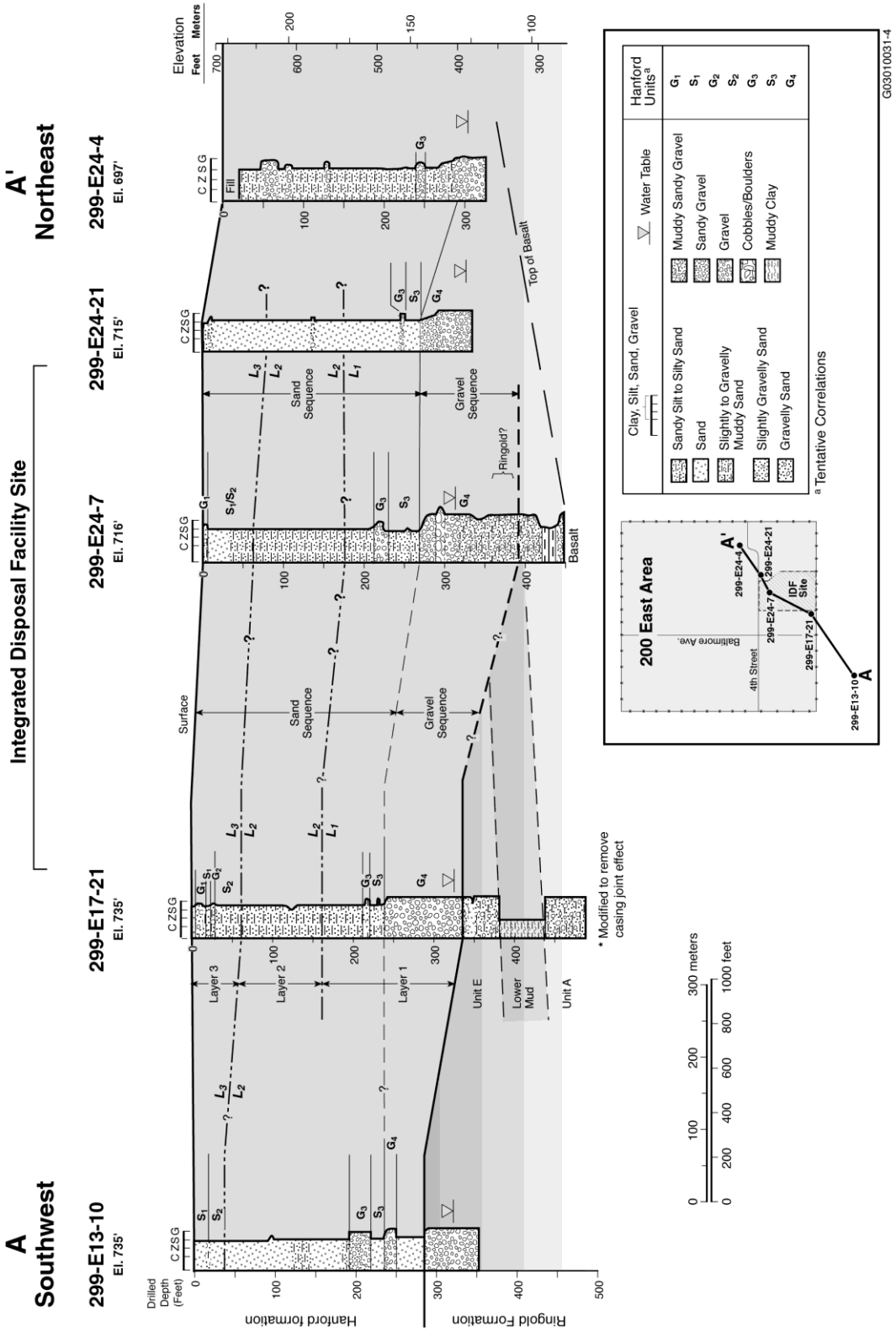


Figure 5.4. Cross-Section through the IDF Site

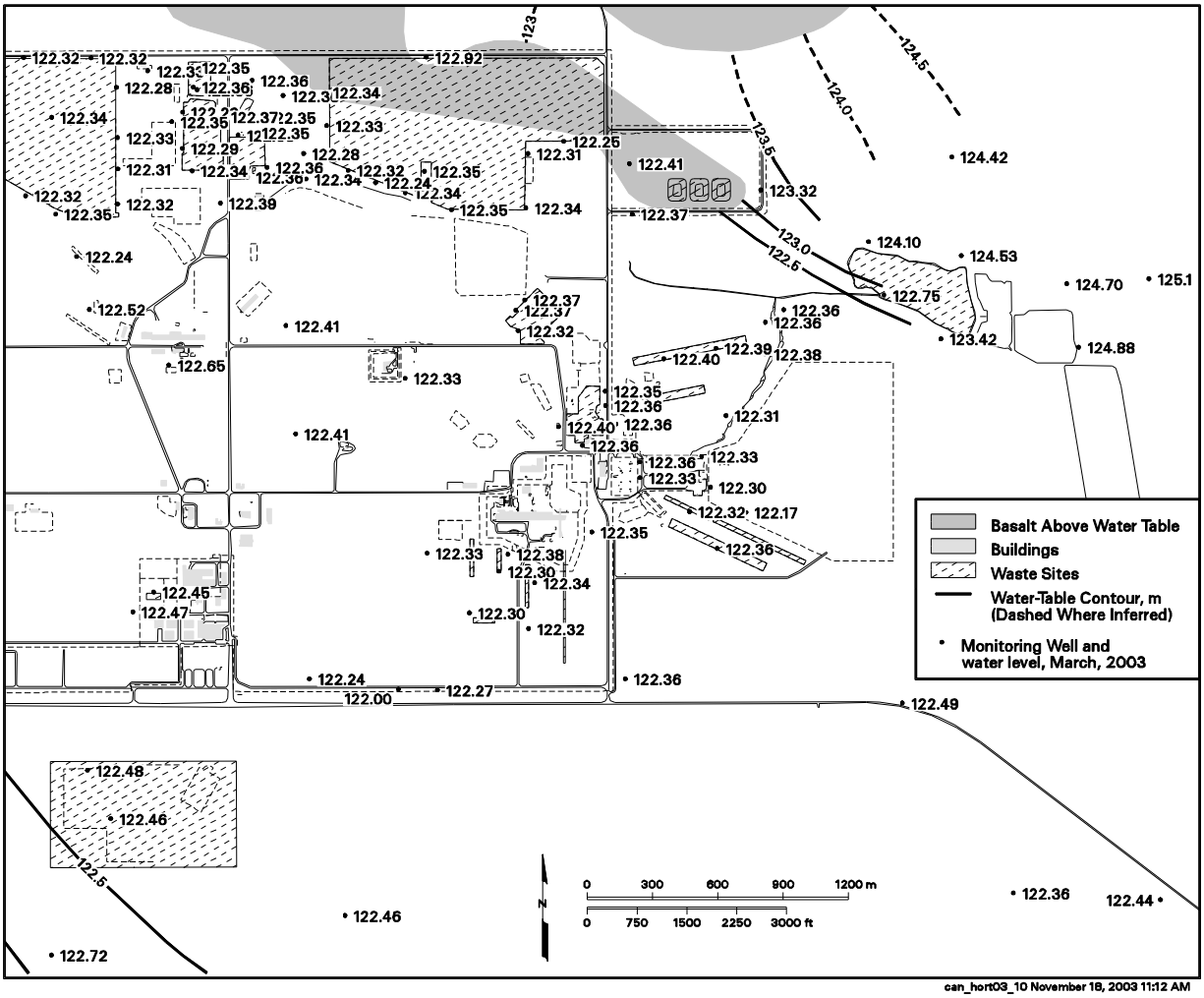
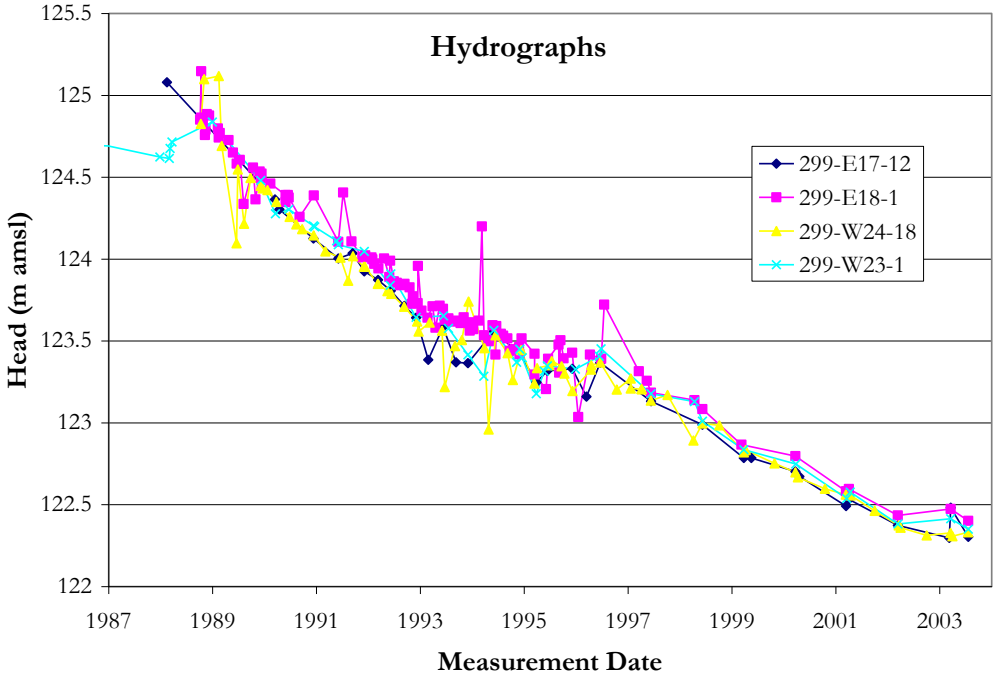


Figure 5.5. Water Table Map for the Hanford Site 200 East Area



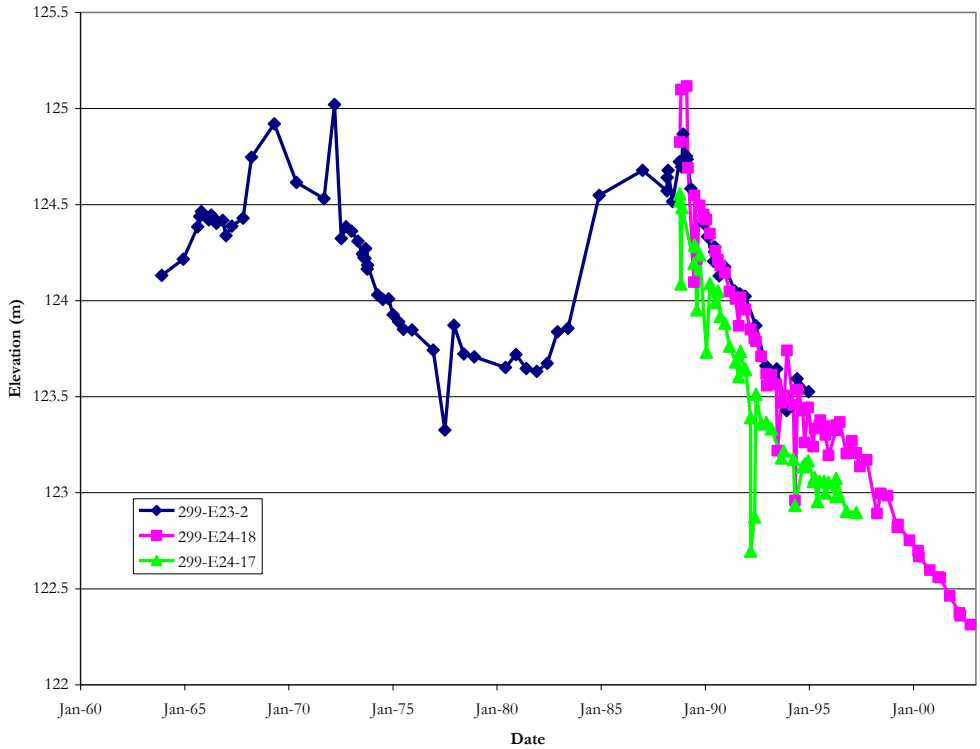
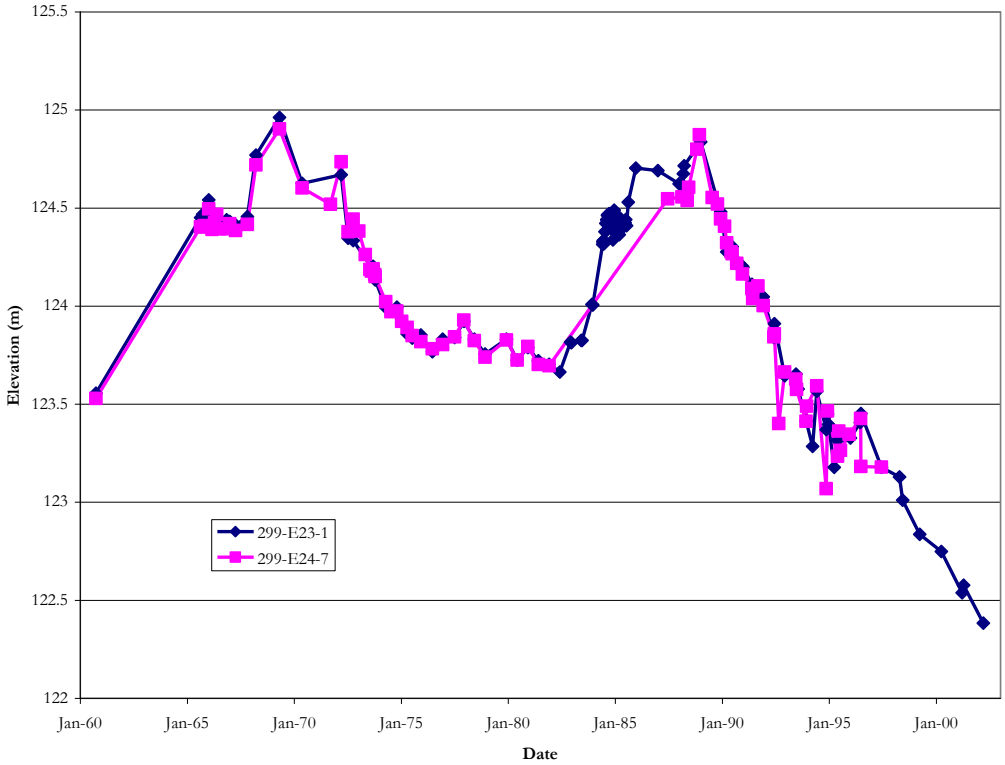


Figure 5.6. Hydrographs for Wells Near the IDF Site



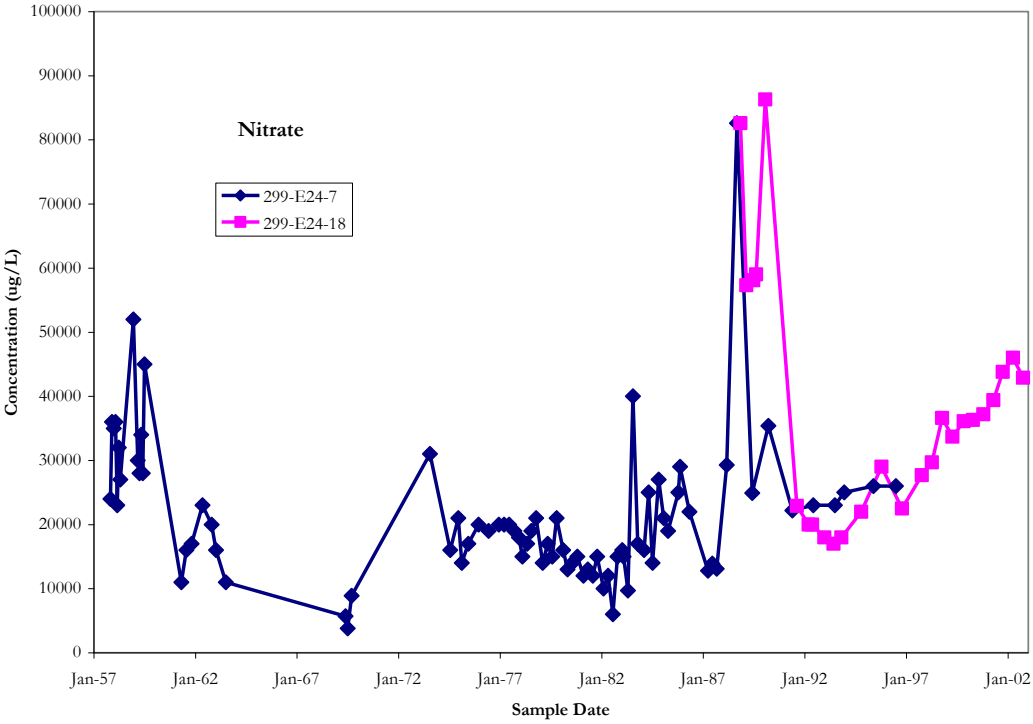


Figure 5.7. Concentration versus Time for Nitrate in Wells 299-E24-7 and 299-E24-18

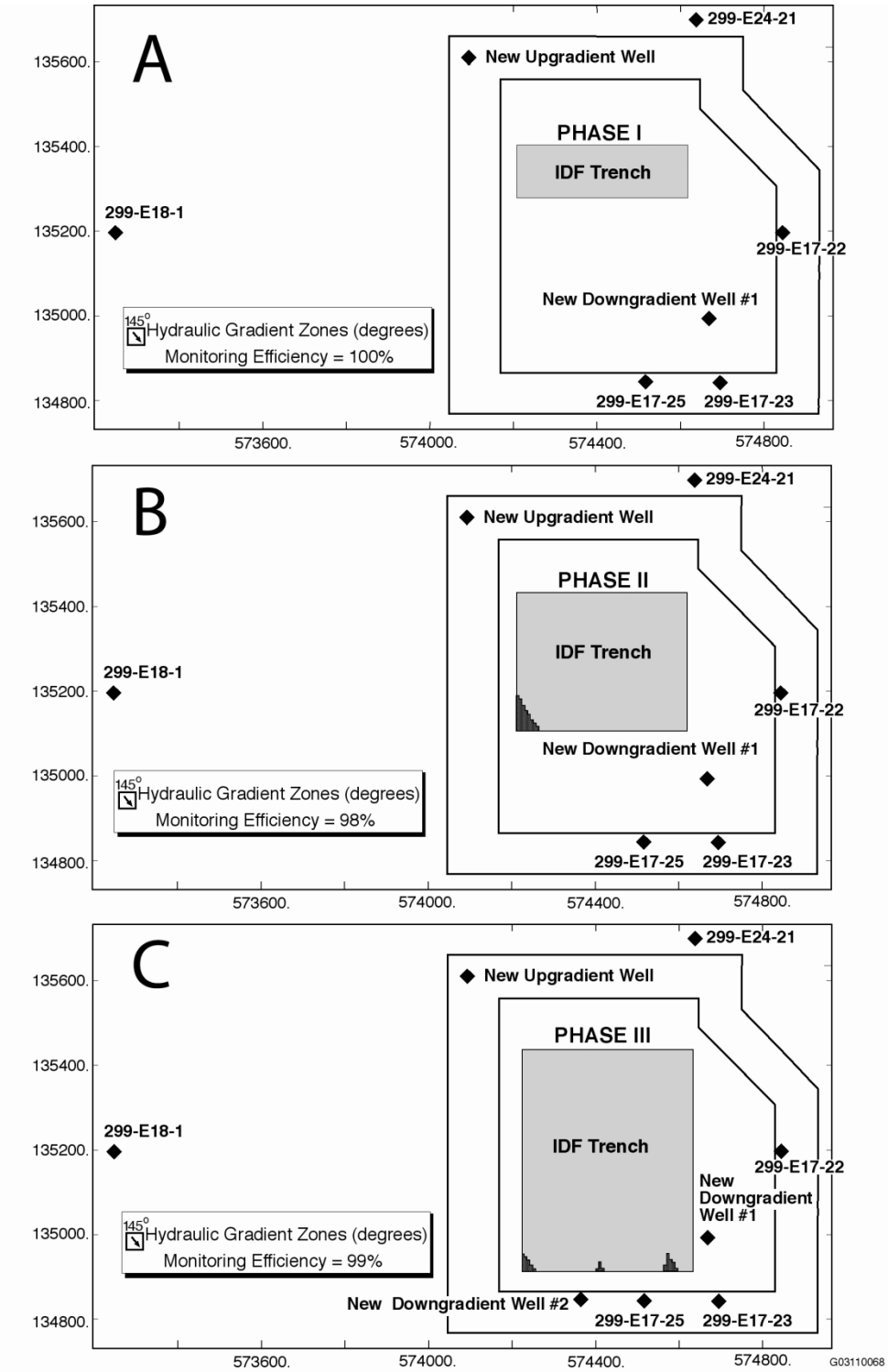


Figure 5.8. Sequence for Installation of Downgradient Monitoring Wells at the IDF

Areas in black are areas from which leaks will not be detected with the array of monitoring wells shown.

A. Area used for disposal and associated monitoring wells for construction phase I;
B. Area used for disposal and associated monitoring wells for construction phase II;
C. Area used for disposal and associated monitoring wells for construction phase III.

Table 5.1. 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 5.2. 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)	

Table 5.3. 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 Aloclors (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^{+2})	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 µg/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 5.3. 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).

N/A = Not applicable

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

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

K_d (acetonitrile) = 0.01 X 16 = 0.16.

[2] Creosote is a coal tar distillate containing high quantities of naphthalene and anthracene (Lewis, R.J., Sr. 1993).

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

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

Table 5.4. 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	Trace Metals:	
	SW 846, Method 6010 or	0.18 - 44.8[2]
	SW 846, Method 6020 or	0.042–8.5
	EPA/600/R-94/111, Method 200.8	.05–50
	Arsenic:	
	SW 846, Method 6010 or	50
	SW 846, Method 6020 or	2
	EPA/600/R-94/111, Method 200.8	0.40
	Cadmium:	
	SW 846, Method 6010 or	4
	SW 846, Method 6020 or	0.86–2.3
	EPA/600/R-94/111, Method 200.8	0.10
	Chromium:	
	SW 846, Method 6010 or	4
	SW 846, Method 6020 or	1.9–3.1
	EPA/600/R-94/111, Method 200.8	0.5
	Lead:	
	SW 846, Method 6010 or	27
	SW 846, Method 6020 or	0.49
	EPA/600/R-94/111, Method 200.8	0.10
	Mercury:	
	SW 846, Method 6020 or	.093
	SW 846 Method 7470 or	0.1
	EPA/600/R-94/111, Method 200.8	0.05
	Selenium:	
	SW 846, Method 6010 or	30
	SW 846, Method 6020 or	1
	EPA/600/R-94/111, Method 200.8	0.30
	Thallium:	
	SW 846, Method 6010 or	32
	SW 846, Method 6020 or	0.6
	EPA/600/R-94/111, Method 200.8	0.10
Semi-Volatile Organics	SW 846, Method 8041 or	Not available
	SW 846, Method 8040	2.0 – 3.7[2]
	SW 846, Method 8270	0.24 – 50[2]
Pesticides/Polychlorinated Biphenyls	SW 846, Method 8081 (Pesticides)	0.0034 –1.9[2]
	SW 846, Method 8082 (PCBs)	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	Cyanide:	
	SW 846, Method 9012 or	2.0–2.4
	Standard Methods 4500-CN or	4
	600/4-79-020, Method 335.2	4
	Sulfide:	
	SW 846, Method 9030	180–730[2]

Table 5.4. 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 Changes to the Analytical Methods require prior approval per WAC 173-303-830, Appendix I, C.2.
2 Detection limit varies according to specific compound. The range of method detection limits for all compounds detected by the specific analytical method is given.
3 Method detection limits are based on historical values reported by the analytical laboratories, where available. MDLs may vary by laboratory and are updated periodically.
4 This MDL is based on Method 310.1, which was used previously. No technical difference is found between Method 310.1 and SM 2320, except the SM covers more information on the principles of the method.

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