2.14 Confined Aquifers

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This section describes groundwater flow and quality within the Ringold Formation and upper basalt-confined aquifers. The Ringold Formation confined aquifer is described only for the 200 Areas Central Plateau and the area near the inactive B Pond system because few wells monitor this aquifer. The upper basalt-confined aquifer is described for much of the Hanford Site, primarily the area south of Gable Butte and Gable Mountain.

2.14.1 Ringold Formation Confined Aquifer

Groundwater quality in the Ringold Formation confined aquifer is monitored because of the potential for downward migration of contaminants from the overlying unconfined aquifer.

The Ringold Formation confined aquifer occurs within fluvial sand and gravel comprising the lowest sedimentary unit of the Ringold formation (unit 9). It is confined below by basalt and above by the lower mud unit (unit 8).

2.14.1.1 Groundwater Flow in the Ringold Formation Confined Aquifer

Figure 2.14-1 presents the potentiometric surface for a portion of the confined aquifer in the Ringold Formation. This map is incomplete and subject to uncertainty because only a few wells monitor this aquifer.

Groundwater in the Ringold Formation confined aquifer flows generally west to east in the vicinity of the 200 West Area and west to east along the south boundary of the aquifer. These flow patterns indicate that recharge occurs west of the 200 West Area (Cold Creek Valley) as well as from the Dry Creek Valley and possibly the Rattlesnake Hills. In the central portion of the aquifer, flow converges on the 200 East Area from the west, south, and east. The 200 East Area is a discharge area for this aquifer, since the confining mud unit (unit 8) is absent. Hydraulic heads indicate a slight upward gradient in this area, which suggests that groundwater discharging from the confined aquifer recharges the overlying unconfined aquifer. After discharging to the unconfined aquifer, the groundwater is interpreted to flow generally southeastward over the top of the confining unit. This is possible because of the southerly dip of the suprabasalt strata.

Groundwater in the Ringold Formation confined aquifer flows generally west to east in the vicinity of the 200 West Area and west to east along the south boundary of the aquifer.

A groundwater mound is present northeast of B Pond as a remnant of past wastewater discharges to this facility. This mound results in southwest flow beneath B Pond, because the May Junction Fault, located east of B Pond, acts as a hydrologic barrier preventing flow to the east (PNNL-12261). A stagnation point occurs south of B Pond, where the flow of water divides with some moving northwest toward the 200 East Area and some moving toward the east or southeast.

The contours on Figure 2.14-1 are similar to the potentiometric surface for the upper basalt-confined aquifer (see Section 2.14.2.1). Hydraulic head and flow patterns in the central portion of the Hanford Site are very similar in both aquifers. The basalt in this area was significantly eroded by late Pleistocene catastrophic flooding (RHO-BWI-LD-5), which facilitates intercommunication between the unconfined and confined aquifers in the Ringold Formation, and the upper basalt-confined aquifer system.

Water levels generally declined in this aquifer during the period from March 2002 to March 2003. Declines ranged from 0.02 to 0.38 meter. The declining water levels are due to the near cessation of wastewater disposal to the soil column at Hanford. The declines were largest in the 200 West Area and the B Pond vicinity. One well in this aquifer along the Rattlesnake Hills showed a water-level increase of 0.10 meter during the same period.

2.14.1.2 Groundwater Quality in the Ringold Confined Aquifer

The 200 Areas Central Plateau and the area near the inactive B Pond system are the two known areas where contamination can migrate from the unconfined aquifer into the confined Ringold aquifer. Groundwater chemistry data for the Ringold Formation confined aquifer are extremely limited because of the lack of deep well completions in the aquifer. During fiscal year 2003, only a few wells were sampled that are completed in the Ringold Formation confined aquifer. Data for constituents of interest are listed in Table 2.14-1.

South and southeast of the B Pond system the major ion composition of groundwater becomes less calcium-bicarbonate type and more of a sodium bicarbonate water. Low tritium concentrations in the area near the 200 Area Treated Effluent Disposal Facility also indicate that groundwater is older in this area and has not been displaced or diluted by wastewater associated with 200 East Area operations (PNNL-13032).

During fiscal year 2003, only a few wells were sampled that are completed in the Ringold Formation confined aquifer. Data indicate that groundwater in this aquifer has not been displaced or diluted by wastewater associated with 200 East Area operations.

Tritium has been discharged intermittently to the ground at the State-Approved Land Disposal Site since late 1995. Tritium concentrations up to 980,000 pCi/L have reached the deepest well (699-48-77C) near this facility during the past few years. Although aquifer tests have indicated confined conditions at depth near this facility, apparently discharged effluent can be driven into these portions of the aquifer if sufficient head is available. An increase in hydraulic head of up to 1 meter above preoperational conditions has resulted from discharges to the State-Approved Land Disposal Site in the immediate vicinity of the facility.

While effluent disposal was occurring at the B Pond system, groundwater mounding increased the driving head and forced groundwater and any associated contamination a limited distance into the confined aquifer. The groundwater moved laterally within the confined aquifer as long as the head remained high from the overlying groundwater mound, although low hydraulic conductivity in the region of the 200 Area Treated Effluent Disposal Facility limited actual flow in a southeasterly direction. Groundwater analyses for fiscal year 2003 at this facility continued to demonstrate isolation of the confined aquifer from disposal activities. Well 699-42-37, which is the well nearest the B Pond system (see Figure 2.11-1 for well locations), typically produces higher concentrations of several major constituents than the more southerly and easterly wells 699-40-36 and 699-41-35, respectively. As an example, sulfate concentration in the January 2003 sample in well 699-42-37 was 26 mg/L, which is 3 to 5 times the average concentrations of sulfate in Treated Effluent Disposal Facility wells 699-40-36 and 699-41-35. The concentration of nitrate for the same period in well 699-42-37 was only 5.7 mg/L, but this is 10 to 20 times the concentrations of this constituent in the other two Treated Effluent Disposal Facility wells.

2.14.2 Upper Basalt-Confined Aquifer

Upper basalt-confined aquifer groundwater quality is monitored because of the potential for downward migration of contaminants from the overlying unconfined aquifer. Contaminants that reach the upper basalt-confined aquifer have the potential to migrate through this aquifer and deeper confined aquifers to areas off the Hanford Site. The upper basalt-confined aquifer is also monitored to assess the potential migration of contaminants onto the Hanford Site from offsite sources. Additional information regarding the potential for contaminants to migrate off the Hanford Site can be found in PNL-10817 and PNNL-14107.

Within the upper basalt-confined aquifer system, groundwater occurs within basalt fractures and joints, interflow contacts, and sedimentary interbeds within the upper Saddle Mountains Basalt. The thickest and most widespread sedimentary unit in this system is the Rattlesnake Ridge Interbed, which is present beneath much of the Hanford Site. Groundwater also occurs within the Levey Interbed, which is present only in the south

portion of the site. An interflow zone occurs within the Elephant Mountain Member of the upper Saddle Mountains Basalt, and also may be significant to the lateral transmission of water. This system is confined by the dense, low-permeability, interior portions of basalt flows and in some places by Ringold Formation silt and clay units overlying the basalt.

Figure 2.14-2 shows the locations of the upper basalt-confined aquifer monitoring wells on the Hanford Site. Most of the wells are completed in the Rattlesnake Ridge Interbed near the 200 East Area in the central part of the Hanford Site. A few wells are completed in the Elephant Mountain interflow zone, the Levey Interbed, or a composite of one or more interbeds and/or interflow zones within the upper Saddle Mountains Basalt.

2.14.2.1 Groundwater Flow in the Upper Basalt-Confined Aquifer

Groundwater flow rates within the Rattlesnake Ridge Interbed have been estimated to be between 0.7 and 2.9 meters per year (PNL-10817). This flow rate is considerably slower than most estimates for the overlying unconfined aquifer system.

Recharge to the upper basalt-confined aquifer system is believed to occur along the margins of the Pasco Basin and results from the infiltration of precipitation and surface water where the basalt and interbeds are exposed at ground surface. Recharge may also occur through the Hanford/Ringold aquifer system in areas where the hydraulic gradient is downward, and from deeper basalt aquifers where an upward gradient is present. The Yakima River may also be a source of recharge. The Columbia River represents a discharge area for this aquifer system in the south portion of the site, but not for the north portion of the site (PNL-8869). Discharge also occurs to the overlying Hanford/Ringold aquifer system in areas where the hydraulic gradient is upward. Discharge to overlying or underlying aquifers in the vicinity of the Gable Butte-Gable Mountain structural area may occur through erosional windows in the basalt.

Groundwater in the upper basalt-confined aquifer system generally flows from west to east across the Hanford Site toward the Columbia River.

Figure 2.14-3 presents an approximation of the March 2003 potentiometric surface for this aquifer system south of Gable Butte and Gable Mountain. The region to the north of Gable Butte and Gable Mountain was not contoured because of insufficient well control. See PNL-8869 for a generalized potentiometric surface map of this area.

South of the Umtanum Ridge/Gable Mountain area, groundwater in the upper basalt-confined aquifer system generally flows from west to east across the Hanford Site toward the Columbia River. In the vicinity of the 200 East Area, the potentiometric surface in Figure 2.14-3 is similar to the potentiometric surface for the Ringold Formation confined aquifer (compare with Figure 2.14-1). The basalt in this area was significantly eroded by late Pleistocene catastrophic flooding, which facilitates aquifer intercommunication. In the vicinity of the 200 East Area and to the immediate north, the vertical hydraulic gradient between the upper basalt-confined aquifer system and the overlying Hanford/Ringold aquifer system is upward. Therefore, it is likely the upper basalt-confined aquifer system currently discharges to the overlying Hanford/Ringold aquifer system in this region.

There is a downward hydraulic gradient from the Hanford/Ringold aquifer system to the upper basalt-confined aquifer in the west portion of the Hanford Site, in the vicinity of the B Pond recharge mound, as well as in the regions north and east of the Columbia River. In the vicinity of B Pond, the vertical head gradient between the unconfined aquifer system and the upper basalt-confined aquifer system has diminished in recent years, but remains downward. In other areas of the Hanford Site, the hydraulic gradient is upward from the upper basalt-confined aquifer to the Hanford/Ringold aquifer system. The May Junction Fault, located east of B Pond and trending north-south, acts as a barrier to groundwater flow in Hanford/Ringold aquifer system (PNNL-12261). It may also impede the movement of water in the upper basalt-confined aquifer system.

Water levels in the upper basalt-confined aquifer declined over most of the site from March 2002 to March 2003, but water levels increased along the Columbia River. The

decline in the 200 East Area and to the immediate north and east (near B Pond) ranged from 0.04 to 0.27 meter over the 12-month period. Water level declines near the 200 West Area ranged from 0.07 to 0.39 meter. These declines are in response to curtailed effluent disposal activities in the 200 Areas and are consistent with water-level declines in the overlying Hanford/Ringold aquifer system. Along the Columbia River in the east part of the site, the water-level increase ranged from 0.07 to 0.23 meter. These increases are consistent with long-term trends in these wells – it is thought that water-levels are rising in this area due to offsite irrigation east of the Columbia River (PNL-8869).

The small amount of contamination detected in the upper basalt-confined aquifer is attributed to areas where confining units of basalt are absent or where wells provided a pathway for migration.

2.14.2.2 Groundwater Quality in the Upper Basalt-Confined Aquifer

The upper basalt-confined aquifer is affected much less from contamination than the overlying unconfined aquifer system. Contamination found in the upper basalt-confined aquifer is most likely attributed to areas where confining units of basalt have been eroded away or were never deposited and where past disposal of large amounts of wastewater resulted in downward hydraulic gradients. In some areas, wells penetrating the upper basalt-confined aquifer provided a downward pathway for contaminant migration. Because of these factors, intercommunication between the aquifers permitted groundwater flow from the unconfined aquifer to the underlying confined aquifer, thereby increasing the potential to spread contamination.

An area of intercommunication between the unconfined and upper basalt-confined aquifer systems was first identified in the northern part of the 200 East Area (RHO-BWI-ST-5, RHO-RE-ST-12 P). Several confined aquifer wells north and east of the 200 East Area have shown evidence of intercommunication with the overlying unconfined aquifer (PNL-10817). Intercommunication between the unconfined and confined aquifers in this region has been attributed to erosion of the upper Saddle Mountains Basalt and a downward hydraulic gradient that resulted from groundwater mounding associated with past wastewater disposal to the ground. However, the groundwater mound has diminished in recent years (see Section 2.14.1).

Approximately 20 wells completed in the upper basalt-confined aquifer system are routinely sampled on the Hanford Site. Most of these wells are sampled every few years, and a few are sampled annually. Most of the upper basalt-confined aquifer wells scheduled for sampling in fiscal year 2003 were cancelled and re-scheduled for early fiscal year 2004 because of project budget cut-backs in fiscal year 2003. During fiscal years 2001 through 2003, 14 samples were collected from 11 wells and analyzed for chemical and radiological constituents. Many of the samples were analyzed for tritium, iodine-129, and nitrate because these constituents are (1) the most widespread in the overlying unconfined aquifer, (2) are some of the most mobile constituents in groundwater, and (3) provide an early warning for potential contamination in the upper basalt-confined aquifer system. Groundwater samples from the upper basalt-confined aquifer were also analyzed for anions (besides nitrate), cations, cyanide, gross alpha, gross beta, gamma-emitters, strontium-90, technetium-99, and uranium isotopes. Data for the primary constituents of interest are listed in Table 2.14-2. A full data set is included in the data files that accompany this report.

Distribution of sample results for selected constituents and wells across the Hanford Site for fiscal years 2001 through 2003 is shown in Figure 2.14-4. Tritium ranged from less than the detection limits near the discharge area in the east-southeast portion of the Hanford Site to 194 pCi/L in the 200 East Area near Gable Mountain. Near the 618-11 burial ground, where a source of tritium has contaminated the unconfined aquifer at high levels, tritium was detected at a concentration of 25.2 pCi/L in the upper basalt-confined aquifer in fiscal year 2001.

In the north part of the 200 East Area, technetium-99 was elevated in the upper basalt-confined aquifer in one well (Figure 2.14-4). The technetium-99 concentration was 1,120 pCi/L in this well (299-E33-12) in 2001; it was not sampled in 2002 or 2003. However this level, which exceeds the drinking water standard (900 pCi/L), is slightly lower than concentrations in the last ~10 years. Contamination in this well is attributed to migration of high-salt waste down the borehole during construction when it was open to both the unconfined and confined aquifers (RHO-RE-ST-12 P). This well is located in the vicinity of a technetium-99 plume in the overlying unconfined aquifer (Section 2.10.1).

Cyanide and nitrate are elevated in an upper basalt-confined aquifer well (299-E33-12) in the north part of the 200 East Area (Figure 2.14-4). However, these co-contaminants are at levels that do not exceed their respective drinking water standards. Concentrations of cyanide and nitrate have not changed significantly at this well in the last ~10 years. Like technetium-99, this contamination is associated with migration of high-salt waste down the borehole during well construction when it was open to both the unconfined and confined aquifers (RHO-RE-ST-12 P). Cyanide and nitrate are co-contaminants with much higher concentrations in the unconfined aquifer in the north part of the 200 East Area.

Some samples collected from upper basalt-confined aquifer wells near Gable Mountain and the 200 East Area were analyzed for iodine-129. These wells are located beneath or near the iodine-129 plume contained within the overlying unconfined aquifer. Iodine-129 was not detected in the upper basalt-confined aquifer during fiscal years 2001 through 2003 (Table 2.14-2).

Table 2.14-2 indicates that the majority of wells showing elevated nitrate in the upper basalt-confined aquifer occur near Gable Mountain and the 200 East Area. Elevated nitrate in the upper basalt-confined aquifer is a hydrochemical indicator of intercommunication with the overlying contaminated unconfined aquifer (RHO-BWI-ST-5; RHO-RE-ST-12 P; PNL-10817). Across the rest of the Hanford Site, nitrate levels in the upper basalt-confined aquifer ranged from less than detectable to ~1 mg/L in fiscal years 2001 through 2003.

Strontium-90 from an upper basalt-confined aquifer well showed a concentration below the minimum detection limits during fiscal year 2001, the most recent year sampled (Table 2.14-2). This well is located near the former Gable Mountain Pond in the central part of the Hanford Site (Figure 2.14-4), where strontium-90 contamination occurs in the overlying unconfined aquifer.

A few samples collected from upper basalt-confined aquifer wells were analyzed for gamma-emitting and uranium isotopes. Gamma-emitting isotopes were not detected in the upper basalt-confined aquifer on the Hanford Site, including the Gable Mountain/200 East Area. Uranium isotopes were not detected in this aquifer in the eastern part of the Hanford Site during fiscal years 2001 through 2003 (Figure 2.14-4).

The primary objective for monitoring groundwater within the upper basalt-confined aquifer is to evaluate the potential for migration of contamination off the south portions of the Hanford Site. Monitoring results indicate that contaminants on the Hanford Site have not migrated through the upper basalt-confined aquifer system to the offsite sample locations south and southeast of the Hanford Site (PNNL-14107; PNL-10817).

Monitoring results indicate that contaminants on the Hanford Site have not migrated through the upper basalt-confined aquifer system to the offsite sample locations.

In summary, cyanide, nitrate, and technetium-99 were elevated in an upper basalt-confined aquifer well in the north part of the 200 East Area. Migration of high-salt waste via the well during its construction is responsible for this contamination. Tritium was detected at very low to undetectable levels, and iodine-129, strontium-90, gamma-emitting isotopes, and uranium isotopes were not detected above the minimum detection limits in the upper basalt-confined aquifer. Contaminants on the Hanford Site have not migrated through the upper basalt-confined aquifer system to offsite sample locations south and southeast of the Hanford Site.

Table 2.14-1. Potential Contaminants in Ringold Confined Aquifer, Fiscal Years 2001 through 2003

Well	Sample Date	Cesium-137 (pCi/L)	Cobalt-60 (µg/L)	Cyanide (mg/L)	Gross Alpha (pCi/L)	Gross Beta (pCi/L)	Iodine-129 (pCi/L)
299-E25-28	04/10/01	NA	NA	NA	NA	NA	2.07 U
299-E25-34	04/10/01	NA	NA	NA	NA	NA	2.18
299-W6-6	01/22/02	NA	NA	NA	0.928 U	9.92	0.036 U
299-W7-3	09/09/03	NA	NA	NA	1.32 U	6.17	-0.048 U
299-W7-6	03/14/01	NA	NA	NA	0.441 U	6.19	NA
699-40-36	07/29/02	NA	NA	NA	1.6 U	4.5	NA
699-41-35	07/29/02	NA	NA	NA	3.9	4.9	NA
699-42-37	07/29/02	NA	NA	NA	2.8	3.5	NA
699-48-77C	07/29/02	NA	NA	NA	1.5 U	3.2	NA

Well	Sample Date	Nitrate (mg/L)	Specific Conductance (µS/cm)	Strontium-90 (pCi/L)	Technetium-99 (pCi/L)	Tritium (pCi/L)
299-E25-28	04/10/01	1.55	215	NA	NA	2,360
299-E25-34	04/10/01	1.02	206	NA	NA	319
299-W6-6	01/22/02	60.2 D	418	NA	NA	268 U
299-W7-3	09/09/03	18.1 D	291	NA	15.8	112 U
299-W7-6	03/14/01	5.31 D	251	NA	NA	262 U
699-40-36	07/29/02	0.204 J	312	NA	NA	2.91 U
699-41-35	07/29/02	0.797	325	NA	NA	0.138 U
699-42-37	07/29/02	6.11	351	NA	NA	1.54 U
699-48-77C	07/29/02	1.12	246	2.3	NA	505,000

D = Analyzed at secondary dilution factor.
J = Estimated value.
NA = Not analyzed.
U = Below detection limit.
Negative values occur when a sample has a lower count than the background.

Table 2.14.2. Potential Contaminants in Upper Basalt-Confined Aquifer, Fiscal Years 2001 through 2003

Well	Sample Date	Cesium-137 (pCi/L)	Cobalt-60 (µg/L)	Cyanide (mg/L)	Gross alpha (pCi/L)	Gross beta (pCi/L)	Iodine-129 (pCi/L)	Nitrate (mg/L)	Specific Conductance (µS/cm)	Strontium-90 (pCi/L)	Technetium-99 (pCi/L)	Tritium (pCi/L)
299-E33-12	06/12/01	1.07 U	4.37 U	29	2.1	330	0.21 U	37.6	341	NA	1,120	194
399-5-2	06/14/01	NA	NA	NA	0.25 U	9.84	NA	0.009 U	351	NA	NA	7.55[a]
699-13-1C	06/28/01	NA	NA	NA	0.83 U	6.82	NA	0.009 U	336	NA	NA	25.2
699-24-1P	11/01/01	NA	NA	NA	4.18	12.3	NA	0.009 U	378	NA	NA	11.5
699-42-E9B	05/15/01	-1.05 U	1.45 U	NA	0.868 U	9.88	0.242 U	0.009 U	420	NA	NA	4.61 U
699-42-E9B	08/09/02	1.64 U	-3.26 U	NA	0.415 U	5.84	-0.0745 U	0.02 U	425	NA	NA	1.2 U
699-42-E9B	08/09/02	-1.07 U	0.228 U	NA	-0.119 U	11.4	0.641 U	0.02 U	425	NA	NA	1.62 U
699-42-E9B	09/10/03	-0.446 U	-0.696 U	NA	0.862 U	6.52	0.0105 U	0.328	425	NA	NA	NA
699-49-57B	06/13/01	NA	NA	NA	2.18	5.29	0.135 U	1.110	301	NA	-5.49 U	21.8
699-52-46A	06/13/01	NA	NA	NA	3.52	8.28	NA	1.640	340	0.18 U	NA	20.6
699-54-34	06/13/01	NA	NA	NA	0.748 U	7.05	NA	16.4 DH	315	NA	NA	15.8
699-56-43	06/14/01	NA	NA	NA	2.94	4.35	NA	4.87 D	321	NA	NA	8.96
699-S11-E12AP	05/29/02	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	18.6
699-S24-19P	07/24/01	NA	NA	NA	NA	NA	NA	1.15	230	NA	NA	43.3 Q
Wells Located South and Southeast of the Hanford Site												
699-ORV-1	11/06/00	NA	NA	NA	0.42 U	5.15	NA	0.102	245	NA	NA	42.70
09N28E04G01	11/06/00	NA	NA	NA	0.07 U	8.87	NA	0.049 U	377	NA	NA	46.50
09N28E06C02	11/06/00	NA	NA	NA	0.82 U	10.20	NA	2.57	534	NA	NA	55.60
10N27E14F03	11/06/00	NA	NA	NA	0.90 U	7.07	NA	0.049 U	282	NA	NA	56.20
10N27E14F03	11/06/00	NA	NA	NA	-0.06 U	8.07	NA	0.049 U	282	NA	NA	56.40
10N28E24R03	10/27/00	NA	NA	NA	0.57 U	12.20	NA	0.049 U	382	NA	NA	34.60
10N29E02Q01	10/27/00	NA	NA	NA	-0.18 U	10.70	NA	0.049 U	456	NA	NA	64.30
10N29E19E01	10/27/00	NA	NA	NA	-0.08 U	11.50	NA	0.049 U	384	NA	NA	56.10

(a) Sample was re-analyzed because batch blank result exceeded criteria.
D = Analyzed at a secondary dilution factor.
H = Analyzed after recommended holding time.
NA = Not analyzed.
Q = Associated quality control sample is out of limits.
U = Below detection limit.
Negative values occur when a sample has a lower count than the background.

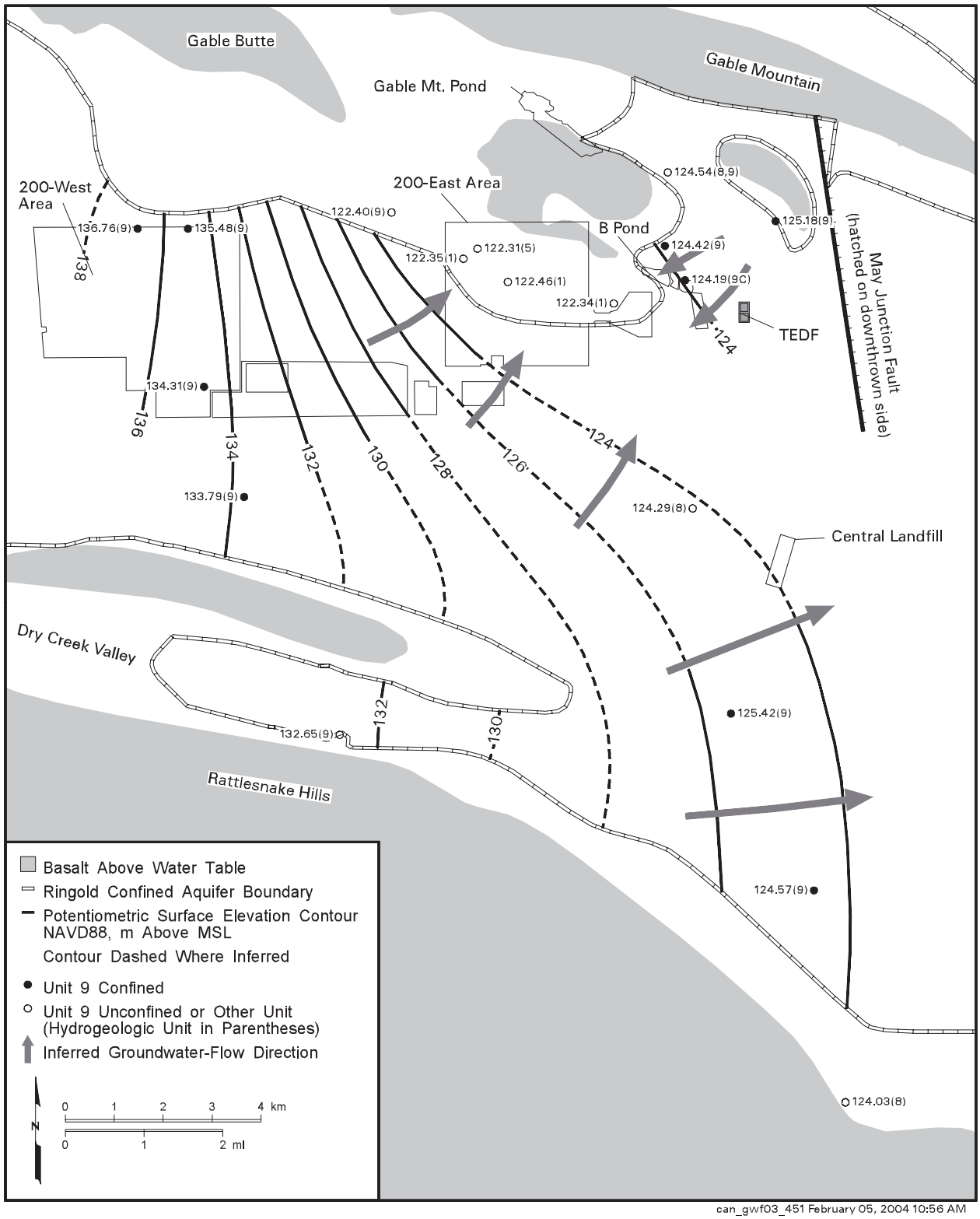

Figure 2.14-1. Potentiometric Surface Map of Ringold Formation Confined Aquifer (Unit 9), Central Hanford Site, March 2003

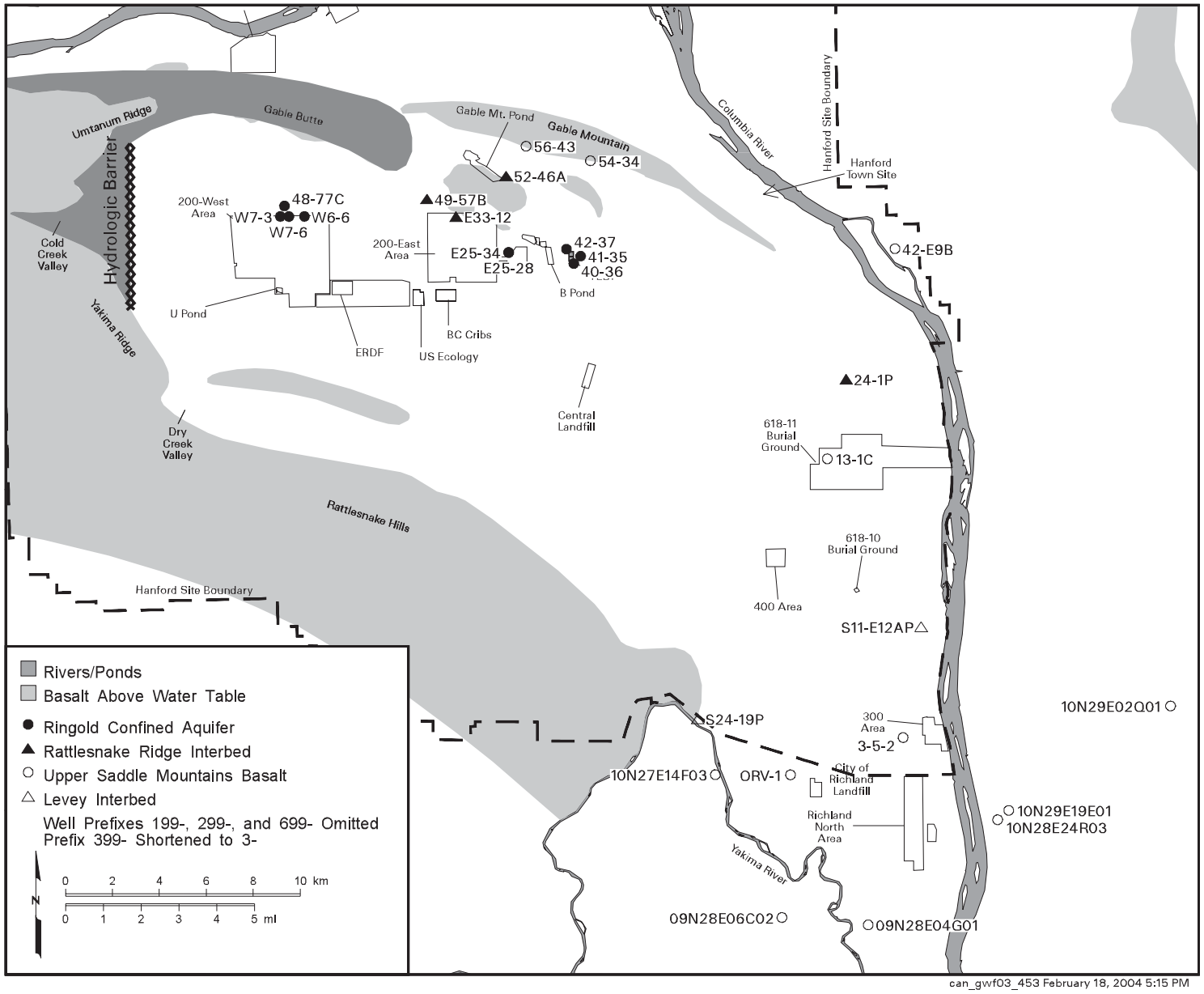

Figure 2.14-2. Groundwater Monitoring Wells Sampled in the Ringold Confined and the Upper Basalt-Confined Aquifers, Fiscal Years 2001 through 2003

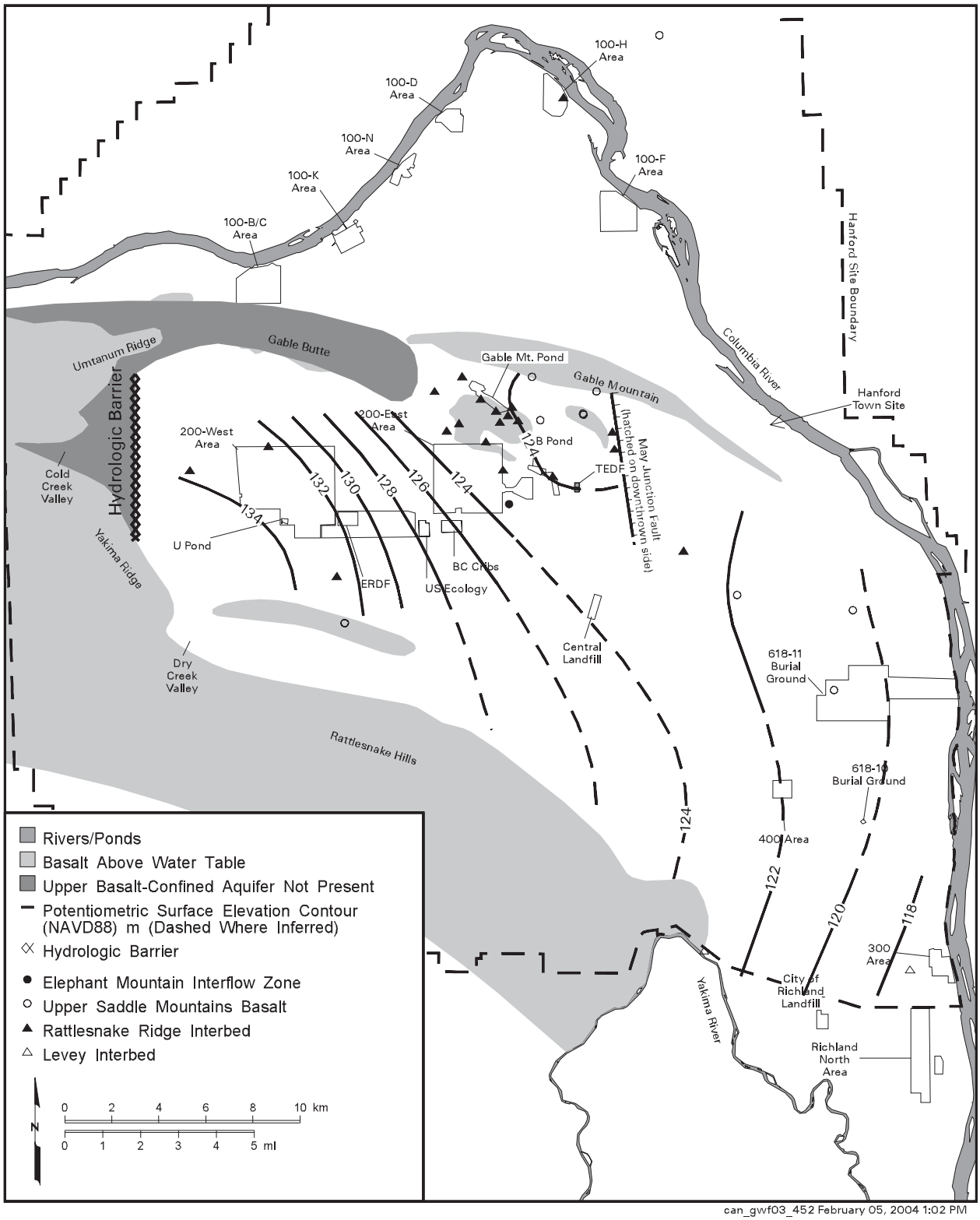

Figure 2.14-3. Potentiometric Surface Map of Upper Basalt-Confined Aquifer System, March 2003

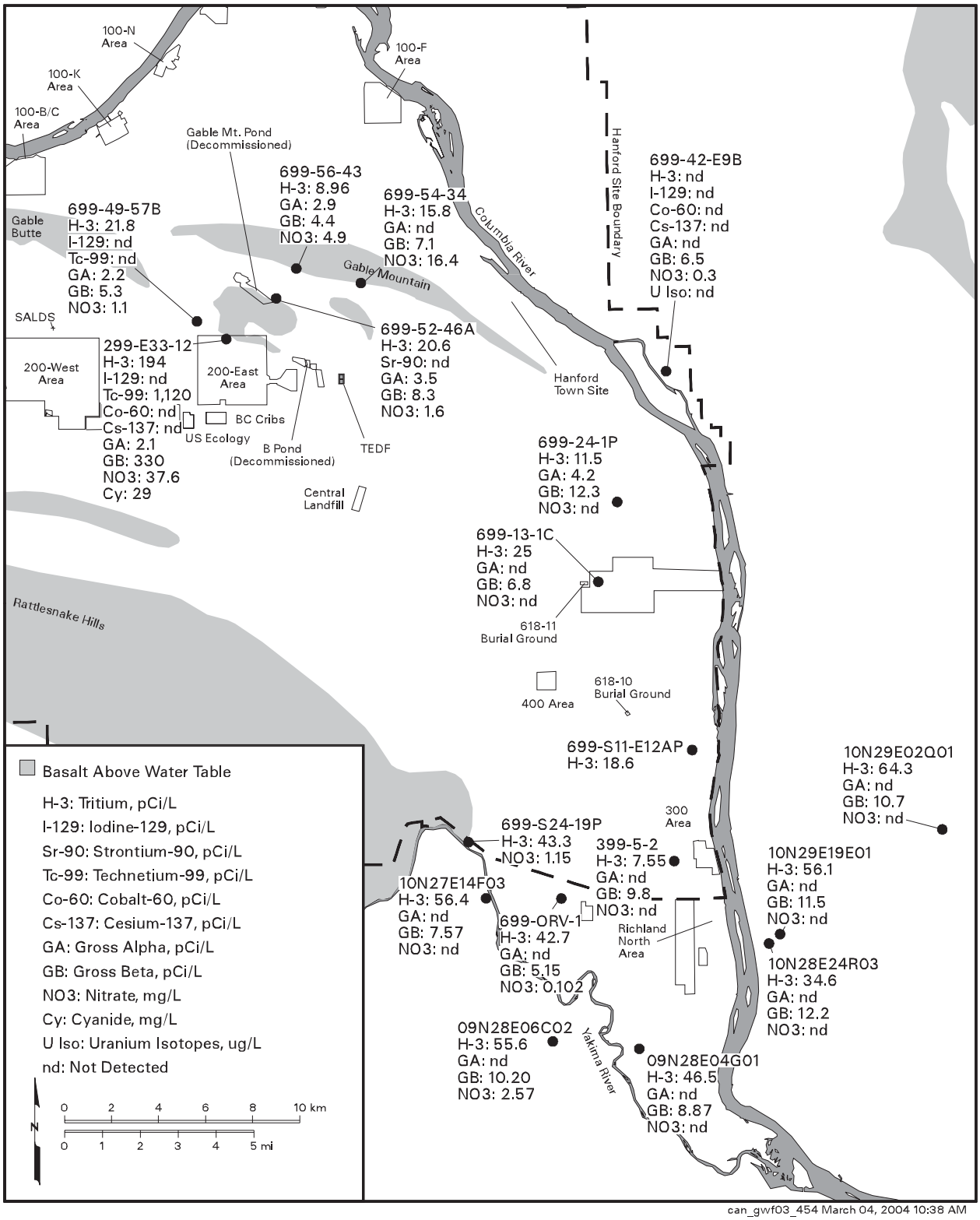

Figure 2.14-4. Distribution of Chemical and Radiological Constituents in the Upper Basalt-Confined Aquifer, Fiscal Years 2001 through 2003