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Pacific Northwest National Laboratory
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Groundwater Chemistry and Hydrogeology of the Upper Saddle Mountains Basalt-Confined Aquifer South and Southeast of the Hanford Site

D. R. Newcomer
E. C. Thornton
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Prepared for the U.S. Department of Energy
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Richland, Washington 99352

Summary

Groundwater monitoring within the upper basalt-confined aquifer is necessary to determine if offsite migration of contamination is occurring across the southern portion of the Hanford Site. During fiscal year 2001, selected offsite wells completed in the upper Saddle Mountains Basalt were sampled in areas bordering the Hanford Site to the south and southeast. Sampling was limited to seven wells, three to the east and southeast of the 300 Area and four near Richland and West Richland. The purpose of the sampling effort was to assess whether constituents analyzed were within the range of natural background concentrations and to evaluate the relationship between groundwater on and outside the Hanford Site.

Groundwater samples analyzed were limited to chemical inorganic and radiological constituents. Dissolved inorganic constituents and parameters analyzed included major anions and cations, trace metals, and pH. Radiological constituents included gross alpha, gross beta, and tritium. Inorganic constituents were analyzed to provide basic information pertaining to water chemistry, including ionic charge balance, aqueous speciation, mineral saturation, and spatial hydrochemical facies distribution. Tritium was analyzed because of its proximity to the onsite tritium plume in the unconfined aquifer. Gross alpha and gross beta were analyzed to provide a general indication of total radioactivity.

Concentrations of all analyzed constituents in the offsite samples were near or within the range of background concentrations. It is concluded that offsite groundwater quality at the upper basalt-confined aquifer sample locations in the area south and southeast of the Hanford Site is not affected by groundwater contamination occurring on the Hanford Site. Although no offsite groundwater contamination was detected, it is recommended that future periodic sampling be conducted to confirm that contamination is not migrating offsite and to obtain additional information related to groundwater flow paths and hydrochemical trends.

Acknowledgments

Several people contributed to the preparation of this report. Technical comments provided by Frank Spane, Stuart Luttrell, Steve Reidel, and Brent Barnett were particularly useful. In addition, the editorial review provided by Launa Morasch is also acknowledged. Thanks are also extended to Dave Lanigan and Chris Newbill for providing graphics support, Eddie Radford for field support in collecting the samples, and laboratory personnel for analyzing the samples. Finally, permission by the well owners to sample the wells is greatly appreciated.

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1.0 Introduction

As part of the U.S. Department of Energy's groundwater monitoring program, Pacific Northwest National Laboratory conducts reconnaissance sampling and analysis of groundwater within the upper confined aquifers of the Saddle Mountains Basalt in areas south and southeast of the Hanford Site. This region was previously identified by Spane and Webber (1995) as a potential pathway for contaminants to migrate off the Hanford Site within the upper basalt-confined aquifer system. During this study, sampling was limited to seven wells, three east and southeast of the 300 Area and four near Richland and West Richland (Figure 1). Sampling was conducted in October and November 2000. Additional groundwater sample data for the upper basalt-confined aquifer system are also included from Spane and Webber (1995) and from recent monitoring activities on the Hanford Site. The purpose of the sampling effort was to assess whether constituents analyzed were within the range of natural background concentrations. Groundwater analytical information also provides a basis for defining hydrochemical trends and groundwater flow paths.

The hydrochemical and radiological sample data can be used to provide hydrologic interpretative information for the upper basalt-confined aquifer system. This information, together with other hydrologic information (e.g., hydraulic properties, potentiometric surface), can be used for evaluating groundwater sources, regional groundwater flow patterns, residence times, rock/water reaction, and intercommunication with overlying aquifers. These evaluations are important for assessing the potential for contaminants to migrate off the Hanford Site through the upper basalt-confined aquifer system.

This report presents the sampling and analysis results of offsite groundwater samples collected from the upper Saddle Mountains Basalt. The hydrogeology of the upper Saddle Mountains Basalt is described in Section 2.0. This section includes geologic cross sections within the study area and background information pertaining to hydraulic head conditions and the potential for offsite migration. Section 3.1 provides criteria used for selecting offsite wells for sampling and general well information. A summary of groundwater sampling and analysis methods is provided in Section 3.2. An evaluation of the groundwater chemistry of the upper basalt units is presented in Section 4.0. The summary and conclusions are given in Section 5.0, and recommendations for future work are provided in Section 6.0. References cited in this report are listed in Section 7.0. A summary and log inventory of wells, sampling procedures, general field parameters, and groundwater sample reports are included in the appendices.

2.0 Hydrogeology

Saddle Mountains Basalt is the uppermost formation of the Columbia River Basalt Group occurring within the offsite study area. This basalt unit reaches a maximum thickness of approximately 290 meters (950 feet) in Pasco Basin (DOE 1988, vol. 2). In the area south and southeast of the Hanford Site, the Saddle Mountains Basalt is approximately 120 to 240 meters (400 to 800 feet) thick (Myers and Price 1979, 1981; DOE 1988, vol.1). Saddle Mountains Basalt consists of five members, each of which may

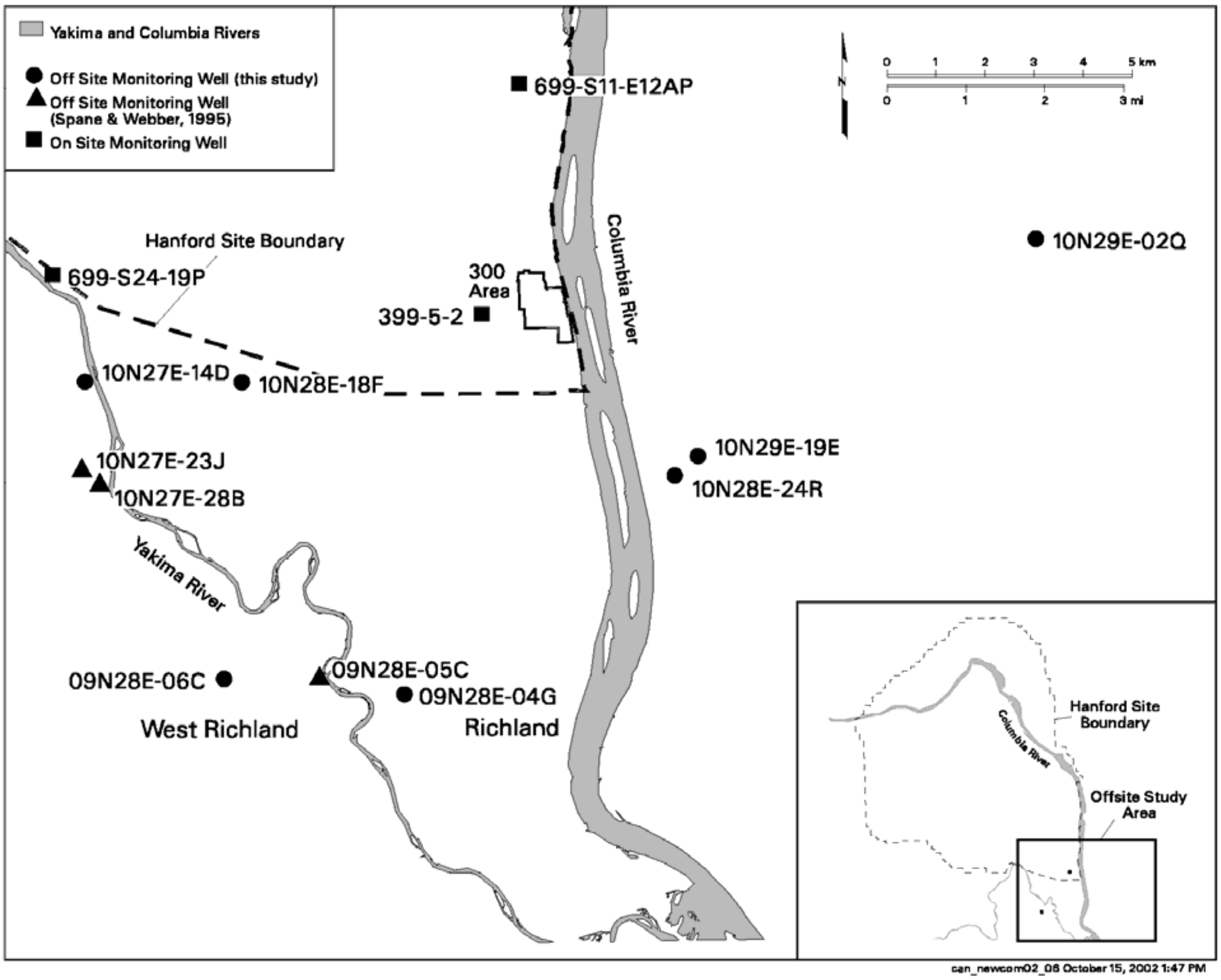

Figure 1. Well Sample Locations

contain one or more basalt flows, in the study area. The five members are, stratigraphically from top to bottom, the Ice Harbor, Elephant Mountain, Pomona, Esquatzel, and Umatilla.

Sedimentary interbeds, collectively a part of the Ellensburg Formation, are inter-layered between many of the basalt flows in the Saddle Mountains Basalt. The Ellensburg Formation is made up of fluvial and lacustrine sediments mud, sand, and gravel that were deposited between intervening volcanic eruptions. The Ellensburg Formation, along with porous basalt flow-tops and flow-bottoms, form basalt-confined aquifers that extend across the area south and southeast of the Hanford Site (DOE 1988, vol. 2). These aquifers are intercalated with confining units consisting of basalt flow interiors. The Levey and Rattlesnake Ridge interbeds and permeable zones between basalt flow contacts in the Elephant Mountain and Ice Harbor Members form the uppermost basalt-confined aquifer system in the southern part of the Hanford Site (Spane and Webber 1995).

2.1 Geologic Cross Sections

Two geologic cross sections, oriented approximately from west to east (A – A') and southwest to northeast (B – B') through the sampled wells, are presented in Plate 1. The inset to Plate 1 shows the locations of the cross sections, and Appendix A provides a summary and log inventory of wells used for the cross sections. The primary purpose of these cross sections is to show the upper Saddle Mountains Basalt and its general hydrogeologic relationships with respect to surface topography and major surface water features (e.g., the Columbia River). These are important for evaluating groundwater chemistry and potential migration of contaminants within the upper basalt-confined aquifer system.

The cross sections depict the well locations, geologic contacts, elevation above mean sea level, and general well completion information. A scale of 2.5 centimeters (1 inch) equals 610 meters (2,000 feet), as per the U.S. Geological Survey's 7.5 Minute Series (Topographic) Quadrangles, with a vertical exaggeration of 40 times was used. Interpretation of the geologic contacts was based on the drilling logs of selected wells and by projecting from off-line wells. Geologic, top of basalt contour, structural cross section, and stratigraphic correlation maps from Myers and Price (1979) and Reidel and Fecht (1994), and hydrogeologic cross sections presented in Liikala (1994) also were used as input in the interpretation.

The cross sections depict an undulating basalt surface that generally conforms to the topography of the land surface. In cross section A – A', the basalt surface slopes gently downward from the Horn Rapids Structure in the west to the Pasco Syncline. From the axis of the syncline, it slopes gently upward to the east. The basalt crops out along the eastern face of the Horn Rapids Structure. Cross section B – B' depicts a somewhat more variable surface, especially to the southwest, where the section transects the Red Mountain Structure. Transected features include the Red Mountain Structure, the Lost Lake Syncline, and the Horn Rapids Structure. Thrust faults that generally dip to the southwest occur along the east flanks of the Red Mountain and Horn Rapids structures. Continuing to the northeast, a much gentler slope is noted through the Pasco Syncline. Outcrops are evident on the northeastern sides of the anticlines. While it is certain that the uppermost basalt in this area is that of the Saddle Mountains Basalt Formation within the Columbia River Basalt Group, individual flows within the upper Saddle Mountains Basalt were identified only where information is available.

2.2 Hydraulic Head Conditions

Figure 2 shows the most comprehensive Hanford Site potentiometric map of the upper basalt-confined aquifer system (Spane and Raymond 1993; Spane and Webber 1995). Hydraulic head values used to construct this map were determined from water levels measured in wells that represent the Rattlesnake Ridge interbed, Elephant Mountain interflow contact zone, Levey interbed, and with less reliance, the top of the upper Saddle Mountains Basalt. Figure 2 shows that few hydraulic head measurements were taken in the upper basalt-confined aquifer system in offsite areas to the south and southeast.

On the Hanford Site, groundwater in the upper basalt-confined aquifer system flows southeast from the Central Plateau region (i.e., near the 200-East Area) to the southeastern part of the site. The inferred lateral groundwater flow pattern indicates flow toward the Columbia River in the southeastern portion of

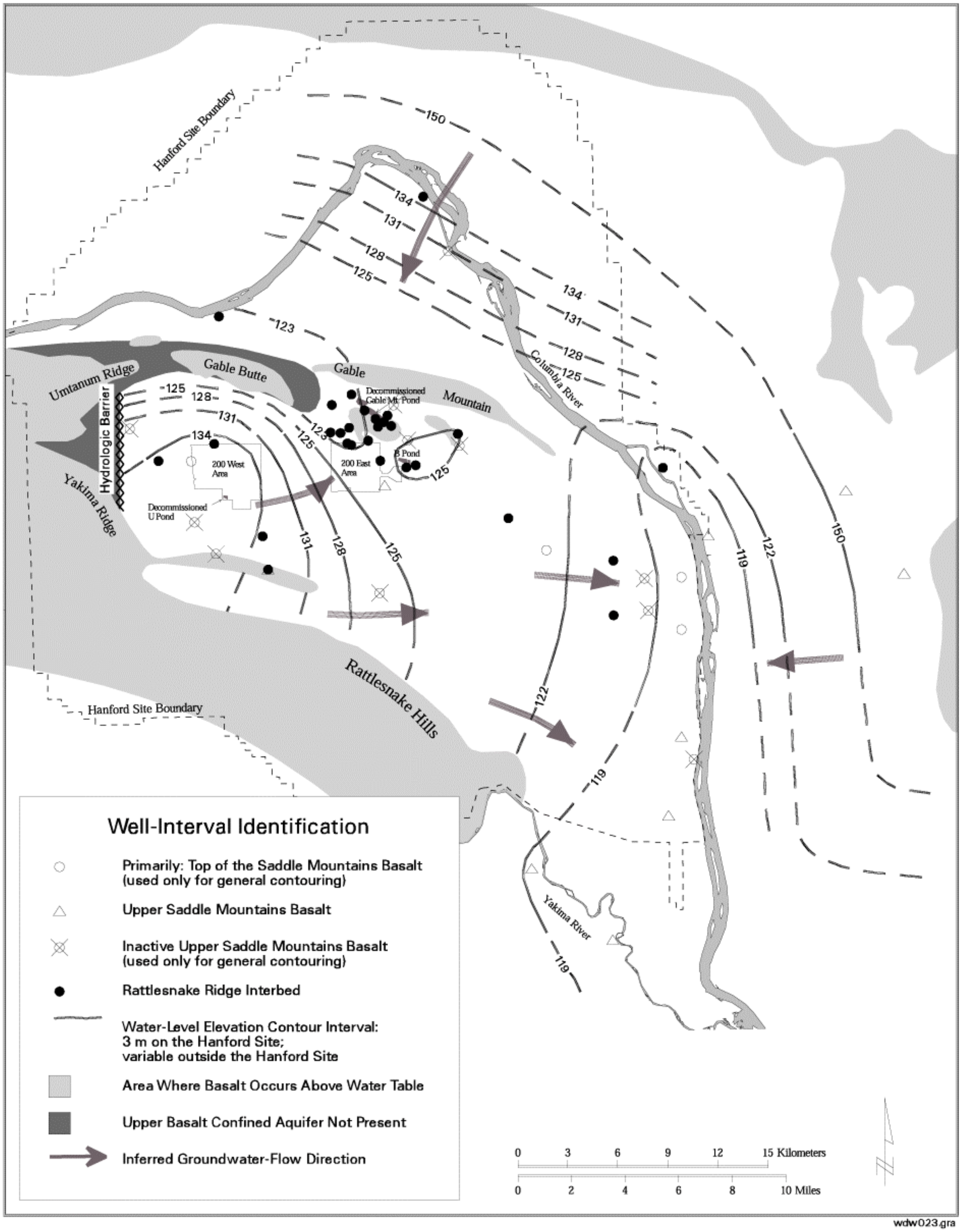

Figure 2. Potentiometric Map of the Upper Basalt-Confined Aquifer System, 1993 (adapted from Spane and Raymond 1993)

the Hanford Site and adjacent offsite areas to the east. The flow patterns indicate that the Columbia River is a line-sink discharge area for the upper basalt-confined aquifer system in these areas.

The right-hand portion of the map (see Figure 2) infers high hydraulic heads and an increased hydraulic gradient east of the Columbia River. Hydraulic heads within the upper basalt-confined aquifer system east of the Columbia River are generally higher than heads on the Hanford Site. Hydraulic heads increase from 119 meters (390 feet) above mean sea level near the river to over 150 meters (492 feet) above mean sea level approximately 10 kilometers (6.2 miles) east of the river (see Figure 2). In comparison, onsite hydraulic heads range from 119 to 134 meters (390 to 440 feet) above mean sea level over most of the Hanford Site. High heads are associated with recharge effects from applied irrigation and canal seepage related to agricultural activities (Spane and Raymond 1993; Drost et al. 1997).

2.3 Potential for Offsite Migration

The potential for offsite migration of contaminants exists through the upper basalt-confined aquifer system, which lies within the upper Saddle Mountains Basalt. Contaminants have been found in this confined aquifer system in the central part of the Hanford Site. Two of the potential offsite migration pathways identified for contamination within the upper basalt-confined aquifer system are across the eastern-southeastern and the southern boundaries of the Hanford Site (Spane and Webber 1995). The potential for contaminants migrating across the eastern-southeastern boundary is considered low for the following reasons:

- lateral groundwater flow velocities along this path are low
- indications suggest that the Columbia River represents a major line-sink discharge area for the upper basalt-confined aquifer system
- high hydraulic head conditions occur east of the river.

The lateral groundwater flow velocity within the upper basalt-confined aquifer system has been estimated to be 0.7 to 2.9 meters per year (2.3 to 9.5 feet per year) by Spane and Webber (1995), based on hydraulic properties of the Rattlesnake Ridge interbed. This is consistent with an average areal groundwater flow velocity of 2.2 meters per year (7.2 feet per year) (also reported in Spane and Webber [1995]) that was estimated using groundwater ages determined from carbon isotopic information.

Hydraulic heads within the upper basalt-confined aquifer system east of the Columbia River are generally higher than heads on the Hanford Site. Hydraulic heads increase from 119 meters (390 feet) above mean sea level near the river to over 150 meters (492 feet) above mean sea level approximately 10 kilometers (6.2 miles) east of the river (see Figure 2). In comparison, onsite hydraulic heads range from 119 to 134 meters (390 to 440 feet) above mean sea level over most of the Hanford Site.

The likelihood for contaminants migrating across the southern boundary of the Hanford Site remains highly uncertain because of a lack of hydrogeologic and hydrochemical data for the upper basalt-confined aquifer system in this area. However, urban development and agricultural activity continues to increase in these areas. As a result, groundwater production from the upper basalt-confined aquifer system is increasing in response to the demand to meet agricultural, municipal, and domestic needs.

The first comprehensive investigation of the Hanford Site upper basalt-confined aquifer system was documented in Spane and Webber (1995). This comprehensive investigation integrated hydrochemical results with hydraulic head conditions (Spane and Raymond 1993) and hydraulic properties (Spane and Vermeul 1994). Hydrogeologic characterization data were also evaluated for the upper basalt-confined aquifer system in the southern part of the Hanford Site (Thorne 1998). A limited amount of onsite sampling of the upper basalt-confined aquifer system is routinely conducted and reported in annual groundwater reports (e.g., Hartman et al. 2002).

This study is a continuation of work presented in Spane and Webber (1995). Spane and Webber (1995) reported hydrochemical and isotopic results for three offsite wells south of the Hanford Site near the Yakima River. Our report focuses on an area outside the Hanford Site to the south and southeast and contains hydrochemical data that can serve as additional baseline information for the upper basalt-confined aquifer system. Because of our modest sampling effort, only a limited number of constituents were analyzed.

3.0 Methods and Limitations

Provided below is a summary of the approach used for selecting wells that were sampled in this study and the procedures associated with groundwater sampling and analysis.

3.1 Well Selection

Selection of offsite sample wells was based on well location, well completion information, the availability of well information, the ability to contact the current well owner, and accessibility. Approximately 400 well logs from a portion (~78 square kilometers [~30 square miles]) of the area south and southeast of the Hanford Site were evaluated. Driller's logs of the sample wells were provided by the Washington State Department of Ecology offices in Yakima and Spokane. Well information also was obtained from U.S. Geological Survey database files, Tacoma, Washington. Wells that were completed solely within the upper Saddle Mountains Basalt over similar depths below the top of basalt were selected for sampling. Selected wells were visited to verify the correct identity of the well and to ensure that the well was accessible for collecting a sample. Based on these criteria, a small subset of wells was selected for sampling.

The selected offsite wells were not designed for groundwater monitoring, but are currently in use for drinking water supply, irrigation, and fire suppression. The offsite well completions (e.g., well seals) were not constructed to current monitoring well construction standards (WAC 173-160) as required for the onsite monitoring wells. Because of this, the potential exists for commingling of upper basalt-confined aquifer groundwater with overlying unconfined groundwater via the well annulus during sample collection. For this study, it is assumed that the component of unconfined groundwater mixing in the sample is negligible.

General well information is presented in Appendix A. Table A.1 shows the well numbers, coordinates, geologic unit, surface elevation, top of basalt elevation, depth of open sample interval, and elevation of open sample interval. The first seven wells listed in Table A.1 were sampled and the additional wells listed were used in developing the geologic cross sections. Well numbers provide the location of the wells according to the official rectangular public-land survey (e.g., 09N28E-04G) or to the Hanford Site well naming system (e.g., 699-S31-1). Rectangular public-land survey numbers are in an abbreviated form that refers to the township, range, section, and a letter indicating the 16.2-hectare (40-acre) subdivision of the section. Coordinates of the seven sample wells were measured in the field using a hand-held Global Positioning System unit. Measured coordinates were recorded in Universal Transverse Mecator grid system (NAD 83) coordinates and then converted to Washington State plane coordinates, south zone (NAD 83) using the software called Corpscon (version 5.11.08, U.S. Army Corps of Engineers 2001). Ground surface elevations were taken from U.S. Geological Survey files or were estimated from 7.5-minute U.S. Geological Survey topographical maps. The sample interval for the wells sampled consists of an open hole or a perforated interval.

The sampled wells represent various depths within the upper 73 meters (239 feet) of the Saddle Mountains Basalt geologic unit. Because of a lack of detailed geological log information for many of the sampled wells, no effort was made to correlate the sampled interval with specific basalt members and/or sedimentary interbeds within the upper Saddle Mountains Basalt. Available well logs presented in Appendix A indicate that most of the sampled wells represent the upper basalt-confined aquifer system referred to in Spane and Webber (1995).

3.2 Groundwater Sampling and Analysis

Sampling of offsite wells followed procedures similar to those for sampling Hanford Site wells. However, slight modifications in the sampling procedure were necessary (see Appendix B). Appendix B describes the sampling procedure followed in this study and field measured parameters associated with sampling the offsite wells.

All groundwater samples collected in this study were analyzed in accordance with procedures used for onsite wells sampled for the U.S. Department of Energy's groundwater monitoring project at the Hanford Site, which are described in Hartman (2000).

4.0 Groundwater Chemistry

Groundwater sample analyses were limited to determination of chemical inorganic and radiological constituents. Chemical inorganic constituents included dissolved trace metals and major cations and anions. Radiological constituents included gross alpha, gross beta, and tritium. The chemical inorganic and radiological constituents are listed in the Hanford Environmental Information System (HEIS) database. The sampling procedure, general parameters measured during sample collection, and well numbers cross referenced to the HEIS database well numbers are presented in Appendix B.

4.1 Chemical Inorganic Constituents

Results of the analyses for the major inorganic constituents are presented in Table 1. The analytical results for the groundwater samples can be assessed for reliability by determining if the equivalents of the major cations and anions are approximately equal (Hem 1985). Charge balance error can be calculated by the following relationship:

$$\%\text{error} = \frac{\Sigma \text{ equivalents of cations} - \Sigma \text{ equivalents of anions}}{\Sigma \text{ equivalents of cations} + \Sigma \text{ equivalents of anions}} \times 100$$

Water analyses are normally considered acceptable if the charge balance error is less than 5% (Freeze and Cherry 1979). The charge balance error for the analyses associated with this study varied from -0.66 to 3.46%.

The concentrations of major inorganic constituents and pH and alkalinity values reported in Table 1 are typical of regional groundwater chemistry within the upper basalt-confined aquifer system. Calculated total dissolved solids were less than 400 mg/L, which is also typical (Spane and Webber 1995). Nitrate concentrations of the wells sampled ranged from nondetect (<0.049 mg/L, N as NO_3) to 2.57 mg/L and are significantly less than the 45-mg/L drinking water standard. Nitrate concentrations of groundwater samples collected from upper basalt-confined aquifers on the southern part of the Hanford Site are typically also low to nondetect (Poston et al. 2001). Analyses of Yakima River samples are also included in Table 1 for comparison to the groundwater samples.

The dissolved trace metal analyses are presented in Table 2. The results for the trace metals yielded several trace metal concentrations found at insignificant or undetectable levels. However, the secondary drinking water standard concentrations were exceeded for aluminum and manganese in several samples. The trace metal concentrations in Table 2 are similar to those reported in Spane and Webber (1995) for the upper basalt-confined aquifer system.

Speciation and saturation calculations were performed for the groundwater analyses using the MINTEQA2 geochemical equilibrium model (Allison et al. 1991). This evaluation indicated that all analyses for calcite were close to saturation. This is consistent with the observation that calcareous cement and caliche is generally an important constituent of sediment in the vicinity of the Hanford Site. Silica was not analyzed in the groundwater samples collected for this study since this analysis is not routinely performed. Detection limits for aluminum and iron by inductively coupled plasma emission spectroscopy (ICP) with optical detection are too high to be useable; thus, an assessment cannot be made of the degree of saturation of the groundwater samples with respect to aluminosilicate and iron oxide mineral phases. The groundwater environment in the upper basalt-confined aquifer system ranges from

Table 1. Dissolved Major Inorganic Constituents, pH, and Estimated Total Dissolved Solids Content

Well Number/ Sample Location	Sample Date	pH	Calculated TDS	Anions					Cations				
				Chloride (mg/L)	Fluoride (mg/L)	Nitrate (mg/L, N as NO_3)	Total Alkalinity (mg/L as $CACO_3$)	Sulfate (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Potassium (mg/L)	Sodium (mg/L)	Charge Balance (% Error)
09N28E-04G	11/6/00	8.16	329	6.7	1.2	<0.049 (U)	184	<0.11 (U)	8.41	1.89	10.0	76.0	2.54
09N28E-06C	11/6/00	7.65	397	15.4	0.44	2.57	146	93.1	43.4	21.4	10.1	32.5	2.23
10N27E-14D	11/6/00	7.86	232	2.8	0.65	<0.049 (U)	118	25.0	21.7	11.1	5.95	20.7	0.93
10N27E-14D[a]	11/6/00	7.86	224	2.7	0.61	<0.049 (U)	118	21.7	20.7	10.6	3.78	20.2	-0.66
10N28E-18F	11/6/00	7.64	206	3.8	0.65	0.102	120	0.75	17.3	6.25	5.68	25.4	1.37
10N28E-24R	10/27/00	8.29	322	12.9	1.8	<0.049 (U)	172	<0.11 (U)	5.41	1.85	14.2	75.5	2.14
10N29E-02Q	10/27/00	7.95	339	8.0	0.50	<0.049 (U)	122	87.8	34.6	17.8	8.09	33.2	3.46
10N29E-19E	10/27/00	8.49	323	12.0	1.7	<0.049 (U)	174	<0.11 (U)	6.56	2.23	13.1	75.1	2.55
399-5-2	6/14/01	8.21	286	8.7	1.3	<0.009 (U)	159	<0.029 (U)	14.1	5.11	8.16	55.2	3.35
699-S11-E12AP	5/16/00	8.05	318	14.2	0.68	0.62	180	<0.11 (U)	22.3	6.11	7.08	47.5	-2.31
699-S24-19P	8/31/98	7.11	217	6.8	0.18	2.48	107	19.7	28.2	9.26	3.77	16.0	2.98
Yakima River[b]	1/13/00	8.1	140	4.4	0.1	4.1	74	8.3	16.3	6.17	1.54	9.1	-2.52
Yakima River[b]	1/11/01	8.1	207	6.5	0.2	6.29	106	13.1	25.2	9.51	2.6	14.4	0.86
Yakima River[b]	4/17/01	9.1	211	7.3	0.2	2.10	111	14.4	24.7	9.17	2.85	15.1	-0.94
Yakima River[b]	6/13/01	8.2	188	5.8	0.2	3.57	96	13.9	22.9	9.04	2.5	13.2	1.72
Yakima River[b]	9/6/01	8.3	215	6.9	0.2	3.82	112	15.4	24.6	9.66	2.76	14.7	-1.67
Background[c]		7.78	251	7.05	0.49	5.68	119	27.1	36.5	11.2	4.58	13.4	2.75

(a) Duplicate sample.
(b) Data from http://waterdata.usgs.gov.
(c) Refers to the geometric mean natural background concentration in the Hanford Site unconfined aquifer, reported in DOE (1997).
TDS = Total dissolved solids.
U = Not detected.

Table 2. Dissolved Trace Metals

Well Number	Sample Date	Trace Metals (µg/L)														
		Ag	**Al**	**Ba**	**Be**	**Cd**	**Cr**	**Co**	**Cu**	**Fe**	**Mn**	**Ni**	**Sb**	**Sr**	**V**	**Zn**
09N28E-04G	11/6/00	U	U	53.7	U	U	U	U	U	U	35.4	U	U	55.4	U	U
09N28E-06C	11/6/00	U	U	39.6	U	U	U	U	U	U	11.3	U	U	331	U	24.6
10N27E-14D	11/6/00	U	U	38.7	U	U	U	U	U	83.7	63.6	U	U	146	U	162
10N27E-14D (a)	11/6/00	U	U	37.3	U	U	U	U	U	60.2	60.3	U	U	139	U	183
10N28E-18F	11/6/00	U	U	72.8	U	U	U	U	9.9	80.1	26.7	U	U	150	U	U
10N28E-24R	10/27/00	U	U	33.5	U	U	U	U	U	U	7.5	U	U	41.4	U	6.6
10N29E-02Q	10/27/00	U	U	33.9	U	U	U	U	7.8	143	34.9	U	U	259	U	35.8
10N29E-19E	10/27/00	U	U	34.0	U	U	U	U	U	U	18.1	U	U	45.9	U	31.5
399-5-2	6/14/01	U	U	83.3	U	U	U	U	U	140	36.7	U	U	104	U	7.8
699-S11-E12AP	5/16/00	U	U	52.8	U	U	U	U	U	98	52.2	U	U	110	15.5	5.5
699-S24-19P	7/24/01	U	U	33.9	U	U	8.1	U	U	27.0	53.6	U	U	106	U	11.7
699-S24-19P	8/31/98	U	U	47.5	U	U	U	U	U	219	197	U	U	124	U	14.0
Background[(b)]		3.42	1.23	31.2	0.583	0.274	0.893	0.274	0.332	55.3	2.22	0.686	23.8	158	1.83	1.27
Reporting Limit		10.0	200	200	5.0	5.0	10.0	50.0	25.0	100	15.0	40.0	60.0	50.0	20.0	20.0
Minimum Detection Limit		7.4	85.2	7.3	0.60	2.8	7.5	4.6	6.4	56.6	1.9	13.3	39.1	1.8	6.9	4.2

(a) Duplicate sample.
(b) Refers to the geometric mean natural background concentration in the Hanford Site unconfined aquifer, reported in DOE (1997).
U = Not detected.

moderately oxidized to slightly reduced in character (DOE 1988), although no oxygen concentration or pH measurements were obtained in this study. Measurements of dissolved oxygen obtained from the unconfined aquifer on the Hanford Site during routine sampling activities generally range from about 2 to 10 mg/L. Reduced conditions are known to exist in the deeper basalt aquifers at the Hanford Site (Dill et al. 1986). It is well known that groundwater systems evolve towards a more reduced chemical state as residence time increases (Freeze and Cherry 1979).

Although the number of offsite wells sampled was low, an evaluation of water chemistry as related to defining hydrochemical facies was undertaken based on major cation and anion chemistry of the groundwater. A Piper trilinear diagram that illustrates the variation in major element chemistry is presented in Figure 3. Data from Table 1 and Spane and Webber (1995) were used for the diagram. Note in particular that the water chemistry appears to evolve along two lines, one from a calcium/magnesium groundwater type toward a sodium-rich type and the other from HCO_3 toward SO_4. The direction of these trends are consistent with increasing specific conductance and total dissolved solid content of the samples and reflect increased rock/water interaction. Measured pH values also generally increase in the samples along these trends, again consistent with the silicate hydrolysis reactions associated with rock/water interaction processes (Hem 1985).

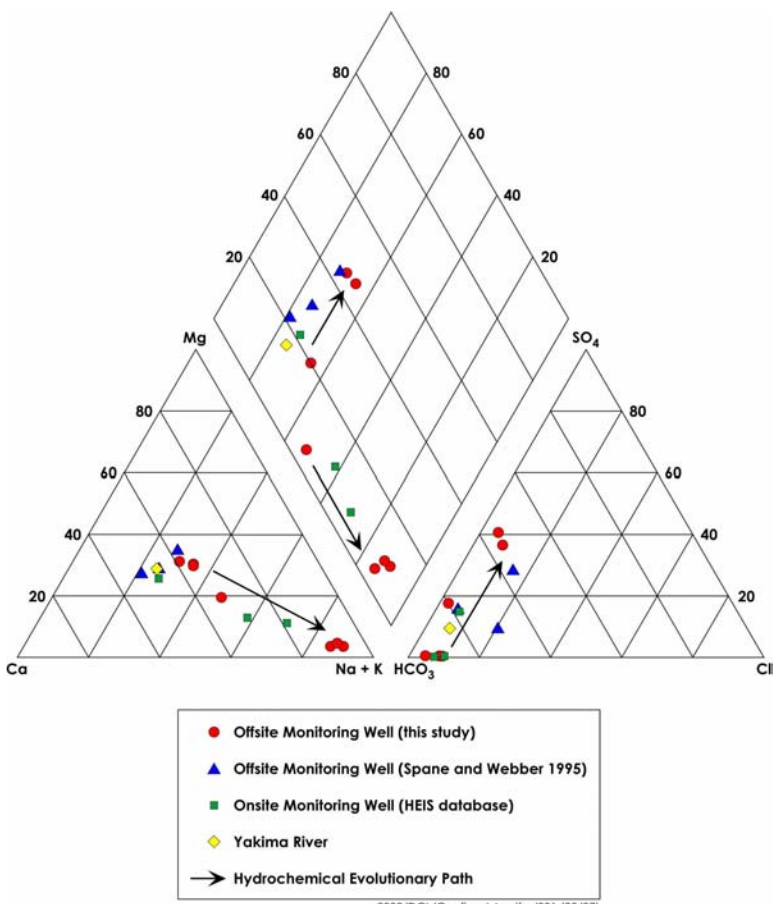

Figure 3. Piper Trilinear Diagram

The major processes responsible for these hydrochemical trends can be summarized using generalized reactions associated with movement of groundwater along flow paths (DOE 1988, vol. 2). Initially, precipitation entering the soil will be slightly acid owing to dissolution of carbon dioxide from the atmosphere, as illustrated by the reaction:

$$CO_{2(g)} + H_2O = H^+ + HCO_3^-.$$

Dissolution of calcite ($CaCO_3$) in sediments may then occur:

$$CaCO_3 + H^+ = Ca^{2+} + HCO_3^-$$

which results in an increase in pH and the calcium and bicarbonate content of the water.

If gypsum ($CaSO_4$) is encountered, the sulfate content of the groundwater will increase:

$$CaSO_4 \cdot 2H_2O = Ca^{2+} + SO_4^{2-} + 2H_2O.$$

The latter reaction is a plausible explanation of the HCO_3 to SO_4 trend present in Figure 3, since gypsum is probably present in small amounts in the vadose zone sediments of the area.

The increase in sodium associated with several of the samples appears to reflect chemical evolution related to basalt/water interaction. In particular, hydrolysis of volcanic glass and feldspar and formation of clay and zeolites, plus associated ion exchange reactions, will tend to consume calcium and magnesium, while releasing sodium and potassium (DOE 1988, vol. 2; Spane and Webber 1995; Thorne 1998). Silicate hydrolysis reactions also result in an increase in pH owing to the consumption of the hydrogen ion. These chemical changes are particularly evident in samples from wells 09N28E-04G, 10N28E-24R, and 10N29E-19E, which are elevated in sodium and potassium, depleted in calcium and magnesium, and have pH values well above 8.

The spatial distribution of hydrochemical facies can be presented by superimposing Stiff diagrams on a map of well locations, as shown in Figure 4. While a limited number of samples are associated with this study, several observations can be made. Samples from wells 09N28E-04G, 10N29E-19E, and 10N28E-24R are sodium-enriched types, and thus, represent a more evolved water chemistry (i.e., longer residence times and hence increased interaction with basalt). It is inferred that groundwater is flowing from the upper basalt-confined aquifer system in these areas and discharging into the Columbia or Yakima rivers (see also Thorne 1998). The chemistry of the water sample from well 10N27E-14D is a less evolved example of a Ca,Mg-HCO_3 type and suggests more recent local recharge from surface water (e.g., Yakima River water). Sample 10N28E-18F is intermediate in composition between these two end members.

Samples from wells 10N29E-02Q and 09N28E-06C are very similar and are evolved groundwater chemistries of a Ca, Mg-SO_4 type (Figure 4). It is suggested that these chemistries are related to irrigation recharge associated with agricultural activities, where sulfate is leached from vadose zone sediments as irrigation water infiltrates downwards. The sulfate-enriched water type appears to be rare on the Hanford

Site. However, sulfate enrichment of unconfined aquifer groundwater has been observed in association with recent effluent discharge activities on the Hanford Site (Thornton 1997). Increasing levels of sulfate have also been observed in some wells in the central part of the Hanford Site, where water levels are decreasing and infiltration from the vadose zone may be affecting water chemistry.

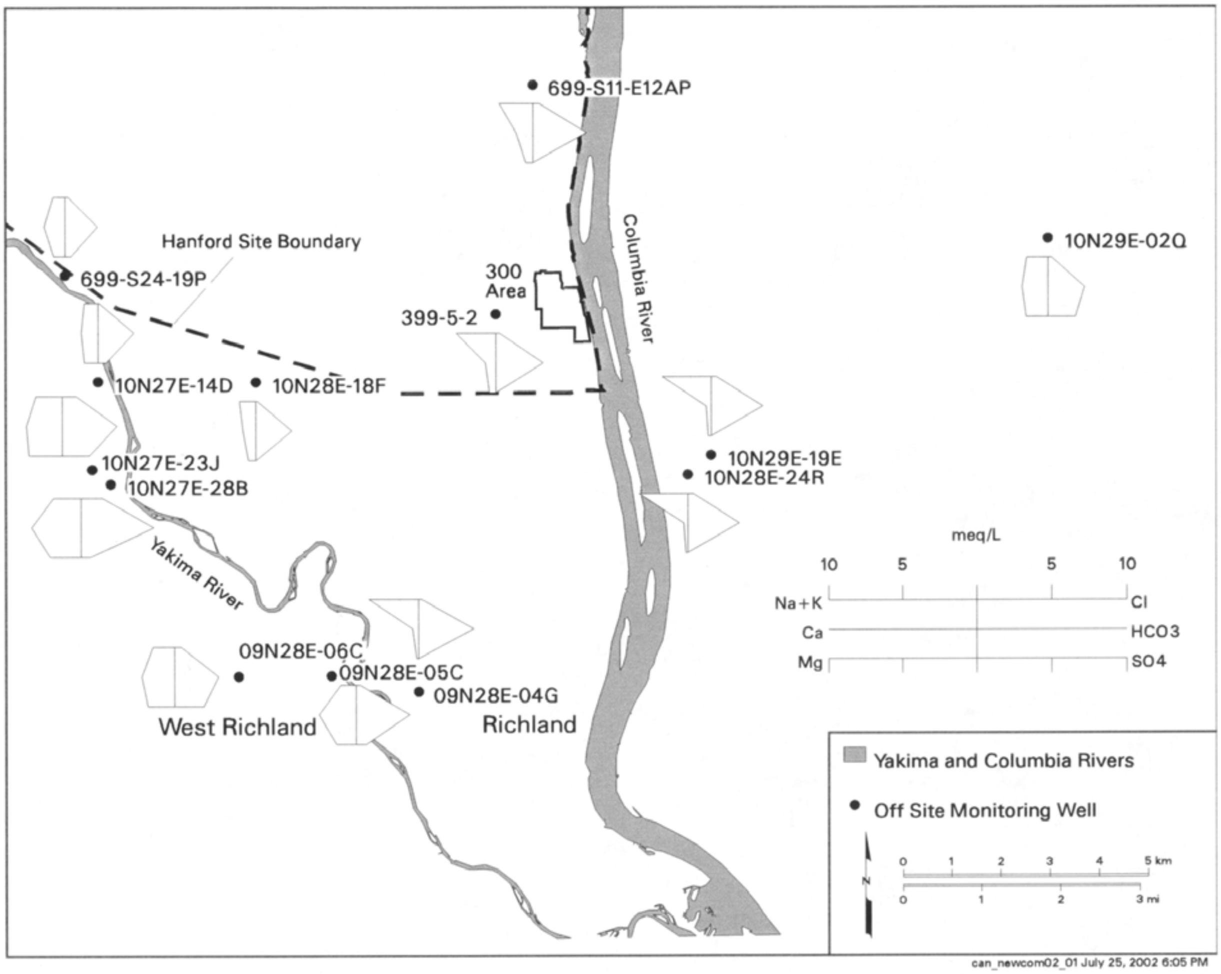

Figure 4. Hydrochemical Facies Stiff Diagram Map for the Upper Basalt-Confined Aquifer System

4.2 Radiological Constituents

Offsite groundwater samples were analyzed for gross alpha, gross beta, and tritium. Gross alpha and gross beta analytical measurements are used as screening tools for measuring gross radioactivity in groundwater. Tritium results for groundwater samples from the upper Saddle Mountains Basalt are useful for identifying the presence of hydrologic intercommunication with tritium-contaminated groundwater in the overlying unconfined aquifer.

4.2.1 Gross Alpha

Gross alpha radioactivity is a measurement of all alpha activity present in a sample, regardless of the specific radionuclide source[1] (Peterson et al. 2002). Alpha particles are positively charged subatomic particles ejected spontaneously by the nuclei of some radioactive elements. Alpha particles are emitted by both natural and manmade radioactive elements. Most alpha-emitting radioactive elements occur naturally in the environment, including uranium-238, radium-226, and other isotopes in the uranium decay series. An example of a manmade alpha-emitting radioactive element in the environment is americium-241, which originated from atmospheric nuclear weapons testing in the 1950s. The major manmade alpha-emitting radionuclide contaminant associated with Hanford Site groundwater is uranium.

Gross alpha concentrations shown in Table 3 indicate low levels of alpha activity in offsite groundwater in the upper basalt-confined aquifer system. Gross alpha results ranged from undetectable levels to 0.4 pCi/L. In comparison, gross alpha ranged from undetectable levels to 6.2 pCi/L in Hanford Site upper basalt-confined aquifer groundwater from 1991 to 2001, with a mean of 1.7 pCi/L. However, onsite levels of gross alpha were not detected for the upper basalt-confined aquifer system in the southern part of the Hanford Site. The background geometric mean gross alpha concentration for the overlying unconfined aquifer on the Hanford Site is 1.09 pCi/L (DOE 1997).

4.2.2 Gross Beta

Gross beta radioactivity is a measurement of all beta activity present in a sample, regardless of the specific radionuclide source[2] (Peterson et al. 2002). Beta particles are charged subatomic particles emitted from the nucleus of an atom by radioactive decay. Beta particles are produced naturally and artificially by many radionuclides. Examples of natural beta-emitting radionuclides include potassium-40 and carbon-14, which are weak beta emitters. Strontium-90 (including daughter product yttrium-90), a much stronger producer of beta particles, was the major manmade beta emitter in the environment from fallout due to atmospheric nuclear weapons testing during the 1950s. However, most strontium-90 worldwide has now decayed away. Other examples of manmade beta emitters include tritium, cobalt-60, technetium-99, cesium-137, iodine-129, and iodine-131. The major manmade beta-emitting radionculide contaminants associated with Hanford Site groundwater include tritium, iodine-129, strontium-90, and technetium-99.

Gross beta concentrations in upper basalt-confined aquifer groundwater south and southeast of the Hanford Site ranged from 5.15 to 12.2 pCi/L, with a mean of 9.2 pCi/L (see Table 3). From 1991 to 2001, gross beta measured in onsite upper basalt-confined aquifer groundwater ranged from undetectable levels to 330 pCi/L, with a mean of 8.9 pCi/L. Elevated onsite levels of gross beta were measured in an area of intercommunication between the upper basalt-confined aquifer and the overlying contaminated unconfined aquifer in the central part of the Hanford Site (i.e., near the 200-East Area). In the southern

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[1] EPA Fact Sheets at website http://www.epa.gov/radiation/understand/alpha.htm.
[2] EPA Fact Sheets at website http://www.epa.gov/radiation/understand/beta.htm.

region of the Hanford Site, gross beta levels ranged from 6.2 to 9.8 pCi/L, with a mean of 8.0 pCi/L. The background geometric mean gross beta concentration for the overlying unconfined aquifer on the Hanford Site is 5.6 pCi/L (DOE 1997).

Table 3. Dissolved Radiological Constituents

Well Number	Sample Date	Gross Alpha (pCi/L)	Gross Beta (pCi/L)	Tritium (pCi/L)
09N28E-04G	11/6/00	0.07 (U)	8.87	46.5
09N28E-06C	11/6/00	0.82 (U)	10.2	55.6
10N27E-14D	11/6/00	0.90 (U)	7.07	56.2
10N27E-14D[a]	11/6/00	-0.06 (U)	8.07	56.4
10N28E-18F	11/6/00	0.42 (U)	5.15	42.7
10N28E-24R	10/27/00	0.57 (U)	12.2	34.6
10N29E-02Q	10/27/00	-0.18 (U)	10.7	64.3
10N29E-19E	10/27/00	-0.08 (U)	11.5	56.1
399-5-2	6/14/01	0.25 (U)	9.84	7.55
699-S11-E12AP	5/9/97	0.12 (U)	7.61	-0.47 (U)
699-S11-E12AP	6/5/98	0.16 (U)	8.48	5.95 (J)
699-S11-E12AP	5/16/00	-0.28 (U)	6.18	7.98 (J)
699-S24-19P	9/29/97	NA	NA	52.6
699-S24-19P	8/31/98	NA	NA	17.2
699-S24-19P	7/24/01	NA	NA	43.3 (Q)
Onsite confined[b]	1991-2001	1.7	8.9	8.4
Background[c]		1.09	5.6	63.9

(a) Duplicate sample.
(b) Refers to the mean concentration in the Hanford Site upper basalt-confined aquifer using data for which analytical methods are similar to the offsite sample analyses. Mean calculated using method described in Gilbert (1987).
(c) Refers to the geometric mean natural background concentration in the Hanford Site unconfined aquifer, reported in DOE (1997).
J = Estimated value.
NA = Not analyzed.
Q = Associated quality control sample is out of limits.
U = Not detected.

4.2.3 Tritium

Background tritium, an unstable isotope, is produced naturally in the atmosphere by the effects of cosmic ray bombardment and artificially by fallout from thermonuclear weapons testing. Prior to the advent of thermonuclear weapons testing (i.e., before the 1940s), background tritium levels in the hydrological cycle were from 5 to 25 pCi/L (Eisenbud 1987). Tritium levels in surface waters associated with weapons testing fallout have decreased over the last several decades because of the decline of nuclear weapons testing and because tritium has a short half-life of 12.35 years. Detectable levels of tritium in

Columbia River water at Priest Rapids Dam, immediately upstream of the Hanford Site, were reported to range from 1,100 to 2,300 pCi/L in 1967, with an average of approximately 1,540 pCi/L (Corley and Wooldridge 1969). By 2000, average tritium levels in Columbia River water at Priest Rapids Dam had decreased to 35 ± 5.6 pCi/L (Poston et al. 2001). The background geometric mean tritium concentration in groundwater from the upper part of the unconfined aquifer at the Hanford Site was determined to be 63.9 pCi/L (DOE 1997). This value was determined statistically on a sitewide basis using data unaffected by site operations. Spane and Webber (1995) reported a median tritium concentration of 0.32 pCi/L for 36 samples collected from the upper basalt-confined aquifer system.

Tritium results for samples collected from wells in the southern region of the Hanford Site and adjacent areas to the south and southeast are shown in Table 3. Tritium concentrations in the offsite upper basalt-confined aquifer system ranged from 34.6 to 64.3 pCi/L with a median of 56.1 pCi/L and a mean of 51.6 pCi/L. These levels are similar to background tritium levels observed in upstream Columbia River water (i.e., Priest Rapids Dam) and to background levels observed in the unconfined aquifer at the Hanford Site. Tritium measured in onsite upper basalt-confined aquifer groundwater ranged from undetectable levels to 194 pCi/L, with a mean of 8.4 pCi/L. These levels represent samples collected from 1991 to 2001 and analyzed using a low-level detection method. Most of the elevated tritium concentrations in onsite upper basalt-confined groundwater are associated with an area of intercommunication with the overlying contaminated unconfined aquifer in the 200 East Area-Gable Mountain region, which lies in the central part of the Hanford Site (Spane and Webber 1995).

The distribution of tritium for the upper Saddle Mountains Basalt in the southern region of the Hanford Site and adjacent areas to the south and southeast is presented in Figure 5. Data from this study, Spane and Webber (1995), and the HEIS database were used for preparing the map. Tritium data for Yakima River water are reported in DOE (1988) and Early et al. (1986). Wells located near the Yakima River generally show slightly elevated tritium levels that are similar to those observed for the Yakima River. These slightly elevated levels are consistent with hydrochemical data indicating a recharge input component from Yakima River water to the upper basalt-confined aquifer in this area. This is an area where the upper Saddle Mountains Basalt is shallow or exposed relative to the surface topography (see Plate 1). The offsite study area near the Yakima River is irrigated mostly by surface water from the Yakima River (Ebbert et al. 1995).

Offsite wells east of the Columbia River show slightly elevated tritium levels while onsite wells in the southeastern portion of the Hanford Site show low levels (see Figure 5). These data indicate a recent recharge input (i.e., since the 1950s) to the upper basalt aquifer in the study area east of the Columbia River, where recharge from agricultural irrigation practices have areally impacted groundwater. The offsite study area east of the Columbia River is irrigated mostly by surface water from the Columbia River (Ebbert et al. 1995).

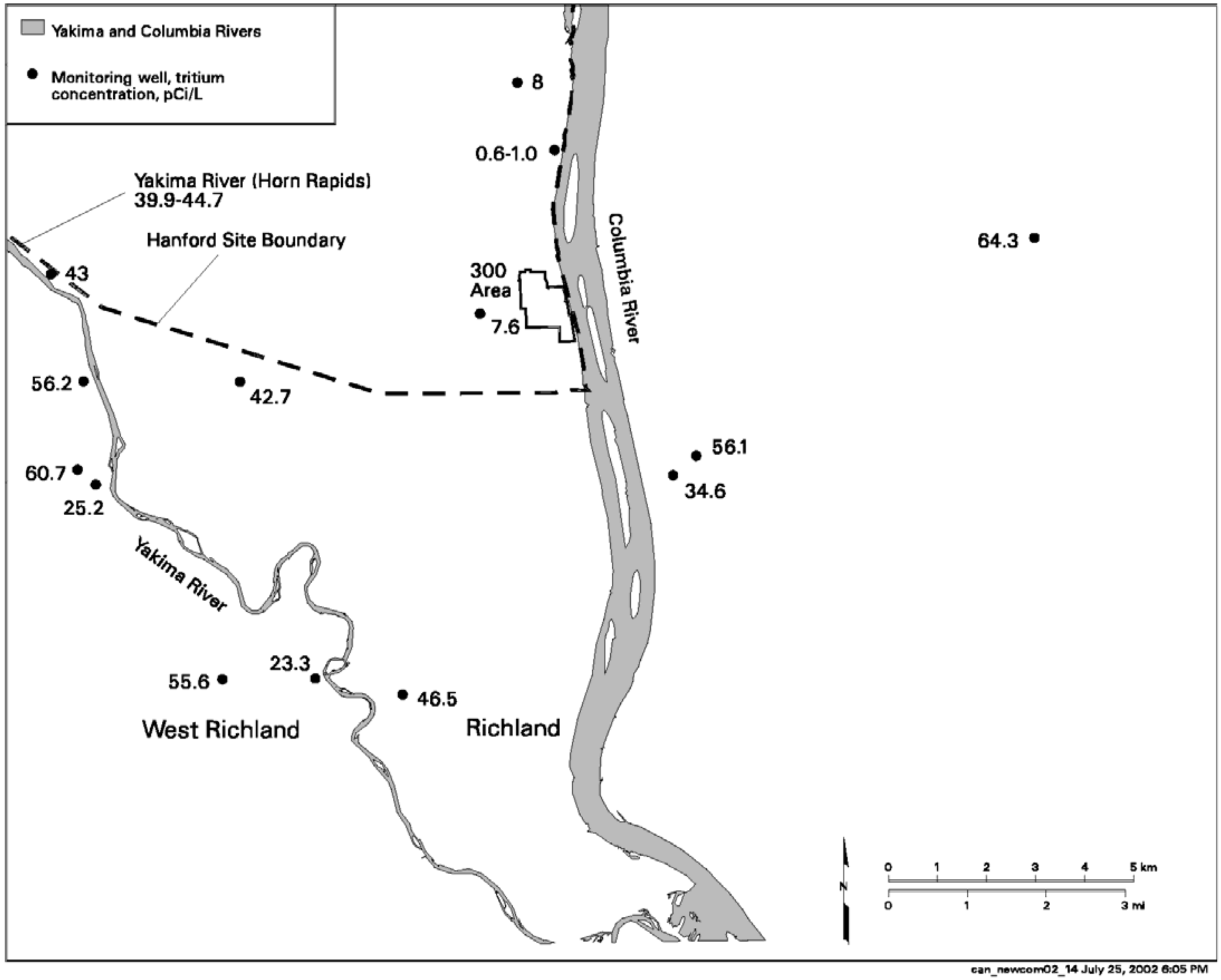

Figure 5. Distribution of Tritium Concentrations in the Upper Basalt-Confined Aquifer System

5.0 Summary and Conclusions

Based on the limited data presented in this report, contaminants on the Hanford Site have not migrated via the upper basalt-confined aquifer system pathway to the offsite sample locations within the study area. Concentrations of constituents analyzed were within the range of background levels expected for the upper basalt-confined aquifer system. The likelihood that contaminants will migrate across the southern boundary of the Hanford Site is highly uncertain because of a lack of hydrogeologic and hydrochemical data for the upper basalt-confined aquifer system in this area. However, development continues to increase in offsite areas south, and to a lesser degree, southeast of the Hanford Site. With increased development and continued groundwater usage from the upper basalt-confined aquifer system, the potential exists for the migration of contaminants from the Hanford Site to offsite areas within this confined aquifer system in the future.

An evaluation of major cation and anion chemistry of the groundwater samples indicates that water chemistry appears to evolve along two trends, one from a calcium/magnesium hydrochemical type towards a sodium-rich type and the other from a bicarbonate type towards a sulfate type. Increase in sodium reflects hydrochemical evolution related to basalt/water interaction. This more evolved groundwater commonly occurs near areas of discharge. The spatial distribution of hydrochemical facies infers that upper basalt-confined aquifer groundwater in the southern region of the Hanford Site and adjacent offsite areas to the south and southeast is flowing toward and discharging to the Columbia or Yakima rivers. High hydraulic heads and an increased hydraulic gradient east of the Columbia River suggest that upper basalt-confined groundwater flows laterally toward the Columbia River within the study area. The hydrochemical trend from bicarbonate towards sulfate suggests irrigation recharge associated with agricultural activities, where sulfate is leached from vadose zone sediments as irrigation water infiltrates downwards.

Spatial distribution of hydrochemical facies and evolutionary trends indicate less evolved groundwater (i.e., calcium/magnesium type) near the Yakima River. This is consistent with previous studies indicating that Yakima River water is a local source of recharge for the upper basalt-confined aquifer south of the Hanford Site. This is an area that is irrigated mostly by surface water from the Yakima River and where the upper Saddle Mountains Basalt is shallow or exposed relative to the surface topography.

Tritium concentrations measured in offsite areas to the south and southeast of the Hanford Site are higher than most of the tritium concentrations measured in onsite upper basalt-confined aquifer groundwater. These higher levels represent background tritium predominantly associated with atmospheric fallout resulting from nuclear weapons testing. These tritium data provide evidence that the upper Saddle Mountains Basalt is recharged locally, most likely by agricultural irrigation activities. Gross alpha and gross beta concentrations showed low levels of radioactivity in offsite upper basalt-confined aquifer groundwater. These levels are comparable to levels found in the upper basalt-confined aquifer over most of the Hanford Site.

6.0 Recommendations

Basalt units and interbeds within the upper Saddle Mountains Basalt in areas to the south and southeast of the Hanford Site should be evaluated. In these areas, very little information is available regarding the extent, thickness, and continuity of basalt units and interbeds within the upper Saddle Mountains Basalt. This information is important to evaluate the upper basalt-confined aquifer system as a potential offsite migration pathway for contaminants.

Hydraulic head measurements should be acquired periodically from wells, where possible, to better define current groundwater flow directions in the southern region of the Hanford Site and adjacent areas to the south and southeast. Offsite wells that are not used for water supply are preferable for measuring hydraulic heads to avoid drawdown effects associated with pumping.

Additional offsite groundwater sampling activities should be undertaken on a periodic basis. Groundwater data from offsite locations are relatively sparse. During these offsite sampling activities, similar groundwater data would be collected from at least one onsite well in the southern part of the Hanford Site to provide a comparison of water chemistry.

Increased offsite groundwater usage increases the need for investigating the upper basalt-confined aquifer system as a potential contaminant migration pathway. Specific areas of offsite groundwater usage from the upper Saddle Mountains Basalt should be identified. Discharge rates in these areas should be estimated using existing data from state and federal agencies.

7.0 References

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Appendix A

Summary and Log Inventory of Wells

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Summary and Log Inventory of Wells

Wells within the study area from which geologic information about the basalt/suprabasalt sediment contact was obtained include fire protection wells for Benton and Franklin Counties, city of Richland production wells, Hanford Site monitoring wells, agricultural irrigation wells, and a West Richland water-supply well. The locations of these wells are shown in the inset to Plate 1. Well construction and lithologic diagrams are contained in this appendix and in Plate 2 (West Richland Municipal Water Supply Well #7). Well completion data are summarized in Table A.1. Drilling logs (water well reports), (Figures A.1 through A.12) were obtained from the Pacific Northwest National Laboratory Well Log Library, Washington State Department of Ecology, city of Richland, and local drilling companies.

The well numbers for the majority of the wells inventoried are given in a sequence that refers to the township, range, and section from the U.S. Geological Survey's 7.5 Minute Series (Topographic) Quadrangles. For some wells, a letter at the end of the sequence further designates the subdivision within the section. Where multiple wells exist within the subdivision, the wells are numbered sequentially. These wells were installed between 1966 and 1999. Generally, they were drilled open hole within the basalt and completed with carbon steel casing extending through the suprabasalt sediments to the surface. A select few are completed with perforated carbon steel casing. No completion information was available for the Fire Station well, and wells 10N/29E-26, 09N/27E-21, 09N/27E-15, and 10N/29E-02Q.

Wells 699-ORV-1 (Figure A.4), 699-ORV-2 (Figure A.7), and 699-LANDFILL (Figure A.8) supply water to the city of Richland's Horn Rapids Off-Road Vehicle (ORV) Park and Horn Rapids Sanitary Landfill. They were installed in the late 1970s and early to mid-1980s. Wells 699-ORV-1 and 699-ORV-2 are completed with perforated carbon steel casing, whereas well 699-LANDFILL is open hole within the basalt.

The Hanford Site monitoring wells 699-S31-1, 699-S28-E0, and 699-S30-E14 (Figures A.9, A.10, and A.11) were drilled between 1951 and 1981. These wells were installed primarily to monitor groundwater contamination resulting from Hanford Site operations. At one point, well 699-S28-E0 was reportedly used to supply water to the Hanford Patrol Training facility. It is unlikely that this practice continues today, with city of Richland services extending farther west to the Hanford's Hazardous Materials Management of Emergency Resources (HAMMER) facility. The Hanford Site monitoring wells are open hole within the basalt, with carbon steel casing extending through the suprabasalt sediments to the surface. All three of the wells are also perforated in the suprabasalt sediments.

References

NAD 83. 1983. North American Datum of 1983.

NGVD 29. 1929. National Geodetic Vertical Datum of 1929.

Table A.1. General Well Information

Well Number	State Plane Northing[a] (m)	State Plane Easting[a] (m)	Geologic Unit Adjacent to Uppermost Basalt Completion Interval	Approximate Surface Elevation[b] (m above MSL)	Approximate Top of Basalt Elevation[b] (m above MSL)	Approximate Depth of Completion Interval (m BGS)	Approximate Elevation of Completion Interval[b] (m above MSL)
09N/28E-04G[c]	107479.7	591328.6	Saddle Mountains Basalt	111	54	55 to 96	15 to 56
09N/28E-06C[c]	107792.9	587654.3	Saddle Mountains Basalt	189	113	132 to 149	40 to 57
10N/27E-14D[c]	113873.3	584820.2	Saddle Mountains Basalt	128	110	19 to 50	78 to 109
699-ORV-1 (10N/28E-18F)[c]	113866.6	588018.4	Saddle Mountains Basalt	145	84	66 to 90, 98 to 118	27 to 47, 55 to 79
10N/28E-24R[c]	111955.5	596841.6	Saddle Mountains Basalt	149	64	125 to 131	18 to 24
10N/29E-02Q[c]	116801.2	604204.7	Saddle Mountains Basalt	207	--	118+	<89
10N/29E-19E[c]	112354.3	597313.2	Saddle Mountains Basalt	152	80	74 to 82	70 to 78
699-ORV-2 (10N/28E-18)	114089.5	588735.5	Saddle Mountains Basalt	139	78	101 to 142	-3 to 38
699-LANDFILL (10N/28E-17)	112939.2	588935.1	Saddle Mountains Basalt	147	71	76 to 95	52 to 71
699-S31-1	114213.3	589749.3	Saddle Mountains Basalt	140	72	67 to 70	70 to 73
699-S28-E0	114963.2	590005.3	Saddle Mountains Basalt	136	68	68 to 72	64 to 68
699-S30-E14	114270.3	594368.0	Frenchman Springs Basalt	122	58	602 to 626	-504 to -480
Fire Station Well	111445.5	598200.4	Saddle Mountains Basalt	155	88	67+	<88
10N/29E-26	111527.8	603506.8	Saddle Mountains Basalt	149	43	107+	<42
09N/27E-21	103162.6	582186.1	Saddle Mountains Basalt	232	28	204+	<28
09N/27E-15	103545.4	582681.8	Saddle Mountains Basalt	219	190	29+	<190
West Richland Water-Supply Well No. 7	107982.9	585641.8	Pomona Basalt	141	128	182 to 198	-57 to -41
699-S51-2	108013.4	589201.8	Saddle Mountains Basalt	118	65	53 to 174	-56 to 65

(a) NAD 83.
(b) NGVD 29.
(c) Well sampled in this study.
BGS = Below ground surface.
MSL = Mean sea level.

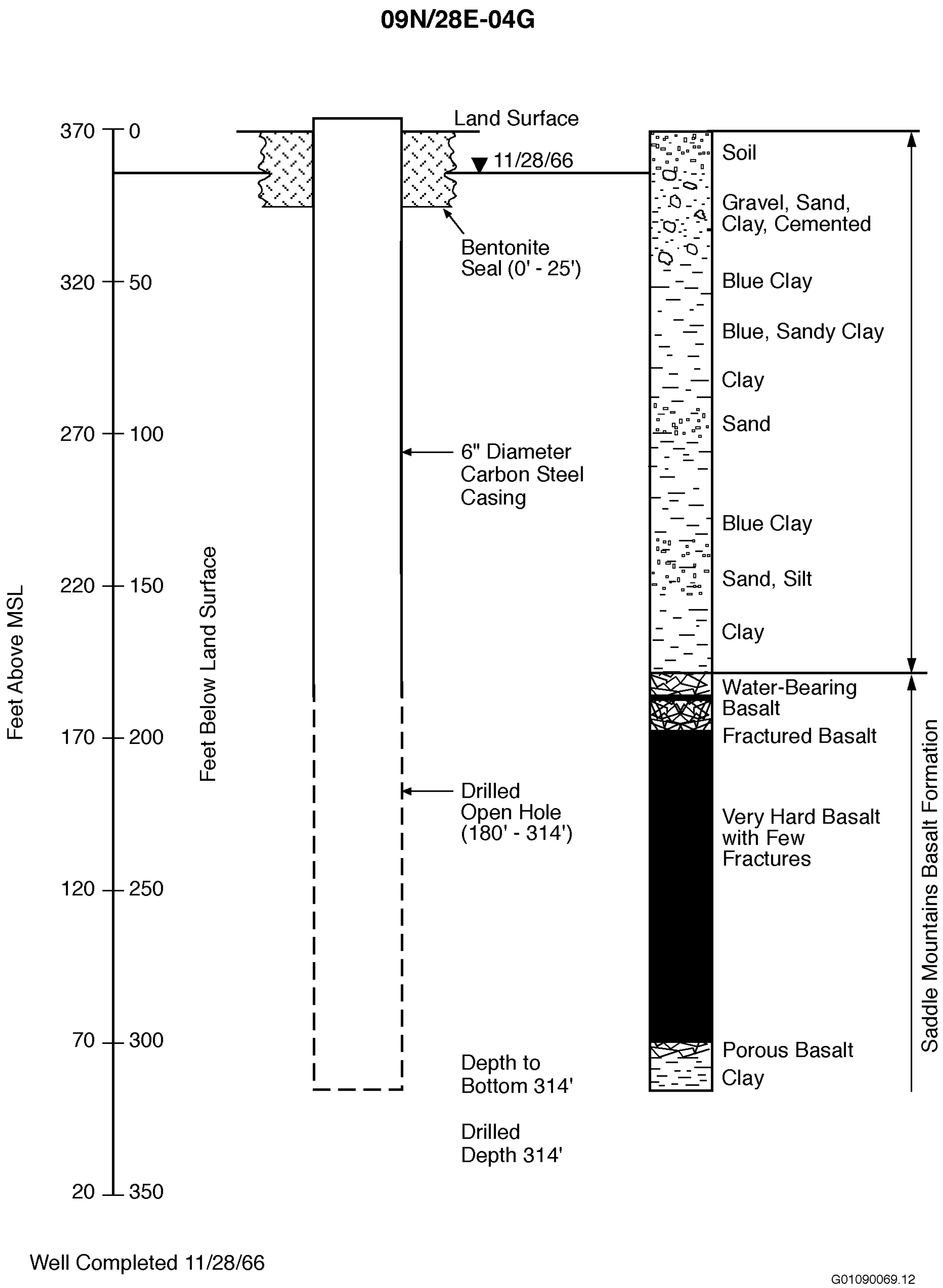

Figure A.1. Well Number 09N/28E-04G, Located South of the Hanford Site

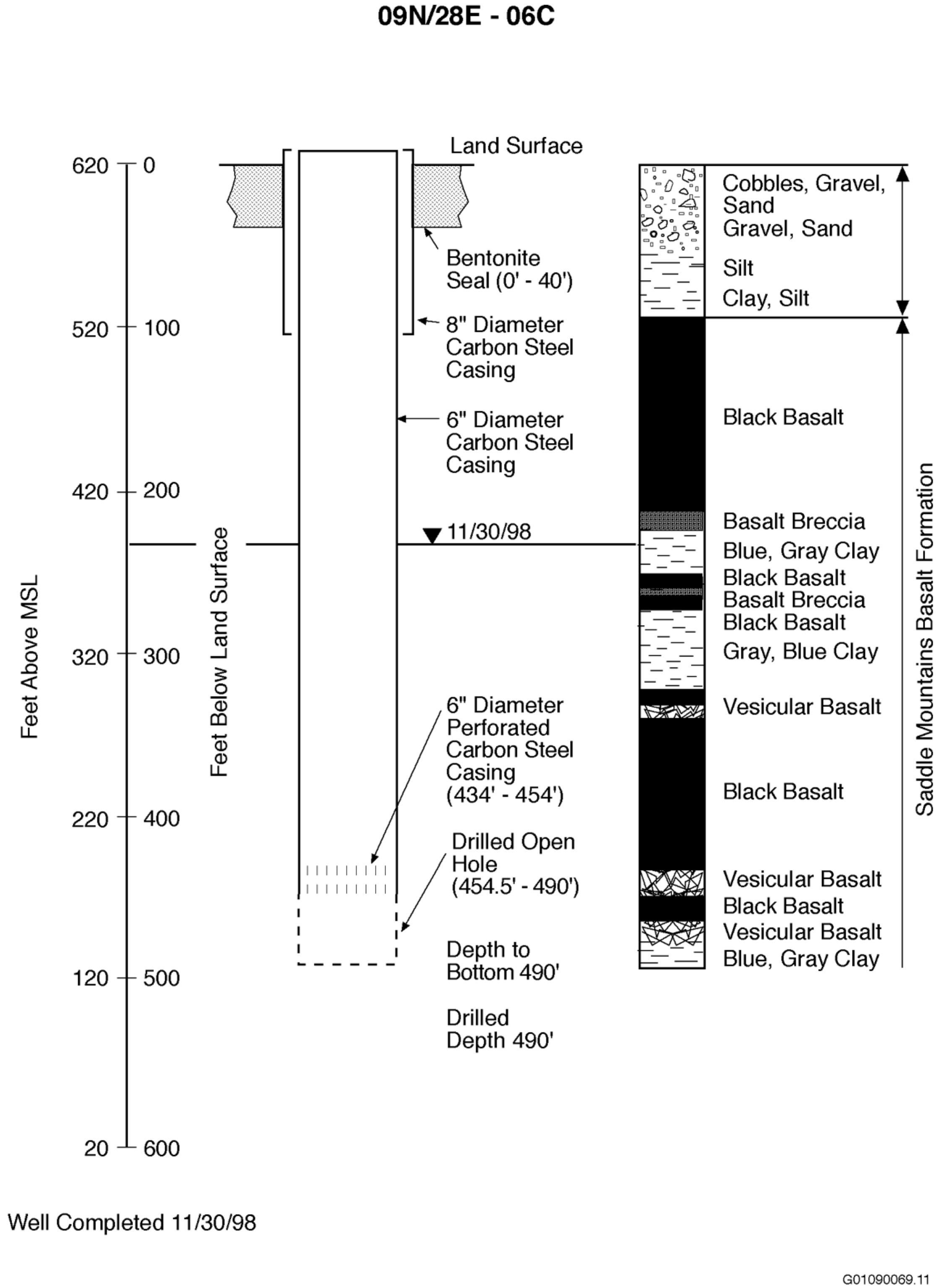

Figure A.2. Well Number 09N/28E-06C, Located South of the Hanford Site

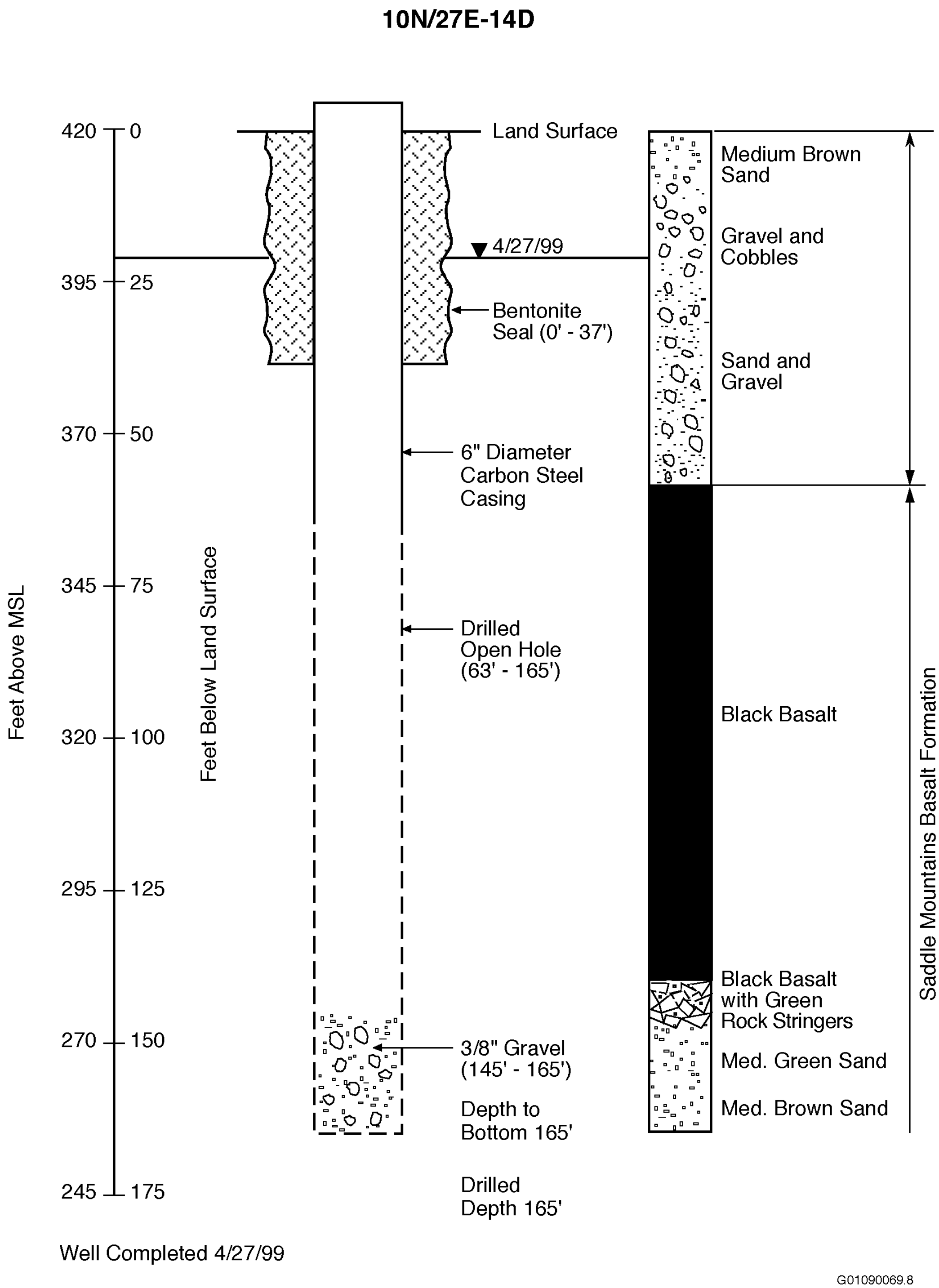

Figure A.3. Well Number 10N/27E-14D, Located Near the Yakima River South of the Hanford Site

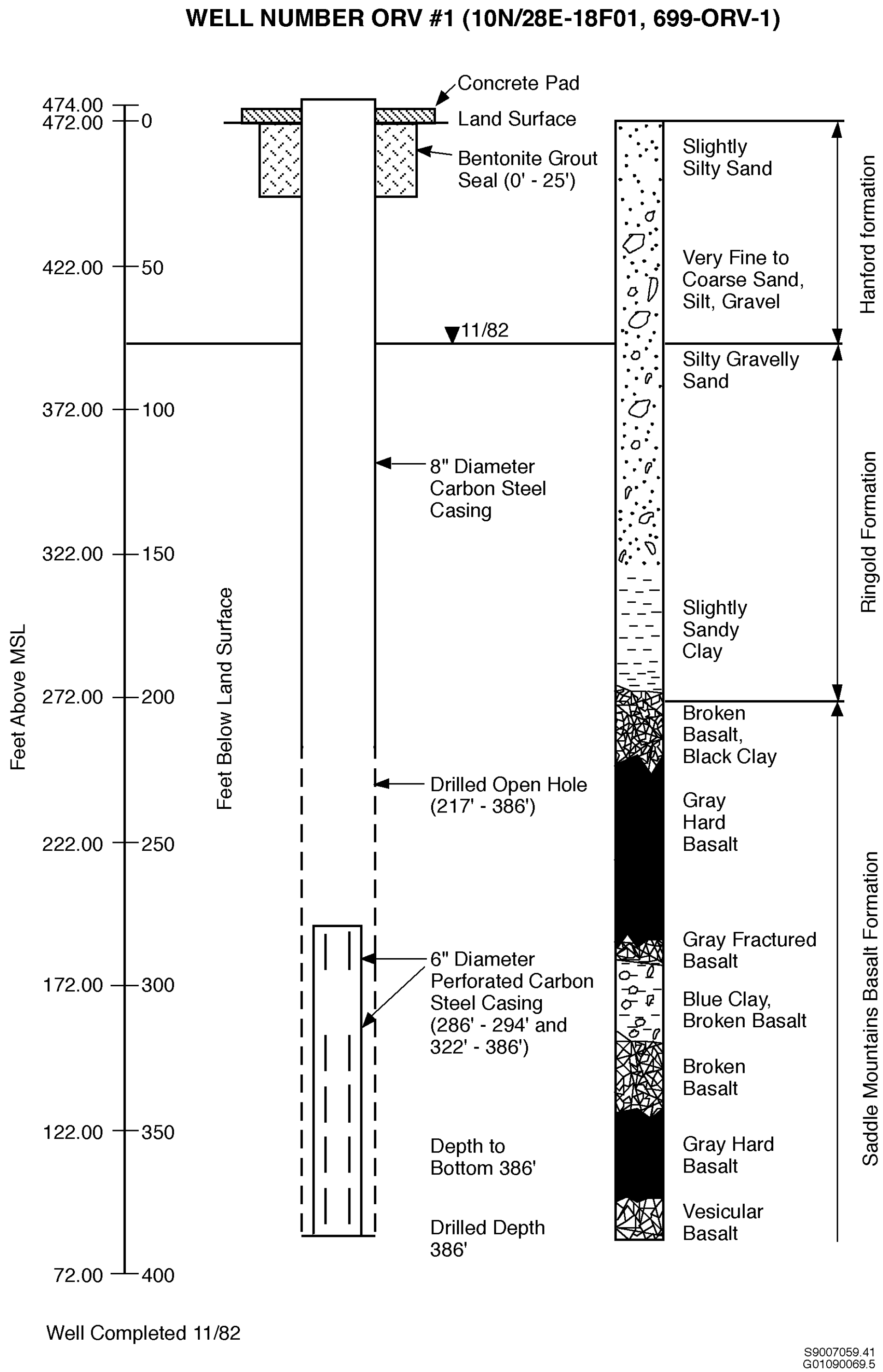

Figure A.4. Well Number 699-ORV-1, Located Just South of the Hanford Site Boundary

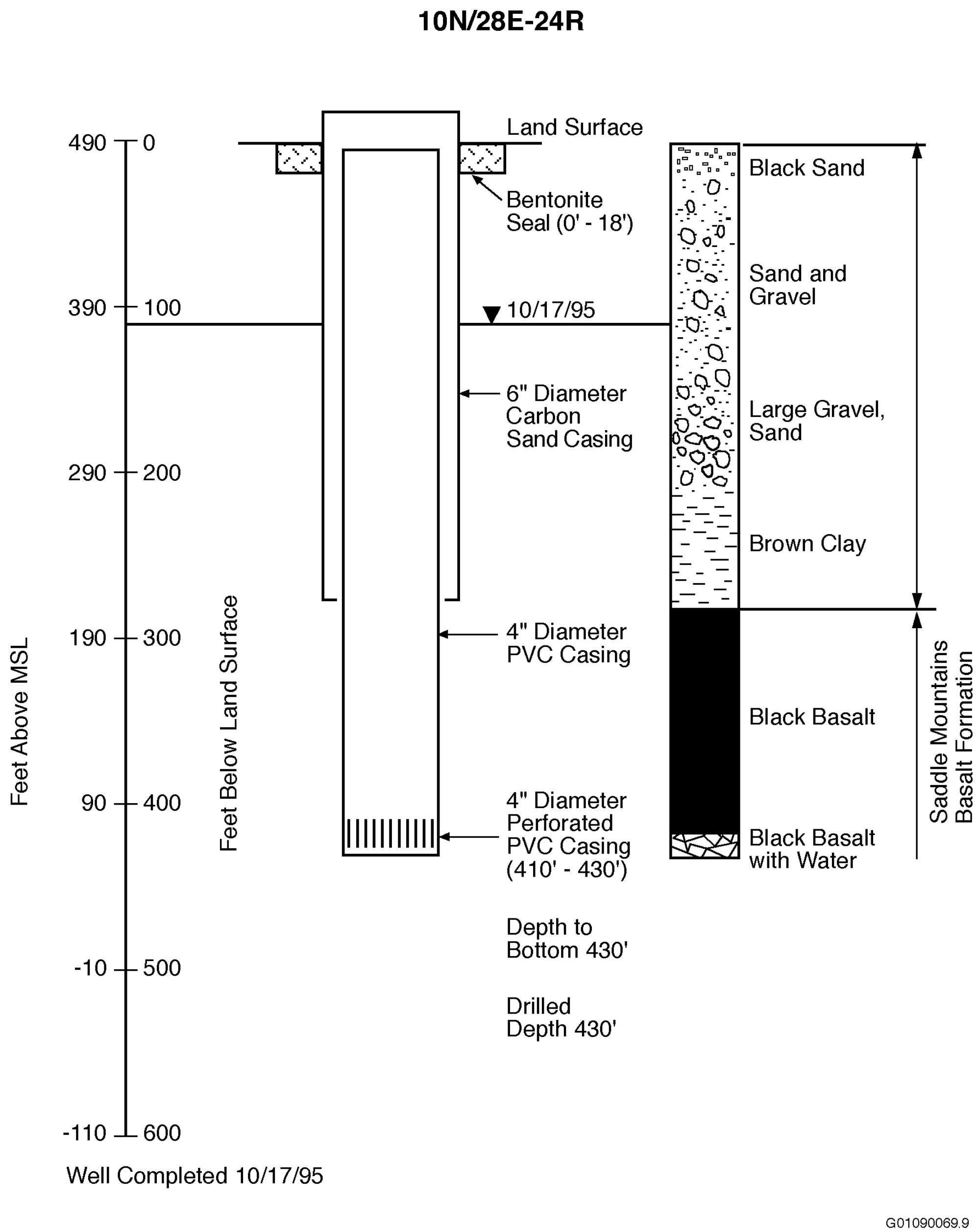

Figure A.5. Well Number 10N/28E-24R, Located Southeast of the Hanford Site

10N/29E - 19E

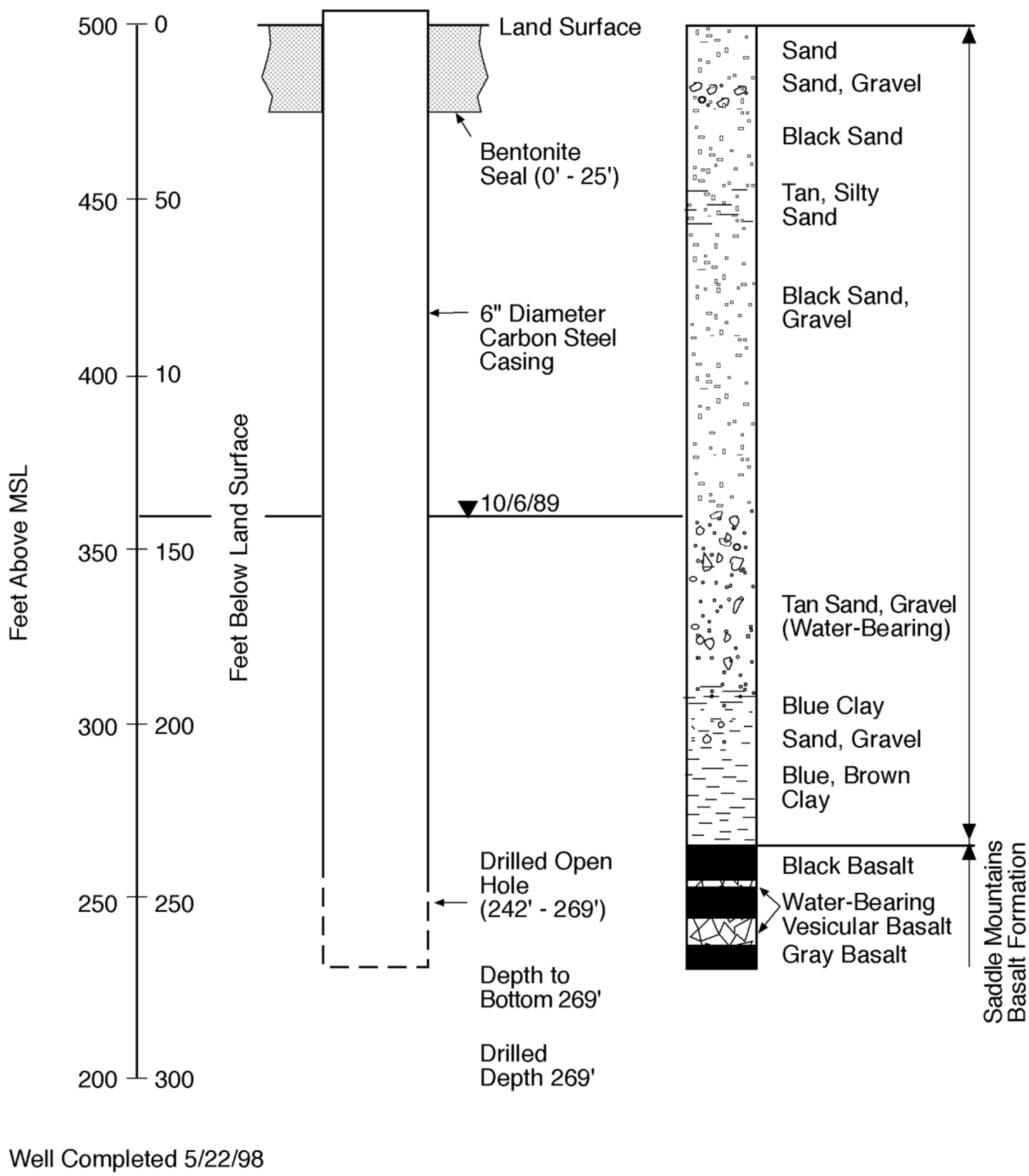

Figure A.6. Well Number 10N/29E-19E, Located Southeast of the Hanford Site

WELL NUMBER ORV #2 (10N/28E-18, 699-ORV-2)

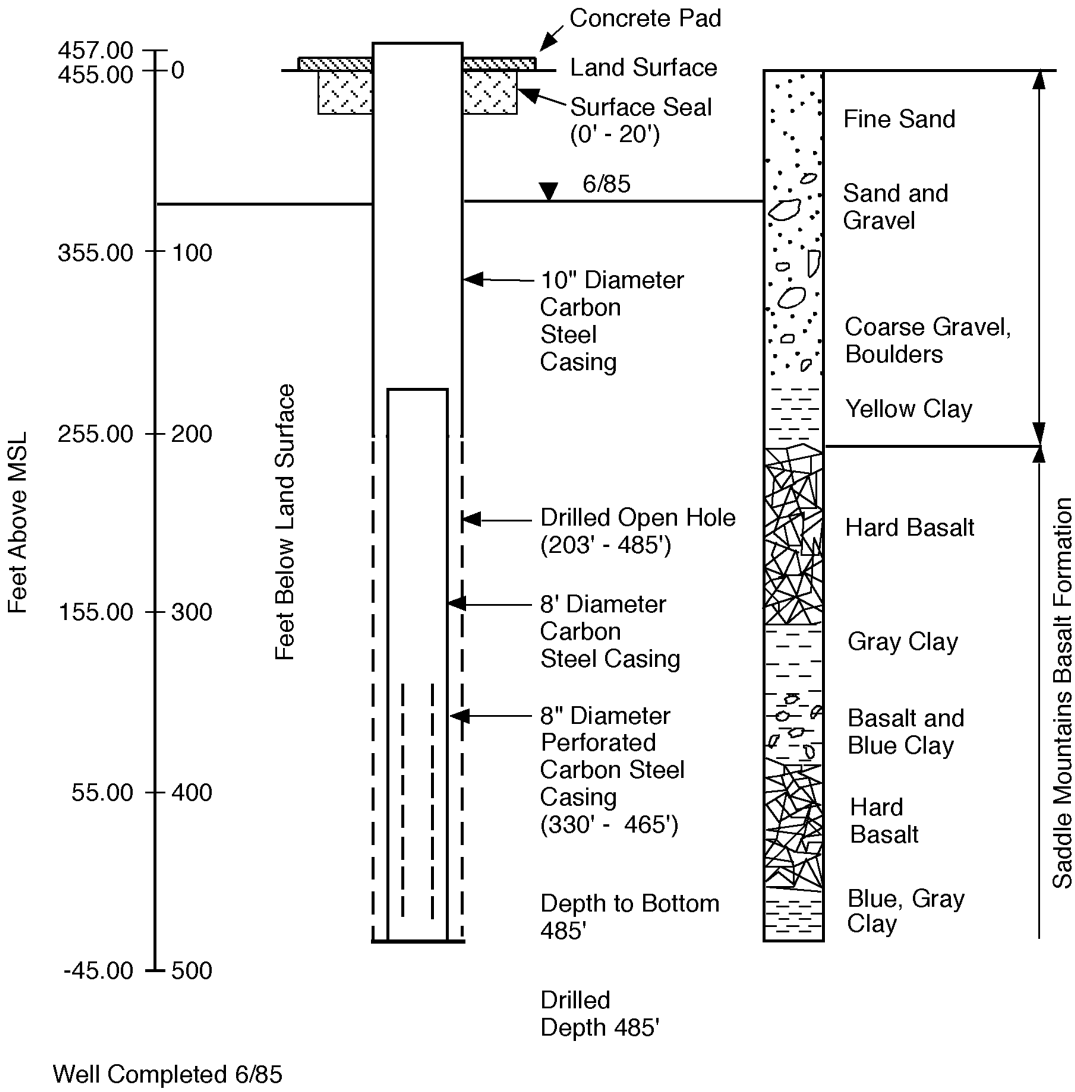

Figure A.7. Well Number 699-ORV-2, Located Just South of the Hanford Site Boundary

LANDFILL WELL (10N/28E-17, 699-LANDFILL)

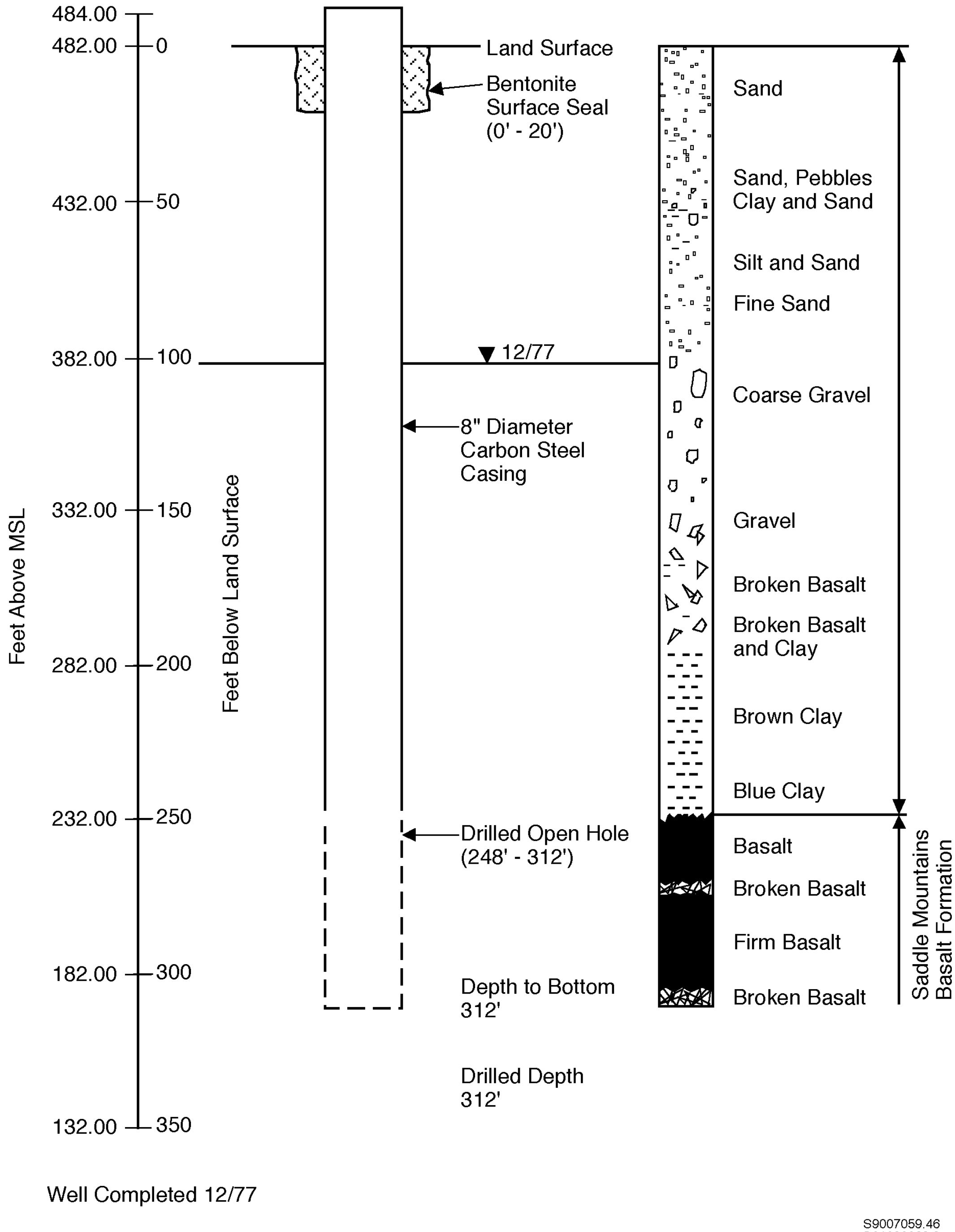

Figure A.8. Landfill Well, Located South of the Hanford Site

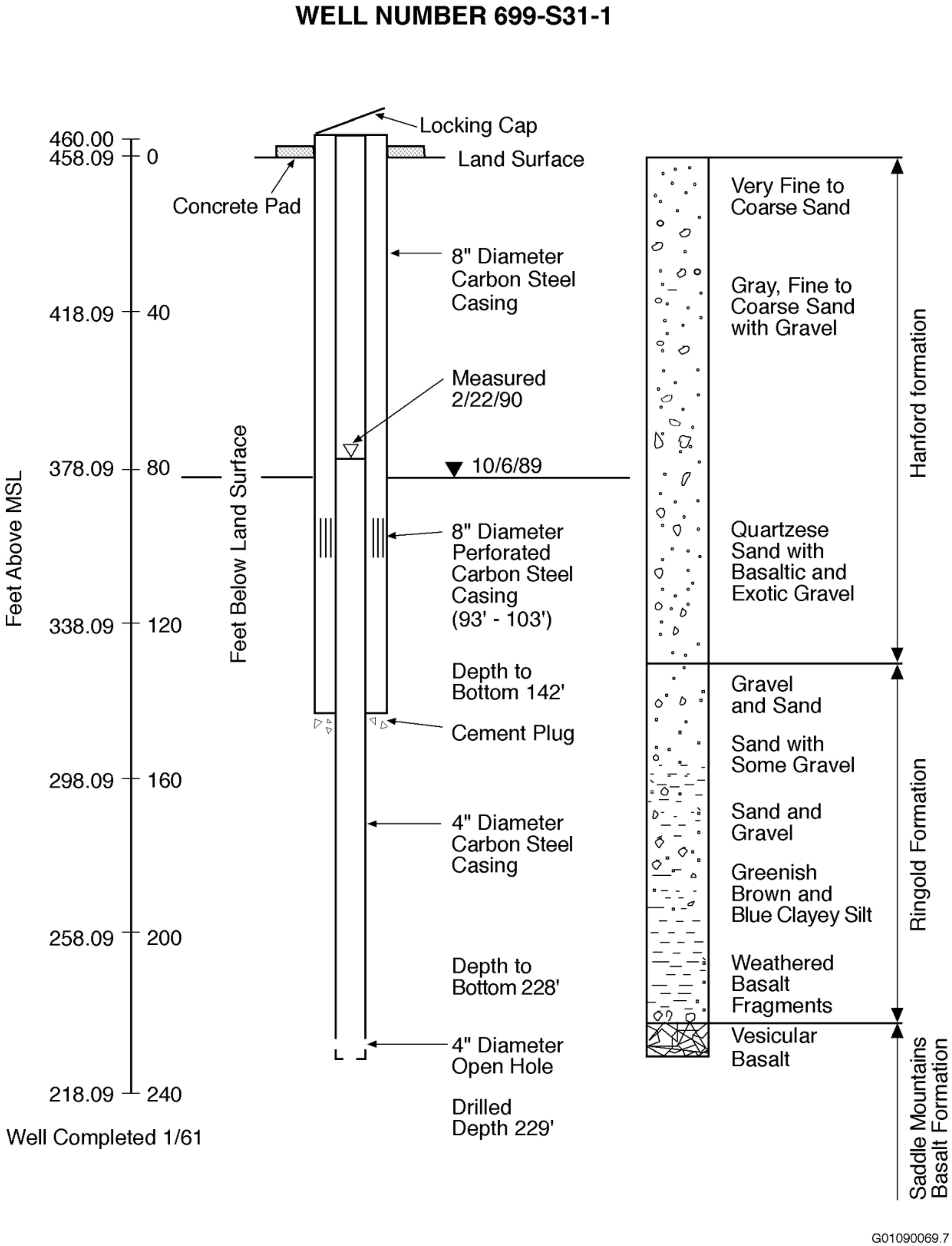

Figure A.9. Well Number 699-S31-1, Located Along the Southern Boundary of the Hanford Site

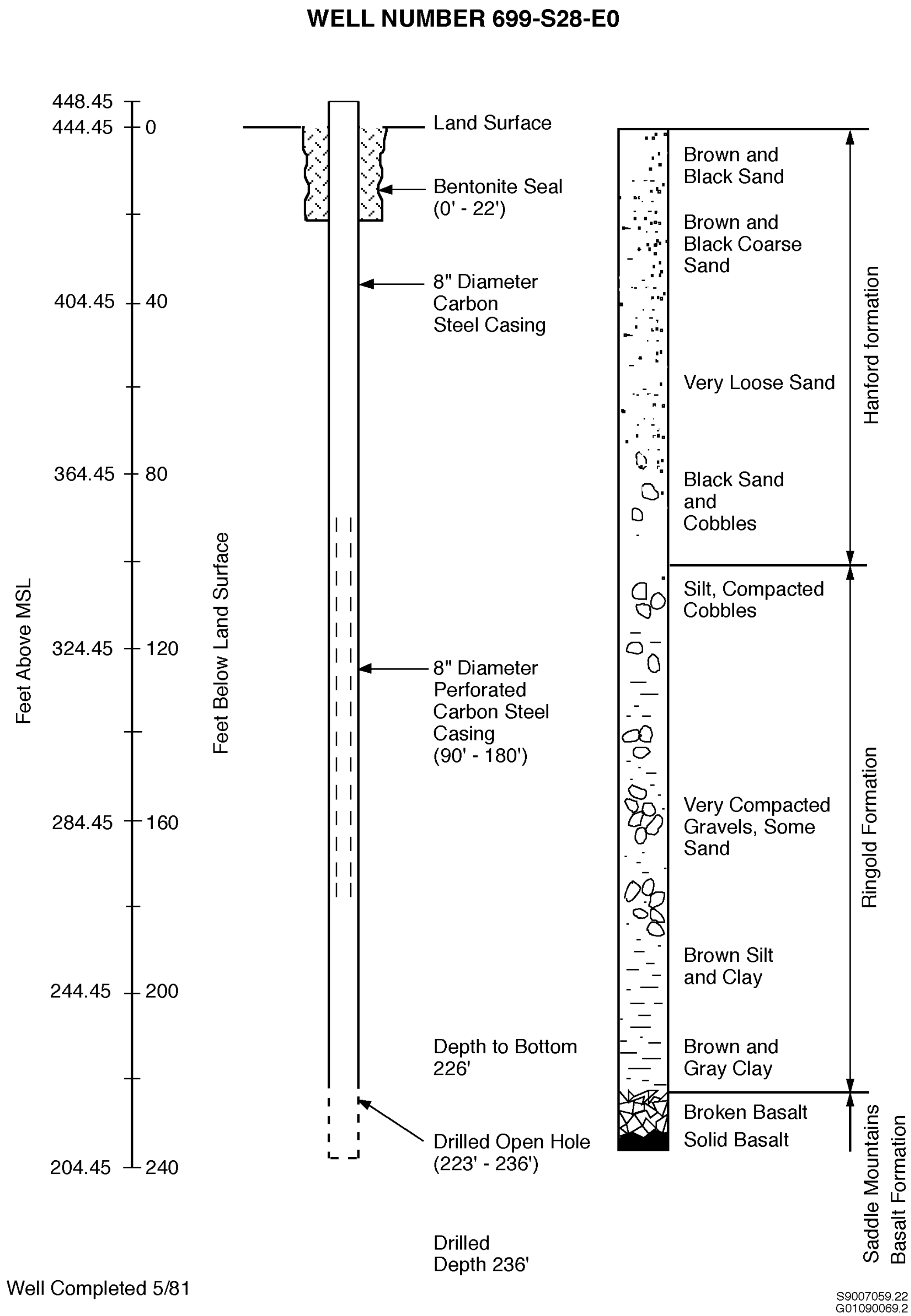

Figure A.10. Well Number 699-S28-E0, Located Near the Southern Boundary of the Hanford Site

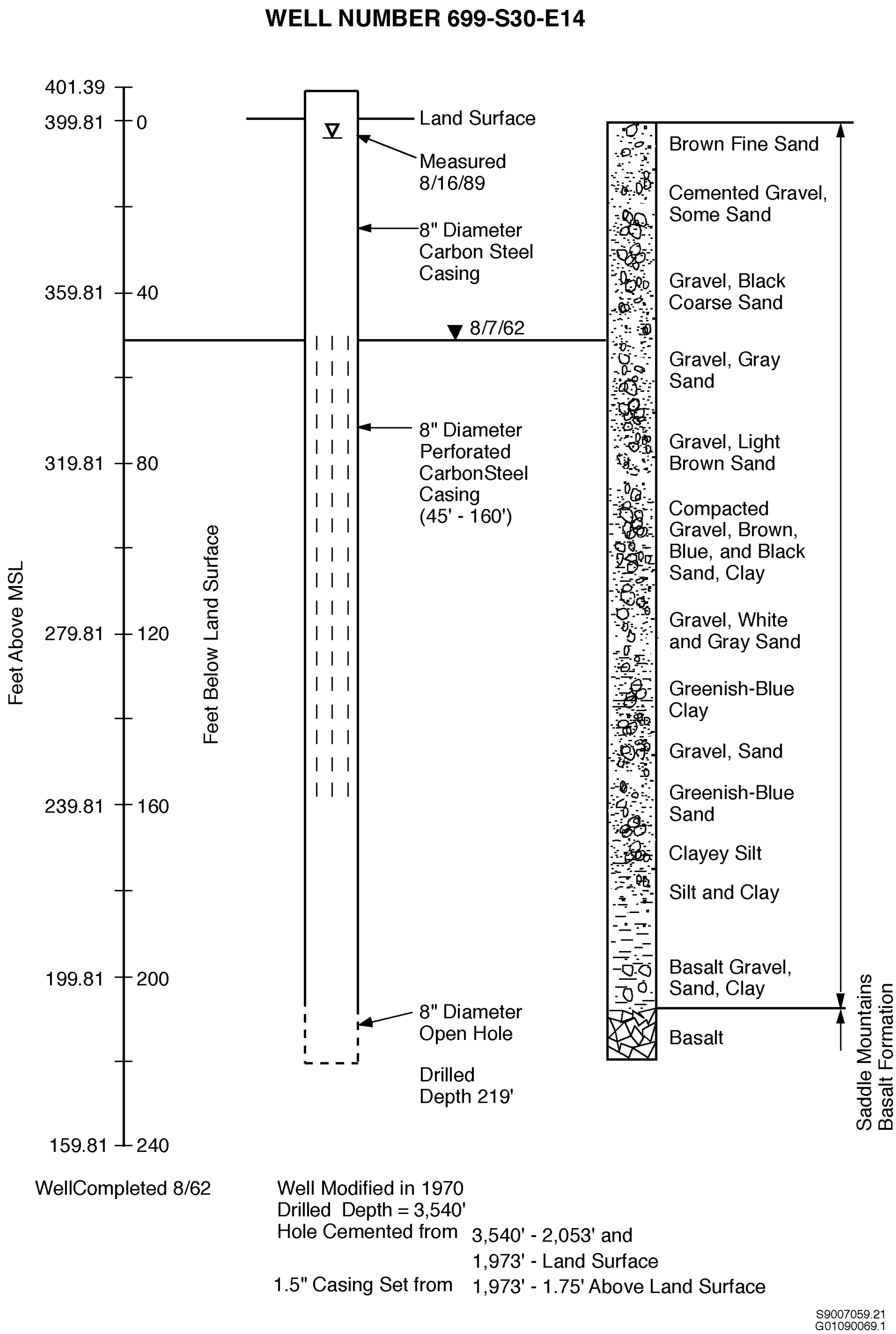

Figure A.11. Well Number 699-S30-E14, Located Near the Southern Boundary of the Hanford Site

WELL NUMBER 699-S51-2

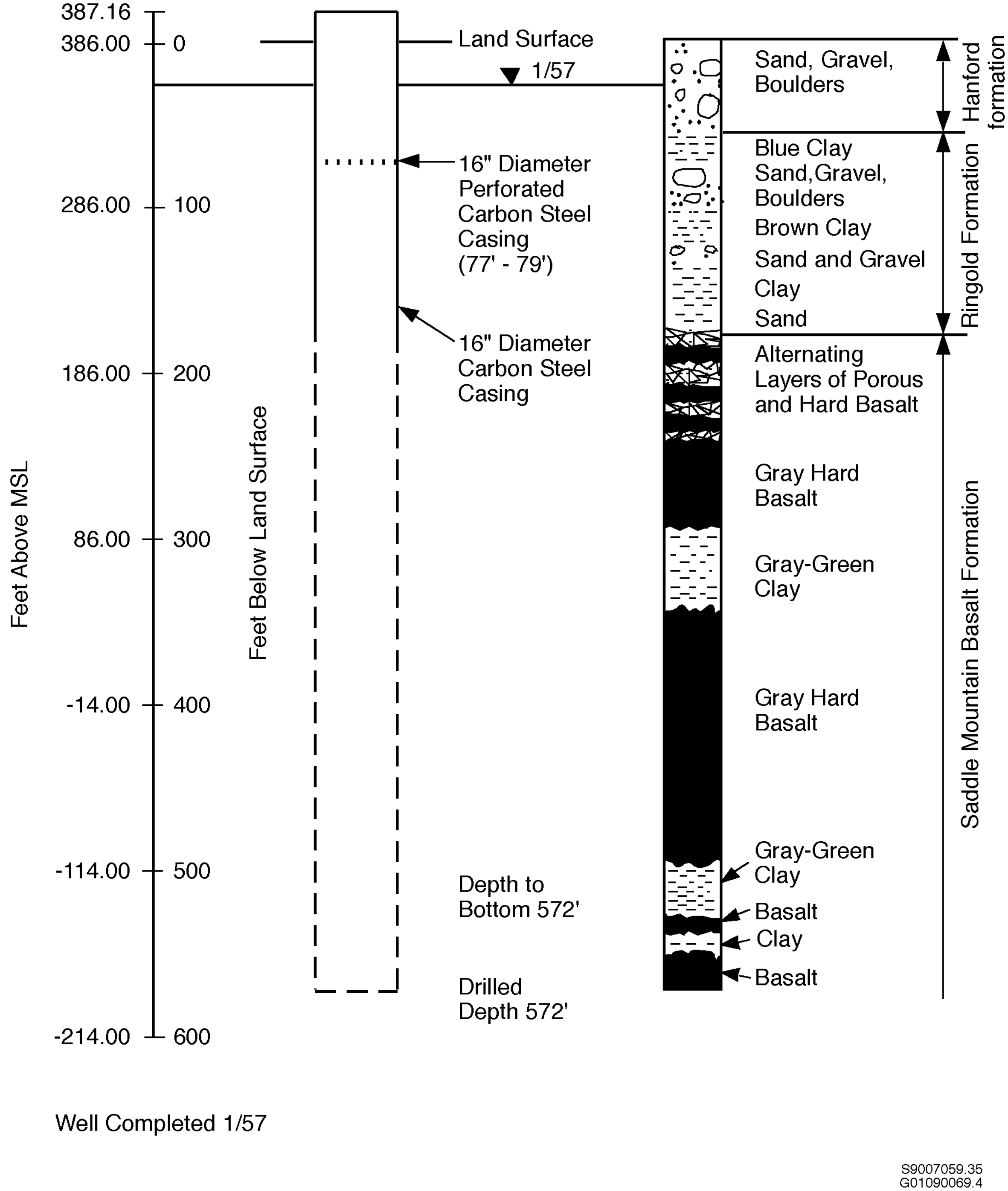

Figure A.12. Well Number 699-S51-2, Located South of the Hanford Site

Appendix B

Sampling Procedure and General Field Parameters

Appendix B

Sampling Procedure and General Field Parameters

Sampling of wells off the Hanford Site followed procedures similar to sampling wells on the Hanford Site. Slight modifications to the sampling procedure were necessary, however, because of issues associated with liability in collecting samples from privately owned wells and because of the variety of wellhead and pumping configurations encountered.

Each well was sampled using the existing dedicated submersible pump. At most of the wells, purge water was directed away from the well using a garden hose and allowed to discharge to the ground surface. At one well (10N/27E-14D), the purge water was not discharged to the ground surface because the wellhead and pump was configured in a closed system. For this well, flow was directed to a storage tank in the closed system.

Unlike most monitoring wells on the Hanford Site, the offsite wells are used for water supply. These water-supply wells are typically pumped intermittently on a daily basis to a storage or pressure tank. Because of this intermittent pumping use, long purge times to evacuate three bore volumes were not necessary during sample collection. Purge times of approximately 15 to 20 minutes were sufficient to evacuate the discharge line. Where possible, low flow rates were estimated using an 18.9-liter (5-gallon) bucket. At high flow rates, the well owner provided an estimate of the pump capacity.

The wells were allowed to purge until field-measured parameters pH, temperature, and specific conductance had stabilized. Results of the stabilization parameters and purge volumes are presented in Table B.1. Total purge times were approximately 15 to 20 minutes for most of the sample wells and the flow rates between sample wells ranged from approximately 8 to 760 liters per minute (2 to 201 gallons per minute). All samples collected were visually clear, indicating a qualitative turbidity range near 5 NTU or less. After field-measured parameters had stabilized, groundwater samples were collected using a 10-liter (2.6-gallon) container. Samples were collected from a spigot near the well, and where possible, ahead of any storage or pressure tank. The 10-liter (2.6-gallon) sample was then used to fill the sample bottles, with separate aliquots for anions, cations, and radionuclides. Cation samples were filtered (0.45-micron filter size) in the field using a peristaltic pump prior to filling the cation sample bottle. Cation sample bottles were preserved with reagent grade HNO_3 prior to entering the field. Hydraulic head measurements were not taken during the sampling event because the wells were inaccessible for measuring water levels.

Sampling information relevant to each well is documented on Groundwater Sample Reports presented in Appendix C. Well names are cross-referenced with the HEIS well number and unique well identification number in Table B.2. Well 10N27E-14D was sampled in duplicate for quality control information.

Table B.1. General Parameters Measured During Sample Collection

Well Number	Sample Date	pH	Temperature (degrees Celsius)	Specific Conductance (microS/cm)	Purge Flow Rate (L/min)	Total Purge Time (min)	Total Purge Volume (L)
09N28E-04G	11/6/00	8.16	16.6	377	7.6	16	122
09N28E-06C	11/6/00	7.65	18.0	534	37.9	14	531
10N27E-14D	11/6/00	7.86	16.4	282	100	5	500
10N28E-18F	11/6/00	7.64	18.3	245	760	18	13680
10N28E-24R	10/27/00	8.29	19.8	382	34	20	680
10N29E-02Q	10/27/00	7.95	17.0	456	18.9	18	340
10N29E-19E	10/27/00	8.49	18.3	384	9.5	21	200
399-5-2[(a)]	6/14/01	8.21	17.9	351	30.3	60	1818
699-S11-E12AP[(a)]	5/16/00	8.05	17.5	365	7.6	65	494
699-S24-19P[(a)]	8/31/98	7.11	20.4	514	NA	NA	NA

(a) Onsite wells in southern region of Hanford Site.
NA = Not available.

Table B.2. Offsite Well Numbers Cross-Referenced to HEIS Well Numbers

Well Number	HEIS Well Number	HEIS Unique Well ID Number
09N28E-04G	09N28E04G01	C3642
09N28E-06C	09N28E06C02	C3643
10N27E-14D	10N27E14F03	C3644
10N28E-18F	699-ORV-1	A9125
10N28E-24R	10N28E24R03	C3645
10N29E-02Q	10N29E02Q01	C3646
10N29E-19E	10N29E19E01	C3648

Appendix C

Groundwater Sample Reports

GROUNDWATER SAMPLE REPORT

Project: OFFSITE GW MONITORING, AUG					Date: 11-6-00	Page 1 of 2
Task Order/Month: 20 SEPT. 00		QC Type:			Calculations: 2x 16 = 32 gal	
Well Number: 09N28E-04G		A# :				
Total Purge Volume (gal): 32		Purge Flow Rate (gal/min): 2				
Pump Type: submersible	Time on:	Water:	Purge: 11:21am	Samp.: 11:37am	Off: 11:38am	

SAMPLES COLLECTED

B0YY74 Severn Trent St. Louis COC No.: X00-026-1

- 1;20mL;P Activity Scan (None)
- 1;500mL;G/P 310.1_ALKALINITY: Alkalinity (1) (Cool 4C)
- 1;500mL;P 300.0_ANIONS_IC: List-1 (5) (Cool 4C)

B0YY85 (Filtered) Severn Trent St. Louis COC No.: X00-026-1

- 1;500mL;G/P 6010_METALS_ICP: List-1 (19) (HNO3 to pH <2)

B0YY96 Severn Trent Incorporated COC No.: X00-026-12

- 3;1000mL;P TRITIUM_ELECT_LSC: H-3 (1) (None)
- 1;20mL;P Activity Scan (None)
- 1;1000mL;P 9310_ALPHABETA_GPC: Alpha + Beta (2) (HNO3 to pH <2)

RECORD COPY
PROJ. 28023
CAT. T3.3
WORKING COPY

Total No. Bottles: 10 Containment Code: Collector: owner/E Radford

FIELD MEASUREMENTS

Water Level (TOC): Drawdown (TOC): Oil Sheen Yes ☐ No ☒

Prev. pH: Prev. DTW: E-Tape No.:

Time	11:24am	11:28	11:36am							
pH	8.05	8.15	8.16							
Temp. (°C)	15.8	16.0	16.6							
Cond. (µs/cm)	375	375.9	376.6							
Turb. (NTU)										
D. O. (mg/L)										

FIELD OBSERVATIONS

Weather:

Field Comments: sampled from well house (before pressure tank)
clear, no turbidity

Pre Check: Post Check:

Comments: SEE ATTACHED SHEETS FOR LOCATION AND PUMPING INSTRUCTIONS. PURGE 15-30 MIN. UNLESS PUMP HAS BEEN RUN RECENTLY. RECORD GPS IF POSSIBLE

Well capped and locked: ☐ Yes ☐ No Logbook/Pg# :

Samples Surveyed for Gamma Radiation by RPTs: ☐ Yes ☐ No

Data Recorded by: E. RADFORD E Radford (Print and sign name) 11-6-00 (Date)

Data Checked by: (Print and sign name) (Date)

GROUNDWATER SAMPLE REPORT

Project: OFFSITE GW MONITORING, AUG						Date: 11-6-00	Page 2 of 2
Task Order/Month: 20 SEPT. 00		QC Type:				Calculations:	
Well Number: 09N28E-04G		A# :					
Total Purge Volume (gal):		Purge Flow Rate (gal/min):					
Pump Type:	Time on:	Water:	Purge:	Samp.: 1158	Off:		

SAMPLES COLLECTED

B0YYB7 PNL Sigma 5 COC No.: X00-026-23

1;1000mL;P Activity Scan (None)

Total No. Bottles: 10 Containment Code: Collector: E Radford

FIELD MEASUREMENTS

Water Level (TOC): | Drawdown (TOC): | Oil Sheen Yes ☐ No ☐

Prev. pH: | Prev. DTW: | E-Tape No.:

Time	11:24	11:36								
pH	8.05	8.16								
Temp. (°C)	15.8	16.6								
Cond. (µs/cm)	375.0	376.6								
Turb. (NTU)										
D. O. (mg/L)										

FIELD OBSERVATIONS

Weather: ________

Field Comments: ________

Pre Check: ________ Post Check: ________

Comments: SEE ATTACHED SHEETS FOR LOCATION AND PUMPING INSTRUCTIONS. PURGE 15-30 MIN. UNLESS PUMP HAS BEEN RUN RECENTLY. RECORD GPS IF POSSIBLE

Well capped and locked: ☐ Yes ☐ No Logbook/Pg# :

Samples Surveyed for Gamma Radiation by RPTs: ☐ Yes ☐ No

Data Recorded by: E. RADFORD E Radford — Print and sign name — Date: 11-6-2000

Data Checked by: ____ Print and sign name — Date

GROUNDWATER SAMPLE REPORT

Project: OFFSITE GW MONITORING, AUG				Date: 11-6-00	Page 1 of 2
Task Order/Month: 20 SEPT. 00		QC Type:		Calculations: RECORD COPY PROJ. 28023 CAT. T3.3 WORKING COPY	
Well Number: 09N28E-06C		A#:			
Total Purge Volume (gal): 140		Purge Flow Rate (gal/min): ~10			
Pump Type: Submersible	Time on:	Water: 12:05	Purge: 12:05pm	Samp.: 12:19	Off: 12:21

SAMPLES COLLECTED

B0YY75 Severn Trent St. Louis COC No.: X00-026-2 ✓

- 1;20mL;P Activity Scan (None)
- 1;500mL;G/P 310.1_ALKALINITY: Alkalinity (1) (Cool 4C)
- 1;500mL;P 300.0_ANIONS_IC: List-1 (5) (Cool 4C)

B0YY86 (Filtered) Severn Trent St. Louis COC No.: X00-026-2 ✓

- 1;500mL;G/P 6010_METALS_ICP: List-1 (19) (HNO3 to pH <2)

B0YY97 Severn Trent Incorporated COC No.: X00-026-13 ✓

- 3;1000mL;P TRITIUM_ELECT_LSC: H-3 (1) (None)
- 1;20mL;P Activity Scan (None)
- 1;1000mL;P 9310_ALPHABETA_GPC: Alpha + Beta (2) (HNO3 to pH <2)

Total No. Bottles: 10 Containment Code: Collector: E Radford

FIELD MEASUREMENTS

Water Level (TOC):			Drawdown (TOC):			Oil Sheen Yes ☐ No ☐				
Prev. pH:			Prev. DTW:			E-Tape No.:				
Time	12:07	12:19								
pH	7.94	7.65								
Temp. (°C)	17.3	18.0								
Cond. (µs/cm)	516.7	523.9								
Turb. (NTU)										
D. O. (mg/L)										

FIELD OBSERVATIONS

Weather:

Field Comments:

Pre Check: Post Check:

Comments: SEE ATTACHED SHEETS FOR LOCATION AND PUMPING INSTRUCTIONS. PURGE 15-30 MIN. UNLESS PUMP HAS BEEN RUN RECENTLY. RECORD GPS IF POSSIBLE

Well capped and locked: ☐ Yes ☐ No Logbook/Pg#:

Samples Surveyed for Gamma Radiation by RPTs: ☒ Yes ☐ No

Data Recorded by: E. RADFORD E Radford — Print and sign name — Date: 11-6-00

Data Checked by: Print and sign name Date

GROUNDWATER SAMPLE REPORT

Project: OFFSITE GW MONITORING, AUG					Date: 11-6-00	Page 2 of 2
Task Order/Month: 20 SEPT. 00	QC Type:				Calculations: 10x14 = 140 gal	
Well Number: 09N28E-06C	A#:					
Total Purge Volume (gal): 140	Purge Flow Rate (gal/min): ~10					
Pump Type: submersible	Time on:	Water:	Purge: 12:05pm	Samp.: 12:19	Off: 12:21	

SAMPLES COLLECTED

• B0YYB8 PNL Sigma 5 COC No.: X00-026-24

1;1000mL;P Activity Scan (None)

Total No. Bottles: 10 Containment Code: Collector: owner

FIELD MEASUREMENTS

Water Level (TOC): | Drawdown (TOC): | Oil Sheen Yes ☐ No ☒

Prev. pH: | Prev. DTW: | E-Tape No.:

Time	12:07pm	12:09	12:12	12:16	12:19					
pH	7.94	7.84	7.91	7.88	7.65	7.9				
Temp. (°C)	17.3	17.6	18.1	18.3	18.0					
Cond. (μs/cm)	516.7	650.0	543.2	531.8	533.9					
Turb. (NTU)										
D. O. (mg/L)										

FIELD OBSERVATIONS

Weather:

Field Comments: irrigation spigot near well
clear, no turbidity

Pre Check: Post Check:

Comments: SEE ATTACHED SHEETS FOR LOCATION AND PUMPING INSTRUCTIONS. PURGE 15-30 MIN. UNLESS PUMP HAS BEEN RUN RECENTLY. RECORD GPS IF POSSIBLE

Well capped and locked: ☐ Yes ☐ No Logbook/Pg#:

Samples Surveyed for Gamma Radiation by RPTs: ☐ Yes ☒ No

Data Recorded by: E. RADFORD [signature] (Print and sign name) 11-6-2000 (Date)

Data Checked by: (Print and sign name) (Date)

GROUNDWATER SAMPLE REPORT

Project: OFFSITE GW MONITORING, AUG		Date: 11-6-00	Page 1 of 3
Task Order/Month: 20 SEPT. 00	QC Type: DUP	Calculations: RECORD COPY	
Well Number: 10N27E-14D	A# :	PROJ. 28023	
Total Purge Volume (gal): ~12.5	Purge Flow Rate (gal/min): ~2 1/2	CAT. T3.3	
Pump Type: submersible		WORKING COPY	

Time on:	Water:	Purge:	Samp.:	Off:
	9:02am	9:02am	9:07am	9:08am

SAMPLES COLLECTED

B0YY77 Severn Trent St. Louis COC No.: X00-026-4 ✓

- 1;20mL;P Activity Scan (None)
- 1;500mL;G/P 310.1_ALKALINITY: Alkalinity (1) (Cool 4C)
- 1;500mL;P 300.0_ANIONS_IC: List-1 (5) (Cool 4C)

B0YY84 Severn Trent St. Louis COC No.: X00-026-11 ✓

- 1;20mL;P Activity Scan (None)
- 1;500mL;G/P 310.1_ALKALINITY: Alkalinity (1) (Cool 4C)
- 1;500mL;P 300.0_ANIONS_IC: List-1 (5) (Cool 4C)

B0YY88 (Filtered) Severn Trent St. Louis COC No.: X00-026-4 ✓

- 1;500mL;G/P 6010_METALS_ICP: List-1 (19) (HNO3 to pH <2)

Total No. Bottles: 19 Containment Code: Collector: owner / E Radford

FIELD MEASUREMENTS

Water Level (TOC): Drawdown (TOC): Oil Sheen Yes ☐ No ☒

Prev. pH: Prev. DTW: E-Tape No.:

Time	9:04am	9:07am								
pH	7.25	7.86								
Temp. (°C)	16.4	16.4								
Cond. (µs/cm)	284.5	282.0								
Turb. (NTU)										
D. O. (mg/L)										

FIELD OBSERVATIONS

Weather:

Field Comments: sampled from pumphouse
clear, no turbidity
limited purge because of alarm

Pre Check: Post Check:

Comments: SEE ATTACHED SHEETS FOR LOCATION AND PUMPING INSTRUCTIONS. PURGE 15-30 MIN. UNLESS PUMP HAS BEEN RUN RECENTLY. RECORD GPS IF POSSIBLE

Well capped and locked: ☐ Yes ☐ No Logbook/Pg# :

Samples Surveyed for Gamma Radiation by RPTs: ☐ Yes ☐ No

Data Recorded by: Eddie RADFORD Eddie Radford (Print and sign name) 11/4/2000 (Date)

Data Checked by: (Print and sign name) (Date)

GROUNDWATER SAMPLE REPORT

Project: OFFSITE GW MONITORING, AUG		Date: 11-6-00	Page 2 of 3
Task Order/Month: 20 SEPT. 00	QC Type:	Calculations:	
Well Number: 10N27E-14D	A# :		
Total Purge Volume (gal): ~12.5	Purge Flow Rate (gal/min): ~2 1/2		
Pump Type: submersible	Time on: Water: 9:02am Purge: 9:02am Samp.: 9:07am Off: 9:08am		

SAMPLES COLLECTED

B0YY95 (Filtered) Severn Trent St. Louis COC No.: X00-026-11 ✓

1;500mL;G/P 6010_METALS_ICP: List-1 (19) (HNO3 to pH <2)

B0YY99 Severn Trent Incorporated COC No.: X00-026-15 ✓

3;1000mL;P TRITIUM_ELECT_LSC: H-3 (1) (None)
1;20mL;P Activity Scan (None)
1;1000mL;P 9310_ALPHABETA_GPC: Alpha + Beta (2) (HNO3 to pH <2)

B0YYB6 Severn Trent Incorporated COC No.: X00-026-22 ✓

3;1000mL;P TRITIUM_ELECT_LSC: H-3 (1) (None)
1;20mL;P Activity Scan (None)
1;1000mL;P 9310_ALPHABETA_GPC: Alpha + Beta (2) (HNO3 to pH <2)

Total No. Bottles: 19 Containment Code: Collector: owner E Ladford

FIELD MEASUREMENTS

Water Level (TOC): Drawdown (TOC): Oil Sheen Yes ☐ No ☒

Prev. pH: Prev. DTW: E-Tape No.:

Time	9:04am	9:07am								
pH	7.25	7.86								
Temp. (°C)	16.4	16.4								
Cond. (µs/cm)	284.5	282.0								
Turb. (NTU)										
D. O. (mg/L)										

FIELD OBSERVATIONS

Weather:

Field Comments: Sampled from pumphouse.
clear, no turbidity
limited purge because of alarm

Pre Check: Post Check:

Comments: SEE ATTACHED SHEETS FOR LOCATION AND PUMPING INSTRUCTIONS. PURGE 15-30 MIN. UNLESS PUMP HAS BEEN RUN RECENTLY. RECORD GPS IF POSSIBLE

Well capped and locked: ☐ Yes ☐ No Logbook/Pg# :

Samples Surveyed for Gamma Radiation by RPTs: ☐ Yes ☐ No

Data Recorded by: Eddie LADFORD E Ladford 11-6-2000
Print and sign name Date

Data Checked by:
Print and sign name Date

GROUNDWATER SAMPLE REPORT

Project: OFFSITE GW MONITORING, AUG			Date: 11-6-00	Page 3 of 3
Task Order/Month: 20 SEPT. 00	QC Type:		Calculations: $2\frac{1}{2} \times 5 = 12.5$ gal/min	
Well Number: 10N27E-14D	A# :			
Total Purge Volume (gal): ~12.5	Purge Flow Rate (gal/min): ~$2\frac{1}{2}$			
Pump Type: submersible	Time on:	Water: 9:02am / Purge: 9:02am / Samp.: 9:07am / Off: 9:08am		

SAMPLES COLLECTED

B0YYC0 PNL Sigma 5 COC No.: X00-026-26

1;1000mL;P Activity Scan (None)

Total No. Bottles: 19 Containment Code: Collector: owner / E Radford

FIELD MEASUREMENTS

Water Level (TOC):			Drawdown (TOC):			Oil Sheen Yes ☐ No ☒				
Prev. pH:			Prev. DTW:			E-Tape No.:				
Time	9:04am	9:07am								
pH	7.25	7.86								
Temp. (°C)	16.4	16.4								
Cond. (µs/cm)	284.5	282.0								
Turb. (NTU)										
D. O. (mg/L)										

FIELD OBSERVATIONS

Weather:

Field Comments: Sampled from pumphouse.
Clear no turbidity
limited purge because of alarm

Pre Check: Post Check:

Comments: SEE ATTACHED SHEETS FOR LOCATION AND PUMPING INSTRUCTIONS. PURGE 15-30 MIN. UNLESS PUMP HAS BEEN RUN RECENTLY. RECORD GPS IF POSSIBLE

Well capped and locked: ☐ Yes ☐ No Logbook/Pg# :

Samples Surveyed for Gamma Radiation by RPTs: ☐ Yes ☐ No

Data Recorded by: E. RADFORD E Radford (Print and sign name) Date: 11-6-2000

Data Checked by: (Print and sign name) Date:

GROUNDWATER SAMPLE REPORT

Project: OFFSITE GW MONITORING, AUG					Date: 11-6-00	Page 1 of 2
Task Order/Month: 20 SEPT. 00	QC Type:				Calculations:	
Well Number: 699-ORV-1	A# :				RECORD COPY PROJ. 28023 CAT. T3.3 WORKING COPY	
Total Purge Volume (gal):	Purge Flow Rate (gal/min): 200					
Pump Type: Submersible	Time on: 10:20 am	Water: 10:20	Purge: 10:20 am	Samp.: 10:38 am	Off: 10:45 am	

SAMPLES COLLECTED

~~TOTAL ACTIVITY~~
~~HPT~~
~~REG. TRUCK~~
psh 9-14-00

B0YY78 Severn Trent St. Louis COC No.: X00-026-5

1;20mL;P Activity Scan (None)
1;500mL;G/P 310.1_ALKALINITY: Alkalinity (1) (Cool 4C)
1;500mL;P 300.0_ANIONS_IC: List-1 (5) (Cool 4C)

B0YY89 (Filtered) Severn Trent St. Louis COC No.: X00-026-5

1;500mL;G/P 6010_METALS_ICP: List-1 (19) (HNO3 to pH <2)

B0YYB0 Severn Trent Incorporated COC No.: X00-026-16

3;1000mL;P TRITIUM_ELECT_LSC: H-3 (1) (None)
1;20mL;P Activity Scan (None)
1;1000mL;P 9310_ALPHABETA_GPC: Alpha + Beta (2) (HNO3 to pH <2)

Total No. Bottles: 10 Containment Code: Collector: owner/E Radford

FIELD MEASUREMENTS

Water Level (TOC):	Drawdown (TOC):	Oil Sheen Yes ☐ No ☒
Prev. pH:	Prev. DTW:	E-Tape No.:

Time	10:30am	10:34am	10:36	10:38						
pH	8.11	7.85	7.69	7.64						
Temp. (°C)	17.6	18.1	18.2	18.3						
Cond. (µs/cm)	246.5	245.0	244.7	244.8						
Turb. (NTU)										
D. O. (mg/L)										

FIELD OBSERVATIONS

Weather:

Field Comments: sampled from wellhouse before chlorinator
clean no turbidity
purged from fire hydrant

Pre Check: Post Check:

Comments: SEE ATTACHED SHEETS FOR LOCATION AND PUMPING INSTRUCTIONS. PURGE 15-30 MIN. UNLESS PUMP HAS BEEN RUN RECENTLY. RECORD GPS IF POSSIBLE

Well capped and locked: ☐ Yes ☐ No Logbook/Pg# :

Samples Surveyed for Gamma Radiation by RPTs: ☐ Yes ☐ No

Data Recorded by: Eddie Radford Eddie Radford Date 11/6/2000
Print and sign name

Data Checked by: Date
Print and sign name

GROUNDWATER SAMPLE REPORT

Project: OFFSITE GW MONITORING, AUG						Date: 11-6-00	Page 2 of 2
Task Order/Month: 20 SEPT. 00		QC Type:				Calculations:	
Well Number: 699-ORV-1		A# :					
Total Purge Volume (gal):		Purge Flow Rate (gal/min):					
Pump Type:	Time on:	Water:	Purge:	Samp.:	Off:		

SAMPLES COLLECTED

B0YYC1 PNL Sigma 5 COC No.: X00-026-27

1;1000mL;P Activity Scan (None)

Total No. Bottles: 10 Containment Code: Collector: E Radford

FIELD MEASUREMENTS

Water Level (TOC):			Drawdown (TOC):			Oil Sheen	Yes ☐		No ☐	
Prev. pH:			Prev. DTW:			E-Tape No.:				
Time	10:30	10:38								
pH	8.11	7.64								
Temp. (°C)	17.6	18.3								
Cond. (μs/cm)	246.5	244.8								
Turb. (NTU)										
D. O. (mg/L)										

FIELD OBSERVATIONS

Weather:

Field Comments:

Pre Check: Post Check:

Comments: SEE ATTACHED SHEETS FOR LOCATION AND PUMPING INSTRUCTIONS. PURGE 15-30 MIN. UNLESS PUMP HAS BEEN RUN RECENTLY. RECORD GPS IF POSSIBLE

Well capped and locked: ☐ Yes ☐ No Logbook/Pg# :

Samples Surveyed for Gamma Radiation by RPTs: ☐ Yes ☐ No

Data Recorded by: E. RADFORD E Radford — Date: 11-6-2000

Print and sign name — Date

Data Checked by:

Print and sign name — Date

GROUNDWATER SAMPLE REPORT

Project: OFFSITE GW MONITORING, AUG						Date: oct 27, 2000	Page 1 of 2
Task Order/Month: 20 SEPT. 00		QC Type:				Calculations: 2½ gallons in 17 sec 9 gal/min X 20 min = 180 gal	
Well Number: 10N28E-24R		A# :					
Total Purge Volume (gal): ~180		Purge Flow Rate (gal/min): 5-10 gal/min					
Pump Type: submersible	Time on: 10:29am	Water:	Purge:	Samp.: 10:49am	Off: 10:50am		

SAMPLES COLLECTED

B0YY79	Severn Trent St. Louis	COC No.: X00-026-6
1;20mL;P	Activity Scan (None)	
1;500mL;G/P	310.1_ALKALINITY: Alkalinity (1) (Cool 4C)	
1;500mL;P	300.0_ANIONS_IC: List-1 (5) (Cool 4C)	
B0YY90 (Filtered)	Severn Trent St. Louis	COC No.: X00-026-6
1;500mL;G/P	6010_METALS_ICP: List-1 (19) (HNO3 to pH <2)	
B0YYB1	Severn Trent Incorporated	COC No.: X00-026-17
3;1000mL;P	TRITIUM_ELECT_LSC: H-3 (1) (None)	
1;20mL;P	Activity Scan (None)	
1;1000mL;P	9310_ALPHABETA_GPC: Alpha + Beta (2) (HNO3 to pH <2)	

Total No. Bottles: 10 Containment Code: Collector: owner

FIELD MEASUREMENTS

Water Level (TOC): Drawdown (TOC): Oil Sheen Yes ☐ No ☒

Prev. pH: Prev. DTW: E-Tape No.:

Time	10:35am	10:47am								
pH	8.30	8.29								
Temp. (°C)	18.2	19.8								
Cond. (µs/cm)	381.8	382.0								
Turb. (NTU)										
D. O. (mg/L)										

FIELD OBSERVATIONS

Weather:

Field Comments: Sampled from spigot and hose outside of pumphouse. Water was clear (no turbidity)

Pre Check: Post Check:

Comments: SEE ATTACHED SHEETS FOR LOCATION AND PUMPING INSTRUCTIONS. PURGE 15-30 MIN. UNLESS PUMP HAS BEEN RUN RECENTLY. RECORD GPS IF POSSIBLE

Well capped and locked: ☐ Yes ☐ No Logbook/Pg# :

Samples Surveyed for Gamma Radiation by RPTs: ☐ Yes ☐ No

Data Recorded by: E. RADFORD E Radford — Print and sign name — Date: 10.27.00

Data Checked by: — Print and sign name — Date:

GROUNDWATER SAMPLE REPORT

Project: OFFSITE GW MONITORING, AUG						Date:	Page 2 of 2
Task Order/Month: 20 SEPT. 00		QC Type:				Calculations: 2.5941 - 17 sec.	
Well Number: 10N28E-24R		A# :					
Total Purge Volume (gal): 180		Purge Flow Rate (gal/min):					
Pump Type:	Time on: 10:29	Water:	Purge:	Samp.: 10:49	Off: 10:50		

SAMPLES COLLECTED

B0YYC2 PNL Sigma 5 COC No.: X00-026-28

1;1000mL;P Activity Scan (None)

Total No. Bottles: 10 Containment Code: Collector: E RADFORD

FIELD MEASUREMENTS

Water Level (TOC): Drawdown (TOC): Oil Sheen Yes ☐ No ☐

Prev. pH: Prev. DTW: E-Tape No.:

Time	10:35	10:47								
pH	8.30	8.25								
Temp. (°C)	18.2	19.8								
Cond. (µs/cm)	381.8	382.0								
Turb. (NTU)										
D. O. (mg/L)										

FIELD OBSERVATIONS

Weather:

Field Comments:

Pre Check: Post Check:

Comments: SEE ATTACHED SHEETS FOR LOCATION AND PUMPING INSTRUCTIONS. PURGE 15-30 MIN. UNLESS PUMP HAS BEEN RUN RECENTLY. RECORD GPS IF POSSIBLE

Well capped and locked: ☐ Yes ☐ No Logbook/Pg# :

Samples Surveyed for Gamma Radiation by RPTs: ☐ Yes ☐ No

Data Recorded by: E. RADFORD E Radford
Print and sign name
Date 10.27.00

Data Checked by:
Print and sign name
Date

GROUNDWATER SAMPLE REPORT

Project: OFFSITE GW MONITORING, AUG			Date: Oct 27, 2000	Page 1 of 2
Task Order/Month: 20 SEPT. 00	QC Type:		Calculations: ~5gal/min x 18min = ~90gal	
Well Number: 10N29E-02Q	A# :			
Total Purge Volume (gal): ~90	Purge Flow Rate (gal/min): ~5gal/min			

Pump Type:	Time on:	Water:	Purge:	Samp.:	Off:
Submersible	9:03am			9:21am	9:22am

SAMPLES COLLECTED

B0YY80 Severn Trent St. Louis COC No.: X00-026-7

- 1;20mL;P Activity Scan (None)
- 1;500mL;G/P 310.1_ALKALINITY: Alkalinity (1) (Cool 4C)
- 1;500mL;P 300.0_ANIONS_IC: List-1 (5) (Cool 4C)

B0YY91 (Filtered) Severn Trent St. Louis COC No.: X00-026-7

- 1;500mL;G/P 6010_METALS_ICP: List-1 (19) (HNO3 to pH <2)

B0YYB2 Severn Trent Incorporated COC No.: X00-026-18

- 3;1000mL;P TRITIUM_ELECT_LSC: H-3 (1) (None)
- 1;20mL;P Activity Scan (None)
- 1;1000mL;P 9310_ALPHABETA_GPC: Alpha + Beta (2) (HNO3 to pH <2)

Total No. Bottles: 10 Containment Code: Collector: John (resident farmer)

FIELD MEASUREMENTS

Water Level (TOC): Drawdown (TOC): Oil Sheen Yes ☐ No ☒

Prev. pH: Prev. DTW: E-Tape No.:

Time	9:03am	9:18am	9:21am							
pH	7.85	7.95	7.95							
Temp. (°C)	13.5	16.3	17.0							
Cond. (µs/cm)	448.2	454.5	456.4							
Turb. (NTU)										
D. O. (mg/L)										

FIELD OBSERVATIONS

Weather:

Field Comments: Sampled from valve on the back of the house (no valve at the well, no treatment system). John (resident farmer) collected sample in 10 Liter container. no turbidity (clear). Pacific Daylight Time

Pre Check: Post Check:

Comments: SEE ATTACHED SHEETS FOR LOCATION AND PUMPING INSTRUCTIONS. PURGE 15-30 MIN. UNLESS PUMP HAS BEEN RUN RECENTLY. RECORD GPS IF POSSIBLE

Well capped and locked: ☐ Yes ☐ No Logbook/Pg# :

Samples Surveyed for Gamma Radiation by RPTs: ☑ Yes ☐ No

Data Recorded by: E. RADFORD E. Radford 10-27-00
Print and sign name Date

Data Checked by:
Print and sign name Date

GROUNDWATER SAMPLE REPORT

Project: OFFSITE GW MONITORING, AUG					Date:	Page 2 of 2
Task Order/Month: 20 SEPT. 00	QC Type:				Calculations:	
Well Number: 10N29E-02Q	A# :					
Total Purge Volume (gal):	Purge Flow Rate (gal/min):					
Pump Type:	Time on:	Water:	Purge:	Samp.:	Off:	

SAMPLES COLLECTED

B0YYC3 PNL Sigma 5 COC No.: X00-026-29

1;1000mL;P Activity Scan (None)

Total No. Bottles: 10 Containment Code: Collector: E LADFORD

FIELD MEASUREMENTS

Water Level (TOC):			Drawdown (TOC):		Oil Sheen Yes ☐ No ☐					
Prev. pH:			Prev. DTW:		E-Tape No.:					
Time	9:03	9:18	9:21							
pH	7.85	7.95	7.95							
Temp. (°C)	17.5	16.3	17.0							
Cond. (µs/cm)	448.2	454.5	456.4							
Turb. (NTU)										
D. O. (mg/L)										

FIELD OBSERVATIONS

Weather:

Field Comments:

Pre Check: Post Check:

Comments: SEE ATTACHED SHEETS FOR LOCATION AND PUMPING INSTRUCTIONS. PURGE 15-30 MIN. UNLESS PUMP HAS BEEN RUN RECENTLY. RECORD GPS IF POSSIBLE

Well capped and locked: ☐ Yes ☐ No Logbook/Pg# :

Samples Surveyed for Gamma Radiation by RPTs: ☐ Yes ☐ No

Data Recorded by: E. RADFORD E Radford (Print and sign name) 10-27-00 (Date)

Data Checked by: (Print and sign name) (Date)

GROUNDWATER SAMPLE REPORT

Project: OFFSITE GW MONITORING, AUG		Date: oct 27, 2000 10-27-00	Page 1 of 2
Task Order/Month: 20 SEPT. 00	QC Type:	Calculations: 2½ gal in 1 min 2½ X 21 min = 52.5 gal	
Well Number: 10N29E-19E	A#:		
Total Purge Volume (gal): 52	Purge Flow Rate (gal/min): 2½		

Pump Type:	Time on:	Water:	Purge:	Samp.:	Off:
submersible	11:20am			11:41am	11:42am

SAMPLES COLLECTED

B0YY82 Severn Trent St. Louis COC No.: X00-026-9

- 1;20mL;P Activity Scan (None)
- 1;500mL;G/P 310.1_ALKALINITY: Alkalinity (1) (Cool 4C)
- 1;500mL;P 300.0_ANIONS_IC: List-1 (5) (Cool 4C)

B0YY93 (Filtered) Severn Trent St. Louis COC No.: X00-026-9

- 1;500mL;G/P 6010_METALS_ICP: List-1 (19) (HNO3 to pH <2)

B0YYB4 Severn Trent Incorporated COC No.: X00-026-20

- 3;1000mL;P TRITIUM_ELECT_LSC: H-3 (1) (None)
- 1;20mL;P Activity Scan (None)
- 1;1000mL;P 9310_ALPHABETA_GPC: Alpha + Beta (2) (HNO3 to pH <2)

Total No. Bottles: 10 Containment Code: Collector: owner

FIELD MEASUREMENTS

Water Level (TOC):	Drawdown (TOC):	Oil Sheen Yes ☐ No ☒
Prev. pH:	Prev. DTW:	E-Tape No.:

Time	11:28am	11:36am	11:39am							
pH	8.52	8.49	8.49							
Temp. (°C)	16.9	18.4	18.3							
Cond. (µs/cm)	381.1	383.3	383.8							
Turb. (NTU)										
D. O. (mg/L)										

FIELD OBSERVATIONS

Weather:

Field Comments: Sampling from spigot in pumphouse before pressure tank. clear (no turbidity)

Pre Check: Post Check:

Comments: SEE ATTACHED SHEETS FOR LOCATION AND PUMPING INSTRUCTIONS. PURGE 15-30 MIN. UNLESS PUMP HAS BEEN RUN RECENTLY. RECORD GPS IF POSSIBLE

Well capped and locked: ☐ Yes ☐ No Logbook/Pg#:

Samples Surveyed for Gamma Radiation by RPTs: ☑ Yes ☐ No

Data Recorded by: E. RADFORD E Radford (Print and sign name) 10-27-00 (Date)

Data Checked by: (Print and sign name) (Date)

GROUNDWATER SAMPLE REPORT

Project: OFFSITE GW MONITORING, AUG						Date:	Page 2 of 2
Task Order/Month: 20 SEPT. 00	QC Type:					Calculations: 2.5 gal in/min	
Well Number: 10N29E-19E	A# :						
Total Purge Volume (gal): 52	Purge Flow Rate (gal/min):						
Pump Type: Submersible	Time on: 11:20	Water:	Purge:	Samp.:	Off: 11:42		

SAMPLES COLLECTED

B0YYC5 PNL Sigma 5 COC No.: X00-026-31

1;1000mL;P Activity Scan (None)

Total No. Bottles: 10 Containment Code: Collector: E Radford

FIELD MEASUREMENTS

Water Level (TOC):			Drawdown (TOC):			Oil Sheen Yes ☐ No ☐				
Prev. pH:			Prev. DTW:			E-Tape No.:				
Time	11:28	11:36	11:39							
pH	8.52	8.49	8.49							
Temp. (°C)	16.9	18.4	18.3							
Cond. (µs/cm)	381.1	383.3	383.8							
Turb. (NTU)										
D. O. (mg/L)										

FIELD OBSERVATIONS

Weather: ___

Field Comments: ___

Pre Check: ___ Post Check: ___

Comments: SEE ATTACHED SHEETS FOR LOCATION AND PUMPING INSTRUCTIONS. PURGE 15-30 MIN. UNLESS PUMP HAS BEEN RUN RECENTLY. RECORD GPS IF POSSIBLE

Well capped and locked: ☐ Yes ☐ No Logbook/Pg# :

Samples Surveyed for Gamma Radiation by RPTs: ☐ Yes ☐ No

Data Recorded by: E. RADFORD E Radford 10-27-00
Print and sign name Date

Data Checked by:
Print and sign name Date

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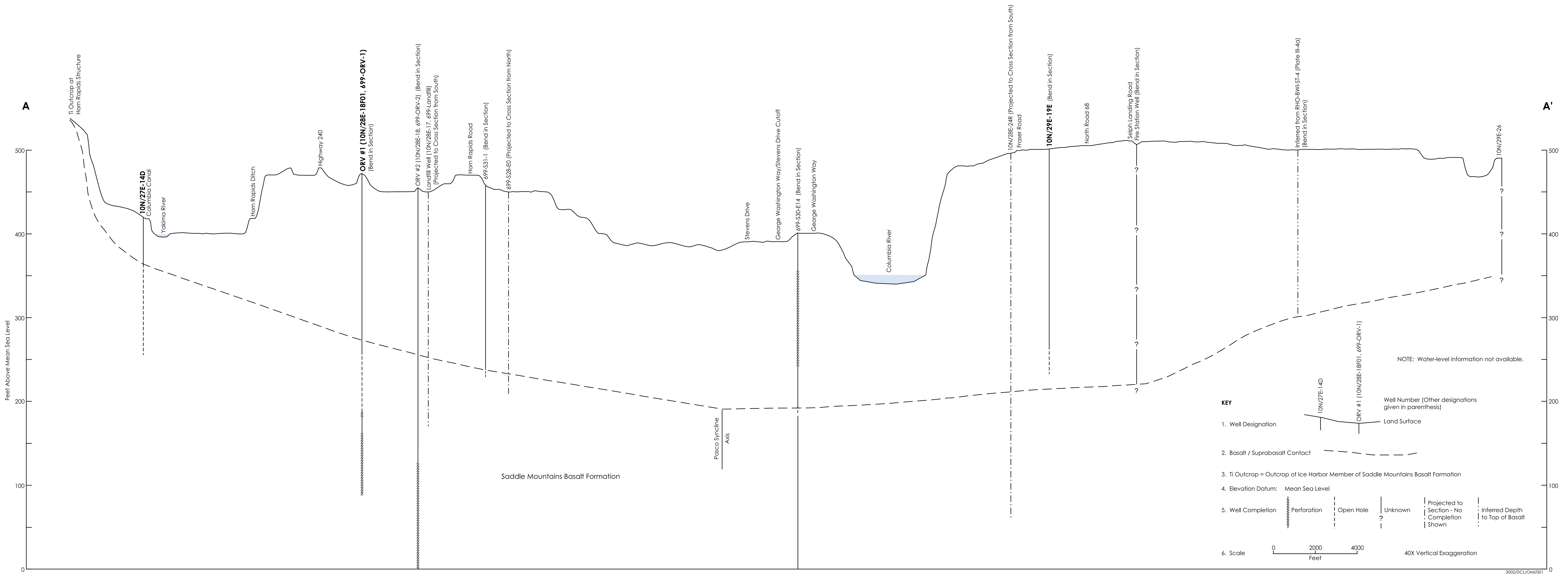
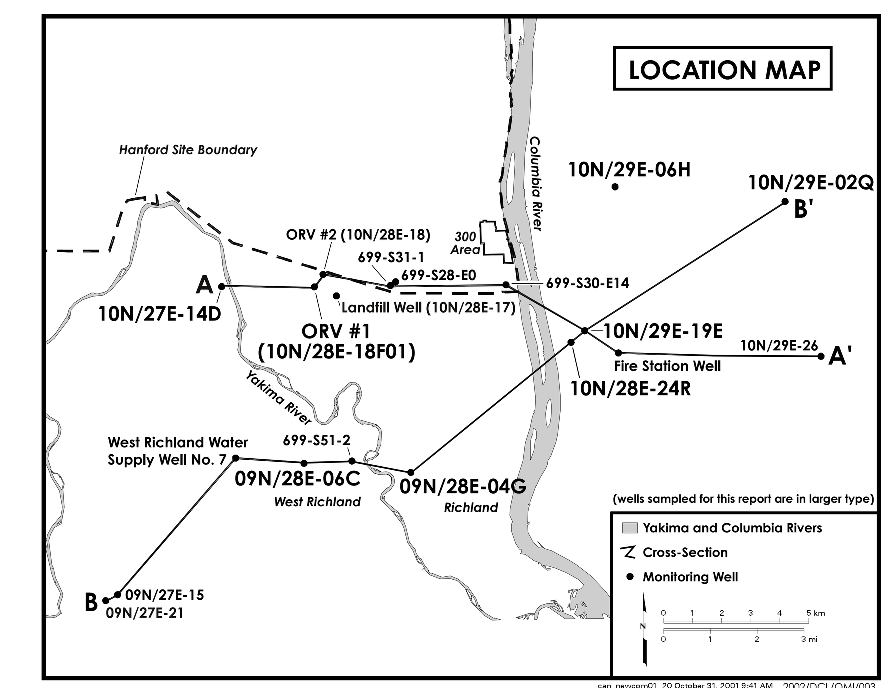
PLATE 1



A
A'
Feet Above Mean Sea Level
Ti Outcrop at Horn Rapids Structure
10N/27E-14D
Yakima River
Horn Rapids Ditch
Highway 240
ORV #1 (10N/28E-18F01, 699-ORV-1) (Bend in Section)
Horn Rapids Road
699-S31-1 (Bend in Section)
699-S28-E0 (Projected to Cross Section from North)
Stevens Drive
George Washington Way/Stevens Drive Cutoff
699-S30-E14 (Bend in Section)
George Washington Way
Columbia River
Fraser Road
10N/29E-19E (Bend in Section)
North Road 68
Saint Landing Road Fire Station Well (Bend in Section)
10N/29E-26
Pasco Syncline Axis
Saddle Mountains Basalt Formation
NOTE: Water-level information not available.
KEY
1. Well Designation
Well Number (Other designations given in parenthesis)
Land Surface
2. Basalt / Suprabasalt Contact
3. Ti Outcrop = Outcrop of Ice Harbor Member of Saddle Mountains Basalt Formation
4. Elevation Datum: Mean Sea Level
5. Well Completion
Perforation
Open Hole
Unknown
Projected to Section - No Completion Shown
Inferred Depth to Top of Basalt
6. Scale
0
2000
4000
Feet
40X Vertical Exaggeration



LOCATION MAP
Hanford Site Boundary
Columbia River
10N/29E-06H
10N/29E-02Q
B'
ORV #2 (10N/28E-18)
699-S31-1
699-S28-E0
300 Area
A
Landfill Well (10N/28E-17)
699-S30-E14
ORV #1 (10N/28E-18F01)
10N/27E-14D
10N/29E-19E
Fire Station Well
10N/29E-26
A'
10N/28E-24R
Yakima River
West Richland Water Supply Well No. 7
699-S51-2
09N/28E-06C
West Richland
09N/28E-04G
Richland
B
09N/27E-15
09N/27E-21
(wells sampled for this report are in larger type)
Yakima and Columbia Rivers
Cross-Section
Monitoring Well

B
B'
Feet Above Mean Sea Level
09N/27E-21
09N/27E-15 (Bend in Section)
Unnamed Anticline Axis
Ti Outcrop
Highway 224
Rattlesnake Hills Structure Axis
West Richland Water Supply Well No. 7 (Bend in Section)
Highway 224
Lost Lake Syncline Axis
09N/28E-06C (Bend in Section)
Horn Rapids Structure Axis
699-S51-2
Yakima River
Van Giesen Street
Jones Road
09N/28E-04G (Bend in Section)
Highway 240
Stevens Drive
George Washington Way
Pasco Syncline Axis
Columbia River
Saint Landing Road
10N/28E-24R (Bend in Section)
10N/29E-19E (Bend in Section)
North Road 68
Helm Drive
Esquatzel Diversion Channel
10N/29E-02Q
Saddle Mountains Basalt Formation
NOTE: Water-level information not available.
Ice Harbor Basalt
Levey Interbed
Elephant Mountain Basalt
KEY
1. Well Designation
Well Number
Land Surface
2. Basalt / Suprabasalt Contact
3. Ti Outcrop = Outcrop of Ice Harbor Member of Saddle Mountains Basalt Formation
4. Elevation Datum: Mean Sea Level
5. Well Completion
Perforation
Open Hole
Unknown
Projected to Section - No Completion Shown
Inferred Depth to Top of Basalt
6. Scale
0
2000
4000
Feet
40X Vertical Exaggeration

PLATE 2
West Richland Municipal Water Supply Well #7