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1994 CHARACTERIZATION REPORT FOR THE PROPOSED STATE-APPROVED LAND DISPOSAL SITE

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6. Author

Name: L.C. Swanson

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7. Abstract

This report describes the characterization work does at the State Approved Land Disposal Site during FY 1994 as part of the implimentation of the Groundwater Monitoring plan. Two downgradient groundwater monitoring wells were installed and aquifer tests were performed at the site.

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LIST OF TERMS

$CaCO_3$	calcium carbonate
CRBG	Columbia River Basalt Group
DOE	U.S. Department of Energy
RCRA	*Resource Conservation and Recovery Act of 1976*
SALDS	state-approved land disposal site

METRIC CONVERSION CHART

If you know	Multiply by	To get
INTO METRIC		
Length		
inches	2.54	centimeters
feet	30.48	centimeters
Volume		
gallons	3.786	liters
cubic feet	0.02832	cubic meters
Temperature		
°Fahrenheit	Subtract 32°, then multiply by 5/9ths	°Celsius
Pressure		
inches water	1.87	mm Hg
inches water	249	pascal (Pa)
OUT OF METRIC		
Length		
centimeters	0.3937	inches
meters	3.28	feet
Volume		
milliliters	1.247×10^{-3}	cubic feet
liters	0.264	gallons
cubic meters	35.31	cubic feet
Temperature		
°Celsius	Multiply by 9/5ths, then add 32°	°Fahrenheit
Pressure		
mm Hg	0.5353	inches water
pascal (Pa)	4.02×10^{-3}	inches water

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1994 CHARACTERIZATION REPORT FOR THE PROPOSED STATE-APPROVED LAND DISPOSAL SITE

1.0 INTRODUCTION

This report summarizes the results of characterization activities at the proposed state-approved land disposal site (SALDS); it updates the original characterization report (WHC 1993a) with studies completed since the first characterization report. The initial characterization report discusses studies from two characterization boreholes, 699-48-77A and 699-48-77B. This revision includes data from implementation of the Groundwater Monitoring Plan (WHC 1993b) and the Aquifer Test Plan (Swanson 1994). The primary sources of data are two downgradient groundwater monitoring wells, 699-48-77C and 699-48-77D, and aquifer testing of three zones in well 699-48-77C.

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2.0 SITE DESCRIPTION

2.1 LOCATION

The SALDS is located on the Hanford Site, approximately 183 m (600 ft) north of the 200 West Area (Figure 1) on the north side of the 200 Areas Plateau. Four boreholes were drilled at the SALDS over the past 3 years (Figure 2; Table 1). Boreholes 699-48-77A and 699-48-77B were drilled as part of the initial characterization activities. Boreholes 699-48-77C and 699-48-77D were drilled as groundwater monitoring wells (WHC 1993a). Final placement of the SALDS crib has borehole 699-48-77D approximately 5 m (16 ft) from the south edge of the crib and borehole 699-48-77C approximately 13 m (40 ft) from the east edge of the crib.

Table 1. Location of Boreholes in the SALDS.

Well no.	Coordinates			Elevations (NGVD'29 ft)			
	200W (ft)	Lambert NAD'83 (m)		Top of brass cap	HydroStar[a] plate N. side	Top of outer casing N. side	Top of inner casing N. side
699-48-77A	N:47602.7	N:137969.02	NGVD'29	672.25	674.74	674.72	N/A
	W:77020.0	E:566413.57					
699-48-77B	N:47590.0	N:137965.15	NGVD'29	671.73	N/A	N/A	N/A
	W:77013.3	E:566415.60					
699-48-77C	N:47989.32	N:138086.801	NGVD'29	671.91	N/A	674.28	N/A
	W:76836.16	E:566468.954					
699-48-77D	N:48096.14	N:138119.268	NGVD'29	671.37	N/A	673.87	N/A
	W:76952.88	E:566433.302					

[a]HydroStar is a trademark of Instrumentation Northwest, Inc., Redmond, Washington.
NAD = North American Datum.
NGVD = National Geodetic Vertical Datum.

2.2 GEOLOGY

The regional geology of the SALDS has been discussed in previous reports and in the initial characterization report. The following sections summarize the regional geology of the SALDS (DOE 1988, Vol. 1).

Figure 1. Hanford Site Location Map.

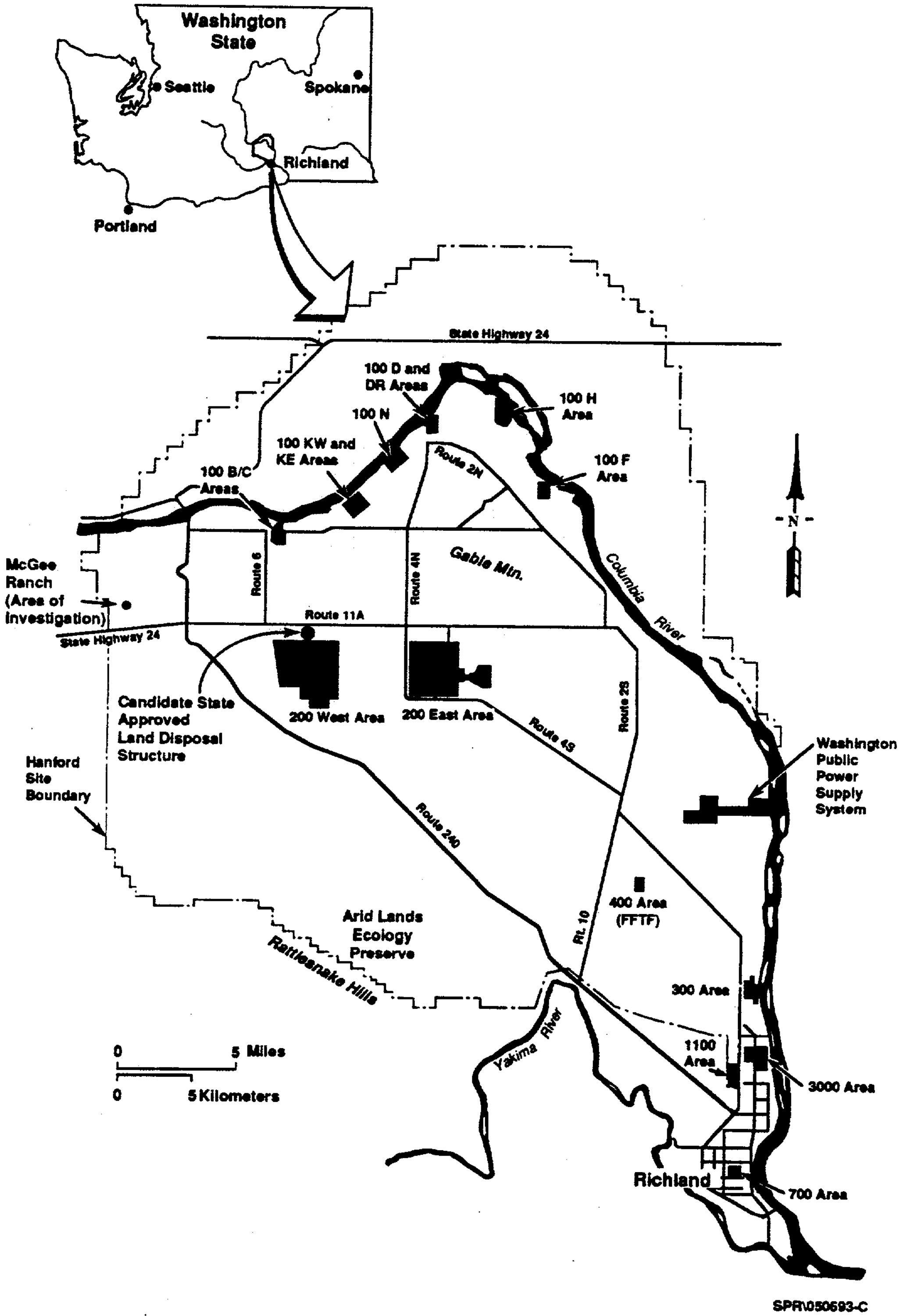
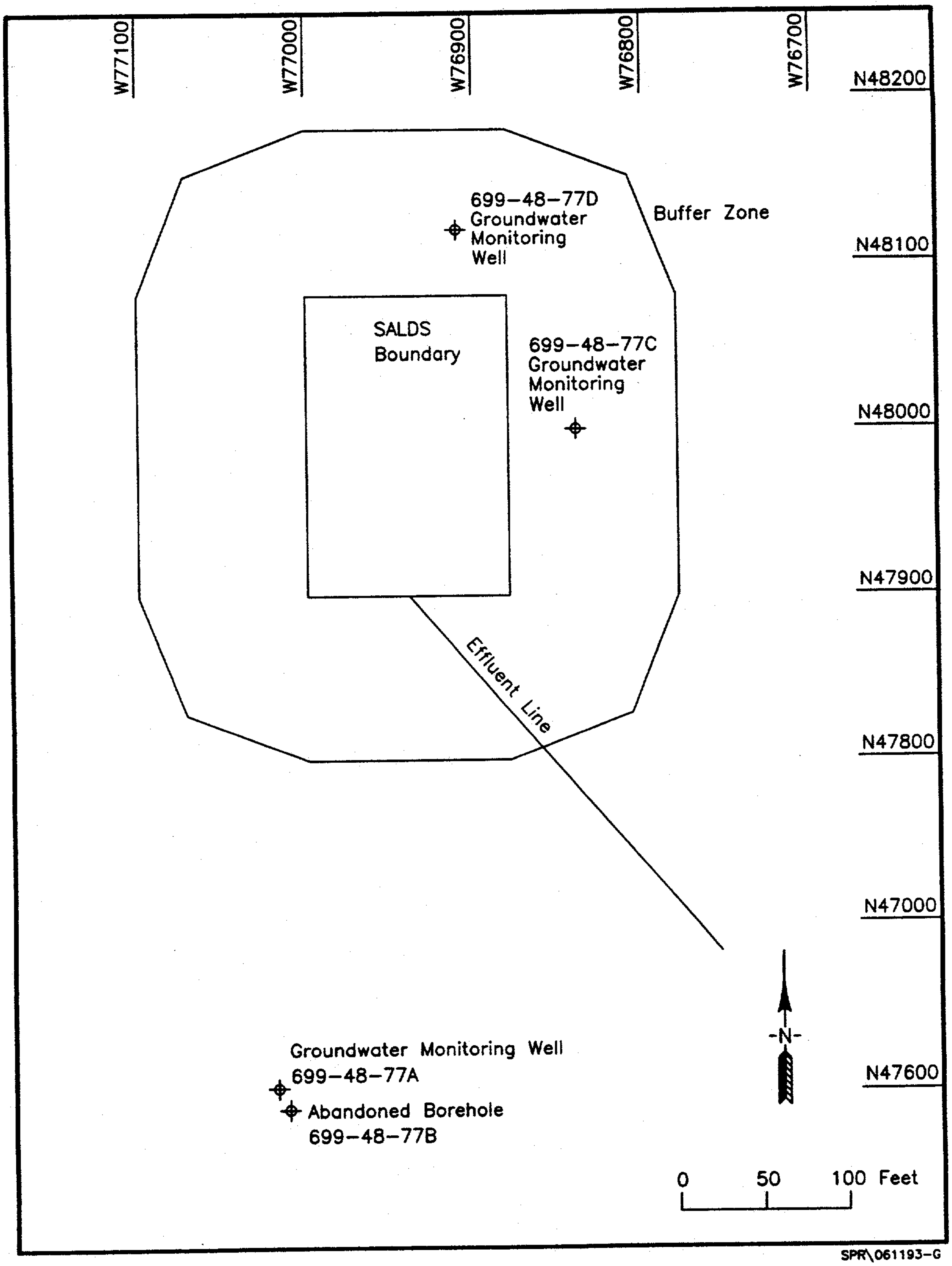


Figure 2. Borehole Location Map.



2.2.1 Regional Geologic Setting

The Hanford Site lies within the Columbia Plateau, a basin formed between the Cascade Range to the west and the Rocky Mountains to the east. The principal rock unit is a thick sequence of tholeiitic basalt flows called the Columbia River Basalt Group (CRBG). These flows have been folded and faulted over the past 17 million years, creating broad structural and topographic basins separated by asymmetric anticlinal ridges. Overlying the CRBG in the synclinal basins are sediments of the late-Miocene, Pliocene, Pleistocene, and Holocene. The Hanford Site lies within one of the larger basins, the Pasco Basin (Figure 3). The Pasco Basin is bounded on the north by the Saddle Mountains and on the south by Rattlesnake Mountain and the Rattlesnake Hills. Yakima Ridge and Umtanum Ridge trend into the Pasco Basin and subdivide it into a series of anticlinal ridges and synclinal valleys. The largest syncline, the Cold Creek syncline, lies between Umtanum Ridge and Yakima Ridge and is the principal structure containing the U.S. Department of Energy (DOE) waste management areas.

Principal stratigraphic units within the Hanford Site and the SALDS include, in ascending order, the CRBG (Miocene), the Ringold Formation (Miocene-Pliocene), and the Hanford formation (Pleistocene) (Figure 4). Plio-Pleistocene alluvium, eolian silt, and lacustrine deposits separate the Hanford formation and Ringold Formation locally. A regionally discontinuous veneer of Holocene alluvium, colluvium, and/or eolian sediments overlies the principal geologic units.

2.2.1.1 Tectonic Framework. The structural grain of the bedrock at the candidate SALDS trends roughly east-west parallel to the major geologic structures bounding the SALDS. The Gable Butte segment of the Umtanum Ridge anticline lies to the north and the Cold Creek syncline and Yakima Ridge anticline lie to the south (see Figure 3). As a result, the Ringold Formation and underlying CRBG gently dip to the south off the Umtanum Ridge anticline into the Cold Creek syncline. Major stratigraphic variations typically occur in a north-south direction parallel to the dip direction.

No faults have been identified at the SALDS (see Figure 3) (DOE 1988) and the closest known faults are along the Umtanum Ridge-Gable Mountain structure north of the SALDS. The closest potentially active fault occurs north of the 200 East Area on Gable Mountain. Over 20 years of seismic monitoring at the Hanford Site shows no seismic activity at the SALDS. A recently completed study (WHC 1994) summarizes the known seismo-tectonic information for the Columbia Basin and was used to compute the seismic hazards for the Hanford Site.

2.2.2 Geology of the Soil Column Disposal Site

The results of previous characterization activities at the candidate SALDS have been described by WHC (1993a). This section revises the initial stratigraphic descriptions using the information obtained in 1994 from the completion of two downgradient groundwater monitoring wells, 699-48-77C and 699-48-77D.

Figure 3. Pasco Basin Location and Tectonic Map.

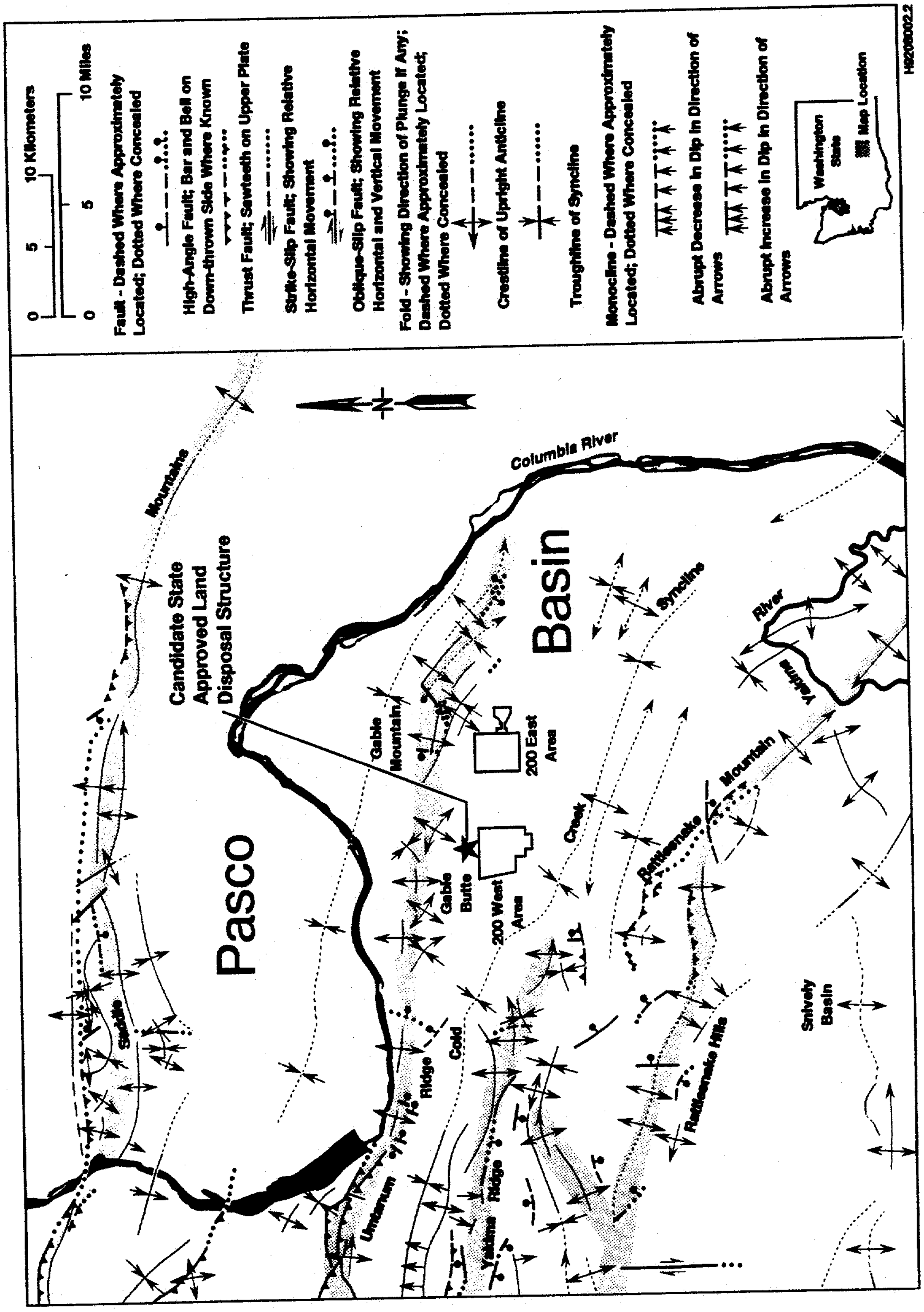
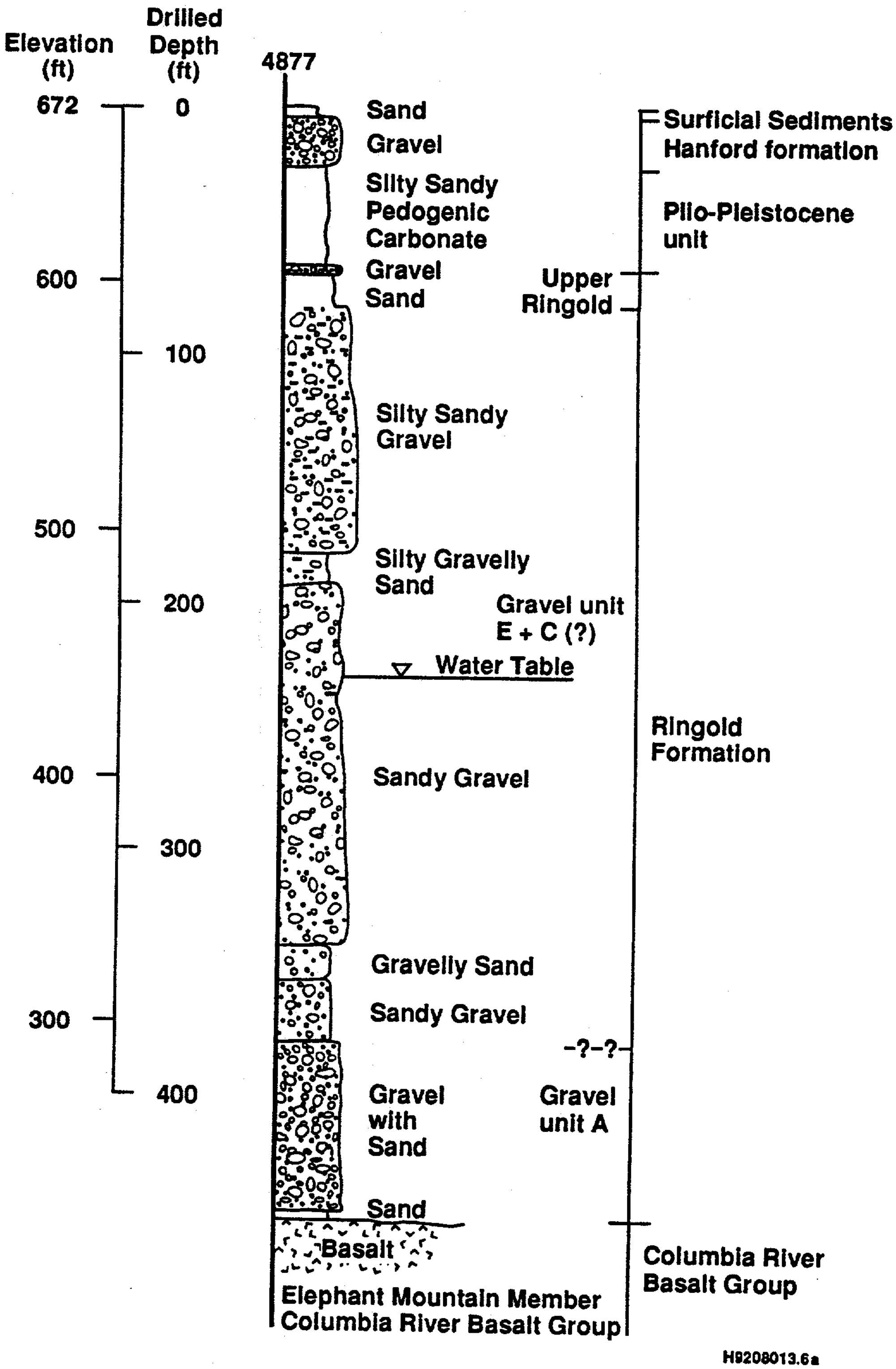


Figure 4. Stratigraphy of the State-Approved Land Disposal Site.



2.2.2.1 Preferred Soil Column Disposal Site Stratigraphy. The four boreholes, 699-48-77A, 699-48-77B, 699-48-77C, and 699-48-77D, were placed along the southern and northern edges of the SALDS (see Figure 2). In general, these boreholes indicate little change in the nature and thickness of the stratigraphic units across the SALDS (Figures 5 and 6).

2.2.2.2 Hanford Formation. The Hanford formation is approximately 7 m (23 ft) thick at the site and thickens both to the north and south of the site. The Hanford formation consists dominantly of open-framework gravels with a sandy matrix typical of deposits of the gravel-dominated facies. A thin silt lens occurs at the base of the gravel sequence above the Plio-Pleistocene unit. A relatively thin (up to 4 m [13 ft]), and extremely variable Holocene calcium carbonate ($CaCO_3$) zone occurs intermittently across the site. Test pits show that this zone is confined to the surface and consists of discontinuous blocks and stringers.

2.2.2.3 Plio-Pleistocene Unit. The thickness of the Plio-Pleistocene unit is approximately 13 m (42 ft), with the depth interval ranging from 7 to 19.8 m (23 to 65 ft). The unit consists of interfingering carbonate-cemented silt, sand, and gravel, and carbonate-poor silt and sand (WHC 1993a). Boreholes 699-48-77A and 699-48-77B showed thin pedogenic $CaCO_3$ lenses at the following horizons: 8.8 m (29 ft); 8.96 to 9.24 m (29.4 to 30.3 ft); 10.8, 10.9, 16.3, and 18.37 to 18.44 m (35.3, 35.8, 53.5, and 60.3 to 60.5 ft); and minor caliche between 19.2 and 19.47 m (63.0 and 63.9 ft). Some cemented sands occur in the unit as well. However, because of the limited core recovery the vertical and lateral extent of these zones is not known (Table A-2, core recovery table).

2.2.2.4 Ringold Formation. The Ringold Formation is approximately 119 m (390 ft) thick at the site and is dominated by fluvial gravels. The Ringold Formation begins at approximately 19.8 m (65 ft) drilled depth and continues to the top of the CRBG at 138.7 m (455 ft). A major cataclysmic flood channelway that is incised into the Ringold Formation occurs approximately 1 km (0.6 mi) north of the site. As a result of significant flood erosion in this channelway, the Plio-Pleistocene unit and much of the Ringold Formation has been removed. The channelway is filled with approximately 45.7 m (150 ft) of Hanford formation gravel-dominated deposits. The exact position of the erosional channelway edge is not known because no boreholes penetrate deep enough in the area between borehole 699-51-75 (located within the channelway) and the SALDS to encounter it.

The sandy sequence that occurs between the base of the Plio-Pleistocene unit (19.8 m [65 ft] depth) and the top of the uppermost Ringold gravels (unit E) (25.3 m [83 ft] depth) at the site is interpreted to be erosional remnants of the Ringold Formation member of Taylor Flat. These strata pinch out to the north, west, and east of the site (Lindsey 1991). This member extends to the south into the northern part of the 200 West Area.

The member of Taylor Flat grades quickly down into the gravels of unit E at 25- to 26.5-m (83- to 87-ft) depth. These gravels form the upper part of the member of Wooded Island and extend to a depth of 93 m (305 ft) with silt content increasing below 51.8 m (170 ft). The next 12.2 m (40 ft) (drilled depths 355-315 ft) consists largely of sand with a significant gravel and silt component. Studies of analogous outcrops suggest that strata like this

Figure 5. Location of State-Approved Land Disposal Site.

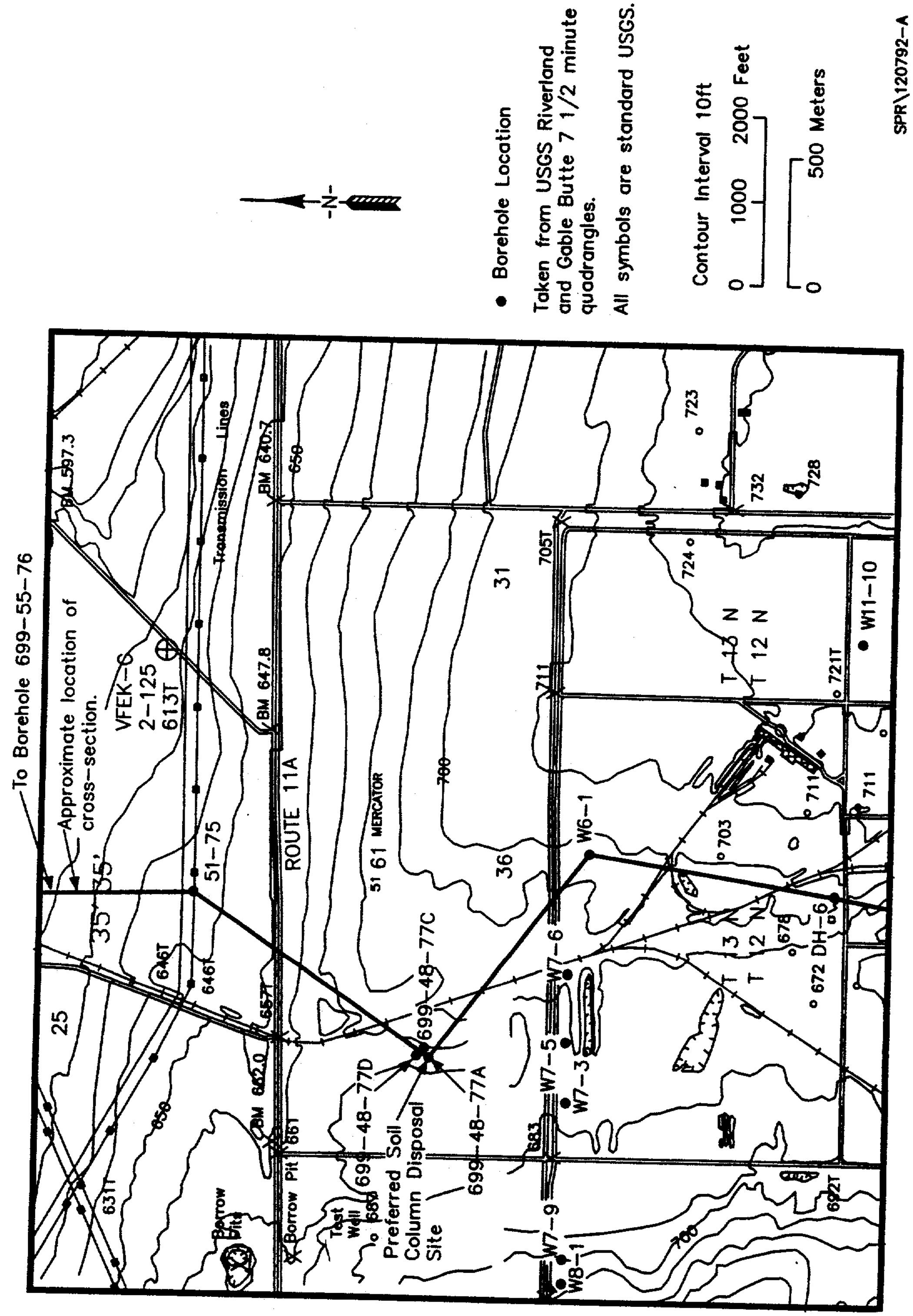
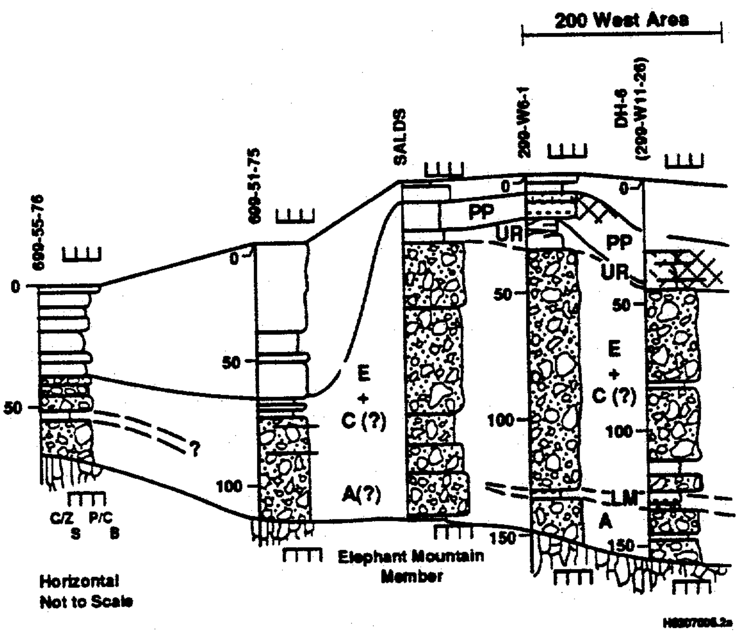


Figure 6. Cross Section Showing the Stratigraphic Units Present at the SALDS.



Explanation for Cross-Section

Grain Size Scale – Horizontal Relief of Section Indicates Grain Size of Dominant Particles in Bed.

C/Z	Clay and silt
S	Sands (fine-grained to granular)
P	Pebble Gravel
C/B	Cobble to Boulder Gravel

Other Lithologies

- Cobbly/bouldery
- Pebbly
- Sandy
- Silt rich
- Clay rich
- Paleosol
- Carbonate-rich
- Ashy
- Columbia River Basalt Group

Other Symbols

- Formation major unit contacts
- Facies contact
- Cementation/Compaction

Abbreviations

PM	– pre-Missoula gravels
EP	– early "Palouse" soil
PP	– Plio-Pleistocene unit
UR	– Upper unit, Ringold Formation
E	– Uppermost gravel-dominated sequence, Ringold Formation
A	– Lowermost gravel-dominated sequence, Ringold Formation
B,C,D	– Discontinuous gravel-dominated sequences below unit E and above unit A, Ringold Formation
LM	– Lower mud (fine-grained) sequence, Ringold Formation

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interval are characterized by gravels interbedded in sands. These deposits are underlain by 12.2 m (40 ft) (drilled depths 120-108 m [395-355 ft]) of sandy gravels that in turn overlie 17.3 m (57 ft) (drilled depths 452-395 ft) of gravels containing only minor sands. It is not clear if these gravels and those found throughout the Ringold Formation have an open-framework texture, although such deposits are rare in outcrops of typical Ringold gravels. The base of the Ringold Formation is marked by a thin sandy unit (0.9 m [3 ft]) overlying the basalt.

The lower mud unit is not present beneath the site and is interpreted to pinch out to the south (Lindsey 1991). With the lower mud unit absent, gravel unit E directly overlies gravel unit A; it is not possible to differentiate the two units. However, if the top of unit A is projected toward the site from the northern part of the 200 West Area, it would occur 10 to 15 m (33 to 50 ft) above the top of the basalt. This interval is near the top of sand-poor gravels at 120-m (395-ft) depth (WHC 1993a). Consequently, much of the lower 18 m (60 ft) of the Ringold section at the site may be part of gravel unit A.

2.2.2.5 Columbia River Basalt Group.

2.2.2.5.1 Elephant Mountain Member. The base of the unconfined aquifer is the CRBG. The uppermost unit encountered in the two deep boreholes (699-48-77A and 699-48-77C) is the Elephant Mountain Member (see Figure 4). This is the top flow of the basalt in the 200 Area Plateau and forms the principal aquitard between the confined and unconfined system.

2.3 HYDROLOGY

The hydrogeology of the Hanford Site has been described in reports by DOE (1988, Vol. 2, Chapter 3); Gephart et al. (1979); Graham et al. (1981, 1984); and Law et al. (1987), and in water level data collected and reported semiannually by Pacific Northwest Laboratory and Westinghouse Hanford Company. The regional hydrology will not be repeated here but summarized for the sake of completeness.

2.3.1 Regional Setting

The Hanford Site has a semiarid climate and receives an average of 6.25 in. of precipitation per year. Most precipitation does not reach the water table but is lost by evapotranspiration. Recharge rates are suggested to range from near 0 to more than 4 in/yr, depending on surface conditions (Gee 1987, pp. 5.1 to 5.4). Small recharge rates occur where fine-textured sediments and deep-rooted plants occur. The larger values are interpreted to occur in areas having a coarse gravelly surface and no vegetative cover. The SALDS is similar to areas where larger recharge values are expected.

Groundwater beneath the Hanford Site occurs under both unconfined and confined conditions. The unconfined aquifer is contained primarily within the middle unit of the Ringold Formation and the Hanford formation. The base of the unconfined aquifer is the basalt surface of the Elephant Mountain Member of the CRBG, or, in some areas, the clay of the lower Ringold Formation (see Figure 4).

Artificial recharge to the unconfined aquifer occurs principally from Hanford Site wastewater disposal practices at surface ponds, ditches, and various cribs within the 200 East and 200 West Areas. Two of the largest recharge mounds have developed beneath the 200 Areas at U and B Ponds. Under U Pond, which was decommissioned in 1985, the water table had risen in excess of 26 m (85 ft) since the start of disposal operations. Since decommissioning of U Pond, the water table has decreased progressively.

The hydraulic properties of the suprabasalt sediments are highly variable. The range of hydraulic conductivities can be several orders of magnitude.

2.3.2 Hydrology of the Soil Column Disposal Site

Boreholes 699-48-77A, 699-48-77C, and 699-48-77D were completed as *Resource Conservation and Recovery Act of 1976* (RCRA) groundwater monitoring wells. Wells 699-48-77A and 699-48-77D were completed in the upper part of the aquifer with a 10-slot and 20-slot, respectively, 6-m (20-ft), stainless steel screen. Borehole 699-48-77D was completed at approximately 72-m (235-ft) drilled depth with a 10-slot, 6-m (20-ft) stainless steel screen. The water table is at about 66.6-m (218.72-ft) drilled depth (approximately 139 m [456 ft] above mean sea level).

2.3.2.1 Hydraulic Gradients. A revised water table map for the SALDS area is presented in Figure 7. The groundwater elevation at the site falls within the previous water table map contours. These data confirm the interpretation by Harris and Delaney (1991, Figure A1); the groundwater flow direction is to the north-northeast.

Groundwater travel times from the preferred SALDS to the Columbia River were estimated by Swanson (1992). Two cases were modeled: one with B Pond in operation, and one with B Pond not in operation. The modeling suggested that groundwater would take approximately 134 years to reach the Columbia River with B Pond in operation and 126 years without B Pond in operation. The estimated standard error is $\pm$20%.

2.3.2.2 Hydrochemical Analyses. Upon completion and well development of borehole 699-48-77A, the groundwater was sampled on June 19, 1992. Groundwater has been sampled on a quarterly schedule since the initial sampling. The results are reported in Table 2.

Figure 7. Water Table Map of the 200 West Area.

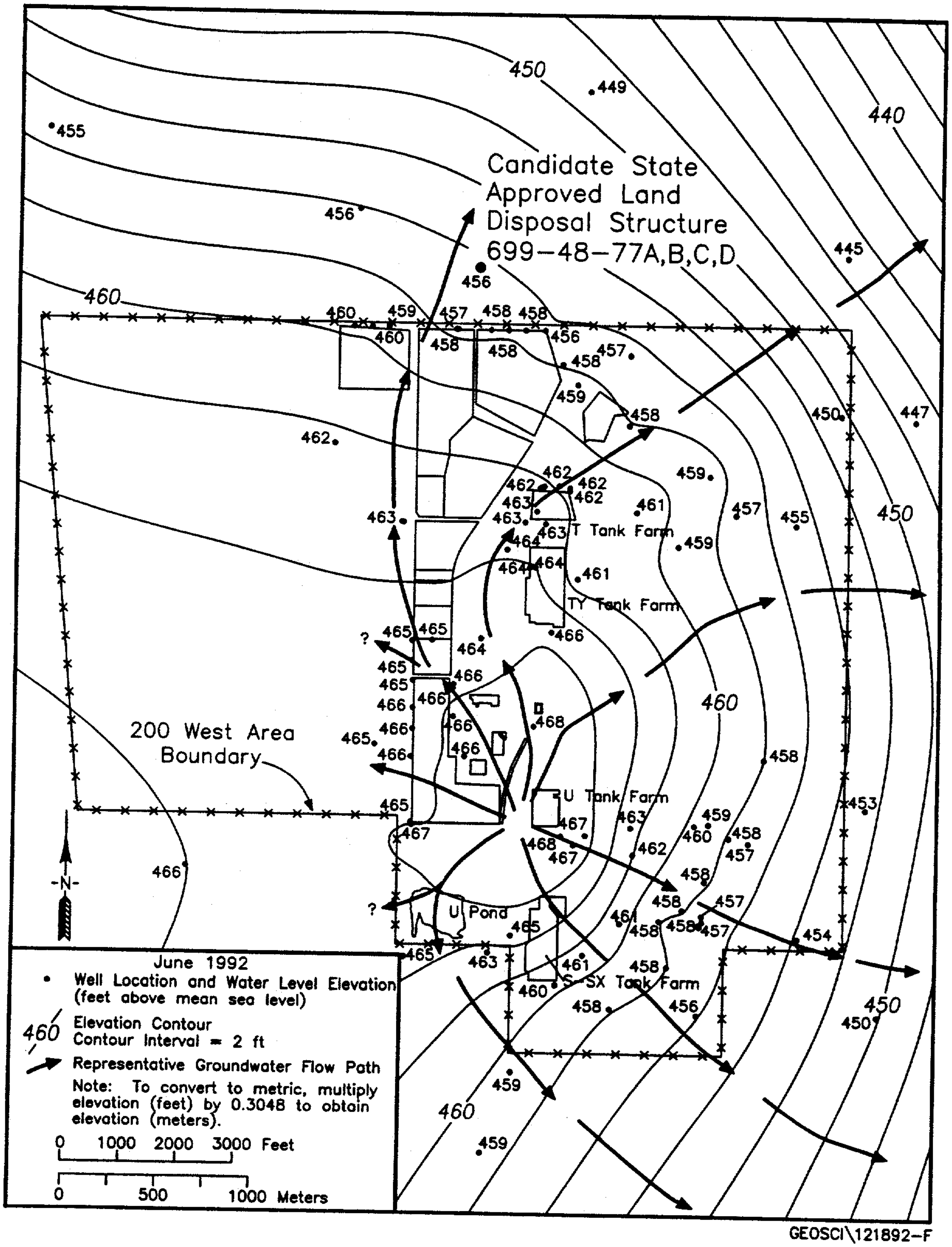

Table 2. Groundwater Analyses for Borehole 699-48-77A. (15 sheets)

Project	Well	Constituent name	Method	Sample date	Sample number	Result
C018H	699-48-77A	1,1,1-Trichloroethane	16	6/19/92	B06W97	5.00 U
				11/02/92	B07LG2	5.00 U
			25	2/22/93	B08702	.50 U
				5/17/93	B08JD2	.07 UD
				9/02/93	B090T6	.07 U
		1,1,2-Trichloroethane	16	6/19/92	B06W97	5.00 U
				11/02/92	B07LG2	5.00 U
			25	2/22/93	B08702	.50 U
				5/17/93	B08JD2	.04 UD
				9/02/93	B090T6	.04 UH
		1,1-Dichloroethane	16	6/19/92	B06W97	5.00 U
				11/02/92	B07LG2	5.00 U
			25	2/22/93	B08702	1.00 U
				5/17/93	B08JD2	.34 UD
				9/02/93	B090T6	.34 U
		1,2-Dichloroethane	16	6/19/92	B06W97	5.00 U
				11/02/92	B07LG2	5.00 U
			25	2/22/93	B08702	.50 U
				5/17/93	B08JD2	.14 UD
				9/02/93	B090T6	.14 U
		1,4-Dichlorobenzene	16	6/19/92	B06W97	5.00 U
				11/02/92	B07LG2	5.00 U
			25	2/22/93	B08702	2.00 U
				5/17/93	B08JD2	.11 UD
				9/02/93	B090T6	.11 U
		1-Butanol	16	6/19/92	B06W97	1000.00 U
				11/02/92	B07LG2	1.00 U
		2,4,6-Trichlorophenol	30	4/15/94	B0BRD9	1.45 U
		2,4-Dichlorophenol	19	5/17/93	B08JD2	2.80 U
				9/02/93	B090T6	2.80 U
			30	4/15/94	B0BRD9	1.50 U
		2,4-Dimethylphenol	30	4/15/94	B0BRD9	1.01 U
		2,4-Dinitrophenol	30	4/15/94	B0BRD9	.96 U
		2,6-Dichlorophenol	30	4/15/94	B0BRD9	1.59 U
		2-Chlorophenol	30	4/15/94	B0BRD9	1.42 U
		2-Methylphenol	19	6/19/92	B06W97	10.00 U
				11/02/92	B07LG2	10.00 U
				2/22/93	B08702	10.00 U
				5/17/93	B08JD2	1.80 U
				9/02/93	B090T6	1.80 U
		2-Nitrophenol	19	5/17/93	B08JD2	3.96 U
				9/02/93	B090T6	3.96 U
			30	4/15/94	B0BRD9	1.56 U
		2-sec-Butyl-4,6-dinitrophenol	30	4/15/94	B0BRD9	1.35 U
		4,4'-DDD	17	6/19/92	B06W97	.10 U
				9/02/92	B078V0	.10 U
				2/22/93	B08702	.10 U
				5/17/93	B08JD2	.00 U
				9/02/93	B090T6	.00 U
		4,4'-DDE	17	6/19/92	B06W97	.05 U
				9/02/92	B078V0	.05 U
				2/22/93	B08702	.05 U
				5/17/93	B08JD2	.00 U
				9/02/93	B090T6	.00 U

Table 2. Groundwater Analyses for Borehole 699-48-77A. (15 sheets)

Project	Well	Constituent name	Method	Sample date	Sample number	Result
		4,4'-DDT	17	6/19/92	B06W97	.10 U
				9/02/92	B078V0	.10 U
				2/22/93	B08702	.10 U
				5/17/93	B08JD2	.01 U
				9/02/93	B090T6	.01 U
		4,6-Dinitro-2-methylphenol	30	4/15/94	B0BRD9	1.18 U
		4-Chloro-3-methylphenol	30	4/15/94	B0BRD9	1.12 U
		4-Methyl-2-pentanone	16	6/19/92	B06W97	50.00 U
				11/02/92	B07LG2	50.00 U
		4-Methylphenol	19	6/19/92	B06W97	10.00 U
				11/02/92	B07LG2	10.00 U
				2/22/93	B08702	10.00 U
				5/17/93	B08JD2	3.54 U
				9/02/93	B090T6	3.54 U
		4-Nitrophenol	30	4/15/94	B0BRD9	.65 U
		Acetone	16	6/19/92	B06W97	100.00 U
				11/02/92	B07LG2	19.00 BQ
		Aldrin	17	6/19/92	B06W97	.05 U
				9/02/92	B078V0	.05 U
				2/22/93	B08702	.05 U
				5/17/93	B08JD2	.05 U
				9/02/93	B090T6	.05 U
		Alpha-BHC	17	6/19/92	B06W97	.05 U
				9/02/92	B078V0	.05 U
				2/22/93	B08702	.05 U
				5/17/93	B08JD2	.01 U
				9/02/93	B090T6	.01 U
		Aluminum	34	5/17/93	B08JD2	130.00 L
				9/02/93	B090T6	83.00 L
				10/15/93	B09B39	150.00 L
				1/17/94	B09Q40	59.00 L
		Aluminum, filtered	34	5/17/93	B08JD6	32.50 U
				9/02/93	B090V0	40.00 L
		Ammonium ion	129	10/15/93	B09B39	70.00 LQ
				1/17/94	B09Q40	40.00 LQ
		Antimony	34	6/19/92	B06W97	200.00 U
				11/02/92	B07LG2	200.00 U
				2/22/93	B08702	200.00 U
				5/17/93	B08JD2	69.40 U
				9/02/93	B090T6	69.40 U
				10/15/93	B09B39	69.40 U
				1/17/94	B09Q40	69.40 U
		Antimony, filtered	34	6/19/92	B06W98	200.00 U
				11/02/92	B07LG6	200.00 U
				2/22/93	B08706	200.00 U
				5/17/93	B08JD6	69.40 U
				9/02/93	B090V0	69.40 U
		Antimony-125	140	10/15/93	B09B39	-24.30 U
		Arsenic	43	6/19/92	B06W97	5.00 U
				11/02/92	B07LG2	5.00 U
				2/22/93	B08702	5.00 U
				5/17/93	B08JD2	1.00 L
				9/02/93	B090T6	1.38 U

Table 2. Groundwater Analyses for Borehole 699-48-77A. (15 sheets)

Project	Well	Constituent name	Method	Sample date	Sample number	Result
		Arsenic, filtered	43	6/19/92	B06W98	5.00 U
				11/02/92	B07LG6	5.00 U
				2/22/93	B08706	5.00 U
				5/17/93	B08JD6	1.00 L
				9/02/93	B090V0	1.38 U
		Barium	34	6/19/92	B06W97	74.00
				11/02/92	B07LG2	70.00
				2/22/93	B08702	70.00
				5/17/93	B08JD2	60.00
				9/02/93	B090T6	57.00
				10/15/93	B09B39	63.00
				1/17/94	B09Q40	59.00
		Barium, filtered	34	6/19/92	B06W98	67.00
				11/02/92	B07LG6	70.00
				2/22/93	B08706	70.00
				5/17/93	B08JD6	50.00
				9/02/93	B090V0	57.00
		Benzene	16	6/19/92	B06W97	5.00 U
				11/02/92	B07LG2	5.00 U
			25	2/22/93	B08702	2.00 U
				5/17/93	B08JD2	.11 UD
				9/02/93	B090T6	.11 U
		Benzothiazole	19	5/17/93	B08JD2	2.55 U
				9/02/93	B090T6	2.55 U
		Beryllium	34	6/19/92	B06W97	3.00 U
				11/02/92	B07LG2	3.00 U
				2/22/93	B08702	3.00 U
				5/17/93	B08JD2	.81 U
				9/02/93	B090T6	.81 U
				10/15/93	B09B39	.81 U
				1/17/94	B09Q40	.81 U
		Beryllium, filtered	34	6/19/92	B06W98	3.00 U
				11/02/92	B07LG6	3.00 U
				2/22/93	B08706	3.00 U
				5/17/93	B08JD6	.81 U
				9/02/93	B090V0	.81 U
		Beta-BHC	17	6/19/92	B06W97	.05 U
				9/02/92	B078V0	.05 U
				2/22/93	B08702	.05 U
				5/17/93	B08JD2	.00 U
				9/02/93	B090T6	.00 U
		Bis(2-ethylhexyl) phthalate	19	5/17/93	B08JD2	4.07 U
				9/02/93	B090T6	4.07 U
		Bromide	124	6/19/92	B06W97	500.00 U
				9/02/92	B078V0	500.00 U
				2/22/93	B08702	500.00 U
				5/17/93	B08JD2	70.00 L
				9/02/93	B090T6	52.80 U
				4/15/94	B0BRD9	52.80 U
		Cadmium	34	6/19/92	B06W97	10.00 U
				11/02/92	B07LG2	10.00 U
				2/22/93	B08702	10.00 U
				5/17/93	B08JD2	4.70 U
				9/02/93	B090T6	4.70 U
				10/15/93	B09B39	4.70 U
				1/17/94	B09Q40	4.70 U

Table 2. Groundwater Analyses for Borehole 699-48-77A. (15 sheets)

Project	Well	Constituent name	Method	Sample date	Sample number	Result
		Cadmium, filtered	34	6/19/92	B06W98	10.00 U
				11/02/92	B07LG6	10.00 U
				2/22/93	B08706	10.00 U
				5/17/93	B08JD6	4.70 U
				9/02/93	B090V0	4.70 U
		Calcium	34	6/19/92	B06W97	33000.00
				11/02/92	B07LG2	31000.00
				2/22/93	B08702	32000.00
				5/17/93	B08JD2	29000.00
				9/02/93	B090T6	29000.00
				10/15/93	B09B39	30000.00
				1/17/94	B09Q40	29000.00
		Calcium, filtered	34	6/19/92	B06W98	31000.00
				11/02/92	B07LG6	32000.00
				2/22/93	B08706	30000.00
				5/17/93	B08JD6	29000.00
				9/02/93	B090V0	28000.00
		Carbon tetrachloride	16	6/19/92	B06W97	1.30 JU
				11/02/92	B07LG2	5.00 U
			25	2/22/93	B08702	1.00 U
				5/17/93	B08JD2	.12 UD
				9/02/93	B090T6	.12 U
		Cesium-137	140	10/15/93	B09B39	-3.22 U
		Chlordane	17	6/19/92	B06W97	.10 U
				9/02/92	B078V0	.10 U
				2/22/93	B08702	.10 U
				5/17/93	B08JD2	.01 U
				9/02/93	B090T6	.01 U
		Chloride	124	6/19/92	B06W97	6600.00
				9/02/92	B078V0	4600.00
				2/22/93	B08702	3700.00
				5/17/93	B08JD2	5300.00
				9/02/93	B090T6	3600.00
				4/15/94	B0BRD9	3200.00
		Chloroform	16	6/19/92	B06W97	5.00 U
				11/02/92	B07LG2	5.00 U
			25	2/22/93	B08702	.50 U
				5/17/93	B08JD2	.04 UD
				9/02/93	B090T6	.04 U
		Chromium	34	6/19/92	B06W97	20.00 U
				11/02/92	B07LG2	50.00
				2/22/93	B08702	30.00
				5/17/93	B08JD2	190.00
				9/02/93	B090T6	76.00
				10/15/93	B09B39	84.00
				1/17/94	B09Q40	69.00
		Chromium, filtered	34	6/19/92	B06W98	20.00 U
				11/02/92	B07LG6	20.00 U
				2/22/93	B08706	20.00 U
				5/17/93	B08JD6	10.00 L
				9/02/93	B090V0	13.00 L

Table 2. Groundwater Analyses for Borehole 699-48-77A. (15 sheets)

Project	Well	Constituent name	Method	Sample date	Sample number	Result
		Cobalt	34	6/19/92	B06W97	20.00 U
				11/02/92	B07LG2	20.00 U
				2/22/93	B08702	20.00 U
				5/17/93	B08JD2	4.05 U
				9/02/93	B090T6	4.05 U
				10/15/93	B09B39	4.05 U
				1/17/94	B09Q40	4.05 U
		Cobalt, filtered	34	6/19/92	B06W98	20.00 U
				11/02/92	B07LG6	20.00 U
				2/22/93	B08706	20.00 U
				5/17/93	B08JD6	4.05 U
				9/02/93	B090V0	4.05 U
		Cobalt-60	140	10/15/93	B09B39	-3.09 U
		Coliforms	144	6/19/92	B06W97	65.00 Y
				9/02/92	B078V0	2.00
				2/22/93	B08702	1.00 U
				5/17/93	B08JD2	1.00 U
				9/02/93	B090T6	1.00 U
				4/15/94	B0BRD9	1.00 U
		Copper	34	6/19/92	B06W97	20.00 U
				11/02/92	B07LG2	20.00 U
				2/22/93	B08702	20.00 U
				5/17/93	B08JD2	15.00 LQ
				9/02/93	B090T6	2.65 U
				10/15/93	B09B39	2.65 U
				1/17/94	B09Q40	2.65 U
		Copper, filtered	34	6/19/92	B06W98	20.00 U
				11/02/92	B07LG6	20.00 U
				2/22/93	B08706	20.00 U
				5/17/93	B08JD6	30.00 Q
				9/02/93	B090V0	2.65 U
		Cresols (methylphenols)	30	4/15/94	B0BRD9	4.66 U
		Cyanide	358	9/02/93	B090T6	1.24 U
			56	6/19/92	B06W97	20.00 UD
				9/02/92	B078V0	20.00 U
				11/02/92	B07LG2	20.00 U
				2/22/93	B08702	20.00 U
				5/17/93	B08JD2	1.24 U
		Decane	19	6/19/92	B06W97	1000.00 U
				11/02/92	B07LG2	10.00 U
				2/22/93	B08702	10.00 U
				5/17/93	B08JD2	4.03 U
				9/02/93	B090T6	4.03 U
		Delta-BHC	17	6/19/92	B06W97	.10 U
				9/02/92	B078V0	.10 U
				2/22/93	B08702	.10 U
				5/17/93	B08JD2	.00 U
				9/02/93	B090T6	.00 U
		Dieldrin	17	6/19/92	B06W97	.05 U
				9/02/92	B078V0	.05 U
				2/22/93	B08702	.05 U
				5/17/93	B08JD2	.02 U
				9/02/93	B090T6	.02 U

Table 2. Groundwater Analyses for Borehole 699-48-77A. (15 sheets)

Project	Well	Constituent name	Method	Sample date	Sample number	Result
		Dodecane	19	6/19/92	B06W97	1000.00 U
				11/02/92	B07LG2	10.00 U
				2/22/93	B08702	10.00 U
				5/17/93	B08JD2	3.62 U
				9/02/93	B090T6	3.62 U
		Endosulfan I	17	6/19/92	B06W97	.10 U
				9/02/92	B078V0	.10 U
				2/22/93	B08702	.10 U
				5/17/93	B08JD2	.00 U
				9/02/93	B090T6	.00 U
		Endosulfan II	17	6/19/92	B06W97	.05 U
				9/02/92	B078V0	.05 U
				2/22/93	B08702	.05 U
				5/17/93	B08JD2	.00 U
				9/02/93	B090T6	.00 U
		Endosulfan sulfate	17	6/19/92	B06W97	.50 U
				9/02/92	B078V0	.50 U
				2/22/93	B08702	.50 U
				5/17/93	B08JD2	.01 U
				9/02/93	B090T6	.01 U
		Endrin	17	6/19/92	B06W97	.10 U
				9/02/92	B078V0	.10 U
				2/22/93	B08702	.10 U
				5/17/93	B08JD2	.01 U
				9/02/93	B090T6	.01 U
		Endrin aldehyde	17	6/19/92	B06W97	.20 U
				9/02/92	B078V0	.20 U
				2/22/93	B08702	.20 U
				5/17/93	B08JD2	.01 U
				9/02/93	B090T6	.01 U
		Ethylbenzene	25	2/22/93	B08702	2.00 U
				5/17/93	B08JD2	.05 UD
				9/02/93	B090T6	.05 U
		Fluoride	124	6/19/92	B06W97	400.00
				9/02/92	B078V0	300.00
				2/22/93	B08702	500.00
				5/17/93	B08JD2	500.00
				9/02/93	B090T6	500.00
				4/15/94	B0BRD9	700.00
		Gross alpha	135	6/19/92	B06W97	1.73 U
				9/02/92	B078V0	1.76 U
				2/22/93	B08702	2.31 U
				5/17/93	B08JD2	2.77
				9/02/93	B090T6	1.67
				10/15/93	B09B39	2.54
				1/17/94	B09Q40	3.24
		Gross beta	136	6/19/92	B06W97	5.05 U
				9/02/92	B078V0	2.70 U
				2/22/93	B08702	5.55 U
				5/17/93	B08JD2	6.74
				9/02/93	B090T6	2.07
				10/15/93	B09B39	7.70
				1/17/94	B09Q40	7.34

Table 2. Groundwater Analyses for Borehole 699-48-77A. (15 sheets)

Project	Well	Constituent name	Method	Sample date	Sample number	Result
		Heptachlor	17	6/19/92	B06W97	.05 U
				9/02/92	B078V0	.05 U
				2/22/93	B08702	.05 U
				5/17/93	B08JD2	.00 U
				9/02/93	B090T6	.00 U
		Heptachlor epoxide	17	6/19/92	B06W97	1.00 U
				9/02/92	B078V0	1.00 U
				2/22/93	B08702	1.00 U
				5/17/93	B08JD2	.00 U
				9/02/93	B090T6	.00 U
		Hydrazine	36	6/19/92	B06W97	30.00 U
				9/02/92	B078V0	30.00 U
				11/02/92	B07LG2	30.00 U
				2/22/93	B08702	30.00 U
				5/17/93	B08JD2	1.89 U
				9/02/93	B090T6	1.89 U
				10/15/93	B09B39	1.89 U
				1/17/94	B09Q40	1.89 U
		Iodine-129	139	6/19/92	B06W97	.19 U
				11/02/92	B07LG2	.04 U
				5/17/93	B08JD2	.37
				9/02/93	B090T6	.35 U
		Iodine-129, Low level	139	9/02/93	B090T6	.35 U
		Iron	34	6/19/92	B06W97	560.00
				11/02/92	B07LG2	350.00
				2/22/93	B08702	160.00
				5/17/93	B08JD2	920.00
				9/02/93	B090T6	420.00
				10/15/93	B09B39	730.00
				1/17/94	B09Q40	420.00
		Iron, filtered	34	6/19/92	B06W98	20.00 U
				11/02/92	B07LG6	40.00
				2/22/93	B08706	20.00 U
				5/17/93	B08JD6	13.00 L
				9/02/93	B090V0	25.00
		Lead	40	6/19/92	B06W97	5.00 U
				11/02/92	B07LG2	5.00 U
				2/22/93	B08702	5.00 U
				5/17/93	B08JD2	.51 U
				9/02/93	B090T6	1.40 L
		Lead, filtered	40	6/19/92	B06W98	5.00 U
				11/02/92	B07LG6	5.00 U
				2/22/93	B08706	5.00 U
				5/17/93	B08JD6	.51 U
				9/02/93	B090V0	1.60 L
		Magnesium	34	6/19/92	B06W97	12000.00
				11/02/92	B07LG2	12000.00
				2/22/93	B08702	12000.00
				5/17/93	B08JD2	11000.00
				9/02/93	B090T6	11000.00
				10/15/93	B09B39	12000.00
				1/17/94	B09Q40	11000.00
		Magnesium, filtered	34	6/19/92	B06W98	12000.00
				11/02/92	B07LG6	12000.00
				2/22/93	B08706	12000.00
				5/17/93	B08JD6	11000.00
				9/02/93	B090V0	11000.00

Table 2. Groundwater Analyses for Borehole 699-48-77A. (15 sheets)

Project	Well	Constituent name	Method	Sample date	Sample number	Result
		Manganese	34	6/19/92	B06W97	27.00
				11/02/92	B07LG2	10.00
				2/22/93	B08702	10.00
				5/17/93	B08JD2	20.00
				9/02/93	B090T6	11.00
				10/15/93	B09B39	18.00
				1/17/94	B09Q40	8.70 L
		Manganese, filtered	34	6/19/92	B06W98	10.00 U
				11/02/92	B07LG6	10.00 U
				2/22/93	B08706	10.00 U
				5/17/93	B08JD6	1.35 U
				9/02/93	B090V0	5.10 L
		Mercury	41	6/19/92	B06W97	.20 U
				2/22/93	B08702	.20 U
				5/17/93	B08JD2	.16 U
				9/02/93	B090T6	.16 U
		Mercury, filtered	41	6/19/92	B06W98	.20 U
				2/22/93	B08706	.20 U
				5/17/93	B08JD6	.16 U
				9/02/93	B090V0	.16 U
		Methoxychlor	17	6/19/92	B06W97	2.00 U
				9/02/92	B078V0	2.00 U
				2/22/93	B08702	2.00 U
				5/17/93	B08JD2	.10 U
				9/02/93	B090T6	.10 U
		Methyl ethyl ketone	16	6/19/92	B06W97	100.00 U
				11/02/92	B07LG2	100.00 U
		Methylene chloride	16	6/19/92	B06W97	5.00 U
				11/02/92	B07LG2	5.00 U
			25	2/22/93	B08702	5.00 U
				5/17/93	B08JD2	.06 UD
				9/02/93	B090T6	.06 U
		Naphthalene	19	6/19/92	B06W97	10.00 U
				11/02/92	B07LG2	10.00 U
				2/22/93	B08702	10.00 U
				5/17/93	B08JD2	6.50 U
				9/02/93	B090T6	6.50 U
		Nickel	34	6/19/92	B06W97	30.00 U
				11/02/92	B07LG2	40.00
				2/22/93	B08702	30.00
				5/17/93	B08JD2	110.00
				9/02/93	B090T6	52.00
				10/15/93	B09B39	66.00
				1/17/94	B09Q40	40.00
		Nickel, filtered	34	6/19/92	B06W98	30.00 U
				11/02/92	B07LG6	30.00 U
				2/22/93	B08706	30.00 U
				5/17/93	B08JD6	17.90 U
				9/02/93	B090V0	17.90 U
		Nitrate	124	6/19/92	B06W97	28000.00
				9/02/92	B078V0	20000.00
				2/22/93	B08702	16000.00
				5/17/93	B08JD2	21000.00
				9/02/93	B090T6	16000.00 DH
				4/15/94	B0BRD9	16000.00 D

Table 2. Groundwater Analyses for Borehole 699-48-77A. (15 sheets)

Project	Well	Constituent name	Method	Sample date	Sample number	Result
		Nitrite	124	6/19/92	B06W97	200.00 U
				9/02/92	B078V0	200.00 U
				2/22/93	B08702	200.00 U
				5/17/93	B08JD2	38.30 U
				9/02/93	B090T6	38.30 UH
				4/15/94	B0BRD9	38.30 U
		Pentachlorophenol	19	6/19/92	B06W97	50.00 U
				11/02/92	B07LG2	50.00 U
				2/22/93	B08702	50.00 U
				5/17/93	B08JD2	8.07 U
				9/02/93	B090T6	8.07 U
			30	4/15/94	B0BRD9	.87 U
		Phenol	19	6/19/92	B06W97	10.00 U
				11/02/92	B07LG2	10.00 U
				2/22/93	B08702	10.00 U
				5/17/93	B08JD2	.83 U
				9/02/93	B090T6	.83 U
			30	4/15/94	B0BRD9	.31 U
		Phosphate	124	6/19/92	B06W97	400.00 U
				9/02/92	B078V0	400.00 U
				2/22/93	B08702	400.00 U
				5/17/93	B08JD2	147.00 U
				9/02/93	B090T6	147.00 UH
				4/15/94	B0BRD9	147.00 U
		Potassium	34	6/19/92	B06W97	3700.00
				11/02/92	B07LG2	3600.00
				2/22/93	B08702	3500.00
				5/17/93	B08JD2	3000.00
				9/02/93	B090T6	3900.00
				10/15/93	B09B39	3000.00
				1/17/94	B09Q40	2700.00
		Potassium, filtered	34	6/19/92	B06W98	3300.00
				11/02/92	B07LG6	3600.00
				2/22/93	B08706	4300.00
				5/17/93	B08JD6	3000.00
				9/02/93	B090V0	1900.00
		Ruthenium-106	140	10/15/93	B09B39	8.03 U
		Selenium	48	6/19/92	B06W97	10.00 U
				11/02/92	B07LG2	10.00 U
				2/22/93	B08702	10.00 U
				5/17/93	B08JD2	1.00 L
				9/02/93	B090T6	1.21 U
		Selenium, filtered	48	6/19/92	B06W98	10.00 U
				11/02/92	B07LG6	10.00 U
				2/22/93	B08706	10.00 U
				5/17/93	B08JD6	1.21 U
				9/02/93	B090V0	1.21 U
		Silver	34	6/19/92	B06W97	20.00 U
				11/02/92	B07LG2	20.00 U
				2/22/93	B08702	20.00 U
				5/17/93	B08JD2	2.87 U
				9/02/93	B090T6	2.87 U
				10/15/93	B09B39	2.87 U
				1/17/94	B09Q40	2.87 U

Table 2. Groundwater Analyses for Borehole 699-48-77A. (15 sheets)

Project	Well	Constituent name	Method	Sample date	Sample number	Result
		Silver, filtered	34	6/19/92	B06W98	20.00 U
				11/02/92	B07LG6	20.00 U
				2/22/93	B08706	20.00 U
				5/17/93	B08JD6	2.87 U
				9/02/93	B090V0	3.20 L
		Sodium	34	6/19/92	B06W97	17000.00
				11/02/92	B07LG2	11000.00
				2/22/93	B08702	11000.00
				5/17/93	B08JD2	11000.00 Q
				9/02/93	B090T6	9100.00
				10/15/93	B09B39	8900.00
				1/17/94	B09Q40	8300.00 B
		Sodium, filtered	34	6/19/92	B06W98	15000.00
				11/02/92	B07LG6	13000.00
				2/22/93	B08706	11000.00
				5/17/93	B08JD6	10000.00 Q
				9/02/93	B090V0	9100.00
		Specific conductance	73	5/17/93	B08JD2	290.00
				9/02/93	B090T6	290.00
				10/15/93	B09B39	280.00
					B09B40	280.00
					B09B41	280.00
					B09B42	280.00
				1/17/94	B09Q40	280.00
					B09Q41	280.00
					B09Q42	280.00
					B09Q43	280.00
			94	6/19/92	B06W97	316.00
				9/02/92	B078V0	296.00
				11/02/92	B07LG2	281.00
					B07LG3	280.00
					B07LG4	275.00
					B07LG5	279.00
				2/22/93	B08702	283.00
				2/22/93	B08703	283.00
					B08704	284.00
					B08705	284.00
				5/17/93	B08JD2	290.00
					B08JD3	287.00
					B08JD4	287.00
					B08JD5	288.00
				9/02/93	B090T6	284.00
					B090T7	285.00
					B090T8	285.00
					B090T9	284.00
				10/15/93	B09B39	282.00
					B09B40	282.00
					B09B41	281.00
					B09B42	282.00
				1/17/94	B09Q40	289.00
					B09Q41	289.00
					B09Q42	288.00
					B09Q43	289.00

Table 2. Groundwater Analyses for Borehole 699-48-77A. (15 sheets)

Project	Well	Constituent name	Method	Sample date	Sample number	Result
		Sulfate	124	6/19/92	B06W97	25000.00
				9/02/92	B078V0	24000.00
				2/22/93	B08702	22000.00
				5/17/93	B08JD2	23000.00
				9/02/93	B090T6	23000.00 D
				4/15/94	B0BRD9	21000.00 D
		Temperature, field	170	6/19/92	B06W97	18.50
				9/02/92	B078V0	18.20
				11/02/92	B07LG2	17.50
					B07LG3	17.70
					B07LG4	17.80
					B07LG5	17.60
				2/22/93	B08702	16.10
				5/17/93	B08JD2	17.80
					B08JD3	17.80
					B08JD4	17.80
					B08JD5	17.70
				9/02/93	B090T6	17.60
					B090T7	17.60
					B090T8	17.50
					B090T9	17.50
				10/15/93	B09B39	17.20
				1/17/94	B09Q40	17.10
		Tetrachloroethene	16	6/19/92	B06W97	5.00 U
				11/02/92	B07LG2	5.00 U
			25	2/22/93	B08702	.50 U
				5/17/93	B08JD2	.05 UD
				9/02/93	B090T6	.05 U
		Tetrachlorophenols	30	4/15/94	B0BRD9	1.05 U
		Tetradecane	19	6/19/92	B06W97	1000.00 U
				11/02/92	B07LG2	10.00 U
				2/22/93	B08702	10.00 U
				5/17/93	B08JD2	2.43 U
				9/02/93	B090T6	2.43 U
		Tetrahydrofuran	16	6/19/92	B06W97	10.00 U
				11/02/92	B07LG2	10.00 U
		Tin	34	6/19/92	B06W97	100.00 U
				11/02/92	B07LG2	100.00 U
				2/22/93	B08702	100.00 U
				5/17/93	B08JD2	51.10 U
				9/02/93	B090T6	51.10 U
				10/15/93	B09B39	51.10 U
				1/17/94	B09Q40	51.10 U
		Tin, filtered	34	6/19/92	B06W98	100.00 U
				11/02/92	B07LG6	100.00 U
				2/22/93	B08706	100.00 U
				5/17/93	B08JD6	51.10 U
				9/02/93	B090V0	51.10 U
		Toluene	16	6/19/92	B06W97	5.00 U
				11/02/92	B07LG2	5.00 U
			25	2/22/93	B08702	2.00 U
				5/17/93	B08JD2	.06 UD
				9/02/93	B090T6	.06 U
		Total dissolved solids	65	9/02/93	B090T6	180.00
				10/15/93	B09B39	180.00
				1/17/94	B09Q40	190.00

Table 2. Groundwater Analyses for Borehole 699-48-77A. (15 sheets)

Project	Well	Constituent name	Method	Sample date	Sample number	Result
		Total organic carbon	122	6/19/92	B06W97	1000.00 U
				2/22/93	B08702	1000.00 U
					B08703	1000.00 U
					B08704	1000.00 U
					B08705	1000.00 U
				5/17/93	B08JD2	400.00 L
					B08JD3	500.00 L
					B08JD4	600.00 L
					B08JD5	400.00 L
				9/02/93	B090T6	400.00 L
					B090T7	400.00 L
					B090T8	500.00 L
					B090T9	400.00 L
				10/15/93	B09B39	600.00 L
					B09B40	600.00 L
					B09B41	600.00 L
					B09B42	600.00 L
				1/17/94	B09Q40	400.00 L
					B09Q41	400.00 L
					B09Q42	400.00 L
					B09Q43	400.00 L
		Total organic halogen	67	6/19/92	B06W97	20.00 P
				11/02/92	B07LG2	10.00 UP
					B07LG3	10.00 UP
					B07LG4	10.00 UP
					B07LG5	10.00 P
					B07LG5	10.00 UP
				2/22/93	B08702	10.00 UP
					B08703	10.00 UP
				2/22/93	B08704	10.00 UP
					B08705	10.00 UP
				5/17/93	B08JD2	8.00 UP
					B08JD2	8.00 UP
					B08JD3	8.00 UP
					B08JD3	8.00 UP
					B08JD4	8.00 UP
					B08JD4	8.00 UP
					B08JD5	8.00 UP
					B08JD5	8.00 UP
				9/02/93	B090T6	8.00 UP
					B090T7	8.00 UP
					B090T8	8.00 UP
					B090T9	8.00 UP
				10/15/93	B09B39	8.00 UPQ
					B09B39	6.00 UPQ
					B09B40	8.00 UPQ
					B09B40	6.00 UPQ
					B09B41	8.00 UPQ
					B09B41	6.00 UPQ
					B09B42	8.00 UPQ
					B09B42	6.00 UPQ
				1/17/94	B09Q40	5.00 U
					B09Q41	5.00 U
					B09Q42	5.00 U
					B09Q43	5.00 U

Table 2. Groundwater Analyses for Borehole 699-48-77A. (15 sheets)

Project	Well	Constituent name	Method	Sample date	Sample number	Result
		Toxaphene	17	6/19/92	B06W97	2.00 U
				9/02/92	B078V0	2.00 U
				2/22/93	B08702	2.00 U
				5/17/93	B08JD2	.89 U
				9/02/93	B090T6	.89 U
		Tributyl phosphate	19	6/19/92	B06W97	10.00 U
				11/02/92	B07LG2	10.00 U
				2/22/93	B08702	10.00 U
				5/17/93	B08JD2	4.42 U
				9/02/93	B090T6	4.42 U
		Trichloroethene	16	6/19/92	B06W97	5.00 U
				11/02/92	B07LG2	5.00 U
			25	2/22/93	B08702	1.00 U
				5/17/93	B08JD2	.07 UD
				9/02/93	B090T6	.07 U
		Trichlorophenols	30	4/15/94	B0BRD9	1.11 U
		Tris-2-chloroethyl phosphate	19	5/17/93	B08JD2	2.88 U
				9/02/93	B090T6	2.88 U
		Tritium	142	6/19/92	B06W97	64.30 UQ
				9/02/92	B078V0	139.00 U
				2/22/93	B08702	94.10 U
				5/17/93	B08JD2	88.60 U
				9/02/93	B090T6	64.00 U
				10/15/93	B09B39	8.35 U
				1/17/94	B09Q40	131.00 U
		Turbidity	126	10/15/93	B09B39	5.60
				1/17/94	B09Q40	3.40
				4/15/94	B0BRD9	4.10
		Vanadium	34	6/19/92	B06W97	30.00 U
				11/02/92	B07LG2	30.00 U
				2/22/93	B08702	30.00 U
				5/17/93	B08JD2	9.10 L
				9/02/93	B090T6	6.10 L
				10/15/93	B09B39	3.84 U
				1/17/94	B09Q40	8.10 L
		Vanadium, filtered	34	6/19/92	B06W98	30.00 U
				11/02/92	B07LG6	30.00 U
				2/22/93	B08706	30.00 U
				5/17/93	B08JD6	5.20 L
				9/02/93	B090V0	9.50 L
		Vinyl chloride	16	6/19/92	B06W97	10.00 U
				11/02/92	B07LG2	10.00 U
			25	2/22/93	B08702	2.00 U
				5/17/93	B08JD2	.27 UD
				9/02/93	B090T6	.27 U
		Xylenes (total)	16	6/19/92	B06W97	5.00 U
				11/02/92	B07LG2	5.00 U
			25	2/22/93	B08702	5.00 U
				5/17/93	B08JD2	.20 UD
				9/02/93	B090T6	.20 U
		Zinc	34	6/19/92	B06W97	87.00
				11/02/92	B07LG2	30.00
				2/22/93	B08702	30.00
				5/17/93	B08JD2	20.00
				9/02/93	B090T6	22.00
				10/15/93	B09B39	61.00
				1/17/94	B09Q40	26.00

Table 2. Groundwater Analyses for Borehole 699-48-77A. (15 sheets)

Project	Well	Constituent name	Method	Sample date	Sample number	Result
		Zinc, filtered	34	6/19/92	B06W98	10.00 U
				11/02/92	B07LG6	10.00 U
				2/22/93	B08706	10.00 U
				5/17/93	B08JD6	4.00 L
				9/02/93	B090V0	23.00
		cis-1,2-Dichloroethylene	25	2/22/93	B08702	1.00 U
				5/17/93	B08JD2	1.38 LD
				9/02/93	B090T6	.13 U
		gamma-BHC (Lindane)	17	6/19/92	B06W97	.05 U
				9/02/92	B078V0	.05 U
				2/22/93	B08702	.05 U
				5/17/93	B08JD2	.00 U
				9/02/93	B090T6	.00 U
		m-Cresol	19	6/19/92	B06W97	10.00 U
				11/02/92	B07LG2	10.00 U
				2/22/93	B08702	10.00 U
				5/17/93	B08JD2	1.44 U
				9/02/93	B090T6	1.44 XU
		pH	125	5/17/93	B08JD2	7.90
				9/02/93	B090T6	8.00
				4/15/94	B0BRD9	8.00
		pH	93	6/19/92	B06W97	7.71
				9/02/92	B078V0	7.70
				11/02/92	B07LG2	6.93
					B07LG3	6.97
					B07LG4	7.02
					B07LG5	7.07
				2/22/93	B08702	7.74
					B08703	7.74
					B08704	7.75
					B08705	7.75
				5/17/93	B08JD2	7.76
					B08JD3	7.76
					B08JD4	7.73
					B08JD5	7.73
				9/02/93	B090T6	7.74
					B090T7	7.72
					B090T8	7.72
					B090T9	7.72
				10/15/93	B09B39	7.97
					B09B40	7.95
					B09B41	7.94
					B09B42	7.94
				1/17/94	B09Q40	7.83
					B09Q41	7.80
					B09Q42	7.80
					B09Q43	7.79

Table 2. Groundwater Analyses for Borehole 699-48-77A. (15 sheets)

Project	Well	Constituent name	Method	Sample date	Sample number	Result
		trans-1,2-Dichloroethylene	16	6/19/92	B06W97	5.00 U
				11/02/92	B07LG2	5.00 U
			25	2/22/93	B08702	1.00 U
				5/17/93	B08JD2	.15 UD
				9/02/93	B090T6	.15 U
	699-48-77C	Tritium	142	4/02/94	B09G23	-62.30 U
					B09G24	-27.90 U
					B09G25	40.00 U

Note:
B = blank associated with analyte is contaminated.
D = analyzed sample is diluted.
H = laboratory holding time exceeded.
J = concentration is estimated.
L = result is greater than or equal to the method detection limit, but less than the contractually required quanitification limit.
P = potential problem.
Q = result associated suspect quality control data.
X = other.

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3.0 DRILLING AND SAMPLING

This section describes the drilling and sampling that was done for the two new groundwater monitoring wells. A borehole completion data package containing all of the collected field data, testing, and laboratory results will be released at a later time.

3.1 PROPOSED DRILLING PLAN

Drilling for two new RCRA-compliant characterization/monitoring wells was proposed in 1993. The location of the new wells were downgradient from the SALDS (see Figure 2). Well 699-48-77D was scheduled for drilling to a depth of 79 m (260 ft) and then completed as a shallow groundwater monitoring well. Well 699-48-77C was scheduled to be drilled into basalt at approximately 140 m (460 ft) and then backfilled to approximately 79 m (260 ft) for completion as a shallow groundwater monitoring well. Well 699-48-77C was scheduled to have three constant discharge aquifer tests performed during the drilling operation. Both wells were to be completed with continuous wrap stainless steel screens in the Ringold unit E fluvial gravels (see Figure 4).

The contractor (ICF-Kaiser Hanford) had granted the C-018H drilling project under an existing contract for fiscal year 1994 to PC Exploration of Bozeman, Montana.

Starter casing was set using a backhoe and the boreholes were drilled to total depth using rotary rigs Driltech Model D40K[1] and Mobile Drill Model B53,[2] which are both supplied by the subcontractor.

3.2 COMPLETED DRILLING

Starter casing was set at well 699-48-77D on January 11, 1994 (Table 3). Drilling with the air rotary rig began on January 13, 1994, and reached total depth at 72.4 m (237.7 ft) on January 24, 1994. Completion on the well started on January 24, 1994, and was finished on January 26, 1994. The total drilling/completion period for well 699-48-77D was 14 days. The actual drilling time was 8 days with the remaining 6 days divided equally between geophysical logging, well completion, and well development.

Starter casing was set at well 699-48-77C on January 12, 1994 (Table 4). Air rotary drilling at this well did not begin until January 31, 1994, and finished on March 30, 1994, with a total depth of 133.3 m (437.2 ft). Well completion on this well was started on March 31, 1994, and was finished on May 6, 1994. The total drilling/completion period for well 699-48-77C was 55 days. The actual drilling time was 28 days with 23 days to complete the well. The remaining 4 days were used for aquifer test preparation.

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[1]Driltech Model 340K is a trademark of Driltech, Alachua, Florida.

[2]Mobile Drill Model B53 is a trademark of Mobile Drill, Indianapolis, Indiana.

Table 3. Summary of Daily Drilling Activities for Well 699-48-77D.

Day 1 (1/11/94)	Set 12-in.-diameter starter casing and sampled to 14 ft. Total footage was 14 ft.
Day 2 (1/13/94	Downsized to 10-in.-diameter casing and drilled from 14 to 64.2 ft. Total footage was 50 ft.
Day 3 (1/14/94)	Drilled and sampled from 64.2 to 72.9 in. Logs reported poor recovery. Total footage was 8.7 ft.
Day 4 (1/15/94)	Drilled and sampled from 72.9 to 107.2 ft. Total footage was 14 ft.
Day 5 (1/18/94)	Drilled and sampled from 107.2 to 121.2 ft. Ready to log borehole. Crew offsite at 11:00. Total footage was 14 ft.
Day 6 (1/19/94)	Geophysics onsite to log borehole (0 to 119 ft). Crew resumed work to downsize to 8-in. casing. Total footage was 0 ft due to downsizing.
Day 7 (1/20/94)	Drilled and sampled from 121.2 to 231.1 ft. Total footage was 110 ft.
Day 8 (1/21/94)	No work at site. Total footage was 0 ft.
Day 9 (1/22/94)	Borehole logged (90 to 229 ft). No drilling at site. Total footage was 0 ft.
Day 10 (1/24/94)	Drilled and sampled from 231 to 237.7 ft. Set screen base and stainless screen and casing. Total footage was 6.7 ft.
Day 11 (1/25/94)	Placed sandpack, bentonite pellets, bentonite crumbles.
Day 12 (1/26/94)	Placed bentonite crumbles and poured cement pad.

Note: See metric conversion table at the beginning of this report.

Table 4. Summary of Daily Drilling Activities for Well 699-48-77C. (4 sheets)

Day 1 (1/12/94)	Set 12-in.-diameter starter casing at 14.4 ft and sampled to 15 ft. Total footage was 15 ft.
Day 2 (1/31/94)	Downsized to 10-in.-diameter casing, drilled, and sampled from 15 to 19 ft. Total footage was 4 ft.
Day 3 (2/01/94)	No work; reported on standby for coring instructions and tools. Total footage was 0 ft.
Day 4 (2/02/94)	Drilled and cored from 20.4 to 23.0 ft with poor recovery. Total footage was 2.6 ft.
Day 5 (2/03/94	Drilled and cored from 23 to 39.3 ft with no or little recovery. Total footage was 16.3 ft.
Day 6 (2/07/94)	Drilled and cored from 39.3 to 59.1 ft with no or little recovery. Total footage was 19.8 ft.
Day 7 (2/08/94)	Drilled from 59.1 to 105.8 ft with poor recovery. Total footage was 46.7 ft.
Day 8 (2/09/94)	Drilled from 105.8 to 166.9 ft with poor recovery. Total footage was 61.1 ft.
Day 9 (2/10/94)	Drilled from 166.9 to 169.5 ft. Crew worked on Holte Manufacturing hammer and attempted to re-enter borehole (7 hours downtime). Total footage was 2.6 ft.
Day 10 (2/14/94)	Drilled from 169.5 to 218.6 ft. Dust continued blowing through hammer, tripped out, and checked assembly (2 hours downtime). Total footage was 49.1 ft.
Day 11 (2/15/94)	Drilled from 218.6 to 220.4 ft. Crew tripped rods out of hole, exchanged drill rigs from Driltech to Mobile Drill Model B53, and tripped in core bit (6 hours). Total footage was 1.8 ft.
Day 12 (2/16/94)	Drilled and cored from 220.4 to 229.5 ft with no or very little recovery. Geologists' record showed six coring runs with no recovery. Total footage was 9.1 ft.
Day 13 (2/17/94)	Drillers cleaned out previous coring interval. No intrusive drilling. Total footage was 0 ft.
Day 14 (2/28/94)	Crew was back on site. Crew tripped out rods and performed general maintenance. Total footage was 0 ft.
Day 15 (3/01/94)	Attempted core run #20 from 229.5 to 230.8 ft with no recovery. Drillers tripped out to log borehole. Borehole logged from 0 to 226 ft (3 hours). Prepared to downsize to 8-in. casing. Total footage was 1.3.
Day 16 (3/02/94)	Downsized/advanced 8-in.-diameter casing to 260 ft and drilled to 260.7 ft. Total footage was 29.9.

Table 4. Summary of Daily Drilling Activities for Well 699-48-77C. (4 sheets)

Day 17 (3/03/94)	Took split spoon sample and prepared for pump test. Pump test ran from March 3 to July 1994.
Day 18 (3/08/94)	Pulled pump and performed slug test. Unable to retrieve screen. During the course of pump installation, the pump was dropped in and subsequently damaged the pump and stainless steel screen. This information was not documented my PC Exploration's field geologist.
Day 19 (3/09/94)	Pulled screen free and moved rig back onsite to resume drilling.
Day 20 (3/10/94)	Drilled from 260.7 to 300.8 ft and prepared to take split spoon sample. Total footage was 40.4.
Day 21 (3/14/94)	Drilled from 300.8 to 315.8 ft. Began tripping out of borehole. Total footage was 15.
Day 22 (3/15/94)	Resumed tripping out of borehole. Prepared to set and run pump for aquifer test. Aquifer test ran from March 15-23, 1994.
Day 23 (3/23/94)	Finished slug test, pulled screen, resumed drilling. Advanced 8-in. casing to 323.4 ft and drilled to 324 ft. Total footage was 8.2.
Day 24 (3/24/94)	Advanced 8-in. casing to 325.1 ft and drilled to 325.8 ft. Material bypassed hammer; made modifications to guide device. Packers were reported worn and replaced. No recovery reported. Total footage was 1.8.
Day 25 (3/25/94)	Hammer was reported not firing and began to trip out. Tripped in and resumed drilling. Geologists reported no recovery from 325.8 to 327.3 ft. Total footage was 1.5.
Day 26 (3/28/94)	Drillers cleaned out 3 ft of plug and resumed drilling from 327.3 to 363 ft. Reported top swivel leaking and fitting on top drive cracked. Repairs noted to fitting problem.
Day 27 (3/29/94)	Water reported blowing out hammer. Resumed drilling from 363.3 to 396.8 ft. Water continued to blow out from hammer. Bit reported jammed. Sample at 380 ft lost because sample sock breached. Total footage was 33.5 ft.
Day 28 (3/30/94)	Drillers cleaned hole and resumed drilling from 396.8 to 436.2 ft. Geologists reported basalt at 433 ft and were advised by Westinghouse Hanford Company (WHC) Geosciences to total depth hole. Total depth was at 436.2 ft. Crew began to demobe from site. Total footage was 39.4 ft.
Day 29 (3/31/94)	Borehole logged from 200 to 435 ft (3 hours). Crew continued to demobe from site.

Table 4. Summary of Daily Drilling Activities for Well 699-48-77C. (4 sheets)

Day 30 (4/01/94)	Crew continued to demobe from site and prepared for pump test. Pump installed and ready for test. Test ran from April 1-4, 1994.
Day 31 (4/04/94)	Pump test completed, transducers removed, and completed slug test.
Day 32 (4/05/94)	Crew reported difficulties in removing screen. Screen removed from borehole (6 hours).
Day 33 (4/06/94)	No completion work performed at site. Crew mixed unmarked 100-lb bentonite sacks and subsequently could not pump the mix.
Day 34 (4/07/94)	Crew reported on standby awaiting instructions. A well construction design was sent to WHC Projects to be forwarded to PC Exploration. Crew decided not to tremie grout and tripped out pipe. Will run Enviroplug (Wyo-Ben, Billings, Montana) as suggested in April 7, 1994 well construction design.
Day 35 (4/08/94)	Crew continued adding bentonite chunks. Prepared to grout at 320 ft. Crew pumped three lifts of 15 bags mixed with 90 gal of water.
Day 36 (4/11/94)	Grouted interval 339.6 to 323.8 ft. Crew resumed adding hole plug to 314.1 ft. Crew added 8-12 sand from 314.1 to 310.8 ft. Crew ran 220.41 ft of stainless screen and casing in.
Day 37 (4/12/94)	Continued to run stainless in well. Total stainless in was 313.42 ft. Finished adding sandpack to 286.9 ft and developed sandpack.
Day 38 (4/13/94)	Developed plug while adding two bags of hole plug. Crew then added 100 gal water to free the plug. Crew tripped in tremie pipe to loosen plug. Spent rest of day attempting to remove plug.
Day 39 (4/14/94)	Crew tripped out tremie pipe. Set and logged borehole to determine if formation was on contact with stainless casing. Finished logging interval 308 to 245 ft. Crew attempted to mix one bag of Wyo-Ben Enviroplug with 14 gal of water per manufacturer's instructions. Geologist weighed mix at 10 lb/gal but grout pump unable to pump mix. Crew spent rest of day cleaning pump. After evaluating the log, WHC recommended to WHC Projects that the stainless steel screen and casing be removed and the borehole cleaned or redrilled to original construction depth.

Table 4. Summary of Daily Drilling Activities for Well 699-48-77C. (4 sheets)

Day 40 (4/19/94)	Crew removed stainless casing sometime between April 15 and April 19, 1994 (not documented). Crew set up and began redrilling interval 280.2 to 283.3 ft.
Day 41 (4/21/94)	Crew spent day trying to free hammer.
Day 42 (4/22/94)	Redrilled from 283 to 297 ft.
Day 43 (4/23/94)	Crew had difficulties entering hole and hammer firing. Redrilled from 297 to 300.1 ft.
Day 44 (4/26/94)	Redrilled from 300.1 to 314.1 ft. Set up and ran stainless casing in borehole.
Day 45 (4/27/94)	Crew installed sandpack.
Day 46 (4/28/94)	Crew developed sandpack and ran in tremie pipe.
Day 47 (4/29/94)	Crew mixed and tremied double batch of bentonite slurry. Geologist drops a section of measuring tape with weight in borehole. Crew tremies in second batch of slurry. Geologist drops second tape section and weight. Crew continued to run slurry.
Day 48 (4/30/94)	Geologist tagged well and drops third tape section and weight. Crew began to add holeplug. Geologist drops fourth tape section and weight.
Day 49 (5/02/94)	Crew continued adding holeplug. Developed bridge in casing. Set up to run tremie pipe.
Day 50 (5/03/94)	Ran slurry through bridge. Driller injured ankle while stepping down from grout pump.
Day 51 (5/04/94)	Continued pumping bentonite slurry.
Day 52 (5/05/94)	Continued pumping bentonite slurry. Tripped out tremie pipe, added bentonite pellets, and installed surface seal.
Day 53 (5/06/94)	Set surface pad and posts. Crew cleaned up site.

Note: See metric conversion table at the beginning of this report.

There were no problems or delays during the drilling and completion process at well 699-48-77D. However, numerous problems and delays were encountered during the drilling and completion at well 699-48-77C (see Appendix A, Table A-2).

The aforementioned data were transcribed from Field Activity Reports compiled by the geologist for PC Exploration.

3.3 PROPOSED GEOLOGIC SAMPLING AND CHARACTERIZATION

Proposed geologic characterization was outlined in the Groundwater Monitoring Plan (WHC 1993b) for the two boreholes. The characterization activities were to include geologic sampling, lithology description, physical and chemical analyses, and geophysical borehole logging.

Representative samples were scheduled to be collected at 1.5-m (5-ft) intervals, at changes in lithology, and when noticeable changes in moisture content were observed. A description of the drill cuttings between sample points were to be recorded to obtain a continuous lithologic record.

Calcium carbonate and moisture content analyses were to be performed on the geologic samples collected at the 1.5-m (5-ft) intervals or on samples collected with a higher moisture content. Other analyses, including sieve analysis, saturated hydraulic conductivity, X-ray diffraction, water retention, and hydrometer analysis were to be performed on collected samples selected by the project scientist.

Special sampling requirements were also requested for each of the boreholes. At well 699-48-77D, a minimum of four split spoons was requested from selected intervals. Well 699-48-77C had coring requirements that included six coring runs of 3 m (10 ft) in length.

Both boreholes were to be logged with a gross-gamma probe after the installation of each temporary casing and when the borehole reaches final depth.

3.4 GEOLOGIC SAMPLING AND CHARACTERIZATION

Geologic samples were collected at 1.5-m (5-ft) intervals during the drilling process at well 699-48-77D. A total of 51 $CaCO_3$ and moisture content samples were collected, sealed, and transported to the Geologic Engineering Laboratory for analysis. A total of five split spoon samples were attempted, with three intervals representative and acceptable for analysis (see Appendix A, Table A-1).

Sample collection at well 699-48-77C was more involved with both coring and grab sampling needed for adequate characterization. Numerous setbacks in the sampling process were also experienced during the sampling process. In the early stages of drilling, $CaCO_3$ and moisture content samples were collected every 1.5 m (5 ft) as required. Because of drilling engineering problems that prevented the collection of representative samples, the $CaCO_3$ and moisture content sampling was terminated at 56 m (185 ft). The number of coring runs at well 699-48-77C initially was scheduled to be six 3-m (10-ft) runs, but because of poor recovery caused by inadequate coring equipment and continued engineering problems, the number of coring runs increased to 19 with individual runs ranging from <0.3 to 0.7 m (<1 to 2.3 ft) in length. Total recovery from the coring attempts was 1.1 m (3.5 ft) or 19% (Appendix A). Because of the continued coring problems at well 699-48-77C, representative samples could not be collected for physical analysis.

4.0 HYDRAULIC TESTS AT WELL 699-48-77C

4.1 INTRODUCTION

This section discusses the results of hydraulic testing at wells 699-48-77A, 699-48-77C, and 699-48-77D from March 4 through March 31, 1994. The test wells and site are located north of the 200 West Area and are shown in Figure 2. Hydraulic tests were performed in conjunction with the other site characterization efforts discussed earlier in this document. Wells 699-48-77A, 699-48-77C, and 699-48-77D, which now make up the current monitoring network, will be used to establish baseline geohydrologic conditions at the site, including groundwater flow directions, groundwater flow rates, and an assessment of the impacts of disposal operations on the groundwater chemistry.

Hydraulic testing consisted of slug tests and three constant rate discharge tests using well 699-48-77C as the pumping well. Several observation wells were used to monitor water level changes during the tests, including upgradient well 699-48-77A (131 m [430 ft] away), downgradient well 699-48-77D (48 m [158 ft] away), and wells 299-W7-2 and 299-W7-3 (>305 m [>1,000 ft] away) located at the north end of the 200 West Area. Pumping influences were only observed at well 699-48-77D during the tests. General test information is presented in Table 5, including when tests were conducted, the discharge rates, and other pertinent test information.

Observation wells 699-48-77A and 699-48-77D were completed in the top 6 m (20 ft) of the aquifer as 10-cm (4-in.) stainless steel groundwater monitoring wells. The pumping well was completed with a temporary 20-cm, 4.6-m (8-in., 15 ft) telescoping wire-wrap screen at three separate test intervals. Figure 8 shows the test intervals and the general relationship of the test intervals to the site hydrogeology.

Field work was directed and controlled the Groundwater Monitoring Plan (WHC 1993b), the hydraulic test plan, and a site health and safety plan. Applicable field procedures are found in the *Environmental Investigations and Site Characterization Manual* (WHC-CM-7-7).

4.2 SUMMARY OF TEST RESULTS

Hydraulic tests provided estimates of transmissivity, hydraulic conductivity, the elastic storage coefficient, and the vertical hydraulic conductivity of the aquifer, although the storage coefficient and the vertical hydraulic conductivity values are more qualitative. Table 6 is a summary table of the calculated hydraulic parameters obtained from each of the testing methods. Table 7 is a chronology of the test activities.

The best estimate for transmissivity (T) for the entire aquifer above the lower fine-grained unit is 604 m^2/day (6,500 ft^2/day) obtained from test interval 2 recovery data at the pumping well. However, the aquifer appears to be heterogenous (see Figure 8) with a lower hydraulic conductivity (K) in test interval 1 at the top of the aquifer. Assuming that the aquifer can be

Table 5. General Test Information for the Hydraulic Tests at the C-018H Disposal Facility Site.

Test #	Screened interval[a]	Screen length (ft)	Screen slot size	Discharge rate (gal/min)	Slug rod volume (ft^3)	Water level[a] (ft)
1	244.37 to 258.40	14.03 (~6 ft in 8-in. casing)	18/20	21 (3-hp Pump)	2.404	217.01
2	299.70 to 315.36	15.66 (~4.4 ft in 8-in. casing)	20	203 (30-hp Pump)	2.404	216.41
3	384.40 to 400.02	15.62 (~4.4 ft in 8-in. casing)	20	157.8 (30-hp Pump)	2.404	216.94

Note: See metric conversion table at the beginning of this report.
[a]All measurements below land surface.

Table 6. Summary of Calculated Hydraulic Parameters for C-018H Aquifer Testing.

Test type	Test interval	Analysis types[a]	T (ft²/d)	K/K_v^2 (ft/d)	S	BE
Pre-test monitoring	48-77A	Barometric efficiency	--	--	--	60%
	48-77C					59%
	48-77D					55%
Slug test	#1	Semi-log	--	20	--	--
	#1 #2 #3		--	11 115 58		
	#1		35	--		
Pumping test #1 Recovery data	48-77C/ 48-77D (PW/OW) #1	Pressure derivative, Type curve, Semi-log	6,500 (Overall test #1 and #2)	(<10)/0.5 Top aquifer	1.6E-03	--
Pumping test #2 Recovery data	48-77C/ 48-77D (PW/OW) #2	Pressure derivative, Type curve, Semi-log	6,500 (Overall test #1 and #2)	(112-120)/0.01 Mid-aquifer	--	--
Pumping test #3 Drawdown/ recovery	48-77C/ 48-77D (PW/OW) #3	Pressure derivative, Type curve, Semi-log	1,290 (dd) 4,350 (rec)	(13) Lower aquifer (41)	--	--

Notes: (1) Parentheses indicate a derived value obtained by dividing the calculated transmissivity by 105 ft. (2) See metric conversion table at the beginning of this report.

[a]The following references apply to each analysis type:
Barometric efficiency = Clark 1967
Slug test = Bouwer and Rice 1976; Bouwer 1989
Pumping test (drawdown)
- Pressure derivative = Novakowski 1989; Spane 1993
- Type curve = Theis 1935; Neuman 1974, 1975
- Straight-line = Cooper and Jacob 1946

Pumping test = (recovery)
- Agarwal 1989
- Same as pumping test

Slug interference
- Novakowski 1989; Spane 1992, 1993; Perez 1989.

Table 7. Chronology of Hydrologic Testing Activities at the C-018H Disposal Facility in March and April 1994. (3 sheets)

Testing activity	Description
1. Pre-Test Baseline	Baseline water level and barometric monitoring started at wells 699-48-77A and 699-48-77D on 02-02-94 at 1700 h. Starting water levels were 219.76 ft below top of casing (btoc) and 219.76 ft, respectively. Baseline monitoring stopped at 1130 and 1235 h on 02-08-94 at both wells. Baseline monitoring continued at well 699-48-77D on 02-08-94 at 1210 stopped at 1102 h on 02-28-94. Both wells 699-48-77A and 699-48-77D were restarted on 02-28-94 at 1400 h, and stopped at 1326 and 1321 h on 03-04-94. Initial water levels were 219.82 and 219.86 ft btoc.
2. Step Drawdown Test #1	Immediate pre-step test monitoring was initiated at wells 699-48-77A and 699-48-77D on 3-04-94, starting at 1330 h, and ending at 1016 h on 3-05-94. Initial water levels in wells 699-48-77A and 699-48-77D were 219.88 and 219.85 ft btoc. Pumping well (699-48-77C) baseline started at 1333 h and stopped at 1411 h on 03-04-94. Starting water level was 216.95 ft below land surface (bls). Pumping started at 1415 h, discharging at 7.25 gal/min. Pump rate stepped up to 15 gal/min at 1545 h. Pump rate changed to 30 gal/min at 1717 h, and pumping stopped at 1740 h. Recovery monitoring initiated at 1741 h, and terminated at 1016 h on 03-05-94.
3. Pumping Test #1	Pumping started at 1058 h on 03-05-94 at 21 gal/min. Test stopped at 0758 h on 03-06-94. Begin monitoring far-field observation wells 299-W7-2 and 299-W7-3 at 1300 h on 03-05-94. Recovery of wells 699-48-77C and 499-48-77D monitored from 0800 h on 03-06-94 to 0728 h on 03-08-94.
4. Slug Test #1	Short-term baseline monitoring for the slug injection test started at well 699-48-77D started at 1030 h on 03-08-94. Slugging rod BR-4 (2.204 ft^3). The slug injection test was monitored in wells 699-48-77C and 699-48-77D starting at 1120 h on 03-08-94. Test was stopped at 1150 h on 03-08-94. Baseline for withdrawal of slug monitoring wells 699-48-77C and 699-48-77D started at 1152 h on 03-08-94. Monitoring was stopped at 1204 h on 03-08-94. The slug was withdrawn and wells 699-48-77C and 699-48-77D monitored starting at 1205 h on 03-08-94 and ending at 1245 h on 03-08-94.

Table 7. Chronology of Hydrologic Testing Activities at the C-018H Disposal Facility in March and April 1994. (3 sheets)

Testing activity	Description
5. Intra-Test Baseline Monitoring	Between test monitoring well 699-48-77D was started at 1700 h on 03-08-94 and stopped at 0500 h on 03-16-94. Starting water level is 219.80 ft btoc. Monitoring of well 699-48-77A was started at 1700 h on 03-08-94. The monitoring rate was change at 2359 h on 03-18-94 during the second 24-hour pump test and continued until just before the third 24-hour pump test. Monitoring of well 699-48-77A was restarted at 1800 h on 03-31-94, and stopped at 1332 h on 04-06-94. The starting water level was 219.79 ft btoc.
6. Step Drawdown #2	Second step drawdown test performed on well 699-48-77C, 20-slot, temporary screen exposed from 299.70 to 315.36 ft bls. Starting static water level (SWL) = 216.41 ft bls. 10-hp GRUNDFOS pump (trademark of GRUNDFOS Pumps Corp., Clovis, California) intake set at 284.83 ft bls. Wells 699-48-77C and 699-48-77D were monitored from the same datalogger along with the barometric pressure. Pre-test baseline monitored and started at 0625 h on 03-16-94 and stopped at 0630 h. Pump started at 0632 h on 03-16-94. Initial pump rate was 83 gal/min. Pump and test stopped at 0637 h because of burst rotometer. Pump re-started at 0647 h on 03-16-94. Initial pump rate of 82.5 gal/min. Pump stopped and recovery test started at 0743 h. Recovery stopped at 0800 h on 03-16-94. 10-hp pump pumping at full capacity with little drawdown. The decision was made to switch to a 30-hp pump. Pump intake at 286.10 ft bls. Baseline monitoring at 1202 h on 03-17-94. Test stopped at 1445 h. Starting SWL = 220.28 ft top of casing (toc), casing stickup = 3.7 ft. Pump started at 1448 h. Stopped at 1452 h because of electrical problem. Monitoring overnight started at 1600 h on 03-17-94, stopped at 0630 h on 03-18-94.
7. Pumping Test #2	For the second 24-hour pump test the equipment configuration was the same as the step drawdown test with the 30-hp pump. Pump started at 0715 h on 03-18-94. Initial pump rate was 205 gal/min. Starting SWL = 220.28 ft toc. Test stopped at 0715 h, pump shut off at 0718 h on 03-19-94. Recovery monitoring stopped at 0745 h on 03-23-94.
8. Slug Test #2	For the second slug test, injection of slug BR-4 (2.204 ft^3) into well 699-48-77C with monitoring in well 699-48-77D at 1320 h on 03-22-94. Test was stopped at 1401 h on 03-22-94. Baseline between injection and withdrawal started at 1404 h, stopped at 1439 h on 03-22-94. Slug withdrawn at 1442 h on 03-22-94. Test stopped at 0702 h on 03-23-94.

Table 7. Chronology of Hydrologic Testing Activities at the C-018H Disposal Facility in March and April 1994. (3 sheets)

Testing activity	Description
9. Pumping Test #3	For the third 24-hour pump test the equipment configuration was as follows for well 699-48-77C, 20-slot, temporary screen exposed from 384.5 to 400.2 ft bls. Starting SWL = 220.92 ft toc. 30-hp GRUNDFOS pump intake set at 288.08 ft bls. 8-in. casing stickup was 3.1 ft. Pre-test baseline started at 1802 h on 04/01/94, test stopped at 1812 h. Pump started at 1815 h on 04-01-94. Initial pump rate 195 gal/min. Starting SWL at 699-48-77D = 219.90 ft toc. Flow rate adjusted to 159 gal/min at 1824 h, because of excessive drawdown. Pump shutoff at 1818 h on 04-02-94. Recovery monitoring stopped at 0820 h on 04-04-94.
10. Slug Test #3	For the third slug test, the baseline for injection of slug BR-4 (2.204 ft^3) into well 699-48-77C with monitoring in 699-48-77D was started at 1024 h on 04-04-94. Test was stopped at 1202 h on 03-08-94. The slug was injected at 1206 h on 04-04-94. Test was stopped at 1255 h on 04-04-94. Baseline for withdrawal of slug was started at 1256 h on 04-04-94. Monitoring was stopped at 1338 h. The slug was withdrawn at 1340 h on 04-04-94 and ending at 1402 h on 04-04-94. Post-testing monitoring of well 699-48-77D was started at 0800 h on 04-04-94 and stopped at 1345 h on 04-06-94. Starting SWL = 220.81 ft toc.

divided into two relatively distinct units with a thickness of about 16 m (53 ft) each, the hydraulic conductivities for the upper and intermediate test intervals are less than 3 and 37 m/day (10 and 120 ft/day), respectively. Figures 9 through 12 show drawdown and analysis plots for test 1, and Figures 13 through 15 are the drawdown and analysis plots for test 2.

The best estimate of transmissivity for test interval 3 below the fine-grained unit is 120 m^2/day (1,290 ft^2/day) based on the drawdown data at the pumping well. Assuming the aquifer thickness ranges between 4.6 m (15 ft) (well screen length) and 34 m (110 ft) (the top of basalt), the hydraulic conductivity falls somewhere between 4 and 26 m/day (12 and 86 ft/day). The geometric mean is calculated at 10 m/day (32 ft/day). Figures 16 through 18 are analysis plots for test interval 3.

In developing the best fitting type curves, a K_D (vertical to horizontal hydraulic conductivity ratio) of 0.5 and 0.01 was assumed for tests 1 and 2, respectively. The difference in assumed K_D values results from the lower versus higher hydraulic conductivities observed between test intervals 1 and 2. A K_D was not estimated for test interval 3 because the drawdown response was analyzed using a semi-log plot.

Figure 8. Hydrogeologic Conceptual Model for Proposed C-018H Disposal Facility.

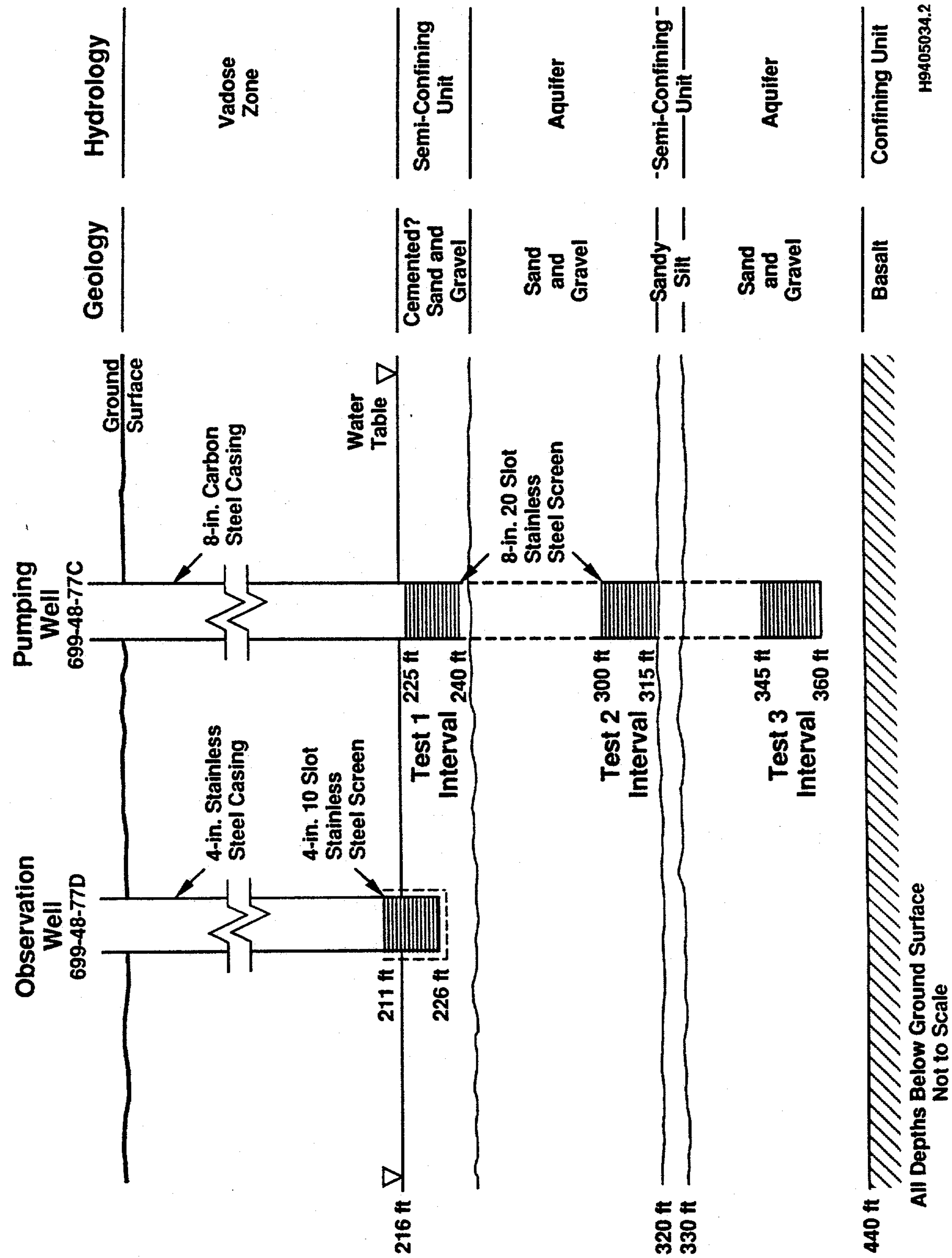


Figure 9. Diagnostic Plot and Theis Type Curve Analysis for Test Interval 1, Pumping Well Drawdown.

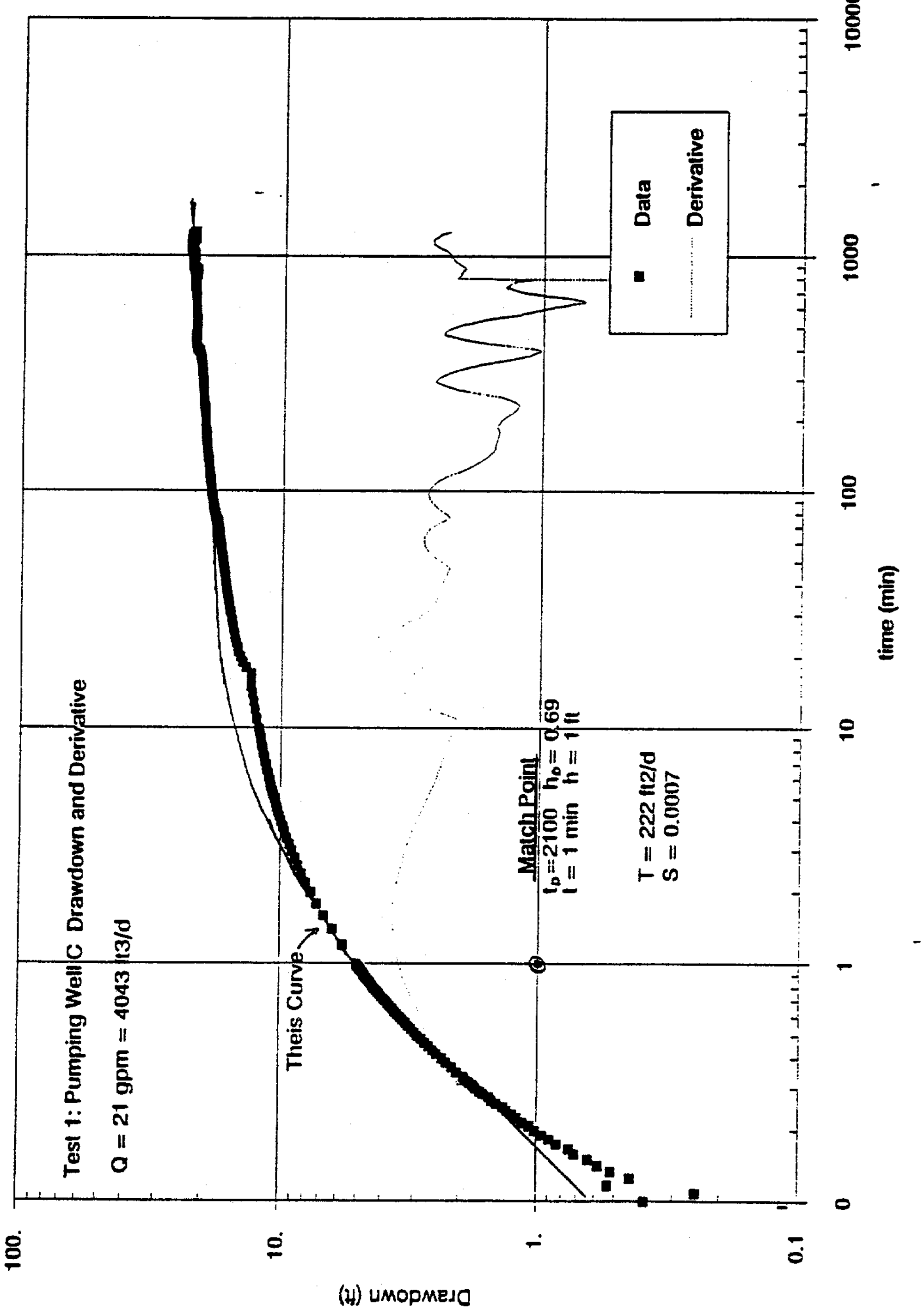


Figure 10. Diagnostic Plot and Theis Type Curve Analysis for Test Interval 1, Pumping Well Recovery.

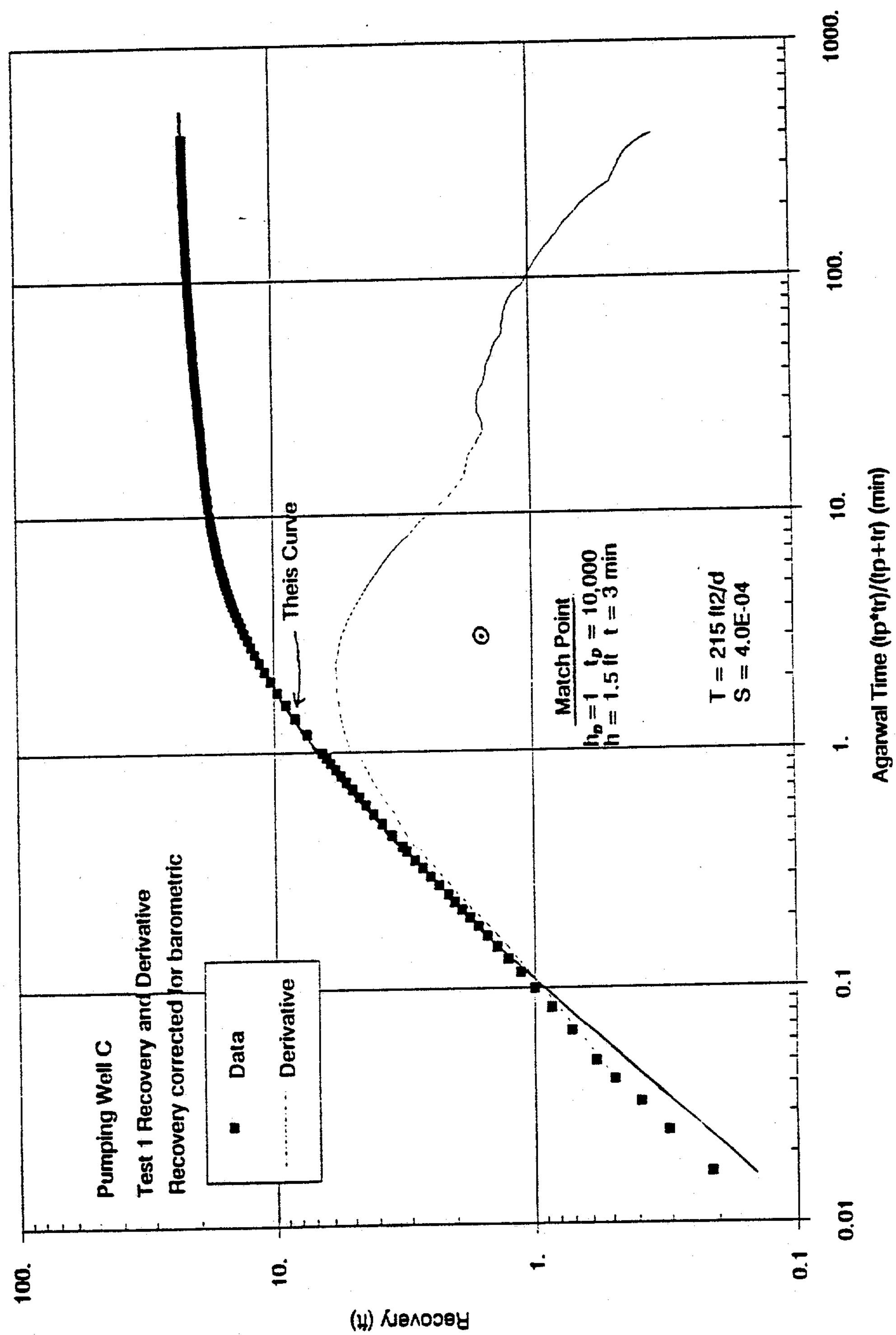


Figure 11. Analysis of Barometric Corrected and Uncorrected Data for Observation Well D, Test Interval 1 Drawdown.

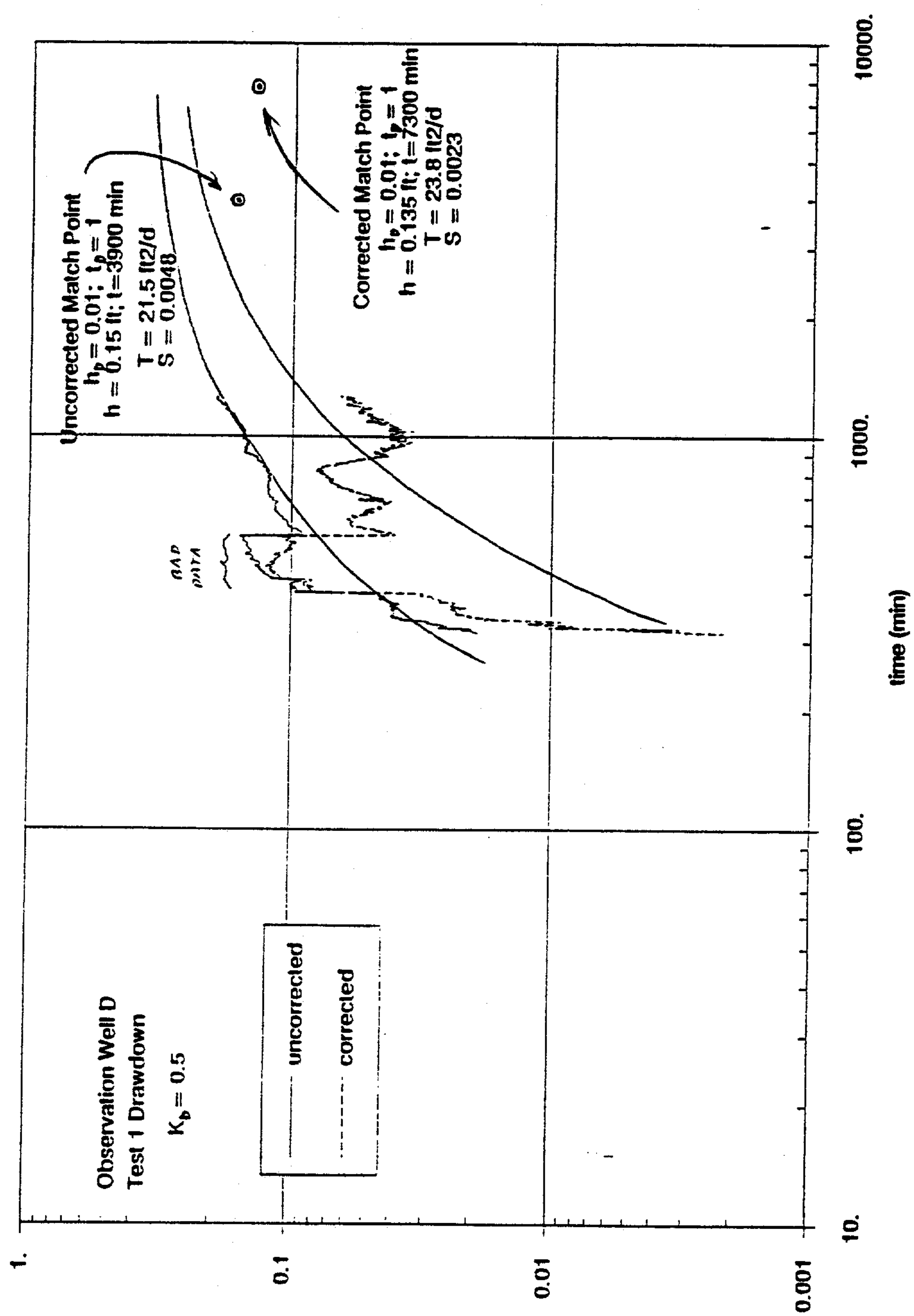


Figure 12. Analysis of Barometric Corrected and Uncorrected Data for Observation Well D, Test Interval 1 Recovery.

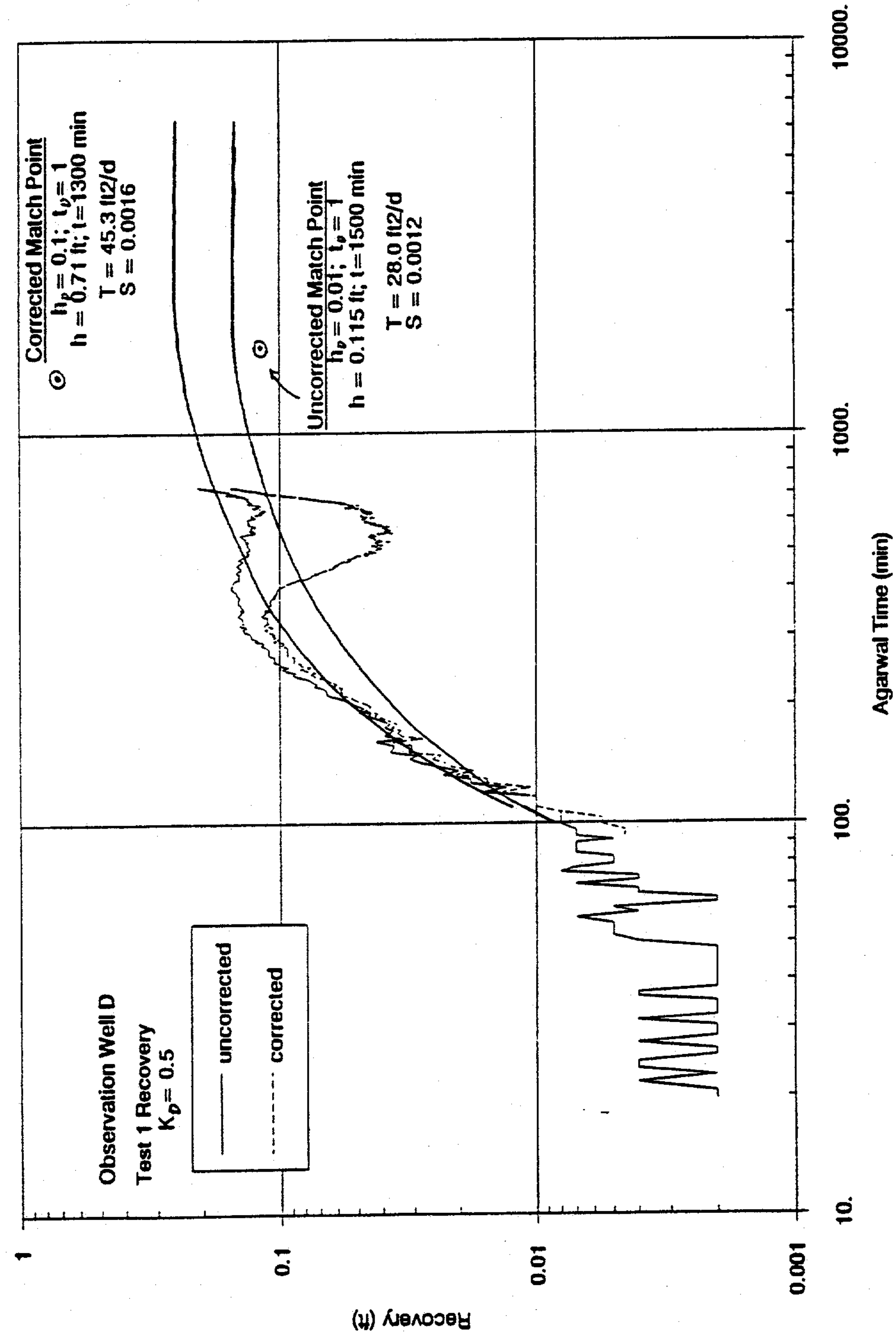


Figure 13. Diagnostic Plot and Theis Type Curve Analysis for Test Interval 2, Pumping Well Drawdown.

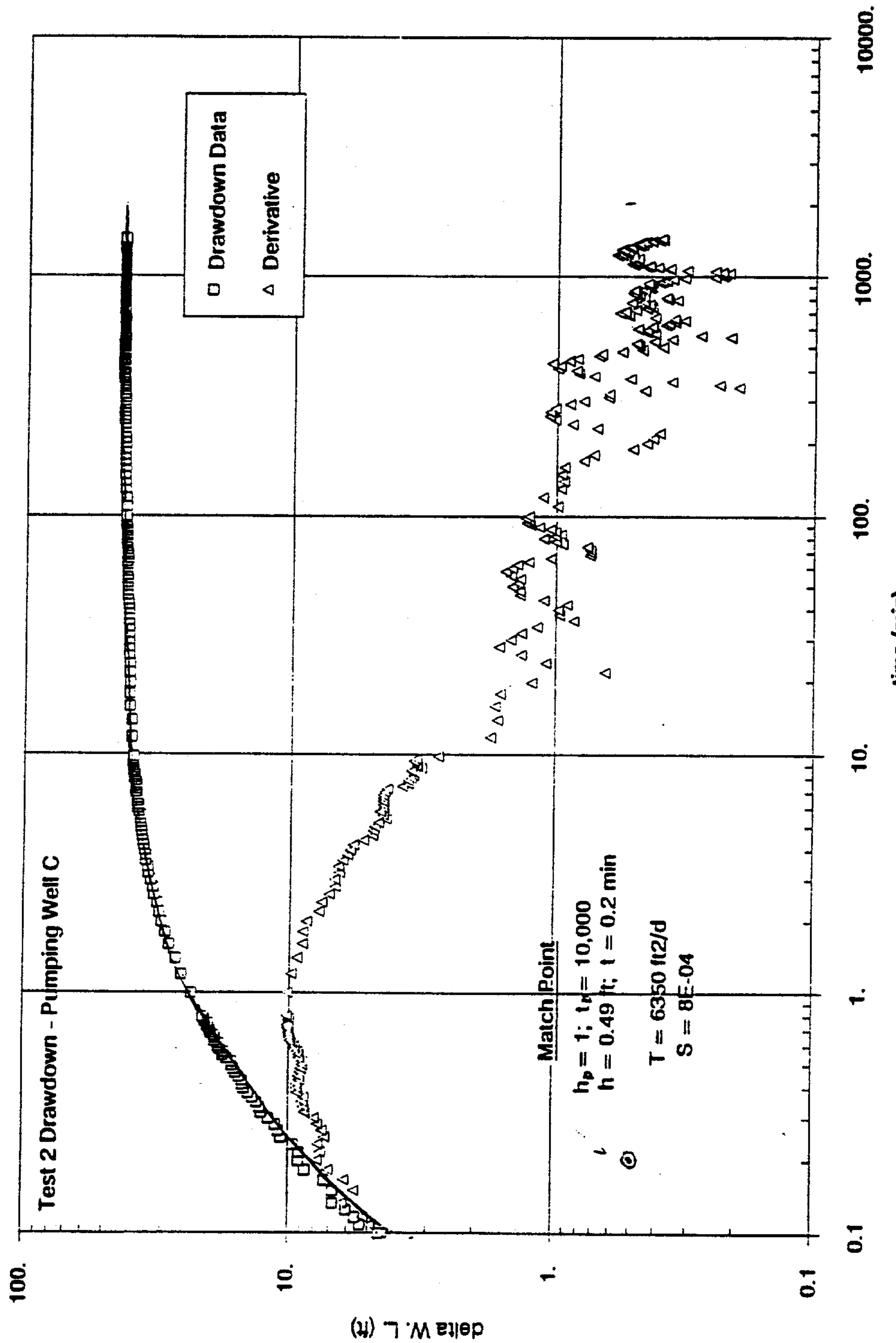


Figure 14. Diagnostic Plot and Theis Type Curve Analysis for Test Interval 2, Pumping Well Recovery.

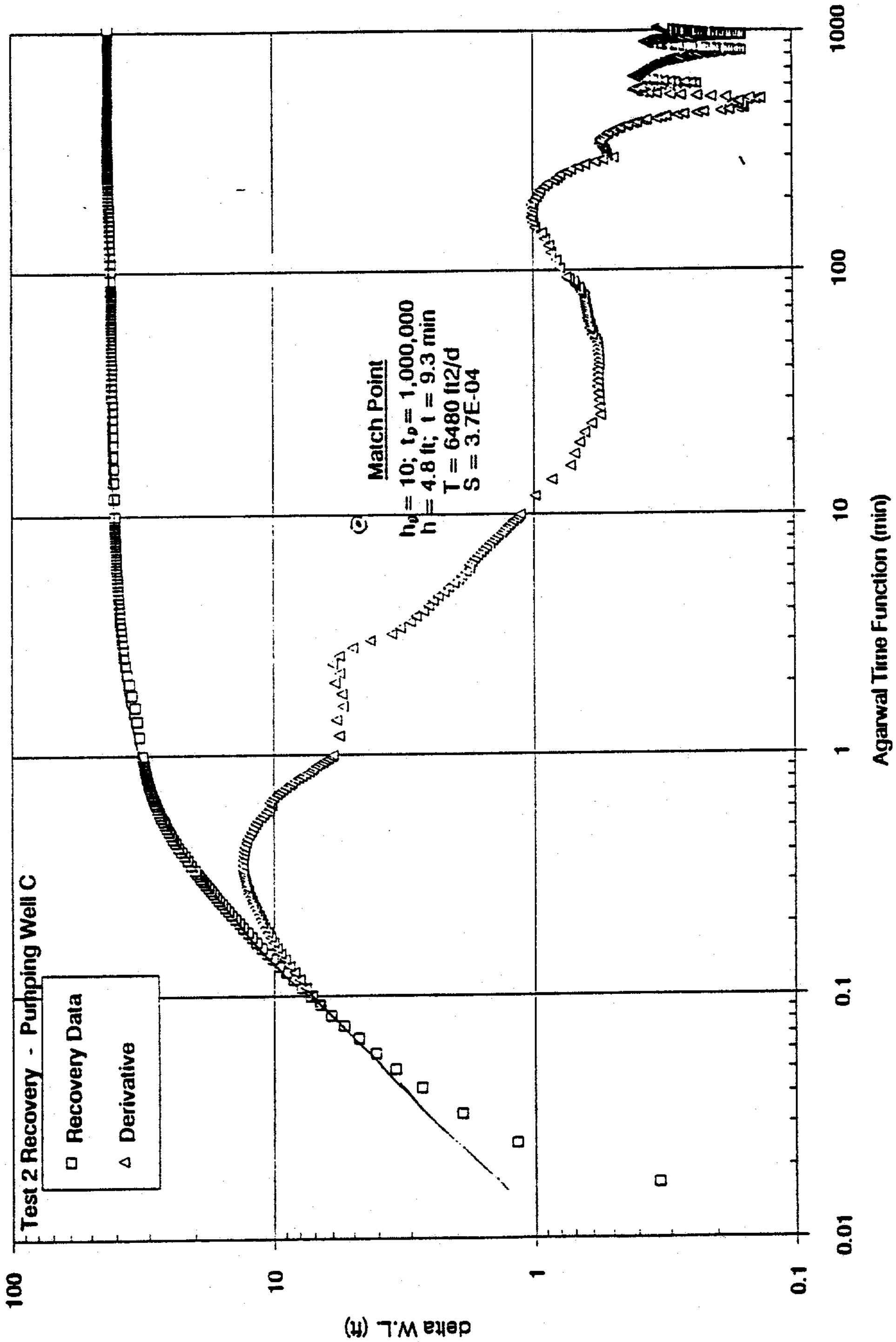


Figure 15. Test 2 Drawdown and Recovery Data at Observation Well D.

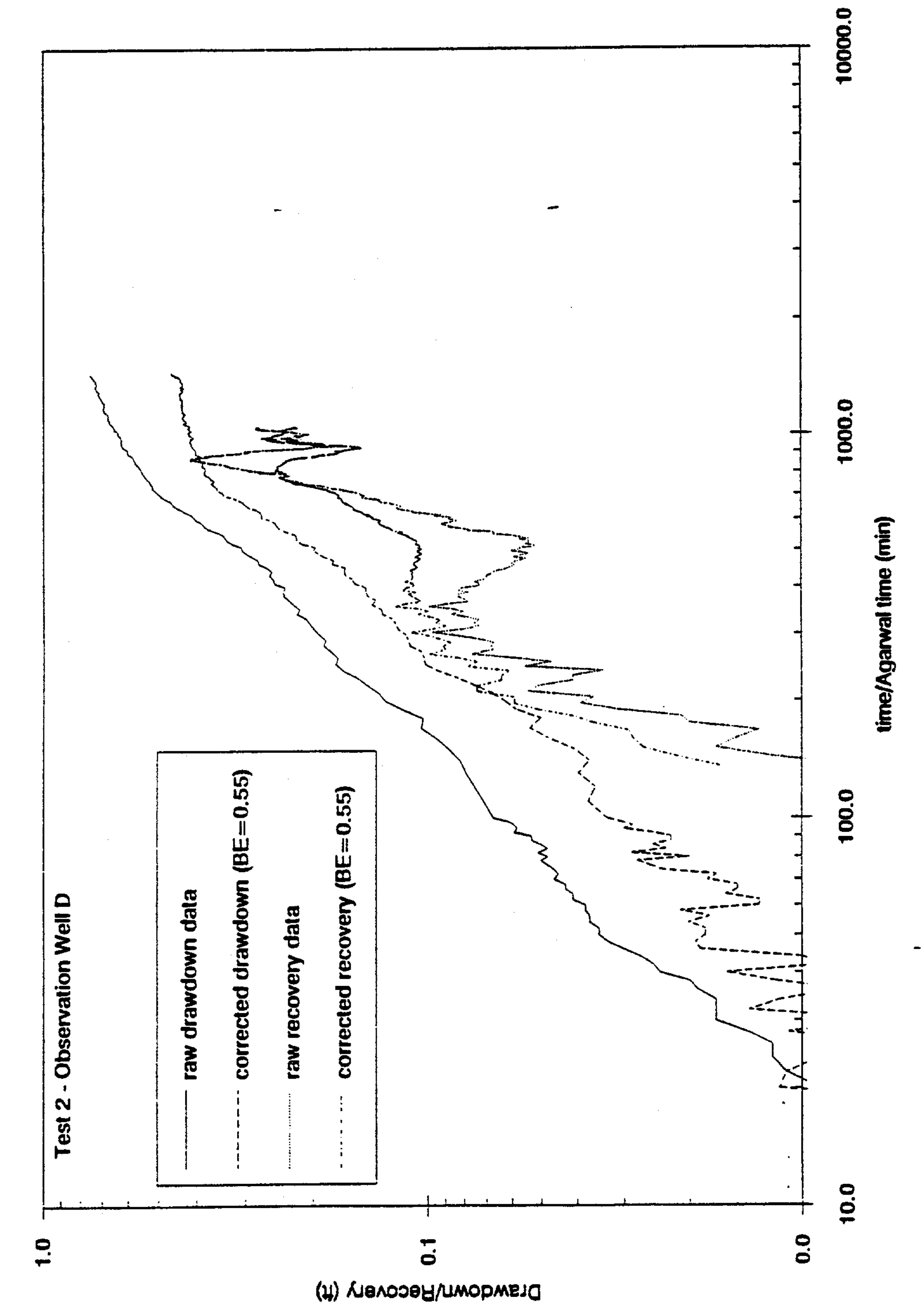


Figure 16. Straight-Line Analysis and Best
Line Fit for Test Interval 3,
Pumping Well Drawdown.

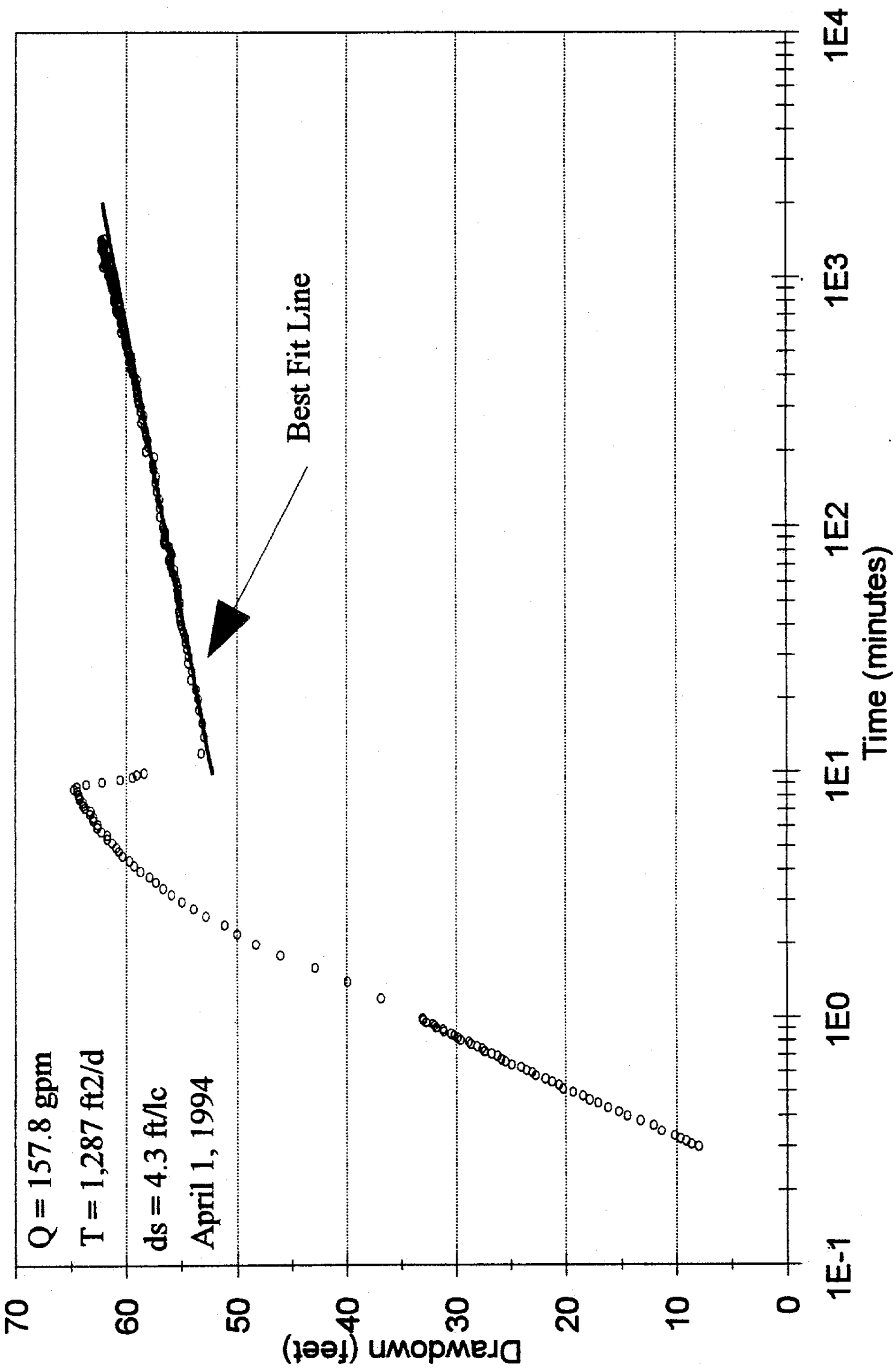


Figure 17. Diagnostic Plot for Test Interval 3,
Pumping Well Drawdown.

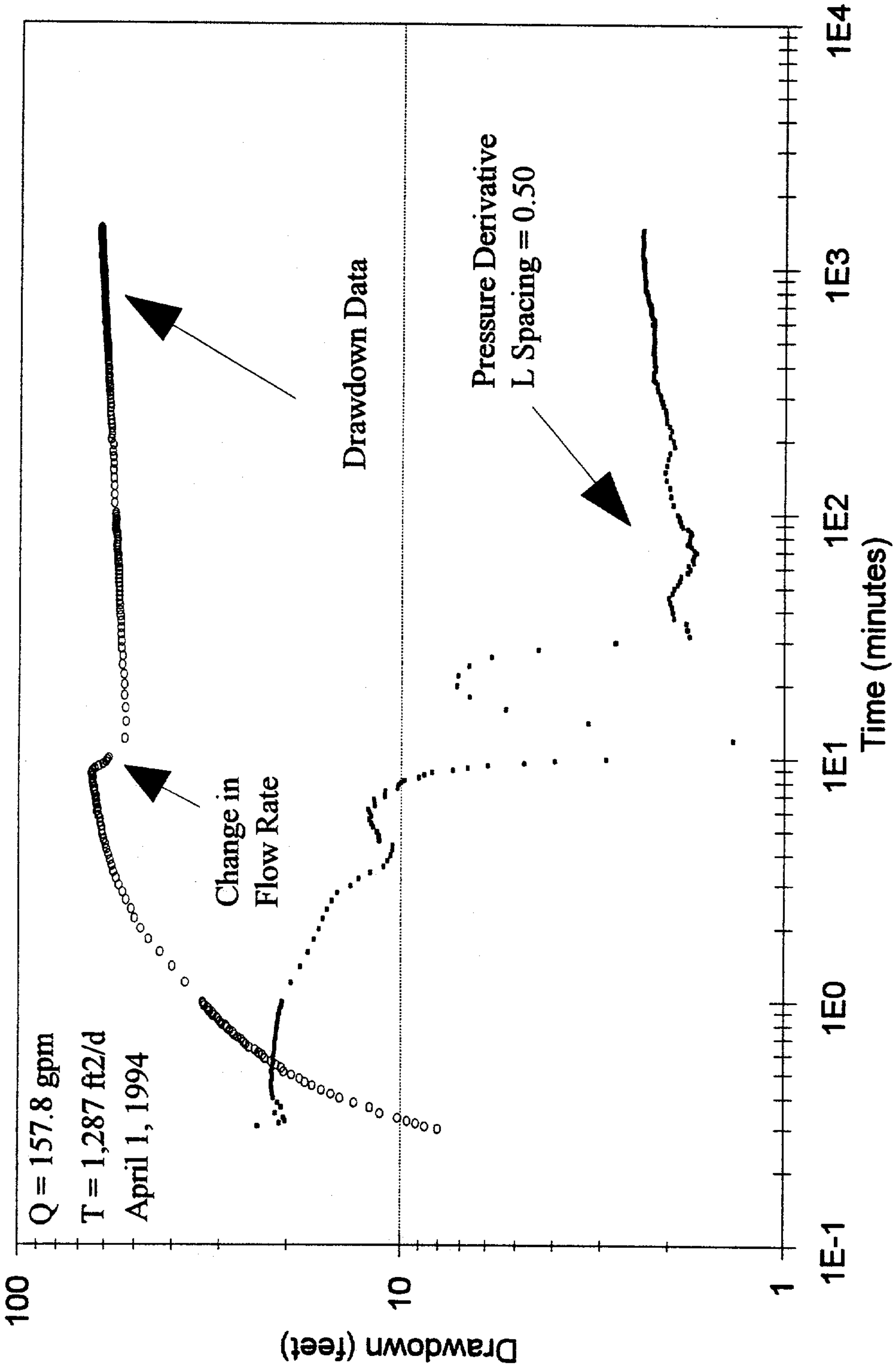
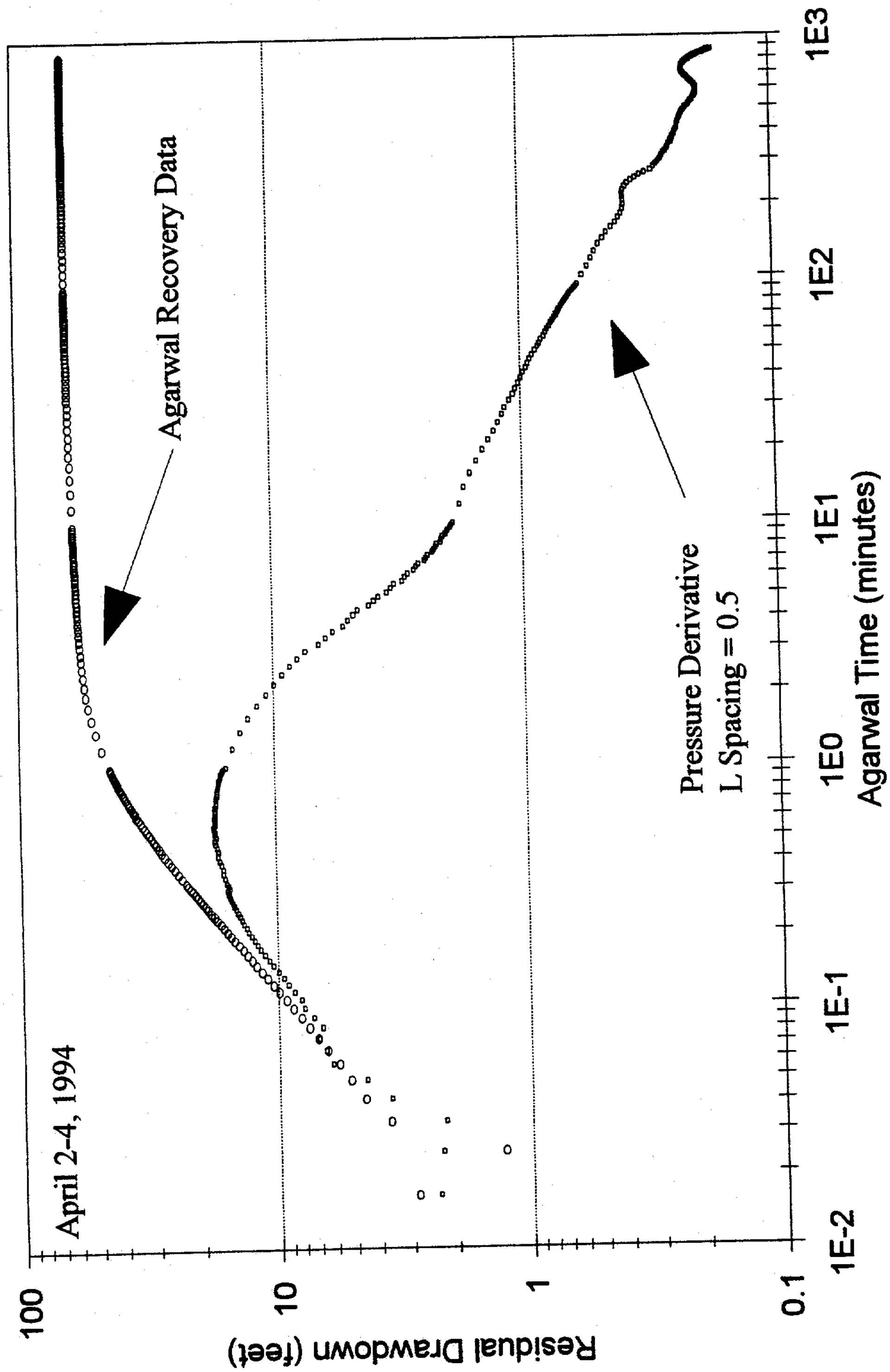


Figure 18. Diagnostic Plot for Test Interval 3, Pumping Well Recovery.



A storativity of 1.6 x 10^{-3} was estimated using the observation well recovery data from test 1. This value is most representative of the upper, less permeable section of the aquifer. However, the irregular data for this well, as noted above, strongly qualify this estimation. For the development of type curves to account for wellbore storage, an aquifer storativity of 5 x 10^{-4} was assumed for test 2.

Slug test results from the three test intervals provided hydraulic conductivities of 3.3, 35, and 18 m/day (11, 115, and 58 ft/day). These values are comparable to the hydraulic conductivities of 3, 37, and 10 m/day (10, 120, and 32 ft/day) estimated from the pumping test data, which implies that under confined conditions, slug test results may provide reasonable estimates of hydraulic conductivity.

4.3 BAROMETRIC EFFICIENCIES

Barometric efficiencies were calculated for each of the observation wells and for the upper pumping well interval using the method of Clark (1967). Plots of the raw water-level data, the corresponding barometric pressure change, and the water levels corrected for barometrically induced fluctuations were used to calculate barometric efficiencies. The analysis plots are shown in Figures 19 through 21. Barometric efficiencies for wells 699-48-77A, 699-48-77C, and 699-48-77D are 60, 59, and 55%, respectively.

4.4 SLUG TEST RESULTS

4.4.1 General Test Procedure

The general procedure for slug testing consisted of injecting and withdrawing a slugging rod 0.018 or 0.062 m^3 (0.194 or 2.204 ft^3) in volume. During injection and withdrawal of the rod a transducer was used to measure the water level changes. A period of water level equilibration was established before initiating each portion of the test.

Slug tests were conducted in the three monitoring wells at different times. The slug test at well 699-48-77A was performed on May 19, 1992; at well 699-48-77D on January 31, 1994; and at well 699-48-77C at the three test intervals, on March 8, March 22, and April 4, 1994. The latter two wells (699-48-77C and 699-48-77D) were tested as part of this drilling and characterization program. Well 699-48-77A was drilled and completed in 1992 as part of an earlier characterization program (the slug test analysis for well 699-48-77A is reported in Swanson (1994).

Figure 19. Clark Analysis Plot for Barometric Efficiency at Observation Well A.

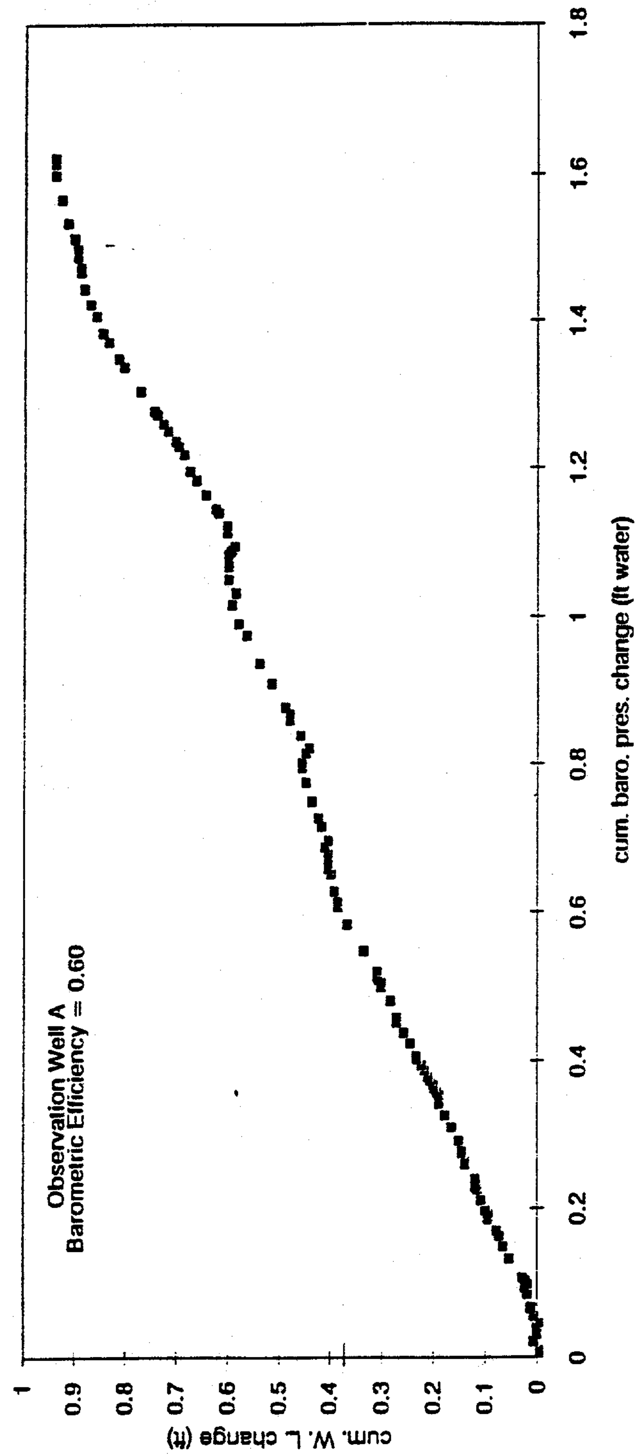


Figure 20. Clark Analysis Plot for Barometric Efficiency at Observation Well C.

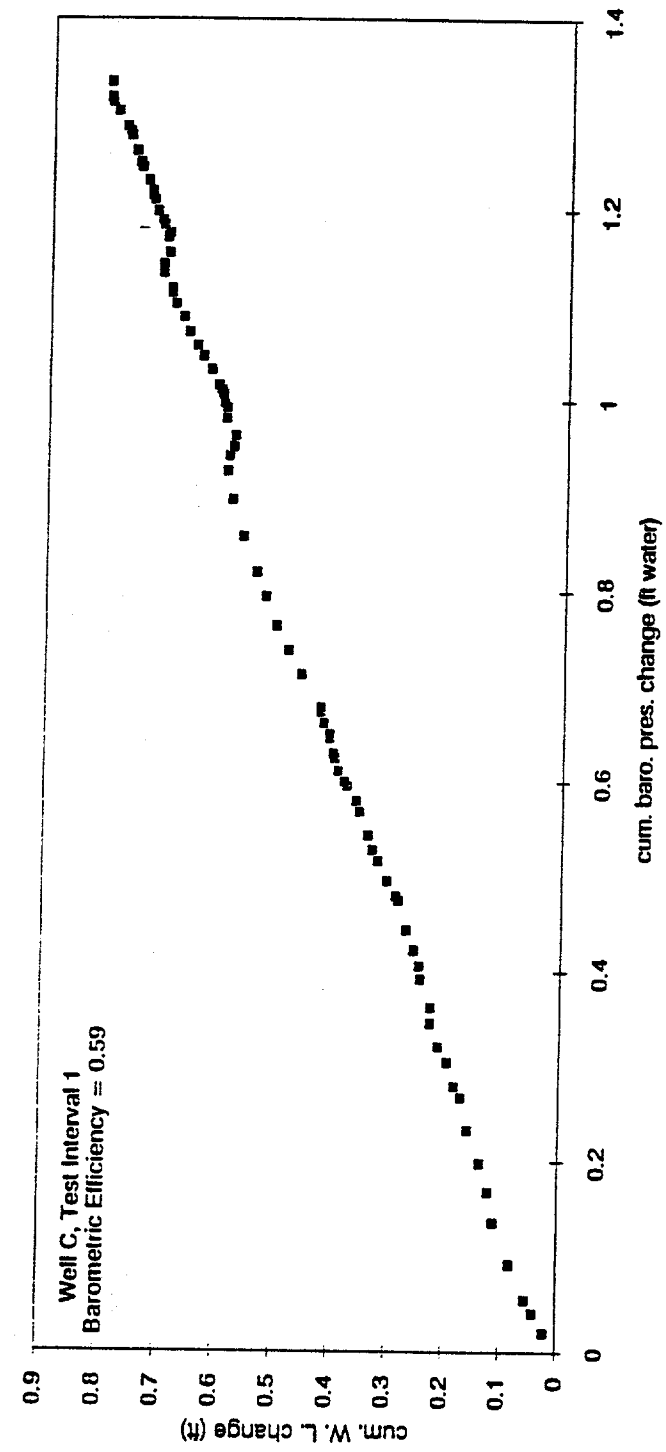
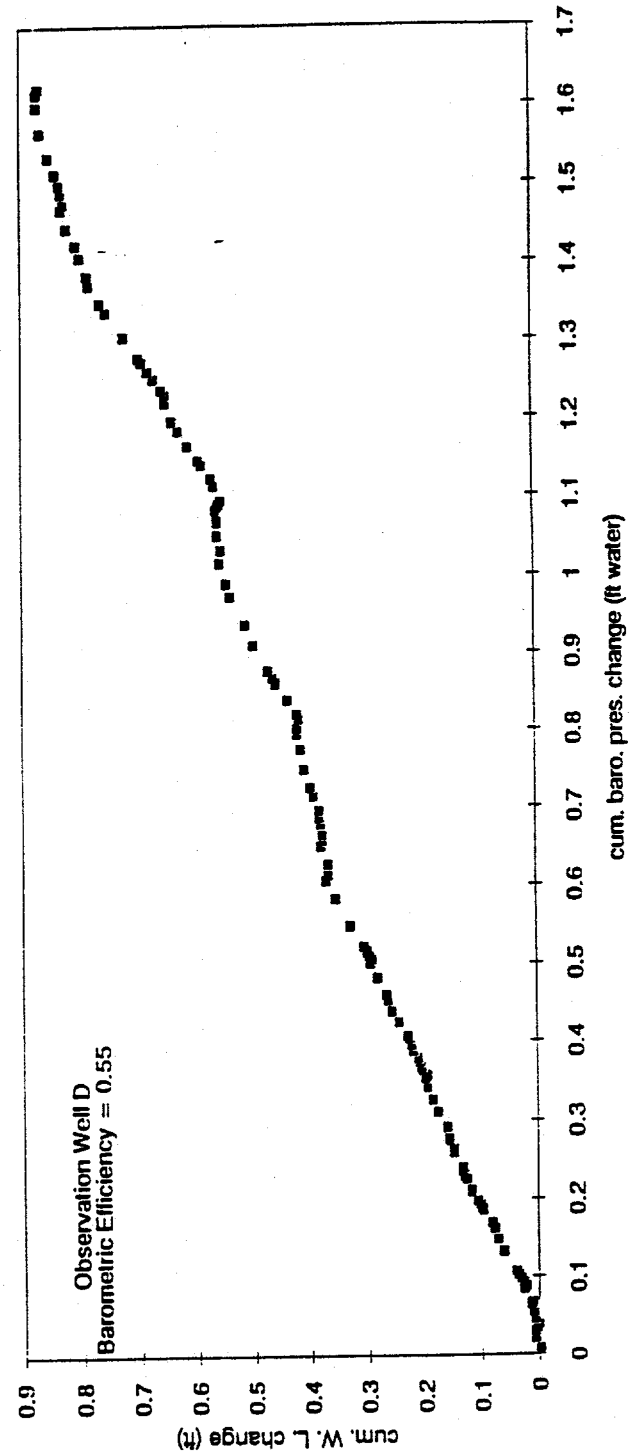


Figure 21. Clark Analysis Plot for Barometric Efficiency at Observation Well D.



4.4.2 Analysis Methods and Results

The test data were analyzed using the Bouwer and Rice (1976) and the Bouwer (1989) methods; for test 3 (well 699-48-77C), the Papadopulos et al. (1973) method was used. The computer software package, ISOAQX,[1] was used to match the best fit line or type curve to the test data and calculate the aquifer hydraulic conductivity or transmissivity. Figures 22 through 26 show the analysis plots for each well test well and interval.

When the rise of the water level during a slug test is in the screened section of a filter packed well, Bouwer (1989) recommends correcting the casing radius term. Following Bouwer's recommendation, the well casing radius was calculated from the equation:

$$r_{ce} = [(1-n)r_c^2 + nr_w^2]^{1/2}$$

where

r_{ce} = effective casing radius (corrected r_c)
r_c = inside casing diameter (well screen; 0.05 m [0.167 ft])
r_w = borehole radius (0.1 m [0.33 ft])
n = filter sand porosity (40%).

This correction accounts for the thickness and porosity of the filter pack. As shown in Table 5, the effective casing radius was calculated as 0.07 m (0.25 ft) for a standard 20-40 mesh filter pack material with a porosity of about 40%. The filter pack porosity estimate is based on unpublished laboratory values.

The slug test results provided estimates of hydraulic conductivity of 6 and 11 m/day (20 and 35 ft/day) for observation wells 699-48-77A and 699-48-77D; and 3, 35, and 18 m/day (11, 115, and 58 ft/day) for the three pumping well test intervals (see Figures 22 through 26). The Papadopulos et al. (1973) analysis method yielded a transmissivity of 349 m^2/day (3,755 ft^2/day). If the aquifer thickness is assumed to be 32 m (105 ft) (see Figure 8), then the transmissivity can be converted into a hydraulic conductivity of 11 m/day (36 ft/day). This value is similar to the other parameter estimations for interval 3. It would appear that slug testing in confined aquifers provides hydraulic parameters that are equivalent to pumping test results.

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[1]ISOAQX is a trademark of HydraLogic, Missoula, Montana.

Figure 22. Bouwer and Rice Slug Withdrawal Test Analysis for Test Interval 1, Pumping Well.

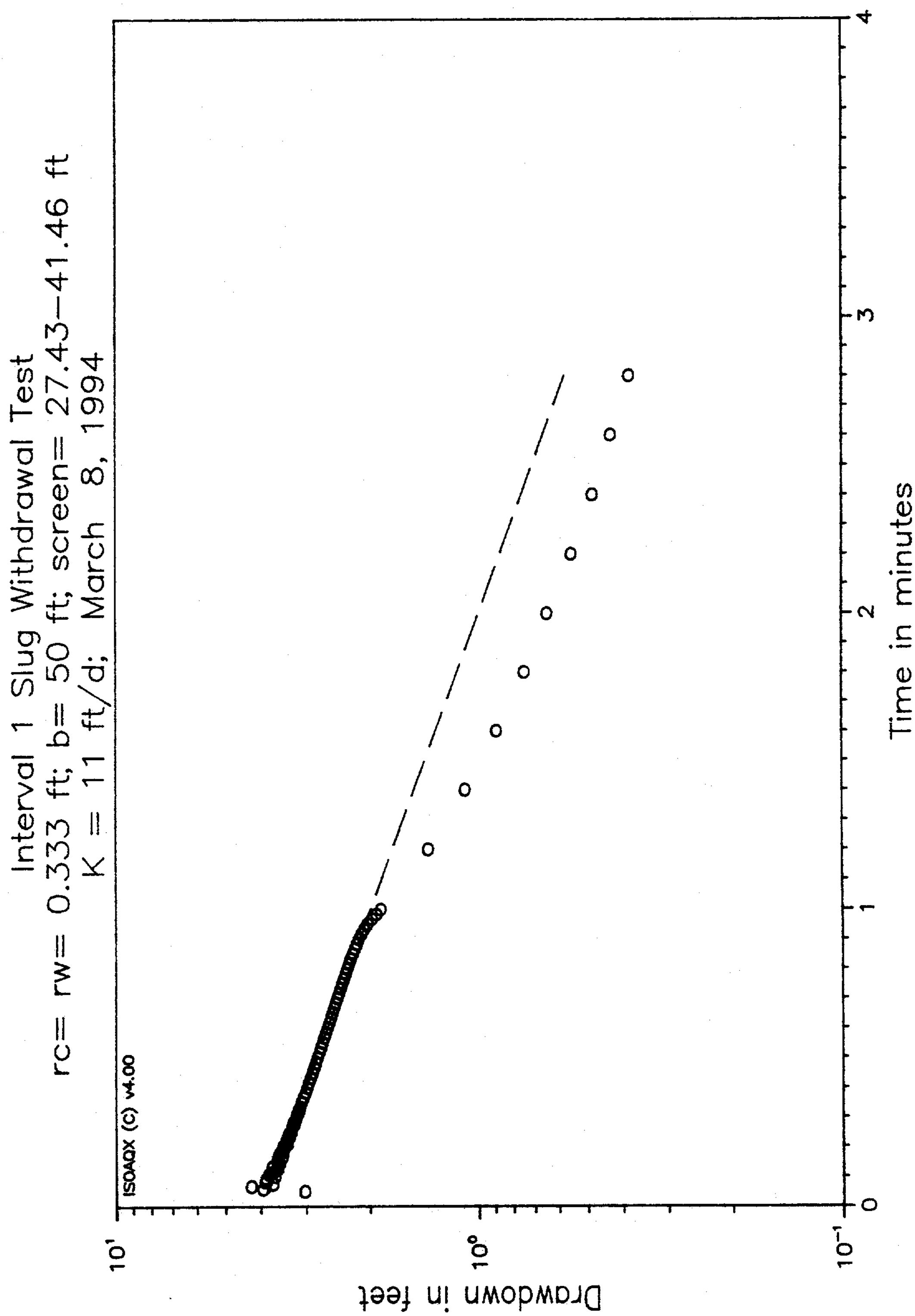


Figure 23. Bouwer and Rice Slug Withdrawal Test Analysis for Test Interval 2, Pumping Well.

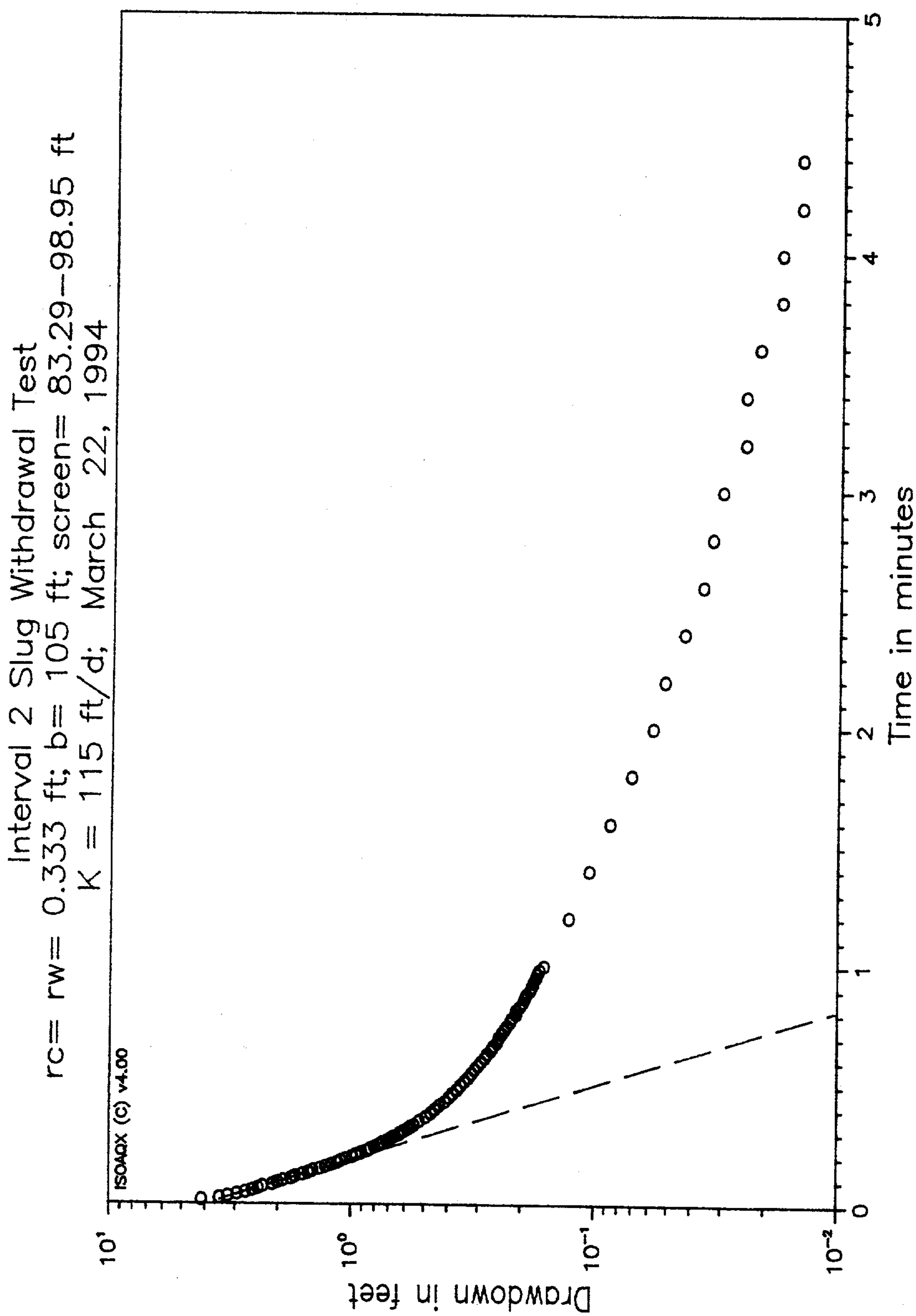


Figure 24. Bouwer and Rice Slug Withdrawal Test Analysis for Test Interval 3, Pumping Well.

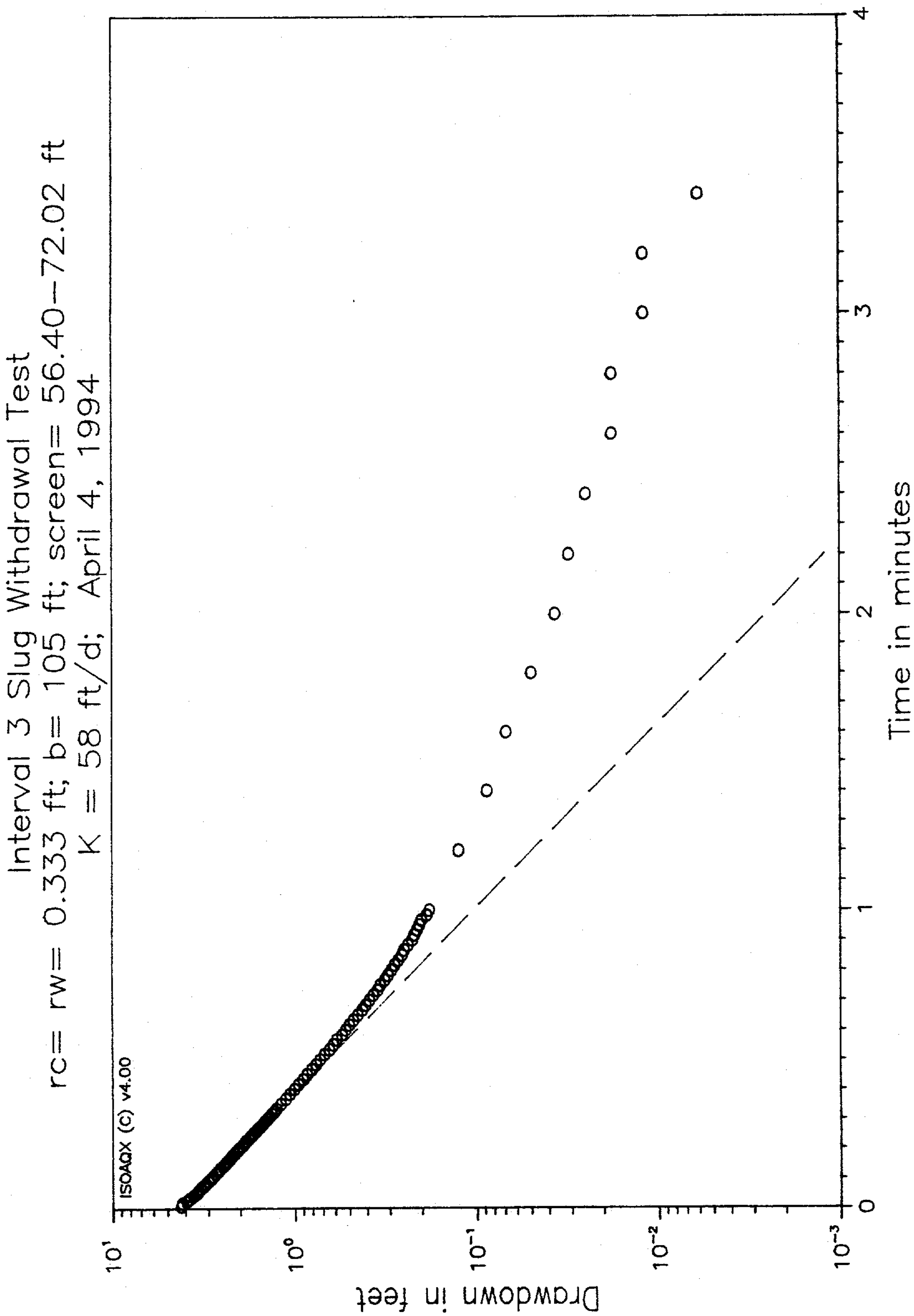


Figure 25. Papadopulos Slug Withdrawal Test
Analysis for Test Interval 3, Pumping Well.

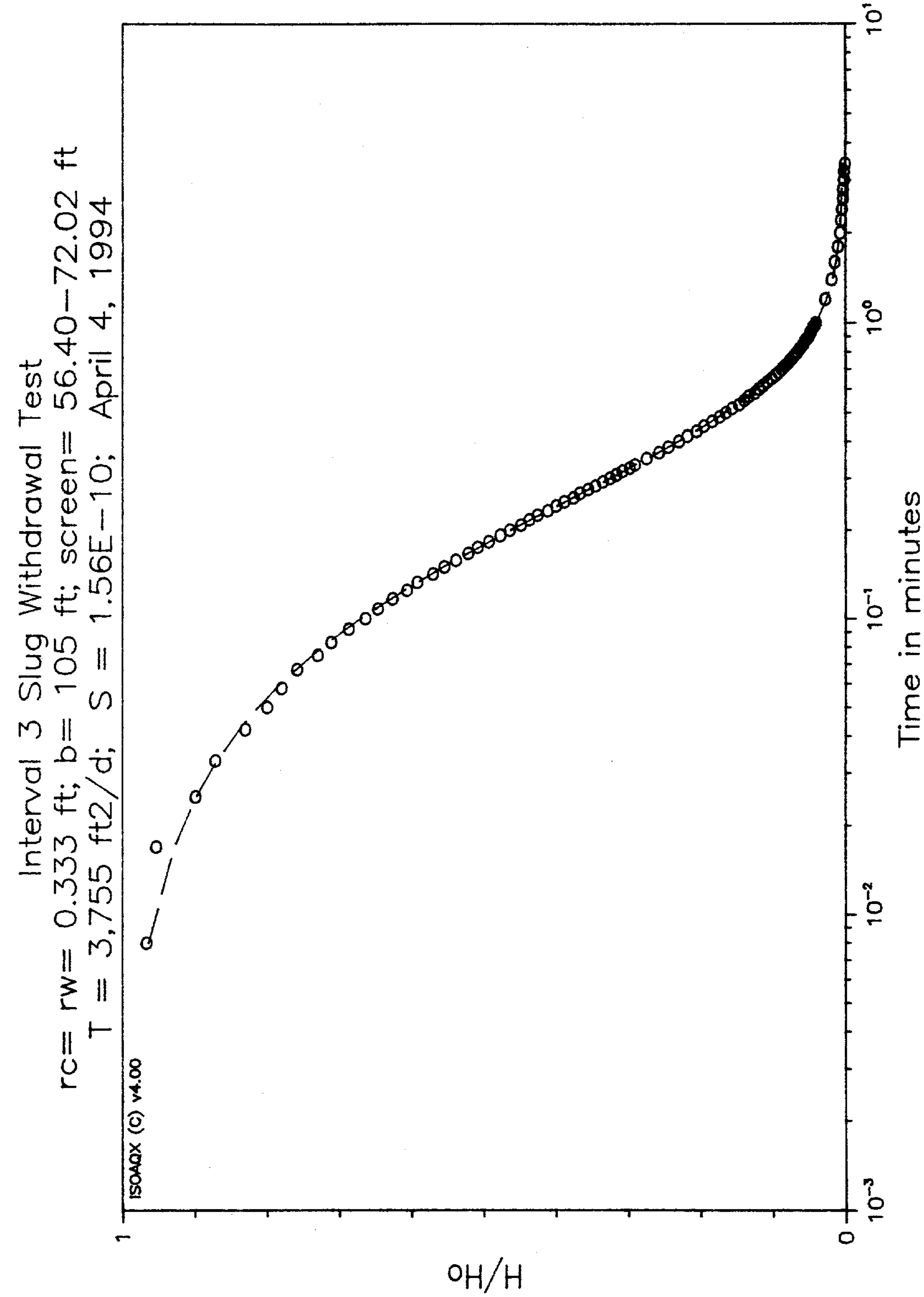
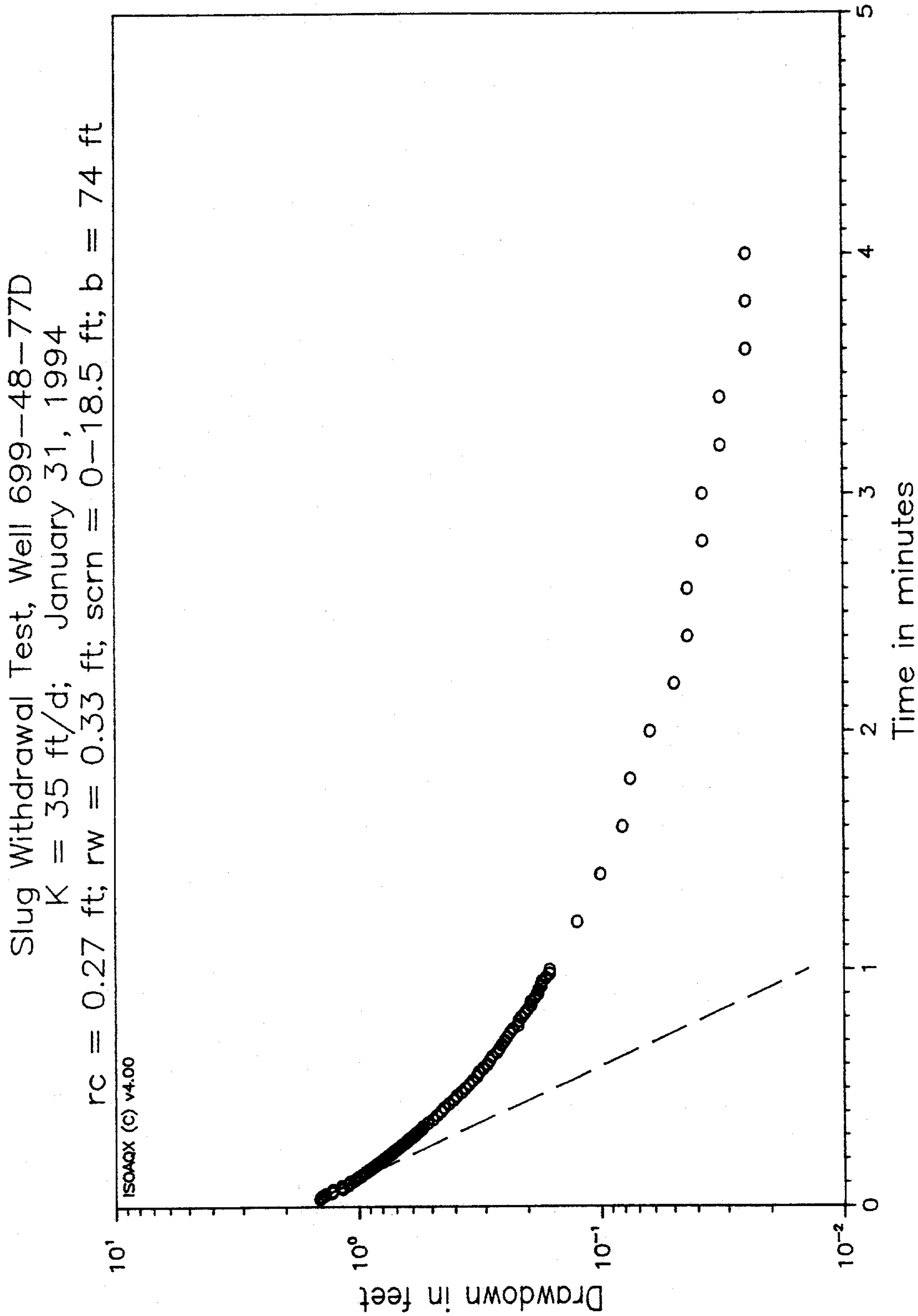


Figure 26. Bouwer and Rice Slug Withdrawal Test Analysis for Test Interval 1, Observation Well D.



4.5 PUMPING TEST RESULTS

4.5.1 General Test Procedure

The baseline or pre-test monitoring period for well 699-48-77D extended from February 8 to February 28, 1994. These data did not indicate any significant trends over this period (Figure 27). For this reason, no trend corrections were made to the data before performing the analyses.

A 3-horsepower GRUNDFOS[1] pump fitted with a check valve was set with the intake 4.6 m (15 ft) below the water table. This pump was used to develop the well and for the constant rate discharge test. Sufficient data were available from the development pumping to determine the pumping rate for the constant discharge test; a step-drawdown test was not conducted.

Pumping tests were conducted at three test intervals in a drill-and-test type of sequence. When drilling reached a targeted test interval, a well screen and pump were set. Some well development was performed and, based on this information, a pumping rate chosen for the longer-term pumping test. Table 5 shows the depth of each test interval, discharge rates, and other relevant test information.

Purgewater was conveyed through an 8-cm (3-in.) discharge line 61 m (200 ft) to the northeast and was discharged to the ground. Flow rates were measured with an in-line rotometer, and confirmed manually using a bucket of known volume and a stop water. It is estimated that over 2,081,970 L (550,000 gal) of water was discharged to the ground from the pumping tests.

The pumping tests were initiated on March 5, March 18, and April 1, 1994, after the well had re-equilibrated overnight from the development pumping or other field activities. Water was discharged at a constant rate from each test zone. In situ pressure transducers measured water-level changes in both pumping and observation wells. Far-field wells 299-W7-2 and 299-W7-3 (located at the north end of 200 West Area) were monitored during test 1 to determine if the cone of depression could be measured over 305 m (1,000 ft) away. No discernable response was observed.

The pumping portion of each test ran about 24 hours. In general, the recovery period for each test ran at least two times the length of the drawdown portion, but longer if the recovery occurred over a weekend. Table 7 is a chronology of aquifer testing activities.

During pumping, indicator parameter water quality information was collected using a HACH[2] kit. Three groundwater samples were collected from test interval 3 and were sent to a laboratory to analyze for tritium and carbon tetrachloride. Figures 28 and 29 are plots of temperature, pH, nitrate, specific conductance, and total dissolved solids. All of these values remained relatively constant throughout the test. Temperature values

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[1]GRUNDFOS Pumps Corp., Clovis, California.

[2]HACH Company, Loveland, Colorado.

Figure 27. Barometric Correction of Drawdown Data at Observation Well A, Test Interval 1.

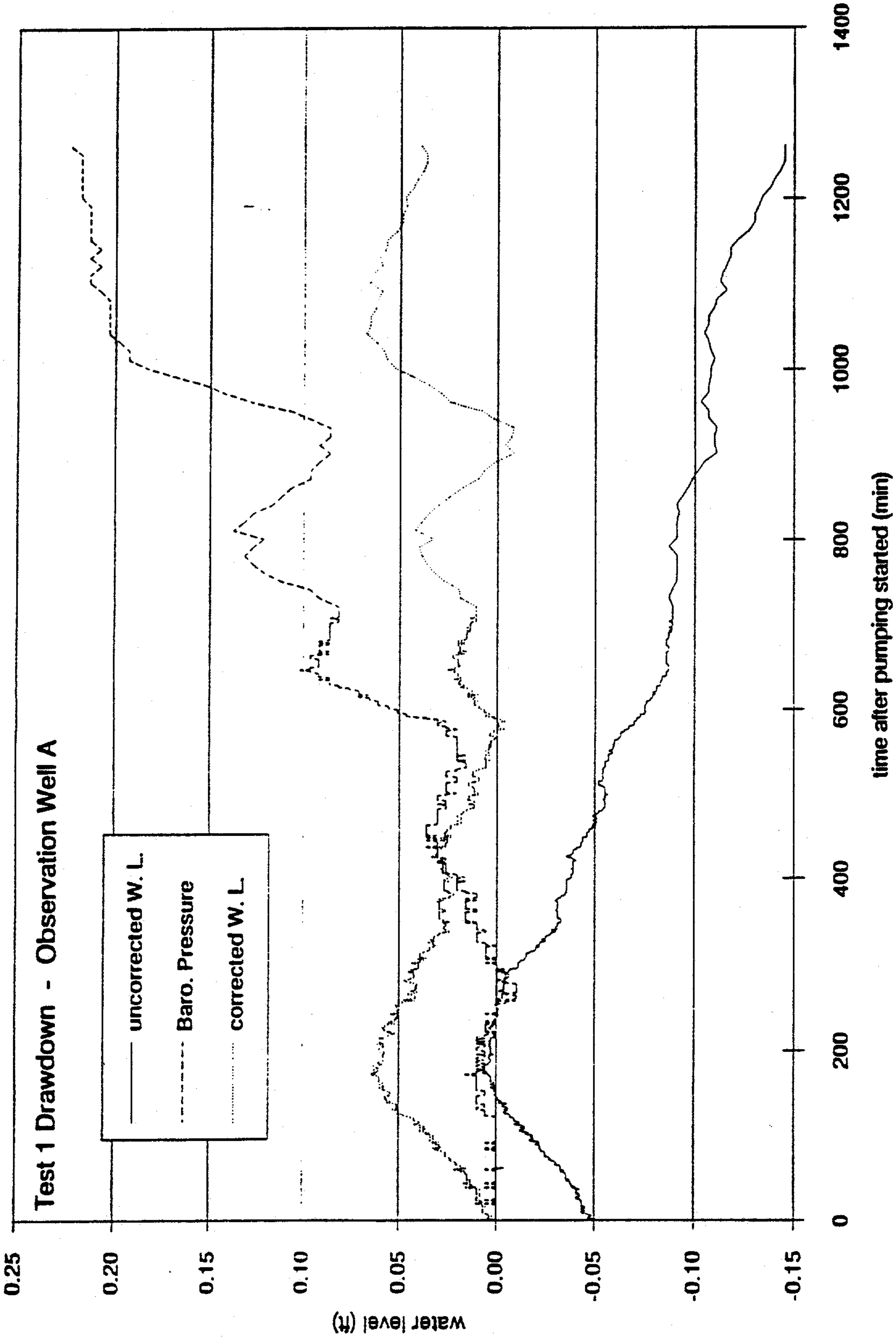


Figure 28. Field Sampling Results for Test Interval 3, Specific Conductance, Nitrates, and Total Dissolved Solids.

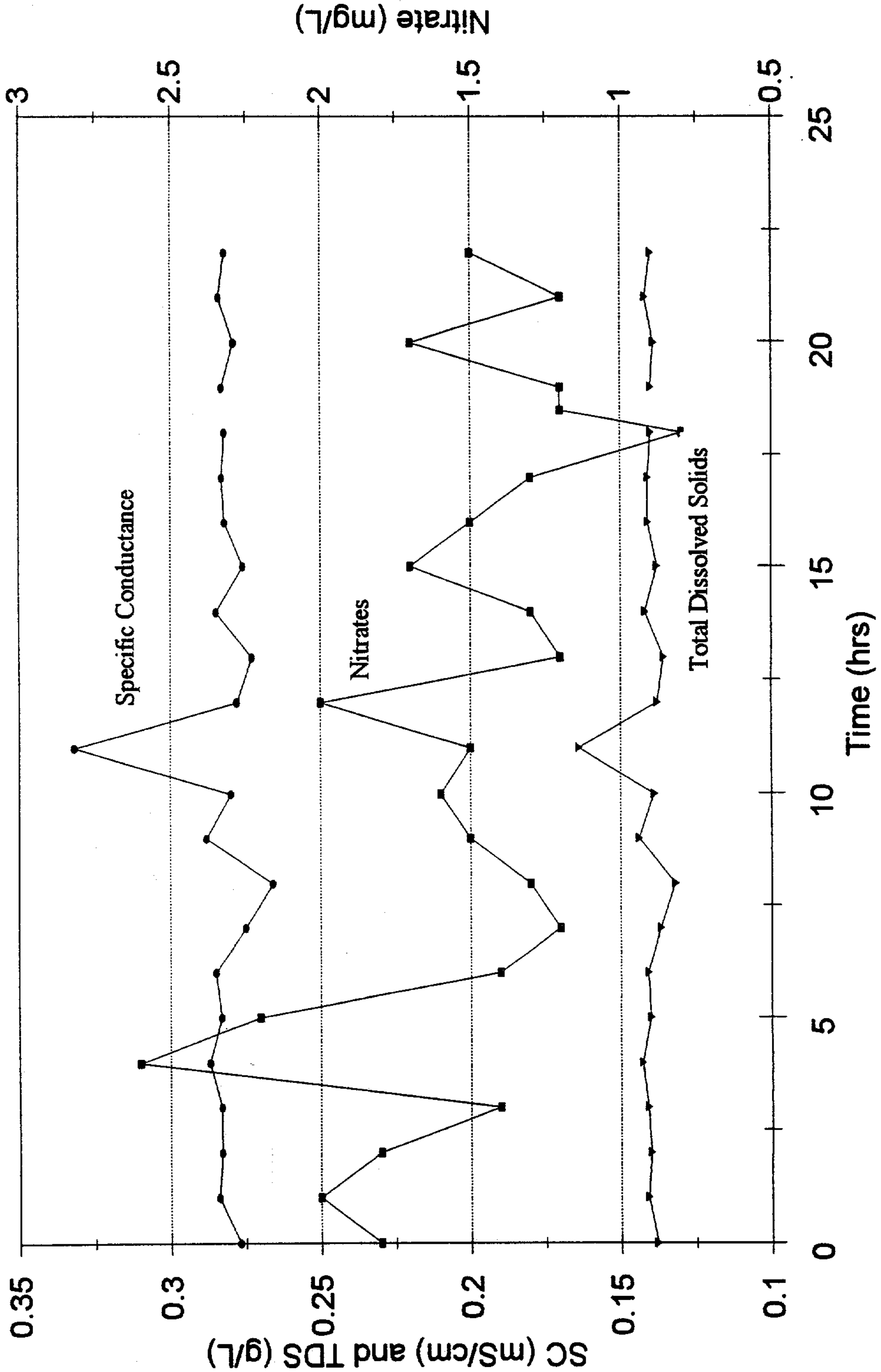
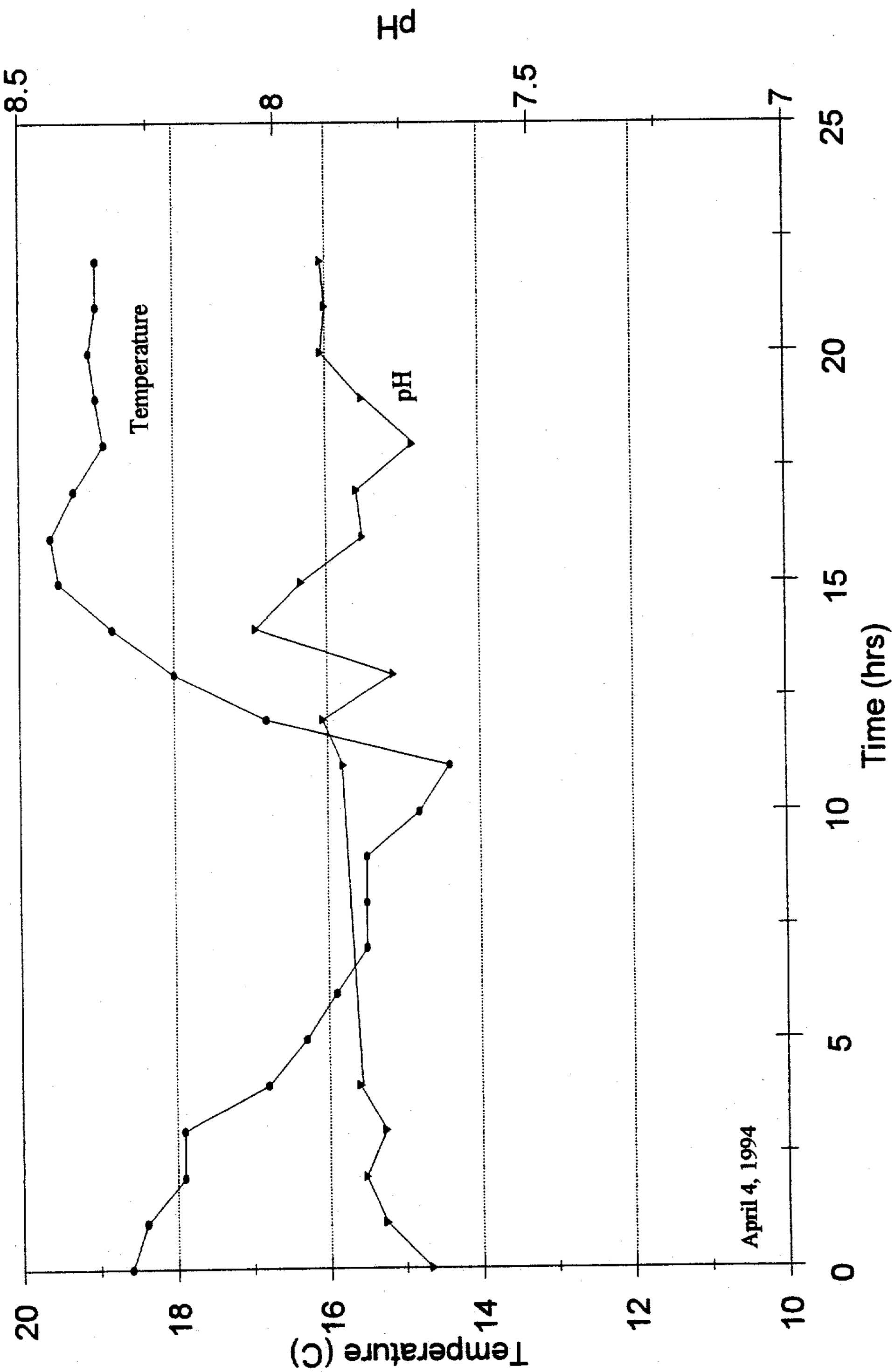


Figure 29. Field Sampling Results for Test Interval 3, Temperature and pH.



did fluctuate somewhat, but this change is thought to correspond to temperature increases during the day.

4.5.2 Analysis Methods and Results

The pumping and recovery drawdown data were analyzed using several complimentary techniques, including the pressure derivative, type curve matches, semi-log straight-line method, and data corrections for barometric fluctuations and water level trends (before analysis). Refer to Spane (1992; 1993) and general publications such as Kruseman and De Ridder (1983) for a description of these analysis techniques and a set of general procedures for applying them. Figures 9 through 18 show the pumping and recovery analysis plots for the pumping and observation well for all three test intervals.

The data were corrected for barometric fluctuations (Clark 1967) using the calculated barometric efficiencies for each well. Figures 19 through 21 show the barometric analyses and the calculated efficiencies. Barometric efficiencies were 60, 59, and 55% for wells 699-48-77A, 699-48-77C, and 699-48-77D, respectively.

A pressure derivative analysis (Bourdet et al. 1989) was performed for both the drawdown and recovery data to make the following determinations:

- When radial flow conditions were established during the test
- The effects of wellbore storage
- The presence or absence of boundary conditions.

Then either a Cooper and Jacob (1946) straight-line analysis (test interval 3), or a Neuman (1974; 1975) type curve match (test intervals 1 and 2) were applied to the pumping and recovery data, and hydraulic parameters were calculated. Applying the Neuman (1974; 1975) type curve to pumping well data is generally not considered valid because of well efficiency losses that bias the calculated transmissivity toward the low end (i.e., the transmissivity is less than the true aquifer value). However, given the close correspondence between the slug test hydraulic parameters and the pumping test hydraulic parameters, the impact of well losses is considered relatively insignificant.

The recovery data for both the pumping well and the observation well were adjusted using the Agarwal (1980) method. This technique transforms the recovery data into an equivalent pumping test response by modifying the time dimension using the equation $t_p*t_r/(t_p+t_r)$, where t_p and t_r are the time since pumping and recovery began, respectively. The data thus transformed can be analyzed using the full range of techniques generally applied to drawdown data. The recovery water levels are based on the change in drawdown using the maximum measured drawdown as the reference value (i.e., the first recovery drawdown value is 0).

The transmissivities and hydraulic conductivities calculated for the three test intervals are given in summary form in Table 7. These results should not be viewed as absolute values because of the noted data and analysis weaknesses. Nevertheless, the reasonable correspondence between the slug test and the pumping test results provides some level of confidence that the test results are reasonably representative aquifer parameters near these wells.

The best estimate for transmissivity (T) for the entire aquifer above the lower fine-grained unit is 604 m^2/day (6,500 ft^2/day), obtained from test interval 2 recovery data at the pumping well. However, the aquifer appears to be heterogenous (see Figure 8) with a lower hydraulic conductivity (K) in test interval 1 at the top of the aquifer. Assuming that the aquifer can be divided into two relatively distinct units with a thickness of about 16 m (53 ft) each, the hydraulic conductivities for the upper and intermediate test intervals are less than 3 and 37 m/day (10 and 120 ft/day), respectively. Figures 9 through 12 show drawdown and analysis plots for test 1, and Figures 13 through 15 show the drawdown and analysis plots for test 2.

The best estimate of transmissivity for test interval 3 below the fine-grained unit is 120 m^2/day (1,290 ft^2/day), based on the drawdown data at the pumping well. Assuming the aquifer thickness ranges between 4.6 m (15 ft) (well screen length) and 36 m (110 ft) (the top of basalt), the hydraulic conductivity falls somewhere between 3.7 and 26 m/day (12 and 86 ft/day). The geometric mean is calculated at 9.8 m/day (32 ft/day). Figures 16 through 18 are analysis plots for test interval 3.

The typical response during the pumping tests can be seen in Figure 10 showing the pressure derivative plot. Early in the test (up to about 20 minutes) wellbore storage dominated the recovery data in the pumping well. The pressure derivative has a downward slope from this time to the end of the test, indicating decreasing drawdown because of a boundary (probably aquifer leakage). Radial flow conditions were never clearly established over the period of the recovery. During test 3, however, it appears that radial flow conditions may have been present for some or much of the drawdown data (see Figure 17) (demonstrated by the pressure derivative data showing an overall slope of about 0).

Based on the pressure derivative, a straight line was matched to the pumping well drawdown data for test 3 from about 40 to 200 minutes. The drawdown data do not appear to be affected by leakage (declining rate of drawdown; see Figure 17), which would give a calculated transmissivity that is somewhat higher than the true aquifer value.

The drawdown and recovery data for observation well 699-48-77D during test 1 displayed an irregular shape (see Figures 11 and 12). Even after correcting for barometric changes, the drawdown response for test 1 appears more irregular than before the correction. For this reason, the analysis results for the observation well are qualitative in nature. The estimate of vertical hydraulic conductivity and storativity were calculated from test 1 data. Drawdown and recovery data for tests 2 and 3 at observation well 699-48-77D were not considered valid because of the poor response, probably because of aquifer heterogeneity.

The two estimates of vertical anisotropy of 0.1 and 0.5 are nonunique and qualitative because of the heterogeneous nature of the aquifer (inferred from the geology and the irregular response observed at observation well 699-48-77D during tests 1 and 2, as just stated (see Figures 12 and 15). Far-field well 699-48-77A did not exhibit an observable response during any of the tests.

A storativity of 1.6×10^{-3} was estimated using the observation well recovery data from test 1. This value is most representative of the upper, less permeable section of the aquifer. However, the irregular data for this well as noted above, strongly qualify this estimation. For the development of type curves to account for wellbore storage, an aquifer storativity of 5×10^{-4} was assumed for test 2.

Note in Figure 11 for well 699-48-77D at about 280 and 400 minutes the sudden upward and then downward offset in the data, respectively. This change may be due to a transducer malfunction, but the true cause of this offset is unknown. The transducer did appear to operate properly during the recovery period (see Figure 12).

5.0 CONCEPTUAL MODEL

With the completion of two characterization boreholes, two downgradient groundwater monitoring wells, and aquifer testing on the deeper monitoring well, a conceptual model can be developed that integrates these data. The conceptual model is a local model that was developed using only local data from the SALDS. The extensive data collected from the 200 West Area provide a regional perspective on the local SALDS model, but because little data were collected north of the 200 West Area where the SALDS is located, better regional control is available only to the south of the SALDS. The absence of data to the north, east, and west of the SALDS imposes constraints on extending this local SALDS model much beyond the actual boundaries of the SALDS.

5.1 HYDRAULIC CONDUCTIVITY

Hydraulic conductivity maps of the 200 West Area show a complex pattern (Figure 30). Values range from 1.5 to 1,524 m/day (5 to 5,000 ft/day) for the upper part of Ringold unit E, which is the principal aquifer. Very little data on conductivities are available for lower parts of unit E and deeper parts of the aquifer. The cause of variation in hydraulic conductivity is not known but is probably a combination of several factors.

During the drilling of the boreholes at the SALDS, it was noticed that the upper part of the aquifer exhibited a zone of apparent cementation as reflected by the establishment of the water table at a higher level after the top of the unconfined aquifer was penetrated. This suggested that there is a finite zone at the top of the aquifer that partly confines the water table at this locality. This lower conductivity zone coincides with the area of lower hydraulic conductivity shown in Figure 30. It appears that the primary control on variation in hydraulic conductivity in Ringold gravels is cementation. However, this has never been unequivically demonstrated by the comparison of aquifer tests to intact core descriptions and analysis.

5.2 CEMENTATION

Variable cementation within Ringold gravels that comprise much of the unconfined aquifer is well established. Table 8 is a description of core from Ringold unit E in borehole DH-11 in the 200 West Area that clearly shows these gravels contain variable cementation. These zones of variable cementation are probably correlative with hydraulic conductivity variations within the aquifer. More cementation reduces hydraulic conductivity; less cementation increases hydraulic conductivity.

Extensive studies on the amount and location of cementation in the suprabasalt sediment package do not exist. However, the apparent correlation between cementation and hydraulic conductivity suggests that the pattern of cementation and related hydraulic conductivity is highly variable, both from lateral and vertical perspectives. This variability makes it difficult to predict the presence and extent of cementation and associated variations in hydraulic conductivity.

Figure 30. Map Showing the Hydraulic Conductivity of the 200 West Area.

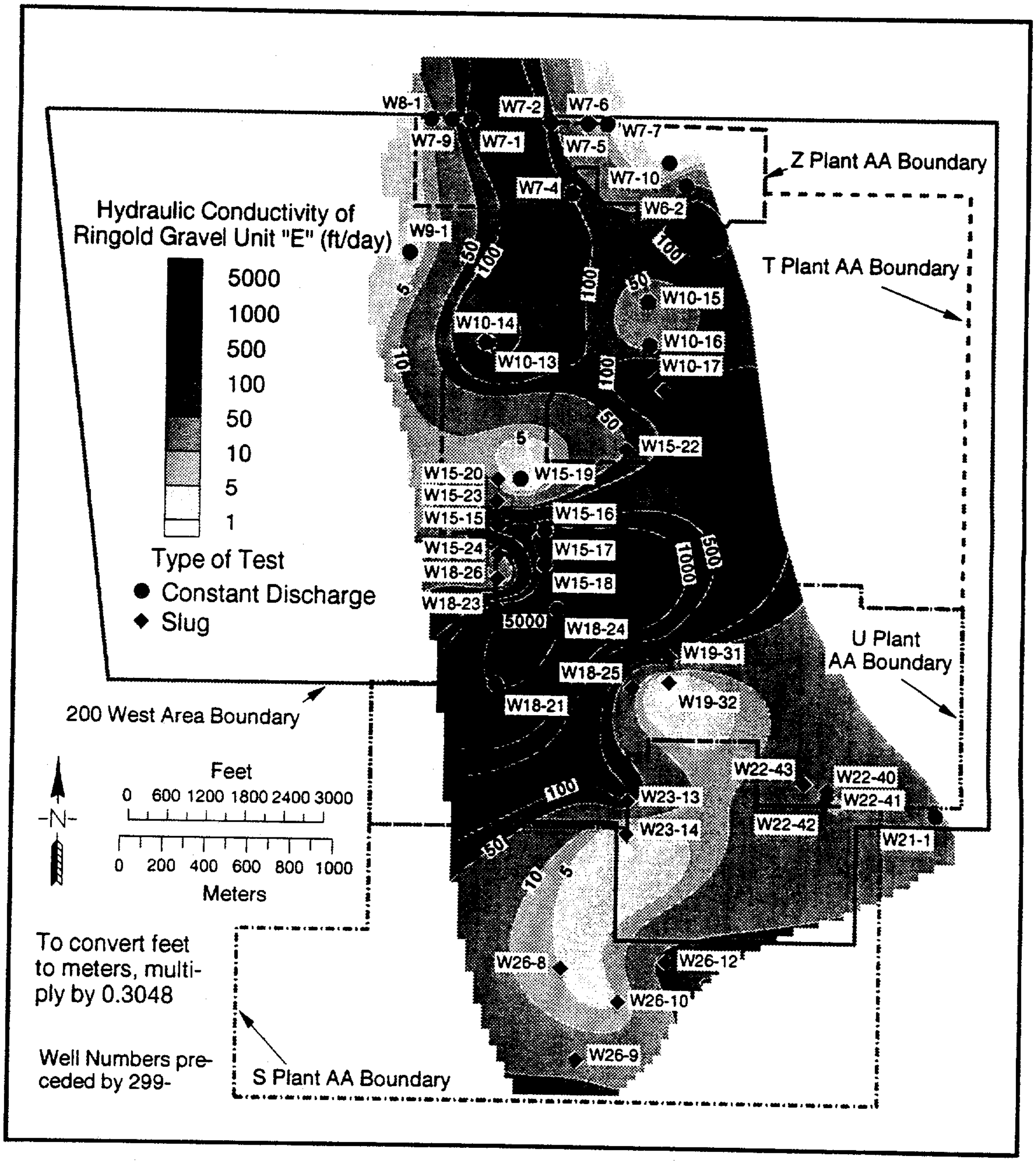


Table 8. Description of Cementation, Compaction, Matrix, and Color Changes Observed in Core from Basalt Waste Isolation Project Borehole DH-11 (W15-14). (4 sheets)

Interval (ft)	Induration and cementation	Description
Above 200	Consolidated; no cement.	Sand matrix color varies from yellow to gray and is mud poor; some black and brown oxidization staining on clasts.
203.5-233	Consolidated; no obvious cement.	Black to brown oxidation staining on clasts fairly common; matrix sand still mud poor and yellow to gray.
233-276	Consolidated, moderately friable (sand matrix easily rubbed of clasts); no cement.	Sands generally gray in color and mud poor, minor yellow and brown staining; little staining on clasts.
276-300	Consolidated with higher mud content although core not very cohesive; no cement.	Gray fine-grained sands containing higher mud content than above; little staining on clasts.
300-303	Consolidated; very minor cement.	Reddish to brown oxidation staining on clasts; none in matrix sands.
303-306	Less consolidated; no cement.	Reddish staining on clasts; none in matrix sands.
307-310	Consolidated; very minor cement.	Sands are not stained and are mud poor; clasts display little staining.
310-311	Poorly consolidated; no cement.	Minor yellowish staining on clasts and in sand matrix.
311-317	Consolidated; minor to moderate cementation in thin (<0.15-m [<0.5 ft]) bands and zones.	Gray sands locally stained to yellow-reddish color, staining is irregular to spotty; orange to yellow staining common on clasts; brown to black banding in both sands and on clasts present, banded zones are the most indurated.
317-322	Poorly consolidated; no cement.	Some brown and reddish staining present on clasts and in matrix sands as spots and bands, although general level of apparent oxidation higher than in overlying strata.

Table 8. Description of Cementation, Compaction, Matrix, and Color Changes Observed in Core from Basalt Waste Isolation Project Borehole DH-11 (W15-14). (4 sheets)

Interval (ft)	Induration and cementation	Description
322-325	Consolidated; slight to moderate cementation in thin (<0.15-m [<0.5 ft]) bands and zones.	Yellow-orange to dark brown staining and spots in matrix sand and on clasts.
325-345	Consolidated to poorly consolidated; slightly cemented to no cement. Both compaction and cementation generally decrease with depth.	Sand varies from gray to yellowish, except at base where begins to darken; minor staining on clasts, sand adhering to clasts easily rubbed off.
345-347	Poorly to moderately consolidated; slight to no cement.	Minor reddish-yellowish staining on clasts and in matrix. Minor calcium carbonate ($CaCO_3$) present.
347-353	Consolidated; cementation uncertain.	Dark brown to yellow oxidized stained sands adhering loosely to clasts; staining is spotty.
353-355	Well consolidated; minor to well cemented in <0.15-m- (<0.5-ft-) thick layers.	Cemented zones consist of dark brown to black stained sand and gravel, many of these zones contain $CaCO_3$ and are very hard.
355-356	Well consolidated; well cemented.	Minor yellow staining in sand matrix, low mud content, minor $CaCO_3$.
356-365	Consolidated; intermittent cement.	Variable brown-red staining in sand matrix and on clasts, where present is cemented.
365-366	Unconsolidated; no cement.	Minor staining.
366-370	Moderately consolidated; moderate cementation.	Sands are yellow-reddish to brown stained and adhere to clasts; minor $CaCO_3$, mud content increases near base.
370-378	Poor to moderate consolidation; minor to no cement.	Minor, spotty reddish-yellow staining on sands.
378-379	Well consolidated; cemented.	Dark brown to black banding in sand matrix and on clasts.

Table 8. Description of Cementation, Compaction, Matrix, and Color Changes Observed in Core from Basalt Waste Isolation Project Borehole DH-11 (W15-14). (4 sheets)

Interval (ft)	Induration and cementation	Description
379-384	Unconsolidated; no cement.	Little staining present.
384-388	Consolidated; no cement.	Increased mud content in matrix, mud decreases with depth; minor staining present.
388-390	Consolidated; intermittent cement.	Variable yellow-reddish staining, increases in cemented zones.
390-396.5	Moderately consolidated; minor to no cement.	Minor yellowish oxidation staining present in matrix and on clasts; sands generally gray in color.
396.5-404.5	Consolidated; no cement but several mud beds present.	Silty beds interbedded in sands dominate; minor yellowish staining present.
404.5-410	Consolidated; minor to no cement.	Minor yellowish-reddish staining in matrix and on clasts; minor muddy intervals also present.
410-412	Consolidated; no cement.	Minor oxidation; high mud content.
412-419	Consolidated; minor to no cement, at 126 m (413.5 ft) well cemented.	Variable spotty yellowish-reddish staining in matrix and on clasts; well-cemented zone darker brown colored.
419-421	Consolidated; variable cementation.	Variable staining, locally dark brown to black were cementation better developed.
421-434	Consolidated; no cement.	Minor yellowish to reddish staining in matrix and on clasts; mud content generally low, some dark brown to black staining present but no increase in corresponding cementation.
434-435	Well consolidated; well cemented.	Dark brown to black banding in cemented zone.
435-438.5	Poorly consolidated; no cement.	Minor yellowish to orange staining in matrix and on clasts.
438.5-439	Consolidated; cemented.	Minor staining, slight $CaCO_3$ development.

Table 8. Description of Cementation, Compaction, Matrix, and Color Changes Observed in Core from Basalt Waste Isolation Project Borehole DH-11 (W15-14). (4 sheets)

Interval (ft)	Induration and cementation	Description
439-440	Consolidated; no cement.	Minor staining and $CaCO_3$.
440-441	Consolidated; moderately cemented.	Intermittent reddish-yellow oxidation staining present in matrix and on clasts, minor $CaCO_3$.
441-453	Consolidated; minor intermittent cement.	Intermittent light staining with darker reddish-brown oxidation present occasionally, darker zone at 443 corresponds to cemented interval.
453-458	Consolidated; no cement.	Increased mud content.
458	Top of lower mud unit.	Stratified to massive muds.

5.2.1 Source of Cementation in Suprabasalt Sediments

Cementation in Ringold gravels is a reflection of the geologic history of the Hanford Site. Ringold gravels are part of a sediment package deposited by the ancestral Columbia River and Salmon River Systems between 10.5 and 5.0 Ma. Lindsey (1991) has shown that the Columbia River System, which laid down these sediments in the 200 Areas, was primarily a gravelly braidplain. This is a complex depositional system characterized by multiple shifting channels that existed in an arid to semiarid environment similar to the present one.

The process of cementation probably began soon after deposition. As the river shifted across the area, variable rainfall and river water levels resulted in a system that produced occasional flooding followed by declining water tables during the dryer seasons and years. The end result was evaporation of soil moisture during dryer seasons and cementation of the sediments as salts were precipitated. This process continued through the entire deposition of the Ringold Formation (nearly 5 million years) until the river system shifted eastward. The process of progressive cementation on an aggrading river system as it shifts its channel across the area produced a complex set of vertically and laterally variable cemented and uncemented zones.

During burial of sediments diagenetic cements also can form. These cements will fill pore space and result in decreased hydraulic conductivity. Because of few detailed studies of Ringold cements, it is not possible to differentiate between cements formed in this manner and those formed as described above.

5.2.2 Subsequent Processes

In addition to cementation, syn- and post-depositional processes must be considered to understand the variation that probably produced the present pattern of hydraulic conductivity. As the river system was meandering across the present 200 Areas, the Yakima Fold Belt was developing. The principal impact of folding was to uplift ridges and cause apparent subsidence in the Cold Creek syncline. Folding tilted the Ringold Formation, producing progressively southerly dips to both stratification and the existing zones of cementation. In addition to tilting, the process of folding also resulted in the development of joints and, less commonly, faults in the Cold Creek syncline.

The joints or fractures provide vertical pathways between zones of cementing. Folding probably made the already complex, laterally and vertically discontinuous cemented zones even more complex as they were tilted southward. Another potential source of vertical connectivity is clastic dikes, which have been observed in all suprabasalt units at the Hanford Site.

5.2.3 Model Summary

The conceptual hydrologic model is typified by a complex flow system controlled by laterally and vertically variable cemented and uncemented zones within the gravels of Ringold unit E. The pump test data indicate higher and lower hydraulic conductivity zones are present beneath the SALDS. These zones are stacked one atop the other. The apparent correlation between aquifer test data and limited borehole sediment samples at the SALDS suggests lower hydraulic conductivity zones correspond to zones with greater relative cementation. This relationship is supported by empirical data derived from cores and outcrops of Ringold data elsewhere in the region.

This model is limited however to a simple two-dimensional model of flow directly beneath the SALDS. Because of the absence of data to the north, west, and east of the site, it is impossible to accurately model aquifer conditions downgradient of the site. This is further complicated by data from Ringold gravel outcrops and cores indicate that the cementation zones which control hydraulic conductivity rarely persist for more than a few hundred meters. Consequently, preferred flow pathways in Ringold gravels may occupy different levels in the stratigraphic section at different locations.

Core observations such as those for DH-11 discussed above indicate numerous well cemented zones interstratified with uncemented intervals may lie one above the other at any one location. This suggests that the vertically variable flow system hinted at by the SALDS aquifer tests may be far more complex. Unfortunately, the failure to recover intact core in these gravels during drilling makes it impossible to reliably characterize the nature and distribution of these complex cemented zones and their potential influence on flow at the SALDS.

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APPENDIX A

CORE RECOVERY FROM BOREHOLES 699-48-77C AND 699-48-77D

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CORE RECOVERY FROM BOREHOLES 699-48-77C AND 699-48-77D

Table A-1. Core Recovery from Borehole 699-48-77D.

Split spoon	Depth of split spoon run	Interval thickness (ft)	Feet and % recovered	Comments
1	24.75-26.85	2.1	1.34/64	Plio-Pleistocene
2	40.0-44.0	4.0	3.0/75	Plio-Pleistocene
3	63.45-67.45	4.0	<0.2/<5	Plio-Pleistocene
4	67.5-71.7	4.2	<0.2/<5	Plio-Pleistocene
5	71.7-75.7	4.0	2.8/71	Plio-Pleistocene

Table A-2. Core Recovery from Borehole 699-48-77C.

	Depth of core run (ft)	Interval thickness (ft)	Feet recovered	Comments
2/2/94	18.1-21.1 21.1-23.0	3.0 1.9	0.3 0.5	--
2/3/94	25.9-27.3	1.4	0.0	--
	27.3-28.4	1.1	0.0	--
	28.4-29.9	1.5	0.0	--
	29.9-30.8	0.9	0.0	--
	30.8-33.4	2.6	2.3	<1.5 ft useful for analysis
	33.4-36.6	3.2	1.9	<1.0 ft useful for analysis
2/7/94	49.1-49.7	0.6	0.25	Caliche in shoe
	49.7-52.3	2.6	0.25	--
	52.3-54.0	1.7	0.25	--
	54.0-54.8	0.8	0.0	--
	54.8-59.1	4.3	0.25	--
2/26/94	220.3-221.1	0.8	0.0	--
	221.1-221.9	0.8	0.0	--
	221.9-223.4	1.5	0.7	All matrix lost, gravel clast-coated with cemented sand
2/26/94 (cont.)	223.4-224.8	1.4	0.0	--
	224.8-228.6	3.8	0.0	--
	228.6-229.5	0.9	0.0	--
Total ft	--	34.8	6.7	--
Percent recovery	--	--	19%	--
Core recovered useful for analysis	--	--	Approx. 3.5 ft	--
Corrected percent	--	--	10%	--