PNNL-14301

Pacific Northwest National Laboratory
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Monitoring Plan for RCRA Groundwater Assessment at The 216-U-12 Crib L

B. A. Williams
C. J. Chou

September 2003

Prepared for the U.S. Department of Energy
under Contract DE-AC06-76RL01830

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UNITED STATES DEPARTMENT OF ENERGY
under Contract DE-AC06-76RL01830

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Pacific Northwest National Laboratory
Richland, Washington 99352

Executive Summary

The 216-U-12 crib (U-12 crib), located in the 200 West Area of the Hanford Site, is regulated under the *Resource Conservation and Recovery Act* (RCRA). The facility, active until February 1988, received process effluent from U-Plant and 224 Building, which has impacted the unconfined aquifer. This document provides a revised and updated monitoring plan for RCRA groundwater assessment that consists of information on the monitoring well network design, monitoring constituents, sampling and analysis protocols and frequency, quality assurance, data management, site hydrogeology, a conceptual model of the RCRA facility, and an integrated *Comprehensive Environmental Response, Liability, and Compensation Act* (CERCLA)/RCRA final-status post closure monitoring plan. Discussions on non-dangerous waste constituents not regulated under RCRA (i.e., radionuclides) and nitrate, a non-dangerous waste constituent, are provided because the information (1) may provide further insight regarding the source, interpretation of groundwater flow, and migration of dangerous waste constituents in groundwater and (2) may serve as a transition to a larger area operable unit monitoring approach that embraces both RCRA sites and CERCLA groundwater operable units.

The U-12 crib has been monitored under a RCRA interim status groundwater assessment monitoring program since the first quarter of 1993 (Williams and Chou 1993). Specific conductance in downgradient wells exceeded the critical mean value and triggered the assessment. The high specific conductance is attributed to elevated nitrate, which exceeds the drinking water standard in groundwater. Results of a Phase I and Phase II RCRA assessment indicated that the facility was the source of the elevated nitrate and the non-RCRA constituent technetium-99 (Williams and Chou 1997) and interim status assessment monitoring must continue because, under existing conditions, downward migration and lateral spreading of these waste components from the vadose zone (and continued elevated specific conductance in downgradient wells) is still occurring.

The objective of the ongoing RCRA assessment focuses on (1) continued groundwater monitoring to determine whether the flux of dangerous waste constituents (e.g., chromium) out of the vadose zone into the groundwater is increasing, staying the same, or decreasing, and (2) monitoring the known contaminants until a near-term interim corrective action is defined. Monitoring under interim status assessment is expected to continue until closure of the U-12 crib has been certified under the RCRA Part-B Permit modification; a final-status post-closure monitoring plan will be implemented following closure certification.

The groundwater beneath the U-12 crib is located within the CERCLA 200-UP-1 Operable Unit and the crib is included as part of the 200 PW-2 Uranium-Rich Process Waste Group Operable Unit (200-PW-2 Operable Unit). A portion of the 200-PW-2 Operable Unit (the U-Plant Area waste sites) is being closed under an accelerated schedule in accordance with a planned focused feasibility study (FFS) (DOE 2003a) and proposed plan (PP) (DOE 2003b). This process will integrate closure and post-closure requirements for the U-12 crib as part of the FFS and PP, which is consistent with the *200 Areas Remedial Investigation/Feasibility Study Implementation Plan-Environmental Restoration Program* (DOE 1998). As part of this integration with CERCLA, the site-specific waste constituent nitrate, which is not a RCRA dangerous waste constituent, will be monitored to evaluate the contribution of nitrate from the U-12 crib into the regional nitrate plume. Post-closure RCRA groundwater monitoring will be conducted in accordance with an integrated final status post-closure groundwater monitoring plan that is outlined in this revised RCRA groundwater assessment monitoring plan. In accordance with the proposed plan for the U Plant closure area waste sites (DOE 2003b), contaminated groundwater beneath these U Plant waste sites will continue to be addressed under the 200-UP-1 Groundwater Operable Unit.

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1.0 Introduction

This plan provides a revised and updated *Resource Conservation and Recovery Act* (RCRA) groundwater assessment monitoring program for the 216-U-12 crib (U-12 crib) and supports the U Plant geographic closure concept as described in the *Focused Feasibility Study for the U Plant Closure Area Waste Site* (DOE 2003a) *and Proposed Plan for the U Plant closure Area Waste Sites* (DOE 2003b). DOE is proposing to implement an integrated RCRA/*Comprehensive Environmental Response, Liability, and Compensation Act* (CERCLA) cleanup in which the U-12 crib ultimately would be included in the *Hanford Facility RCRA Permit* through a formal permit modification. This proposal is consistent with the 200 Areas implementation plan (DOE 1998) and the approved Tri-Party Agreement (Ecology et al. 1998) change requests associated with the Central Plateau Project, which allow DOE to submit and coordinate closure of treatment, storage, and disposal units with operable unit remediation documentation. In summary, the CERCLA documents (e.g., DOE 2003a, 2003b) will be used to evaluate and select appropriate cleanup alternatives for the U-12 crib. These documents incorporate the elements typically found in a closure plan, as described in the 200 Areas implementation plan (DOE 1998). The RCRA and state dangerous waste closure elements are identified in the CERCLA documents, thus integrating the technical closure requirement of the closure regulations. Therefore, this plan updates the ongoing RCRA interim status groundwater assessment monitoring program and provides a proposed RCRA final status post-closure groundwater monitoring program.

Discussions on non-dangerous waste constituents not regulated under RCRA (i.e., radionuclides) and nitrate, a non-dangerous waste constituent, are provided because the information (1) may provide further insight regarding the source, interpretation of groundwater flow, and migration of dangerous waste constituents in groundwater and (2) may serve as a transition to a larger area operable unit monitoring approach that embraces both RCRA sites and CERCLA groundwater operable units.

1.1 Description of 216-U-12 Crib

The U-12 crib was built in 1960 to replace the 216-U-8 crib when it showed signs of potential cave-in. The U-12 crib was operational until 1988, when the pipeline was cut and capped. The retired U-12 crib was replaced by the 216-U-17 crib, which operated from 1988 to 1994. Information about the U-12 crib and its underlying geology and hydrogeology has been provided in the original groundwater monitoring plan by Jensen et al. (1990) and is revised and updated in this plan.

The crib is located downgradient of several other liquid waste disposal cribs in the 200 West Area of the Hanford Site. These cribs received large volumes of liquid effluent containing radioactive and hazardous waste at various times during the operational history of the U and S Plants (Figure 1.1). Details of all the facilities are provided in the Waste Information Data System (WIDS) database, managed by Bechtel Hanford, Inc.

The U-12 crib was a liquid water-disposal facility composed of an unlined, gravel bottomed, percolation crib, 3 x 30 m (10 x 100 ft), 4.6 m (15 ft) deep. The gravel bottom crib has a plastic barrier

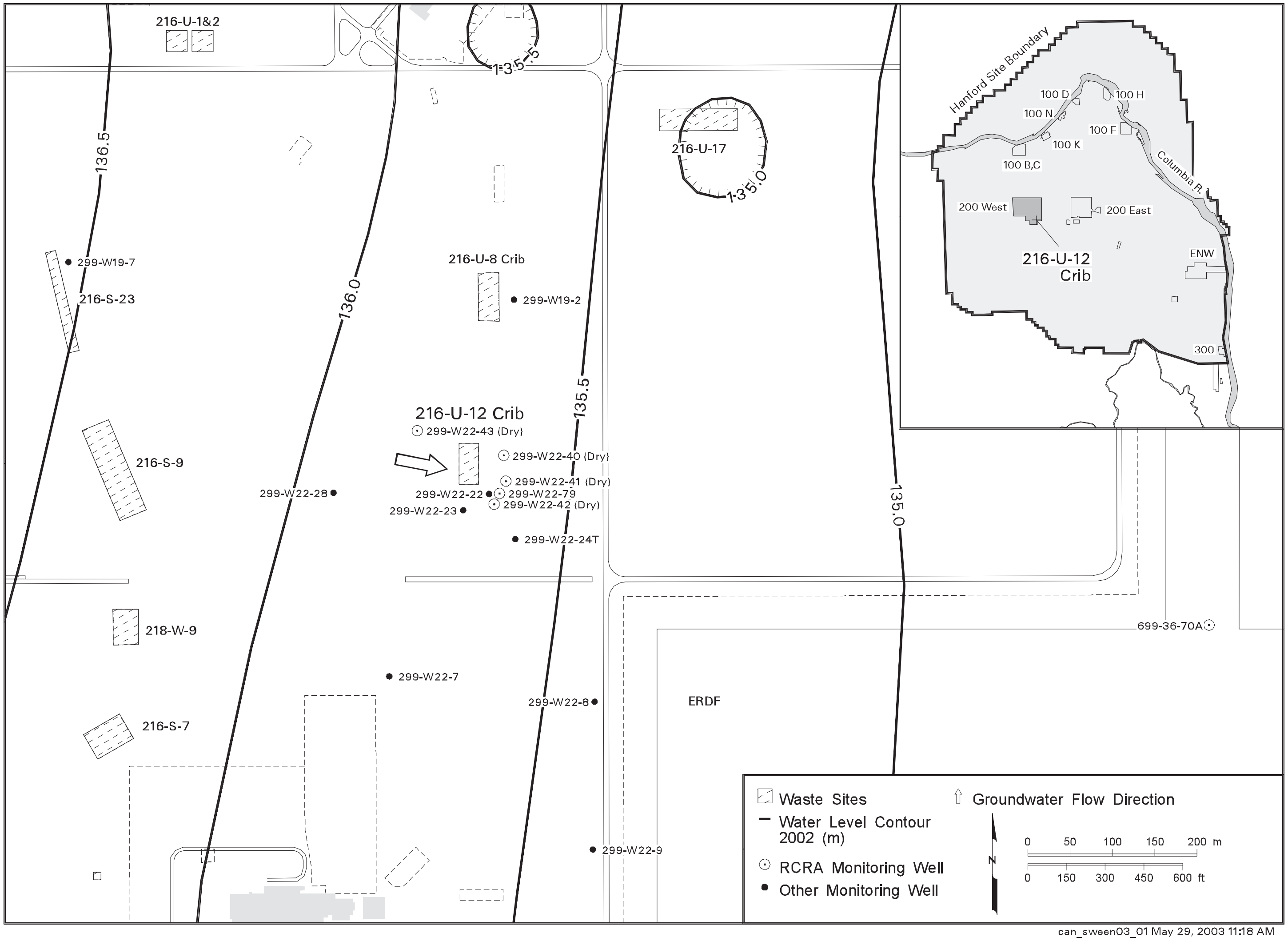

Figure 1.1. Location of 216-U-12 Crib on the Hanford Site, Washington

cover and is backfilled with the original excavated sediment. Effluent was transferred to the crib via a vitrified clay pipe, and spread along a vitreous distributor pipe which is buried in the gravel. The crib was used to dispose (neutralize) dangerous and corrosive waste composed of effluent and process condensate from the 224-U Building (UO_3 Plant) and included 291-U-1 stack drainage.

The crib received this liquid waste from 1960 through 1972 when the crib was deactivated. The crib was reactivated in November 1981 and received waste until it was permanently retired in February 1988. A yearly average of over 1.33×10^8 L/yr (3.5×10^7 gal/yr) of effluent was disposed to the crib from 1960 through 1972 (Maxfield 1979). Effluent discharged to the U-12 crib during its operational life is shown in Figure 1.2. The effluent received was nitric acid waste and low-level radioactive waste known to have included plutonium, ruthenium, cesium, strontium, and uranium. More detailed information about the waste characteristics is available in the assessment results report by Williams and Chou (1993).

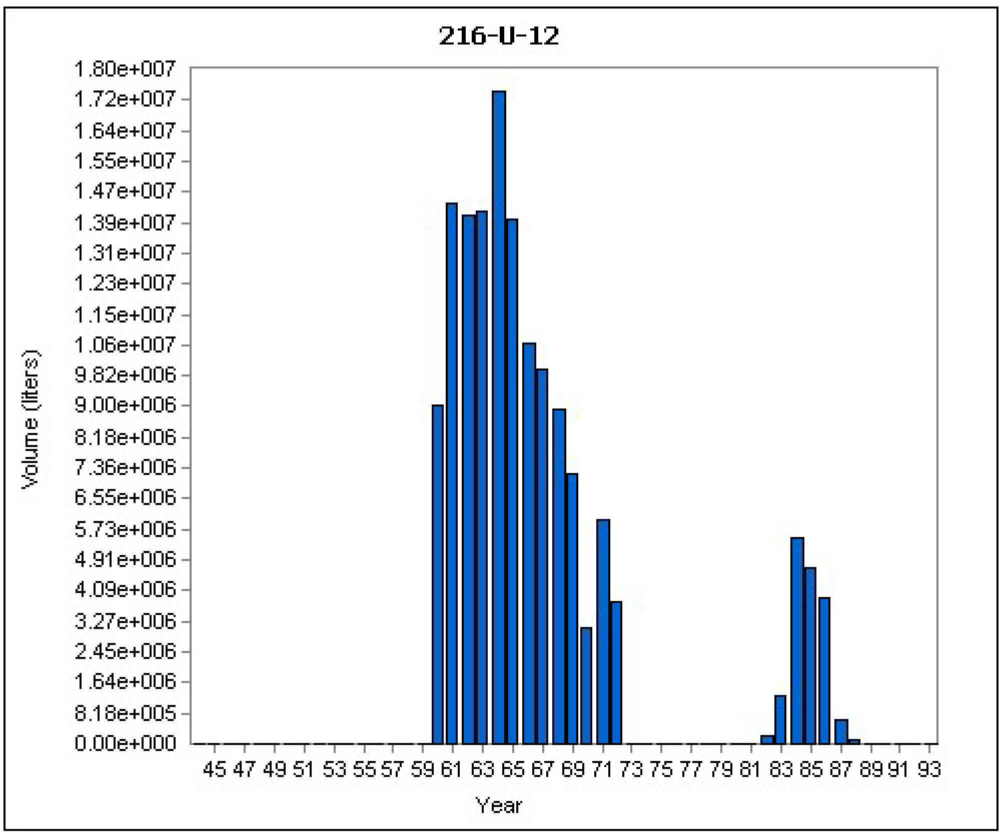

Figure 1.2. Effluent Volume Discharged to the 216-U-12 Crib

1.2 Objectives of RCRA Monitoring

Results of the groundwater quality assessment monitoring activities conducted for the U-12 crib (Williams and Chou 1997) indicate that the U-12 crib is the source of the elevated nitrate and technetium-99 contamination observed in groundwater downgradient of the crib; the site must remain in interim-status groundwater assessment monitoring. However, in the interim remedial measures for the

200-UP-1 Operable Unit, the Washington State Department of Ecology (Ecology) and the U.S. Environmental Protection Agency (EPA) determined that nitrate (and tritium) in groundwater will not be remediated until practical treatment options are available that will allow cost-effective removal (Swanson 1996). Furthermore, the Tri-Party Agreement (Ecology et al. 1998) has assigned CERCLA as the program that will address the corrective action provisions of RCRA. Therefore, any future cleanup of contaminants in groundwater at the crib will be part of the CERCLA 200-UP-1 Groundwater Operable Unit investigation and subsequent remedial or corrective action decisions. Any soil remediation required at the U-12 crib will be performed under the CERCLA U Plant focused feasibility study (FFS)/proposed plan (PP) waste site remediation documentation, which for the U-12 crib will ultimately require a permit modification.

Based on the information presented in the paragraph above, the current objectives of interim status assessment monitoring for the U-12 crib, rather than delineating the existing known plumes, include the following:

1. Continue groundwater monitoring to assess the migration of potential dangerous waste constituents out of the vadose zone into the groundwater.

2. Monitor the known contaminants until a near-term interim corrective action is defined.

3. Monitor under interim-status assessment until a final-status monitoring plan is implemented following closure of the facility.

Closure of the U-12 crib will be coordinated with and conducted under CERCLA per the U-Plant waste sites FFS (DOE 2003a) and proposed plan (DOE 2003b). RCRA groundwater monitoring objectives will remain the same from now until closure of the U-12 crib and then shift to a final-status post-closure plan that is outlined in Section 7.0.

1.3 History of RCRA Monitoring at 216-U-12 Crib

The RCRA groundwater monitoring plan (Jensen et al. 1990) presented the initial groundwater monitoring program to determine the crib's impact on the quality of groundwater in the uppermost aquifer beneath the site. A groundwater monitoring well network was established in 1990 and monitoring began in 1991. This initial network consisted of one upgradient and three downgradient point-of-compliance wells located at the waste site boundary (Figure 1.3). The wells were screened in the upper 6 m (20 ft) of the uppermost aquifer.

In accordance with RCRA regulations 40 CFR 265.92, initial background levels for the contaminant indicator parameters (i.e., pH, specific conductance, total organic carbon, and total organic halogens) were established using groundwater samples collected between September 1991 and June 1992. The background (upgradient) well was 299-W22-43. Specific conductance data collected during September 1992 from downgradient wells 299-W22-41 and 299-W22-42 showed a statistically significant increase over background values [40 CFR 265.93 (c) (2)]. Data obtained in subsequent quarters corroborated these findings.

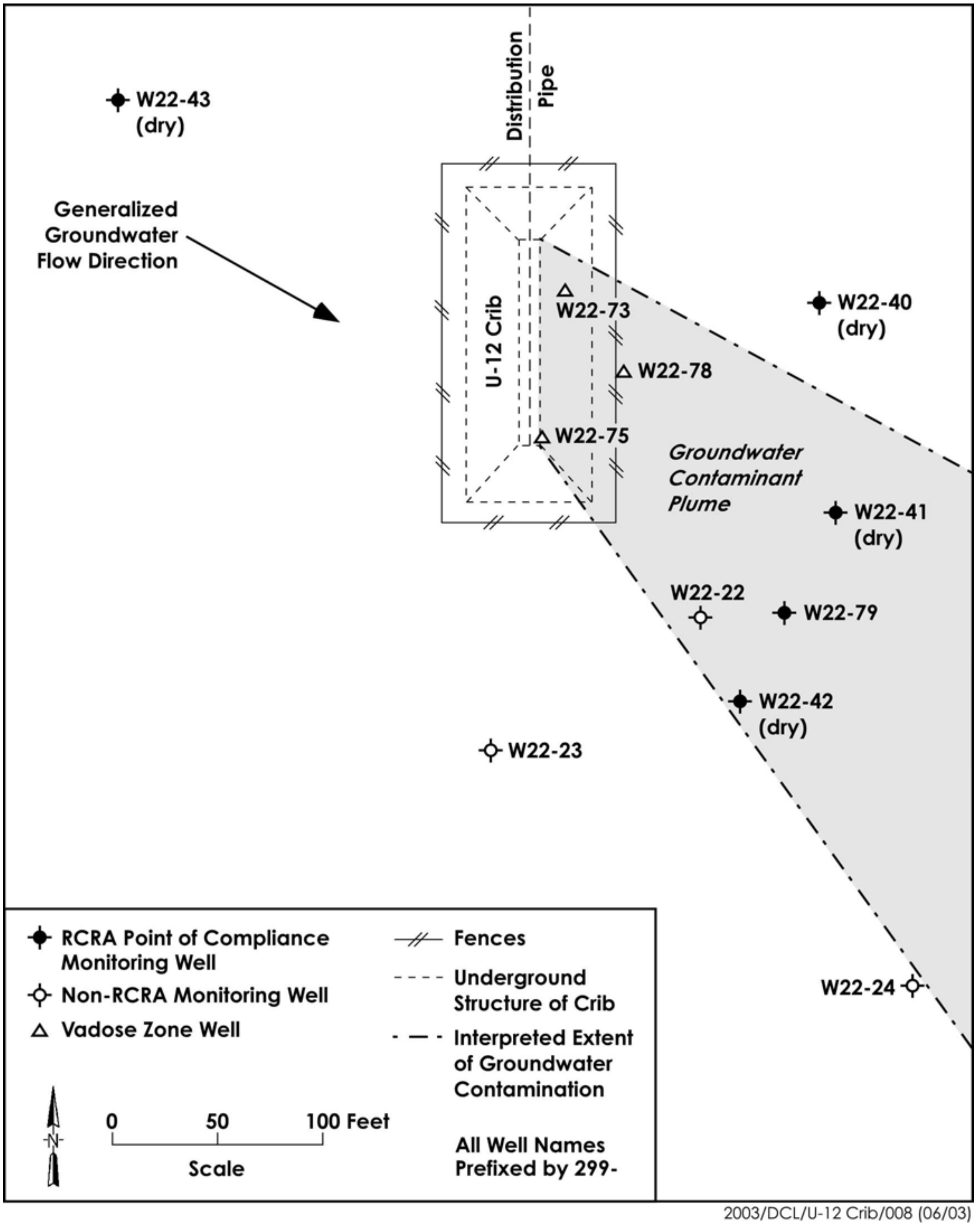

Figure 1.3. Initial RCRA Groundwater Monitoring Network for the 216-U-12 Crib

Based on these results, a RCRA interim-status groundwater quality assessment monitoring program was implemented for the crib in January 1993. Since then, the groundwater monitoring well network at the crib has been sampled quarterly in accordance with the groundwater quality assessment plan (Williams and Chou 1993) [40 CFR 265.94(d)(4)]. The assessment plan was developed to determine whether the crib is the source of the observed contamination (i.e., Phase I) and if so, to determine the concentration, rate, and extent of migration of the contaminant plumes (Phase II).

The groundwater monitoring network was expanded in 1993 by adding two existing older wells (non-RCRA-compliant) to the network. Two wells were added to the network: upgradient well 299-W22-23 for source identification purposes and downgradient well 299-W22-22 for source delineation. This expansion was necessary to assist in determining whether the crib was the source or if one of several upgradient disposal facilities could be the source of the detected contaminants.

In 1995, well 699-36-70A was added downgradient near the Environmental Remediation Disposal Facility (ERDF) to support the Phase II assessment to determine the rate and extent of the contamination (Figure 1.1). Data from the borehole also provided depth specific groundwater chemistry data, which has been used to delineate the vertical distribution of certain contaminants in the thick uppermost aquifer. In 1995, wells 299-W22-22 and 299-W22-23 were dropped from the network because of excessive turbidity problems and declining water levels in the wells.

In 1997, results of RCRA Groundwater Quality Assessment Program at the U-12 crib (Williams and Chou 1997) indicated that the U-12 crib is the source of elevated specific conductance, including elevated calcium, nitrate, and technetium-99. Elevated levels of iodine-129 and tritium are from upgradient sources caused by past disposal of process condensate waste from the nuclear fuel dissolution and extraction activities at the REDOX Plant located near the south end of the 200 West Area. In addition, elevated levels of carbon tetrachloride are most likely from various Plutonium Finishing Plant waste disposal sites located northwest of the U-12 crib.

Even though the U-12 crib has been closed since 1988, elevated nitrate and technetium-99 are still present in the groundwater, but concentrations are declining over time (Figures 1.4 and 1.5), indicating there is still vadose drainage that is contaminating the aquifer.

In 1998, well 299-W22-79 was installed as a replacement well between downgradient wells 299-W22-41 and 299-W22-42 because they were going dry (Figure 1.5). By 2002, all four of the original detection monitoring wells (299-W22-40, -41, -42, and -43) had gone dry due to declining water levels across the 200 West Area. The current well network for RCRA groundwater assessment monitoring consists of just two wells, 299-W22-79 and 699-36-70A, both downgradient of the U-12 crib. Ecology and the U.S. Department of Energy (DOE) annually negotiate and prioritize installation of new monitoring wells. These agreements are documented in the annual TPA Milestone M-24-00 interim change forms.[1]

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[1] Letter 02-RCA-0556 from U.S. Department of Energy, Richland Operations Office, Richland, Washington, to Michael Wilson, Washington State Department of Ecology, dated September 20, 2002: *Hanford Federal Facility Agreement and Consent Order (Tri-Party Agreement) Change Request M-24-02-01, Establish Calendar Year 2002 Resource Conservation and recovery Act (RCRA) Monitoring Well Installation Interim Milestones*.

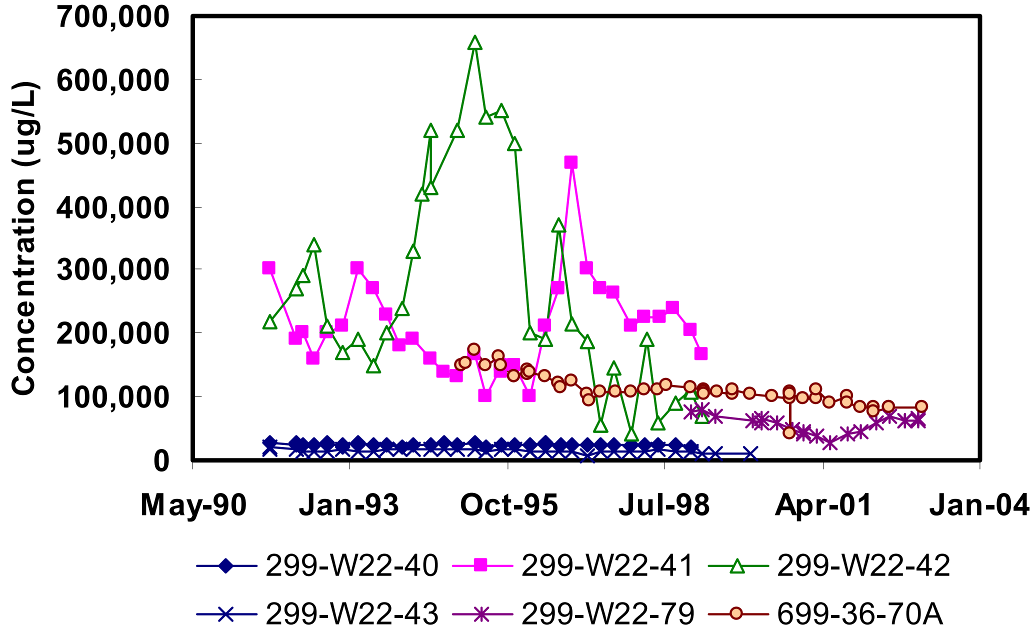

Figure 1.4. Nitrate Concentrations versus Time Plot for the 216-U-12 Crib

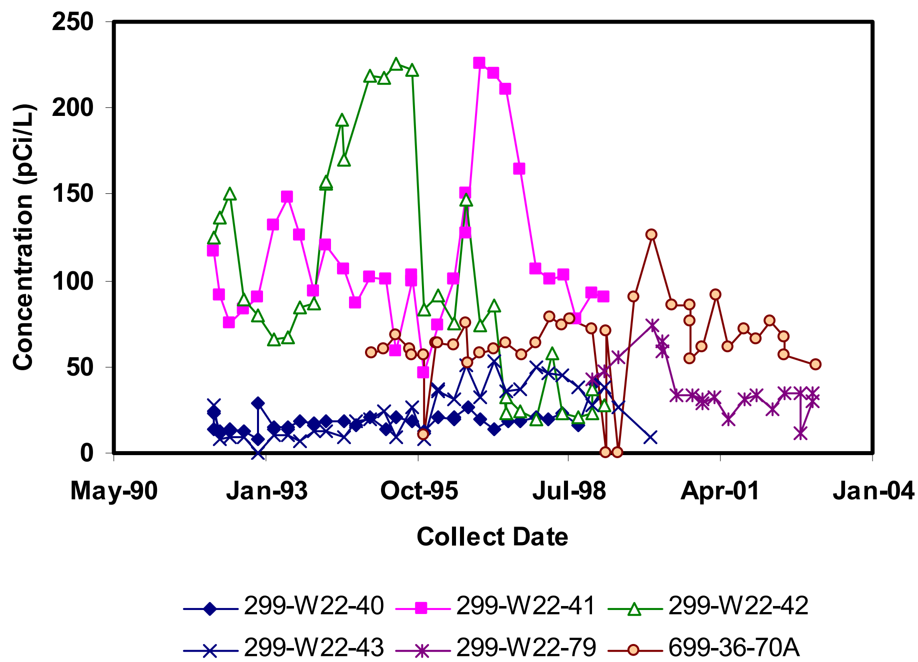

Figure 1.5. Technetium-99 Concentrations versus Time Plot for the 216-U-12 Crib

Table 1.1 summarizes groundwater monitoring results for the U-12 crib from 1992 until present based on selected constituents of interest identified in Reidel et al. (1993) and in Williams and Chou (1997) except for acetone and mercury. Mercury was not analyzed in samples from the four original network wells (299-W22-40, -41, -42, and -43) after September 1993 and was not analyzed in samples from well 699-36-70A after March 1996. Mercury was essentially not detected in all wells. Acetone, a common lab contaminant, was not detected except for occasionally hits in well 699-36-70A (5 detects out of a total 16 analyses). Currently, nitrate concentrations in the two remaining network (downgradient) wells 299-W22-79 (61,100 μg/L, December 2002) and 699-36-70A (83,700 μg/L, January 2003) exceed the maximum contaminant level of 45,000 μg/L.

In 2002, the DOE initiated the Cleanup, Challenges, and Constraints Team (C3T) team to develop, streamline, and integrate the groundwater programs managed under three separate regulatory acts (CERCLA, RCRA, and the Atomic Energy Act of 1954) into one. This has been accomplished through the data quality objective (DQO) process (Byrnes and Williams 2003). This process has been used to identify and integrate wells needed across the 200 Area Plateau. In accordance with this DQO, additional wells are justified at the U-12 crib if well deepening technology cannot be used to deepen and reactivate key monitoring wells, i.e., at least two downgradient wells. Up to two new wells could be required if well deepening is not practicable. Once the wells identified in the DQO document have been deepened and/or installed, the upgraded U-12 crib network will be integrated into the 200-UP-1 Operable Unit groundwater monitoring network to regionally monitor groundwater conditions at the operable unit.

1.4 Integration of RCRA and CERCLA Closure Activities

The U-12 crib is scheduled to be closed under RCRA final status (Part-B Permit modification) requirements. The proposed RCRA Permit Modification for the U-12 crib is due in December 31, 2005. All RCRA Part-B closure requirements for the U-12 crib will be fulfilled by the CERCLA/RCRA integration process for the U Area waste sites. Any groundwater cleanup or corrective action that may be required for the 200-UP-1 Groundwater Operable Unit, which includes contaminants sourced from the U-12 crib, will be conducted under CERCLA (Byrnes and Robinson 2003). The groundwater monitoring network for the 200-UP-1 operable unit includes select wells from the U-12 crib RCRA network as defined in this plan and in Byrnes and Williams (2003).

Because the U-12 crib is within the CERCLA 200-UP-2 Operable Unit, remediation and closure of the U-12 crib will be integrated with closure of the U-Plant Area waste sites. The CERCLA 200-UP-1 Operable Unit is responsible for addressing contaminants within the groundwater beneath the 200-UP-2 Operable Unit. One outcome of the C3T process was that an integrated CERCLA/RCRA groundwater monitoring plan for the 200 Area waste sites is needed. This plan is intended to serve as a transition to a larger area operable monitoring approach that embraces both the RCRA site (i.e., U-12 crib) and the CERCLA 200-UP-1 Operable Unit.

Table 1.1. Summary of Groundwater Monitoring Results at the 216-U-12 Crib

Well[(a)]	Time Period	Number of Samples				Detected Analyses		
		n	GT	LT	Excl.	Max.	Min.	Ave.
Nitrate (μg/L)								
299-W22-43 (dry)	2/92 – 9/93	33	33	0	0	18,000	8,190	14,600
299-W22-40 (dry)	2/92 – 1/99	32	32	0	0	28,300	19,700	24,600
299-W22-41 (dry)	2/92 – 3/99	32	32	0	0	469,000	99,000	209,000
299-W22-42 (dry)	2/92 – 3/99	34	33	0	1	660,000	41,400	258,400
299-W22-79	12/98 – 12/02	20	20	0	0	79,700	27,900	57,000
699-36-70A	9/94 – 1/03	53	47	0	6	172,000	76,700	113,100
Fluoride (μg/L)								
299-W22-43 (dry)	2/92 – 1/00	33	33	0	0	1,000	393	620
299-W22-40 (dry)	2/92 – 1/99	32	32	0	0	900	460	614
299-W22-41 (dry)	2/92 – 3/99	32	32	0	0	1,100	460	686
299-W22-42 (dry)	2/92 – 3/99	34	32	0	2	1,200	414	686
299-W22-79	12/98 – 12/02	20	20	0	0	650	530	584
699-36-70A	9/94 – 1/03	42	35	6	1	1,000	280	525
Sulfate (μg/L)								
299-W22-43 (dry)	2/92 – 1/00	33	33	0	0	31,000	18,400	25,300
299-W22-40 (dry)	2/92 – 1/99	32	31	0	1	33,000	27,600	30,750
299-W22-41 (dry)	2/92 – 3/99	32	32	0	0	37,000	22,800	30,000
299-W22-42 (dry)	2/92 – 3/99	34	33	0	1	48,500	25,300	30,900
299-W22-79	12/98 – 12/02	20	20	0	0	28,800	16,400	20,000
699-36-70A	9/94 – 1/03	42	41	1	0	37,600	23,000	33,500
Uranium (μg/L)								
299-W22-43 (dry)	2/92 – 9/93	8	8	0	0	4.1	2.4	3.1
299-W22-40 (dry)	2/92 – 3/94	11	11	0	0	4.1	1.3	3.3
299-W22-41 (dry)	2/92 – 9/93	8	8	0	0	2.5	1.8	2.1
299-W22-42 (dry)	2/92 – 6/98	15	15	0	0	4.1	2.4	3.2
299-W22-79		---	---	---	---	---	---	---
699-36-70A	9/94 – 1/03	21	19	1	1	3.9	0.6	2.9
Filtered Chromium (μg/L)								
299-W22-43 (dry)	2/92 – 1/00	28	11	16	1	25	3.4	7.5
299-W22-40 (dry)	2/92 – 3/98	28	16	11	1	24	2.8	10.0
299-W22-41 (dry)	2/92 – 3/99	28	13	15	1	18	2.7	7.1
299-W22-42 (dry)	2/92 – 3/99	28	14	13	2	31	4.2	10.9
299-W22-79	12/98 – 12/02	7	6	1	0	10.6	1.7	4.8
699-36-70A	9/94 – 1/03	39	23	16	0	10	1.5	5.4
Filtered Arsenic (μg/L)								
299-W22-43 (dry)	2/92 – 9/93	8	3	5	0	5.5	3.6	4.4
299-W22-40 (dry)	2/92 – 3/95	11	6	5	0	5.8	4.3	5.2
299-W22-41 (dry)	2/92 – 3/95	9	3	6	0	5.1	2.9	3.9
299-W22-42 (dry)	2/92 – 9/93	8	2	6	0	3.2	2.3	2.8
299-W22-79		---	---	---	---	---	---	---
699-36-70A	1/95 – 3/02	17	14	3	0	5.2	1.2	3.1

Table 1.1. (contd)

Well[a]	Time Period	Number of Samples				Detected Analyses		
		n	GT	LT	Excl.	Max.	Min.	Ave.
Potassium (μg/L)								
299-W22-43 (dry)	2/92 – 1/00	28	26	1	1	10,000	2,200	4,070
299-W22-40 (dry)	2/92 – 3/98	28	27	0	1	5,520	2,800	4,250
299-W22-41 (dry)	2/92 – 3/99	28	27	0	1	5,000	2,330	4,130
299-W22-42 (dry)	2/92 – 3/99	28	27	0	1	8.620	3,730	5,720
299-W22-79	12/98 – 12/02	7	7	0	0	4,800	2,690	3,670
699-36-70A	9/94 – 1/03	29	29	0	6	10,000	4,800	6,030
Technetium-99 (pCi/L)								
299-W22-43 (dry)	2/92 – 1/00	33	31	2	0	53.2	6.67	26.06
299-W22-40 (dry)	2/92 – 1/99	32	31	0	1	40.7	8.21	18.41
299-W22-41 (dry)	2/92 – 3/99	32	32	0	0	226	45.78	113.39
299-W22-42 (dry)	2/92 – 3/99	33	33	0	0	226	19.4	99.81
299-W22-79	12/98 – 12/02	20	20	0	0	73.9	12.1	37.87
699-36-70A	9/94 – 1/03	44	36	0	8	126	10.92	67.06
Strontium-90 (pCi/L)								
299-W22-43 (dry)	12/93 – 12/94	5	0	5	0	ND	ND	ND
299-W22-40 (dry)	12/93 – 12/94	5	0	5	0	ND	ND	ND
299-W22-41 (dry)	12/93 – 12/94	5	0	5	0	ND	ND	ND
299-W22-42 (dry)	12/93 – 12/94	6	0	6	0	ND	ND	ND
299-W22-79		---	---	---	---	---	---	---
699-36-70A	9/94 – 3/96	8	0	8	0	ND	ND	ND
Tritium (pCi/L)[b]								
299-W22-43 (dry)	2/92 – 1/00	33	26	7	0	2,690	296	1,500
299-W22-40 (dry)	2/92 – 1/99	32	32	0	0	4,370	1,030	2,130
299-W22-41 (dry)	2/92 – 3/99	32	32	0	0	15,400	463	3,040
299-W22-42 (dry)	2/92 – 3/99	33	32	0	1	54,500	9,120	23,940
299-W22-79	12/98 – 12/02	14	14	0	0	22,300	5,200	14,430
699-36-70A	9/94 – 1/03	37	32	0	5	388,000	53,700	150,800
Iodine-129 (pCi/L)[b]								
299-W22-43 (dry)	3/93 – 1/00	21	4	17	0	6.6	0	1.65
299-W22-40 (dry)	3/93 – 3/98	19	4	15	0	1.94	0.22	0.89
299-W22-41 (dry)	3/93 – 3/99	21	6	15	0	0.66	0	0.29
299-W22-42 (dry)	3/93 – 3/99	21	20	1	0	12.3	2.0	7.09
299-W22-79	12/98 – 12/02	9	0	9	0	ND	ND	ND
699-36-70A	1/95 – 1/03	35	32	2	1	38.8	6.38	15.24
Carbon tetrachloride (μg/L)[b]								
299-W22-43 (dry)	12/92 – 9/94	12	11	1	0	10	3.7	6.9
299-W22-40 (dry)	2/92 – 8/96	16	16	0	0	10	6.7	8.1
299-W22-41 (dry)	2/92 – 9/94	12	12	0	0	8.1	4.7	6.6
299-W22-42 (dry)	2/92 – 12/94	14	14	0	0	6.8	3.1	5.3
299-W22-79	1/95 – 3/96	2	2	0	0	4	3	3.5
699-36-70A	1/95 – 1/03	17	16	1	0	11	3	7.3

(a) Bold and italic denotes upgradient well.
(b) Sources are from upgradient past disposal sites.
n = Number of samples; Excl. = excluded; GT = greater than; LT = less than; Max = maximum; Min = minimum; Ave = average; ND = not detected; --- = no data.

The schedule and plan for waste site closure, closure option/strategy for the U-12 crib, and post-closure groundwater monitoring will be integrated with the U-Plant Area waste sites FFS (DOE 2003a) and PP (DOE 2003b). This FFS/PP is designed to conduct remedial actions for source control at primarily high-risk waste sites in the U Area that is to include an engineering evaluation of an engineered surface barrier for the U-12 crib. TPA Milestone M-015-47 requires the FFS/PP to be submitted to the regulators by June 30, 2003. As defined in the record of decision (ROD 1997), the U Area Waste sites, which include the U-12 crib, are to be remediated by September 30, 2006.

The groundwater monitoring requirements of this plan will provide the documentation for RCRA assessment groundwater monitoring and satisfy those RCRA requirements. This plan also includes a final-status monitoring plan that is intended to fulfill RCRA final status post-closure monitoring requirements (Section 7). The RCRA closure plan requirements for the U-12 crib will be integrated into the U-Plant Area waste sites FFS (DOE 2003a) and PP (DOE 2003b) in lieu of a separate closure plan. After closure plan documentation requirements are met, a proposed permit modification, supported by the CERCLA documentation, will incorporate the remedial decision into the *Hanford Facility RCRA Permit*. All permit requirements for the U-12 crib consistent with the CERCLA record of decision would be identified in Part V of the *Hanford Facility RCRA Permit.* The text in CERCLA or other supporting documents that corresponds to specific RCRA treatment, storage, and disposal closure plan requirements would be included as an attachment to the permit. The permit conditions in the Part V chapter and the attachment would become an enforceable part of the permit. Changes to the chapter and the attachment would be subject to the permit modification process. This groundwater monitoring plan and its subsequent updates could be referenced in the forthcoming CERCLA documents, an integrated area groundwater monitoring plan (e.g., operation and maintenance plan), and/or RCRA Part-B Permit Modification.

The U-12 crib also is part of the 200-PW-2 Source Operable Unit. TPA Milestone M15-43B requires submittal of the 200-PW-2 Operable Unit remedial investigation report by June 30, 2004. TPA Milestone M-15-43C requires submittal of the 200-PW-2 Operable Unit FFS/PP by December 31, 2005. However, rather than closing the U-12 crib under the 200-PW-2 Operable Unit FFS/PP, it will be closed in accordance with the accelerated U Area waste sites proposed plan (DOE 2003b).

2.0 Hydrogeology

This section summarizes available and new interpretations of the hydrogeology of the U-12 crib. Data on physical characteristics of the U-12 crib and the surrounding area (e.g., boreholes) are used to refine understanding of the local hydrogeology beneath the site and the potential contaminant transport pathways from the subsurface, toward groundwater, and toward potential receptors. These data are used to develop the conceptual model beneath the site (Section 3.0). In addition, these data also are needed to provide engineering information to develop and screen remedial action alternatives. Early studies relied on limited borehole and well data to describe the stratigraphy and hydrogeology of the area. In recent years, more wells have been drilled in the surrounding area specifically targeted to collect more characterization data. As a result, the quantity and quality of the geologic data have been enhanced, which improves the hydrogeologic model development and its interpretation.

The U-12 crib is located in the southeast 200 West Area on the Central Plateau, a broad, flat area that constitutes a local topographic high around the 200 Areas. The plateau is one of the flood bars (i.e., Cold Creek Bar) formed during the cataclysmic flooding events of the Missoula floods that occurred over 13,000 years ago. The north boundary of the flood bar is defined by an erosional channel, and present day topographic low, that runs northwest-southeast near Gable Butte just north of the 200 West Area boundary (Williams et al. 2002). Most of the 200 West Area, including the U-12 crib, is situated on the flood bar (Figure 2.1).

The geology of the Central Plateau, and particularly the Pasco Basin, has been studied in great detail (DOE 1988). The focus of this section is on the sediment above the basalt bedrock, or the suprabasalt sediment, contained within the Hanford, Cold Creek (formerly Plio-Pleistocene), and Ringold Formations, because these strata comprise the uppermost aquifer system and vadose zone in the area. Detailed descriptions of these geologic units are available in Bjornstad (1984, 1985), DOE (2002), Tallman et al. (1979), Myers and Price (1981), Graham et al. (1981), and Lindsey (1995). The most detailed description of the stratigraphy beneath the U-12 crib could be found in Jensen et al. (1990).

Williams et al. (2002) provides an updated re-interpretation of the hydrogeology in the 200 West Area and vicinity that includes characterization of the entire suprabasalt aquifer system. The most recent description of the groundwater contamination in the region of the Hanford Site surrounding the U-12 crib is presented in Section 2.8 of Hartman et al. (2003).

2.1 Stratigraphy

Two separate Hanford Site stratigraphic classifications are available (Figure 2.2); one developed by Lindsey (1995) is based on lithology (labeled Geology Column), and the second, developed by Pacific Northwest National Laboratory (PNNL) (Wurstner et al. 1995; Thorne et al. 1993), is the hydrogeologic stratigraphy (labeled Hydrogeologic Column) that combines the geology with the hydrologic properties of the sediment. This plan uses PNNL's hydrogeologic classification because it is more applicable to groundwater movement in the suprabasalt sediment. This hydrogeologic nomenclature and its geologic relationship are illustrated in Figure 2.2. The uppermost suprabasalt aquifer system is contained in the

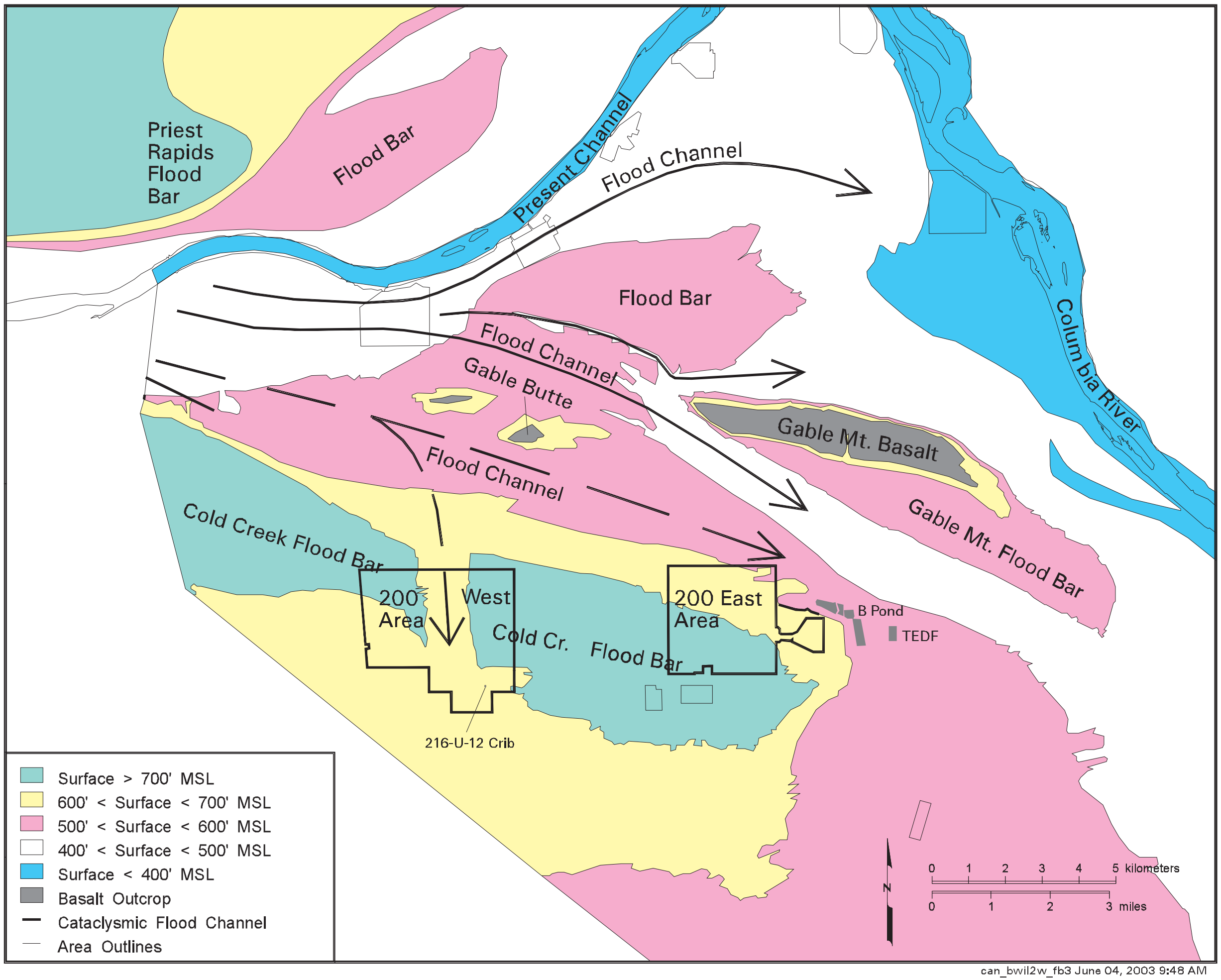

Figure 2.1. Topographic Illustration of Pleistocene Flood Channels and the Present-Day Columbia River Channel Pathways, with Outlines of the 200 West and East Areas, Hanford Site, Washington

Ringold Formation, and the Hanford formation and Cold Creek (Plio-Pleistocene unit) comprise the vadose zone. The Ringold Lower Mud Unit (hydrogeologic unit 8) separates the supra basalt aquifer system into a confined and unconfined aquifer (Williams et al. 2002). The uppermost surface of the Elephant Mountain member basalt is considered the base of the suprabasalt aquifer system (bedrock) because of its dense, low permeability interior, relative to the overlying sediments. This surface is considered to be a groundwater no-flow boundary. The basalt surface beneath the U-12 crib dips south-southwest forming the southern limb of the Gable Mountain-Gable Butte anticline and the northeast flank of the Cold Creek syncline (after Fecht et al. [1987]). Figures 2.3 (south-north) and 2.4 (east-west) illustrate the stratigraphic position and relationship of these hydrogeologic units as they exist beneath the south 200 West Area and the U-12 crib. Figure 2.5 provides a more detailed hydrogeologic profile beneath the U-12 crib.

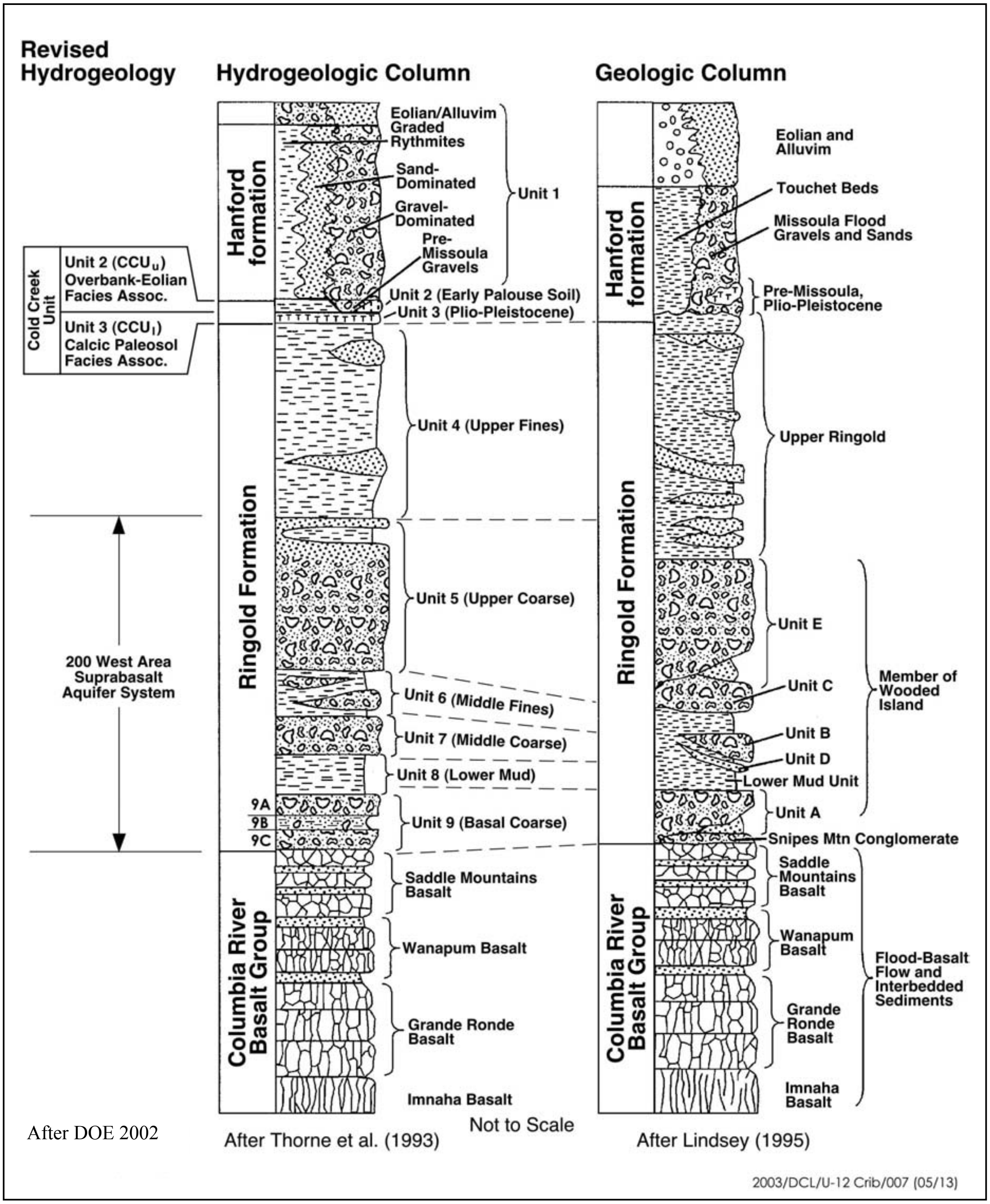

Figure 2.2. Comparison of Hydrogeologic and Geologic Classifications

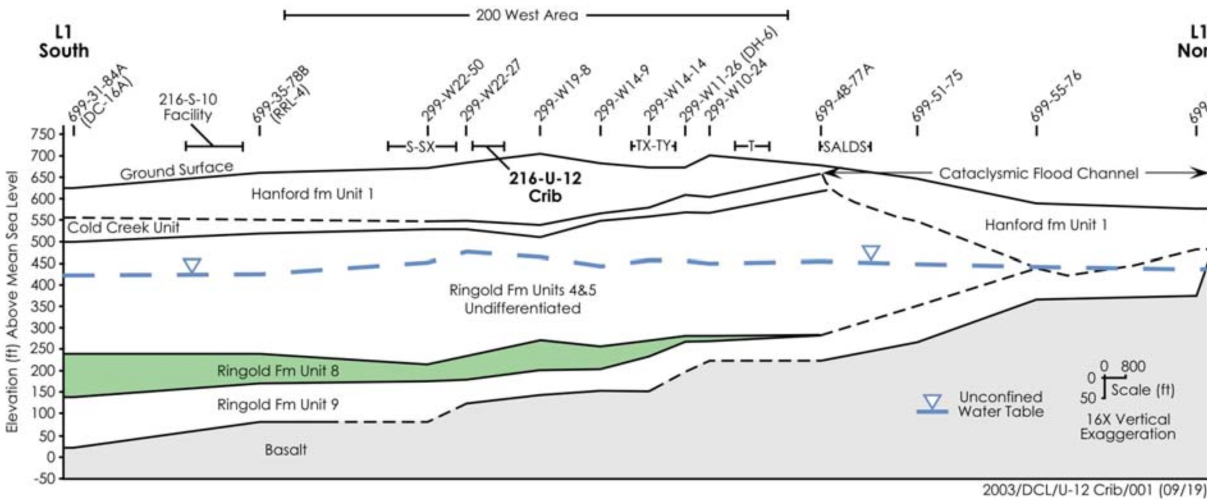

Figure 2.3. Hydrogeologic South-North Cross Section in the 200 West Area Near 216-U-12 Crib

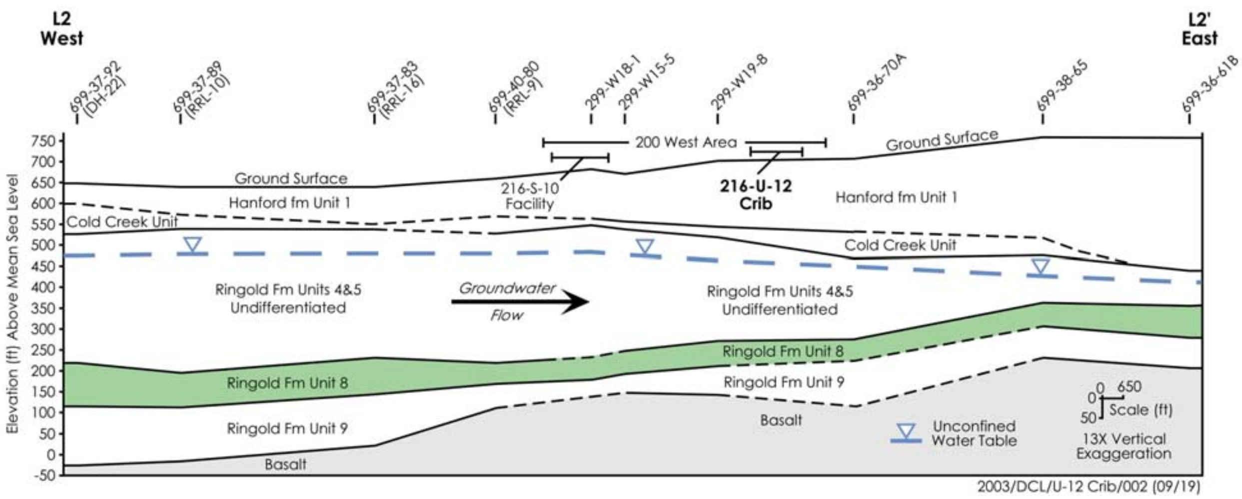

Figure 2.4. Hydrogeologic East-West Cross Section in the 200 West Area Near 216-U-12 Crib

The U-12 crib lies at an elevation of about 211 m (~692 ft) above mean sea level. The suprabasalt stratigraphy at the U-12 crib includes the following (from lower to upper):

- Ringold Formation.
- Cold Creek Unit (formerly Plio-Pleistocene Unit).
- Hanford formation.

Geology beneath the U-12 crib is described in detail in the following sections from oldest to youngest.

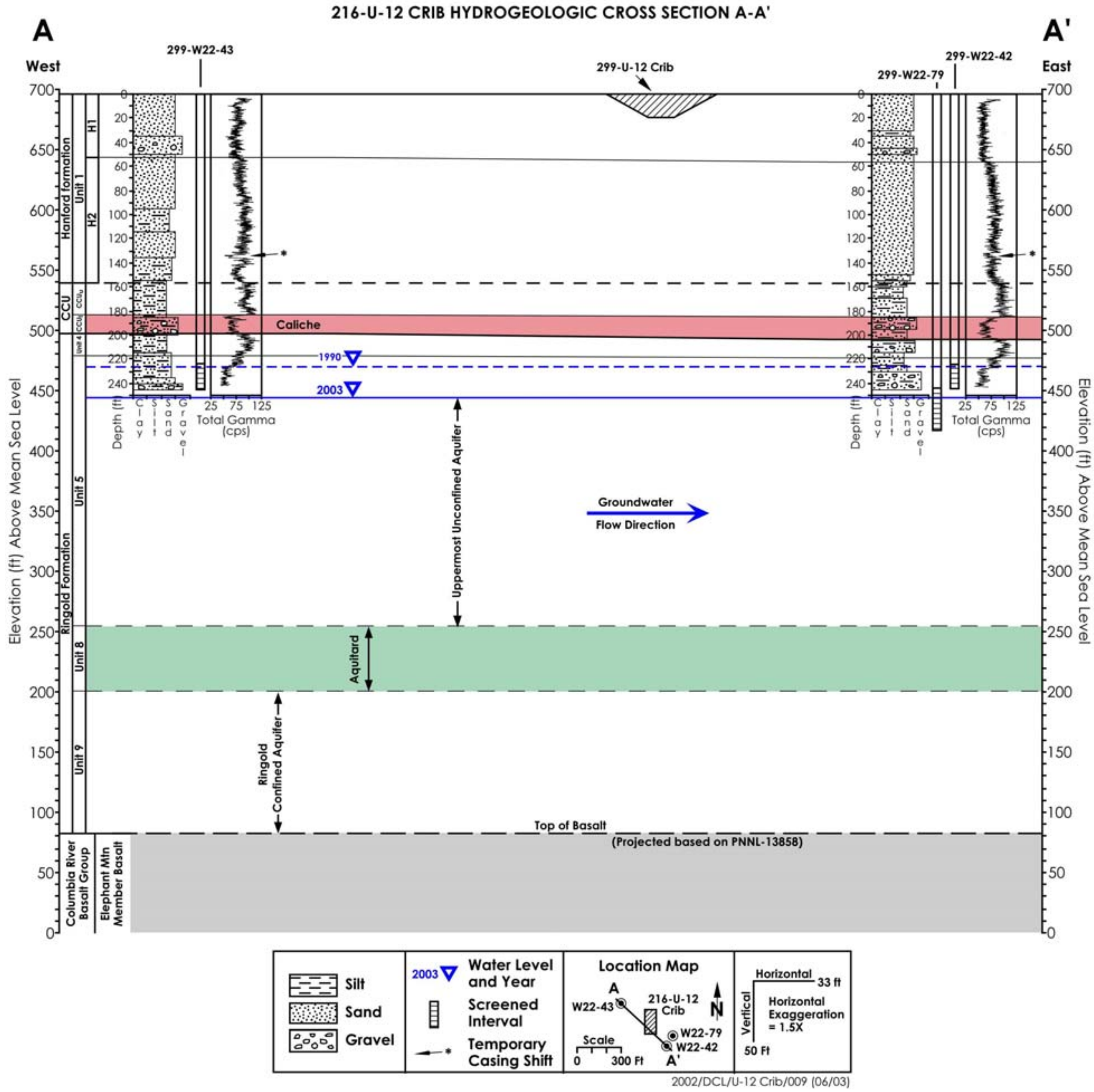

Figure 2.5. Detailed Hydrogeologic Cross Section at the 216-U-12 Crib

2.1.1 Ringold Formation (Units 4 through 9)

Units 4 through 9 correspond to the Ringold Formation (Figure 2.2) and consist of continental fluvial and lacustrine sediments deposited on the Elephant Mountain member basalt by ancestral Columbia and Clearwater-Salmon Rivers during late Miocene to Pliocene time (DOE 1988). From the oldest to youngest, the hydrogeologic intervals are the Unit 9 fluvial gravel, Unit 8 composed of the paleosol/ overbank facies beneath lacustrine fine-grained facies (Bjornstad 1984; DOE 1988; Last et al. 1989; Bjornstad 1990), Unit 5 fluvial gravel, and Unit 4 fines.

Ringold Units 4 through 9 consist of intercalated layers of indurated to semi-indurated and/or pedogenically altered sediment, including clay, silt, fine-to-coarse grained sand, and granule-to-cobble gravel. Within the area of the U-12 crib, this sequence consists of four distinct stratigraphic intervals designated Units 4, 5, 8, and 9. Units 5, 8, and 9 correspond generally to Lindsey's Ringold Formation fluvial gravel Unit E, lower mud unit and fluvial gravel Unit A, respectively (Figure 2.2).

Unit 9. The Ringold Unit 9 gravel is located 150 m (492 ft) beneath the U-12 crib and is approximately 22 m (72 ft) thick. This unit dips to the south-southwest and lies uncomformably on top of the Columbia River Basalt. Unit 9 is composed primarily of semi-consolidated and cemented silty sandy gravel with secondary lenses and interbeds that can consist of gravel, gravely sand, sand, muddy sand, and/or silt/clay.

Unit 8 (Lower Mud Unit). Unit 8 is composed of a thick sequence of fluvial overbank, paleosol, and lacustrine silts and clay with minor sand and gravel. Unit 8 forms the most significant and extensive confining unit within the suprabasalt aquifer system at the Hanford Site (Williams et al. 2000). More detailed descriptions of Unit 8 (the lower mud unit) can be found in Lindsey (1995). This unit is approximately 9 m (30 ft) thick and located approximately 141 m (462 ft) beneath the U-12 crib.

Unit 5. The Ringold Unit 5 gravel is a relatively thick unit, ranging up to 76 m (250 ft) thick, composed primarily of indurated fluvial gravel to silty sandy gravel and sand that grades upward into Unit 4 (interbedded fluvial sand and silt). Unit 5 has not been subdivided further due to the lack of distinctive and correlable stratigraphy or lithologic units. The saturated portion of Unit 5 comprises the uppermost unconfined aquifer and is over 65 m (213 ft) thick beneath the U-12 crib. Unit 5 overlies the Unit 8 (Ringold lower mud unit).

Unit 4. The Ringold Unit 4 is only locally present in the 200 West Area, and consists of fluvial sand and silt that overlies the Ringold Unit 5 gravel. This unit is present in the wells surrounding the U-12 crib. More information on the areal extent and details of this unit can be found in Lindsey (1995).

2.1.2 Cold Creek Unit (formerly Plio-Pleistocene Unit) (Units 2 and 3)

Units 2 and 3 represent relatively thin but significant depositional units that are post-Ringold and pre-Hanford sedimentation. Unit 3 is a calcic paleosol horizon that has developed on the eroded Ringold Formation (either Unit 4 or 5). Unit 3 is commonly referred to as the calcic sequence (or "caliche" zone) and is also referred to as the lower Cold Creek Unit (CCU_l). Unit 2 is described as an overlying fine-grained overbank-eolian sequence considered to belong to the upper portion of the Cold Creek Unit

(CCU_u) (DOE 2002). It is equivalent to what has been called the early "Palouse" soil (Connelly et al. 1992) and/or Plio-Pleistocene Unit in previous reports. Unit 3 is easily differentiated from the underlying (Unit 5) and overlying overbank-eolian sequence (Unit 2) because it is highly weathered, heavily cemented with calcium carbonate, poorly sorted, and shows a distinct decrease in natural gamma activity compared to the upper Unit 2. The Unit 2 is very fine grained, un-cemented, consisting of alternating thin lenses (typically less than 15.2 cm [6 in.]) of very fine sand to silt and clay, and has a relatively high natural gamma activity. The stratigraphic contact between the Unit 3 and the Ringold Unit 4 or 5 is fairly distinct and sharp, whereas the contact between the Unit 2 and the overlying Hanford Unit (H2) is gradational, dependent on grain size. In most cases, geophysical gamma logs greatly improve the accuracy of these correlations. Figure 2.5 illustrates these contacts beneath the facility.

At the U-12 crib, the Unit 3 is relatively thick, ~4.6 m (15 ft). Unit 2 is ~9.1 m (30 ft) thick. Unit 2 is located approximately ~45.7 m (155 ft) in depth below the surface.

2.1.3 Hanford Formation (Unit 1)

The Hanford formation is the informal name given to Pleistocene-age cataclysmic flood deposits in the Pasco Basin (Lindsey et al. 1994). It consists predominantly of unconsolidated sediments, which cover a wide range in grain size from pebble- to boulder-gravel, fine- to coarse-grained pebbly sand to sand, silty sand, and silt. Gravel clasts are composed of mostly subangular to subrounded basalt. Beneath the U-12 crib the Unit 1 consists of essentially two facies, the lower facies (Hanford H_2 unit) is composed of fine-grained sand to sandy silt that ranges from 32 to 30.5 m (105 to 100 ft) in thickness. This fine-grained facies is overlain with a fine to coarse sand to sandy gravel sequence that is approximately 16 m (53 ft) in thickness. This coarse grained interval is designated the Hanford H_1 unit. The subtle but sharp contact between the two facies is indicated by slightly gravelly sand to sandy gravel above the thick fairly uniform fine sand of the H_2 unit. This contact is easily distinguishable with the aid of geophysical gamma logs at a depth of about 52 to 55 ft (Figure 2.5).

2.2 Hydrogeology Beneath the U-12 Crib

Information on the vadose zone and the suprabasalt aquifer system at the U-12 crib is obtained from well-log data for wells and boreholes surrounding the facility and from published reports. In the 200 West Area and vicinity of U-12 crib, Williams et al. (2002) used data from borehole and groundwater monitoring to subdivide the suprabasalt sediments into two aquifers, an upper unconfined (Hanford/Ringold) unconfined aquifer) and a lower confined (Ringold confined) aquifer. The hydrogeology beneath the U-12 crib utilizes their interpretation.

The uppermost aquifer beneath the U-12 crib is unconfined; the aquifer comprises the saturated portion of the Upper Ringold Unit 4 and Ringold Unit 5 and is approximately 65.3 m (214 ft) thick (2003 measurement). Most known contaminant plumes that emanate from the 200 West Area migrate through

Unit 5 toward the east. The groundwater flow direction is approximately toward the southeast and is estimated based on water-level measurements taken in network and surrounding wells (e.g., Figure 2.1-1 in Hartman et al. 2003).

Site-specific hydraulic conductivity values, derived from slug test data at 299-W22-79 near the U-12 crib, range from 4.2 to 5.4 m (13.8 to 17.7 ft) per day (Spane et al. 2001). These values are within the range of hydraulic conductivities presented in Table 2.1 that have been calculated for hydrogeologic units beneath the 200 West Area. These data reflect averages of data collected from wells throughout the Central Plateau. Based on these values and parameters listed in Hartman et al. (2003, Table A.2), the groundwater flow rate (Darcy velocity) ranges from 0.02 to 0.08 m (0.1 to 0.3 ft) per day.

Within the 200 West Area, including the U-12 crib, the water table is declining rapidly due to site-wide cessation of past (non-permitted) liquid effluent disposal practices. Hydrographs for monitoring wells near the U-12 crib are presented in Figure 2.6. The falling water table is causing wells that monitor the U-12 crib and surrounding monitoring wells to go dry (Figure 2.6).

Table 2.1. Hydraulic Conductivities for Major Hydrogeologic Units

Hydrogeologic Unit	Estimated Range of Saturated Hydraulic Conductivities (m/d)	Reference(s)
Unit 5 (Ringold Formation Unit E)	0.1 to 200	Wurstner et al. (1995): Thorne and Newcomer (1992)
Unit 8 (Ringold Formation Lower Mud Unit)	0.0003 to 0.09	Wurstner et al. (1995): Thorne and Newcomer (1992)
Unit 9 undifferentiated Ringold Formation Unit A	0.1 to 200	Wurstner et al. (1995): Thorne and Newcomer (1992)
Note: This table is modified from Cole et al. (1997).		

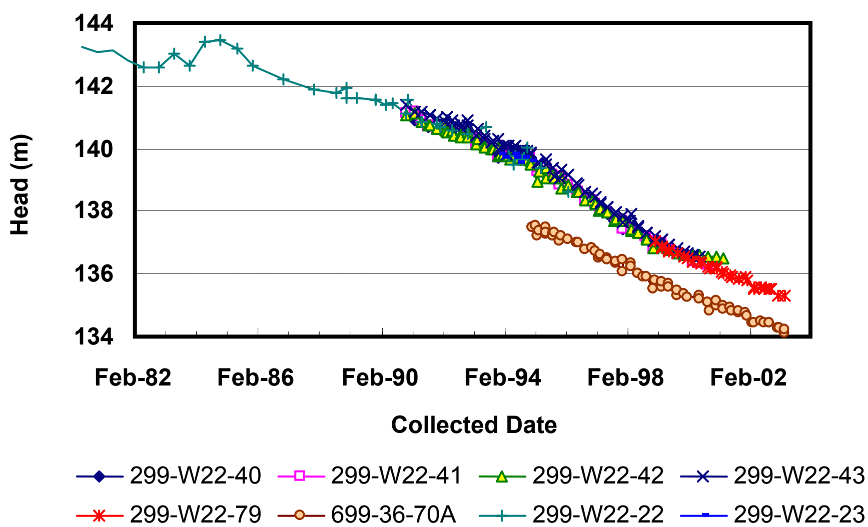

Figure 2.6. Hydrographs of Wells Monitoring the 216-U-12 Crib

It is not known if preferential paths of groundwater flow exist in this thick uppermost aquifer, or if flow paths are changing due to falling water levels, because existing Unit 5 hydrogeologic data has not supported subdivision of the unit into more discrete flow zones. However, the depositional nature and character of this unit, and the lithologic variability between boreholes, indicates that lithologic variations do occur on all scales; the intrinsic hydrologic properties will influence groundwater movement. The preferred method used to intercept and monitor the uppermost aquifer flow zone(s) requires installation of longer screens to maximize the life of the well due to rapidly declining water levels. Monitoring screens are being installed up to 10 m (35 ft) long depending on location and aquifer thickness.

The vertical variability in contaminant distribution in the aquifer has not been evaluated at U-12 crib. However, data from nearby wells indicate that contaminants from other disposal operations have spread vertically and laterally throughout most of the unconfined aquifer beneath the 200 West Area (Williams et al. 2002). For example, carbon tetrachloride, tritium, and nitrate, have all been detected at depths below the screened interval in well 699-36-70A, located over 900 m (2,950 ft) downgradient of the U-12 crib (Williams 1995).

The top of Unit 8 (lower mud unit) comprises the base of the uppermost-unconfined aquifer (Williams et al. 2002). South of the U-12 crib the vertical hydraulic conductivity of Unit 8, as measured from a splitspoon soil sample collected in well 299-W27-2, is 0.051 m (0.17 ft) per day and falls within the expected range reported by Thorne and Newcomer (1992) (Table 2.1). Unit 8 (lower mud unit) is an aquitard and separates and confines groundwater in the underlying Ringold Unit 9 gravel (confined Ringold aquifer) from the unconfined aquifer in Unit 5. Groundwater in the confined Ringold aquifer is interpreted to flow laterally through Unit 9 gravel due to the thickness and relatively low vertical hydraulic conductivity of the overlying confining Unit 8.

Regionally, groundwater in the confined Ringold aquifer flows from west to east similar to groundwater in the uppermost unconfined aquifer. In the 200 West Area and around the U-12 crib, it is more difficult to determine flow direction because there are currently no wells completed within the confined Ringold aquifer. Limited data are available below the confining Unit 8 (lower mud unit) for the 200 West Area; however, groundwater heads measured in several deep/shallow well pairs, and deep wells drilled into the Ringold Unit 9 confined aquifer (e.g., Johnson and Horton 2000) indicate a downward vertical hydraulic gradient beneath the 200 West Area from the unconfined Unit 5 into the confined Unit 9 (Williams et al. 2002).

Beneath the U-12 crib, groundwater in the uppermost unconfined aquifer is assumed to be isolated from groundwater in the confined Ringold aquifer by Unit 8 (lower mud unit). Intercommunication between Units 5 and 9 is assumed to be insignificant beneath the U-12 crib because groundwater flow through Unit 8 is extremely low due to the thickness and relatively low permeability of the confining unit.

The vadose zone beneath the U-12 crib is approximately 76.4 m (251 ft) thick. The vadose zone includes hydrogeologic Units 1, 2, 3, and the upper, unsaturated portion of Units 4 and 5 (Figure 2.2). Figure 2.5 provides input to the conceptual model for the area near the U-12 crib and includes depths, relative thicknesses, and hydraulic relationship of the hydrogeologic units beneath the facility.

Recharge to the unconfined aquifer beneath the U-12 crib is from artificial and possibly natural sources. Any natural recharge that occurs originates from precipitation. Estimates of recharge from precipitation range from 0 to 10 cm (0 to 4 in.) per year and are largely dependent on soil texture and the type and density of vegetation (DOE 2000). While the liquid waste disposal facilities were operating, many localized areas of saturation or near saturation were created in the soil column. Artificial recharge from years of liquid effluent disposal accounts for most of the liquid influx to the aquifer and is the main driver and transport medium for potential contaminants disposed at the facility.

The downward flux of moisture in the vadose zone decreased with the cessation of artificial recharge in the U-12 crib. Areas with high residual water saturation in the sediment will result in continued gravity drainage for an unknown period of time. When stable unsaturated conditions are reached, the moisture flux into the aquifer becomes less significant. In the absence of artificial recharge, the potential for recharge from precipitation becomes more important as a driving force for any potential contamination remaining in the vadose zone.

3.0 Conceptual Model

A groundwater conceptual model is an evolving hypothesis that identifies the important features, events and processes that control groundwater and contaminant movement (Hartman 2002). Conceptual models are based on data results, field observations, and previous studies and form the basis for future investigations and data collection objectives. The characteristics of the hydrogeologic and source conceptual model developed for the U-12 crib are described in the following paragraphs.

A detailed conceptual model for the U-12 crib is presented in Williams and Chou (1997). The following characteristics and working assumptions summarize that conceptual model for the U-12 crib:

- Most of the hazardous (corrosive) waste that went into the crib was strongly acidic, composed primarily of nitric acid. This waste was also radioactive. Total volumes disposed to the crib averaged over 1.33×10^8 L/yr (3.5×10^7 gal/yr) from 1960 through 1978 (Maxfield 1979). The crib was permanently retired in 1988.

- The contaminated effluent infiltrated beneath the crib into the vadose zone, but the corrosive waste was neutralized by natural occurring calcium carbonate cement in vadose sediment before it reached groundwater. Most radioactive waste constituents remain sorbed, by design, to sediment in the thick vadose interval (>68 m [225 ft]) (Smith and Kasper 1983).

- Although process information suggests several mobile constituents may have been released to the crib (Figure 3.1), groundwater monitoring indicates that nitrate and technetium-99 (not RCRA dangerous waste constituents) are the only significant contaminants of concern that have been detected (Williams and Chou 1997). Nitrate and technetium-99 are mobile in the groundwater. The vadose zone is a continuing source of these constituents to the groundwater. Both nitrate and technetium-99 concentrations are declining as residual drainage from the vadose zone beneath the crib decreases.

- Nitrate and technetium-99 concentrations are higher in far field monitoring well 699-36-70A than in the wells immediately downgradient of the crib. This is due to the long groundwater travel time between the U-12 crib and this well and reflects the passing of the higher concentration portion of the migrating plumes (i.e., reached groundwater years earlier than what is currently detected near the crib).

- The contaminant plumes extend east from the crib and mingle with other similar contaminant plumes from nearby and adjacent waste disposal facilities (e.g., 216-U-8 crib) creating a larger area of contamination downgradient of the U-12 crib.

- Declining water levels are stranding wells dry above the water table and reducing the ability to track plumes and confirm these contaminant declines. Groundwater flow direction remains essentially unchanged, to date, since groundwater monitoring began.

The conceptual model developed for the U-12 crib is that, during operation, semi-saturated to saturated flow conditions existed beneath the facility (Figure 3.1). The acidic liquid waste saturated into the vadose sediment where neutralization occurred as the waste moved deeper through calcium carbonate containing sediment. The buffering capacity of the thick sediments of the vadose zone was determined adequate to neutralize all nitric acid waste, liberating the nitrate anion which does not interact with sediment and thus continued to migrate with water through the vadose zone. Because technetium-99 also has essentially zero retardation, it also traveled with the nitrate in water migrating through the vadose zone to the aquifer.

The consistent relationship between the constituents indicates that the hydrogeologic processes acting on nitrate and technetium-99 and the migration pathway are essentially the same. RCRA assessment groundwater monitoring results downgradient of the crib indicate that continued migration of neutralized reaction constituents (nitrate and associated radionuclides) is still occurring. Continued drainage of mobile constituents from the vadose zone is expected based on vadose-transport modeling, which has estimated that the travel time for natural moisture within the vadose zone to migrate to the aquifer can take many years (Fayer and Walters 1995).

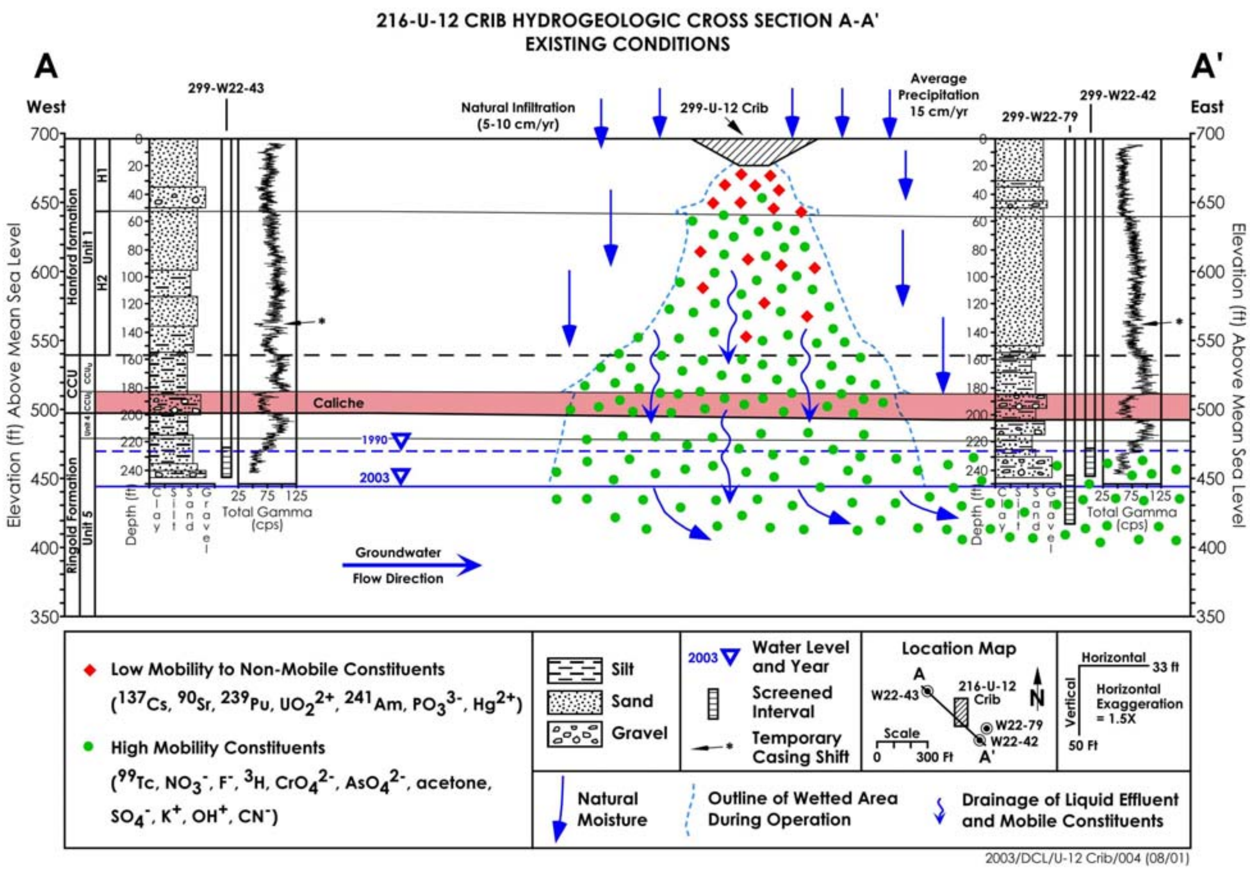

Figure 3.1. Conceptual Model Developed for the 216-U-12 Crib

4.0 Sampling and Analysis Plan

This section describes the monitoring program for the RCRA interim status groundwater assessment for the U-12 crib, which is designed to assess facility impacts to groundwater as described in Section 1.2 above. Interim status monitoring will remain in effect until the U-12 crib has been closed per the CERCLA U Area Waste Sites Proposed Plan (DOE 2003b) and certified under a RCRA Part-B Permit modification. Closure of the U-12 crib is scheduled in conjunction with the CERCLA U Area Waste Sites Proposed Plan closure dates, which will be determined later.

4.1 Groundwater Monitoring Well Network

The assessment monitoring network for the U-12 crib has been defined in the DQO for the 200 Areas CERCLA/RCRA integrated groundwater monitoring network (Byrnes and Williams 2003). The U-12 crib network currently consists of two RCRA compliant (WAC 173-160) wells, 299-W22-79 and 699-36-70A (Figure 4.1). These two wells monitor the top of the unconfined aquifer which is believed to be where most contaminants travel in groundwater. The initial four network wells have gone dry (Williams and Chou 1993). Two additional downgradient wells will be added to this network either by, (1) deepening of existing dry wells (299-W22-8 and 299-W21-51), or (2) drilling new wells if deepening is not practicable. Figure 4.1 provides the location of the four wells proposed for this network (Table 4.1). Since the U-12 crib has impacted groundwater and is in RCRA assessment, the upgradient well, which has gone dry, will not be replaced or deepened unless downgradient monitoring reveals a significant increase in the detected contaminants or new contamination. Appendix A provides well as-built information about the proposed network wells for continuing interim status assessment groundwater monitoring at the U-12 crib.

4.2 Constituent List and Sampling Frequency

Samples will continue to be analyzed quarterly as required by RCRA regulations. Water levels will also be collected at the same time the wells are sampled. Some constituents will be analyzed annually, as necessary, to assist in data evaluation. Based on waste stream characteristics, selected constituents for this site are: alkalinity, anions (specific for nitrate), metals (specific for arsenic and chromium), pH, specific conductance, technetium-99, temperature, total dissolved solids, and turbidity. Technetium-99 is a non-RCRA constituent that is being tracked to assist in determining groundwater flow rate and direction beneath the crib. Table 4.2 provides the list of wells, constituents, and frequency of sampling and water-level monitoring for the network.

4.3 Sampling and Analysis Protocol

RCRA groundwater monitoring for the U-12 crib is part of the groundwater project. This section describes the groundwater project's protocols for sample collection and analysis. Project staff schedule sampling and initiate paperwork. The project uses subcontractors for sample collection, shipping, and analysis.

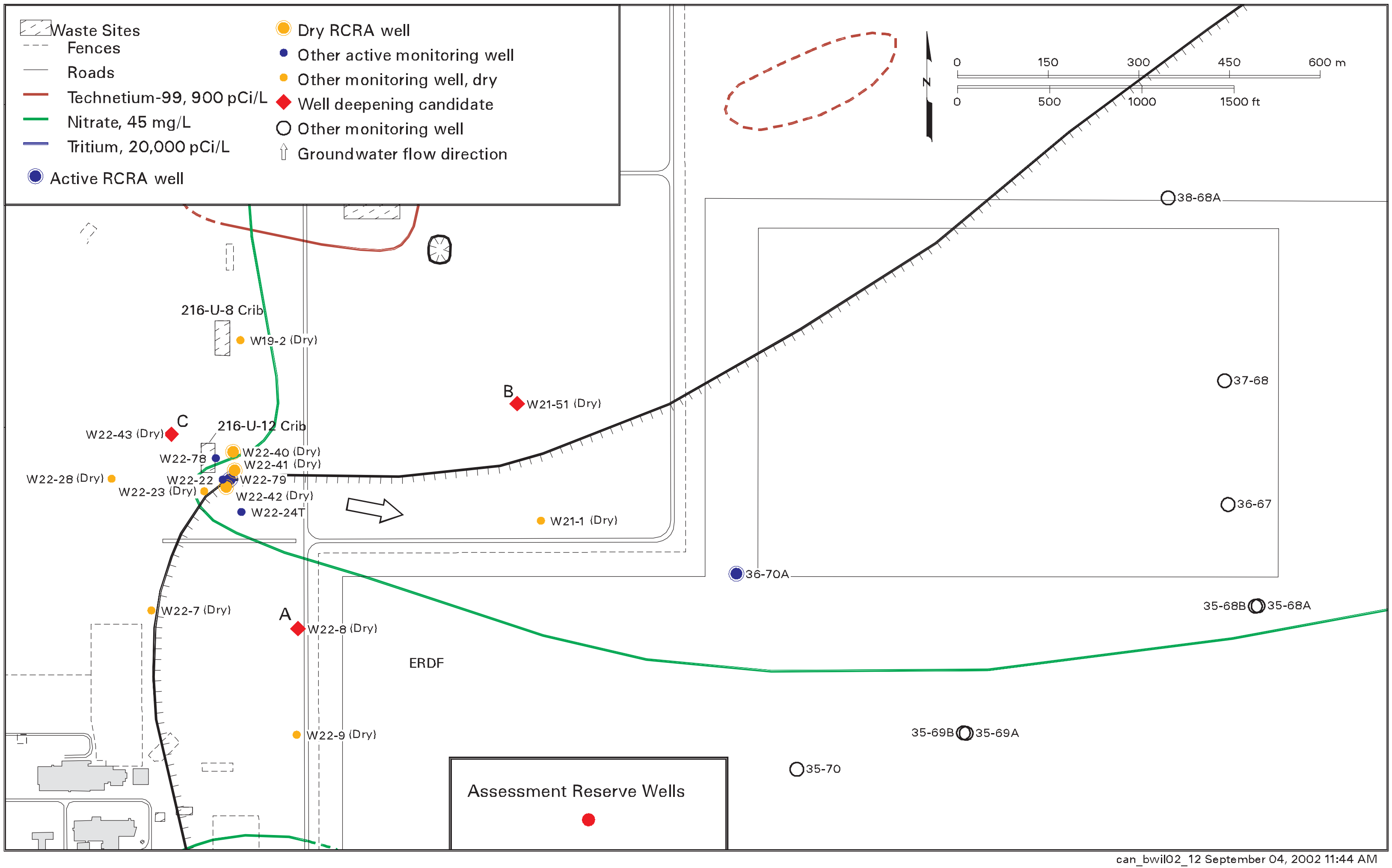

Figure 4.1. Well Location Map for the 216-U-12 Crib

Table 4.1. U-12 Crib Groundwater Monitoring Network

Well	Well Standard	Unit Monitored	Comment	Other Users
299-W22-8	To be deepened	Top of unconfined	Currently dry; proposed for deepening	CERCLA
299-W22-51	To be deepened	Top of unconfined	Currently dry; proposed for deepening	CERCLA
299-W22-79	WAC 173-160	Top of unconfined	In current network	CERCLA
699-36-70A	WAC 173-160	Top of unconfined	In current network	CERCLA

Table 4.2. Well Constituents, and Frequency of Sampling at the U-12 Crib

	Constituents Required Under This Plan			Constituents Supporting Interpretation														
Well Number	Arsenic	Chromium (total; filt.)	Nitrate	Alkalinity	Chloride	Nitrate	Sulfate	Calcium (filtered)	Potassium (filtered)	Magnesium (filtered)	Sodium (filtered)	Tc-99[a]	TDS	pH	Specific conductance	Temperature	Turbidity	Water Levels[b]
299-W22-8	A	A	Q	A	Q	Q	Q	A	A	A	A	Q	A	Q	Q	Q	Q	Q
299-W22-51	A	A	Q	A	Q	Q	Q	A	A	A	A	Q	A	Q	Q	Q	Q	Q
299-W22-79	A	A	Q	A	Q	Q	Q	A	A	A	A	Q	A	Q	Q	Q	Q	Q
699-36-70A	A	A	Q	A	Q	Q	Q	A	A	A	A	Q	A	Q	Q	Q	Q	Q

(a) Not regulated under RCRA; co-contaminant analyzed to help determine groundwater flow rate and direction and to support CERCLA and AEA monitoring
(b) Measured before purging well for sampling
A = annually; Q = quarterly
Italics: Wells to be added to network based on TPA M-24-00 milestone.

4.3.1 Scheduling Groundwater Sampling

The groundwater project's scheduling procedure provides direction for scheduling and document production. Many Hanford Site wells are sampled for multiple objectives and requirements, e.g., RCRA, CERCLA, or the *Atomic Energy Act of 1954*. Following the scheduling procedure helps manage the overlap, eliminating redundant sampling and meeting the needs of each sampling objective. The scheduling procedure includes the following steps:

- Each fiscal year, project scientists provide well lists, constituent lists, and sampling frequency. Each month, project scientists review the sampling schedule for the following month. Changes are requested via change request forms and approved by the sampling and analysis task lead and the monitoring project manager.

- Project staff track sampling and analysis through an electronic schedule database, stored on a server at PNNL. Quality control samples also are managed through this database. A scheduling program generates unique sample numbers and a special user interface generates sample authorization forms, field services reports, groundwater sample reports, chain of custody forms, and sample container labels.

- Sampling and analysis staff verify that such things as well name, sample numbers, bottle sizes, and preservatives are indicated properly on the paperwork, which is transmitted to the sampling subcontractor. Staff complete a checklist to document that the paperwork was generated correctly.

- At each month's end, project staff use the schedule database to determine if any wells were not sampled as scheduled. If the wells or sampling pumps require maintenance, they are rescheduled following repair. If a well can no longer be sampled, the sampling is cancelled and the reason is recorded in the database.

4.3.2 Chain of Custody

The sampling subcontractor uses chain of custody forms to document the integrity of groundwater samples from the time of collection through data reporting. The forms are generated during scheduling (see Section 4.3.1) and managed through subcontractor procedure DFSNW-SSPM-001 SP 1-1.

4.3.3 Sample Collection

The procedure for groundwater sampling is described in subcontractor procedure DFSNW-SSPM-001 SP 3-1. Samples generally are collected after three casing volumes of water have been purged from the well or after field parameters (pH, temperature, specific conductance, and turbidity) have stabilized (i.e., after two consecutive measurements are within 0.2 units pH, 0.2 degrees C for temperature, 10% for specific conductance, and turbidity <5 NTU). For routine groundwater samples, preservatives are added to the collection bottles before their use in the field according to subcontractor procedure DFSNW-SSPM-001 SP 2-1. Samples to be analyzed for metals are usually filtered in the field so that results represent dissolved metals.

4.3.4 Analytical Protocols

Procedures for field measurements are specified in subcontractor's procedures DFSNW-SSPM-001 SP 6-2 (turbidity), SP 6-3 (pH), SP 6-5 (specific conductance), and SP 6-7 (temperature). Each instrument is assigned a unique number that is tracked on field documentation and is calibrated and controlled according to procedure DFSNW-SSPM-001 6-1. Additional calibration and use instructions are specified in the instrument user's manuals.

Laboratory analytical methods are specified in contracts with the laboratories, and most are standard methods from *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods* (EPA 1986a). Alternative procedures meet the guidelines of EPA (1986b, Chapter 10). Analytical methods are described in Section 8 of Hartman (2000).

4.4 Quality Control

The Hanford Groundwater Monitoring Project's quality control (QC) program is designed to assess and enhance the reliability and validity of groundwater data. This is accomplished through evaluating the results of quality control samples, conducting audits, and validating groundwater data. This section describes the quality control program for the entire groundwater project, which includes the U-12 crib.

The QC practices of the groundwater project are based on guidance from EPA (EPA 1979, 1986a, 1986b, 1986c). Accuracy, precision, and detection are the primary parameters used to assess data quality (Mitchell et al. 1985). Data for these parameters is obtained from two categories of QC samples: those that provide checks on field and laboratory activities (field QC) and those that monitor laboratory performance (laboratory QC). Table 4.3 summarizes the types of samples in each category along with the sample frequencies and characteristics evaluated.

Table 4.3. Quality Control Samples

Sample Type	Primary Characteristics Evaluated	Frequency
Field QC		
Full Trip Blank	Contamination from containers or transportation	1 per 20 well trips
Field Transfer Blank	Airborne contamination from the sampling site	1 each day VOC samples are collected
Equipment Blank[(a)]	Contamination from non-dedicated sampling equipment	1 per 10 well trips or as needed[(b)]
Duplicate Samples	Reproducibility	1 per 20 well trips
Laboratory QC		
Method Blank	Laboratory contamination	1 per batch
Lab Duplicates	Laboratory reproducibility	Method/contract specific[(c)]
Matrix Spike	Matrix effects and laboratory accuracy	Method/contract specific[(c)]
Matrix Spike Duplicate	Laboratory reproducibility and accuracy	Method/contract specific[(c)]
Surrogates	Recovery/yield	Method/contract specific[(c)]
Laboratory Control Sample	Accuracy	1 per batch
Double Blind Standards	Accuracy and precision	Varies by constituent[(d)]

(a) Not applicable for U-12 crib -- dedicated sampling equipment used.
(b) When a new type of non-dedicated sampling equipment is used, an equipment blank should be collected every time sampling occurs until it can be shown that less frequent collection of equipment blanks is adequate to monitor the equipment's decontamination procedure.
(c) If called for by the analytical method, duplicates, matrix spikes, and matrix spike duplicates are typically analyzed at a frequency of 1 per 20 samples. Surrogates are routinely included in every sample for most gas chromatographic methods.
(d) Double blind standards containing known concentrations of selected analytes are typically submitted in triplicate or quadruplicate on a quarterly, semi-annual, or annual basis.

QC data are evaluated based on established acceptance criteria for each QC sample type. For field and method blanks, the acceptance limit is generally two times the instrument detection limit (metals), method detection limit (other chemical parameters), or minimum detectable activity (radiochemistry parameters). However, for common laboratory contaminants such as acetone, methylene chloride, 2-butanone, and phthalate esters, the limit is five times the method detection limit. Groundwater samples that are associated (i.e., collected on the same date and analyzed by the same method) with out-of-limit field blanks are flagged with a Q in the database to indicate a potential contamination problem.

Field duplicates must agree within 20%, as measured by the relative percent difference (RPD), to be acceptable. Only those field duplicates with at least one result greater than five times the appropriate detection limit are evaluated. Unacceptable field duplicate results are also flagged with a Q in the database.

For chemical analyses, the acceptance criteria for laboratory duplicates, matrix spikes, matrix spike duplicates, surrogates, and laboratory control samples are generally derived from historical data at the laboratories in accordance with EPA (1986a). Typical acceptance limits are within 25% of the expected values, although the limits may vary considerably with the method and analyte. For radiological analyses, the acceptance limits for laboratory QC samples are specified in the laboratory contract. Current values for laboratory duplicates, matrix spikes, and laboratory control samples are 20% RPD, 60-140%, and 70-130%, respectively. These values are subject to change if the contract is modified or replaced.

Table 4.4 lists the acceptable recovery limits for the double blind standards. These samples are prepared by spiking background well water with known concentrations of constituents of interest.

Spiking concentrations range from the detection limit to the upper limit of concentration determined in groundwater on the Hanford site. Double blind standard results that are outside the acceptance limits are investigated and appropriate actions are taken if necessary.

Holding time is the elapsed time period between sample collection and analysis. Exceeding recommended holding times could result in changes in constituent concentrations due to volatilization, decomposition, or other chemical alterations. Recommended holding times depend on the analytical method, and are listed in the annual groundwater monitoring report (e.g., Table B.8 of Hartman et al. 2003). Data associated with exceeded holding times are flagged with an “H” in HEIS.

Additional QC measures include laboratory audits and participation in nationally-based performance evaluation studies. The contract laboratories participate in national studies such as the EPA sanctioned Water Pollution and Water Supply Performance Evaluation studies. The groundwater project periodically audits the analytical laboratories to identify and solve quality problems, or to prevent such problems. Audit results are used to improve performance. Summaries of audit results and performance evaluation studies are presented in the annual groundwater monitoring report.

Table 4.4. **Recovery Limits for Double Blind Standards**

Constituent	Frequency	Recovery Limits	Precision Limits (RSD)
Specific conductance	Quarterly	75–125%	25%
Total organic carbon[(a)]	Quarterly	75–125%	Varies with spiking compound
Total organic halides[(b)]	Quarterly	75–125%	Varies with spiking compound
Cyanide	Quarterly	75–125%	25%
Fluoride	Quarterly	75–125%	25%
Nitrate	Quarterly	75–125%	25%
Chromium	Annually	80–120%	20%
Carbon tetrachloride	Quarterly	75–125%	25%
Chloroform	Quarterly	75–125%	25%
Trichloroethene	Quarterly	75–125%	25%
Gross alpha[(c)]	Quarterly	70–130%	20%
Gross beta[(d)]	Quarterly	70–130%	20%
Tritium	Annually	70–130%	20%
Tritium (low level)	Semiannually	70–130%	20%
Cesium-137	Annually	70–130%	20%
Cobalt-60	Annually	70–130%	20%
Strontium-90	Semiannually	70–130%	20%
Technetium-99	Quarterly	70–130%	20%
Iodine-129	Semiannually	70–130%	20%
Uranium	Quarterly	70–130%	20%
Plutonium-239	Quarterly	70–130%	20%

(a) The spiking compound generally used for total organic carbon is potassium hydrogen phthalate. Other spiking compounds may also be used.
(b) Two sets of spikes for total organic halides will be used. The first should be prepared with 2,4,5-trichlorophenol. The second set will be spiked with a mixture of carbon tetrachloride, chloroform, and trichloroethene.
(c) Gross alpha standards will be spiked with plutonium-239.
(d) Gross beta standards will be spiked with strontium-90.
RSD = Relative Standard Deviation.

5.0 Data Management

This section describes how the groundwater project loads analytical and field data into HEIS, how suspect data are reviewed, and how the data are interpreted.

5.1 Loading and Verifying Data

The contract laboratories report analytical results electronically and in hard copy. The electronic results are loaded into HEIS. Hard-copy data reports and field records are considered to be the record copies and are stored at PNNL. Project staff perform an array of computer checks on the electronic file for formatting, allowed values, data flagging (qualifiers), and completeness. Verification of the hard copy results include checks for (1) completeness, (2) notes on condition of samples upon receipt by the laboratory, (3) notes on problems that arose during the analysis of the samples, and (4) correct reporting of results. If data are incomplete or deficient, staff work with the laboratory to get the problems corrected. Notes on condition of samples or problems during analysis may be used to support data reviews (see Section 5.2).

Field data such as specific conductance, pH, temperature, turbidity, and depth to water, are recorded on field records. Data management staff enter these into HEIS manually through data-entry screens, verify each value against the hard copy, and initial each value on the hard copy.

5.2 Data Review Procedure

The groundwater project's data review procedure describes the process for reviewing specific groundwater analytical data or field measurements when results are in question. Groundwater staff document the process on a "Request for Data Review" (RDR) form and results are used to flag the data appropriately in HEIS. Various staff may initiate an RDR, e.g., project scientists, data management, quality control. The data review process includes the following steps.

- The initiator fills out required information on the RDR form, such as sample number, constituent, and reason for the request (e.g., "result is two orders of magnitude greater than historical results and disagrees with duplicate"). The initiator recommends an action, such as a data recheck, sample re-analysis, well re-sampling, or simply flagging the data as suspect in HEIS.

- The data review coordinator determines that the RDR does not duplicate a previously-submitted RDR, then assigns a unique RDR number and records it on the form. A temporary flag is assigned to the data in HEIS, indicating the data are undergoing review ("F" flag).

- If laboratory action is required, the data review coordinator records the lab's response on the RDR form. Other documentation also may be relevant, such as chain-of-custody forms, field records, calibration logs, or chemist's sheets.

- A project scientist assigned to reviewing RDRs determines and records the appropriate response and action on the RDR form, including changes to be made to the data flags in HEIS. Actions may include updating HEIS with corrected data or result of re-analysis, flagging existing data (e.g., R for reject, Y for suspect, G for good), and/or adding comments. Data management updates the temporary "F" flag to the final flag in HEIS.

- The data review coordinator signs the RDR form to indicate its closure.

- If an RDR is filed on data that are not "owned" by the groundwater project, the data review coordinator forwards a copy of the partially-filled form to the appropriate contact for their action. The RDR is then closed.

5.3 Interpretation

After data are validated and verified, the acceptable data are used to interpret groundwater conditions at the site. Interpretive techniques include:

- Hydrographs – graph water levels vs. time to determine decreases, increases, seasonal, or man-made fluctuations in groundwater levels.

- Water-table maps – use water-table elevations from multiple wells to construct contour maps to estimate flow directions. Groundwater flow is assumed to be perpendicular to lines of equal potential.

- Trend plots – graph concentrations of chemical or radiological constituents vs. time to determine increases, decreases, and fluctuations. May be used in tandem with hydrographs and/or water-table maps to determine if concentrations relate to changes in water-level or in groundwater flow directions.

- Plume maps – map distributions of chemical or radiological constituents areally in the aquifer to determine extent of contamination. Changes in plume distribution over time aid in determining movement of plumes and direction of flow.

- Contaminant ratios – can sometimes be used to distinguish between different sources of contamination.

6.0 Reporting

Chemistry and water-level data are reviewed after each sampling event and are available in HEIS. Summaries of sampling results for the U-12 crib are included in informal quarterly reports to Ecology. Interpretive reports are issued annually in March (e.g., Hartman et al. 2003). New groundwater monitoring issues may also be reported in monthly reports to DOE, Richland Operations Office (RL).

Interim changes to sampling and analysis may be needed because of field conditions (e.g., dry wells, broken pumps) or analytical results (e.g., unexpected change in contaminant concentration or detection). Required actions for various types of changes are listed in Table 6.1.

Table 6.1. Change Control for Groundwater Monitoring at the 216-U-12 Crib

<table>
<tr><th>Type of Change</th><th>Action</th><th>Documentation</th></tr>
<tr><td>Adding constituents, wells, or increasing sampling frequency</td><td rowspan="2">Project Management Approval; notify regulator if appropriate; update sampling and analysis plan</td><td rowspan="2">Project’s schedule tracking system, Interim Change Notice (ICN) to the groundwater monitoring plan or complete plan revision</td></tr>
<tr><td>Changes to supporting constituents</td></tr>
<tr><td>Deleting required constituents, wells, or reducing frequency</td><td>Notify regulator; update sampling and analysis plan</td><td rowspan="2">Letter or signed meeting minutes; project’s schedule tracking system, Interim Change Notice (ICN) to the groundwater monitoring plan or complete plan revision</td></tr>
<tr><td>Unavoidable changes (e.g., dry wells; delayed samples, one-time missed samples due to broken pump, lost bottle, etc.)</td><td>Notify regulator</td></tr>
<tr><td>Initiation of post-closure monitoring (Section 7)</td><td>Regulator approval of monitoring program via permitting documents; revise groundwater monitoring plan</td><td>Approved Permit modification and revised monitoring plan</td></tr>
</table>

7.0 Final Status (Post-Closure) Groundwater Monitoring Plan

This section proposes a RCRA post-closure monitoring program for the U-12 crib assuming that the crib is not clean closed. It includes information on the closure alternatives defined for the U-Plant Area waste sites, including the U-12 crib. The post-closure groundwater monitoring program is proposed for the U-12 crib based on results from the conceptual site model and risk assessment provided in Appendix C of the U-Plant Area waste sites FFS (2003a). This post-closure groundwater monitoring program includes monitoring constituents, network design, sample frequencies, and sampling and analysis methods. If the crib is clean closed, then groundwater monitoring will not be necessary. Discussions on non-dangerous waste constituents not regulated under RCRA (i.e., radionuclides) and nitrate, a non-dangerous waste constituent, are provided because the information (1) may provide further insight regarding the source, interpretation of groundwater flow, and migration of dangerous waste constituents in groundwater and (2) may serve as a transition to a larger area operable unit monitoring approach that embraces both RCRA site (i.e., U-12 crib) and the CERCLA 200-UP-1 Operable Unit.

Groundwater monitoring activities conducted under the interim status assessment level program, as described in Sections 3 and 4, will continue until certification of the final closure of the site. After completion and certification of closure of the U-12 crib, groundwater monitoring activities, cover design, surveillance and maintenance, and inspection plan (if needed when clean closure is not achieved) will be conducted to fulfill requirements of WAC-173-303-610 (8)(b)(i). The RCRA groundwater monitoring activities will be integrated with the CERCLA operations and maintenance plan and site-wide programs under the 200-UP-1 groundwater monitoring plan as necessary. A final status monitoring plan, based on the proposed plan in this section, will be prepared.

7.1 Closure Alternatives

Four alternatives were evaluated in the FFS for the U Plant closure area waste sites (DOE 2003a). These alternatives are:

- Alternative 1 – No action.

- Alternative 2 – Institutional controls/Natural attenuation. Under this alternative, existing soil covers would be maintained as needed and would be available to provide protection from intrusion by biological receptors, along with legal and physical barriers to prevent human access to the site.

- Alternative 3 – Remove and Dispose. Under this alternative, structures and soil with contaminant concentrations above preliminary remediation goals would be excavated using conventional techniques and would be disposed to an approved disposal facility, most probably ERDF. Contaminant concentrations exceeding the human health direct contact or ecological preliminary remediation goals would require removal to a maximum depth of 4.6 m (15 ft). Removal of contaminants beyond the 4.6 m (15 ft) depth may be required to ensure groundwater protection preliminary remediation goals are met. Clean excavated soil would be used as backfill, and contaminant soil would be disposed of at the ERDF.

- Alternative 4 – Capping. Capping consists of constructing surface barriers over contaminated waste sites to prevent infiltration of water and/or to prevent intrusion by human or ecological receptors. The plan proposes an alternative cap for groundwater and human health protection as well as for ecological protection from contaminants.

Of the four options, Alternative 4 (the surface cover) is the proposed closure strategy for the U-12 crib. This alternative would break potential exposure pathways to receptors through placement of a surface barrier and institutional controls. Institutional controls would be maintained until the preliminary remediation goals are achieved. Monitoring the continued integrity of the caps would be incorporated through the CERCLA operations and maintenance plan as necessary.

7.2 Post-Closure Conceptual Model

After placement of a surface barrier (infiltration barrier) over the U-12 crib, vertical transport conditions are expected to change markedly from the case depicted in Section 2.0 (existing conditions). A site contaminant distribution model was developed in the U-Plant Area waste sites FSS (see Figure 2-9 of DOE 2003a) and risk assessments were conducted (Appendix C of DOE 2003a). Based on the FSS and risk assessment results, only nitrate and nitrite were identified as contaminants of concern for the groundwater pathway. Although uranium, technetium-99, cesium-137, and strontium-90 were identified in the vadose zone, they were excluded from the contaminants of concern for the groundwater pathway either because they are retained in the vadose zone or the concentrations (e.g., technetium-99) were below the risk screening criteria.

The more recent core (boreholes 299-W22-75 and 299-W22-78) data, upon which the above risk assessment was based, is consistent with deep coring results from earlier studies, as discussed in the following paragraphs. In addition, most recent spectral gamma logging data collected in 2003 from borehole 299-W22-75 reveals that uranium is not detected approximately 24.7 m (81 ft) below the surface (DOE 2003?). This indicates that no further downward movement of uranium has occurred since previous log results were collected (Brodeur et al. 1993).

Contaminants are the same as described for the effluent discharged to the U-17 crib (Reidel et al. 1993) with the exception that the U-12 crib received acidified radioactive waste. Cores drilled through the crib in the early 1980s (Smith and Kasper 1983) document the effect of the acidic waste on vertical migration of strontium-90 which reached a depth of at least 48 m (157.5 ft). The highest concentrations of strontium-90 are in the interval from 27 to 48 m (88.6 to 157.5 ft). The low pH effluent enhanced the downward migration of strontium-90 while cesium-137 remained near the top (in the upper 12 m [39.4 ft]) of the soil column (Figure 7.1). The difference in behavior is attributed to the different sorption mechanisms for these two fission products.

The depth profiles of calcium carbonate and strontium-90 (Figure 7.1) suggest the fine grain Cold Creek Upper Unit and the deeper, high carbonate, layer (caliche) acted as vertical barriers to further downward migration of the strontium-90. This is consistent with the absence of any evidence of strontium-90 observed in groundwater monitoring wells for the U-12 crib. Based on the crib vadose zone characterization data and past groundwater monitoring data, strontium-90 and other reactive (strong to moderately adsorbed) contaminants should remain above the caliche layer.

As the residual moisture (from the previously oversaturated intervals) gradually drains from the wetted zone beneath the crib, mobile contaminant transport through the vadose zone to groundwater will greatly diminish (due to the surface barrier). Groundwater flow direction will be eastward as the water table declines and returns to pre-Hanford conditions. The groundwater flow rate will very likely also decrease and should be less than 25 m (82 ft) per year.

Under the above conditions, post-closure monitoring frequencies can be relaxed to biennially or triennially. If new sources of contamination are detected in the monitoring network from other source areas (i.e., past-practice discharges from upgradient sites), a larger monitoring network and sampling and analysis plan revision may be required.

7.3 Post-Closure Monitoring Objectives

Groundwater monitoring objectives during the post-closure period are to provide groundwater monitoring data to:

- assess the integrity of the cap and final cover
- track trends (e.g., nitrate) and/or contaminant migration into site-wide plumes
- support decisions concerning integration of RCRA, CERCLA, and site-wide *Atomic Energy Act of 1954* programs into regional monitoring activities
- demonstrate that groundwater protection standards are not exceeded

7.4 Monitoring Constituents and Sampling Frequencies

Post-closure monitoring constituents are derived from groundwater monitoring results for the U-12 crib and on the CERCLA risk assessment data (DOE 2003a). Mobile constituents of interest identified from the, groundwater quality assessment program conducted at the U-12 crib attributed the U-12 crib as the source of elevated nitrate and technetium-99 (Williams and Chou 1997).

The downward migration of nitrate and technetium-99 from the vadose zone as described in Williams and Chou (1997) is still occurring under the current site conditions but concentrations are declining over time (see Figures 1.3 and 1.4). Iodine-129 and tritium were detected at levels above background and/or interim drinking water standards in both upgradient and downgradient wells, however, Williams and Chou (1997) concluded that the U-12 crib is not the source of the elevated tritium and iodine-129.

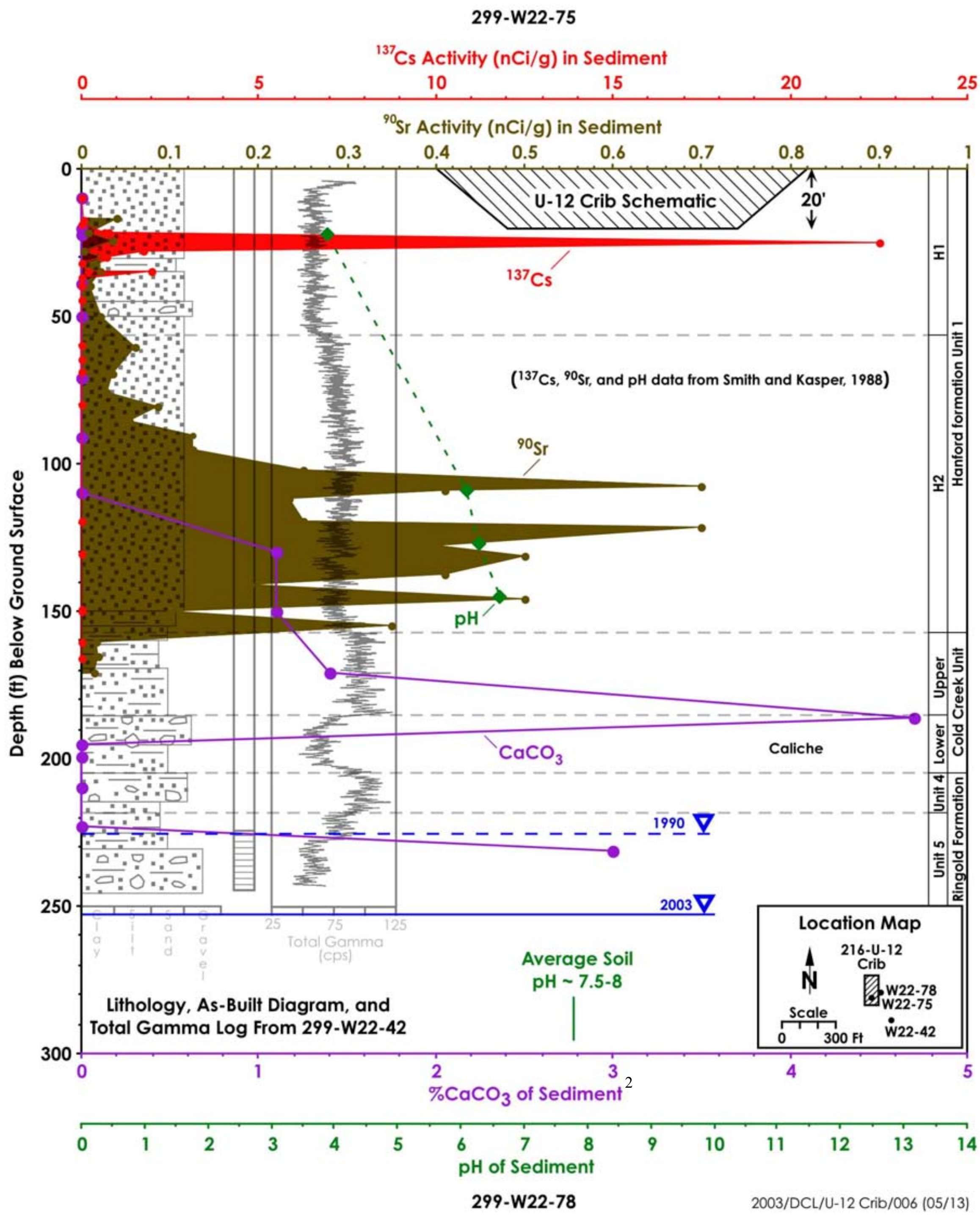

Figure 7.1. Composite Hydrogeology and Contaminant Profile Beneath the 216-U-12 Crib

[2] Data reported in Kelty et al. (1995).

Tritium and iodine-129 are probably caused by an upgradient source of past disposal of process condensate waste from the nuclear fuel dissolution and extraction activities at the REDOX Plant located near the south end of the 200 West Area. Additionally, carbon tetrachloride has been detected in both upgradient and downgradient wells of the U-12 crib. However, carbon tetrachloride is most likely from past disposal of Z-Plant (Plutonium Finishing Plant) process waste in cribs located northwest, upgradient of the U-12 crib. Carbon tetrachloride, iodine-129, and tritium are included in the list of constituents for CERCLA and Surveillance (Atomic Energy Act) monitoring purposes.

Based on the conceptual model as presented in DOE 2003a (Figure 2-9) and results of groundwater monitoring and risk assessment, the constituents and sampling frequencies proposed for the U-12 crib during the post-closure monitoring period are listed in Table 7.1. The list includes the primary RCRA groundwater pathway contaminants of concern (nitrogen in nitrate/nitrite) identified from the risk assessment for the U-12 crib. Mobile constituents previously identified as site-specific CERCLA contaminants are included in the list for performance monitoring purposes (i.e., technetium-99) and to confirm conclusions concerning retention of uranium in the vadose zone. The other constituents identified as "site-wide" are included for the area wide (regional) integrated groundwater monitoring network. Analysis of monitoring data will consist of tracking trends in contaminant concentrations in relation to maximum contaminant levels.

7.5 Monitoring Network

The post-closure groundwater monitoring network for the U-12 crib will be composed of the same four wells as described in Section 4.1 for assessment monitoring. This network will comprise wells installed initially for the RCRA interim-status assessment network for the U-12 crib. They include two existing RCRA standard (WAC 173-160) downgradient wells, 299-W22-79 and 699-36-70A, and two proposed wells that are not yet completed. This network is integrated with the 200-UP-1 Operable Unit regional network (Byrnes and Williams 2003) and will support post-closure monitoring objectives defined above. This network monitors conditions that exist in the upper 10 m (32.8 ft) of the unconfined aquifer. If the two additional network wells have not been completed at the time of closure certification, then this plan will be revised accordingly.

Table 7.1. Proposed Post-Closure Monitoring Constituents and Sampling Frequencies for the 216-U-12 Crib

Constituents	Programs	Sampling Frequency[(a)]
Nitrate	RCRA site specific	Annual
Uranium	CERCLA site specific	Annual
Technetium-99	CERCLA site specific	Annual
Carbon Tetrachloride	CERCLA/site wide	Annual
Iodine-129	CERCLA/site wide	Annual
Tritium	CERCLA/site wide	Annual
(a) Subject to change based on regional or long term monitoring objectives.		

The requirements, objectives, and network design for RCRA groundwater monitoring at the U-12 crib and for the 200-UP-1 Operable Unit regional network have been defined in Byrnes and Williams (2003). Based on the objectives defined in this DQO, the existing interim status U-12 crib network will be modified to increase the number of monitoring wells from the existing two wells (299-W22-79 and 699-36-70A) to four wells. Well deepening will be attempted in two existing dry wells to re-activate the wells. Dry wells 299-W22-8 and 299-W21-51 are identified as well deepening candidate wells (Byrnes and Williams 2003). If well deepening is not practicable then two new replacement wells will be installed at these locations to complete the network. This U-12 crib groundwater monitoring network supports groundwater monitoring objectives for the regional 200-UP-1 groundwater monitoring network (Byrnes and Williams 2003).

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Appendix A

Network Well Information

SUMMARY OF CONSTRUCTION DATA AND FIELD OBSERVATIONS
RESOURCE PROTECTION WELL - 299-W22-8

WELL DESIGNATION	:	299-W22-8
CERCLA UNIT	:	200 Aggregate Area Management Study
RCRA FACILITY	:	Not applicable
HANFORD COORDINATES	:	N 35,409 W 72,710
LAMBERT COORDINATES	:	N 440,524 E 2,222,524 [HANCONV]
DATE DRILLED	:	Apr56
DEPTH DRILLED (GS)	:	286-ft
MEASURED DEPTH (GS)	:	~227.2-ft, 15Jul92
DEPTH TO WATER (GS)	:	236-ft, Apr56; ~226.6-ft, 15Jul92
CASING DIAMETER	:	8-in carbon steel, ~+1.5-283.5-ft
ELEV TOP CASING	:	683.55-ft
ELEV GROUND SURFACE	:	682.0-ft, Estimated
PERFORATED INTERVAL	:	223-283-ft
SCREENED INTERVAL	:	None documented
COMMENTS	:	FIELD INSPECTION, 15Jul92, 8-in carbon steel casing. No pad, no posts, capped and locked. No permanent identification. Not in radiation zone. OTHER:
AVAILABLE LOGS	:	Driller
TV SCAN COMMENTS	:	Not applicable
DATE EVALUATED	:	Not applicable
EVAL RECOMMENDATION	:	Not applicable
LISTED USE	:	Water levels measured, 27Aug67-18Jun90; Not on water sample schedule
PUMP TYPE	:	None documented
MAINTENANCE	:	

WELL CONSTRUCTION AND COMPLETION SUMMARY

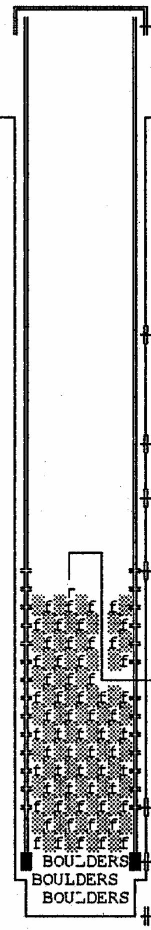
Drilling Method: Cable tool	Sample Method: Hard tool	WELL NUMBER: 299-W22-8 TEMPORARY WELL NO: 241-S-17
Drilling Fluid Used: Water	Additives Used: Not documented	Hanford Coordinates: N/S N 35,409 E/W W 72,710
Driller's Name: Row/Richards	WA State Lic Nr: Not documented	State NAD83 Coordinates: N 440,524 E 2,222,524
Drilling Company: Not documented	Company Location: Not documented	Start Card #: Not documented T___ R___ S___
Date Started: 06Apr56	Date Complete: 19Apr56	Elevation Ground surface (ft): 682.0 Estimated

Depth to water: 236-ft Apr56
(Ground surface) ~226.6-ft Jul92

GENERALIZED STRATIGRAPHY   Driller's Log

0-30: Sandy SILT
30-145: SAND-SILT
145-150: Sandy SILT
150-180: Heavy SILT and SAND
180-215: Heavy SILT-fine GRAVEL
215-230: Heavy SILT
230-232: Small GRAVEL
232-245: SILT-SAND and fine GRAVEL
245-255: GRAVEL, SAND-very little SILT
255-265: GRAVEL-SAND
265-280: Coarse GRAVEL-SAND
280-286: SAND, GRAVEL, some SILT

REMEDIATION:
Sep57 by Row/Roberts
Attempted to clean sand from well. Estimated more than 15-yds of sand removed from hole. Backfilled bottom of well with boulders.



Elevation of reference point: (top of casing)	[683.55-ft]
Height of reference point above ground surface	[~1.5-ft]
Depth of surface seal	[ND]
Type of surface seal: None documented	
I.D. of surface casing (If present)	[ND]
I.D. of riser pipe:	[8-in]
Type of riser pipe: Carbon steel	
Diameter of borehole:	[9-in nom]
Type of filler: Not documented	
Elevation/depth top of seal Type of seal: Not documented	
Depth top of perforations:	[223-ft]
Description of perforations: 223-267-ft, 1 hole/ft spiraled; 267-277-ft, 4 holes/ft; 277-283-ft, 1 hole/ft spiraled	
Depth to bottom, ~227.2-ft, 15Jul92	
Depth bottom of perforations:	[283-ft]
Depth bottom of casing:	[283.5-ft]
Depth bottom of borehole:	[286-ft]

Drawing By: RKL/2W22-08.ASB   Date: 20Apr93

Reference: HANFORD WELLS

SUMMARY OF CONSTRUCTION DATA AND FIELD OBSERVATIONS
RESOURCE PROTECTION WELL - 299-W22-43

WELL DESIGNATION	:	2-W22-43
CERCLA UNIT	:	200 Aggregate Area Management Study
HANFORD COORDINATES	:	N 36,339.1 W 73,376.5 [200W-18Jun90]
LAMBERT COORDINATES	:	N 441,453 E 2,221,855 [HANCONV] N 134,539.24m E 567,532.48m [NAD83-18Jun90]
DATE DRILLED	:	May90
DEPTH DRILLED (GS)	:	244.0-ft
MEASURED DEPTH (GS)	:	244.9-ft, 13May91
DEPTH TO WATER (GS)	:	226.2-ft, Apr90; 230.7-ft, 09Sep92
CASING DIAMETER	:	4-in, stainless steel, +ND~223.7-ft; 6-in, stainless steel, +2.83~0.5-ft (not documented)
ELEV TOP CASING	:	691.35-ft, [200W-18Jun90]
ELEV GROUND SURFACE	:	688.40-ft, Brass cap [200W-18Jun90]
PERFORATED INTERVAL	:	Not applicable
SCREENED INTERVAL	:	223.7~244.0-ft, #10-slot, stainless steel
COMMENTS	:	FIELD INSPECTION, 13May91; Stainless steel casing. 4-ft by 4-ft concrete pad, 4 posts, 1 removable capped and locked, brass cap in pad with well ID. Not in radiation zone. OTHER:
AVAILABLE LOGS	:	Driller
TV SCAN COMMENTS	:	Not applicable
DATE EVALUATED	:	Not applicable
EVAL RECOMMENDATION	:	Not applicable
LISTED USE	:	U-12 Crib Quarterly water level measurement, 20Nov90~09Sep92; Not on water sample schedule
PUMP TYPE	:	Hydrostar
MAINTENANCE	:	

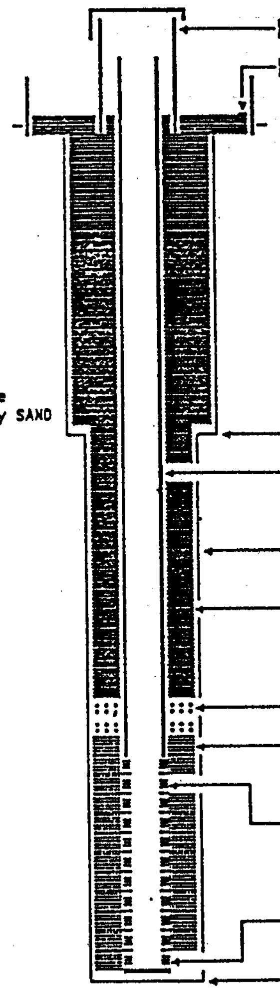
WELL CONSTRUCTION AND COMPLETION SUMMARY

Drilling Method: Cable tool	Sample Method: Drive barrel Hard tool	WELL NUMBER: 299-W22-43 TEMPORARY WELL NO:
Drilling Fluid Used: Water	Additives Used: None	Hanford Coordinates: N/S N 36,339.1 E/W W 73,376.5
Driller's Name: D. Ludke	WA State Lic Nr: Not documented	State NAD83 N 134,539.24m E 567,532.48m Coordinates: N 441,453 E 2,221,855
Drilling Company: Kaiser Engineers Han	Company Location: Richland, WA	Start Card #: Not documented T___ R___ S___
Date Started: 22Feb90	Date Complete: 15May90	Elevation Ground surface (ft): 688.40 Brass cap

Depth to water: 226.2-ft Apr90
(Ground surface) 230.7-ft Sep92

GENERALIZED STRATIGRAPHY — Geologist's Log

5: Slightly muddy SAND
10: Slightly gravelly SAND
15-35: SAND
40: Slightly gravelly SAND
45: Gravelly SAND
50: Slightly gravelly SAND
55-95: SAND
100-110: Slightly muddy SAND
115-135: SAND
140,145: Slightly muddy SAND
150,155: Muddy SAND
160-180: Sandy MUD
185: Sandy MUD, caliche
190: Muddy sandy GRAVEL, caliche
195,200: Slightly gravelly muddy SAND
205-215: Sandy MUD
220-235: Muddy SAND
240: SAND
245: Muddy sandy GRAVEL



Elevation of reference point: [691.35-ft]
(top of casing)
Height of reference point above ground surface [2.83-ft]
Depth of surface seal [0-18-ft]
Type of surface seal:
4-ft by 4-ft concrete pad
Cement grout to 18.0-ft

10 3/4-in nominal hole to 134.9-ft.

I.D. of riser pipe: [4-in]
Type of riser pipe:
Type 304 stainless steel

Diameter of borehole: [9-in nom]
134.9-244.0-ft

Type of filler, 18.0-216.0-ft:
Bentonite crumbles
8-20 mesh

Bentonite pellets, 1/2-3/8-in
216.0-219.4-ft
Depth top of sand pack: [219.4-ft]
40-mesh silica sand
to 242.9-ft

Depth top of screen: [223.7-ft]
4-in, #10-slot, Johnson type 304
stainless steel, wire wrapped,
with bottom cap.

Depth bottom of screen: [244.0-ft]

Depth bottom of borehole: [244.0-ft]

Drawing By: RKL/2W22-43.ASB Date: 07Dec92

Reference: WHC-MR-0208, October 1990
KEH Survey Data Report 18Jun90

WELL SUMMARY SHEET

Page 1 of 1
Date: 9/30/98

Well ID: B8552	Well Name: 299-W22-79
Location: 1/4 mi South of U-Plant, 200W	Project: 1998 RCRA Drilling
Prepared By: DC Weekes — Date: 9/29/98	Reviewed By: EC Rafuse — Date: 10/02/98
Signature: DC Weekes	Signature: EC Rafuse

CONSTRUCTION DATA

Description

8" carbon steel protective casing 3' a.g. to 3' bgs.

4" ID Type 304 stainless steel riser: 2' a.g. — 242.7'

4" ID Type 304 stainless steel continuous wire wrap screen (0.010-in slot): 242.7'–277.8'

Portland cement 0' – 11.1'

Dry bentonite (1/4" + 3/8" pellets and medium chunks): 11.1'–230.4'

Colorado Silica Sand (20-40 mesh): 230.4'–282.6'

Slough 282.6'–286.0'

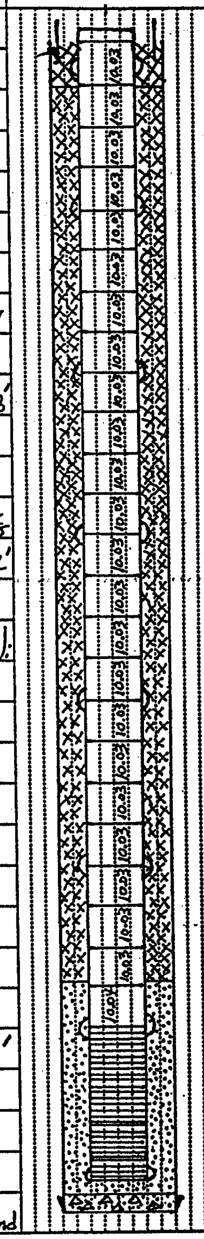
SS Centralizers above and below the screen and every 40 ft and as indicated

Water level (9/30/98): 241.91'

All temporary casing removed.

All depths are in ft below ground

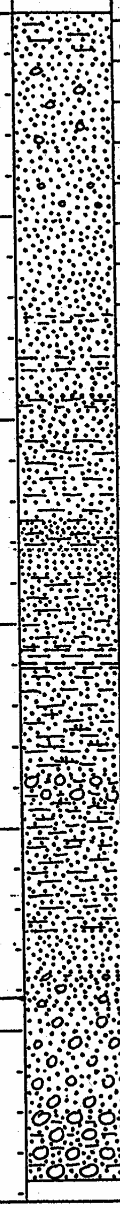
Diagram



GEOLOGIC/HYDROLOGIC DATA

Depth in Feet: 0, 50, 100, 150, 200, 250

Graphic Log



Lithologic Description

0'–12': Silty SAND
12'–34': Gravelly SAND
34'–94': SAND
thin layers of silty sand 76'–78'
thin layers of silty sand @ 85' + 88'
94'–98': Silty SAND
98'–104': SAND
104'–125': Silty SAND
125'–128': SAND
128'–132': Silty SAND
132'–138': SAND
138'–156': Silty SAND
156'–161': SILT
161'–187': Sandy SILT
187'–194': Silty Sandy GRAVEL
194'–226': Sandy SILT
226'–236': SAND
236'–238': Slightly Silty Gravelly SAND
238'–245': Gravelly SAND
245'–270': Sandy GRAVEL
270'–286': Silty Sandy GRAVEL
TD @ 286' 9/26/98

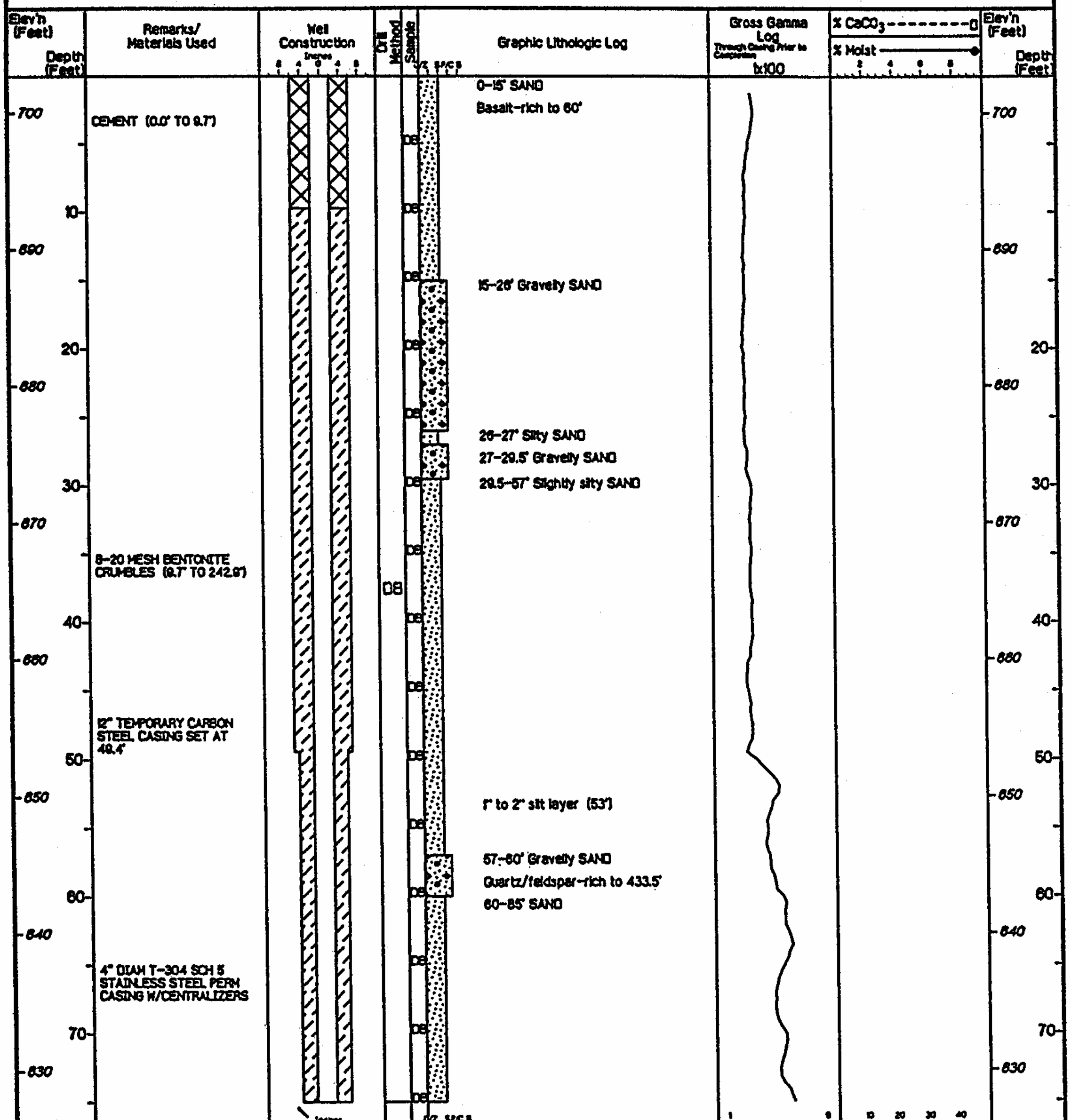
Project: W-152/216-U-12 CRIB RCRA GROUNDWATER MONITORING WELL INSTALLATION		Well No: 699-36-70A	Page 1 of 6
		Total Depth: 440	Static Water Level: 257.85
Date Started: 9-8-94	Date Completed: 5-11-95	Surface Elevation: 702.74	Casing Elevation: 705.43
Location: 200' E OF 200W PERIMETER FENCE		Northing: 134308.839	Easting: 568466.679
Prepared By: CE DEGENHART, et. al.		Hanford N: 35576.56	Hanford W: 70312.20
Drilling Co: KEH	Driller: C WAMSLEY/K OLSON	Drill Meth: CABLE TOOL	Drill Equip: N/A

Screen: 30.26' OF 4" DIAMETER 10-SLOT TYPE 304 STAINLESS STEEL CONTINUOUS WIREWRAP SET FROM 257.48' TO 287.74'

Filter Pack: 20-40 MESH SILICA SAND FROM 246.9' TO 289.5'

Permanent Casing: 4" DIAMETER TYPE 304 SCHEDULE 5 STAINLESS STEEL WITH CENTRALIZERS SET TO 257.48'

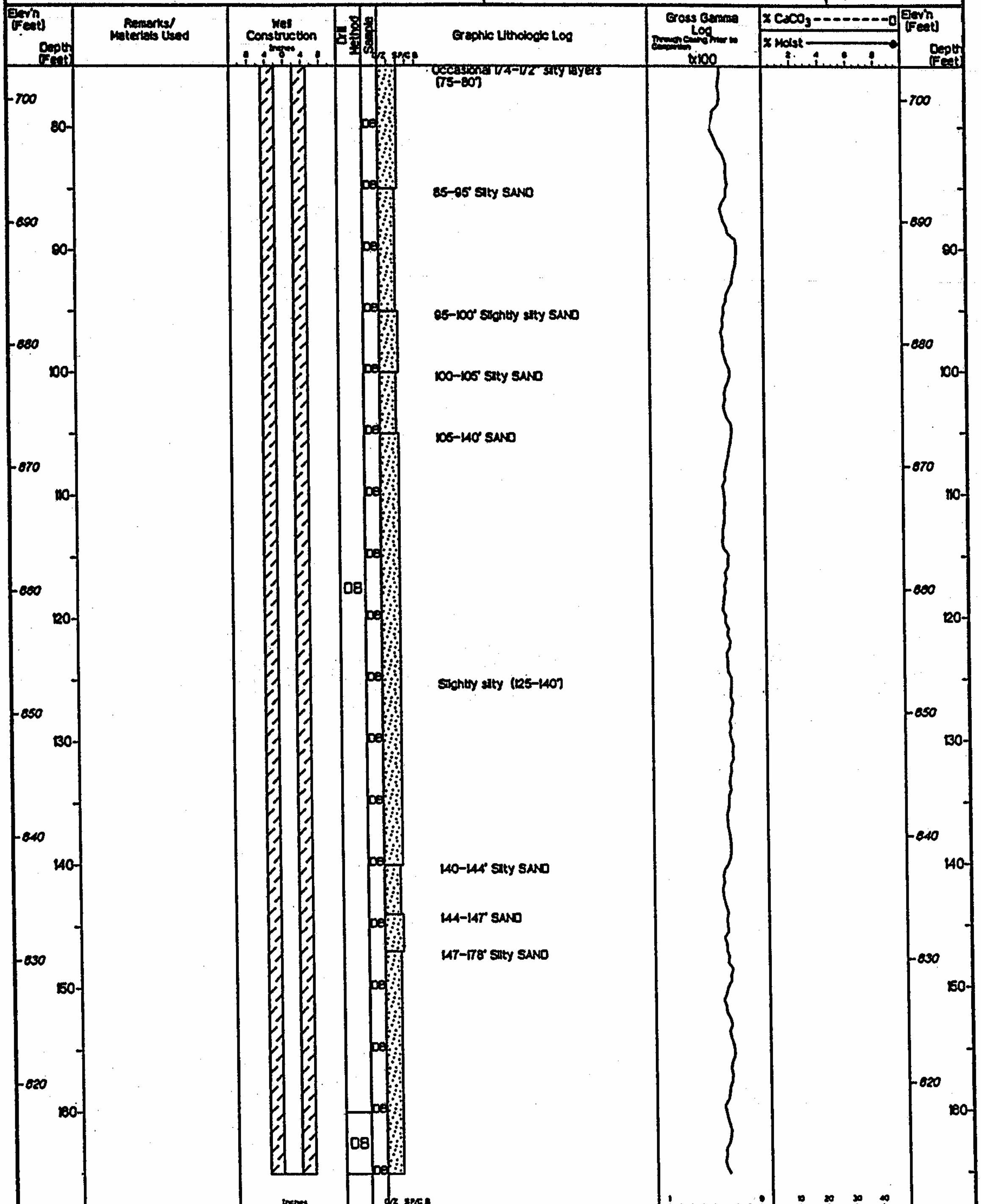
Comments:



Reviewed By: [signature] Date: 7/5/95

Project: W-152/216-U-12 CRIB RCRA GROUNDWATER MONITORING WELL INSTALLATION

Well No: 699-36-70A



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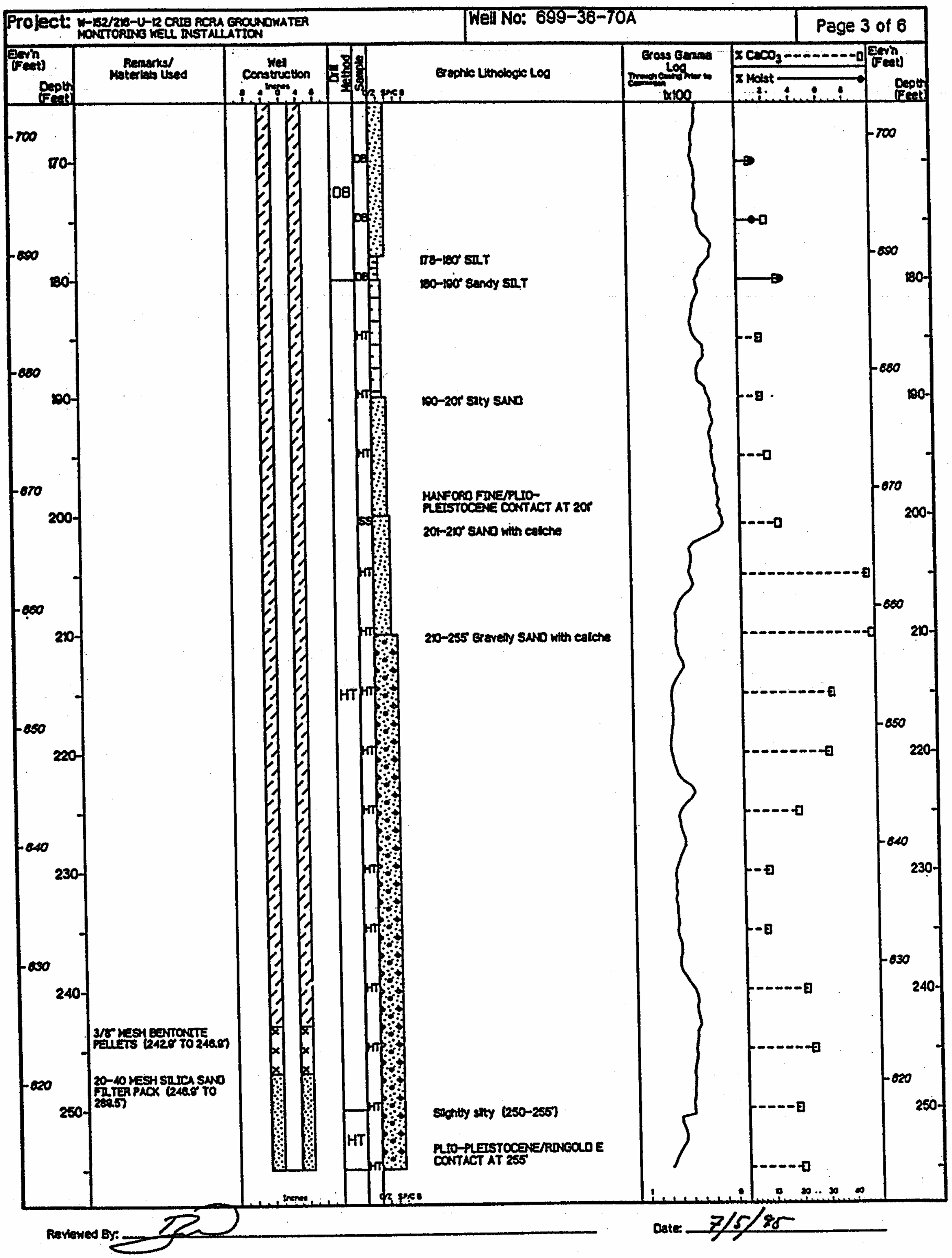
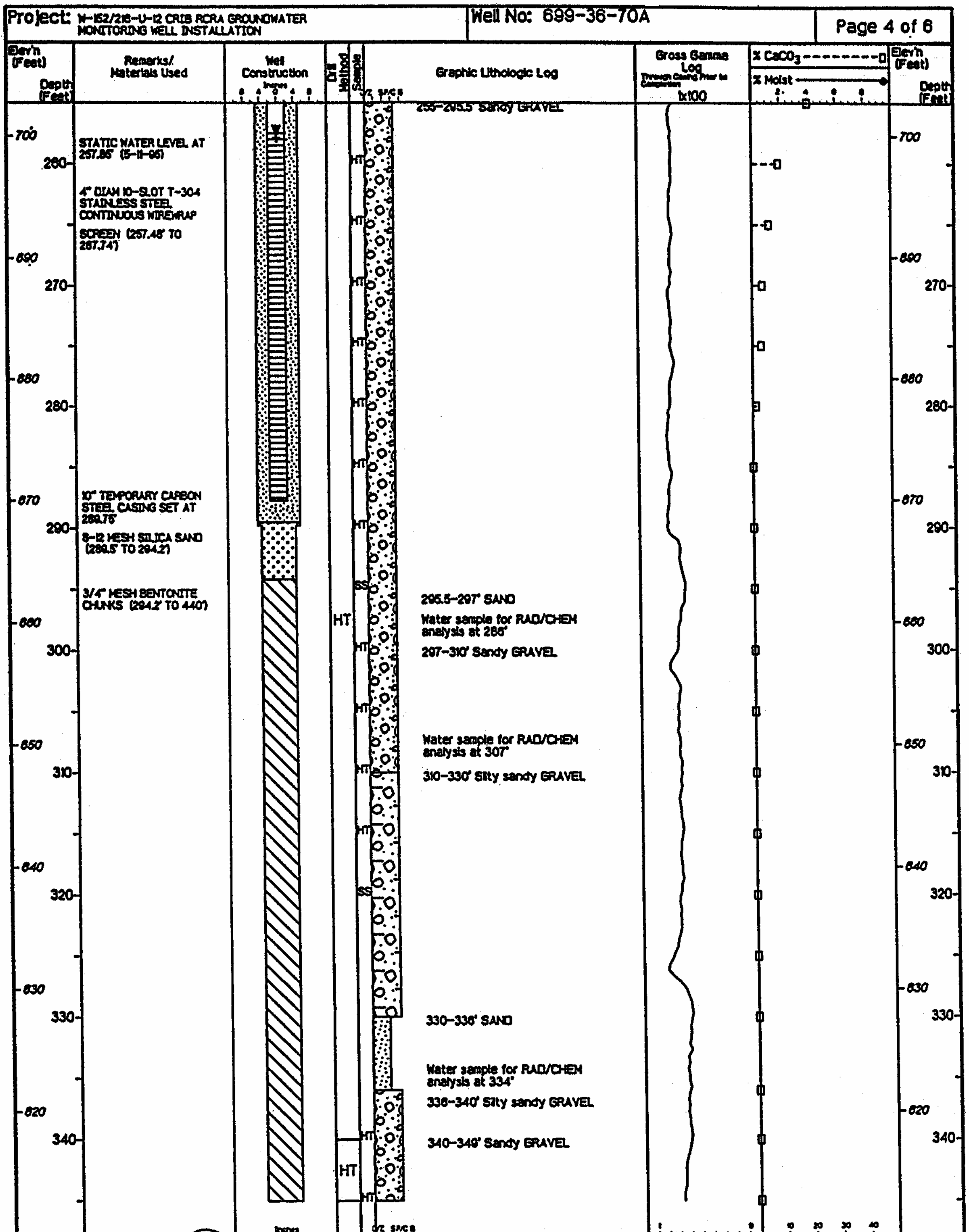
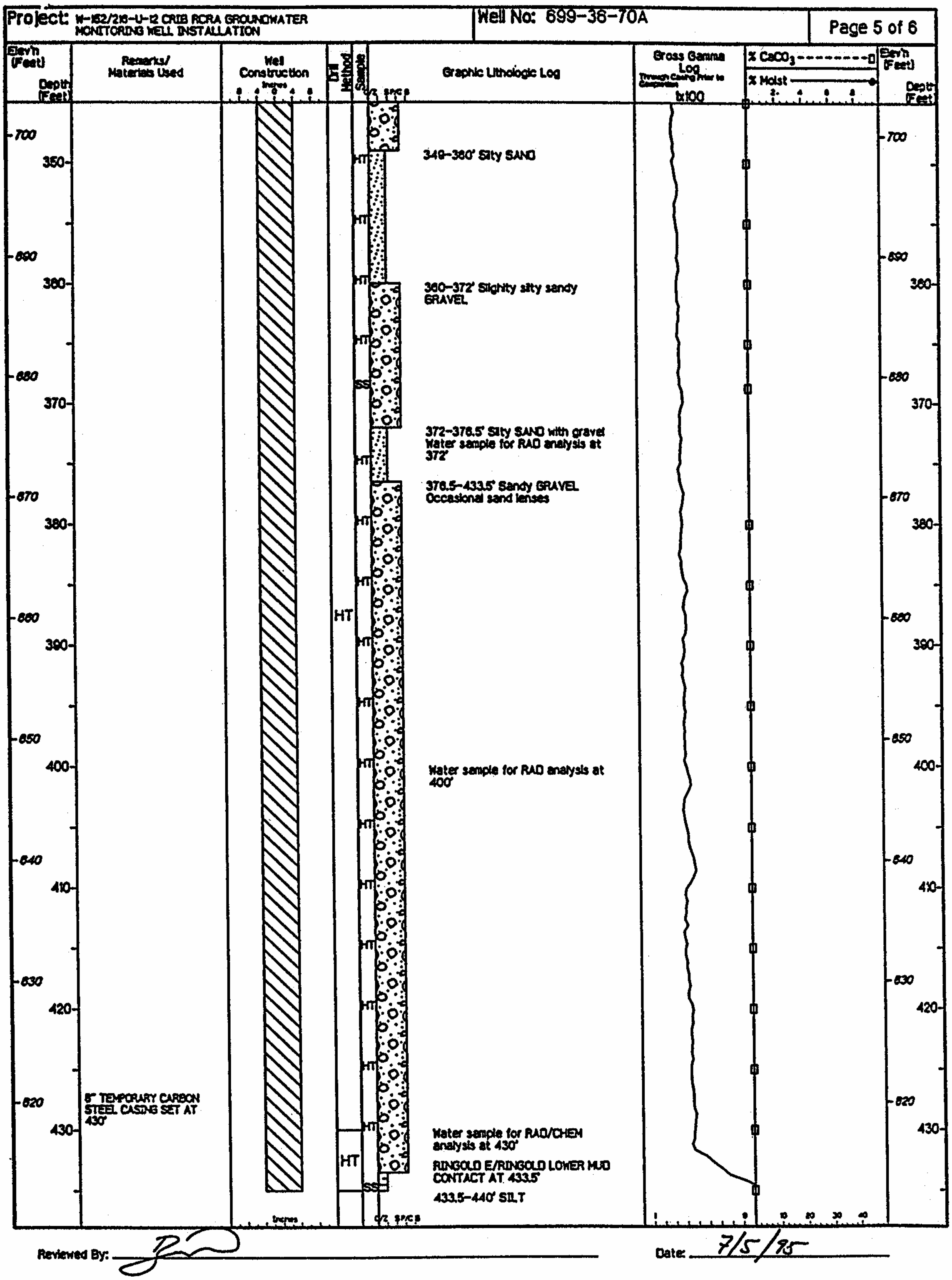

Project: W-152/216-U-12 CRIB RCRA GROUNDWATER MONITORING WELL INSTALLATION
Well No: 699-36-70A
Page 3 of 6
Elev'n (Feet)
Depth (Feet)
Remarks/ Materials Used
Well Construction
Drill Method
Sample
Graphic Lithologic Log
Gross Gamma Log
x100
% CaCO3
% Moist
178-180' SILT
180-190' Sandy SILT
190-201' Silty SAND
HANFORD FINE/PLIO-PLEISTOCENE CONTACT AT 201'
201-210' SAND with caliche
210-255' Gravelly SAND with caliche
Slightly silty (250-255')
PLIO-PLEISTOCENE/RINGOLD E CONTACT AT 255'
3/8" MESH BENTONITE PELLETS (242.9' TO 246.9')
20-40 MESH SILICA SAND FILTER PACK (246.9' TO 268.5')
Reviewed By:
Date: 7/5/95



Reviewed By: ____________________ Date: 7/5/25



Project: W-152/216-U-12 CRIB RCRA GROUNDWATER MONITORING WELL INSTALLATION
Well No: 699-36-70A
Page 5 of 6
Elev'n (Feet)
Depth (Feet)
Remarks/ Materials Used
Well Construction
Drill Method
Sample
Graphic Lithologic Log
Gross Gamma Log
1x100
% CaCO3
% Moist
349-360' Silty SAND
360-372' Slightly silty sandy GRAVEL
372-376.5' Silty SAND with gravel
Water sample for RAD analysis at 372'
376.5-433.5' Sandy GRAVEL
Occasional sand lenses
HT
Water sample for RAD analysis at 400'
8" TEMPORARY CARBON STEEL CASING SET AT 430'
Water sample for RAD/CHEM analysis at 430'
RINGOLD E/RINGOLD LOWER MUD CONTACT AT 433.5'
433.5-440' SILT
Reviewed By:
Date: 7/5/95

Project: W-152/216-U-12 CRIB RCRA GROUNDWATER MONITORING WELL INSTALLATION

Well No: 699-36-70A

Elev'n (Feet)	Depth (Feet)	Remarks/ Materials Used	Well Construction (Inches)	Drill Method	Sample	Graphic Lithologic Log	Gross Gamma Log (Through Casing Prior to Completion) ttx100	% $CaCO_3$ / % Moist	Elev'n (Feet)	Depth (Feet)
700				HT					700	
	440	TOTAL DEPTH = 440'			HT					
690	450								690	450
680	460								680	460
670	470								670	470
660	480								660	480
650	490								650	490
640	500								640	500
630	510								630	510
620	520								620	520

Reviewed By: [signature]

Date: 7/5/95

Appendix B

Data Logs for Well 299-W22-75

Stoller
Grand Junction Office established 1959

299-W22-75 (A7879)
Log Data Report

Borehole Information:

Borehole:	299-W22-75 (A7879)		Site:	216-U-12 Crib	
Coordinates (WA State Plane)		GWL (ft)[1]:	Not reached	GWL Date:	5/22/03
North	East	Drill Date	TOC[2] Elevation	Total Depth (ft)	Type
134,490.42 m	567,595.19 m	April 1982	211.586 m	176.25	Cable tool

Casing Information:

Casing Type	Stickup (ft)	Outer Diameter (in.)	Inside Diameter (in.)	Thickness (in.)	Top (ft)	Bottom (ft)
Threaded Steel	1.25	6 11/16	6	0.344	+1.25	169
Threaded Steel	0.5	8 5/8	Unknown	Unknown	+0.5	60

The logging engineer measured the casing stickup using a steel tape. A caliper was used to determine the outside casing diameter. The caliper and inside casing diameter were measured using a steel tape, and measurements were rounded to the nearest 1/16 in. Casing thickness was calculated.

Borehole Notes:

Borehole coordinates, elevation, and well construction information, as shown in the above tables, are from measurements by Stoller and Duratek field personnel, Ledgerwood (1993), and HWIS[3]. Zero reference is the top of the 6-in. casing. Grout is not present at the surface in the annulus between the casings but is observed on the ground surface surrounding the 8-in. casing.

Logging Equipment Information:

Logging System:	Gamma 2E		Type: 70% HPGe (34TP40587A)
Calibration Date:	03/2003	Calibration Reference:	GJO-2003-430-TAC
		Logging Procedure:	MAC-HGLP 1.6.5, Rev. 0

Logging System:	Gamma 1C		Type: High Rate Detector (39A314)
Calibration Date:	04/2003	Calibration Reference:	GJO-2003-429-TAC
		Logging Procedure:	MAC-HGLP 1.6.5, Rev. 0

Spectral Gamma Logging System (SGLS) Log Run Information:

Log Run	1	2	3	4/ Repeat	
Date	5/22/03	5/22/03	5/27/03	5/27/03	
Logging Engineer	Spatz	Spatz	Spatz	Spatz	
Start Depth (ft)	176.0	59.0	44.0	82.0	
Finish Depth (ft)	58.0	43.0	2.0	64.0	
Count Time (sec)	100	200	200	100	
Live/Real	R	R	R	R	

Log Run	1	2	3	4/ Repeat	
Shield (Y/N)	N	N	N	N	
MSA Interval (ft)	1.0	1.0	1.0	1.0	
ft/min	N/A[4]	N/A	N/A	N/A	
Pre-Verification	BE031CAB	BE031CAB	BE032CAB	BE032CAB	
Start File	BE031000	BE031119	BE032000	BE032043	
Finish File	BE031118	BE031135	BE032042	BE032061	
Post-Verification	BE031CAA	BE031CAA	BE032CAA	BE032CAA	
Depth Return Error (in.)	N/A	0	0	0	
Comments	Fine gain adjustments made after files: -012, -023, -077, and -118.	No fine-gain adjustment.	No fine-gain adjustment.	No fine-gain adjustment.	

High Rate Logging System (HRLS) Log Run Information:

Log Run	1	2/Repeat			
Date	6/03/03	6/03/03			
Logging Engineer	Spatz	Spatz			
Start Depth (ft)	27.0	26.0			
Finish Depth (ft)	20.0	24.0			
Count Time (sec)	300	300			
Live/Real	R	R			
Shield (Y/N)	N	N			
MSA Interval (ft)	1.0	1.0			
ft/min	N/A	N/A			
Pre-Verification	AC071CAB	AC071CAB			
Start File	AC072000	AC072008			
Finish File	AC072007	AC072010			
Post-Verification	AC072CAA	AC072CAA			
Depth Return Error (in.)	N/A	0			
Comments	No fine-gain adjustment.	No fine-gain adjustment.			

Logging Operation Notes:

Zero reference was top of the 6-in. casing. Logging was performed with a centralizer installed on the sonde. Pre- and post-survey verification measurements for the SGLS were acquired with the Amersham KUT (^{40}K, ^{238}U, and ^{232}Th) verifier with serial number 118. HRLS data were collected using Gamma 1C. Pre- and post-survey verification measurements for the HRLS were acquired with the ^{137}Cs verifier with serial number 1013.

Analysis Notes:

Analyst:	Sobczyk	Date:	6/5/03	Reference:	GJO-HGLP 1.6.3, Rev. 0

SGLS pre-run and post-run verification spectra were collected at the beginning and end of the day. All of the verification spectra were within the control limits except for pre-run verification spectrum BE031CAB. BE031CAB was below the lower control limit for the 609-keV, 1461-keV, and 2615-keV full-width at half-maximum values. The peak counts per second (cps) at the 609-keV, 1461-keV, and 2615-keV photopeaks on the post-run verification spectra as compared to the pre-run verification spectra for each day were between 0.3 and 2.4 percent lower at the end of the day. Examinations of spectra indicate that the detector appears to have functioned normally during logging, and the spectra are accepted.

HRLS pre-run and post-run verification spectra were collected at the beginning and end of the day. The spectra were within the acceptance criteria for the field verification of the Gamma 1C logging system (HRLS).

Log spectra were processed in batch mode using APTEC SUPERVISOR to identify individual energy peaks and determine count rates. Post-run verification spectra were used to determine the energy and resolution calibration for processing the data using APTEC SUPERVISOR. Concentrations were calculated in EXCEL (source files: G2EMar03.xls and G1CApr03). Zero reference was the top of the 6-in. casing. On the basis of Ledgerwood (1993), the casing configuration was assumed to be a string of 8-in. casing with a thickness of 0.322 in. to 60 ft, a string of 6-in. casing with a thickness of 0.344 in. to 168 ft, and open-hole below 168 ft. The 8-in. casing thickness of 0.322 in. is the published value for ASTM schedule-40 steel pipe (a commonly used casing material at Hanford). Where more than one casing exists at a depth, the casing correction is additive (e.g., the correction for both the 8-in. and 6-in. casing would be 0.322 in. + 0.344 in. = 0.666 in.). A water correction was not needed or applied to the data.

Using the SGLS, dead time greater than 40 percent was encountered in the interval from 21 to 26 ft, and data from this region were considered unreliable. At SGLS dead time greater than 40 percent, peak spreading and pulse pile-up effects may result in underestimation of activities. This effect is not entirely corrected by the dead time correction, and the extent of error increases with increasing dead time. SGLS dead time corrections were applied when dead time surpassed 10 percent. The HRLS was utilized to obtain data where the SGLS dead time exceeded 40 percent.

Log Plot Notes:

Separate log plots are provided for gross gamma and dead time, naturally occurring radionuclides (^{40}K, ^{238}U, and ^{232}Th), and man-made radionuclides. Plots of the repeat logs versus the original logs are included. In addition, a comparison log plot of man-made radionuclides is provided to compare the data collected by Westinghouse Hanford Company's Radionuclide Logging System (RLS) with SGLS data. For each radionuclide, the energy value of the spectral peak used for quantification is indicated. Unless otherwise noted, all radionuclides are plotted in picocuries per gram (pCi/g). The open circles indicate the minimum detectable level (MDL) for each radionuclide. Error bars on each plot represent error associated with counting statistics only and do not include errors associated with the inverse efficiency function, dead time correction, or casing correction. These errors are discussed in the calibration report. A combination plot is also included to facilitate correlation. The ^{214}Bi peak at 1764 keV was used to determine the naturally occurring ^{238}U concentrations on the combination plot rather than the ^{214}Bi peak at 609 keV because it is less affected by the presence of radon in the borehole.

Results and Interpretations:

^{137}Cs, ^{235}U (based on the 186-keV photopeak), and ^{238}U (based on the 1001-keV photopeak) were the man-made radionuclides detected in this borehole. ^{137}Cs was detected in the interval from 17 to 61 ft with concentrations ranging from 0.3 to 8,400 pCi/g. The maximum concentration of ^{137}Cs was measured at 25 ft. ^{137}Cs was detected at a depth of 12 ft with a concentration near the MDL (0.2 pCi/g). ^{238}U was detected in the intervals from 17 to 20 ft, 29 to 31 ft, 37 to 53 ft, and 61 to 81 ft with an MDL of at least 10 pCi/g. In the interval from 17 to 20 ft, ^{238}U was detected with concentrations ranging from 55 to 330 pCi/g. In the interval from 29 to 31 ft, ^{238}U was detected with concentrations ranging from 20 to 30 pCi/g. In the interval from 37 to 53 ft, ^{238}U was detected with concentrations ranging from 17 to 75 pCi/g. ^{238}U was detected in the interval from 61 to 81 ft with concentrations ranging from 17 to 335 pCi/g. The maximum concentration of ^{238}U was measured at 76 ft, although the highest concentration may be in the interval of high dead time where the MDL significantly increases. ^{235}U was detected in the intervals from 18 to 19 ft, 68 to 81 ft, and at 44 ft with an MDL of at least 1.5 pCi/g. ^{235}U concentrations ranged from 6 to 9 pCi/g at 18 and 19 ft. In the interval from 68 through 81 ft, ^{235}U concentrations ranged from 1.8 to 22 pCi/g. ^{235}U was detected at a depth of 44 ft with a concentration of 5 pCi/g. It is probable that ^{235}U exists in the same intervals as the ^{238}U (based on the 1001-keV photopeak), but the ^{235}U concentration falls below its respective MDL.

The behavior of the naturally occurring ^{238}U log (measured by ^{214}Bi) suggests that radon may be present inside the borehole casing. Determination of ^{238}U is based on measurement of gamma activity at 609 and/or 1764 keV associated with ^{214}Bi, under the assumption of secular equilibrium in the decay chain. However, ^{214}Bi is also a short-term daughter of ^{222}Rn. When radon is present, ^{214}Bi will tend to "plate" onto the casing wall and will quickly reach equilibrium with ^{222}Rn. Because the additional ^{214}Bi resulting from radon is on the inside of the casing, the effect of the casing correction is to amplify the 609 photopeak relative to the 1764 photopeak. (The magnitude of the casing correction factor decreases with increasing energy, but gamma rays originating inside the casing are not attenuated.) The reason for variations in radon content between log runs on successive days is not known. Variations in radon content in boreholes are probably related to variations in surface weather conditions. Radon daughters such as ^{214}Bi may also "plate" onto the sonde itself. When this occurs, there is a gradual increase in total counts as well as photopeak counts associated with ^{214}Bi and ^{214}Pb. This phenomenon appears to best explain the observed discrepancy in ^{238}U values based on 609 keV versus those based on 1764 keV between 82 and 44 ft.

The presence of radon is not an indication of man-made contamination; it is derived from decay of naturally occurring uranium. As a gas, radon moves easily in the subsurface, and concentrations of radon and its associated progeny can change quickly.

The plots of the repeat logs demonstrate reasonable repeatability of the HRLS and SGLS data. ^{137}Cs (662-keV) concentrations are comparable between the repeat and original HRLS log runs. Taking into account the effects of radon, the plots of the repeat logs demonstrate reasonable repeatability of the SGLS data for the man-made radionuclides and natural radionuclides at energy levels of 186, 662, 1001, 1461, 1764, and 2614 keV.

Recognizable changes in the KUT logs occurred in this borehole. A gradual increase of approximately 8 pCi/g in apparent ^{40}K concentrations occurs between 30 and 62 ft. Above 20 ft, ^{40}K concentrations are relatively low, which indicates the surface seal of grout around the borehole reported by Ledgerwood (1993). ^{232}Th concentrations increase by 0.5 pCi/g at 19 ft. The increase in ^{40}K and ^{232}Th concentrations at 37 ft may correspond with the silt layer identified at 37 ft in the geologist's log (Ledgerwood 1993).

Comparison log plots of data collected in 1991 by Westinghouse Hanford Company and in 2003 by Stoller are included. The 1991 concentration data for ^{137}Cs are decayed to the date of the HRLS logging event in June 2003 and shifted from a ground level reference to a TOC reference. The RLS tool saturated in the interval from 21 to 27 ft. On the 2003 logs, the apparent ^{137}Cs concentrations are as predicted by decay alone when compared to the 1991 log except for the depths of 138, 148, 164, and 166 ft. The report written at the time of the 1991 RLS logging event reported that no man-made radionuclides were detected below 80 ft. Comparing the two logging events, the $^{235/238}U$ concentrations based on the RLS appear slightly higher than the SGLS.

Because of the presence of $^{235/238}U$ in the vadose zone, it is recommended that this borehole be logged periodically to verify that changes in $^{235/238}U$ concentrations are not occurring. The interval from ground surface to total depth should be logged again in 5 years.

References:

Ledgerwood, R.K., 1993. *Summaries of Well Construction Data and Field Observations for Existing 200-West Resource Protection Wells*, WHC-SD-ER-TI-005, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

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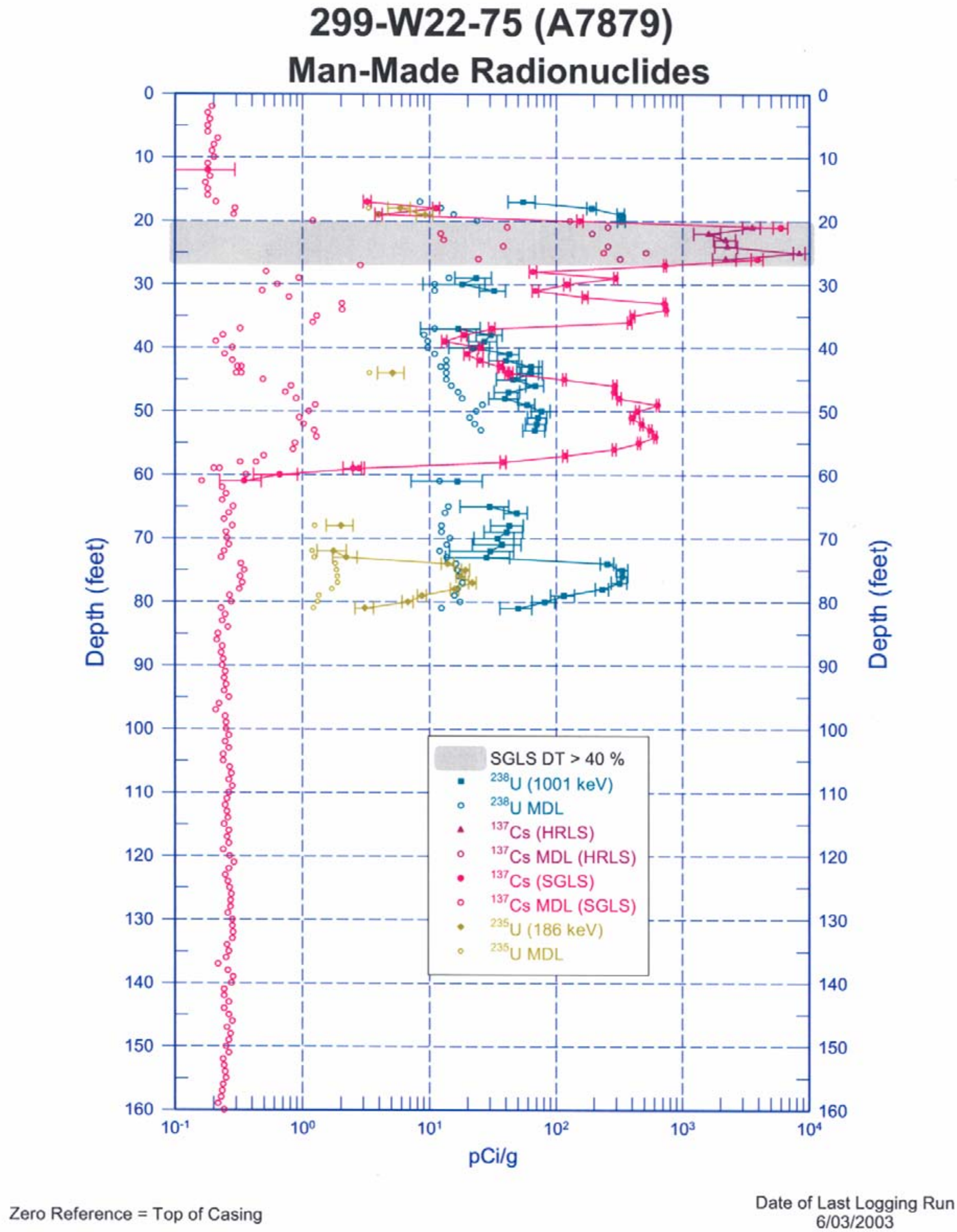
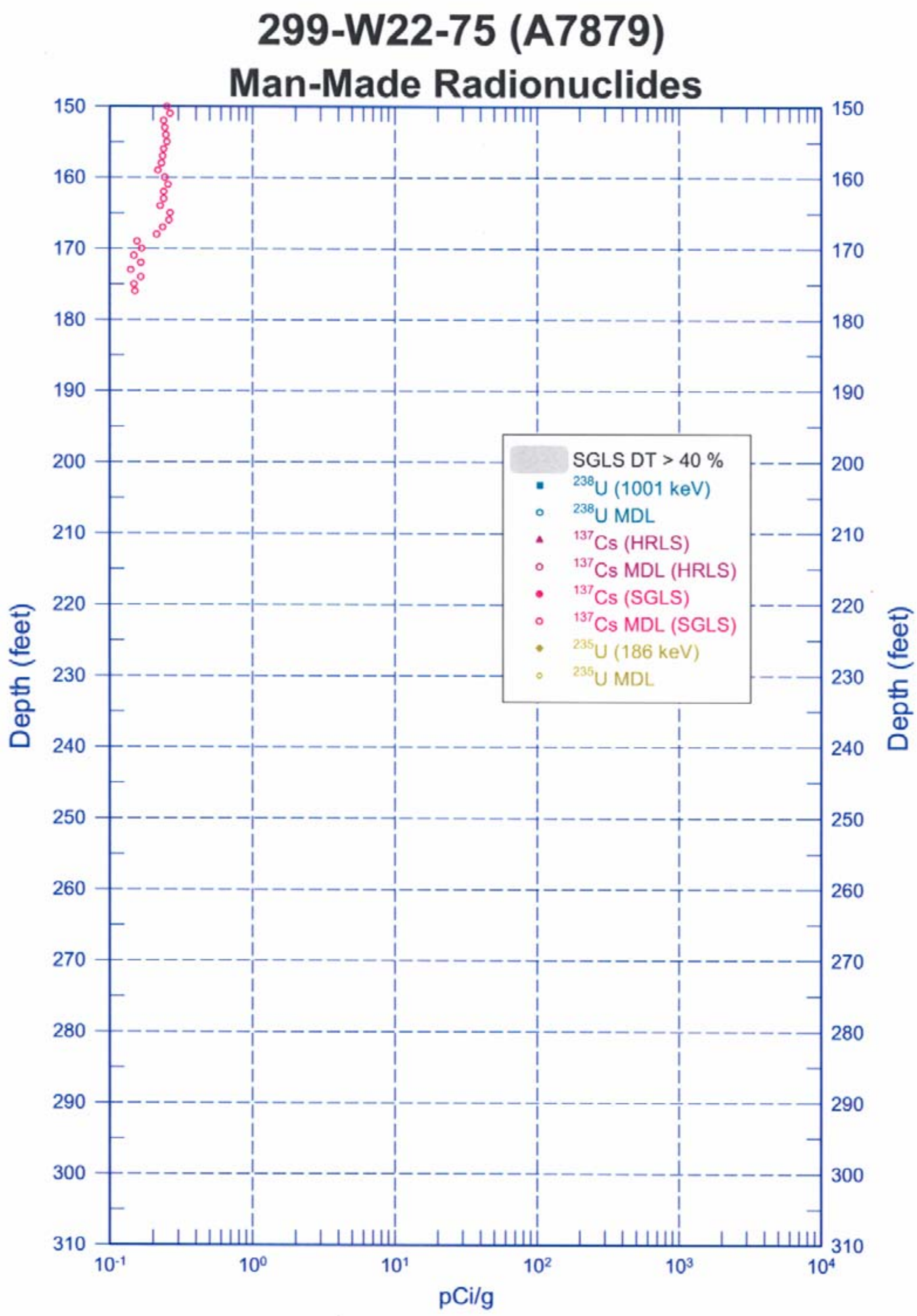
[1] GWL – groundwater level
[2] TOC – top of casing
[3] HWIS – Hanford Well Information System
[4] N/A – not applicable

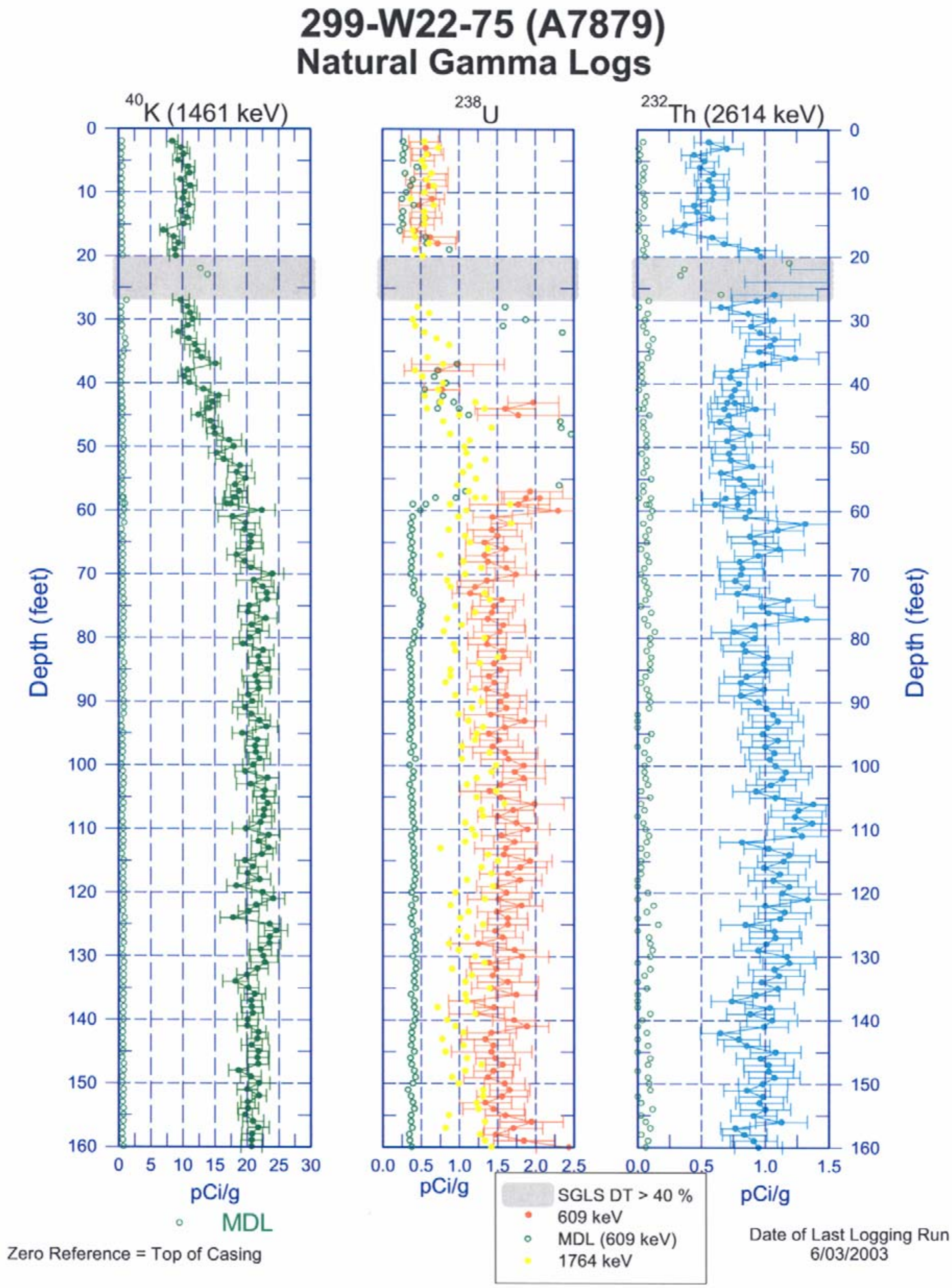


299-W22-75 (A7879)
Man-Made Radionuclides
Depth (feet)
pCi/g
SGLS DT > 40 %
238U (1001 keV)
238U MDL
137Cs (HRLS)
137Cs MDL (HRLS)
137Cs (SGLS)
137Cs MDL (SGLS)
235U (186 keV)
235U MDL
Zero Reference = Top of Casing
Date of Last Logging Run
6/03/2003

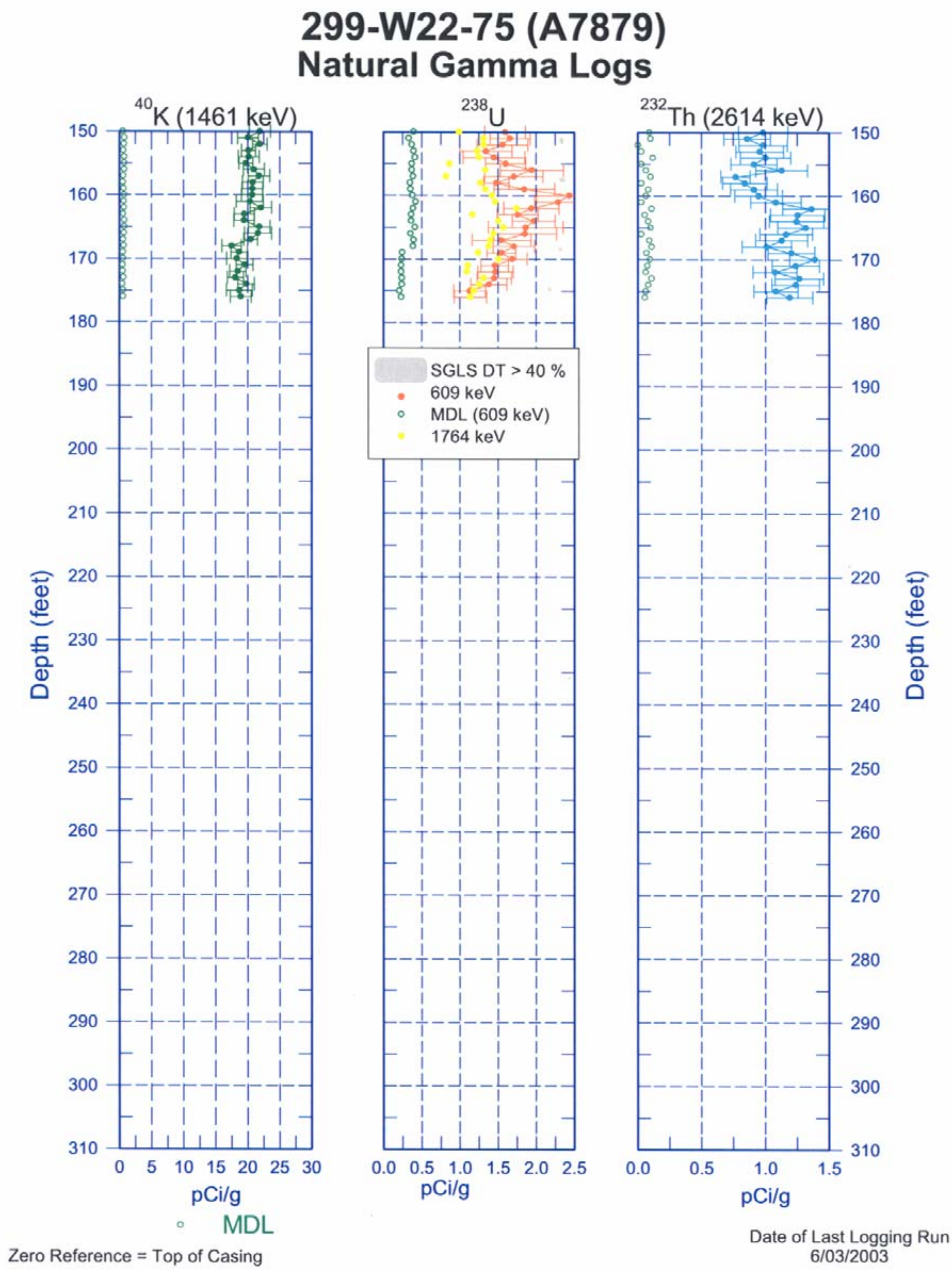


Zero Reference = Top of Casing

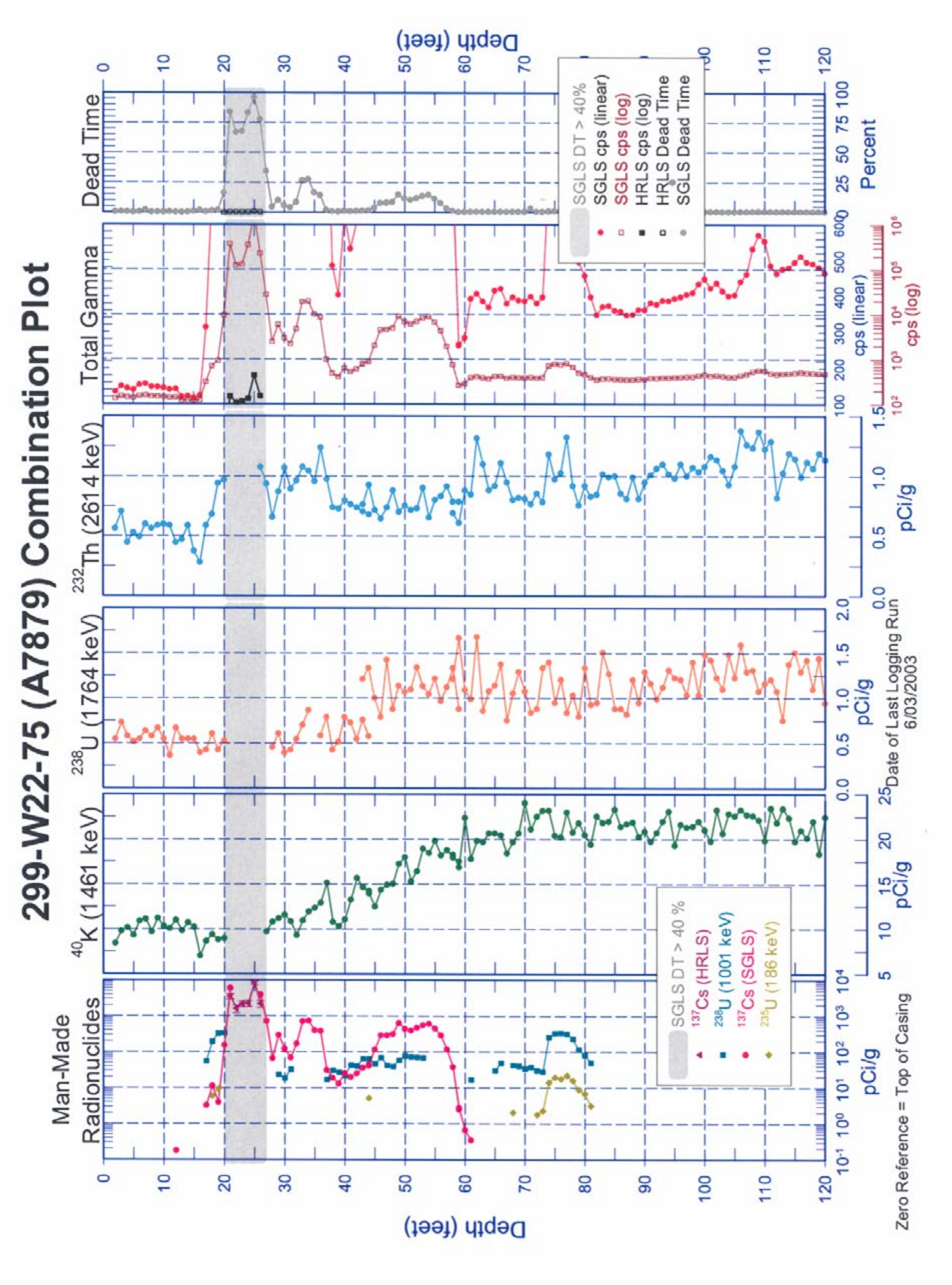
Date of Last Logging Run
6/03/2003

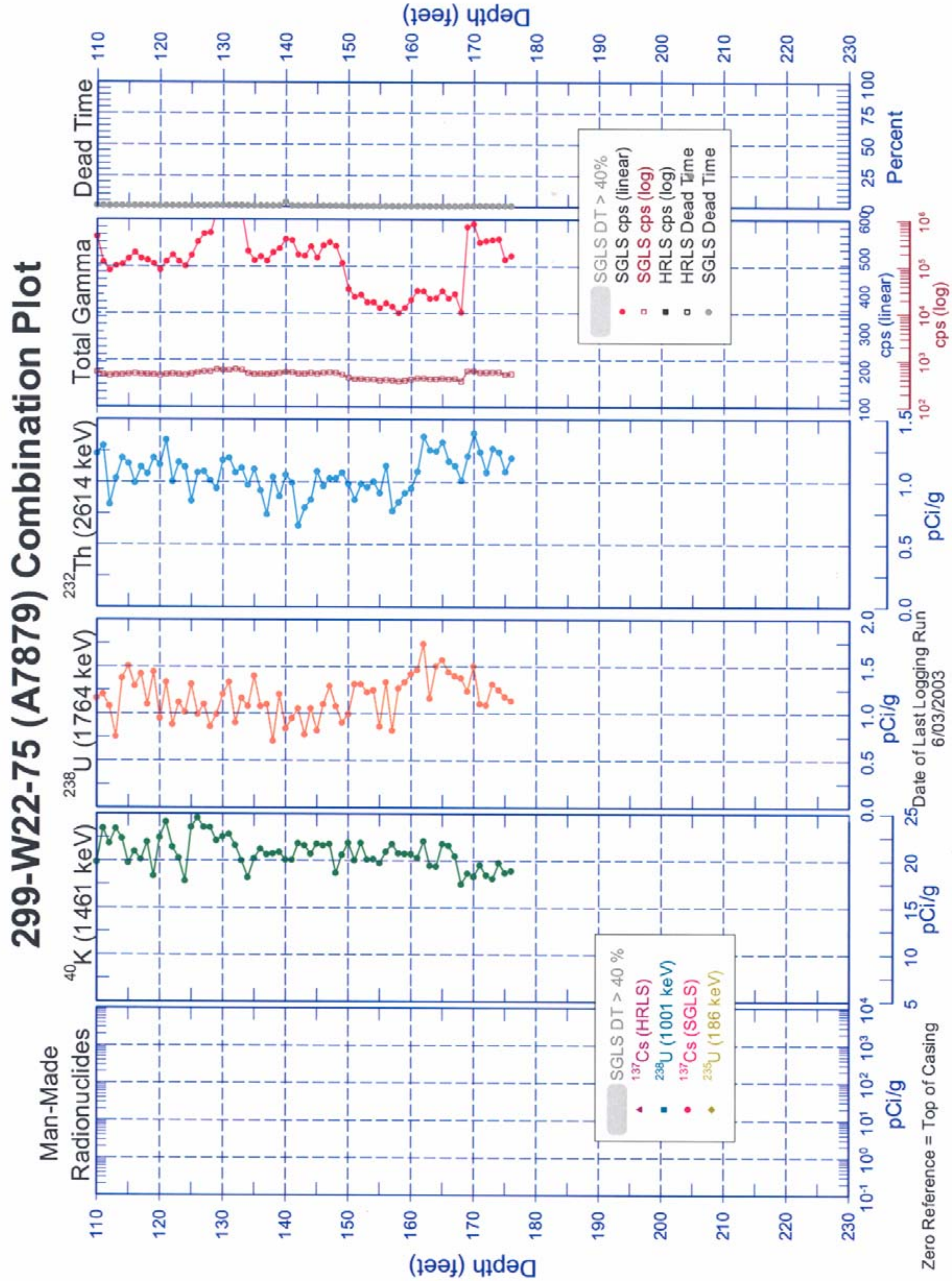


299-W22-75 (A7879)
Natural Gamma Logs
40K (1461 keV)
238U
232Th (2614 keV)
Depth (feet)
pCi/g
MDL
SGLS DT > 40 %
609 keV
MDL (609 keV)
1764 keV
Zero Reference = Top of Casing
Date of Last Logging Run
6/03/2003

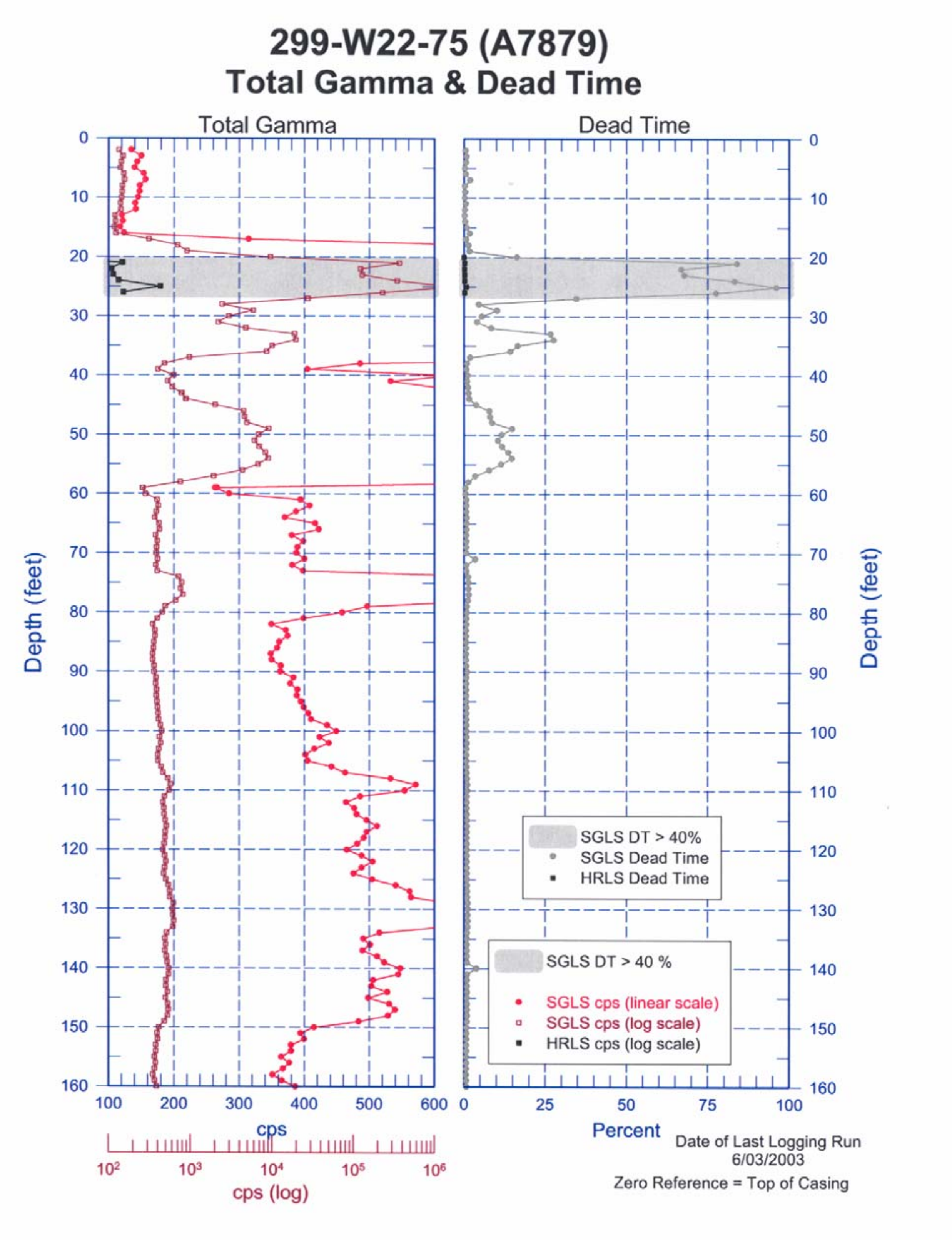


299-W22-75 (A7879)
Natural Gamma Logs
40K (1461 keV)
238U
232Th (2614 keV)
Depth (feet)
pCi/g
MDL
SGLS DT > 40 %
609 keV
MDL (609 keV)
1764 keV
Zero Reference = Top of Casing
Date of Last Logging Run
6/03/2003

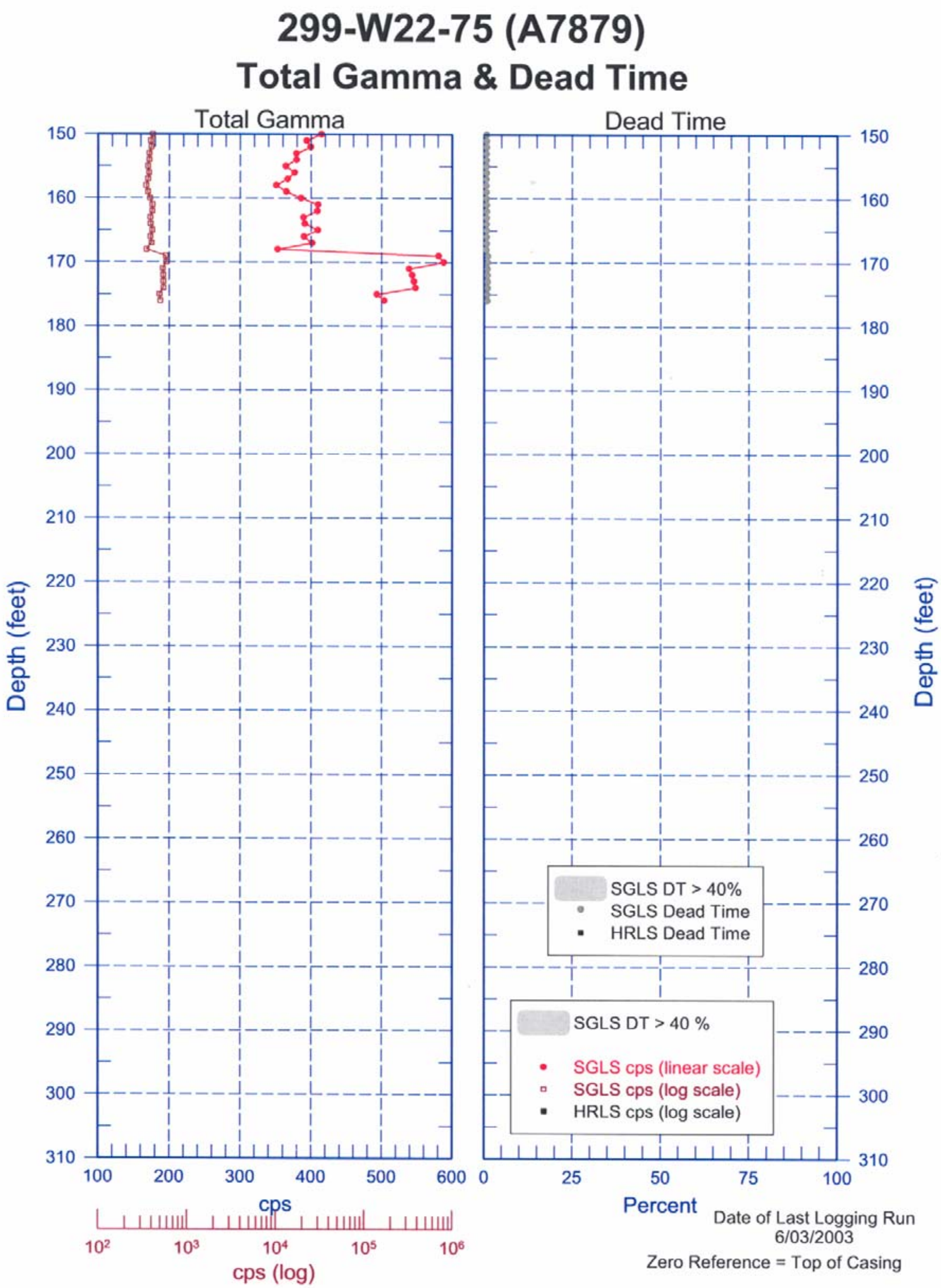

299-W22-75 (A7879) Combination Plot
Man-Made Radionuclides
^{40}K (1461 keV)
^{238}U (1764 keV)
^{232}Th (2614 keV)
Total Gamma
Dead Time
Depth (feet)
pCi/g
cps (linear)
cps (log)
Percent
Date of Last Logging Run 6/03/2003
Zero Reference = Top of Casing
SGLS DT > 40 %
^{137}Cs (HRLS)
^{238}U (1001 keV)
^{137}Cs (SGLS)
^{235}U (186 keV)
SGLS DT > 40%
SGLS cps (linear)
SGLS cps (log)
HRLS cps (log)
HRLS Dead Time
SGLS Dead Time



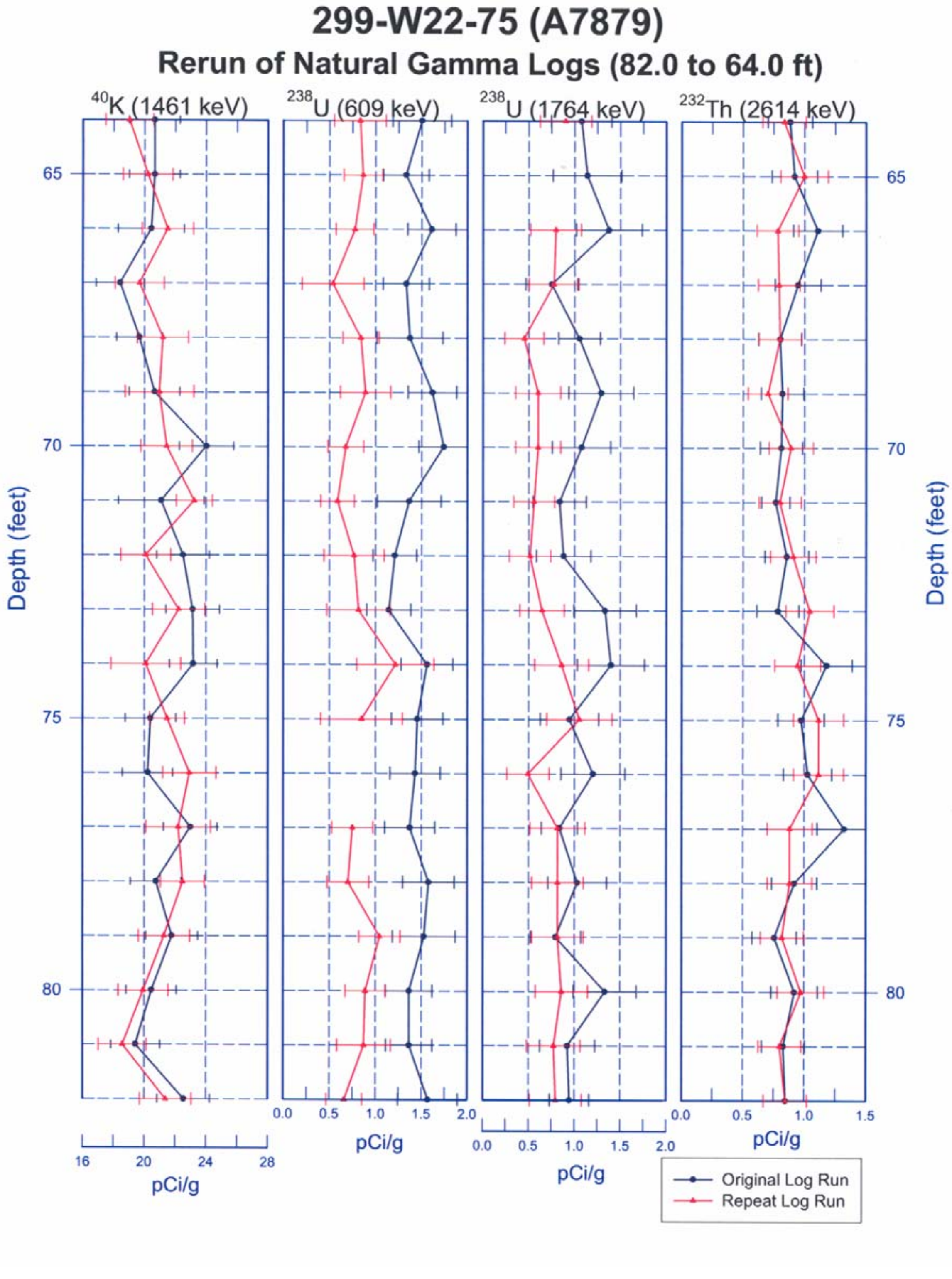
299-W22-75 (A7879) Combination Plot
Man-Made Radionuclides
40K (1461 keV)
238U (1764 keV)
232Th (2614 keV)
Total Gamma
Dead Time
Depth (feet)
pCi/g
cps (linear)
cps (log)
Percent
SGLS DT > 40 %
137Cs (HRLS)
238U (1001 keV)
137Cs (SGLS)
235U (186 keV)
SGLS DT > 40%
SGLS cps (linear)
SGLS cps (log)
HRLS cps (log)
HRLS Dead Time
SGLS Dead Time
Date of Last Logging Run
6/03/2003
Zero Reference = Top of Casing

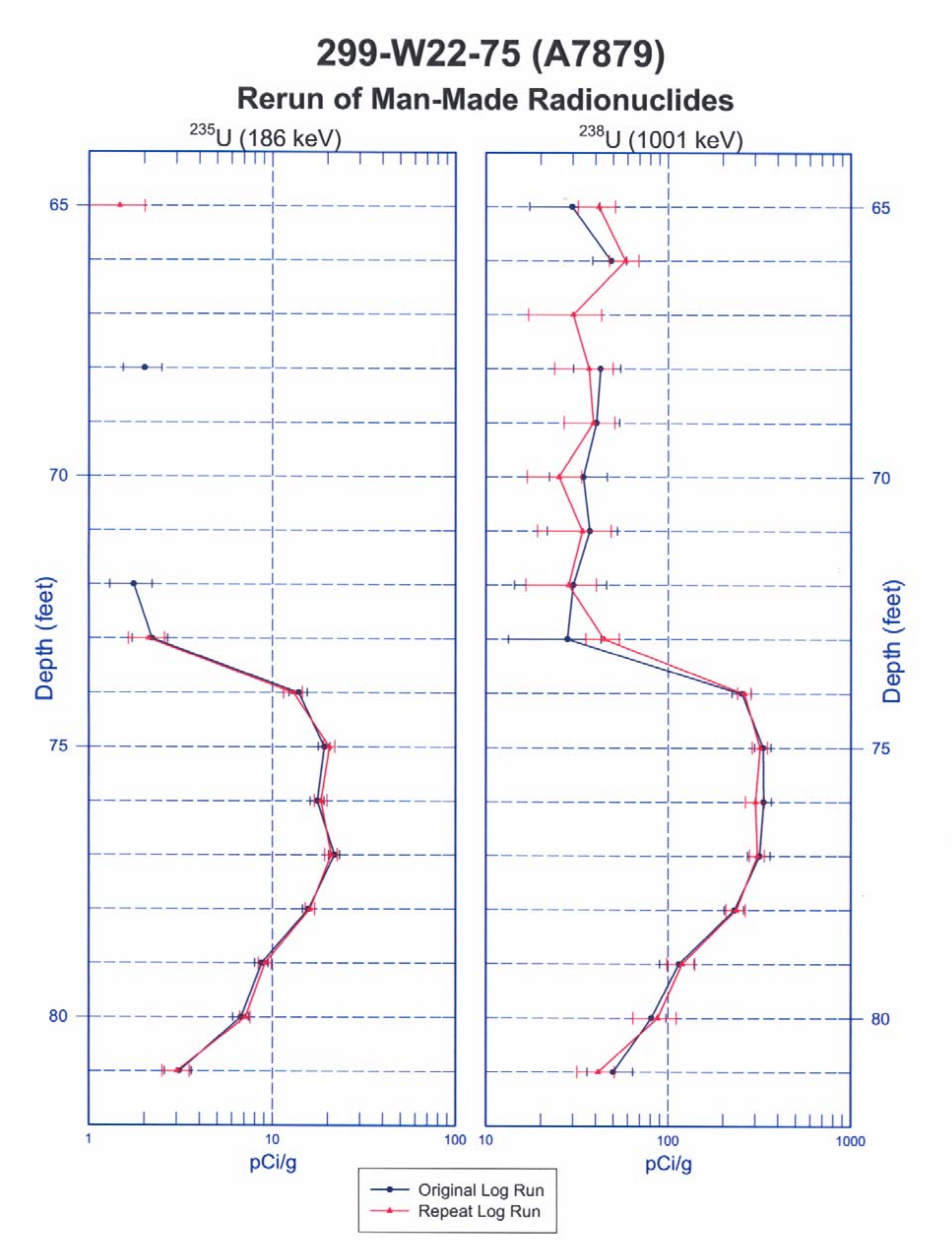


299-W22-75 (A7879)
Total Gamma & Dead Time
Total Gamma
Dead Time
Depth (feet)
cps
cps (log)
Percent
SGLS DT > 40%
SGLS Dead Time
HRLS Dead Time
SGLS DT > 40 %
SGLS cps (linear scale)
SGLS cps (log scale)
HRLS cps (log scale)
Date of Last Logging Run
6/03/2003
Zero Reference = Top of Casing



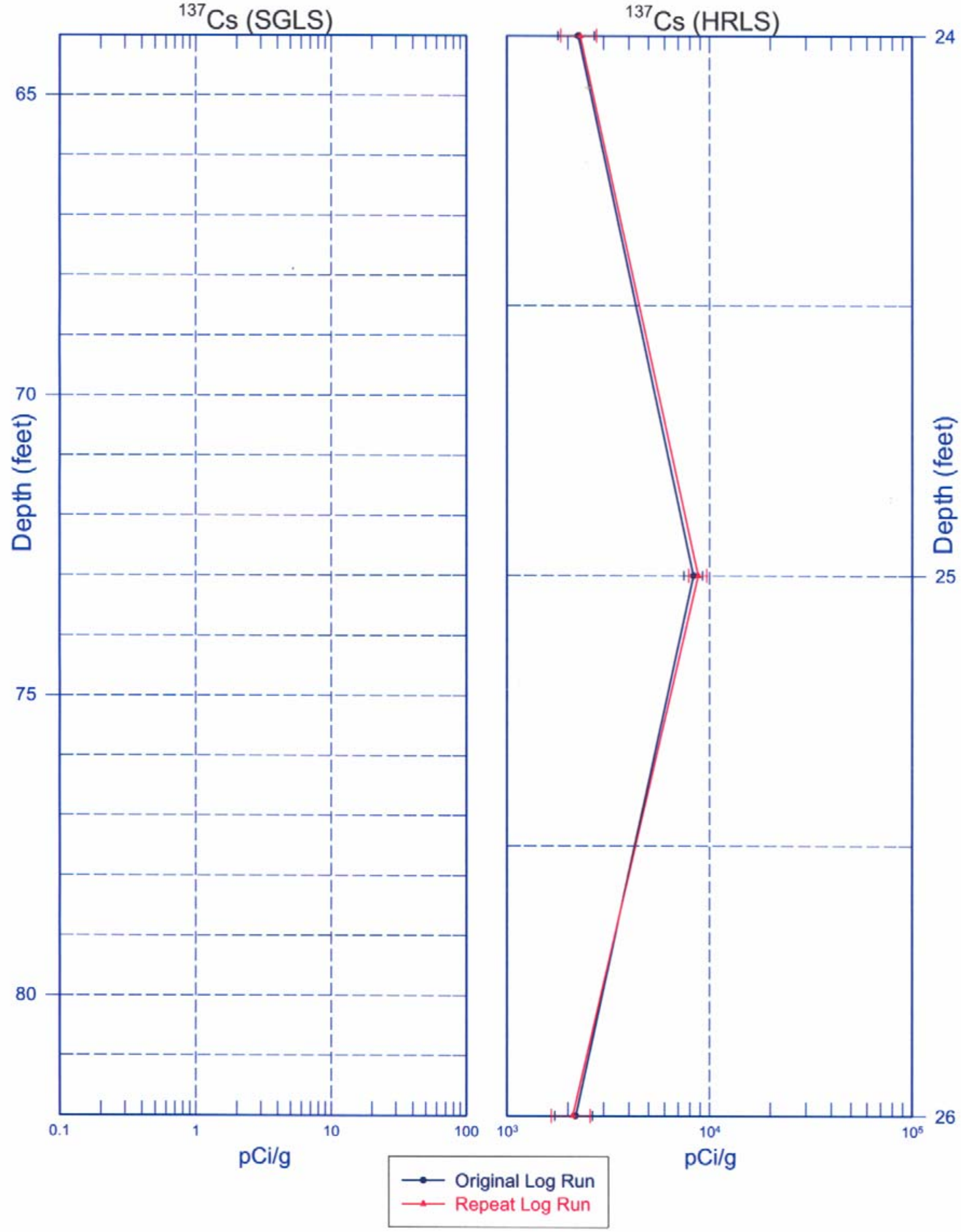
299-W22-75 (A7879)
Total Gamma & Dead Time
Total Gamma
Dead Time
Depth (feet)
150
160
170
180
190
200
210
220
230
240
250
260
270
280
290
300
310
100
200
300
400
500
600
cps
10^2
10^3
10^4
10^5
10^6
cps (log)
0
25
50
75
100
Percent
SGLS DT > 40%
SGLS Dead Time
HRLS Dead Time
SGLS DT > 40 %
SGLS cps (linear scale)
SGLS cps (log scale)
HRLS cps (log scale)
Date of Last Logging Run
6/03/2003
Zero Reference = Top of Casing

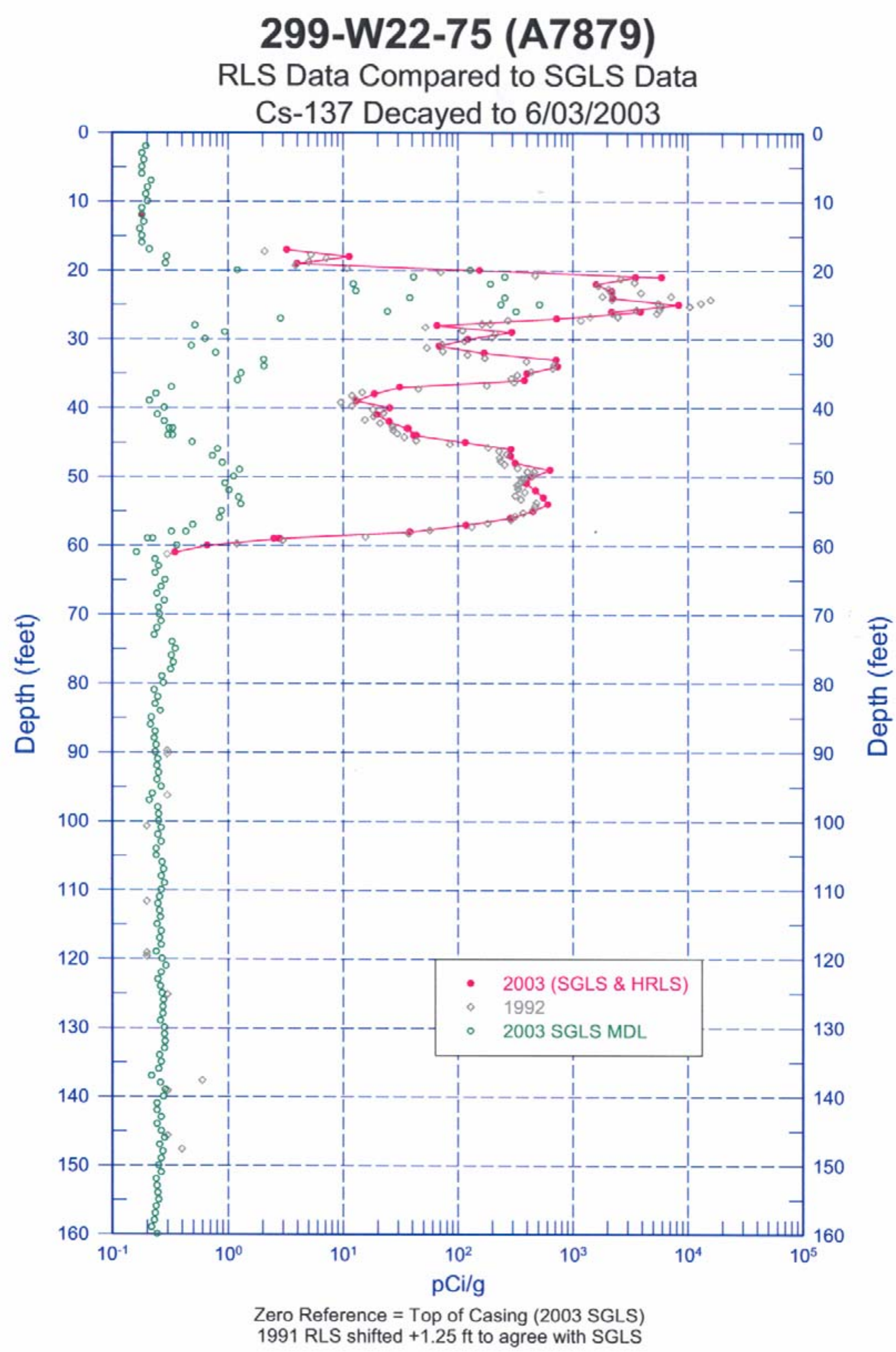

299-W22-75 (A7879)
Rerun of Natural Gamma Logs (82.0 to 64.0 ft)
40K (1461 keV)
238U (609 keV)
238U (1764 keV)
232Th (2614 keV)
Depth (feet)
65
70
75
80
16
20
24
28
pCi/g
0.0
0.5
1.0
1.5
2.0
pCi/g
0.0
0.5
1.0
1.5
2.0
pCi/g
0.0
0.5
1.0
1.5
pCi/g
Original Log Run
Repeat Log Run

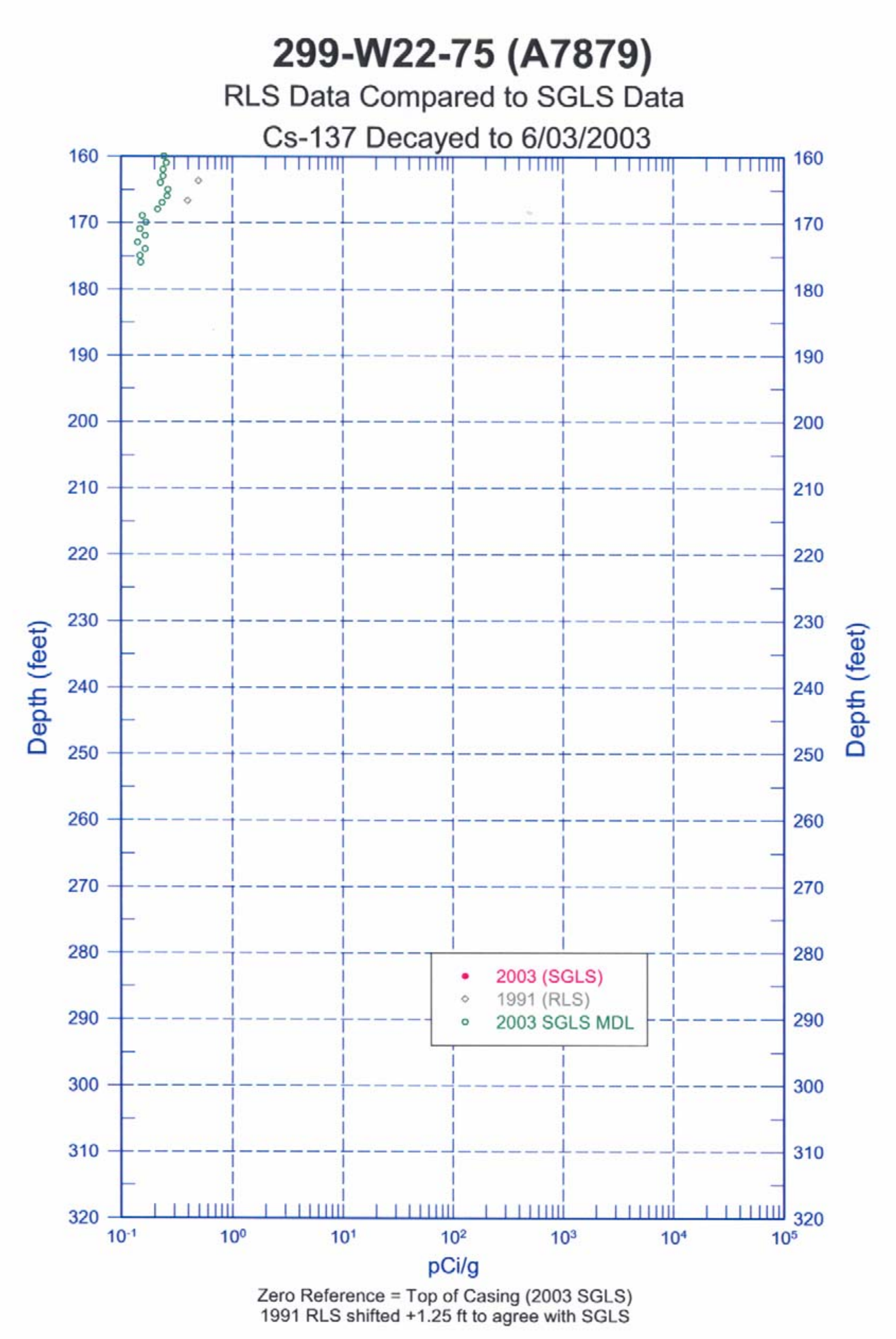

299-W22-75 (A7879)
Rerun of Man-Made Radionuclides
^{235}U (186 keV)
^{238}U (1001 keV)
Depth (feet)
65
70
75
80
1
10
100
1000
pCi/g
Original Log Run
Repeat Log Run

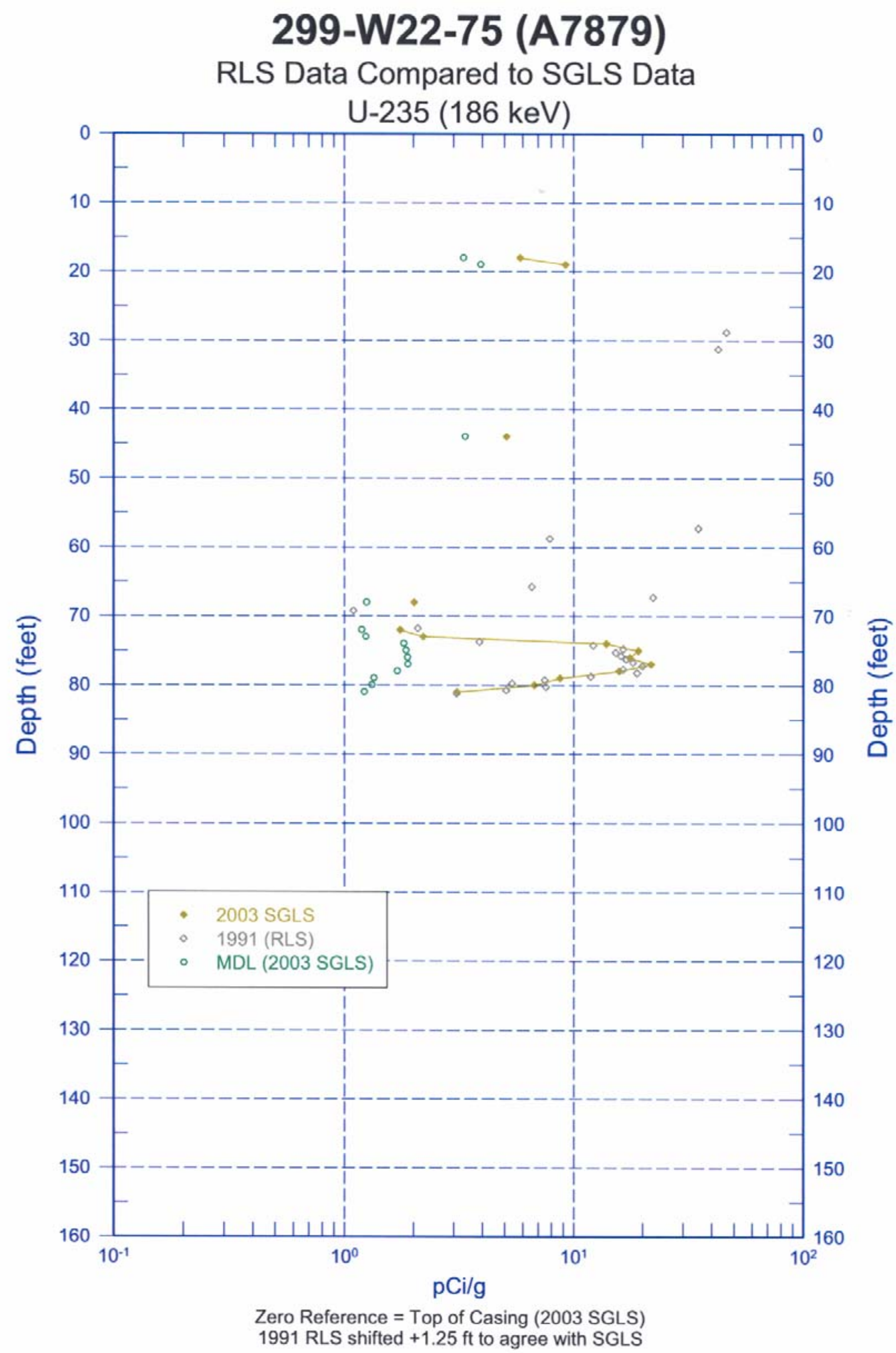
299-W22-75 (A7879)

Rerun of ^{137}Cs

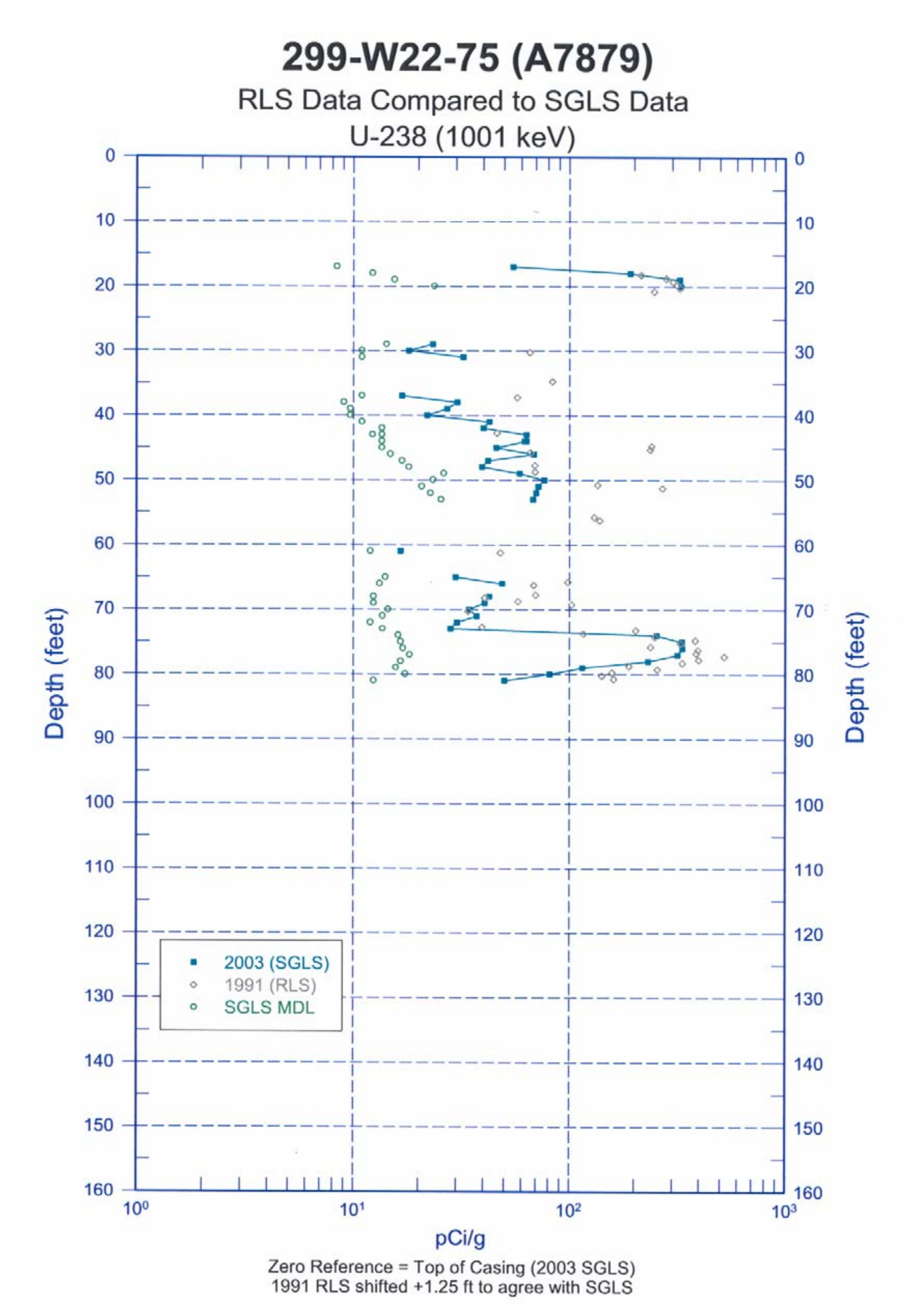



299-W22-75 (A7879)
RLS Data Compared to SGLS Data
Cs-137 Decayed to 6/03/2003
Depth (feet)
pCi/g
2003 (SGLS & HRLS)
1992
2003 SGLS MDL
Zero Reference = Top of Casing (2003 SGLS)
1991 RLS shifted +1.25 ft to agree with SGLS


299-W22-75 (A7879)
RLS Data Compared to SGLS Data
Cs-137 Decayed to 6/03/2003
Depth (feet)
pCi/g
2003 (SGLS)
1991 (RLS)
2003 SGLS MDL
Zero Reference = Top of Casing (2003 SGLS)
1991 RLS shifted +1.25 ft to agree with SGLS



299-W22-75 (A7879)
RLS Data Compared to SGLS Data
U-235 (186 keV)
Depth (feet)
pCi/g
2003 SGLS
1991 (RLS)
MDL (2003 SGLS)
Zero Reference = Top of Casing (2003 SGLS)
1991 RLS shifted +1.25 ft to agree with SGLS



299-W22-75 (A7879)
RLS Data Compared to SGLS Data
U-238 (1001 keV)
Depth (feet)
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
2003 (SGLS)
1991 (RLS)
SGLS MDL
10^0
10^1
10^2
10^3
pCi/g
Zero Reference = Top of Casing (2003 SGLS)
1991 RLS shifted +1.25 ft to agree with SGLS

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