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SUBSURFACE CONDITIONS DESCRIPTION OF THE T AND TX-TY WASTE MANAGEMENT AREAS

M.I. Wood, Fluor Hanford, Inc., for T.E. Jones, CH2MHill Hanford Group
R. Schalla, B.N. Bjornstad and F.N. Hodges, PNNL
Richland, WA 99352
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Abstract: This document provides a discussion of the subsurface conditions relevant to the occurrence and migration of contaminants in the vadose zone and groundwater underlying the 241-T, -TX and -TY tank farms. A concise summary is provided of existing information in support of characterization plannning. A description is provided of the available environmental contamination data and a limited, qualitative interpretation of these data.

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Surface Conditions Description of the T-TX-TY Waste Management Area

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

CH2MHILL
Hanford Group, Inc.
Richland, Washington
Contractor for the U.S. Department of Energy
Office of River Protection under Contract DE-AC06-99RL14047

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RPP-7123
Revision 0

Surface Conditions Description of the T-TX-TY Waste Management Area

M. I. Wood
Fluor Hanford Inc.

T. E. Jones
CH2M HILL Hanford Group

R. Schalla
B. N. Bjornstad
F. N. Hodges
Pacific Northwest National Laboratory

Date Published
January 2001

CH2MHILL
Hanford Group, Inc.
P. O. Box 1500
Richland, Washington

Contractor for the U.S. Department of Energy
Office of River Protection under Contract DE-AC06-99RL14047

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TERMS

CFR	*Code of Federal Regulations*
DQO	data quality objective
EPA	U.S. Environmental Protection Agency
H/PP Interval	Hanford Formation (?)/Pliocene-Pleistocene Unit (?) Interval
HEIS	Hanford Environmental Information System
PUREX	Plutonium-Uranium Extraction (Process)
RCRA	*Resource Conservation and Recovery Act of 1976*
RCW	*Revised Code of Washington*
REDOX	Reduction-Oxidation (Process)
SST	single-shell tank
TBP	tributyl phosphate
Tri-Party Agreement	*Hanford Federal Facility Agreement and Consent Order*
WMA	Waste Management Area

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SUBSURFACE CONDITIONS DESCRIPTION OF THE T AND TX-TY WASTE MANAGEMENT AREAS

1.0 INTRODUCTION

This document discusses the subsurface conditions relevant to the occurrence and migration of contaminants in the groundwater underlying the T, TX, and TY tank farms. These tank farms, located in the 200 West Area of the Hanford Site, make up the T and TX-TY Waste Management Areas (WMA). This document describes the available environmental contamination data and contains a limited qualitative interpretation of the data as they apply to contaminant behavior.

1.1 BACKGROUND

Figure 1-1 shows the location of the T and TX-TY WMAs, and some other facilities in the 200 West Area. To facilitate *Resource Conservation and Recovery Act of 1976* (RCRA) groundwater monitoring programs, the T, TX, and TY tank farms were grouped into two WMAs. Figure 1-2 provides more detail on the T and TX-TY WMAs and surrounding area. Figure 1-2 also shows liquid discharge sites used extensively in tank farm operations (e.g., trenches and cribs) and active RCRA groundwater monitoring wells. Recent groundwater chemistry data from these wells suggest that tank waste has reached the unconfined aquifer from T and TX-TY WMA sources. These data are summarized in Chapter 3.

Because a connection between T and TX-TY WMAs sources and groundwater contamination has been made, the Washington State Department of Ecology (Ecology), the U.S. Environmental Protection Agency (EPA) and the U.S. Department of Energy (DOE) negotiated the *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement) Change Control Form M-45-98-03 (Ecology et al. 1999). The proposed Tri-Party Agreement milestones mandate a series of activities addressing the T and TX-TY WMA contamination. The goal of these activities is to determine whether corrective action is needed to mitigate the impact of contamination from single-shell tanks (SST) on the surrounding environment. One of the first significant efforts in this process is to complete additional characterization of current contamination conditions in the subsurface underlying the T and TX-TY WMAs. Spectral gamma baseline data have been collected from all drywells in the three tank farms; summary reports of these data are available. Information generated by these and future characterization activities will support waste management decisions for interim corrective measures, SST waste retrieval, and SST closure.

1.2 PURPOSE

Within the context of the characterization and evaluation program, this document fulfills several purposes. In the immediate future, a data quality objective (DQO) process will be convened to plan characterization activities for the T and TX-TY WMAs, particularly the vadose zone. Given the numerous vadose zone and possibly relevant groundwater contamination events that have occurred in the T and TX-TY WMAs, several characterization activities clearly are

Figure 1-1. Location Map of the T and TX-TY Waste Management Areas and Related Facilities.

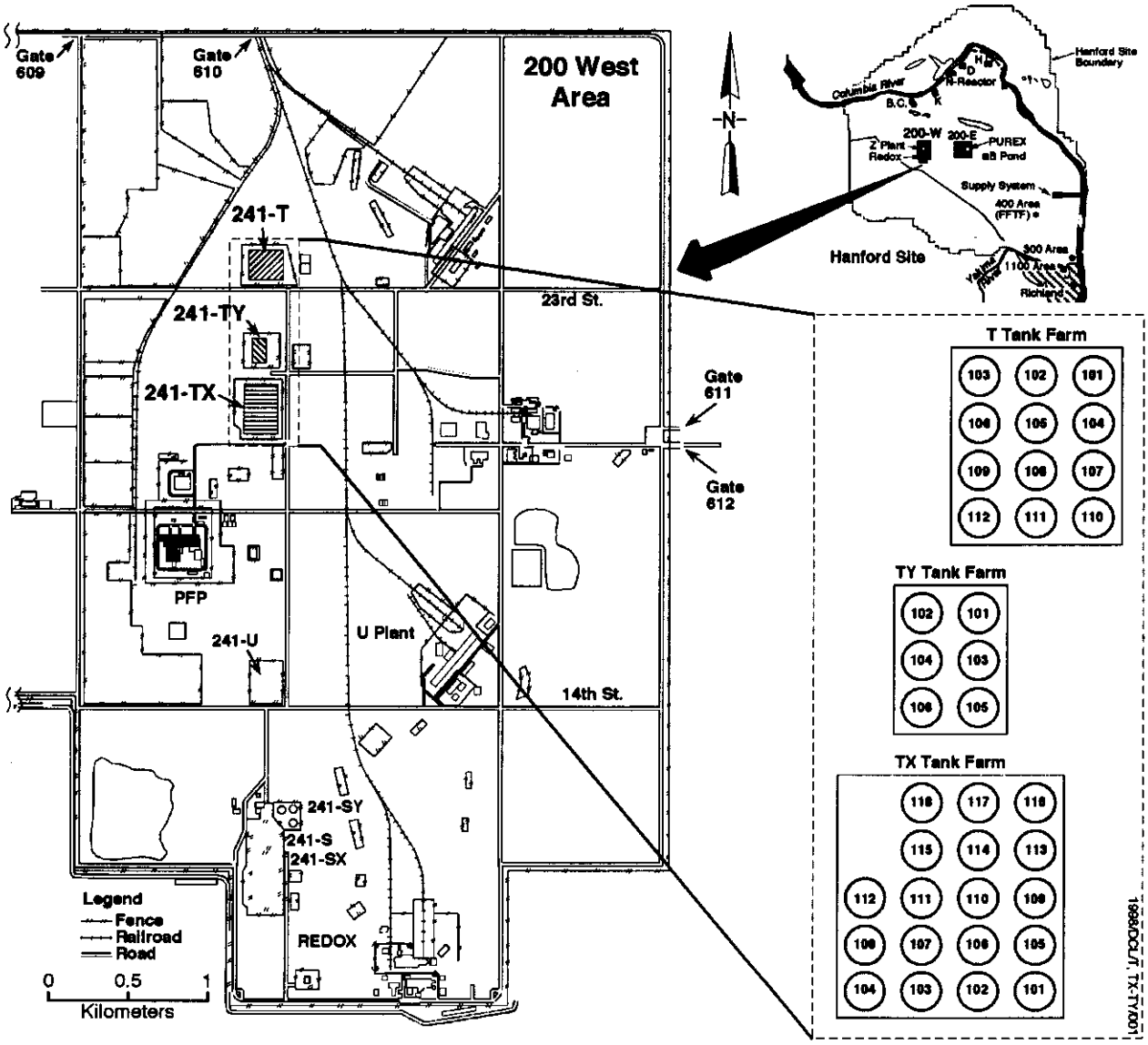
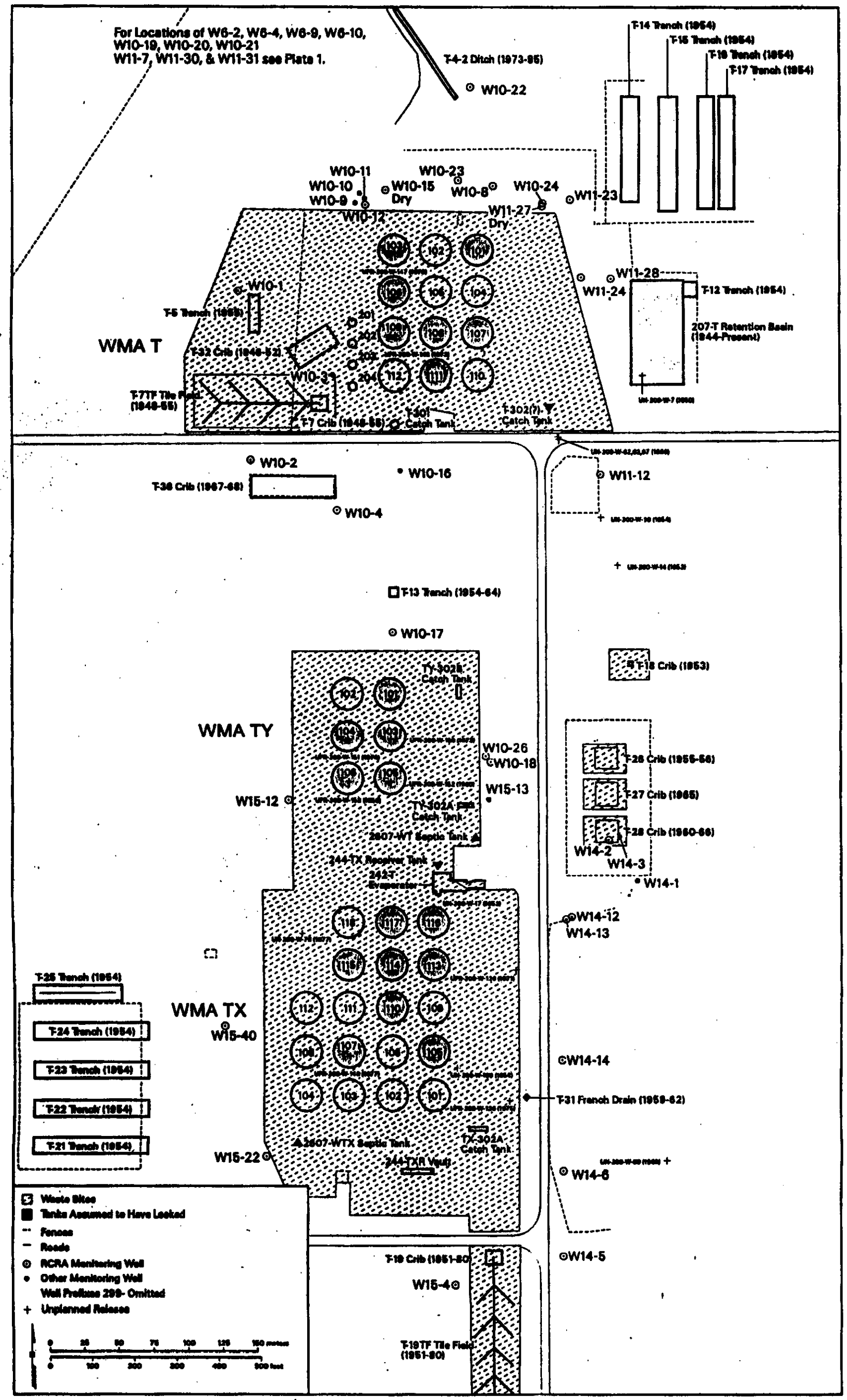


Figure 1-2. The T and TX-TY Waste Management Areas and Surrounding Facilities.



plausible. Obviously, an efficient characterization approach that adequately evaluates the WMAs is needed. To aid in selecting the proper approach, characterization focuses on waste site-specific data that define the occurrence and migration of contaminants within the system to date. This document includes a concise description and limited interpretation of these critical data. A systematic description of the environmental conditions affecting contaminant migration still is needed to identify data gaps, recognize significant relationships among different data types, and organize data inputs to contaminant migration models. This document provides a framework for completing a systematic description as more data are collected, interpreted, and integrated with currently available information.

1.3 SCOPE

The first part of this document describes the two primary components of the subsurface condition database: the physical setting of the T and TX-TY WMAs and the contaminants contained within each WMA. Chapter 2 describes the physical setting, including the tank farm infrastructure, geology, hydrology and infiltration mechanisms, and geochemistry. The tank farm infrastructure description emphasizes those parts of the system that allowed fluids to discharge into the soil column and the time periods during which these parts operated. The geology description emphasizes the impact of the geologic strata on fluid movement. The hydrology and infiltration discussion emphasizes infiltration mechanisms, infiltration history, and hydrologic properties of the geologic strata that control fluid movement. The geochemistry section emphasizes the characteristics that control contaminant movement, particularly in relation to fluids.

The second component of the subsurface characterization database is the description of contaminant occurrences and movement within the vadose zone and the unconfined aquifer. Chapter 3 describes this component. First, the chapter summarizes contamination events to orient the reader to the historical sequence. This is important because of the multiple fluid discharges in and near the T and TX-TY WMAs and multiple occurrences of contamination currently observed in the unconfined aquifer underlying the T and TX-TY WMAs. Second, the chapter summarizes the synthesis of the historical and spectral gamma database for the T, TX, and TY tank farms. These data are unique because of their extent, both temporal and spatial. The overview demonstrates the observed spatial variability of contaminant concentration and provides the most comprehensive indication of the diversity among various contaminating events. Third, the chapter describes separate leak events. The key data in this discussion include tank waste inventory and chemistry information derived from process history, the corroborating gamma data, and soil sample data where available. Finally, groundwater contamination data relevant to tank waste sources are discussed.

Chapter 4 contains a brief qualitative integration of the data and relates the data to a conceptualization of the contamination events. Because the events are diverse, database interpretations are given for each specific contaminating occurrence or type of occurrence.

Chapter 5 identifies key uncertainties and data gaps that are important to understanding potential future contamination of the unconfined aquifer and provides recommendations for resolving these uncertainties.

Appendix A contains the text of the T and TX-TY WMAs historical summary document (Williams 2000). Appendices B and C provide supporting geologic data. Appendix D provides supporting hydrologic and groundwater contaminant data. Appendix E summarizes the analyses of gamma logging data. Appendix F provides supporting data for the tank T-106 leak, one of the largest and most studied SST leaks.

2.0 PHYSICAL SETTING

2.1 T AND TX-TY WMA INFRASTRUCTURE AND OPERATIONS HISTORY

This section discusses the infrastructure and briefly summarizes the T, TX, and TY tank farm operations history, including the use of ancillary equipment and nearby cribs, trenches, and wells. A more detailed historical review is provided in Williams (2000). Excerpts from this report are provided in Appendix A. This section identifies the infrastructure elements known or suspected to have discharged fluids to the vadose zone, along with elements that remain capable of future discharges.

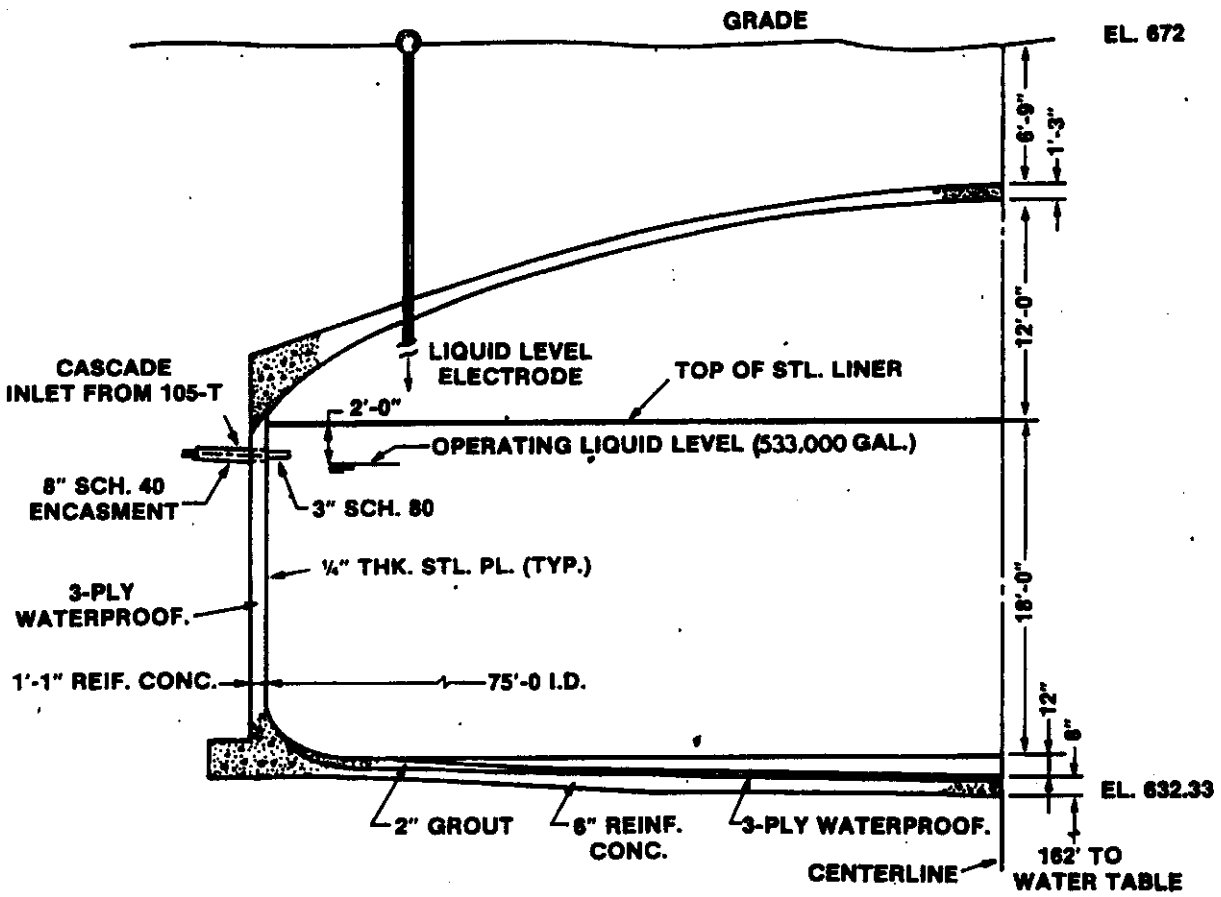
2.1.1 T and TX-TY WMA Infrastructure

The three tank farms, T, TX, and TY are divided into two WMAs, with the T tank farm in one and the TX and TY tank farms in the other. Within the T WMA, the primary structures through which tank waste has been stored, transported, and discharged are the 12 primary tanks (241-T-101 through -T-112), 2 cribs (T-32 and T-7), 1 trench (T-5) and 4 ancillary tanks (201 through 204). Each primary tank is 23 m (75-ft) in diameter with a nominal 2025 kL (535,000-gal) storage capacity. A cross section of tank 241-T-106 is provided in Figure 2-1. Note that the inlet-outlet ports are about 20 ft below the surface. This cross section also is representative of the other primary tanks in the T tank farm. Each ancillary tank is 6.1 m (20 ft) in diameter and holds 208 kL (55,000 gal).

The T tank farm also contains an assortment of ancillary equipment used to move tank waste during operations (e.g., waste transfer lines, catch tanks, leak detection systems). The initial primary waste transfer piping system was rather simple. The 12 tanks were divided into 4 sets of 3 tanks each (e.g., tanks T-101, T-102, and T-103) with each set connected by waste transfer pipes running east and west. The easternmost tank received waste first. When waste levels rose above the height of the open waste transfer line, waste cascaded into the next tank by gravity feed.

Within the TX-TY WMA, the primary structures are 2 tank farms containing a total of 24 tanks (TY-101 through TY-106 and TX-101 through TX-118), the 242-T Evaporator, and the T-19 crib and tile field. The tanks are the same diameter as those in the T farm, but they are approximately 8.5 m (28 ft) tall and hold 2869 kL (758,000 gal). As with T farm, waste transfer lines connected two, three, or four tanks in series (three sets of two tanks in the TY tank farm and three sets of four tanks and two sets of three tanks in the TX tank farm) to move waste from east to west by gravity feed.

Figure 2-1. Cross Section and Schematic for Tank 241-T-106 (Routson et al. 1979).



Outside the WMA boundaries are several liquid discharge facilities: near T tank farm, trenches T-14 through T-17 to the northeast, crib T-36 to the south, and the 207-T retention basin to the east; near TY tank farm, cribs T-18 and T-26 through T-28 to the east; near TX tank farm, the TX trenches T-21 through T-25, to the west. Finally, a number of active or abandoned water lines cross the T and TX-TY WMAs. Leaks from these water lines may have enhanced contaminant migration toward the unconfined aquifer.

2.1.2 Operations History

The T and TX-TY tank farm complexes received waste generated by a variety of major chemical processing operations, roughly in parallel with operations at the B, BX, and BY tank farms. The initial operation was the bismuth phosphate plutonium extraction process that generated large amounts of waste requiring storage and, frequently, disposal. The T and TX tank farms and surrounding cribs and trenches were primarily involved in this process. The T tank farm was built in 1943 to 1944, and began receiving bismuth phosphate waste in 1944. Because

of limited tank space, intentional discharge of the more diluted varieties of bismuth phosphate waste (1C, 2C, 5-6, and 224) to the soil column began somewhat later at several facilities. Primary facilities in the T WMA included the T-32 crib (2.9 x 10^7 L of 224 waste received from 1946 through 1952), the T-7 trench (1.1 x 10^8 L of 2C, 5-6, and 224 waste received from 1948 through 1955), and the T-5 trench (4.5 x 10^7 L of 2C waste received in 1955).

From 1947 through 1949, the TX tank farm was constructed to handle the larger volumes of generated waste. In 1951, the 242-T Evaporator was built to reduce the volume of 1C waste and the T-19 crib and tile field were constructed and began receiving condensate from the evaporator. Eventually, more disposal facilities became necessary to dispose of 1C waste, particularly with the advent of the uranium recovery program, which monopolized the resources of the evaporator in 1953. In 1954, 1C waste was intentionally discharged to the T trenches (2.9 x 10^6 L via an overland pipe from tank T-106) and the TX trenches (5 x 10^6 L via overland pipe from tank TX-110). The final 1C evaporation run occurred between December 1954 and July 1955. The noncondensate portion of this waste stream was sent to the TY tank farm and allowed to settle. The supernatant liquid (1.2 x 10^7 L) was discharged to crib T-26 in 1955 and 1956. Also, in 1955, the T-7 trench reached its disposal capacity and bismuth phosphate waste (2C, 5-6, and 224) was rerouted to the T-19 crib through August 1956.

The next large-scale processing operation to use the T and TX tank farms was uranium recovery. Beginning in 1952, uranium-rich waste was sluiced from the tanks and processed in U Plant to extract the uranium. The byproduct waste stream, tributyl phosphate (TBP) waste, was returned to the tank farms. The TY tank farm was constructed in 1952. Between July 1953 and November 1954, TBP waste was processed through the 242-T Evaporator and condensate was discharged into the T-19 crib and tile field. The ^{137}Cs and ^{90}Sr were scavenged from the TBP waste using ferrocyanide-induced extraction beginning in October 1953. From this process, one batch of waste (9.7 x10^5 L) was discharged to the T-18 test crib in December 1953.

T Plant was converted into a central decontamination facility in 1958 and the derived liquid waste was sent to tank 241-T-112. Supernatant liquid waste was discharged to the TY trenches, T-27 and T-28, beginning in 1960. Waste from the 340 Laboratory also was discharged to these facilities beginning in 1963. From 1960 through 1966, 4.9 x 10^7 L of waste were discharged to the T-27 and T-28 cribs.

The discovery or assumption of leaking tanks in the T, TX, and TY tank farms between 1959 and 1977 prompted a decision to put the tanks out of service and remove the remaining liquid from these tanks. The first attempt to remove the liquid involved heating the tanks (no tanks in the T, TX. or TY tank farm) and transferring the fluid to the 242-T Evaporator. Some condensate from this source was discharged to the T-19 tile field. Because this process was so inefficient, the saltwell pumping process began in 1972 and was used on the T, TX, and TY tanks beginning in 1976.

Currently, each tank in the T, TX, and TY tank farms has shallow radiation monitoring wells (drywells) installed around it as a secondary leak detection system. Chapter 3 summarizes the data collected from these wells. Groundwater monitoring wells also are present around the tank farms and have been in place in various locations since tank farm operations began.

2.2 GEOLOGY

This section summarizes the geologic setting and presents an updated conceptual geohydrologic model of the area in the vicinity of the T, TX, and TY tank farms. This analysis is based on a dense network of boreholes and wells (Table 2-1) located within 300 m (1,000 ft) of the T, TX, and TY tank farms (Figure 2-2). The information in this section provides the framework for interpreting stratigraphic and structural controls on moisture and contaminant movement through the vadose zone to groundwater. See Appendix B for stratigraphic cross sections, isopach maps, and structure contour maps of the suprabasalt units. See Appendix C for summary geologic logs for key boreholes used in this study.

2.2.1 Geomorphology

The T and TX-TY WMAs lie within the west-central portion of the Hanford Site at an elevation between 200 and 210 m (660 and 690 ft) above mean sea level. The site lies in a low-relief area atop Cold Creek Bar, a large compound flood bar formed during Pleistocene ice-age floods (Figure 2-3). The T and TX-TY WMAs lie along the east flank of a north-south trending secondary cataclysmic flood channel that bisects Cold Creek Bar. Present topography indicates the last ice-age flood that overtopped Cold Creek Bar incised a wide, broad channel a few tens of meters west of the tank farms at an elevation of 200 m (660 ft). Since that time, wind has been the only natural geomorphic agent active in this area. A thin (1 m or less) sheet of windblown sand occurs at the surface in undisturbed areas within the T and TX-TY WMAs. The semi-arid climate, combined with the relatively young age and high permeability of the near-surface sediments, has resulted in no natural surface-drainage channels being developed in the immediate vicinity of the T and TX-TY WMAs.

2.2.2 Structural Geology

The T and TX-TY WMAs and the 200 West Area lie along the north limb of the Cold Creek syncline, about 5 km (1.5 mi) northeast of the synclinal axis, as shown in Figure 2-4). The Gable Mountain-Gable Butte segment of the Umtanum Ridge anticline lies to the north of the study area. These structures are part of the Yakima Fold Belt structural subprovince, which formed as a result of north-south regional compression of the crust since the Miocene Epoch (DOE 1988). The Yakima Fold belt is characterized by a series of segmented, narrow, asymmetric east-west trending anticlines. The northern limbs of these anticlines generally dip steeply to the north, are vertical or even overturned thrust or high-angle reverse faults with fault planes that generally parallel fold axial trends. The southern limbs of the Yakima folds dip gently to the south. The anticlinal ridges are separated by broad synclines or basins that, in many cases, contain thick accumulations of Neogene- to Quaternary-age sediments.

The bedrock surface (i.e., top of basalt) beneath the T and TX-TY WMAs dips about 0.7 degree to the southwest toward the axis of the Cold Creek syncline, with up to 150 m (500 ft) of sediments overlying basalt.

Table 2-1. Summary Table of 118 Boreholes Located Within 300 m (1,000 ft) of the T-TX-TY Tank Farms. (3 sheets)

Boring No. (299-)	Alternate Borehole Designation	Northing (m)	Easting (m)	Total Depth (ft)	Purpose	Drill Method	Surf. Elev. (ft)	Completion Date	Open Interval (ft bgs)	Drillers' Log	Geologists' Log	Geophysical Logs	Characterization Data			Quality Ranking	Comments
													Grain Size (depth interval [ft.])	$CaCO_3$ (depth interval [ft.])	Moisture (depth interval [ft.])		
W10-1		136734	566663	305.0	GW monitoring	HT	672	8/7/47	190-270	Y	N	NG, T, N, D	0-300	0-300	ND	2	
W10-10		136806	566751	250.0	GW monitoring	CT	672	7/1/74	196-248	Y	N	ND	5-250	ND	ND	4	
W10-101	50-01-02	136772.0	566850.1	98.0	Vadose monitoring	CT	672	7/27/73	NA	Y	N	SG	10-95	ND	ND	3	
W10-105	50-01-12	136778.4	566837.9	92.0	Vadose monitoring	CT	672	8/11/73	NA	Y	N	SG	10-90	ND	ND	3	
W10-106	50-06-06	136720	566777	123.0	Vadose monitoring	CT		3/18/77	NA	Y	N	SG	ND	ND	ND	4	DB = 100-123'; SS = 121-123'
W10-107	50-06-03	136730.4	566790.8	122.0	Vadose monitoring	CT	673	3/25/77	NA	Y	N	SG	ND	ND	ND	4	SS = 102-114'; DB = 114-122'
W10-108	50-06-02	136744	566786	123.0	Vadose monitoring	CT		5/19/77	NA	Y	N	SG	ND	ND	ND	4	DB=94-114'; SS=114-125'
W10-109	50-06-08	136723.9	566767.3	124.0	Vadose monitoring	CT	671	3/4/77	NA	Y	N	SG	10-25	ND	ND	3	DB=92-123' EXCEPT SS=101-106'
W10-11		136802.2	566755.3	250.0	GW monitoring	CT	673	6/24/74	196-248	Y	N	SG	5-240	ND	ND	3	
W10-110	50-06-04	136729	566789	93.0	Vadose monitoring	CT		7/19/73	NA	Y	N	SG	ND	ND	ND	4	
W10-111	50-06-05	136723.1	566785.6	113.0	Vadose monitoring	CT	671	6/9/77	NA	Y	N	SG	ND	ND	ND	4	DB=94-113'; SS=113-122'
W10-112	50-08-09	136705.1	566792.4	122.0	Vadose monitoring	CT	671	4/1/77	NA	Y	N	SG	10-85	ND	ND	3	DB=87-121' EXCEPT SS=107-112'
W10-113	50-05-06	136720.4	566806.1	120.0	Vadose monitoring	CT	671	5/12/77	NA	Y	N	SG	1, 30, 75	ND	ND	4	DB=87-121' EXCEPT SS=107-112'
W10-114	50-09-10	136714	566767	121.0	Vadose monitoring	CT		4/12/77	NA	Y	N	SG	ND	ND	ND	4	DB=91-122' EXCEPT SS=93-96'
W10-115	50-06-11	136744	566767	87.0	Vadose monitoring	CT		7/13/73	NA	Y	N	SG	10-85	ND	ND	3	
W10-116	50-02-08	136758	566792	87.0	Vadose monitoring	CT		7/17/73	NA	Y	N	SG	5-85	ND	ND	3	
W10-117	50-03-05	136751.4	566789.5	124.0	Vadose monitoring	CT	671	3/30/81	NA	Y	N	SG	ND	ND	ND	4	DB=91-123'
W10-118	50-03-04	136759	566789	87.0	Vadose monitoring	CT		4/7/81	NA	Y	N	SG	ND	ND	ND	4	DB=97-123'
W10-12	50-03-04	136798	566756	250.0	GW monitoring	HT	672	6/14/74	196-248	Y	N	SG	ND	ND	ND	5	
W10-120	50-09-09	136703.5	566763.4	122.0	Vadose monitoring	CT	671	5/5/76	NA	Y	N	SG	10-90	Y	ND	2	DB=92-121'
W10-121	50-05-11	136747.8	566800.2	92.0	Vadose monitoring	CT	671	3/24/81	NA	Y	N	SG	10-90	Y	ND	2	DB=91-123'
W10-122	50-02-02	136774.7	566818.1	92.0	Vadose monitoring	CT	672	2/27/74	NA	Y	N	SG	15-91	Y	ND	2	
W10-124	50-02-10	136771	566792	91.0	Vadose monitoring	CT		3/1/74	NA	Y	N	SG	15-91	ND	ND	3	
W10-125	50-02-12	136778.6	566805.3	94.0	Vadose monitoring	CT	673	2/25/74	NA	Y	N	SG	15-92	Y	ND	2	
W10-134	50-09-05	136688.3	566784.8	95.0	Vadose monitoring	DB	673	3/13/74	NA	Y	N	SG	15-94	Y	ND	2	
W10-135	50-10-05	136660.4	566844.0	96.0	Vadose monitoring	DB	674	2/19/74	NA	Y	N	SG	15-95	Y	ND	2	
W10-141	50-12-10	136677.0	566761.7	123.0	Vadose monitoring	DB	671	2/17/77	NA	Y	N	SG	15-94	Y	ND	2	
W10-143	50-08-05	136689.3	566814.1	93.0	Vadose monitoring	DB	672	3/19/74	NA	Y	N	SG	15-93	Y	ND	2	grain size every foot
W10-147	50-04-07	136720.1	566832.0	100.0	Vadose monitoring	DB	672	2/3/75	NA	Y	N	SG	15-100	Y	ND	2	
W10-148	50-04-08	136728.0	566823.4	100.0	Vadose monitoring	DB	672	1/22/75	NA	Y	N	SG	15-100	Y	ND	2	
W10-15		136808	566771	222.3	RCRA monitoring	DB/HT	672	11/7/89	201.0-222.0	N	Y	NG	ND	ND	ND	2	DB=0-96'; HT=96-222'
W10-16		136607	566781	219.8	RCRA monitoring	DB/HT	670	10/25/89	198.3-219.3	N	Y	NG	ND	ND	ND	2	DB=0-43, 50-120; HT=43-50, 120-219
W10-161		136456.9	566734.2	103.0	Vadose monitoring	CT	671	7/21/77	NA	Y	N	ND	ND	ND	ND	5	
W10-162	50-06-17	136721	566782	122.0	Vadose monitoring	DB		7/10/75	NA	Y	N	SG	10-120	ND	ND	3	
W10-164	50-09-01	136718	566792	150.0	Vadose monitoring	CT		10/14/75	NA	Y	N	SG	Y	ND	ND	3	DB=0-120'; HT=121-150'
W10-165	50-05-07	136721	566801	120.0	Vadose monitoring	DB		10/14/75	NA	Y	N	SG	ND	ND	35 - 52	4	
W10-166	50-09-02	136708	566791	122.0	Vadose monitoring	DB		10/14/75	NA	Y	N	SG	65-120	ND	ND	3	
W10-167	50-06-16	136726	566788	126.0	Vadose monitoring	DB		10/14/75	NA	Y	N	SG	15-125	ND	ND	3	
W10-168		136726	566755	122.0	Vadoze monitoring	DB		2/15/77	NA	Y	N	ND	ND	ND	ND	5	
W10-17		136491	566776	222.9	RCRA monitoring	DB/HT	671	1/17/91	201.4-222.7	N	Y	NG	ND	5-215	5-135	1	DB=0-137; HT=137-223
W10-18		136397	566847	222.6	RCRA monitoring	DB/HT	671	12/12/90	199.8-221.1	N	Y	NG	ND	0-220	0-110	1	DB=0-113', 150-162; HT=113-150', 162-222
W10-196	50-06-18	136725	566788	179.6	Vadoze Zone Char.	DB/SS	671	3/1/93	NA	N	Y	SG	ND	ND	10-180	1	drilled for 241-T-106 leak, GAO-89-157
W10-2		136614	661672	230.0	GW Monitoring	CT	672	2/27/53	200-228	Y	N	NG, T, D, N	10-225	10-125	ND	2	
W10-22		136883	566833	300.0	RCRA Monitoring	DB/HT	684	8/1/94	215.6-245.5	N	Y	SG	ND	ND	ND	3	0-106'=DB; 106-300=HT
W10-23		136815	566824	272.0	RCRA Monitoring	AR	678	8/19/98	225.8-260.9	N	Y	SG	ND	ND	ND	3	4 moisture data points
W10-24		136799	566885	432.5	RCRA Monitoring	AR	686	10/21/98	232.9-268.0	N	Y	SG	ND	ND	ND	3	
W10-26		136401	566843	262.0	RCRA Monitoring	AR	672	8/25/98	217.0-252.1	N	Y	SG	ND	ND	ND	3	2 moisture samples
W10-3		136673	566732	239.0	GW Monitoring	CT	671	11/1/51	194-230	Y	N	NG, D, N	0-235	0-235	ND	2	
W10-4		136578	566735	245.0	GW Monitoring	CT	669	11/10/52	190-245	Y	N	NG, D, N	0-245	0-245	ND	2	
W10-5		136466	566579	240.0	GW Monitoring	CT	671	5/18/54	175-220	Y	N	NG, N, T	5-240	0-135	ND	2	
W10-51		136715	566796	148.0	Vadose Monitoring	CT	669	10/5/44	NA	Y	N	NG	ND	ND	ND	4	
W10-8	50-00-01	136811	566849	252.0	GW Monitoring	CT	677	6/27/73	211-251	Y	N	ND	5-252	ND	ND	3	
W10-88	52-01-01	136460.3	566778.1	100.0	Vadose Monitoring	CT	671	12/10/71	NA	Y	N	SG	ND	ND	ND	4	
W10-89	52-01-05	136436.2	566778.1	100.0	Vadose Monitoring	CT	671	10/8/71	NA	Y	N	SG	ND	ND	ND	4	
W10-9		136799	566749	225.0	GW Monitoring	CT	672	10/2/73	194-214	Y	N	ND	0-225	ND	ND	4	
W10-90	52-01-09	136445.3	566758.6	100.0	Vadose Monitoring	CT	671	12/17/71	NA	Y	N	SG	ND	ND	ND	4	

Table 2-1. Summary Table of 118 Boreholes Located Within 300 m (1,000 ft) of the T-TX-TY Tank Farms. (3 sheets)

Boring No. (299-)	Alternate Borehole Designation	Northing (m)	Easting (m)	Total Depth (ft)	Purpose	Drill Method	Surf. Elev. (ft)	Completion Date	Open Interval (ft bgs)	Drillers' Log	Geologists' Log	Geophysical Logs	Characterization Data			Quality Ranking	Comments
													Grain Size (depth interval [ft.])	$CaCO_3$ (depth interval [ft.])	Moisture (depth interval [ft.])		
W10-93	52-02-09	136445.3	566727.5	100.0	Vadose Monitoring	CT	671	12/14/71	NA	Y	N	SG	ND	ND	ND	4	
W10-94	52-03-12	136430.1	566773.3	100.0	Vadose Monitoring	CT	671	12/29/71	NA	Y	N	SG	ND	ND	ND	4	
W10-95	52-03-03	136414.3	566787.9	100.0	Vadose Monitoring	CT	671	12/1/71	NA	Y	N	SG	ND	ND	ND	4	
W10-96	52-03-06	136400.3	566773.3	100.0	Vadose Monitoring	CT	671	12/6/71	NA	Y	N	SG	ND	ND	ND	4	
W10-97	52-04-02	136425.8	566752.5	100.0	Vadose Monitoring	CT		12/14/71	NA	Y	N	SG	ND	ND	ND	4	
W10-98	52-04-06	136400.2	566742.2	100.0	Vadose Monitoring	CT	671	12/7/71	NA	Y	N	SG	ND	ND	ND	4	
W10-99	52-04-09	136416.6	566727.6	100.0	Vadose Monitoring	CT	671	12/10/71	NA	Y	N	SG	ND	ND	ND	4	
W11-12		136604	566927	250.0	GW Monitoring	CT	679	12/21/53	**200-250**	Y	N	NG, N, T	0-240	0-240	ND	2	
W11-23	50-00-02	136801	566905	252.0	GW Monitoring	CT	685	7/14/73	**200-240**	Y	N	ND	0-252	ND	ND	5	missing drill log from 0-141'
W11-24		136745	566913	250.0	GW Monitoring	HT/DB	684	8/24/73	210-250	Y	N	ND	ND	ND	ND	5	HT = 0-35, 115-250; DB = 35-115
W11-26		136563.7	567044.7	515.0	Characterization	HT/MR	694	2/27/76	NA	Y	Y	NG, N, T, D	0-145	0-145	ND	1	DH-6; continuous diamond core below 90' depth
W11-27		136797	566885	235.0	RCRA Monitoring	DB/HT	681	11/21/91	213.2-233.6	N	Y	NG	ND	0-235	0-125	1	DB = 0-125'; HT = 125-235'
W11-28		136744	566935	247.4	RCRA Monitoring	DB/HT	689	12/11/91	224.0-244.9	N	Y	NG	ND	0-247'	0-180	1	DB = 0-180'; HT = 180-247
W14-1		136311	566954	240.0	GW Monitoring	CT	665	2/1/54*	**20-150; 195-230**	Y	N	NG, T, N, D, SG	0-240	0-240	ND	2	Well modified on 2/83
W14-12		136284	566906	222.5	RCRA Monitoring	DB/HT	667	11/4/91	198.4-218.7	N	Y	NG	216.5-218.5	0-222	0-100	1	0-102'=DB; 102-222=HT
W14-13		136282	566902	262.0	RCRA Monitoring	AR	670	8/31/98	216.6-251.7	N	Y	SG	ND	ND	ND	3	2 moisture samples
W14-14		136181	566898	443.0	RCRA Monitoring	AR	671	11/13/98	217.0-252.3	N	Y	SG, N	ND	ND	0-215	1	
W14-2		136341	566933	223.0	GW Monitoring	CT	666	5/11/1955*	**181-222**	Y	N	NG, N, D, SG	0-223	0-223	ND	3	Well modified on 1/83
W14-3		136343	566941	270.0	GW Monitoring with piezometers	DB/HT	665	12/27/61	**208-268**	Y	N	NG, N, D, SG	ND	ND	ND	3	
W14-4		136424	567099	205.0	GW Monitoring	DB/HT	666	7/7/66	?	Y	N	NG, N, D, SG	ND	ND	ND	4	
W14-5		136040	566900	240.0	GW Monitoring	DB/HT	664	10/18/74	**190-225**	Y	N	ND	15-240	15-240	ND	5	DB = 0-85', HT = 85-240'
W14-6		136101	566899	240.0	GW Monitoring	DB/HT	665	12/3/74	**195-225**	Y	N	NG, T, N	5-25;145-235	5-25;145-235	ND	4	
W15-1		135942	566553.9	300.0	GW Monitoring	CT	670	5/2/47	**190-270**	Y	Y	ND	0-300	0-300	ND	3	
W15-10		135981.2	566449	300.0	GW Monitoring	DB/HT	673	1/22/68	**183-297**	Y	N	NG, N, D, SG	105-210	ND	ND	5	Schlumberger= HGNS, LDS, APS logs; erroneous data?
W15-12		136369	566700	225.0	GW Monitoring	CT	667	10/4/73	**195-215**	Y	N	T	0-225	0-225	ND	3	
W15-126		136170.4	566742.8	100.0	Vadose Monitoring	DB	671	12/2/71	NA	Y	N	ND	ND	ND	ND	5	
W15-127	51-03-06	136141.1	566742.9	150.0	Vadose Monitoring	-	671	12/10/71	NA	Y	N	SG	15-100	Y	ND	3	
W15-128	51-03-09	136157.0	566728.2	100.0	Vadose Monitoring	DB	670	11/8/71	NA	Y	N	SG	15-100	50-100	0-100	2	
W15-13		136370	566845	225.0	GW Monitoring	CT	667	9/5/73	**197-225**	Y	N	ND	0-225	0-225	ND	3	
W15-131	51-04-08	136148.4	566699.6	100.0	Vadose Monitoring	CT	671	12/12/71	NA	Y	N	SG	30-100	Y	ND	2	
W15-133	51-07-04	136177.4	566754.1	100.0	Vadose Monitoring	DB	671	12/1/71	NA	Y	N	SG	15-100	Y	ND	2	
W15-134	51-07-09	136189.2	566708.7	100.0	Vadose Monitoring	DB	671	11/18/71	NA	Y	N	SG	15-80	Y	ND	2	
W15-155	51-01-09	136157.4	566789.8	113.0	Vadose Monitoring	CT	671	12/26/73	NA	Y	N	SG	15-105	ND	ND	3	
W15-159	51-12-01	136231.6	566719.5	100.0	Vadose Monitoring	CT	670	12/20/73	NA	Y	N	SG	15-90	ND	ND	3	
W15-160	51-15-09	136250.2	566728.9	100.0	Vadose Monitoring	CT	668	12/4/73	NA	Y	N	SG	15-100	ND	ND	3	
W15-161	51-16-04	136277.2	566818.7	100.0	Vadose Monitoring	CT	671	11/29/73	NA	Y	N	SG	15-90	ND	ND	3	
W15-162	51-16-11	136294.9	566800.1	100.0	Vadose Monitoring	CT	671	11/21/73	NA	Y	N	SG	15-90	ND	ND	3	
W15-163	51-16-07	136269	566793.2	100.0	Vadose Monitoring	CT	671	12/4/73	NA	Y	N	SG	15-100	ND	ND	3	
W15-164	51-17-11	136294.8	566772.4	100.0	Vadose Monitoring	DB	671	10/30/73	NA	Y	N	SG	15-100	ND	ND	3	
W15-166	51-01-02	136165.1	566817.2	112.0	Vadose Monitoring	CT	671	1/22/74	NA	Y	N	SG	15-105	ND	ND	3	
W15-167	51-01-04	136149.9	566817.2	113.0	Vadose Monitoring	CT	673	12/21/73	NA	Y	N	SG	0-115	ND	ND	3	
W15-171	51-05-07	136173.6	566801.0	111.0	Vadose Monitoring	CT	673	1/17/74	NA	Y	N	SG	30-111	Y	ND	3	
W15-177	51-11-01	136231.4	566748.8	112.0	Vadose Monitoring	CT	671	11/24/74	NA	Y	N	SG	15-106	Y	ND	3	Grain size every foot
W15-178	51-07-01	136201.2	566749.5	110.0	Vadose Monitoring	CT	670	1/22/74	NA	Y	N	SG	30-110	ND	ND	3	
W15-180	51-12-10	136222.1	566698.8	100.0	Vadose Monitoring	CT	670	4/30/74	NA	Y	N	SG	15-100	Y	ND	3	Grain size every foot
W15-184	52-06-06	136371.2	566747.2	100.0	Vadose Monitoring	DB	671	8/14/74	NA	Y	N	SG	15-100	Y	ND	2	
W15-22		136111	566683	221.9	RCRA Monitoring	DB/HT	667	1/16/91	198.5-219.8	N	Y	NG	ND	5-210	5-135	1	DB =0-137'; HT = 137-222
W15-3	52-06-07	136372	566799	245.0	GW Monitorng	CT	670	9/11/52	**200-245**	Y	N	NG, SG	5-245	ND	ND	3	
W15-4		136018.9	566820.7	225.0	GW Monitoring	CT	660	1/31/56	**170-216**	Y	N	NG, T, D, N, SG	ND	ND	ND	4	Well modifications performed 5/83
W15-40		136205	566653	262.4	RCRA Monitoring	AR	673	9/16/98	217-252	N	Y	SG	ND	ND	5-115	1	
W15-41		136032	566758	239.0	RCRA Monitoring	S/AR	666	1/17/00	215.9-230.9	N	Y	SG, N	ND	ND	ND	1	

Table 2-1. Summary Table of 118 Boreholes Located Within 300 m (1,000 ft) of the T-TX-TY Tank Farms. (3 sheets)

Boring No. (299-)	Alternate Borehole Designation	Northing (m)	Easting (m)	Total Depth (ft)	Purpose	Drill Method	Surf. Elev. (ft)	Completion Date	Open Interval (ft bgs)	Drillers' Log	Geologists' Log	Geophysical Logs	Characterization Data			Quality Ranking	Comments
													Grain Size (depth interval [ft.])	$CaCO_3$ (depth interval [ft.])	Moisture (depth interval [ft.])		
W15-67	51-00-03	136202.6	566823.2	150.0	Vadose Monitoring	CT	671	1/28/49	NA	Y	N	NG, SG	5-150	Y	ND	2	
W15-69	51-00-06	136137.5	566758.5	150.0	Vadose Monitoring	CT	671	2/10/49	NA	Y	N	NG	5-150	Y	ND	2	
W15-7		135920.7	566674.6	350.0	GW Monitoring	DB/HT	661	3/30/66	**182-350**	Y	N	NG, T, D, N,SG	0-350	ND	ND	2	DB = 0-120, HT = 120-350
W15-70	51-00-05	136137.7	566820.3	150.0	Vadose Monitoring	CT	671	2/1/49	NA	Y	N	ND	5-150	Y	ND	3	
W15-71	51-03-02	136168.0	566758.4	150.0	Vadose Monitoring	CT	671	2/9/49	NA	Y	N	SG	5-150	Y	ND	2	
W15-72	51-11-02	136230.2	566758.2	150.0	Vadose Monitoring	CT	671	2/8/49	NA	Y	N	SG	5-150	Y	ND	2	
W15-73	51-00-07	136137.4	566696.6	150.0	Vadose Monitoring	CT	669	3/7/49	NA	Y	N	NG, SG	5-150	Y	ND	2	
W15-75	51-00-10	136264.5	566711.5	150.0	Vadose Monitoring	CT	670	3/4/49	NA	Y	N	NG, SG	5-150	Y	ND	2	
W15-79	52-06-05?	136371.6	566755.1	150.0	Vadose Monitoring	CT	671	9/25/52	NA	Y	N	NG, SG	5-150	ND	ND	2	

HT = Hard Tool
DB = Drive Barrel
CT = Cable Tool
SS = Split Spoon
S = Sonic
AR = Air Rotary

Bold = Perforated casing
NA = not applicable

ND = No data
NG=Natural (gross) gamma
SG=Spectral Gamma
N=Neutron (moisture)
D=Density
T=Temperature

1 = highest quality
5 = lowest quality

RCRA = *Resource Conservation and Recovery Act of 1976*

Figure 2-2. Borehole Location Map.

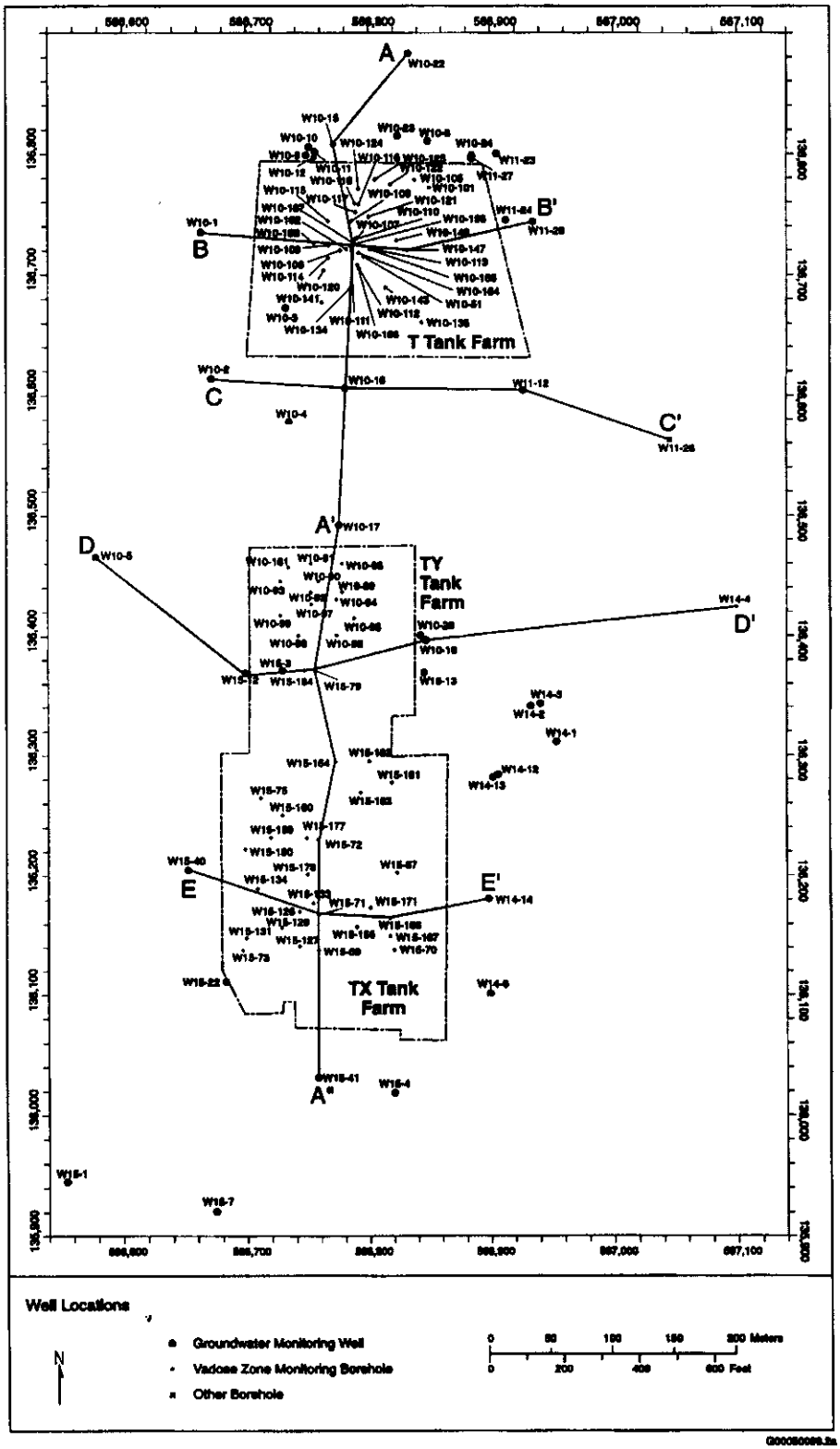
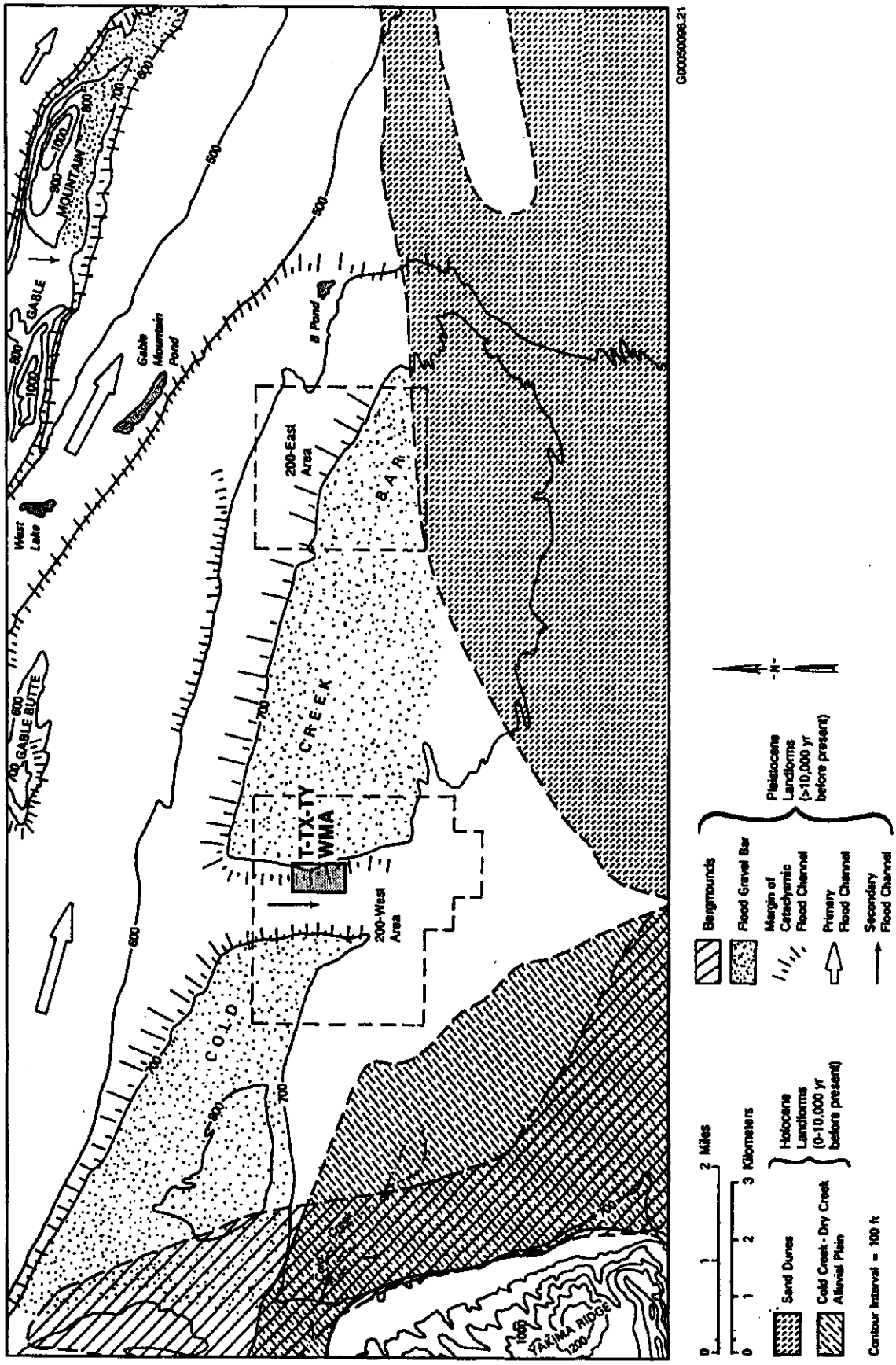


Figure 2-3. Geomorphic Map.



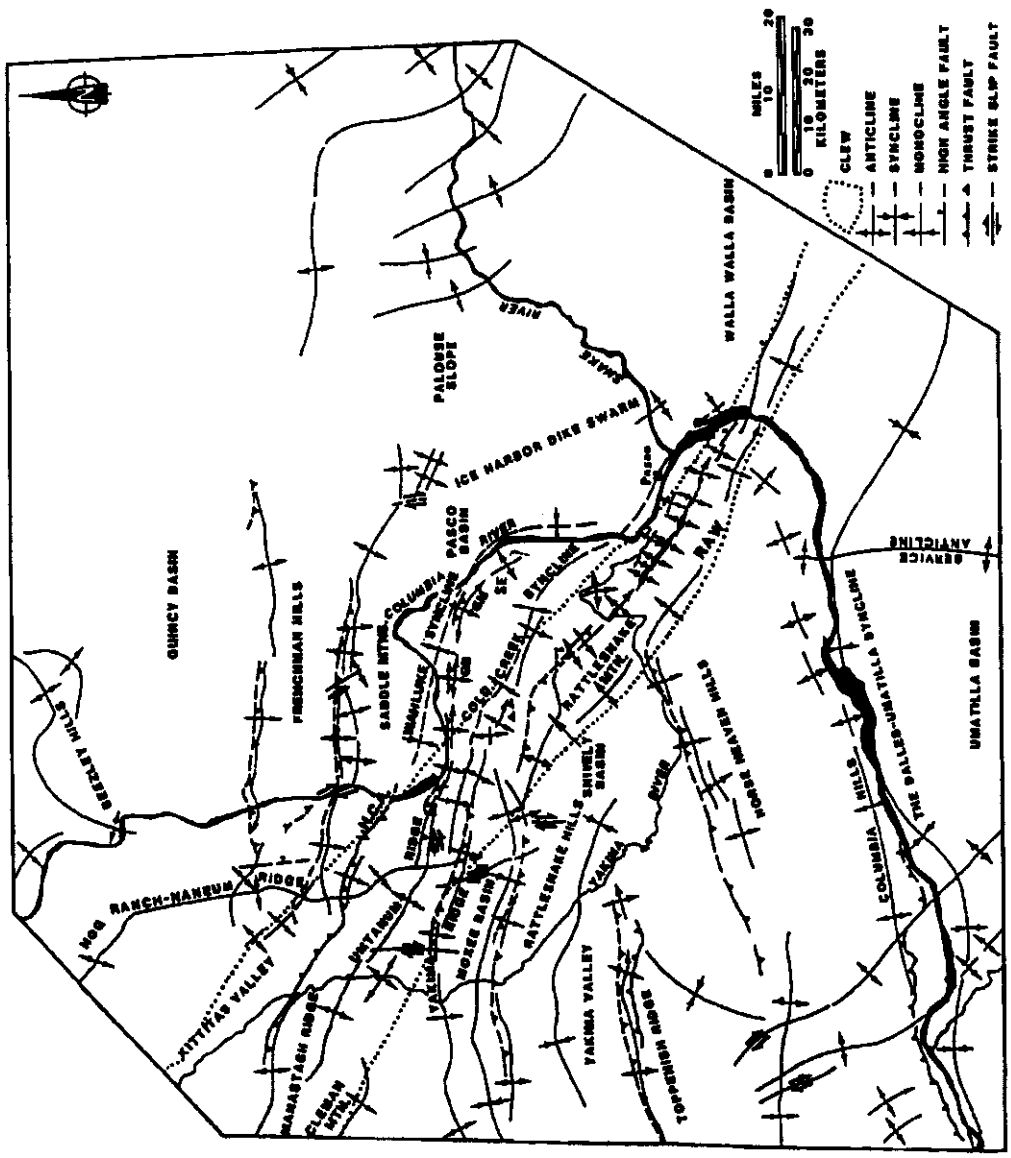


Figure 2-4. Structural Elements of the Yakima Fold Belt Subprovince (After DOE 1988).

2.2.3 General Stratigraphy

The stratigraphy beneath the T and TX-TY WMAs is represented in Figure 2-5. Columbia River basalt forms the basement bedrock. Approximately 150 m (500 ft) of continental sediments overlie basalt. From oldest to youngest, these deposits include the following:

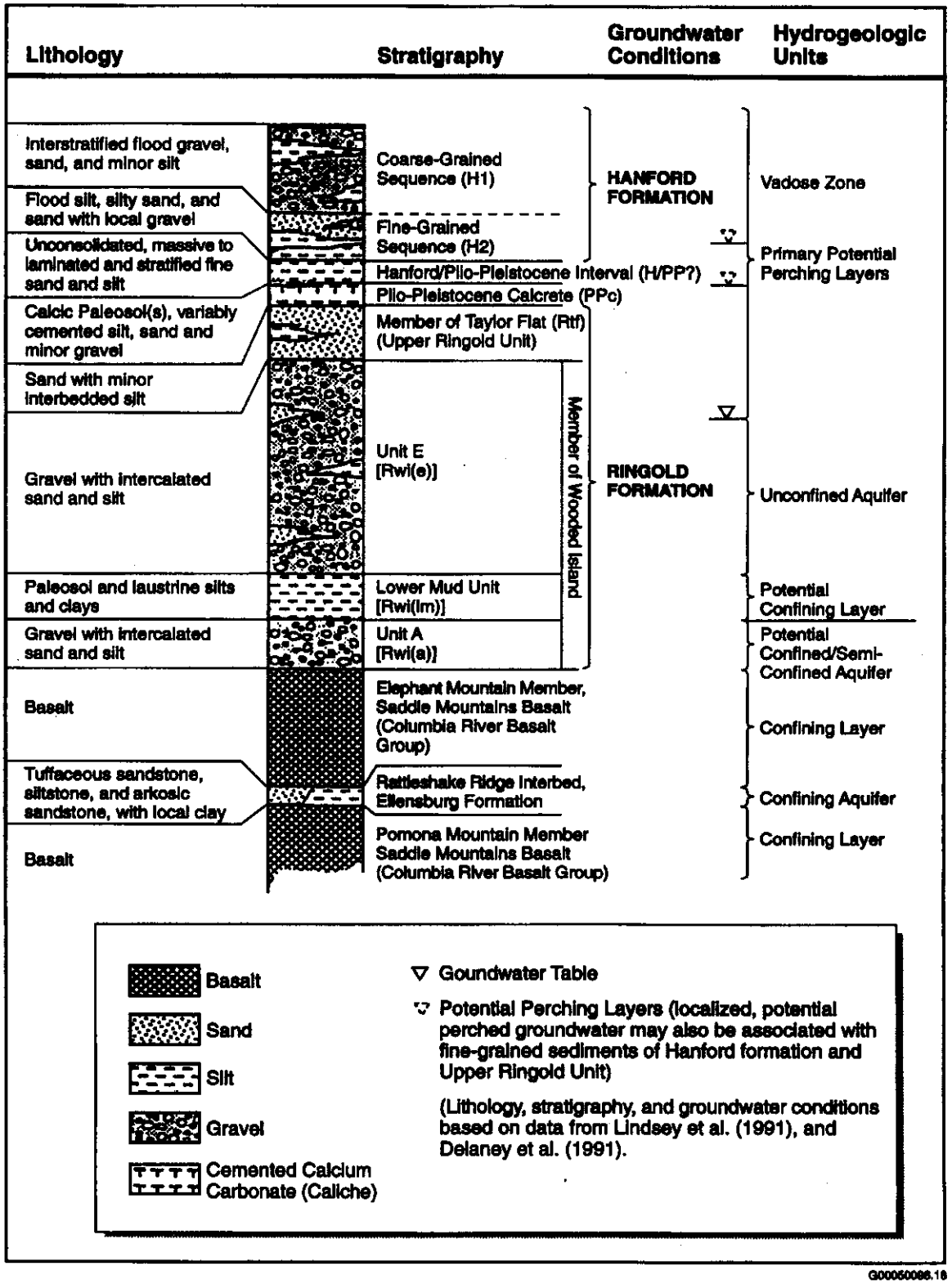
- Several facies of the Miocene-to-Pliocene age, fluvial-lacustrine Ringold Formation
- Variably cemented and pedogenically altered deposits of the Plio-Pleistocene unit, which developed on the eroded and weathered surface of the Ringold Formation
- A relatively loose, fine-grained silty to sandy unit, designated the Hanford Formation (?)/Pliocene-Pleistocene Unit (?) Interval (H/PP Interval)
- Deposits from Pleistocene-age cataclysmic floods (i.e., Hanford formation) that blanket the study area with mostly sand- and silt-dominated facies, capped by a sequence of gravel-dominated facies.

2.2.4 Methodology

The sources of available geologic data, the quality of these data, and how they are used to develop the conceptual geohydrologic model for the T and TX-TY WMAs are described in the following paragraphs.

2.2.4.1 Data Sources. Geologic characterization data for the area near the T and TX-TY WMAs are found in reports for the Basalt Waste Isolation Project (DOE 1988), waste management activities (Price and Fecht 1976, Caggiano and Goodwin 1991, and DOE 1992 and 1993), Hanford Site groundwater monitoring (Lindberg et al. 1999), and related geologic studies supporting these efforts (Tallman et al. 1979, Last et al. 1989, Bjornstad 1990, Connelly et al. 1992, and Lindsey et al. 1991 and 1994a). The current study attempts to build on the preexisting geohydrologic conceptual models and integrate available data for the 118 boreholes, including several recently drilled holes, within 300 m (1,000 ft) of the WMAs (Figure 2-2). Borehole data include drillers' logs, geologists' logs, archived samples, and geophysical logs, along with limited physical characterization data (grain-size distribution, $CaCO_3$, and moisture content). Most boreholes have several types of data available but rarely have a complete set of all types of data collected over the 55 years of drilling at the Hanford Site (Table 2-1).

Figure 2-5. Stratigraphy Beneath the T-TX-TY Tank Farms.



Some of the data are summarized in borehole summary reports (Horton and Hodges 1999a, 1999b, and 2000) and detailed reports on the individual T, TX, and TY tank farms within the T and TX-TY WMAs (Freeman-Pollard et al. 1994; DOE-GJ 1997, 1998). Table 2-1 summarizes the types of data available for boreholes within the study area, including drillers' logs, geologists' logs, grain-size data, $CaCO_3$ data, geophysical logs, and moisture logs. Most of these data are available in the borehole-archive files maintained by the Pacific Northwest National Laboratory. Digital files and displays of some of these data also have been compiled by D. B. Stephens and Associates.

Initially, well site geologists' logs and drillers' logs were examined and compared to geophysical logs. The quality of the drillers' logs varies because many wells and boreholes were drilled without a geologist present; this is generally true for all boreholes drilled before the mid-1980's. Until then, drillers would collect sediment samples every 1.5 m (5 ft) and record general descriptions of the formation materials and problems encountered on drilling summary forms. Most of the archived sediment samples from these pre-1980 borings were subsequently analyzed in the laboratory for grain-size distribution and $CaCO_3$ content. These results reside in a database called ROCSAN, which no longer is operational. For this study, grain-size distribution and $CaCO_3$-content were reentered manually into EXCEL[1] and ROCKWARE spreadsheets from the ROCSAN database printout.

The quality of the grain-size distribution data depends largely on the drilling method used. Intervals drilled with a hard tool tend to contain more fines because of the pulverizing action of the hard-tool bit. Samples acquired by a drive-barrel display better preservation of the original grain-size distribution, but some pulverization still can occur in the gravel-rich lithologies. A third method for collecting sediment samples is with the split-spoon, a small-diameter core barrel that permits collection and preservation of sediment core within a metal or plastic sleeve. The split-spoon method provides the best quality sample for geologic description and laboratory analysis, although, as with the core barrel, some pulverization of gravelly lithologies does occur. Other drilling methods included air rotary and sonic (Table 2-1) drilling, which, similarly to hard-tool drilling, tend to break apart clasts and produce an unrepresentative excess of fine-grained particles. Unlike grain-size distribution data, the quality of the $CaCO_3$ data is believed to be representative regardless of the drill method used because nothing exists to suggest that the drill method affects the bulk chemistry of the sample.

Beginning in the mid-1980's (about the time geologists assumed responsibility for lithologic descriptions at drill sites) samples stopped being routinely analyzed in the laboratory. Therefore, quantitative grain-size distribution and $CaCO_3$ data are not available for most boreholes drilled since the mid-1980's; these parameters are provided, qualitatively, in geologists logs. However, unlike standardized laboratory analyses, visual tests performed in the field can be extremely subjective and the results often are inconsistently interpreted and reported among geologists.

Gross-gamma ray logs are available for most boreholes. These logs are of highly variable quality and are useful for identifying some, but not all, principal stratigraphic contacts

[1] EXCEL is a trademark of Microsoft Corporation.

(Bjornstad 1990 and DOE-GJ 1997 and 1998). Gross-gamma ray logs sometimes may be interpreted to show lithologic differences because of differing amounts of natural gamma-ray emitters, most commonly ^{40}K. Generally, the proportion of ^{40}K increases with decreasing grain size, therefore clay and silt emit more natural gamma rays and yield an increased gamma-ray response. The gross-gamma log often is useful for more accurately determining depths of gamma-emitting fine-grained layers, especially those that are a meter or more thick. However, thinner clay and/or silt layers often still go undetected on gross gamma logs. The proportion of ^{40}K also can be influenced by feldspar mineralogy in arkosic/felsic clastic sediments, with ^{40}K increasing as sediment becomes more arkosic.

Spectral-gamma borehole geophysical logs recently were obtained from 67 boreholes in the T tank farm (DOE-GJ 1999), 22 boreholes in the TY tank farm (DOE-GJ 1998) and 94 boreholes in the TX tank farm (DOE-GJ 1997). Most of these boreholes, installed in the early- to mid-1970's, were drilled to a 30 m (100-ft) depth; however, a few go to 50 m (150 ft) or more. Spectral-gamma logs were obtained to map the subsurface distribution of radioactive contamination near the tank farms, trenches, French drains, cribs, and tile fields located in the T and TX-TY WMAs. Where radionuclides are present, they emit radiation at a much higher rate than the natural background gamma signal. This means that stratigraphic contacts often appear washed out on these logs. However, fluids escaping from the tanks often collect and concentrate along boundaries between contrasting lithologies beneath and adjacent to the tanks, so moisture and accompanying gamma-emitting radiation may be an indirect indication of contrasting lithology. For example, spikes of gamma-emitting radiation may occur along the tops of perching silt beds and/or where a sharp contact occurs between fine- over coarse-grained sediments.

Another data source useful for interpreting the lithology is moisture content. Within the vadose zone moisture content generally increases along interfaces between materials with highly contrasting grain size. This is particularly true where high-permeability material (gravel and/or sand) overlies lower permeability material (sand and/or silt). However, moisture also may concentrate along interfaces where a fine-grained unit overlies a coarse sand or gravel.

2.2.4.2 Development of Geohydrologic Model. The conceptual geohydrologic model presented here was developed from available drillers' logs, geologists' logs, geophysical logs, archived sediment samples, and field and laboratory characterization data. All available data for each borehole included in the study (i.e., within 300 m [1,000 ft] of the T, TX, and TY tank farms) were compiled and summarized onto borehole summary sheets; a separate summary sheet was compiled for each borehole; these are presented in Appendix C. Boreholes in the vicinity of the T and TX-TY WMAs are ranked in Table 2-1 (second column from the right) according to the quality of data and degree of uncertainty in the interpretation of the borehole geology. Each borehole is ranked from 1 to 5, with boreholes ranked 5 having the least confidence and most uncertainty in the geologic interpretation and those ranked 1 having the most confidence and least uncertainty. Boreholes ranked 5 (least confidence and most uncertainty) have little or no information or conflicting information. In contrast, boreholes ranked 1 (most confidence and least uncertainty) have geologist's logs accompanied by a gross-gamma and perhaps a moisture log, as well as grain-size, $CaCO_3$, and/or other characterization data. Only about 10 percent (11 out of 118) of the borings have relatively complete data sets available; these are ranked 1 in Table 2-1.

The model building process followed a series of investigative steps designed to honor the data and give preferential treatment to the higher ranked boreholes. First, the main stratigraphic units and contacts were identified in boreholes ranked 1 or 2. This was done by comparing available data and picking depths to major lithologic contacts. Elevations and thicknesses of the major stratigraphic contacts then were calculated from the depths. Next, the same procedure was performed on lower ranked boreholes. The next step was to prepare structure-contour maps of these major units to determine if the contacts are realistic and geologically sensible. Subsequently, isopach maps were generated with the aid of the computer by subtracting the elevation of the lower bounding surface of an interval from the elevation of the upper bounding surface. Grids were generated using an inverse-distance method in the ROCKWARE[2] software program. Isolated, large, steep-gradient "bulls-eyes" on contour maps indicate contacts that may be miscalculated, based on erroneous data, and/or reflect facies changes not readily accounted for in the stratigraphic model. In these cases, boreholes were reevaluated and the contact adjusted as necessary. Final elevations used to construct structural contours and isopach grids for thickness maps of the various stratigraphic units are presented in Table 2-2.

The next step in building a geohydrologic model of the subsurface was to construct scaled cross sections linking boreholes together. Six cross sections, located in Figure 2-2, are presented in Appendix B (Figures B-1 to B-6). One long cross section (A-A' and A'-A") runs lengthwise (north-south) across the T and TX-TY WMAs. Four shorter cross sections trend at roughly right angles (east-west) to the long axis of the WMA.

2.2.5 Uncertainty

Sources of uncertainty for contact locations and physical properties between stratigraphic units in boreholes and correlations between boreholes include the following:

- **Borehole related**. This includes the drilling method, source and quality of the borehole and geophysical logs, and borehole spacing
- **Sampling related**. This includes the method of drilling and sampling, sampling frequency, and bias induced by the sampling techniques
- **Geology related**. This includes the three-dimensional shape of the sedimentary features, lateral facies changes in relative proportion of sand, silt, and gravel, and bed-form properties of the sediment layers.

[2] ROCKWARE is a trademark of PurOptix, Inc.

Table 2-2. Boreholes and Elevations (in Feet) of Stratigraphic Units Used to Construct Structure Contour and Isopach Maps. (4 sheets)

Well No.	Northing	Easting	Elevation	Recent	H1	H2	H/PP	PPc	Rtf	Rwi(e)	Rwi(lm)	Rwi(a)	TOB	TD
W10-1	136734.7	566663.45	672	NP	672	610	596	578	562	531				306
W10-10	136806	566751	672	NP	672	644	599	582	556	538				422
W10-101	136772	566850.2	672	672	NP	634	591	584						574
W10-105	136778.4	566837.97	672	672	NP	634	592	584						580
W10-106	136720	566777												
W10-107	136730.4	566790.84	673	673	635	633	592	581	563					551
W10-108	136744	566786												
W10-109	136723.9	566767.39	671	671	NP	633	591	581	566	549				547
W10-11	136802.2	566755.31	673	NP	673	645	590	578	550	539				423
W10-110	136729	566789												
W10-111	136723.1	566785.68	671	671	NP	633	590	578	564					558
W10-112	136705.1	566792.43	671	671	633	631	586	572	561					549
W10-113	136720.4	566806.11	671	671	633	630	590	579	562	553				551
W10-114	136714	566767												
W10-115	136744	566767												
W10-116	136758	566792												
W10-117	136751.4	566789.57	671	671	633	628	588	581	568	549				547
W10-118	136759	566789												
W10-12	136797.6	566755.9	672	NP	673	612	590	582	559	537				423
W10-120	136703.5	566763.48	671	671	633	631	590	580	562	550				549
W10-121	136747.8	566800.25	671	671	NP	631	590	580	568	548				547
W10-122	136774.7	566818.16	672	672	NP	632	590	582						580
W10-124	136771	566792												
W10-125	136778.6	566805.35	673	673	633	615	591	581						579
W10-134	136688.3	566784.85	673	673	NP	633	585	579						578
W10-135	136660.4	566844.05	674	674	NP	634	586	580						578
W10-141	136677.0	566761.72	671	671	NP	631	589	577	556	550				548
W10-143	136689.3	566814.11	672	672	NP	632	587	579						577
W10-147	136720.1	566832.02	672	672	NP	632	590	579						572
W10-148	136728.0	566823.46	672	672	NP	635	588	581						572

Table 2-2. Boreholes and Elevations (in Feet) of Stratigraphic Units Used to Construct Structure Contour and Isopach Maps. (4 sheets)

Well No.	Northing	Easting	Elevation	Recent	H1	H2	H/PP	PPc	Rtf	Rwi(e)	Rwi(lm)	Rwi(a)	TOB	TD
W10-15	136808	566771	672	672	662	612	599	579	557	537				450
W10-16	136606.9	566781.2	670	670	664	615	587	575	565	541				450
W10-161	136456.9	566734.23	671	671	626	615	586	571						568
W10-162	136721	566782												
W10-164	136718	566792												
W10-165	136721	566801												
W10-166	136708	566791												
W10-167	136726	566788												
W10-168	136726	566755												
W10-17	136491.5	566775.7	671	NP	671	629	581	571	559	543				448
W10-18	136396.5	566847.2	671	671	665	627	584	574	556	541				448
W10-196	136725	566788	671	671	NP	633	589	579	566	550				491
W10-2	136614	566672	672	672	665	609	587	575	559	545				442
W10-22	136883	566833	684	NP	684	651	601	591	573	540				384
W10-23	136815	566824	678	678	670	635	598	590	568	547				406
W10-24	136799	566885	686	686	683	644	603	588	578	558				245
W10-26	136401	566843	672	672	669	630	584	575	562	545				410
W10-3	136673	566732	671	671	648		586	578	561	544				432
W10-4	136578	566735	670	NP	670	618	581	571	555	538				425
W10-5	136465.9	566579.06	671	NP	671	586	571	561	542	536				421
W10-51	136715	566796	669					577						
W10-8	136811	566849	677	NP	677	633	592	583	561	552				426
W10-88	136460.3	566778.11	671	671	626	624	576							571
W10-89	136436.2	566778.17	671	671	626	621	581							571
W10-9	136799	566749	672	NP	672	622	589	579	NP	538				447
W10-90	136445.3	566758.64	671	671	626	618	581							571
W10-91	136460.3	566752.50	671	671	626	621	577							571
W10-92	136436.2	566752.56	671	671	626	618	576							571
W10-93	136445.3	566727.55	671	671	626	623	581							571
W10-94	136430.1	566773.30	671	671	626	606	581							571

Table 2-2. Boreholes and Elevations (in Feet) of Stratigraphic Units Used to Construct Structure Contour and Isopach Maps. (4 sheets)

Well No.	Northing	Easting	Elevation	Recent	H1	H2	H/PP	PPc	Rtf	Rwi(e)	Rwi(lm)	Rwi(a)	TOB	TD
W10-95	136414.3	566787.97	671	NP	626	596	579							571
W10-96	136400.3	566773.38	671	671	626	591	579							571
W10-97	136426	566753	672	672	627	612	580							572
W10-98	136400.2	566742.29	671	671	626	616	581							571
W10-99	136416.6	566727.62	671	671	626	624	581							571
W11-12	136604	566927	679	NP	679	651	588	576	NP	552				429
W11-23	136801	566905												
W11-24	136745	566913	684	NP	684	649	590	582	572	549				434
W11-26	136563.7	567044.7	694	NP	694	629	594	589	NP	552	281	264	190	185
W11-27	136797	566885	681	681	671	646	596	586	561	554				446
W11-28	136743.7	566934.9	689	NP	689	649	592	584	565	546				442
W14-1	136311.4	566953.6	665	NP	665	637	585	567	547	543				425
W14-12	136284	566906	667	667	662	633	573	565	NP	541				444
W14-13	136282	566902	670	670	665	637	581	572	558	545				408
W14-14	136181	566898	671	NP	671	638	577.5	563	561	548	269			228
W14-2	136341	566933	666	666	651	630	581	574	NP	549				443
W14-3	136343.2	566940.7	665	NP	665	637	587	570	552	547				395
W14-4	136424	567099	666	NP	666	626	594	574	NP	551				461
W14-6	136101	566899.4	665	NP	665	636	577	562	NP	549				425
W15-1	135945.5	566553.9	670	NP	670	640	559	554	NP	535				370
W15-12	136369	566699.5	667	NP	671	626	577	569	NP	549				446
W15-126	136170.4	566742.88	671	671	626	616								571
W15-127	136141.1	566742.95	671	671	622	616								570
W15-128	136157.0	566728.28	670	670	621	617								570
W15-13	136369.5	566845.4	667	NP	667	607	574	569	547	534				427
W15-131	136148.4	566699.66	671	671	NP	622								571
W15-133	136177.4	566754.14	671	671	622	616								571
W15-134	136189.2	566708.70	671	671	NP	622								571
W15-155	136157.4	566789.84	671	671	NP	622	569							558
W15-159	136231.6	566719.55	670	670	NP	621	574							570

Table 2-2. Boreholes and Elevations (in Feet) of Stratigraphic Units Used to Construct Structure Contour and Isopach Maps. (4 sheets)

Well No.	Northing	Easting	Elevation	Recent	H1	H2	H/PP	PPc	Rtf	Rwi(e)	Rwi(lm)	Rwi(a)	TOB	TD
W15-160	136250.2	566728.95	668	668	NP	618	578							568
W15-161	136277.2	566818.79	671	671	NP	622	581							571
W15-162	136294.9	566800.16	671	671	NP	622	581							571
W15-163	136269	566793.21	671	671	621	616	581							571
W15-164	136294.8	566772.42	671	671	622	606	576							571
W15-166	136165.1	566817.25	671	671	622	618	571	561						559
W15-167	136149.9	566817.25	673	673	624	618	573	563						560
W15-171	136173.6	566801.07	673	673	NP	624	573	565						562
W15-177	136231.4	566748.81	671	671	622	606	573	566						559
W15-178	136201.2	566749.50	670	670	621	610	574	565						560
W15-180	136222.1	566698.86	670	670	621	612								570
W15-184	136371.2	566747.24	671	671	NP	626	579							571
W15-22	136111	566683	667	NP	667	620	565	557	547	541				445
W15-3	136371.7	566729.5	670	NP	670	616	572	562	546	531				425
W15-4	136018.9	566820.7	660	NP	660	620	570	556	NP	539				435
W15-40	136205	566653	673	NP	673	606	576	564	548	541				411
W15-41	136032	566758	666	NP	666	614	573	562	554	545				427
W15-67	136202.6	566823.25	671	671	NP	622	574	566	NP	546				521
W15-69	136137.5	566758.50	671	671	622	618	568	561	NP	544				521
W15-7	135920.7	566674.6	661	661	656	611	559	551	NP	537				311
W15-70	136137.7	566820.37	671	671	NP	622	567	563	NP	549				521
W15-71	136168.0	566758.43	671	671	NP	622	568	559	NP	539				521
W15-72	136230.2	566758.26	671	671	619	613	575	563	NP	541				521
W15-73	136137.4	566696.64	669	669	620	616	567	558	NP	543				519
W15-75	136264.5	566711.54	670	670	640	621	570	562	NP	539				520
W15-79	136371.6	566755.16	671	671	NP	626	579	563	543	533				521

2.2.5.1 Borehole-Related Uncertainty. Most boreholes near the T and TX-TY WMAs have been drilled using cable-tool percussion techniques. Cable-tool drilling historically has been the standard technique used at the Hanford Site because it does not require the use of drilling fluids that could potentially transport or spread subsurface contamination. In cable-tool drilling, the borehole is advanced using a drive barrel or hard tool while driving temporary casing to keep the borehole open. The technique generally has proven successful, especially in the loose, unconsolidated gravel-dominated facies of the Hanford formation. However, cable-tool drilling has several disadvantages, including the following:

- Cable-tool drilling is slow compared to most other methods and therefore costly
- Drillers have difficulty retaining samples within the drive barrel in the vadose zone. (Often, small volumes of water must be added to give the sample cohesive strength so that it will stay in the drive barrel)
- Gravels are not easily retrieved because they are not easily retained in the drive barrel
- The depth of the sample is difficult to control
- Cemented units or zones with large gravel clasts must be drilled with a "hard tool," which pulverizes the material and alters the grain-size distribution of the recovered samples. Pulverization occurs to a lesser degree with the drive barrel.

Furthermore, borehole coverage usually is dictated by factors other than addressing geologic questions. Therefore the spacing and distribution of boreholes is often inadequate to confidently address geologic problems.

Most of the length of boreholes W10-196 and W11-26 was cored continuously within the T and TX-TY WMAs (Table 2-1). In addition to the core collected from borehole W10-196, a considerable number of samples were analyzed for chemical and physical properties of the sediments in the vadose zone (Freeman-Pollard et al. 1994). Core is superior to drill cuttings because it preserves the in situ stratification and structure of the sediments, which are destroyed by most drilling methods.

2.2.5.2 Sampling-Related Uncertainty. The type and quantity of data collected vary substantially from one borehole to another, which adds uncertainty and complicates stratigraphic correlations based on different data sets or data quality. Furthermore, sample collection in the unconsolidated vadose zone often is challenging because the samples are typically dry and are not easily retained in the drive barrel.

The most-important factor affecting quality of the geologic data is the borehole log. Before 1980, when geologists generally were not present during drilling on the Hanford Site, drillers were the only personnel at the drill site. This meant the drillers themselves were responsible for collecting the samples (one lithologic sample collected into a glass jar every 1.5 m [5 ft]) and completing the drilling/borehole log, as well as drilling the borehole and constructing the well. Because of widely different experience and backgrounds and lack of training in geologic descriptions, the quality of drillers' logs is highly variable and inconsistent. General grain size, color, and, infrequently, mineralogy, were recorded on drillers' logs. The

quantity, quality, and consistency of information recorded on borehole logs improved significantly in the 1980's when the responsibility for geologic logging and sampling of the boreholes shifted to the geologists. Unfortunately, about the same time, the quantitative analyses of grain size and $CaCO_3$ were discontinued.

The quality of the geophysical logging (i.e., gross-gamma log) also has varied over the years. Earlier logs often were uncalibrated to a standard and/or run at rapid rates, which adversely affected data quality. However, the older logs are still useful for qualitative comparison and for identifying some lithologic contacts.

Boreholes are ranked in Table 2-1 according to the amount and quality of available geohydrologic data. Only about 10 percent (i.e., those ranked 1 in Table 2-1) of the 118 boreholes located within 300 m (1,000 ft) of the T, TX, and TY tank farms are considered to provide high quality data that are representative of the geohydrologic conditions at the site.

2.2.5.3 Geologic-Related Uncertainty. The geometric shape and distribution of the sediment bodies contains uncertainty. Because of the scale and dynamic nature of the cataclysmic flooding that produced the Hanford formation, very few analogs are available to compare the geologic model at the T, TX, and TY tank farms to a field locality. Consequently, bedform distribution, the nature of erosive contacts, and the extent of lithologic interfingering is difficult to interpret and realistically portray on maps and cross sections.

2.2.6 Columbia River Basalt Group and Ellensburg Formation Beneath the T and TX-TY WMAs

The surface of the Columbia River Basalt Group (CRBG) forms the bedrock base of the aquifer beneath the T and TX-TY WMAs. At least 50 basalt flows exist beneath the Hanford Site with a combined thickness of more than 3000 m (10,000 ft) (DOE 1988). The Elephant Mountain Member of the Saddle Mountains Basalt, the youngest flow in the area, lies about 150 m (500 ft) below land surface. The Elephant Mountain Member is about 25 to 27 m (80 to 90 ft) thick in the 200 West Area (Reidel and Fecht 1981) and dated by the potassium/argon method to be 10.5 Ma (McKee et al. 1977). The Elephant Mountain Member consists of medium- to fine-grained tholeiitic basalt with abundant microphenocrysts of plagioclase (DOE 1988). The top of basalt dips gently southwest about 0.7 degree toward the axis of the Cold Creek syncline (Figure 2-6). In general, lava flows of the Saddle Mountains Basalt and the overlying suprabasalt sediments thicken to the south toward the axis of the Cold Creek syncline. Only one borehole (299-W11-26, also referred to as DH-6) within 300 m (1,000 ft) of these WMAs extends to the basalt bedrock.

Sandwiched between various basalt flows are sedimentary interbeds, collectively referred to as the Ellensburg Formation, which include fluvial and lacustrine sediments consisting of mud, sand, and gravel deposited between volcanic eruptions. Little evidence exists of significant erosion into the top of the Elephant Mountain member within the 200 West Area and no indication of erosional "windows" through the basalt into the underlying Rattlesnake Ridge interbed (Connelly et al. 1992).

2.2.7 Ringold Formation Beneath the T and TX-TY WMAs

The Ringold Formation records fluvial-lacustrine deposition associated with the ancestral Columbia River drainage system, following the last eruption of basalt at the Hanford Site about 10.5 million years ago (Tallman et al. 1981, DOE 1988, Lindsey et al. 1994b, Lindsey 1996). Deformation of the Yakima folds, which began in the middle Miocene Epoch, concurrent with the Columbia River basalt volcanism, continued into Ringold time so the centers of downwarped basins received more sediments than the margins. The Ringold Formation is up to 185 m (600 ft) thick in the center of the basin and pinches out against the basin-bounding basalt ridges of the Yakima folds. The Ringold Formation at one time may have filled the basin to 275 m (900 ft) as indicated by erosional remnants of the Ringold Formation found at this elevation around the margins of the Pasco Basin. The top of the Ringold Formation beneath the T and TX-TY WMAs is presently about 175 m (575 ft), suggesting that up to 100 m (325 ft) of Ringold Formation was removed in this area during a post-Ringold regional incision and downcutting event that abruptly terminated Ringold deposition about 3.4 million years ago (Fecht et al. 1987).

The Ringold Formation consists of semi-indurated clay, silt, fine- to coarse-grained sand, and variably cemented granule to cobble gravel. Ringold Formation sediments have been classified into the following five sediment facies associations (Lindsey 1996).

- **Fluvial Gravel**. Clast-supported granule to cobble gravel with a sandy matrix dominates this facies association. Intercalated sand and mud also are found. The most common clasts are composed of basalt, quartzite, porphyritic volcanics, and greenstone. Silicic plutonic rocks, gneisses, and volcanic breccias also are found. Sand in the association generally is quartzo-feldspathic, with basalt content usually ranging between 5 and 25 percent. Low-angle to planar stratified, massive bedded, and large-scale cross-bedded facies are found in outcrops. The facies association records deposition in a gravelly fluvial braidplain characterized by multiple wide, shallow, shifting river channels.

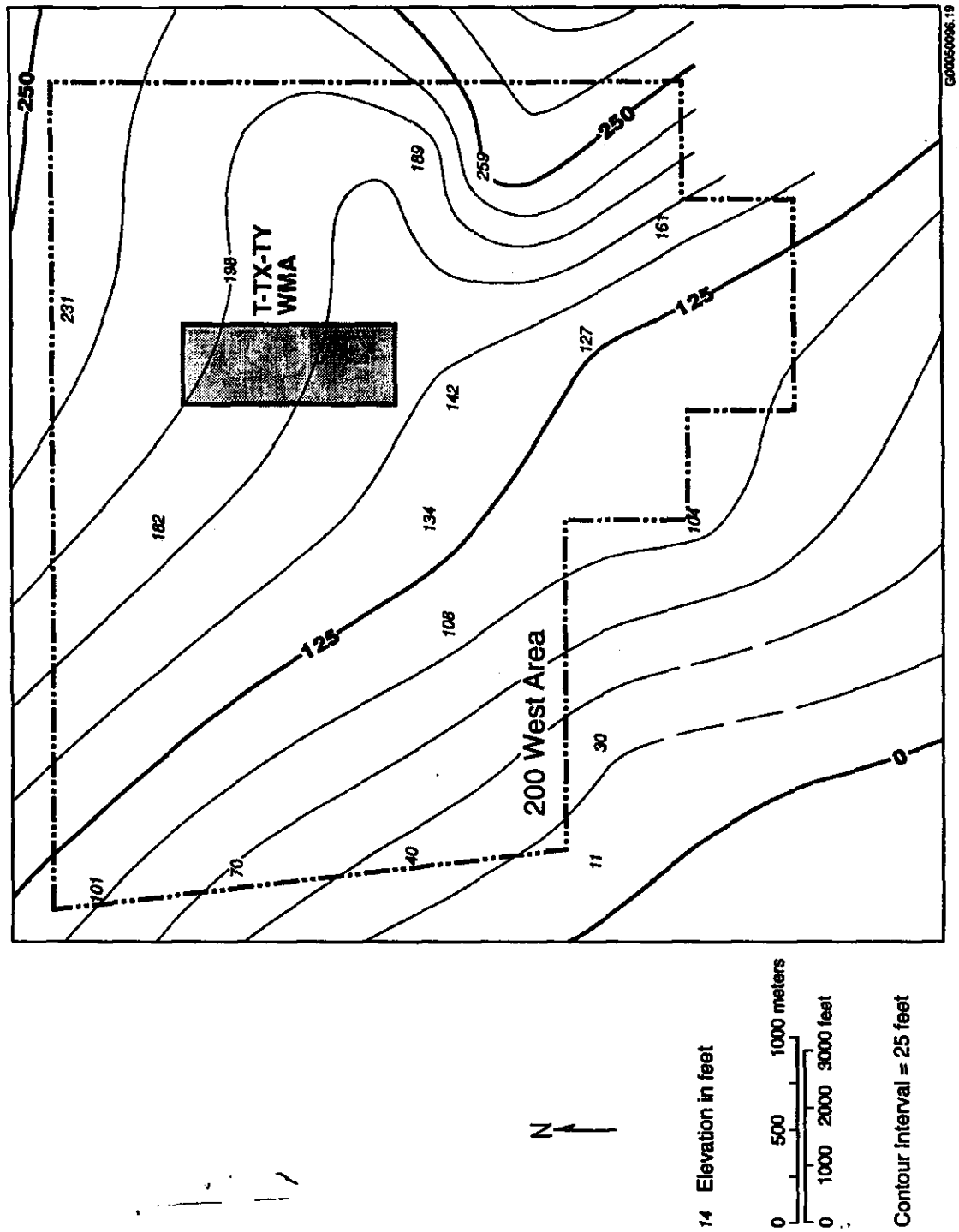


Figure 2-6. Top of Basalt Map for the 200 West Area (modified after Connelly et al. 1992).

- **Fluvial Sand**. Quartzo-felspathic sand displaying cross bedded and cross laminated facies in outcrop dominates this facies association. The sand usually contains less than 15 percent basalt lithic fragments, although as much as 50 percent basalt may be present locally (Goodwin 1993). Intercalated strata consist of lenticular silty sand and clay up to 3 m (10 ft) thick and thin (<0.5 m) gravel. Fining upward sequences ranging from less than 1 m to several meters thick are common. Strata composing the association were deposited in wide, shallow river channels.

- **Overbank Deposits**. This facies association consists of laminated to massive silt, silty fine-grained sand, and paleosols containing varying degrees of pedogenic alteration, including both secondary clay and calcium-carbonate horizons. Overbank deposits occur as thin (<0.5 to 2 m) lenticular interbeds in the fluvial gravel and fluvial sand associations and as thick (up to 10 m [33 ft]), laterally continuous sequences. These sediments record deposition in proximal-levee to more distal-floodplain conditions.

- **Lacustrine Deposits**. Finely laminated, stratified to massive clay to silt facies with thin intercalated silty sand facies displaying occasional soft-sediment deformation characterize this facies association. Coarsening upward sequences less than 1 m (3 ft) thick to 10 m (33 ft) thick are common. This facies association was deposited in a lake under standing water to deltaic conditions.

- **Alluvial Fan**. Massive to crudely stratified, weathered to unweathered basaltic detritus dominates this facies association. These basaltic deposits generally are found around the periphery of the basin. The facies association records deposition by debris flows in alluvial fan settings and in sidestreams draining into the Pasco Basin.

Of these, all but the alluvial-fan facies association is represented beneath the T and TX-TY WMAs.

The stratigraphic distribution of these facies associations provides the basis for subdividing the Ringold Formation into three mappable, informal members (Wooded Island, Taylor Flat, and Savage Island) exposed along the White Bluffs, located 25 km (15 mi) east of the T and TX-TY WMAs along the eastern boundary of the Hanford Site (Lindsey 1996). The member of Wooded Island consists predominantly of fluvial gravel with lesser occurrences of the other facies associations. Fluvial sand and overbank deposits characterize the member of Taylor Flat. The member of Savage Island consists predominantly of lacustrine deposits. Ringold strata beneath these WMAs are assigned to the members of Wooded Island locally overlain by an erosional remnant of the member of Taylor Flat (Lindsey 1996). During the period of post-Ringold incision, the member of Savage Island was completely eroded away from the center of the basin, including beneath the T and TX-TY WMAs.

Fluvial gravels belonging to the member of Wooded Island are the predominant facies association represented beneath the T and TX-TY WMAs (Lindsey et al. 1994a, Lindsey 1996). These are further subdivided into the unit A and unit E gravels, which are separated by a lacustrine and/or overbank facies interval designated the lower mud unit.

2.2.7.1 Member of Wooded Island.

Unit A. Unit A consists predominantly of the fluvial gravel facies association. Only boreholes W10-24, W14-14, and W-11-26 extend into unit A within the T and TX-TY WMAs. Unit A is about 20 m (65 ft) thick. A less-than-2 m (5-ft) sequence of massive, fine-grained sand and silt belonging to the overbank facies association is found, at least locally, near the center of unit A.

Lower Mud Unit. As with unit A, only three boreholes (W10-24, W14-14, and W-11-26) near the T and TX-TY WMAs penetrate into the overbank/lacustrine deposits of the lower mud unit. Based on a regional evaluation, the lower mud unit appears to be continuous beneath these WMAs, where it is between 6 and 11 m (20 and 36 ft) thick (DOE 1993, Lindsey et al. 1994a, Lindsey 1996). The lower mud unit pinches out a few thousand feet to the east, apparently removed during post-Ringold erosion (Figure 2-7). The top of the lower mud unit generally conforms to the top of basalt, dipping gently (0.6 degree) to the southwest. The dip of this unit probably is structural as a result of post-depositional tectonic folding; in this case, beds dip toward the axis of the Cold Creek syncline located south of the study area.

Unit E. Unit E consists predominantly of the fluvial-gravel facies association with occasional thin beds of the fluvial-sand and/or the overbank facies associations. Within the T and TX-TY WMAs, unit E averages about 85 m (275 ft) thick and the top of the unit dips gently to the southwest (see Figure B-7), consistent with the top of basalt and underlying Ringold units. There exists 23 ft (7 m) of relief on top of the Ringold unit E beneath these WMAs. The water table lies within unit E gravels at about 70 m (225 ft) deep, about half way between basalt bedrock and the ground surface.

2.2.7.2 Member of Taylor Flat (Upper Ringold Unit). The Ringold Formation informal member of Taylor Flat within the T and TX-TY WMAs (formerly referred to as the upper Ringold unit) consists of interstratified, well-bedded fine to coarse sand to silt belonging to a mixture of fluvial sand and overbank facies associations. The member is discontinuous across the study area because of post-Ringold erosion and pedogenesis. In some areas erosion has stripped away the member entirely, while in others up to 10 m (30 ft) are sandwiched between the Plio-Pleistocene unit and the Ringold member of Wooded Island gravels.

The distribution and thickness of the member of Taylor Flat is highly variable beneath these WMAs. Thickness ranges from 0 to 10 m (0 to 33 ft) (Figure B-8). Generally, the member of Taylor Flat is absent to the south and becomes thicker to the north. It is locally absent beneath the TX tank farm. The top of the unit dips to the southwest and, where the unit is present, up to 9.4 m (31 ft) of relief exists on top of it (Figure B-9).

Weathering and soil development associated with the overlying Plio-Pleistocene unit often is overprinted onto the member of Taylor Flat. Because the degree of Plio-Pleistocene pedogenesis decreases with depth, the contact with the overlying Plio-Pleistocene unit is gradational and generally defined by an upward decrease in gross gamma-ray activity, increase in $CaCO_3$ content, and/or decrease in mud content (indicative of more cementation).

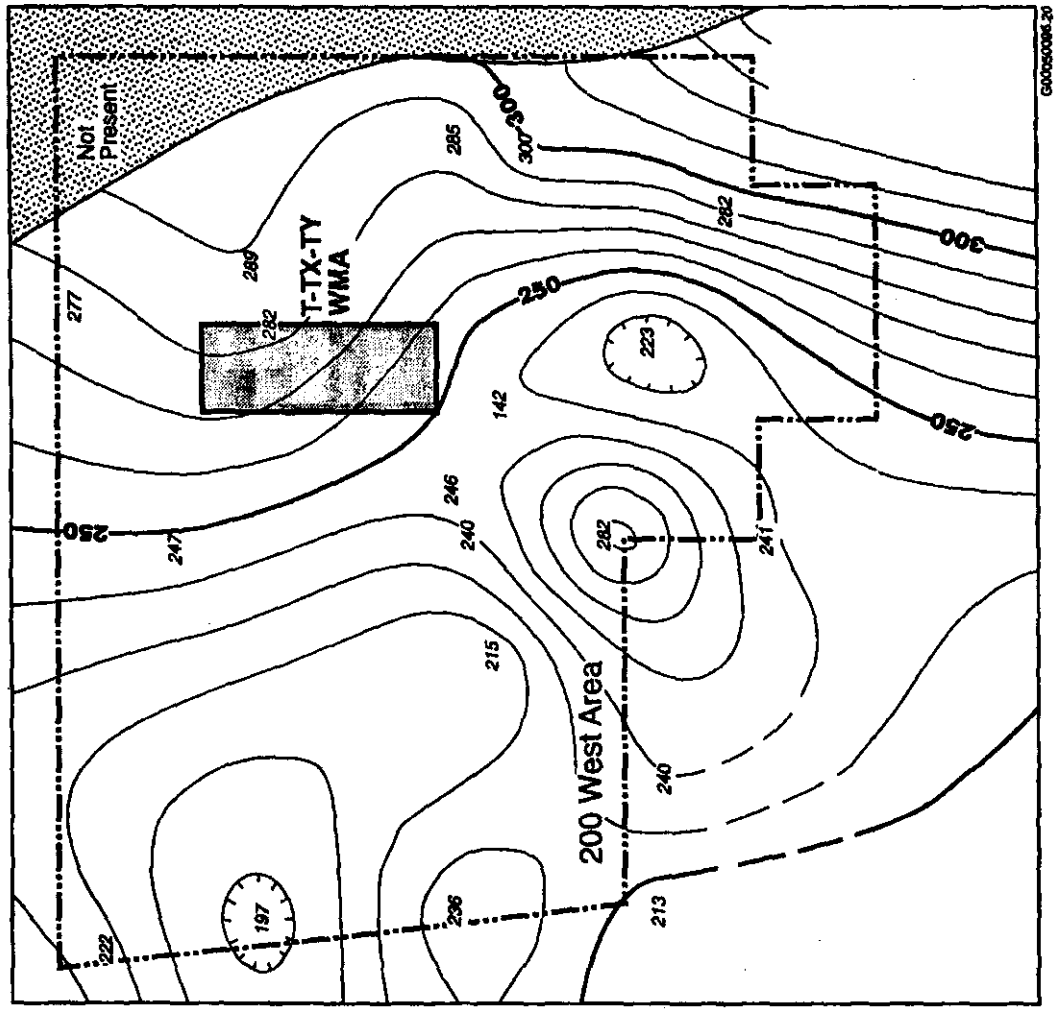


Figure 2-7. Top of Ringold Lower Mud Unit Within the 200 West Area (modified after Connelly et al. 1992).

2.2.8 Plio-Pleistocene Unit Beneath the T and TX-TY WMAs

The Plio-Pleistocene unit lies unconformably on the tilted and truncated Ringold Formation that formed following incision and downcutting of the Ringold Formation by the ancestral Columbia River system, which began about 3.4 million years ago. Several different facies make up the Plio-Pleistocene unit at the Hanford Site. They are pedogenic calcrete (i.e., calcic paleosol), sidestream alluvium, coarse-grained mainstream alluvium (Bjornstad 1984, DOE 1988, Lindsey et al. 1994b, Slate 1996, Wood et al. 2000), and a silt-rich alluvial and/or eolian facies (Lindsey et al. 1994b, Wood et al. 2000). Neither the mainstream alluvial facies of the Plio-Pleistocene unit, also referred to as the pre-Missoula gravels, nor the sidestream alluvial facies are present beneath these WMAs. The calcrete facies of the Plio-Pleistocene unit, also referred to as the "caliche layer," and the silt-rich alluvial and/or eolian facies are well represented and ubiquitous beneath the study area. The following discussion focuses on the Plio-Pleistocene calcrete facies. The silt-rich alluvial and/or eolian facies, formerly called the early Palouse soil, is discussed in Section 2.2.9.

Diagnostic features of the pedogenic calcrete facies of the Plio-Pleistocene unit include induration associated with a high concentration of calcium-carbonate cement, presence of root traces and animal burrows in cores, and white color (Bjornstad 1990). As a result of a long period of surficial weathering in a semi-arid environment similar to current conditions, calcic-soils (up to morphogenetic stage V) developed atop the Ringold Formation (Figure 2-8). While some aggradation of new material may be associated with the calcrete, much of the material is the result of in situ weathering of the uppermost Ringold Formation (either unit E gravels or fine-grained deposits of the member of Taylor Flat). The $CaCO_3$ overprint may occur on a variety of lithologies, including silt, felsic sand and gravel, and basaltic sand and gravel (Lindsey et al. 2000). The amount of $CaCO_3$ within the Plio-Pleistocene calcrete averages about 10 to 20 wt%, but has been measured as high as 70 wt%. The top of the Plio-Pleistocene calcrete is well defined by a coincident significant increase in $CaCO_3$ content and decrease in mud content and sorting, accompanied by a sudden drop in total gamma activity (i.e., ^{40}K) on borehole geophysical logs (Bjornstad 1990, DOE-GJ 1997, 1998). In this report we define the top of the Plio-Pleistocene calcrete as the top of the first pedogenically altered, carbonate-rich, cemented zone, accompanied by a sudden drop in gross gamma activity.

The several morphogenetic stages of calcic soil development, as described in Gile et al. (1966), Rettalack (1988), and Machette (1985), are presented in Figure 2-8. Characteristic features associated with calcic soil development range from dispersed calcareous filaments (stage I) to a meter or more of massive carbonate-plugged horizons with more than 50 wt% $CaCO_3$ (stage IV to VI). Stage I calcic soils may form in as little as a few tens of thousands of years, while advanced stages of calcic soil development (greater than or equal to stage IV) can take a million years or more to develop. Examples of surface analogs of calcic soil horizons located in the region, ranging from stage II to V, are presented in Figure 2-9. The Plio-Pleistocene calcrete beneath the T and TX-TY WMAs probably contains the range of physical and chemical properties comparable to those presented in Figure 2-9.

Figure 2-8. Morphogenetic Stages of Calcic-Soil Development Observed in Arid to Semiarid Environments (modified after Rettalack 1990).

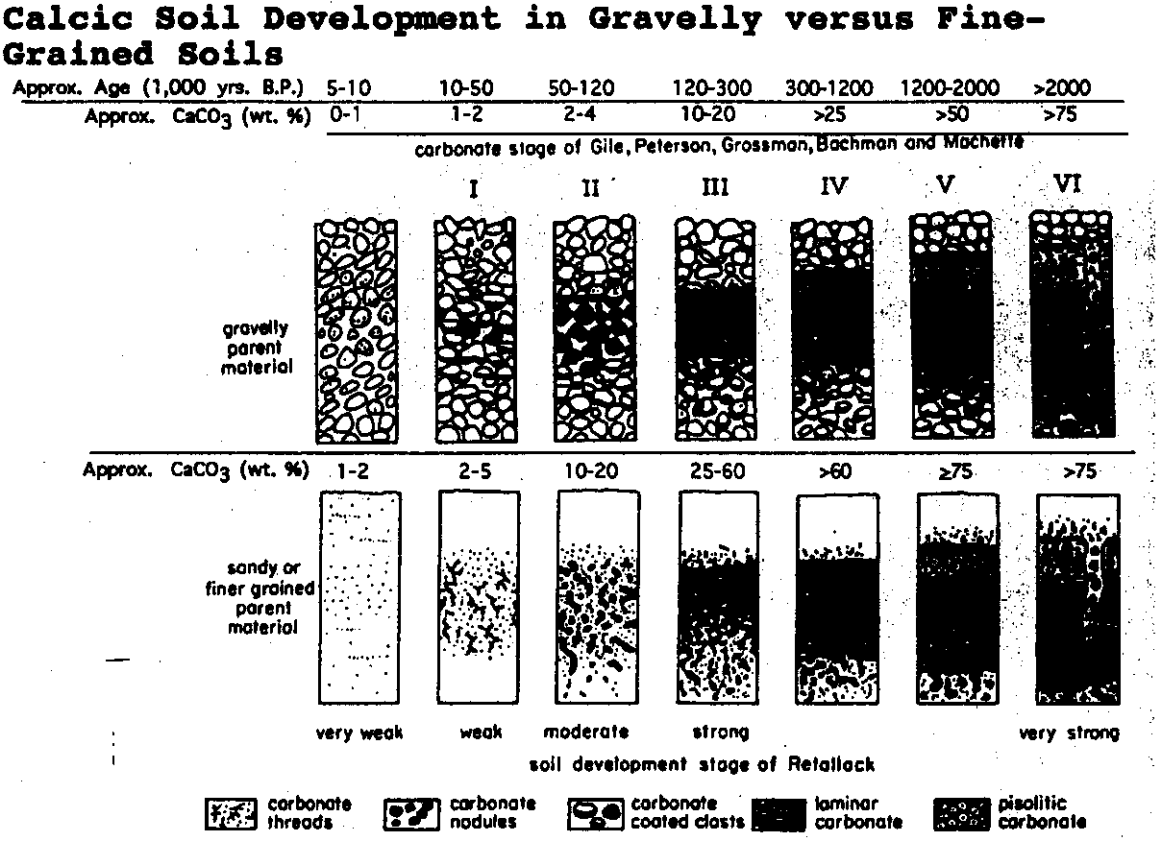


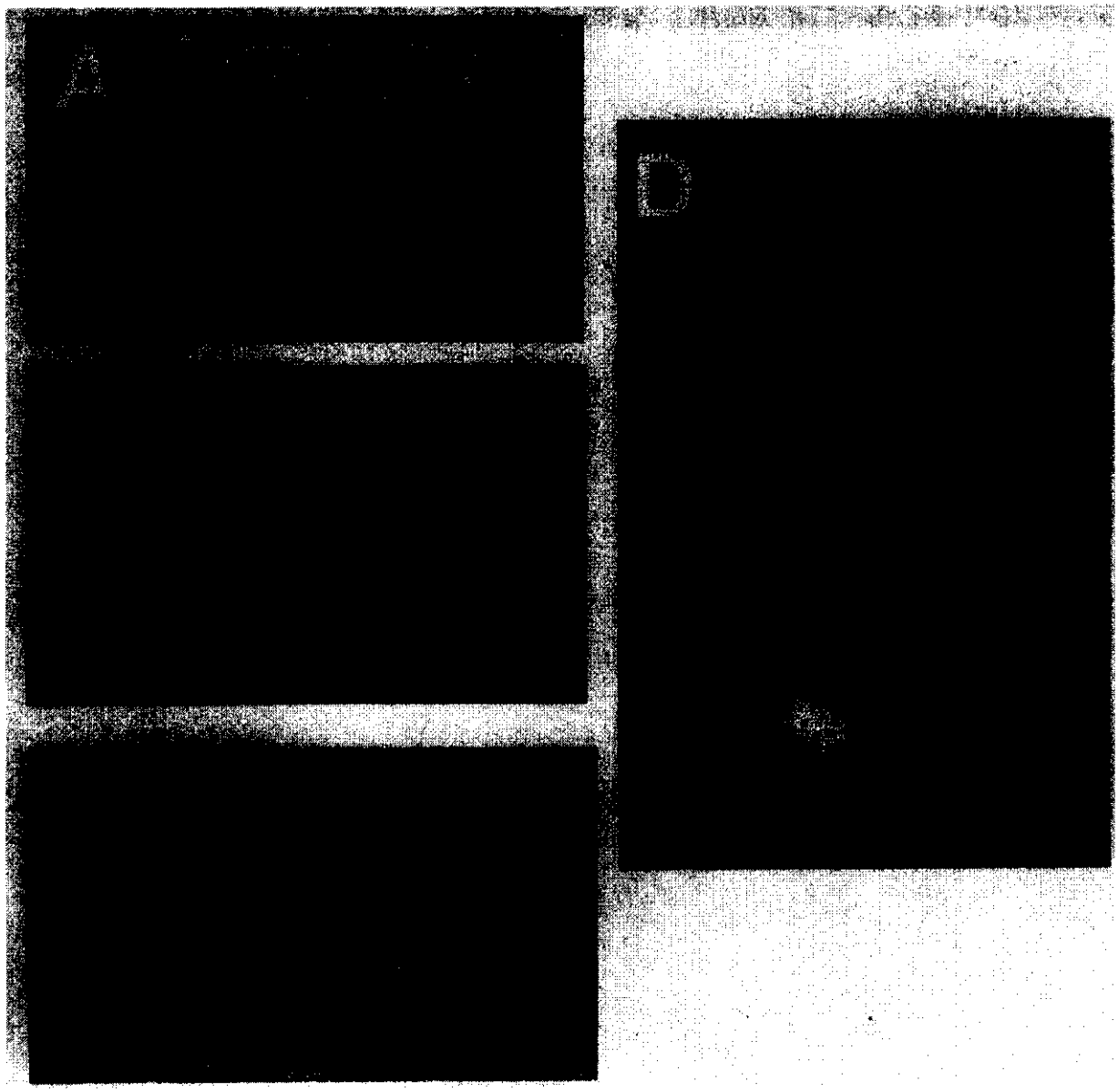
Figure 13.3 Stages of the morphology of carbonate accumulations in soils formed on gravelly and on sandy or finer grained alluvium (modified from Gile *et al.* 1966 and Machette 1985, with permission of Williams & Wilkens Co. and the Geological Society of America).

Table 13.2 Stages of carbonate accumulation in paleosols (from Machette 1985)

Stage	Paleosols developed in gravel	Paleosols developed in sand, silt or clay
I	Thin discontinuous coatings of carbonate on underside of clasts	Dispersed powdery and filamentous carbonate
II	Continuous coating all around and in some cases between clasts: additional discontinuous carbonate outside main horizon	Few to common carbonate nodules and veinlets with powdery and filamentous carbonate in places between nodules
III	Carbonate forming a continuous layer enveloping clasts: less pervasive carbonate outside main horizon	Carbonate forming a continuous layer formed by coalescing nodules: isolated nodules and powdery carbonate outside main horizon
IV	Upper part of solid carbonate layer with a weakly developed platy or lamellar structure capping less pervasively calcareous parts of the profile	
V	Platy or lamellar cap to the carbonate layer strongly expressed: in places brecciated and with pisolites of carbonate	
VI	Brecciation and recementation as well as pisoliths common in association with the lamellar upper layer	

Figure 2-9. Examples of Calcic Soils Developed in Fine-Grained Deposits in the Pasco Basin that are Analogous to the Plio-Pleistocene Calcrete Facies Beneath the T and TX-TY WMAs.

(Arranged in order of advancing calcic-soil development: (A) carbonate nodules (stage II), (B) subhorizontal carbonate stringers (stage II), (C) petrocalcic stringers and nodules (stage III-IV), and (D) thick, massive petrocalcic layer (stage V).)



The thickness and degree of calcic soil development within the Plio-Pleistocene calcrete varies laterally. Sometimes a single, thin (1 m or less), well-cemented horizon is all that is represented, as in borehole 299-W14-14 (see cross section, Figure B-6). Elsewhere, multiple carbonate-rich horizons indicate that many periods of soil development occurred, locally separated by relatively non calcareous, uncemented sand, silt, or even locally derived basaltic gravel (e.g., borehole 299-W10-18, see cross section, Figure B-5). Petrocalcic (greater than or equal to stage IV) horizons are reported as being fractured; this may be the result of percussion-induced fragmentation that occurs while driving the split-spoon through a cemented interval and/or natural variation in $CaCO_3$ content and in situ stress.

The top of the Plio-Pleistocene calcrete dips to the southwest at about 1 degree (Figure B-10). Some of the dip probably reflects the paleotopography that existed following post-Ringold incision and during the subaerial weathering of the eroded Ringold surface. Because the relief, 12.2 m (40 ft) on top of the Plio-Pleistocene calcrete, is almost double that of the top of the Ringold lower mud unit (0.6 degree), at least some of the relief must be nontectonic (i.e., sloping floodplain dipping toward valley axis). The Plio-Pleistocene calcrete interval is generally between 3 and 7 m (10 and 20 ft) thick beneath the T, TX, and TY tank farms (Figure B-11), and somewhat thicker to the north and east.

2.2.9 Hanford Formation(?)/Plio-Pleistocene(?) Deposits Beneath the T and TX-TY WMAs

A distinctive silt-rich interval, referred to here as H/PP deposits, overlies the Plio-Pleistocene calcrete facies over most of the 200 West Area (Brown 1960, Tallman et al. 1979, Bjornstad 1984, DOE 1988). Recent investigators have included the H/PP deposits (formerly called early Palouse soil) as a subunit of the Plio-Pleistocene unit (Lindsey et al. 1994b). Unlike the lower boundary of these strata, which easily is differentiated from the underlying Plio-Pleistocene calcrete, the upper contact with the overlying Hanford formation in the vicinity of these WMAs can be difficult to identify. Because the upper portion of these deposits may appear similar to or grade upward into the Hanford formation, we refer to this interval as H/PP deposits. Historically, deposits of the H/PP interval have been described as a massive, unconsolidated, micaceous, brown to yellow, loess-like silt and minor fine-grained sand (Price and Fecht 1976, Tallman et al. 1981, Bjornstad 1984 and 1990, DOE 1988, Last et al. 1989, Lindsey et al. 1991, DOE 1993). Brown (1959) originally reported this well-sorted, buff-colored, eolian unit to be up to 21 m (70 ft) thick in the southern portion of the 200 West Area. The H/PP deposits generally were thought to be derived from the eolian reworking of the underlying Ringold member of Taylor Flat (upper Ringold unit) and/or the Plio-Pleistocene calcrete facies (Brown 1960, DOE 1988).

More recent investigations indicate the H/PP deposits may contain facies other than eolian silt and fine sand (Lindsey et al. 1994b, Slate 1996, Lindsey et al. 2000). For example, a study in the S-SX WMA, located approximately 1.8 km (1 mi) south of the T and TX-TY WMAs, indicates the H/PP interval is composed of mostly intercalated layers of fine sand and silt, more characteristic of alluvial deposits (Lindsey et al. 2000), at least at this location. It appears then that this interval may consist of a mixture of fine-grained deposits from both eolian and alluvial depositional environments. Regardless of its exact stratigraphic

relationship and origin, the H/PP interval is a distinctive lithostratigraphic unit that significantly influences the moisture and contaminant distribution within the vadose zone.

Based on its fine-grained texture and high natural gamma activity on geophysical logs (DOE 1988, Last et al. 1989, Bjornstad 1990), this unit can be correlated across most of the 200 West Area. The H/PP deposits generally are absent away from the 200 West Area. An exception is just north of the B tank farm in the 200 East Area, where a similar-appearing fine-grained deposit lies between the Hanford formation and a mainstream facies of the Plio-Pleistocene unit (Wood et al. 2000).

In general, the top of the H/PP interval is identified based on an increase in background gamma activity on geophysical logs (DOE-GJ 1997) and an increase in mud content (up to 75 wt%). Calcium carbonate content often is a few weight percent more than for the overlying fine-grained Hanford formation (H2 unit), and usually is significantly less than for the underlying pedogenic calcrete facies of the Plio-Pleistocene unit. The basal contact is distinct, indicated by a sharp drop in total gamma activity and percent mud content (Bjornstad 1990). Also, compared to the pedogenically altered and cemented Plio-Pleistocene calcrete, the H/PP deposits are relatively loose and friable. While the H/PP interval often contains moderate to high concentrations of $CaCO_3$, it appears to be evenly disseminated and therefore probably is of detrital origin. This is in sharp contrast to the underlying Plio-Pleistocene calcrete, where the $CaCO_3$ is concentrated within discrete calcic horizons.

Similar to the other stratigraphic units, the top of the H/PP interval dips gently to the southwest (Figure B-12). As much as 13.4 m (44 ft) of relief exists on top of the H/PP deposits across the T and TX-TY WMAs. The H/PP deposits generally are 2 m to 5 m (5 to 15 ft) thick beneath the T, TX, and TY tank farms (Figure B-13). The maximum thickness within the study area is 7 m (20 ft) in borehole 299-W14-4 (Figure B-5).

2.2.10 Hanford Formation Beneath the T and TX-TY WMAs

The Hanford formation is the informal name given to all glacio-fluvial strata deposited from cataclysmic ice-age floods within the Pasco Basin (DOE 1988). Sources for floodwaters included Glacial Lake Missoula, Pluvial Lake Bonneville, and ice-margin lakes that formed around the margins of the Columbia Plateau (Baker et al. 1991). Cataclysmic floods were released during at least four major glacial events that occurred between about 1 Ma and 13 Ka (early to late Pleistocene time). The Hanford formation consists predominantly of unconsolidated sediments that cover a wide range in grain sizes from pebble to boulder gravel, fine- to coarse-grained sand, silty sand, and silt. The Hanford formation is further subdivided into gravel-, sand-, and silt-dominated facies. Gravel-, sand-, and silt-dominated facies also are referred to as the coarse-grained, transitional, and rhythmite facies, respectively, of the Hanford formation (Baker et al. 1991). Facies of the Hanford formation are commonly described as laterally interfingering. The relative proportion of each facies at any given location is related to distance from main, high-energy flood flows at the time of deposition.

Gravel-Dominated Facies. This facies generally consists of coarse-grained basaltic sand and granule to boulder gravel. These deposits display an open framework texture, massive bedding,

plane to low-angle bedding, and large-scale planar cross bedding in outcrop. Gravel-dominated beds sometimes grade upward into sand- and silt-dominated facies. Gravel clasts are dominantly basalt with lesser amounts of Ringold Formation clasts, granite, quartzite, and gneiss. The small pebble size fraction of these deposits typically consists almost entirely of basalt. The gravel-dominated facies was deposited by high-energy floodwaters in or immediately adjacent to the main cataclysmic flood channelways.

Sand-Dominated Facies. This facies consists of fine- to coarse-grained sand and granule gravel. The coarser sands typically have a high basalt content and are commonly referred to as black, gray, or "salt-and-pepper" sands. Finer sands can be more quartzo-feldspathic. The facies may contain small pebbles, rip-up clasts, and pebble-gravel interbeds, and often grade upward into zones of silt-dominated facies less than 1 m thick. This facies also commonly displays plane lamination and bedding and less commonly channel cut-and-fill sequences. The sand-dominated facies was deposited adjacent to main flood channelways during the waning stages of flooding. The facies is transitional between the gravel-dominated facies and the silt-dominated facies.

Silt-Dominated Facies. This facies consists of thin-bedded, plane-laminated, and ripple cross-laminated silt and fine- to coarse-grained sand. Beds are typically a few inches to several tens of inches thick and commonly display normally graded-bedding. Sediments of this facies were deposited under slack water conditions and in back-flooded areas (DOE 1988, Baker et al. 1991).

The sand and gravel fractions of the Hanford formation average about 50 percent mafic (i.e., basalt) and 50 percent felsic material (Tallman et al. 1979). This mineral assemblage gives the Hanford formation its characteristic salt and pepper appearance, often noted in drillers' and geologists' logs. The felsic component consists of quartz and feldspar with some samples containing greater than 10 percent pyroxene, amphibole, mica, chlorite, ilmenite, and magnetite. The silt- and clay-sized fractions consist of quartz, feldspar, mica, and smectite.

Based on lithologies observed at the T and TX-TY WMAs, the Hanford formation is divided into two informal units designated H1and H2. These units are equivalent to the upper coarse (Hc) and lower fine (Hf) units of the Hanford formation, respectively, as reported in DOE (1993).

2.2.10.1 Fine-Grained Sequence (H2 Unit). The H2 unit consists of predominantly sand-dominated facies of the Hanford formation. Internally this sequence probably contains multiple graded beds of plane- to forest-bedded sand, several meters or more thick, with minor intercalated gravelly sand. Some of the deposits are normally graded, grading upward into silty sand. Many more silt layers may be present in the subsurface than are reported in drillers' and geologists' logs and appear in the cross sections (Appendix B). This is because, using this drill method and/or sampling interval (normally every 1.5 m [5 ft]), we often cannot distinguish layers less than a few feet thick. At least three 0.3 m (1-ft)-thick, fine-grained silt beds occur within the H2 unit in borehole 299-W15-166 (Appendix C). Lindsey et al. (2000) noted that such intercalated silt horizons are relatively rare in correlative sand deposits sampled in nearly continuous split-spoon samples, at the S-SX tank farms, located about 1.8 km (1 mi) south of the T and TX-TY WMAs. Cementation is minor or absent, and total $CaCO_3$ content generally is only a few weight percent or less.

The Hanford formation fine-grained sequence (H2 unit) is continuous beneath the T and TX-TY WMAs. The base of the H2 unit sometimes is difficult to distinguish from the underlying H/PP interval with which it may share a similar grain-size distribution. However, the gross gamma geophysical log is useful for differentiating the two units. The base of the H2 unit is picked based on the point where the gross gamma log begins to increase significantly. The H2 unit also has been identified on the basis of an abrupt transition from well-stratified sand to highly interstratified sand and silt in some continuous, recently cored boreholes at the S-SX tank farms (Lindsey et al. 2000).

In general, the top of the Hanford formation H2 unit is chosen based on the first appearance of flood gravels more than or equal to 1.5 m (5 ft) thick in an upward direction. There does not appear to be a single planar surface separating the H2 unit from the overlying flood gravels of the H1 unit, however. Instead, it appears that discontinuous lenses of flood gravel are dispersed throughout the H2 unit with lateral facies changes occurring locally between flood gravels and flood sands (Figures B-1 through B-6). This makes the choice of drawing the contact difficult and can account for the irregular contour patterns observed on the structure contour map of this surface (Figure B-14).

Overall, the top of the H2 unit dips to the west (Figure B-14). The map shows about 20 m (65 ft) of relief on the surface of the H2 unit beneath the T and TX-TY WMAs. The top of this unit is sometimes complicated where the sand sequence is interbedded with gravels; when this occurs picking the contact between the fine-grained sequence (H2 unit) and the overlying flood gravels (H1 unit) is difficult. Interbedding of flood sands and gravels probably represents lateral facies changes as a result of a transitional depositional environment or gravel-starved areas during deposition. The H2 unit generally thickens to the southeast beneath these WMAs because of the greater distance to the nearest high-energy flood flows in this direction (Figure B-15).

2.2.10.2 Coarse-Grained Sequence (H1 Unit). The H1 unit overlies the H2 unit everywhere beneath the T and TX-TY WMAs, except where the H1 unit has been removed by excavation. This sequence is equivalent to the gravel sequence of the Hanford formation described by Last et al. (1989), and to the Qfg [quarternary fine gravel] described by Reidel and Fecht (1994).

Based on observations of outcrop and intact core samples, the Hanford formation coarse-grained sequence is interpreted to consist of the high-energy, gravel-dominated facies interbedded with lenticular and discontinuous layers of the sand-dominated facies. Silt-dominated facies also may be present although they probably constitute a relatively small percentage of the total.

The H1 unit generally is thicker in the western portion of these WMAs (Figure B-16), perhaps because of higher energy deposition associated with the north-south trending paleochannel, expressed topographically in Figure 2-3. The H1 unit is locally thinner beneath the tank farms as a result of excavation and backfilling near the tanks. In a few places, all the H1 unit appears to have been removed during excavation for the tanks beneath the T, TX, and TY tank farms (DOE-GJ 1998) (Figure B-16).

2.2.11 Holocene Deposits Beneath the T-TX-TY WMA

Holocene deposits emplaced over the T and TX-TY WMAs since the last floods are limited to recent windblown silt and sand and construction backfill. Eolian sheet sands occur sporadically at the surface and generally are less than 1 to 2 m thick. Eolian sand does not overlie the tank farms themselves, having been removed during excavation, but does occur around the periphery of the tank farms. Backfill material occurs to depths of 15 m (55 ft), associated with the installation of the T, TX, and TY tank farms. The backfill, described as poorly sorted gravelly sand to sandy gravel (Price and Fecht 1976, Caggiano and Goodwin 1991), consists of Hanford formation sediments (H1 unit) excavated from depths from 14 to 17 m (45 to 55 ft) to make room for waste storage tanks. These deposits were stockpiled next to the tank farms and later used to fill in around the tanks. Sediments foreign to the TY tank farms may have been introduced during backfill to improve traction for construction vehicles (DOE-GJ 1998).

2.2.12 Clastic Dikes

Clastic dikes are vertical to subvertical sedimentary structures that crosscut normal sedimentary layering. The dikes are common to ice-age flood deposits, especially in the sand- and silt-dominated facies of the Hanford formation (Black 1979, Fecht and Weekes 1996, Fecht et al. 1999). Clastic dikes are much less common in the gravel-dominated facies of the Hanford formation. Some clastic dikes were noted during excavation of the T, TX, and TY tank farms (Price and Fecht 1976). Clastic dikes were intersected in boreholes 299-W15-134 and 299-W15-\-180, two vadose-zone borings in the TX tank farm (see Appendix C).

Where clastic dikes intersect the ground surface and are not covered with younger deposits, a feature know as patterned ground can be observed (Fecht et al. 1999). Well-developed patterned ground exists just south of the 200 West Area. Within the 200 West Area and the T and TX-TY WMAs, however, patterned ground is scarce because of the many human-caused surface disturbances and/or because it is buried under a thin cover of recent eolian sand. Clastic dikes occur in swarms and form four types of networks: regular-shaped polygonal-patterns, irregular-shaped polygonal-patterns, preexisting fissure fillings, and random occurrences. Clastic dikes near the T, TX, and TY tank farm probably occur randomly in the gravel-dominated facies of the Hanford formation (H1 unit) and as regular-shaped polygons in the finer grained facies (H2 unit). Regular polygonal networks resemble 4- to 8-sided polygons and typically range from 3 cm (1.2 in) to 1 m (3 ft) wide, from 2 m (5 ft) to greater than 20 m (65 ft) deep, and from 1.5 m to 100 m (5 to 325 ft) along strike. Smaller dikelets, sills, and small-scale faults and shears are commonly associated with master dikes that form the polygons.

In general, a clastic dike has an outer skin of clay with coarser in-filling material. Clay linings are commonly 0.03 mm to 1.0 mm thick, but linings up to about 10 mm are known. The width of individual in-filling layers ranges from as little as 0.01 mm to more than 30 cm (12 in.) and their length can vary from about 0.2 m (1 ft) to more than 20 m (65 ft). In-filling sediments are typically poorly to well-sorted sand, but may contain clay, silt, and gravel.

2.3 RECHARGE SOURCES AND EVENTS

The facility infrastructure, infiltration of water from natural sources and tank farm operations, and hydrologic properties of the stratigraphic units beneath the study area control the moisture and waste movement through the vadose zone to groundwater. This section summarizes available information on infiltration from natural resources; discharges caused by tank farm operations, and observed spatial and temporal effects on subsurface hydrologic properties. Supporting data tables and figures are provided in Appendix D.

Fluid infiltration into the soil column from natural sources and tank farm operations had a substantial effect on current environmental contamination conditions in the T and TX-TY WMAs. Temporal changes in vadose zone moisture distribution and water table elevation in response to historical variations in natural and artificial recharge, combined with aquifer properties, account for the rate and direction of contaminant dispersal in the aquifer.

2.3.1 Infiltration from Natural Sources

The tank farm surface characteristics and infrastructure create an environment conducive to enhanced general recharge and infiltration from transient high-intensity events. Natural infiltration, runoff events, and rapid snowmelt are discussed in Sections 2.3.1.1 through 2.3.1.3.

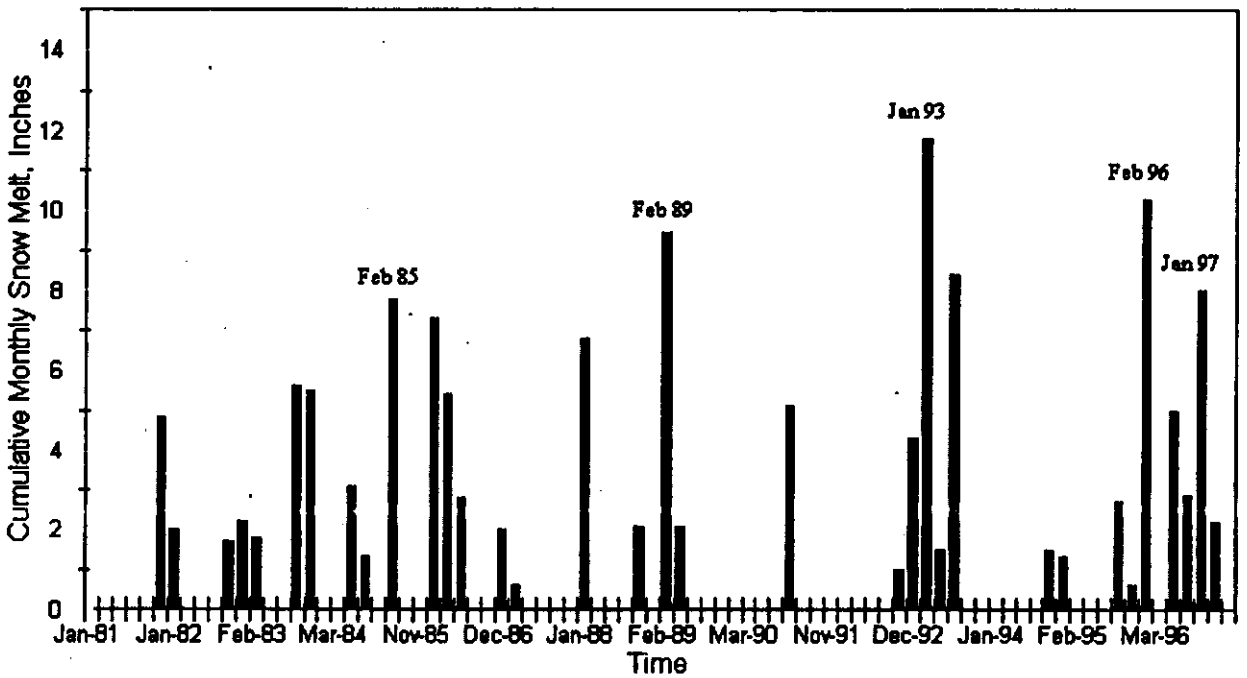
2.3.1.1 Infiltration. The natural infiltration rate under the T and TX-TY WMAs has not been measured directly. However, observations from similar disturbed gravel-covered areas on the Hanford Site indicate that as much as 10 cm/year (3.9 in./year) can infiltrate a vegetation-free coarse gravel surface (Gee et al. 1992; Fayer and Walters 1995; Fayer et al. 1996). This represents about 60 percent of the average annual precipitation (rainfall plus snowmelt). Fayer and Walters indicate that the T and TX-TY WMAs are in an area estimated to receive about 5 to 10 cm/year (1.97 to 3.9 in./year) of recharge from natural infiltration. This averaged infiltration estimate is based on soil type, lack of vegetation, and land use. Actual recharge is non-uniform because of the presence of the tanks and the surrounding disturbed soil. Recharge is blocked by the tank domes and "shed" into the soil near the tank walls. Thus, infiltration rates near tank edges and between tank rows are likely manyfold higher than average areal infiltration rates.

2.3.1.2 Runoff Events. Transient saturation from runoff collecting in low spots could be more significant as a driving force than average annual infiltration. For example, rapidly melting snow is one natural event that can lead to surface flooding. This type of occurrence has been documented at the T tank farm (Hodges 1998), but no similar record is available for the TX-TY WMA. The T WMA is a topographical low. Slopes adjacent to the WMA, especially along the east side, tend to funnel surface runoff directly into the T tank farm. This occurrence was documented in photographs following rapid snow melt in February 1979 (Hodges 1998). This ponded water over and around the tanks definitely infiltrated the vadose zone and drove any existing vadose zone contamination deeper into the soil column. The TX-TY WMA also is likely to have significant runoff recharging areas near and through the tank farms.

2.3.1.3 Rapid Snowmelt. Records of snowmelt have been kept since 1981 at the Hanford Meteorology Station, located between the 200 West and 200 East Areas. Figure 2-10 summarizes the total snowmelt per month for a 24-hour period. These records indicate periods

when unusual accumulations or ponding of water may have resulted in transient saturation events, particularly when preceded by a weather cold enough to freeze near-surface soils and facilitate surface migration, possibly leading to transport of contaminants through the vadose zone to groundwater. Several events in addition to the February 1979 snowmelt ponding event mentioned in Section 2.3.1.2 likely have occurred over the last 20 years, as shown in Figure 2-10. The snowmelt events, along with maximum monthly precipitation since 1946 (Appendix D, Table D-1), are correlated with groundwater contamination occurrences in Figure 2-11.

Figure 2-10. Monthly Summaries of Rapid Snowmelt Events, 1981 Through 1997.



2.3.2 Fluid Discharges from Tank Farm Operations

Throughout the operational history of the T, TX, and TY tank farms, fluids were discharged to the ground, both deliberately and inadvertently. Current groundwater contamination conditions are caused by these discharges, particularly large intentional discharges to reverse wells, cribs, and trenches. A list of intentional discharge sites and unplanned releases with descriptive information is provided in Appendix A in the table from Appendix A of Williams (2000). Liquid discharge events and locations are summarized by tank farm in the following paragraphs.

2.3.2.1 Intentional Releases. At T farm, significant amounts of liquid were discharged into three facilities within the T WMA and west of the T tanks. From 1946 through 1952, 224 waste (2.9×10^7 L) was disposed in the two 216-T-32 cribs (see Table 1 in Appendix A for radionuclide inventory estimates). From 1947 through 1955, and 2C, 5-6, and 224 waste (1.1×10^8 L) were discharged into the soil column through the 216-T-7 crib and tile field. In 1951, a discharge pipe was connected between the 216-T-7 crib and tank 241-T-112, the last

tank in the cascade series receiving 2C and 5-6 waste; this allowed continuous flow into the crib. In 1955, 2C waste (4.5 x 10^7 L) was discharged into the soil column through the 216-T-5 trench.

Several facilities received liquid waste adjacent to and outside of the T WMA. Just south of the T farm, crib 216-T-36 received 5.2 x 10^5 L of decontamination and condensate waste liquids in 1967 and 1968. Finally, to the northeast of T farm in trenches 216-T-14, -15, -16, and –17, a total estimated discharge of 3.8 x 10^6 L of 1C waste in 1954 is reported.

At the TX tank farm, the 216-T-19 crib and tile field at the southeast corner of the tank farm and within the TX-TY WMA received liquid waste from 1951 through 1980. In all, 4.3 x 10^8 L were discharged; the bulk of the material was condensate from the 242-T Evaporator operations with some bismuth phosphate waste (2C, 5-6, and 224 waste). To the west of the TX tank farm and outside the TX-TY WMA, the 216-T-21, -22-, -23, -24, and –25 trenches received 8.0 x 10^6 L of 1C waste in 1954.

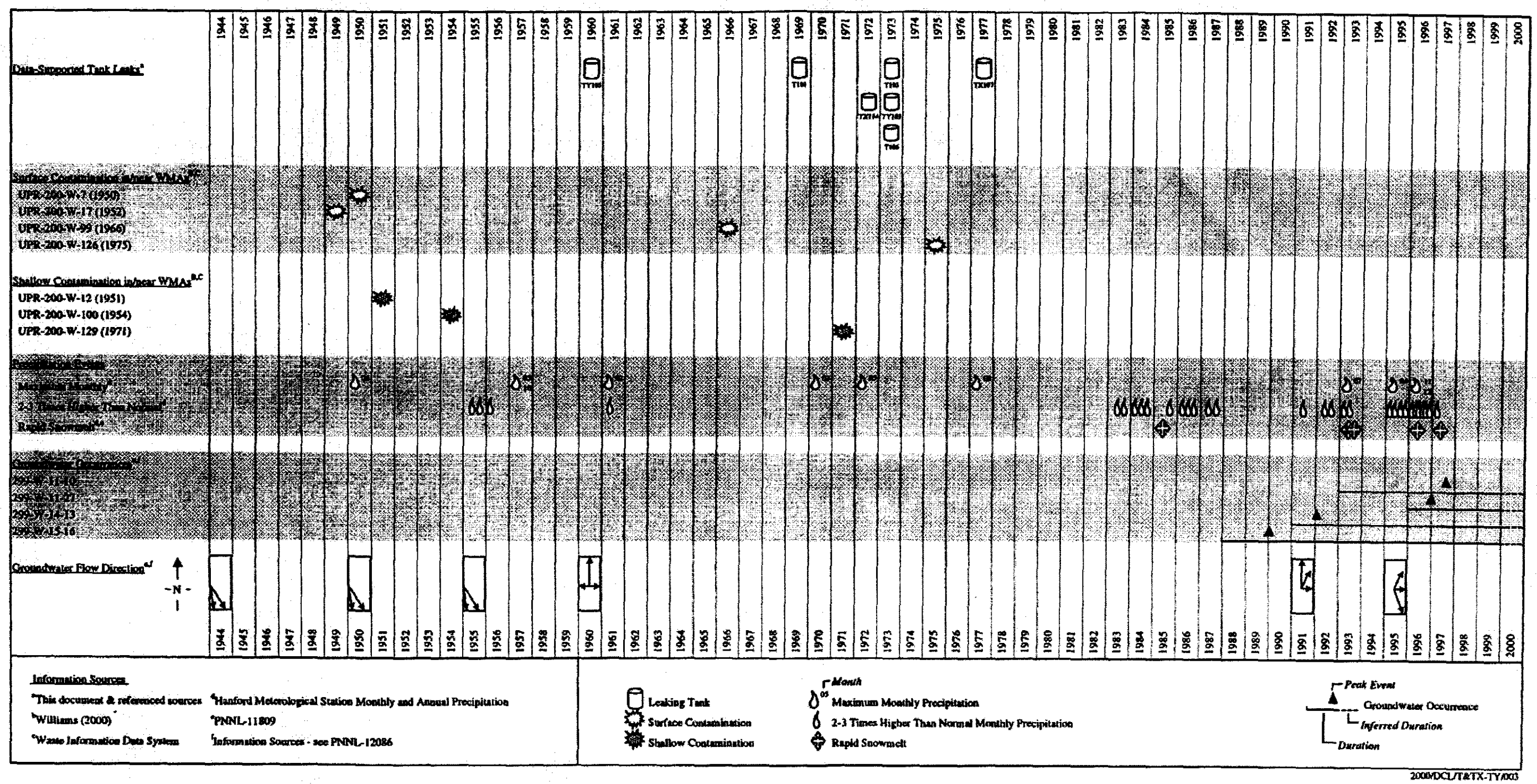
At the TY farm, no facilities inside the WMA boundary were used to intentionally discharge liquid waste. Primary liquid discharge facilities are located east of the TY farm. They include the 216-T-18 crib which received 1 x 10^6 L of scavenged TBP waste in 1953; the 216-T-26 crib, which received 1.2 x 10^7 L of scavenged 1C waste in 1955 and 1956; and the 216-T-27, and –28 cribs, which received 4.9 x 10^7 L of 340 Building laboratory waste from 1960 through 1966.

2.3.2.2 Unplanned Releases. Several unplanned releases (UPR) are reported within and around the T and TX-TY WMAs. These are shown in Appendix A in the table from Appendix B of Williams (2000). The largest UPRs within the T and TX-TY WMAs were the tank leaks (particularly the leak from tank 241-T-106) that could have been leaks from the tank or transfer lines attached to the tanks. These are discussed in more detail in Section 3.3. The following paragraphs summarize the smaller UPRs, arranged in chronological order by tank farm.

At the T tank farm, multiple UPRs occurred at the southeast corner in piping associated with diversion boxes 241-T-151 and 241-T-152. The first release occurred in 1950 in piping directly attached to the diversion boxes (UPR-200-W-7). No indication is given of the quantity of waste lost to the ground. The top foot of contaminated soil was removed and replaced with clean fill. In 1954, a transfer line connecting the diversion boxes to the 242-T Evaporator feed tank about 30 m south of the diversion boxes ruptured (UPR-W-29) and released 1,000 gal or less of 1C waste. In this incident a cave-in occurred around the pipe. Contamination was washed into the soil and the caved in are was filled with clean soil. In 1966, this transfer line was used again by mistake, releasing an unspecified quantity of liquid to the soil column (UPR-200-W-62). UPR-200-W-97 may be the same incident as UPR-200-62 or a similar incident with release at a different nearby location in the transfer line closer to the diversion boxes. In 1969, surface contamination from previous leaks in this area was discovered and removed (UPR-200-W-64). Finally, in the early 1990's, leaks may have occurred in a transfer line between the 207-T retention basin and the 2-4-T ditch.

At the TX tank farm, in 1951, a few gallons of waste were released through a riser on the south side of the 242-T Evaporator building (UPR-200-W-12), creating surface soil contamination. The contaminated soil was partially removed and replaced with clean fill.

Figure 2-11. Time Line of Hydrologic and Tank Farm Operations Events.



In 1952, less than 1 gal of waste leaked onto the surface from a waste pump being transported between tank 241-TX-106 and tank 241-TX-114 (UPR-200-W-17). Subsequently, high winds spread contamination southward. In 1954, an underground pipe leak of 1C waste between tank 241-TX-105 and tank 241-TX-108 (UPR-200-W-100) was detected by the discovery of surface contamination. Clean soil was placed over the contaminated area. Two incidents of airborne contamination originating from diversion box 241-TX-153 occurred, one in 1966 (200-UPR-W-99) and another in 1975 (200-UPR-W-126). In 1971, waste was released at the 241-TA-13A pump pit near tank 241-TX-113 (UPR-200-W-129).

The total liquid amounts released to the ground within the T and TX-TY WMAs from UPRs are not well quantified. However, the descriptions indicate that these releases were uniformly small (no more than a few gallons) within the T and TX-TY WMAs, with the possible exception of UPR-200-W-100, the underground pipe leak between tank 241-TX-105 and tank 241-TX-108. This UPR is unusual and may be a relatively large leak. The leak is discussed in greater detail in Section 3.3. Quantitative estimates of the leak probably cannot be generated. UPRs adjacent to the T and TX-TY WMAs also are apparently small, the largest (1,000 gal or less) being associated with the transfer line south of the T tank farm.

2.3.3 Subsurface Discharge

2.3.3.1 Vadose Zone Moisture Distribution and Migration. Substantial fluid volumes of tank waste and tank waste condensates were discharged into cribs and trenches adjacent to T and TX-TY WMAs. These fluids migrated into the unconfined aquifer and could have migrated into the vadose zone beneath the T and TX-TY WMAs. Some evidence based on groundwater chemistry indicates that aquifer contamination occurred. In the 1960's and 1970's high beta contamination was detected in nearby groundwater monitoring wells. Given that 20 to 40 years have passed since crib and trench discharges adjacent to the T and TX-TY WMAs occurred and the soils are highly permeable at the surface, any moisture remaining in the vadose zone from these sources is likely to be stored in silt-rich layers underlying the area. Fluid migration within the vadose zone could have been partially controlled by stratigraphic features. For example, when migrating fluids contact the caliche layer they may deflect laterally, wetting vadose zone soils and entering the groundwater at locations horizontally displaced from the starting point in the vadose zone (Schalla 1982).

Fluid volumes discharged by tank or waste transfer line leaks were much smaller than crib and trench volumes and are less likely to have percolated to the unconfined aquifer. However, migration within the vadose zone may have been significant. Based on a likely recharge scenario that 40 percent of the annual precipitation, which occurs almost exclusively during the winter, contributes to recharge, a flux rate of 70 mm/yr is estimated. Because the average water content in the coarse sediments is about 10 percent by volume, the pore water velocity will be 10 times the recharge rate or 0.7 m/yr penetration into the vadose zone. Over 20 years fluids may have migrated approximately 14 m into the subsurface (Ward et al. 1997).

2.3.3.2 Water Table and Artificial Recharge. General flow directions under the T and TX-TY WMAs have changed substantially because of Hanford Site operations. The flow direction in the local water table aquifer was from west to east before Hanford Site operations

began. The water table changed significantly after tank farm operations began in the early 1950's. In particular, during the time of most active waste disposal in the late 1940's and the 1950's in this area, groundwater flowed toward the south or southeast primarily because of large volumes disposed of in T Pond. The shift in discharge of large volumes of wastewater in the early 1950's to U Pond raised the water table in the vicinity of the T and TX-TY WMAs as much as 19 m (62 ft) above the pre-Hanford Site-operations level (Hartman 1999). Starting in the early 1950's, effluent discharges to U Pond, located approximately 450 m (1,475 ft) southeast of the U WMA, created a broad flat 26 m (85-ft) mound on the existing water table that quickly shifted to a dominant northeasterly flow through the T, TX-TY, and U WMAs (Graham et al. 1981). This northeasterly flow continued to dominate during the 1960's through 1980's and most of the 1990's. As a result of U Pond being decommissioned in 1984, water table elevations across the 200 West Area have been declining since 1985 (see Figure 1-2 for locations of wells monitored to track recent water level changes and contamination events). Water level declines have become even more pronounced since other effluent discharges throughout the 200 Areas ceased in 1995. Water levels have declined approximately 7 m (23 ft) in the last 10 years around the T and TX-TY WMAs (Figures 2-12 and 2-13). Water levels are expected to continue to decline, but at a decreasing rate (excluding pump-and-treat activity areas).

In the T and TX-TY WMAs, new wells with longer screened intervals have replaced older wells that have gone dry. For example, well 299-W10-23 replaced well 299-W10-15 and 299-W10-24 replaced well 299-W11-27. Along with the water level decline in this area has been a decrease in the hydraulic gradient and, in the last few years, changes in the flow direction in some portions of the T and TX-TY WMAs (Figure 2-11 and Figure 2-14). The mound caused by discharges to the U Pond, though relatively flat, continues to influence groundwater flow to this day. However, groundwater flow direction is becoming more easterly (i.e., the original pre-Hanford Site operations flow direction) as shown in a recent water level contour map (Figure 2-15). However, remediation pumping that began at 200-ZP-1 in 1994 and the resulting cone of depression gradually created a south-to-southeasterly flow component at the southern end of the TX and TY tank farms (Figure 2-14).

Hydraulic response of the aquifer to pump and treat operations at 200-ZP-1 has been reported in other documents (DOE/RL 1999 and 2000), and its most recent impact on water levels is shown in Figure 2-14. Pumping at 200-ZP-1 developed in three phases. Phase I consisted of one pilot well extracting water at 150 L/min (45 gal/min) from August 29, 1994, to July 19, 1996. In Phase II, three wells were used to extract water at 570 L/min (150 gal/min) from August 5, 1996, to August 7, 1997 (DOE/RL 1999). Phase III began on August 29, 1997, using 5 wells to extract contaminated water at a rate of 720 L/min (190 gal/min). Phase III pump and treat of the water from the carbon tetrachloride plume continues at approximately this rate to the present (DOE/RL 2000). Water levels have declined rapidly, but the future rate of long-term changes in water levels at the T and TX-TY WMAs is uncertain, partly because of pump-and-treat activities. Screen lengths in new wells are 11 m (35 ft) in anticipation of significant continuing water level decline over the next several years.

Figure 2-12. Historical Water Levels Near the T WMA (Hodges 1999a).

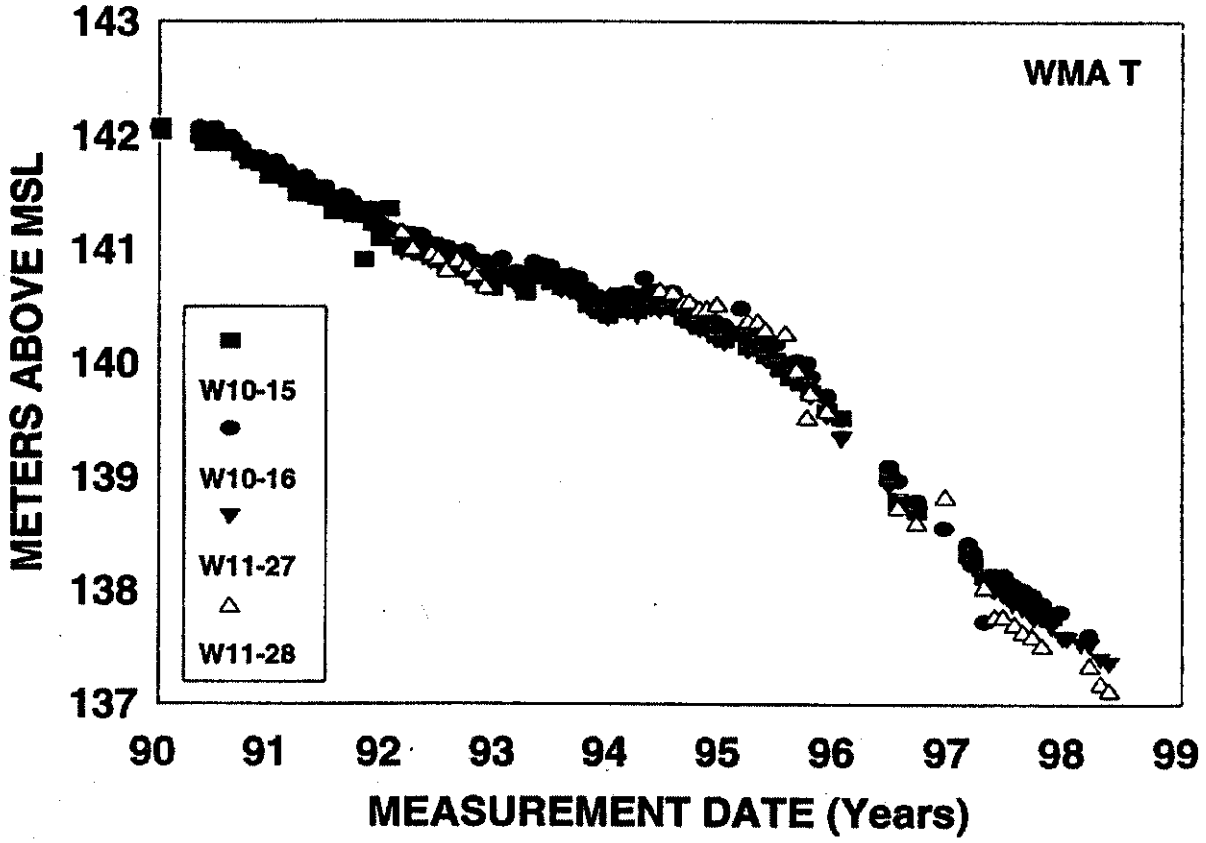


Figure 2-13. Historical Water Levels Near the TX-TY WMA (Hodges 1999b).

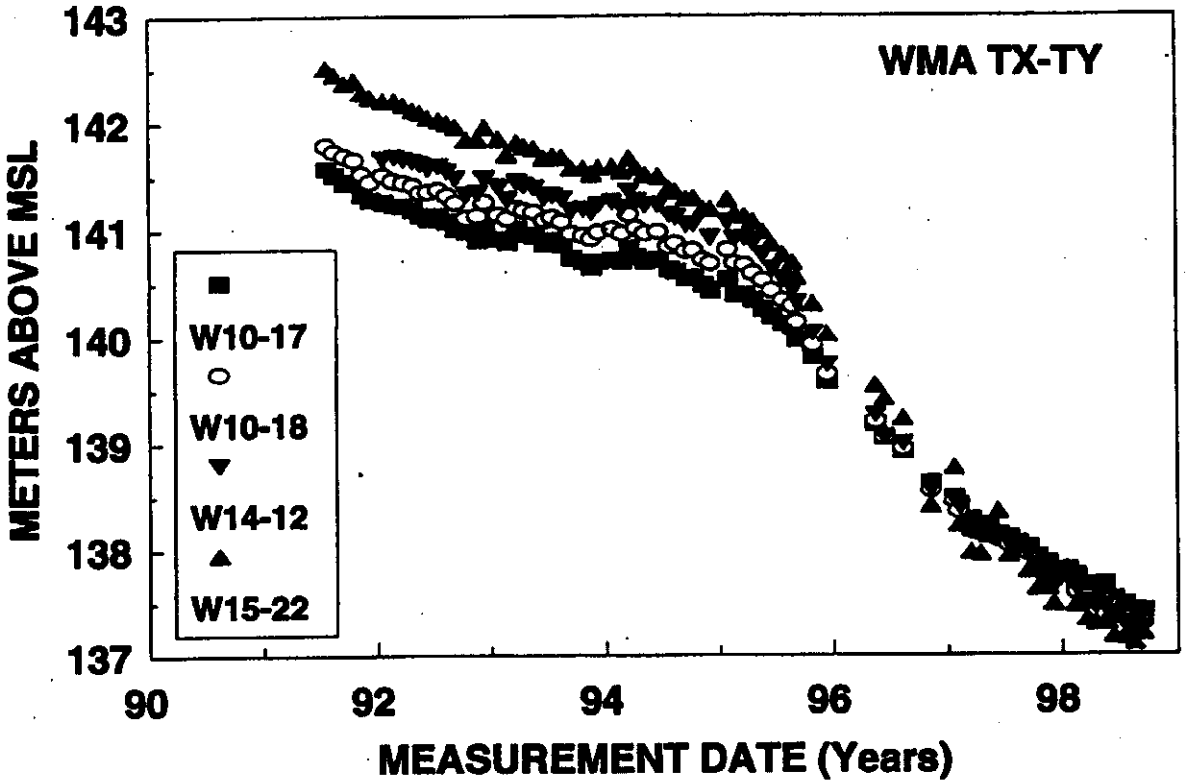
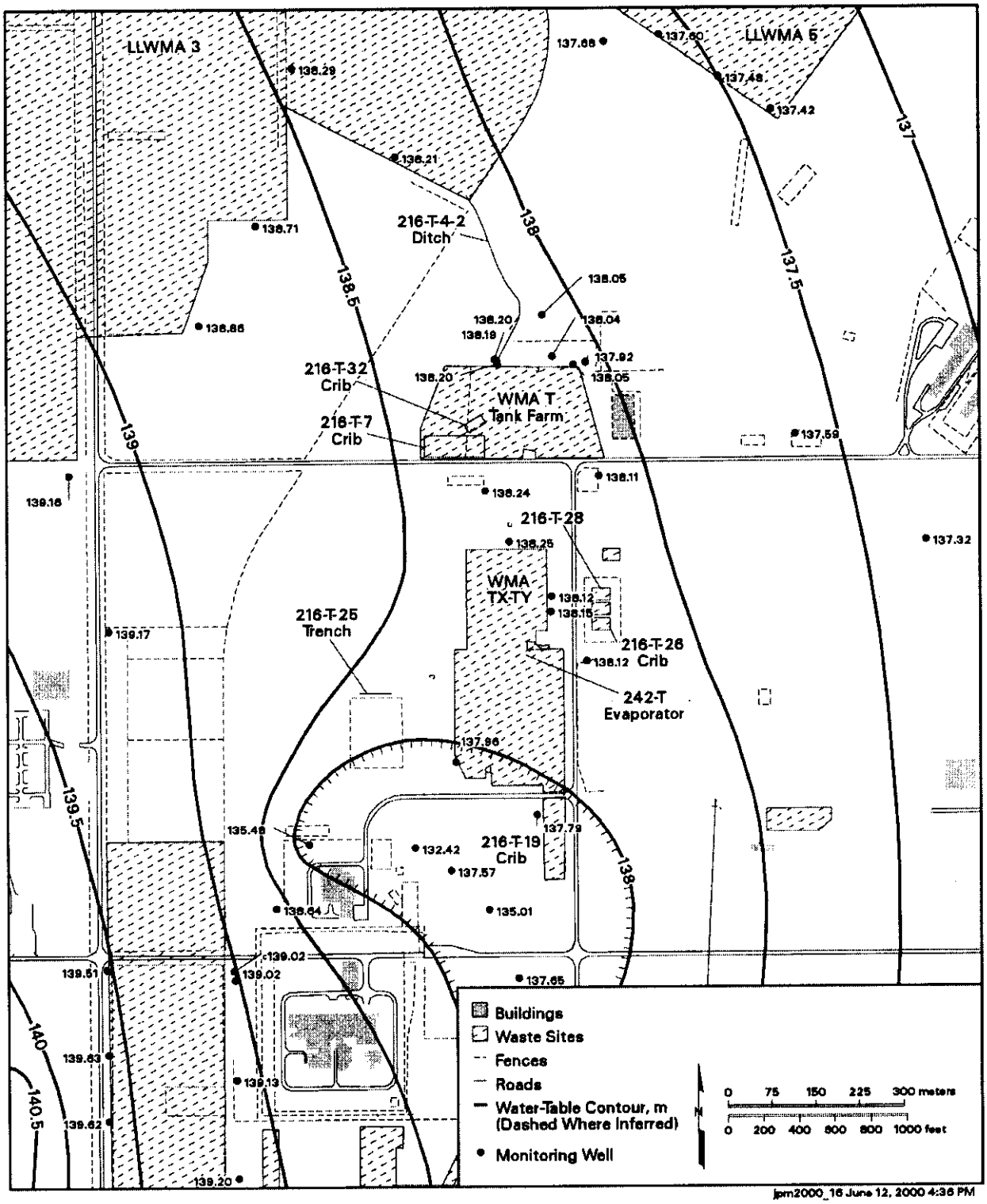


Figure 2-14. Water Table Map of the 200 West Area in 1999.



2.4 HYDROLOGIC PROPERTIES

2.4.1 Vadose Zone Properties

Khaleel and Freeman (1995) summarizes vadose zone hydrologic properties of Hanford Site sediments. A subset of this database is included in Appendix D, Table D-2. The database information consists of the location of the sample, the depth at which the sample was collected, particle size distribution, moisture retention curve data, and saturated hydraulic conductivity values. Generally, the soils are variable mixtures of sands and gravels. Well-defined horizontal strata with distinctly different hydraulic properties favoring lateral movement in the vadose zone (e.g., silty sands) are probably present locally, but are not widespread.

2.4.2 Aquifer Properties

This section provides information on the current nature of the unconfined aquifer in the immediate region of the T and TX-TY WMAs. Aquifer properties were determined from stratigraphic interpretations, current water elevations, and hydraulic conductivity values based on aquifer tests.

The unconfined aquifer beneath the T and TX-TY WMAs is within unit E of the Ringold formation (Lindsey 1995). Gravels within the Ringold Formation unit E vary greatly in degree of cementation, and therefore, exhibit a wide range of hydraulic properties. In the vicinity of the T and TX-TY WMAs, reported hydraulic conductivity values range from 15 to 33 m/d (950 to 100 ft/d) and transmissivity values range from 47 to 93 m^2/d (500 to 1,000 ft^2/d) (Connelly et al. 1992; DOE/RL 1993). A fluorescein dye tracer test conducted near the northwest corner of the T WMA in 1974 as part of the tank 241-T-106 leak study, indicated groundwater flow velocity on the order of 0.4 m/d (1.3 ft/d) (Routson et al. 1979). On the basis of the water table map presented by Routson et al. (1979), the hydraulic gradient presently is approximately half the value it was in 1974 (Hodges 1998). Therefore, the current groundwater flow velocity is estimated at approximately 0.2 m/d (0.7 ft/d).

The hydraulic gradient is sufficiently steep across the 200 West Area to be measurable. With about 100 cm (32.8 in.) of change or more across each WMA, the use of discrete water elevations to determine flow direction is easily accomplished. Even steeper gradients occur south of the TX-TY WMA because of pump-and-treat activities begun at 200ZP-1. In this region, comparing data between individual wells to determine the upgradient versus downgradient locations is routine because the total error in water elevations between any two wells is small. Sources of vertical uncertainty that had to be addressed were the survey datum, survey loop or traverse errors, errors caused by the well itself being out of plumb, and occasional spurious water level errors. To reduce errors, a single current datum is now used for all wells in the 200 West Area (Hartman 1999). Barometric effects have been addressed in part by collecting contemporaneous water level measurements over a few hours or a day for each data set. Barometric effects on water level elevation measurements at the Hanford Site are just beginning to be addressed (Spane 1999). The level of uncertainty provided by barometric pressure variations to hydraulic gradient estimates is unlikely to be significant.

2.5 GEOCHEMISTRY

This section covers geochemical factors and material properties of the vadose zone and unconfined aquifer underlying the T and TX-TY WMAs. It addresses those factors that control contaminant mobility in the soil column. Radionuclide and hazardous-constituent mobility can be substantially different depending on the innate characteristics of the contaminant, the geochemistry of the natural soil-water system, and the changes in soil and water chemistry that occur from contact with tank fluid. In these soils, all factors are expected to be influential. Different contaminants present in the soils are variably mobile and, depending on interactions of tank fluids with the soil-water system, a given contaminant's mobility can be considerably different at different locations and times within the vadose zone and unconfined aquifer.

The geochemical characteristics and contaminant mobility are best considered in terms of behavior in relatively undisturbed soils versus soils that have interacted with tank waste fluids. In addition, tank fluid chemistry varies. Both types of soil conditions are expected in the vadose zone underlying the T and TX-TY WMAs. For relatively undisturbed soils, a substantial Hanford Site-specific database is available that quantifies geochemical characteristics and contaminant behavior, particularly for radionuclides (e.g., Ames and Rai 1978; Serne and Wood 1990; Serne et al. 1993; Kaplan, Parker, and Kutynakov 1998, and Kaplan and Serne 1999). This database is not specific for the T and TX-TY WMAs. Average soil properties are described in Section 2.2. Soil water in the vadose zone and groundwater in the unconfined aquifer have similar characteristics. They are moderately alkaline (pH about 8) and contain moderated concentrations of cations and anions. Dominant cations are calcium (about 50 mg/L), magnesium (about 14 mg/L), sodium (about 30 mg/L), and potassium (about 9 mg/L). Dominant anions are carbonate (about 70 mg/L) and sulfate (75 mg/L).

Within the T and TX-TY WMAs, quantitative, site-specific radionuclide sorption/solubility data are not available. However, spectral gamma data from the drywell systems and soil analyses from borehole 299-W10-196 near the tank 241-T-106 leak source provide qualitative indications of the reactivity of detected constituents and some ability to compare radionuclide behavior known to occur in undisturbed Hanford Site soil environments. For radionuclides present in most contaminated regions, spectral gamma data show that their spatial distributions relative to the expected source of leaks and other radionuclides tend to be consistent. Further, a three-dimensional view of contaminant distribution is derived for tank leaks that apparently have contaminated several drywells at varying distances from the leak location. In particular, the leak from tank 241-T-106 has contaminated enough drywells to show fairly distinct patterns of radionuclide distribution that are consistent with our understanding of relative degrees of sorption on soils and associated mobility. Given this database, the following observations are generally seen across the WMAs for the most commonly observed gamma-emitting radionuclides:

- Cesium-137 is concentrated in drywells near the potential sources of tank leaks. This suggests relatively rapid and complete sorption onto soil near the point of discharge. Vertical distribution in borehole 299-W10-196 shows ^{137}Cs peaks just under the tank bottom and extending no more than 10 m deeper into the soil column. In some cases (e.g., the tank 241-TX-107 and -TY-105 leaks) ^{137}Cs cannot be found, possibly because of very localized sorption beneath the nearby tank. This behavior is consistent with measured K_d values in Hanford Site soil of more than 100 mL/g.

- Cobalt-60 is highly mobile. When present in a drywell, it is routinely distributed over several tens of feet below the tank bottom and often extends to the drywell bottoms and is horizontally distributed at the greatest distance from the potential leak source. The most extensive example of this is associated with the tank 241-T-106 leak (Section 3). The ^{60}Co distribution in borehole 299-W10-196 is similar to the distribution of ^{99}Tc and nitrate. Cobalt-60 concentrations are fairly constant (`100 pCi/g) between the bottom of the tank (about 40 ft) and 110 ft. In this instance, the chemistry of numerous tank fluids clearly plays an important role in providing complexing agents that cause ^{60}Co to be highly mobile, with a K_d value near 0 mL/g.

- Europium-154 and ^{152}Eu appear to be somewhat less mobile than ^{60}Co but much more mobile than ^{137}Cs. In the set of drywells that appear to be contaminated by the tank T-106 leak or the tank TX-107 leak, europium isotopes appear at locations farther from the source than ^{137}Cs, but do not extend quite as far as ^{60}Co. This suggests that europium sorption is significantly lower than ^{137}Cs sorption but not as low as ^{60}Co sorption. As with ^{60}Co, fluid chemistry appears to reduce europium reactivity in disturbed soils compared to undisturbed soils. One would expect relatively high sorption for lanthanide aqueous species (Serne and Wood 1990) in undisturbed soils such that europium distribution would be similar to cesium distribution.

These data suggest that tank fluid chemistry has had little observable effect on ^{137}Cs mobility. In these tank farms, ^{137}Cs continues to be highly reactive and immobile in the soil column and is a good indicator of leak source location. Assigning a K_d value of 100 mL/g or more is a reasonable estimate. Tank fluid chemistry does have a significant effect on ^{60}Co and europium isotopes, reducing reactivity with the soil and enhancing mobility. Some small degree of sorption may occur, but assigning a K_d value of 0 mL/g is a reasonably conservative estimate. The particular fluid chemistry characteristics enhancing ^{60}Co mobility are unclear and no distinctly different effects on gamma radionuclide behavior caused by variability in tank fluid chemistry are apparent. The location of ^{60}Co also could show an approximate location of ^{99}Tc in the vadose zone underlying the T, TX, and TY tank farms if the borehole 299-W10-196 radionuclide distributions with depth are representative.

3.0 TANK WASTE CHEMISTRY AND LEAK CHARACTERISTICS

From the mid-1940's through 1980, the tanks in the T, TX, and TY tank farms were used to store waste of a wide variety of types. The operational histories of these tank farms are summarized in Williams (2000) (narrative and tables attached as Appendix A) and Section 2.1.2. A number of tanks in these farms are known or suspected to have leaked and significant evidence exists of near-surface leaks in and near these tank farms. In addition, millions of gallons of tank waste were intentionally discharged to cribs and trenches within 150 m of the tank farms. The subsurface contamination in and around these tank farms reflects the complexities of their long-term operating histories.

3.1 GAMMA RAY LOGGING INFORMATION

Two types of gamma ray logging data were collected in the T, TX, and TY tank farms. As part of a tank leak detection program (Isaacson and Gasper 1981), gross gamma logging was conducted from the early 1960's through 1994. Recently, the gross gamma logging data from tank farms T, TX, and TY were evaluated to assess potential movement of gamma-emitting radionuclides in the vadose zone (Randall et al. 2000a and 2000b, Appendix E).

3.1.1 Spectral Gamma Ray Logging Data

Comprehensive spectral gamma logging of all drywells in the T and TX-TY WMAs was completed between 1997 and 1999. Spectral gamma logging reports were available for the T (DOE-GJ 1999a), TX (DOE-GJ 1997), and TY (DOE-GJ 1999b) tank farms. Drywell location maps in each tank farm and summary figures of the individual drywell spectral gamma logs are provided in Appendix E.

Specific examples of the use of gamma logging data to assess potential tank leak scenarios are included in the discussion of specific tank farms (see Section 3.3). In some cases, the spectral gamma data provide information that can be correlated with time-dependent waste transfer and storage records for specific tanks. This allows identification of specific waste types. The spectral gamma data also provide an independent means of evaluating the veracity of reported tank leaks.

Some limitations are associated with the gamma logging methods.

- First, gamma logging interrogates only about 30 cm to 45 cm (12 to 18 in.) of the soil around the well.
- Second, uncertainties associated with distinguishing gamma contamination in the well or on the well casing from gamma activity originating in the soil may make data inaccurate.
- Finally, gamma activity monitored by these methods provides little information about the tank waste-related non-gamma-emitting radionuclides and chemicals.

These limitations must be considered in evaluating the referenced data reports. Nevertheless, the gamma logging data summarized in the referenced reports provide the most comprehensive data set available for assessing the nature and extent of gamma contamination in the soil column under these WMAs.

3.1.2 Synthesis of T, TX, and TY Tank Farm Historical and Spectral Gamma Logging Data

Because gross gamma logging was conducted over two decades, evaluating these data provides information on the time-dependent behavior of the gamma-emitting radionuclides in the subsurface. Three reports have been issued on this subject, one each for the T tank farm (Randall et al. 2000a), the TX tank farm (Randall et al 2000b) and the TY tank farm (Appendix E).

The concentrations of the individual gamma-emitting isotopes that contributed to the gross gamma curves over time were estimated using the recently collected spectral gamma data (concentrations of specific gamma-emitting radionuclides) from the drywells used to collect gross gamma data. By factoring in decay, these calculated curves were propagated over time and compared with the gross gamma curve histories. Using this process, we frequently can distinguish between changes in the curves caused simply by decay or by decay plus changes in gamma radionuclide concentrations at a given location over time.

Appendix E summarizes the results for the T, TX, and TY tank farms. The summary figures (Figure 2 for each tank farm) indicate which drywells contain gamma-emitting radionuclides and which do not. Of particular interest are the drywells indicating a change in radionuclide concentrations at a given location over time that cannot be attributed solely to radioactive decay. These conditions are referred to as unstable events. For each location, the borehole number, the depth below the surface, the radionuclide present, the time over which changes in concentration were deduced, and the concentration increase or decrease over that period are listed.

Near-surface changes assumed to be caused by tank farm operations are broken out separately from changes that occur at greater depths and apparently indicate leakage and migration of tank waste. The changes in radionuclide concentration over time in the T, TX, and TY tank farms attributed to tank farm activity are listed in Table 3 in all three tank farm discussions. These changes occur within 6 m (20 ft) of the surface and generally occurred from 1975 to 1985 over most of the tank farm areas. This observation is consistent with a common drywell spectral gamma pattern in which a maximum radionuclide concentration (usually ^{137}Cs) of 10 pCi/g to 100 pCi/g or occasionally higher near the surface diminishes with depth to about 1 pCi/g 6 m to 9 m (20 to 30 ft) below ground. We consider this pattern to be consistent with surface or near-surface leaks of contaminated fluid.

The remainder of the radionuclide migration events (e.g., referred to as unstable zones) listed (Appendix E, Table 6, in the T, TX, and TY discussions) occur at depths near the tank bottoms or lower. Over the time during which measurements were taken, unstable conditions are observed in 22 drywells in the T farm, 15 drywells in the TX tank farm, and 5 drywells in the TY tank farm. The majority of unstable zones in the T tank farm (14 drywells) are plausibly associated with the tank 241-T-106 leak. Cesium-137 movement is indicated in drywells near

the leak source from 1975 through 1980 and migration of ^{106}Ru and ^{60}Co is indicated in almost all drywells ranging over the entire period of historical gamma logging. Five of the unstable zones are plausibly associated with the tank 241-T-101 and -T-102 leaks. The largest number of unstable zones in the TX farm are plausibly associated with the tank TX-107 leak and the tank 241-TX-114, -110, and -113 leak (seven and five drywells, respectively). Finally, in the TY tank farm, two occurrences, in drywells 52-05-07 and 52-06-05, and perhaps a third occurrence, in drywell 52-03-06, may be related to the tank 241-TY-105 leak.

3.2 TANK WASTE CHEMISTRY AND LEAK CHARACTERISTICS

The inventory of chemicals and radionuclides lost to the vadose zone in the T and TX-TY WMAs is a function of the waste types stored in the tanks over their decades of use. Because of their long operational history, the tank farms received waste generated by all of the major processes. The T and TX tank farms initially received waste streams discharged from the bismuth phosphate process operating in T Plant. By the end of 1952, the T, TX, and TY tank farms were being used to support the uranium recovery program being conducted in the U Plant, as well as the bismuth phosphate process. Once the Reduction-Oxidation (REDOX), Plutonium-Uranium Extraction (PUREX), and isotope recovery processes in B Plant came on line, tanks within these WMAs received multiple waste types. A number of tanks within the T and TX-TY WMAs served as feeder tanks for the 242-T Evaporator. Thus, because tanks and associated infrastructure failed at different times, various waste types were lost to the vadose zone in these WMAs. Estimates of leak chemistry and radionuclide constituents for T and TX-TY tank farm leaks are provided in Jones et al. (2000). Best estimates of specific sources for each leak event are provided in Section 3.3.

The volume of waste lost from many of the T, TX, and TY tanks is highly uncertain. Except for losses from tank 241-T-106 (Routson et al. 1979), no detailed analyses of known or suspected leaks have been done in these WMAs. Available information on specific leak events is provided in Section 3.3.

3.3 T AND TX-TY WMA TANK LEAK EVENTS

Hanlon (1999) lists seven tanks in the T tank farm, eight tanks in the TX tank farm, and five tanks in the TY tank farm as "confirmed or assumed leakers." Estimated leak volumes vary from less than 3785 L to 435,321 L (1,000 to 115,000 gal). No estimated leak volume is provided for eight of these tanks, indicating a lack of direct measurement of the leak volume.

Available information was reviewed to ascertain potential leak events that occurred in these WMAs and require additional field characterization. In addition to the spectral and historical gamma logging data (see Section 3.1), waste transfer records (Agnew 1997) and various leak documents were reviewed to develop the list of tanks or associated waste transfer piping that most likely leaked. This approach was taken to identify locations where subsurface characterization likely would enhance our understanding of the leak events and subsequent vadose zone contamination. For example, a number of tanks are listed as confirmed or suspected leakers by Hanlon (1999), but neither the waste level data nor the gamma logging data support the designation. Also, the depth of gamma contamination at a given location was evaluated to

identify waste transfer or cascade line leaks rather than tank leaks and to identify the appropriate characterization tools.

3.3.1 T Tank Farm

Seven of the twelve 23 m (75-ft)-diameter tanks in the T tank farm are listed as being confirmed or suspected leakers (Hanlon 1999). Of these, reliable leak estimates are available only for tank 241-T-106. Tanks 241-T-107, -T-108, -T-109, and -T-111 are listed in Hanlon (1999) as suspected leakers because of small drops in liquid level in the tank that could be spurious or explained by numerous nonleak processes.

Elevated gamma readings in drywells monitoring tanks 241-T-107 and -T-109 also were used as evidence of leaking from these tanks (DOE-GJO 1999). Tank 241-T-107 was included on the suspected tank list because of elevated gross gamma readings at tank bottom depth in drywell 50-07-03 in 1976. Current ^{60}Co concentrations of 0.1-1 pCi/g occur at about 14 m (45 ft). Also, a small ^{137}Cs peak (10 pCi/g) occurs at 14 m (45 ft) in drywell 50-07-07. The two contamination zones are unlikely to be related. Tank 241-T-109 was included on the suspected tank list because of elevated gross gamma readings at 12 m (39 ft) in drywell 50-09-01 in 1974. The timing and proximity of this drywell to tank 241-T-106 indicate that the source of elevated gamma is more likely the leak from tank 241-T-106, not tank 241-T-109.

Given this information, we conclude that tanks T-107, T-108, T-109, and T-111 either did not leak or leaked so little that they should not be considered leakers for the purpose of additional characterization or risk assessment. The remaining assumed leakers have more substantial evidence of leakage and are considered to be candidates for additional characterization. The available leak-indicating information, largely from information collected in DOE-GJO (1999), for these tanks is summarized in Sections 3.3.1.1 and 3.3.1.2.

3.3.1.1 Tanks 241-T-101 and 241-T-102. Two lines of evidence point to a leak associated with tank T-101. First, in 1969, a tank overfill (2,040,330 L [539,000 gal]) was recorded and an unknown amount of liquid discharged into the soil column through a spare fill line. Second, a very thick zone of high ^{137}Cs concentration occurs in drywell 50-01-04 beginning about 8 m (25 ft) and extending intermittently to the bottom of the drywell (38 m [125 ft]). This drywell was drilled in 1973. The occurrence of high ^{137}Cs at the 8 m (25-ft) level supports the hypothesis that leakage from the waste transfer or cascade line occurred rather than a tank wall breach. The presence of a large ^{60}Co and europium contamination zone in drywell 50-01-06 and the lack of any other nearby potential source suggests that this zone represents a continuation of this leak to the south in the vadose zone. The interpreted historical gamma data also show indications of ^{60}Co, europium isotopes, and ^{106}Ru influx at different times and depths in drywells 50-01-04 and 50-01-06. Tank 241-T-101 was the gateway tank for the T tank farm. Consequently, large and frequent volumes of liquid passed through this tank, which reduces the ability to track liquid losses. Based on the time of the leak and the tank waste history (Jones et al. 2000), waste lost from these tanks was REDOX cladding waste.

A second drywell, 50-01-09, also drilled in 1973, shows a small ^{137}Cs peak (200 to 300 pCi/g) at about 6 m (20 ft) and ^{60}Co contamination at greater depths (11 m to 15 m and 21 m to 26 m [35 to 50 and 70 to 85 ft]). The ^{137}Cs depth suggests that a separate waste transfer line leak occurred in addition to the leak that contaminated drywell 50-01-04 because contamination

depths are the same in both drywells and the tank sits between them, preventing a connecting path.

An additional 28,390 L (7,500-gal) leak is postulated in 1992 (Deaton 1992) based on a reported 6.6 cm (2.6-in.) liquid level decrease from July to September 1992. An evaluation of the measurement has not been reported. This event is the basis for the leak estimate in Hanlon (1999). No gamma data show evidence of leakage at this time so the location, and even the veracity, of the leak are in question.

Tank 241-T-102 is not listed as a leaker in Hanlon (1999). However, a small ^{137}Cs peak (1000 pCi/g) at 12 m (40 ft) in drywell 50-02-05 indicates a nearby leak. The leak occurred before 1973 because the drywell, constructed in 1973, was driven through an existing contamination zone. No liquid level drop information about Tank 241-T-102 exists, but the occurrence of apparent waste transfer leaks in tanks 241-T-101 and -T-103, both linked by cascade lines with tank 241-T-102, provides circumstantial evidence that similar leaks in the same type of lines also could have occurred near tank 241-T-102.

3.3.1.2 Tanks 241-T-103 and 241-T-106. These two tanks are considered together because they leaked roughly at the same time and the gamma data suggest a partial mixing of discharged fluids from each source. Because of proximity and timing, both tanks frequently have been evaluated together. Given the time of the leaks and the tank waste histories (Jones et al. 2000), waste lost from these tanks was B Plant waste, generated by ^{137}Cs recovery from PUREX supernatant liquid.

The apparent driving force for leakage from tank T-103 was a 98,420 L (26,000 gal) tank overfill in 1973 (Brevick et al. 1995), causing an estimated 4921 L (1,300 gal) discharge (ARH 1973) through a spare fill line. The uncertainty of this estimate is large. An additional estimate of about 3785 L (1,000 gal) (Hanlon 1999) was based on an observed liquid level drop of 0.8 cm (0.3 in.) in late 1973 and early 1974. Because this change is so small, the reliability of this hypothesis is highly uncertain. Regardless of the uncertainty surrounding the number of leak events and total leak volume, spectral gamma data from several nearby drywells indicate leakage has occurred. Only one drywell, 50-03-04, contains a small zone of ^{137}Cs (1-10 pCi/g) at 6 m (20 ft). Presumably, this is the well closest to the source. The other gamma-producing contaminants in this well include ^{60}Co, europium isotopes, ^{125}Sb, ^{94}Nb, and ^{126}Sn. Drywells 50-03-05, 50-02-08, and 50-02-09 also appear to contain contamination from this leak. Interpreted historical gamma data from drywell 50-02-09 indicate migration of ^{106}Ru, ^{125}Sb, and europium isotopes from 1976 through 1985 at 8 m to 15 m (32 to 48 ft).

The 241-T-106 tank leak is the largest, most thoroughly documented single-shell tank leak. In addition to the most recent spectral gamma logging of surrounding drywells, several earlier studies have been completed. The first extensive study of these two leaks was done shortly after they occurred (ARH 1973) and a follow-up study was completed in 1978 (Routson, et al 1979). More recently, an extensive sampling and analysis program was completed on soil samples taken from a borehole near the center of the tank T-106 leak. The program was conducted to improve our understanding of its nature and the extent of contamination in the vadose zone produced by this event (Freeman-Pollard et al. 1994). Supporting data from these sources are provided in Appendix F.

Appendix F contains a detailed log of liquid level drops in tank 241-T-106. The liquid level drops are unambiguous because they were significantly larger than background fluctuations and permit an unusually reliable estimate of leakage (435,321 L [115,000 gal]) and leak rate. A large number of drywells contain contamination from this leak because of the large extent of the leak and the high density of drywells constructed to quantify the soil column contamination caused by this leak. For many of these wells, historical and spectral gamma data were collected in 1973, 1978, and in the mid 1990's, providing the most complete characterization data set of any tank farm leak on the Hanford Site. Appendix F also contains a summary table including ranges and peaks from the 1973, 1978, and 1990's spectral gamma data (^{106}Ru, ^{60}Co, europium isotopes, and ^{137}Cs) from these drywells for comparison.

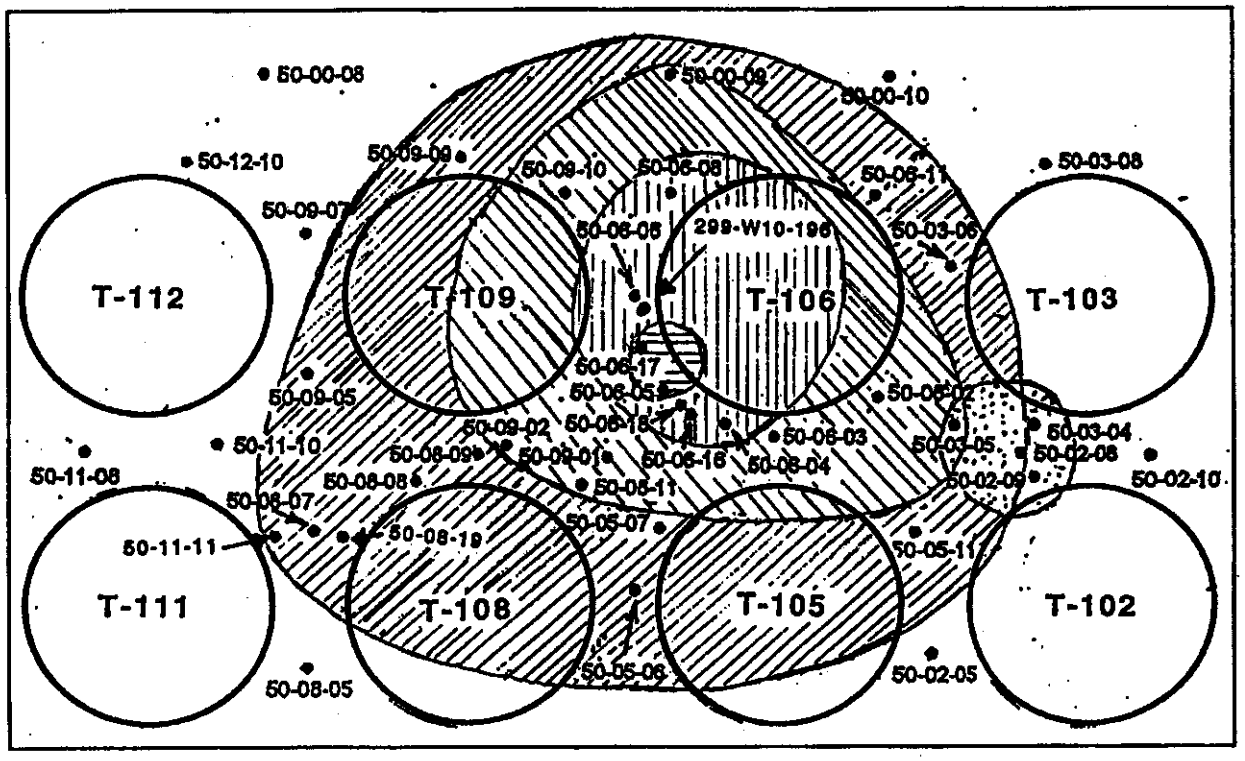
The spectral gamma data from these wells reveals what appear to be four zones of different gamma signatures with increasing distance from the leak source. These are drawn in Figure 3-1. All the zones are estimated to extent beneath tank T-106. Zone 1 is closest to the leak source and Zone 4 is farthest away. The two wells in Zone 1 nearest the leak source at the southern section of tank 241-T-106 are characterized by thick zones of very high ^{137}Cs concentrations (about 10^8 pCi/g) beginning near tank bottom depth (about 11 m [35 ft]). Zone 2 drywells typically show thin zones of high ^{137}Cs concentration at 11 m to 14 m (35 to 45 ft) and ^{60}Co plus europium isotopes that frequently extend to the drywell bottoms. Occasionally, other isotopes are present, including uranium, ^{126}Sn, and ^{125}Sb. Zone 3 drywells show no ^{137}Cs, sporadic occurrences of europium isotopes and ^{60}Co from 11 m (35 ft) to the bottom of the drywells. Zone 4 drywells show only ^{60}Co from 20 m (65 ft) to the bottom of the drywells. The map view distribution of the different zones is quite similar to the 1 μCi/l ruthenium isopleth (Figure 3-2) estimated by Routson et al. (1979).

Interpretation of the historical gamma data collected from 1975 through 1994 indicates ^{106}Ru and ^{60}Co migration in almost all the wells in Zones 1 through 4. Migration of ^{106}Ru and ^{60}Co at Zone 3 drywells 50-00-09 and 50-09-10 appears to have occurred near the tank bottom around 1980 and again at greater depths (about 18 m to 30 m [60 to 100 ft]) in the late 1980's. Cesium-137 migration is indicated in Zone 1 in the late 1970's.

3.3.2 TX Tank Farm

Eight of the eighteen 23 m (75-ft)-diameter tanks in the TX tank farm are listed as being confirmed or suspected leakers (Hanlon 1999). Reliable leak estimates are not available for any of these tanks. Except for tank 241-TX-107, all tanks are estimated to have leaked about 30,283 L (8,000 gal). This is a non-tank-specific value averaged over 19 tanks located in several tank farms that are considered to have leaked a total of 150 kgal. Tanks 241-TX-105 and -TX-110 are listed in Hanlon (1999) as suspected leakers because of small drops in liquid level in the tank. These drops could be spurious or could be explained by numerous nonleak processes. No reported liquid level drops are available for the assumed leaking tanks 241-TX-113, -TX-114, -TX-115, -TX-116, and -TX-117. Several small drops in liquid level were noted in tank 241-TX-107 in 1975 and later (GJO-DOE 1997); these appear to be true indicators of leakage. Historical and spectral gamma data also suggest leakage from tank 241-TX-107 in the same period. Because large volumes of supernatant liquid were transferred through tank 241-TX-107 during the leak period, the liquid loss estimates are highly unreliable. The extent of the contamination attributed to this tank leak suggests that the leak volume estimate of 9464 L (2,500 gal) is low, perhaps substantially low.

Figure 3-1. Spectral Gamma Characteristics in Vadose Zone Soils Contaminated by Tank Waske Leaked from Tanks 241-T-106 and 241-T-103.



Drywell Spectral Gamma Characteristics Due to Tank 241-T-106 Leak

Zone 1: Thick regions of > 10^7 pCi/g C137 concentration from 35-100 ft

Zone 2: Small regions of > 10^7 pCi/g Cs from 35-45 ft; Co-60 and europium isotopes from 35-100 ft

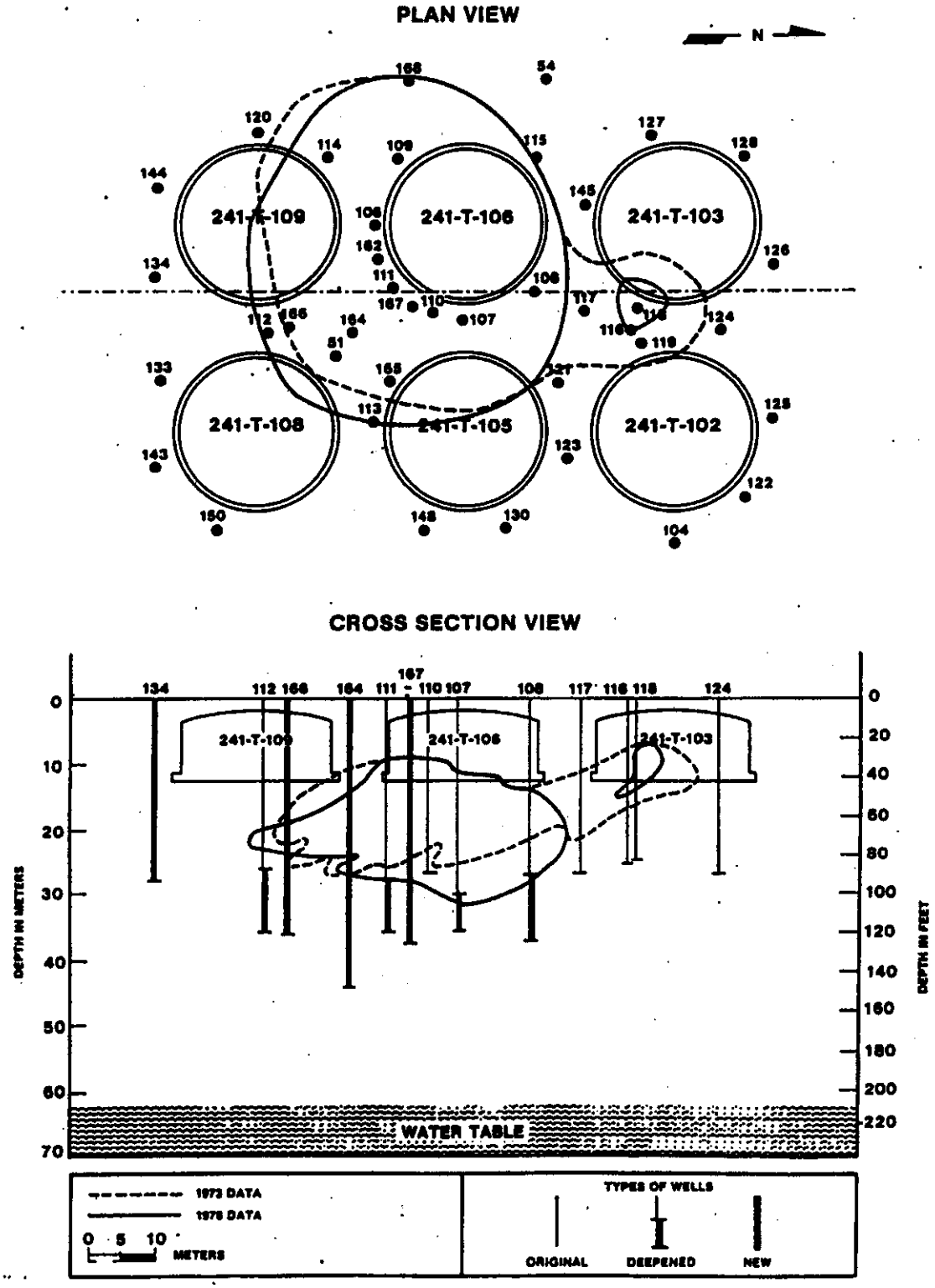
Zone 3: No Cs-137 present; Co-60 from 35-100 ft and sporadic europium isotopes from 35-100 ft

Zone 4: Co-60 65 ft and below, frequently to the bottom of the drywell(~100 ft)

Drywell Spectral Gamma Characteristics Due to Tank 241-T-103 Leak

Estimated zone of contamination from the tank T-103 leak primarily Co-60 and europium isotopes from 20-90 ft

Figure 3-2. Map View and Cross Section of 1 μCi/L ^{106}Ru Contours in 1973 and 1978 Created After Tank Waste Leaked from Tanks 241-T-106 and 241-T-103.



Elevated gamma readings in drywells monitoring tanks 241-TX-105, -TX-107, -TX-110, -TX-113, and -TX-114 also were used as evidence of leaking from these tanks (DOE-GJO 1997). Connections between specific drywell data and individual tank leaks include the following:

- Interpreted historical gamma data in drywell 51-05-08 indicate migration of ^{106}Ru at 11 m to 16 m (36 to 54 ft) between 1975 and 1977. Given several recorded instances of unexplained liquid level drops in Tank 241-TX-105 starting in 1973, the ^{106}Ru movement may be a corroborating indicator of leakage from this tank or piping associated with this tank.

- Drywells 51-03-01, 51-03-11, 51-03-12, 51-07-18, 51-07-07, 51-03-09, and 51-04-05 show commonality in current spectral gamma characteristics and historical migration patterns suggesting leakage from tank 241-TX-107 beginning about 1975. The primary gamma emitter is ^{60}Co, which is present from 14 m to 21 m (45 to 70 ft). Europium-154 also is present at 15 m to 18 m (50 to 60 ft) in all but the two southernmost drywells, 51-03-09 and 51-04-05. Historical gamma data indicate migration of ^{60}Co from northeast to the southwest over time between 1977 and 1992. Interpreted historical gamma data (Randall et al 2000b) suggest more than one migration event in drywells 51-03-11, 51-07-18, 51-07-07, and 51-04-05. Given the time of the leak and the tank waste history (Jones et al. 2000), waste lost from this tank was B Plant waste, generated by ^{137}Cs recovery from PUREX supernatant liquid.

- A common set of drywells, 51-10-01, 51-10-13, 51-10-25, and 51-14-04, is situated between tanks 241-TX-110, -TX-113, and -TX-114. Gamma activity in these wells has been assumed as leak indicators for all these tanks. Of these drywells, 51-14-04 appears to be closest to a leak source with a small zone of ^{137}Cs above detection limit at tank bottom level. This drywell is closest to tank 241-TX-114, making tank 241-TX-114 the most likely leaker. The source of gamma contamination in the other wells is ambiguous. Interpreted historical gamma data of the other drywells show ^{106}Ru migration between 1978 and 1985.

- Increased gamma activities around drywells 51-15-04 and 51-15-11 in 1972 are the data used to suggest the tank 241-TX-115 leak. Current gamma contamination consists of ^{137}Cs with maximum concentrations near the surface, clearly indicating surface contamination events. This is a common characteristic in drywells just to the north of tank 241-TX-118. Interpreted historical gamma data show ^{106}Ru migration in drywells 51-15-04 from 5 m to 15 m (16 to 50 ft) from 1980 through 1985. Activity at this depth interval also suggests a surface contamination event.

Given this information, we conclude that tanks 241-TX-105, -TX-110, -TX-113, -TX-114, -TX-115, -TX-116, and -T-117 either did not leak or leaked such a negligible amount that they should not be considered leakers when determining the need for additional characterization or for risk assessment. The remaining assumed leaker, tank 241-TX-107, has more substantial evidence of leakage and is considered a candidate for additional characterization.

In the remainder of the TX tank farm, two areas of uranium contamination occur that are not obviously connected to an assumed tank leak. First, ^{238}U and ^{235}U are found in a set of

drywells around tanks 241-TX-105 and 241-TX-101, including drywells 51-00-03, 51-05-01, 51-05-03, 5101-05, 51-05-07, 51-01-09, and 51-01-08. A range of ^{238}U concentrations from 1 to more than 100 pCi/g exists in this set of drywells from 14 m to 23 m (45 to 75 ft) with the higher contamination levels occurring at shallower depths in the northeast drywells. The ^{235}U concentrations mirror the ^{238}U values at about an order of magnitude lower. Second, ^{238}U and ^{235}U are found at similar relative concentrations in a set of drywells around tank 241-TX-104, including drywells 51-04-02, 51-03-09, 51-04-05, 51-04-06, and 51-00-07. A range of ^{238}U concentrations from 1 to about 100 pCi/g exists in this set of drywells wells from 14 m to 30 m (45 to 100 ft) with the higher contamination levels occurring at shallower depths in the northeast drywells, 51-04-02 and 51-04-05. In both cases, a line drawn around the listed drywells outlines a rough oval with the long axis running northeast to southwest. The presence of uranium contamination at these concentrations strongly indicates leakage of metal waste in the early 1950's. No other substantive information is available that describes the nature of this leak.

3.3.3 TY Tank Farm

Five of the six 23 m (75-ft)-diameter tanks in the TY tank farm are listed as being confirmed or suspected leakers (Hanlon 1999). Reliable leak estimates are not available for any of these tanks. Tanks 241-TY-101, -TY-103, -TY-104, -TY-105, and -TY-106 are listed in Hanlon (1999) as suspected leakers. Except for tank 241-TY-106, small drops in liquid level in each tank are used as evidence of leakage. However, the small leaks (less than 2.5 cm [1 in.]) could be spurious or could be explained by numerous nonleak processes.

Elevated gamma readings in monitoring drywells around tanks 241-TY-101, -TY-103, and -TY-105 also were used as evidence of leaking from these tanks (DOE-GJO 1998). Connections between specific drywell data and individual tank leaks include the following:

- Tank 241-TY-101 was included on the suspected tank list because of elevated gross gamma readings in 1973 (at 16 m [53 ft] in drywell 52-01-09 and at 13 m [44 ft] in drywell 52-01-05) and in 1978 at 54 ft in drywell 52-01-05. Current ^{137}Cs concentrations of 0.1 to 10 pCi/g occur at about 12 m (40 ft).

- Tank 241-TY-103 was included on the suspected leak list because of elevated gross gamma readings at drywell 52-03-06 in 1974. Current contamination in this drywell includes a small amount of ^{137}Cs (less than 1pCi/g) and ^{60}Co from 15 m (50 ft) to the drywell bottom. Also, a small zone of ^{137}Cs concentration above detector limits exists at 13 m to 15 m (45 to 50 ft) in drywell 52-03-03.

- Elevated gamma activity was reported in either drywell 52-06-05 or drywell 52-06-07 in 1959. This activity was attributed to leakage from tank 241-TY-106 (Warrent 1960).

Given this information, we conclude that tanks 241-TY-101, -TY-103, and -TY-104 either did not leak or leaked such a negligible amount that they should not be considered leakers to determine the need for additional characterization or for risk assessment. Tank 241- TY-102 also may have leaked. This is shown by elevated ^{137}Cs readings in drywell 52-02-11 and historical gamma data taken between 1976 and 1980, indicating a possible addition of ^{137}Cs around this drywell. However, this is the only drywell showing this behavior and no liquid level

losses are reported from tank 241-TY-102. We conclude that this possible leak is not substantial enough to be a source of significant groundwater contamination.

Assumed leakage from tank 241-TY-106 in 1959 is problematic because the estimated 75708 L (20,000-gal) leak is not reflected in the drywell data nor is the liquid level decrease evidence recorded. Contaminants from a leak of this size should be observed even with the paucity of drywells located nearby and, given the estimated size of this leak, unambiguous liquid level drops also should have been observed. Similarly, it is difficult to understand the rationale for adding 30 tons of diatomaceous earth to this tank in 1972.

Only the leak from tank 241-TY-105 appears to be sufficiently large to be a source of potentially significant groundwater contamination based on spectral and historical gamma data and liquid level observations. The leak volume estimate is large (132,489 L [35,000 gal]), but not clearly substantiated in the record. Drywells 52-03-06 (described above), 52-05-07 and 52-06-06, all located around tank 241-TY-105 contain elevated gamma readings, supporting the plausibility of a substantial leak. Drywell 52-05-07 contains ^{137}Cs approximately 1 to 30 pCi/g located from 15 m to 27 m [50 to 90 ft]) and ^{60}Co (approximately 1 to 10 pCi/g located from 15 m to 30 m [50 to 98 ft]). Drywell 52-06-05 also contains ^{137}Cs and ^{60}Co located between 15 m and 46 m (50 and 150 ft), but because the casing is perforated, this contamination could be caused by the perforated casing forming a local artifical preferential pathway. Given the time of the leaks and the tank waste histories (Jones et al. 2000), waste lost from these tanks was unscavenged tributyl phosphate (TBP) waste, generated by uranium recovery from metal waste in U Plant processing operations.

3.4 SUMMARY OF LEAK INFORMATION FROM T AND TX-TY WMAS

The leak information for the 20 tanks in the T and TX-TY WMAs listed as confirmed or assumed leakers is summarized in Table 3-1. The two strongest indicators of leak events are historical liquid level records for individual tanks and gamma logging data of contamination around the tanks. Historical records of liquid level changes and liquid transfer operations for individual tanks show liquid losses unaccounted for by waste transfer operations. High gamma readings (frequently at concentration levels above spectral gamma logging tool detection limits for Cs-137) are the consequence of interactions between tank fluids and the soil.

Considered collectively, zones contaminated by tank waste in the T and TX-TY WMAs are marked by nearby zones with high concentrations of ^{137}Cs and/or ^{60}Co. Zones of contamination originating at the surface that do no represent tank leaks are distinguished from those originating at waste transfer line depth (8 m to 9 m [25 to 30 ft]) or tank bottom (14 m to 15 m [45 to 50 ft]). As Table 3-1 indicates, an important conclusion from this review is that no credible evidence of leakage exists for numerous tanks assumed to be leakers. Consequently, to make useful characterization decisions, these tanks are not considered to be sources of current vadose zone contamination.

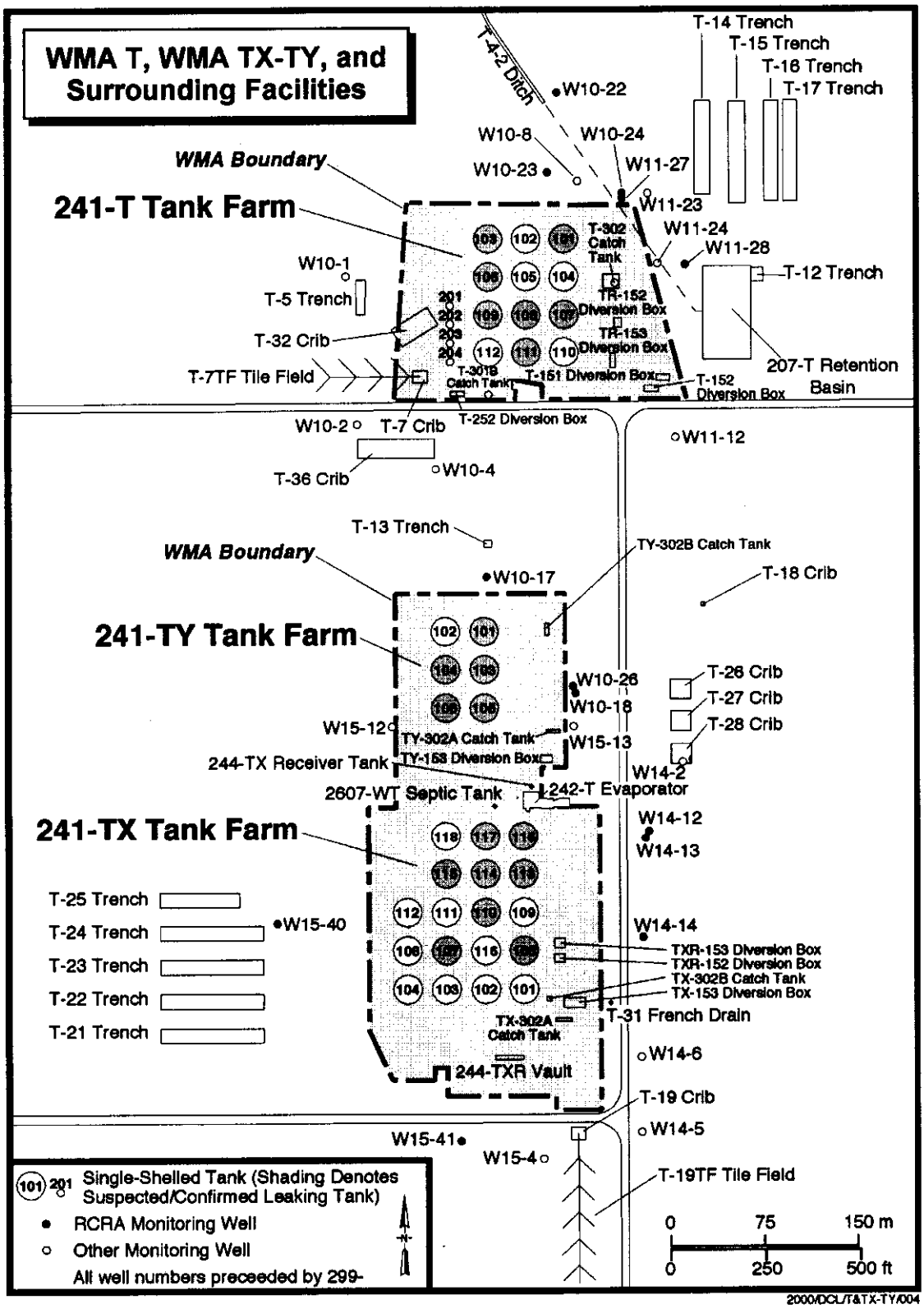
Table 3-1. Tank Leak Information Summary

Tank Number	Liquid Levels/Waste Transfer Record Indicate Leak?	Gamma Logging Data Indicate Leak?	Leak/Assumed Leak Date
T-101	yes	yes	1969
T-103	yes	yes	1973
T-106	yes	yes	1973
T-107	no	no	unlikely or negligible (before 1976)
T-108	no	no	unlikely or negligible (around 1974)
T-109	no	no	unlikely or negligible (around 1974)
T-111	no	no	unlikely or negligible (around 1974)
TX-105	no	maybe	questionable (around 1977)
TX-107	no	yes	1977
TX-110	no	no	unlikely
TX-113	no	no	unlikely
TX-114	no	yes	very small (around 1972)
TX-115	no	no	unlikely
TX-116	no	no	unlikely
TX-117	no	no	unlikely
TY-101	no	no	unlikely or negligible (around 1973)
TY-103	no	yes	1973
TY-104	no	no	unlikely
TY-105	yes	yes	1960
TY-106	ambiguous	no	questionable around 1960

3.5 GROUNDWATER CONTAMINANT INFORMATION

This section covers the current state of contamination surrounding the T and TX-TY WMAs, including historic constituent trends that depict the temporal and spatial distribution of contaminants. Several distinct suites of contaminants are recognized, based on spatial relationships. Given the complicated history of waste discharges to the subsurface in the last 50 years combined with artificial changes in the natural flow direction and the rapid changes in the current flow, identifying sources is challenging. However, with careful groundwater monitoring and data analysis, possible sources for the observed contamination are tentatively identified where possible. The WMA boundaries and monitoring well locations, along with associated tanks, and diversion boxes, are shown in Figure 3-3.

Figure 3-3. The WMA Boundaries and Monitoring Well Locations, Along with Associated Tanks, Diversion Boxes, and Sites of Unplanned Waste Releases.



3.5.1 Background

Since the early 1950s, groundwater monitoring has been conducted near the T and TX-TY WMAs in accordance with the *Atomic Energy Act of 1954*. Following the 1989 signing of the Tri-Party Agreement (Ecology et al. 1986), the single-shell tank farms that make up this WMA were designated as hazardous waste units and are regulated under RCRA and Washington's "Hazardous Waste Management Act" (*Revised Code of Washington* [RCW] 70.105). As such, these facilities are subject to the interim-status regulations in Title 40 *Code of Federal Regulations* (CFR) Part 265 (Subpart F) and the *Washington Administrative Code* (WAC) 173-303.

In 1991, a system of RCRA-compliant wells was installed around this WMA to monitor the quality of the groundwater (Hodges 1998). More detailed information regarding Site hydrogeology and the history of these WMAs can be found in several publications (Jensen et al. 1989; Caggiano and Goodwin 1991; Caggiano and Chou 1993; Connelly et al. 1992; and DOE/RL 1992). RCRA groundwater monitoring at the T and TX-TY WMAs moved from interim status detection level monitoring to assessment monitoring (40 CFR 265.93) in 1993 because specific conductance limits were exceeded in downgradient wells at the two WMAs, as set forth in the Phase 1 Assessment Plan (Caggiano and Chou 1993). Specific conductance is a RCRA indicator parameter that measures the quantity of ionic species in solution. The increased specific conductance in well 299-W11-27, starting in late 1995, has pushed the specific conductance above the critical mean in the T WMA. Even though this well was replaced in 1998 by deeper well 299-W10-24, which has a longer screened interval, concentrations of contaminants remain relatively high. The increased specific conductance in these two wells is a result of increased concentrations of calcium, magnesium, nitrate, and sulfate; associated with this trend are increasing activities of ^{99}Tc and tritium. High specific conductance also is present at downgradient wells 299-W10-17, 299-W14-12 in the TX-TY WMA.

The historic and recent RCRA groundwater data for these WMAs are stored in the Hanford Environmental Information System (HEIS) and are available electronically as needed. The RCRA data are released on a floppy disk annually in the Hanford Site groundwater monitoring report (e.g., Hartman 1999). The RCRA data are collected in accordance with established quality assurance and quality control procedures (EPA 1986). These documents are described in Hartman (1999).

3.5.2 Contaminants

Although the primary inorganic constituents in tank waste at the T and TX-TY WMAs include nitrate, sulfate, ^{137}Cs, ^{90}Sr, ^{99}Tc, aluminum, cyanide, and other heavy metals, most of these constituents are not mobile. The main tank constituents known to be highly mobile and used for tracking tank-related waste are nitrate, chromium, and ^{99}Tc (presumably present as TcO_4^-). Chromium and ^{99}Tc are found in discrete locations. Groundwater samples also are analyzed for ^{60}Co, which generally is made mobile in the vadose zone under the influence of tank fluid chemistry, but rarely is seen in groundwater. Tritium and nitrate are widespread in the 200 West Area and are present everywhere in groundwater underlying the T or TX-TY WMAs. Tritium is more likely linked to crib and trench discharges. Nitrate is derived from numerous

sources, including trench, crib, and tank leak sources. Plume maps of tritium, nitrate, iodine, ^{99}Tc, and chromium are presented in Appendix D.

3.5.2.1 T WMA Groundwater Contamination.

Groundwater to the northeast of the T WMA has been characterized by very low ionic strength, essentially contaminant-free groundwater, resulting from leaks from a transfer line taking T Plant effluent from retention basin 207-T to the 2-4-T ditch (Figure 3-3). The line is made of 24-in.-diameter vitrified clay pipe, which is very brittle. The changes in water chemistry suggest that the line was damaged during the drilling of well 299-W11-27. In late 1995, following termination of surface effluent discharges within the 200 West Area, Well 299-W11-27, located at the northeast corner of the T WMA, exhibited a rapid increase in specific conductance, showed other constituents (calcium, chromium, nitrate, magnesium, sulfate), and showed ^{99}Tc reaching a maximum of 21,700 pCi/L (DWS = 900 pCi/L) in February 1997 (Hodges 1998). Figure 3-4 shows chemical variation in wells 299-W10-16, an upgradient well, and well 299-W11-27 through mid-1997. The plots show that before late 1995, ^{99}Tc concentrations in well 299-W11-27 were considerably lower than background values, apparently a result of the water line leak already mentioned. Technetium-99 concentrations peaked in well 299-W11-27 in 1997, then began to decline.

Two newer nearby wells, 299-W10-24 and 299-W11-23, show a continuing, although less consistent pattern of reduced ^{99}Tc (Figure 3-5). In well 299-W10-24, the replacement well for 299-W11-27, ^{99}Tc has ranged between 1,960 and 3,660 pCi/L. The sampling pump in well 299-W10-24 is set at a depth of approximately 4.6 m below the water table. Technetium-99 concentrations in well 299-W11-23 started to increase in November 1997, reaching a high of 8,540 pCi/L in November 1998. Technetium-99 subsequently dropped to 2,755 pCi/L in March 1999 before rebounding to 7,110 pCi/L in August 1999. Finding ^{99}Tc in well 299-W11-23 is apparently a result of the change in groundwater flow direction from northeast to east. Apparently, the plume stretching northeast from well 299-W11-27 is moving eastward across well 299-W11-23. The location and concentrations of the plume inside the waste management area that initially affected well 299-W11-27 are unknown at this time.

Chromium concentrations in well 299-W11-27 exhibited a peak in fiscal year 1996 as shown in Figure 3-4 (Hodges 1998). The chromium in replacement well 299-W10-24 is higher than currently found in well 299-W11-27, unlike ^{99}Tc, which currently is higher in well 299-W11-27, perhaps indicating different sources for chromium and ^{99}Tc or a common source and slightly different mobility in the soil column. The distribution of filtered chromium concentrations in the T WMA is shown in Figure D-4.

Figure 3-4. Contaminant Concentrations/Activities in Two Wells at T WMA (after Hodges 1998).

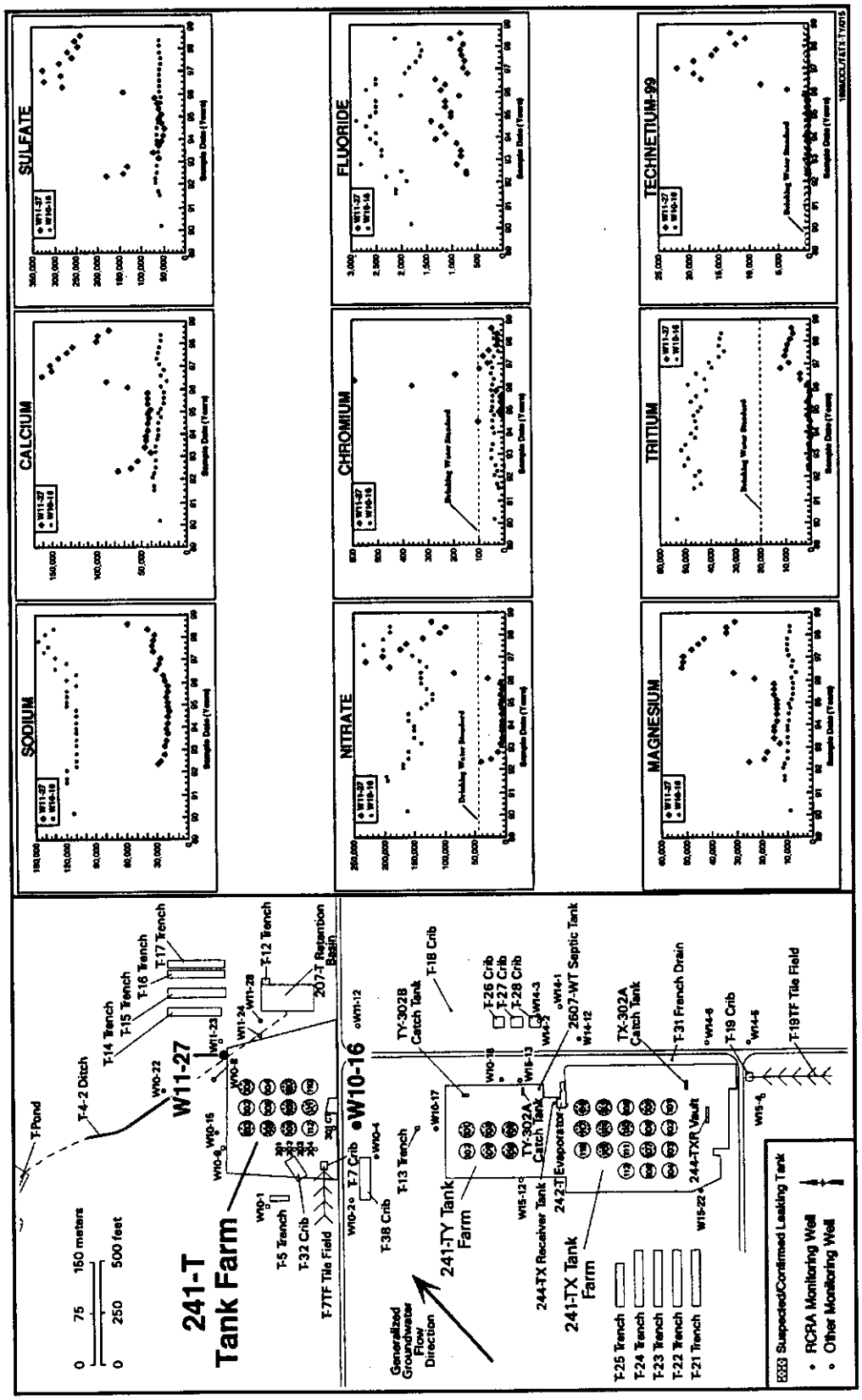
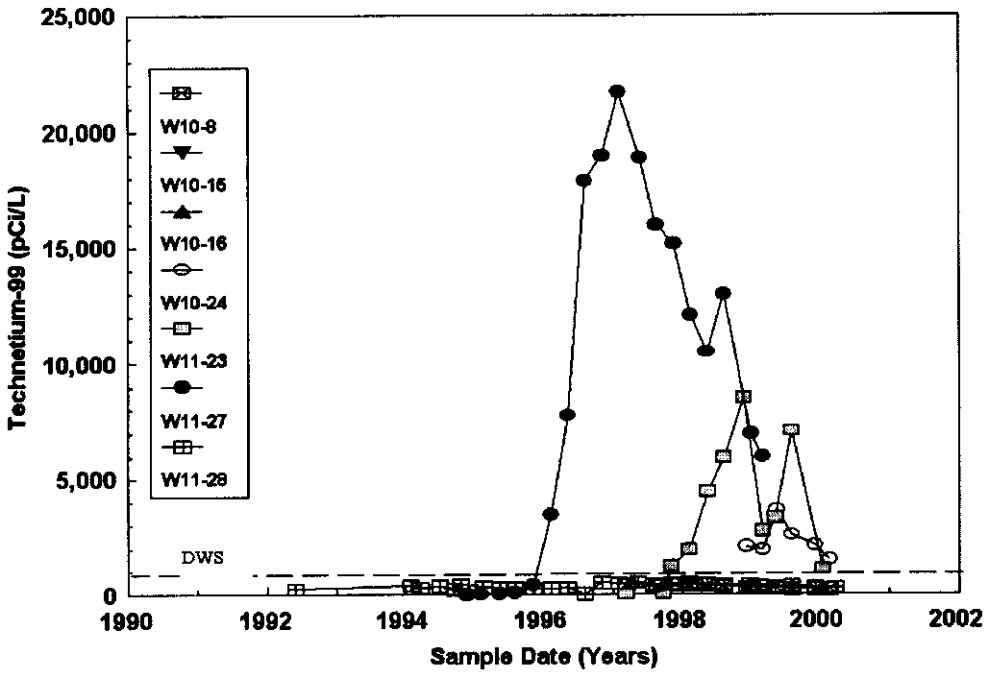


Figure 3-5. Historical Technetium-99 Concentrations Near the T WMA.



Nitrate concentration trends in well 299-W11-27 and its replacement, well 299-W10-24, are shown in Figure 3-6. The recent increase in nitrate concentration in well 299-W11-27 is strongly correlated with the ^{99}Tc trend (Figures 3-5 and 3-6), but this correlation does not carry through to the replacement well, 299-W10-24. The nitrate concentration in well 299-W10-24 is much higher than in well 299-W11-27, whereas the ^{99}Tc concentration is lower. This reversal in relative concentration suggests the presence of multiple nitrate sources that contribute contamination to groundwater intercepting well 299-W10-24. Figures D-1 and D-5 in Appendix D illustrate the nitrate and ^{99}Tc distribution in groundwater underlying the T WMA, showing that nitrate is far more widespread than ^{99}Tc because it originates from several high-volume liquid-waste disposal facilities. Thus, the nitrate and ^{99}Tc present in well 299-W11-27 plausibly could come largely from waste stored in the T tank farm and exist high in the aquifer, but in well 299-W10-24, nitrate also is supplied from a different and more distant source present deeper in the aquifer.

Because of the complexity of groundwater at these WMAs and the multiple potential sources of contamination, a unique linkage of groundwater contaminant patterns to particular sources in various locations is not readily established. Hodges (1998) has proposed elemental isotopic ratios of mobile groundwater constituents as indicators of distinct sources that define mixing lines for groundwater compositions. An example is provided in Figure 3-7 where nitrate/^{99}Tc ratios are plotted versus ^{99}Tc concentrations. In this figure, two groups of points are proposed, each showing trends that could result from mixing a low nitrate-^{99}Tc component with a high nitrate-^{99}Tc component. The interpretation is that contamination characteristics are influence by the addition of tank waste contaminants (the low nitrate-^{99}Tc component) with contaminants derived from other sources (the high nitrate-^{99}Tc component).

Figure 3-6. Historical Concentrations of Nitrate in Monitoring Wells at the T WMA (after Hartman 2000).

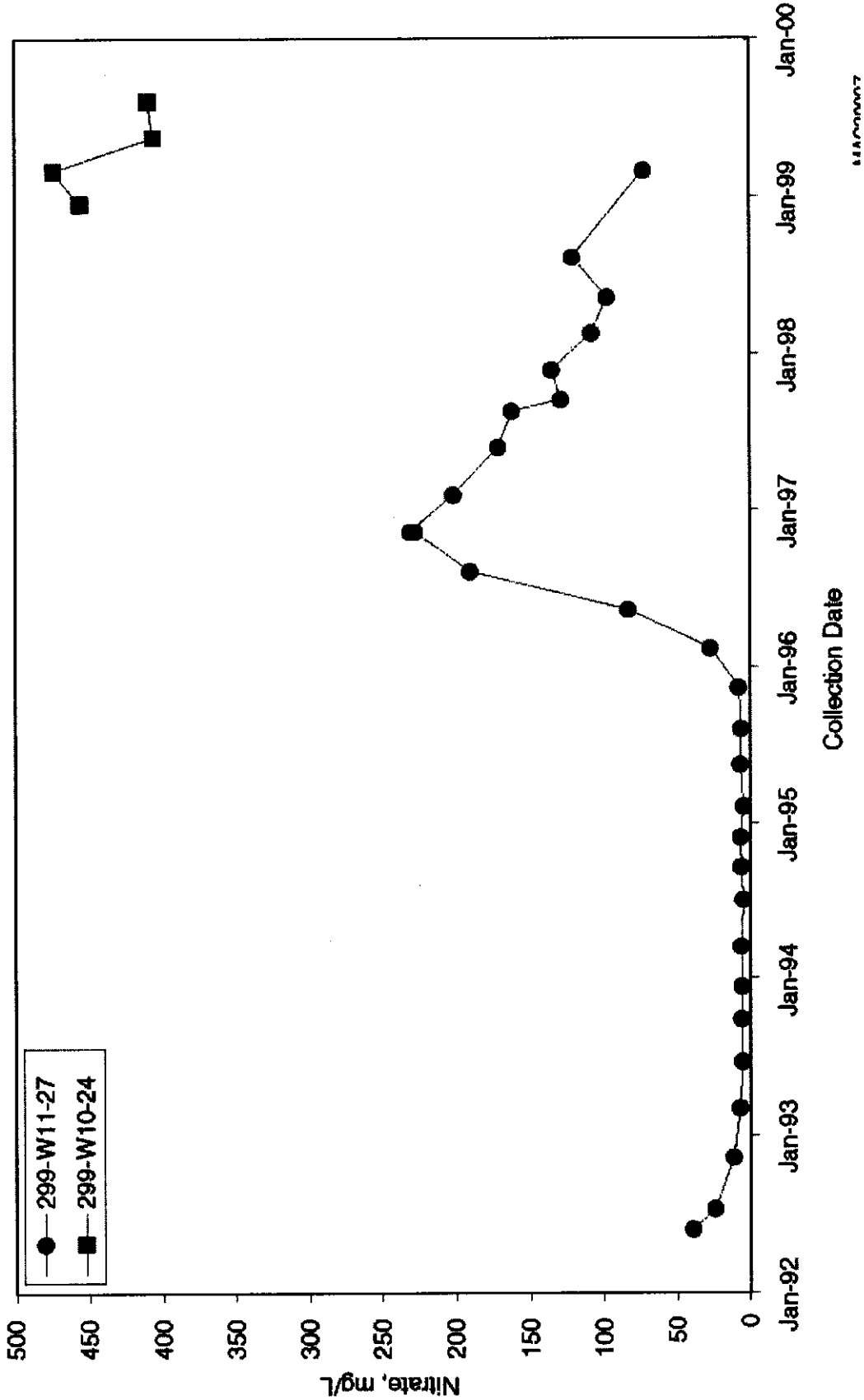
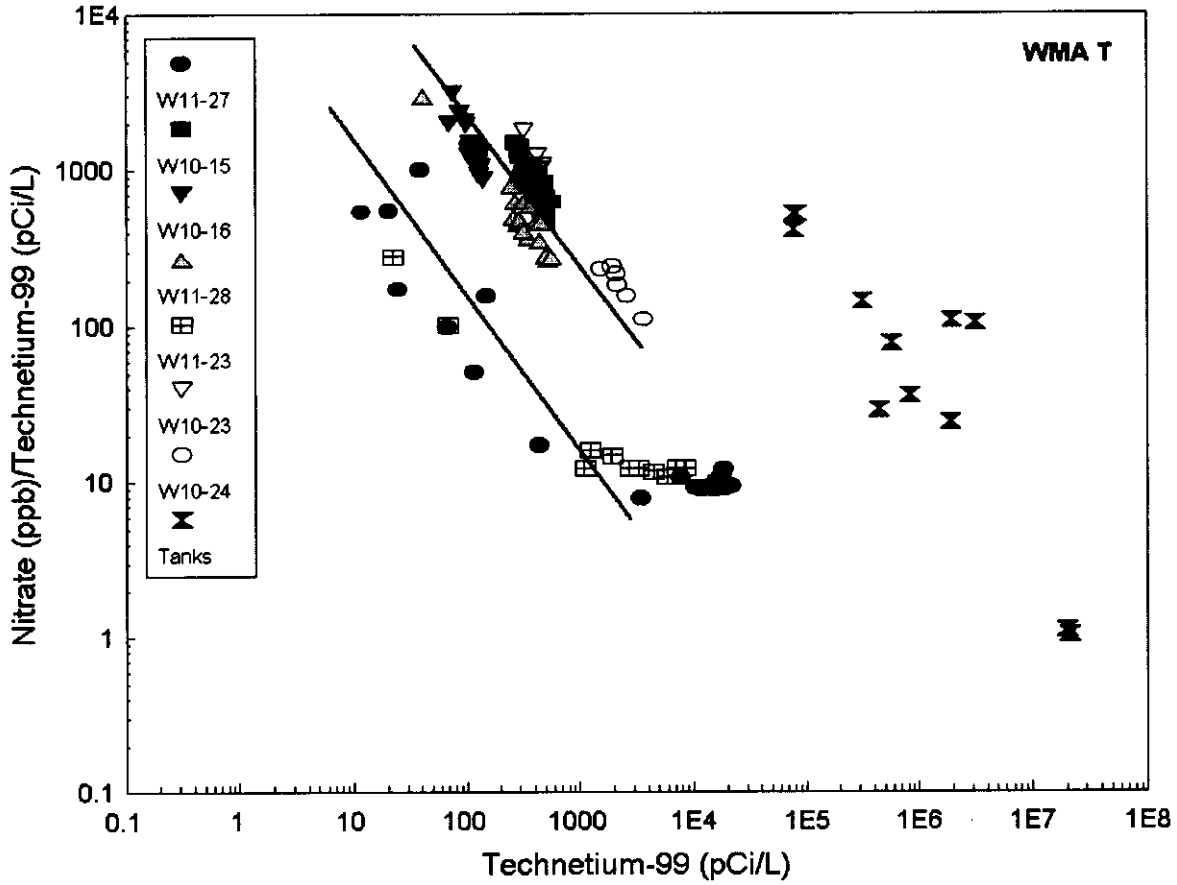


Figure 3-7. Plot of Nitrate-^{99}Tc Versus Technetium (µg/L) in Monitoring Wells at the T WMA.



3.5.2.2 TX-TY WMA Groundwater Contamination.

Groundwater chemistry near the TX-TY WMA has been dominated by groundwater containing high concentrations of sodium and nitrate and various concentrations of tritium, ^{99}Tc, and other contaminants resulting from 50 years of waste management activities. This chemistry is a mixture of two primary sources, tank supernatant liquid disposed of to the ground during tank cascading, and carbon tetrachloride and nitrate-rich water from waste disposal in the Plutonium Finishing Plant (PFP) trenches. Another significant, tritium-rich component is apparently from the disposal of evaporator condensate in the 216-T-19 crib and tile field south of the TX-TY WMA. Recent increases in tritium (3,2000,000 pCi/L) and ^{129}I (81 pCi/L) in well 299-W14-2 indicate the possibility of contamination also resulting from leaks at the 242-T Evaporator located between the TX and TY tank farms.

Wells 299-W14-12, 299-W14-13, 299-W15-22, and 299-W15-4 near the TX-TY WMA contain contaminants considered to have originated from tank leaks. Contaminant levels of chromium, ^{60}Co, ^{129}I, nitrate, ^{99}Tc, and tritium were elevated in well 299-W14-12 when it was first sampled in 1992 and remained high for several years before dropping to low levels in 1996. Technetium-99 had a high value of 13,300 pCi/L in November 1992 (Figure 3-8). Similarly,

chromium had its highest value of 600 μg/L in November 1992 (Figure 3-9). At about the same time, elevated levels of other constituents have also occurred in well 299-W14-12, including calcium and magnesium and, to a lesser extent, sodium (Figure 3-10).

Recently, both ^{99}Tc and chromium increased in this well until it went dry and was replaced by well 299-W14-13 where ^{99}Tc and chromium continue to increase in concentration. Groundwater flow direction in the vicinity of well 299-W14-12 was toward the northeast when monitoring was initiated, but gradually changed to a southeasterly flow, probably in response to the 200 ZP-1 Operable Unit pump-and-treat operations south of the TX-TY WMA. It seems plausible that recent increases in contaminant concentrations in well 299-W14-13 are related to this new driving force. It is unclear whether the source of this new contamination is the same or a different source than the one providing the contamination peaks in 1992. The present location and extent of the earlier pulse are uncertain because of the lack of monitoring wells to the east of the TX-TY WMA.

Technetium-99 in well 299-W15-22 (located in the southwestern corner of the TX-TY WMA) was increasing in fiscal year 1998 to an average activity of 3,100 pCi/L. Slight increases in chromium and nitrate also were observed. In the water samples that were collected, no clear increases in other constituents are observed as in well 299-14-12. The near-simultaneous increase of these three constituents suggests a tank leak source, not necessarily the same leak source that affects wells 299-W14-12 and 299-W14-13. Again, expecting that the 200-ZP-1 operable unit pump-and-treat operation has had some influence on these observations is reasonable. Because of declining water levels, this well cannot be sampled again and has not yet been replaced.

Finally, ^{99}Tc levels also have increased in well 299-W15-4 since the initiation of the 200-ZP-1 operable unit pump-and-treat operations south of the TX-TY WMA. Concentrations exceeded the drinking water standard of 900 pCi/L in July 1999, though the most recent sample in October 1999 was below the drinking water standard. Well 299-W15-4, original constructed to monitor the 216-T-19 crib, is directly south of the waste management area in a direct flow path between the TX-TY WMA and the nearest extraction well. It is possible that a TX-TY WMA tank leak is the source of the ^{99}Tc observed in well 299-W15-4.

Figure 3-8. Historical ^{99}Tc Concentrations Near the TX-TY WMA.

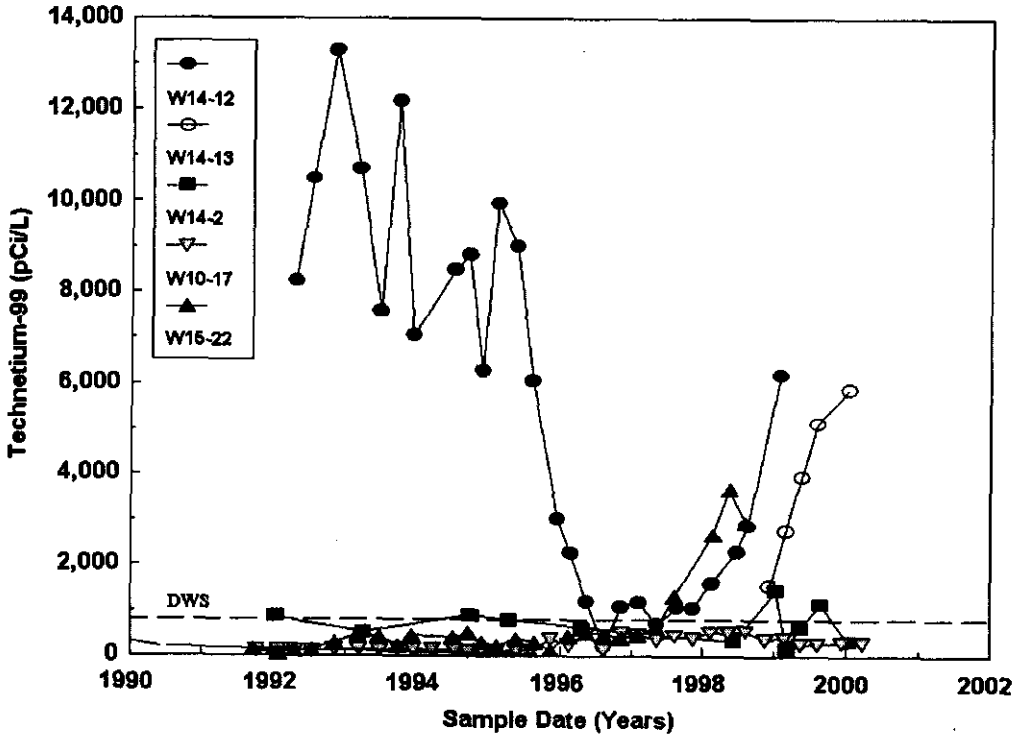


Figure 3-9. Chromium in Wells 299-14-12 and 299-W14-13.

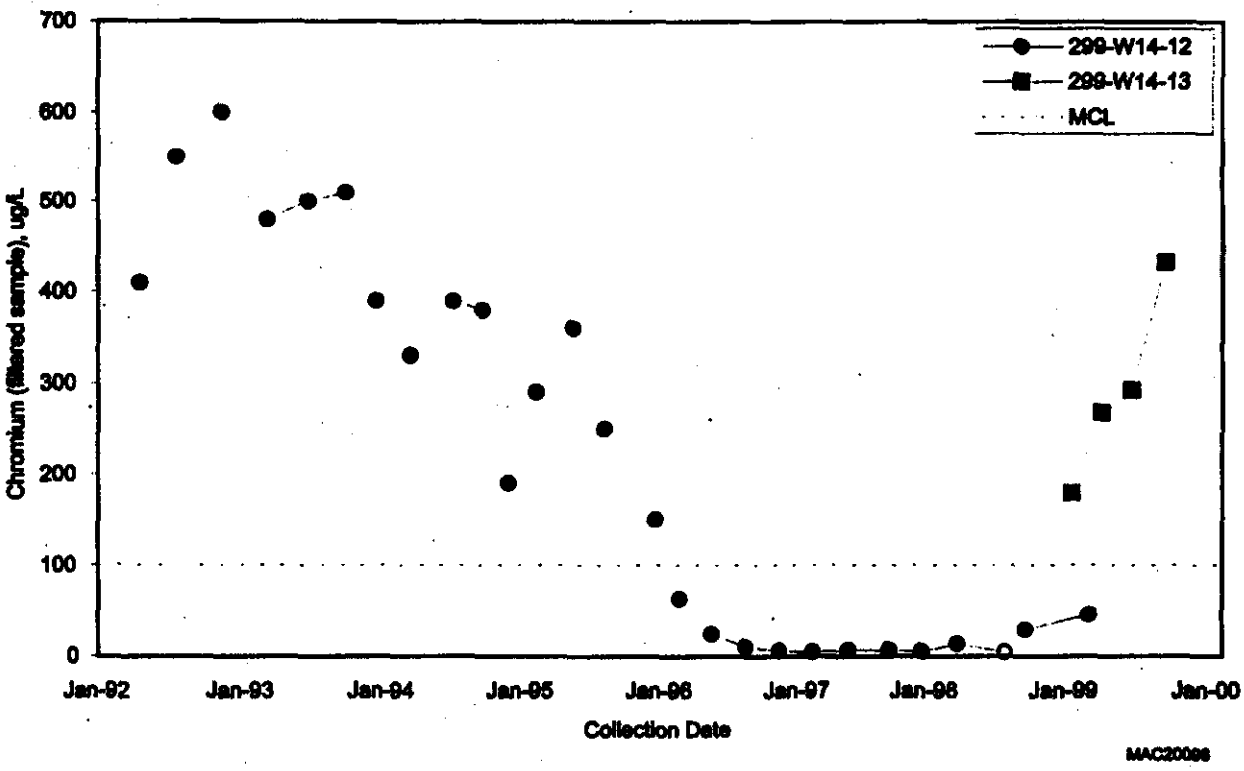
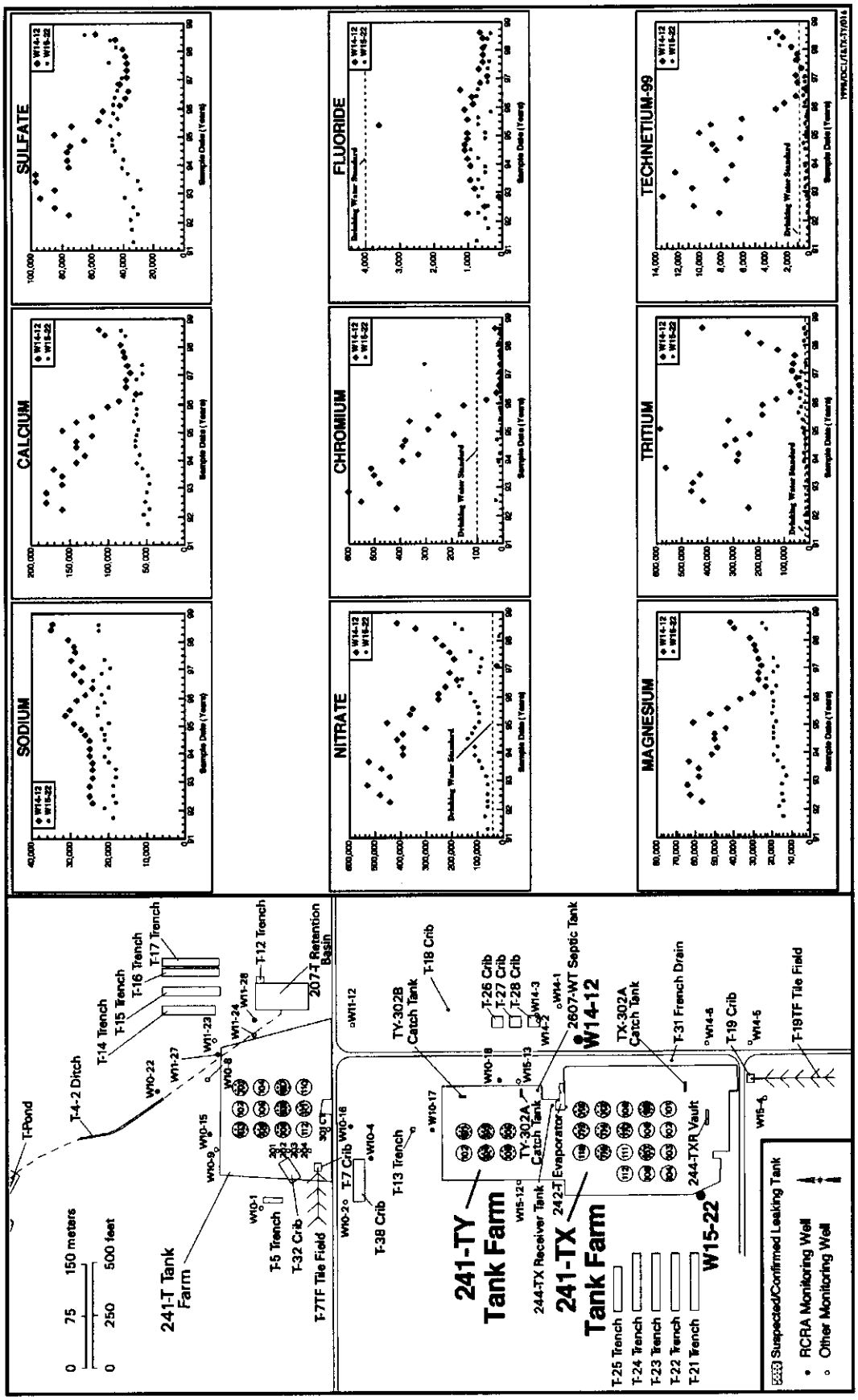


Figure 3-10. Contaminant Concentrations and Activities in Two Wells at the TX-TY WMA (after Hodges 1998).



4.0 DATA INTEGRATION AND CONTAMINANT MIGRATION CONCEPTUALIZATION

This section provides qualitative hypotheses and conclusions about the nature and distribution of contamination present in the T and TX-TY WMAs. The bases for these observations are the data described in Chapter 3 and the appendices of this document.

4.1 GENERAL OBSERVATIONS

Multiple, highly variable vadose zone contamination events have occurred in the T and TX-TY WMAs. Evidence for these events is provided by the historical record, historical and spectral gamma data, and groundwater contamination characteristics. Outstanding characteristics of contaminant occurrences in these WMAs include the following:

- Cesium-137 contamination is found 0.3 m to 9 m (1 to 30 ft) below ground surface (bgs) in most drywells in the T, TX, and TY tank farms. The most highly contaminated surface occurs at the TX farm where concentrations of 10 to 100 pCi/g are common. The most highly contaminated zone occurs between tanks 241-TX-117 and 241-TX-118 where concentrations between 100 and 1000 pCi/g occur from 0.3 m to 6 m (1 to 20 ft) bgs. At the T and TY farms, surface contamination is typically 1 to 10 pCi/g or less. At the T tank farm, surface contamination is largely constrained to the first 3 m (10 ft) of the soil column.

- Cesium-137 also occurs in zones of very high contamination (10^4 to 10^8 pCi/L) near postulated leak source locations. The largest grouping of drywells containing high contamination occurs to the south of tank 241-T-106. This is consistent with the largest recorded leak in the T and TX-TY WMAs being released from or near this tank. Individual isolated drywell high-contamination zones are present on the east side of tank 241-T-101 (drywell 50-03-04), the east side of tank 241-TY-103 (drywell 52-03-03), and the east side of tank 241-TX-114 (drywell 51-14-04). These drywells all show small zones (about 1.5 m (5 ft) thick) of concentrations greater than 1000 pCi/g at tank bottom depths, except for drywell 50-03-04 where the ^{137}Cs concentration zone of greater than detector saturation extends from 6 m to 21 m (20 to 70 ft). The concentration is 1000 to 10,000 pCi/g from 21 m (70 ft) to the bottom of the hole (37 m [120 ft]).

- No zones of high ^{137}Cs contamination are found in several areas where evidence of other leak events exists (e.g., the occurrence of other radionuclides in the soil column and/or historical record). These include soils in the vicinity of tanks 241-T-103, 241-TY-103, 241-TX-105, 241-TX-107, and 241-TX-104.

- Cobalt-60 and europium isotopes occur together near postulated leak locations. These include drywells nearly all the way around tank 241-T-106, to the southwest of tank 241-T-103, south of tank 241-T-101, and southwest of tank 241-TX-107.

- Cobalt-60 occurs alone at lower depths (about 20 m to 30 m [65 to 100 ft] or to the bottom of the drywell) in numerous wells around postulated leak locations. This behavior is most prevalent in the T tank farm, particularly those wells where soil was

contaminated by the tank 241-T-106 leak. Two wells to the southwest of tank 241-T-107 also show this characteristic. Also, in the TY tank farm, ^{60}Co is found at depth in some wells near tank 241-T-105.

- The distributions of ^{137}Cs, europium isotopes, and ^{60}Co relative to postulated sources and each other indicate a consistent pattern of relative mobility. Cesium-137 is highly sorptive, europium isotopes are slightly sorptive, and ^{60}Co is nearly nonsorptive. In these leaks, ^{137}Cs tends to behave as it would under undisturbed soil-water conditions. Conversely, the europium and ^{60}Co geochemical behavior in the soil column apparently continues to be controlled by the tank waste chemistry, which was deliberately manipulated in processing to mobilize these radioelements to selectively remove ^{137}Cs from dissolved fuel sent from the PUREX Plant to B Plant.

- Uranium is concentrated in two sets of drywells, one underlying and to the southwest of tank 241-TX-105 and one underlying and to the southwest of tank 241-TX-104. Uranium-238 concentrations between 10 and 100 pCi/g occur at 12 m to 30 m (40 to 100 ft) in each region.

- Two patterns of groundwater contamination occur under the T and TX-TY WMAs. Nitrate and tritium are ubiquitous, forming a large, complex pattern that extends throughout the WMAs and beyond. This contamination is the result of intentional and often-repeated liquid waste discharges containing these contaminants from the various cribs and trenches within and surrounding the WMAs. Conversely, ^{99}Tc and chromium occur in a small number of wells downstream of tank waste. These include wells at the northeast corner of T tank farm, downstream of tanks 241-T-106, 241-T-103, and 241-T–101 and wells east of TX farm, downstream of tanks 241-TX-105, 241-TX-107, and 241-TX–104. These characteristics support the hypothesis of leaked tank waste as the sources of ^{99}Tc and chromium contamination.

- Since the beginning of T, TX, and TY tank farms operations, discharge of water into the local vadose zone has been sporadic, derived from various sources, and varied in intensity. The combination of highly permeable tank farm covers and vadose zone soils maximizes recharge rates from precipitation. Topographic lows in T tank farm enhance the potential of recharge from runoff collection on the tank farm surface. The likelihood of water and waste transfer line leaks is high and a good percentage of these leaks are undetectable and therefore, undocumented. Consequently, the influences of these events on contaminant migration from the T and TX-TY WMAs into the unconfined aquifer are difficult to gauge because of limited waste-site-specific groundwater monitoring activities. Correlation of specific recharge events from high-intensity precipitation events with contaminant migration is highly uncertain.

These observations clearly show that multiple contamination events have occurred and varying degrees of contamination in the vadose zone have resulted. Integration of the data and conceptualization of leak events associated with the larger contamination areas in the T and TX-TY WMAs are described in greater detail in the Section 4.2.

4.2 CONCEPTUALIZATION OF PRIMARY VADOSE CONTAMINATION EVENTS

4.2.1 Surface Contamination Events

Spectral gamma logging data from the drywells in the T, TX, and TY tank farms shows a variable distributions and concentrations of ^{137}Cs from the surface down to about 3 m to 6 m (10 to 20 ft) indicating spills of contaminated fluid resulting from tank farm operations. The severity and frequency of ^{137}Cs contamination indicates that the greatest amount of spills occurred in the TX tank farm. In this tank farm the highest inventory contamination occurs between tanks 241-TX-117 and 241-TX–118. Because no specific unplanned release event has been recorded near this location, leak volume and other constituents are not known. However, the largest concentration (about 10^3 pCi/g) is not large relative to tank waste and found only in adjacent drywells 51-17-10 and 51-18-03. These drywells are unusual because small concentrations of ^{60}Co and ^{154}Eu are present near the ground surface along with cesium. The maximum concentrations occur near the surface and rapidly tail off to about 1 pCi/g at 9 m (30 ft).

The ^{137}Cs presence near surface is consistent with initial rapid sorption out of the migrating solution as it moved deeper into the soil column. If other more mobile constituents were present in the spilled liquids, presumably they would migrated with the liquid, possibly to depths below the drywells. Alternatively, there may not have been enough concentration of other mobile constituents in many spills to be measurable.

4.2.2 Tank 241-T-106 and 241-T-103 Data Integration and Interpretation

The tank 241-T-106 leak is the largest tank waste leak at the Hanford Site and, because of its size, has received the most thorough characterization of all the leaks to date. The following conceptual model of the leak is proposed, which is consistent with these data. Changes in tank liquid level measurements indicate a large leak of tank supernatant liquid (approximately 435,321 L [115,000 gal]) occurred over 50 days in April and May 1973. The leakage source and direction can be inferred from the distribution of various gamma-emitting radionuclides in the soil column each dropping out of solution and sorbing onto soils at different rates (described in Chapter 3 as four zones of differing gamma characteristics). The data suggest that ^{137}Cs sorbed and dropped out of solution most quickly, ^{106}Ru did not sorb, ^{60}Co sorbed very little and the europium isotopes sorbed at an intermediate rate. Other mobile constituents (notably technetium, chromium, and nitrate) are inferred to have behaved similarly to ruthenium, or ^{60}Co. The leak location appears to be on the southeast part of the tank wall near the bottom of the tank about 11 m to 12 m (35 to 40 ft). This location is suggested by the ^{137}Cs content in drywell 50-06-05, which is shown from spectral gamma data. Cesium-137 concentrations exceed upper detection levels at 35 ft and extend to the bottom of the drywell (35 m [115 ft]), showing the maximum degree of ^{137}Cs contamination of all drywells surrounding tank 241-T-106. Part of this zone may be the result of preferential drainage provided by the installation of the drywell, which occurred after the leak event.

The leak immediately spread laterally and vertically downward, creating temporary regions of saturation or near saturation. Early lateral distribution is indicated by thin bands

(1.5 m to 3 m [5 to 10 ft] thick) of ^{137}Cs oversaturation zones in the Zone 2 drywells on the south to southeast side of tank 241-T-106. The depth of these bands (about 11 m to 14 m [35 to 45 ft) is the same as the packed soil base supporting the tanks and suggests some initial preferential lateral flow along this horizon. During this phase of migration, essentially all of the ^{137}Cs in solution was removed from the migrating fluid through sorption. Once most of the fluid migrated below the tank bottoms, lateral and vertical downward movement continued carrying ^{60}Co, europium isotopes, ^{106}Ru, and ^{99}Tc. The majority of the lateral distribution appears to have occurred in the first few years following the leak as shown by a comparison of the projected 1973 and 1978 ^{106}Ru 1 μCi/L isopleth contours (Figure 3-2) with the current spectral gamma fingerprint (see Figure 3-1). A general similarity in spatial distribution exists.

Over time, as the driving force of the leak event dissipated, lateral movement slowed and essentially ceased. Vertical movement became the dominant direction of flow, but at a considerably slower rate than the lateral movement during the initial stage. The vertical movement also was controlled by drainage, recharge from precipitation, and whatever pipe leaks might have occurred in the region. Slightly sorbing radionuclides (e.g., europium isotopes) gradually fell out of the migrating fluid with increasing distance from the source, leaving only mobile constituents at greater depth in the soil column (shown in Zone 4 drywells where ^{60}Co is the remaining gamma emitting radionuclide). A few nearby downstream wells contain contaminants suggesting that the most mobile constituents in the tank waste have recently reached groundwater. Technetium-99, nitrate, and chromium peaks occurred in well 299-W11-27 in late 1996 and early 1997, and ^{99}Tc and nitrate peaks occurred in well 299-W10-24 in 1999.

The tank 241-T-103 leak appears to have evolved similarly to the tank 241-T-106 leak, but on a much smaller scale. Assuming that ^{137}Cs is the first gamma-emitting radionuclide to drop out of solution, drywell 50-03-04 appears to be closest to the leak source, although a thicker zone of greater ^{137}Cs contamination is expected to be nearby. The shallow depth (6 m [20 ft]) of the ^{137}Cs in drywell 50-03-04 supports the hypothesis that a waste transfer or spare fill line is the actual leak source. Subsequently, the leak spread laterally and vertically toward the southeast with ^{60}Co and europium isotopes remaining in solution. The true extent of this leak migration is difficult to determine because it overlaps with the tank 241-T-106 leak migrating from the south.

4.2.3 Tank 241-T-101 and 241-T-102 Integration and Interpretation

The historical record and spectral gamma data suggest that several leaks may have occurred around tanks 241-T-101 and 241-T-102. Two leaks around tank 241-T-101 appear to be associated with transfer line leaks rather than loss of tank wall integrity, as shown by the high ^{137}Cs concentrations beginning about 6 m (20 ft) bgs in drywells 50-01-04 and 50-01-09. The leak near drywell 50-01-04 appears to be substantially larger than the one near drywell 50-01-09 because the ^{137}Cs concentration oversaturation zone extends from 6 m to 21 m (20 to 68 ft) and again from 34 m to 37 m (110 to 120 ft). Strong evidence of the leak duration and volume is not available, but the best estimate appears to be associated with a tank overfill of about 34 kL (9,000 gal) in 1969. This leak fluid appears to have migrated laterally and vertically to the southeast at least to drywell 50-01-06 where a signature for ^{60}Co and europium isotopes appears at drywell 50-01-06 beginning at 15 m (50 ft). Extension of this leak farther to the southeast may be indicated by the presence of ^{60}Co at 20 m (65 ft) and below in drywells 50-04-10 and

50-04-08. As with the tank 241-T-106 leak, ^{137}Cs apparently sorbed quickly and dropped out of solution near the source. If this leak event occurred as postulated, the gamma characteristics match those of the tank 241-T-106 leak event on a smaller scale.

A small zone of moderate ^{137}Cs contamination occurs in drywell 50-02-05 and leakage from a spare infill line attached to tank 241-T-102 has been proposed as the source (DOE-GJO 1999). If this is correct, drywell 50-02-05 is some distance from the source because the ^{137}Cs contamination zone occurs at the packed soil zone directly beneath the tank bottoms. Vertical migration would have begun at about 6 m (20 ft) and continued until reaching the packed soil supporting the tanks, which form a preferential horizontal path. The maximum ^{137}Cs concentration of 1,000 pCi/g with no indication of ^{137}Cs contamination in surrounding drywells indicates a small, relatively isolated leak.

4.2.4 Tank 241-TX-105/241-TX-101 and 241-TX-104 Leak Area Integration and Interpretation

An elongated uranium contamination region underlies tanks 241-TX-105 and 241-TX-101 in the vadose zone at 15 m to 30 m (50 to 100 ft) with the long axis of the footprint running northeast to southwest. The extent of the zone is well constrained on the north, west, and south sides by the absence of uranium in existing drywells, but not on the east side where no drywells are present. The uranium signature indicates a metal waste source that could have occurred only during the early 1950's, similar to the leak east of tank 241-BX-102. The only historical indication of a leak event that could be related to this contamination is UPR-200-W-100, which is described as an underground pipe leak that occurred in 1954. This leak is associated with the cascading tanks 241-TX-105 through 241-TX-108. The historical record suggests loss of 1C of waste, but the relatively high uranium content in the vadose zone can originate only from metal waste. Therefore, either this unplanned release is not related to this contamination event or the record is incorrect. Neither hypothesis can be discounted. However, this leak event is clearly not linked to the leak event listed in Hanlon (1999) and postulated to have occurred in 1973.

The historical record provides no indication of leak volume. The relative concentrations and positions of uranium contamination that define the contamination region suggest that the leak began near the northeast part of the contamination zone and moved southwest and deeper into the vadose zone. This sequence is suggested by the occurrence of thicker zones of uranium contamination closer to the surface in the northeast drywells 51-05-01, 51-05-03, and 51-05-05. The depth at which contamination begins in these drywells (about 15 m to 18 m [50 to 60 ft]) coincides with the soil layer at the tank bottom. If the leak originated from a waste transfer pipe, fluid would have been released higher in the soil column, requiring vertical migration of waste until it reached the soil layer adjacent to the tank bottom and subsequently began to move laterally. One would also expect to find a small zone of high ^{137}Cs contamination nearby, perhaps adjacent to tank 241-TX-105, but no ^{137}Cs contamination has been found in the existing set of drywells.

When the primary migration event ended, uranium precipitated and/or remained in leak fluid that subsequently would have begun to drain and migrate according to the recharge forces created by natural precipitation and operational discharges (e.g., unintentional pipe leaks in the vicinity). Contaminants from this region may or may not have entered the groundwater.

Technetium-99, which would be expected to be present in the metal waste fluid, has appeared in downstream wells W14-12 and W14-13 showing peaks in 1993, 1999, and perhaps currently. However, the simultaneous peaks of chromium in these wells are not consistent with a metal waste source. The other constituent from this source that should have reached groundwater at about the same time as ^{99}Tc is the soluble uranium, which has not been measured in groundwater samples.

An elongated uranium contamination region underlies tank 241-TX-104. This region is similar to the contaminated region underlying tank 241-TX-105 and tank 241-TX-101. This contamination zone occurs in the vadose zone at between 14 m and 30 m (45 and 100 ft) with the long axis of the footprint running northeast to southwest. The extent of the zone is well constrained on the north, west, and east sides by the absence of uranium in existing drywells. However, the extent of the zone on the south side where no drywells are present, is unknown. As with the tank 241-TX-105/241-TX-101 leak event, the historical record provides no indication of leak volume.

Given the similarities of the two contamination zones, the source of the leak could very well be related to the tank 241-TX-105/241-TX-101 leak. The contamination spreading scenario described for the tank 241-TX-105/241-TX-101 leak event is considered to be applicable to this leak event as well. Contaminants from this region may or may not have entered the groundwater. Technetium-99, which would be expected to be present in the metal waste fluid, has appeared in wells 299-W15-22 and 299-W15-4 showing peaks in 1998 and perhaps currently. A complicating factor is the pump-and-treat operation occurring just south of the TX tank farm. This operation may be pulling contamination from underneath the tank farm toward the south. If so, at least three sources are plausible for the contamination found in these two monitoring wells, including the two uranium contamination regions and contamination from the tank 241-TX-107 leak event (Section 4.2.5). The soluble uranium may have reached groundwater at about the same time as ^{99}Tc, but it has not been measured in groundwater samples.

4.2.5 Tank 241-TX-107 Leak Integration and Interpretation

An elongated ^{60}Co and europium isotope contamination region begins at the southwest portion of tank 241-TX-107 and extends in a southwesterly direction beneath parts of and between tanks 241-TX-103 and 241-TX-104. This contamination zone occurs in the vadose zone at 15 m to 30 m (50 to 100 ft) bgs. The extent of the zone is well constrained on the north, west, and east sides by the absence of ^{60}Co and europium in existing drywells, but not on the south side where no drywells are present. The estimated leak volume of 95 kL (2,500 gal) has no firm basis and appears to be too small to generate the apparent size of the contamination zone. Historical records show that large amounts of fluids were being transferred through this tank at the time of the leak, making the leak volume difficult to observe and measure.

The ^{60}Co and europium signature is clearly associated with a series of historical gamma log data taken in real time as the leak was migrating (DOE-GJO 1999). These data indicate a leak beginning near tank 241-TX-107 in the late 1970's and progressing to the south and east in the vadose zone as late as 1986. The spectral gamma data set showing contamination from this leak are consistent with the historical gamma data. Near the source of the leak, ^{60}Co and europium occur at the highest level in the soil column (15 m to 21 m [50 to 70 ft]), 15 m (50 ft)

being the depth of the tank bottom. One also would expect to find a small high-^{137}Cs contamination zone nearby and closer to the leak location, perhaps underlying tank 241-TX-107, but none has been found in the existing set of drywells. Without knowing the location of a ^{137}Cs contamination zone, a more definitive determination of source location is uncertain.

At drywells 51-04-05 and 51-03-09, the farthest from tank 241-TX-107 , ^{154}Eu, the somewhat less mobile constituent, is not present and ^{60}Co occurs deeper in the soil column at 28 m to 30 m (60 to 100 ft). These data suggest that both lateral and vertical migration occur over time and the mobile constituents remain in solution the longest. Additional migration of mobile constituents from this leak to the aquifer may or may not have occurred. Technetium-99 and chromium in downstream wells W14-12 and W14-13 are potential constituents of this leak. Technetium-99 in wells W15-22 and W15-4 also may have originated from this source.

4.2.6 Tank 241-TY-105 Leak Integration and Interpretation

Conceptualization of the leak from tank 241-TY-105 is hampered by a minimal historical record of the event and sparsely distributed drywells near this tank. The record indicates a leak occurrence in 1960. The drywells that appear to be associated with this event, 52-05-07, 52-03-06 and 52-06-05, and possibly 52-03-12, suggest that the leak occurred nearest drywell 52-05-07 because this drywell contains the most extensive ^{137}Cs contamination beginning near the tank-bottom depth. Thus, either the leak originated at the tank bottom or at a shallower depth some distance from the drywell and migrated downward. Once the leaking fluid got below the tank bottom, it flowed horizontally to the north and southwest, contaminating the area around drywell 52-03-06, possibly drywells 52-03-12 and 52-06-05. Flow also could have occurred to the south, east, and southeast, but there are no drywells in these directions to measure migration. Cobalt-60 contamination remains near these existing drywells and also suggests vertical migration, particularly at drywell 52-03-06 where ^{60}Co exists at relatively high concentrations (more than 10 pCi/g) down to the drywell bottom at 30 m (100 ft).

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5.0 RECOMMENDATIONS FOR FURTHER CHARACTERIZATION OF THE T AND TX-TY WMAS

Chapters 1 through 3 present information pertinent to the occurrence of contaminants in the vadose zone underlying the T and TX-TY WMAs and the groundwater contamination observed in several groundwater monitoring wells to the northeast of the T tank farm and around the southern end of TX tank farm. Chapter 4 presents qualitative hypotheses of events leading to the observed vadose zone and aquifer contamination.

From these observations and process knowledge, we conclude that the primary locations of interest for additional aquifer contamination have been identified. For most of these areas, we do not expect contamination extensive enough to warrant remediation. However, we recommend further characterization primarily because of the following four data gaps.

- The volumes of most leaks are not well documented because no clear means of measuring leaks was available.
- Measurements of leaked waste fluids are rare and incomplete.
- Groundwater monitoring data in the unconfined aquifer underlying or directly downstream of the T and TX-TY WMAs was essentially nonexistent before 1991. Consequently, any number of mobile contaminant releases from the vadose zone into the unconfined aquifer could have occurred between 1951 and 1991 and gone undetected.
- The spectral gamma data do not provide information about the nature and extent of non-gamma-producing contaminants. In particular, the distribution and inventory of ^{99}Tc is of interest.

5.1 Description of Characterization Alternatives

The primary goal of additional characterization is to determine the nature and extent of tank waste contaminants in the vicinity of known or suspected leaks. This is to be done primarily through sampling soil in the regions of interest and analyzing the samples for expected contaminants of concern; soil water pH, electrical conductivity, moisture content, and, if feasible, hydrologic properties. Of particular interest are known mobile constituents, ^{99}Tc, uranium, and nitrate. Other contaminants, particularly ^{137}Cs and ^{60}Co, are of interest because they provide some indication of contaminant migration and distribution. Neither radionuclide is expected to contaminate groundwater to unacceptable levels in the future. Finally, spectral gamma and neutron probe logging for moisture is recommended where feasible.

Table 5-1 lists the critical factors that influence future characterization decisions in the T, TX, and TY tank farms. These factors are primary indicators of the nature and extent of contamination underlying these WMAs in the vadose zone and are listed for separate, potentially significant contamination zones associated with the tanks listed in the top row of the table. The critical factors are leak volumes and contaminant inventory and distribution. Leak volumes are based on liquid level measurements, waste transfer records, or averaging estimates. Contaminant distribution is indicated by the location and concentration of gamma–emitting radionuclides in drywells, and estimates of key radionuclide inventories based on the Hanford Defined Waste

(HDW) Model (Agnew 1997). This model tracks the tank waste inventory over time using available tank farm operations records and knowledge of the chemistry and radionuclide inventory of feed streams. The values for ^{99}Tc, ^{137}Cs, and ^{60}Co chemical and radionuclide inventory shown in Table 5-1 are generated by this model using assumed leak volumes (also shown in Table 5-1) and leak time (Jones et al. 2000).

Quantitative estimates of the critical factors are provided in Table 5-1 where available and appropriate. Other factors are qualitative, and quantities are defined relatively. Finally, leak volume and contaminant information are evaluated for reliability and consistency.

The second part of Table 5-1 lists the three primary additional characterization options to improve the estimate of the nature and extent of contamination. It also presents the feasibility of completing each characterization option for each contamination area. The applicability of each option was evaluated for each contamination region in the following ways:

- Krieging is a mathematical technique for extrapolating or interpolating concentration data in a given region based on discrete data points within that region. This technique is only useful if a certain density and number of data points are available. Given the present database, enough concentration data are available for the tank 241-T-106 leak, the uranium plumes around tanks 241-TX-105 and 241-TX-101 and tank 241-TX-104, and the tank 241-TX-107 leak.

- Direct push or cone penetrometer characterization allows limited down-hole measurements (gamma and moisture measurements) and soil sampling. The primary limitation of the technique is that the feasible penetration depth is shallow, typically 9 m to 12 m (30 to 40 ft), preventing exploration of contaminated soils beneath the tank bottom. Thus, this technique is potentially useful only if the contamination of interest exists above the tank bottom. Given the present database, contamination zones near tanks 241-T-101, 241-T-103, 241-T-106, and 241-TX-104 could be investigated by the direct push method.

- Borehole drilling and sampling provide the greatest potential for collecting soil samples and indirect measurements. These techniques can be used anywhere in the soil column unoccupied by tanks and infrastructure. For the technique to be useful, sufficient evidence of contamination must be available to properly place the borehole to intercept the more highly concentrated portion of the contamination zone. Given the present database, primarily spectral gamma data, boreholes could be placed adequately in contamination zones near tanks 241-T-106, 241-TX-104, 241-TX-105 and 241-TX-102, and 241-TX-107.

5.2 RECOMMENDATIONS FOR ADDITIONAL CHARACTERIZATION IN THE T AND TX-TY WMAS

The third part of Table 5-1 checks the recommended characterization actions by specific tank area. Characterization is recommended for contamination zones around tank 241-T-106, tanks 241-TX-105 and 241-TX-101, and tank 241-TX-107. Characterization is not recommended for contamination zones around tanks 241-T-101, 241-T-103, 241-TY-105, and 241-TY-106. The rationale for each recommendation is discussed briefly in Sections 5.2.1 through 5.2.5.

5.2.1 Tank 241-T-106 Area Characterization

The database describing the tank 241-T-106 leak is more extensive than that of any other leak in the single-shell tank farms because it is the largest well-substantiated leak event. Because of the large areal extent of this leak (Figures 3-1 and 3-2) and the projected high level of contamination, an additional borehole is recommended to improve estimates of the nature and extent of contaminant occurrence, particularly non-gamma-emitting radionuclides and chemicals associated with tank fluids (e.g., nitrate). The data to be collected are a complete set of chemical and radiological soil sample analyses with depth for comparison with the existing database from borehole 299-W10-196 (Freeman-Pollard et al 1994). To complement data collected from borehole 299-W10-196, which are collected near the source of the tank leak, the new borehole should be located some distance away from the source to get perspective on the spatial distribution of non-gamma-emitting radionuclides, particularly ^{99}Tc. The spectral gamma data indicate slight preferential movement of the more concentrated portions of the plume to the southeast. Therefore, placement of the new borehole between tanks 241-T-106, 241-T-105, 241-T-108, and 241-T-109 is recommended.

Some changes in data collection relative to the previous borehole are recommended to improve the database. Experience gained from recent borehole drilling tasks in the SX and BX tank farms should be applied to minimize drag-down effects while retrieving soil from this borehole. Water and acid leaching of soil samples should be completed to provide empirical sorption values for contaminants of interest. These types of data were not generated previously for soils contaminated by the 241-T-106 tank leak. Consideration should be given to finding better methods for identifying organic complexants that may have influenced radionuclide mobility.

Krieging is recommended for this area. A large spectral gamma database is available for use and krieging estimates of the gamma radionuclide inventory can be developed and compared with estimates from other sources.

5.2.2 Tank 241-TX-105 and -TX-101 Area Characterization

The spectral gamma database shows a potentially large metal waste contamination zone indicated by high uranium concentrations in several drywells around and between tanks 241-TX-105 and 241-TX-101. Contaminant information is not available for this zone except for the uranium isotopes. For example, it is expected that ^{99}Tc will be present in this zone. The concentration and distribution of ^{99}Tc can be partially determined by completing a deep borehole to groundwater in the middle of the plume. The data to be collected are a complete set of chemical and radiological soil sample analyses with depth. This database will substantially increase our understanding of the nature and extent of non-gamma-emitting constituents in this zone because no information exists. Because the waste source is metal waste, a relatively high inventory of ^{99}Tc may be present. Collecting at least one groundwater sample also is recommended to determine if this source currently is contaminating groundwater.

Krieging also is recommended for this area. An adequate spectral gamma database is available for use and krieging estimates of the gamma radionuclide inventory can be developed. This is particularly important in this zone because there is no historical record of this leak. Krieging results will provide an initial inventory estimate that then could be compared with the

tank 241-BX-102 leak event where a volume-inventory ratio is available. Although crude, this approach will provide some estimate of the severity of this leak.

5.2.3 Tank 241-TX-107 Area Characterization

An extensive and fairly well-defined contamination zone from this leak is defined by the spectral gamma database. Similarly, the historical gross gamma record provides a relatively detailed tracking of the leak event. Because of the relatively high concentrations of ^{60}Co and europium isotopes shown by the spectral gamma database, the rather high ^{99}Tc inventory predicted by the HDW model (4.75 Ci in Table 5-1), and the recent occurrence of ^{99}Tc peaks in nearby groundwater monitoring wells, we recommend constructing a deep borehole to groundwater near the source of the plume just south of tank 241-TX-107. The data to be collected are a complete set of chemical and radiological soil sample analyses with depth. These data will substantially increase our understanding of the nature and extent of non-gamma-emitting constituents in this zone because no information is available. We also recommend collecting at least one groundwater sample to determine if this source currently is contaminating groundwater.

Krieging also is recommended for this area. A moderate spectral gamma database is available for use and krieging estimates of the gamma radionuclide inventory can be developed and compared with estimates from other sources.

5.2.4 Tank 241-TX-104 Area Characterization

The spectral gamma database shows a potentially large metal waste contamination zone east and south of tank 241-TX-104. Our knowledge about this contamination zone is the same as that for tanks 241-TX-105 and 241-TX-101. A borehole currently is not recommended for this area, the expectation being that data collected from the borehole near tanks 241-TX-105 and 241-TX-101 also will apply to this contamination zone. The nature and extent of contamination in the two regions is similar and likely to be the outcome of similar leaks.

Krieging is recommended for this area. An adequate spectral gamma database is available for use and krieging estimates of the gamma radionuclide inventory can be developed. This is particularly important in this zone because no historical record of this leak exists. Krieging results will provide an inventory estimate that then could be compared with the tank 241-BX-102 event where a volume-inventory ratio is available. Although crude, this approach will provide some estimate of the severity of this leak.

5.2.5 Characterization of Other Contamination Zones

Other contamination zones have been identifed in this report. These include the regions near tanks 241-T-101 and -T-102, 241-T-103, 241-TY-102, 241-TY-103, 241-TY-105, 241-TY-106, and 241-TX-110, -TX-113, and -TX-114. Also, surface contamination is present in all tank farms. These areas are not recommended for further characterization because the levels of contamination are either minimal (generally 100 pCi/L of ^{137}Cs or less) or concentrated in very small areas (e.g., a 1.5 m [5-ft]-thick zone in an isolated drywell).

Of the individual assumed tank leaks, only the estimates for leaks from tanks 241-TY-105 and 241-TY-106 are large (132 kL and 76 kL [35,000 and 20,000 gal], respectively). Despite the large volume estimate associated with these two tanks, no evidence supports the assumption of a potentially large contaminant inventory in the vadose zone. First, the contamination in the surrounding drywells consists of small zones of low-concentration ^{137}Cs and ^{60}Co in three drywells. Second, the historical record provides no corroborating information to justify the leak volume estimates. Finally, the inventory estimate for mobile radionuclides shows little total inventory from either leak (e.g., less than 1 Ci of ^{99}Tc, [see Table 5-1]), even when the large leaks are assumed. Therefore, leaked waste from these tanks would have been a rather dilute waste and no additional characterization efforts are recommended for these areas at this time.

Table 5.1 Critical Factors Evaluation.

Critical Factors*	Tank-Specific Contamination Regions								
	T-101	T-103	T-106	TY-103	TY-105	TY-106	TX-104 (MW)	TX-105 (MW)	TX-107
Identified leak event	Yes	Yes	Yes	Yes	Yes	Yes	No	No	Yes
Leak volume (gal) estimate (Hanlon or MACTEC sources)	7,500	1,300	115,000	3,000	35,000	20,000	None	8,000	2,500
leak volume (gal) estimate (HDW inventory estimate)	10,000	3,000	115,000	3,000	35,000	20,000	None	None	8,000
Volume estimate reliability	Poor, based on wrong event (low?)	Fair	Good	Poor	Poor	Poor	None	Very poor, based on different event with no real basis	Poor (low), losses masked by large flow through tank
Consistency of leak volume estimate vs. spectral gamma characteristics associated with leak (qualitative assessment)	Consistent, but poor data	Good	Good	Consistent, but poor data	Inconsistent, based on sparse data set	Insufficient data to compare, leak may not be real	Insufficient data to make comparison	Insufficient data to make comparison	Consistent, but volume appears low (even HDW estimate)
Drywell coverage	Fair	Good	Excellent	Poor	Poor	Poor	Fair	Good	Good
Leak boundary controls	Poor	Fair	Good	Fair	Poor	Poor	Good in three directions	Good in three directions	Good
Contamination depth	25-100 ft at source, 60-100 ft at next drywell away	20 to 90 ft at source, 40 to 80 ft at next drywell away	20 to 100 ft near source, 60 to 100 ft away from source	40-85 ft	50-100 ft	Not applicable; no contamination clearly linked to this assumed leak event	40 to 55 ft near source, 60 to 100 ft away from source	40 to 55 ft near source, 60 to 100 ft away from source	50 to 100 ft near source, 60 to 100 ft away from source
Relative contamination level	Middle	Low	High	Middle	Low	Low	Middle/high	Middle/high	Middle
Tc inventory (Ci) estimate (HDW model)	0.382	1.45	60.1	1.28	0.654	0.369	none	none	4.75
Tc inventory estimate reliability	Poor	Fair	Fair	Poor	Poor	Unreliable	Poor	Poor	Poor

Table 5.1 Critical Factors Evaluation.

Critical Factors*	Tank-Specific Contamination Regions								
	T-101	T-103	T-106	TY-103	TY-105	TY-106	TX-104 (MW)	TX-105 (MW)	TX-107
Cs-137 inventory (Ci) estimate (HDW model)	1230	529	21100	2720	1720	972	None	None	6760
Consistency of ^{137}Cs inventory vs. spectral gamma data	Good	Poor	Good	Poor	Poor	No, no Cs shown	None	None	No, no Cs shown
Co-60 inventory (Ci) estimate (HDW model)	0.0434	0.235	9.78	0.185	0.0216	0.0122	None	None	0.724
Potential for Useful Data Collection (Tc, pH, nitrate, Cs, concentrations and distribution)									
Krieging	No	No	Yes	No	No	No	Yes	Yes	Yes
Direct push (cone pen to refusal)	Yes, near source only	Yes, near source	Yes, near source	Unlikely	Unlikely	?	Yes, near source	Unlikely	Unlikely
Borehole	Yes, near source	Yes, near source	Possibly at intermediate distance from source	Uncertain; poor locating criteria; low gamma data base and concentrations	Uncertain; poor locating criteria; low gamma data base and concentrations	Uncertain; poor locating criteria; low gamma data base and concentrations	Yes	Yes	Yes
Recommended Approach									
Krieging			X				X	X	X
Direct push									
Borehole			X					X	X

*HDW leak volume assumptions and inventory estimates provided in Jones et al. (2000)

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APPENDIX A

HISTORICAL BACKGROUND OF T, TX, AND TY TANK FARMS OPERATIONS AND CONTAMINATION EVENTS

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APPENDIX A

HISTORICAL BACKGROUND OF T, TX, AND TY TANK FARMS OPERATIONS AND CONTAMINATION EVENTS

This appendix includes narrative description from *Historical Vadose Zone Contamination from T, TX and TY Tank Farm Operation*, RPP-5957, Rev. 0 (Williams 2000). It includes only the narrative about the T, TX, and TY tank farm operations that relate to contaminant discharges into the vadose zone underlying the T and TX-TY Waste Management Areas and the surrounding cribs, trenches, and wells. This appendix also includes figures of the piping systems placed in the tank farms.

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Revision 0

HISTORICAL VADOSE ZONE CONTAMINATION FROM T, TX, AND TY TANK FARM OPERATIONS

MARCH 2000

Prepared by
Fluor Federal Services
for
CH2M Hill Hanford Group
for the
U. S. Department of Energy
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ABBREVIATIONS/ACRONYMS

AEC	Atomic Energy Commission
DCRT	Double-contained receiver tank
GE	General Electric Company
HEW	Hanford Engineer Works
HI	Health Instruments
IMUST	Inactive miscellaneous underground storage tank
ITS	In-tank solidification
MW	Metal waste
PFP	Plutonium Finishing Plant
PNNL	Pacific Northwest National Laboratory (Battelle)
SST	Single-shell tank
TBP	Tri-butyl phosphate
UPR	Unplanned release
UR	Uranium recovery
WIDS	Waste Information Data System
1C	First-cycle waste
2C	Second-cycle waste
224	Plutonium concentrator waste
5-6	T Plant cell drainage waste

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GLOSSARY

Crib: An underground liquid waste disposal site filled with soil and/or crushed gravel utilizing the ion exchange properties to remove radioactive contamination. Typically, cribs were operated until contamination was observed in the groundwater beneath the crib.

Double-Contained Receiver Tank (DCRT): A reinforced concrete structure containing a receiver tank for radioactive liquid waste, a pump pit, and a filter pit.

French Drain: A buried horizontal pipe filled with rock, open-ended or perforated, for disposal of liquid waste by seepage into the ground.

Interim Isolation: The process of establishing at least one physical barrier to any credible source of liquid addition to a single-shell tank or other facility, such as a diversion box, and separating the tank atmosphere from the outside air by a filtered ventilation system.

Interim Stabilization: The process of pumping all supernatant waste and as much drainable interstitial liquid as possible from a single-shell tank (SST), typically using a saltwell pump, to minimize the volume of liquid available to leak into the ground.

Reverse Well: A buried vertical pipe with the lower end open or perforated to allow seepage of liquid waste into the ground. Also called *dry well*.

Specific Retention Trench: An unlined excavation used for the disposal of a designated volume of low-level or intermediate-level radioactive waste. Liquid is retained in the trench soil and does not migrate to the groundwater.

Supernate: The supernatant liquid in a tank when all suspended solids have settled.

Vadose Zone: The portion of the soil below the surface but above the groundwater.

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HISTORICAL VADOSE ZONE CONTAMINATION FROM T, TX, AND TY TANK FARM OPERATIONS

1.0 INTRODUCTION

This document is a collection of historical information regarding radioactive contamination of the soil surface and vadose zone in the vicinity of the 241-T, 241-TX, and 241-TY tank farms. Specifically, the historical information is compiled for the tank farms, all known liquid radioactive waste disposal sites (cribs), and all known unplanned releases (UPRs) in the vicinity. The area of interest is approximately 900 000 m^2 (225 acre), extending from 19th Street north to the T trenches, and from the TX trenches to the 241-TX-155 diversion box (see figure 1, all figures are shown in Appendix L). Although not directly associated with tank farm operations, nearby cribs associated with the 231-Z Facility are included in this report because of their potential impact on the vadose zone. Releases are included from initial construction in 1944 to the present. A list of disposal sites is contained in Appendix A, and a list of UPRs is included in Appendix B.

Two sites have been remediated and are not included in this report. Site 216-T-13 was the decontamination solution disposal pit for the old 269-W regulated garage. Contaminated soil was removed in 1972 and the site was released from radiological controls. Site 216-T-31 was a French drain for Site steam condensate that was contaminated during an attempt to unplug a waste line in 1959. Contaminated soil was removed in 1962 and the site was released from radiological controls (reference WIDS).

Excluded from this report are nonradioactive wastes such as fuel spills, septic tanks, and buried radioactive solid waste. Water discharges to the soil, either from precipitation, waterline leaks, or decontamination activities are addressed in Gaddis (1999).

The timeline of events is included in Appendix C.

The primary focus of this report is on cribs rather than spills. Crib disposal outlets are typically located 3 to 10 m (9 to 30 ft) below grade, while most spills occur at ground level and contaminate only the surface. Many spill sites were quickly cleaned up and decontaminated. Additionally, the sitewide volume of waste discharged to the cribs is more than 100 times the volume of waste leaked from tanks (Consort 1994).

The 216-T-3 reverse well and the 216-T-6 crib are located east of 241-T farm. Although slightly outside the area of interest, these facilities are included in this report because of their close association with tank farm operations and their potential impact on the vadose zone. Trench 216-T-5, crib 216-T-7, and crib 216-T-32 are located just to the west of T farm; and crib 216-T-36 is southwest of T -farm. Crib 216-T-19 is just to the south of TX farm. The T trenches (216-T-14 through 217-T-17) are northeast of T farm. The TX trenches (216-T-21 through 216-T-25) are to the west of TX farm. To the east of TY farm are the three TY cribs (216-T-26 through 216-T-28) and the 216-T-18 test crib. A fourth TY crib apparently was built but never used.

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The groundwater beneath the T/TX/TY tank farm complex is 74 m underground and the regional gradient is from west to east. Generally, groundwater in the 200-West (200W) Area moves to the east, but there is a flow to the south/southwest under TX farm and the 216-T-19 crib due to groundwater contours. The groundwater level beneath 200W Area has been decreasing since crib and pond discharges were discontinued and represents the Hanford Site's greatest decline in groundwater elevation from 1979 to 1995. The groundwater mounds under the cribs are still decreasing, and additional groundwater level declines are occurring from the use of pump-and-treat injection wells (Hartman 1999).

2.0 SUMMARY AND CONCLUSIONS

A number of significant discharges of radioactive contamination to the surface soil and vadose zone occurred throughout the operating history of the Hanford Site. The most significant discharges to the area of interest around the T/TX/TY tank farm complex are summarized as follows:

- The largest discharge (431 million liters) was to crib 216-T-19. This crib received 242-T evaporator condensate from the various waste evaporation campaigns.
- 110 million liters of a combination of second cycle (2C), T Plant cell drainage waste (5-6), and plutonium concentrator waste (224) was discharged to crib 216-T-7.
- Four cribs at 231-Z received very high discharges. Crib 216-Z-16 received 102 million liters, 216-Z-7 received 48 million liters, 216-Z-17 received 37 million liters, and 216-Z-5 received 31 million liters. Crib 216-Z-7 may have received 80 million liters (see below). The waste discharged to these cribs was 231-Z process waste, but 216-Z-7 also received some waste from the 340 Building.
- Crib 216-T-6 received 45 million liters of 5-6 waste. Crib 216-T-32 received 29 million liters of 224 waste. The 216-T-3 reverse well received 11 million liters of a combination of 224 and 5-6 waste.
- Other significant discharges were to the TY cribs: 42 million liters of T Plant decontamination waste and 300 Area laboratory waste to crib 216-T-28, 12 million liters of scavenged 1C to 216-T-26, and 7 million liters of 300 Area laboratory waste to crib 216-T-27.
- Eleven million liters of first-cycle waste (1C) were discharged to the T and TX trenches (216-T-14 through 216-T-17 and 216-T-21 through 216-T-25).
- The largest leak of high-level waste occurred in 1973, when 435 000 liters escaped from Tank 241-T-106.

The available information is generally consistent regarding dates, volumes, and waste types of spills and crib discharges. Small discrepancies are noted in this report. The only large discrepancy involves the volume of waste discharged to trench 216-Z-7 (see Appendix I).

There are other cribs in 200W Area outside the scope of this report but mentioned here for comparison. Trenches 216-T-34 and 216-T-35 received 23 million liters of liquid waste from

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300 Area. Crib 216-T-33 received 2 million liters of decontamination waste from T Plant. Crib 216-S-20 received 135 million liters of liquid waste from 222-S Laboratory and the 300 Area. Cribs 216-U-8 and 216-U-12 received a total of 513 million liters of tri-butyl phosphate (TBP) plant condensate from U Plant (Maxfield 1979).

This report supports previous work on discharges to the cribs associated with the B/BX/BY tank farm complex (Williams 1999). Studies similar to these could be made for the other separation plants and tank farms. Upon completion, these studies can be integrated into a single report. This approach is necessary to account for waste streams that affect more than one plant or tank farm complex. For example, the uranium recovery mission affected U Plant, U farm, B/BX/BY tank farms, C farm, and T/TX/TY tank farms.

3.0 FACILITIES HISTORICAL BACKGROUND

The 241-T tank farm contains 12 first-generation, reinforced concrete tanks with carbon steel liners covering the sides and bottoms. The tanks are 23 m (75 ft) in diameter and 4.9 m (16 ft) deep, with a capacity of 2 million liters (530,000 gallons). The tanks are arranged in four rows of three tanks. The tanks in each row are piped together so that when the first tank fills, it overflows (cascades) into the second tank, and the second into the third. Five diversion boxes and a booster pump pit are provided in T farm. The farm also contains four smaller "200-series" tanks that are 6.1 m (20 ft) in diameter and hold 0.2 million liters (55,000 gallons). These four tanks are piped to diversion box 241-T-252 and to crib 216-T-32. (See figure 1.)

The 241-TX tank farm contains 18 second-generation tanks similar to T farm tanks, but with a 2.9-million liter (758,000-gallon) capacity. The tanks are arranged in three, 4-tank cascades and two, 3-tank cascades. TX farm has four diversion boxes and the 244-TXR process vault. There are no 200-series tanks in TX farm. (See figure 1.)

The 241-TY tank farm contains 6 tanks of identical design to the tanks in 241-TX farm, arranged in three, 2-tank cascades. TY tank farm contains one diversion box, the 244-TX double-contained receiver tank (DCRT), and no 200-series tanks. (See figure 1.)

Other facilities are contained in and around the T/TX/TY tank farm complex. The 207-T retention basin and the 216-T-12 pit are east of T farm. The 242-T Evaporator Facility includes the evaporator building and control room between the TX and TY farms, and the 242-T-151 diversion box and 242-TA receiver vault inside TX farm. Piping for saltwell pumping is located throughout the T/TX/TY complex. The 241-TX-155 diversion box and 216-T-20 pit are to the east of TX farm. The 231-Z Facility, southwest of the tank farm complex, includes the isolation building, 231-W-151 sump tank vault, and seven cribs. (See figure 1.)

The T/TX/TY complex operations can be separated into six distinct operational phases:

- From 1943 to 1945, T farm received liquid waste from the Manhattan Project bismuth phosphate plutonium separation operations in T Plant. (See figure 2.)
- From 1946 until T Plant shutdown in 1956, the tank farms were expanded and received liquid waste from the bismuth phosphate operations. Liquid waste disposal to the soil column was initiated. (See figure 3.)

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- From 1952 to 1958, high-level waste from the tank farms was sent to U Plant for uranium recovery (UR) and fission product scavenging. Scavenged waste was discharged to the cribs. Low-level process condensate was also discharged to the cribs. (See figure 4.)
- Since 1958, T Plant has served as the central decontamination facility for the Hanford Site. Decontamination waste was discharged to the cribs until January 1969. Liquid waste from the 300 Area was also discharged to the cribs around T, TX, and TY farms during this time.
- In-tank solidification (ITS) operations occurred from 1965 to 1974, using the 242-T Evaporator Facility. Condensate was discharged to the cribs. (See figure 5.)
- Tank farm interim stabilization (saltwell pumping) and isolation began in 1975. The 242-T evaporator and the 231-Z Facility were shut down during this period. (See Figure 6.)

Sanitary water was not supplied to the T/TX/TY tank farms during wartime bismuth phosphate operations, but was supplied to the 231-W Isolation Building. During the 1950s, sanitary water was supplied to the 242 T evaporator and the 271-TXR control house. All sanitary water piping to the tank farms is believed to be capped off and abandoned.

3.1 Wartime Bismuth Phosphate Operations, 1943-1945

The 241-T tank farm was constructed in 1943-1944 as part of the Manhattan Project Hanford Engineer Works (HEW) to provide storage for the radioactive liquid waste produced at T Plant. Figure 2 shows the facilities constructed at this time. T Plant used the bismuth phosphate process to separate plutonium from irradiated fuel slugs.

The bismuth phosphate process produced five waste streams:

- Metal waste (MW) was the byproduct from the plutonium separation phase of the bismuth phosphate process. MW contained unfissioned uranium and approximately 90% of the fission products of the irradiated fuel.
- First-cycle waste (1C) was the byproduct from the first plutonium decontamination cycle of the bismuth phosphate process. This waste contained about 10% of the fission products of the irradiated fuel. This waste stream also contained coating-removal waste.
- Second-cycle waste (2C) was the byproduct from the second and last plutonium decontamination cycle of the bismuth phosphate process. This waste contained less than 0.1% of the fission products of the irradiated fuel.
- The 224 waste was low-level liquid waste from the 224-T Plutonium Concentrator Building. This waste stream was the primary contributor to plutonium contamination of the soil. This waste was routed to the 241-T-361 settling tank, and then discharged to the 216-T-3 reverse well near T Plant. It was later routed to the 200-series tanks for settling and discharged to crib 216-T-32.
- The 5-6 waste was low-level liquid waste from floor drains in individual process cells in T Plant. This waste was discharged to the 216-T-4 pond during the T Plant startup

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testing "cold run," but was routed to the 5-6 tank in T Plant when processing of irradiated fuel began in December 1944. Waste stored in the 5-6 tank was discharged along with 224 waste to the 241-T-361 tank and the 216-T-3 reverse well.

MW, 1C, and 2C were stored in tanks at T farm. These waste streams were also sent to the 241-U tank farm, which is outside the scope of this study (Parker 1944).

From the 224-T Concentrator Building, the plutonium solution was transported by truck to the 231-W Isolation Building (later called 231-Z), where final preparation of the plutonium nitrate paste was conducted. So-called "clean" waste such as cooling water, steam condensate, and floor drainage went to the 216-U-10 pond via the 216-Z-1 ditch. Process waste was neutralized in the 231-W-151 sump tank and discharged to the 216-Z-10 reverse well. The well plugged on May 6, 1945, and waste was rerouted to the 216-Z-6 temporary crib until the 216-Z-5 double crib was finished on May 31, 1945.

Little documentation is available for pit 216-Z-4, which was also used as a temporary disposal site. Reports from May 1945 describe "temporary" facilities in use within 24 hours, and a "covered" disposal basin (apparently 216-Z-6) in use by May 10, 1945. It is considered most likely that pit 216-Z-4 was dug immediately, but was not large enough to accommodate the waste inflow and may have overflowed. It was used for a day or so until 216-Z-6 was constructed (Acken 1945a; Acken 1945b; DuPont 1945; Owens 1981). The hurried construction and lack of documentation is consistent with HEW priorities of the time: the German surrender occurred during this period, and Los Alamos did not yet have enough plutonium to assemble the Trinity and Nagasaki atomic bombs.

Ground disposal of aqueous industrial waste, relying on the ion-exchange properties of the soil to decontaminate the water as it percolates to the aquifer, was a commonly accepted method in the 1940s. The ability of Hanford Site topsoil and substrate to adsorb radioactive material was tested at the Clinton site in Tennessee (later Oak Ridge National Laboratory) and at the University of California at Berkeley in 1944. Tests determined that ground disposal of 5-6 and 224 was acceptable, but ground disposal of 1C and 2C was not. Methods to treat 1C and 2C to facilitate ground disposal were investigated at the time, but were unsuccessful (Parker 1944; Patterson 1945; Leader 1945).

3.2 Postwar Bismuth Phosphate Operations, 1946-1956

In September 1946, the Army Corps of Engineers Manhattan District selected General Electric Company (GE) to replace DuPont as the Site prime contractor. Pursuant to the McMahon Atomic Energy Act of 1946, control of the Hanford Site passed from the Army to the civilian Atomic Energy Commission (AEC) on January 1, 1947. The AEC opted to maintain Hanford as a permanent facility rather than dismantle it, as happened to many other wartime munitions plants. Wartime production had filled all available waste tank storage space, so plans were made to increase high-level waste storage capacity and to recover some tank space. These plans included disposing of the relatively low-level 2C waste into the ground and concentrating the intermediate-level 1C waste in an evaporator. Plans were also made to recover the unfissioned uranium in the MW (by 1947, most of the world's known supply of uranium was in Hanford waste tanks).

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From 1947 to 1949, many new facilities were constructed at Hanford. The TX tank farm, facilities for the planned uranium recovery mission (see section 3.3), and other facilities beyond the scope of this report (BX/BY tank farms, Z Plant, H Reactor, DR Reactor, Hot Semi-Works) were all built during this period (Gerber 1991). The 241-TX-155 diversion box was a central waste distribution facility, capable of routing waste between T Plant, U Plant, T/TX tank farms, and U tank farm. When TY farm was constructed in 1952, it was also connected to the 241-TX-155 diversion box. Figure 3 shows facilities constructed for postwar bismuth phosphate and waste disposal operations.

Disposal of 224 in a reverse well was quickly recognized as a "definite mistake" because of the potential for groundwater contamination, and the 216-T-3 reverse well was replaced by the 216-T-6 double crib in August 1946. An additional problem was that the 241-T-361 settling tank had filled with very hard sludge, making it unusable as a settling tank. Consequently, the 5-6 waste line was modified in October 1946 to bypass 241-T-361, and 5-6 waste was discharged directly to the 216-T-6 cribs without settling. This was considered unsatisfactory, but necessary. At the same time, the 224 waste line was rerouted to the 200-series tanks in T farm for settling and overflow to the 216-T-32 double crib. The 224 waste discharged to the tanks was sampled for plutonium (Pu) and fission product content, but the final overflow to the crib was not routinely sampled. Occasional checks indicated that "virtually all" radioactivity was retained in the 200 series tanks. The waste discharged to the 216-T-3 reverse well, the 216-T-6 cribs, and the 216-T-32 cribs is summarized below (USAEC 946; GE 1946; Brown 1948; Keene 1951; Anderson 1976).

Table 1

224 and 5-6 WASTE DISCHARGES

Crib	216-T-3	216-T-6	216-T-32
Dates of Operation	1944-1946	1946-1951	1946-1952
Waste type	224, 5-6	5-6	224
Total waste (L)	1.13E+07	4.50E+07	2.90E+07
Pu (g)	3350	3900	3200
U (kg)	N/A	22.7	22.7
β emitters (Ci)	2380	18 000	1500
^{90}Sr (Ci)	557	360	30
^{106}Ru (Ci)	1280	600	50
^{137}Cs (Ci)	595	300	25
^{60}Co (Ci)	N/A	50	1

Note: Curies are uncorrected for decay.

In February 1947, sludge buildup sealed the bottom of the 216-Z-5 cribs, and the 231-Z Building waste was rerouted to trench 216-Z-7. Construction of the Plutonium Finishing Plant (PFP) in

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1949 required replacing part of the 216-Z-1 ditch – from 231-Z to the PFP – with an underground pipeline (Brown 1948; Patterson 1949; Owens 1981).

Ground disposal of waste had always been regarded as an expedient, temporary disposal method, and treatment of 224, 5-6, and other waste types by such means as evaporation, scavenging, or ion exchange were investigated. Experiments with 2C revealed that most activity was concentrated in the sludge settling at the tank bottom, leaving a low-activity supernatant liquid that met existing criteria for ground disposal. The continuing shortage of waste tank space led to the decision to send 2C waste to a crib after cascading and settling (Piper 1949; Burns 1949; Brown 1950).

Crib 216-T-7 and its tile field were constructed in 1947 in T farm to dispose of 2C waste. Initially, the crib was piped to a riser between 241-T-110 and 241-T-111 in T farm, accessible via an overground line, and waste was discharged one month per year. From September 1949 to December 1950, the average activity of 2C discharged to the crib was 3.8 μg/L of Pu and 16 μCi/L of beta emitters. In May 1951, the crib line was piped directly to tank 241-T-112 (the final tank in the cascade series used for 2C storage), and the cascade continuously overflowed to the crib (GE 1947; Keene 1951; GE 1951b).

Research in 1950 determined that combining 5-6 waste with 2C and again allowing it to settle before discharge to a crib was a safer disposal method than direct discharge to crib 216-T-6. In June 1951, 5-6 waste was sent to the 241-T-110/111/112 cascade along with 2C waste, allowed to settle, and overflowed to crib 216-T-7. The average activity of the combined waste stream discharged to the crib was 2.4 μg/L of Pu and 43 μCi/L of beta emitters. In June 1952, 224 was also diverted to this cascade when the 200-series tanks filled with sludge and were no longer usable for settling. The average activity of this waste stream was 1.06 μg/L of Pu and 27.2 μCi/L of beta emitters. Crib 216-T-7 reached its radionuclide limit in December 1955. The crib was isolated and the waste rerouted to crib 216-T-19 (see below). Analytical data for discharges to crib 216-T-7 are in Appendix D (GE 1950a; Ruppert 1952; Ruppert 1954; Heid 1956).

One processing run in early 1955 resulted in an unusually high level of activity in the 2C waste. Even after cascading and settling, the activity was still too high (66 μg/L of Pu and 47 μCi/L of beta emitters) to crib. Approximately half of the batch (2.65 million liters) was sent to specific retention trench 216-T-5 in May; the remainder stayed in 241-T-112 (Paas 1955).

The 242-T evaporator was built in 1951 to reduce the volume of 1C waste. Operations began late April 1951. The evaporator received 1C waste from feed Tank 241-TX-118. Evaporator condensate was sent to crib 216-T-19 and its tile field via the 242-T-151 and 241-TX-153 diversion boxes. This condensate had an average plutonium concentration of 0.049 μg/L and an average beta emitter concentration of 0.044 μCi/L. Analytical data for discharges to crib 216-T-19 are in Appendix E. Cooling water was sent to the 241-T-4 pond via the 207-T retention basin. Evaporator bottoms were sent to Tanks 241-TX-113, -116, and -117. This waste was then re-evaporated in a second pass. From startup in 1951 to shutdown in 1954, the 242-T evaporator reclaimed 34.7 million liters (9 million gallons) of tank space in T farm, TX farm, and the newly constructed TY farm (GE 1951c; Ruppert 1952; Anderson 1990).

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When the 242-T evaporator was needed for TBP waste (see next section), ground disposal of 1C was pursued. In May 1953, direct disposal of 1C to specific retention trenches was approved, at a maximum discharge rate of 5,280 L/m^2 (150 gal/ft^2) to ensure retention of waste in the soil. Evaporation of 1C was discontinued in June 1953. Approximately 17 million liters of 1C in 200E and 200W Areas had not been evaporated at that time. From January to June 1954, 2.9 million liters of 1C were sent to the T trenches via an overground line from 241-T-106. From June to August 1954, 5 million liters of 1C were sent to the TX trenches via an overground line from 241-TX-110. Trench disposal of evaporator bottoms was approved in June 1954, and 3 million liters were discharged to 216-T-25 in September (Healy 1953; Carpenter 1953; Ruppert 1954; Anderson 1990). Details of 1C discharges to the T and TX trenches, including analytical data, are provided in Appendix F

Evaporation of TBP waste was discontinued in September 1954, following the development of the ferrocyanide scavenging process. As described in the following section, the scavenging process removed the principal long-lived fission products, ^{137}Cs and ^{90}Sr, from the waste to enable ground disposal of the supernate. This process was also applied to 1C beginning in October 1954 to remove ^{137}Cs (^{90}Sr concentration in 1C already met existing limits for discharging the waste to cribs). It was necessary to segregate coating waste from 1C to accomplish this. The 242-T evaporator resumed evaporating stored 1C that had not been pumped to cribs in December 1954, and began evaporating newly generated scavenged 1C in March 1955. After 1C evaporation was finished in July 1955, scavenged 1C was stored in TY farm for settling, and supernate was discharged to crib 216-T-26 (see Appendix F). (Ludlow 1954; Anderson 1990).

Although the evaporator was shut down, discharges to crib 216-T-19 resumed in December 1955. Since crib 216-T-7 had reached its radionuclide limit, the combined 2C/5-6/224 waste stream was diverted from there to 216-T-19 via the 241-TX-155 diversion box until T Plant shutdown in August 1956 (Heid 1957).

In addition to ongoing Pu isolation work for T Plant, 231-Z received Pu solution from the Reduction Oxidation Plant (REDOX) starting in 1953, and from the Plutonium-Uranium Extraction Plant (PUREX) in 1956. (PUREX product was intended to be pure enough to bypass 231-Z and go directly to PFP, but it took a year to work the bugs out of the process.) REDOX and PUREX product streams went directly to PFP after 1956. 231-Z was converted to a plutonium metallurgy laboratory in 1957, and discharges to crib 216-Z-7 ceased (WADCP 1998).

Six UPRs are associated with bismuth phosphate operations (WIDS):

- In 1950, diversion box 241-TX-155 overflowed and 1C ran down the hillside to the west (UPR-200-W-5). WIDS has no further information on this UPR, but a review of all Health Instruments (H.I.) Division Monthly Reports for 1950 suggests that it occurred in March and involved only slightly contaminated water, which was pumped from the catch tank to crib 216-T-19 (Patterson 1950).
- Diversion box work in the spring of 1950 resulted in contamination spread to the ground around 241-T-151 and 241-T-152 (UPR-200-W-7).

- In the spring of 1951, a riser leak in the 242-T discharge line allowed "a few gallons" of 1C evaporator bottoms to spill onto the ground (UPR-200-W-12).
- In September 1952, a waste pump being transferred from 241-TX-106 to 241-TX-114 dripped contamination onto the ground, personnel, and vehicles (UPR-200-W-17).
- In October 1952, a leak in the underground line between 242-T and 207-T allowed some contaminated cooling water to leak (UPR-200-W-14).
- In March 1954, 1C escaped from a leaking underground pipe between 241-TX-105 and 241-TX-108 (UPR-200-W-100).
- In 1954, a broken transfer line between the 241-T-152 and 241-TX-153 diversion boxes caused a leak of 3,785 liters of 1C and a cave-in of soil (UPR-200-W-29). The area was backfilled and covered with gravel.

Two minor spills occurred during this time frame, but were not assigned UPR numbers. Removal of electrodes from 241-TX-105 in autumn 1951 resulted in the spread of contamination to the surrounding ground area. Construction work in spring 1952 resulted in contamination of the heel and sluice jets of 241-TX-107 (Ruppert 1953).

In December 1954, approximately 10 m^3 of sludge were dredged from the 207-T retention basin and buried in pit 216-T-12. This sludge had the following composition: (Clukey 1955).

Table 2

216-T-12 BURIED SLUDGE

Isotope	Curies
Total α	9.1E-01
Total β	1.4E-03
Rare Earth	6.1E-01
Cesium	1.3E-01
Zirconium	3.3E-02
Ruthenium	6.4E-03
Strontium	4.7E-04
Plutonium	9.8E-05

Curies are uncorrected for decay

3.3 Uranium Recovery Operations (1952-1958)

U Plant was originally constructed during World War II as a bismuth phosphate plant, but was not needed for that purpose so the facility was used as a simulator. It was modified in 1951 for UR operations using the TBP process. For this reason, U Plant was frequently referred to as the

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"TBP Plant." Beginning in 1952, MW was sluiced from T and TX tank farms, treated in the 244-TXR process vault, and transferred to U Plant. MW from C, B, and U tank farms was also sent to U Plant for uranium recovery. Until T Plant was shut down in 1956, newly generated MW was also sent to U Plant for uranium recovery (Rodenhizer 1987; Anderson 1990).

The uranium recovery facilities in the T/TX/TY tank farm complex include the 271-TXR control house, the 244-TXR vault, four diversion boxes (one for T farm and three for TX farm), the 241-TR-153 booster pump pit, and modifications to the underground piping system. The TY cribs were also constructed for the uranium recovery mission, but were used for other purposes. Figure 4 shows facilities constructed for uranium recovery.

Uranium recovery operations produced two waste streams, TBP waste and low-level waste. TBP waste, concentrate from the waste concentrator, was returned to the tank farms (including the 241-T-107/108/109 cascade, 241-TX-103 and 241-TX-115 in TX farm; and 241-TY-103, 241-TY-104, 241-TY-105, and 241-TY-106 in TY farm). TBP waste was also transferred to 200E Area. The design called for the same volume of TBP waste to be produced as the volume of MW processed, but inefficiencies in the process resulted in approximately twice as much TBP waste produced as the MW processed. A total of 215 million liters of TBP waste was produced. Low-level waste included condensate from the feed concentrator, waste concentrator, and HNO_3 fractionator. This waste was discharged to various cribs that are outside the scope of this report. Cooling water and cell drainage were discharged to U pond, also outside the scope of this report (Waite 1991; DiLorenzo, et. al. 1994; GE 1951a).

Despite additional tank farm construction and ongoing volume reduction efforts, tank space was not sufficient to support both the uranium recovery mission and plutonium production. To reduce the volume of stored waste, TBP waste from T farm was concentrated in the 242-T evaporator beginning in July 1953. The condensate discharged to crib 216-T-19 had an average concentration of 0.045 μg/L of Pu and 0.086 μCi/L of beta emitters. Additionally, a ferrocyanide scavenging process was developed to remove the principal long-lived fission products, ^{137}Cs and ^{90}Sr, from the TBP waste to enable disposal of the waste supernate to the cribs. Beginning in September 1954, TBP waste was scavenged in U Plant to remove ^{90}Sr and ^{137}Cs, instead of being evaporated. Scavenged waste was sent to BY tank farm for settling, then to the BY cribs and BC cribs and trenches from 1954 to 1957. These cribs are outside the scope of this report but are described in Williams (1996). The 242-T evaporator was modified to scavenge TBP waste that was stored in the TX and TY tank farms, but was never used for this purpose and that waste was not scavenged. The 242-T control room was used for other UR operations until the program ended in January 1958. Following the end of uranium recovery operations, many tanks in the T/TX/TY tank farms received REDOX plant waste. (Ruppert 1954; Anderson 1990, Waite 1991).

Waste from a scavenging process test run in late 1953 was pumped from U Plant to Tank 241-T-101 to settle. Because of poor pH control during the test, only half of the waste could be cribbed. This waste was pumped to a test crib, later designated as 216-T-18, from December 8 through December 21, 1953. Approximately 970 000 liters of waste were discharged, containing the constituents shown below. There is a discrepancy regarding the type of waste discharged to the crib. Maxfield (1979) describes it as being scavenged 1C, but all contemporary documents (Christy 1954a; Ruppert 1954) describe it as being a test batch of scavenged TBP. Maxfield (1979) is believed to be based on incorrect information.

Table 3

216-T-18 SCAVENGED TBP TEST WASTE ANALYSIS

Constituent	Total (Ci)	Concentration (µCi/mL)
Pu	0.089	9.2E-05
U	0.054	5.6E-05
Cs	290	0.27
Sr	49	0.05
Ru	180	0.19
Sb	130	0.14
Y, rare earths	190	0.20
Total	840	0.85

Curies are uncorrected for decay.

Six incidents are associated with the 241-TX-155 diversion box, which was built in 1948 as a central transfer point between T Plant, U Plant, and the tank farms:

- Catch tank 241-TX-302B was constructed of carbon steel. In anticipation of use with acidic waste, Operations requested a stainless steel tank to replace it, but they were overruled by Engineering on cost considerations. The original tank was removed and replaced with an epoxy-painted tank designated 241-TX-302B(R) in February 1952 (GE 1952a; Koberg 1953). No UPR is associated with this incident.
- In November 1952, 1,330 liters of 50% HNO_3 was inadvertently pumped from the 241-WR vault to the 241-TX-155 diversion box, and drained to catch tank 241-TX-302B(R). The acid was subsequently neutralized and discharged to pit 216-T-20 that month (GE 1952b).
- In March 1953, a severe jumper leak filled catch tank 241-TX-302B(R). When soda ash (sodium carbonate) was added to the tank to neutralize the waste prior to pumping out the tank, a foamy solution erupted out of the riser (UPR-200-W-131). By now, the catch tank was damaged beyond repair, and it was abandoned in place and later replaced with a third catch tank, this one with the old designation of 241-TX-302B. This tank was made of stainless steel (Keene 1953; Koberg 1953; GE 1954).
- During installation of the new catch tank in April 1954, a 0.7-m (2-ft) sinkhole northwest of the diversion box was noticed. Investigation revealed that the sinkhole was caused by waste leaking from a failed jumper in the diversion box, escaping from the damaged catch tank, and flowing along the 7-66 pipe encasement (UPR-200-W-135). In the spring

of 1954, a jumper leak contaminated the area to the west of the diversion box (UPR-200-W-28) (Corley 1954; Christy 1954b). These two UPRs may be the same event.

- Another contamination event occurred in December 1954, but was not assigned a UPR number (Keene 1955).
- Some of the above areas were removed from radiation zone status in 1970. However, radioactive rabbit dung with activity as high as 100 mR/hr was found around the diversion box in 1977. This contamination was spread over a 164 m (500-ft) radius around the box (UPR-200-W-76). As soil was removed in the attempt to decontaminate the site, radioactivity increased due to subsurface contamination. The subsurface contamination was designated as UPR-200-W-113 in 1979. Several decontamination efforts have taken place, most recently in 1990. The site is posted as an "underground radioactive material" area and is surveyed annually. 241-TX-302B is the only inactive miscellaneous underground storage tank (IMUST) that is regularly monitored for liquid level (Hanlon 1999; WIDS).

3.4 Central Decontamination and In-Tank Solidification Operations (1960-1974)

Following the end of plutonium separation operations, T Plant was converted into a central decontamination facility in 1958. The 2706-T decontamination annex was built in 1959. Waste was sent to the 241-T-112 tank for settling, and supernate was discharged to the TY cribs beginning in February 1960. The TY crib inlet line was rerouted from TY farm to 241-T-112 for this purpose (see figure 5). Laboratory waste from the 340 Building in 300 Area was also discharged to crib 216-T-28 beginning in October 1963 (previously, it had been discharged to crib 216-S-20, which is outside the scope of this report). This waste was delivered by truck from the 300 Area and discharged via a riser. The 340 Building waste was diverted to crib 216-T-27 beginning in September 1965. Discovery of groundwater contamination under the TY cribs in November 1965 resulted in diverting of 340 Building waste to trench 216-Z-7. No T Plant decontamination waste was cribbed during the September-November 1965, but this waste was discharged to 216-T-28 in December 1965 and January 1966. A final discharge was made in July 1966. Details of discharges to the TY cribs, including analytical data, are included in Appendix G. T Plant decontamination waste was discharged to crib 216-T-36 from May 1967 until January 1969. Afterwards, this waste was transferred to tank farms. Trench 216-Z-7 reached its radionuclide capacity in May 1966, and 340 Building waste was discharged to trenches 216-T-34 and 216-T-35. Although trenches 216-T-34 and 216-T-35 are outside the scope of this report, analytical data for them is included in Appendix H, along with data for 216-T-36 (Bayless 1964; Gerber 1994).

Concern over the integrity of single-shell tanks (SST) (the first confirmed tank leak was in 1959) resulted in the decision to remove all liquid waste supernate from SSTs. The In-Tank Solidification (ITS) program was initiated to concentrate nonboiling waste to produce a partially mobile salt cake. In 200E area, in-tank heaters were installed in two tanks to evaporate the waste. The 242-T evaporator was modified for continuous operation and restarted in December 1965 as the ITS system for 200W Area. New piping was installed to facilitate transfers to 242-T (see figure 5). Evaporator condensate was again sent to crib 216-T-19 (Liverman 1975; Rodenhizer 1987; Williams 1999). Figure 5 shows facilities constructed for central decontamination and in-tank solidification operations.

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Battelle Northwest Laboratory (now Pacific Northwest National Laboratory [PNNL]) took over 231-Z operations in January 1967, and constructed an office space addition to the south side of the building. Since trench 216-Z-7 had reached its radionuclide capacity, a new liquid waste disposal crib was needed. Waste was discharged to the 216-Z-17 temporary trench during construction of crib 216-Z-16, which began receiving waste in March 1968. The line to these cribs bypassed the 231-W-151 sump tank vault, which was isolated at this time (see figure 5). During construction, underground contamination was discovered (UPR-200-W-130). A consolidated storage and maintenance facility was constructed on the north side of the building in 1974. Crib discharges continued until the end of 231-Z operations in January 1977. Details of discharges to these cribs, including analytical data, are provided in Appendix I. Although waste-generating activities at 231-Z ended in January 1977, the building was used for other purposes until 1994 (Owens 1981; WADCP 1998).

There is some confusion regarding the discharges to 216-T-19 following the restart of 242-T. Beginning in 1968, steam condensate was reported discharged to 216-T-19, in addition to process condensate. Vacuum jet water was discharged from 1968-1970. These discharges were not reported for 1967, but the total volume was estimated and included as a footnote in the 1968 report. These discharges were not reported in 1966, and it is believed that they resulted from piping changes that occurred in 1967. The 242-T steam condensate was also reported as discharged to the 216-T-4-2 ditch (see figure 1). The discharge information in Appendix E represents the best available information. Since these discharges involve normally uncontaminated water, this discrepancy does not affect the total amount of radioactivity discharged to the crib. When these discharges are added to the evaporator condensate discharges, the total agrees to within 3% with Maxfield (1979).

Since the beginning of 1968, all tanks constructed or planned have been a double-shell design. In 1968, the AEC decided to remove all liquid waste from SSTs by 1975, using ITS. The 242-T evaporator was modified again in 1972 to concentrate Plutonium Finishing Plant (PFP) high-salt waste as well as tank farm waste. The 242-TA receiver vault was constructed next to the evaporator for this purpose, and received waste from PFP via an encased underground line (see figure 5). Since the 242-A evaporator was not yet built, 242-T also concentrated high strontium waste from 241-A tank farm, with the bottoms going to the 242-S evaporator. In 1973, the effluent line to 216-T-19 was modified to bypass the crib and discharge directly to the tile field. Disappointing performance resulted in ITS being superseded by saltwell pumping (see next section) as a method of liquid waste removal, and the ITS program was discontinued in 1974. The 242-T evaporator continued to operate until 1976, and was formally shut down in 1980 (Roal 1975; Williams 1968; Liverman 1975; Anderson 1990; WIDS).

Seven UPRs are associated with ITS operations. The broken transfer line which had caused UPR-200-W-29 in 1954 was mistakenly used again in 1966, and liquid waste surfaced and ran to the edge of Camden Avenue (UPR-200-W-97). On May 4, 1966, 2C being transferred from 241-T-107 to 242-T escaped from a ruptured transfer line and came to the surface (UPR-200-W-62). These two UPRs may be the same event. This time, the jumper was removed from 241-TX-153. While transporting the jumper to T Plant for decontamination, waste dripped from the jumper and contaminated the 23rd Street roadway (UPR-200-W-63). This area was decontaminated and removed from radiation zone status in 1972. The site was again cleaned up, but mud samples read 600 cpm in 1969 (UPR-200-W-64) and this area is now surveyed annually for radiation (WIDS).

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There is a discrepancy regarding the type of waste involved in UPR-200-W-62. WIDS describes the waste as 2C being pumped from 241-T-107 to 242-T. However, Anderson (1990) reports that 241-T-107 held a combination of 1C and TBP in 1966, and 8000 gallons of this was sent to 241-TX-118 (the feed tank for 242-T). This is corroborated by the waste status summary (Roberts 1967). The original occurrence report cited in WIDS is not available. The type of waste is most likely 1C/TBP.

In September 1966, two plumes of airborne material originating from diversion box 241-TX-153 contaminated Camden Avenue (UPR-200-W-99). In January 1971, contaminated caustic sprayed from a pump pit cover in 241-TX-113 during a leak test of a new jumper assembly (UPR-200-W-129). In May 1975, a small amount of airborne contamination was released during replacement of a gasket at the 241-TX-153 diversion box (UPR-200-W-126) (WIDS).

3.5 Stabilization and Isolation, 1975-Present

Seven leaking SSTs were identified in T/TX/TY between 1959 and 1977. These leaks are identified in Appendix B. In accordance with Hanford operating policy at the time, liquid waste removal from tanks of questionable integrity was expedited and the tank was removed from service. Interstitial liquid was removed by saltwell jet pumping. The most severe tank leak was a leak of 435 000 liters from 241-T-106 in May 1973 (UPR-200-W-148). This leak released approximately 40 000 curies of ^{137}Cs, 14 000 curies of ^{90}Sr, 6 curies of plutonium, and 297 000 curies of various fission products to the soil (USAEC 1973; Liverman 1975; Anderson 1990; WIDS).

Interim stabilization is the process of removing all supernatant liquid and as much drainable liquid as possible; this process began in 1972. The T/TX/TY complex tanks were interim stabilized beginning in 1976, with the interstitial liquid pumped to receiver Tank 241-TX-107, and from there to the 242-S evaporator (the 242-T evaporator was shut down). The saltwell system for T/TX/TY farms included a pump pit for each tank, the saltwell and jet pump, piping from the pump pits to the receiver tank, and associated instrumentation and controls. See figure 6 for an illustration of the saltwell system piping arrangement (Smith 1975; Grimes 1977; Hanlon 1999).

In 1975, AEC policy was to direct all liquid waste to double-shell tanks. To discontinue the use of a SST, the saltwell waste receiver, 244-TX DCRT was constructed in 1980, tying into the existing saltwell piping. PFP high-salt waste, formerly sent to 242-TA, was also routed to 244-TX. PFP high-salt waste was not generated between 242-T shutdown in 1976 and 244-TX construction in 1980. To facilitate transfer of saltwell liquid waste, the 241-TX-152 diversion box was constructed in 1980 to replace the 241-TX-155 diversion box. The 242-S evaporator also shut down in 1980, and all waste went to 242-A for evaporation via 241-TX-152 (Mirabella 1977a; Hanson 1980).

Eight tanks in the T/TX/TY farm complex were interim stabilized prior to construction of 244-TX. Most tanks were stabilized in 1983. All tanks in the T/TX/TY complex are now interim stabilized (Hanlon 2000).

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Following interim stabilization, SSTs were interim isolated by establishing at least one physical barrier between the tank contents and the environment, to preclude inadvertent addition of liquid. Cutting and blanking all process piping to and from the tank, blanking all risers and equipping the tank with a filtered ventilation system accomplished this. Eleven T farm tanks (including the 200-series tanks) are interim isolated, and five tanks are partially interim isolated. All TX and TY farm tanks are interim isolated. The 244-TXR vault, the 241-T-301, 241-TX-302A, 241-TX-302B, 241-TX-302X, 241-TY-302A, and 241-TY-302B catch tanks, and all diversion boxes (except 241-TX-152) and associated transfer lines were isolated by project B-231 in 1984-1985. The 244-TX DCRT is currently the only facility available to transfer waste out of T farm. 244-TX also receives waste from PFP and T Plant, and transfers all waste to double-shell tanks via 241-TX-152 and the 244-S DCRT (Liverman 1975; Hanlon 2000; WIDS).

Spills have not been recorded since 1977. Surface contamination from TY farm that had migrated beyond the tank farm boundaries over the years was cleaned up in 1986 and designated as UPR-200-W-167. Similar contamination around T farm was cleaned up in 1992 and designated as UPR-200-W-166.

4.0 MONITORING TEST WELLS

Monitoring test wells were drilled in each tank farm as part of original construction to check for tank leakage. To avoid groundwater contamination, these wells were drilled only to 46 m (150 ft) and did not extend to the upper aquifer (groundwater depth was 76 m [250 ft]). Wells were checked weekly. Test wells were also drilled near cribs as part of original construction to monitor vadose zone contamination. Typically, wells would be drilled to 46 m (150 ft), but major disposal sites had at least one 92 m (300 ft) well to check for nuclide migration to groundwater (Parker 1944; Brown and Ruppert 1950).

At the time of initial construction, knowledge of the groundwater hydrology of the Hanford area was limited to a few reports from the 1910s and 1920s. These reports were general in scope and limited in content. Poor information on groundwater depth in 1944 resulted in drilling for the 216-T-3 reverse well inadvertently breaking through to the aquifer. A new well was redrilled several feet away to a much shallower depth. The new well was used for waste disposal and later designated 216-T-3, and the old well was used as a groundwater monitoring well (299-W11-22). When use of reverse wells was discontinued in 1949, the wells were used as vadose zone monitoring wells. Well 216-T-3 is also designated as well 299-W11-71, and 216-Z-10 is designated as 299-W15-51 as shown in figure 2a (Parker 1944, Brown and Ruppert 1950).

The continuing need to dispose of 1C and 2C waste to the ground led the AEC to contract with the U.S. Geological Survey to drill a series of test wells in the late 1940s to evaluate the 200 Area plateau soil for waste disposal suitability, and for general groundwater research. These wells are shown in figure 3a (Brown and Ruppert 1950).

Monitoring wells in other locations were drilled as needed. In April 1963, well 299-W11-13 was drilled to the unusual depth of 152 m (500 ft) (see figure 5a). In the 1970s, additional wells were drilled in all three tank farms to monitor groundwater contamination (see figure 6a). An extensive discussion of monitoring wells inside the tank farms is included in Gaddis (1999).

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DOE (1993) reports that leaks from the T, TX, or TY tank farms have contaminated the vadose zone but not the uppermost aquifer. Some cribs may have contaminated the uppermost aquifer, based on soil porosity and volume of waste discharged. Gross gamma logging of test wells in the vicinity of the cribs was done to verify contamination. Based on this evaluation, the 216-T-7 crib, the TY cribs, the 216-Z-5 cribs, and the 216-Z-7 trench were shown to have contaminated the uppermost aquifer. The 216-T-18 test crib, the 216-T-19 crib, the 216-T-12 pit, the 216-Z-10 reverse well, and the 216-Z-17 temporary trench have the potential to contaminate the uppermost aquifer, but no gamma logging was done to verify this. The 216-T-3 reverse well and 216-T-6 cribs, the 216-T-32 cribs, the 216-T-34 and 216-T-35 trenches, the TX trenches, the 216-T-5 trench, and the 216-Z-16 crib also have the potential to contaminate the uppermost aquifer, but gamma logging indicates that this has not occurred. The 216-T-6 trench, the T trenches, the 216-T-20 pit, the 216-Z-4 pit, and the 216-Z-6 temporary crib do not have the potential to contaminate the uppermost aquifer.

A listing of all occurrence reports for the T/TX/TY farms from 1973 to 1980 is contained in Appendix K.

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APPENDIX A

INTENTIONAL RELEASE QUANTITIES

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INTENTIONAL RELEASE QUANTITIES

Crib	Location	Source	Type	Date	Quantity (L)	Comments
216-T-3	Reverse well E of T Farm	221-T; 224-T	5-6; 224	6/45-8/46	1.13E+07	Replaced by T-6
216-T-5	Trench W of T Farm	221-T	2C	5/55	2.6E+06	Capacity reached
216-T-6	2 cribs E of T Farm	221-T	5-6	8/46-5/51	4.5E+07	
216-T-7	Crib & tile field inside T Farm	221-T	2C	9/47 11/55	1.1E+08	Capacity reached
			5-6	6/51-11/55		
			224	6/52-11/55		
216-T-12	Pit NE corner of 207-T	207-T	Contaminated sludge	11/54	5.0E+06	Backfilled
216-T-14	Trench W of T Plant	221-T	1C	1/54	1E+06	Capacity reached
216-T-15	Trench W of T Plant	221-T	1C	2/54	1E+06	Capacity reached
216-T-16	Trench W of T Plant	221-T	1C	2/54	1E+06	Capacity reached
216-T-17	Trench W of T Plant	221-T	1C	2/54-6/54	7.85E+05	Capacity reached
216-T-18	Crib E of TY Farm	221-T	Scavenged TBP	12/53	1E+06	Test crib
216-T-19	Crib and tile field S of TX Farm	242-T	Condensate	9/51-7/55	4.31E+08	
		221-T	5-6/2C/224	12/55-8/56		
		242-T	Condensate	12/65-7/80		
216-T-20	Pit E of TX Farm	241-TX-155	Contaminated nitric acid	11/52	1.89E+04	
216-T-21	Trench W of TX Farm	221-T	1C	6/54-8/54	4.65E+05	Capacity reached
216-T-22	Trench W of TX Farm	221-T	1C	7/54-8/54	1.53E+06	Capacity reached
216-T-23	Trench W of TX Farm	221-T	1C	7/54-8/54	1.48E+06	Capacity reached

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INTENTIONAL RELEASE QUANTITIES

Crib	Location	Source	Type	Date	Quantity (L)	Comments
216-T-24	Trench W of TX Farm	221-T	1C	8/54	1.53E+06	Capacity reached
216-T-25	Trench W of TX Farm	221-T	1C bottoms	9/54	3.0E+06	Backfilled
216-T-26	Crib E of TY Farm	221-T	Scavenged 1C	8/55-11/56	1.2E+07	
216-T-27	Crib E of TY Farm	340 Bldg	Lab waste	9/65-11/65	7.19E+06	
216-T-28	Crib E of TY Farm	340 Bldg	Lab Waste	2/60-12/66	4.23E+07	
216-T-32	2 cribs inside T Farm	224-T	224	11/46-5/52	2.9E+07	
216-T-34	Trench NE of T Farm	340 Bldg	Lab waste	5/66-3/67	1.73E+07	Capacity reached
216-T-35	Trench NE of T Farm	340 Bldg	Lab waste	3/67-12/67	5.72E+06	
216-T-36	Crib S of T Farm	221-T, 221-U	Decon waste, condensate	5/67-12/68	5.22E+05	
216-Z-4	Pit E of 231-Z	231-Z	231 waste	6/45	<1E+04	Backfilled
216-Z-5	2 cribs NE of 231-Z	231-Z	231 waste	6/45-2/47	3.1E+07	Plugged
216-Z-6	Crib E of 231-Z	231-Z	231 waste	6/45	9.8E+04	Temporary
216-Z-7	2 trenches E of 231-Z	231-Z	231 waste	2/47-2/67	4.8E+07	Capacity reached
216-Z-10	Dry well E of 231-Z	231-Z	231 waste	2/45-6/45	1.0E+06	Plugged
216-Z-16	Crib N of 231-Z	231-Z	231 waste	3/68-1/77	1.0E+08	
216-Z-17	Trench E of 231-Z	231-Z	231 waste	2/67-2/68	3.7E+07	Temporary

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APPENDIX B

UNPLANNED RELEASE QUANTITIES

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UNPLANNED RELEASE QUANTITIES

Site Number	Location	Date	Leak Type	Waste Type	Quantity (L)	Comments
UPR-200-W-5 (UN-216-W-5)	241-TX-155	1950	Diversion box leak	1C	unknown	
UPR-200-W-7	241-T-151	Spring 1950	Diversion box leak			
UPR-200-W-12	S of 242-T	Spring 1951	Riser leak	"Concentrate"	"A few gallons"	
UPR-200-W-14	Between 242-T and 207-T	10/52	Underground piping leak	Contaminated cooling water		
UPR-200-W-17	TX farm	9/12/52	Surface contamination	MW		
UPR-200-W-28	241-TX-155	Spring 1954	Diversion box leak			Remediated
UPR-200-W-29	Camden & 23rd	11/15/54	Underground piping leak	1C	<3800	See UPR-200-W-64.
UPR-200-W-62	Camden & 23rd	5/4/66	Underground piping leak	1C/TBP		See UPR-200-W-64.
UPR-200-W-63	Bridgeport & 23rd	9/21/66	Spill from truck	Sr-90	1 Ci	
UPR-200-W-64	Camden & 23rd	2/13/69	Surface contamination	Previous leaks		See UPR-200-W-29, -62, and -97.
UPR-200-W-76	241-TX-155	8/24/77	Surface contamination	Rabbit dung		See UPR-200-W-113
UPR-200-W-97	Camden & 23rd	5/66	Underground piping leak			See UPR-200-W-64.
UPR-200-W-99	241-TX-153	9/21/66	Surface contamination			
UPR-200-W-100	241-TX farm	3/54	Underground piping leak	1C		
UPR-200-W-113 (UN-216-W-23)	241-TX-155	1979	Surface contamination	Previous leaks		See UPR-200-W-76
UPR-200-W-126	241-TX-153	5/8/75	Surface contamination	Broken gasket pieces		
UPR-200-W-129	241-TX-113	1/7/71	Pump pit flooding	Contaminated caustic		
UPR-200-W-130	231-Z	1/20/67	Underground piping leak			

ref - RPP-5957, Rev. 0

UNPLANNED RELEASE QUANTITIES

Site Number	Location	Date	Leak Type	Waste Type	Quantity (L)	Comments
UPR-200-W-131	241-TX-155	3/13/53	Catch tank riser spray	TBP		
UPR-200-W-135	241-TX-155	4/5/54	Cave-in			See UPR-200-W-113
UPR-200-W-147	241-T-103	1973	Tank leak			
UPR-200-W-148	241-T-106	4/20/73	Tank leak		4.35E+05	
UPR-20-W-149	241-TX-107	1977	Tank leak		9463	
UPR-200-W-150	241-TY-103	1973	Tank leak		1.14E+04	
UPR-200-W-151	241-TY-104	1974	Tank leak		5300	
UPR-200-W-152	241-TY-105	1960	Tank leak		1.35E+05	
UPR-200-W-153	241-TY-106	1959	Tank leak		7.57E+04	
UPR-200-W-166 (UN-216-W-31)	NE of T farm	1991	Surface contamination			
UPR-200-W-167 (UN-216-W-32)	NE of TY farm	1986	Surface contamination			Remediated

ref. RPP-5957, Rev. 0

APPENDIX C

HISTORICAL TIME LINE OF EVENTS

ref. RPP-5957, Rev. 0

HISTORICAL TIME LINE OF EVENTS

1943-1944	Construction of T Plant and T Farm.
10/8/44	T Plant cold run.
12/26/44	T Plant begins operations. MW, 1C, 2C from T Plant discharged to T Farm.
2/2/45	First Pu shipped to Los Alamos. 231-W waste to reverse well.
5/45	216-Z-10 reverse well plugs. 231-W waste sent to 216-Z-4 pit, then 216-Z-6 temporary crib until 216-Z-5 permanent cribs are built later that month.
8/14/45	WWII ends. Large inventory of irradiated slugs still left in 200N.
12/45	Pipeline constructed to U Farm.
8/46	216-T-6 cribs built to replace 216-T-3 reverse well.
10/46	241-T-361 tank fills with solidified sludge. 224 waste sent to 241-T-201 tank (216-T-32 crib); 5-6 line to 216-T-6 modified to bypass 241-T-361.
1/1/47	General Electric replaces DuPont as Hanford prime contractor.
1947	R&D started on uranium recovery. Construction of vaults, pipelines, and TX farm.
2/47	216-Z-5 cribs clog; 231-Z waste rerouted to 216-Z-7 trench.
9/47	T Plant 2C waste is pumped from SSTs to 216-T-7 crib.
7/49	216-Z-1 ditch from 231-Z to just south of PFP is backfilled and replaced with underground pipeline.
1949	TBP process chosen for uranium recovery.
8/49	T Plant waste sent to TX Farm.
1949-52	Korean War expansion, following Soviet espionage and A-bomb development. TY farm and 242-T constructed, also REDOX, 100C, and fish lab.
1950	Diversion box 241-TX-155 overflows; waste runs down side of hill (UPR-200-W-5).
5/1/51	Begin evaporation of 1C waste in 242-T evaporator. Evaporator condensate discharged to 216-T-19.
Spring '51	Waste leak from riser at 242-T (UPR-200-W-12).
6/51	5-6 rerouted from 216-T-6 to 216-T-7.
6/52	200-series tanks removed from service; 224 rerouted from 216-T-32 to SSTs and 216-T-7.
Autumn '51	TX Farm contaminated while moving thermocouple tree (no UPR number).

ref - RPP-5957, Rev. 0

HISTORICAL TIME LINE OF EVENTS

5/55	2C discharged to 216-T-5.
7/55	242-T evaporator shut down.
8/55	Scavenged 1C waste sent from TY Farm to 216-T-26 crib.
12/55	2C, 5-6, and 224 rerouted from 216-T-7 to 216-T-19.
3/20/56	T Plant shut down.
2/57	231-Z converted to Pu metallurgy lab.
2/57	T/TX Farm and U Farm MW recovery complete (TY not used).
1/1/58	UR Project completed.
8/59	20-kgal leak from TY-106, diatomite added (UPR-200-W-153).
2/60	T Plant decon waste to 216-T-28 crib.
9/60	35-kgal leak from 241-TY-105 (UPR-200-W-152).
10/63	340 lab waste to 216-T-28 crib.
9/65	340 lab waste to 216-T-27 crib.
11/65	Groundwater contamination discovered beneath TY cribs. 340 lab waste to 216-Z-7.
12/3/65	242-T modified for continuous evaporation and restarted for ITS.
5/66	216-Z-7 trench reaches radionuclide capacity. 340 lab waste to 216-T-34, 216-T-35.
5/4/66	Waste leak while using previously failed line between 241-T-152 and 241-TX-153 (see UPR-200-W-29) (UPR-200-W-62, -97).
9/21/66	Jumper from diversion box 216-TX-153 being moved to T Plant drips waste onto 23rd St. (UPR-200-W-63).
9/21/66	Airborne dust from 216-TX-153 contaminates Camden Ave (UPR-200-W-99).
1/20/67	Excavation for 216-Z-16 trench discovers underground pipe leak (UPR-200-W-130).
5/67	216-T-36 crib used for T Plant decon waste.
1/67	231-Z waste to 216-Z-17 temporary trench.
3/67	231-Z waste rerouted from 216-Z-17 to 216-Z-16 permanent crib.
2/13/69	Contaminated mud noted around 241-TX-153 (UPR-200-W-64).
1/7/71	Contaminated caustic spray from 241-TX-113 (UPR-200-W-129).

ref. RPP-5957, Rev. 0

HISTORICAL TIME LINE OF EVENTS

1972	242-T modified to neutralize/concentrate PFP waste. 242-TA constructed.
5/72	216-T-4-2 pond & ditch replace 216-T-4-1 pond & ditch.
1973	Leak from 241-T-103 (UPR-200-W-147).
1973	Leak from 241-TY-103 (UPR-200-W-150).
4/20/73	115 kgal leak from 241-T-106 (UPR-200-W-148).
5/73	3-kgal leak from 241-TY-103 (UPR-200-W-147).
1974	Leak from 241-TY-104 (UPR-200-W-151).
1976	Begin interim stabilization.
5/8/75	Surface contamination of TX Farm from broken gasket pieces (UPR-200-W-126).
4/15/76	242-T shut down.
1977	Last discharge to 216-T-4-2 ditch & pond. Dry until stabilization in 1995.
1977	Leak from 241-TX-107 (UPR-200-W-149).
8/24/77	Surface contamination noticed at 241-TX-155 (UPR-200-W-76, -113).
1980	244-TX DCRT constructed.
1980	241-TX-152 constructed to replace 241-TX-155.
7/24/80	216-T-19 crib decommissioned.
1986	Surface contamination noted at TY Farm (UPR-200-W-167).
1992	Surface contamination noted at T trenches (UPR-200-W-166).

ref. RPP-5957, Rev. 0

APPENDIX D

CRIB 216-T-7 DISCHARGE HISTORY

ref. RPP-5957, Rev. 0

CRIB 216-T-7 DISCHARGE HISTORY

Date	Volume (L)	Pu (g)	β (Ci)	Waste Type	Comments	Reference
Sep-47	1.59E+06	Unknown	Unknown	2C	From 241-T-111	HAN-45802
Nov-47	7.57E+04	Unknown	Unknown	2C	From 241-T-112	WHC-MR-0132
Apr-48	1.36E+06	Unknown	Unknown	2C	From 241-T-105	HW-9922
Jul-48	1.56E+06	Unknown	Unknown	2C	From 241-T-106	WHC-MR-0132
Aug-48	1.70E+06	Unknown	Unknown	2C	From 241-T-112	HW-11226
Mar-49	5.73E+05	Unknown	Unknown	2C	From 241-T-112	HW-12937
Apr-49	1.21E+06	Unknown	Unknown	2C	From 241-T-112	HW-13190
May-49	2.08E+05	Unknown	Unknown	2C	From 241-T-112	HW-13561
Nov-49	8.14E+05	Unknown	Unknown	2C	From 241-T-112	HW-15267
Dec-49	2.19E+06	Unknown	Unknown	2C	From 241-T-112	HW-15550
Jun-50	4.88E+05	Unknown	Unknown	2C	From 241-T-112	HW-18221
Oct-50	1.24E+06	Unknown	Unknown	2C	From 241-T-112	HW-19325
Nov-50	1.90E+06	5.70	28.00	2C	From 241-T-112	HW-20583
Dec-50	4.50E+05	3.20	9.00	2C	From 241-T-112	HW-20583
Mar-51	5.41E+05	N/A	N/A	2C	From 241-T-112	Original records
Apr-51	0.00	N/A	N/A	2C	Hard piped to 241-T-112	Original records
May-51	3.83E+05	N/A	N/A	2C		Original records
Jun-51	4.78E+05	N/A	N/A	2C & 5-6		Original records
Jul-51	4.78E+05	N/A	N/A	2C & 5-6		Original records
Aug-51	4.50E+05	N/A	N/A	2C & 5-6		Original records
Sep-51	4.55E+05	N/A	N/A	2C & 5-6		Original records
Oct-51	5.38E+05	N/A	N/A	2C & 5-6		Original records
Nov-51	5.86E+05	N/A	N/A	2C & 5-6		Original records
Dec-51	5.31E+05	N/A	N/A	2C & 5-6		Original records
Jan-52	1.11E+05	0.40	29.00	2C & 5-6		HW-25301
Feb-52	8.43E+05	8.60	47.00	2C & 5-6		HW-25301
Mar-52	1.18E+06	1.70	79.00	2C & 5-6		HW-25301
Apr-52	1.08E+06	2.30	43.00	2C & 5-6		HW-25301

ref. RPP-5957, Rev. 0

CRIB 216-T-7 DISCHARGE HISTORY

Date	Volume (L)	Pu (g)	β (Ci)	Waste Type	Comments	Reference
May-52	4.55E+05	1.30	13.00	2C & 5-6		HW-25301
Jun-52	5.39E+05	N/A	N/A	2C/5-6/224		HW-25301
Jul-52	1.39E+06	4.00	49.00	2C/5-6/224		HW-33591
Aug-52	1.64E+06	0.90	156.00	2C/5-6/224		HW-33591
Sep-52	5.50E+05	1.60	40.00	2C/5-6/224		HW-33591
Oct-52	9.80E+05	0.60	24.00	2C/5-6/224		HW-33591
Nov-52	9.70E+05	0.50	11.00	2C/5-6/224		HW-33591
Dec-52	1.33E+06	0.50	15.00	2C/5-6/224		HW-33591
Jan-53	9.70E+05	0.80	12.00	2C/5-6/224		HW-33591
Feb-53	1.17E+06	0.20	13.00	2C/5-6/224		HW-33591
Mar-53	1.69E+06	0.30	16.00	2C/5-6/224		HW-33591
Apr-53	9.60E+05	0.20	8.00	2C/5-6/224		HW-33591
May-53	1.08E+06	15.80	11.00	2C/5-6/224		HW-33591
Jun-53	1.51E+06	1.20	31.00	2C/5-6/224		HW-33591
Jul-53	9.50E+05	0.60	9.00	2C/5-6/224		HW-33591
Aug-53	1.08E+06	0.20	10.00	2C/5-6/224		HW-33591
Sep-53	1.21E+06	3.20	12.00	2C/5-6/224		HW-33591
Oct-53	1.32E+06	3.20	97.00	2C/5-6/224		HW-33591
Nov-53	1.52E+06	0.20	55.00	2C/5-6/224		HW-33591
Dec-53	1.75E+06	0.30	50.00	2C/5-6/224		HW-33591
Jan-54	2.10E+06	0.20	54.00	2C/5-6/224		HW-33591
Feb-54	1.97E+06	26.80	740.00	2C/5-6/224		HW-33591
Mar-54	2.13E+06	3.20	640.00	2C/5-6/224		HW-33591
Apr-54	1.00E+06	0.30	100.00	2C/5-6/224		HW-33591
May-54	1.91E+06	0.60	1.40	2C/5-6/224		HW-33591
Jun-54	2.01E+06	0.50	0.20	2C/5-6/224		HW-33591
Jul-54	2.34E+06	0.37	0.56	2C/5-6/224		HW-38562
Aug-54	2.42E+06	0.30	0.62	2C/5-6/224		HW-38562
Sep-54	2.48E+06	0.47	2.98	2C/5-6/224		HW-38562
Oct-54	2.18E+06	0.23	1.08	2C/5-6/224		HW-38562

ref - RPP-5957, Rev. 0

CRIB 216-T-7 DISCHARGE HISTORY

Date	Volume (L)	Pu (g)	β (Ci)	Waste Type	Comments	Reference
Nov-54	2.27E+06	1.64	16.00	2C/5-6/224		HW-38562
Dec-54	2.67E+06	0.45	1.24	2C/5-6/224		HW-38562
Jan-55	3.18E+06	1.06	2.72	2C/5-6/224		HW-38562
Feb-55	2.64E+06	0.20	0.63	2C/5-6/224		HW-38562
Mar-55	2.71E+06	0.41	106.00	2C/5-6/224		HW-38562
Apr-55	2.21E+06	0.45	1.09	2C/5-6/224		HW-38562
May-55	2.98E+06	6.62	76.80	2C/5-6/224		HW-38562
Jun-55	3.26E+06	0.44	1.17	2C/5-6/224		HW-38562
Jul-55	3.09E+06	4.87	4.20	2C/5-6/224		HW-44784
Aug-55	3.26E+06	0.94	26.30	2C/5-6/224		HW-44784
Sep-55	3.90E+06	0.90	0.06	2C/5-6/224		HW-44784
Oct-55	2.96E+06	1.02	3.10	2C/5-6/224		HW-44784
Nov-55	2.42E+06	3.06	0.20	2C/5-6/224		HW-44784
Dec-55	0.00	0.00	0.00	2C/5-6/224		HW-44784
Totals	1.04E+08	113	2647			

Curies are uncorrected for decay.

ref. RPP-5957, Rev. 0

APPENDIX E

CRIB 216-T-19 DISCHARGE HISTORY

ref. RPP-5957, Rev. 0

CRIB 216-T-19 DISCHARGE HISTORY

FIRST EVAPORATOR CAMPAIGN, 1951-1956							
Date	Volume (L)	U (kg)	Pu (g)	β (Ci)	Waste Type	Reference	Comments
May-51	5.72E+05	N/A	N/A	N/A	1C condensate	HW-21260	242-T startup
Jun-51	1.08E+06	N/A	N/A	N/A	1C condensate	HW-21506	
Jul-51	1.53E+06	N/A	N/A	N/A	1C condensate	HW-21802	
Aug-51	1.67E+06	N/A	N/A	N/A	1C condensate	HW-22075	
Sep-51	1.47E+06	N/A	N/A	N/A	1C condensate	HW-22304	
Oct-51	1.08E+06	N/A	N/A	N/A	1C condensate	HW-22610	
Nov-51	1.58E+06	N/A	N/A	N/A	1C condensate	HW-22875	
Dec-51	7.89E+05	N/A	N/A	N/A	1C condensate	HW-23140	
Jan-52	1.63E+06	N/A	N/A	0.070	1C condensate	HW-25301	
Feb-52	1.49E+06	N/A	N/A	0.034	1C condensate	HW-25301	
Mar-52	1.52E+06	N/A	N/A	0.198	1C condensate	HW-25301	
Apr-52	1.04E+06	N/A	N/A	0.034	1C condensate	HW-25301	
May-52	8.40E+05	N/A	N/A	0.015	1C condensate	HW-25301	
Jun-52	1.47E+06	N/A	0.097	0.015	1C condensate	HW-25301	
Jul-52	1.48E+06	N/A	0.060	0.020	1C condensate	HW-33591	
Aug-52	3.00E+05	N/A	0.020	0.010	1C condensate	HW-33591	
Sep-52	1.10E+05	N/A	0.020	0.000	1C condensate	HW-33591	
Oct-52	0.00	N/A	0.00	0.00	N/A	HW-33591	Down for repairs
Nov-52	0.00	N/A	0.00	0.00	N/A	HW-33591	Down for repairs
Dec-52	0.00	N/A	0.00	0.00	N/A	HW-33591	Down for repairs
Jan-53	0.00	N/A	0.00	0.00	N/A	HW-33591	Down for repairs
Feb-53	2.20E+05	N/A	0.020	0.010	1C condensate	HW-33591	
Mar-53	7.50E+05	N/A	0.070	0.030	1C condensate	HW-33591	
Apr-53	6.80E+05	N/A	0.840	0.020	1C condensate	HW-33591	
May-53	4.20E+05	N/A	0.520	0.010	1C condensate	HW-33591	

ref. RPP-5957, Rev. 0

CRIB 216-T-19 DISCHARGE HISTORY

FIRST EVAPORATOR CAMPAIGN, 1951-1956							
Date	Volume (L)	U (kg)	Pu (g)	β (Ci)	Waste Type	Reference	Comments
Jun-53	6.10E+05	N/A	0.030	1.810	1C condensate	HW-33591	
Jul-53	5.10E+05	N/A	0.030	0.080	TBP cond	HW-33591	
Aug-53	1.05E+06	N/A	0.070	0.170	TBP cond	HW-33591	
Sep-53	9.40E+05	N/A	0.070	0.150	TBP cond	HW-33591	
Oct-53	6.10E+05	N/A	0.050	0.100	TBP cond	HW-33591	
Nov-53	5.30E+05	N/A	0.050	0.010	TBP cond	HW-33591	
Dec-53	6.10E+05	N/A	0.050	0.040	TBP cond	HW-33591	
Jan-54	5.40E+05	N/A	0.050	0.090	TBP cond	HW-33591	
Feb-54	1.80E+05	N/A	0.020	0.030	TBP cond	HW-33591	
Mar-54	5.70E+05	N/A	0.050	0.090	TBP cond	HW-33591	
Apr-54	4.10E+05	N/A	0.030	0.020	TBP cond	HW-33591	
May-54	5.90E+05	N/A	0.050	0.070	TBP cond	HW-33591	
Jun-54	6.00E+05	N/A	0.020	0.180	TBP cond	HW-33591	
Jul-54	6.80E+05	N/A	0.026	0.302	TBP cond	HW-38562	
Aug-54	6.16E+05	N/A	0.047	0.027	TBP cond	HW-38562	
Sep-54	3.97E+05	N/A	0.031	0.118	TBP cond	HW-38562	242-T shutdown
Oct-54	0.00	N/A	0.00	0.00	N/A	HW-38562	
Nov-54	0.00	N/A	0.00	0.00	N/A	HW-38562	
Dec-54	6.88E+05	N/A	0.040	0.020	1C	HW-38562	242-T restart
Jan-55	8.99E+05	N/A	0.718	0.233	1C	HW-38562	
Feb-55	8.12E+05	N/A	0.062	0.096	1C	HW-38562	
Mar-55	8.46E+05	N/A	0.049	0.130	Scav 1C	HW-38562	
Apr-55	7.93E+05	N/A	0.074	0.216	Scav 1C	HW-38562	
May-55	5.53E+05	N/A	0.248	0.920	Scav 1C	HW-38562	
Jun-55	3.77E+05	N/A	0.252	0.069	Scav 1C	HW-38562	
Jul-55	2.26E+05	N/A	0.001	0.001	Scav 1C	HW-44784	
Aug-55	0.00	N/A	0.00	0.00	Scav 1C	HW-44784	242-T shutdown
Sep-55	0.00	N/A	0.00	0.00	N/A	HW-44784	

ref. RPP-5957, Rev. 0

CRIB 216-T-19 DISCHARGE HISTORY

FIRST EVAPORATOR CAMPAIGN, 1951-1956							
Date	Volume (L)	U (kg)	Pu (g)	β (Ci)	Waste Type	Reference	Comments
Oct-55	0.00	N/A	0.00	0.00	N/A	HW-44784	
Nov-55	0.00	N/A	0.00	0.00	N/A	HW-44784	
Dec-55	2.12E+06	N/A	0.029	0.054	2C/5-6/224	HW-44784	Formerly to 216-T-7
Jan-56	1.60E+06	N/A	5.410	0.036	2C/5-6/224	HW-44784	
Feb-56	1.87E+06	N/A	1.880	1560.00	2C/5-6/224	HW-44784	
Mar-56	1.79E+06	N/A	1.370	224.00	2C/5-6/224	HW-44784	
Apr-56	1.61E+06	N/A	0.487	166.00	2C/5-6/224	HW-44784	
May-56	5.25E+05	N/A	0.316	33.90	2C/5-6/224	HW-44784	
Jun-56	5.07E+05	N/A	0.154	22.90	2C/5-6/224	HW-44784	
Jul-56	2.98E+05	N/A	0.010	10.10	2C/5-6/224	HW-48518	
Aug-56	2.64E+05	N/A	0.180	10.20	2C/5-6/224	HW-48518	T Plant shutdown
Totals	4.70E+07		13.60	2032.63			

Curies are uncorrected for decay.

ref - RPP-5957, Rev. 0

CRIB 216-T-19 DISCHARGE HISTORY

SECOND EVAPORATOR CAMPAIGN, 1965-1976									
Date	Volume (L)	U (kg)	Pu (g)	β (Ci)	^{60}Co (Ci)	^{90}Sr (Ci)	^{137}Cs (Ci)	^{106}Ru (Ci)	Reference
Dec-65	1.41E+06								HAN-93551
Jan-66	4.77E+06	N/A	N/A	0.04	N/A	N/A	0.03	N/A	ISO-698
Feb-66	2.07E+06	N/A	N/A	0.03	N/A	N/A	0.01	N/A	ISO-698
Mar-66	2.51E+06	N/A	N/A	0.01	N/A	N/A	0.01	N/A	ISO-698
Apr-66	2.45E+06	N/A	N/A	0.65	N/A	N/A	0.39	N/A	ISO-698
May-66	2.46E+06	N/A	N/A	3.90	N/A	N/A	2.60	N/A	ISO-698
Jun-66	2.52E+06	N/A	N/A	0.20	N/A	N/A	0.10	N/A	ISO-698
Jul-66	2.48E+06	N/A	N/A	0.10	N/A	N/A	0.10	N/A	ISO-698
Aug-66	2.58E+06	N/A	N/A	2.90	N/A	N/A	2.90	N/A	ISO-698
Sep-66	1.99E+06	N/A	N/A	0.02	N/A	N/A	0.02	N/A	ISO-698
Oct-66	3.21E+06	N/A	N/A	19.40	N/A	N/A	10.80	N/A	ISO-698
Nov-66	3.01E+06	N/A	N/A	0.97	N/A	N/A	0.78	N/A	ISO-698
Dec-66	3.29E+06	N/A	N/A	0.11	N/A	N/A	0.05	N/A	ISO-698
Jan-67	2.08E+06	N/A	N/A	2.64	N/A	N/A	1.68	N/A	ARH-486
Feb-67	3.06E+06	N/A	N/A	0.08	N/A	N/A	0.08	N/A	ARH-486
Mar-67	2.60E+06	N/A	N/A	0.48	N/A	N/A	0.48	N/A	ARH-486
Apr-67	2.18E+06	N/A	N/A	0.12	N/A	N/A	0.07	N/A	ARH-486
May-67	1.91E+06	N/A	N/A	0.06	N/A	N/A	0.04	N/A	ARH-486
Jun-67	1.87E+06	N/A	N/A	0.08	N/A	N/A	0.06	N/A	ARH-486
Jul-67	1.92E+06	N/A	N/A	0.81	N/A	N/A	0.59	N/A	ARH-486
Aug-67	1.10E+05	N/A	N/A	0.90	N/A	N/A	N/A	N/A	ARH-486
Sep-67	2.30E+06	5.00E-03	1.00E-03	0.04	5.00E-03	7.00E-03	0.02	N/A	ARH-486
Oct-67	2.12E+06	5.00E-03	1.00E-03	0.09	5.00E-03	1.00E-02	0.04	N/A	ARH-486
Nov-67	1.99E+06	1.00E-03	1.00E-03	0.02	2.00E-03	5.00E-03	0.02	N/A	ARH-486
Dec-67	1.59E+06	1.00E-03	6.00E-02	0.34	1.00E-03	8.00E-02	0.24	N/A	ARH-486
Jan-68	1.51E+06	4.55E-03	1.00E-03	0.01	N/A	N/A	N/A	N/A	ARH-1159
Feb-68	1.36E+06	4.55E-04	1.00E-02	0.05	1.00E-03	4.00E-02	0.01	5.00E-02	ARH-1159

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CRIB 216-T-19 DISCHARGE HISTORY

SECOND EVAPORATOR CAMPAIGN, 1965-1976									
Date	Volume (L)	U (kg)	Pu (g)	β (Ci)	^{60}Co (Ci)	^{90}Sr (Ci)	^{137}Cs (Ci)	^{106}Ru (Ci)	Reference
Mar-68	1.78E+06	1.36E-02	2.00E-03	3.60	4.00E-03	7.00E-01	2.20	6.60E-01	ARH-1159
Apr-68	1.78E+06	1.82E-02	1.00E-03	0.41	3.00E-03	8.00E-02	0.26	1.10E-02	ARH-1159
May-68	1.63E+06	5.00E-03	1.00E-03	0.91	1.00E-03	2.00E-03	0.43	N/A	ARH-1159
Jun-68	5.30E+05	2.27E-02	4.00E-02	0.28	4.00E-04	1.00E-02	0.18	7.10E-02	ARH-1159
Jul-68	1.63E+06	8.64E-02	8.00E-03	0.64	2.00E-04	5.00E-03	0.28	1.90E-02	ARH-1159
Aug-68	1.25E+06	8.60E-02	3.00E-03	1.31	N/A	7.00E-03	0.72	N/A	ARH-1159
Sep-68	1.40E+06	9.09E-03	1.00E-02	0.34	N/A	2.00E-03	0.13	3.70E-02	ARH-1159
Oct-68	1.44E+06	9.00E-03	1.00E-02	0.26	N/A	1.00E-03	0.09	3.10E-02	ARH-1159
Nov-68	6.82E+05	5.00E-03	6.00E-03	0.10	N/A	1.00E-03	0.06	N/A	ARH-1159
Dec-68	6.82E+05	5.00E-03	6.50E-03	0.20	N/A	1.00E-03	0.12	7.00E-03	ARH-1159
Jan-69	1.14E+06	6.82E-03	1.10E-02	1.70	N/A	1.40E-03	0.28	1.30E-02	ARH-1608
Feb-69	1.44E+06	3.00E-04	1.40E-02	1.30	N/A	2.30E-03	0.28	1.40E-02	ARH-1608
Mar-69	9.20E+05	1.10E-04	5.90E-05	0.26	N/A	5.00E-04	0.28	1.30E-02	ARH-1608
Apr-69	1.89E+06	2.82E+00	8.10E-05	0.49	N/A	1.27E-03	0.28	1.40E-02	ARH-1608
May-69	1.57E+06	8.18E-03	7.00E-05	0.90	N/A	1.90E-03	0.59	3.20E-02	ARH-1608
Jun-69	1.46E+06	7.73E-03	1.10E-04	0.55	N/A	9.70E-04	0.32	1.50E-02	ARH-1608
Jul-69	1.50E+06	8.00E-03	4.00E-05	0.32	N/A	7.80E-04	0.14	2.50E-02	ARH-1608
Aug-69	1.47E+06	8.00E-03	2.00E-04	0.37	N/A	1.80E-03	0.18	7.80E-03	ARH-1608
Sep-69	1.51E+06	1.00E-02	9.00E-05	0.55	N/A	1.20E-03	0.26	8.00E-03	ARH-1608
Oct-69	1.18E+06	7.00E-03	5.00E-05	0.68	3.80E-04	2.10E-03	0.32	1.40E-02	ARH-1608
Nov-69	4.96E+05	3.14E-03	6.00E-05	0.58	5.00E-05	3.30E-03	0.31	3.90E-03	ARH-1608
Dec-69	2.12E+05	1.10E-03	5.90E-04	0.30	6.00E-05	2.70E-03	0.09	2.00E-03	ARH-1608
Jan-70	8.02E+05	8.64E-03	8.65E-04	0.548	7.86E-05	6.99E-03	0.204	2.55E-03	ARH-2015
Feb-70	7.19E+05	7.73E-03	8.99E-05	0.137	4.23E-05	1.60E-03	0.088	3.54E-03	ARH-2015
Mar-70	4.85E+05	3.20E-03	1.93E-04	0.187	8.06E-05	2.47E-03	0.114	3.71E-03	ARH-2015
Apr-70	7.12E+05	2.57E-03	1.04E-04	0.186	8.82E-05	3.62E-03	0.106	1.14E-03	ARH-2015
May-70	1.80E+06	1.00E-02	1.85E-04	0.418	2.90E-04	1.40E-02	0.264	2.76E-03	ARH-2015
Jun-70	1.65E+06	9.10E-03	7.79E-05	0.205	2.22E-05	1.87E-03	0.137	2.22E-03	ARH-2015

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SECOND EVAPORATOR CAMPAIGN, 1965-1976									
Date	Volume (L)	U (kg)	Pu (g)	β (Ci)	^{60}Co (Ci)	^{90}Sr (Ci)	^{137}Cs (Ci)	^{106}Ru (Ci)	Reference
Jul-70	1.17E+06	6.40E-03	5.02E-06	0.548	2.28E-04	3.08E-03	0.376	7.52E-03	ARH-2015
Aug-70	1.06E+06	5.45E-03	4.55E-05	0.109	6.42E-06	1.20E-03	0.071	2.08E-03	ARH-2015
Sep-70	5.30E+05	4.34E-04	3.64E-05	0.042	3.63E-05	1.86E-03	0.045	6.00E-04	ARH-2015
Oct-70	9.35E+05	5.00E-03	1.04E-04	0.059	3.11E-05	8.10E-04	0.043	8.39E-04	ARH-2015
Nov-70	1.06E+06	5.45E-03	7.75E-05	0.135	3.64E-05	6.55E-04	0.066	9.68E-04	ARH-2015
Dec-70	9.99E+05	5.00E-03	6.44E-05	0.173	4.70E-05	2.16E-03	0.100	1.39E-03	ARH-2015
Jan-71	1.45E+06	7.65E-03	6.23E-05	0.141	5.39E-05	2.29E-03	0.096	1.61E-03	ARH-2353
Feb-71	1.34E+06	7.26E-03	1.44E-04	0.204	5.98E-05	3.79E-03	0.106	5.91E-03	ARH-2353
Mar-71	1.18E+06	6.74E-03	7.62E-05	0.084	4.22E-05	4.31E-03	0.051	2.47E-03	ARH-2353
Apr-71	1.09E+06	5.98E-03	7.04E-05	0.071	1.42E-04	1.88E-03	0.039	9.82E-04	ARH-2353
May-71	1.28E+06	6.77E-03	8.94E-05	0.108	1.05E-04	3.73E-03	0.058	9.15E-04	ARH-2353
Jun-71	9.79E+05	5.69E-03	7.58E-06	0.120	6.65E-05	7.84E-03	0.061	1.42E-03	ARH-2353
Jul-71	1.15E+06	6.89E-03	4.55E-04	1.002	5.86E-04	7.86E-02	0.610	3.64E-03	ARH-2353
Aug-71	1.75E+06	9.75E-03	4.17E-04	0.618	1.67E-04	1.12E-01	0.157	6.27E-03	ARH-2353
Sep-71	1.55E+06	8.62E-03	9.97E-05	0.244	1.56E-04	1.37E-02	0.142	1.84E-03	ARH-2353
Oct-71	1.27E+06	6.96E-03	5.39E-05	0.116	1.61E-04	3.98E-03	0.074	7.93E-04	ARH-2353
Nov-71	1.43E+06	8.53E-03	6.76E-05	0.290	1.91E-04	1.93E-03	0.263	1.37E-03	ARH-2353
Dec-71	1.24E+06	9.41E-03	6.97E-05	0.536	1.04E-04	1.35E-03	0.401	1.02E-03	ARH-2353
Jan-72	1.48E+06	1.24E-02	3.58E-04	1.610	1.35E-04	3.25E-03	0.796	2.82E-03	ARH-2757
Feb-72	1.33E+06	7.25E-03	5.71E-05	0.598	1.31E-04	2.49E-03	0.290	1.25E-03	ARH-2757
Mar-72	1.36E+06	7.73E-03	6.41E-05	0.300	1.93E-04	1.97E-03	0.145	9.24E-04	ARH-2757
Apr-72	1.24E+06	6.57E-03	4.05E-05	0.251	1.40E-04	2.48E-03	0.117	1.44E-03	ARH-2757
May-72	1.34E+06	7.19E-03	7.51E-05	0.287	1.54E-04	4.11E-03	0.140	1.92E-03	ARH-2757
Jun-72	1.22E+06	6.59E-03	5.04E-05	0.324	1.31E-04	3.36E-03	0.151	1.34E-03	ARH-2757
Jul-72	1.16E+06	6.26E-03	5.99E-05	0.407	9.15E-05	4.05E-03	0.202	2.09E-03	ARH-2757
Aug-72	1.33E+06	7.15E-03	6.27E-05	0.560	1.69E-04	6.66E-03	0.282	1.97E-03	ARH-2757
Sep-72	1.33E+06	7.15E-03	5.46E-05	0.554	2.41E-04	7.46E-03	0.266	2.71E-03	ARH-2757
Oct-72	1.38E+06	7.46E-03	5.38E-05	0.542	1.29E-04	6.91E-03	0.262	3.66E-03	ARH-2757

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SECOND EVAPORATOR CAMPAIGN, 1965-1976									
Date	Volume (L)	U (kg)	Pu (g)	β (Ci)	^{60}Co (Ci)	^{90}Sr (Ci)	^{137}Cs (Ci)	^{106}Ru (Ci)	Reference
Nov-72	1.36E+06	7.27E-03	9.35E-05	0.657	2.20E-04	4.94E-03	0.324	6.84E-03	ARH-2757
Dec-72	1.36E+06	7.31E-03	5.26E-05	0.475	1.24E-04	1.03E-02	0.223	7.56E-03	ARH-2757
Jan-73	1.27E+06	6.83E-03	5.46E-05	0.592	1.25E-04	1.03E-02	0.261	1.34E-02	ARH-2806
Feb-73	1.27E+06	1.44E-02	5.46E-05	0.640	2.75E-04	8.47E-03	0.297	2.23E-02	ARH-2806
Mar-73	2.35E+05	2.40E-03	1.41E-03	0.825	3.87E-04	2.46E-01	0.098	7.15E-02	ARH-2806
Apr-73	7.22E+05	4.20E-03	4.35E-04	0.610	8.31E-05	1.03E-01	0.159	6.56E-03	ARH-2806
May-73	1.06E+06	5.72E-02	1.00E-03	0.674	1.56E-04	3.61E-02	0.286	1.62E-02	ARH-2806
Jun-73	4.13E+05	2.29E-03	1.70E-03	0.181	9.70E-05	1.68E-02	0.072	3.16E-03	ARH-2806
Jul-73	1.80E+05	1.09E-03	4.42E-04	0.086	2.76E-05	6.66E-03	0.035	1.68E-03	ARH-2806
Aug-73	1.06E+06	5.08E-03	1.28E-02	0.383	1.10E-04	1.43E-02	0.168	3.95E-03	ARH-2806
Sep-73	6.48E+05	4.45E-03	1.03E-02	0.243	6.46E-05	1.88E-02	0.104	2.86E-03	ARH-2806
Oct-73	7.07E+05	3.85E-03	2.58E-05	0.325	7.66E-05	9.90E-03	0.153	2.84E-03	ARH-2806
Nov-73	3.09E+05	1.80E-03	8.67E-04	0.092	3.52E-05	3.92E-03	0.039	2.49E-03	ARH-2806
Dec-73	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	ARH-2806
Jan-74	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	ARH-3093
Feb-74	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	ARH-3093
Mar-74	1.03E+05	5.53E-04	2.53E-04	0.060	1.05E-05	6.21E-03	0.015	2.56E-04	ARH-3093
Apr-74	2.94E+05	1.61E-03	1.89E-03	0.094	2.62E-05	1.76E-03	0.045	5.55E-04	ARH-3093
May-74	9.27E+05	5.39E-03	1.99E-03	0.238	9.19E-05	9.80E-03	0.105	3.23E-03	ARH-3093
Jun-74	5.30E+05	3.14E-03	4.10E-03	0.459	7.30E-05	1.30E-02	0.217	1.43E-03	ARH-3093
Jul-74	7.31E+05	3.96E-03	5.44E-03	0.316	8.24E-05	2.84E-02	0.121	2.95E-03	ARH-3093
Aug-74	8.32E+05	4.57E-03	5.19E-03	0.376	3.03E-04	3.76E-01	0.598	7.98E-03	ARH-3093
Sep-74	8.21E+05	8.33E-03	2.73E-03	0.625	5.03E-04	1.25E-02	0.221	1.84E-02	ARH-3093
Oct-74	8.64E+05	8.72E-03	2.58E-03	0.591	2.72E-04	8.49E-02	0.152	1.11E-02	ARH-3093
Nov-74	6.90E+05	6.98E-03	4.59E-03	0.344	4.34E-04	2.73E-02	0.132	1.41E-02	ARH-3093
Dec-74	7.37E+05	7.45E-03	2.10E-03	0.245	1.24E-04	1.49E-02	0.094	9.03E-03	ARH-3093
Jan-75	2.51E+05	2.58E-03	5.94E-05	0.075	3.44E-04	5.18E-03	0.008	5.47E-03	ARH-CD-371
Feb-75	0.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	ARH-CD-371

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CRIB 216-T-19 DISCHARGE HISTORY

SECOND EVAPORATOR CAMPAIGN, 1965-1976									
Date	Volume (L)	U (kg)	Pu (g)	β (Ci)	^{60}Co (Ci)	^{90}Sr (Ci)	^{137}Cs (Ci)	^{106}Ru (Ci)	Reference
Mar-75	1.40E+04	1.44E-04	3.32E-06	0.004	6.73E-06	2.90E-04	0.000	3.06E-04	ARH-CD-371
Apr-75	1.88E+05	1.94E-03	1.56E-04	0.074	2.22E-03	6.56E-03	0.004	N/A	ARH-CD-371
May-75	2.59E+05	2.66E-03	5.80E-04	0.113	4.96E-04	7.87E-03	0.037	8.56E-03	ARH-CD-371
Jun-75	1.91E+05	1.97E-03	2.30E-04	0.125	2.95E-04	7.11E-03	0.032	9.79E-03	ARH-CD-371
Jul-75	5.42E+05	5.50E-03	2.59E-04	0.170	4.16E-04	2.09E-02	0.049	1.65E-02	ARH-CD-371
Aug-75	8.94E+05	9.02E-03	6.56E-04	0.400	1.87E-04	1.01E-01	0.083	6.85E-03	ARH-CD-371
Sep-75	8.06E+05	8.16E-03	2.22E-04	0.492	3.41E-04	7.41E-02	0.094	6.82E-03	ARH-CD-371
Oct-75	8.65E+05	8.76E-03	5.12E-04	0.358	1.81E-04	3.06E-02	0.144	8.23E-03	ARH-CD-371
Nov-75	4.86E+05	4.93E-03	2.26E-04	0.292	2.89E-04	3.44E-02	0.100	5.36E-03	ARH-CD-371
Dec-75	5.01E+05	5.08E-03	1.38E-03	0.311	2.16E-04	3.12E-02	0.096	5.89E-03	ARH-CD-371
Jan-76	5.00E+05	N/A	2.58E-04	0.210	N/A	2.30E-02	0.017	1.98E-03	ARH-CD-743
Feb-76	3.24E+05	N/A	1.10E-03	0.261	N/A	2.19E-02	0.063	3.57E-03	ARH-CD-743
Mar-76	5.54E+05	N/A	2.16E-06	0.199	N/A	2.63E-02	0.061	4.68E-03	ARH-CD-743
Apr-76	8.71E+04	N/A	2.07E-04	0.047	N/A	4.51E-03	0.012	6.90E-04	ARH-CD-743

Curies are uncorrected for decay.

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216-T-19 DISCHARGE SUMMARY											
Date	Volume (L)	U (kg)	Pu (g)	β (Ci)							
1951	9.78E+06	N/A	0.000	0.000							
1952	9.88E+06	N/A	0.197	0.396							
1953	6.93E+06	N/A	1.800	2.430							
1954	5.27E+06	N/A	0.364	0.947							
1955	6.63E+06	N/A	1.433	1.719					Corrections for Additions		
1956	8.46E+06	N/A	9.807	2027.136	^{60}Co (Ci)	^{90}Sr (Ci)	^{137}Cs (Ci)	^{106}Ru (Ci)	Steam	Vac jet	Total
1965	1.41E+06	0.000	0.00E+00	0.000	0.00E+00	0.000	0.000	0.000	Unknown		
1966	3.33E+07	N/A	N/A	28.330	N/A	N/A	17.790	N/A	Unknown, but Possible		
1967	2.37E+07	0.012	6.30E-02	5.660	1.30E-02	0.102	3.320	0.000	Estimated		4.88E+07
1968	1.57E+07	0.265	9.85E-02	8.110	9.60E-03	0.849	4.480	0.886	2.03E+07	2.87E+07	4.90E+07
1969	1.48E+07	2.879	2.64E-02	8.000	4.90E-04	0.020	3.315	0.162	1.78E+07	3.52E+07	5.30E+07
1970	1.19E+07	0.069	1.85E-03	2.747	9.87E-04	0.040	1.614	0.029	1.89E+07	4.92E+05	1.94E+07
1971	1.57E+07	0.090	1.61E-03	3.535	1.83E-03	0.236	2.058	0.028	8.14E+06		8.14E+06
1972	1.59E+07	0.090	1.02E-03	6.565	1.86E-03	0.058	3.198	0.035	2.06E+07		2.06E+07
1973	7.87E+06	0.104	2.91E-02	4.651	1.44E-03	0.474	1.672	0.147	1.02E+07		1.02E+07
1974	6.53E+06	0.051	3.09E-02	3.349	1.92E-03	0.575	1.700	0.069	1.29E+07		1.29E+07
1975	5.00E+06	0.051	4.28E-03	2.414	4.99E-03	0.319	0.646	0.074	6.50E+06		6.50E+06
1976	1.47E+06	N/A	1.57E-03	0.717	0.00E+00	0.076	0.152	0.011	1.90E+06		1.90E+06
Totals	2.00E+08	3.61	13.86	2106.70	0.036	2.75	39.94	1.44	1.17E+08	6.44E+07	2.30E+08
Grand Total	4.31E+08										

Curies are uncorrected for decay.

ref · RPP-5957, Rev. 0

APPENDIX F

FIRST CYCLE WASTE DISPOSAL TO CRIBS AND TRENCHES

ref · RPP-5957, Rev. 0

FIRST CYCLE WASTE DISPOSAL TO CRIBS AND TRENCHES

FIRST CYCLE WASTE DISPOSAL TO T TRENCHES									
Date	Trench	Tank	Liters	Pu (g)	U (g)	β (Ci)	^{137}Cs (Ci)	^{90}Sr (Ci)	Reference
1/15/54	T-14	T-104	4.60E+05	0.36	14500	547	230	1.01	HW-38562
1/22/54	T-14	T-105	5.46E+05	0.42	14700	437	229	4.75	HW-38562
1/29/54	T-15	T-105	9.15E+05	0.75	23300	686	403	20.1	HW-38562
2/4/54	T-15	T-106	1.27E+05	0.08	2850	108	610	1	HW-38562
2/10/54	T-16	T-106	1.02E+06	0.58	21400	878	510	8.67	HW-38562
2/13/54	T-17	T-106	3.48E+05	0.21	9400	278	157	0.42	HW-38562
6/10/54	T-17	T-106	4.37E+05	0.27	10100	367	208	2.54	HW-38562

FIRST CYCLE WASTE DISPOSAL TO TX TRENCHES									
Date	Trench	Tank	Liters	Pu (g)	U (g)	β (Ci)	^{137}Cs (Ci)	^{90}Sr (Ci)	Reference
6/24/54	T-21	TX-109	4.63E+05	1.25	521	7290	389	7.87	HW-38562
7/23/54	T-22	TX-110	1.54E+06	1.90	2170	3800	1850	49.3	HW-38562
7/30/54	T-23	TX-110	7.48E+05	0.21	842	935	591	16.5	HW-38562
8/6/54	T-23	TX-111	7.38E+05	0.66	244	2440	738	23.6	HW-38562
8/13/54	T-24	TX-111	1.54E+06	2.48	8320	4200	1420	38.5	HW-38562

FIRST CYCLE EVAPORATOR BOTTOMS DISPOSAL TO 216-T-25									
Date		Tank	Liters	Pu (g)	U (g)	β (Ci)	^{137}Cs (Ci)	^{90}Sr (Ci)	Reference
9/19/54		TY-101	2.48E+06	0.58	855	11000	7190	3.97	HW-38562
9/22/54		TY-102	5.07E+05	0.02	258	3240	1170	0.14	HW-38562
Total			2.99E+06	0.60	1113	14240	8360	4.11	HW-38562

ref. RPP-5957, Rev. 0

FIRST CYCLE WASTE DISPOSAL TO CRIBS AND TRENCHES

SCAVENGED FIRST CYCLE WASTE DISPOSAL TO 216-T-26									
Date		Tank	Liters	Pu (g)	U (g)	β (Ci)	^{137}Cs (Ci)	^{90}Sr (Ci)	Reference
Aug-55		TY-104	2.07E+06	7.09	17700	3760	22.5	252	HW-44784
Aug-55		TY-103	1.65E+06	6.38	1560	6330	55	263	HW-44784
Oct-55		TY-101	1.92E+06	24.4	66900	5600	76.4	112	HW-44784
Dec-55		TY-103	2.00E+06	7.66	47900	6550	1.58	23.8	HW-44784
Nov-56		TY-101	2.11E+06	8.15	13200	5310	5.02	7.81	HW-48518
Nov-56		TY-103	1.33E+06	4.93	2560	1250	4.22	9.5	HW-48518
Total			1.11E+07	58.61	149820	28800	164.72	668.11	HW-48518

Curies are uncorrected for decay.

ref - RPP-5957, Rev. 0

APPENDIX G

WASTE DISCHARGES TO TY CRIBS

ref. RPP-5957, Rev. 0

WASTE DISCHARGES TO TY CRIBS

216-T-27 (340 Bldg. Waste)					
Date	Vol (L)	U (kg)	Pu (g)	β (Ci)	Reference
Sep-65	1.40E+06	0.2	3.4	620	ISO-98
Oct-65	3.96E+07	0.2	9.1	1254	ISO-98
Nov-65	8.00E+05	N/A	0.1	112	ISO-98
Dec-65	0.00	N/A	N/A	N/A	ISO-98
Totals	4.18E+07	0.4	12.6	1986	

Curies are uncorrected for decay.

There is a discrepancy regarding the amount of waste discharged to this crib. ISO-98 originally reported a discharge of 3.96E+07 L (1.05E+07 gal) in October. This is believed to be a typographical error, since the next report, ISO-698, listed the total amount discharged to the crib as 6.0E+06 L (1.6E+06 gal). If the amount for October were 3.96E+06 L (1.05E+06 gal), it would make the total 5.5E+06 L (1.45E+06 gal), similar to the 6.0E+06 L (1.6E+06 gal) reported in ISO-698. ARH-486 and later documents report a total discharge amount of 7.19E+06 L (1.9E+06 gal). There is no available report of another discharge. The 7.19E+06 value is assumed in Appendix A for conservatism.

216-T-28 (340 Bldg. Waste)					
Date	Vol (L)	U (kg)	Pu (g)	β (Ci)	Reference
Jan-60	0.00				HW-69071
Feb-60	8.80E+04	0.702	1.651	2.882	HW-69071
Mar-60	6.20E+04	4.545	0.000	6.787	HW-69071
Apr-60	1.60E+04	0.210	0.040	2.358	HW-69071
May-60	6.10E+04	2.504	0.143	1.738	HW-69071
Jun-60	1.79E+05	1.708	1.060	9.054	HW-69071
Jul-60	0.00	N/A	N/A	N/A	HW-69072
Aug-60	5.80E+04	3.122	0.019	13.848	HW-69072
Sep-60	6.70E+04	0.225	0.195	0.122	HW-69072
Oct-60	1.08E+05	0.962	0.223	1.757	HW-69072

ref. RPP-5957, Rev. 0

WASTE DISCHARGES TO TY CRIBS

216-T-28 (340 Bldg. Waste)					
Date	Vol. (L)	U (kg)	Pu (g)	β (Ci)	Reference
Nov-60	6.70E+04	0.009	0.212	0.009	HW-69072
Dec-60	1.89E+05	1.575	0.357	4.303	HW-69072
Jan-61	6.00E+03	0.004	0.228	0.228	HW-71971
Feb-61	1.30E+05	8.014	0.175	11.224	HW-71971
Mar-61	2.28E+05	0.621	0.296	45.950	HW-71971
Apr-61	1.17E+05	2.980	0.147	5.318	HW-71971
May-61	8.40E+04	0.209	0.009	2.388	HW-71971
Jun-61	2.76E+05	1.989	0.375	16.622	HW-71971
Jul-61	1.55E+05	4.040	0.174	5.594	HW-72956
Aug-61	2.20E+05	2.429	2.902	13.188	HW-72956
Sep-61	2.04E+05	3.925	0.242	2.750	HW-72956
Oct-61	1.70E+05	1.045	0.103	76.944	HW-72956
Nov-61	2.92E+05	2.225	0.216	13.514	HW-72956
Dec-61	3.06E+05	1.736	1.055	9.169	HW-72956
Jan-62	2.10E+05	1.900	0.120	26	HW-76638
Feb-62	3.00E+05	9.600	0.310	150	HW-76638
Mar-62	3.30E+05	3.800	4.000	37	HW-76638
Apr-62	2.90E+05	9.400	5.640	512	HW-76638
May-62	6.00E+04	0.100	0.020	39	HW-76638
Jun-62	0.00	N/A	N/A	N/A	HW-76638
Jul-62	5.20E+05	6.900	0.300	821	HW-76638
Aug-62	0.00	N/A	N/A	N/A	HW-76638
Sep-62	3.50E+05	1.400	N/A	394	HW-76638
Oct-62	1.90E+05	1.900	N/A	88	HW-76638
Nov-62	0.00	N/A	N/A	N/A	HW-76638
Dec-62	4.00E+05	5.900	0.110	128	HW-76638
Jan-63	1.90E+05	2.420	0.036	241	HW-80877
Feb-63	1.20E+05	0.980	0.033	42	HW-80877

ref · RPP-5957, Rev. 0

WASTE DISCHARGES TO TY CRIBS

Mar-63	0.00	N/A	N/A	N/A	HW-80877
Apr-63	2.90E+05	2.580	0.093	675	HW-80877
May-63	2.70E+05	3.570	0.326	185	HW-80877
Jun-63	1.90E+05	1.340	0.114	504	HW-80877
Jul-63	1.70E+05	0.720	0.044	2926	HW-80877
Aug-63	0.00	N/A	N/A	N/A	HW-80877
Sep-63	2.00E+05	2.020	0.052	134	HW-80877
Oct-63	1.70E+06	1.920	0.883	868	HW-80877
Nov-63	1.75E+06	1.570	1.575	1215	HW-80877
Dec-63	1.34E+06	0.200	37.000	126	HW-80877
Jan-64	1.80E+06	2.702	1.055	2186	BNWC-91
Feb-64	1.18E+06	0.468	0.067	41	BNWC-91
Mar-64	1.71E+06	6.110	1.731	4416	BNWC-91
Apr-64	1.10E+06	0.164	0.060	193	BNWC-91
May-64	1.76E+06	2.552	2.574	2062	BNWC-91
Jun-64	1.21E+06	1.660	0.341	2076	BNWC-91
Jul-64	1.14E+06	2.160	3.510	420	BNWC-91
Aug-64	1.20E+06	204.999	2.260	1495	BNWC-91
Sep-64	1.26E+06	26.850	1.363	4301	BNWC-91
Oct-64	1.06E+06	1.400	3.100	711	BNWC-91
Nov-64	1.25E+06	1.290	1.649	640	BNWC-91
Dec-64	1.86E+06	0.00	0.054	139	BNWC-91
Jan-65	1.30E+06	N/A	1.0	934	ISO-98
Feb-65	1.00E+06	N/A	7.4	200	ISO-98
Mar-65	2.30E+06	N/A	4.7	8427	ISO-98
Apr-65	2.10E+06	N/A	5.8	2335	ISO-98
May-65	1.10E+06	N/A	3.7	970	ISO-98
Jun-65	2.30E+06	N/A	0.3	1489	ISO-98
Jul-65	1.10E+06	N/A	1.4	957	ISO-98
Aug-65	1.80E+06	N/A	4.6	14940	ISO-98

ref. RPP-5957, Rev. 0

WASTE DISCHARGES TO TY CRIBS

Sep-65	0.00	N/A	N/A	N/A	ISO-98
Oct-65	0.00	N/A	N/A	N/A	ISO-98
Nov-65	0.00	N/A	N/A	N/A	ISO-98
Dec-65	2.00E+05	N/A	1.1	124	ISO-98
Jan-66	3.20E+05	3.100	0.900	63.100	ISO-698
Jul-66	3.10E+05	4.790	0.100	91.500	ISO-698
Total	4.23E+07	361	109	58567	

Curies are uncorrected for decay.

ref - RPP-5957, Rev. 0

APPENDIX H

WASTE DISCHARGES TO TRENCHES 216-T-34, 216-T-35, AND 216-T-36

ref. RPP-5957, Rev. 0

WASTE DISCHARGES TO TRENCHES 216-T-34, 216-T-35, AND 216-T-36

216-T-34 DISCHARGE HISTORY (340 Bldg. Waste)										
Date	Vol (L)	U (kg)	Pu (g)	β (Ci)	^{60}Co (Ci)	^{90}Sr (Ci)	^{137}Cs (Ci)	^{106}Ru (Ci)	^{144}Ce (Ci)	Reference
May-66	8.33E+05	0.38	N/A	308	N/A	N/A	N/A	N/A	N/A	ISO-698
Jun-66	1.08E+06	0.06	0.00	393	N/A	N/A	N/A	N/A	N/A	ISO-698
Jul-66	5.30E+05	0.50	1.40	280	N/A	N/A	N/A	N/A	N/A	ISO-698
Aug-66	1.19E+06	0.50	94.50	3150	N/A	N/A	N/A	N/A	N/A	ISO-698
Sep-66	1.38E+06	0.60	4.70	4380	N/A	N/A	N/A	N/A	N/A	ISO-698
Oct-66	1.48E+06	0.06	2.00	3159	N/A	N/A	N/A	N/A	N/A	ISO-698
Nov-66	1.80E+06	0.35	4.75	665	N/A	N/A	N/A	N/A	N/A	ISO-698
Dec-66	1.67E+06	N/A	N/A	61	N/A	N/A	N/A	N/A	N/A	ISO-698
Jan-67	1.44E+06	0.22	0.48	755	1.49	0.51	1.55	N/A	N/A	ARH-486
Feb-67	1.31E+06	0.52	0.83	425	0.68	0.88	2.29	N/A	N/A	ARH-486
Mar-67	5.50E+05	0.20	0.87	61	0.16	1.52	1.23	N/A	N/A	ARH-486
Total (est.)	1.73E+07	4.12	107.20	26241	7.33	322.90	275.10	275.10	100	ARH-486

Curies are uncorrected for decay.

216-T-35 DISCHARGE HISTORY (340 Bldg. Waste)											
Date	Vol (L)	U (kg)	Pu (g)	β (Ci)	^{60}Co (Ci)	^{90}Sr (Ci)	^{137}Cs (Ci)	^{106}Ru (Ci)	^{144}Ce (Ci)	^{147}Pm (Ci)	Reference
Mar-67	7.19E+05	0.230	12.00	78.10	0.18	0.72	2.50	16.00	14.00	21.00	ARH-486
Apr-67	1.55E+06	48.000	2.60	96.00	1.50	2.00	5.60	19.00	92.00	34.00	ARH-486
May-67	7.57E+05	0.222	9.90	140.00	1.00	0.76	4.90	64.00	60.00	75.00	ARH-486
Jun-67	1.15E+06	0.127	20.00	164.00	0.43	6.20	4.10	20.00	44.00	23.00	ARH-486
Jul-67	5.30E+05	0.163	13.00	150.00	0.08	0.74	0.85	4.30	9.00	13.00	ARH-486
Aug-67	6.81E+05	0.077	2.60	96.00	0.06	0.05	1.10	2.90	8.60	0.51	ARH-486
Sep-67	1.89E+05	0.054	1.00	119.00	0.13	0.03	0.43	2.10	9.50	7.67	ARH-486
Oct-67	0.00										ARH-486
Nov-67	3.80E+04	0.011	4.80	2.80	0.00	0.03	0.09	0.25	0.49	0.79	ARH-486
Dec-67	0.00										ARH-486

ref - RPP-5957, Rev. 0

WASTE DISCHARGES TO TRENCHES 216-T-34, 216-T-35, AND 216-T-36

216-T-35 DISCHARGE HISTORY (340 Bldg. Waste)											
Date	Vol (L)	U (kg)	Pu (g)	β (Ci)	^{60}Co (Ci)	^{90}Sr (Ci)	^{137}Cs (Ci)	^{106}Ru (Ci)	^{144}Ce (Ci)	^{147}Pm (Ci)	Reference
Jan-68	1.14E+05	0.006	0.30	83.00	0.03	9.50	0	1.77	7.30	84.00	ARH-1159
Total	5.73E+06	48.890	66.20	928.90	3.42	20.03	19.98	130.32	244.89	258.97	

Curies are uncorrected for decay.

216-T-36 DISCHARGE HISTORY (221-T Decontamination Waste)												
Date	Vol (L)	U (kg)	Pu (g)	β (Ci)	^{60}Co (Ci)	^{90}Sr (Ci)	^{137}Cs (Ci)	^{106}Ru (Ci)	^{144}Ce (Ci)	^{147}Pm (Ci)	^{125}Sb (Ci)	Reference
May-67	6.70E+04	0.208	0.200	30.70	0.002	0.37	0.62	2.05	3.40	1.10	0.25	ARH-486
Jun-67	1.10E+05	0.240	0.040	9.57	0.160	4.97	1.60	36.32	24.40	7.91	0.50	ARH-486
Jul-67	5.30E+04	0.001	0.002	21.00	0.001	0.74	0.15	0.48	1.14	3.00	0.06	ARH-486
Aug-67	1.06E+05	0.104	1.610	26.80	0.038	1.43	1.35	3.52	17.90	7.23	0.44	ARH-486
Sep-67	0.00											ARH-486
Oct-67	0.00											ARH-486
Nov-67	3.50E+04	0.136	0.600	4.10	0.002	0.10	0.70	1.78	0.10	0.81	N/A	ARH-486
Dec-67	0.00											ARH-486
Oct-68	5.07E+04	0.121	0.003	0.91	0.07	0.08	0.50	0.11	0.05	0.27	N/A	ARH-1159
Dec-68	5.07E+04	0.241	0.028	0.10	0.24	0.02	1.40	1.60	0.32	0.25	N/A	ARH-1159
Jan-69	5.07E+04	0.127	0.001	0.28	0.00	0.00	0.10	0.22	N/A	N/A	N/A	ARH-1608
Total	5.23E+05	1.178	2.48	93.46	0.52	7.72	6.42	46.08	47.31	20.57	1.25	

Curies are uncorrected for decay.

APPENDIX B

SUPPORTING STRATIGRAPHIC INFORMATION

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APPENDIX B

SUPPORTING STRATIGRAPHIC INFORMATION

This appendix contains a series of cross sections and structural contour maps that delineate the stratigraphy underlying the T and TX-TY WMAs. The locations of the cross sections are shown in Figure B-1.

Figure B-1. Borehole Location Map.

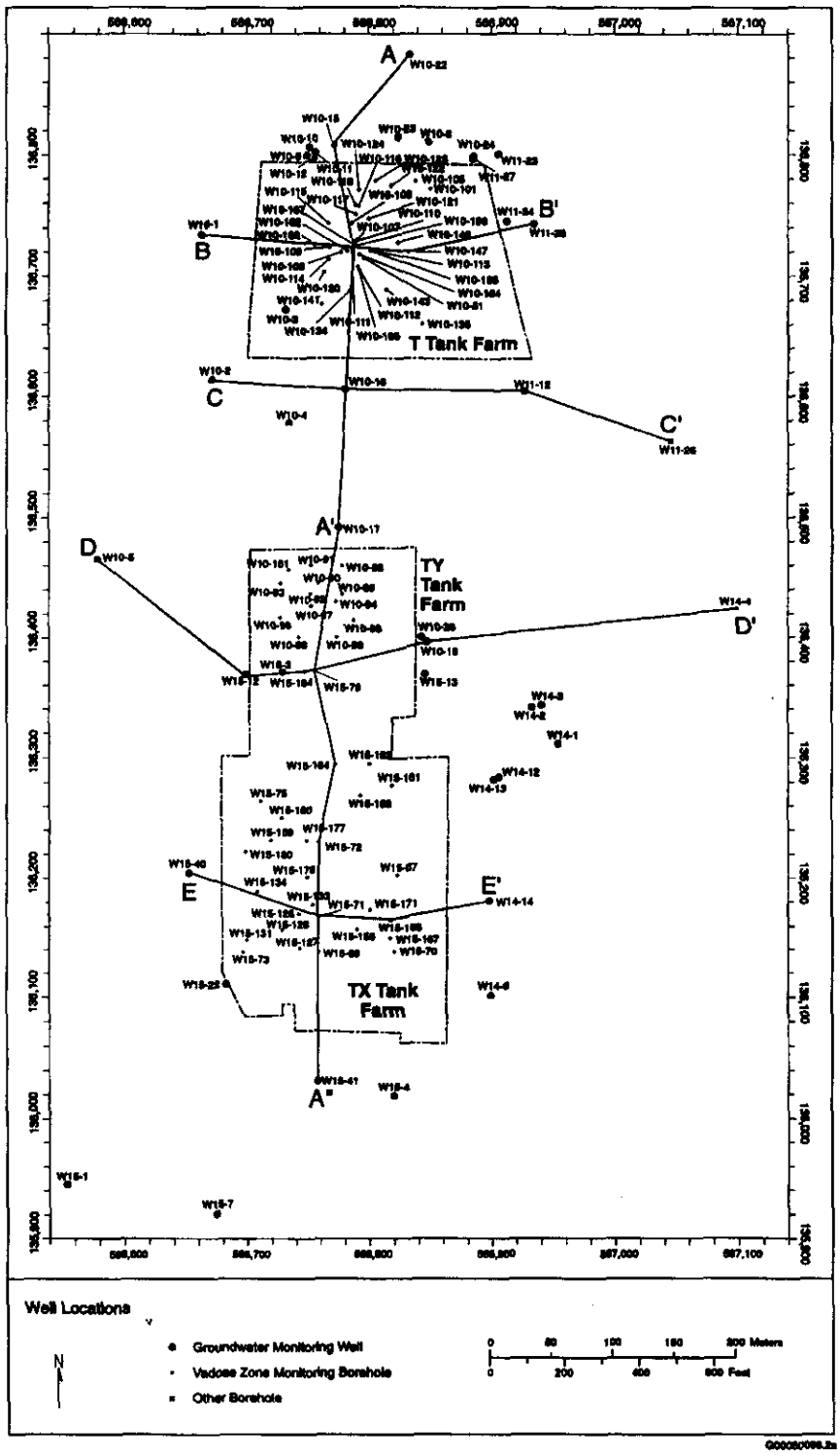


Figure B-2. Geologic Cross Section A-A'.

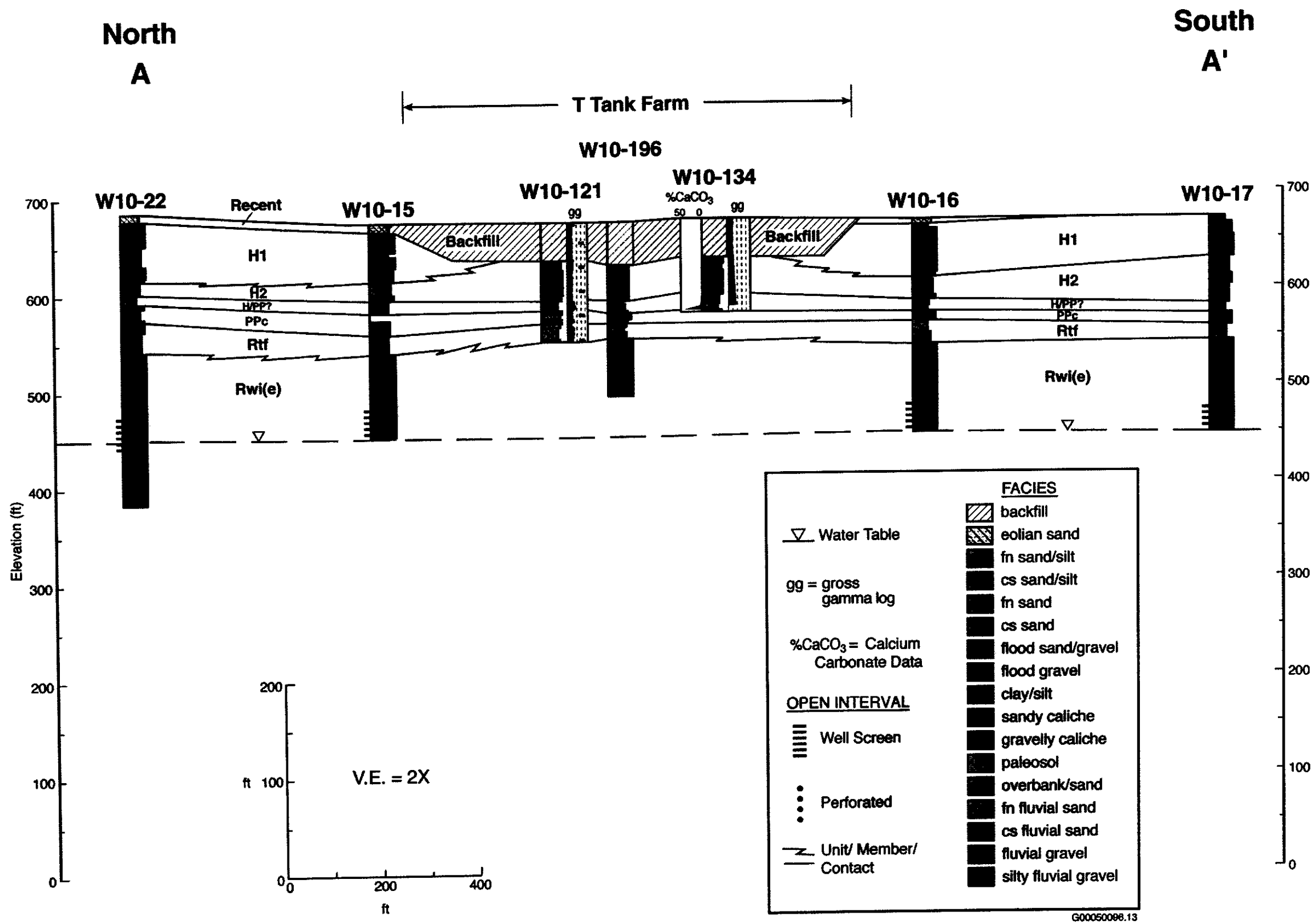


Figure B-3. Geologic Cross Section A'-A".

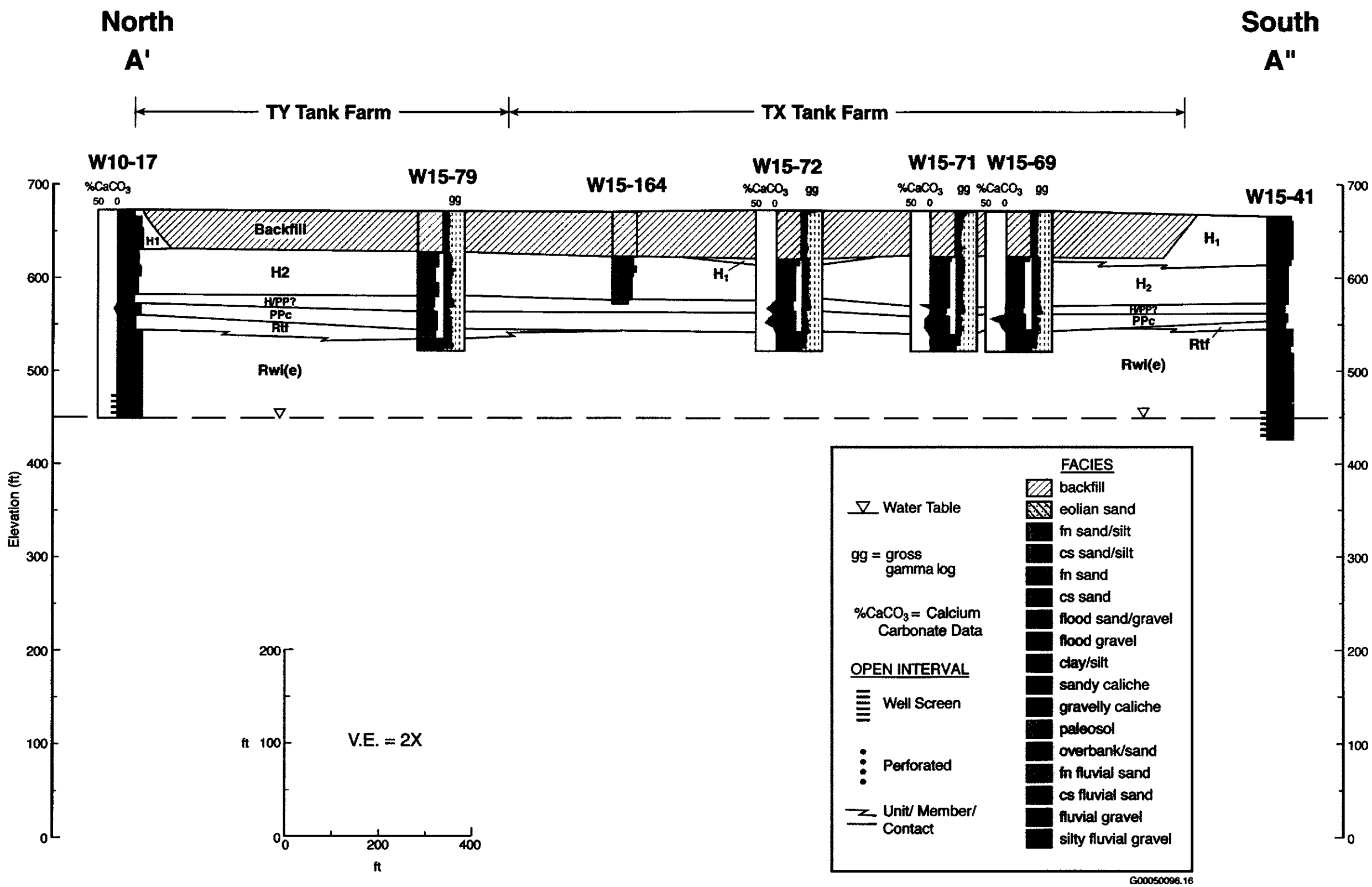


Figure B-4. Geologic Cross Section B-B'

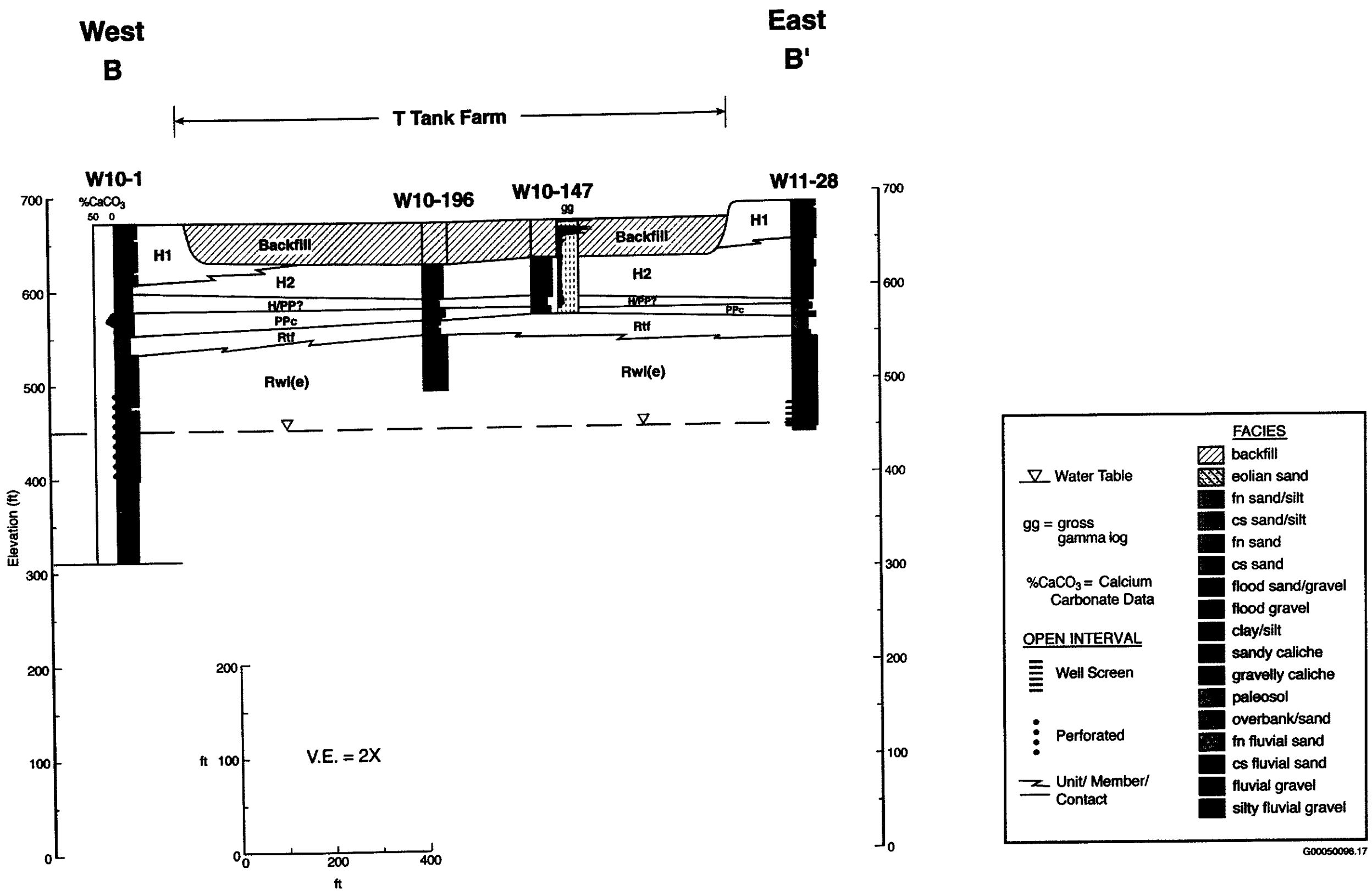


Figure B-5. Geologic Cross Section C-C'.

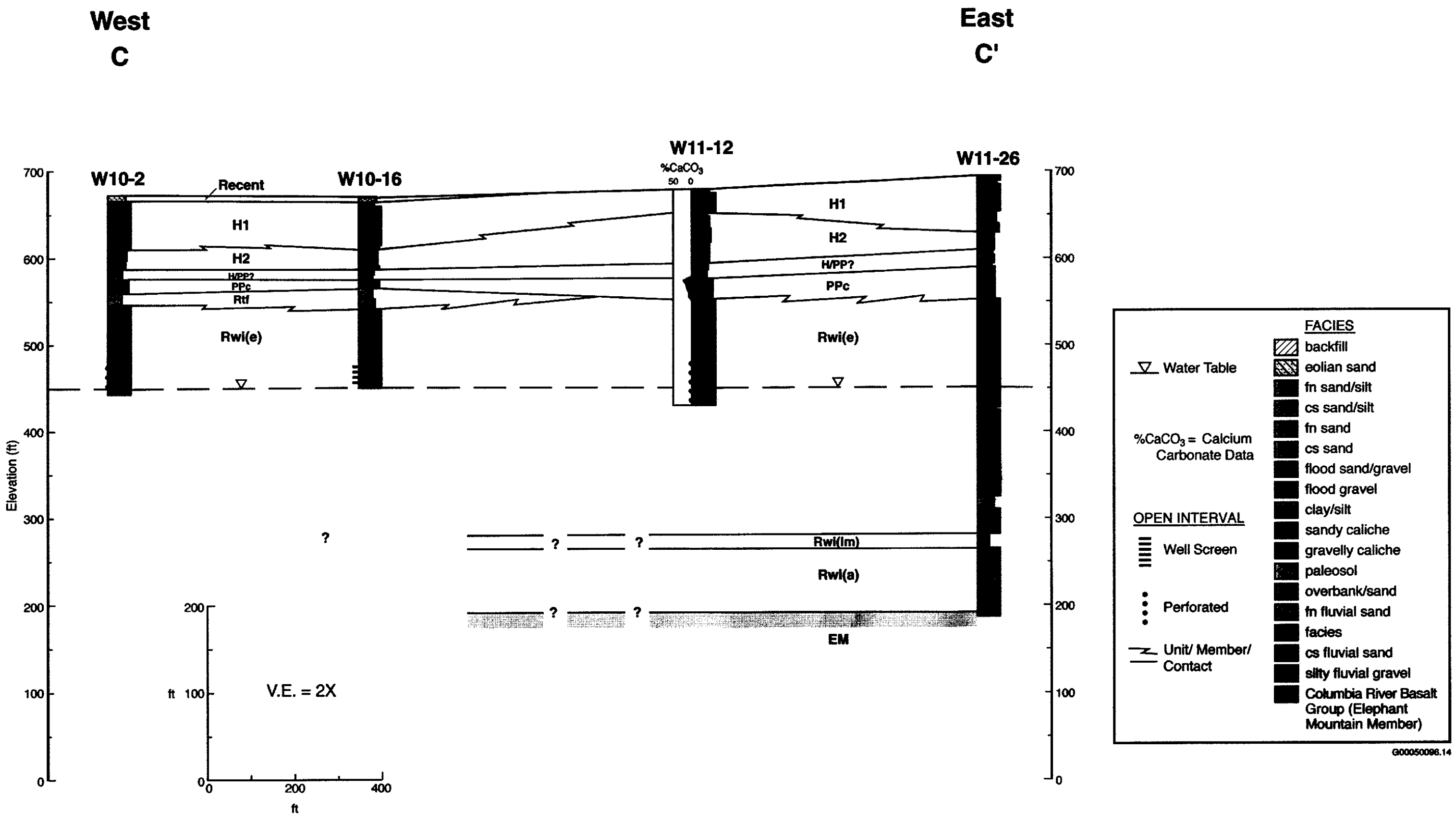


Figure B-6. Geologic Cross Section D-D'.

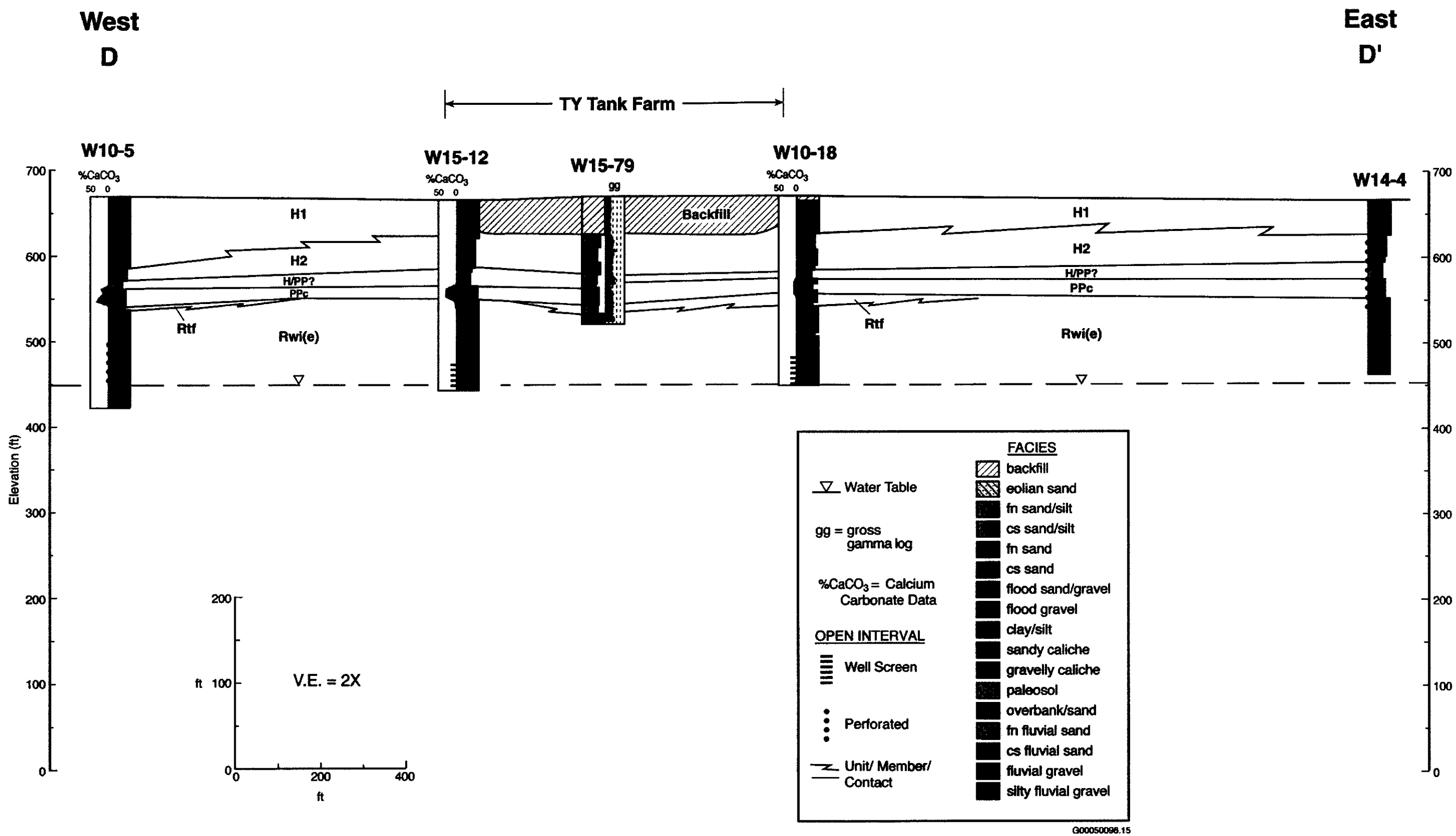


Figure B-7. Geologic Cross Section E-E'.

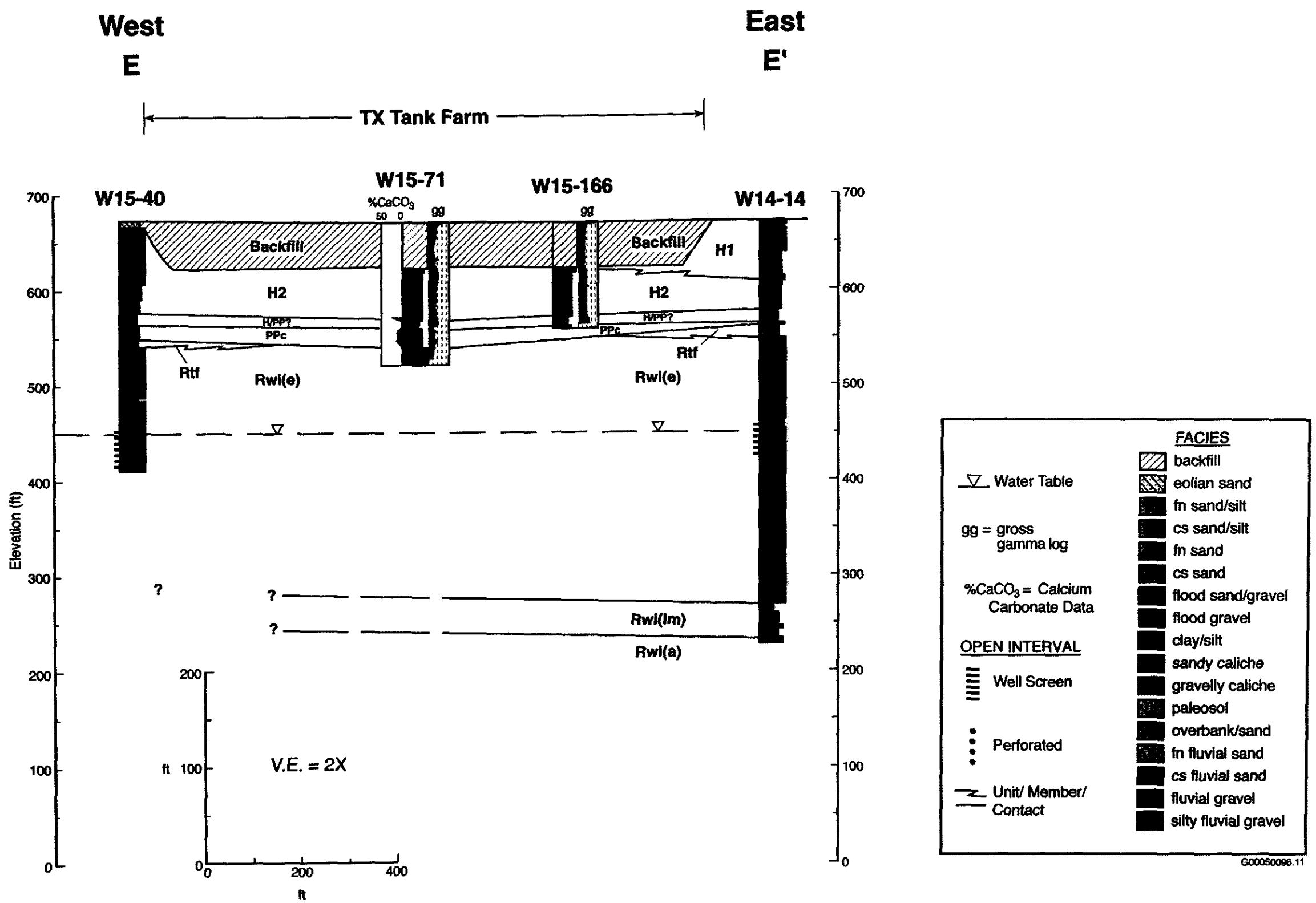


Figure B-8. Structure Contour Map on Top of Ringold Unit E.

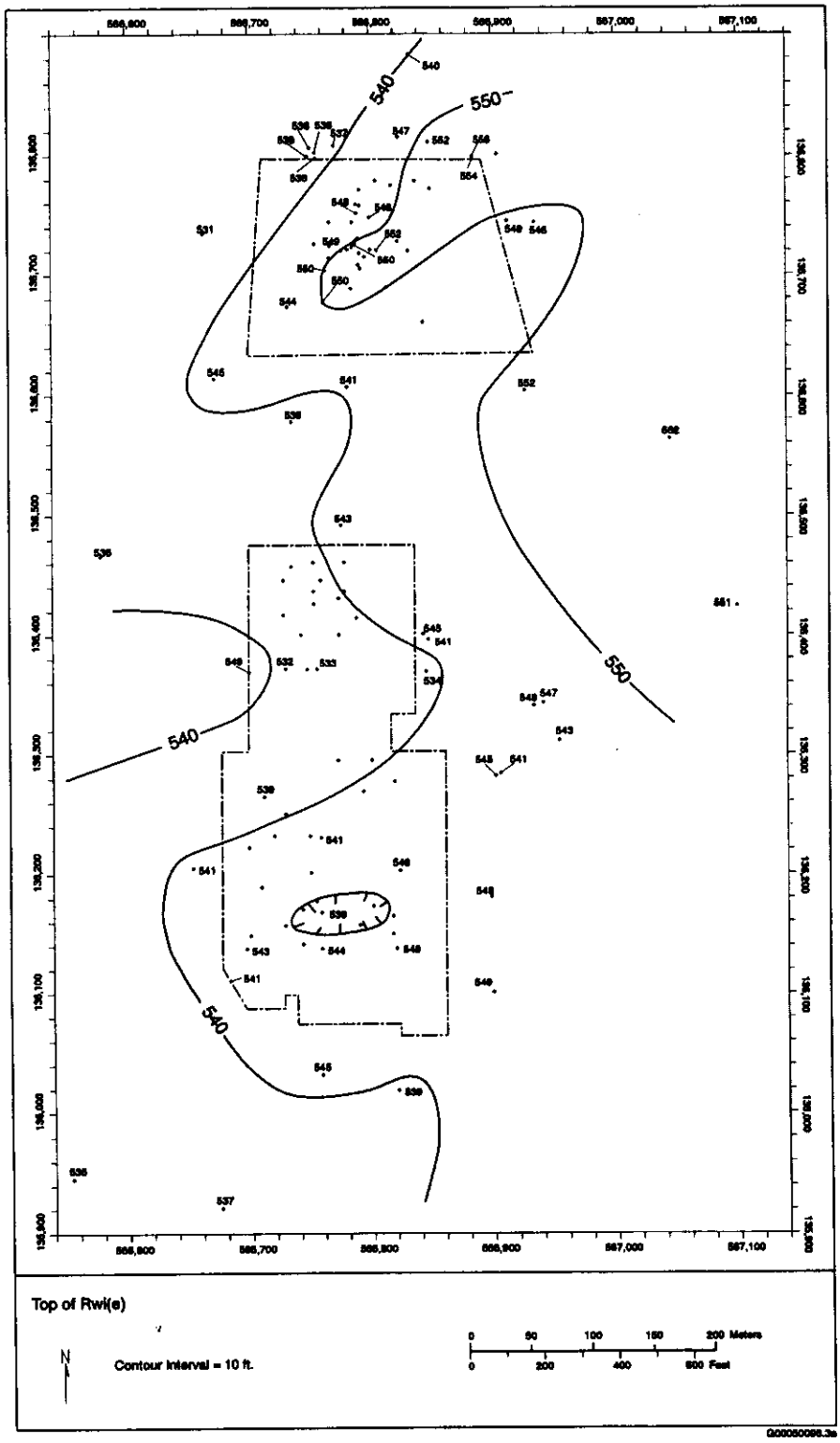


Figure B-9. Isopach Thickness Map of the Member of Taylor Flat (Upper Ringold Unit).

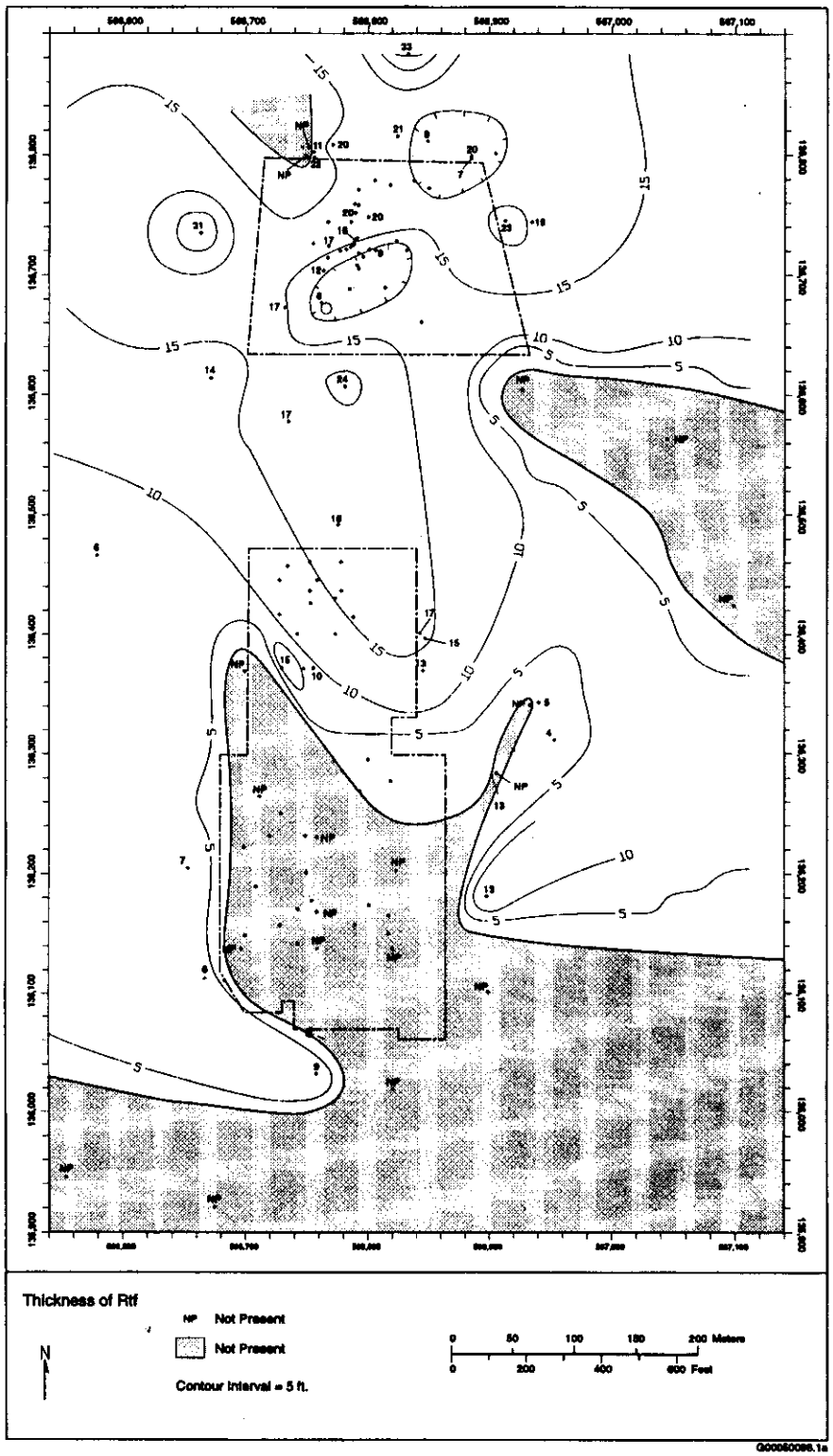


Figure B-10. Structure Contour Map on Top of Member of Taylor Flat (Upper Ringold Unit).

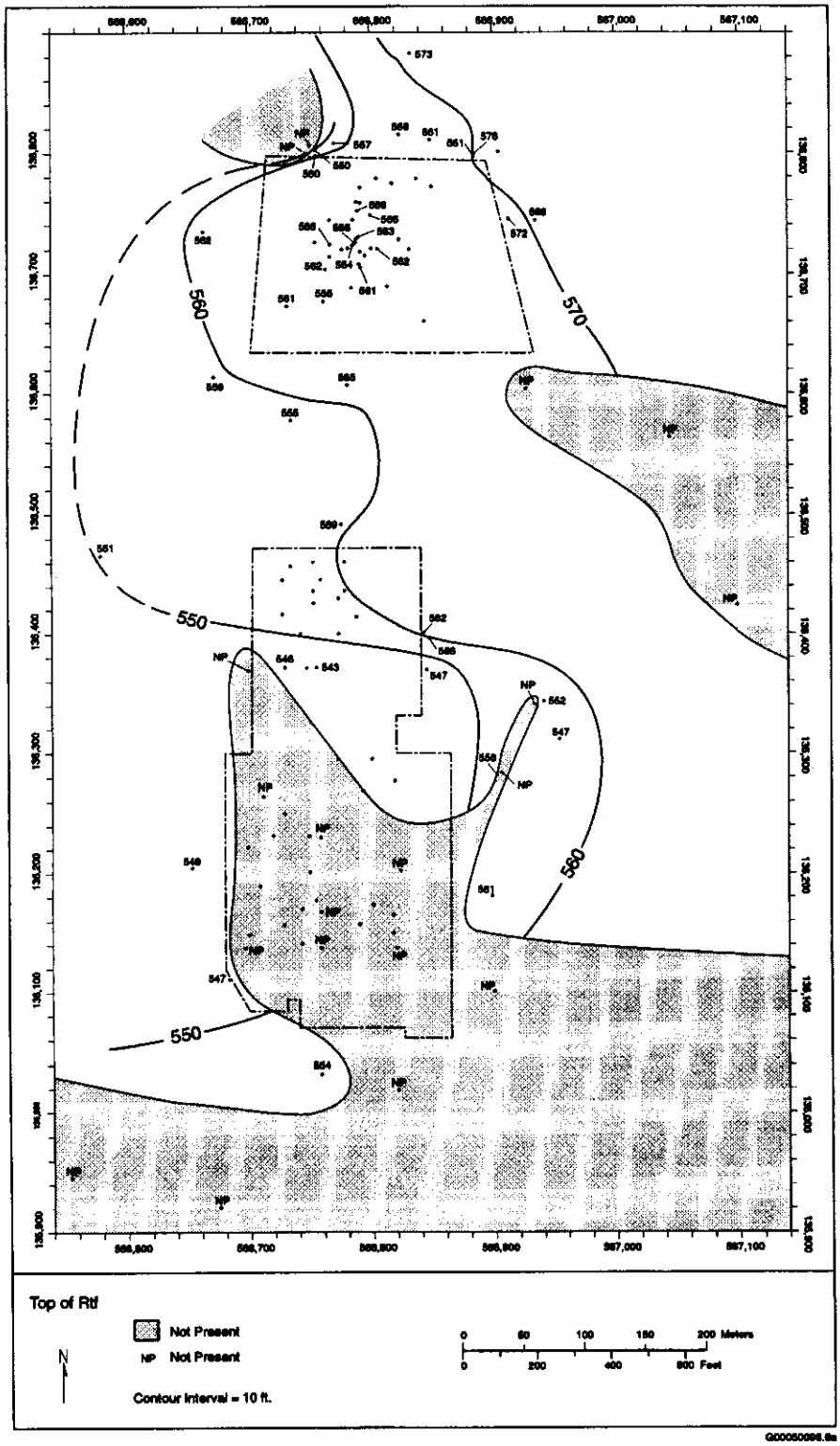


Figure B-11. Structure Contour Map on Top of the Plio-Pleistocene Calcrete.

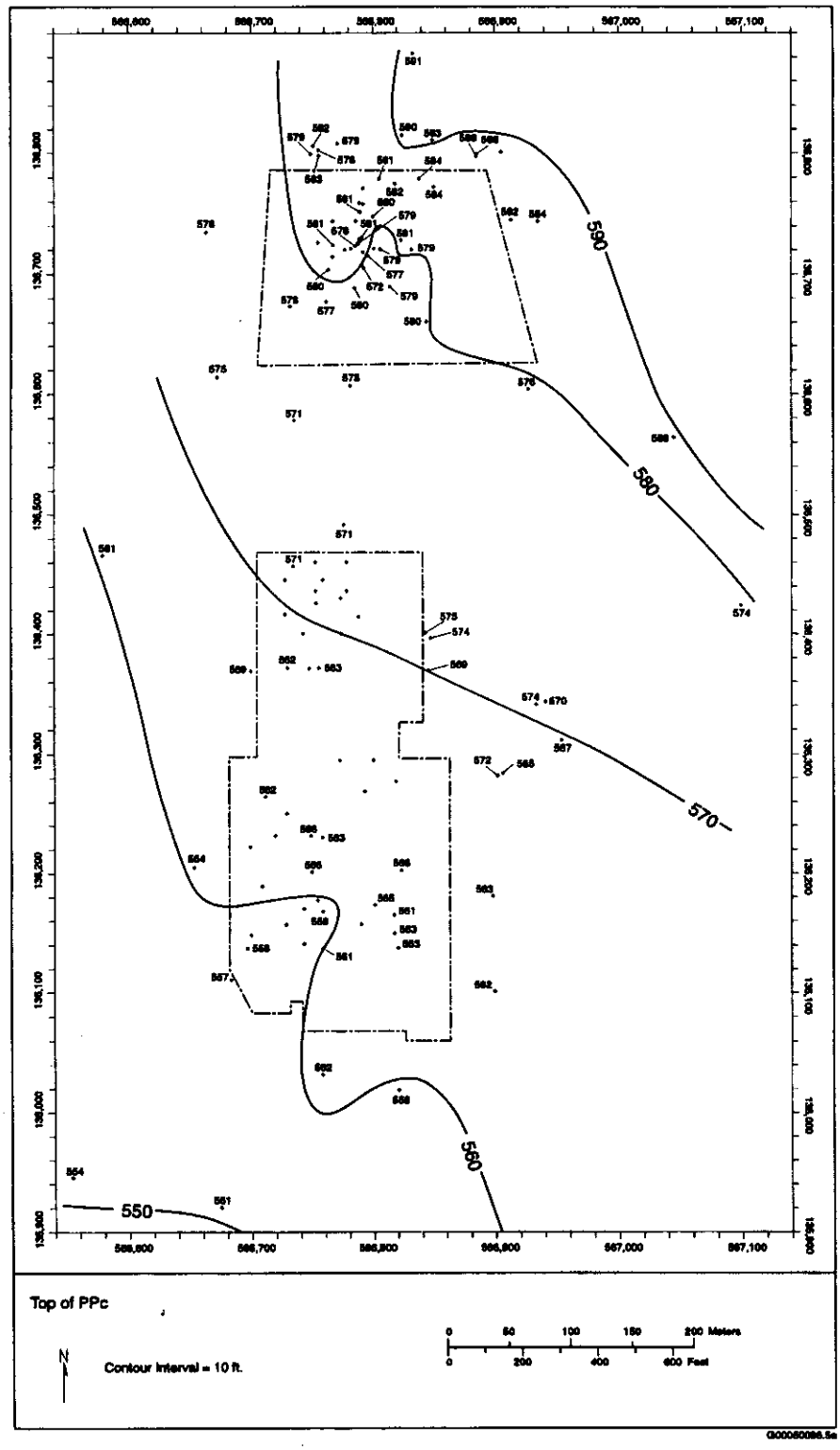


Figure B-12. Isopach Thickness Map of the Plio-Pleistocene Calcrete.

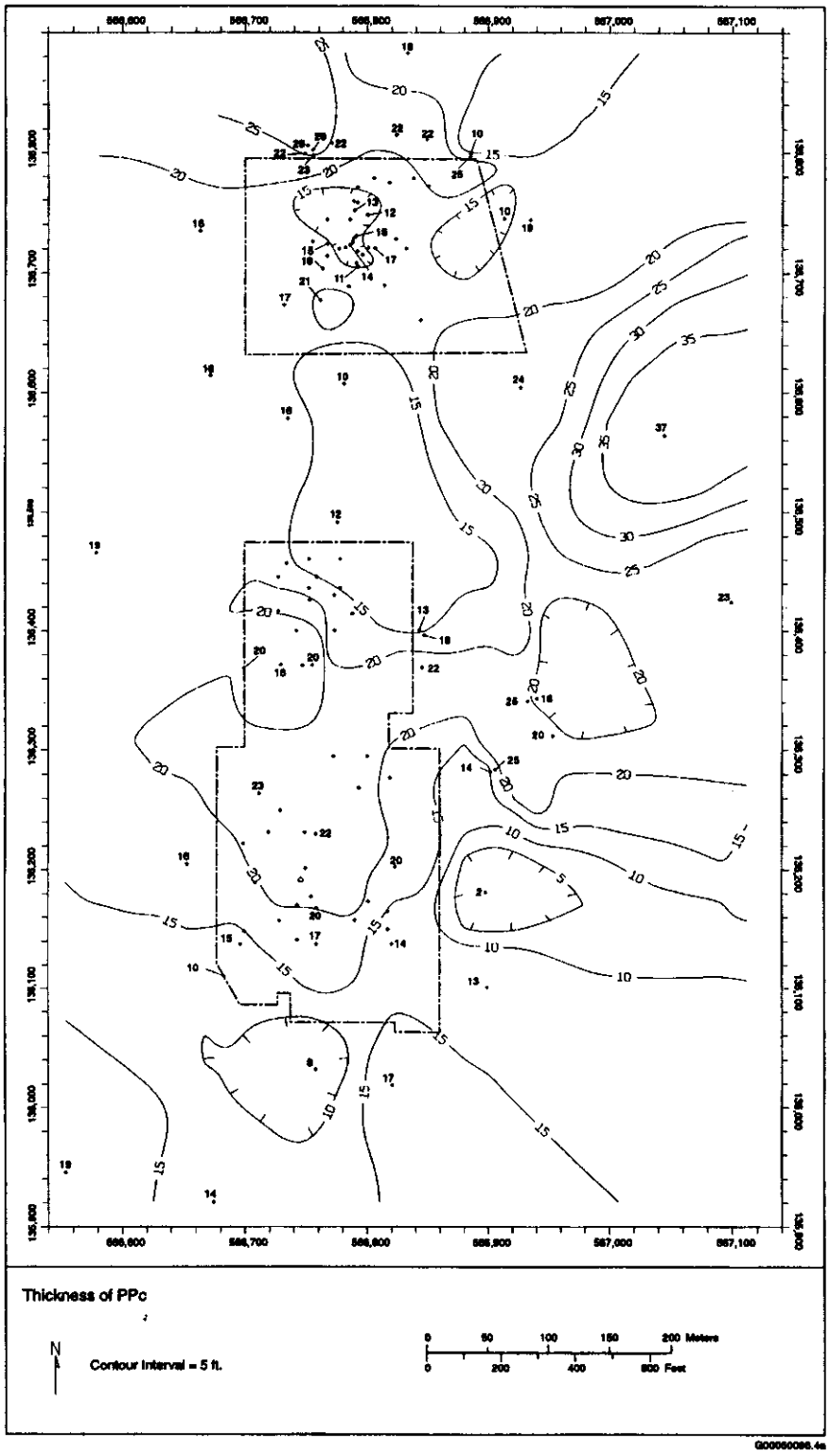


Figure B-13. Structure Contour Map on Top of H/PP Deposits.

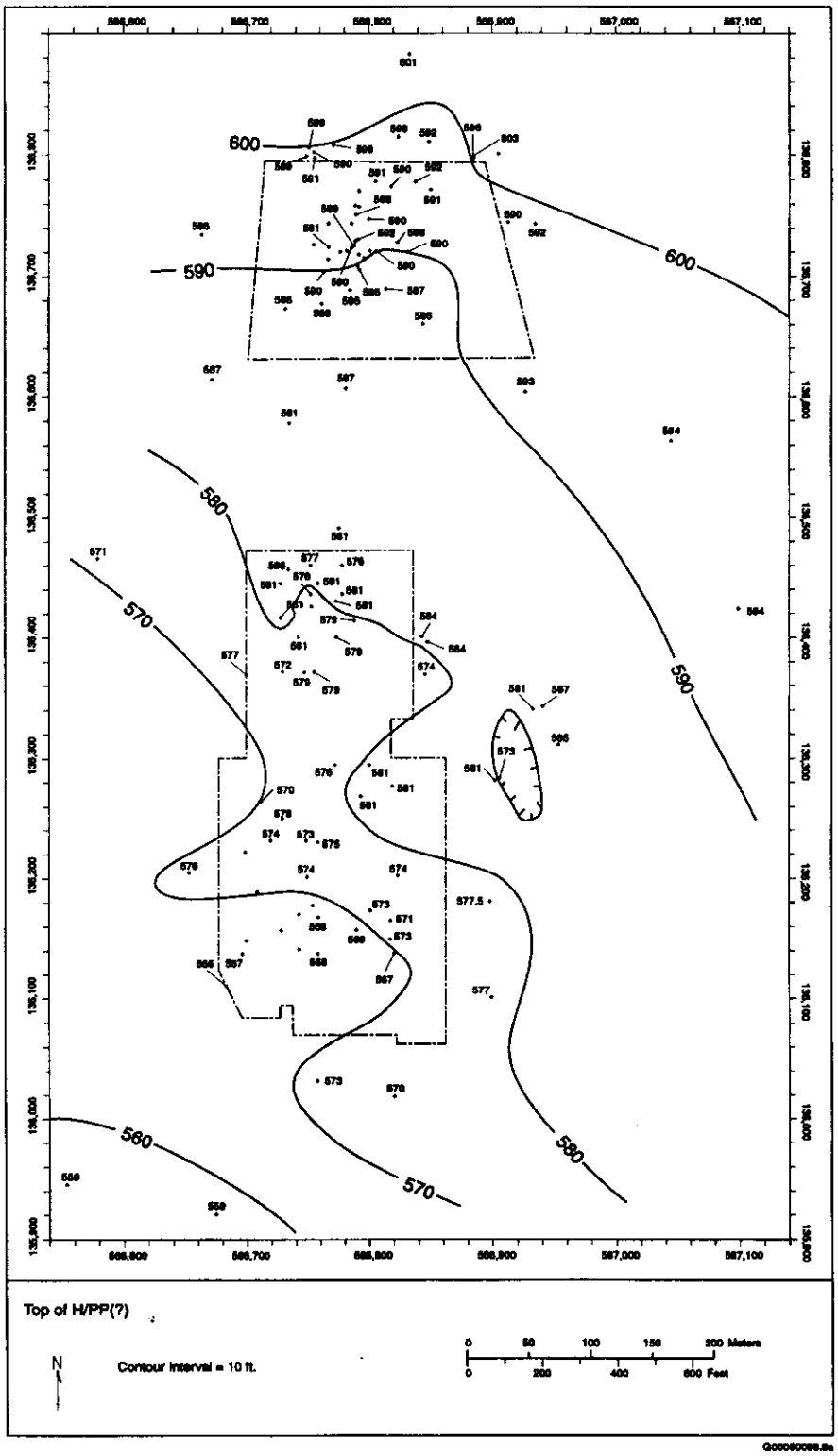


Figure B-14. Isopach Thickness Map of the H/PP Deposits.

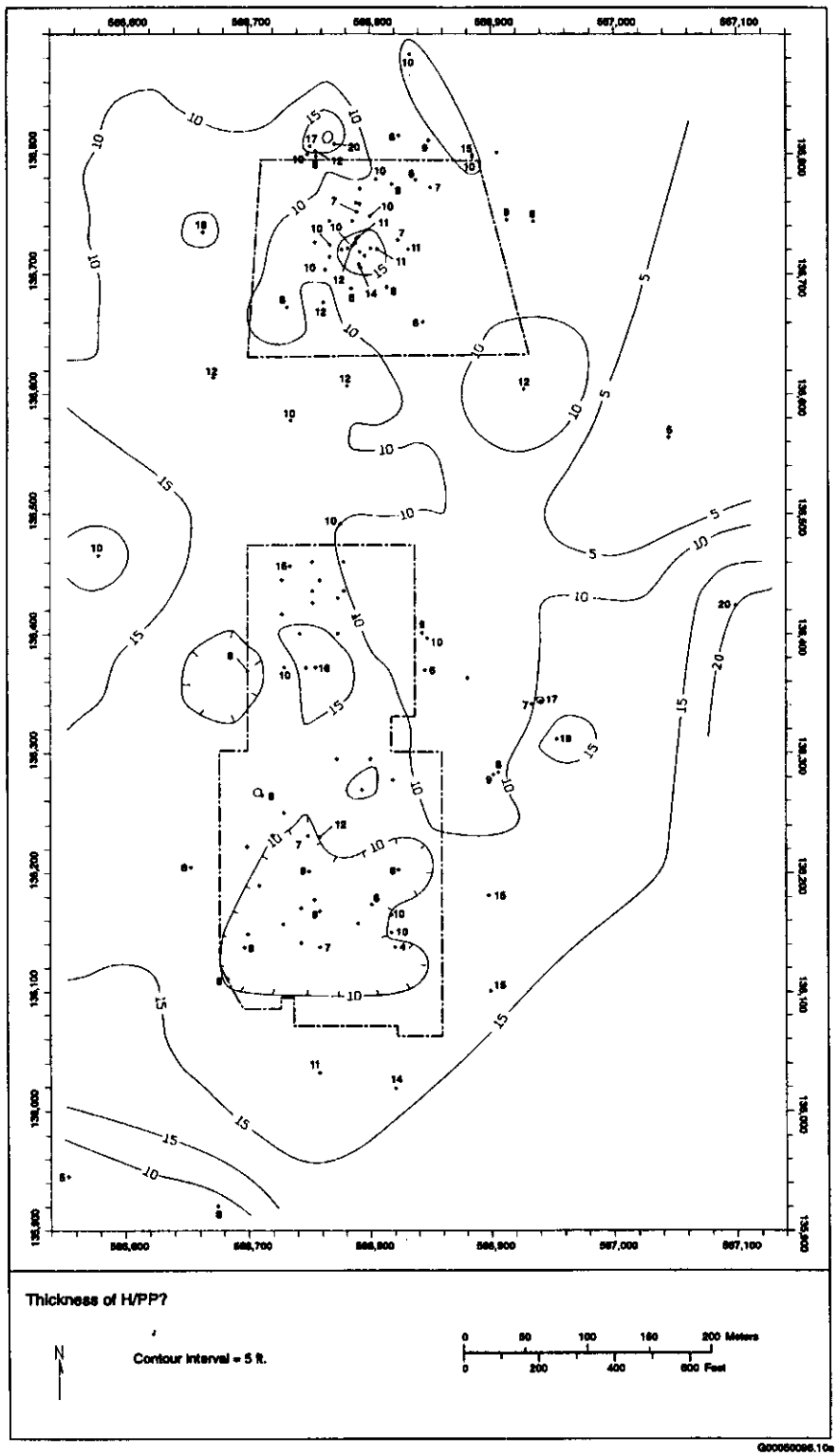


Figure B-15. Structure Contour Map on Top of Hanford Formation Fine-Grained Sequence (H2 Unit).

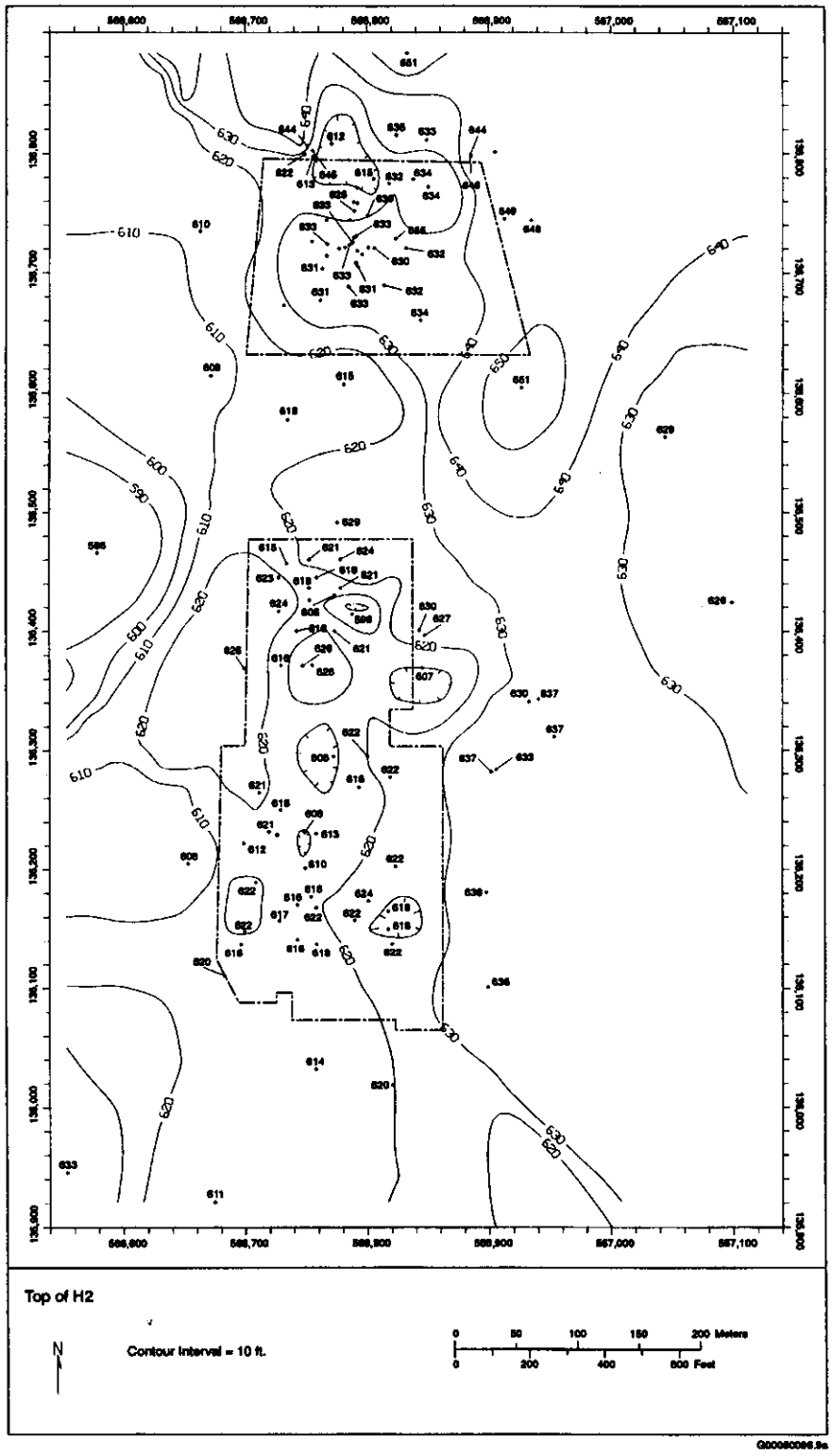


Figure B-16. Isopach Thickness Map of the Hanford Formation Fine-Grained Sequence (H2 Unit).

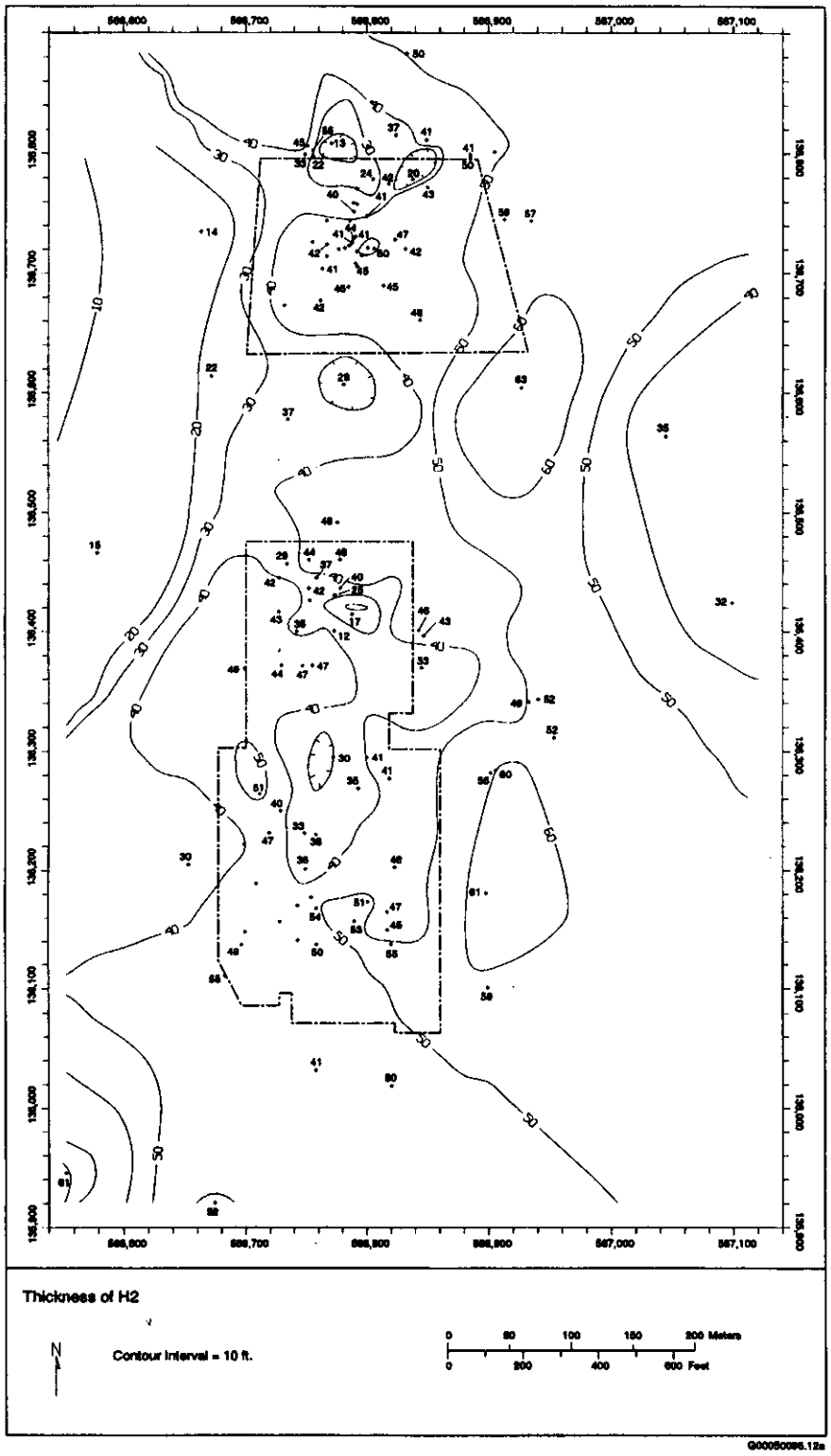
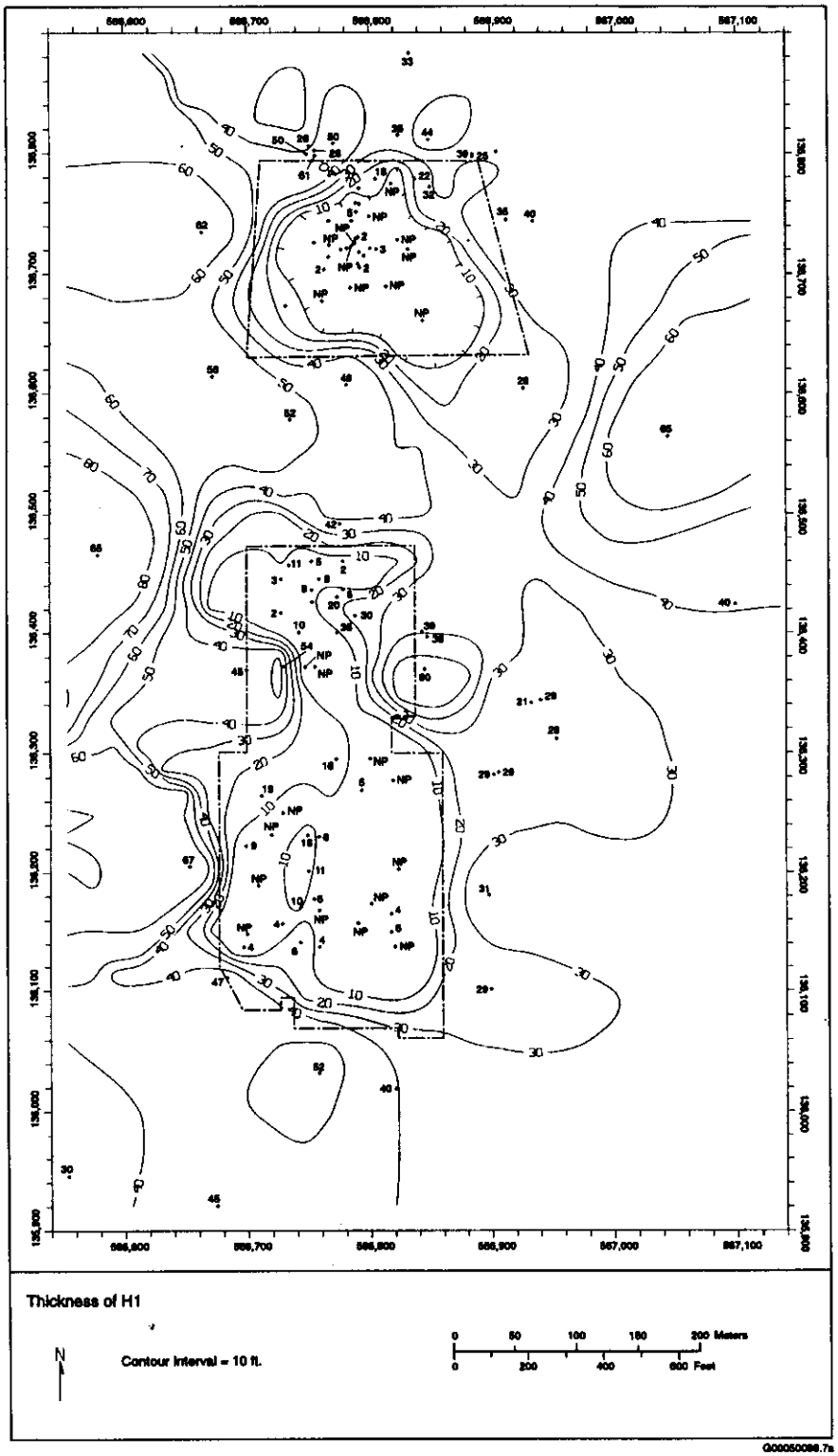


Figure B-17. Isopach Thickness Map of the Hanford Formation Coarse-Grained Sequence (H1 Unit).



APPENDIX C

BOREHOLE SUMMARY LOGS

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APPENDIX C

BOREHOLE SUMMARY LOGS

Sediment facies are defined on the basis of unique physical properties, such as grain size, color, sedimentary structure, and mineralogy and their use allows geologists to characterize sediment properties and interpret sediment origins consistently (Walker 1984, 1994; Reading 1986). The facies identified on the borehole logs are interpreted from borehole geologic and drillers' logs, split-spoon samples of analogous strata elsewhere at the Hanford Site, laboratory analytical data, natural-gamma response on geophysical logs, and outcrop observations. Based on this information, facies descriptions given below include observed and inferred physical characteristics such as dominant and subordinate grain size, stratification, color, friability, cohesion, induration, cement, calcium carbonate reaction, and general mineralogy. Terminology used in these descriptions are based on usage described in Compton (1962), Folk (1974), Collinson (1986), Reading (1986), and Miall (1994).

Backfill. Backfill predominantly consists of loose, poorly sorted fine to coarse sand and pebble-cobble gravel with minor silt; colors typically range from dark grayish brown to olive brown; calcium carbonate reaction is typically slight to moderate.

Fine Sand/Silt. Stratified, alternating beds of friable, sandy silt to silty fine sand; individual beds are less than an inch to several inches thick; planar laminae, ripple cross lamination, and isolated medium to coarse sand layers 1.27 cm (<0.5 in. thick) are present; colors range from light gray to olive gray to olive; mineralogy is dominantly felsic and micaceous; calcium carbonate reaction is moderate to strong, usually disseminated (i.e., detrital).

Coarse Sand/Silt. Stratified, friable, fine to medium sand with minor interbedded silty sand; individual beds are a few centimeters to several centimeters thick; planar laminae, ripple cross lamination, and normally graded intervals are several inches or more thick; colors range from olive gray to olive; mineralogy is dominantly arkosic, although basalt lithic grains locally can exceed 25 percent in coarser fractions (giving a speckled or salt-and-pepper appearance); calcium carbonate reaction is weak to strong.

Fine Sand. Stratified, friable, fine to medium sand; commonly displays platy bedding cleavage, planar lamination, and normally graded bedding; normally graded intervals are 0.5 to 1 m (1.6 to 3.3 ft) thick, grading upwards from more basaltic to more felsic sand; colors include dark grayish brown, olive brown, and olive; calcium carbonate reaction is weak to strong.

Coarse Sand. Stratified, friable, medium to coarse sand with a trace of granules; planar lamination and normally graded bedding are present; normally graded intervals are 0.5 to 1 m (1.6 to 3.3 ft) thick, grading upwards from more basaltic to more felsic sand; fine sand occurs as thin <7.62 cm (<3 in.) thick interbeds throughout the facies; colors include dark grayish brown, olive brown, and olive; calcium carbonate reaction is weak to strong.

Flood Sand/Gravel. Friable, medium to coarse sand, granules, and pebble gravel; bedding character not well expressed in split spoon samples, although grain size and color variations

suggest the presence of bedding features a few centimeters to several tens of centimeters thick that are inferred to be associated with larger scale cross-bedded features; pebble content is estimated to generally be less than 25 percent in hand sample, the largest unbroken pebbles are less than 4 cm (2 in.) in diameter (larger broken pebbles are rare), and gravel is typically matrix supported; coarse sand, granule, and the gravel fraction is basalt-dominated; colors range from olive gray to gray and a salt-and-pepper speckling is common because of a high basalt content in the coarse sand fraction; calcium carbonate reaction is weak to moderate.

Flood Gravel. Friable, pebble-cobble gravel with minor medium-granule sand matrix; outcrops sometimes show a matrix-poor open framework character; bedding not typically well expressed in split spoon samples, although color and grain size variations, coupled with outcrop observations, suggest these deposits typically are stratified; clast lithology typically exceeds 50 percent; basalt and coarse/granule sand fraction typically exceeds 75 percent basalt; if clay or silt is present, facies outcrop observations suggest that it is associated predominantly with clast coatings and less frequently with discrete interbeds.

Clay/Silt. Massive, moderately plastic, cohesive silt to clay, contains little to no visible sand; facies is blocky and displays little to no observable evidence of bedding; oxidized mottles and dark organic fragments are present; color typically is olive; calcium carbonate reaction is weak to moderate. Well-laminated gray to brown clay or silt layer indicates a lacustrine environment.

Sandy Caliche. Massive, fine to coarse sand containing calcium carbonate as filaments, clasts, nodules, and/or discrete petrocalcic layers (Stage II to IV); sand typically consists of a mix of basalt (alluvial-derived) and felsic mineralogies (reworked Ringold); calcium carbonate content may range from 10 to 50 percent. Colors range from gray to white.

Gravelly Caliche. Massive, fine to coarse sand, granules, and pebble gravel containing calcium carbonate as coatings, filaments, clasts, and/or thin petrocalcic layers; sand and gravel ranges from predominantly basalt (more than 90 percent) to felsic; colors range from gray to white; calcium carbonate reaction is variable, from weak on clean grains to strong on calcium carbonate pieces and/or coatings.

Paleosol. Massive to blocky or crumbly silt with minor clay and fine sand; sometimes mottled and/or bioturbated; decomposed organic matter common; faint remnant bedding, disrupted beds, and root/burrow traces can be present; calcium carbonate reaction is weak to strong; colors include shades of green, blue, olive, brown, gray, and black.

Overbank/Sand Facies. In the Hanford formation, consists of massive silty fine sand containing black, possibly organic filaments, mottles suggestive of bioturbation, light olive to brown colors, and moderate to strong calcium carbonate reaction; in the Ringold Formation consists of silty fine to silty coarse sand containing disrupted beds, floating gravel clasts, variable induration, speckled colors ranging from white-gray to gray brown, and little to no calcium carbonate.

Fine Fluvial Sand. Fine to medium grained, friable sand; where basalt content exceeds 25 percent the facies has a salt-and-pepper look; white mica flakes are common and minor (less than 10 percent) pebbles are present; felsic grains are commonly stained yellow brown; induration is slight to moderate; calcium carbonate reaction is weak to absent.

Coarse Fluvial Sand. Medium to coarse grained, friable sand; where basalt content exceeds 25 percent the facies has a salt and pepper look; white mica flakes are common and minor (less than 10 percent) pebbles are present; felsic grains are commonly stained yellow brown; induration is slight to moderate; calcium carbonate reaction is weak to absent.

Fluvial Gravel. Variably indurated, bimodal, moderately to well sorted, fine to coarse sand and pebble/cobble gravel typical of Ringold Formation conglomerate (Lindsey 1996); matrix sand typically is felsic and yellow brown in color; clasts are multi-lithologic and range from clast to matrix supported; calcium carbonate reaction is weak to absent.

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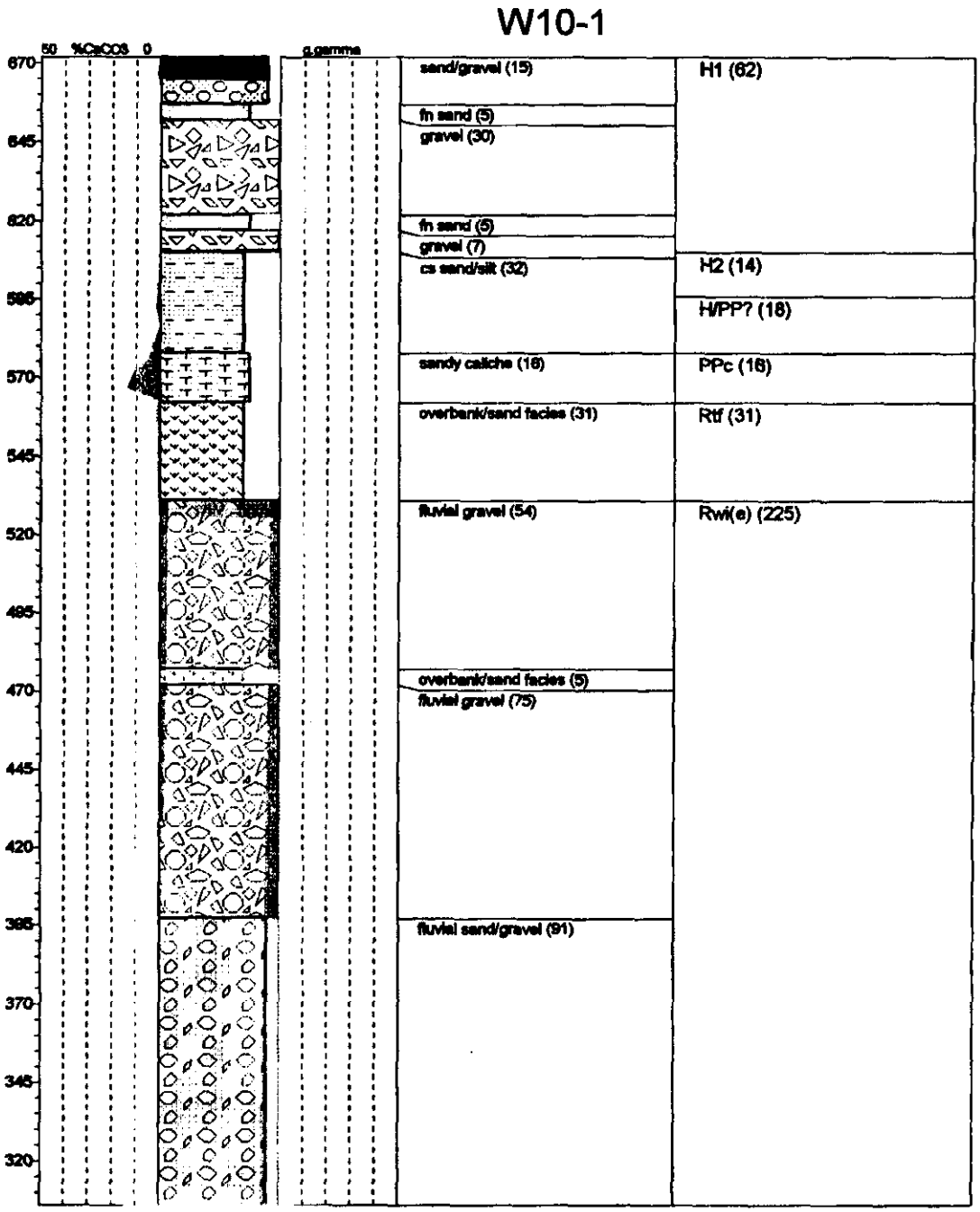
Figure C-1. Boring No. W10-1.



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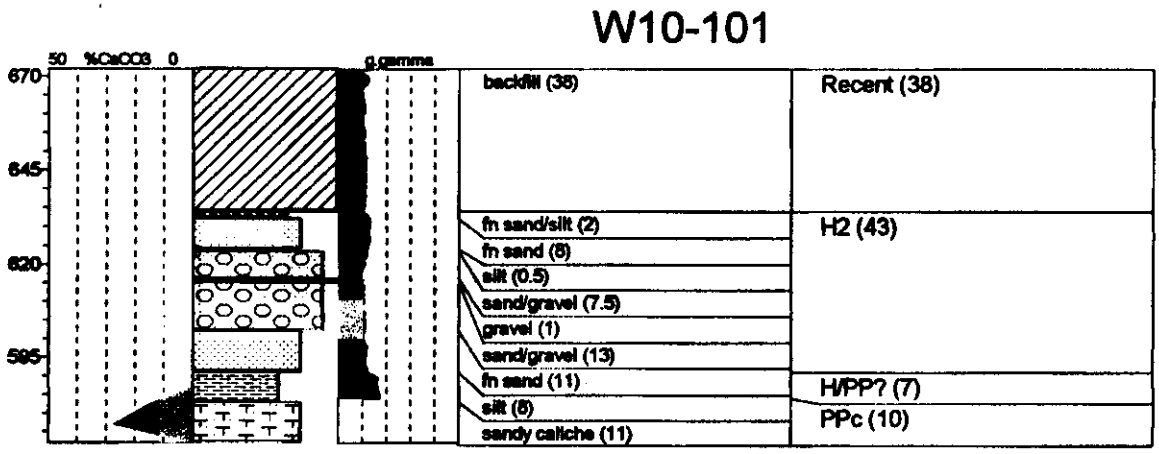

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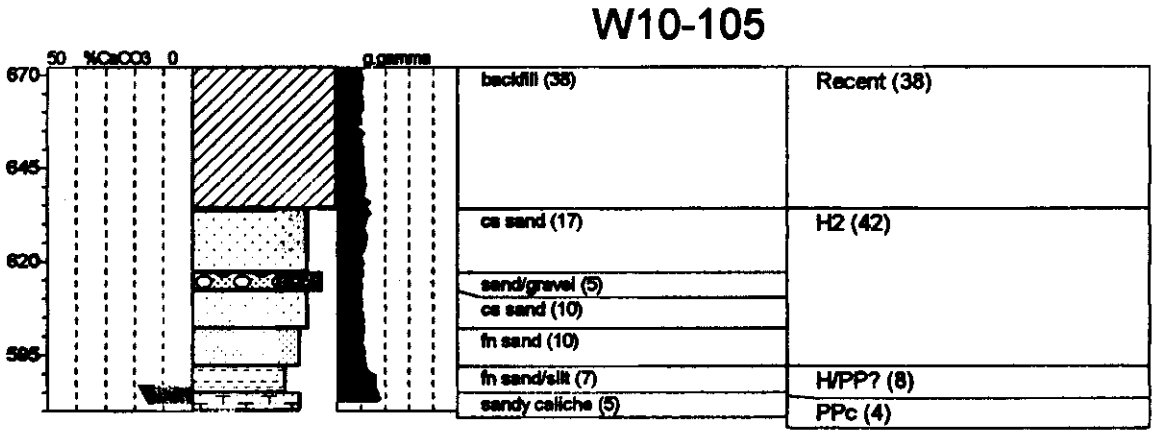

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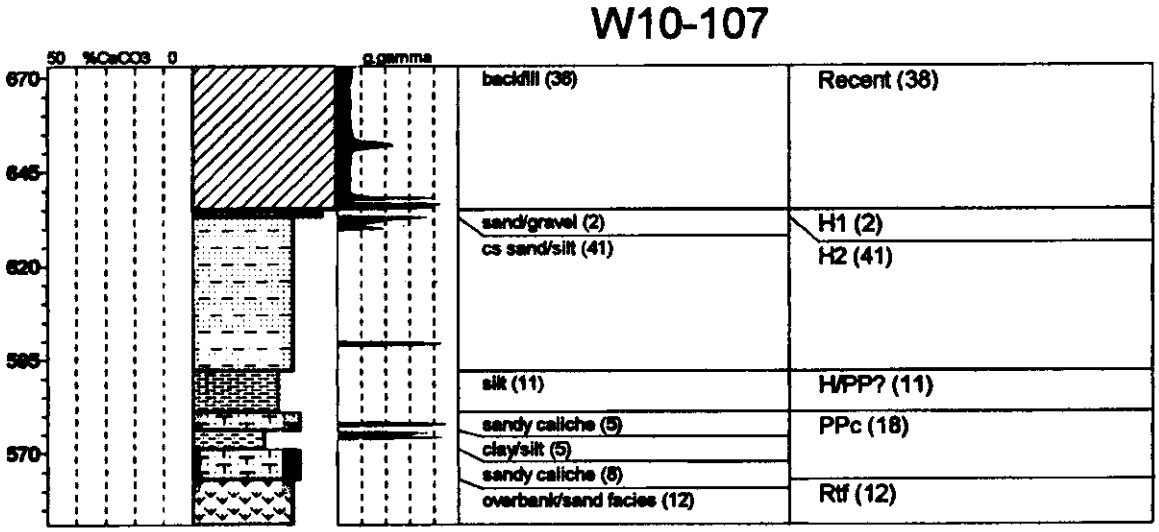

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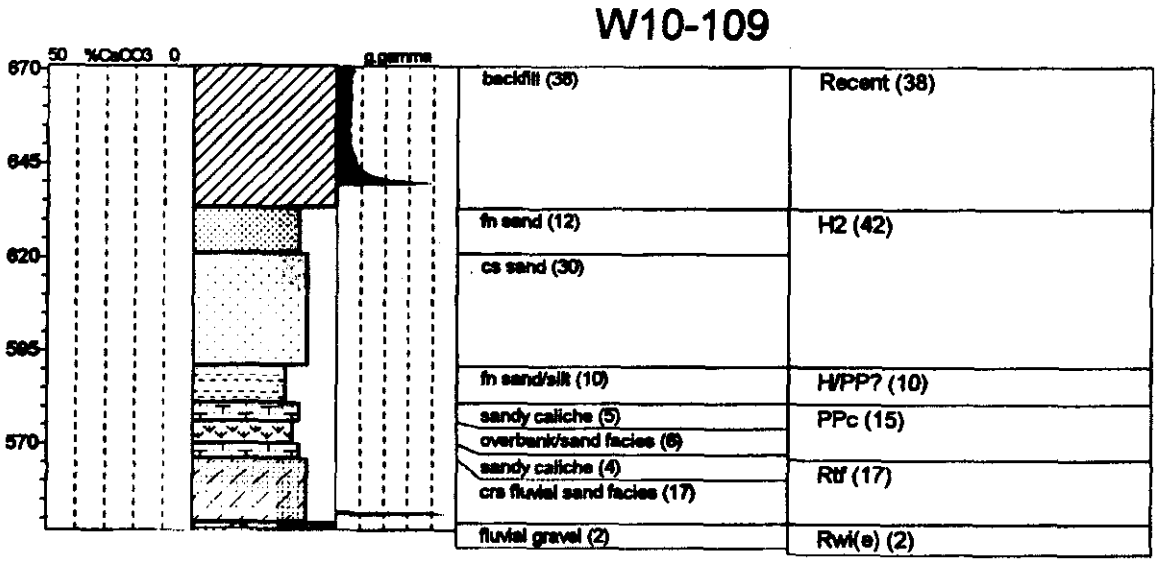

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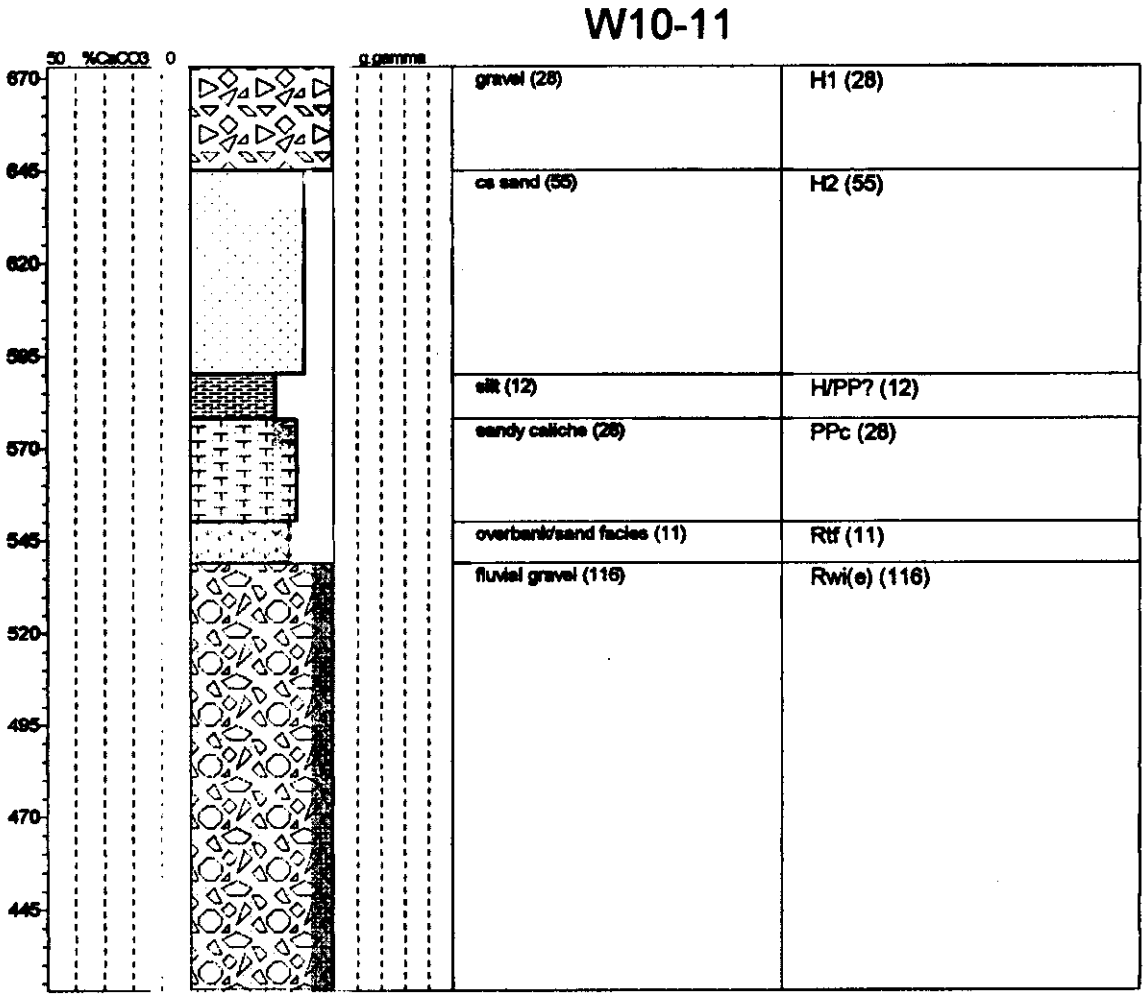

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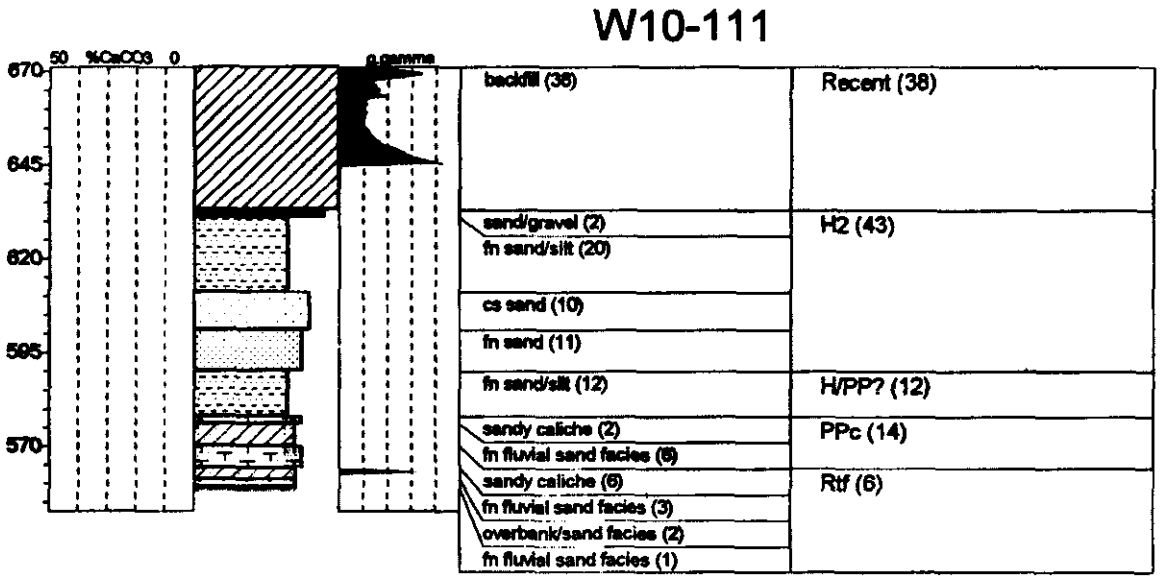

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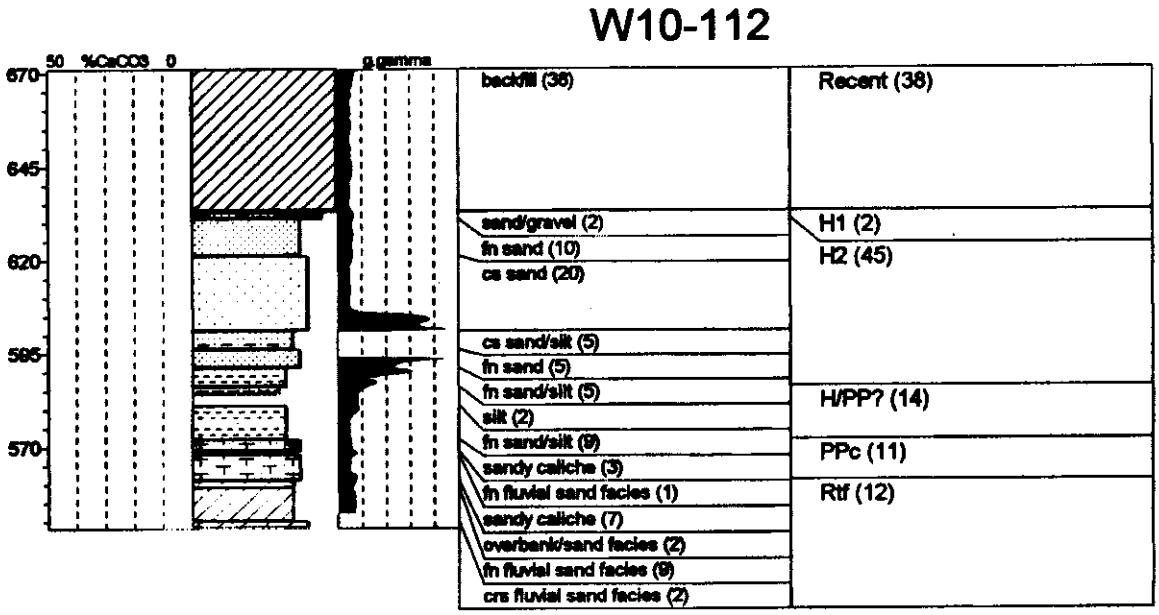

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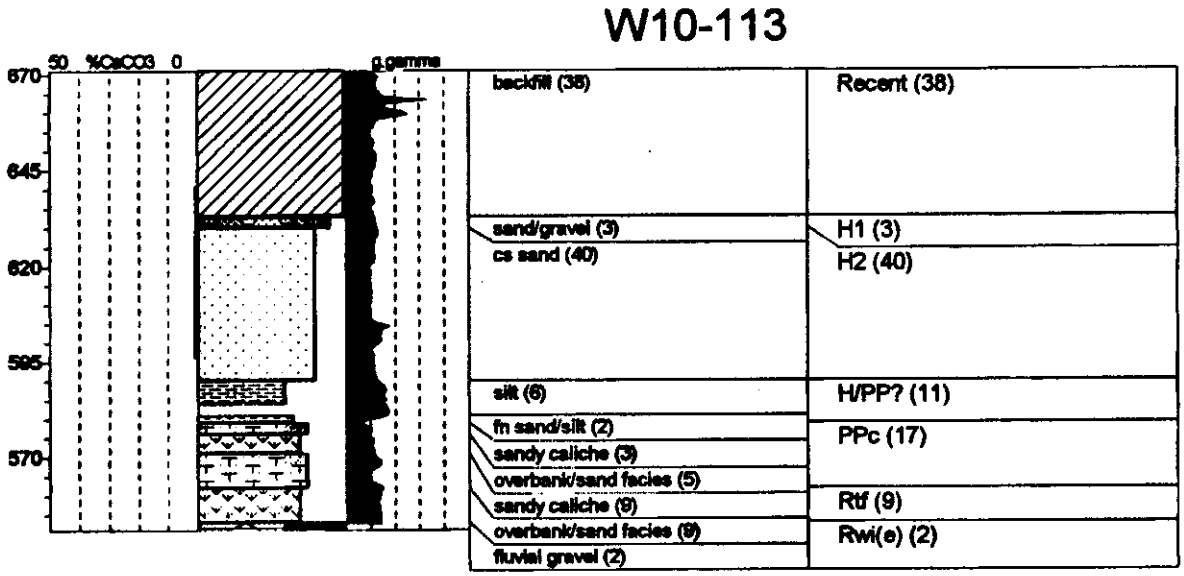

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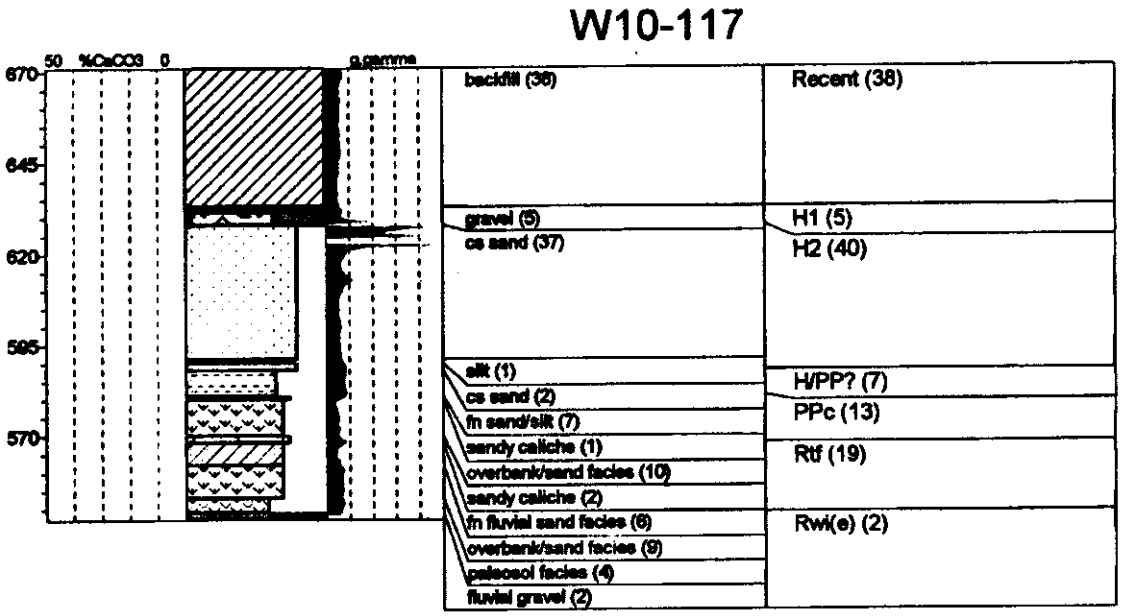

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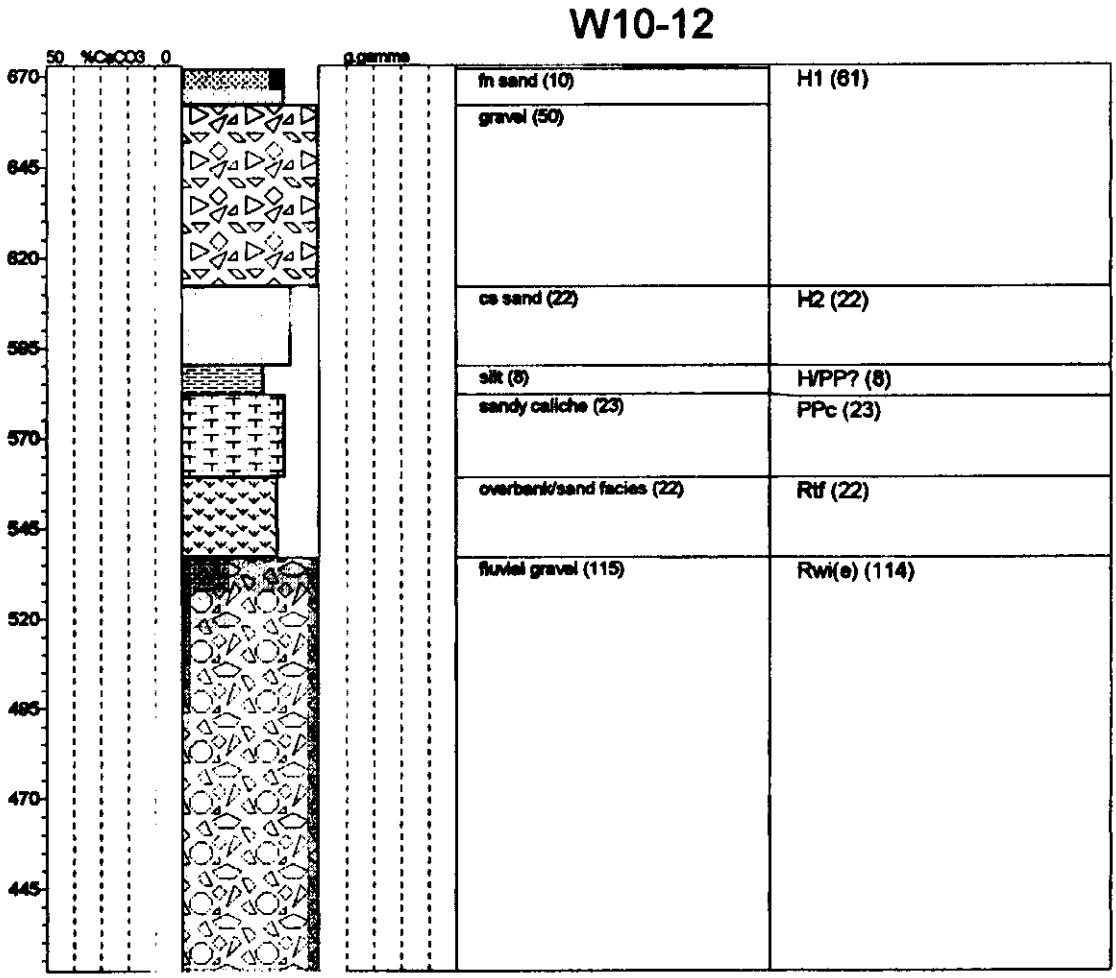

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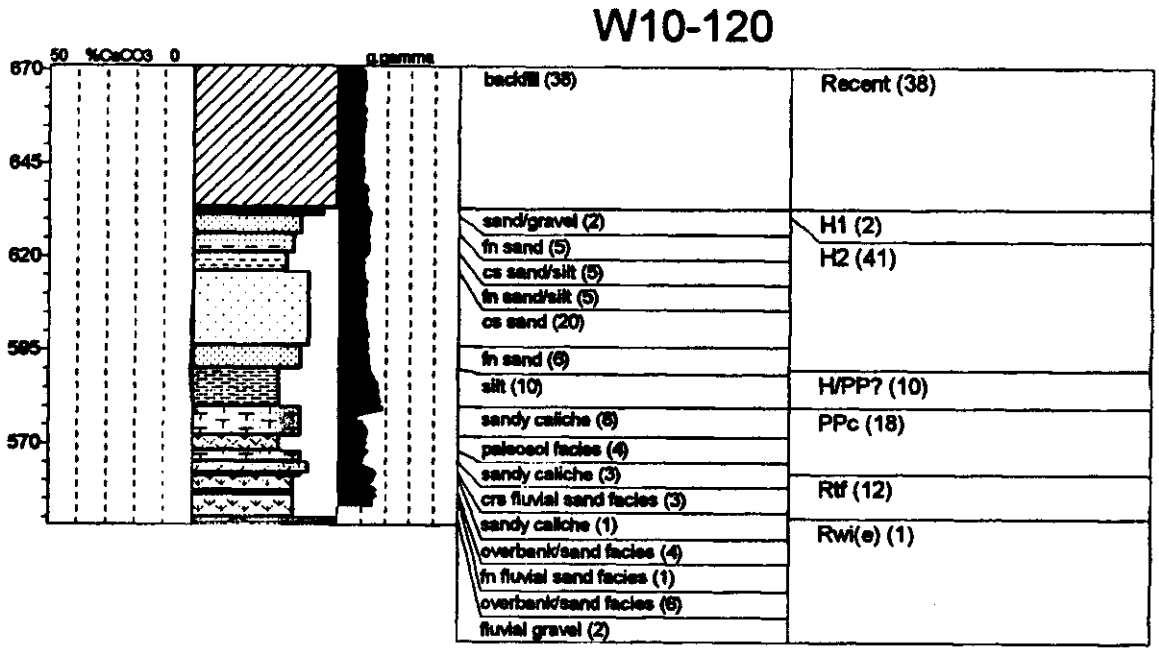

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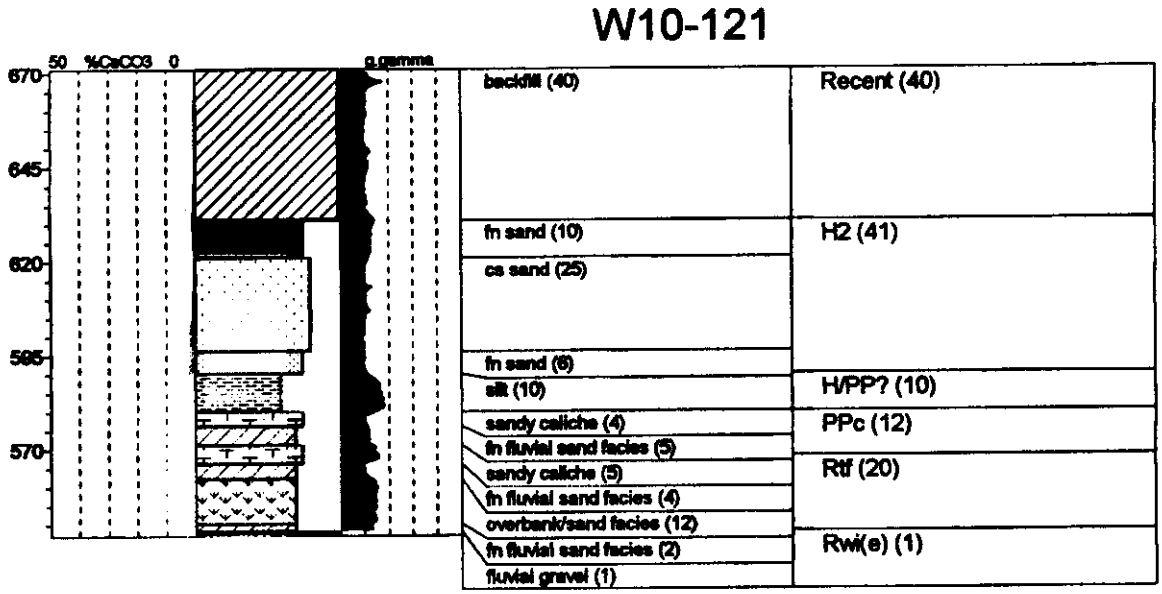

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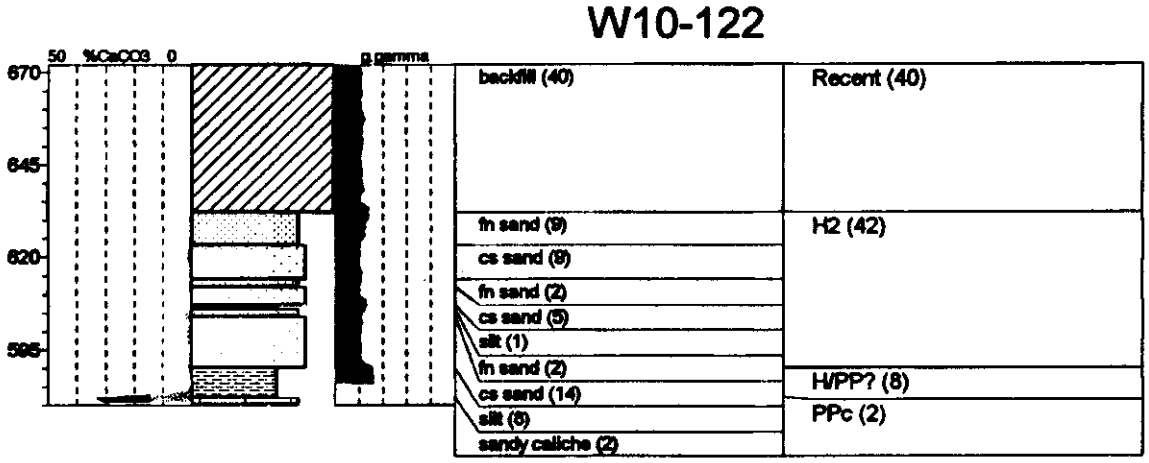

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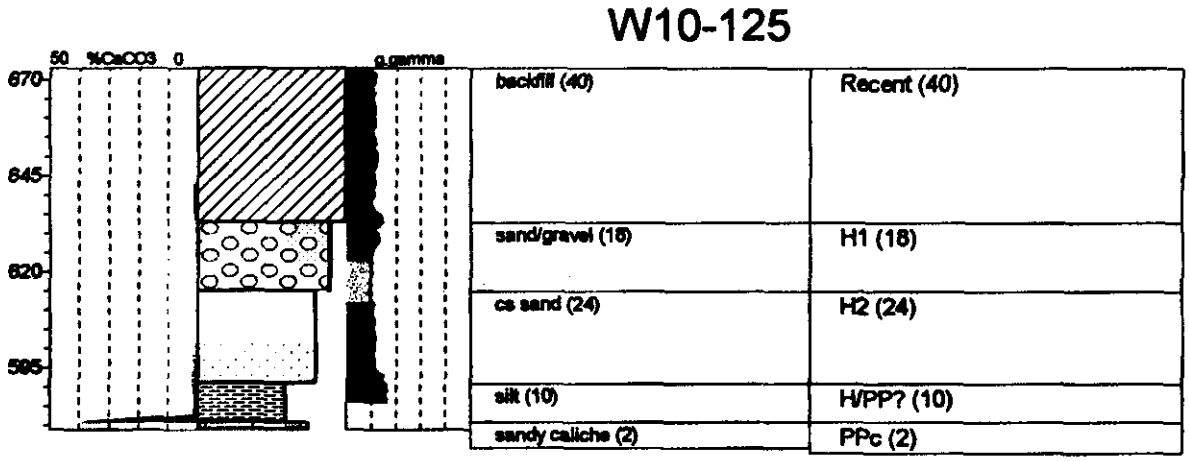

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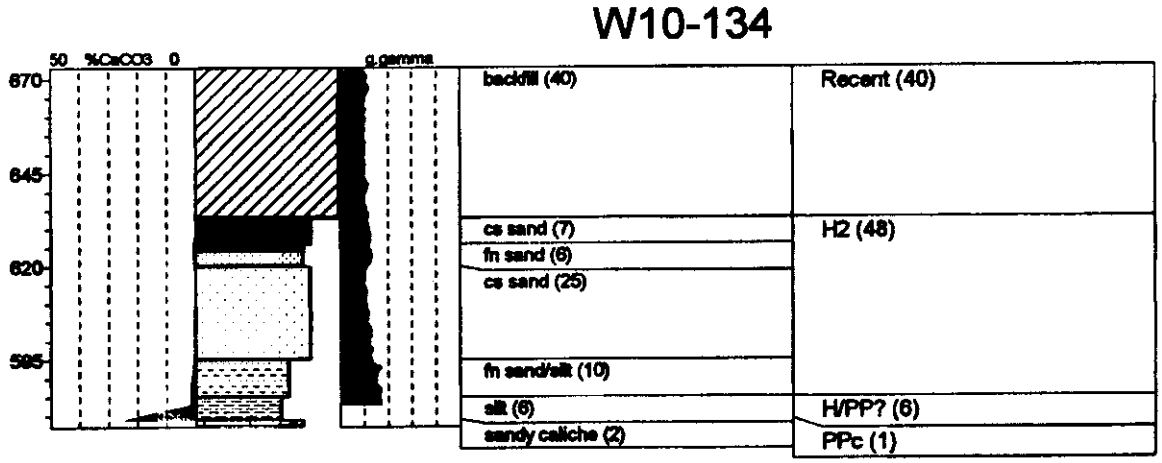

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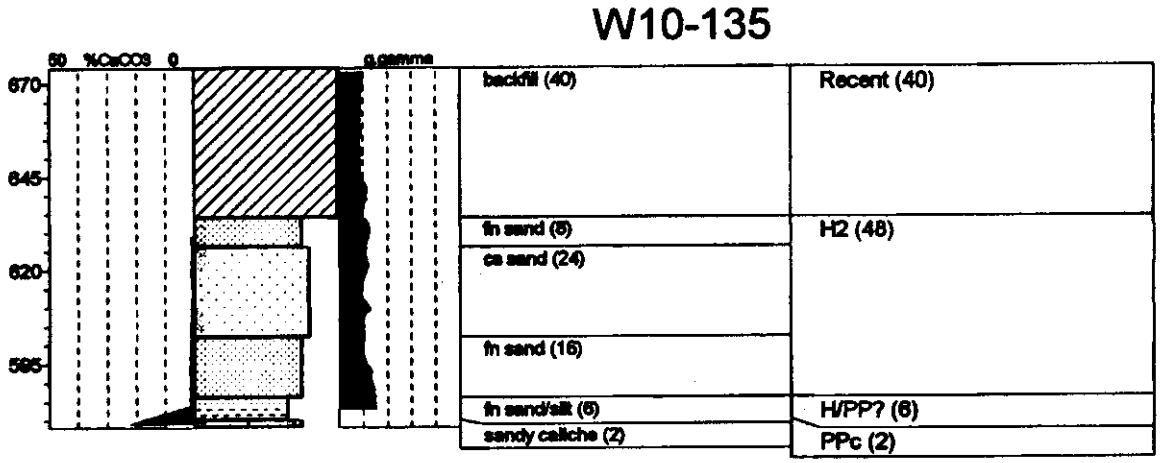

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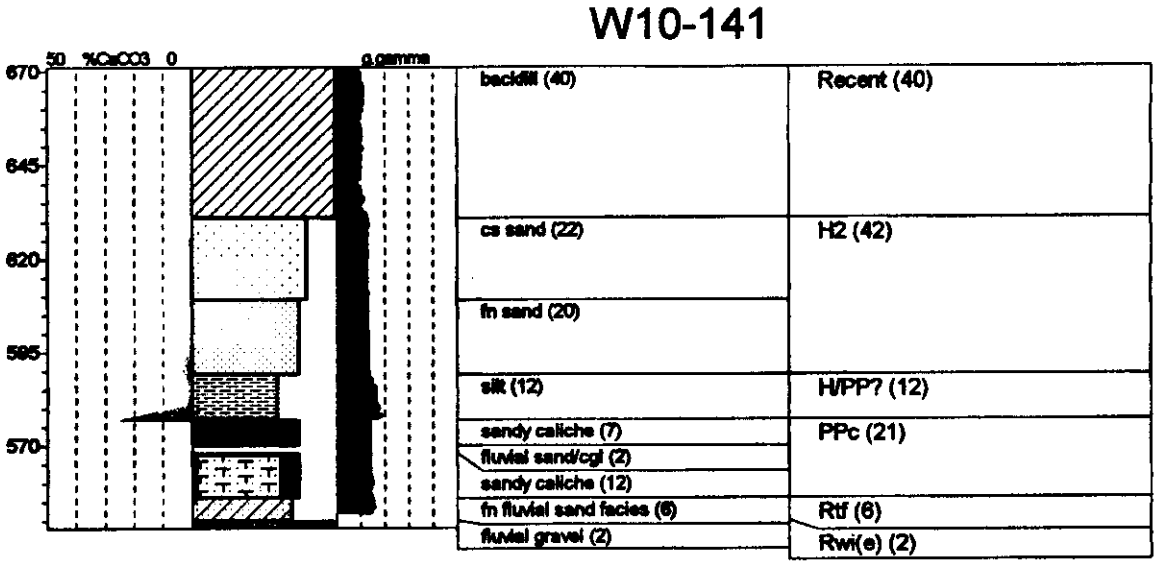

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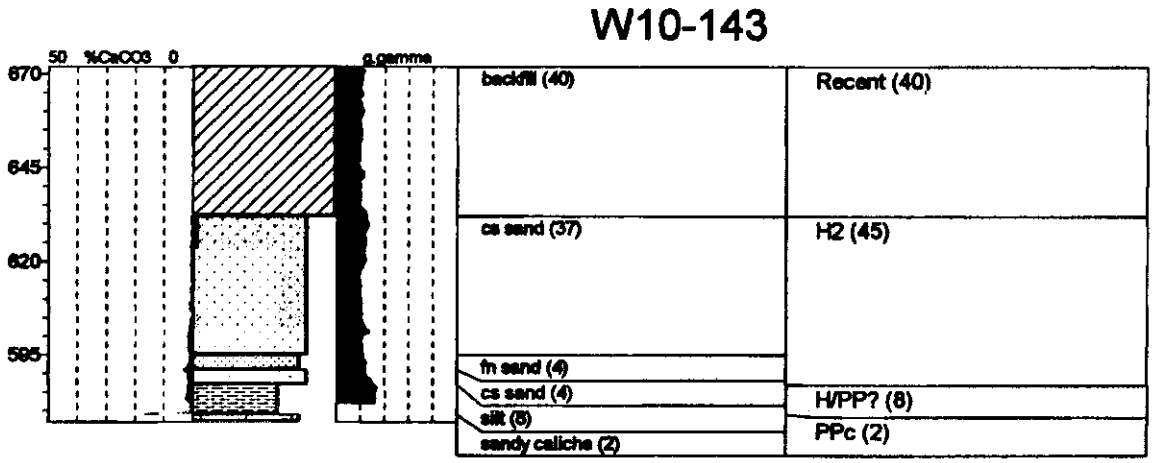

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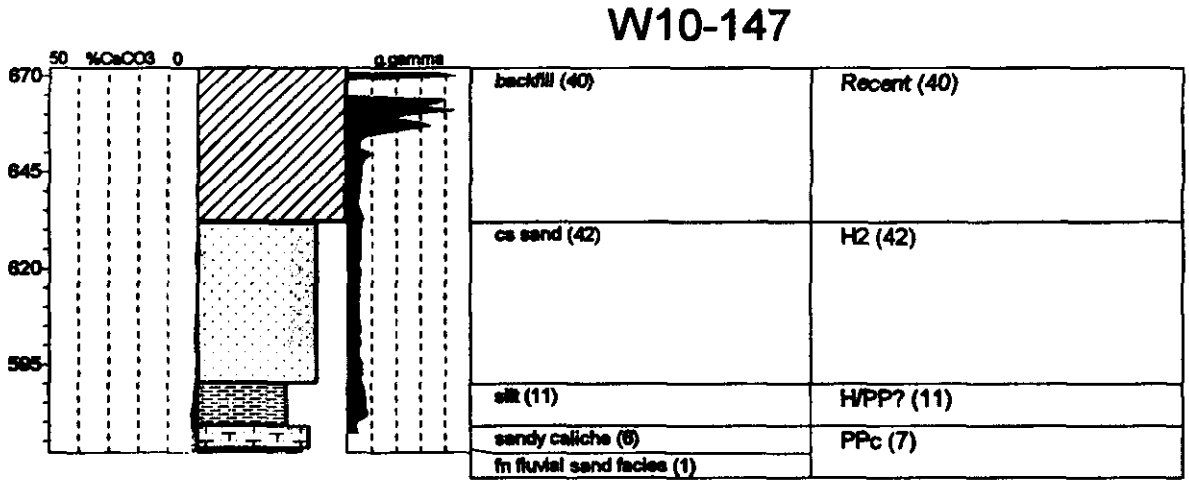

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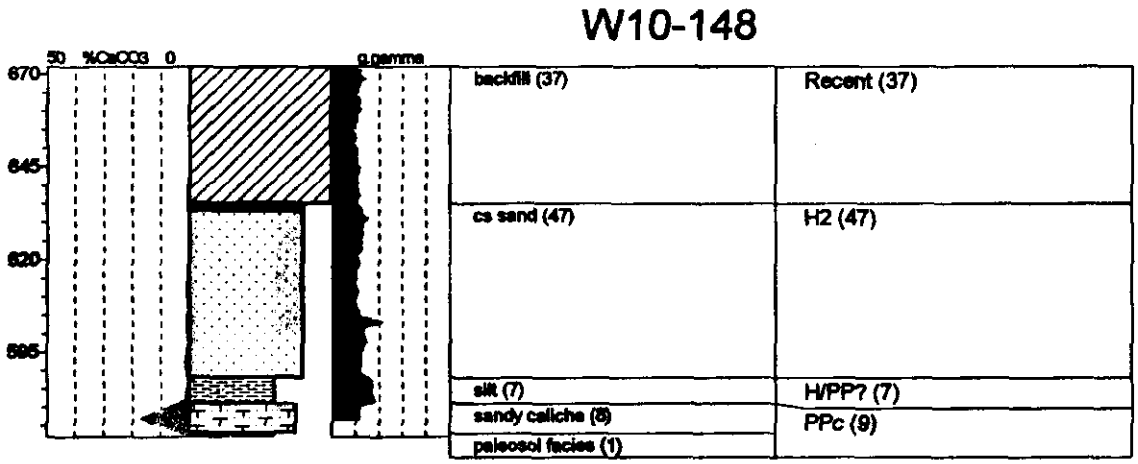


Figure C-22. Boring No. W10-15.

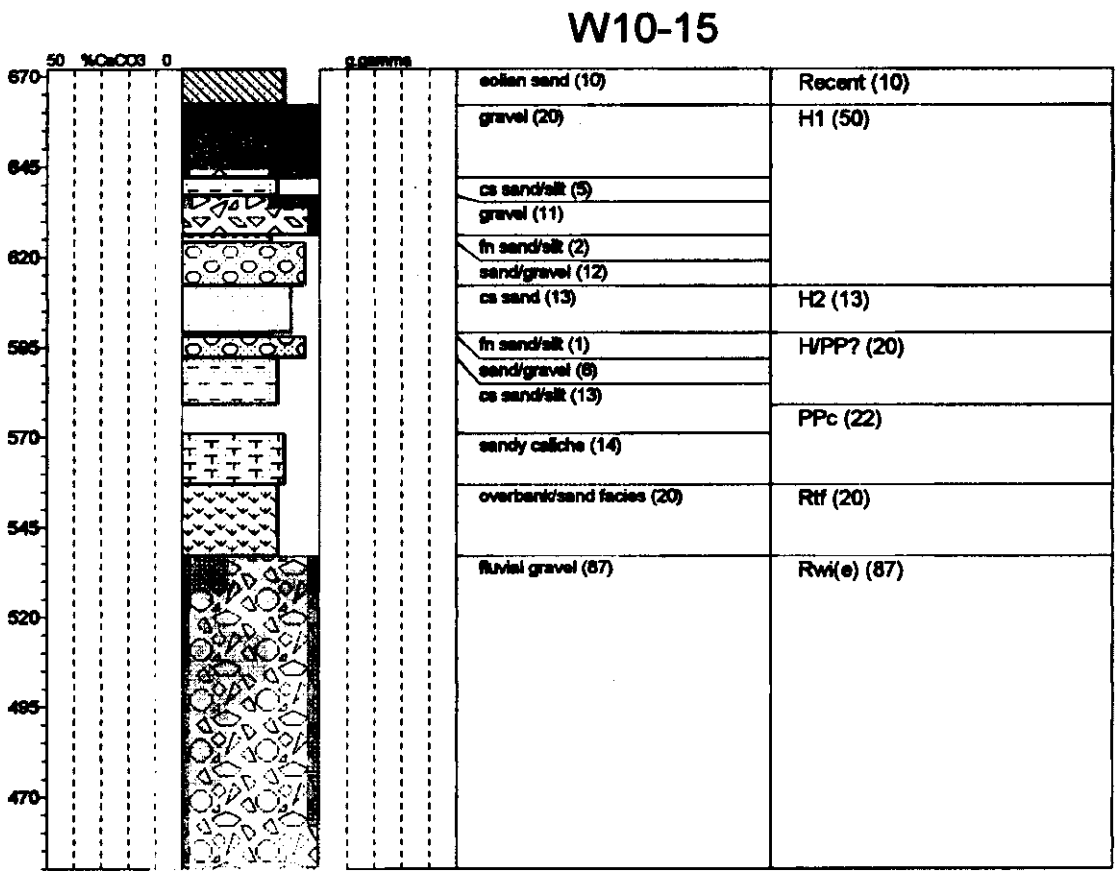
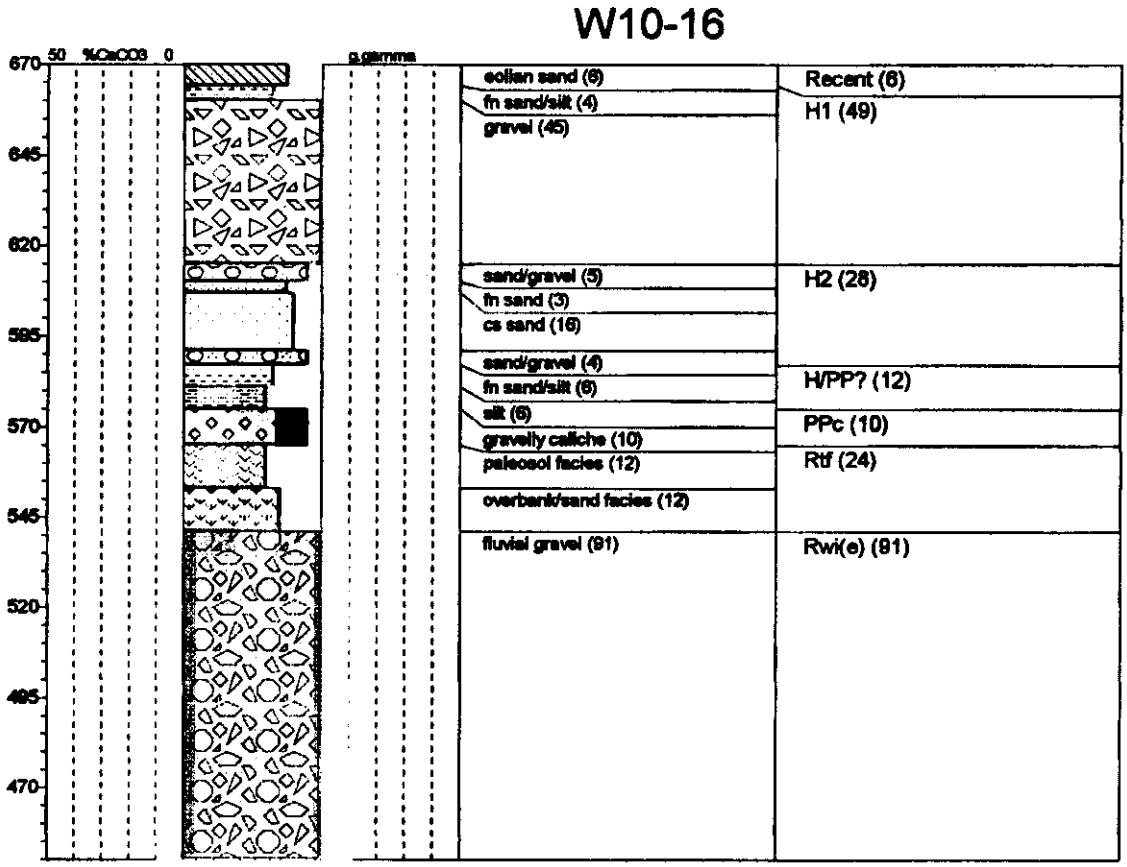


Figure C-23. Boring No. W10-16.



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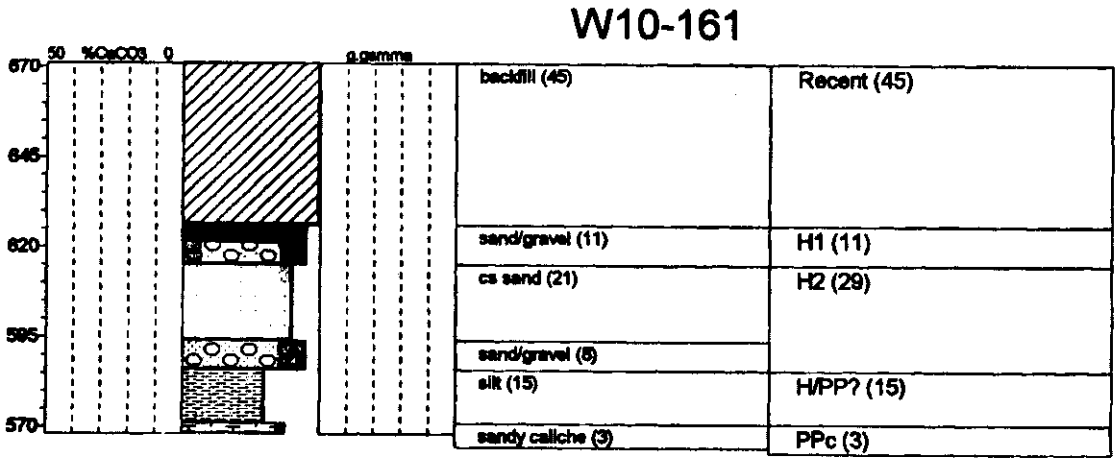

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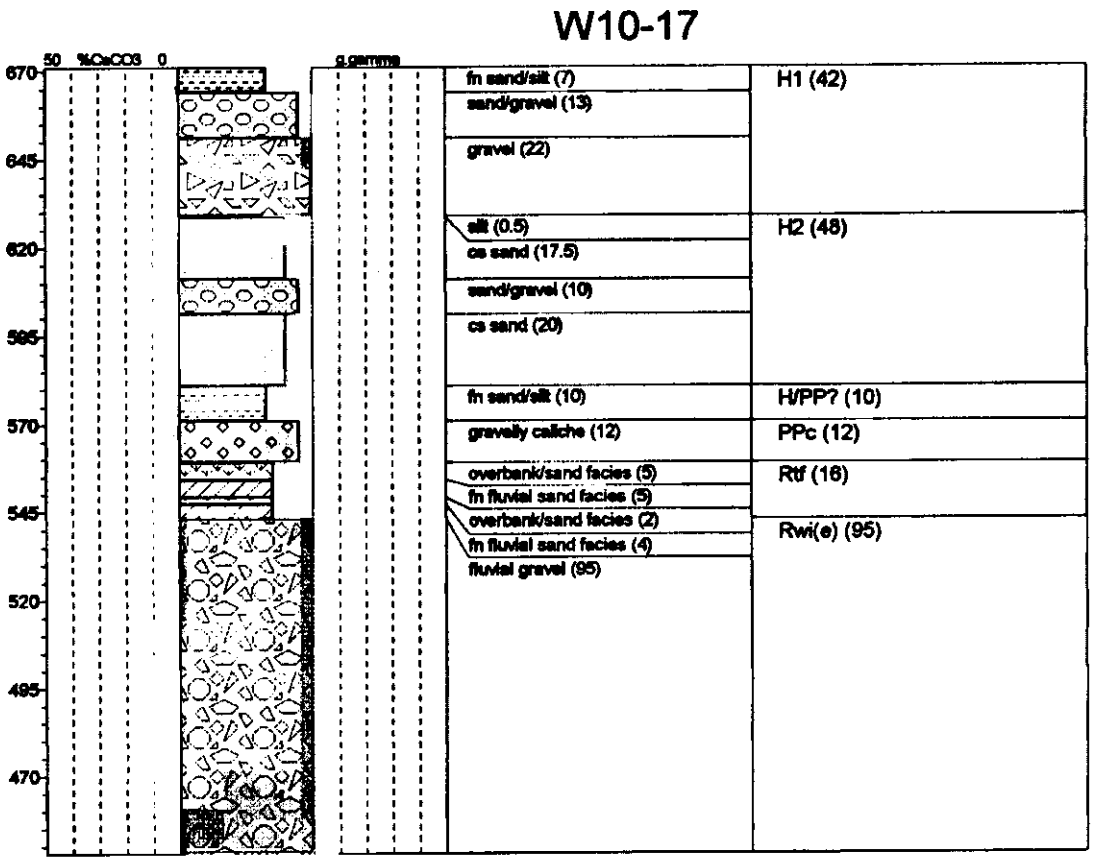

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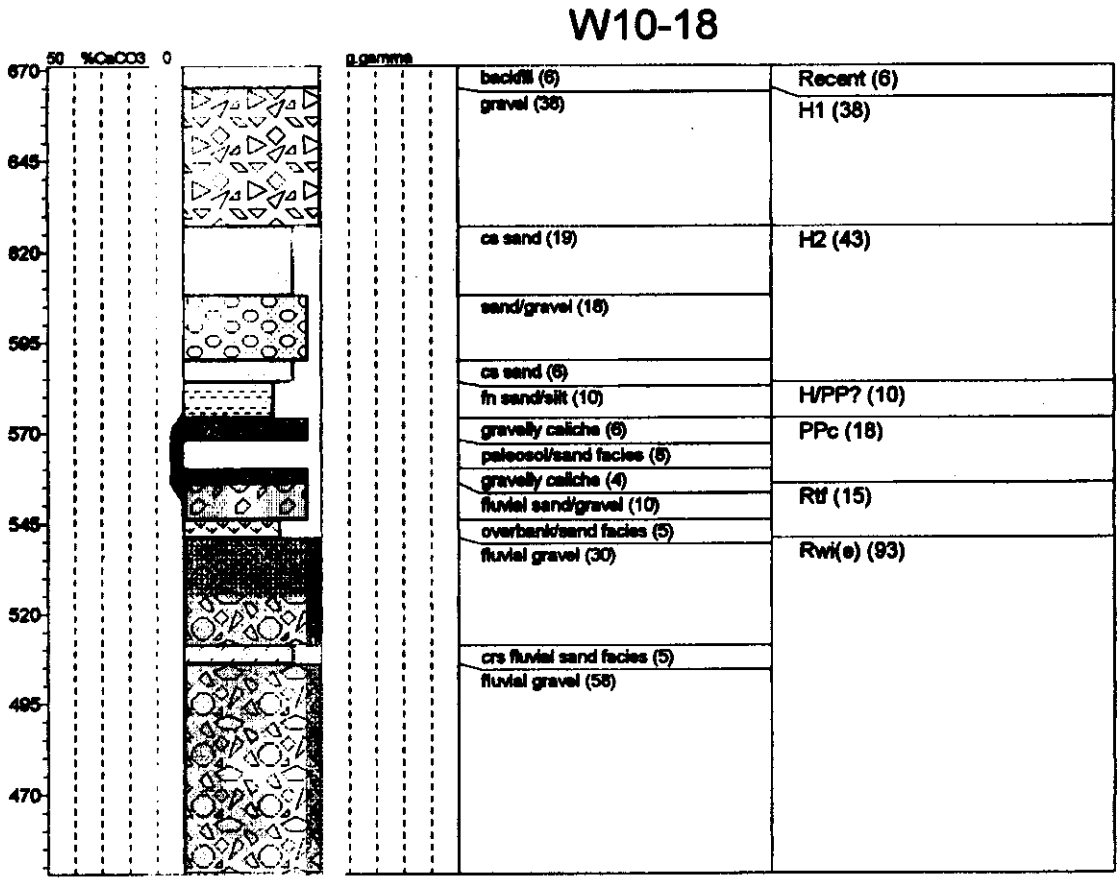
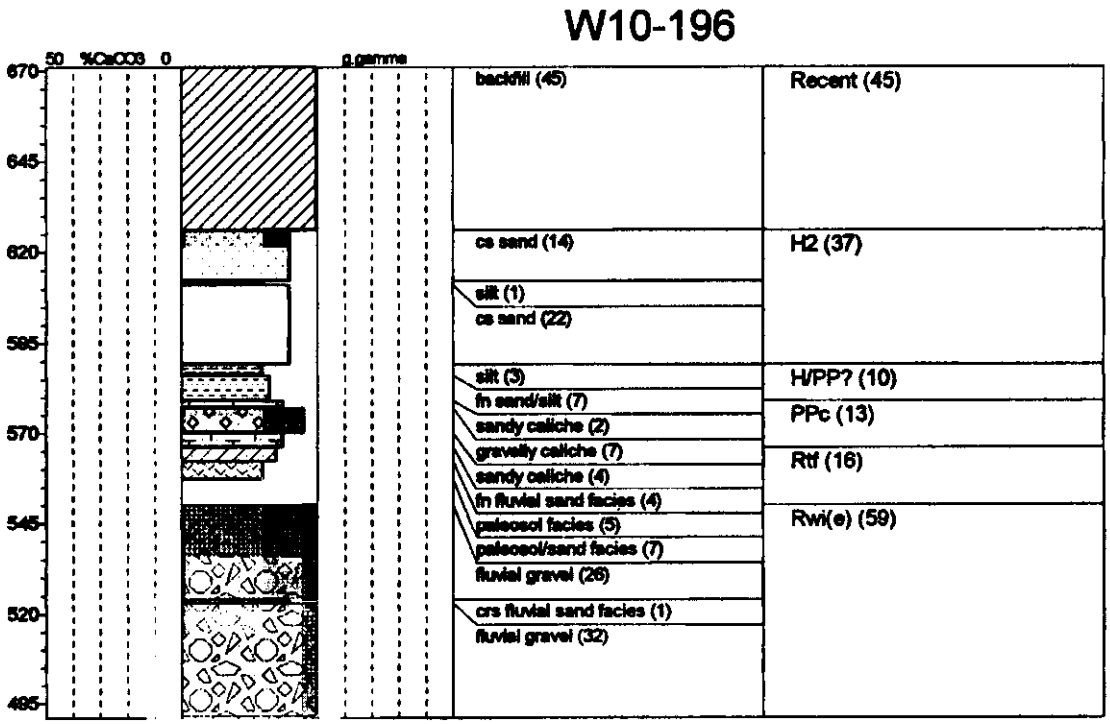


Figure C-27. Boring No. W10-196.



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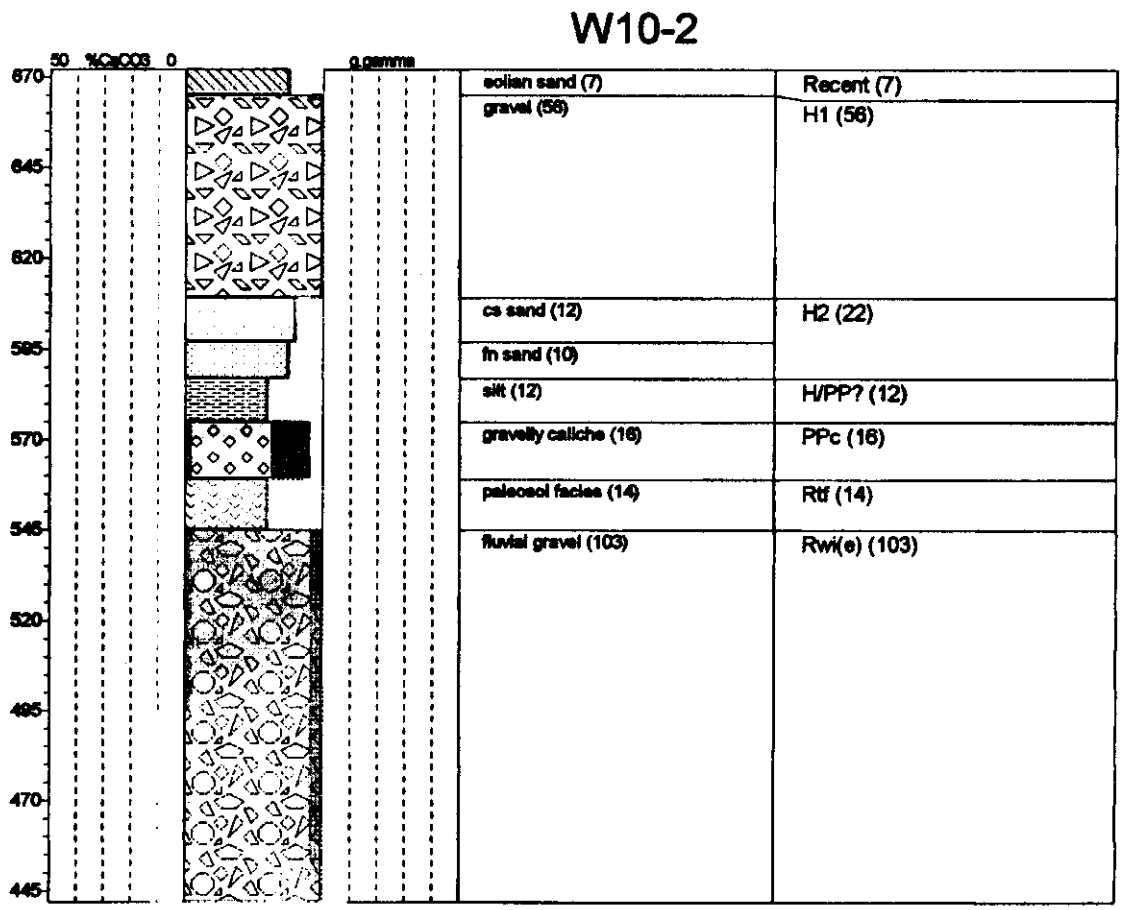
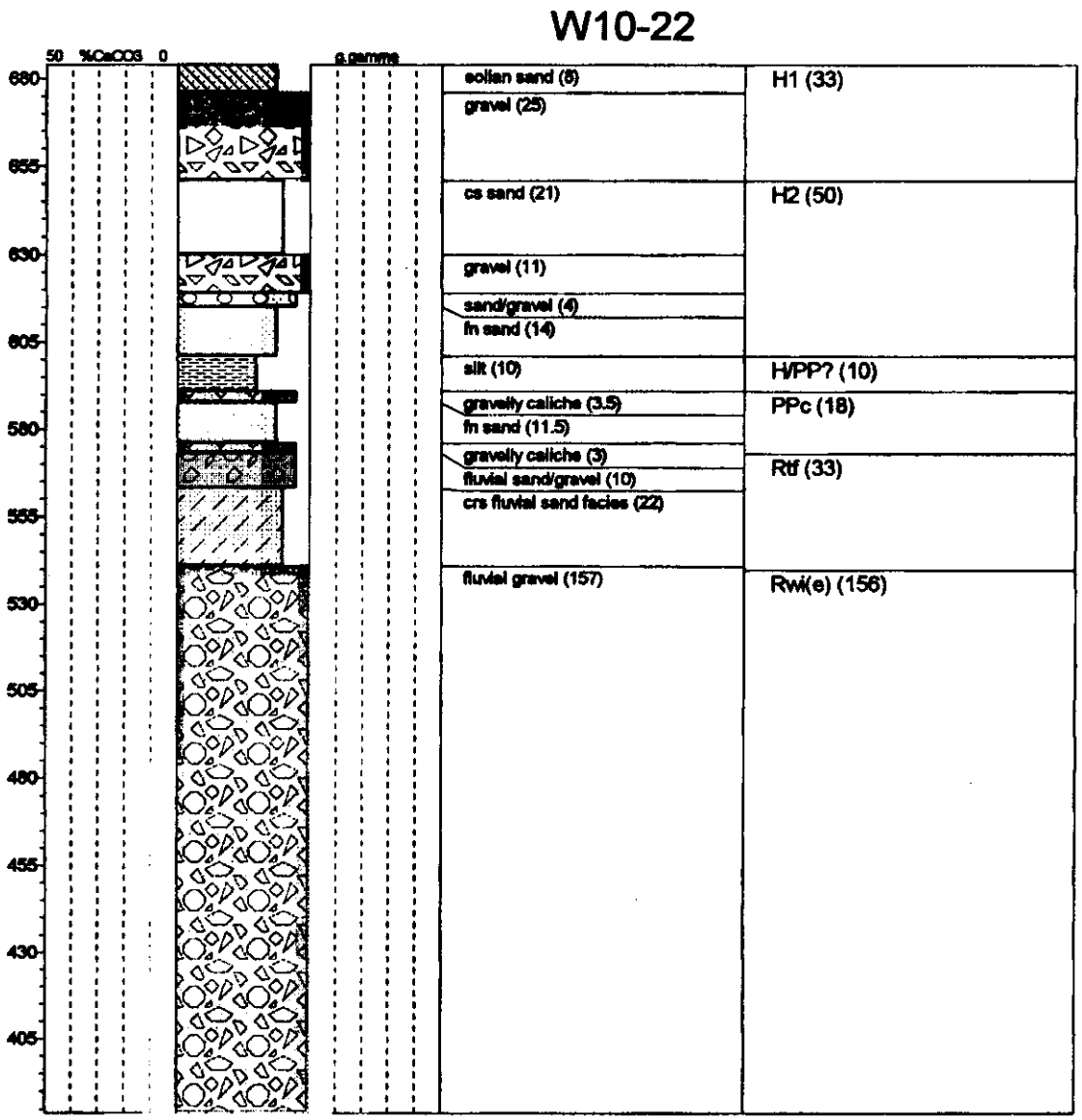


Figure C-29. Boring No. W10-22.



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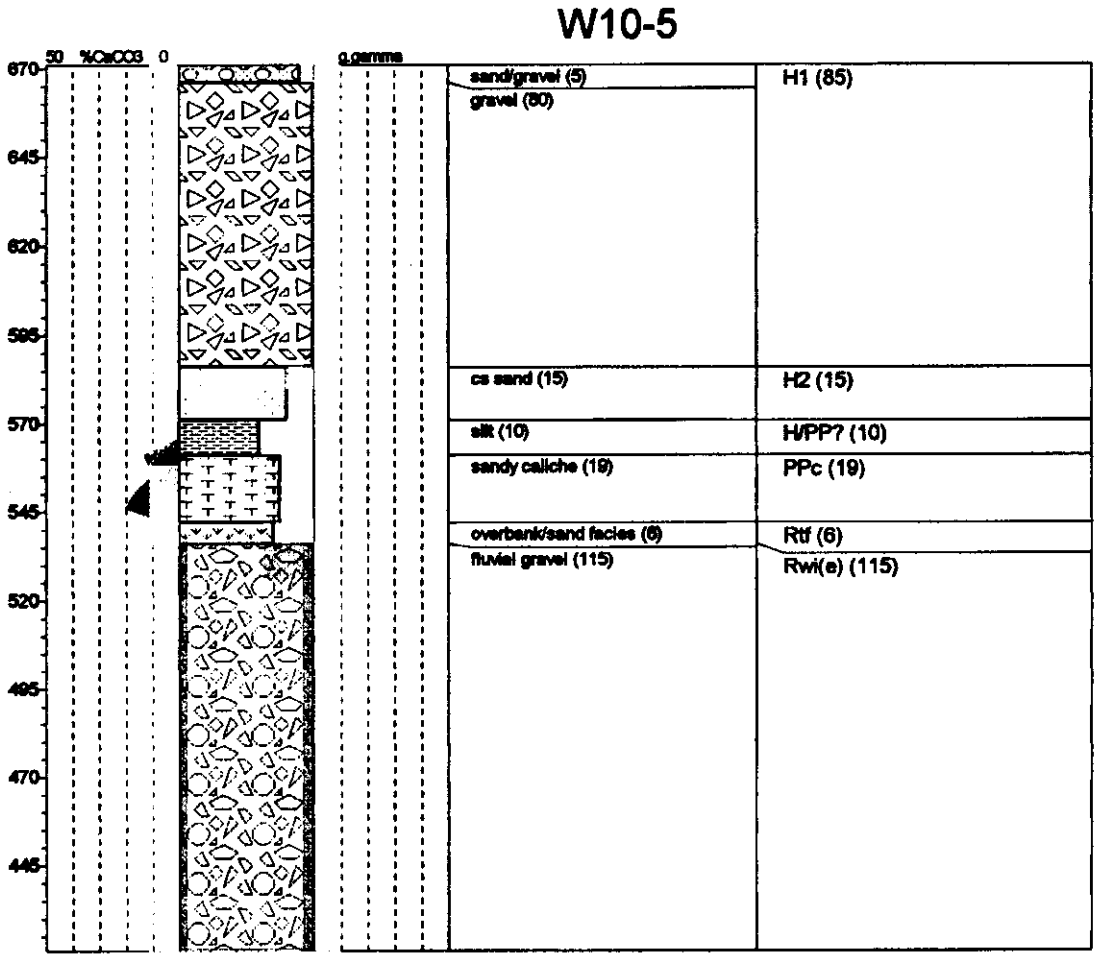
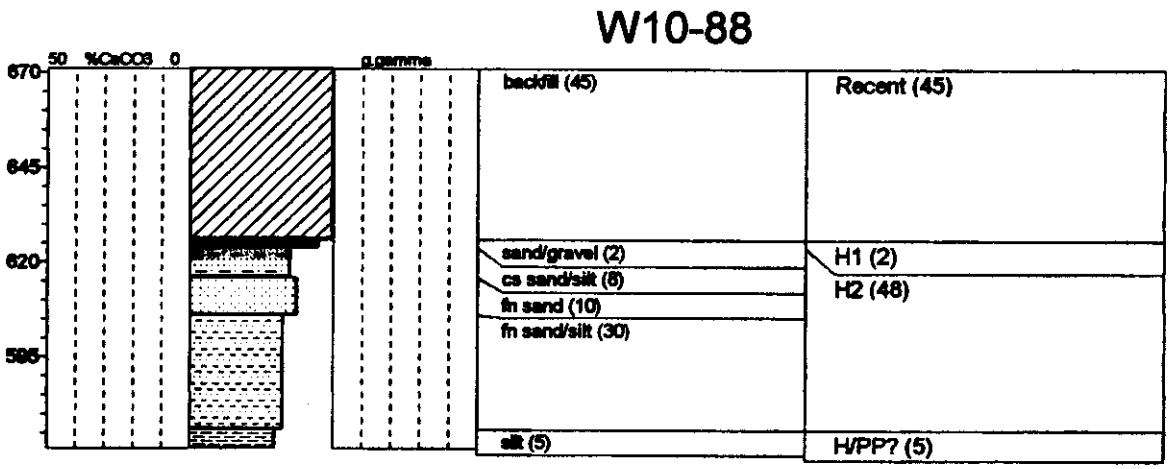


Figure C-31. Boring No. W10-88.



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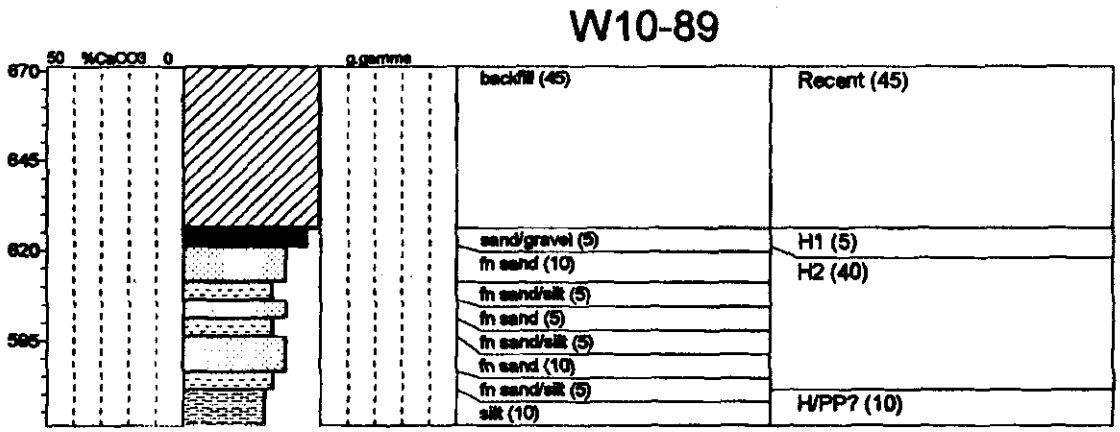
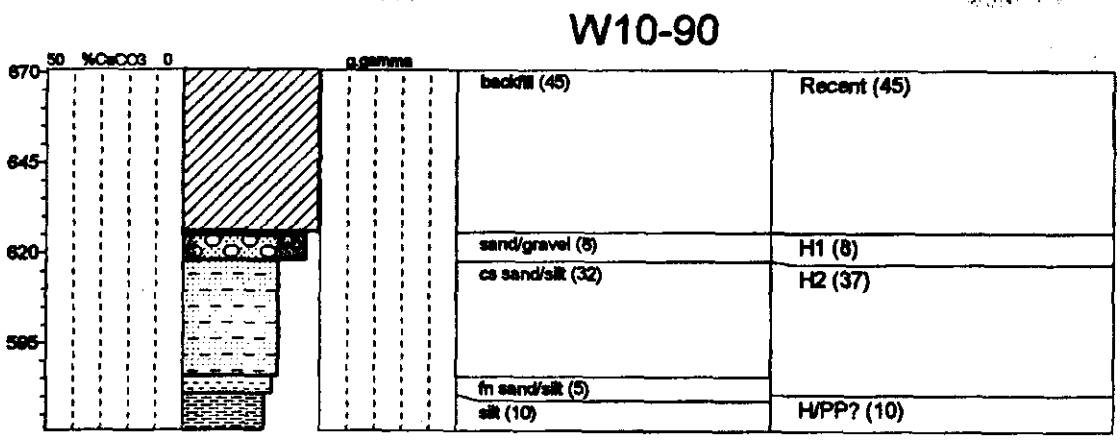


Figure C-33. Boring No. W10-90.



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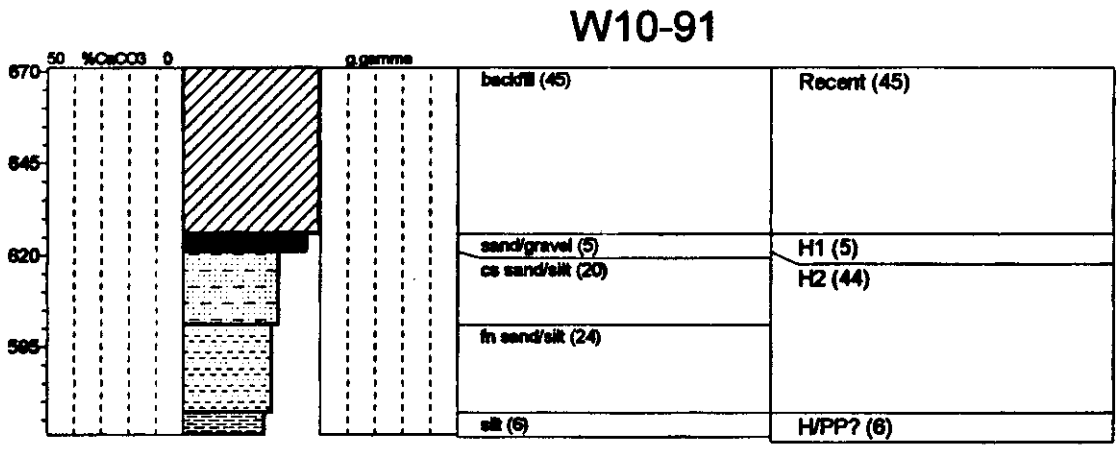

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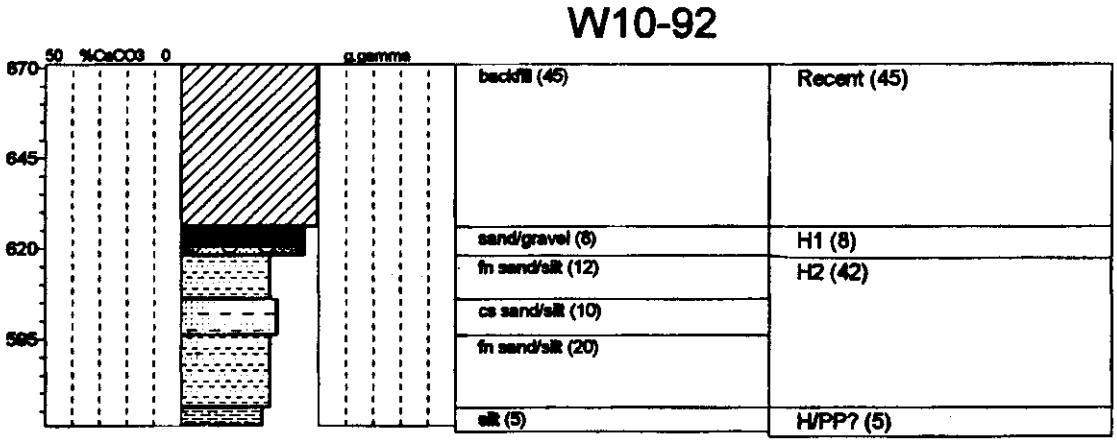

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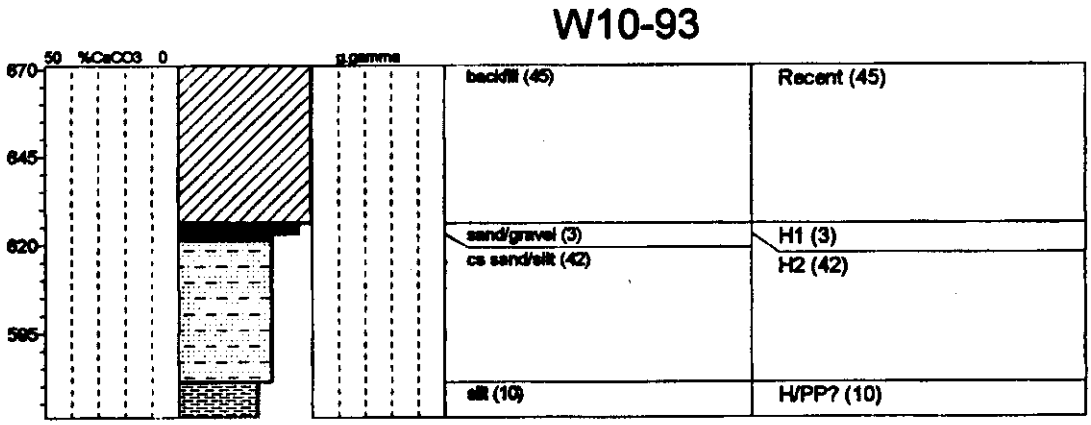

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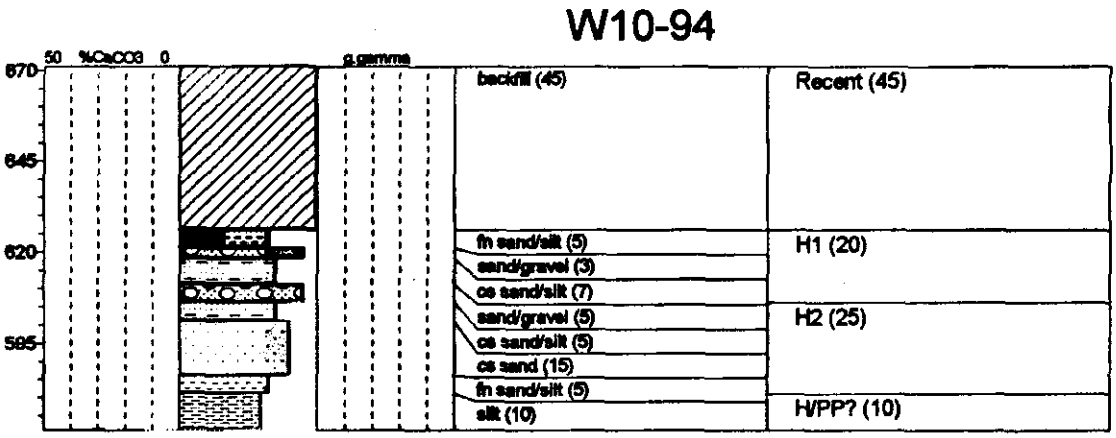

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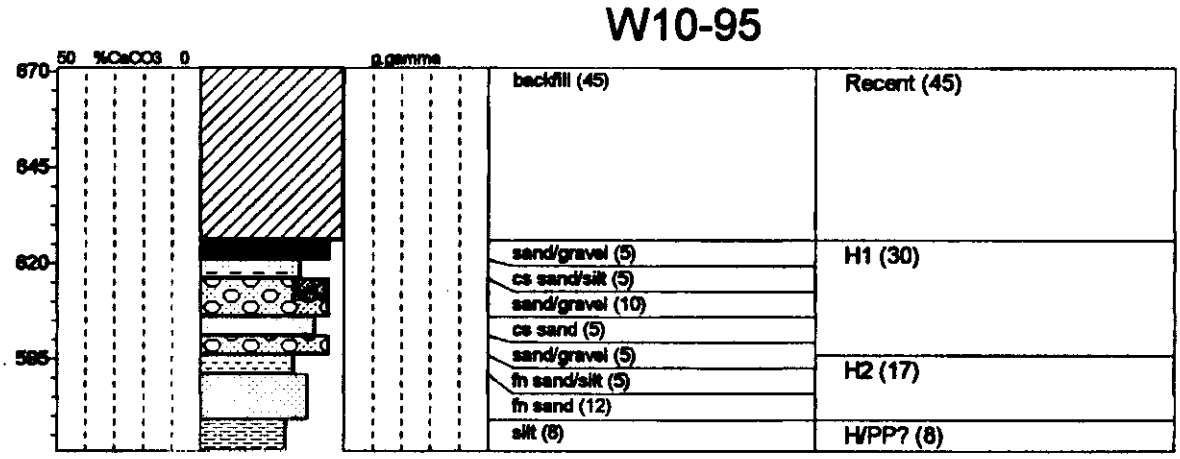

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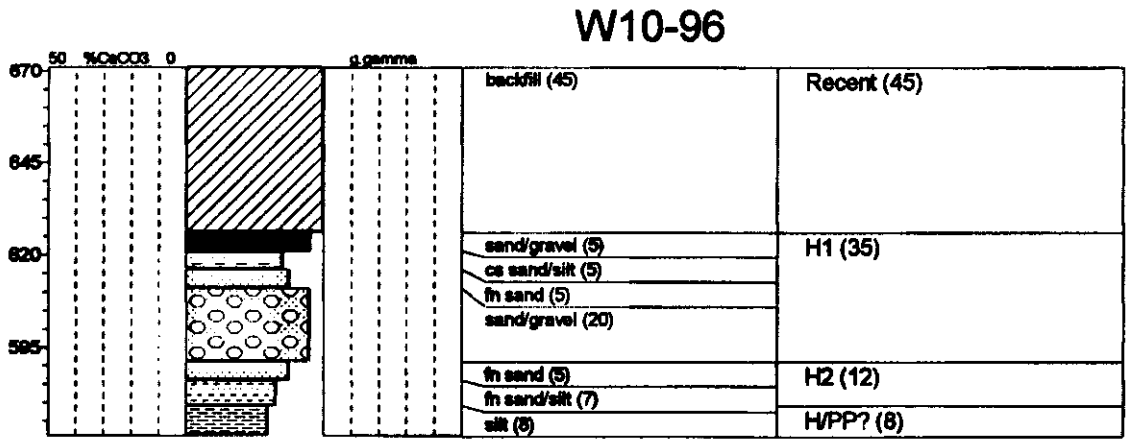

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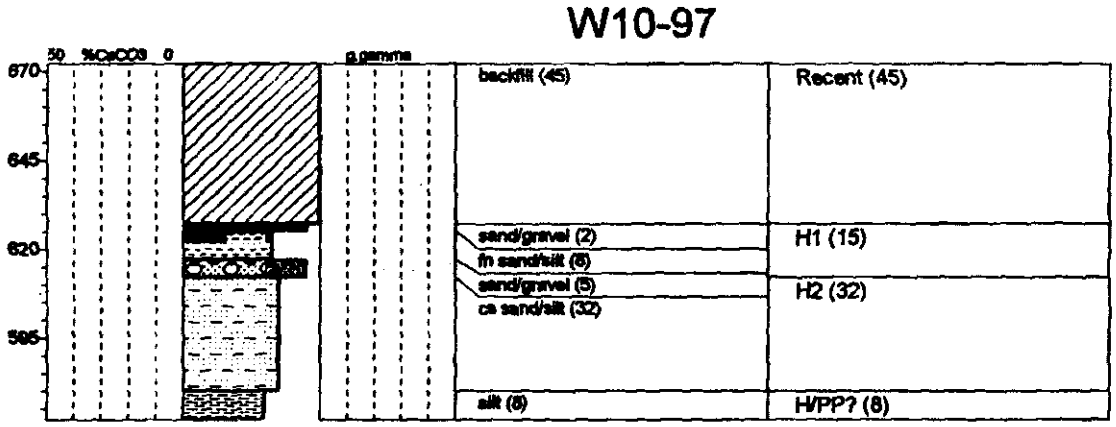
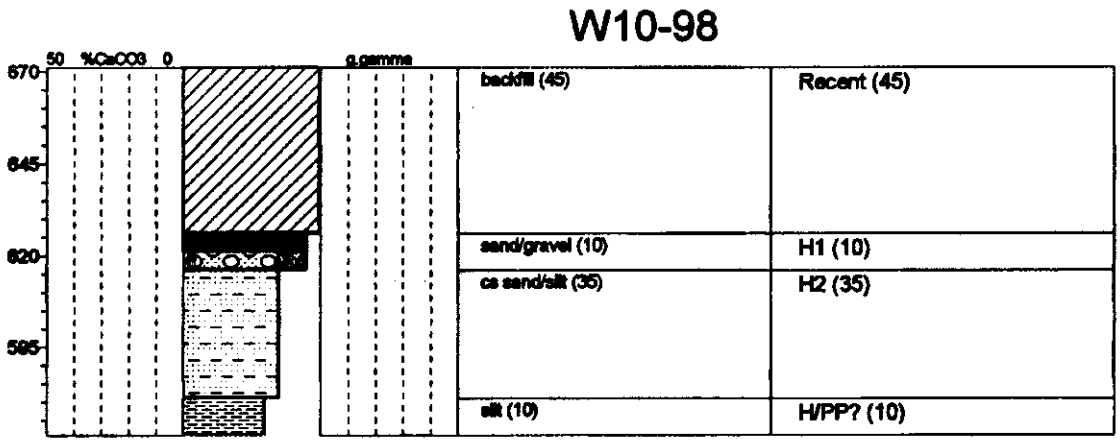


Figure C-41. Boring No. W10-98.



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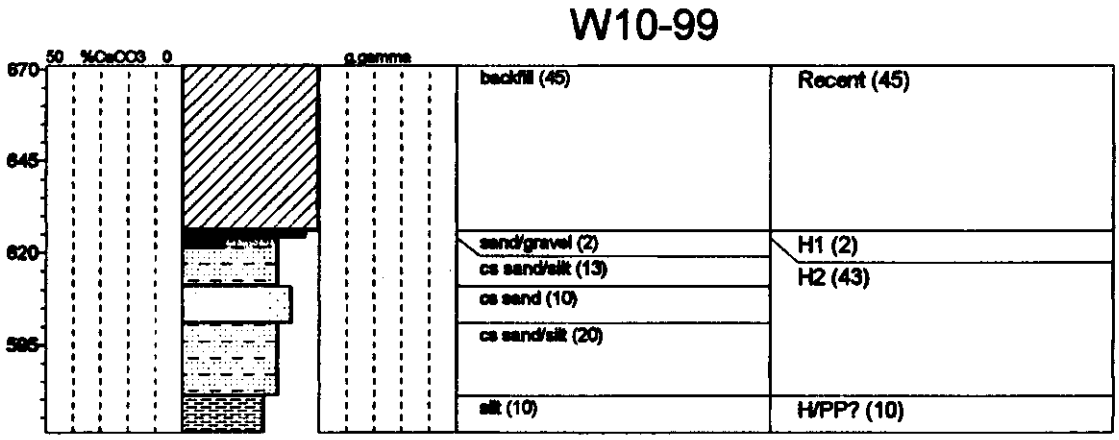


Figure C-43. Boring No. W11-12.

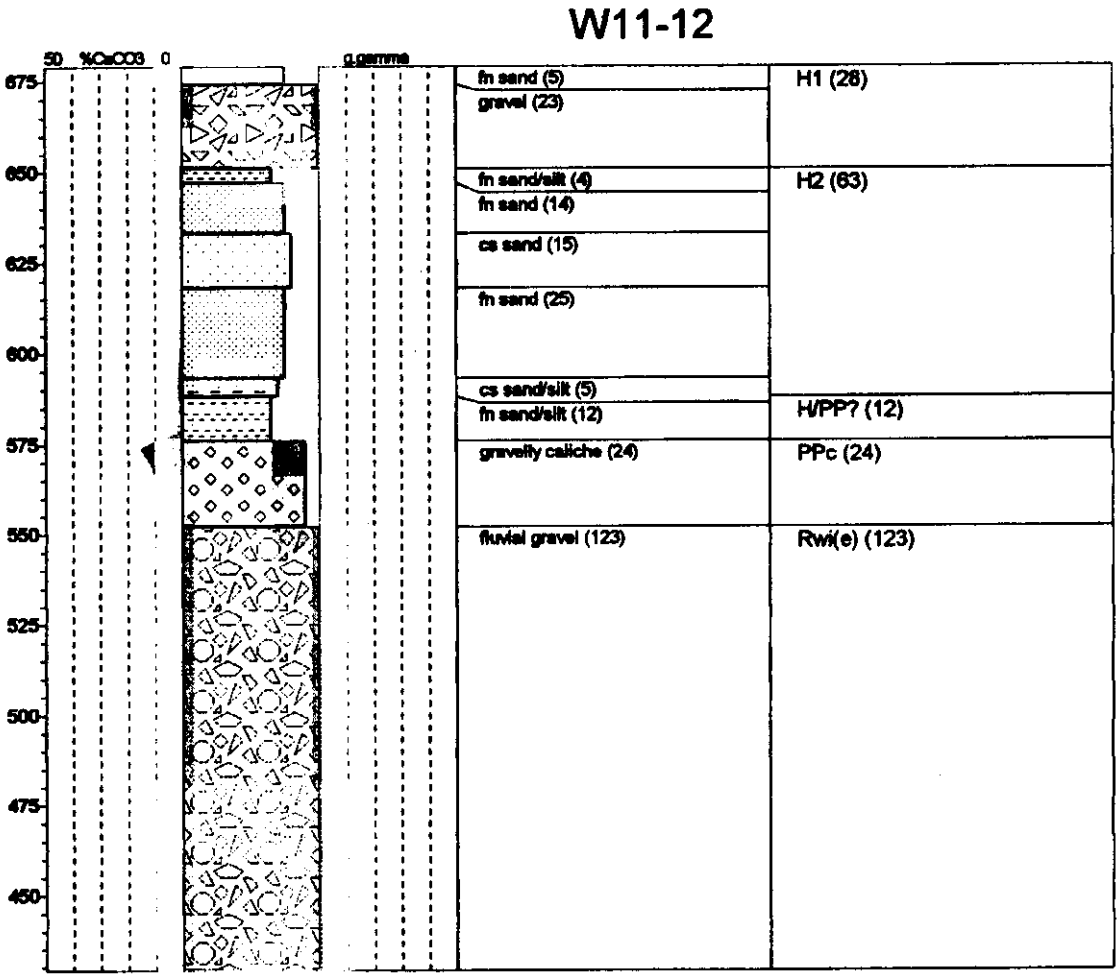
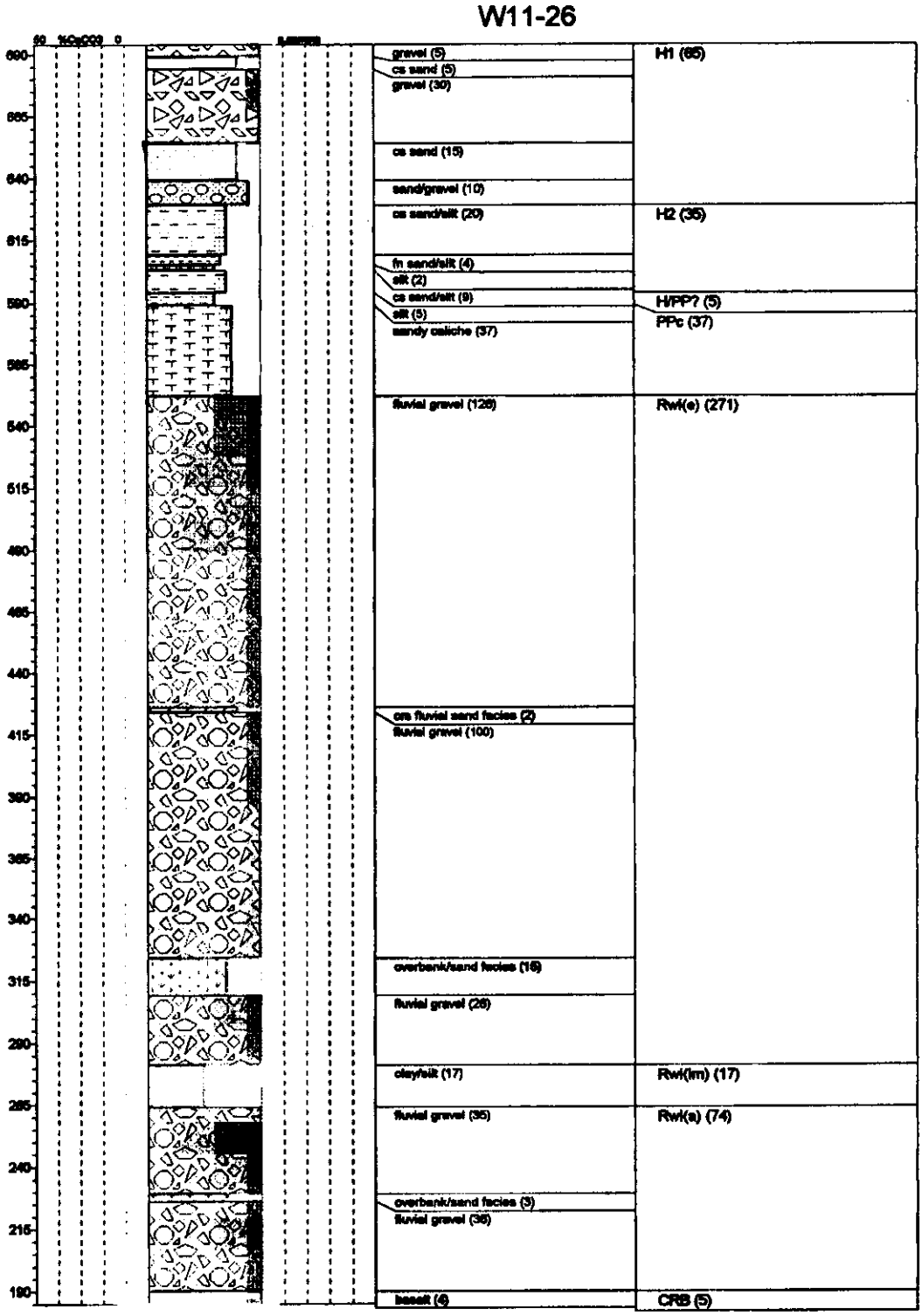


Figure C-44. Boring No. W11-26.



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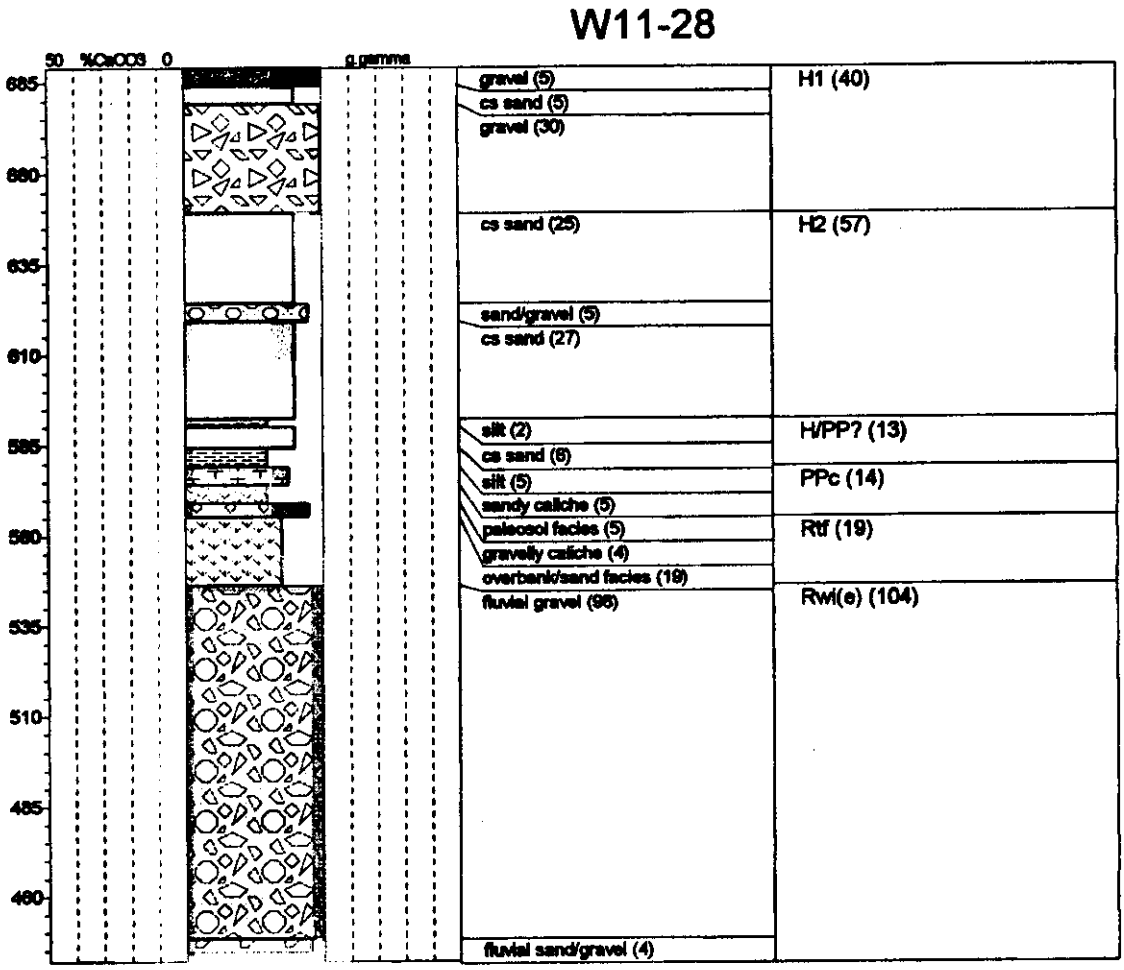


Figure C-46. Boring No. W14-1.

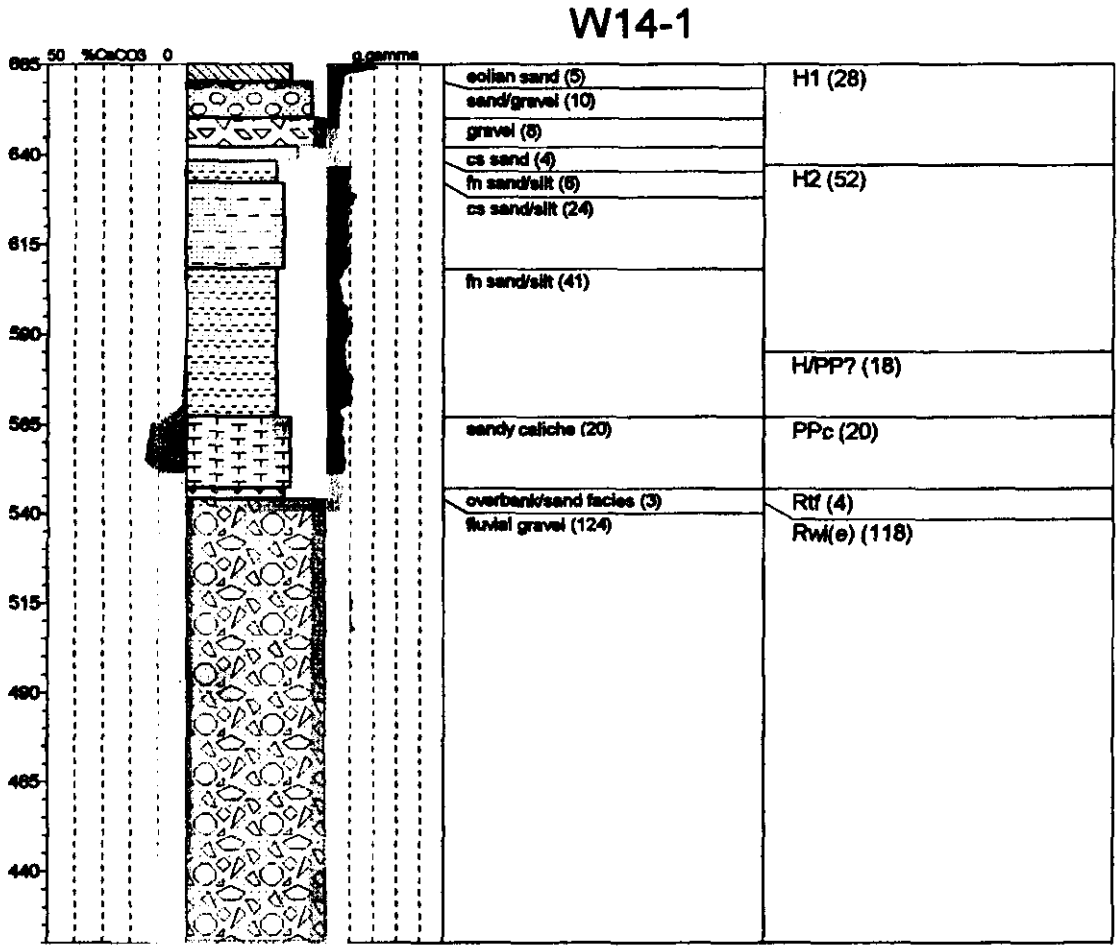
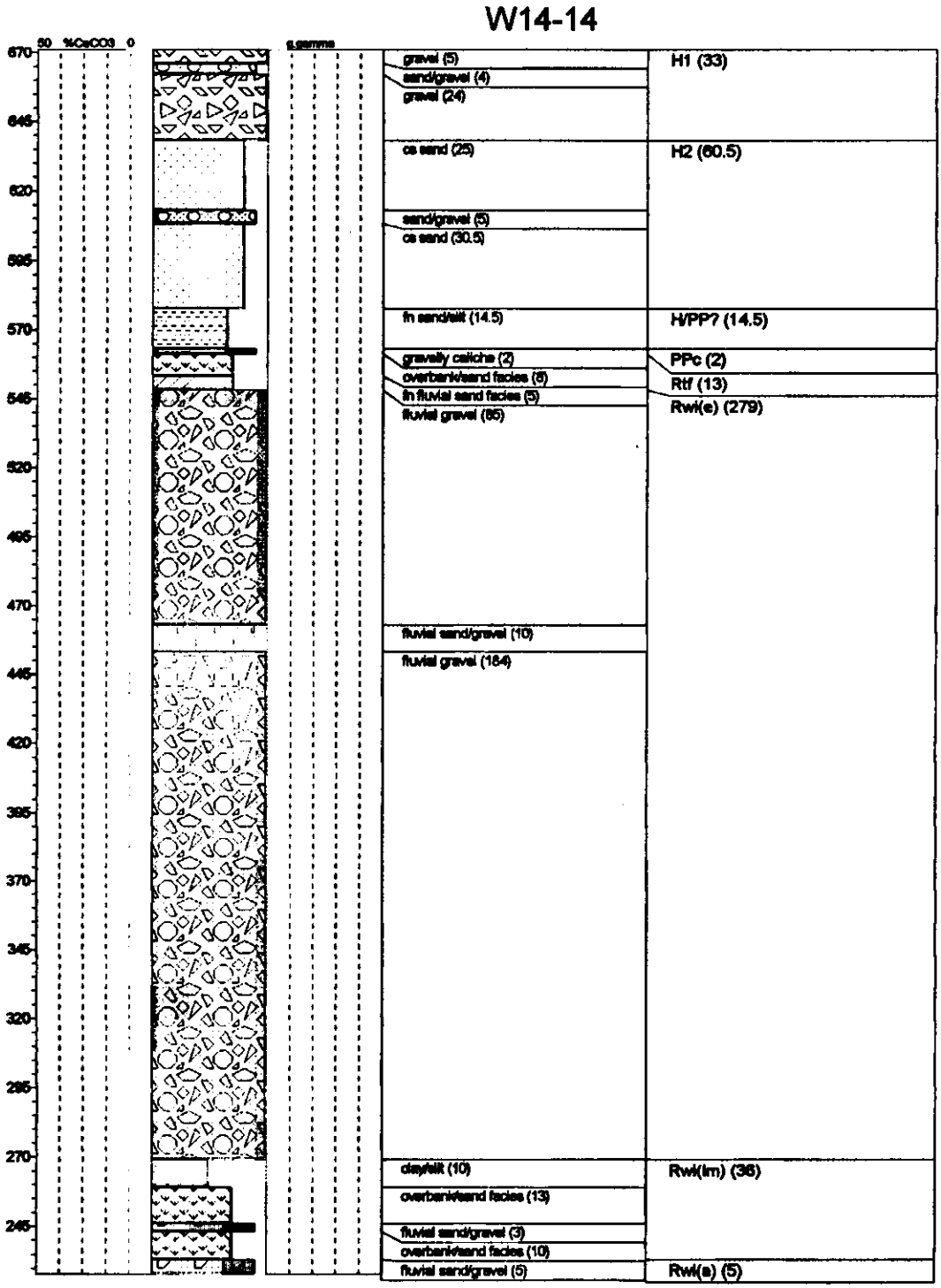


Figure C-47. Boring No. W14-14.



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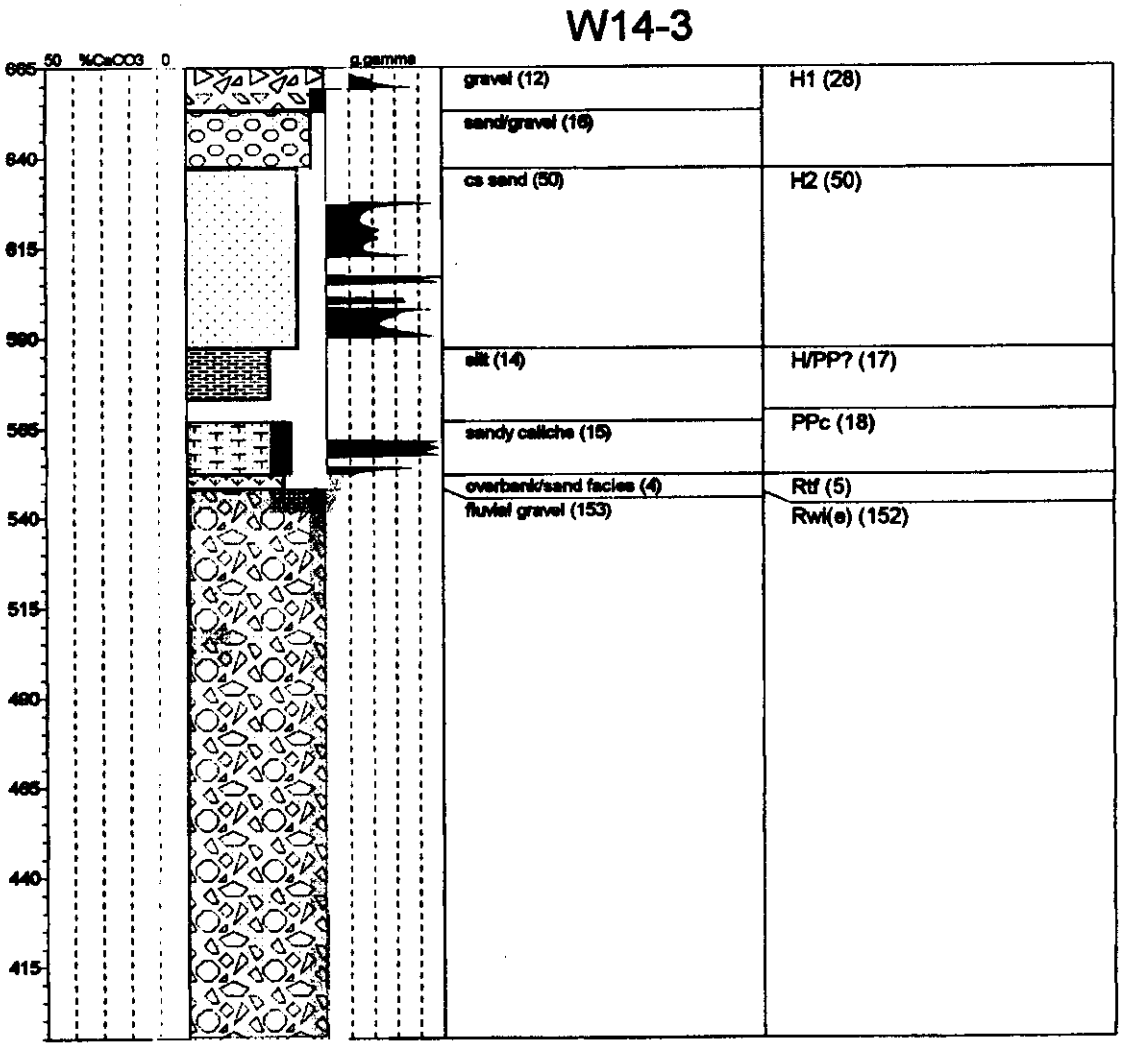


Figure C-49. Boring No. W14-4.

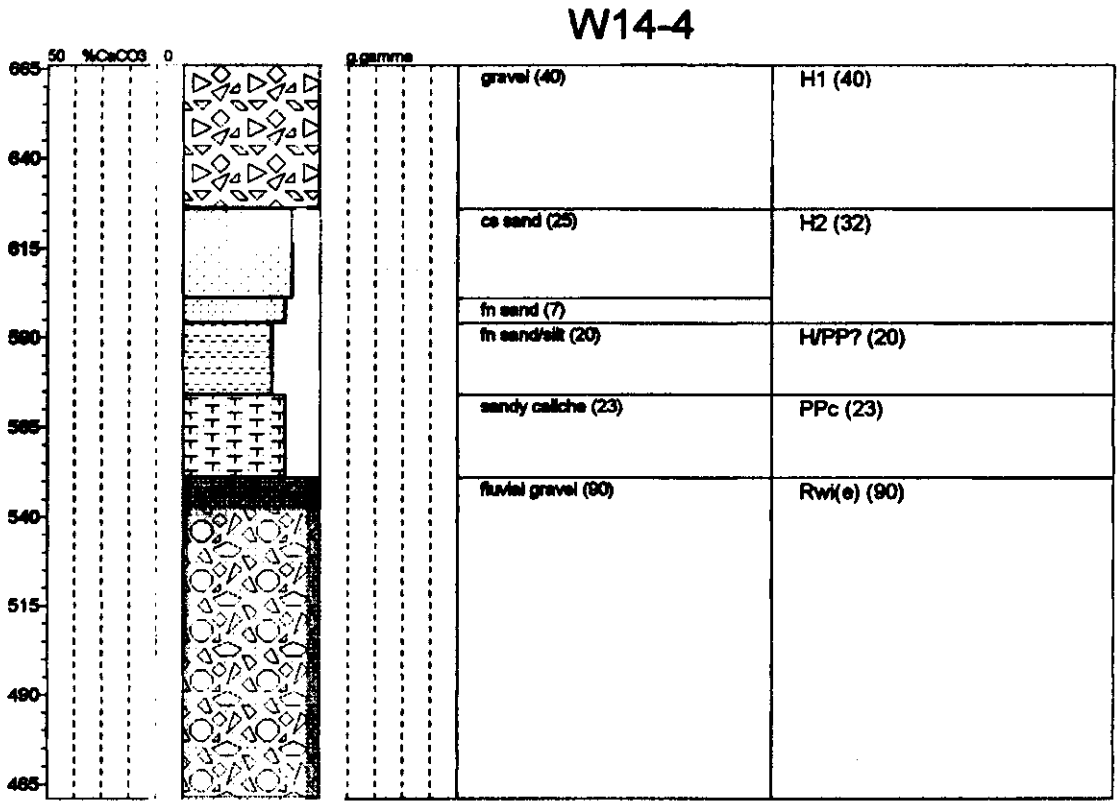


Figure C-50. Boring No. W14-6.

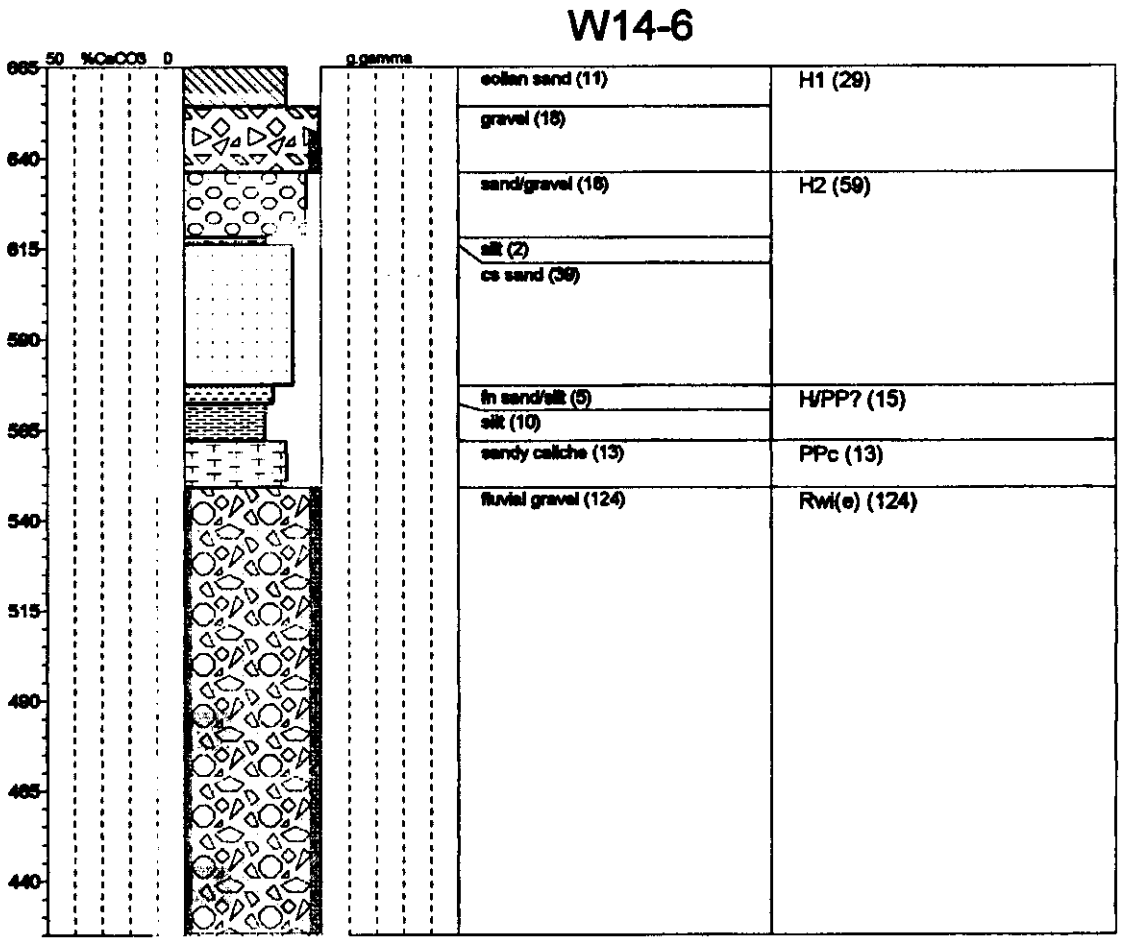


Figure C-51. Boring No. W15-1.

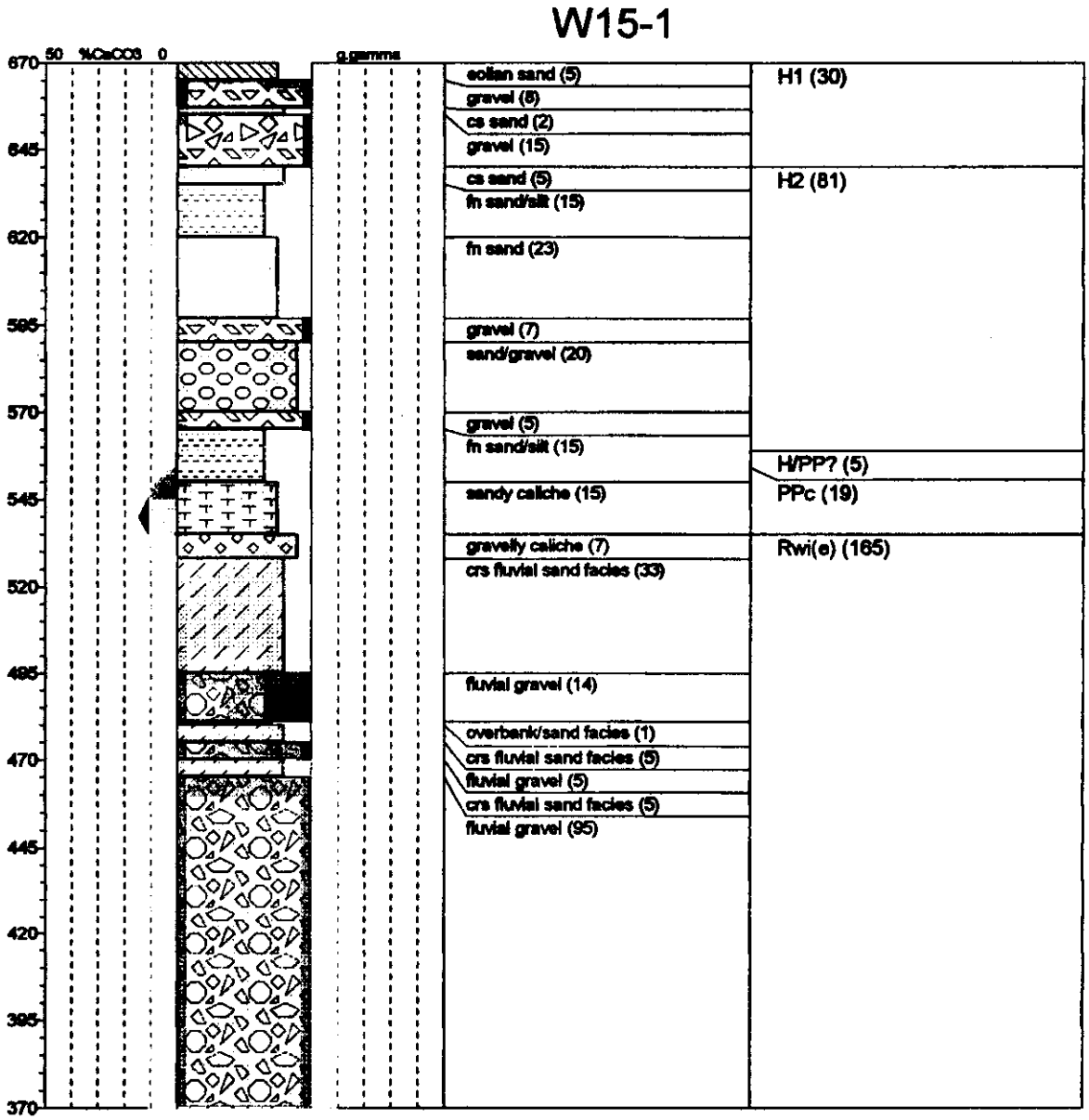


Figure C-52. Boring No. W15-12.

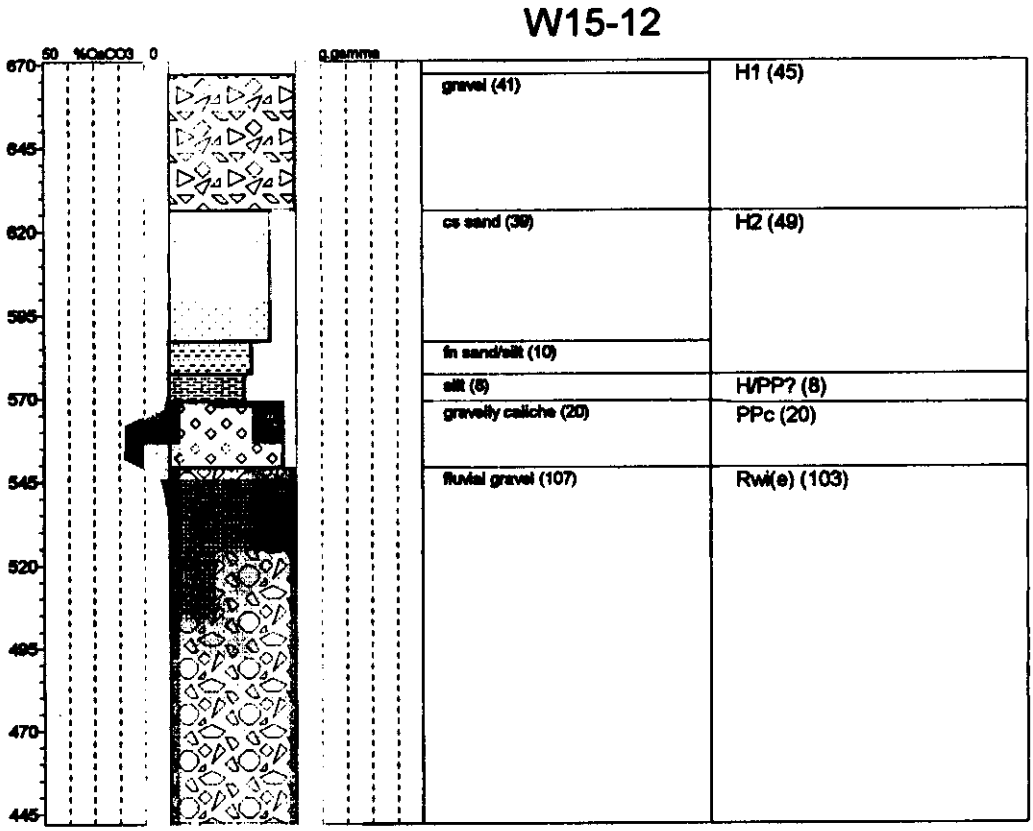


Figure C-53. Boring No. W15-126.

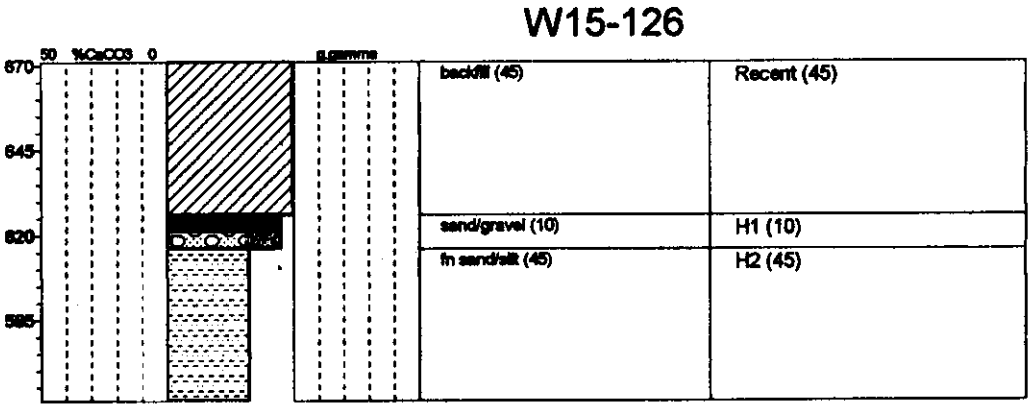
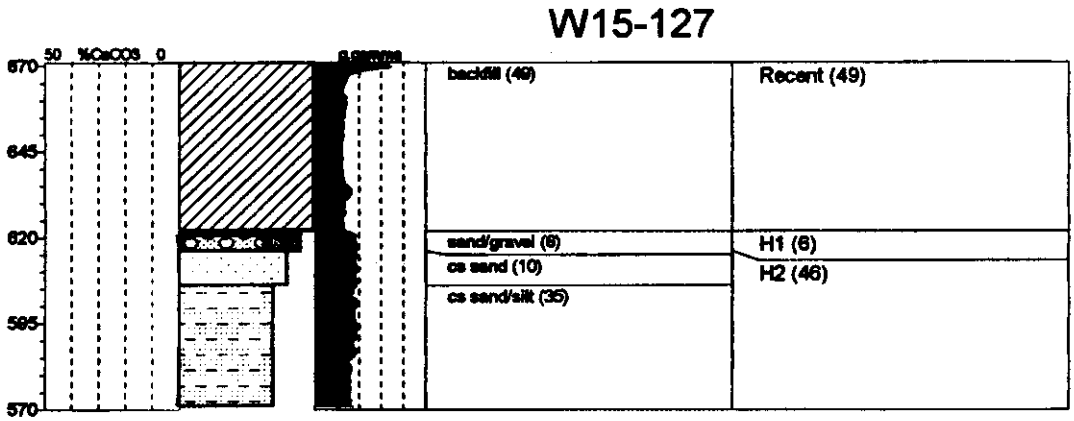


Figure C-54. Boring No. W15-127.



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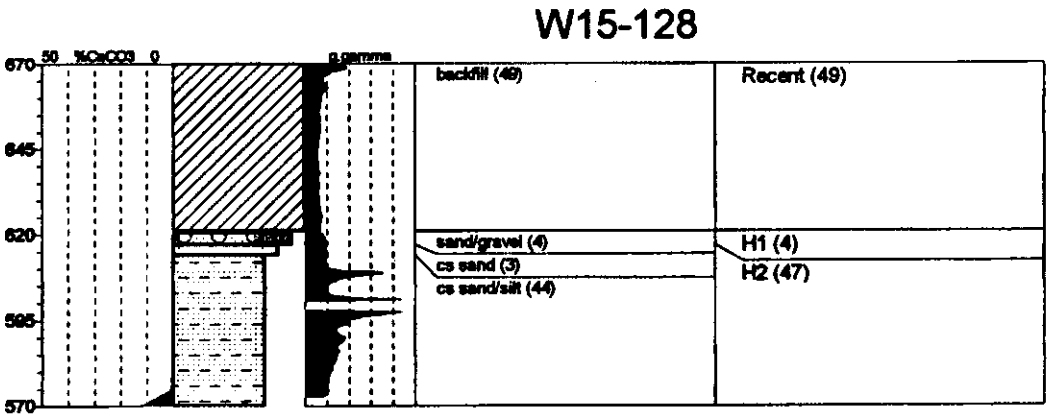


Figure C-56. Boring No. W15-13.

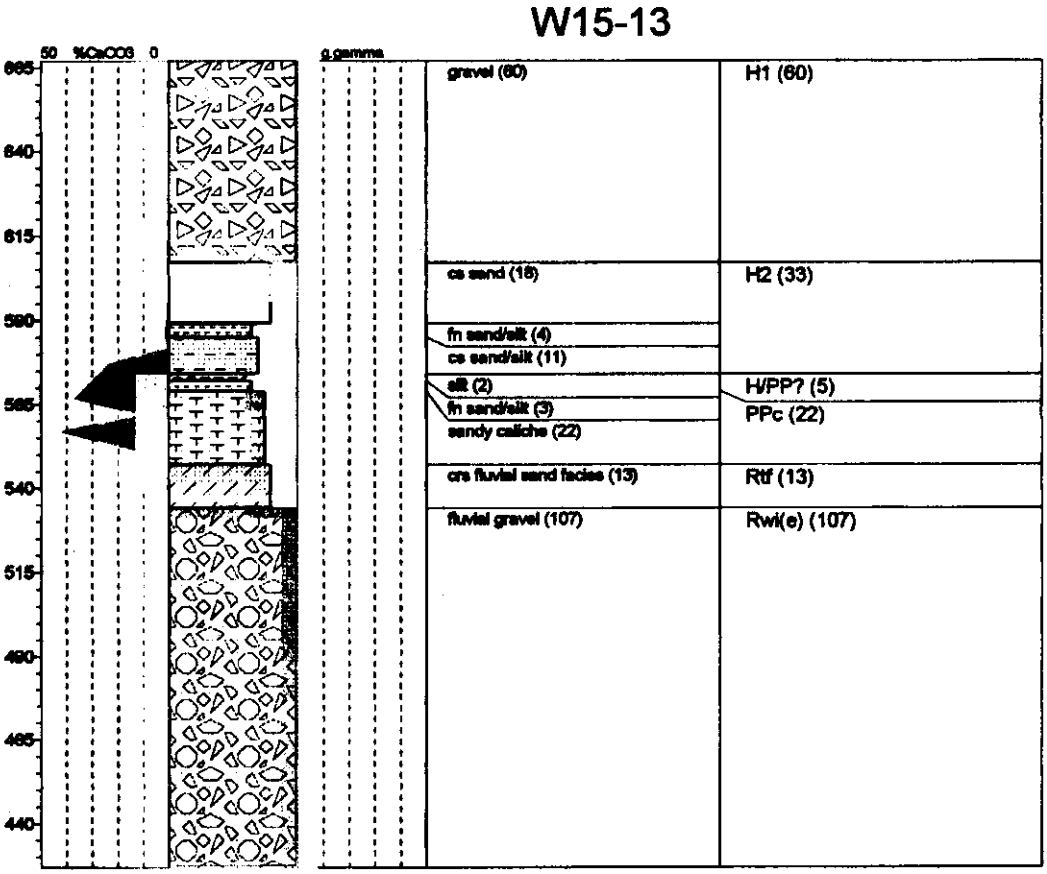


Figure C-57. Boring No. W15-131.

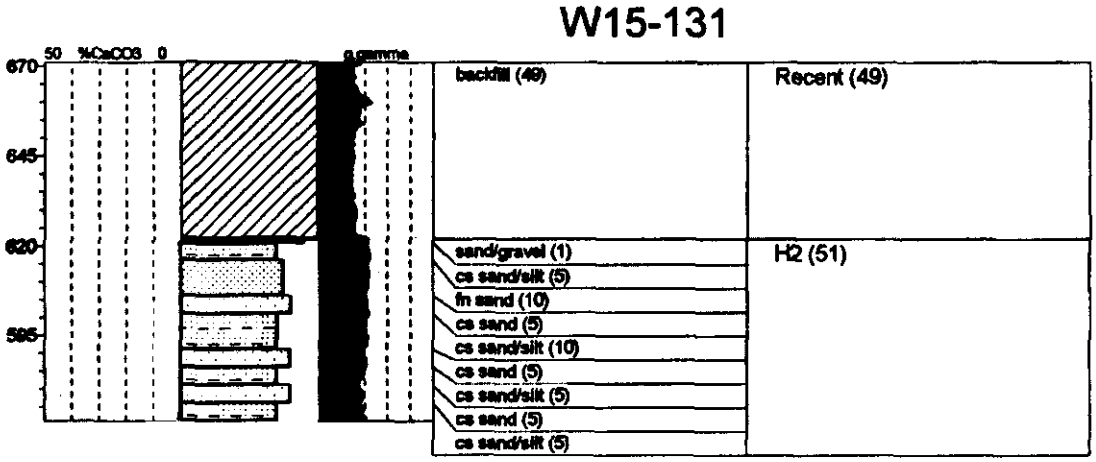


Figure C-58. Boring No. W15-133.

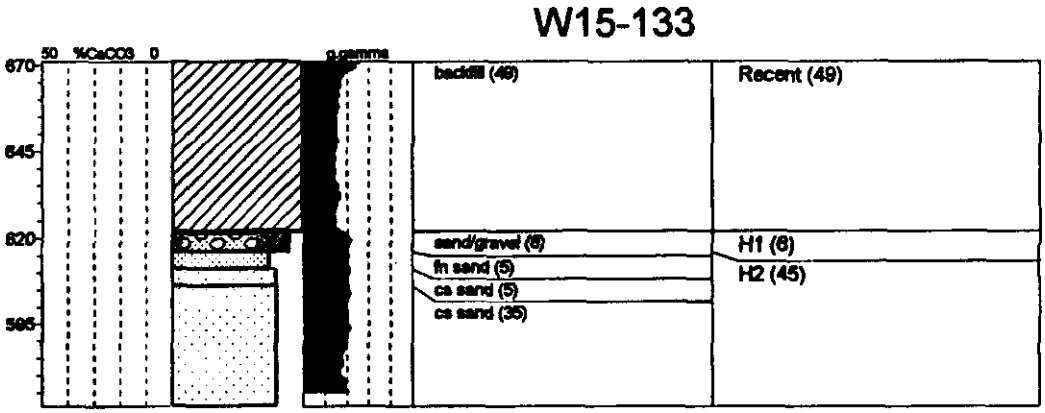


Figure C-59. Boring No. W15-134.

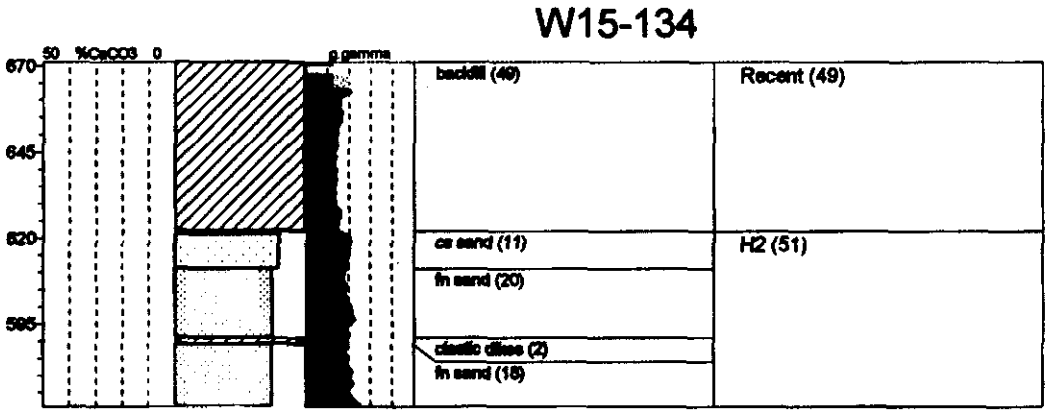


Figure C-60. Boring No. W15-155.

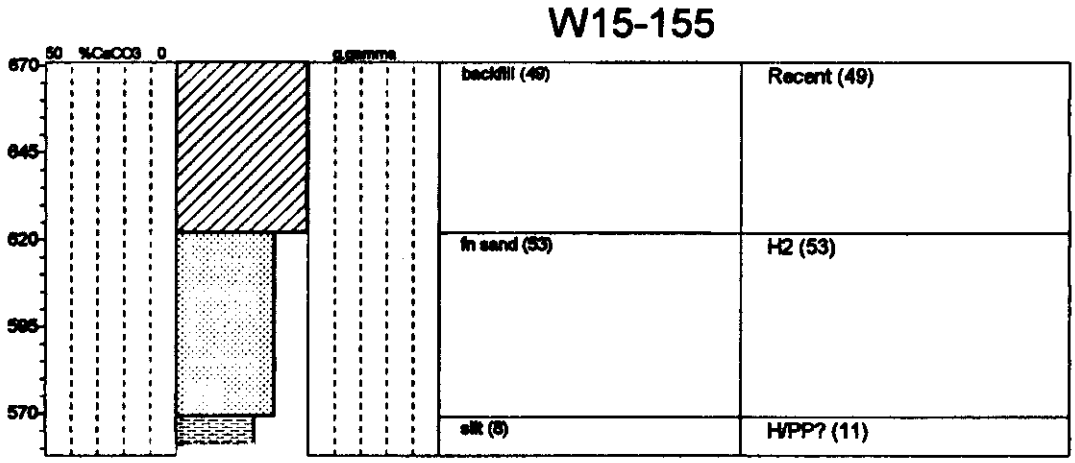


Figure C-61. Boring No. W15-159.

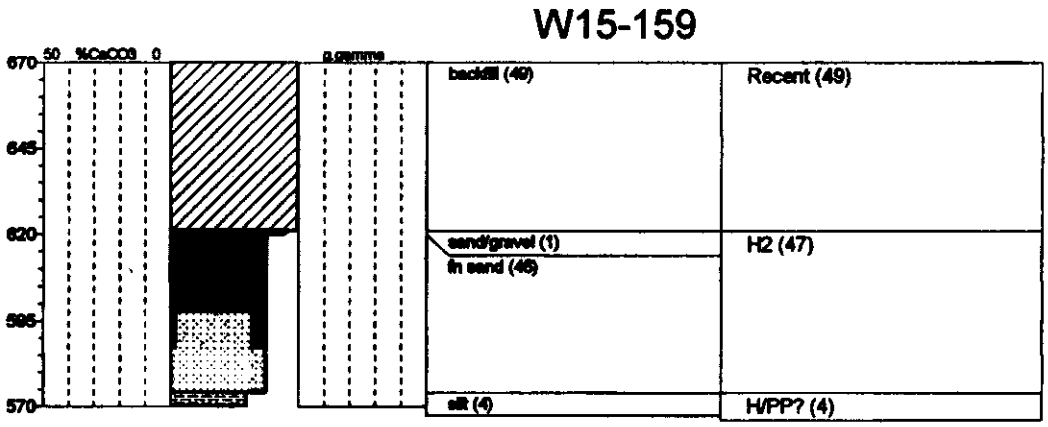


Figure C-62. Boring No. W15-160.

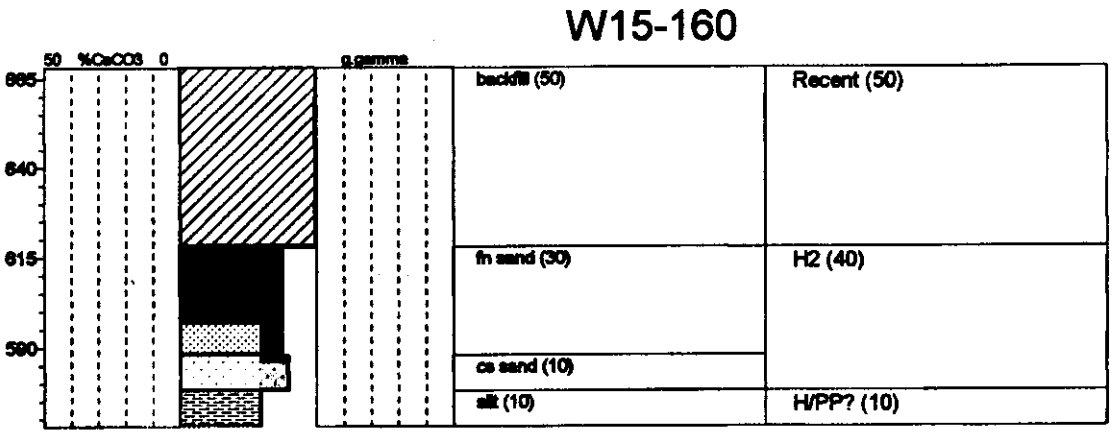


Figure C-63. Boring No. W15-161.

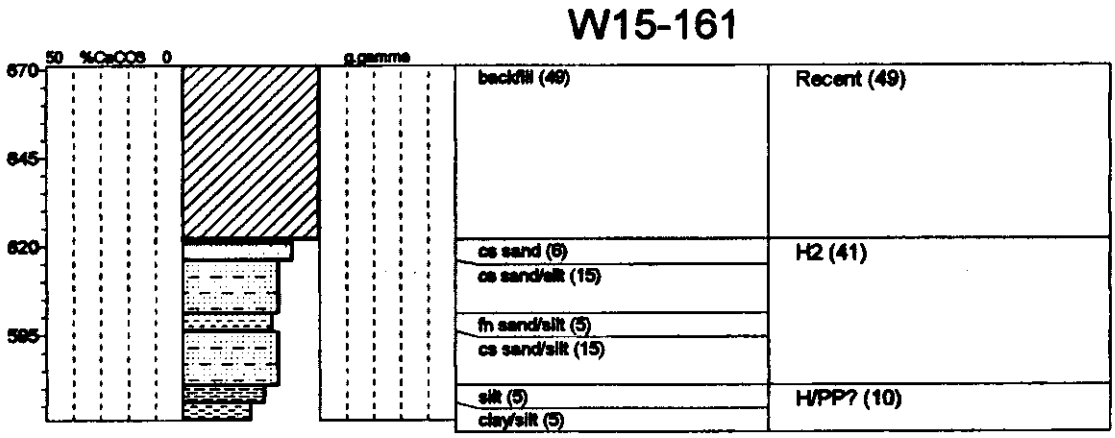


Figure C-64. Boring No. W15-162.

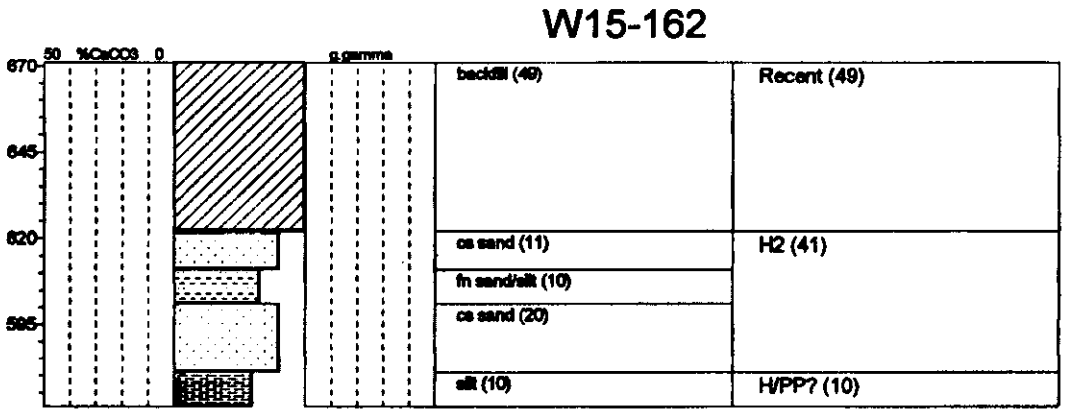


Figure C-65. Boring No. W15-163.

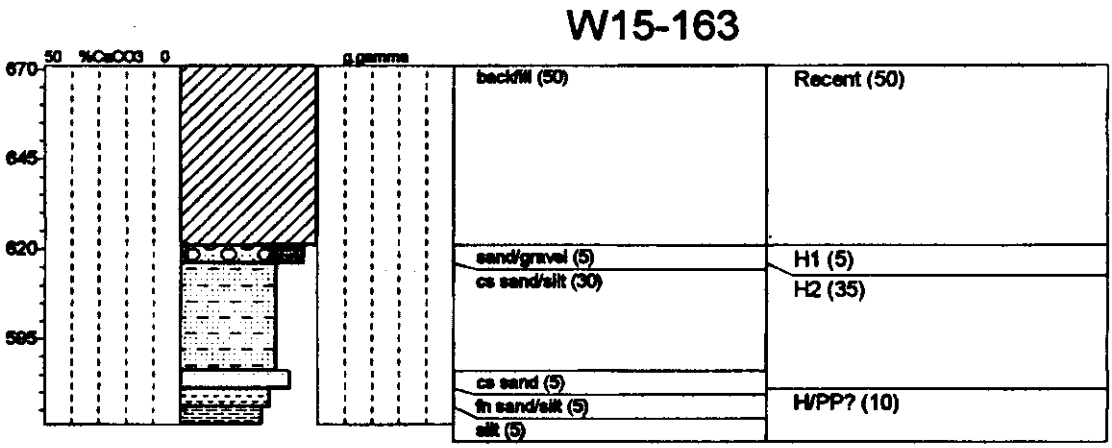


Figure C-66. Boring No. W15-164.

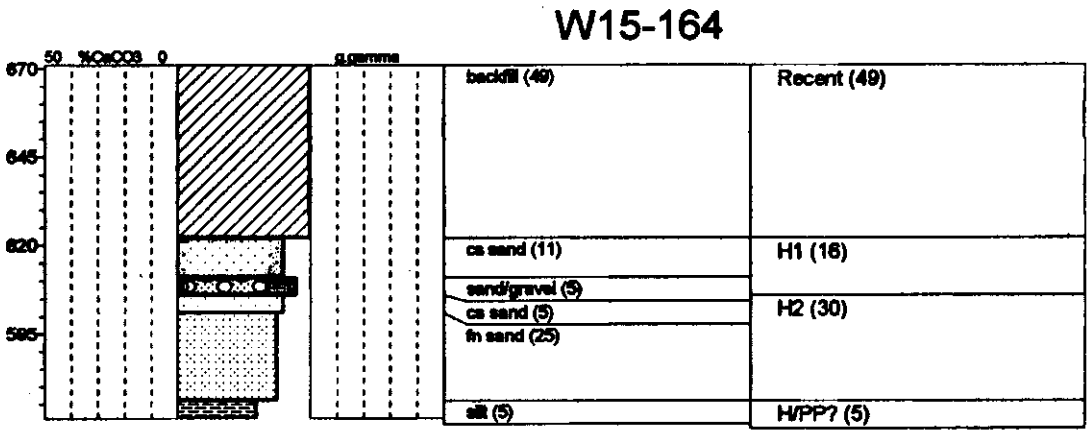


Figure C-67. Boring No. W15-166.

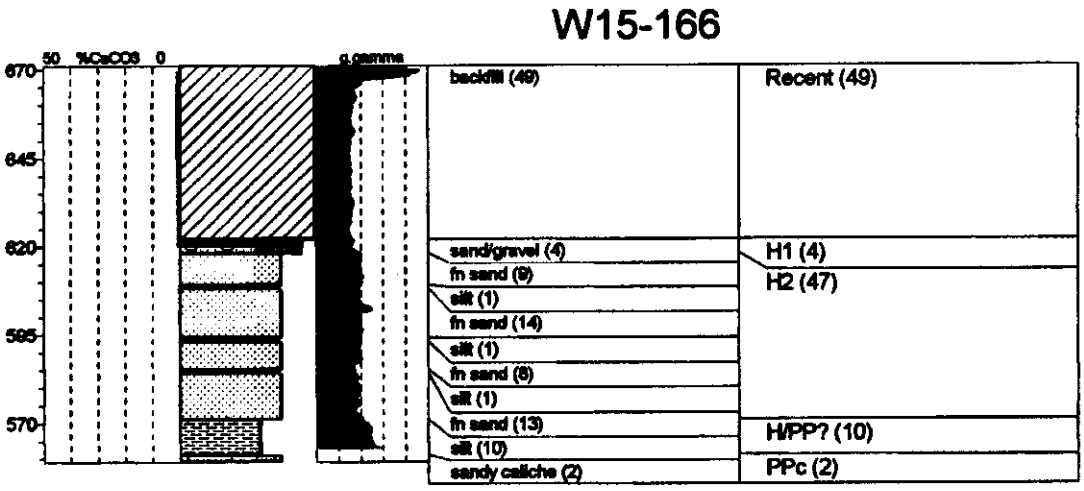


Figure C-68. Boring No. W15-167.

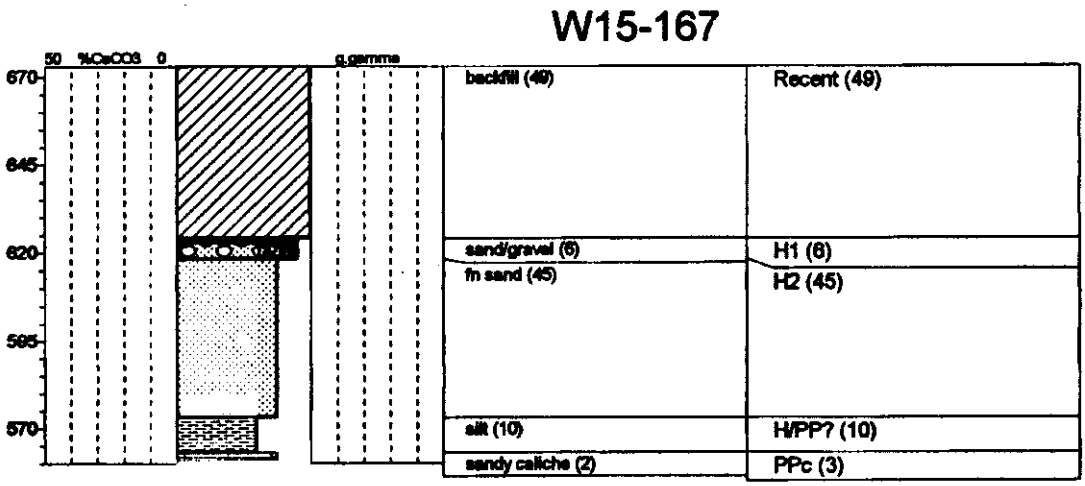


Figure C-69. Boring No. W15-171.

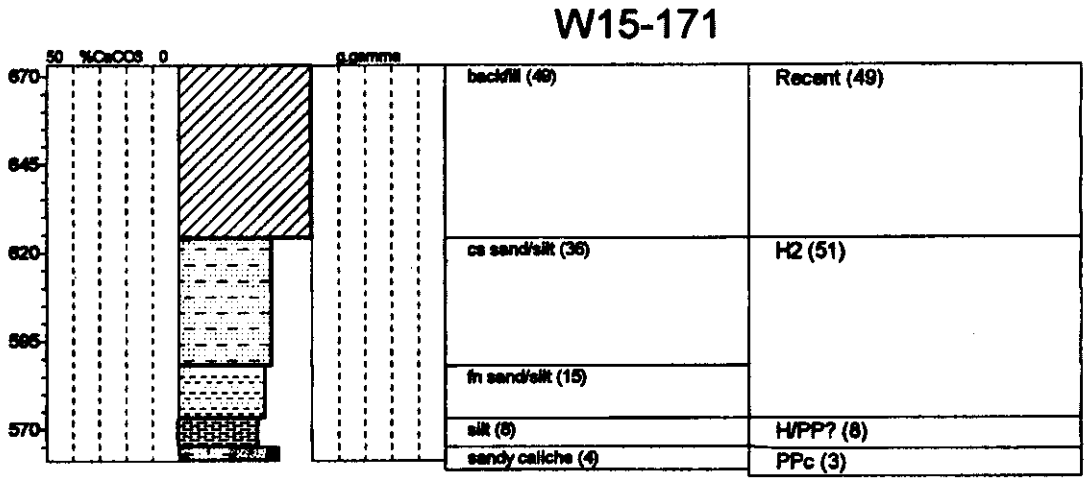


Figure C-70. Boring No. W15-177.

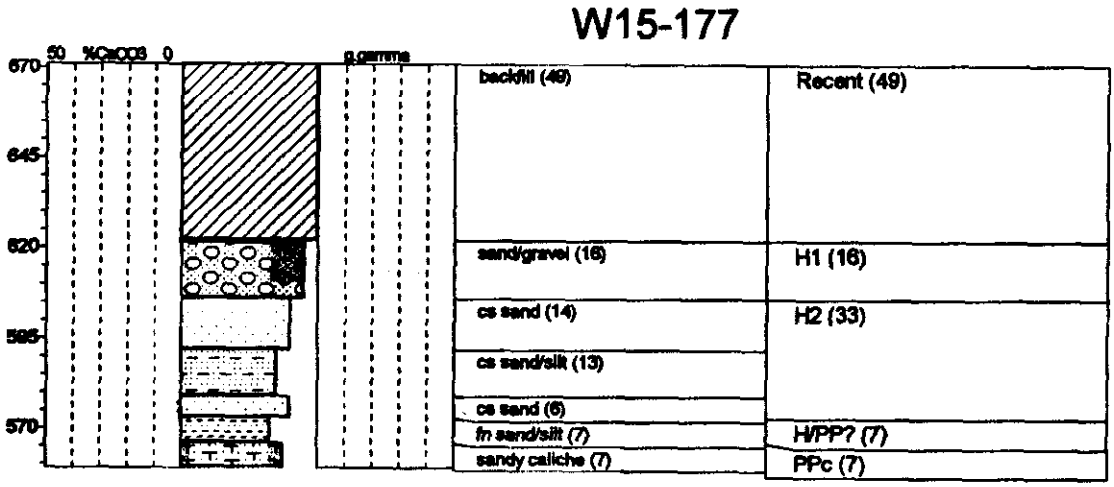


Figure C-71. Boring No. W15-178.

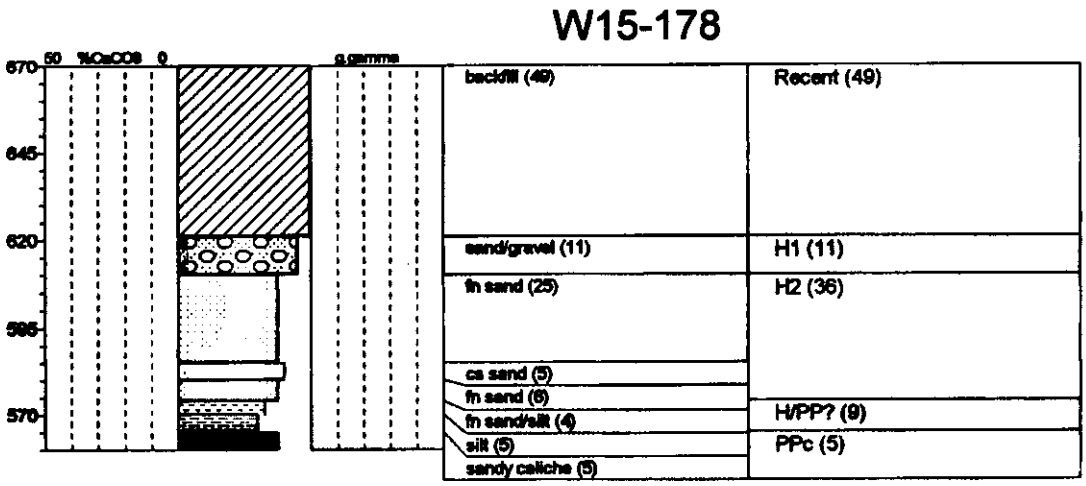


Figure C-72. Boring No. W15-180.

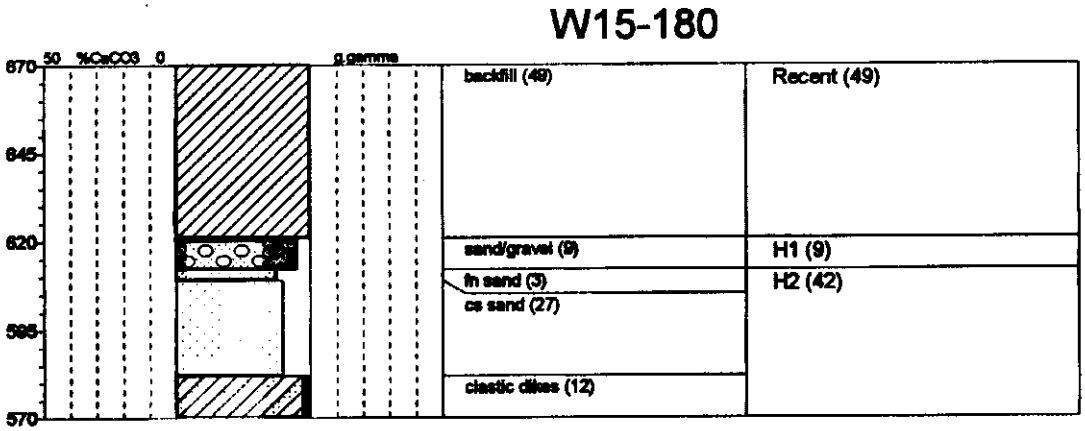


Figure C-73. Boring No. W15-184.

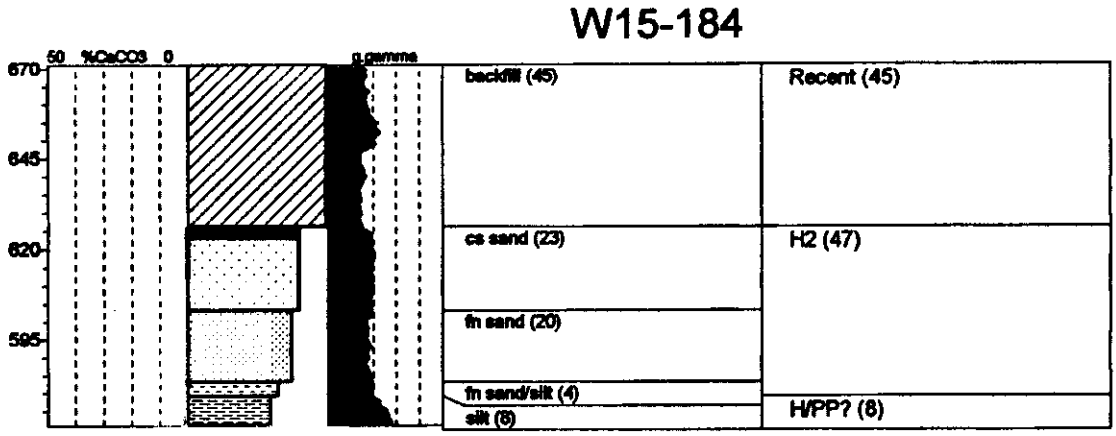
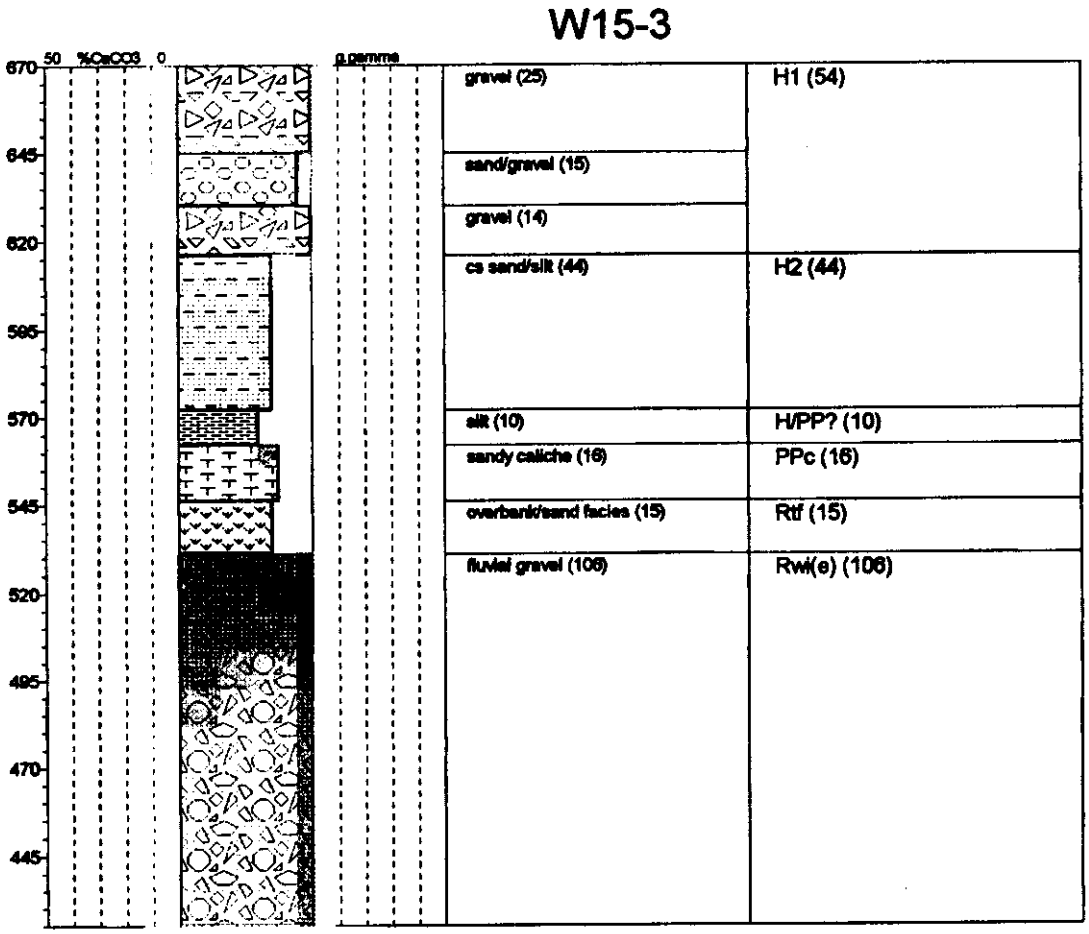


Figure C-74. Boring No. W15-3.



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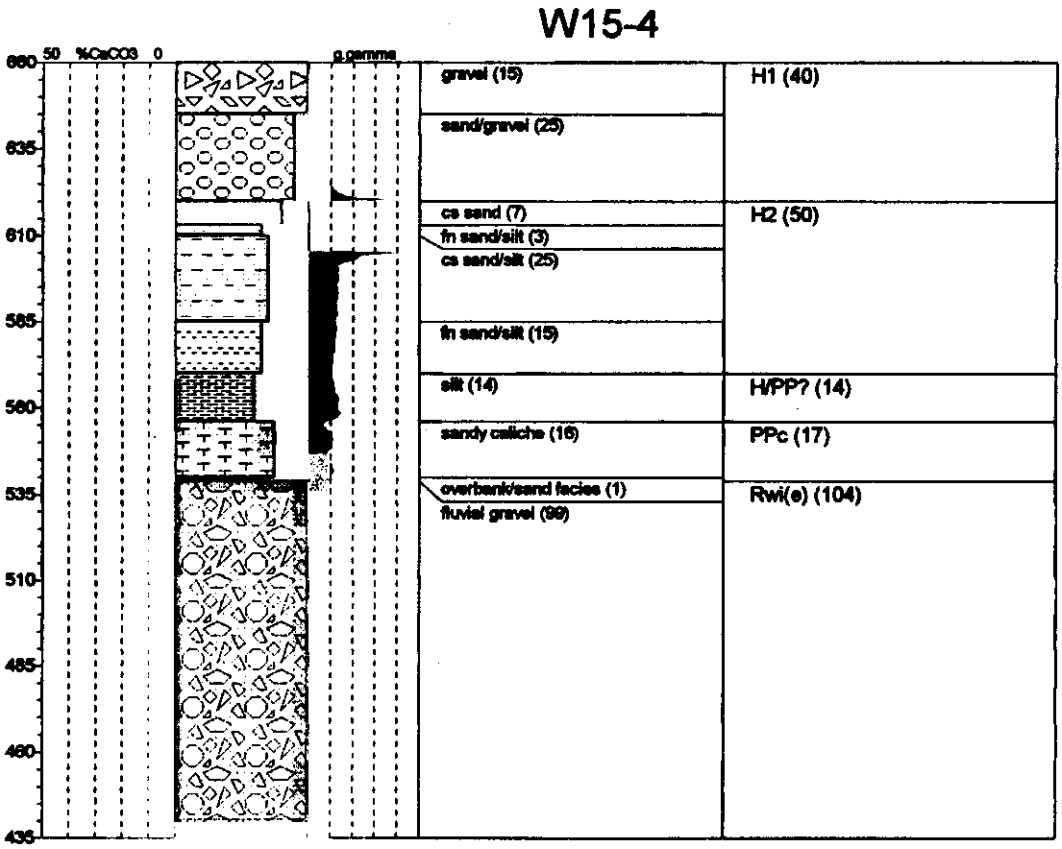


Figure C-76. Boring No. W15-40.

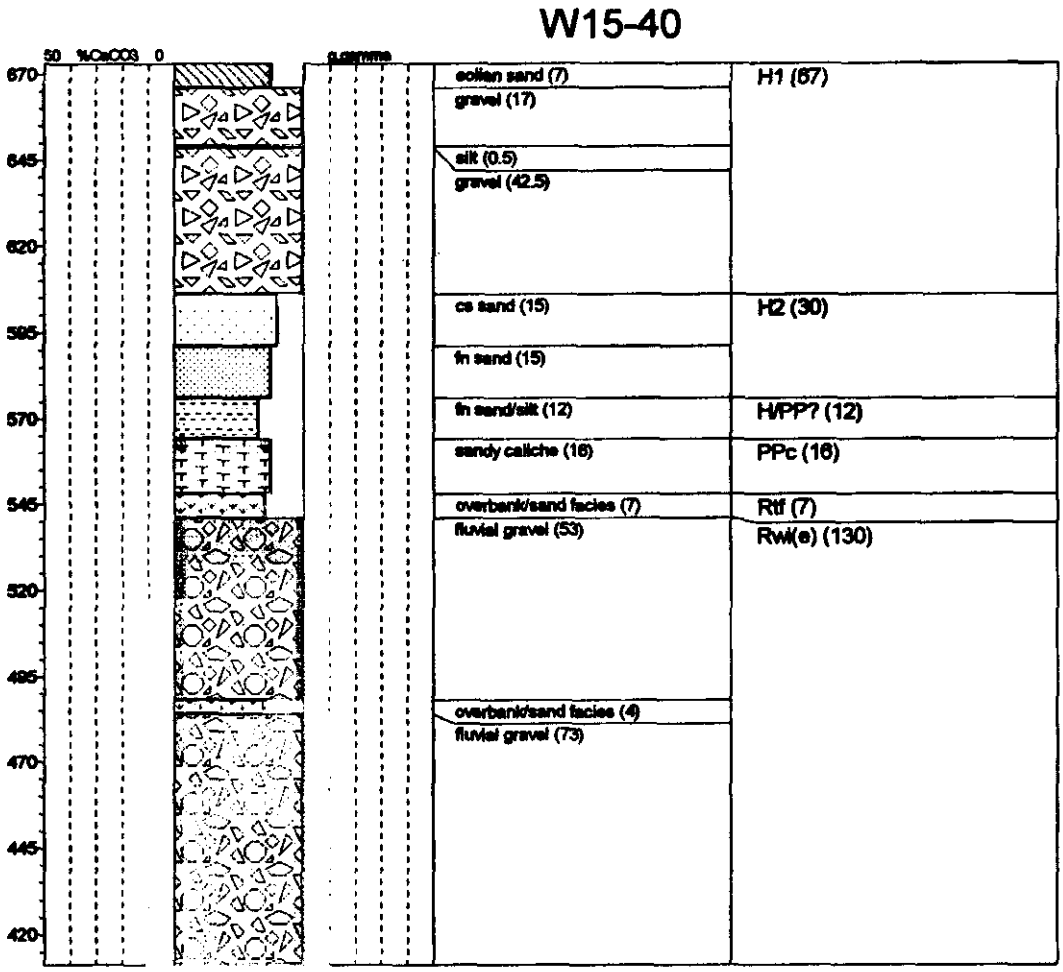


Figure C-77. Boring No. W15-41.

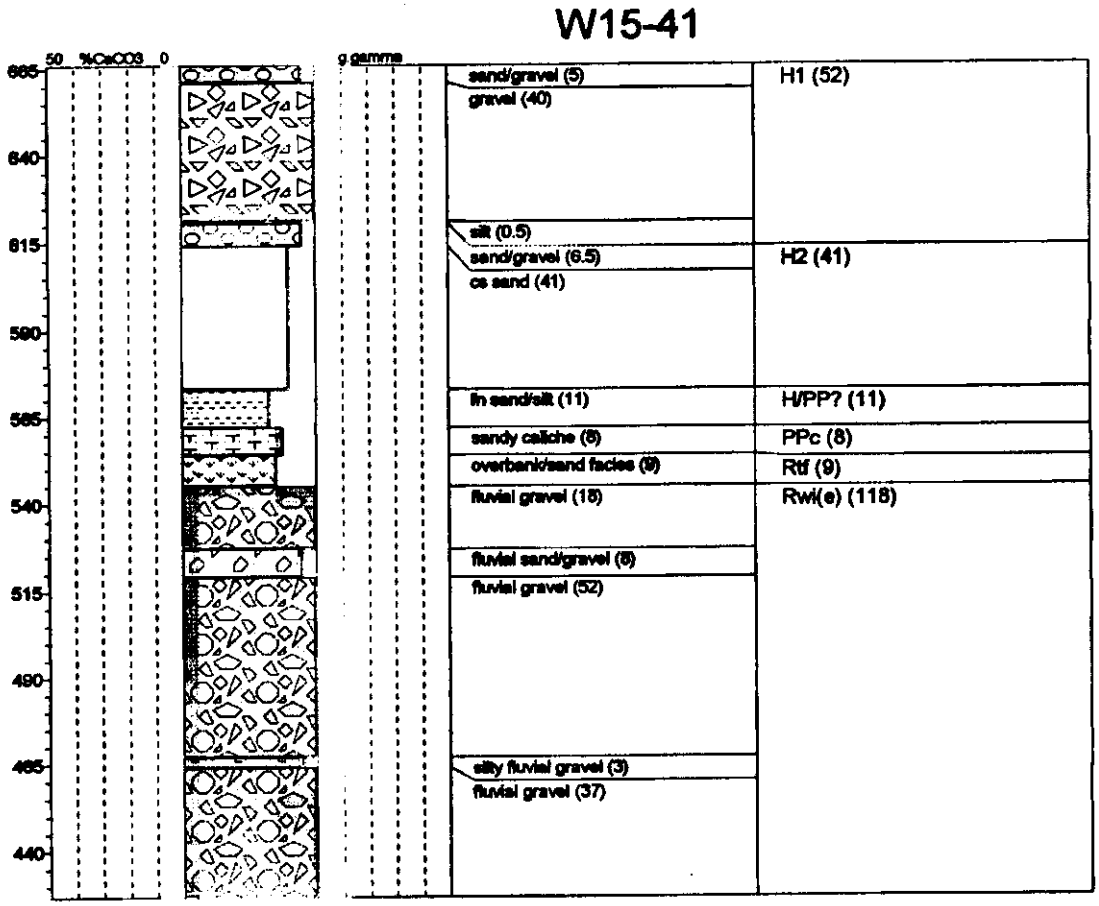


Figure C-78. Boring No. W15-67.

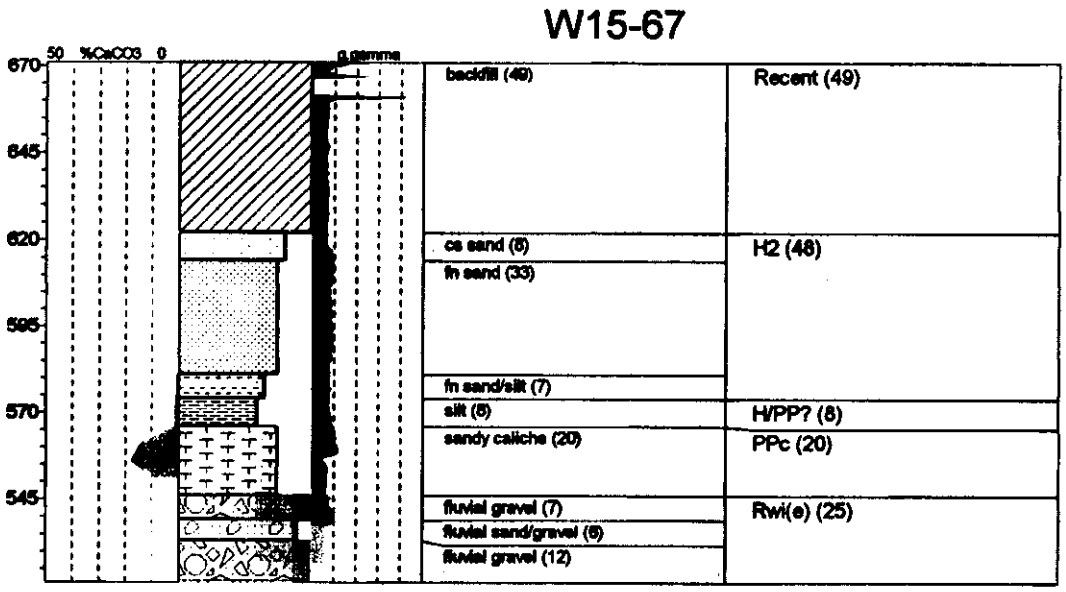


Figure C-79. Boring No. W15-69.

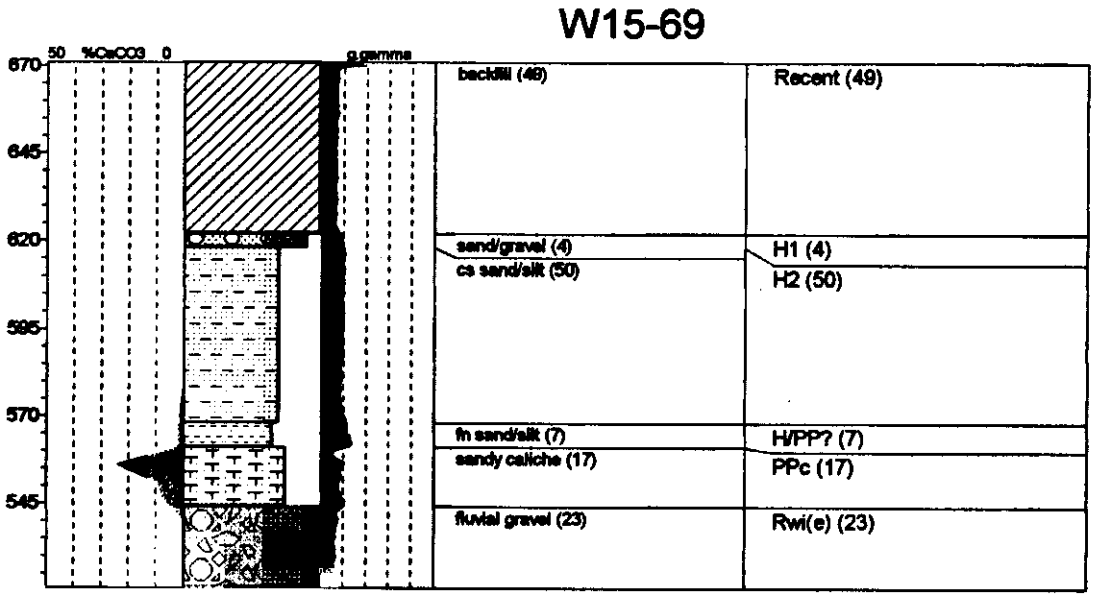


Figure C-80. Boring No. W15-7.

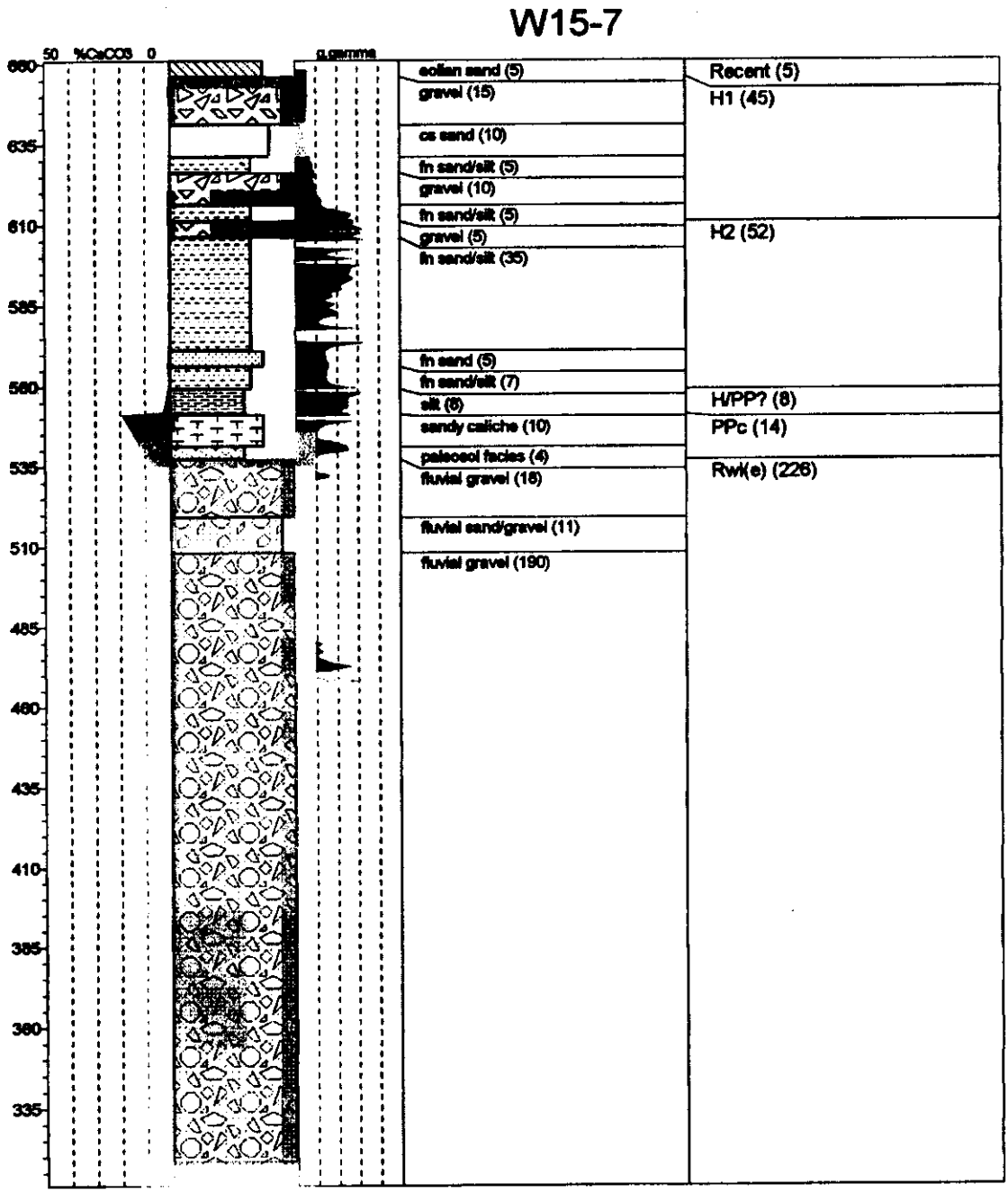


Figure C-81. Boring No. W15-70.

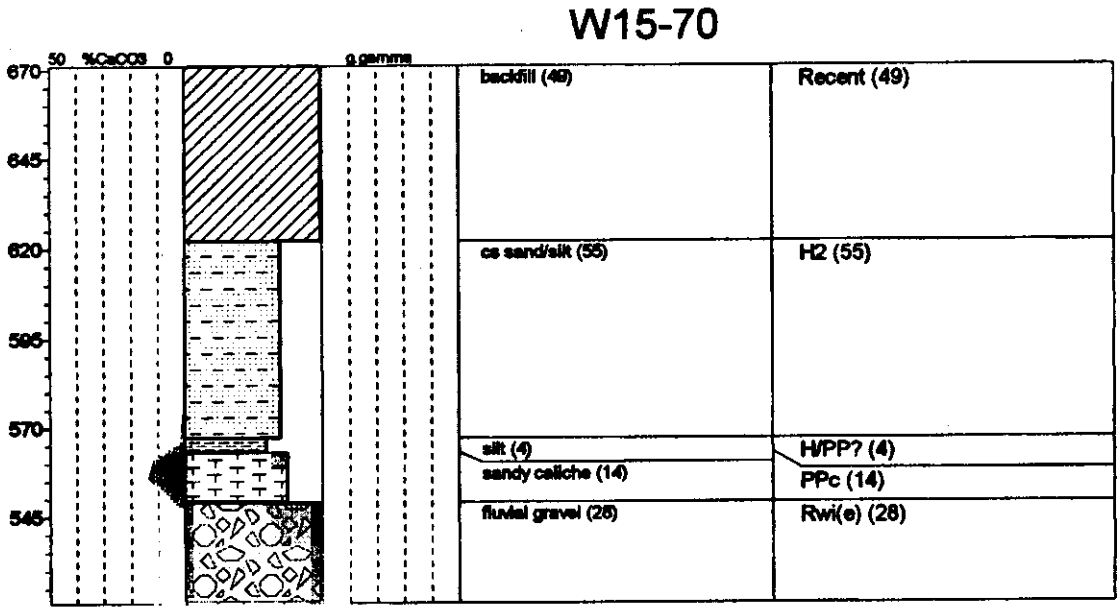


Figure C-82. Boring No. W15-71.

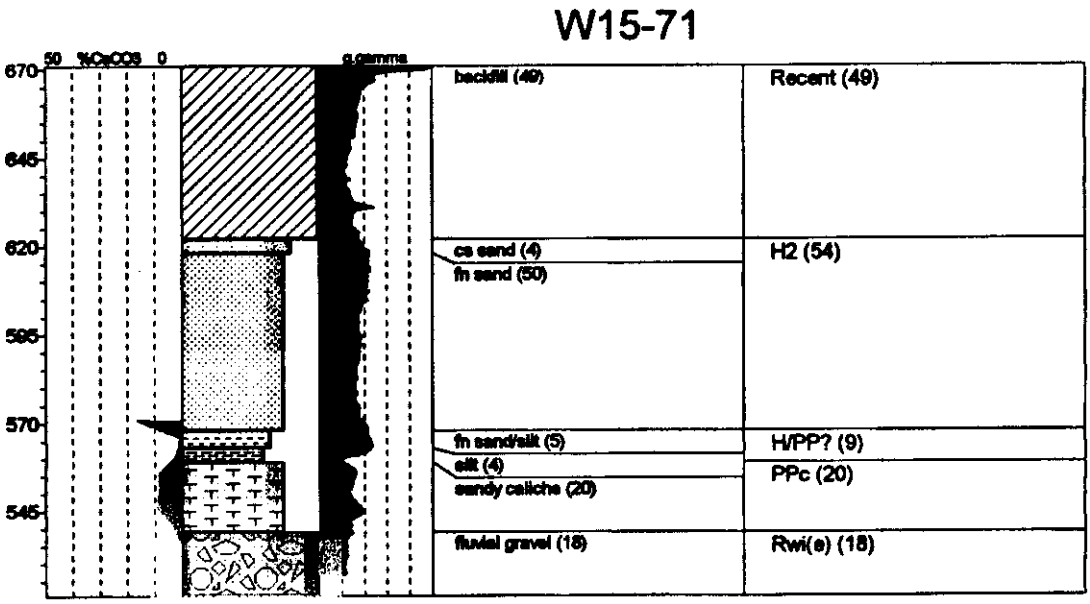


Figure C-83. Boring No. W15-72.

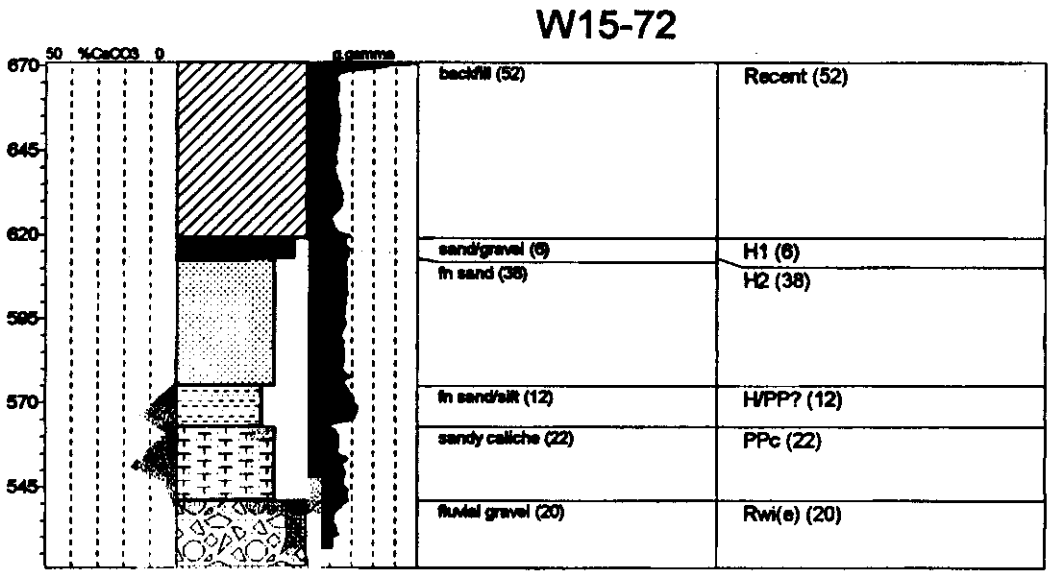


Figure C-84. Boring No. W15-73.

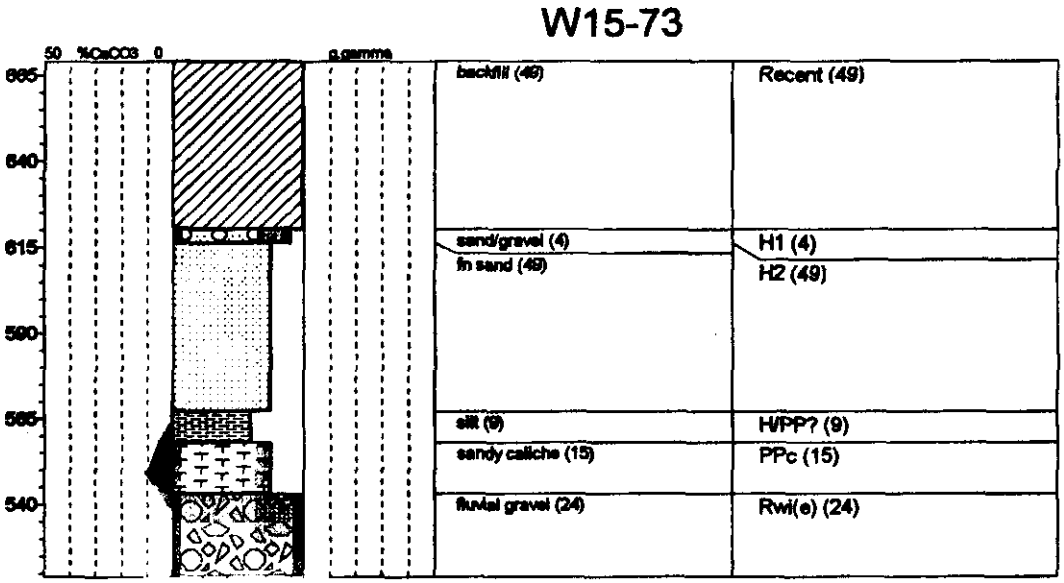


Figure C-85. Boring No. W15-75.

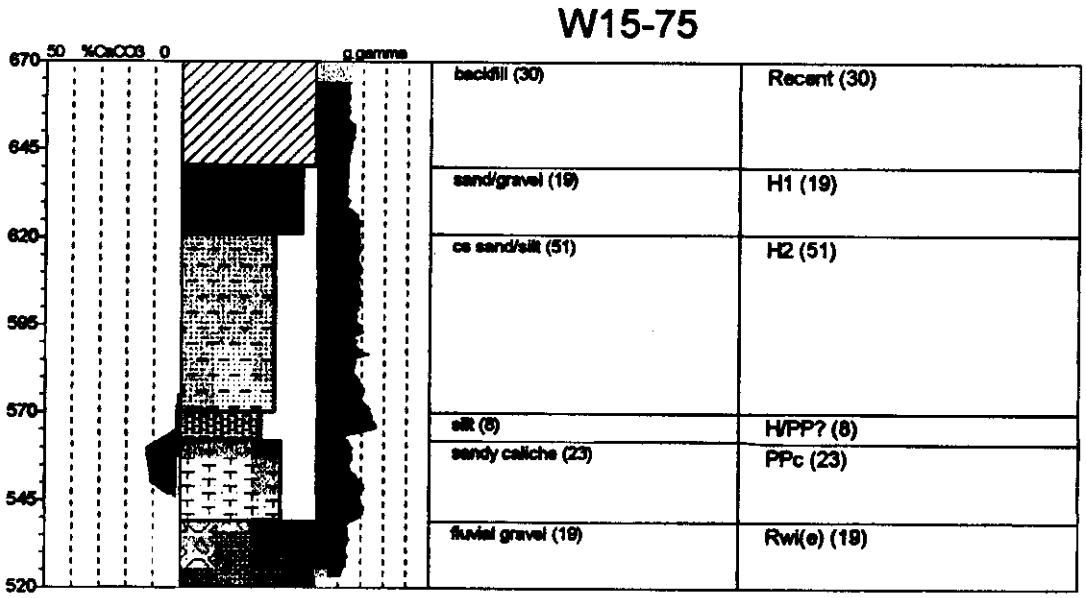
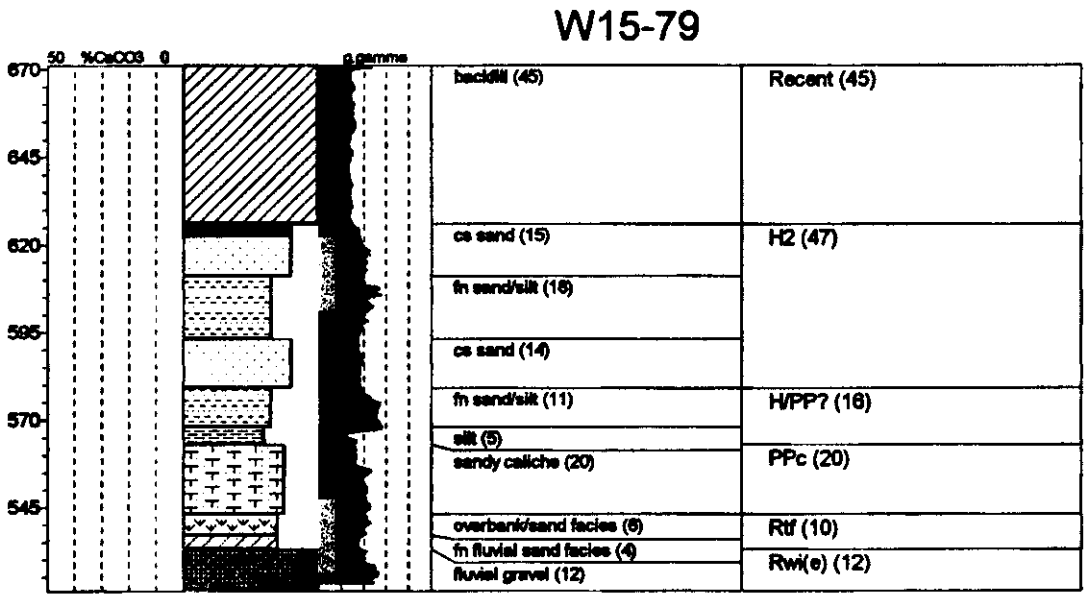


Figure C-86. Boring No. W15-79.



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APPENDIX D

SUPPORTING METEOROLOGICAL, HYDROLOGIC, AND GROUNDWATER CONTAMINATION DATA

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APPENDIX D

SUPPORTING METEOROLOGICAL, HYDROLOGIC, AND GROUNDWATER CONTAMINATION DATA

Table D-1 summarizes monthly and annual precipitation at the Hanford Site from 1946 to 1998. Table D-2 summarizes the physical and hydrologic soil property data collected from soil samples in the 200 West Area. Figures D-1 through D-4 provide supplemental regional views of radionuclide contamination in the unconfined aquifer underlying and surrounding the T and TX-TY Waste Management Areas. Nitrate and tritium distribution are widespread and apparently caused by large intentional liquid waste discharges in nearby cribs and trenches. Iodine-129 contamination is more localized and plausibly caused by intentional discharges from one or more of the TY cribs, 216-T-26 through 216-T-28. Chromium distribution is localized beneath the T tank farm. Its location and limited distribution suggest that the waste from the 241-T-106 tank leak is a plausible source.

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Table D-1. Monthly and Annual Precipitation at the Hanford Site, 1946 to 1998.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1946	—	—	—	—	—	—	0.15	0.35	0.52	0.65	0.66	0.11	—
1947	0.32	0.27	0.42	0.70	0.02	1.07	0.71	0.68	1.34	2.20	0.81	0.75	9.29
1948	1.36	0.69	0.07	0.95	1.71	1.47	0.40	0.39	0.16	0.45	0.95	1.11	9.71
1949	0.13	0.68	1.12	0.02	0.16	0.01	0.01	0.03	0.23	0.10	1.47	0.16	4.12
1950	1.80	1.06	0.87	0.47	0.27	2.92	0.07	T	0.01	2.46	0.55	0.97	11.45
1951	0.84	0.51	0.46	0.53	0.43	1.38	0.37	0.15	0.10	0.71	0.82	0.70	7.00
1952	0.65	0.50	0.06	0.13	0.58	1.07	T	0.08	0.08	0.04	0.20	0.77	4.16
1953	2.16	0.25	0.17	0.77	0.28	0.55	T	0.96	0.13	0.20	0.96	0.49	6.92
1954	1.48	0.28	0.59	0.07	0.41	0.10	0.22	0.42	0.51	0.42	0.86	0.35	5.71
1955	0.56	0.22	0.17	0.40	0.59	0.28	0.57	0	0.77	0.40	1.54	2.03	7.53
1956	1.71	0.56	0.10	T	0.22	0.86	T	0.38	0.01	1.03	0.15	0.58	5.60
1957	0.48	0.23	1.86	0.38	0.82	0.47	0.05	0.02	0.34	2.72	0.39	0.53	8.29
1958	1.74	1.48	0.46	0.64	0.74	0.81	0.02	T	0.05	0.19	0.77	1.84	8.74
1959	2.05	1.17	0.40	0.20	0.50	0.23	T	0.03	1.26	0.56	0.41	0.26	7.07
1960	0.51	0.58	0.67	0.53	0.71	0.14	T	0.26	0.23	0.23	0.92	0.64	5.42
1961	0.33	2.10	1.02	0.48	0.80	0.42	0.15	0.09	T	0.07	0.49	0.89	6.84
1962	0.13	0.90	0.14	0.34	1.35	0.12	T	0.50	0.38	0.95	0.65	0.60	6.06
1963	0.95	0.69	0.53	1.17	0.43	0.28	0.31	0.01	0.02	0.04	0.74	1.14	6.31
1964	0.37	0.01	0.03	0.11	0.04	0.90	0.04	0.24	0.09	0.28	0.94	2.34	5.39
1965	0.93	0.14	0.03	0.09	0.15	0.49	0.11	0.03	0.11	0.01	1.17	0.39	3.65
1966	0.68	0.03	0.39	0.03	0.05	0.43	0.81	T	0.27	0.39	2.25	0.60	5.93
1967	0.32	T	0.14	0.90	0.56	0.57	T	T	0.05	0.13	0.16	0.43	3.26
1968	0.88	0.58	0.02	0.01	0.06	0.19	0.04	0.51	0.25	0.93	1.23	1.25	5.95
1969	1.24	0.54	0.10	1.22	0.51	0.75	T	T	0.48	0.10	0.13	1.29	6.36
1970	2.47	0.75	0.27	0.45	0.54	0.25	0.01	T	0.03	0.24	0.71	0.61	6.33
1971	0.78	0.10	1.02	0.07	0.56	0.71	0.13	0.09	1.13	0.18	0.46	1.07	6.30
1972	0.19	0.27	0.58	0.10	2.03	0.66	0.16	0.56	0.02	T	0.55	1.27	6.39

Table D-1. Monthly and Annual Precipitation at the Hanford Site, 1946 to 1998.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1973	0.90	0.21	0.08	T	0.24	0.01	T	0.02	0.43	1.72	2.64	2.02	8.27
1974	0.90	0.41	0.52	0.46	0.28	0.12	0.71	T	0.01	0.21	0.71	0.97	5.30
1975	1.43	0.98	0.33	0.42	0.38	0.24	0.32	1.16	0.03	0.87	0.60	0.70	7.46
1976	0.56	0.33	0.23	0.41	0.08	0.11	0.13	0.96	T	0.04	T	0.11	2.99
1977	0.08	0.57	0.41	T	0.65	0.37	0.06	1.36	0.66	0.15	0.63	1.47	6.41
1978	1.72	0.92	0.30	0.46	0.41	0.09	0.52	0.57	0.11	T	1.21	0.26	6.57
1979	0.54	0.17	0.54	0.52	0.10	T	0.09	0.38	0.20	0.67	1.36	0.99	5.56
1980	1.32	1.30	0.30	0.86	1.41	0.96	T	0.02	0.85	0.33	0.44	1.89	9.68
1981	0.56	0.60	0.70	0.02	0.99	0.43	0.19	0.03	0.60	0.39	1.08	1.45	7.04
1982	0.33	0.57	0.30	0.75	0.28	0.75	0.22	0.20	0.55	1.33	0.91	1.79	7.98
1983	1.44	1.36	1.00	0.42	0.52	0.68	0.31	0.12	0.46	0.52	2.12	2.12	11.07
1984	0.23	0.94	1.01	0.60	0.55	0.99	0.06	T	0.42	0.07	1.83	0.57	7.27
1985	0.34	0.82	0.36	0.01	0.12	0.15	0.12	0.01	0.63	0.46	1.24	0.84	5.10
1986	1.76	1.37	0.76	T	0.30	T	0.21	0.02	0.96	0.29	0.65	0.77	7.09
1987	0.80	0.19	1.05	0.14	0.17	0.11	0.50	0.07	0.01	T	0.40	1.63	5.07
1988	0.48	T	0.39	1.12	0.33	0.11	0.13	0	0.39	0.01	0.82	0.40	4.18
1989	0.21	1.67	1.56	0.84	0.59	0.01	0.01	0.26	0.02	0.42	1.04	0.29	6.92
1990	0.77	0.09	0.10	0.40	0.86	0.36	0.14	0.83	T	0.78	0.02	0.72	5.07
1991	0.33	0.19	1.12	0.45	0.49	1.44	0.29	0.07	0	0.53	1.44	0.40	6.75
1992	0.44	0.94	0.09	0.94	T	1.14	0.39	0.20	0.27	0.61	1.07	1.82	7.90
1993	1.30	1.17	0.67	0.71	0.60	0.12	1.76	0.24	0.04	0.09	0.19	0.94	7.83
1994	0.44	0.11	0.03	0.61	1.27	0.38	0.15	0.08	0.08	0.93	0.68	1.36	6.12
1995	2.14	0.69	0.95	1.54	0.79	0.77	0.34	0.07	0.79	0.87	1.04	2.32	12.31
1996	1.42	1.22	0.83	0.43	0.62	0.05	0.14	0.02	0.22	0.88	2.67	3.69	12.19
1997	1.51	0.25	0.70	0.33	0.33	0.46	0.19	0.06	0.32	0.92	1.01	0.31	6.39
1998	1.24	1.15	0.50	0.07	0.52	0.48	0.34	0.04	0.10	0.28	1.29	0.44	6.45
Avg	0.93	0.63	0.51	0.45	0.53	0.53	0.22	0.24	0.32	0.55	0.91	1.01	6.82
Norm	0.79	0.62	0.47	0.41	0.51	0.38	0.18	0.27	0.31	0.39	0.91	1.03	6.26

Table D-2. Summary of Soil Physical and Hydrologic Parameters in the 200 Areas. (4 sheets)

Formation	Site	Sample no.	Borehole	Depth (m)	gr	cs	Sieve Analysis fs	Silt	Clay	Soil Type #	alpha (1/cm)	n	theta_r	theta_s	Ks (cm/s)	Sampling Technique	Source
Hanford sand	218-W-5 [2,4]	0-073	299-W7-9	20.3	0	27	54	10	9	loamy sand (1)	0.0008	1.9785	0.0600 [f]	0.4134	N/A	splitspoon	Relyea, 1995
Plio-Pleistocene		0-082	299-W7-9	24.5	2	38	47	8	5	sand (2)	0.0064	1.7084	0.1483	0.3336	6.30E-04	splitspoon	"
Plio-Pleistocene		0-085	299-W7-9	26.9	0	50	37	5	8	sand (2)	0.0049	2.1261	0.0578	0.2105	1.30E-04	splitspoon	"
Upper Ringold		0-101	299-W7-9	31.8	0	85	8	2	5	sand (2)	0.0695	1.4447	0.0228	0.2082	2.10E-04	splitspoon	"
Upper Ringold		0-104	299-W7-9	34.2	0	72	24	3	1	sand (2)	0.0849	1.3106	0.0000	0.2082	1.10E-03	splitspoon	"
Palouse paleosol		5-0001	299-W7-9	21.6	4	4	79	8	5	sand (2)	0.0057	2.8152	0.0200 [f]	0.3727	1.40E-04	splitspoon	"
Plio-Pleistocene		5-0002	299-W7-9	24.9	2	38	47	8	5	sand (2)	0.0039	1.9321	0.0678	0.3454	1.32E-04	splitspoon	"
Upper Ringold		5-0003	299-W7-9	43.2	0	74	22	1	3	sand (2)	0.0414	1.9382	0.0211	0.3004	1.80E-04	splitspoon	"
Upper Ringold		5-0004	299-W7-9	30.3	0	58	30	7	5	sand (2)	0.0102	1.5737	0.0267	0.3256	1.65E-04	splitspoon	"
Palouse paleosol		5-0005	299-W7-9	21.1	0	0	73	22	5	sandy loam (1)	0.0069	2.2430	0.0400 [f]	0.3851	6.70E-05	splitspoon	"
Hanford sand		5-0006	299-W7-9	19.9	0	27	54	10	9	loamy sand (1)	0.0064	2.2593	0.0584	0.3274	N/A	splitspoon	"
Upper Ringold		5-0007	299-W7-9	40.3	0	80	13	5	2	sand (2)	0.1308	1.7017	0.0231	0.3502	3.00E-03	splitspoon	"
Plio-Pleistocene	218-W-5 [1,5]	W7-2-65	299-W07-02	19.8	35	38	11	16	0	silty sandy gravel (3)	0.02102	1.4563	0.064	0.3752	6.80E-02	splitspoon	Bjornstad, 1990
Upper Ringold		W7-2-94	299-W07-02	28.6	48	39	7	6	0	sandy gravel (5)	0.0557	1.9669	0.0223	0.2168	3.70E-02	splitspoon	"
Middle Ringold		W7-2-154	299-W07-02	46.9	32	36	15	17	0	silty sandy gravel (3)	0.1027	1.3782	0.0150 [f]	0.3071	2.10E-02	splitspoon	"
Middle Ringold		W7-2-219	299-W07-02	66.8	39	35	18	8	0	sandy gravel (5)	0.068	1.7788	0.0617	0.1594	2.70E-03	splitspoon	"
Hanford Sand		W10-13-45	299-W10-13	13.7	0	62	33	5	0	sand (2)	0.0408	2.0672	0.0396	0.3915	5.80E-02	splitspoon	"
Hanford Gravel		W10-13-80	299-W10-13	24.4	64	25	6	5	0	sandy gravel (5)	0.2758	1.3718	0.0367	0.1781	2.70E-02	splitspoon	"
Hanford gravel	241-T-106 [2,4]	3-0210	299-W10-196	3.1	48	30	22	0	0	sandy gravel (5)	0.0115	2.2692	0.0450	0.1854	1.00E-03	splitspoon	Relyea, 1995
Hanford gravel		3-0213	299-W10-196	5.6	31	33	36	0	0	gravelly sand (4)	0.0040	2.4233	0.0494	0.2083	1.02E-03	splitspoon	"
Hanford gravel		3-0279	299-W10-196	1.8	46	32	20	2	0	sandy gravel (5)	0.0061	2.1046	0.0337	0.1492	N/A	splitspoon	"
Hanford sand		3-0589	299-W10-196	25.5	2	56	42	0	0	sand (2)	0.0040	2.0685	0.0575	0.3443	1.38E-05	splitspoon	"
Middle Ringold		3-0667	299-W10-196	42.2	80	13	7	0	0	sandy gravel (6)	0.0115	1.3466	0.0000	0.0718	2.83E-05	splitspoon	"
Middle Ringold		3-0668	299-W10-196	38.9	63	15	12	10	0	sandy gravel (5)	0.0023	1.5765	0.0100 [f]	0.1470	1.60E-03	splitspoon	"
Middle Ringold		3-0682	299-W10-196	46.1	0	54	35	10	1	sand (1)	0.0128	2.0864	0.0519	0.4334	4.57E-05	splitspoon	"

Table D-2. Summary of Soil Physical and Hydrologic Parameters in the 200 Areas. (4 sheets)

Formation	Site	Sample no.	Borehole	Depth (m)	gr	cs	Sieve Analysis fs	Silt	Clay	Soil Type [e]	alpha (1/cm)	n	theta_r	theta_s	Ks (cm/s)	Sampling Technique	Source
Middle Ringold		3-0688	299-W10-196	48.5	0	38	28	28	6	sandy loam (1)	0.0036	1.6568	0.0302	0.3230	N/A	splitspoon	Relyea, 1995
Middle Ringold		3-0689	299-W10-196	52.2	0	36	30	25	9	sandy loam (1)	0.0022	1.6651	0.0300 [f]	0.3208	N/A	splitspoon	"
Middle Ringold		3-0690	299-W10-196	53.7	0	39	31	23	7	sandy loam (1)	0.0042	1.6376	0.0564	0.3683	6.55E-06	splitspoon	"
Plio-Pliestocene	C-018-H [2,4]	2-1169	699-48-77	8.1	14	40	44	2	0	gravelly sand (4)	0.0076	2.5367	0.0569	0.3069	5.30E-03	splitspoon	Relyea, 1995
Plio-Pliestocene		2-1170	699-48-77	8.9	22	42	33	3	0	gravelly sand (4)	0.0048	1.9770	0.0635	0.3011	1.30E-04	splitspoon	"
Plio-Pliestocene		2-1176	699-48-77	13.0	1	79	20	0	0	sand (2)	0.0223	1.7587	0.0262	0.2230	2.00E-02	splitspoon	"
Plio-Pliestocene		2-1181	699-48-77	14.1	8	82	10	0	0	sand (2)	0.0728	1.3096	0.0230	0.2147	8.20E-03	splitspoon	"
Plio-Pliestocene		2-1431	699-48-77A	20.6	-----	-----	N/A	-----	-----	sand (2)	0.0227	1.5859	0.0432	0.2346	1.80E-02	splitspoon	"
Middle Ringold		2-1432	699-48-77A	27.6	51	30	15	4	0	sandy gravel (5)	0.0083	1.5938	0.0191	0.1128	1.40E-02	splitspoon	"
Hanford sand	ERDF [2,6]	4-0637	699-36-63A	74.9	-----	-----	N/A	-----	-----	sand (2)	0.0261	3.2937	0.0278	0.3743	N/A	splitspoon	Relyea, 1995
Hanford sand		4-0642	699-35-69A	25.7	0	60	30	10	0	sand (2)	0.0119	1.6727	0.0566	0.3513	N/A	splitspoon	Weekes and Borghese 1994
Hanford sand		4-0644	699-35-69A	49.8	0	27	56	12	5	loamy sand (1)	0.0069	2.2673	0.0828	0.3922	N/A	splitspoon	"
Hanford sand		4-0791	699-35-65A	63.2	0	50	50	0	0	sand (2)	0.0217	2.4513	0.0303	0.3371	N/A	splitspoon	"
Middle Ringold		4-0792	699-35-65A	75.4	70	21	8	1	0	sandy gravel (6)	0.0276	1.6636	0.0091	0.0825	N/A	splitspoon	"
Hanford sand		4-0855	699-35-66B	12.2	0	7	83	5	5	sand (2)	0.0088	3.2652	0.0689	0.3936	N/A	splitspoon	"
Hanford sand		4-0973	699-35-68A	37.0	0	21	64	12	3	loamy sand (1)	0.0169	2.0085	0.0190 [f]	0.3525	1.27E-04	splitspoon	"
Upper Ringold		4-0983	699-35-68A	82.9	17	35	42	4	2	gravelly sand (4)	0.0156	2.0226	0.0100 [f]	0.3373	5.43E-05	splitspoon	"
Plio-Pleistocene		4-1011	699-35-69A	73.0	0	4	60	28	8	loamy sand (1)	0.0042	1.5218	0.0450 [f]	0.4913	1.00E-05	splitspoon	"
Middle Ringold		4-1012	699-35-69A	73.9	50	20	20	7	3	sandy gravel (5)	0.0062	1.6452	0.0100 [f]	0.1643	5.10E-05	splitspoon	"
Middle Ringold		4-1013	699-35-69A	77.9	77	6	12	3	2	sandy gravel (5)	0.0064	1.6574	0.0214	0.1397	1.90E-07	splitspoon	"
Hanford sand		4-1056	699-32-72B	61.7	0	6	88	4	2	sand (2)	0.0071	2.7253	0.0350 [f]	0.4288	N/A	splitspoon	"
Hanford sand		4-1057	699-32-72B	49.5	0	2	68	24	6	loamy sand (1)	0.0046	2.2861	0.0890	0.4877	N/A	splitspoon	"
Hanford sand		4-1058	699-32-72B	64.7	0	1	41	43	15	loam (1)	0.0029	1.5267	0.1023	0.5661	N/A	splitspoon	"

Table D-2. Summary of Soil Physical and Hydrologic Parameters in the 200 Areas. (4 sheets)

Formation	Site	Sample no.	Borehole	Depth (m)	gr	cs	Sieve Analysis fs	Silt	Clay	Soil Type #	alpha (1/cm)	n	theta_r	theta_s	Ks (cm/s)	Sampling Technique	Source
Hanford sand		4-1076	699-35-61A	76.4	0	75	25	0	0	sand (2)	0.0235	2.0956	0.0265	0.3433	N/A	splitspoon	Weekes and Borghese, 1994
Middle Ringold		4-1079	699-35-61A	90.9	65	24	11	0	0	sandy gravel (5)	0.0073	1.6668	0.0295	0.1236	1.30E-03	splitspoon	"
Middle Ringold		4-1080	699-35-61A	93.5	63	24	10	3	0	sandy gravel (5)	0.0062	1.6601	0.0302	0.1316	3.30E-06	splitspoon	"
Warden silt loam	FLTF [1,5]	D02-10	N/A	<6.1	0	2	54	34	10	sandy loam (1)	0.0049	1.9773	0.0778	0.4531	1.20E-04	excavation	Gee et al., 1989
Warden silt loam		D02-16	N/A	<6.1	0	2	63	25	10	sandy loam (1)	0.0035	2.4632	0.0820 [f]	0.4630	1.20E-04	excavation	Volk, 1993
Warden silt loam		D04-04	N/A	<6.1	0	4	58	28	10	sandy loam (1)	0.0072	1.6501	0.0700 [f]	0.4508	1.20E-04	excavation	"
Warden silt loam		D04-10	N/A	<6.1	0	3	58	30	9	sandy loam (1)	0.0066	1.7574	0.0800 [f]	0.4428	2.90E-04	excavation	"
Warden silt loam		D05-03	N/A	<6.1	0	4	63	23	10	sandy loam (1)	0.0055	1.8647	0.0860 [f]	0.4332	2.90E-04	excavation	"
Warden silt loam		D07-04	N/A	<6.1	0	3	58	30	9	sandy loam (1)	0.0051	1.9424	0.0820 [f]	0.4435	1.20E-04	excavation	"
Warden silt loam		D08-15	N/A	<6.1	0	2	57	31	10	sandy loam (1)	0.0059	1.8533	0.0850 [f]	0.4543	1.20E-04	excavation	"
Warden silt loam		D09-01	N/A	<6.1	0	3	51	37	9	sandy loam (1)	0.0066	1.7677	0.0800 [f]	0.4544	1.20E-04	excavation	"
Warden silt loam		D09-02	N/A	<6.1	0	2	57	31	10	sandy loam (1)	0.0069	1.8498	0.0825	0.4559	1.20E-04	excavation	"
Warden silt loam		D09-05	N/A	<6.1	0	7	60	29	4	sandy loam (1)	0.0088	1.6183	0.0681	0.4461	2.90E-04	excavation	"
Warden silt loam		D10-04	N/A	<6.1	0	6	59	30	5	sandy loam (1)	0.0064	1.7899	0.0850 [f]	0.4481	1.20E-04	excavation	"
Warden silt loam		D11-06	N/A	<6.1	0	4	57	33	6	sandy loam (1)	0.0061	1.8575	0.0850 [f]	0.4308	1.20E-04	excavation	"
Warden silt loam		D11-08	N/A	<6.1	0	5	58	32	5	sandy loam (1)	0.0061	1.7567	0.0850 [f]	0.4312	1.20E-04	excavation	"
Warden silt loam		D12-14	N/A	<6.1	0	3	52	34	11	sandy loam (1)	0.0063	1.7576	0.0980 [f]	0.4686	1.20E-04	excavation	"
Warden silt loam		D13-08	N/A	<6.1	0	4	52	35	9	sandy loam (1)	0.0070	1.7877	0.0820 [f]	0.4513	1.20E-04	excavation	"
Warden silt loam		D14-04	N/A	<6.1	0	3	56	36	5	sandy loam (1)	0.0065	1.8553	0.0837	0.4586	1.20E-04	excavation	"
Plio-Pleistocene	VOC [2,4]	*3-0647	299-W18-246	42.9	0	2	78	14	6	loamy sand (1)	0.0051	2.0531	0.0400 [f]	0.4995	2.00E-04	splitspoon	Relyea, 1995
Middle Ringold		3-0648	299-W18-246	59.6	62	18	20	0	0	sandy gravel (5)	0.0124	1.6450	0.0000	0.1462	8.70E-03	splitspoon	

Table D-2. Summary of Soil Physical and Hydrologic Parameters in the 200 Areas. (4 sheets)

Formation	Site	Sample no.	Borehole	Depth (m)	gr	cs	Sieve Analysis fs	Silt	Clay	Soil Type #	alpha (1/cm)	n	theta_r	theta_s	Ks (cm/s)	Sampling Technique	Source
Plio-Peistocene		3-0649	299-W18-247	41.1	0	10	38	40	12	loam (1)	0.0010	1.7024	0.0600 [f]	0.5331	N/A	splitspoon	Relyea, 1995
Plio-Peistocene		3-0650	299-W18-247	45.1	0	46	28	15	11	sandy loam (1)	0.0120	1.5539	0.2412	0.6306	2.60E-07	splitspoon	"
Plio-Peistocene		3-0651	299-W18-247	46.9	0	58	24	9	9	loamy sand (1)	0.0286	1.9721	0.1006	0.3728	9.40E-03	splitspoon	"
Hanford Sand		3-0652	299-W18-248	38.4	0	40	52	4	4	sand (2)	0.0092	1.8848	0.0300 [f]	0.3586	3.70E-04	splitspoon	"
Plio-Peistocene		3-0653	299-W18-248	42.5	0	24	54	14	8	loamy sand (1)	0.0067	1.8378	0.1096	0.4223	5.80E-06	splitspoon	"
Plio-Peistocene		3-0654	299-W15-216	35.6	59	30	3	4	4	sandy gravel (5)	0.0119	1.2618	0.0186	0.1933	2.70E-04	splitspoon	"
Upper Ringold		3-0655	299-W15-216	36.9	34	28	8	24	6	silty sandy gravel (3)	0.0029	1.6285	0.0559	0.2625	1.58E-04	splitspoon	"
Middle Ringold		3-0656	299-W15-216	39.0	42	40	18	0	0	sandy gravel (5)	0.0166	1.3941	0.0090	0.1814	1.36E-02	splitspoon	"
Hanford Sand		3-0657	299-W15-217	37.4	34	38	10	10	8	silty sandy gravel (3)	0.0145	1.3692	0.0469	0.2505	2.67E-04	splitspoon	"

* swelling clay; not included in variability and scaling analyses.
[f] signifies that the residual moisture content has been fixed to improve the curve fit through the measured data.
 # soil category :
(1) - SS, sand mixed with finer fraction.
(2) - S, sand.
(3) - SSG, sand and gravel mixed with finer fraction.
(4) - GS, gravelly sand.
(5) - SG1, sandy gravel with gravel content approximately <60%.
(6) - SG2, sandy gravel with gravel content approximately >60%.

1 - K_s measured by falling head permeameter.
2 - K_s measured by constant head permeameter.

Moisture Retention Data Measurements
3 - 0 to -60 cm, hanging water column; -100 to -15300 cm, pressure plate extraction (Klute 1986).
4 - 0 to -1000 cm, Tempe cell; -500 to -15300 cm, pressure plate extraction.
5 - 0 to -150 cm, hanging water column; -310 to -15300 cm, pressure plate extraction; <-15300 m, thermocouple psychrometer (Rawlins and Campbell 1986).
6 - 0 to -1000 cm, Tempe cell; -500 to -10000 cm, pressure plate extraction; < -10000 cm, thermocouple psychrometer.

Figure D-1. Nitrate Concentrations in the Unconfined Aquifer Underlying T and TX-TY WMAs (PNNL 13116).

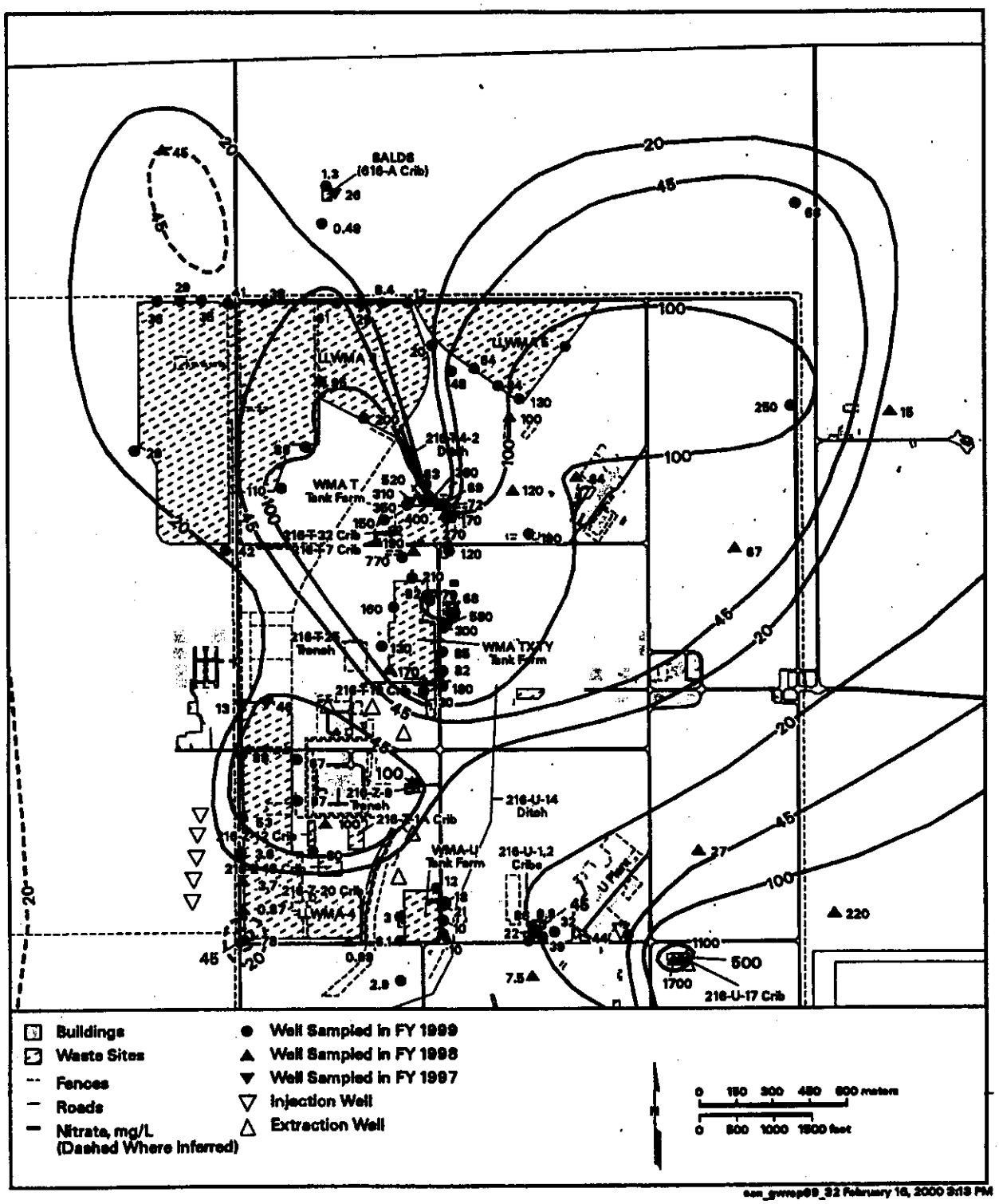


Figure D-2. Tritium Plume in the 200 West Area.

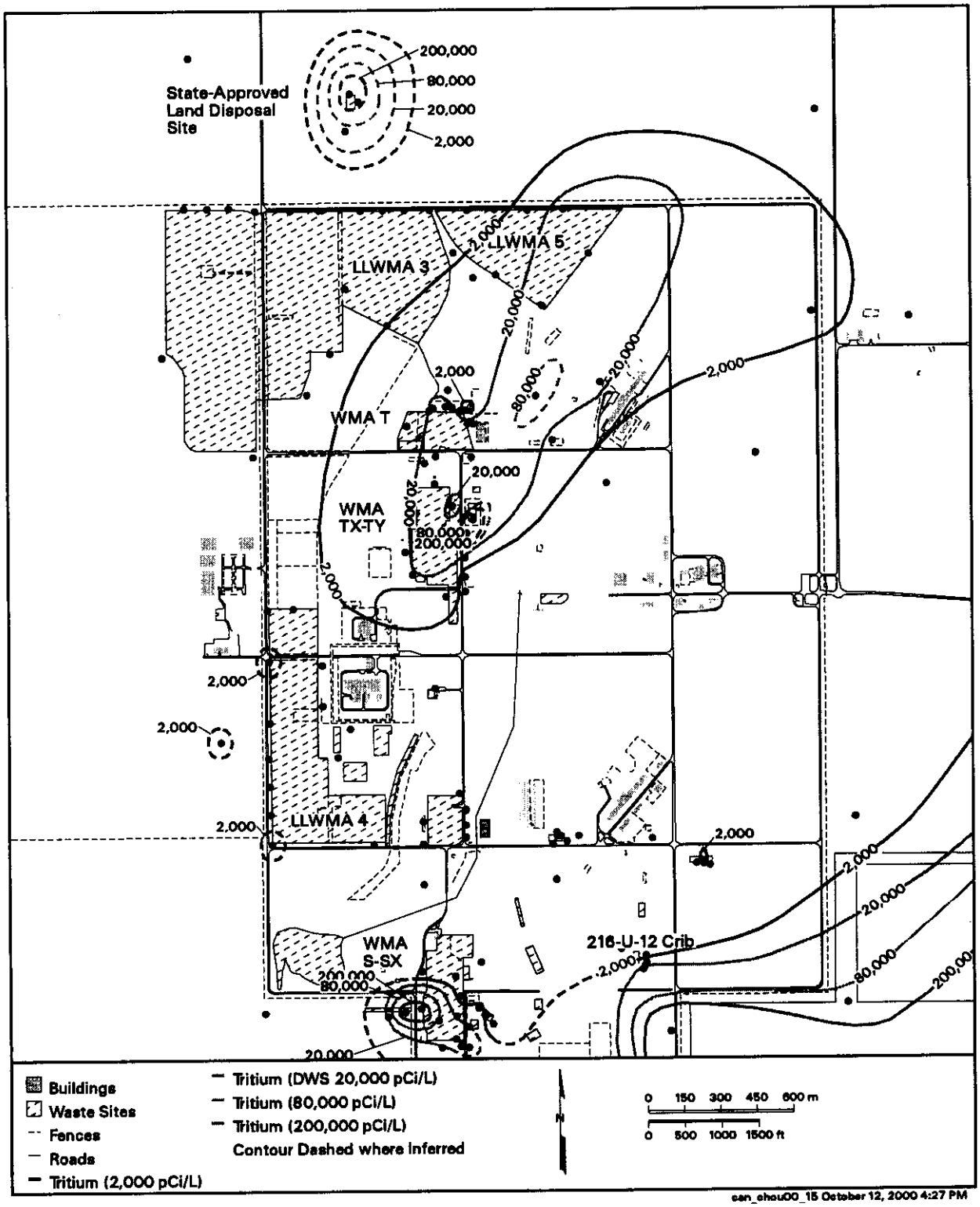


Figure D-3. Iodine-129 Concentrations in the Unconfined Aquifer Adjacent to T and TX WMAs (PNNL 13116).

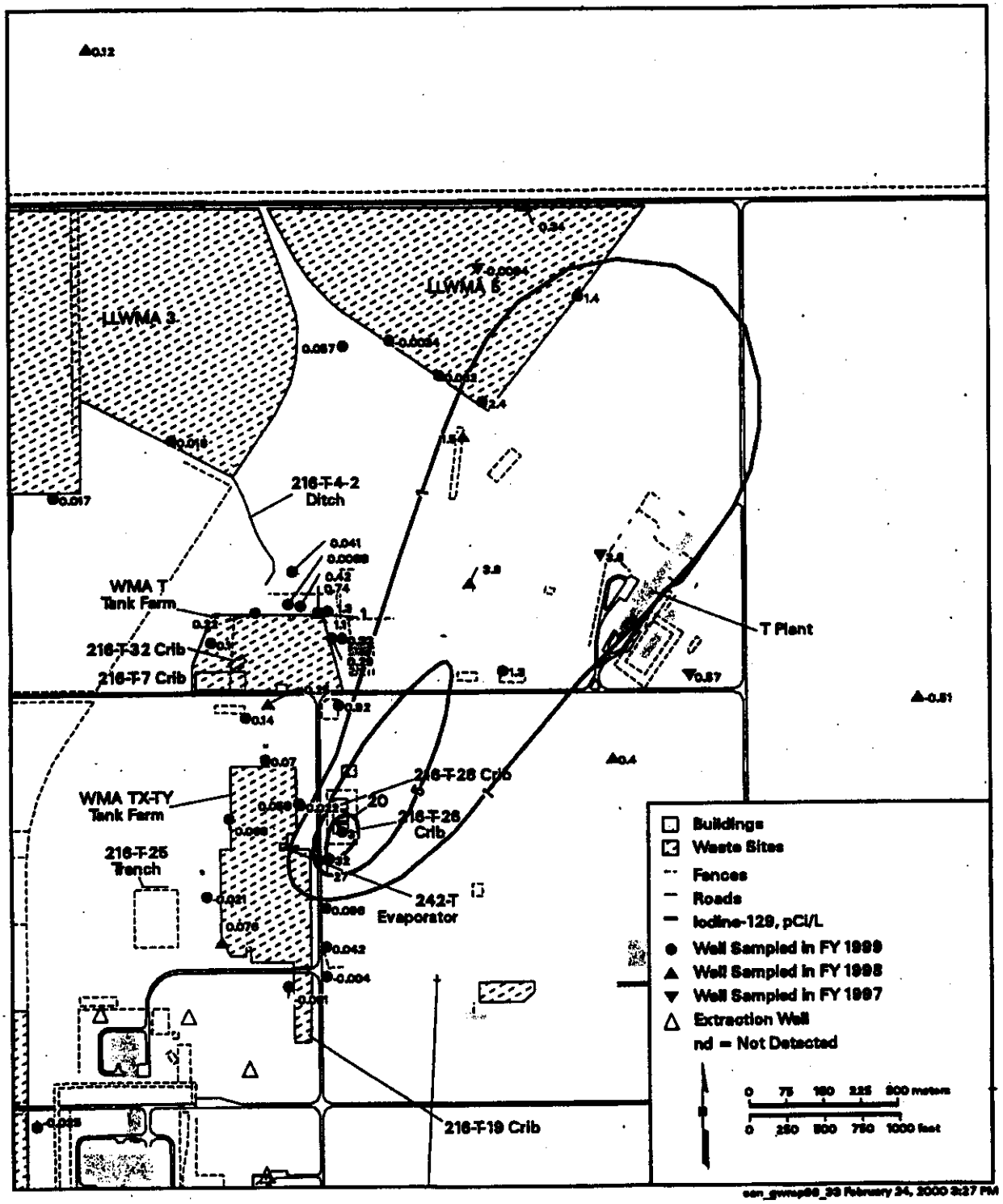


Figure D-4. Chromium Concentrations in the Unconfined Aquifer Underlying the T WMA (PNNL 13116).

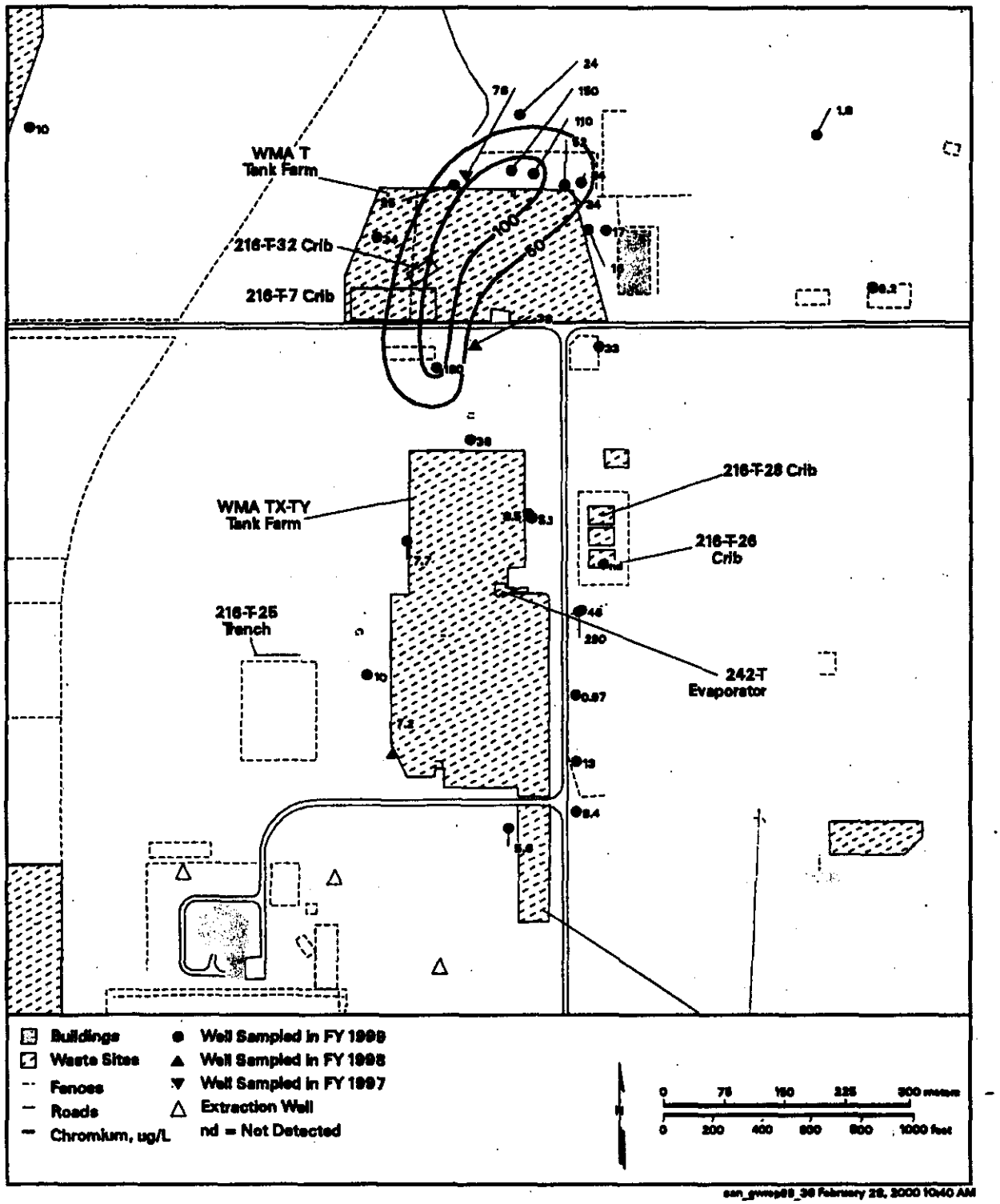
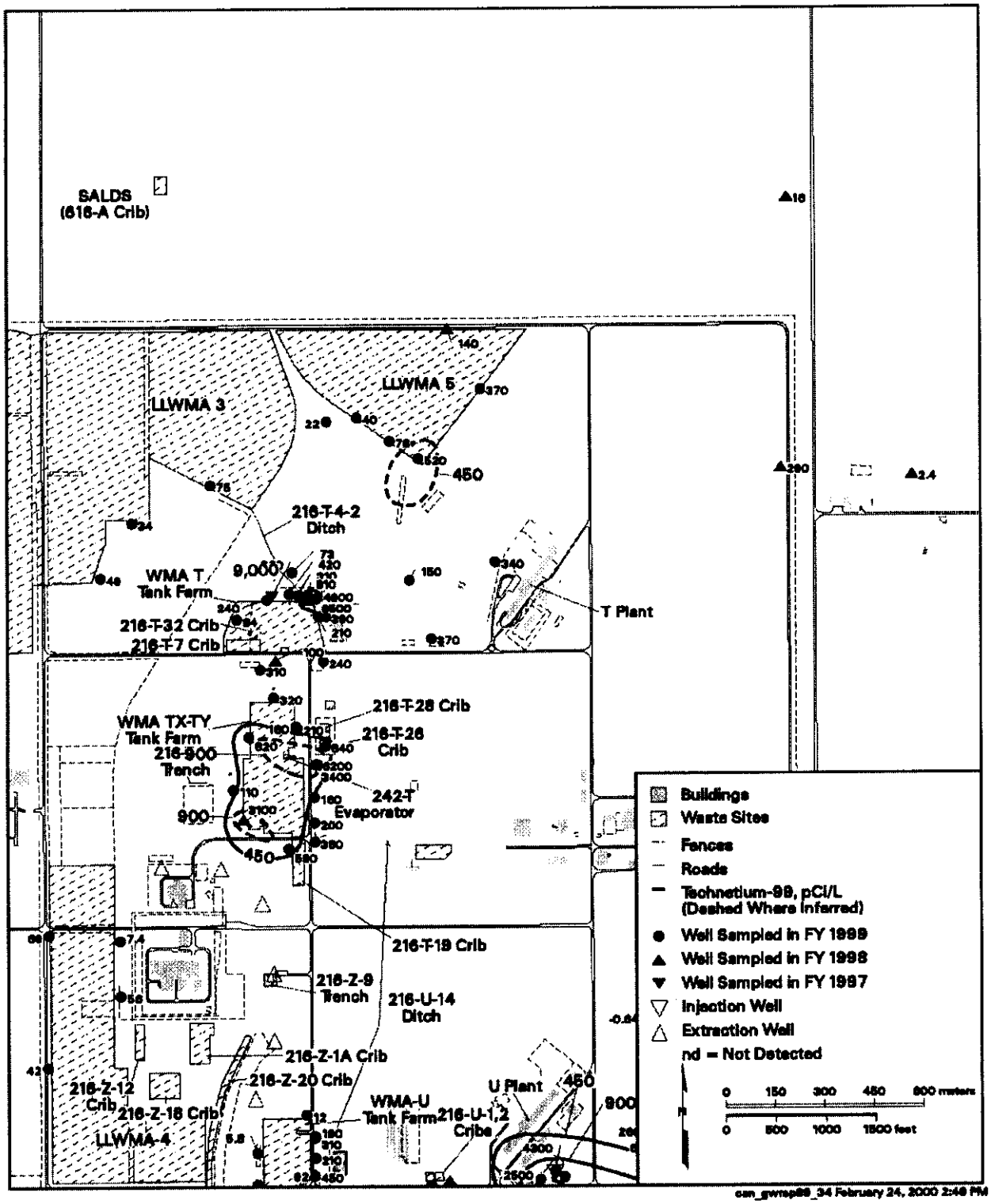


Figure D-5. Technetium-99 Concentrations in the Unconfined Aquifer Underlying the T and TX-TY WMAs (from Hartman et al. 2000)."



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APPENDIX E

SUPPORTING GAMMA LOGGING DATA

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APPENDIX E

SUPPORTING GAMMA LOGGING DATA

Appendix E contains the drywell spectral gamma logging profiles that MACTEC-ERS prepared for the T, TX, and TY tank farms. Some drywell profiles are not included because gamma concentrations above detection level are not measured. This appendix also includes table summaries of drywells indicating radionuclide migration at some time between 1975 and 1994. These conclusions are based on the synthesis of historical gross and spectral gamma logging data.

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DOE-GJ, 1999a, *Hanford Tank Farms Vadose Zone T Tank Farm Report*, GJO-99-101-TAR-GJO-HAN-27, U.S. Department of Energy, Grand Junction Office, Grand Junction, Colorado.

DOE-GJ, 1999b, *Hanford Tank Farms Vadose Zone TY Tank Farm Report*, GJO-97-30-TAR-GJO-HAN-16, U.S. Department of Energy, Grand Junction Office, Grand Junction, Colorado.

Randall, R., R. Price, and J. Caggiano, 2000a, *Analysis and Summary Report of Historical Dry Well Gamma Logs for the 241-T Tank Farm-200 West*, RPP-6088, Rev. 0, Three Rivers Scientific, West Richland, Washington.

Randall, R., R. Price, and J. Caggiano, 2000b, *Analysis and Summary Report of Historical Dry Well Gamma Logs for the 241-TX Tank Farm-200 West*, RPP-6353, Rev. 0, Three Rivers Scientific, West Richland, Washington.

T TANK FARM DRY WELL SPECTRAL GAMMA LOGGING PLOTS

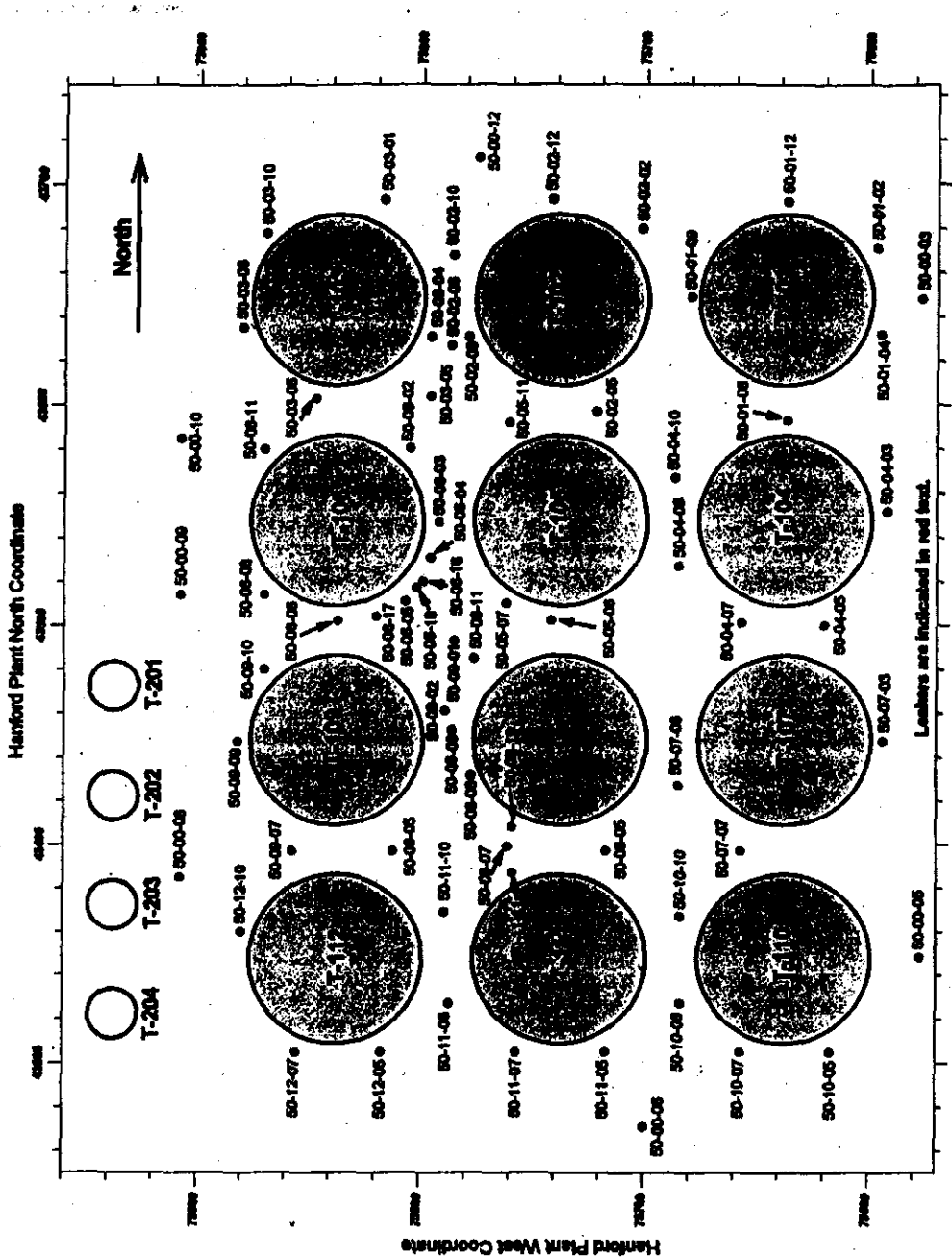


Figure 14-17. Plan Map of the T Tank Farm Showing the Location of the Tank Monitoring Boreholes

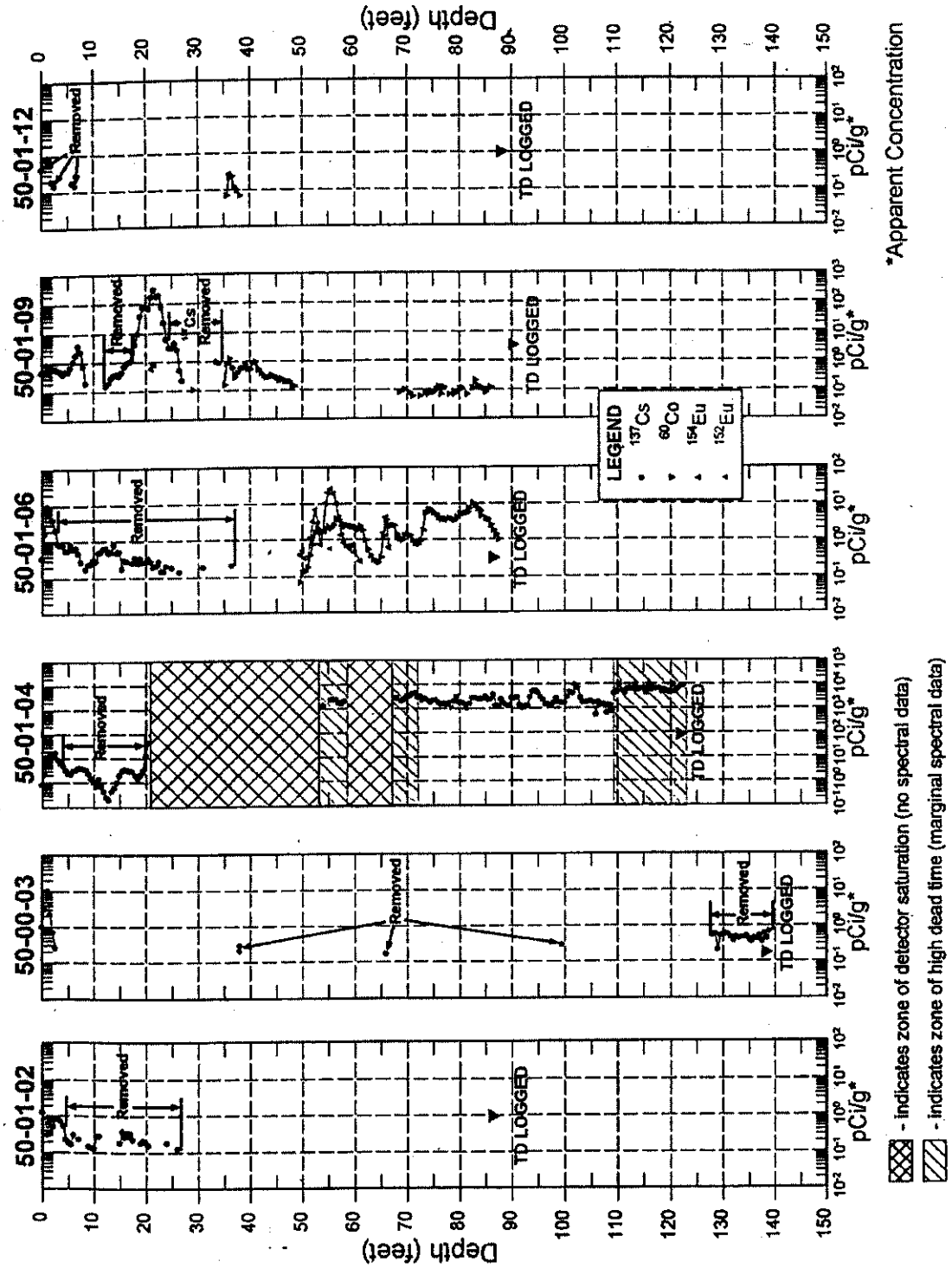
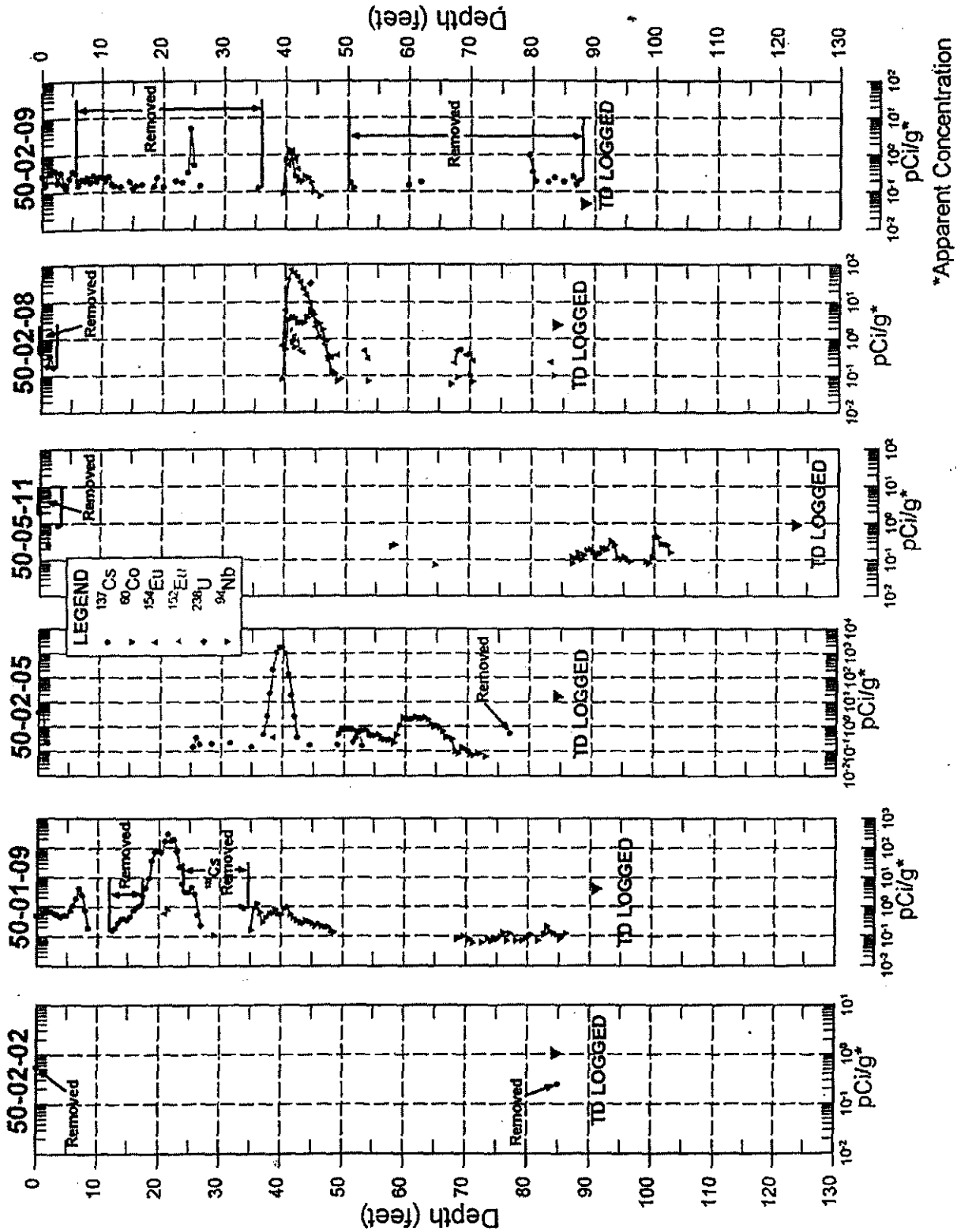


Figure B-1. Correlation Plot of ^{137}Cs, ^{60}Co, ^{152}Eu, and ^{154}Eu Concentrations in Boreholes Surrounding T-101


50-02-02
50-01-09
50-02-05
50-05-11
50-02-08
50-02-09
Depth (feet)
pCi/g*
Removed
TD LOGGED
LEGEND
137Cs
60Co
154Eu
152Eu
238U
94Nb
*Apparent Concentration

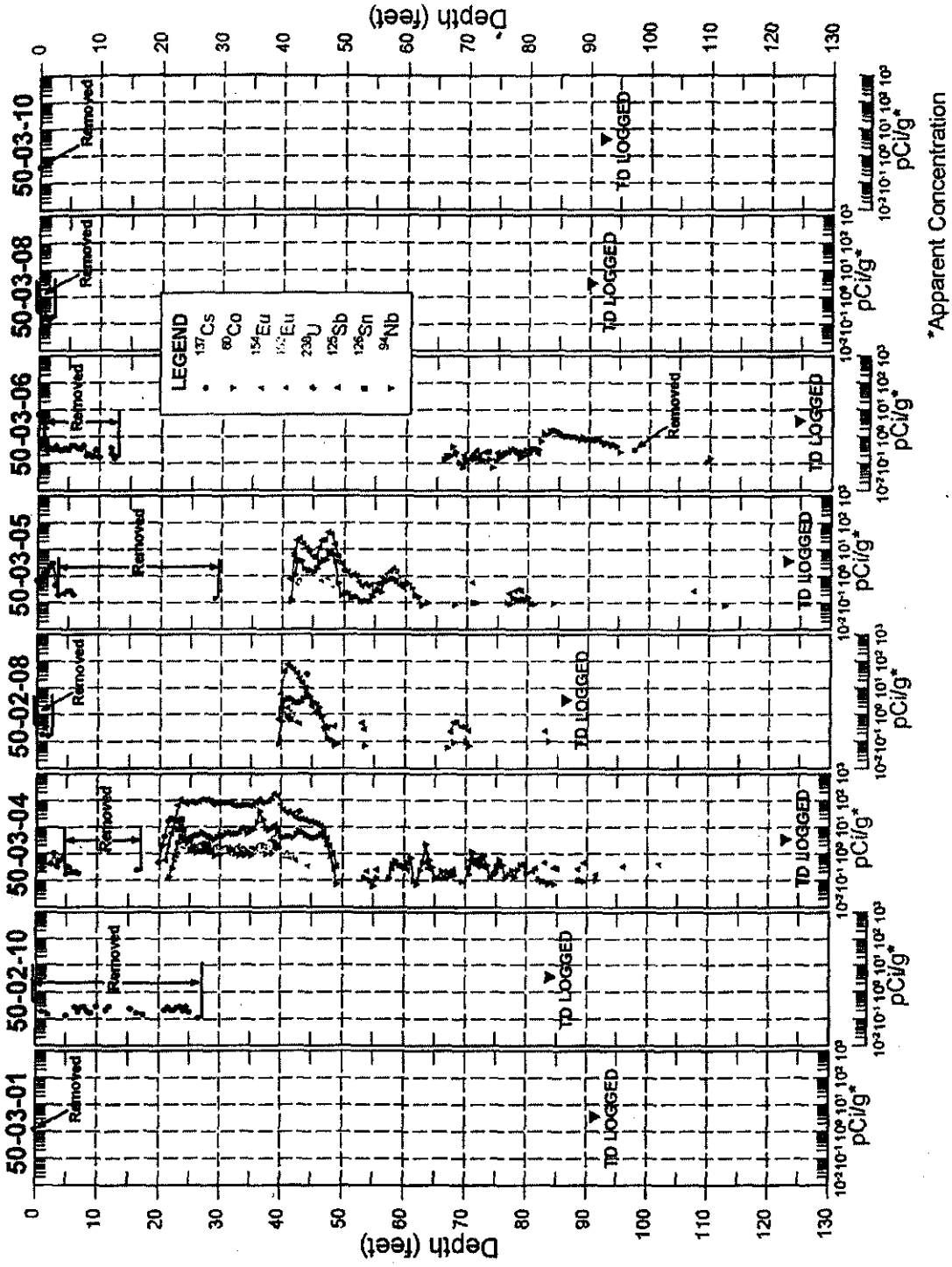


Figure B-3. Correlation Plot of ^{137}Cs, ^{60}Co, ^{152}Eu, ^{154}Eu, ^{239}U, ^{125}Sb, ^{126}Sn, and ^{94}Nb Concentrations in Boreholes Surrounding T-103

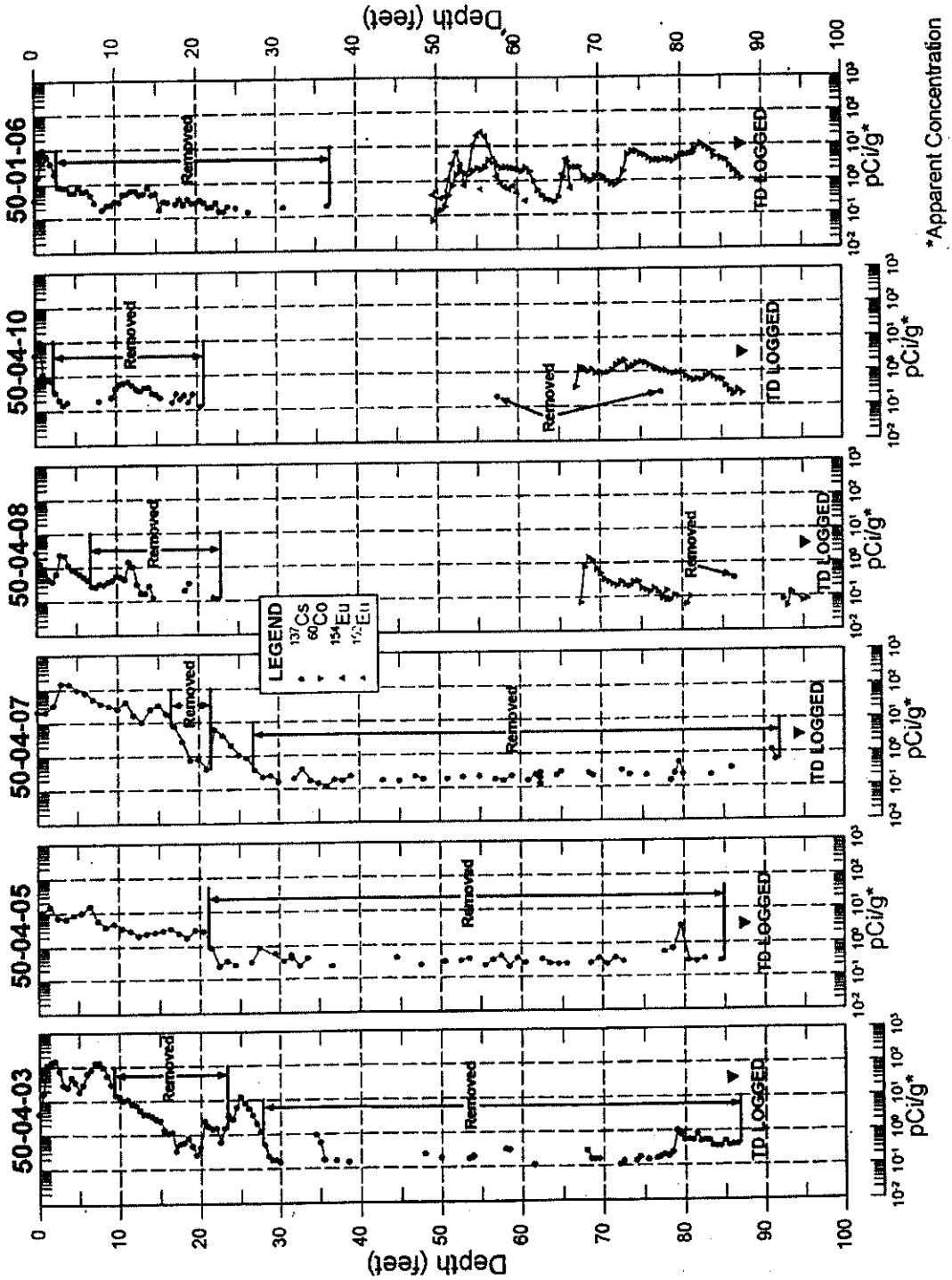


Figure B-4. Correlation Plot of ^{137}Cs, ^{60}Co, ^{152}Eu, and ^{154}Eu Concentrations in Boreholes Surrounding T-104

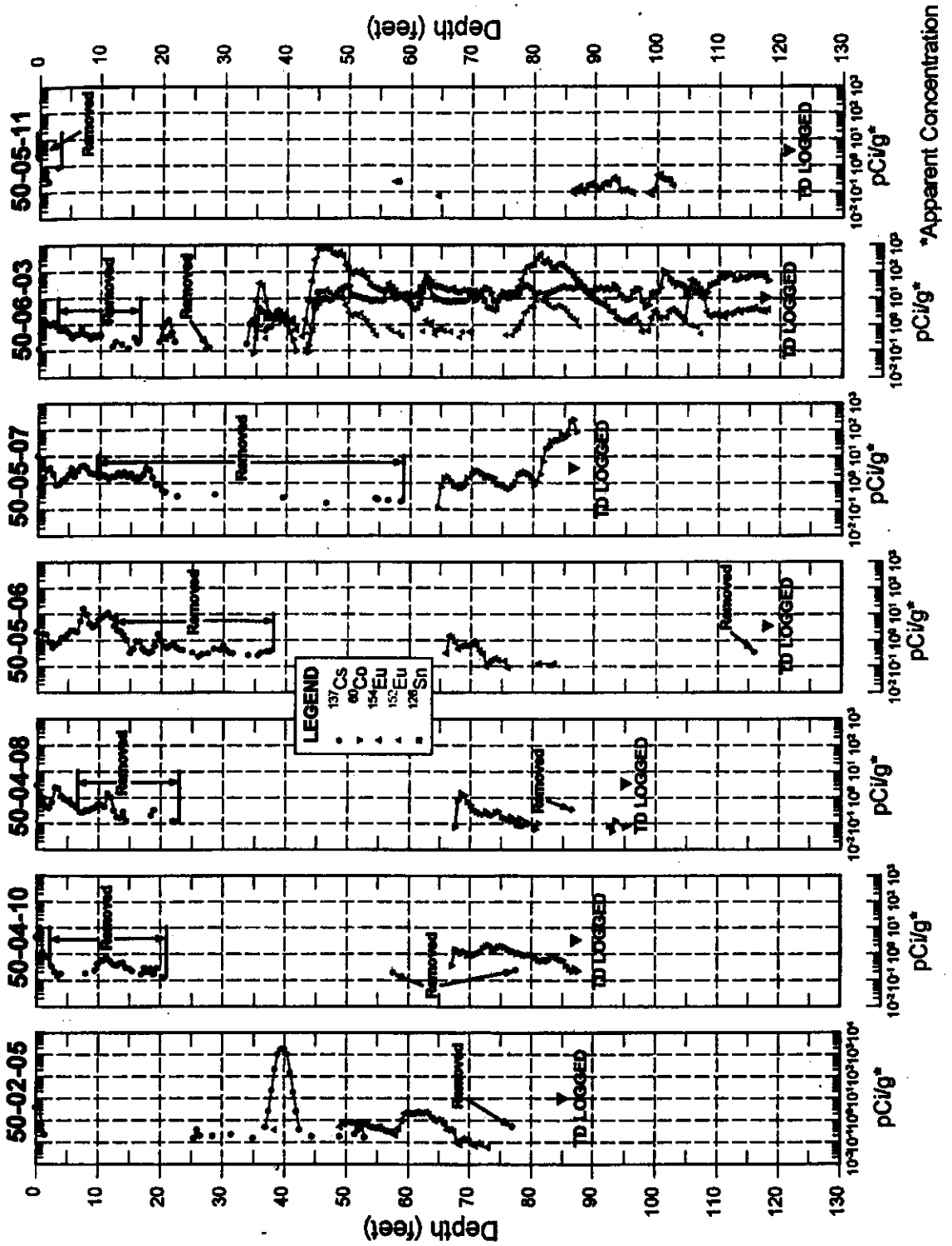


Figure B-5. Correlation Plot of ^{137}Cs, ^{60}Co, ^{152}Eu, ^{154}Eu, and ^{126}Sn Concentrations in Boreholes Surrounding T-105

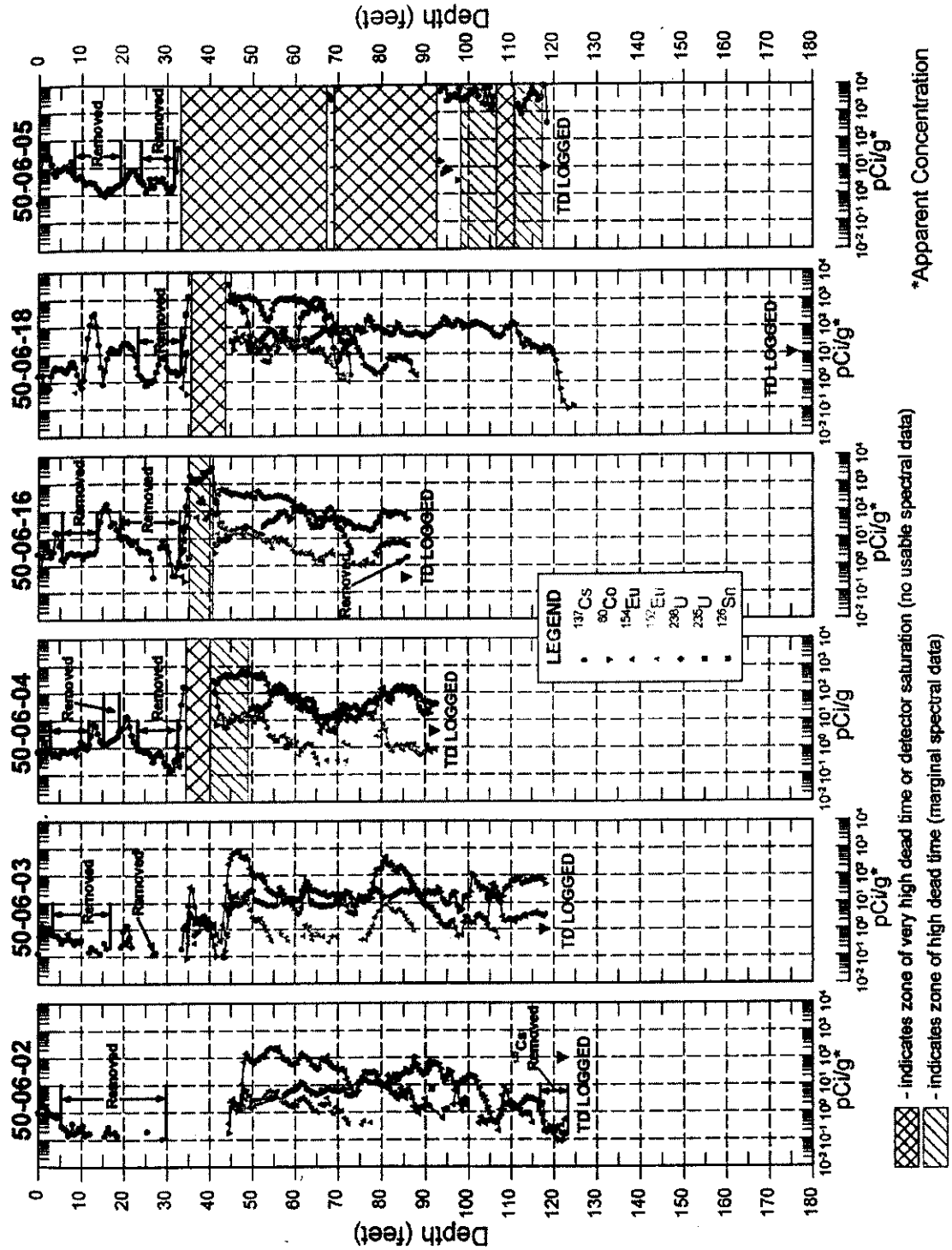


Figure B-6. Correlation Plot of ^{137}Cs, ^{60}Co, ^{152}Eu, ^{154}Eu, ^{238}U, ^{235}U, ^{125}Sb, and ^{126}Sn Concentrations in Boreholes Surrounding T-106

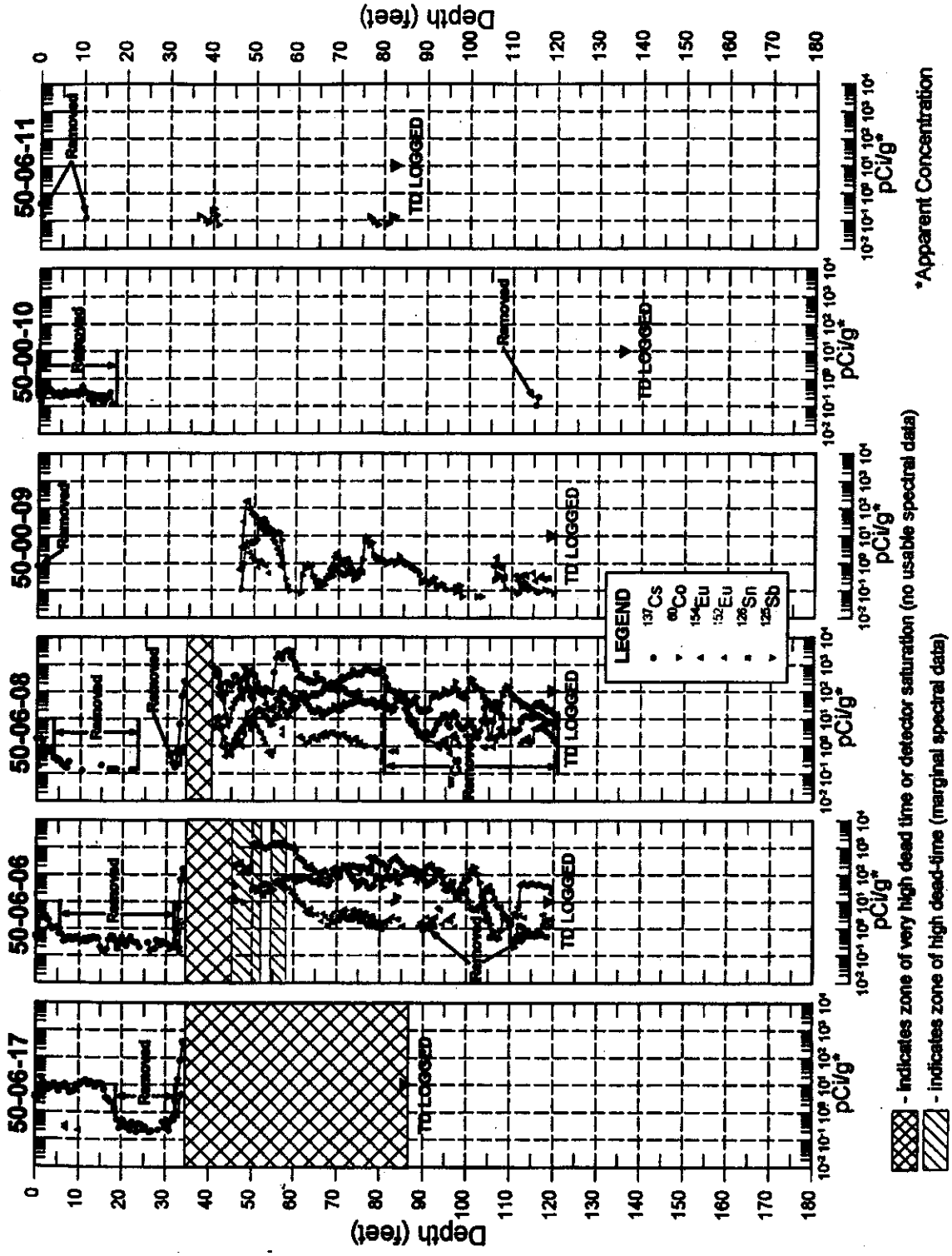


Figure B-6 (continued). Correlation Plot of ^{137}Cs, ^{60}Co, ^{152}Eu, ^{154}Eu, ^{238}U, ^{235}U, ^{125}Sb, and ^{126}Sn Concentrations in Boreholes Surrounding T-106

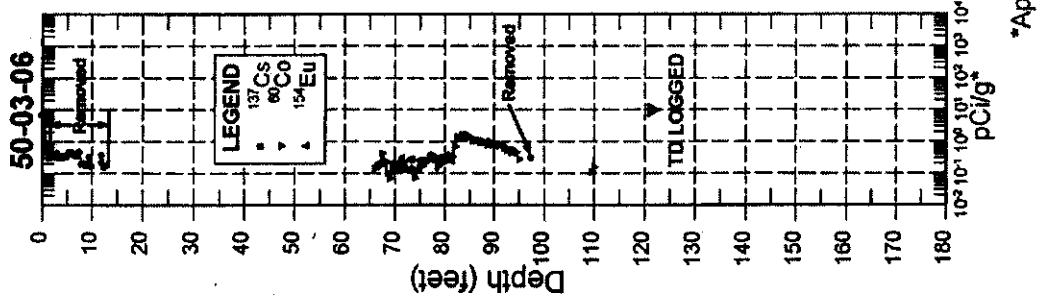


Figure B-6 (continued). Correlation Plot of ^{137}Cs, ^{60}Co, ^{152}Eu, ^{154}Eu, ^{238}U, ^{235}U, ^{125}Sb, and ^{126}Sn Concentrations in Boreholes Surrounding T-106

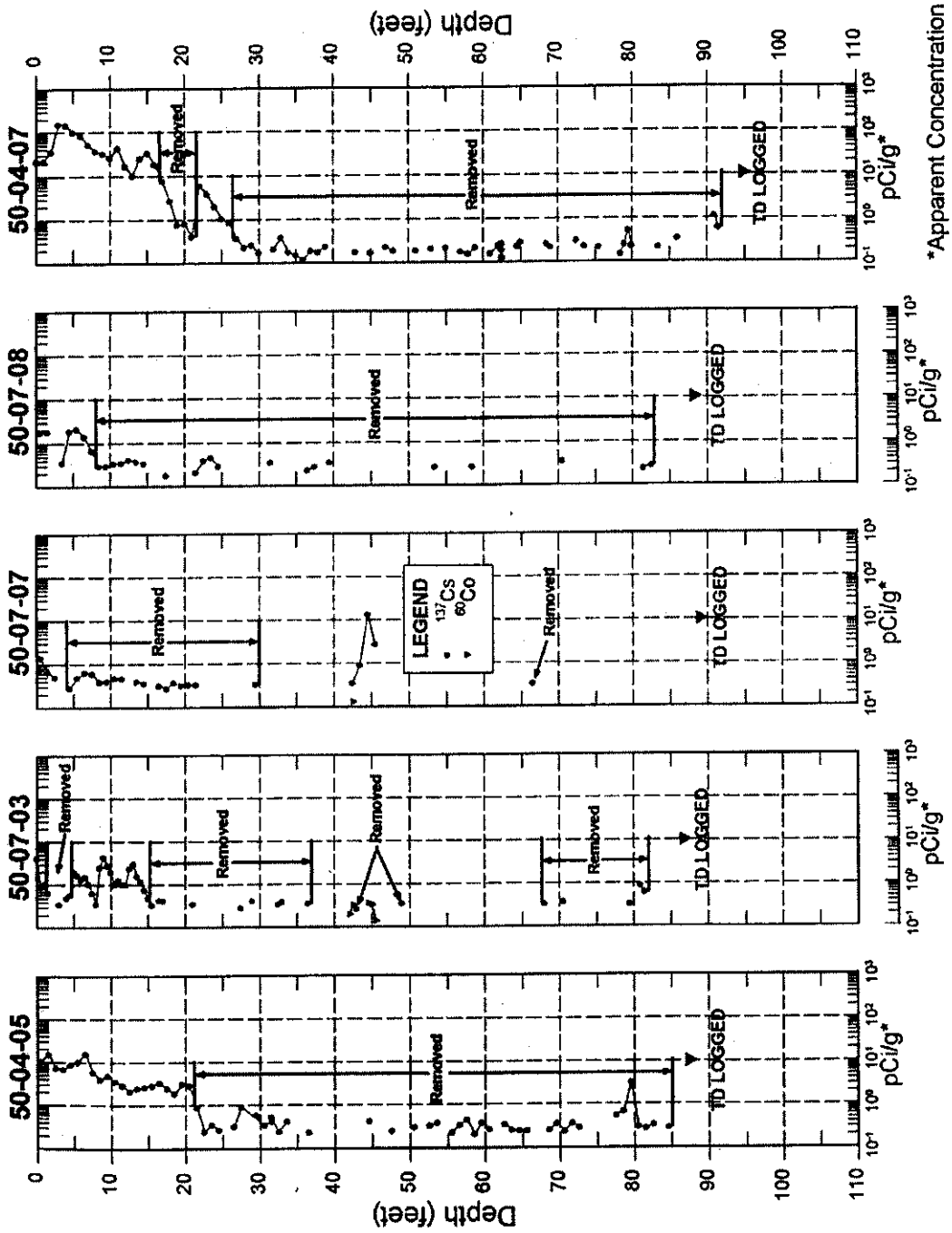


Figure B-7. Correlation Plot of ^{137}Cs and ^{60}Co Concentrations in Boreholes Surrounding T-107

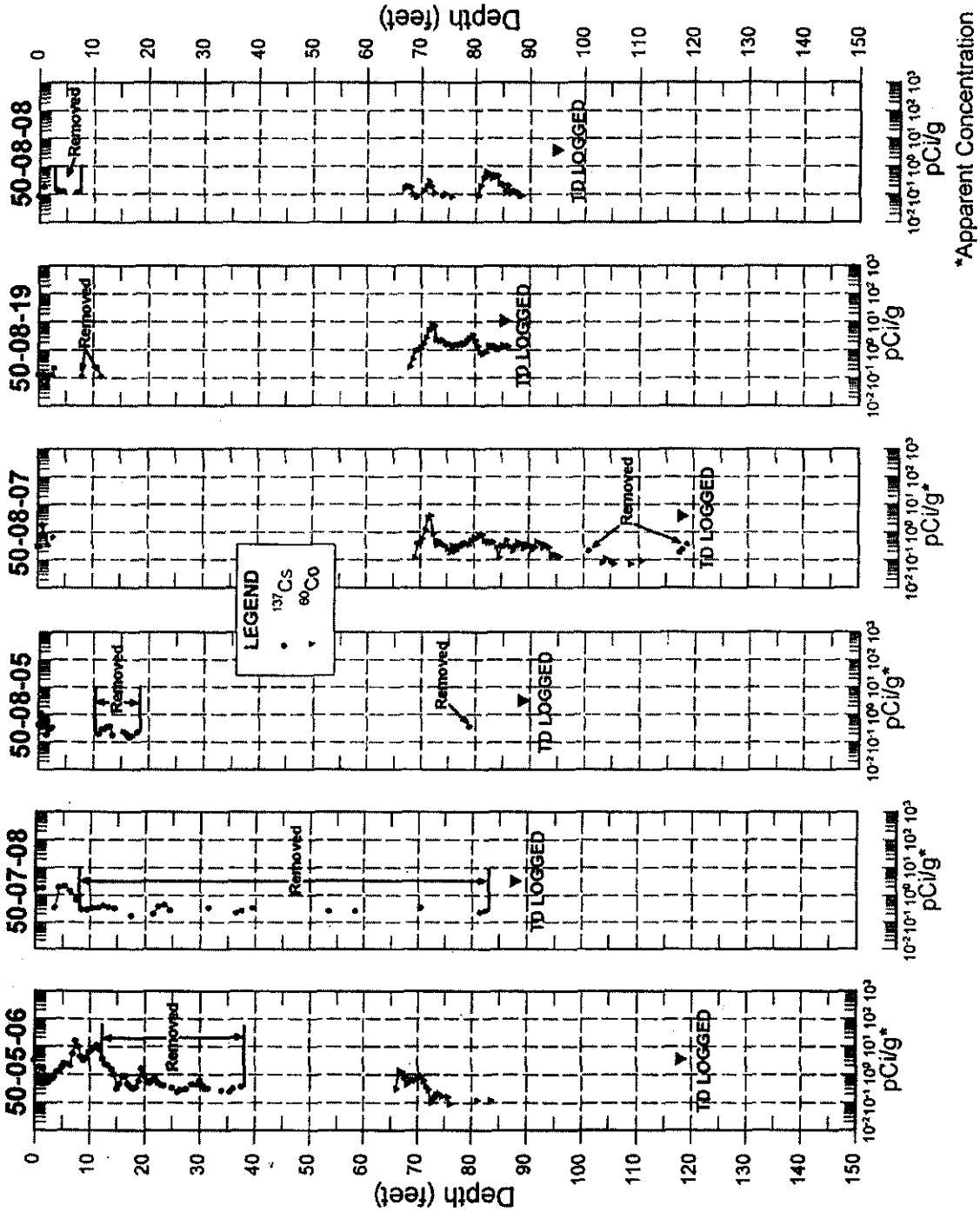


Figure B-8. Correlation Plot of ^{137}Cs, ^{60}Co, ^{152}Eu, and ^{154}Eu Concentrations in Boreholes Surrounding T-108

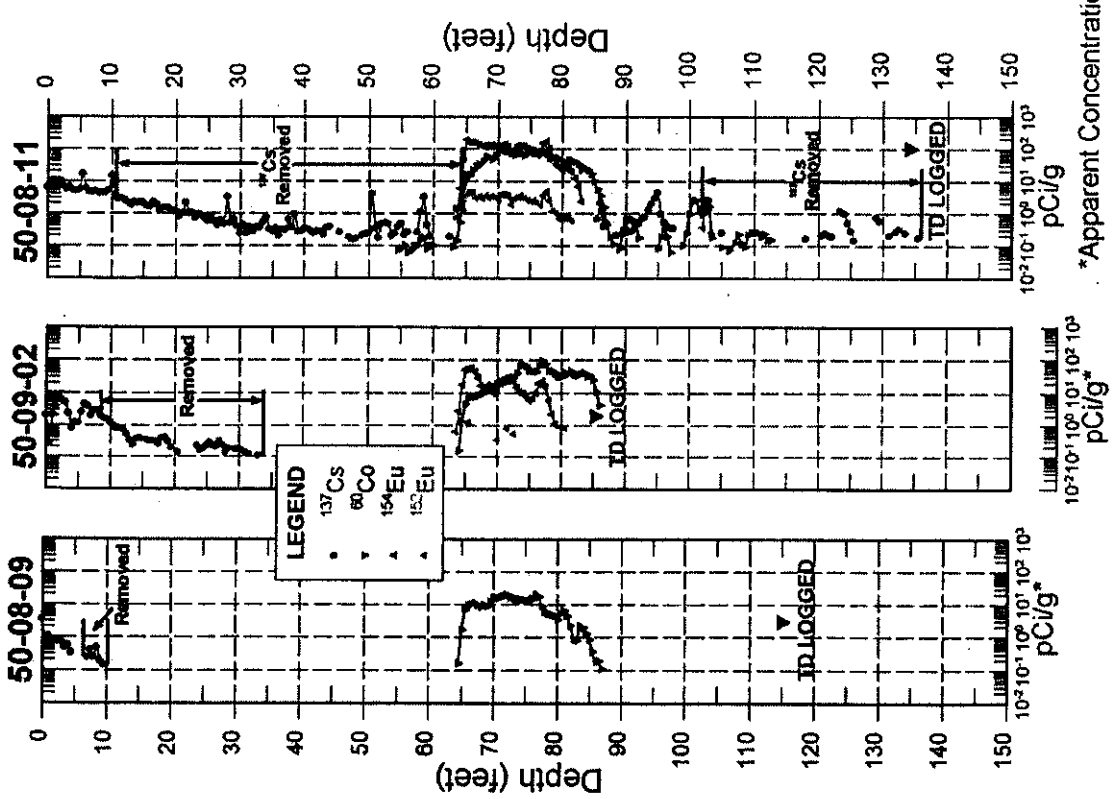


Figure B-8 (continued). Correlation Plot of ^{137}Cs, ^{60}Co, ^{152}Eu, and ^{154}Eu Concentrations in Boreholes Surrounding T-108

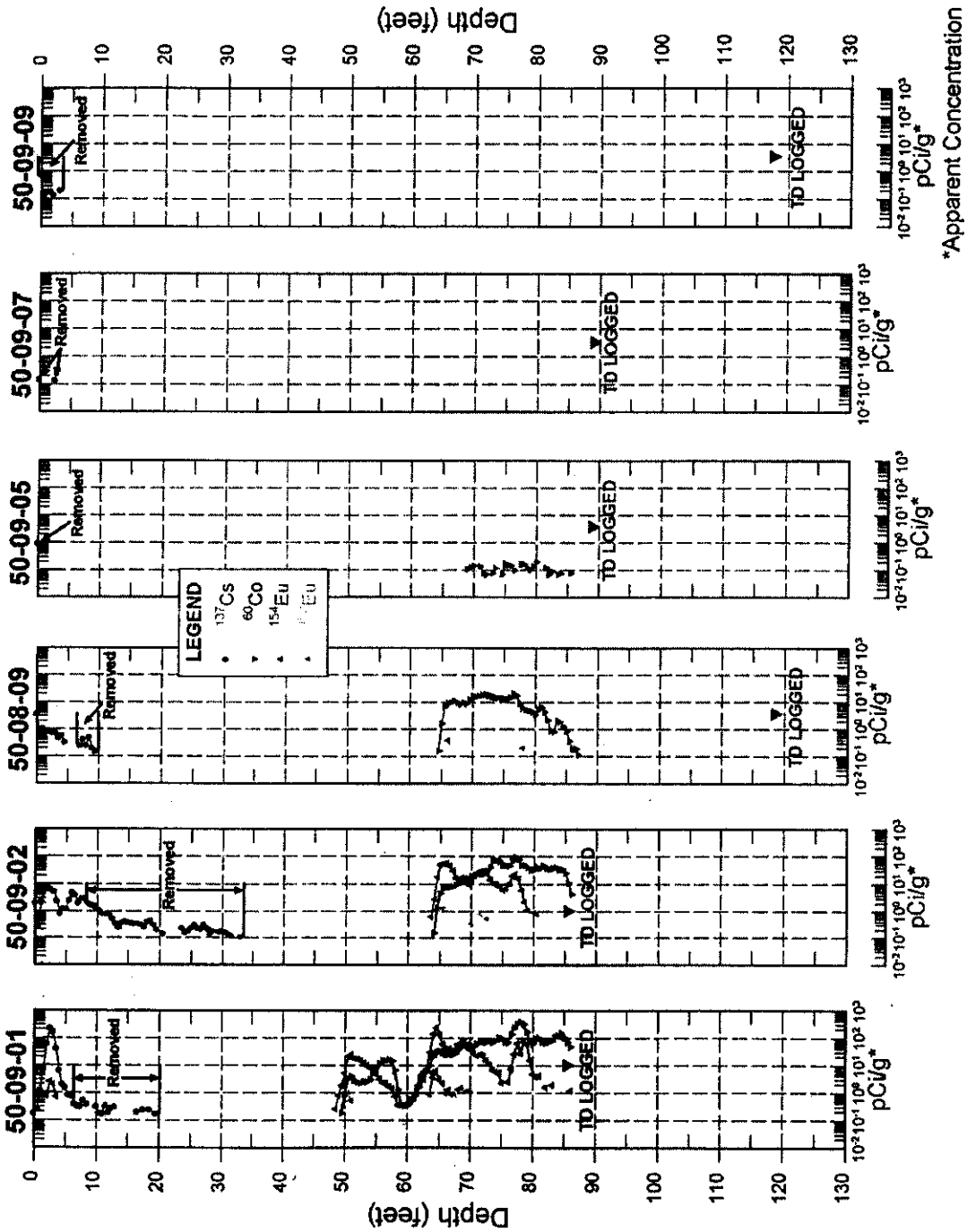


Figure B-9. Correlation Plot of ^{137}Cs, ^{60}Co, ^{152}Eu, ^{154}Eu, ^{125}Sb, and ^{125}Sn Concentrations in Boreholes Surrounding T-109

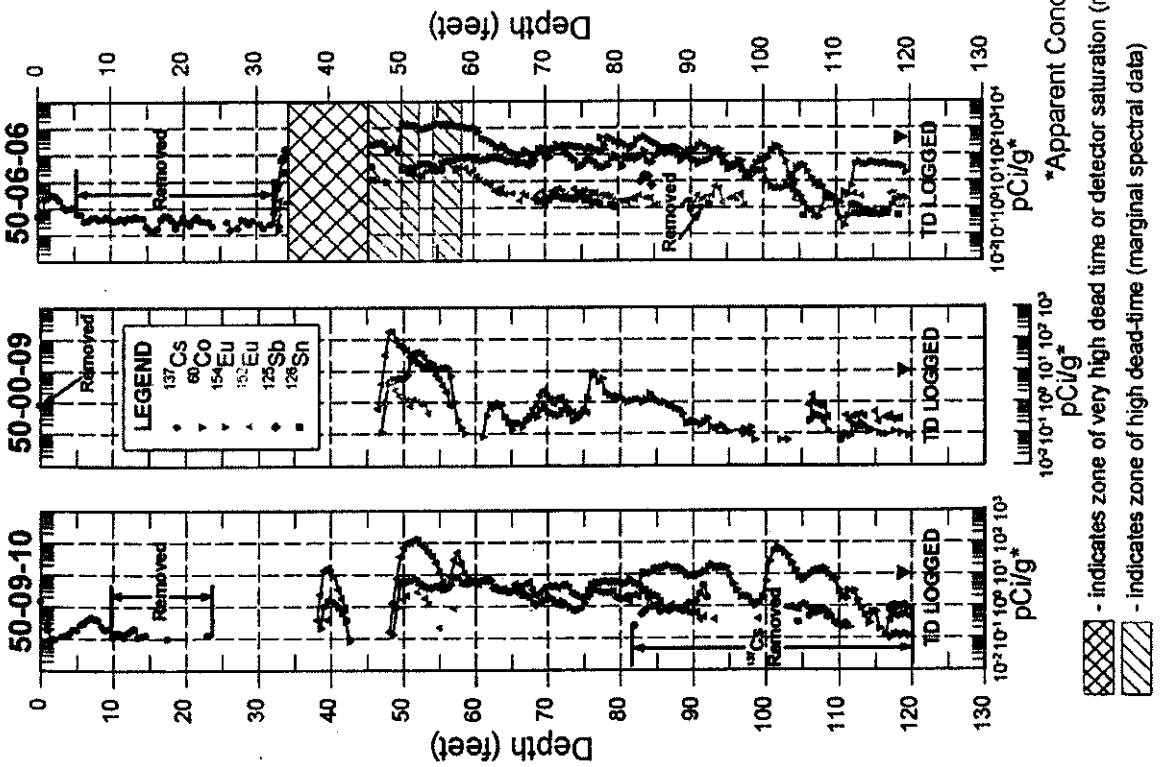


Figure B-9 (continued). Correlation Plot of ^{137}Cs, ^{60}Co, ^{152}Eu, ^{154}Eu, ^{125}Sb, and ^{126}Sn Concentrations in Boreholes Surrounding T-109

TX TANK FARM DRYWELL SPECTRAL GAMMA LOGGING LOTS

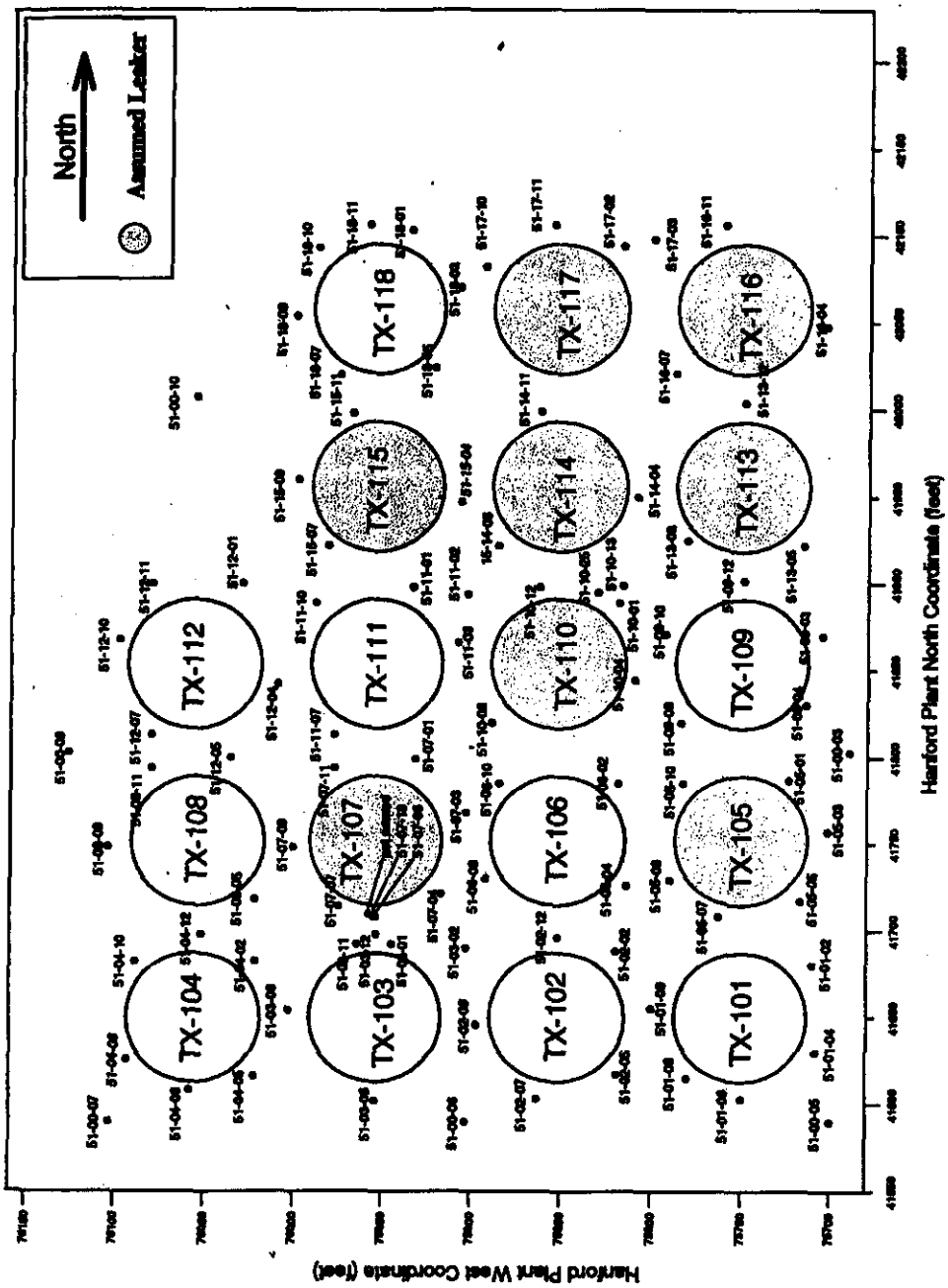


Figure 14-23. Plan View of the TX Tank Farm Showing Borehole Locations

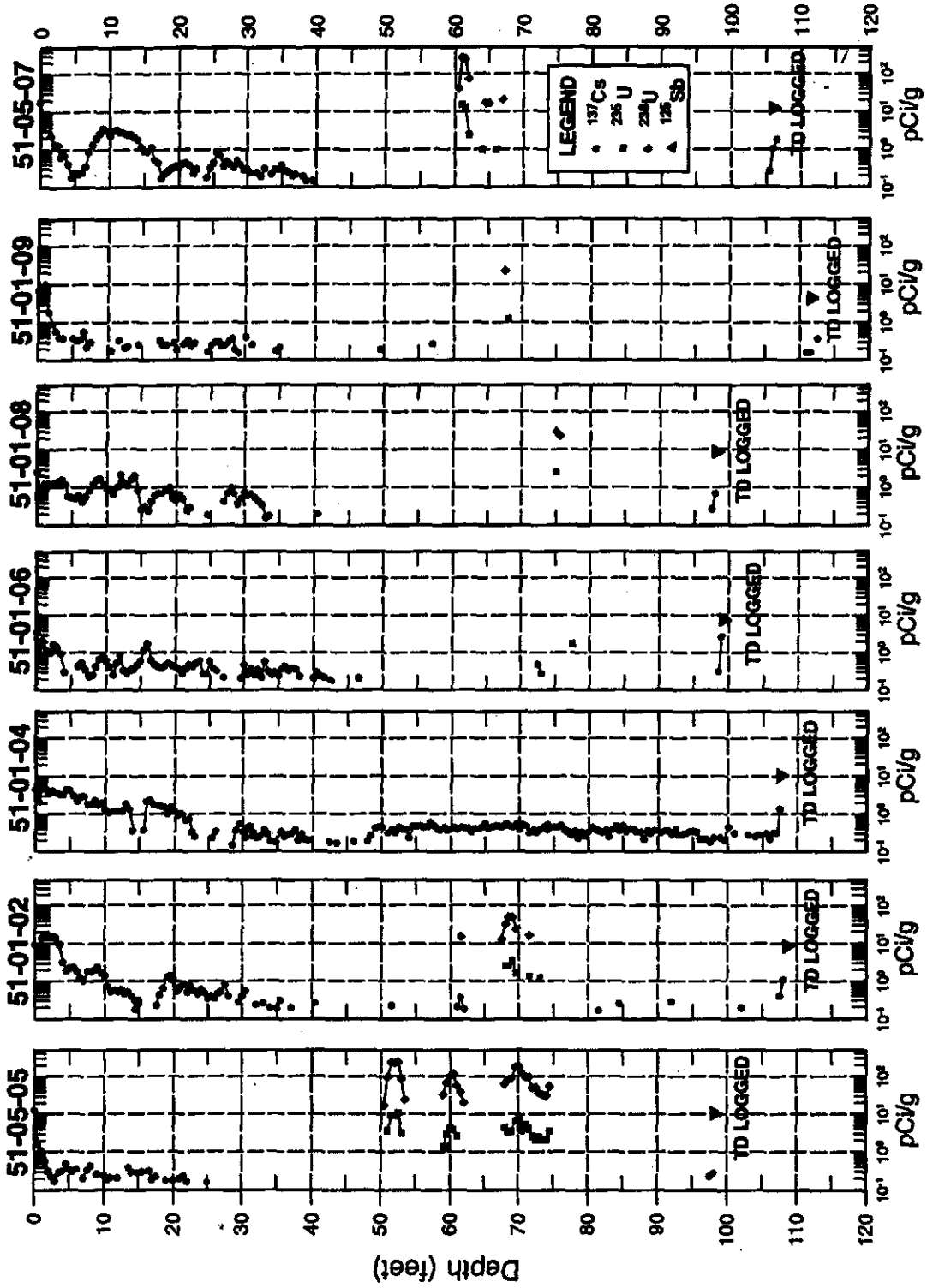


Figure A-1. Correlation Plot of ^{137}Cs, ^{236}U, ^{238}U, and ^{125}Sb Concentrations in Boreholes Surrounding Tank TX-101

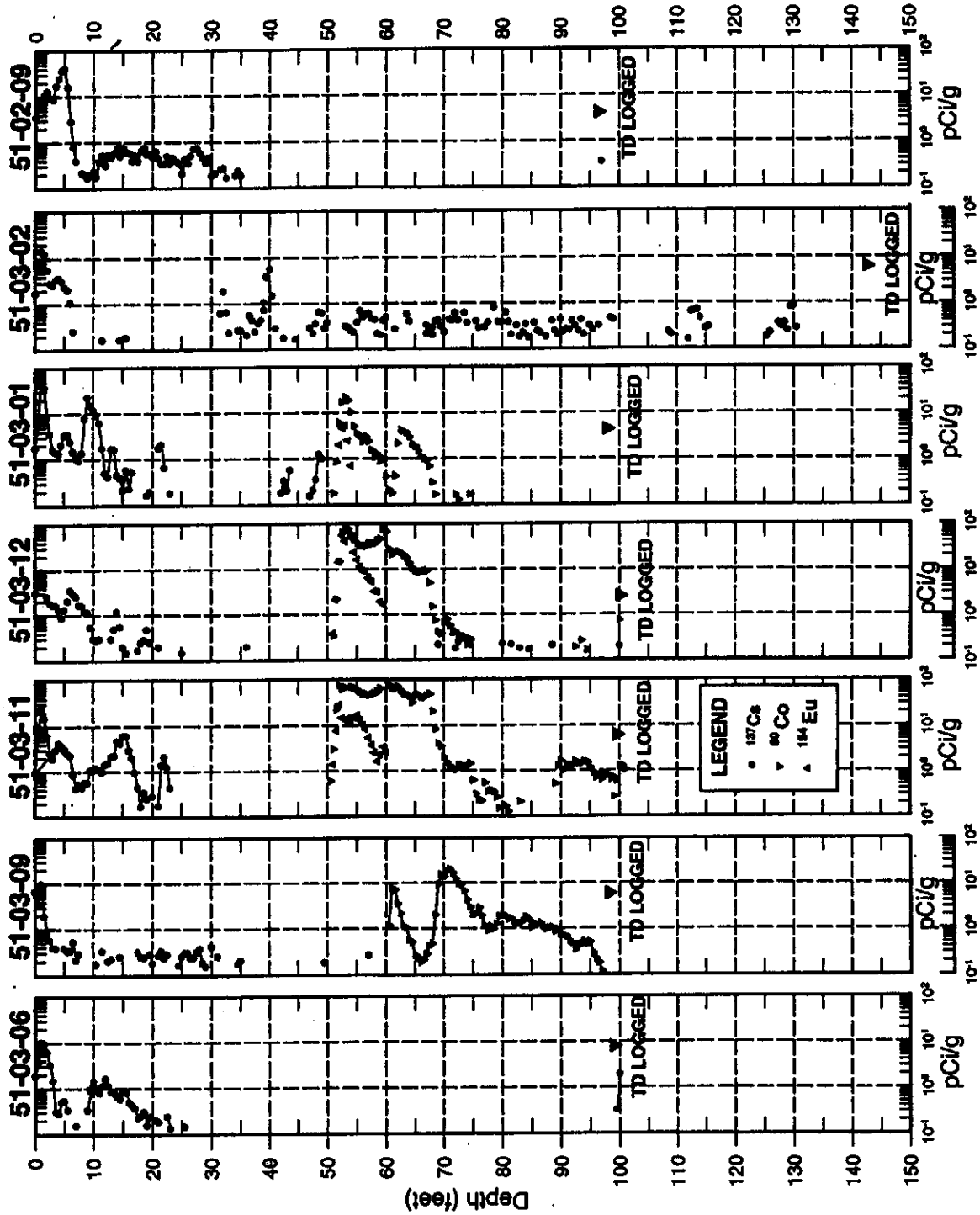


Figure A-3. Correlation Plot of ^{137}Cs, ^{60}Co, and ^{154}Eu Concentrations in Boreholes Surrounding Tank TX-103

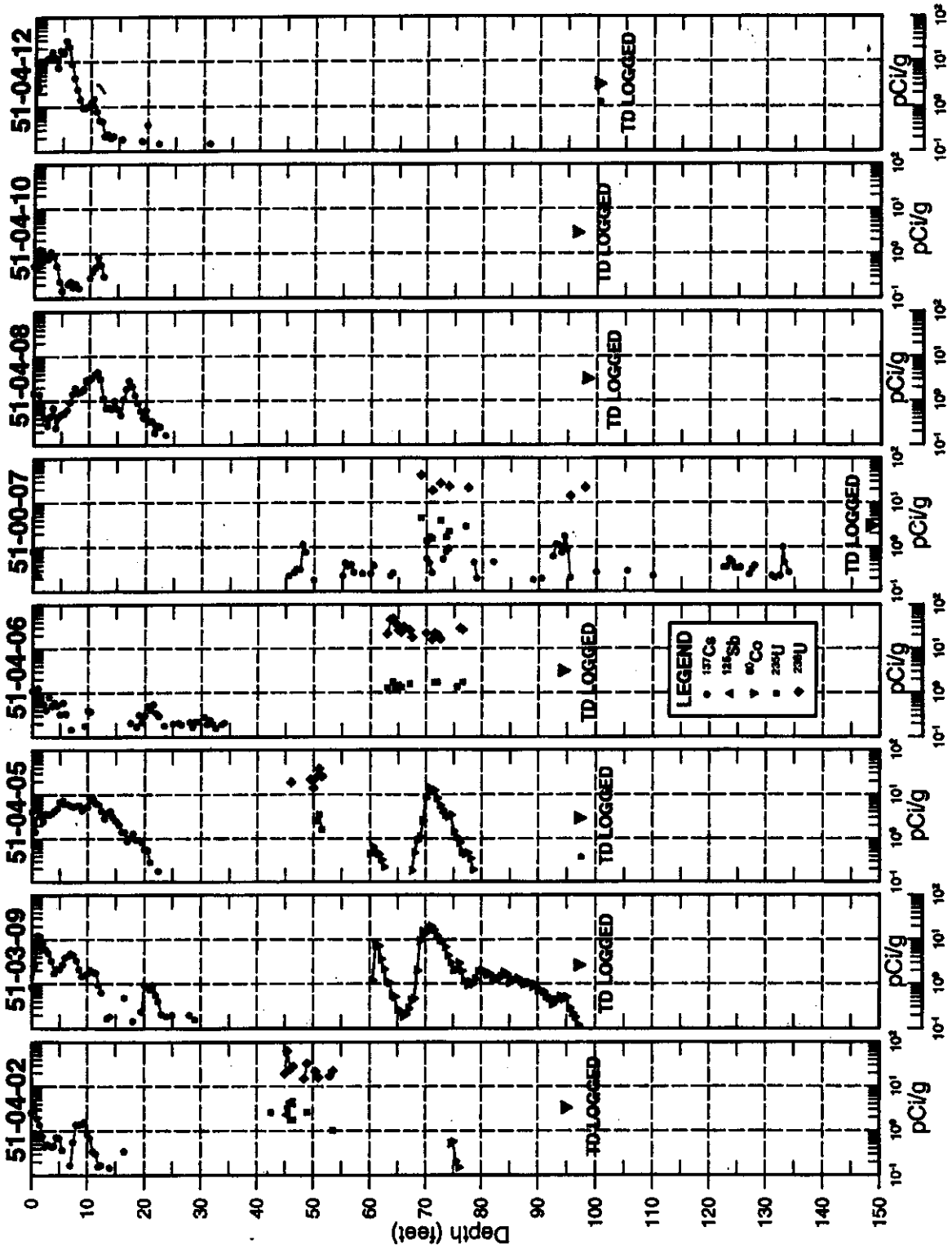


Figure A-4. Correlation Plot of ^{137}Cs, ^{125}Sb, ^{60}Co, ^{235}U, and ^{238}U Concentrations in Boreholes Surrounding Tank TX-104

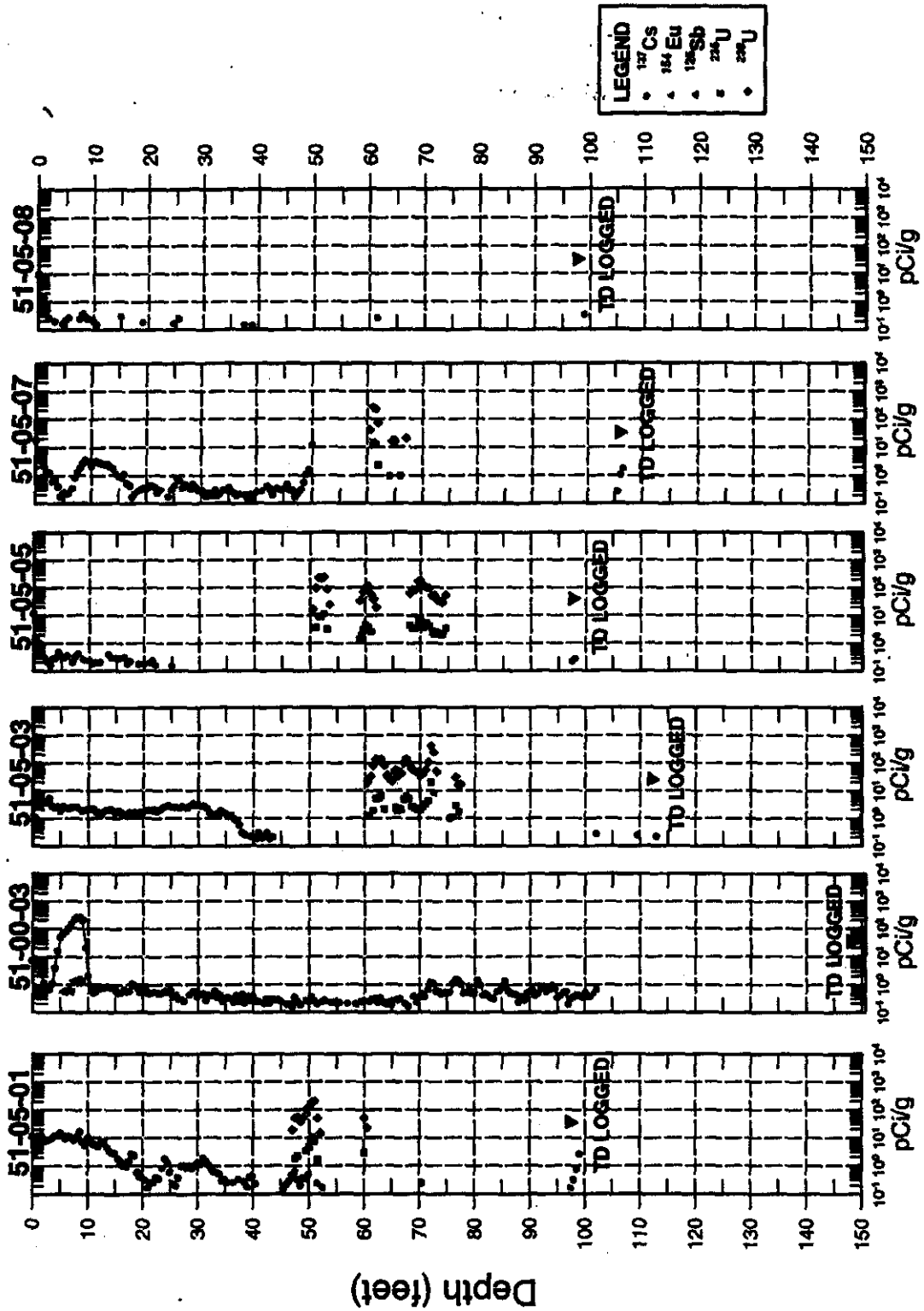


Figure A-5. Correlation Plot of ^{137}Cs, ^{154}Eu, ^{125}Sb, ^{235}U, and ^{238}U Concentrations in Boreholes Surrounding Tank TX-105

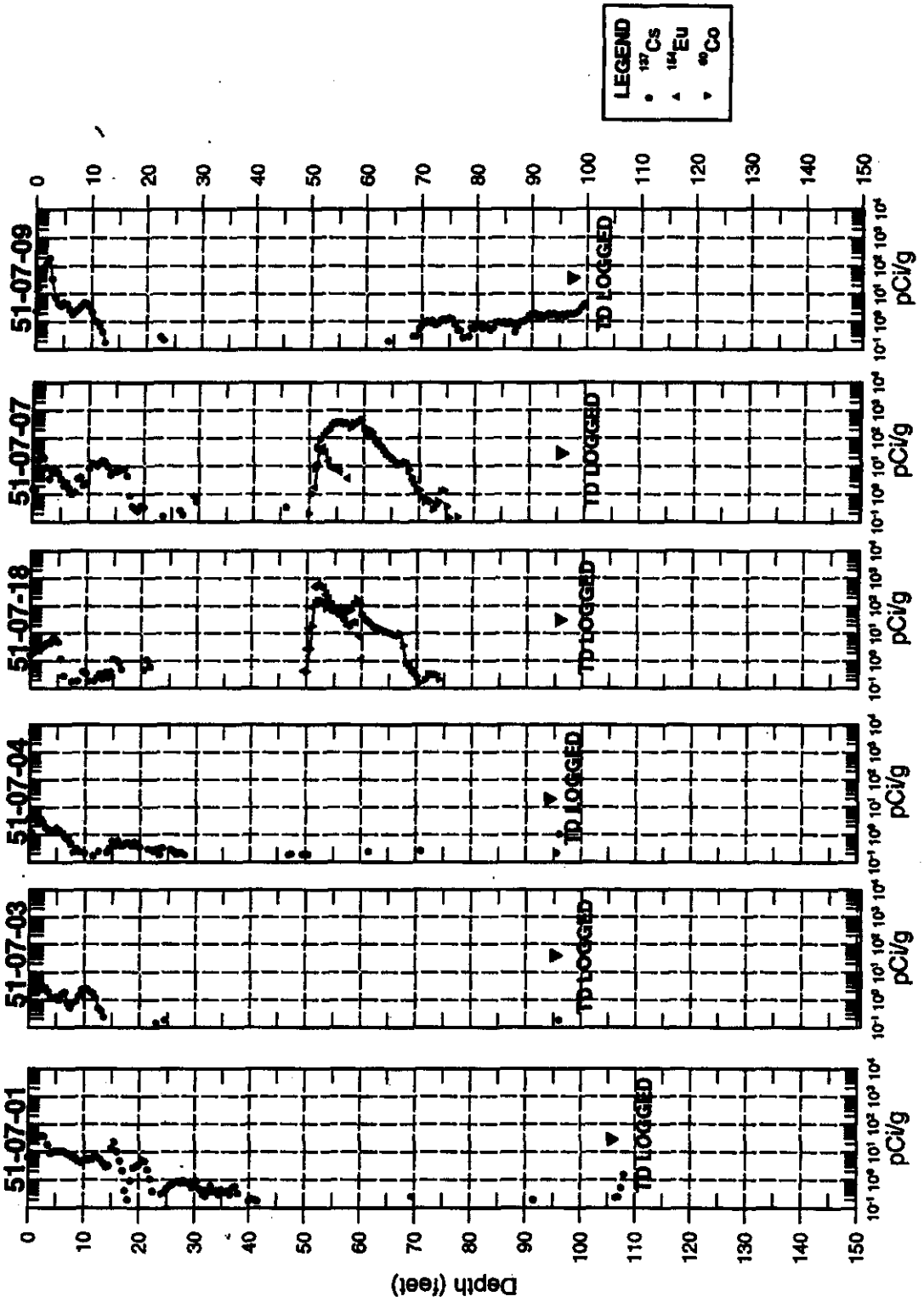


Figure A-7. Correlation Plot of ^{137}Cs, ^{154}Eu, and ^{60}Co Concentrations in Boreholes Surrounding Tank TX-107

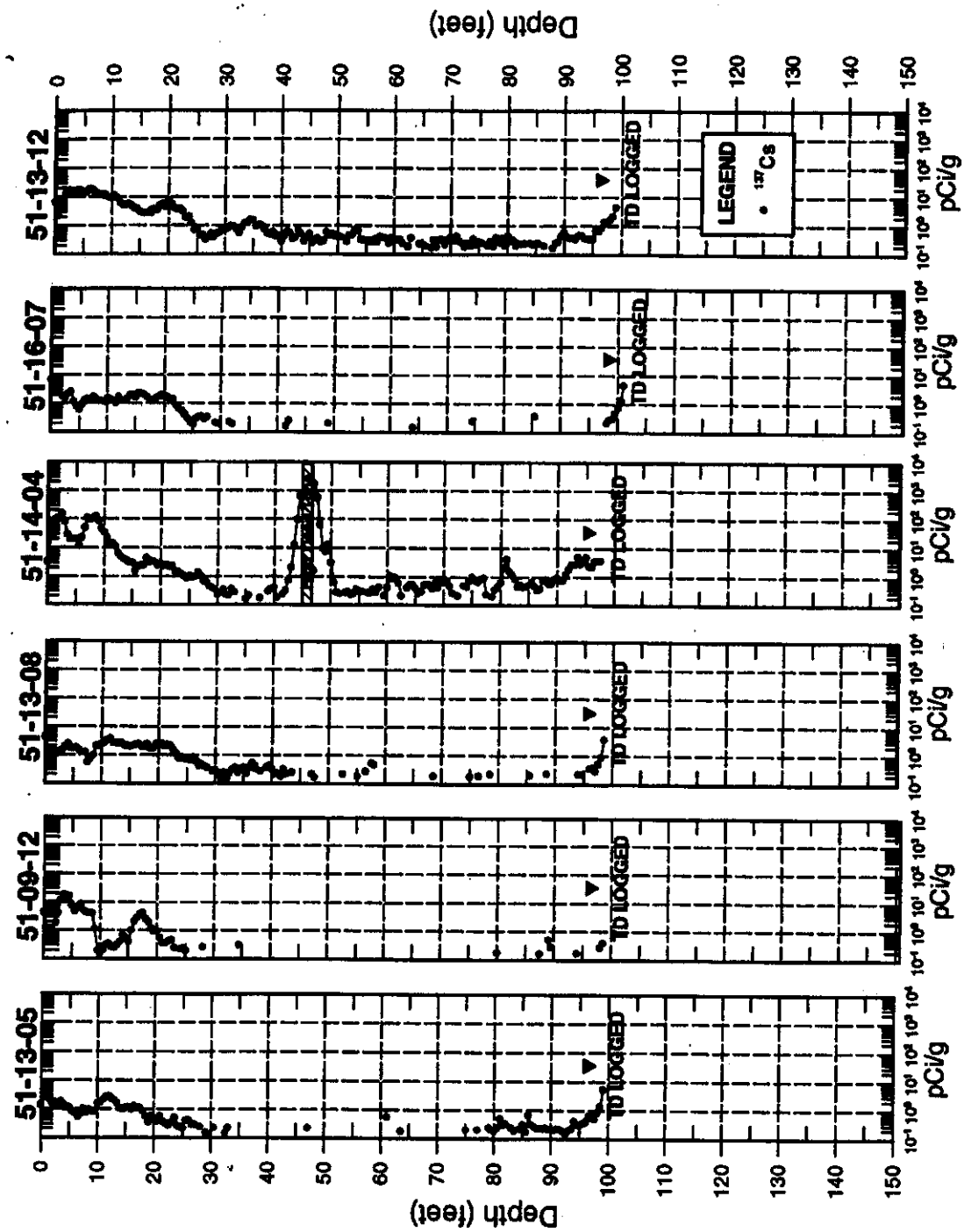


Figure A-13. Correlation Plot of ^{137}Cs Concentrations in Boreholes Surrounding Tank TX-113

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Page 1 of 1

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SUBSURFACE CONDITIONS DESCRIPTION OF THE T AND TX-TY WASTE MANAGEMENT AREAS

M.I. Wood, Fluor Hanford, Inc., for T.E. Jones, CH2MHill Hanford Group
R. Schalla, B.N. Bjornstad and F.N. Hodges, PNNL
Richland, WA 99352
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Abstract: This document provides a discussion of the subsurface conditions relevant to the occurrence and migration of contaminants in the vadose zone and groundwater underlying the 241-T, -TX and -TY tank farms. A concise summary is provided of existing information in support of characterization plannning. A description is provided of the available environmental contamination data and a limited, qualitative interpretation of these data.

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Surface Conditions Description of the T-TX-TY Waste Management Area

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

CH2MHILL
Hanford Group, Inc.
Richland, Washington
Contractor for the U.S. Department of Energy
Office of River Protection under Contract DE-AC06-99RL14047

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RPP-7123
Revision 0

Surface Conditions Description of the T-TX-TY Waste Management Area

M. I. Wood
Fluor Hanford Inc.

T. E. Jones
CH2M HILL Hanford Group

R. Schalla
B. N. Bjornstad
F. N. Hodges
Pacific Northwest National Laboratory

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CH2MHILL
Hanford Group, Inc.
P. O. Box 1500
Richland, Washington

Contractor for the U.S. Department of Energy
Office of River Protection under Contract DE-AC06-99RL14047

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TERMS

CFR	*Code of Federal Regulations*
DQO	data quality objective
EPA	U.S. Environmental Protection Agency
H/PP Interval	Hanford Formation (?)/Pliocene-Pleistocene Unit (?) Interval
HEIS	Hanford Environmental Information System
PUREX	Plutonium-Uranium Extraction (Process)
RCRA	*Resource Conservation and Recovery Act of 1976*
RCW	*Revised Code of Washington*
REDOX	Reduction-Oxidation (Process)
SST	single-shell tank
TBP	tributyl phosphate
Tri-Party Agreement	*Hanford Federal Facility Agreement and Consent Order*
WMA	Waste Management Area

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SUBSURFACE CONDITIONS DESCRIPTION OF THE T AND TX-TY WASTE MANAGEMENT AREAS

1.0 INTRODUCTION

This document discusses the subsurface conditions relevant to the occurrence and migration of contaminants in the groundwater underlying the T, TX, and TY tank farms. These tank farms, located in the 200 West Area of the Hanford Site, make up the T and TX-TY Waste Management Areas (WMA). This document describes the available environmental contamination data and contains a limited qualitative interpretation of the data as they apply to contaminant behavior.

1.1 BACKGROUND

Figure 1-1 shows the location of the T and TX-TY WMAs, and some other facilities in the 200 West Area. To facilitate *Resource Conservation and Recovery Act of 1976* (RCRA) groundwater monitoring programs, the T, TX, and TY tank farms were grouped into two WMAs. Figure 1-2 provides more detail on the T and TX-TY WMAs and surrounding area. Figure 1-2 also shows liquid discharge sites used extensively in tank farm operations (e.g., trenches and cribs) and active RCRA groundwater monitoring wells. Recent groundwater chemistry data from these wells suggest that tank waste has reached the unconfined aquifer from T and TX-TY WMA sources. These data are summarized in Chapter 3.

Because a connection between T and TX-TY WMAs sources and groundwater contamination has been made, the Washington State Department of Ecology (Ecology), the U.S. Environmental Protection Agency (EPA) and the U.S. Department of Energy (DOE) negotiated the *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement) Change Control Form M-45-98-03 (Ecology et al. 1999). The proposed Tri-Party Agreement milestones mandate a series of activities addressing the T and TX-TY WMA contamination. The goal of these activities is to determine whether corrective action is needed to mitigate the impact of contamination from single-shell tanks (SST) on the surrounding environment. One of the first significant efforts in this process is to complete additional characterization of current contamination conditions in the subsurface underlying the T and TX-TY WMAs. Spectral gamma baseline data have been collected from all drywells in the three tank farms; summary reports of these data are available. Information generated by these and future characterization activities will support waste management decisions for interim corrective measures, SST waste retrieval, and SST closure.

1.2 PURPOSE

Within the context of the characterization and evaluation program, this document fulfills several purposes. In the immediate future, a data quality objective (DQO) process will be convened to plan characterization activities for the T and TX-TY WMAs, particularly the vadose zone. Given the numerous vadose zone and possibly relevant groundwater contamination events that have occurred in the T and TX-TY WMAs, several characterization activities clearly are

Figure 1-1. Location Map of the T and TX-TY Waste Management Areas and Related Facilities.

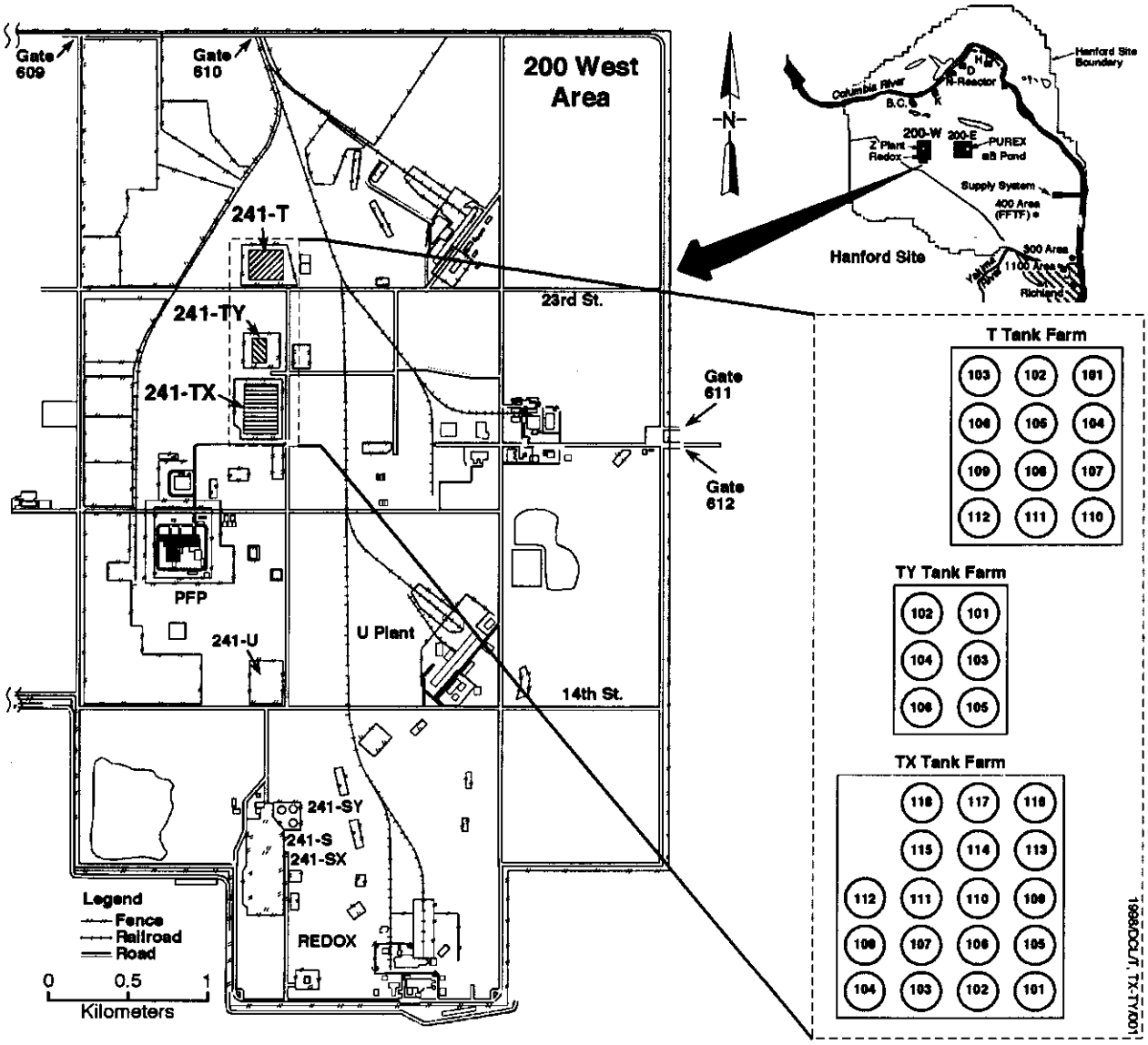
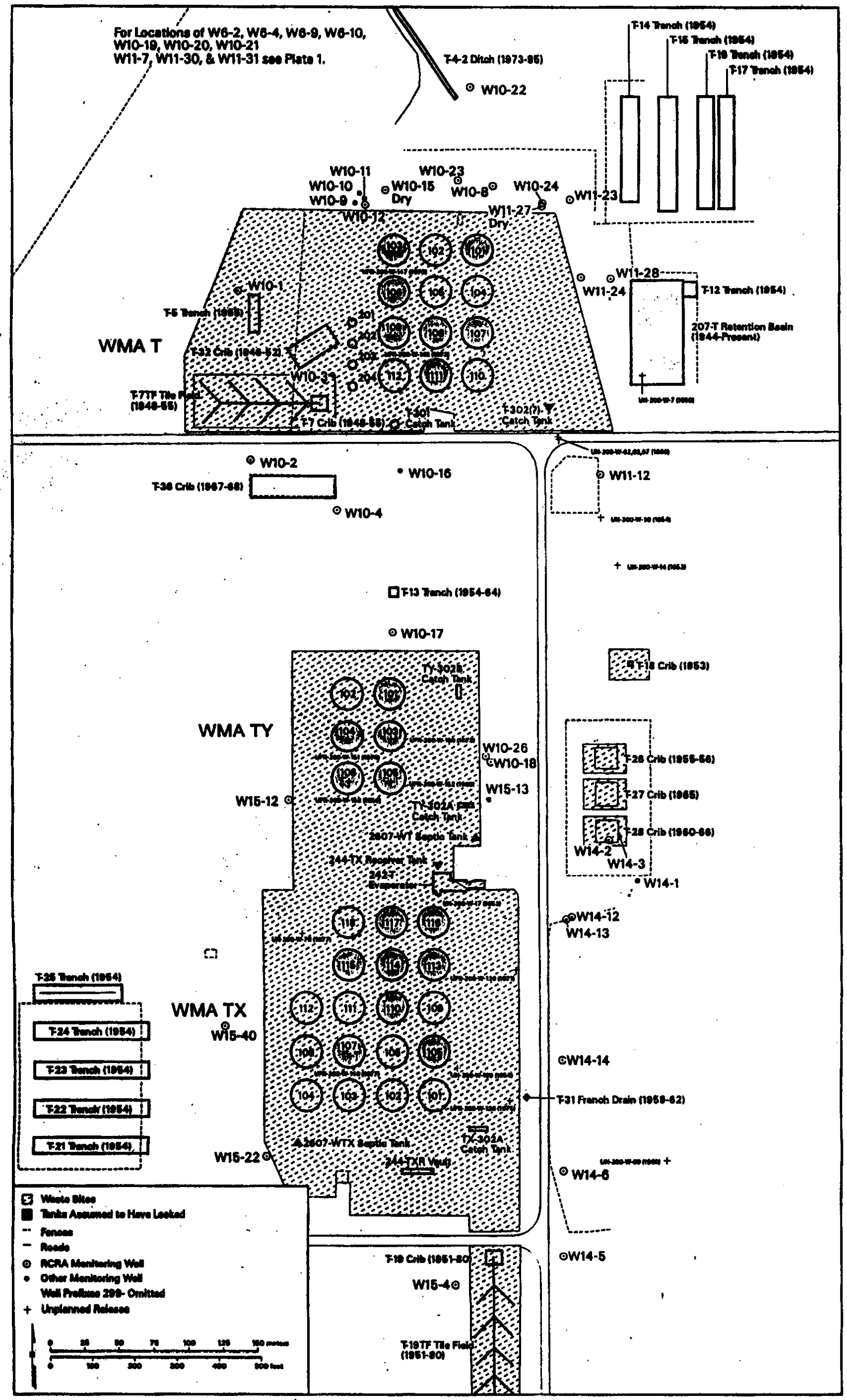


Figure 1-2. The T and TX-TY Waste Management Areas and Surrounding Facilities.



plausible. Obviously, an efficient characterization approach that adequately evaluates the WMAs is needed. To aid in selecting the proper approach, characterization focuses on waste site-specific data that define the occurrence and migration of contaminants within the system to date. This document includes a concise description and limited interpretation of these critical data. A systematic description of the environmental conditions affecting contaminant migration still is needed to identify data gaps, recognize significant relationships among different data types, and organize data inputs to contaminant migration models. This document provides a framework for completing a systematic description as more data are collected, interpreted, and integrated with currently available information.

1.3 SCOPE

The first part of this document describes the two primary components of the subsurface condition database: the physical setting of the T and TX-TY WMAs and the contaminants contained within each WMA. Chapter 2 describes the physical setting, including the tank farm infrastructure, geology, hydrology and infiltration mechanisms, and geochemistry. The tank farm infrastructure description emphasizes those parts of the system that allowed fluids to discharge into the soil column and the time periods during which these parts operated. The geology description emphasizes the impact of the geologic strata on fluid movement. The hydrology and infiltration discussion emphasizes infiltration mechanisms, infiltration history, and hydrologic properties of the geologic strata that control fluid movement. The geochemistry section emphasizes the characteristics that control contaminant movement, particularly in relation to fluids.

The second component of the subsurface characterization database is the description of contaminant occurrences and movement within the vadose zone and the unconfined aquifer. Chapter 3 describes this component. First, the chapter summarizes contamination events to orient the reader to the historical sequence. This is important because of the multiple fluid discharges in and near the T and TX-TY WMAs and multiple occurrences of contamination currently observed in the unconfined aquifer underlying the T and TX-TY WMAs. Second, the chapter summarizes the synthesis of the historical and spectral gamma database for the T, TX, and TY tank farms. These data are unique because of their extent, both temporal and spatial. The overview demonstrates the observed spatial variability of contaminant concentration and provides the most comprehensive indication of the diversity among various contaminating events. Third, the chapter describes separate leak events. The key data in this discussion include tank waste inventory and chemistry information derived from process history, the corroborating gamma data, and soil sample data where available. Finally, groundwater contamination data relevant to tank waste sources are discussed.

Chapter 4 contains a brief qualitative integration of the data and relates the data to a conceptualization of the contamination events. Because the events are diverse, database interpretations are given for each specific contaminating occurrence or type of occurrence.

Chapter 5 identifies key uncertainties and data gaps that are important to understanding potential future contamination of the unconfined aquifer and provides recommendations for resolving these uncertainties.

Appendix A contains the text of the T and TX-TY WMAs historical summary document (Williams 2000). Appendices B and C provide supporting geologic data. Appendix D provides supporting hydrologic and groundwater contaminant data. Appendix E summarizes the analyses of gamma logging data. Appendix F provides supporting data for the tank T-106 leak, one of the largest and most studied SST leaks.

2.0 PHYSICAL SETTING

2.1 T AND TX-TY WMA INFRASTRUCTURE AND OPERATIONS HISTORY

This section discusses the infrastructure and briefly summarizes the T, TX, and TY tank farm operations history, including the use of ancillary equipment and nearby cribs, trenches, and wells. A more detailed historical review is provided in Williams (2000). Excerpts from this report are provided in Appendix A. This section identifies the infrastructure elements known or suspected to have discharged fluids to the vadose zone, along with elements that remain capable of future discharges.

2.1.1 T and TX-TY WMA Infrastructure

The three tank farms, T, TX, and TY are divided into two WMAs, with the T tank farm in one and the TX and TY tank farms in the other. Within the T WMA, the primary structures through which tank waste has been stored, transported, and discharged are the 12 primary tanks (241-T-101 through -T-112), 2 cribs (T-32 and T-7), 1 trench (T-5) and 4 ancillary tanks (201 through 204). Each primary tank is 23 m (75-ft) in diameter with a nominal 2025 kL (535,000-gal) storage capacity. A cross section of tank 241-T-106 is provided in Figure 2-1. Note that the inlet-outlet ports are about 20 ft below the surface. This cross section also is representative of the other primary tanks in the T tank farm. Each ancillary tank is 6.1 m (20 ft) in diameter and holds 208 kL (55,000 gal).

The T tank farm also contains an assortment of ancillary equipment used to move tank waste during operations (e.g., waste transfer lines, catch tanks, leak detection systems). The initial primary waste transfer piping system was rather simple. The 12 tanks were divided into 4 sets of 3 tanks each (e.g., tanks T-101, T-102, and T-103) with each set connected by waste transfer pipes running east and west. The easternmost tank received waste first. When waste levels rose above the height of the open waste transfer line, waste cascaded into the next tank by gravity feed.

Within the TX-TY WMA, the primary structures are 2 tank farms containing a total of 24 tanks (TY-101 through TY-106 and TX-101 through TX-118), the 242-T Evaporator, and the T-19 crib and tile field. The tanks are the same diameter as those in the T farm, but they are approximately 8.5 m (28 ft) tall and hold 2869 kL (758,000 gal). As with T farm, waste transfer lines connected two, three, or four tanks in series (three sets of two tanks in the TY tank farm and three sets of four tanks and two sets of three tanks in the TX tank farm) to move waste from east to west by gravity feed.

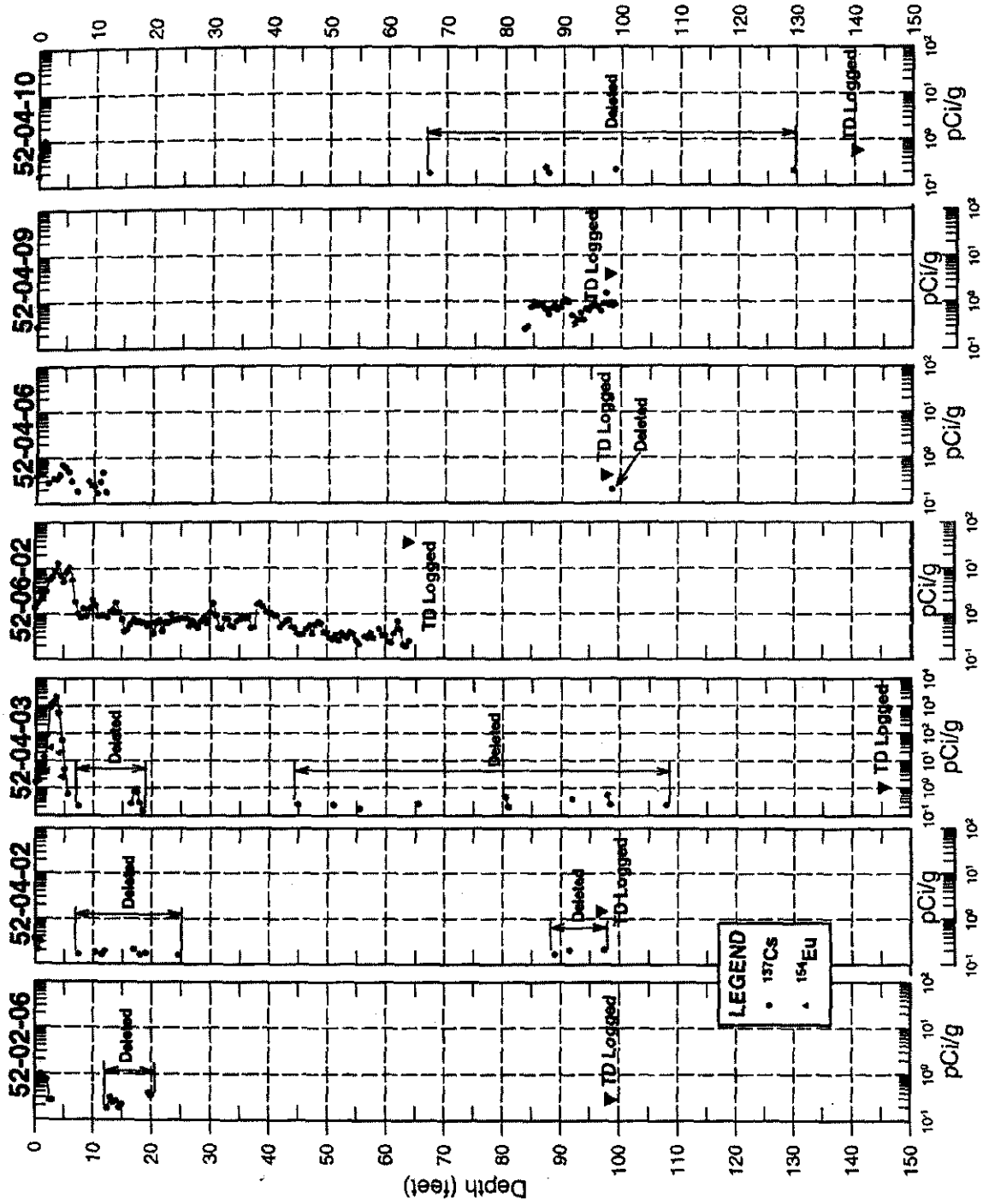


Figure B-4. Correlation Plot of ^{137}Cs and ^{154}Eu Concentrations in Boreholes Surrounding Tank TY-104

Figure 2-12. Historical Water Levels Near the T WMA (Hodges 1999a).

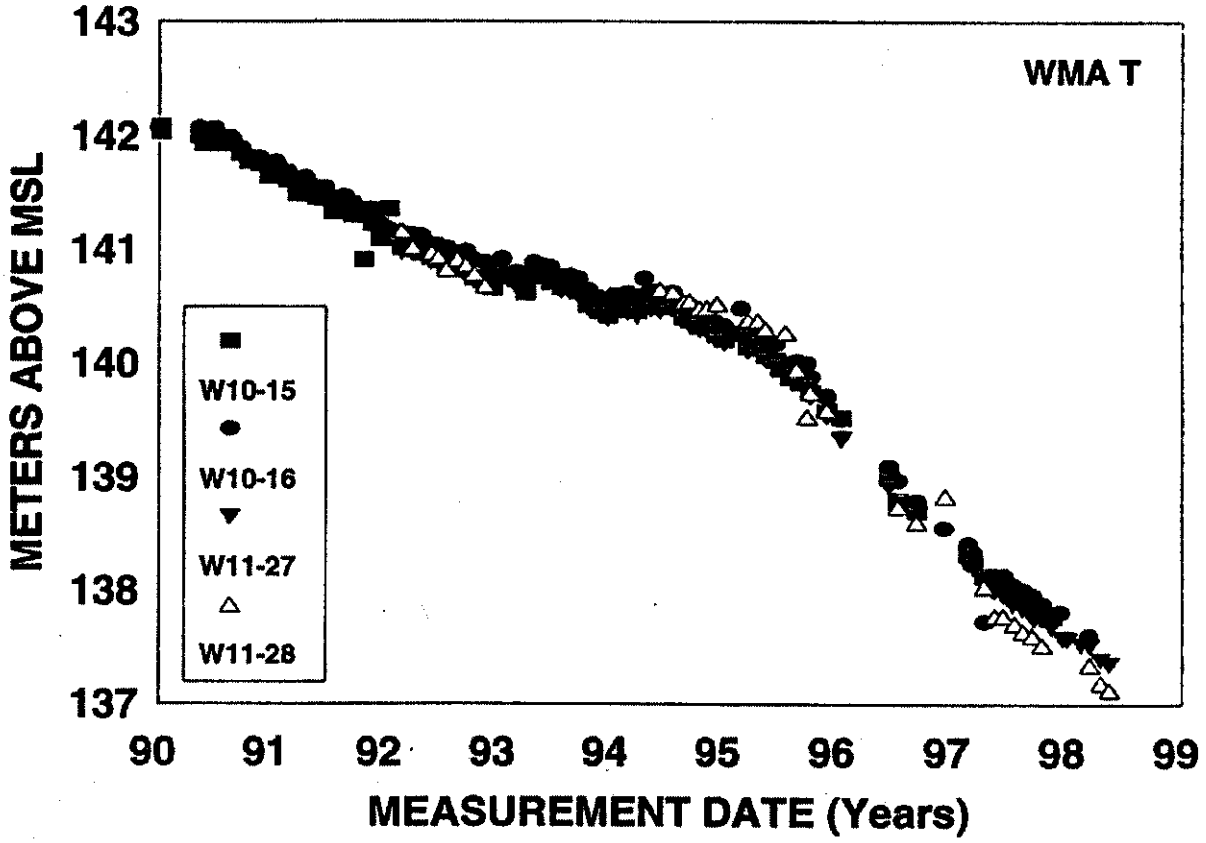


Figure 2-13. Historical Water Levels Near the TX-TY WMA (Hodges 1999b).

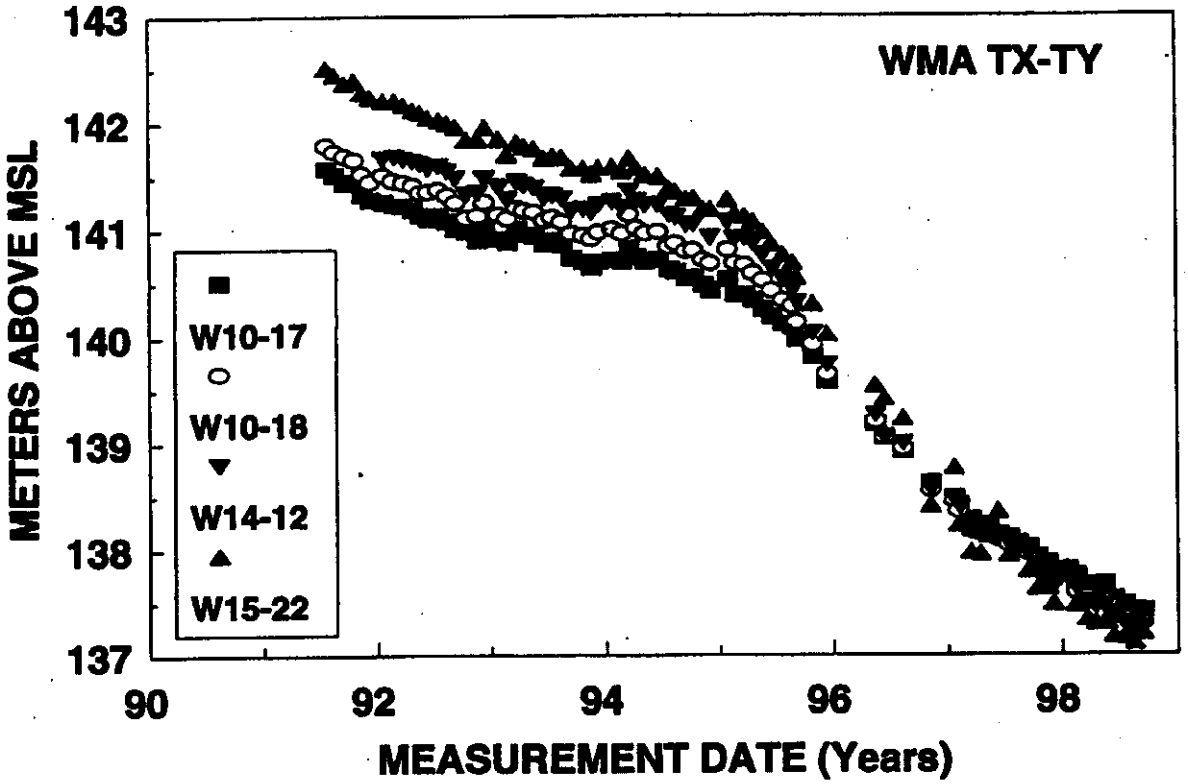
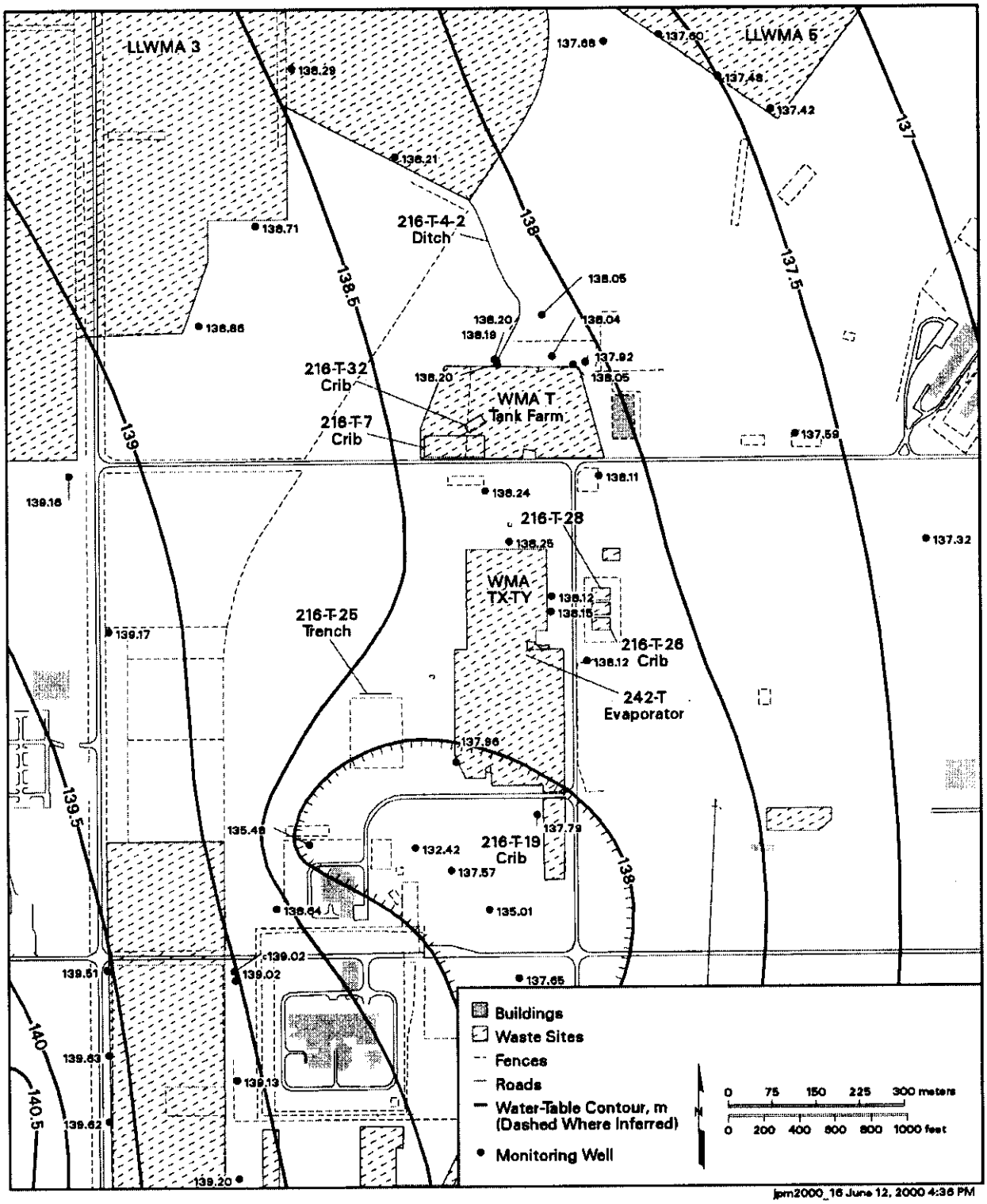


Figure 2-14. Water Table Map of the 200 West Area in 1999.



2.4 HYDROLOGIC PROPERTIES

2.4.1 Vadose Zone Properties

Khaleel and Freeman (1995) summarizes vadose zone hydrologic properties of Hanford Site sediments. A subset of this database is included in Appendix D, Table D-2. The database information consists of the location of the sample, the depth at which the sample was collected, particle size distribution, moisture retention curve data, and saturated hydraulic conductivity values. Generally, the soils are variable mixtures of sands and gravels. Well-defined horizontal strata with distinctly different hydraulic properties favoring lateral movement in the vadose zone (e.g., silty sands) are probably present locally, but are not widespread.

2.4.2 Aquifer Properties

This section provides information on the current nature of the unconfined aquifer in the immediate region of the T and TX-TY WMAs. Aquifer properties were determined from stratigraphic interpretations, current water elevations, and hydraulic conductivity values based on aquifer tests.

The unconfined aquifer beneath the T and TX-TY WMAs is within unit E of the Ringold formation (Lindsey 1995). Gravels within the Ringold Formation unit E vary greatly in degree of cementation, and therefore, exhibit a wide range of hydraulic properties. In the vicinity of the T and TX-TY WMAs, reported hydraulic conductivity values range from 15 to 33 m/d (950 to 100 ft/d) and transmissivity values range from 47 to 93 m^2/d (500 to 1,000 ft^2/d) (Connelly et al. 1992; DOE/RL 1993). A fluorescein dye tracer test conducted near the northwest corner of the T WMA in 1974 as part of the tank 241-T-106 leak study, indicated groundwater flow velocity on the order of 0.4 m/d (1.3 ft/d) (Routson et al. 1979). On the basis of the water table map presented by Routson et al. (1979), the hydraulic gradient presently is approximately half the value it was in 1974 (Hodges 1998). Therefore, the current groundwater flow velocity is estimated at approximately 0.2 m/d (0.7 ft/d).

The hydraulic gradient is sufficiently steep across the 200 West Area to be measurable. With about 100 cm (32.8 in.) of change or more across each WMA, the use of discrete water elevations to determine flow direction is easily accomplished. Even steeper gradients occur south of the TX-TY WMA because of pump-and-treat activities begun at 200ZP-1. In this region, comparing data between individual wells to determine the upgradient versus downgradient locations is routine because the total error in water elevations between any two wells is small. Sources of vertical uncertainty that had to be addressed were the survey datum, survey loop or traverse errors, errors caused by the well itself being out of plumb, and occasional spurious water level errors. To reduce errors, a single current datum is now used for all wells in the 200 West Area (Hartman 1999). Barometric effects have been addressed in part by collecting contemporaneous water level measurements over a few hours or a day for each data set. Barometric effects on water level elevation measurements at the Hanford Site are just beginning to be addressed (Spane 1999). The level of uncertainty provided by barometric pressure variations to hydraulic gradient estimates is unlikely to be significant.

2.5 GEOCHEMISTRY

This section covers geochemical factors and material properties of the vadose zone and unconfined aquifer underlying the T and TX-TY WMAs. It addresses those factors that control contaminant mobility in the soil column. Radionuclide and hazardous-constituent mobility can be substantially different depending on the innate characteristics of the contaminant, the geochemistry of the natural soil-water system, and the changes in soil and water chemistry that occur from contact with tank fluid. In these soils, all factors are expected to be influential. Different contaminants present in the soils are variably mobile and, depending on interactions of tank fluids with the soil-water system, a given contaminant's mobility can be considerably different at different locations and times within the vadose zone and unconfined aquifer.

The geochemical characteristics and contaminant mobility are best considered in terms of behavior in relatively undisturbed soils versus soils that have interacted with tank waste fluids. In addition, tank fluid chemistry varies. Both types of soil conditions are expected in the vadose zone underlying the T and TX-TY WMAs. For relatively undisturbed soils, a substantial Hanford Site-specific database is available that quantifies geochemical characteristics and contaminant behavior, particularly for radionuclides (e.g., Ames and Rai 1978; Serne and Wood 1990; Serne et al. 1993; Kaplan, Parker, and Kutynakov 1998, and Kaplan and Serne 1999). This database is not specific for the T and TX-TY WMAs. Average soil properties are described in Section 2.2. Soil water in the vadose zone and groundwater in the unconfined aquifer have similar characteristics. They are moderately alkaline (pH about 8) and contain moderated concentrations of cations and anions. Dominant cations are calcium (about 50 mg/L), magnesium (about 14 mg/L), sodium (about 30 mg/L), and potassium (about 9 mg/L). Dominant anions are carbonate (about 70 mg/L) and sulfate (75 mg/L).

Within the T and TX-TY WMAs, quantitative, site-specific radionuclide sorption/solubility data are not available. However, spectral gamma data from the drywell systems and soil analyses from borehole 299-W10-196 near the tank 241-T-106 leak source provide qualitative indications of the reactivity of detected constituents and some ability to compare radionuclide behavior known to occur in undisturbed Hanford Site soil environments. For radionuclides present in most contaminated regions, spectral gamma data show that their spatial distributions relative to the expected source of leaks and other radionuclides tend to be consistent. Further, a three-dimensional view of contaminant distribution is derived for tank leaks that apparently have contaminated several drywells at varying distances from the leak location. In particular, the leak from tank 241-T-106 has contaminated enough drywells to show fairly distinct patterns of radionuclide distribution that are consistent with our understanding of relative degrees of sorption on soils and associated mobility. Given this database, the following observations are generally seen across the WMAs for the most commonly observed gamma-emitting radionuclides:

- Cesium-137 is concentrated in drywells near the potential sources of tank leaks. This suggests relatively rapid and complete sorption onto soil near the point of discharge. Vertical distribution in borehole 299-W10-196 shows ^{137}Cs peaks just under the tank bottom and extending no more than 10 m deeper into the soil column. In some cases (e.g., the tank 241-TX-107 and -TY-105 leaks) ^{137}Cs cannot be found, possibly because of very localized sorption beneath the nearby tank. This behavior is consistent with measured K_d values in Hanford Site soil of more than 100 mL/g.

- Cobalt-60 is highly mobile. When present in a drywell, it is routinely distributed over several tens of feet below the tank bottom and often extends to the drywell bottoms and is horizontally distributed at the greatest distance from the potential leak source. The most extensive example of this is associated with the tank 241-T-106 leak (Section 3). The ^{60}Co distribution in borehole 299-W10-196 is similar to the distribution of ^{99}Tc and nitrate. Cobalt-60 concentrations are fairly constant (`100 pCi/g) between the bottom of the tank (about 40 ft) and 110 ft. In this instance, the chemistry of numerous tank fluids clearly plays an important role in providing complexing agents that cause ^{60}Co to be highly mobile, with a K_d value near 0 mL/g.

- Europium-154 and ^{152}Eu appear to be somewhat less mobile than ^{60}Co but much more mobile than ^{137}Cs. In the set of drywells that appear to be contaminated by the tank T-106 leak or the tank TX-107 leak, europium isotopes appear at locations farther from the source than ^{137}Cs, but do not extend quite as far as ^{60}Co. This suggests that europium sorption is significantly lower than ^{137}Cs sorption but not as low as ^{60}Co sorption. As with ^{60}Co, fluid chemistry appears to reduce europium reactivity in disturbed soils compared to undisturbed soils. One would expect relatively high sorption for lanthanide aqueous species (Serne and Wood 1990) in undisturbed soils such that europium distribution would be similar to cesium distribution.

These data suggest that tank fluid chemistry has had little observable effect on ^{137}Cs mobility. In these tank farms, ^{137}Cs continues to be highly reactive and immobile in the soil column and is a good indicator of leak source location. Assigning a K_d value of 100 mL/g or more is a reasonable estimate. Tank fluid chemistry does have a significant effect on ^{60}Co and europium isotopes, reducing reactivity with the soil and enhancing mobility. Some small degree of sorption may occur, but assigning a K_d value of 0 mL/g is a reasonably conservative estimate. The particular fluid chemistry characteristics enhancing ^{60}Co mobility are unclear and no distinctly different effects on gamma radionuclide behavior caused by variability in tank fluid chemistry are apparent. The location of ^{60}Co also could show an approximate location of ^{99}Tc in the vadose zone underlying the T, TX, and TY tank farms if the borehole 299-W10-196 radionuclide distributions with depth are representative.

ref. RPP-6353, Rev. 0.

2.2.1 Tank Farm Activity

A sudden, significant change in the intensity of gross gamma rays between successive gross gamma surveys at or near the ground surface suggests that contamination may have resulted from tank farm activities or logging procedure changes. Radioactive contamination occurs near the surface in 34 wells, apparently as the result of tank farm activities (i.e., logging procedure changes, transfer line operations, valve box and conduit leaks, surface spills, etc.). These wells are listed in Table 3.

Table 3. TX Tank Farm Activity Zones

Borehole Number	Survey Depth (feet)	Probe	Category	Zone Depth (feet)	Max GTP (ft x c/s)	Year Max GTP	Isotope Present
51-00-03	150'	4	TF Activity	0-16	40K	1975	Cs^{137}
51-01-02	110'	4	TF Activity	0-8	300	1976	Cs^{137}
51-02-09	100'	4	TF Activity	0-10	600	1976	Cs^{137}
51-03-01	100'	4	TF Activity	0-4	300	1980	Cs^{137}
51-03-09	100'	4	TF Activity	0-5	150	1985	Cs^{137}
51-04-10	100'	4	TF Activity	0-6	200	1985	Cs^{137}
51-04-12	100'	4	TF Activity	0-10	800	1984	Cs^{137}
51-05-01	100'	4	TF Activity	0-16	400	1975	Cs^{137}
51-06-08	100'	4	TF Activity	0-10	1.3K	1976	Cs^{137}
51-07-01	110'	4	TF Activity	0-10	800	1975	Cs^{137}
51-07-07	100'	4	TF Activity	0-6	150	1985	Cs^{137}
51-07-09	100'	4	TF Activity	0-6	1.2K	1975	Cs^{137}
51-08-05	100'	4	TF Activity	0-12	400	1985	Cs^{137}
51-09-10	100'	4	TF Activity	0-18	100	1976	Cs^{137}
51-09-12	100'	4	TF Activity	0-20	400	1980	Cs^{137}
51-10-04	100'	4	TF Activity	0-10	400	1985	Cs^{137}
51-10-08	100'	4	TF Activity	0-10	500	1982	Cs^{137}
51-10-13	98'	4	TF Activity	0-14	400	1985	Cs^{137}
51-10-25	100'	4	TF Activity	0-15	200	1985	Cs^{137}
51-12-11	100'	4	TF Activity	0-10	150	1975	Cs^{137}
51-13-12	100'	4	TF Activity	0-24	900	1975	Cs^{137}
51-14-04	100'	14	TF Activity	0-12	300	1985	Cs^{137}
51-14-08	100'	4	TF Activity	0-16	300	1975	Cs^{137}
51-14-11	100'	4	TF Activity	0-16	1K	1980	Cs^{137}
51-15-11	100'	4	TF Activity	0-12	400	1985	Cs^{137}
51-16-04	100'	4	TF Activity	0-13	900	1975	Cs^{137}
51-16-11	100'	4	TF Activity	0-18	1.2K	1975	Cs^{137}
51-17-03	145'	4	TF Activity	0-10	800	1975	Cs^{137}
51-17-10	100'	4	TF Activity	0-17	250K	1976	Cs^{137};Co^{60};Eu^{154}
51-17-11	100'	4	TF Activity	0-10	1K	1985	Cs^{137}
51-18-01	100'	4	TF Activity	0-10	700	1975	Cs^{137}
51-18-03	80'	4	TF Activity	0-9	7K	1975	Cs^{137}

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APPENDIX A

HISTORICAL BACKGROUND OF T, TX, AND TY TANK FARMS OPERATIONS AND CONTAMINATION EVENTS

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Table F-1. Compilation of Spectral and Interpreted Historical Gamma Data from Dry Wells Contaminated by Tank T-106 and T-103 Leaks.

Drywell Number	Isotope	Spectral Gamma Data						Historical Gamma Migration	
		1973		1978		1990's			
		Depth (ft) Range/Peak	Conc. Range (µCi/L)	Depth (ft)*** Range/Peak	Conc. Range (µCi/L)	Depth (ft) Range/Peak	Conc. Range (pCi/g)	Time Period	Depth (ft)
50-09-05	Cs-137		*		*		#		#
50-09-09	Cs-137		#		#		#		#

* not analyzed.

**"b" indicates that the depth listed is the drywell bottom.

#analyzed, but not observed or estimated.

$ present, but not migrating.

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