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All drawings located at the end of the document.

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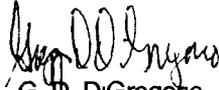
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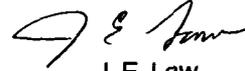
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TRANSMITTAL OF THE FINAL PRE-REMEDIAL INVESTIGATION OF IHSS 118.1 DATA SUMMARY REPORT - JEL-131-97

KH-00003NS1A

December 18, 1997

Discussion and/or Comments:

Attached are seven (7) copies of the Final Pre-Remedial Investigation of IHSS 118 1 Data Summary Report Please distribute three (3) copies to K-H and transmit three (3) copies to DOE, RFFO by December 19, 1997 There is one additional copy to be sent to the Administrative Record If you have any questions please contact me at extension 4385

Attachments
As Stated

- cc
- C Cowdery
- A C Crawford
- J E Law
- A L Pirmrose
- Administrative Record
- RMRS Records

RF/RMRS-97-111 UN

Final

Pre-Remedial Investigation of IHSS 118 1

Data Summary Report

December 18, 1997

Revision: 0

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1 0 INTRODUCTION

A pre-remedial field investigation was conducted in September 1997 to identify and delineate the extent of the volatile organic compound (VOC) nonaqueous phase liquid (NAPL) in the subsurface derived from Individual Hazardous Substance Site (IHSS) 118 1 - Multiple Solvent Spills West of Building 730, and to further characterize this IHSS. These data will be used to determine whether an interim remedial action is required, and how a potential remedial action would be implemented if one is necessary.

While an interim remedial action will not constitute a complete source removal, if implemented it would remove some of the NAPL contributing to a plume of VOC contamination in groundwater in this area. The source area is ranked 8th on the Environmental Restoration (ER) Ranking, and the associated groundwater plume is ranked 19th [revised Attachment 4 to the Rocky Flats Cleanup Agreement (RFCA) (DOE 1996a)]. Removal of the source material is consistent with the Rocky Flats Environmental Technology Site (RFETS) strategy for groundwater, which is to prevent contamination of surface water by removal of contaminant sources that impact groundwater.

1 1 Background

IHSS 118 1 is located due north of Building 776 and near Building 730, in the RFETS Industrial Area (Figure 1). This area is part of the Industrial Area Operable Unit (OU). IHSS 118 1 is an area of known subsurface soil contamination resulting from leaks and spills associated with an underground storage tank containing carbon tetrachloride. The tank was installed around 1963 and was removed in 1981 after being replaced by an above ground tank.

The 5,000 gallon capacity, underground steel tank was used to store carbon tetrachloride for use in Building 776. The tank had a concrete containment structure on the south side around the intake area and a concrete stirrup supporting the tank on the north end (Figure 2). Numerous surface spills were known to have occurred before 1970, some potentially up to 200 gallons. The intake to the tank failed in June 1981 and released a small amount (volume unknown) of carbon tetrachloride into the containment structure. The tank was subsequently removed (DOE 1992).

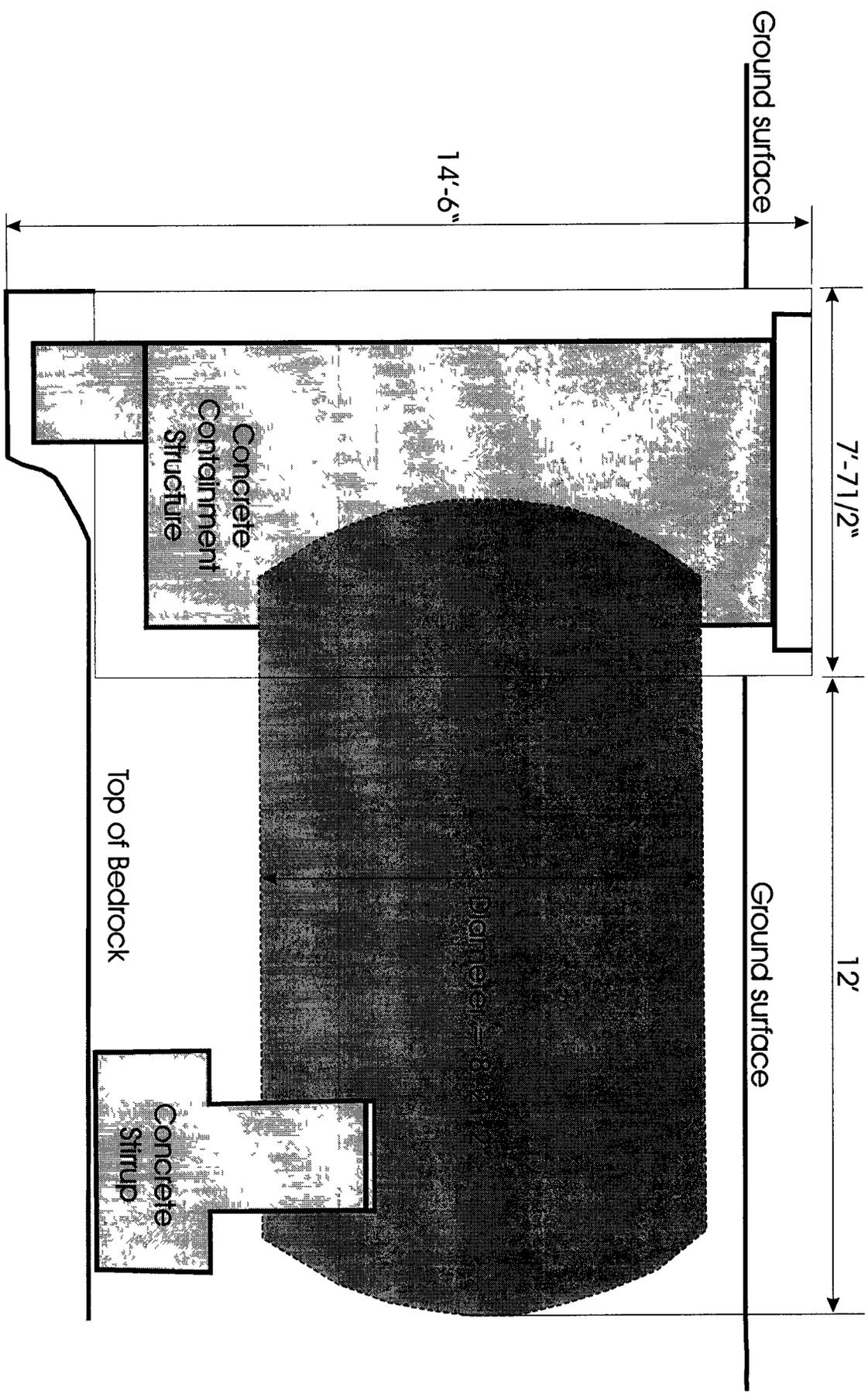


Figure 2. Cross Section of Former Carbon Tetrachloride Tank
 (Based on Engineering Drawing)

Retiree interviews conducted during the investigation found that at least two major spills occurred during tank filling operations. In the late 1970s, the sight gauge used to indicate the level of the contents in the tank malfunctioned, and showed that the tank was nearly empty. The nearly full tank was refilled, and up to 1,000 gallons of carbon tetrachloride was spilled on the ground. The spilled carbon tetrachloride flowed in the gutter and along the street north of Building 776 (south of Building 701), then flowed to the north along the west side of Building 701 towards Building 771. On a later occasion, another sight gauge malfunctioned, the tank was again overfilled and about 200 to 300 gallons of carbon tetrachloride was spilled through the vent pipe onto the ground. While the tank may have also leaked, based on the volume of carbon tetrachloride spilled on the surface, the spills are the most likely cause of the detected NAPL.

The carbon tetrachloride tank was located immediately east of and within the excavation for a group of four underground process waste tanks referred to as tank groups (Tanks) T-9 and T-10 (IHSS 132). These tanks were part of the original process waste system (IHSS 121). Tank T-9 consists of two 22,500 gallon concrete storage tanks. Tank T-10 consists of two 4,500 gallon concrete storage tanks. Both tanks were installed in 1955 but are no longer used as process waste tanks. Tank T-9 is currently utilized as plenum deluge catch tanks for Building 776. Tank T-10 was cleaned and foamed as part of the Underground Storage Tank accelerated action in 1996 (RMRS 1996a). No releases from either set of tanks have been documented (DOE 1995).

After the steep-side pit was excavated, Tanks T-9 and T-10 were constructed in-place. A pumphouse, Building 730, was constructed over the tanks and provides access. Based on depth to bedrock in the nearest borehole in an undisturbed location (43592 - Figure 1), the previous depth to bedrock was approximately 8 feet below ground surface. The excavation is at least 22 feet deep, with the current bedrock surface at that depth. The engineering drawings for T-9 and T-10 show a sump beneath the tanks at a depth of 21.6 feet and it is likely that the pit was excavated at least one foot beneath the sump, making the depth to bedrock approximately 23 feet below ground surface. Borehole data indicates that the excavation was backfilled with previously excavated material, along with sand, gravel, cobbles, trash and debris.

There are numerous underground and overhead utilities and structures in this area, which interfered with this investigation and will have an impact on future remedial actions. The

underground utilities are generally within 6 feet of the ground surface and include vitreous clay sanitary sewer lines, electrical lines, water lines, tunnels between buildings, building footing drains, process waste lines and process waste tanks, and other unidentified (or classified) utilities. Information from excavations in other areas and interviews with workers indicate that most of the buried utilities were backfilled using previously excavated native materials.

1.2 Prior Investigations

During the 1995 OU 9 Phase I Remedial Investigations, soil borings, groundwater samples, and subsurface soil samples were collected in this area including soil borings drilled near the four corners of Tanks T-9 and T-10 (DOE 1995)(Figure 1). High soil concentrations of VOCs, but not radionuclides, were observed. The concentrations for contaminants above the RFCA Action Levels are shown in Table 1 along with radionuclides above background levels. These data support the contention that the observed contamination is due to spills from the carbon tetrachloride tank, and not leakage from Tanks T-9 and/or T-10. Based on process waste contaminant concentrations, high concentrations of americium, and plutonium would be expected if the contamination were due to leakage from Tanks T-9 or T-10, (RMRS 1996a).

Table 1 VOCs Detected Above RFCA Tier I Subsurface Soil Action Levels and Radionuclides Detected Above Background Concentrations in Previous Investigations

Location	Depth (in feet)	Carbon Tetrachloride (mg/kg)	Chloroform (mg/kg)	Americium-241 (pCi/g)	Plutonium-239/240 (pCi/g)
02695	0-0.5	<0.012	ND	0.064	0.429
	6.3-8.3*	0.005J	ND	NA	—
	22.0-22.8*	81,000	3,800	—	—
02795	0-0.5	<0.011	ND	0.185	2.038
	4.6-5.1*	0.034	ND	—	—
02895	0-0.5**	<0.011	ND	1.602	7.386
	4.6-6.9*	<0.012	ND	—	—
	22.0-22.5*	25,000	ND	—	—
02995	0-0.5	<0.011	ND	—	—
	8.0-9.4*	0.017	ND	—	—
	26.0-27.8*	9,800	ND	—	—
RFCA Tier I Subsurface Soil Action Levels		11	152	209***	1,088***

* Sample depth below the water table

** Duplicate sample, real sample results were less than detection limits

*** Action level based on presence of a single radionuclide only (presence of additional radionuclides will result in lower action levels)

ND Not detected

NA Not analyzed

— Result is below background concentrations

Water samples were collected adjacent to each borehole using a Hydropunch™ (Figure 1). The water sample collected from boring 2795 separated into two distinct liquid phases, indicating the presence of NAPL. Analysis of the groundwater samples indicated that carbon tetrachloride was the primary contaminant. However, other VOCs were also detected in the samples, along with low levels of radionuclides. Table 2 presents the results of these groundwater samples (DOE 1995) along with the RFCA groundwater Tier I action levels.

Table 2 VOCs (µg/l) and Radionuclides (pCi/l) Detected in Previous Groundwater Sampling in the IHSS 118 1 Area (derived from DOE 1995)

Compound	Borehole 2695	Borehole 2795	Borehole 2895	Borehole 2995	RFCA Groundwater Tier I Action Level
Acetone	ND	110	ND	13	365,000
Carbon Tetrachloride	2,000	1,500	ND	390	500
Chloroform	1,200	450	ND	620	11,000
Methylene Chloride	22	ND	ND	ND	500
Tetrachloroethene	12	14	ND	ND	500
2-Methylnaphthalene	ND	ND	100	ND	-
4-Methyphenol	ND	ND	150	ND	-
Naphthalene	ND	ND	32	ND	146,000
Phenanthrene	ND	ND	12	ND	-
Phenol	ND	ND	100	ND	2,190,000
Americium-241	0.092	0.008	0.410	0.539	14.5
Plutonium-239/-240	0.089	0.026	2.453	0.058	15.1
Radium-226	ND	1.3	2.9	33	2000
Tritium	115	-109	-19	-49	66,600
Uranium-233/-234	29.09	9.20	5.67	17.32	298
Uranium-235	1.04	0.40	0.48	0.53	101
Uranium-238	20.73	6.87	5.37	17.42	76.8

- No action level established

ND Compound was not detected at the method detection limit

2.0 RECENT INVESTIGATION

The September 1997 pre-remedial investigation was planned to obtain data for determining the need for a remedial action. As stated in the Sampling and Analysis Plan (RMRS 1997), the investigation had the following objectives:

- Better determine the extent of the NAPL,
- Determine the bedrock topography in the area, and
- Obtain information for design of potential remedial actions

Refining the extent of the known contaminated groundwater plume associated with this area, and the potential impact to surface water was not a part of this investigation. A groundwater investigation will be conducted at a later date, currently scheduled for 1998.

2.1 Planned Investigation

Eight geoprobe holes were planned in the area of suspected NAPL to define the extent of NAPL and to identify depth to bedrock. Soil samples were to be collected every four feet or where there were indications of NAPL. If PID readings, visible staining of the core, or the presence of NAPL on downhole tools indicated that NAPL was present, temporary wells were to be installed within the NAPL interval, and water levels checked within three days of completion. If sufficient liquid existed, a sample was to be collected, however, the well would not be purged prior to sample collection. If the recovered liquid separated into distinct phases, the amount of each phase was to be estimated, and a sample collected from each phase. Boreholes where PID readings remained near background levels, where there was no indication of free liquid, and where the core was not stained, were to be abandoned (RMRS 1997).

In addition, if potentially recoverable NAPL was encountered, additional geoprobe holes were to be pushed on an approximately twenty foot spacing to further define the extent of the contamination. Two additional geoprobe locations were planned, and the locations of these were also to be dependent on the site conditions encountered such as utilities, obstructions and/or safety concerns (RMRS 1997).

2.2 Implemented Investigation

Of the eight borehole locations planned, seven could not be drilled where initially located due to conflicts with utilities. However, the revised borehole locations were adequate to conduct the investigation, and viable information was obtained. Six of the borehole locations were relocated to avoid utilities and the seventh, the planned location for 05697, was abandoned because of the number of overhead and underground utilities. At that location (between 05597 and 05797) a viable offset was impossible. This borehole number was assigned to an additional location to offset wells 05997 and 05397 and was located near the former carbon tetrachloride tank location to determine the western extent of NAPL contamination in the subsurface (Figure 1). No other viable offsets were possible due to the numerous buildings and utilities in the area. One

additional location, 05997, was placed near the previously drilled borehole 02795, where NAPL staining was observed in 1995, but where depth to bedrock could not be determined

Stainless steel wells were installed in every borehole except 05297, 05597, and 05797 which were abandoned as neither NAPL nor high concentrations of VOCs were observed during coring operations. A well was installed in borehole 05197 as it was downgradient of the former carbon tetrachloride tank location and contained sufficient groundwater for continued monitoring.

2.3 Investigation Results

Each borehole was continuously cored, and the core was visually inspected and logged. Depth to bedrock was interpreted for each borehole, however, use of excavated bedrock as fill material, and poor core recovery made interpretation of the bedrock contact difficult.

Even with use of a core catcher, core recovery in the fill material and alluvium was poor due to the nature of these materials, however, recovery greatly exceeded that obtained by earlier investigations using auger drilling (DOE 1995). Alluvial and fill material consisted of clay, gravely to sandy clay, and iron-stained sand. Asphalt fragments and cobbles were noted at 05297, 05697, 05997 and gravel lenses were noted in the fill material throughout the investigation area. Much of the core that was not recovered was probably loose, coarse material which tends to fall out of core barrels. Previous investigations found wood and trash within the fill material (DOE 1995). This type of material, while likely present, was not recovered during this investigation. Wood and trash materials were probably pushed to the side rather than recovered by the smaller size core bit and lower power drilling methods used during this investigation.

While coring the fill material, loose material often sloughed into the borehole between core runs. Usually this material was easy to identify due to its disrupted appearance. However, since claystone was also used to backfill the excavation, loose gravel present in disrupted claystone could also be in-place and required careful examination of the core. After the core was examined and logged in the field, it was reexamined by experts knowledgeable with core at RFETS, and changes were noted on the borehole logs.

Core recovery improved once bedrock claystones were contacted. The claystone was predominantly gray to olive brown and massive, with iron staining and carbonaceous flecks common. The bedrock contact was difficult to determine due to reworked bedrock claystone in the fill material, unusual lithologies in the bedrock, and poor recovery. However, the bedrock contacts selected for each location are consistent with a steep-sided excavation into bedrock. Table 3 provides the depth to bedrock for each location. Details for each location are provided in Section 2.3.1.

Table 3 Total Depth, Depth to Bedrock and Depth to Groundwater for each Borehole

Location	Total Depth (in feet)	Depth to Bedrock (in feet)	Well (yes/no)	Depth to Ground-water (feet bgs*)	Comments
05197	28 0	13 6	yes	7 49	Bedrock claystone contains sandy intervals and pebbles appear similar to fill material but also correlate with bedrock at other locations
05297	27 0	20 8	no	-	
05397	27 0	21 5	yes	8 50	silt and sand lenses in claystone
05497	27 0	22 1	yes	6 52	
05597	12 0	8 0	no	-	No recovery from 6 0 to 8 0 feet. No PID detects
05697	22 0	18 8	yes	6 85	Sand layer in the fill just above bedrock surface
05797	12 0	5 8	no	-	No PID detects were observed
05897	24 0	21 4	yes	6 75	
05997	30 0	24 0	yes	7 37	

* feet bgs - measured depth in feet from the ground surface to the groundwater table

2.3.1 Drilling Results

Following is a description of the investigation and results for each borehole according to the drilling sequence. At location 05197, the top of bedrock was encountered at a depth of 13.6 feet. However, small pebbles and sandy lenses were noted in the claystone below that depth. These pebbles could represent a conglomeratic layer in the Arapahoe Formation such as is occasionally present on plant site (EG&G 1995a), or could be brought down from further up hole. If the pebbles and sands indicate the presence of disturbed claystone which was returned to the excavation, the bedrock surface may be as deep as 27.2 feet below ground surface, well below the anticipated depth of the excavation. The core from the 24.0 to 27.2 foot interval jammed in the core barrel, and was removed using a hand drill, making an interpretation difficult.

Even though neither NAPL nor high concentrations of volatile organic compounds were encountered during coring operations, a well was installed at location 05197 to monitor the

downgradient groundwater. The well was intended to be screened across the bedrock contact, but was screened from 18 to 28 feet below ground, due to the uncertainty of the bedrock contact, and to a small VOC detection on the PID in this interval.

Location 05297 was cored to a depth of 27 feet, with bedrock at 20.8 feet. Neither NAPL nor high concentrations of VOCs were observed during coring operations, and the geoprobe hole was plugged and abandoned.

At location 05397, bedrock was encountered at a depth of 21.5 feet, with a total depth of 27 feet. When drilling operations penetrated this surface, NAPL ran into the hole and was retrieved during the next core run, indicating that the NAPL was apparently pooled on the claystone bedrock surface. A well was installed and was screened from 14.5 feet to 24.5 feet.

Locations 05597 and 05797 were located on the road a significant distance south of the originally planned locations due to the overhead and underground gas lines, above ground steam lines, below ground domestic water lines, evaporation tower return lines, above and below ground process waste line and hot laundry lines, and other utilities at these locations. The plan to place a third borehole on the road was abandoned for the same reasons. At location 05597, bedrock claystone was encountered at a depth of 8 feet with a total depth of 12 feet. Bedrock claystone was encountered at 5.8 feet at location 05797 with a total depth of 12 feet. There were no VOCs observed at either location. These locations were outside the southern limit of the Tanks T-9 and T-10 excavation, and the geoprobe holes were plugged and abandoned.

Three boreholes were drilled due west of Tanks T-9 and T-10 (05497, 05697 and 05997), and wells were installed in each. Location 05997 is within the excavated area. During coring operations, an impenetrable surface was encountered at a depth of 19.5 feet. Fragments in the core shoe indicated that this material was concrete. The concrete may be part of the footing for Tanks T-9 and T-10, or a large chunk of concrete. The borehole was offset 1.1 feet southwest, and drilled to a depth of 30 feet. Bedrock was encountered at a depth of 24 feet below ground, and NAPL was encountered while coring in that interval. Due to poor core recovery and the uncertainty of the bedrock surface, the borehole was continued to a depth of 30 feet below ground. A well was installed with a screen from 19 to 24 feet below ground.

Location 05497 was drilled as planned, however, a concrete structure was encountered in the subsurface which is believed to be the concrete stirrup supporting the northern end of the former carbon tetrachloride tank (Figure 2). This structure was encountered in the subsurface at depths of 7.5 to 9 feet. Numerous offsets were required, and a core barrel was lost downhole before bedrock was successfully encountered at a depth of 22.1 feet, with a total depth of 27 feet below ground. No NAPL was encountered during drilling operations. However, a well was installed at this location because elevated PID readings and a sweet odor were noted when drilling at depth. The well was screened between 17 and 22 feet, and produced sufficient quantities of NAPL during groundwater sampling to collect both a NAPL and a NAPL duplicate sample.

Location 05697 was the planned offset for 05997 and 05397 to define the western boundary of the NAPL. This location is believed to be on the west side of the former carbon tetrachloride tank. A coarse, unconsolidated sand was encountered immediately above the claystone bedrock contact, but poor core recovery prevented determination of thickness. An offset was driven, and the sand was found to occur from 15.2 to 18.8 feet. This sand is similar in appearance to the Arapahoe Number One Sandstone, however, it is unconsolidated, contains up to 1/2 inch diameter pebbles, and is most likely fill material. Bedrock was encountered at 18.8 feet, immediately below the sand. While no NAPL was encountered during drilling operations, a well was installed, with the screened interval from 13.7 feet to 18.8 feet immediately above the bedrock contact, and within this sand interval to test this preferential pathway. No NAPL was encountered during groundwater sampling for this well.

Due to nearby, abandoned process waste lines, 05897 was drilled at the only location possible on the east side of the Tanks 9 and 10. This location was a twin of the previously drilled 02895, however, little data were collected during the previous investigation at this location. Bedrock was encountered at a depth of 21.4 feet, and total depth was 24 feet below ground. NAPL was seen in the core at depths below 20 feet, therefore, a well was installed. The well was screened from 17.2 to 22.3 feet below ground surface.

2.4 Contamination in Subsurface Soil

Soil samples were expected to be collected every four feet or where there were indications of NAPL. However, poor core recovery resulted in deviations from this plan, and samples were collected as close to a four foot interval as was possible. Where NAPL was encountered, no

additional core runs were taken as the NAPL would run into the borehole and compromise the integrity of the deeper samples

The primary contaminant detected in soil in the investigation area was carbon tetrachloride, along with lesser amounts of chloroform and methylene chloride. Both methylene chloride and chloroform are degradation products of carbon tetrachloride. However, both chemicals are common lab contaminants, and were also used on site, methylene chloride and chloroform were both known to have been used in Building 776. Table 4 provides the analytical results for the primary contaminants for each sample. Methylene chloride was encountered at all depths with detectable concentrations of 330 ug/kg to 2,000 ug/kg. The highest concentrations of carbon tetrachloride and chloroform in soils are found at depths greater than 20 feet below ground surface. These data agree with the previous investigation, and indicate that the NAPL may be present only at that depth.

Table 4 Primary Subsurface Soil VOC Contaminants (in ug/kg)

Location	Sample No	Depth (ft below ground)	Methylene Chloride	Carbon Tetrachloride	Chloroform	Comments
05197	BH10118RM	2 0-2 3	610 J	<630	<630	
05197	BH10112RM	2 8-3 1	610 J	<630	<630	real
05197	BH10113RM	3 1-3 4	540 J	<630	<630	duplicate
05197	BH10120RM	5 4-5 7	560 J	<630	<630	
05197	BH10116RM	6 7-7 0	580 J	<630	<630	
05197	BH10122RM	9 1-9 4	910	<630	<630	
05197	BH10126RM	14 0-14 3	950	<630	<630	
05197	BH10124RM	14 6-14 9	910	<630	<630	
05197	BH10128RM	17 8-18 1	1,100	<630	<630	
05197	BH10130RM	19 1-19 3	1,100	<630	<630	
05197	BH10132RM	21 1-21 4	1,100	780	<630	
05197	BH10134RM	26 0-26 5	1,400	12,000	50,000 E	cuttings, depth approximate
05297	BH10135RM	2 8-3 1	1,100	<630	320 J	
05297	BH10138RM	6 6-6 9	870	<630	<630	
05297	BH10140RM	10 8-11 0	920	<630	<630	
05297	BH10142RM	12 9-13 2	880	<630	<630	
05297	BH10144RM	16 6-16 8	990	<630	<630	
05297	BH10146RM	21 0-21 2	880	6,000	<630	
05297	BH10148RM	26 2-26 4	710	570 J	<630	
05397	BH10150RM	2 2-2 5	770	<630	<630	
05397	BH10153RM	7 0-7 3	330 J	<630	<630	
05397	BH10156RM	10 3-10 5	<630	<630	<630	real
05397	BH10155RM	10 5-10 7	<630	<630	<630	duplicate
05397	BH10158RM	14 4-14 7	<630	<630	<630	
05397	BH10160RM	17 8-18 1	<630	<630	<630	
05397	BH10162RM	21 2-21 5	<630	8,100	270 J	
05397	BH10165RM	24 25-24 5	<630	370,000 E	2,900	
05397	BH10167RM	26 3-26 5	<630	7,200	<630	

Table 4 Primary Subsurface Soil VOC Contaminants (in ug/kg) (continued)

Location	Sample No	Depth (ft below ground)	Methylene Chloride	Carbon Tetrachloride	Chloroform	Comments
05497	BH10227RM	1 9-2 2	1,500 B	460 J	<630	
05497	BH10241RM	5 8-6 0	1,400 B	570 J	<630	
05497	BH10231RM	9 0-9 3	1,500 B	530 J	<630	
05497	BH10233RM	13 4-13 7	1400 B	600 J	<630	
05497	BH10235RM	19 5-19 8	300 JB	4,500	1,600	
05497	BH10237RM	23 9-24 2	310 JB	3,200	2,200	
05497	BH10239RM	25 7-26 0	<630	51,000 E	1,800	
05597	BH10176RM	3 2-3 5	630	<630	<630	
05597	BH10179RM	5 5-5 8	600 J	<630	<630	
05597	BH10181RM	11 1-11 4	370 J	<630	<630	
05697	BH10216RM	1 4-1 7	<630	390 J	<630	
05697	BH10219RM	4 8-5 0	1,400 B	1,200	<630	
05697	BH10221RM	8 6-8 9	1,400 B	5,400	<630	Asphalt fragments in sample
05697	BH10223RM	12 8-13 1	1,400 B	1,400	<630	
05697	BH10225RM	19 5-19 7	1,300 B	720	<630	
05797	BH10169RM	3 0-3 3	<630	670	<630	
05797	BH10173RM	5 5-5 7	<630	370 J	<630	duplicate
05797	BH10171RM	5 7-6 0	620 J	280 J	<630	real
05797	BH10174RM	11 2-11 5	610 J	<630	<630	
05897	BH10183RM	2 2-2 5	340 J	<630	<630	
05897	BH10188RM	5 6-5 8	<630	<630	<630	duplicate
05897	BH10186RM	5 8-6 1	250 J	<630	<630	real
05897	BH10189RM	8 4-8 6	260 J	<630	<630	
05897	BH10191RM	12 3-12 6	270 J	<630	<630	
05897	BH10193RM	16 5-16 7	<630	610 J	<630	
05897	BH10195RM	20 4-20 7	790	450,000 E	71,000 E	real
05897	BH10197RM	20 7-21 0	2,000 B	1,200	250 J	duplicate
05997	BH10198RM	1 4-1 6	1100 B	<630	<630	
05997	BH10202RM	5 8-6 1	1700 B	<630	<630	
05997	BH10204RM	9 1-9 4	1500 B	<630	<630	
05997	BH10206RM	12 8-13 1	1400 B	1,800	1,900	
05997	BH10208RM	16 7-17 0	1400 B	460 J	540 J	
05997	BH10212RM	20 1-20 4	<630	12,000	<630	
05997	BH10210RM	20 9-21 2	1300 B	370,000 E	730	
05997	BH10213RM	slough ~25'	1500 B	390,000 E	35,000 E	real
05997	BH10215RM	slough ~25'	1400 B	140,000 E	12,000	duplicate

E - estimated value, concentration outside of calibration range

J - estimated value, concentration is below the detection limit

B - analyte also detected in the blank analysis

As shown in Table 5, other contaminants were found in the soil samples. The other contaminants are primarily dehalogenation byproducts of carbon tetrachloride, and even low levels of these indicate that oxidation is not occurring at this location. However, fifteen of the nineteen detects were J or JB qualified indicating that these values were below the detection limit (J), or below the detection limit and also detected in the blank analysis (JB). In addition, these contaminants

are not consistently present in the soil samples, and where duplicate samples were collected, do not occur in both the real and duplicate samples

Only one sample yielded results for these other contaminants above the detection limit, tetrachloroethene at 1,800 ug/kg and carbon disulfide at 910 ug/kg. However, the duplicate sample for this interval did not contain detectable quantities of either contaminant. One detect of naphthalene was found, as this also occurred in the blank, it is probably not representative of the contamination at this location.

Table 5 Other Subsurface Soil VOC Contaminants (in ug/kg)

Analyte	Location	Depth	Sample No	Results	Comments
Tetrachloroethene	05897	20 4-20 7	BH10195RM	1,800	Real sample - not in duplicate
	05997	12 8-13 1	BH10206RM	290 J	Real sample - not in duplicate
		20 9-21 2	BH10210RM	480 J	
		slough ~25'	BH10213RM	550 J	
Naphthalene	05197	5 4-5 7	BH10120RM	310 J,B	
Hexachlorobutadiene	05397	24 25-24 5	BH10165RM	560 J	Real sample - not in duplicate
	05497	25 7-26 0	BH10239RM	900 J	
	05897	20 4-20 7	BH10195RM	1,500	
	05997	20 1-20 4	BH10212RM	680	
20 9-21 2		BH10210RM	560 J		
slough ~25'		BH10213RM	510 J		
Acetone	05597	3 2-3 5	BH10176RM	260 J	Duplicate sample - not seen in real
	05897	20 7-21 0	BH10197RM	500 J	
Carbon Disulfide	05897	20 4-20 7	BH10195RM	910	Real sample - not in duplicate
Hexachloroethane	05497	25 7-26 0	BH10239RM	12,000 J	Real sample - not in duplicate
	05897	20 4-20 7	BH10195RM	31,000 J	
	05997	20 1-20 4	BH10212RM	8,100 J	
20 9-21 2		BH10210RM	10,000 J		
slough ~25'		BH10213RM	9,700 J		

E - estimated value, concentration outside of calibration range
J - estimated value, concentration is below the detection limit
B - analyte also detected in the blank analysis

The results of the radiological samples with activities above background are provided in Table 6. As described in the Sampling and Analysis Plan (RMRS 1997) these samples were collected from the upper three feet of core. The analytical results were compared against the background surface soil values of 0.066 pCi/g for plutonium 239/240, and 0.0227 pCi/g for americium 241 (EG&G 1995b).

Table 6 Radionuclides Detected in Pre-remedial Action Investigation Soils (pCi/g) and Corresponding RFCA Action Levels

Location	Depth (ft)	Plutonium-239/240	Americium-241
05197	2.4 - 2.8	—	0.049 (0.060)
05297	2.2 - 2.6	—	0.044 (0.098)
05397	1.8 - 2.2	—	—
05797	1.0 - 1.4	—	—
05597	0.8 - 1.5	—	0.087 (0.098)
05897	1.6 - 2.2	—	—
05997	0.8 - 1.4	—	0.063 (0.063)
05997	0.2 - 0.8	0.192 (0.091)	—
05697	0.8 - 1.4	—	—
05497	1.5 - 1.9	0.256 (0.120)	0.105 (0.089)
RFCA Tier I Surface Soil Action Level		1,088*	209*

- - Result is not above background
- () - Value represents total error
- * - Action level based on presence of a single radionuclide only

2.5 Contamination in the Groundwater

Wells were installed at 6 locations, water levels were measured and groundwater samples were collected. Groundwater was present 6 to 9 feet below ground surface (Table 3). The soil sampling data indicate that the NAPL occurs only in the interval directly above the bedrock contact. While it was possible to collect separate groundwater and NAPL samples from 4 locations (05397, 05497, 05897 and 05997), depth to NAPL was verified with an interface probe at only one location (05497) at a depth of 21 feet below ground surface. At the other locations, the interface probe did not reach the estimated depth of the NAPL primarily due to the well casing deviating from vertical, or the presence of silt in the well. The contaminants detected in the groundwater and NAPL samples are the same as those seen in the soil samples, primarily carbon tetrachloride, with lesser amounts of chloroform and methylene chloride. Methylene chloride and chloroform are degradation products of carbon tetrachloride, but both were also used on site and are common lab contaminants. Table 7 presents the results of the groundwater and NAPL analyses. Sample results should be considered qualitative due to the high concentrations present in the samples, requiring a high dilution for the analyses.

Table 7 Groundwater/NAPL VOC Results for IHSS 118 1 Investigation (in ug/l)

Well	Sample No	Methylene Chloride	Carbon Tetrachloride	Chloroform	Physical Description of Collected Sample
05197	GW10016RM	2,300 J	240,000 E	35,000	Very silty water, possible NAPL droplets present
05397	GW10019RM	25,000 JB	680,000	26,000 J	Water layer above NAPL, very thin LNAPL slick present
05397	GW10022RM	< 5,000,000	120,000,000	< 5,000,000	NAPL sample - sample vial had up to 40% water as a separate phase
05397	GW10027RM	<5	3 5 J	<5	Rinsate
05497	GW10018RM	2,500,000	180,000,000 E	2,700,000	NAPL sample (real)
05497	GW10026RM	3,600,000 J	130,000,000	< 5,000,000	NAPL sample (duplicate)
05497	GW10023RM	180,000	1,100,000 E	< 5,000,000	Water layer above NAPL -sample vial had <10% separate phase DNAPL and thin LNAPL slick
05697	GW10017RM	190 J,B	6,600	3,500	No NAPL observed
05897	GW10020RM	32,000 JB	510,000	88,000	Water layer above NAPL
05897	GW10025RM	2,600,000 J	250,000,000 E	3,800,000 J	NAPL sample
05997	GW10021RM	< 5,000,000	240,000,000 E	3,600,000 J	NAPL sample
05997	GW10024RM	13,000 J	880,000	160,000	Water layer above NAPL - vial had up to 25% separate phase NAPL
N/A	GW10028RM	<5	3 7 J	<5	Field Blank

E - estimated value, concentration outside of calibration range

J - estimated value, concentration is below the detection limit

B - analyte also detected in the blank analysis

Groundwater concentrations observed are higher than those samples collected during the 1995 investigation. Since the 1995 samples were collected using a Hydropunch™, it is possible that representative samples were not collected at that time, either because the NAPL interface was not reached, or that subsurface conditions precluded the acquisition of a representative sample

The samples were also analyzed for total petroleum hydrocarbons. These analyses were not planned as part of the Sampling and Analysis Plan, however, the samples of NAPL collected were a dark brown color which is not associated with carbon tetrachloride. Due to the presence of fuel oil tanks near IHSS 118 1, it was postulated that the color was due to the presence of hydrocarbons, and analyses for total petroleum hydrocarbons was requested. The original laboratory sent the samples to another lab, resulting in exceedance of the holding times. Sample results should be considered qualitative due to exceedance of the holding times, and the high concentrations present in the samples, requiring a high dilution for the analyses. However, the results confirmed the presence of hydrocarbons in the samples.

As shown in Table 8, the samples contained Number 2 (No 2) diesel fuel. The most likely source of this contamination is spills and/or leaks from the numerous underground and above ground fuel oil tanks in the area, including those north of Building 776 or south of Building 771.

Table 8 Groundwater Total Petroleum Hydrocarbon Results (in mg/kg)

Location	Sample No	No 2 Diesel Fuel	Jet Fuel - Kerosene	Motor Oil	Physical Description of Collected Sample
05197	GW10016RM	<6.2	<6.2	<9.4	Very silty water, possible NAPL droplets present
05397	GW10019RM	<6.2	<6.2	<9.4	Water layer above NAPL, very thin LNAPL slick present
05397	GW10022RM	1,700	<250	<250	NAPL sample - sample vial had up to 40% water as a separate phase
05497	GW10023RM	3,200	<250	<250	Water layer above NAPL - sample vial had <10% separate phase NAPL and a thin LNAPL slick
05497	GW10018RM	3,100	<250	<250	NAPL (real sample)
05497	GW10026RM	3,200	<250	<250	NAPL (duplicate sample)
05697	GW10017RM	<6.2	<6.2	<9.4	No NAPL observed
05897	GW10020RM	<6.2	<6.2	<9.4	Water sample above NAPL
05897	GW10025RM	2,600	<250	<250	NAPL sample
05997	GW10024RM	2,700	<250	<250	Water layer above NAPL - vial had up to 25% separate phase NAPL
05997	GW10021RM	2,600	<250	<250	NAPL sample

As the color of No 2 Diesel Fuel is a light brown, its presence does not explain the dark brown color of the NAPL. The color may be a result of one or more of the following reasons:

- Organic material in the fill may have been dissolved by the carbon tetrachloride,
- The process waste tank may have been coated with a bituminous anti-corrosion coating which was dissolved by the carbon tetrachloride,
- Surface carbon tetrachloride spills may have dissolved the asphalt in the road way,
- Degradation/weathering of No 2 Diesel can result in a darker brown color, and/or
- Presence of other, unknown compounds (such as Shell Vitrea)

2.6 Quality Assurance

The field sampling program as outlined in the Sampling and Analysis Plan (RMRS 1997) was 90% complete with 9 out of the 10 planned boreholes completed. This met the field completion goal of 90%. The appropriate number of field duplicate samples was collected (i.e., one duplicate for every 20 samples collected). In addition, rinse samples and a field blank were

collected during the groundwater/NAPL sampling. The results of the quality control samples are discussed in the following sections:

Soil Samples

Due to the small diameter of core collected, duplicate soil samples were not true duplicates, but were obtained by halving the core (i.e., collecting one sample from a core interval and another sample from immediately below the first sample). Table 9 provides the analytical data for detected compounds in the real and duplicate soil samples.

In uncontaminated intervals, there was good correlation between the duplicate and real samples. However, in the highly contaminated intervals, poor correlation between the real and duplicate samples was observed and is likely attributable to the halving method used to collect the duplicate. Specifically, when the samples were removed from the core liner and placed into the sample bottle, the fluid NAPL generally poured into the first bottle, leaving only residual amounts of NAPL for inclusion in the second sample bottle. The most notable discrepancy is between the real sample BH10195RM and the corresponding duplicate BH10197RM. An evaluation of the correlation of the other samples indicates that the reproducibility is acceptable (i.e., within two times the detection limit).

Table 9 Real and Duplicate Soil Sample Results (in ug/kg)

	Real	Dup										
	BH10 112RM	BH10 113RM	BH10 156RM	BH10 155RM	BH10 171RM	BH10 173RM	BH10 186RM	BH10 188RM	BH10 195RM	BH10 197RM	BH10 213RM	BH10 215RM
Carbon Tetra-chloride	<630	<630	<630	<630	370 J	280 J	<630	<630	450,000 E	1,200	390,000 E	140,000 E
Chloroform	<630	<630	<630	<630	<630	<630	<630	<630	71,000 E	250 J	35,000 E	12,000
Methylene Chloride	610 J	540 J	<630	<630	<630	620 J	250 J	<630	790	2,000 B	1,500 B	1,400 B
Tetrachloro ethene	<630	<630	<630	<630	<630	<630	<630	<630	1,800	<630	550 J	<630
Hexachloro butadiene	<630	<630	<630	<630	<630	<630	<630	<630	1,500	<630	510 J	<630
Acetone	<13,000	<13,000	<13,000	<13,000	<13,000	<13,000	<13,000	<13,000	<13,000	500 J	<13,000	<13,000
Carbon Disulfide	<630	<630	<630	<630	<630	<630	<630	<630	910	<630	<630	<630
Hexachloro ethane-TIC	ND	31,000 J	ND	9,700 J	ND							

E - estimated value, concentration outside of calibration range
 J - estimated value, concentration is below the detection limit
 B - analyte also detected in the blank analysis
 TIC - Tentatively Identified Compound
 ND - Not Detected

Groundwater/NAPL Samples

Table 10 lists the compounds detected in the duplicate groundwater/NAPL samples. Real and duplicate analytical results for these samples were within the same order of magnitude, and precision, where calculable, is within 40% relative percent difference. Analytical results for the rinsate and field blank samples indicated that neither chloroform nor methylene chloride were detected. Carbon tetrachloride was estimated in both samples at concentrations below the detection limit: 3.5 ug/l in the rinsate, and 3.7 ug/l in the field blank. Because concentrations for carbon tetrachloride in the samples were greater than 5 times the associated blank concentrations, these values indicate that the sampling equipment was adequately decontaminated. The associated laboratory analyses are considered acceptable.

Table 10 Groundwater/NAPL Quality Assurance Sample Results (in ug/l)

Sample No	Methylene Chloride	Carbon Tetrachloride	Chloroform	No. 2 Diesel Fuel	Sample Type
GW10027RM	<5	3.5 J	<5	NA	Rinsate
GW10018RM	2,500,000	180,000,000 E	2,700,000	3,100	Real
GW10026RM	3,600,000 J	130,000,000	< 5,000,000	3,200	Duplicate
GW10028RM	<5	3.7 J	<5	NA	Field Blank

E - estimated value, concentration outside of calibration range
 NA - Not Analyzed

3.0 CONCEPTUAL MODEL

Borehole logs from boreholes adjacent to the investigation area indicate that the original bedrock surface in the investigation area was approximately 8 feet below ground surface and was originally overlain by Rocky Flats Alluvium. During installation of Tanks T-9 and T-10 in 1955, a pit was excavated to a depth of approximately 22 to 24 feet below ground surface. The underground carbon tetrachloride tank was installed in 1963 at the western edge of the original excavation.

While the areal extent of the depression was not confirmed on the west or north sides, with the exception of the former carbon tetrachloride tank to the west, there are no other known subsurface structures or excavations immediately to the north or west. The building immediately

west of the excavation, Building 701, is built on a concrete slab. Therefore, the excavation is believed to be a closed depression into the bedrock surface. The bedrock sides and bottom of the depression consist of the Arapahoe Formation claystone. Groundwater is present 6 to 9 feet below the ground surface (Table 3).

Due to the high concentrations of carbon tetrachloride, and the lack of radiological contamination, the NAPL is assumed to be a result of spills and leaks from the carbon tetrachloride storage tank. Because both the NAPL samples and high concentrations in soil are found only near the bottom of the excavation, the carbon tetrachloride is thought to currently occur in a thin layer, approximately one foot thick, pooled on the bedrock surface at the bottom of the closed depression. The carbon tetrachloride may fill the bottom of the excavation, including underneath Tanks T-9 and T-10 and the associated sump (Figure 3). However, there is a possibility that the NAPL is pooled at several intervals near the bottom of the excavation, rather than a continuous shallow layer. Installation of the wells could have intercepted several small pools which then drained into the well, giving the appearance of a single pool of NAPL. Insufficient data exists to fully differentiate between these scenarios. However, as the NAPL is thought to occur within a one foot interval near the bottom of the excavation, and it is likely that the NAPL is trapped on top of the undisturbed bedrock claystone.

The low-permeability claystone at the bottom of the excavation acts as a barrier to prevent substantial downward migration of the carbon tetrachloride, while the groundwater above prevents evaporation. Dissolution of carbon tetrachloride into the overlying groundwater may be limited due to stagnant groundwater conditions, i.e., the bottom of the depression is isolated from the active groundwater flow path.

The vertical migration of NAPL into bedrock was evaluated by an earlier study, which concluded that there is no apparent threat to surface water or to deeper aquifers (RMRS 1996b). All occurrences of the NAPL layer are at too great of depths to migrate along utility corridors, or along the original bedrock surface. Therefore, the only risk to surface water is through migration of the dissolved phase in groundwater.

To roughly estimate the volume of NAPL that may be present, the depths to the NAPL and high soil concentrations were used to estimate a thickness for the NAPL. Using this information, a conservative estimate of the volume of NAPL potentially present was calculated. The following assumptions were used for the NAPL volume calculation:

- Based on the available engineering design drawings for Tanks T-9 and T-10, the bottom of the tanks are 20.7 feet below the ground surface with a 12 foot square by 1 foot deep sump below the tanks.
- Based on these investigation results, the excavation depth was assumed to be 22.1 feet below ground surface.
- A NAPL thickness of 1.1 feet was estimated by subtracting depth to NAPL from the interface probe measurement from the assumed depth of the excavation (22.1 feet).
- The area of NAPL contamination was estimated based on the wells containing NAPL (05397, 05497, 05897, 05997) (see Figure 1) and assuming that the NAPL occurs in the fill material throughout the excavation. This results in an estimate of a 46 foot by 46 foot area.
- The fill material containing the NAPL consists of unconsolidated clay, gravel, and sand, with a porosity conservatively estimated to be between 25 and 35 percent (Freeze and Cherry, 1979).

Based on the estimated extent of NAPL and the pore volume, three methods were used to estimate the volume of free phase NAPL.

Method 1- As a conservative assumption, it was assumed that 50 % of the void space is filled with NAPL and 50% is filled with water.

Method 2 - The maximum VOC concentrations of soil samples taken from wells with free phase NAPL were averaged, and the average concentration was applied to the calculated volume of the NAPL layer.

Method 3 - A range of residual saturations of 0.01 to 0.4 was derived from experimental studies in sand (Pankow and Cherry 1996) and were applied to the estimated pore volume.

The results of these three methods are presented in Table 11. The results are reported at three different recovery rates, 5%, 15%, and 50%. The 5% and 50% recovery rates are considered

minimum and maximum rates, respectively. The 15% recovery rate is based on a petroleum industry rate under favorable conditions (Pankow and Cherry 1996). Because the NAPL resides in the bottom of an excavation rather than as pools of NAPL on a natural bedrock surface, the recovery rates are expected to be higher at IHSS 118 1 than at a typical NAPL site.

The volume calculation based on the soil concentrations (Method 2) probably does not represent the actual volume of NAPL present at this site. The soil concentrations are probably residual concentrations, as opposed to concentrations expected from a sample where the pore spaces are filled with liquid. The NAPL generally flowed out of the core during sampling events, leaving only residual amounts in the soil.

Table 11 Volume Estimates of Total and Recoverable NAPL (in gallons)

Methodology	Residual Saturation	Porosity (%)	Estimated Total Volume of NAPL Present	Estimated Total Volume Recovered		
				Recovery Rate		
				5%	15%	50%
Method 1 - Estimate volume by assuming that 50% of porosity is filled by NAPL		25	2,042	102.1	245.0	816.8
		30	2,450	122.5	294.1	980.2
		35	2,859	142.9	343.1	1,143.5
Method 2 - Estimate volume based on soil concentrations			7.8	0.4	1.2	3.9
Method 3 - Estimate volume based on residual saturation	0.01	25	41	2.0	6.1	20.4
	0.01	30	49	2.5	7.4	24.5
	0.01	35	57	2.9	8.6	28.6
	0.4	25	1,634	81.7	245.0	816.8
	0.4	30	1,960	98.0	294.1	980.2
	0.4	35	2,287	114.4	343.1	1,143.5

Appendix A contains the calculations and assumptions used to generate these estimates.

4.0 RECOMMENDATIONS FOR FUTURE ACTIONS

An interim remedial action is being considered as the NAPL is in contact with groundwater and is probably the principle contributor to the suspected dissolved-phase contaminated groundwater plume extending to the east. This will be evaluated as part of a groundwater investigation scheduled for 1998. This investigation will also determine if there is a plume of LNAPL contamination in groundwater, this is suspected due to the No. 2 fuel oil discovered during this

investigation Further interpretation of the data, and evaluation of alternatives will be developed as part of the Interim Measure/Interim Remedial Action process

5 0 REFERENCES

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6 0 ACRONYMS

ALF	Action Level Framework
CDPHE	Colorado Department of Public Health and Environment
CERCLA	Comprehensive Environmental Resource, Compensation, and Liability Act
DOE	Department of Energy
DNAPL	Dense Non-aqueous Phase Liquid
ER	Environmental Restoration
HPGe	High Purity Germanium
HRR	Historical Release Report
IHSS	Individual Hazardous Substance Site
mg/kg	milligram per kilogram
LNAPL	Light Non-aqueous Phase Liquid

NAPL	Non-aqueous Phase Liquid
OU	Operable Unit
pCi/g	picocuries per gram
pCi/l	picocuries per liter
PPM	parts per million
RCRA	Resource Conservation and Recovery Act
RFCA	Rocky Flats Cleanup Agreement
RFETS	Rocky Flats Environmental Technology Site
RFI	RCRA Facility Investigation
RI	Remedial Investigation
ug/kg	microgram per kilogram
ug/l	microgram per liter
VOCs	Volatile Organic Compounds

APPENDIX A
NAPL VOLUME CALCULATIONS

Calculations by C. D. Cowdery

Checked By M. Peters

Signature C. D. Cowdery Date 12/16/97

Signature M. Peters Date 12/18/97

IHSS 118.1 Non-Aqueous Phase Liquid (NAPL) Volume Estimate

Objective: To estimate the range of potential volumes of subsurface free-phase NAPL at IHSS 118 1 and to estimate a range of how much can be recovered

Methodology: Two steps were taken to calculate the volumes of free phase NAPL and the volume of recoverable NAPL. First, the volume of the NAPL layer and the volume of the pore space within that layer were estimated. Then three different methods were then used to calculate the volume of free phase NAPL present and the volume of NAPL that could be recovered. The three methods were used to estimate the amount of NAPL in the saturated layer below the water table.

1) **Method 1** - As a conservative estimate, it was assumed that 50% of the pore space was NAPL with remaining 50% being filled by water.

2) **Method 2** - The highest Pre-Remedial Investigation soil concentrations from each boring containing free-phase NAPL were averaged and applied to the pore space volume in the NAPL layer.

3) **Method 3** - Empirically derived NAPL residual saturations were used.

The areal extent and the thickness of the NAPL layer were determined from data from the IHSS 118 1 Pre-Remedial Investigation. The range of porosities was based on the different types of fill materials detected in the cores and typical ranges (*Groundwater*, Freeze, R. A., and Cherry, J. A., Prentice-Hall, 1979). The range of recovery rates was based on best professional judgment, rules of thumbs, and typical rates from the petroleum industry (Pankow and Cherry, 1996, p. 502).

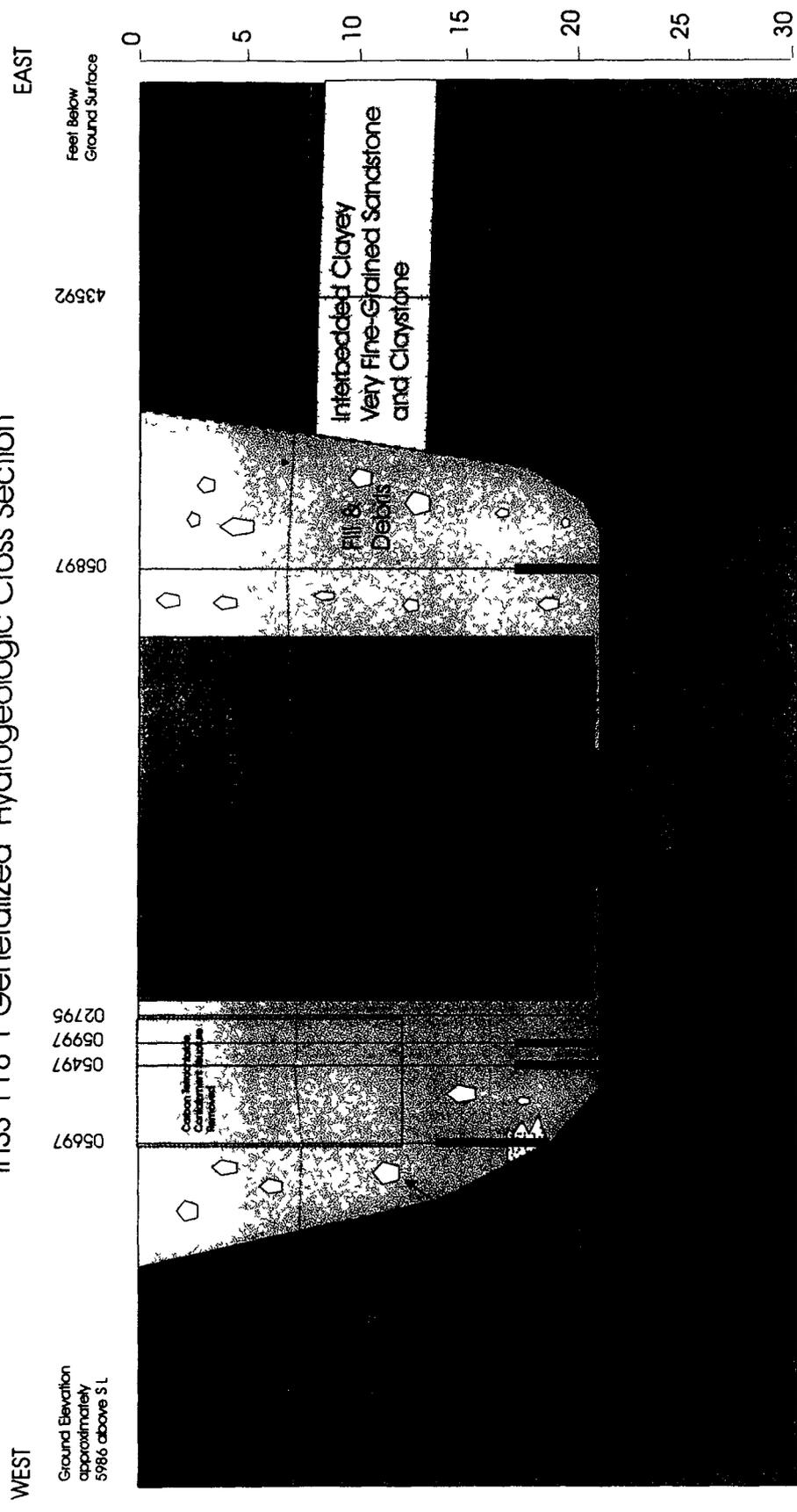
Based on the surficial chemistry of the soil and the NAPL, the soil has a greater affinity for water so that though the NAPL is present in the larger pore volumes in the saturated layer, the smaller pores could have entrapped water.

Calculation of Bulk and Pore Space Volumes of NAPL Layer

Assumptions:

1) The areal extent of the NAPL was based on the distance between Well 05497 and Well 05897. These wells are on opposite sides of the process waste tank and both contained free phase NAPL (see attached cross-section). It was assumed that

IHSS 118 1 Generalized Hydrogeologic Cross Section



DIMENSIONS USED IN ESTIMATING VOLUME OF NAPL LAYER

Calculations by C. D. CowderyChecked By M. PetersSignature C. D. CowderyDate 12/18/97Signature M. PetersDate 12/18/97

the NAPL would extend this distance from the tanks but no further. These wells are approximately 46 feet apart so the areal extent was estimated to be a 46' x 46' square.

2) The thickness of the NAPL was assumed to be approximately 1.1 feet based on bedrock depth of 22.1 and NAPL level of 21 feet based on measurements made with an oil/water interface meter.

3) The sump below the process waste tanks displaces a volume with dimensions of 12' x 12' to a depth of about one foot or a volume of 144 cubic feet

4) The range of porosities was based on 25% as a low value for sand (*Groundwater, Freeze, R A, and Cherry, J A, Prentice-Hall, 1979*) to a high value of 35% that was a conservative estimate for the fill material at the site

Calculations:

The bulk volume of the NAPL layer was calculated using the following equation

$$V_L = W_N L_N d_N - V_{\text{Sump}}$$

where,

- V_L - Volume of the NAPL layer
- W_N - Width of NAPL Layer (46')
- L_N - Length of NAPL Layer (46')
- d_N - Thickness of NAPL Layer (1.1')
- V_{Sump} - Volume displaced by the Sump

$$V_{\text{Sump}} = W_{\text{Sump}} L_{\text{Sump}} d_{\text{Sump}}$$

where,

- W_{Sump} - The width of the sump (12')
- L_{Sump} - The length of the sump (12')
- d_{Sump} - The thickness of the sump (1')

so

$$\begin{aligned} V_{\text{Sump}} &= (12')(12')(1') \\ &= 144 \text{ ft}^3 \end{aligned}$$

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$$\begin{aligned}
 \text{so } V_L &= (46')(46')(1 \text{ } 1') - 144 \text{ ft}^3 \\
 &= 2,328 \text{ ft}^3 - 144 \text{ ft}^3 \\
 &= 2,184 \text{ ft}^3
 \end{aligned}$$

The pore space volume is calculated as follows

$$V_p = V_L n/100\%$$

where,

$$\begin{aligned}
 V_p &- \text{Pore Space Volume} \\
 n &- \text{Soil Porosity Percent (25\% - 35\%)}
 \end{aligned}$$

The pore space volume was estimated at three different porosities 25%, 30%, and 35%

For 25% this yielded,

$$\begin{aligned}
 V_p &= (2,184 \text{ ft}^3)(25\%/100\%) \\
 &= 546 \text{ ft}^3
 \end{aligned}$$

For 30% this yielded,

$$\begin{aligned}
 V_p &= (2,184 \text{ ft}^3) (30\%/100\%) \\
 &= 655 \text{ } 2 \text{ ft}^3
 \end{aligned}$$

For 35% this yielded,

$$\begin{aligned}
 V_p &= (2,184 \text{ ft}^3) (35\%/100\%) \\
 &= 764 \text{ } 4 \text{ ft}^3
 \end{aligned}$$

Method 1 - Estimate NAPL Volume by Assuming that 50% of Porosity is NAPL

The equation used to calculate the NAPL volume is as follows

$$V_{\text{NAPL}} = V_p X_{\text{NAPL}}$$

where,

Calculations by C. D. CowderyChecked By. M. PetersSignature C. D. Cowdery Date 12/18/97Signature M. Peters Date 12/18/97 V_{NAPL} - Volume of the free phase NAPL X_{NAPL} - Fraction of pore space volume containing free phase NAPL (50%)

The volume of recoverable NAPL is calculated as follows

$$V_R = V_{\text{NAPL}} X_R$$

where,

 V_R - Volume of Recoverable NAPL X_R - Fraction of NAPL that is recoverable

The recovery rates were evaluated over a range of values from 5 to 50% in 5% increments. The range of the recovery rate was based on 5% which is a rate from the petroleum industry to 50% which was based on professional judgement. The results of this calculation are presented on the attached spreadsheet.

Method 2 - Estimate Volume of NAPL Based on Concentrations

Assumptions

In calculating the volume based on concentration data, it was assumed that all organic compounds besides methylene chloride, carbon tetrachloride and chloroform were in negligible concentrations. Wells 05197, 05297, 05597, 05697, and 05797 were not used because NAPL was not present and because these boreholes are farther out from the T-9/T-10 tanks. It should be noted that many soil concentrations were estimated because they exceeded the calibration range of the gas chromatograph/mass spectrometer.

Because the NAPL is residing in fill material that represents a variety of origins and because measured bulk densities at RFETS have not shown much variability, the soil density was based on the midpoint for the range of values for silty sand and gravel. The minimum and maximum are 89 and 146 lb/ft³ (Lamb, T. W. and Whitman, R. V., *Soil Mechanics*, 1969) respectively, therefore the median dry density is about 117 lb/ft³. For calculating the wet density, a porosity of 30% was used because it is the midpoint between the range of porosities considered (25% - 35%). The density of the liquid was assumed to be 1.1 g/cm³ because the density was increased 10% over the density of water to account for the organic fraction.

IHSS 118 1 DNAPL Volume Estimate - Method 1

IHSS 118.1 Estimate of Potential Non-Aqueous Phase Fluid (NAPL) Recovery Method 1 - Assume a 50% Residual DNAPL Saturation (Gallons)			
	Porosity (%)		
Recovery Rate (%)	25	30	35
5	102	123	143
10	204	245	286
15	306	368	429
20	408	490	572
25	511	613	715
30	613	735	858
35	715	858	1001
40	817	980	1144
45	919	1103	1286
50	1021	1225	1429
Estimated Total	2042	2450	2859
NAPL Volume (gallons)			

Calculations by C. D. CowderyChecked By M. PetersSignature C. D. CowderyDate 12/18/97Signature M. PetersDate 12/18/97**Calculations**

The well concentrations were averaged for three compounds, methylene chloride, carbon tetrachloride and chloroform. The averages were not immediately combined into a single average because each of the compounds had a different density. The following equation was used to determine the volume of the NAPL

$$V_{NAPL} = V_L \rho_w \sum \frac{C_i}{\rho_i}$$

where,

- V_{NAPL} - Volume of the free phase NAPL
- V_L - Bulk volume of the NAPL layer
- ρ_w - Bulk wet density of the NAPL layer
- ρ_i - Density of individual organic compounds
- C_i - Concentration of individual organic compounds

The bulk wet density was calculated as follows

$$\rho_w = \rho_d + \rho_{liq} \frac{n}{100\%}$$

where,

- ρ_d - Bulk dry density of NAPL layer
- ρ_{liq} - Density of pore space liquid
- n - Percent porosity of NAPL layer

The volume of recoverable NAPL was calculated using the same equation as Method 1. The results of these calculations are presented in the attached spreadsheet

Method 3 - Estimate Volume of NAPL Based on Residual Saturation**Assumptions**

The third method is based on empirically derived residual saturations (Pankow, J. F. and Cherry, J. A., *Dense Chlorinated Solvents and Other DNAPLs in Groundwater*, 1996, Waterloo Press, Portland Oregon, p. 98). These values are from three

IHSS 118 1 DNAPL Volume Estimate - Method 2

Calculation of the average concentration in the NAPL layer at IHSS 118 1					
Method 2 - Calculate DNAPL Volume Based on Analytical Concentrations					
Well Number	Soil Concentrations (ug/kg)			Total NAPL Concentration	
	Methylene Chloride	Carbon Tetrachloride	Chloroform		
5397	-	370,000 00	2,900 00	372,900 00	
5497	-	51,000 00	1,800 00	52,800 00	
5897	790 00	450,000 00	71,000 00	521,790 00	
5997	1,500 00	390,000 00	35,000 00	426,500 00	
Total (ug/kg)	2,290 00	1,261,000 00	110,700 00	1,373,990 00	
Average	572 5	315250	27675	343,497 50	
Density (g/cm3)	1 33	1 59	1 49		
Density (kg/gal)	5 03405	6 01815	5 63965		
Total Volume (ft3)	2184				
Total Volume (m3)	61 85088				
Bulk Soil Density Dry	117	lb/ft3			
Bulk Soil Density Wet	138	lb/ft3			
(assume a 30 % porosity with a liquid that is 1 1 g/cm3)					
Total weight	300,500 9	lb			
	136,591 3	kg			
Weight of Contaminants (kg)	0 08	43 06	3 78		
Volume of Contaminants (gallons)	0 016	7 16	0 67	7 8	
Recovered Gallons (Gallons)					
Recovery Rate (%)					
5	0 4				
10	0 8				
15	1 2				
20	1 6				
25	2 0				
30	2 4				
35	2 7				
40	3 1				
45	3 5				
50	3 9				
Estimated Total NAPL Volume (gallons)	7 8				

Calculations by C. D. CowderyChecked By M PetersSignature Craig CowderyDate 12/18/97Signature M PetersDate 12/18/97

different studies were all from sands and ranged from 0.01 to 0.4. The residual DNAPL saturation is the fraction of the total pore volume that is taken up by DNAPL.

Calculations

The volume was calculated using the following equation

$$V_{\text{NAPL}} = V_p S_{\text{NAPL}}$$

where,

V_{NAPL} - Volume of free phase NAPL

V_p - Volume of pore space in the NAPL layer

S_{NAPL} - Residual saturation of the NAPL

The volume of recoverable NAPL was calculated using the same equation as Method 1. The results of these calculations are presented in the attached spreadsheet.

Results:

Methodology	Residual Saturation	Porosity (%)	Estimated Total Volume of NAPL Present (gallons)	Estimated Volume of NAPL Recovered (gallons)		
				Recovery Rate		
				5%	15%	50%
Method 1 - Estimate by Assuming that 50% of Porosity is NAPL		25	2042	102.1	245.0	816.8
		30	2450	122.5	294.1	980.2
		35	2859	142.9	343.1	1143.5
Method 2 - Estimate Volume Based on Concentration			7.8	0.4	1.2	3.9
Method 3 - Estimate Volume Based on Residual Saturation	0.01	25	41	2.0	6.1	20.4
		30	49	2.5	7.4	24.5
		35	57	2.9	8.6	28.6
	0.4	25	1634	81.7	245.0	816.8
		30	1960	98.0	294.1	980.2
		35	2287	114.4	343.1	1143.5

IHSS 118.1 Estimate of Potential Non-Aqueous Phase Fluid (NAPL) Recovery (Gallons)							
Method 3 - Use Empirically Derived Residual DNAPL Concentrations							
Residual Saturation = 0.01				Residual Saturation = 0.4			
	Porosity (%)				Porosity (%)		
Recovery	25	30	35	Recovery	25	30	35
5	2 04	2 45	2 86	5	82	98	114
10	4 08	4 90	5 72	10	163	196	229
15	6 13	7 35	8 58	15	245	294	343
20	8 17	9 80	11 44	20	327	392	457
25	10 21	12 25	14 29	25	408	490	572
30	12 25	14 70	17 15	30	490	588	686
35	14 29	17 15	20 01	35	572	686	800
40	16 34	19 60	22 87	40	653	784	915
45	18 38	22 05	25 73	45	735	882	1029
50	20 42	24 50	28 59	50	817	980	1144
Estimated	41	49	57	Estimated	1634	1960	2287
NAPL Volume (gallons)				NAPL Volume (gallons)			

Figure 3

IHSS 118 1 Generalized Hydrogeologic Cross Section

WEST

EAST

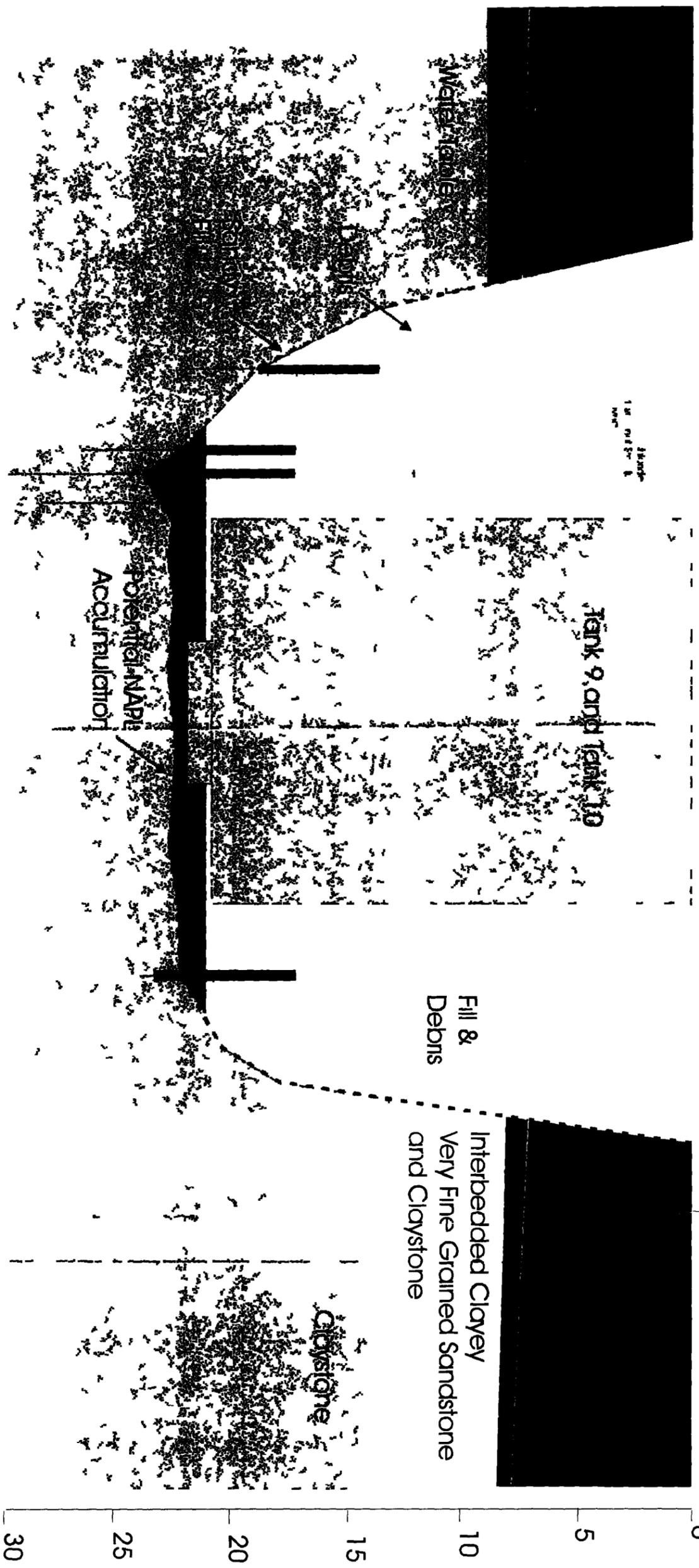
Ground Elevation
approximately
5986 above S.L.

05697
05497
05997
02795

05897

43592

Feet Below
Ground Surface



Scale
1 inch = 10 feet horizontal
1 inch = 5 feet vertical

10 feet