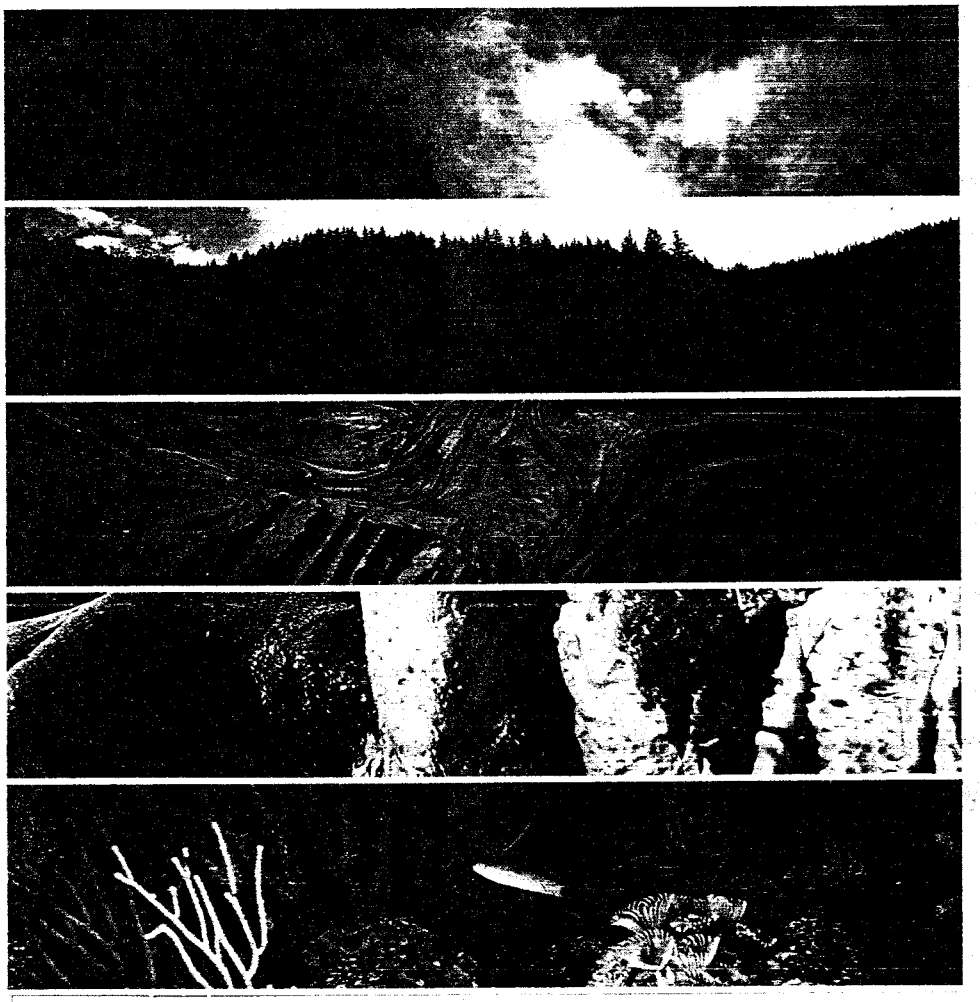
NOTICE

All drawings located at the end of the document.



SUMMARY AND INTERPRETATION OF CONTAMINANT HYDROGEOLOGICAL CONDITIONS AT IHSS 119.1, OU1, 881 HILLSIDE, ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE COLORADO

DAMES & MOORE

JAN 2003
RECEIVED
RECORDS CENTER

ADMIN RECORD

Best Available Copy

8/2/95

TABLE OF CONTENTS

Page

1.0 INTRODUCTION 1

2.0 HYDROGEOLOGIC CONDITIONS 2
- 2.1 GROUNDWATER AND SURFACE WATER 2
- 2.2 GEOCHEMISTRY 12
- 2.3 SUMMARY OF HYDROGEOLOGIC CONDITIONS 17

3.0 DETAILED HYDROGEOLOGIC CONCEPTUAL MODEL 18

4.0 NATURE AND EXTENT OF CONTAMINATION (IHSS 119.1) 21

5.0 FATE AND TRANSPORT 33

6.0 SUMMARY OF CONCLUSIONS 34

7.0 REFERENCES 35

LIST OF FIGURES

2-1 Hydraulic Conductivities for Upper and Lower HSU Materials at OU1 3
2-2 Upper Hydrostratigraphic Unit Water Table Elevation Map, First Quarter (January) 1992 5
2-3 Upper Hydrostratigraphic Unit Water Table Elevation Map, Second Quarter (April) 1992 6
2-4 Water Elevations 8
2-5 Precipitation and Water Level - Well 4387 9
2-6 French Drain Geologic Cross-section 10
2-7 Location of Model Section 11
2-8 Stiff Diagrams for Surface Water and Groundwater from the Upper Hydrostratigraphic Unit 13
2-9 Stiff Diagrams for Surface Water and Groundwater from the Lower Hydrostratigraphic Unit 14
2-10 Piper Plot of Groundwater from the Upper Flow System at OU1 15
2-11 Piper Plot of Groundwater from the Lower Flow System at OU1 16
3-1 Hydrogeologic Conceptual Model 19
3-2 Likely Flow Vs Observed Hydraulic Gradient 20
4-1 Surface Expression of Potential Groundwater Migration Pathways 22
4-2 Organic Compounds Detected in Lower Hydrostratigraphic Unit Groundwater . . . 23
4-3 Well Locations 24
4-4 Observed Concentrations - Well 0974 25
4-5 Observed Concentrations - Well 4387 26

1.0 INTRODUCTION

This report presents an interpretation and summary of the hydrogeologic and contaminant conditions in the vicinity of IHSS 119.1, OU1, Rocky Flats Environmental Technology Site (RFETS), including:

- Hydrogeologic and geochemical conditions which define and control the release, transport and fate of Volatile Organic Compounds (VOCs)
- Location and release of VOCs
- Migration rate and fate of VOCs
- Refined hydrogeologic conceptual model of the area around IHSS 119.1.

This information has been presented to the Colorado Department of Public Health and Environment (CDPHE) and the U.S. Environmental Protection Agency Region, March 16, 1995. The presentation used an overhead-slide/oral-presentation format, and was prepared in response to the concerns of the CDPHE (1994) and EPA (1994) regarding the OU1 Corrective Measures/Feasibility Study (DOE 1995b). The data contained in the this summary is derived primarily from the OU1 Phase III RFI/RI (DOE 1994), with additional data obtained from the OU1 CMS/FS (DOE 1995a) and the Rocky Flats Environmental Database System (DOE 1995c).

2.0 HYDROGEOLOGIC CONDITIONS

The following sections summarize the surface hydrology and subsurface hydrogeology of the 881 Hillside in the vicinity of IHSS 119.1.

2.1 GROUNDWATER AND SURFACE WATER

- Steep hillside covered with grass promotes runoff rather than groundwater recharge.

- Average precipitation = 15 in/yr.

  40% in spring (about 2 months)
  30% in summer (about 2 months)
  30% in autumn and winter (about 8 months)

  This indicates that groundwater recharge is episodic, and that a discontinuous saturated zone in the colluvium is to be expected. The hillside is dry at the surface most of the year.

- Average potential evapotranspiration (ET) = 39 in/yr; ET >>> precipitation. This also indicates very dry hydrogeological conditions are to be expected.

- Three main hydrogeologic units were identified in the Phase III RFI/RI (Figure 2-1):

  — Colluvium, weathered claystone and siltstone with some sandstone (correlates approximately with the so-called upper hydrostratigraphic unit). Saturated hydraulic conductivity is about 10^{-4} cm/sec indicative of silty sand.

  — Claystone and siltstone with some sandstone (correlates approximately with the so-called lower hydrostratigraphic unit and bedrock). Saturated hydraulic conductivity is about 10^{-6} cm/sec indicative of silt.

— Alluvium (along Woman Creek) (part of the upper hydrostratigraphic unit). Hydraulic conductivity is slightly greater than that of the colluvium.

- Groundwater occurrence in colluvium and alluvium:

  — Typically there are about 40% dry wells in winter and 20% in spring; large areas of the hillside are typically dry even in the spring (Figures 2-2 and 2-3, Table 2-1).

  — Well hydrographs often show dry conditions in many wells (Figure 2-4).

  — Groundwater levels fluctuate with precipitation (Figure 2-5). This indicates episodic recharge (short periods of recharge with long dry periods in between).

  — Saturated thickness varies by 30% or more over a typical year, indicating short-term dynamic conditions.

- Apparent vertical downward gradients (colluvium to bedrock) are indicated by observed water levels (DOE 1994). This is addressed further in Section 3.0.

- Flow is downhill from IHSS 119.1 toward Woman Creek (Figures 2-2 and 2-3).

- Flow is channelized due to variations in colluvium thickness (DOE 1994, 1995a) (Figures 2-6 and 2-7). A model based on this interpretation has been used to calibrate a groundwater flow and transport model (DOE 1995a). More flow occurs through these so-called "bedrock channels" because of greater saturated cross-sectional area (Figure 2-6).

From the above observations and interpretations, it is concluded that saturated flow is discontinuous in time and space.

2.0 HYDROGEOLOGIC CONDITIONS

The following sections summarize the surface hydrology and subsurface hydrogeology of the 881 Hillside in the vicinity of IHSS 119.1.

2.1 GROUNDWATER AND SURFACE WATER

- Steep hillside covered with grass promotes runoff rather than groundwater recharge.

- Average precipitation = 15 in/yr.

  40% in spring (about 2 months)
  30% in summer (about 2 months)
  30% in autumn and winter (about 8 months)

  This indicates that groundwater recharge is episodic, and that a discontinuous saturated zone in the colluvium is to be expected. The hillside is dry at the surface most of the year.

- Average potential evapotranspiration (ET) = 39 in/yr; ET >>> precipitation. This also indicates very dry hydrogeological conditions are to be expected.

- Three main hydrogeologic units were identified in the Phase III RFI/RI (Figure 2-1):

  — Colluvium, weathered claystone and siltstone with some sandstone (correlates approximately with the so-called upper hydrostratigraphic unit). Saturated hydraulic conductivity is about 10^{-4} cm/sec indicative of silty sand.

  — Claystone and siltstone with some sandstone (correlates approximately with the so-called lower hydrostratigraphic unit and bedrock). Saturated hydraulic conductivity is about 10^{-6} cm/sec indicative of silt.

LIST OF FIGURES

Page

4-6 Observed Concentrations - Well 0487 27
4-7 Well 4387 29
4-8 Observed Concentration and Water Level - Well 0487 30
4-9 Total VOC & PAH Detections in the Vicinity of IHSS 119.1 31
4-10 PCE Molecular Counts in Soil Gas 32

LIST OF TABLES

2-1 Monthly Water Level Measurements for Monitoring Wells in the Western Portion of OU1 7

APPENDIX A - CALCULATION OF RESIDUAL DNAPL MASS

Table 2-1 Monthly Water Level Measurements for Monitoring Wells in the Western Portion of OU1 (DOE, 1994)

Location	JAN '92	FEB '92	MAR '92	APR '92	MAY '92	JUNE '92	JULY '92
6986	5918.67	Well destroyed during french drain construction			-	-	-
0187	5986.09	5984.16	-	5986.16	5984.48	-	5982.80
5187	Dry	-	-	Dry	-	-	Dry
5287	5959.98*	-	-	5960.04*	-	-	5959.52
5387	5956.82	-	-	5956.45*	-	-	5954.46
5487	5954.33	Dry	5954.90	5953.88*	Dry	5955.04	5953.52
31791	Dry	5870.58*	5870.72	5873.60	5870.82*	-	5869.75
35391	Dry	Dry	Dry	Dry	Dry	Dry	Dry
35691	5929.31	5926.50*	5925.05	5925.33	5925.24*	-	5924.91
35991	Dry	Dry	Dry	Dry	Dry	Dry	Dry
36191	5953.34	5957.77	5950.75	5959.45	5960.56	5959.97	5951.30
36991	Dry	Dry	Dry	-	-	-	Dry
37791	5982.98*	-	5983.82	5984.72*	-	-	5985.11
39691	Dry	Dry	Dry	6000.12	Dry	-	Dry

29 DRY MEASUREMENTS OUT OF 68 TOTAL: 42.65% DRY

* Average of 2 measurements collected
\- No data avaliable
Dry Water level below bottom of screen or bedrock contact

Water Elevations
881 Hillside

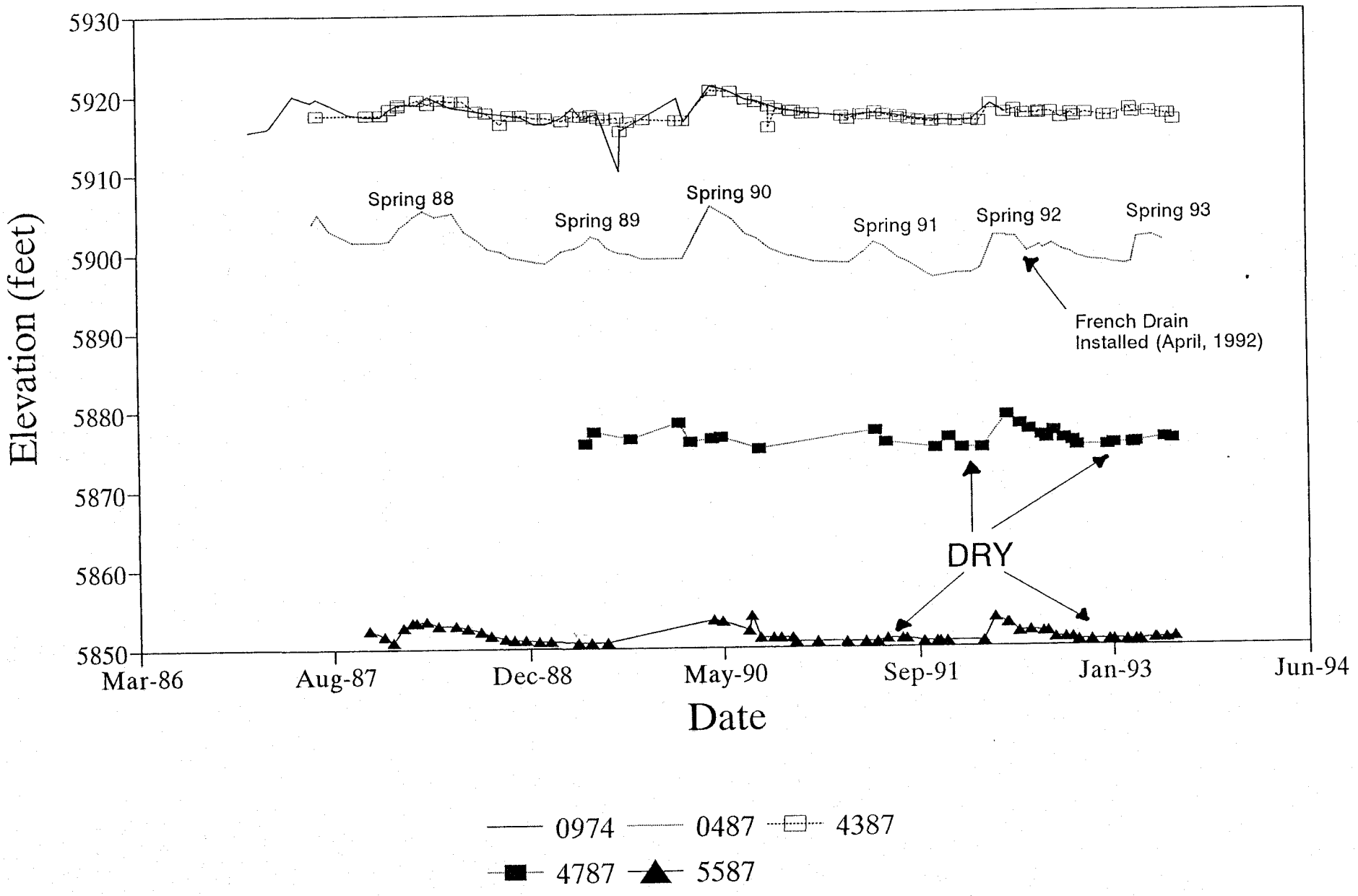


FIGURE 2-4

12

Precipitation and Water Level
881 Hillside - Well 4387

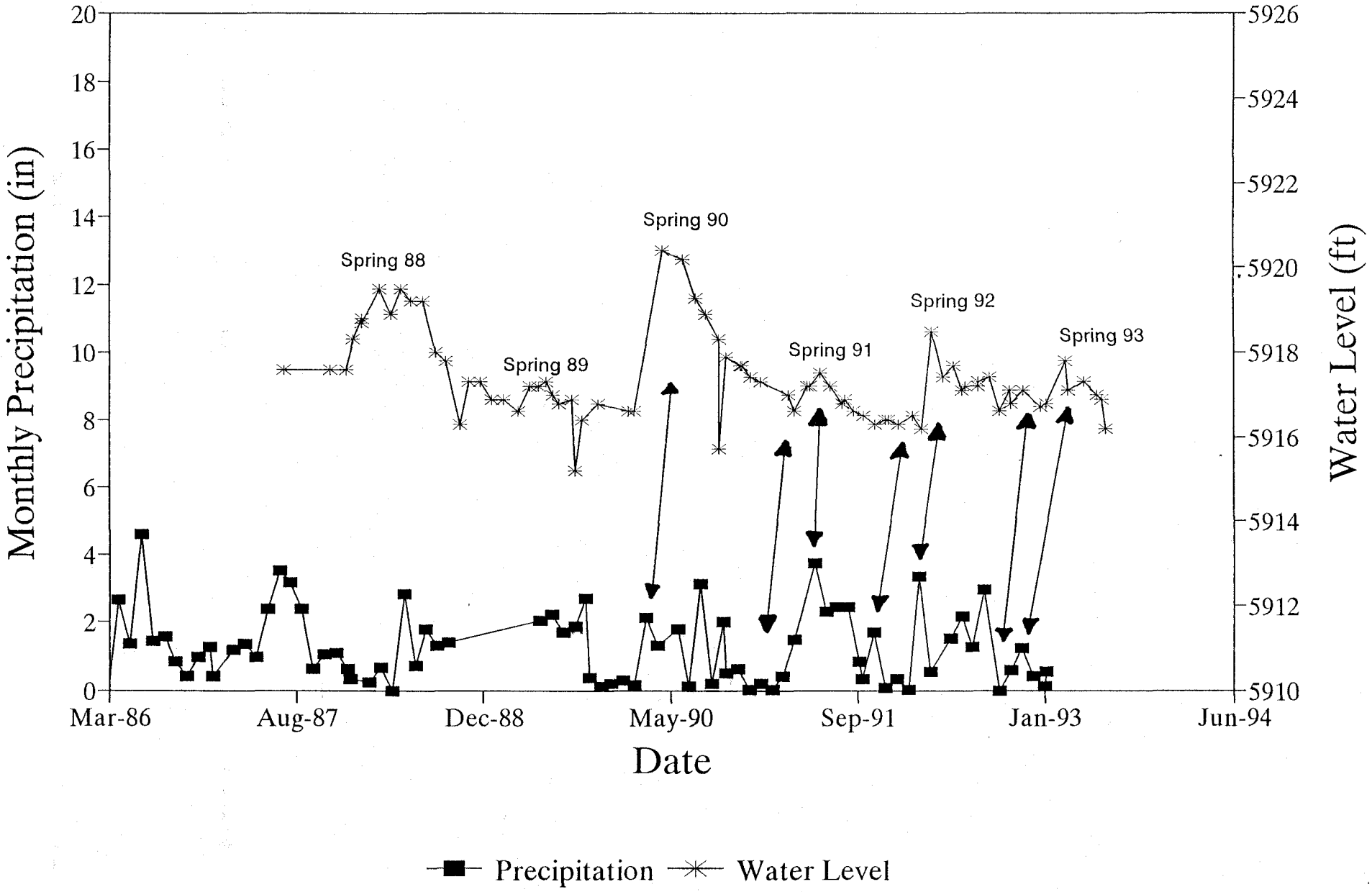


FIGURE 2-5

2.0 HYDROGEOLOGIC CONDITIONS

The following sections summarize the surface hydrology and subsurface hydrogeology of the 881 Hillside in the vicinity of IHSS 119.1.

2.1 GROUNDWATER AND SURFACE WATER

- Steep hillside covered with grass promotes runoff rather than groundwater recharge.

- Average precipitation = 15 in/yr.

  40% in spring (about 2 months)
  30% in summer (about 2 months)
  30% in autumn and winter (about 8 months)

  This indicates that groundwater recharge is episodic, and that a discontinuous saturated zone in the colluvium is to be expected. The hillside is dry at the surface most of the year.

- Average potential evapotranspiration (ET) = 39 in/yr; ET >>> precipitation. This also indicates very dry hydrogeological conditions are to be expected.

- Three main hydrogeologic units were identified in the Phase III RFI/RI (Figure 2-1):

  — Colluvium, weathered claystone and siltstone with some sandstone (correlates approximately with the so-called upper hydrostratigraphic unit). Saturated hydraulic conductivity is about 10^{-4} cm/sec indicative of silty sand.

  — Claystone and siltstone with some sandstone (correlates approximately with the so-called lower hydrostratigraphic unit and bedrock). Saturated hydraulic conductivity is about 10^{-6} cm/sec indicative of silt.

1.0 INTRODUCTION

This report presents an interpretation and summary of the hydrogeologic and contaminant conditions in the vicinity of IHSS 119.1, OU1, Rocky Flats Environmental Technology Site (RFETS), including:

- Hydrogeologic and geochemical conditions which define and control the release, transport and fate of Volatile Organic Compounds (VOCs)
- Location and release of VOCs
- Migration rate and fate of VOCs
- Refined hydrogeologic conceptual model of the area around IHSS 119.1.

This information has been presented to the Colorado Department of Public Health and Environment (CDPHE) and the U.S. Environmental Protection Agency Region, March 16, 1995. The presentation used an overhead-slide/oral-presentation format, and was prepared in response to the concerns of the CDPHE (1994) and EPA (1994) regarding the OU1 Corrective Measures/Feasibility Study (DOE 1995b). The data contained in the this summary is derived primarily from the OU1 Phase III RFI/RI (DOE 1994), with additional data obtained from the OU1 CMS/FS (DOE 1995a) and the Rocky Flats Environmental Database System (DOE 1995c).

2.2 GEOCHEMISTRY

The following is a summary of the geochemistry of the area in the vicinity of IHSS 119.1.

- Winter (low recharge) data was analyzed in the Phase III RFI/RI (DOE 1994).

- Two types of water are indicated: low total dissolved solids (TDS) and high TDS.

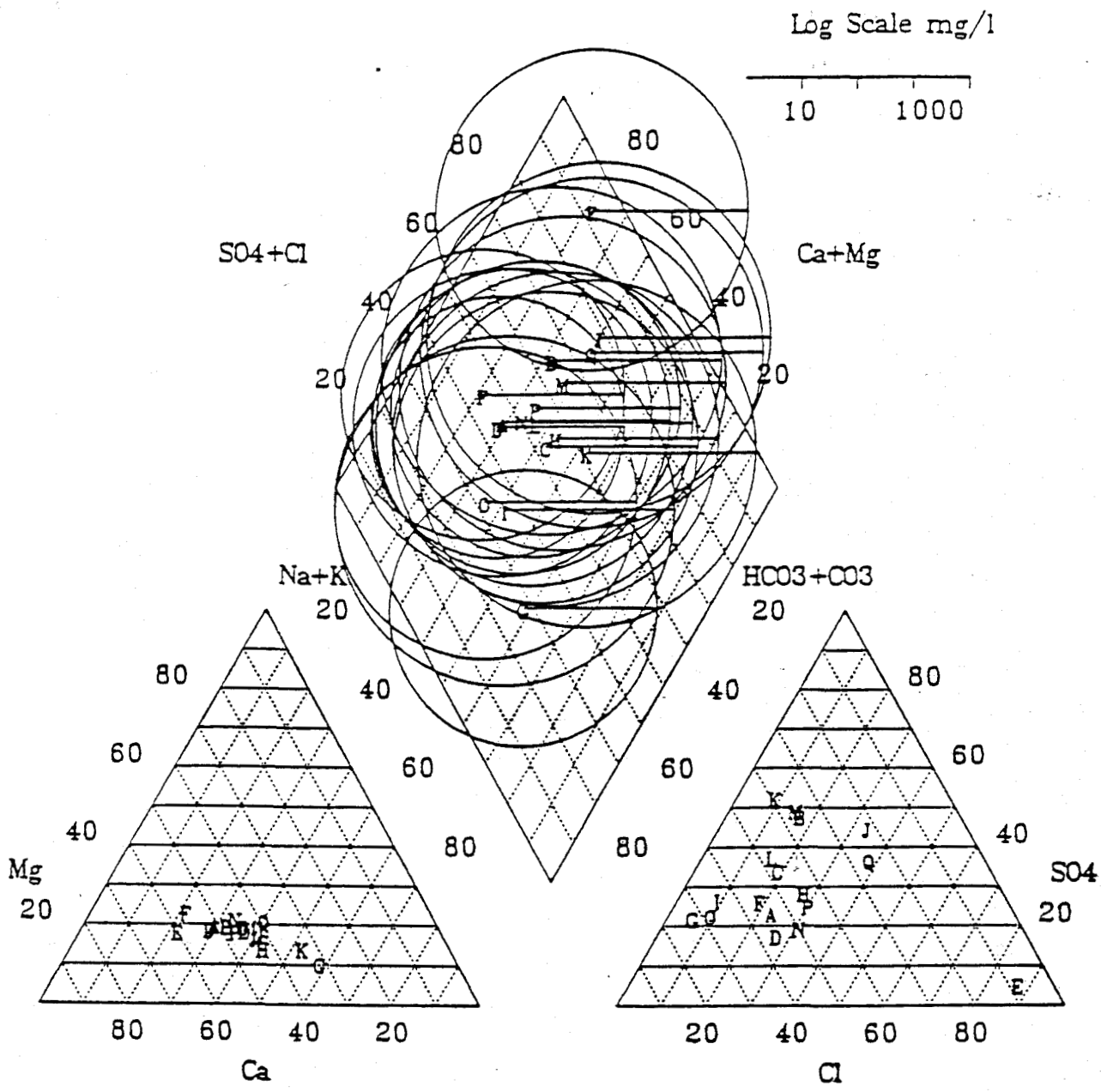
- Within each of the two types, water quality is generally homogeneous indicative of single common water source (Figures 2-8, 2-9, 2-10, and 2-11). High TDS occurs in bedrock and colluvium; low TDS occurs in surface water, in colluvium at the top of the hillside and in alluvium near Woman Creek.

- Groundwater in colluvium is basically equivalent to groundwater in bedrock (Figures 2-8, 2-9, 2-10, and 2-11) except at the top and bottom of the hillside.

- High TDS water indicates slow moving, older water. As water moves through the saturated zone, the longer it is contact with rock and sediments (longer residence time), the higher the TDS will be. There are no major changes in lithology, like rocksalt beds, that could change chemistry. Caliche, a potential source of soluble salts, is formed in the vadose zone in arid environments where recharge is episodic and groundwater is scarce except at great depth. Caliche is present in the subsurface at the site (DOE 1994).

- Water at top and bottom of hillside is basically equivalent to stream water indicative of recharge (younger) water (Figure 2-8). At the top of the hillside, where the more permeable and flat-lying Rocky Flats Alluvium is present, recharge is more likely to occur. The transition between the Rocky Flats Alluvium and colluvium is evidenced by seepage and springs at the top of the hillside (DOE 1994).

- Water quality in Woman Creek is generally better than groundwater (Figure 2-8), indicating that surface water and runoff are main components of hydrologic cycle, and that groundwater is a minor component. Again, this suggests a dry, slow moving groundwater flow system).



Log Scale

Log of total dissolved solids concentration represented by radius of circle

A = 31891	G = 6386	M = 6986
B = 35691	H = 0487	N = 0287
C = 38591	I = 37191	O = 0187
D = 6886	J = 4387	P = 5187
E = 34791	K = 5287	Q = 31791
F = 37591	L = 5487	

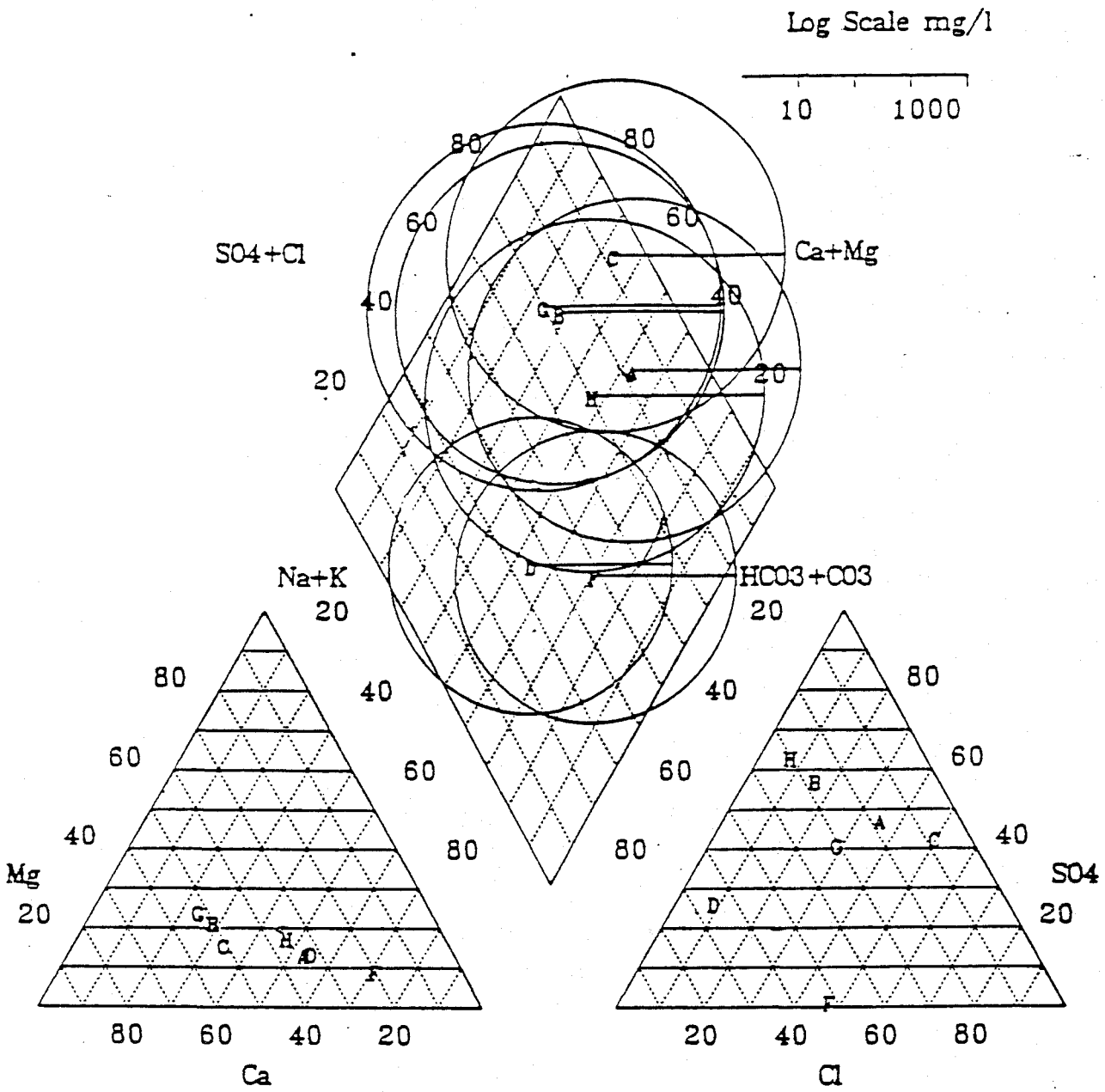
U.S. DEPARTMENT OF ENERGY
Rocky Flats Environmental Technology Site
Golden, Colorado

881 HILLSIDE AREA
OPERABLE UNIT NO. 1
PHASE III RFI/RI REPORT FIGURE 5-6

Piper Plot of Groundwater from the Upper Flow System at OU1

Figure 2-10

K:\MODELING\RFP\OU1\NEWCM\R74276



Log Scale

Log of total dissolved solids concentration represented by radius of circle

A = 37891
B = 37991
C = 39191
D = 4587
F = 0387
G = 0587
H = 0887

U.S. DEPARTMENT OF ENERGY
Rocky Flats Environmental Technology Site
Golden, Colorado

881 HILLSIDE AREA
OPERABLE UNIT NO. 1
PHASE III RFI/RI REPORT FIGURE 5-7

Piper Plot of Groundwater from the Lower Flow System at OU1

Figure 2-11

K:\MODELING\RFP\OU1\NEWCM\R74277

19

- Oxidizing conditions limit VOC degradation (DOE 1994). This will be discussed further in Section 5.0.

2.3 SUMMARY OF HYDROGEOLOGIC CONDITIONS

The following is a summary of the previous sections.

- Low permeability colluvium, alluvium and bedrock.

- Episodic recharge with periods of dry conditions between recharge events. Average infiltration is zero; net discharge to land surface is indicated.

- Flow is channelized due to dry conditions and thicker colluvium.

- Slow moving groundwater flow system. Large zones of dry colluvium exist. Flow is discontinuous in time and space.

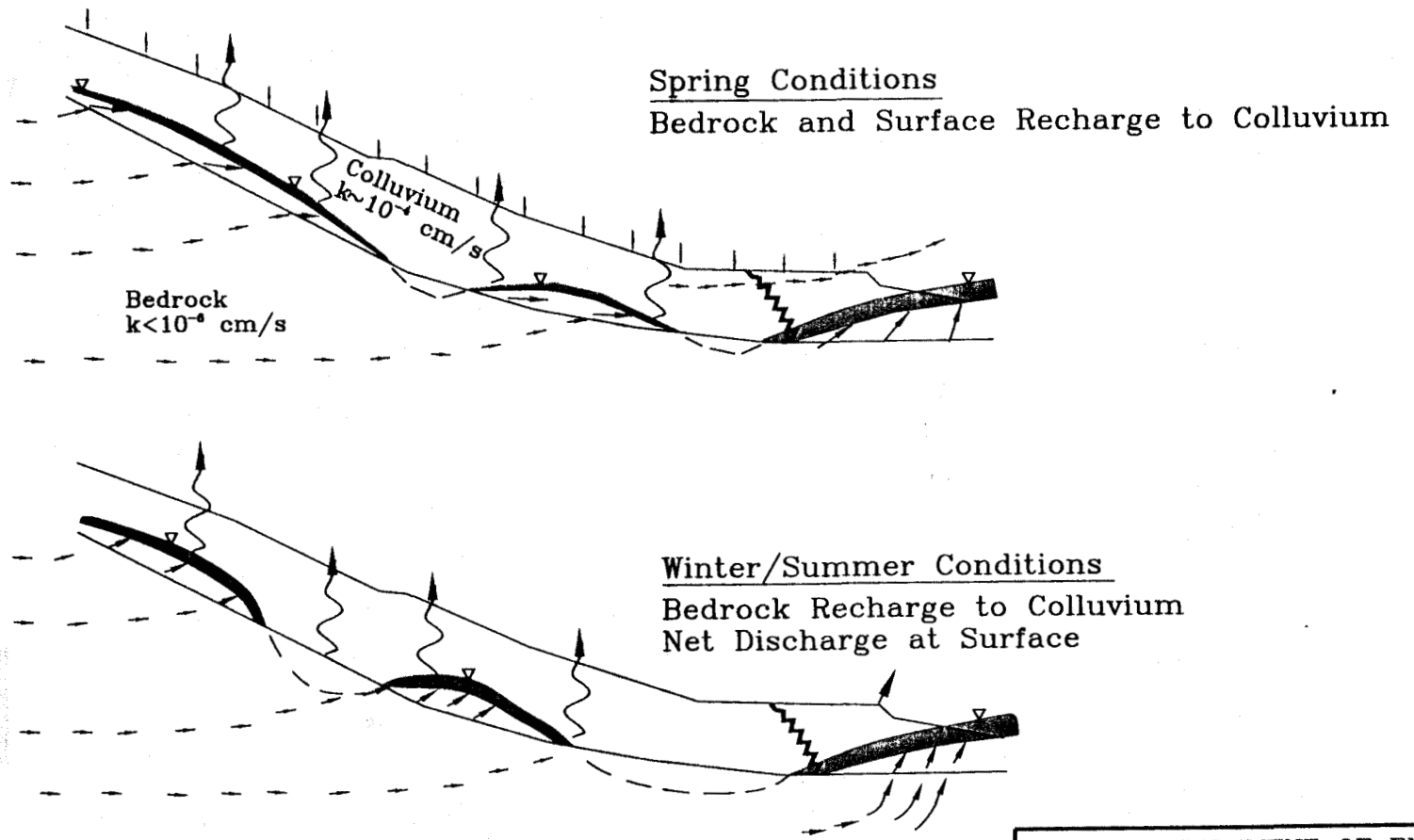
- Water source for colluvium is bedrock except during spring/summer high-precipitation periods.

3.0 DETAILED HYDROGEOLOGIC CONCEPTUAL MODEL

Figure 3-1 illustrates the hydrogeologic conceptual of the area in the vicinity of IHSS 1191. Groundwater flow is downhill. Recharge is primarily from bedrock, with smaller amounts from Rocky Flats Alluvium and episodic recharge. Discharge is by evapotranspiration from land surface, to Woman Creek, and to the French Drain.

Figure 3-2 shows how apparent vertically downward gradients could be measured at the site. In the figure, the two wells measure different flow lines, and the apparent vertical gradient does not indicate actual vertical downward flow.

K:\MODELING\RFP\OU1\NEWCM\GWCM



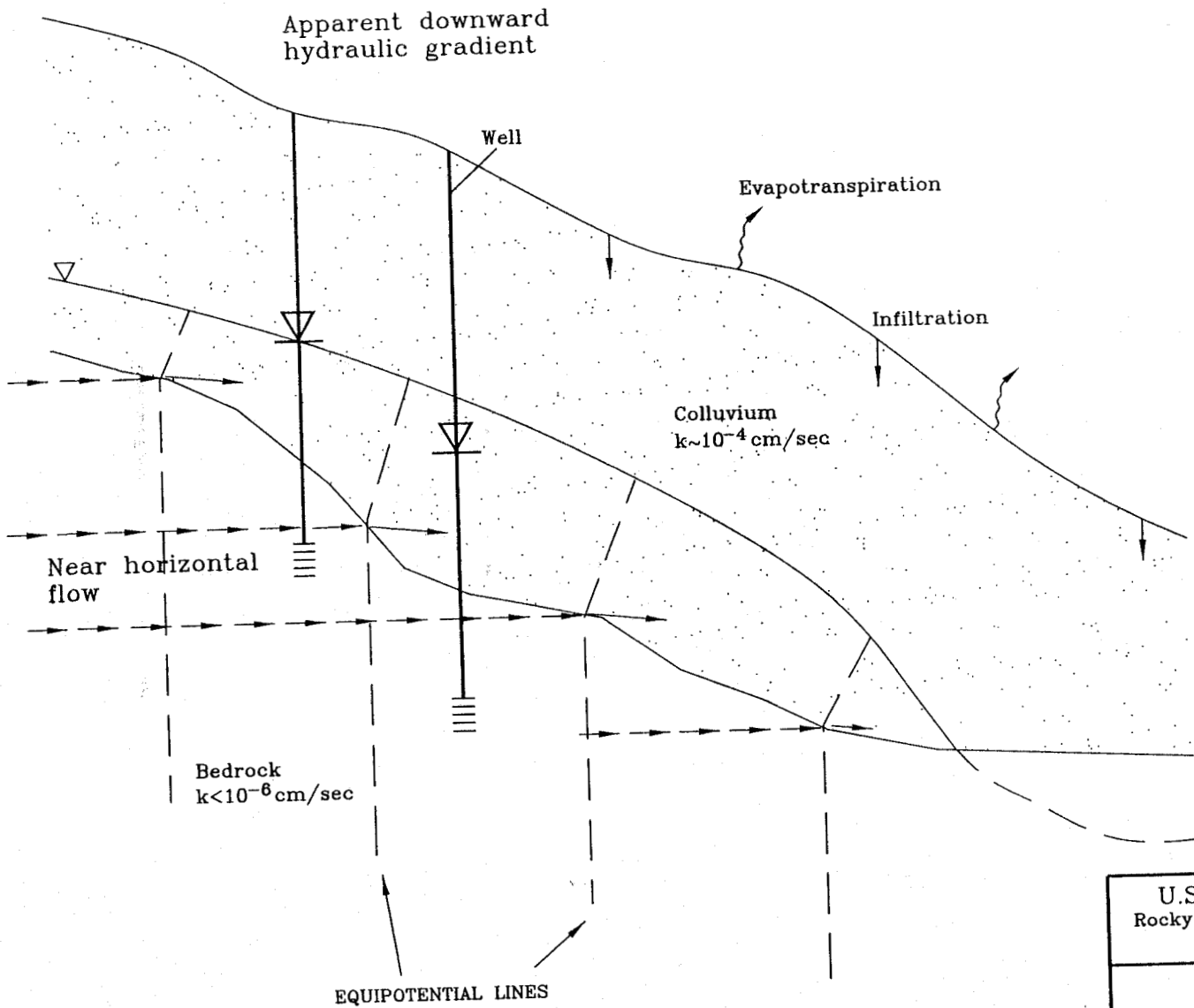
EXPLANATION

- LOWER TDS
- HIGHER TDS

U.S. DEPARTMENT OF ENERGY
Rocky Flats Environmental Technology Site
Golden, Colorado

881 HILLSIDE AREA
OPERABLE UNIT NO. 1
PHASE III RFI/RI REPORT

Hydrogeologic
Conceptual Model
Figure 3-1



U.S. DEPARTMENT OF ENERGY
Rocky Flats Environmental Technology Site
Golden, Colorado

881 HILLSIDE AREA
OPERABLE UNIT NO. 1

Likely Flow Vs Observed
Hydraulic Gradient
Figure 3-2

K:\MODELING\RFP\OU1\NEWCM\FLOW

23

4.0 NATURE AND EXTENT OF CONTAMINATION (IHSS 119.1)

The following is a summary of the nature and extent of contamination in the vicinity of IHSS 119.1.

- Figure 4-1 is an aerial photograph which shows where suspected drums containing waste were stored in IHSS 119.1.

- Significant groundwater contamination has not been observed in bedrock (Figure 4-2). Significant contamination in colluvium is indicated in wells 4387, 1074, 974 and 487 (Figure 4-3). These are the target wells.

- The distances from well 4387 to well 1074, and from well 4387 to well 487 are about the same. Based on the rule-of-thumb that dissolved concentrations below 1% of a VOCs solubility limit do not indicate the presence of a dense non-aqueous phase liquid (DNAPL), DNAPL is assumed to occur near wells 4387, 974 and 1074, but not at well 487. Mobile DNAPL is not likely because of the short distance to well 487. This indicates that DNAPL is immobile. Consideration of the available data has indicated that the suspected DNAPL is in a residual state.

- Transient fluctuations of concentrations in the target wells are shown in Figures 4-4, 4-5 and 4-6. Fluctuations in 4387 and 974 indicate that steady-state concentrations exist near the source of VOCs. Fluctuations in well 487 indicate increasing but near steady-state concentrations. The large spike in concentrations in 1992 were caused by the installation of the French Drain. The subsequent decrease in concentrations after the French Drain was installed were caused by the installation of the extraction well. The French Drain pulled the VOC plume toward well 487, and the extraction well pulled the plume back.

- Suspected residual DNAPL zone in IHSS 119.1

  — Groundwater concentrations in wells 4387, 1074 and 974 indicate the presence of DNAPL (Figures 4-4, 4-5, and 4-6).

Observed Concentrations - Well 0974
881 Hillside

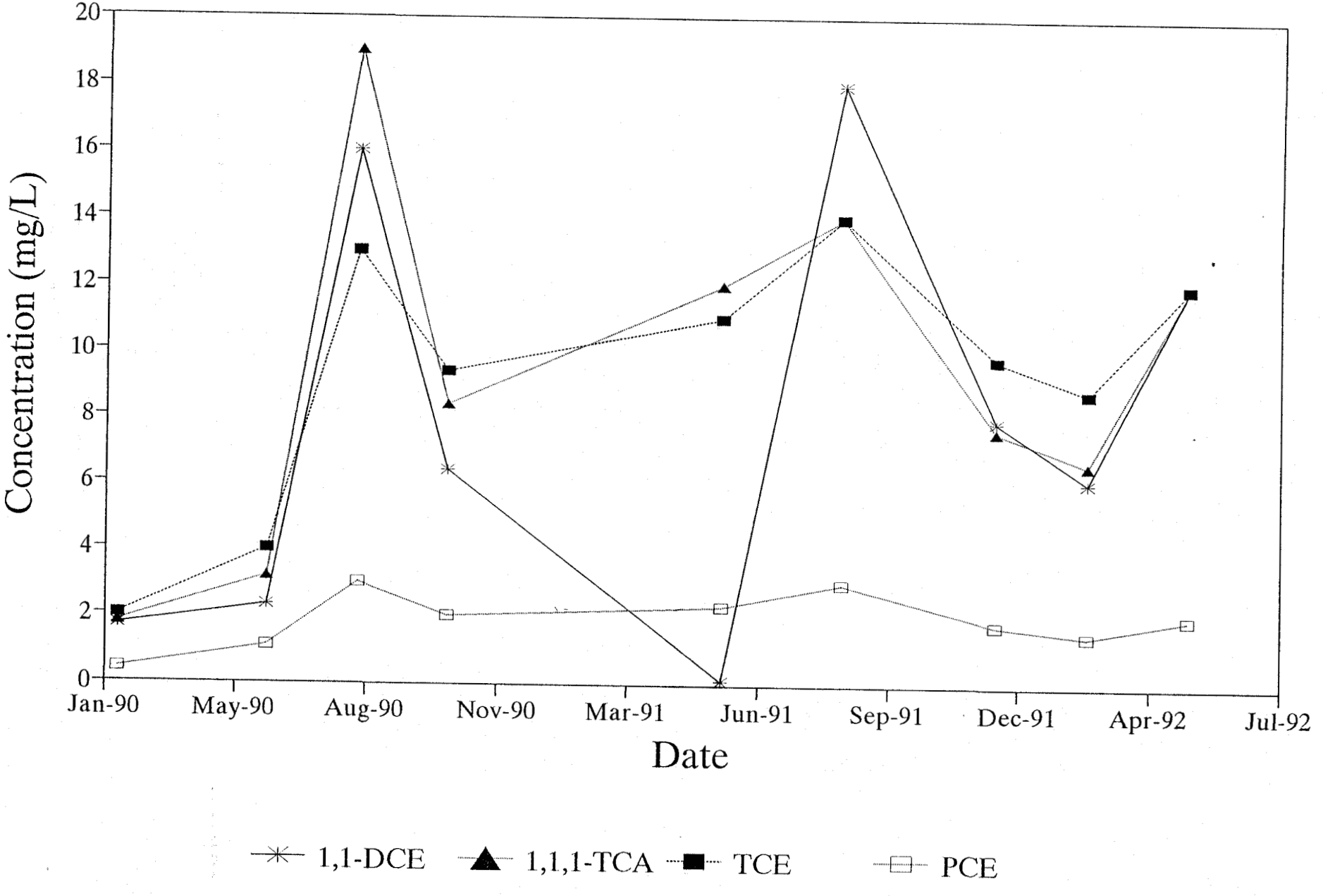


FIGURE 4-4

Observed Concentrations - Well 4387
881 Hillside

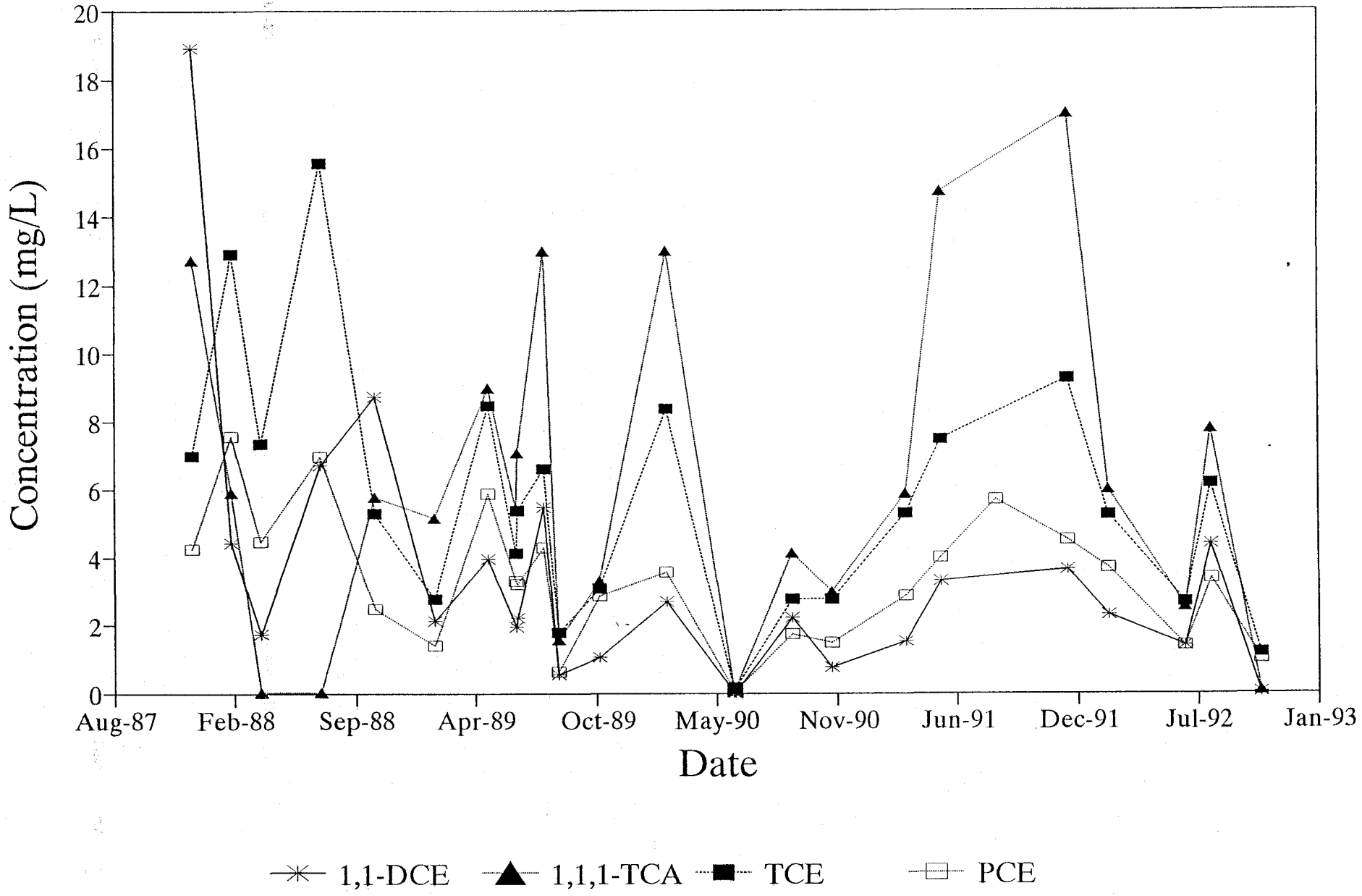


FIGURE 4-5

Observed Concentrations - Well 0487
881 Hillside

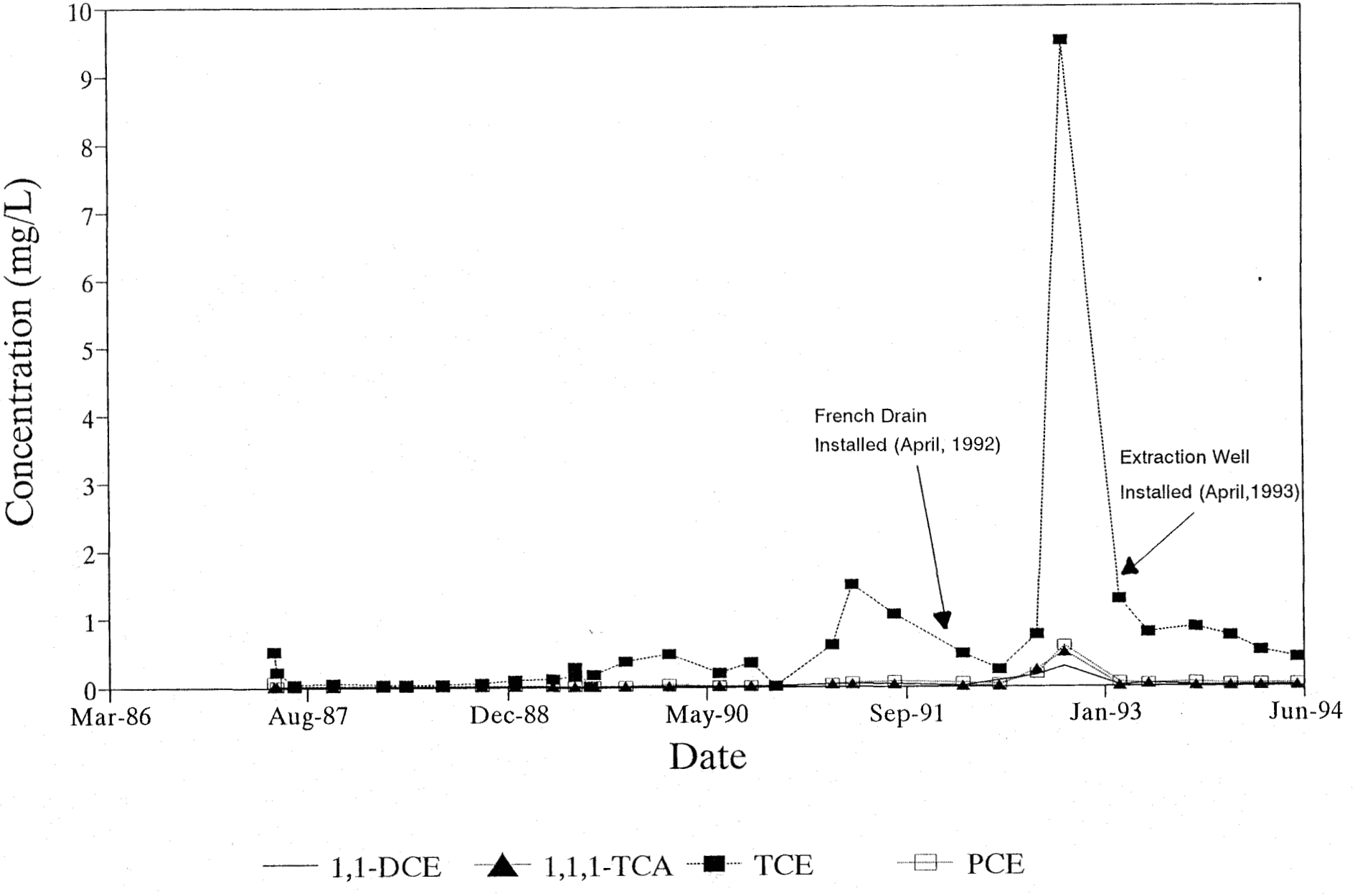


FIGURE 4-6

— The variation in TCE concentration versus saturated thickness for wells 4387 and 487 are shown in Figures 4-7 and 4-8. TCE Concentration is inversely correlated with saturated thickness in well 4387 but not in well 487. It is hypothesized that residual DNAPL exists below the water table near well 4387, but not near 487. Constant mass transfer from residual DNAPL into water at well 4387 results in the observed correlation. At well 487, the correlation may be direct rather than inverse: concentrations at 487 are probably diluted by episodic recharge from precipitation. This supports the concept that recharge is episodic.

— Concentration of VOCs in soil are shown in Figure 4-9. VOCs are concentrated in the bedrock channel below the water table. VOCs are not indicated outside the channel. Dry conditions are indicated in the subsurface away from the bedrock channel.

— Concentrations of VOCs in Soil gas are shown in Figure 4-10. Anomalous (high) concentrations correlate well with where suspected drums were located (Figure 4-1).

From this information it is concluded that there is probably a residual, immobile DNAPL phase in the areas where suspected drums were stored. The DNAPL is below the water table and above bedrock, and is confined to the area where the bedrock channel crosses through the IHSS 119.1 area.

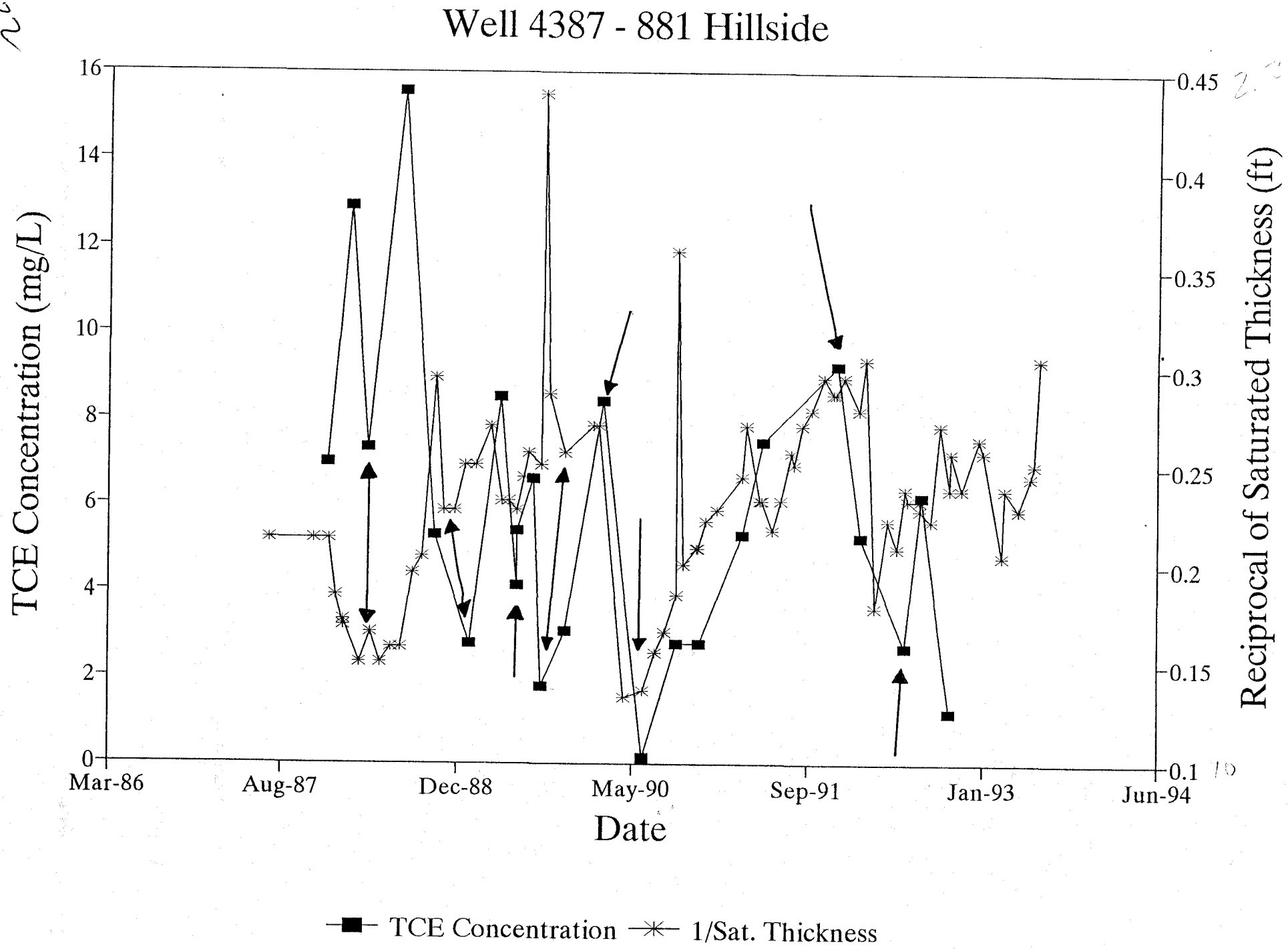

Well 4387 - 881 Hillside
TCE Concentration (mg/L)
Reciprocal of Saturated Thickness (ft)
Date
0
2
4
6
8
10
12
14
16
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
Mar-86
Aug-87
Dec-88
May-90
Sep-91
Jan-93
Jun-94
TCE Concentration
1/Sat. Thickness

FIGURE 4-7

Observed Concentration and Water Level
881 Hillside - Well 0487

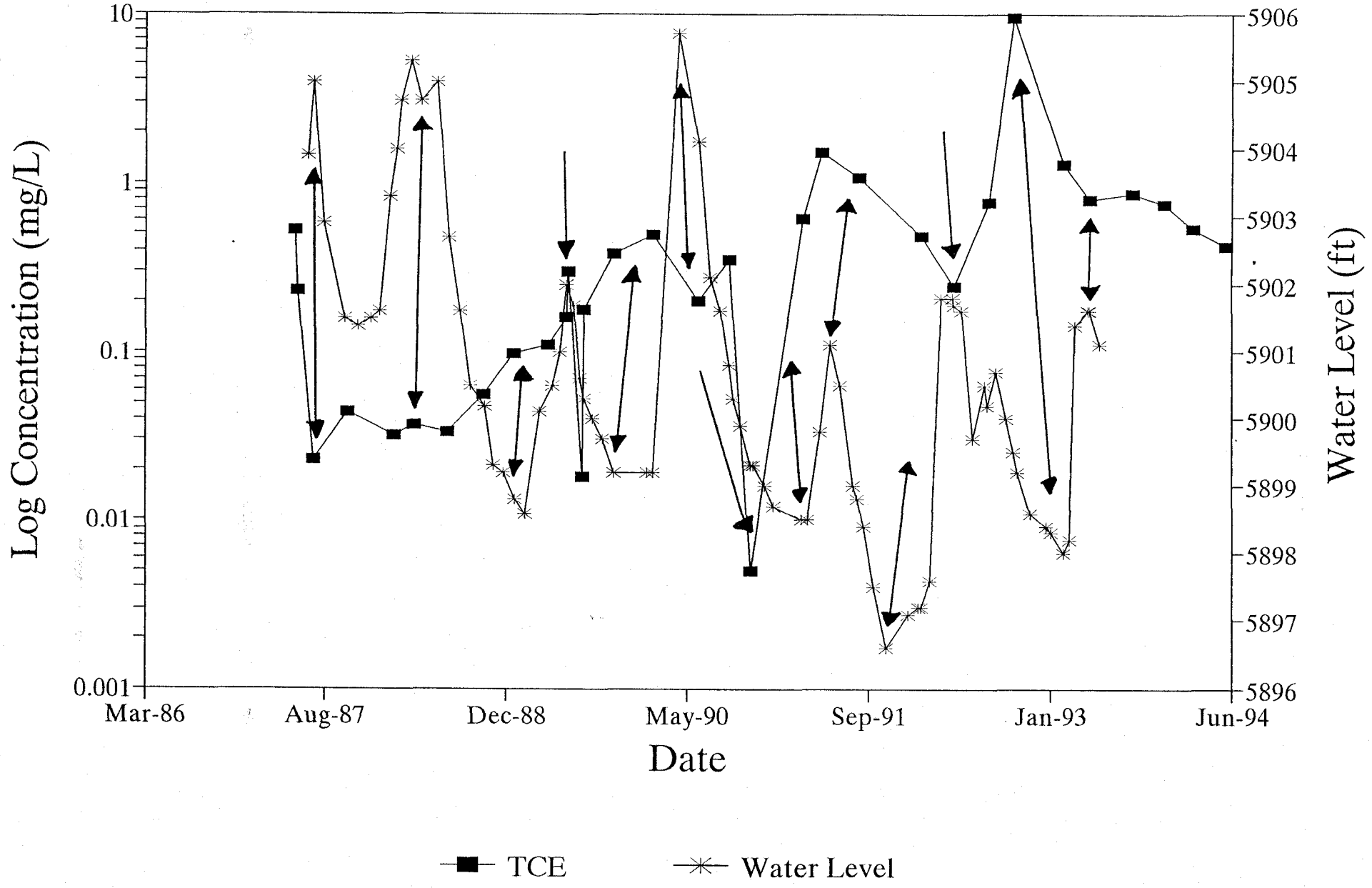
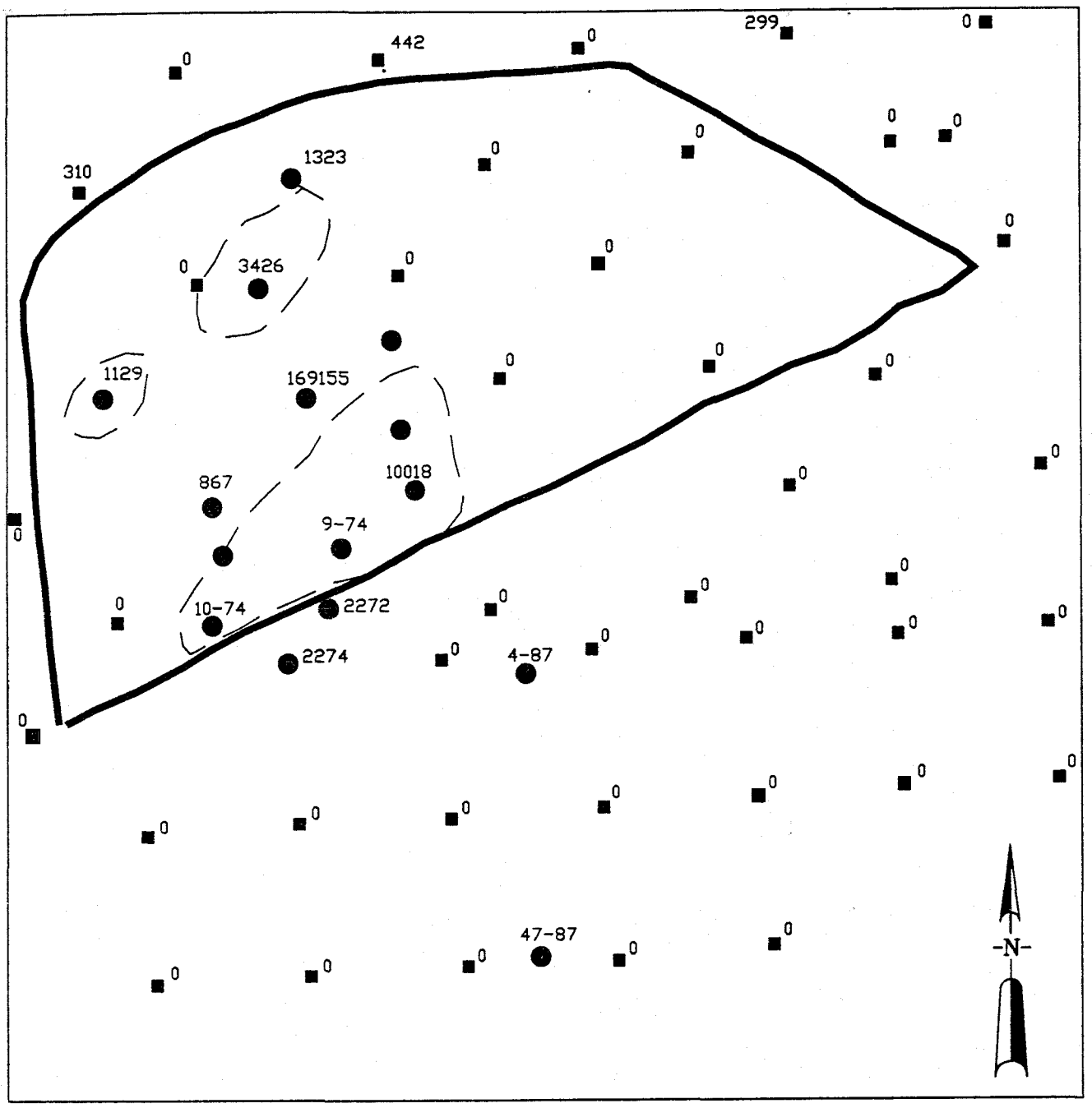


FIGURE 4-8



EXPLANATION

- Soil gas hits; Data approximately located from Phase III RFI/RI
- Points with greater than 500 counts PCE in soil gas
- Approximate location of drums as interpreted from Figure 3-26 of the Phase III RFI/RI

U.S. DEPARTMENT OF ENERGY
Rocky Flats Environmental Technology Site
Golden, Colorado

881 HILLSIDE AREA
OPERABLE UNIT NO. 1
FROM PHASE III RFI/RI REPORT FIGURE 4-36

PCE Molecular
Counts in Soil Gas

Figure 4-10

K:\MODELING\RFP\OU1\NEWCM\4-36

35

5.0 FATE AND TRANSPORT

This section summarizes the transport and fate of VOC contaminants in the vicinity of IHSS 119.1.

- Decay is probably occurring but at a slow rate. Dichoroethylene, a common degradation product, has been detected in groundwater. Groundwater transport rates are probably high enough that concentrations at well 487 should be nearly equal to those near well 4387. However, this is not the case. Therefore, it is concluded that VOCs volatilize from the saturated zone into the vadose zone and escape to the atmosphere. The dissolved VOC plume is passively removed from the subsurface.

- Dissolution of the residual DNAPL phase is the source of dissolved VOCs in groundwater. The source is below water table, above bedrock and confined to the area where suspected drums were stored in IHSS 119.1 (Figure 4-1).

- Rate of movement of VOCs:

Hydrogeology	3.3 to 803 ft/yr	(Phase III RFI/RI, DOE 1994)
Modeling	22 ft/yr	(Feasibility Study, DOE 1995a)
French Drain	< 10 ft/yr	[Recent monitoring of the French Drain has indicated that no VOCs have arrived at the French Drain according to data in the Rocky Flats Environmental Database System (DOE 1995c)]

- Mass of residual DNAPL:

Model	24 Liters	(See attached draft calculations)
"Dissolution"	30 Liters	(See attached draft calculations)

6.0 SUMMARY OF CONCLUSIONS

- Site hydrogeology is well understood
- French Drain and Woman Creek are local hydrogeological boundaries
- Contamination at site is well understood
- Contaminants moving very slowly to not at all
- Plume is being passively remediated
- DNAPL is in residual state and immobile
- Maximum of 30 Liters of DNAPL
- Residual DNAPL is below water and restricted to the area beneath where drums were stored
- Model predictions are conservative by at least one order of magnitude (DOE 1995a).

7.0 REFERENCES

CDPHE, 1994. *CDPHE Comments on August 1994 Draft Final Corrective Measures Study/Feasibility Study (CMS/FS) 881 Hillside Area (Operable Unit 1) Rocky Flats Environmental Technology Site,* Colorado Department of Public Health and Environment, Colorado, August 1994.

EPA, 1994. *EPA Comments on August 1994 Draft Final Corrective Measures Study/Feasibility Study (CMS/FS) 881 Hillside Area (Operable Unit 1) Rocky Flats Environmental Technology Site,* U. S. Environmental Protection, Colorado, August 1994.

DOE, 1994. *Final Phase III RFI/RI, Rocky Flats Plant, 881 Hillside Area (Operable Unit 1),* U.S. Department of Energy, Rocky Flats Plant, Golden, Colorado, June 1994.

DOE, 1995a. *Final Corrective Measures Study/Feasibility Study Rocky Flats Environmental Technology Site 881 Hillside Area (Operable Unit No. 1),* U.S. Department of Energy, Rocky Flats Environmental Technology Site, Golden, Colorado, February 1995.

DOE, 1995b. *Response to CDPHE and EPA Comments on August 1994 Draft Final Corrective Measures Study/Feasibility Study (CMS/FS) 881 Hillside Area (Operable Unit 1) Rocky Flats Environmental Technology Site,* U.S. Department of Energy, Rocky Flats Environmental Technology Site, Golden, Colorado, February 1995.

DOE, 1995c. *Rocky Flats Environmental Database System*, U.S. Department of Energy, Rocky Flats Environmental Technology Site, Golden, Colorado, 1995.

DAMES & MOORE

Sheet No. 1 of 2
Calc. No.
Rev. No.

Job No. 10805-991-103 Job OU1 FS Support
Client EG&G RFETS Subject Residual DNAPL in IHSS 119.1

By POS Date 5/10/
Chk'd. Date

Purpose: To estimate mass and volume of DNAPL in IHSS 119.1

Method: use mass-transfer equation given by Mercer & Cohen, 1990, J. of Contam Hydrology to estimate a reasonable upper bound of mass in place

Equation: $t = \frac{M}{\bar{V} n C_w A}$ where t = time (T)
M = Mass of DNAPL (M)
$\bar{V}$ = particle velocity of ground water (L/T)
n = porosity (–)
C_w = Concentration in ground water at source (M/L^3)
A = cross sectional area through which ground water flows through Residual DNAPL Zone

Given: density of pure PCE = $(1.6311\ g/cc)(1\times10^6\ \mu g/g)(1000\ cc/l)$
$= 1.6311\times10^9\ \mu g/l$

Assumptions: ① $A = 80\ ft \times 3\ ft$ –
3 ft → approximate long-term average depth of water in area of source
80 ft → approximate lateral extent of where drums were stored in IHSS 119.1

39

946.9 (7/91)

DAMES & MOORE

Sheet No. 2 of 2
Calc. No.
Rev. No.
Job No. Job By Date
Client Subject Chk'd. Date

② $\bar{v}$ = 10 ft/yr based on fact that contamination has not yet reached the French Drain. This is consistent w/ calibrated FS model

③ n = 0.36 based on calibrated FS model

④ C_w = 2000 μg/L (28.32 L/ft³) PCE this is an approximate average of observed concentra in Well #387

= ~~56,060~~ 56,633 μg/ft³

Rearrange equation: $M = t\bar{v}nC_wA$ 56,633

$= t(10\ ft/yr)(.36)(\cancel{56,060}\ \mu g/ft^3)(3 \times 80\ ft$

$= t(4.8 \times 10^7\ \mu g/yr)$ 4.9×10⁷ "

(Convert to Liters of PCE)

$= t(2.97 \times 10^{-2}\ L/yr)$

t(yr)	Volume of Pure PCE (L)
20	0.6 ✓
100	3 ✓
1000	30 ✓

⇐ ANS

Checked 5/11/95

40

946.9 (7/91)

DAMES & MOORE

Sheet No. 1 of 1
Calc. No.
Rev. No.

Job No. 10805-991-103 Job OU1 FS Support By POS Date 5/10/9
Client EG&G RFETS Subject Residual DNAPL in IHSS 119.1 Chk'd. Date

Purpose: To estimate mass and volume of DNAPL in IHSS 119.1

Method: use results of calibrated FS model to make estimate

Given: Volume of source cell in model is 3 x 1 x 1 ft^3/lateral ft

Lateral length of where drums were stored in IHSS 119.1 = 80 ft

∴ total volume of modeled source = 80 x 3 = 240 ft^3

Porosity = 0.36 based on calibrated FS model

Assume: residual saturation of PCE is 10% based on notes from Cherry et al, 1990, Dense Immiscible Phase Liquid Contaminants (DNAPLs) in Porous and Fractured Media, Short Course, Waterloo Center for Groundwater Research.

Calculation:

Volume of PCE = (240 ft^3)(.36)(.1)(~~28.03~~ 28.32 L/ft^3) = 242 L ✓ 244

ANS

Checked by [illegible] 5/11/95

41/41

946.9 (7/91)

UPPER HSU

Rocky Flats Alluvium
- Phase III RFI/RI (1 Single Well)

Colluvium
- Phase I & II RI (5 Single Well Tests)
- Phase III RFI/RI (9 Single Well Tests)

Woman Creek Valley Fill
- Phase I & II RI (4 Single Well Tests)
- Phase III RFI/RI (1 Single Well Test)
- Phase III RFI/RI (1 Multiple Well Test)

Weathered Claystone
- Phase III (1 Single Well Test)
- Phase I & II (1 Packer Test)
- French Drain Geotechnical Investigation (67 Packer Tests)
- Phase III RFI/RI (1 Packer Test)

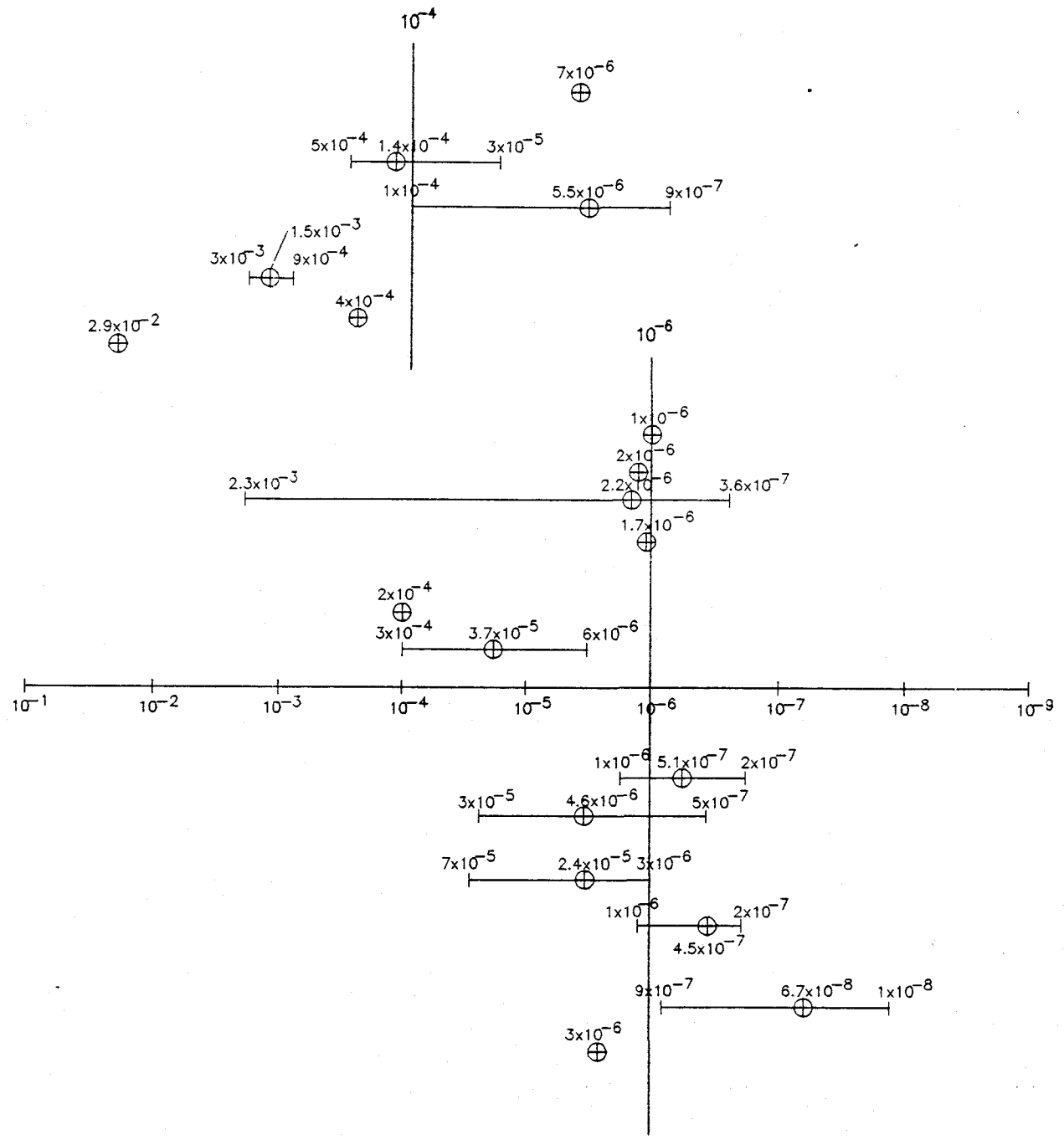
Bedrock Sandstone
- Phase III RFI/RI (2 Single Well Tests)
- Phase I & II (3 Single Well Tests)

LOWER HSU

Weathered Claystone
- Phase I & II (3 Packer Tests)
- Phase III RFI/RI (6 Single Well Tests)

Bedrock Sandstone
- Phase I & II RI (3 Single Well Tests)
- Phase I & II RI (2 Packer Tests)

Unweathered Claystone
- Phase I & II RI (13 Packer Tests)
- Phase I & II RI (1 Single Well Test)



NOTES:
All Hydraulic Conductivity Values in cm/sec presented in Tables 3-6, 3-7, 3-8, 3-13, and 3-14

⊕ Geometric Mean of Range Presented

10^{-4} Approximate Average Hydraulic Conductivity

U.S. DEPARTMENT OF ENERGY
Rocky Flats Environmental Technology Site
Golden, Colorado

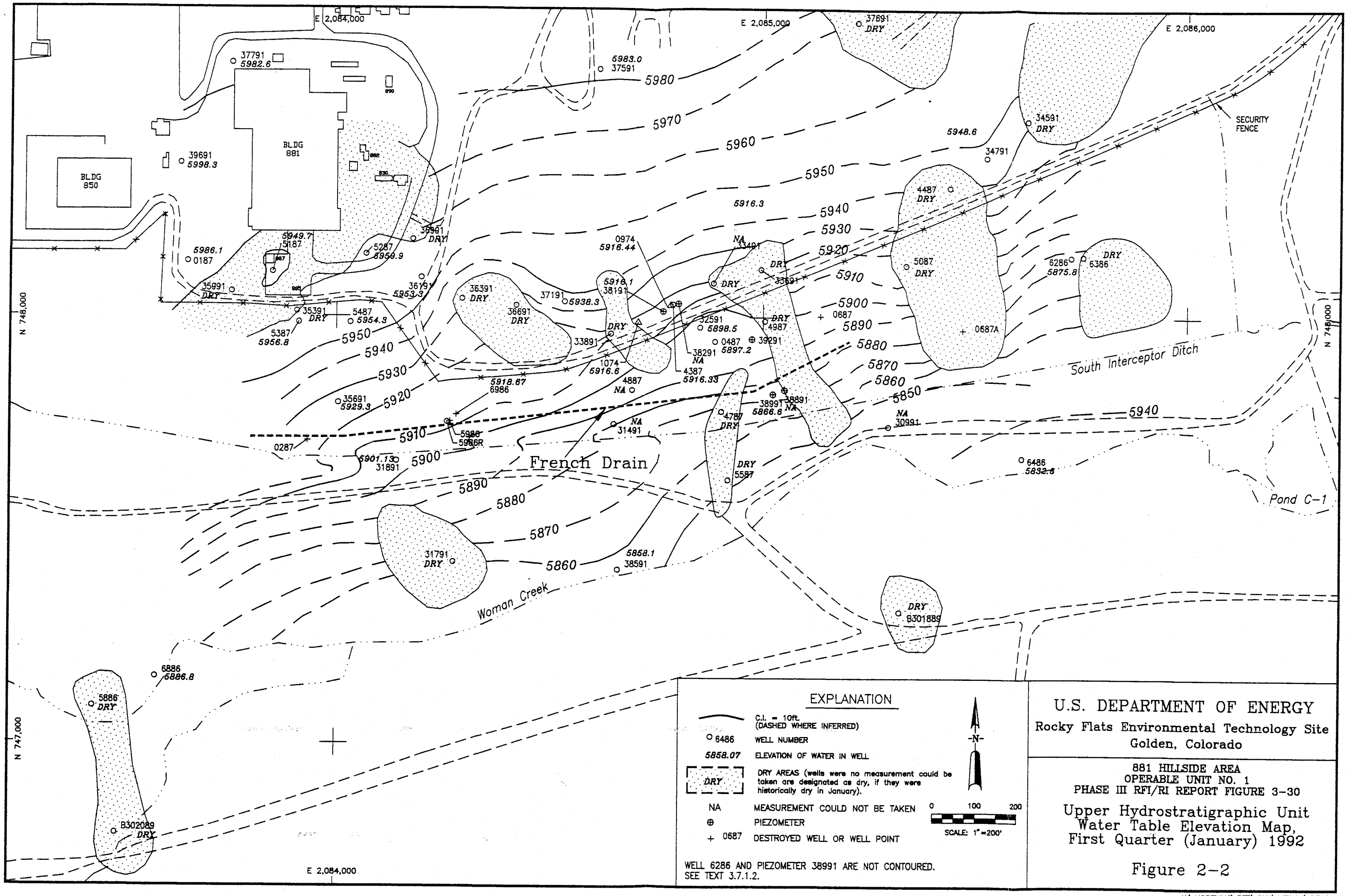
881 HILLSIDE AREA
OPERABLE UNIT NO. 1
PHASE III RFI/RI REPORT FIGURE 3-42

Hydraulic Conductivities for Upper and Lower HSU Materials at OU1

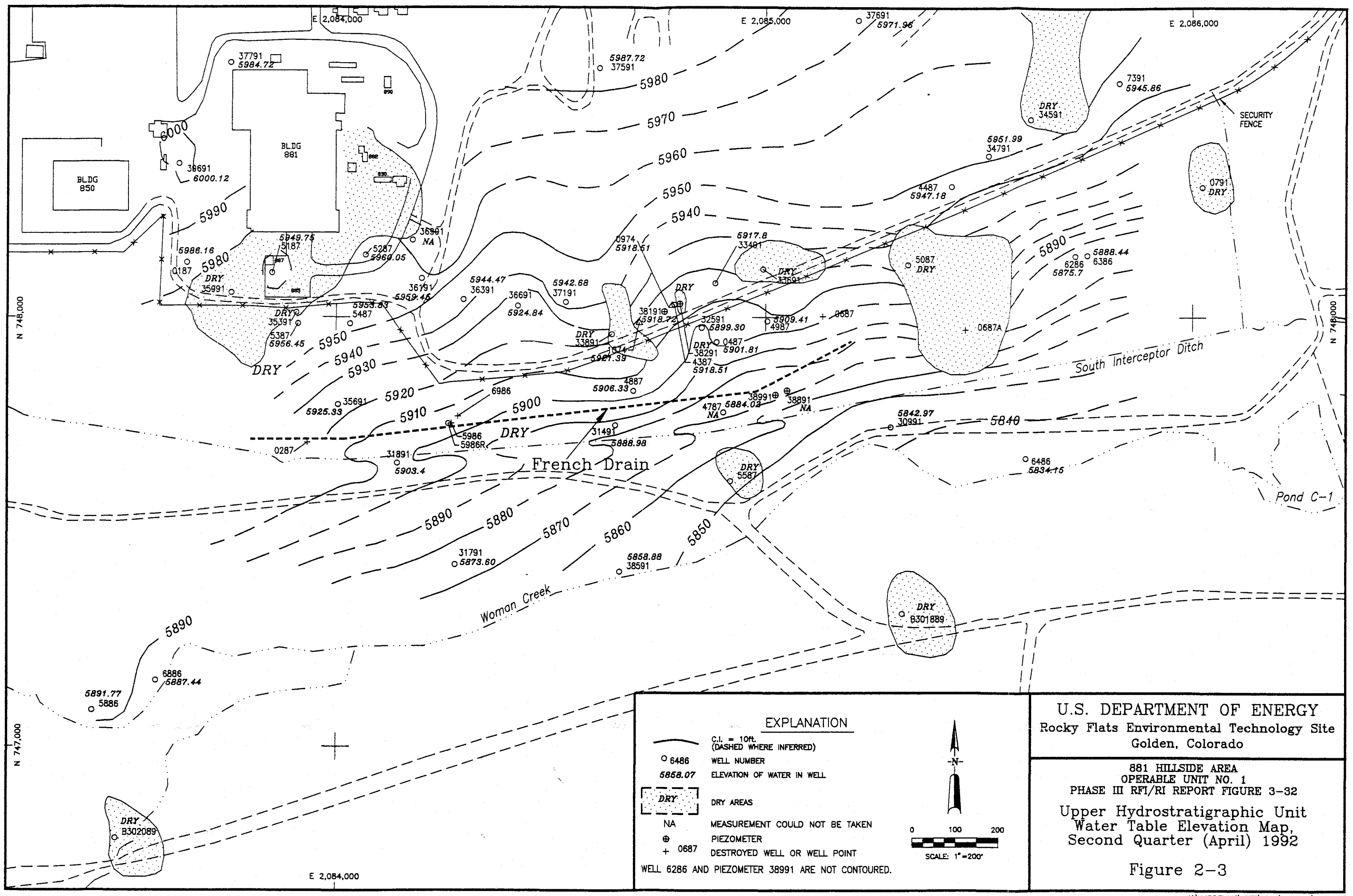
Figure 2-1

K:\MODELING\RFP\OU1\NEWCM\R74027

6



K:\MODELING\RFP\OU1\NEWCM\R74001



U.S. DEPARTMENT OF ENERGY
Rocky Flats Environmental Technology Site
Golden, Colorado

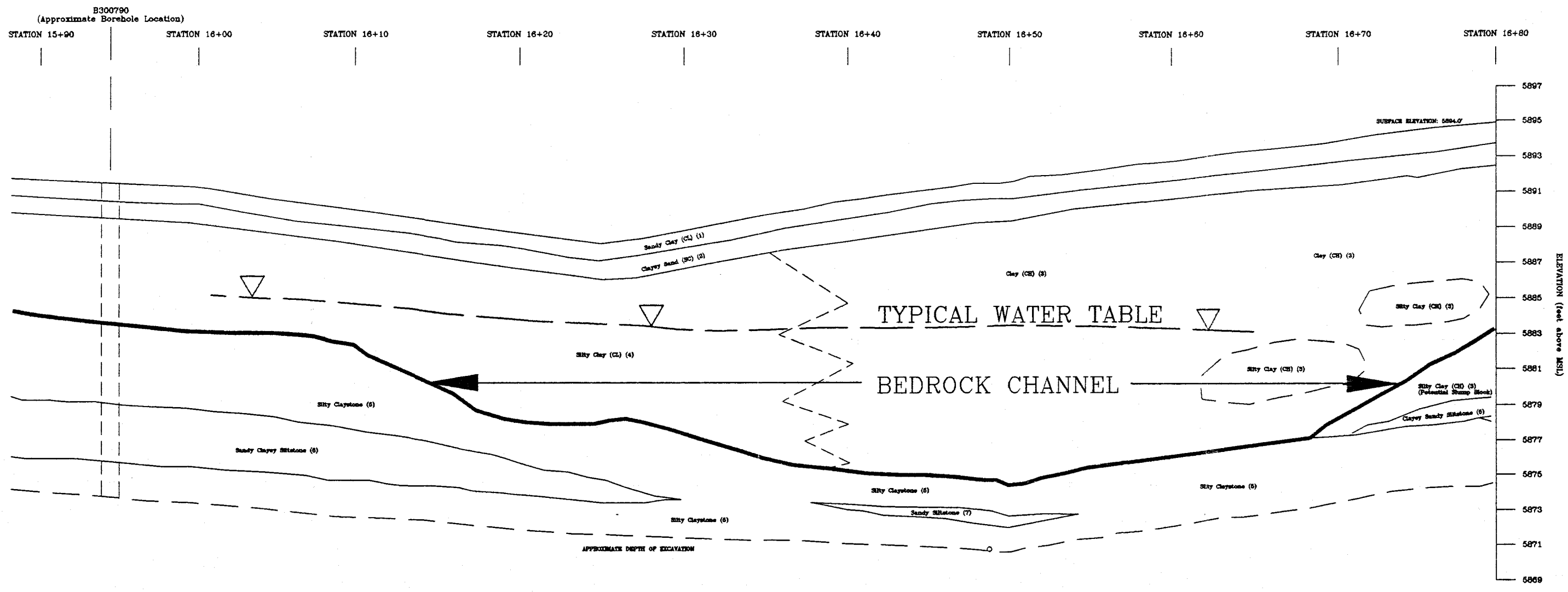
881 HILLSIDE AREA
OPERABLE UNIT NO. 1
PHASE III RFI/RI REPORT FIGURE 3-32

Upper Hydrostratigraphic Unit
Water Table Elevation Map,
Second Quarter (April) 1992

Figure 2-3

K:\MODELING\RFP\OU1\NEWCM\R74007

9



EXPLANATION

Refer to geologic cross-sections from Appendix A, Attachment A4-2, Phase III RFI/RI for details of section.

U.S. DEPARTMENT OF ENERGY
Rocky Flats Environmental Technology Site
Golden, Colorado

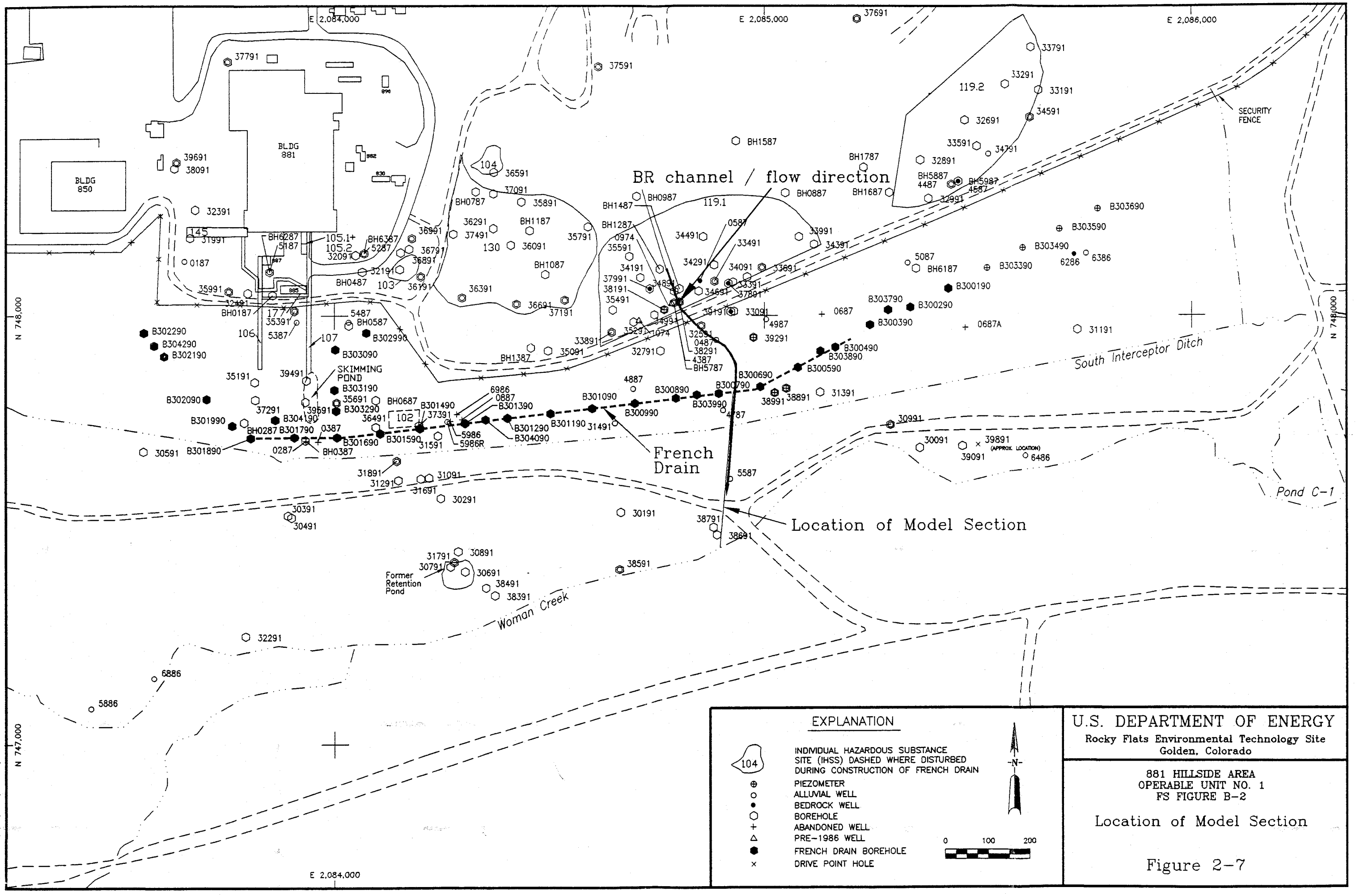
881 HILLSIDE AREA
OPERABLE UNIT NO. 1

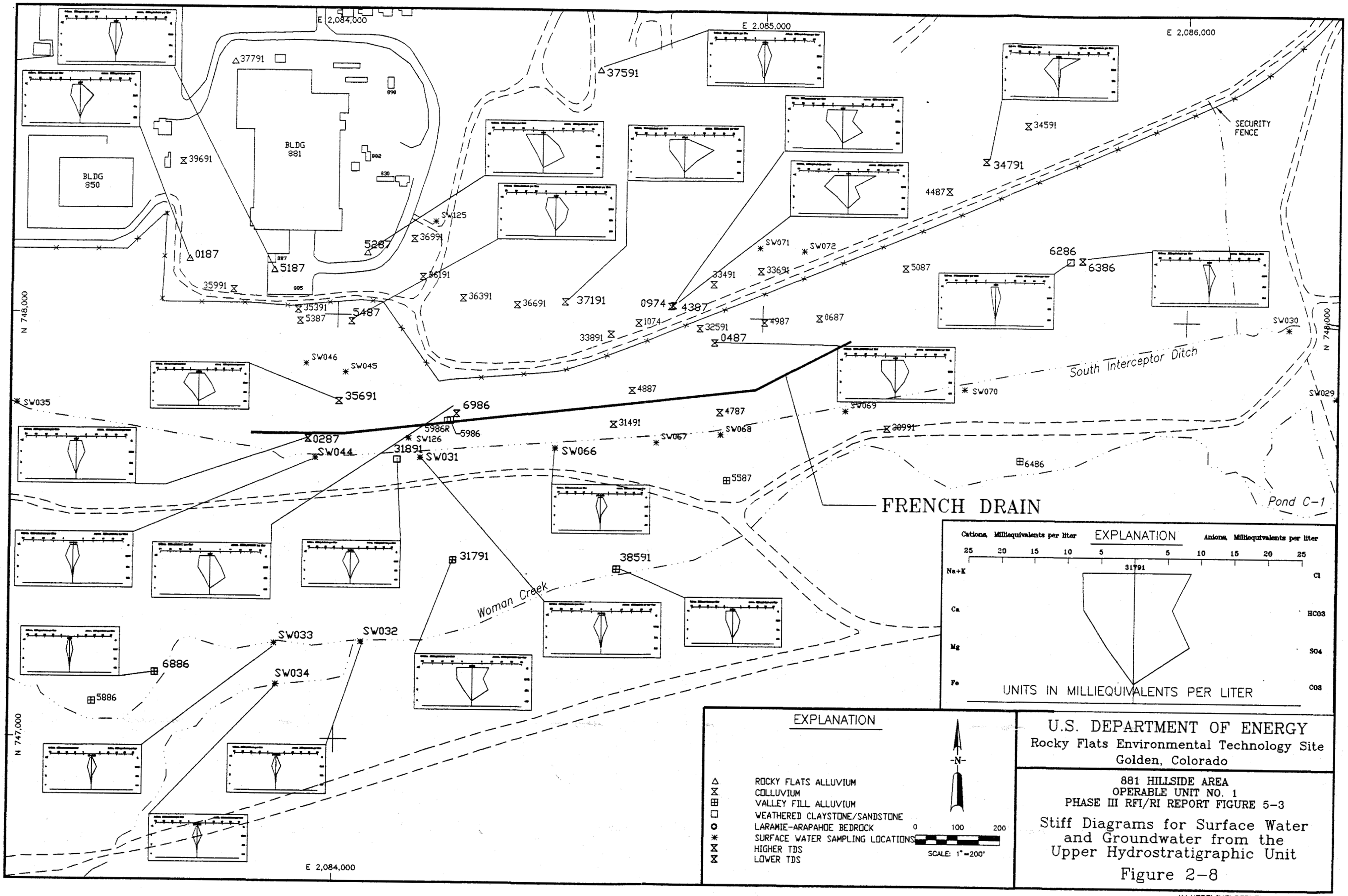
French Drain Geologic Cross-section

Figure 2-6

K:\MODELING\RFP\OU1\NEWCM\SECTION

13


BR channel / flow direction
French Drain
Location of Model Section
South Interceptor Ditch
Pond C-1
Woman Creek
Former Retention Pond
SKIMMING POND
BLDG 881
BLDG 850
SECURITY FENCE
E 2,084,000
E 2,085,000
E 2,086,000
N 748,000
N 747,000
EXPLANATION
INDIVIDUAL HAZARDOUS SUBSTANCE SITE (IHSS) DASHED WHERE DISTURBED DURING CONSTRUCTION OF FRENCH DRAIN
PIEZOMETER
ALLUVIAL WELL
BEDROCK WELL
BOREHOLE
ABANDONED WELL
PRE-1986 WELL
FRENCH DRAIN BOREHOLE
DRIVE POINT HOLE
0 100 200
-N-
U.S. DEPARTMENT OF ENERGY
Rocky Flats Environmental Technology Site
Golden, Colorado
881 HILLSIDE AREA
OPERABLE UNIT NO. 1
FS FIGURE B-2
Location of Model Section
Figure 2-7
K:\MODELING\RFP\OU1\NEWCM\LOC-MSEC.DWG



U.S. DEPARTMENT OF ENERGY
Rocky Flats Environmental Technology Site
Golden, Colorado

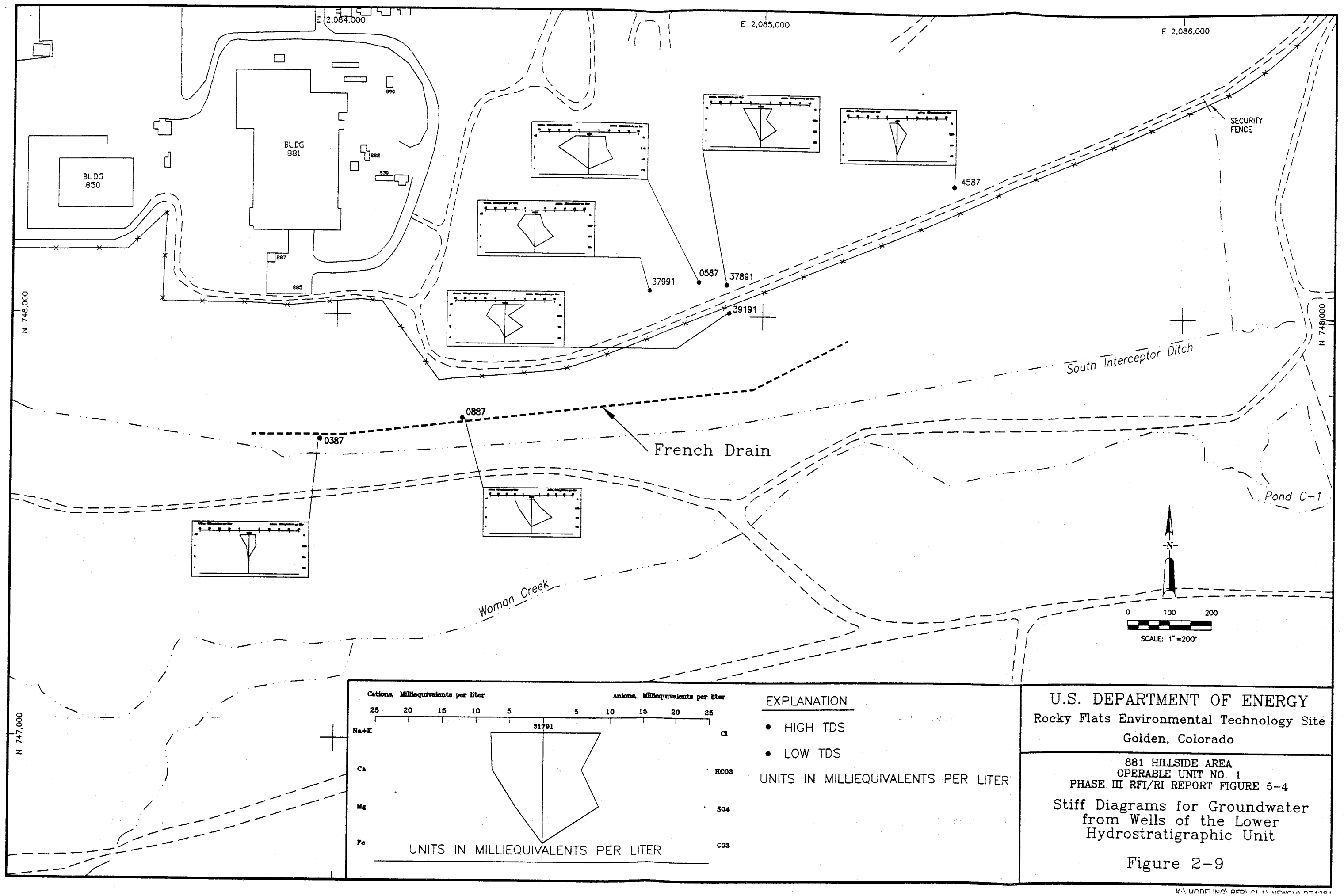
881 HILLSIDE AREA
OPERABLE UNIT NO. 1
PHASE III RFI/RI REPORT FIGURE 5-3

Stiff Diagrams for Surface Water and Groundwater from the Upper Hydrostratigraphic Unit

Figure 2-8

K:\MODELING\RFP\OU1\NEWCM\R74198

16


E 2,084,000
E 2,085,000
E 2,086,000
N 748,000
N 747,000
BLDG 850
BLDG 881
899
882
830
887
885
37991
0587
37891
39191
4587
SECURITY FENCE
South Interceptor Ditch
0887
0387
French Drain
Pond C-1
Woman Creek
N
0 100 200
SCALE: 1"=200'
Cations, Milliequivalents per liter
Anions, Milliequivalents per liter
25 20 15 10 5 5 10 15 20 25
31791
Na+K
Ca
Mg
Fe
Cl
HCO3
SO4
CO3
UNITS IN MILLIEQUIVALENTS PER LITER
EXPLANATION
HIGH TDS
LOW TDS
UNITS IN MILLIEQUIVALENTS PER LITER
U.S. DEPARTMENT OF ENERGY
Rocky Flats Environmental Technology Site
Golden, Colorado
881 HILLSIDE AREA
OPERABLE UNIT NO. 1
PHASE III RFI/RI REPORT FIGURE 5-4
Stiff Diagrams for Groundwater from Wells of the Lower Hydrostratigraphic Unit
Figure 2-9

17

EXPLANATION

104 — INDIVIDUAL HAZARDOUS SUBSTANCE SITE (IHSS)

← INDICATES SURFACE DRAINAGE THAT APPEARS TO BE COINCIDENT WITH POTENTIAL GROUNDWATER MIGRATION PATHWAYS

NOTE: Photo taken by Colorado Aerial Photo Service
SCALE: 1" = 200'; DATED: 5/24/69

Best Available Copy

-N-

0 100 200
SCALE: 1"=200'

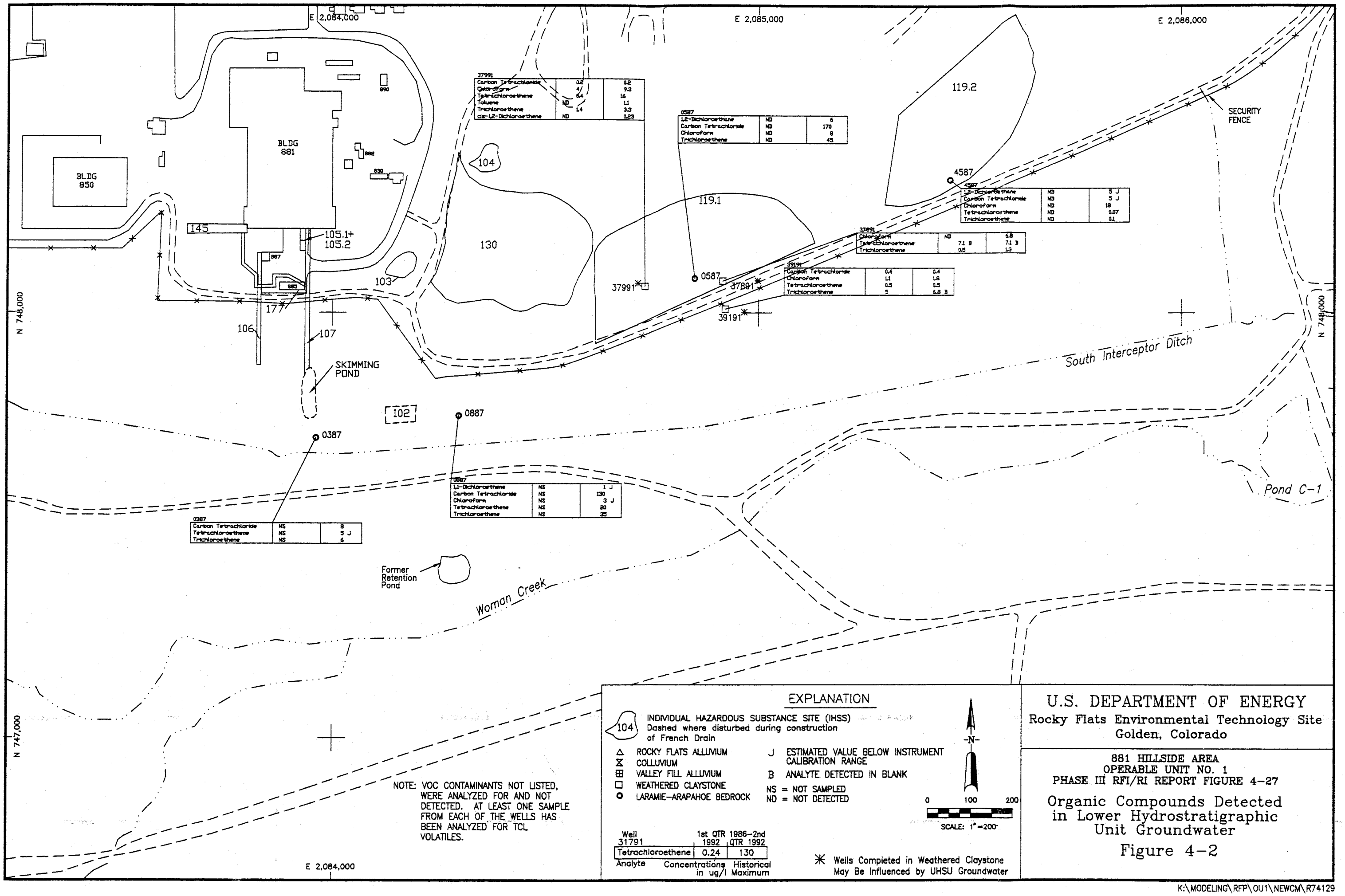
U.S. DEPARTMENT OF ENERGY
Rocky Flats Environmental Technology Site
Golden, Colorado

881 HILLSIDE AREA
OPERABLE UNIT NO. 1
PHASE III RFI/RI REPORT FIGURE 3-26

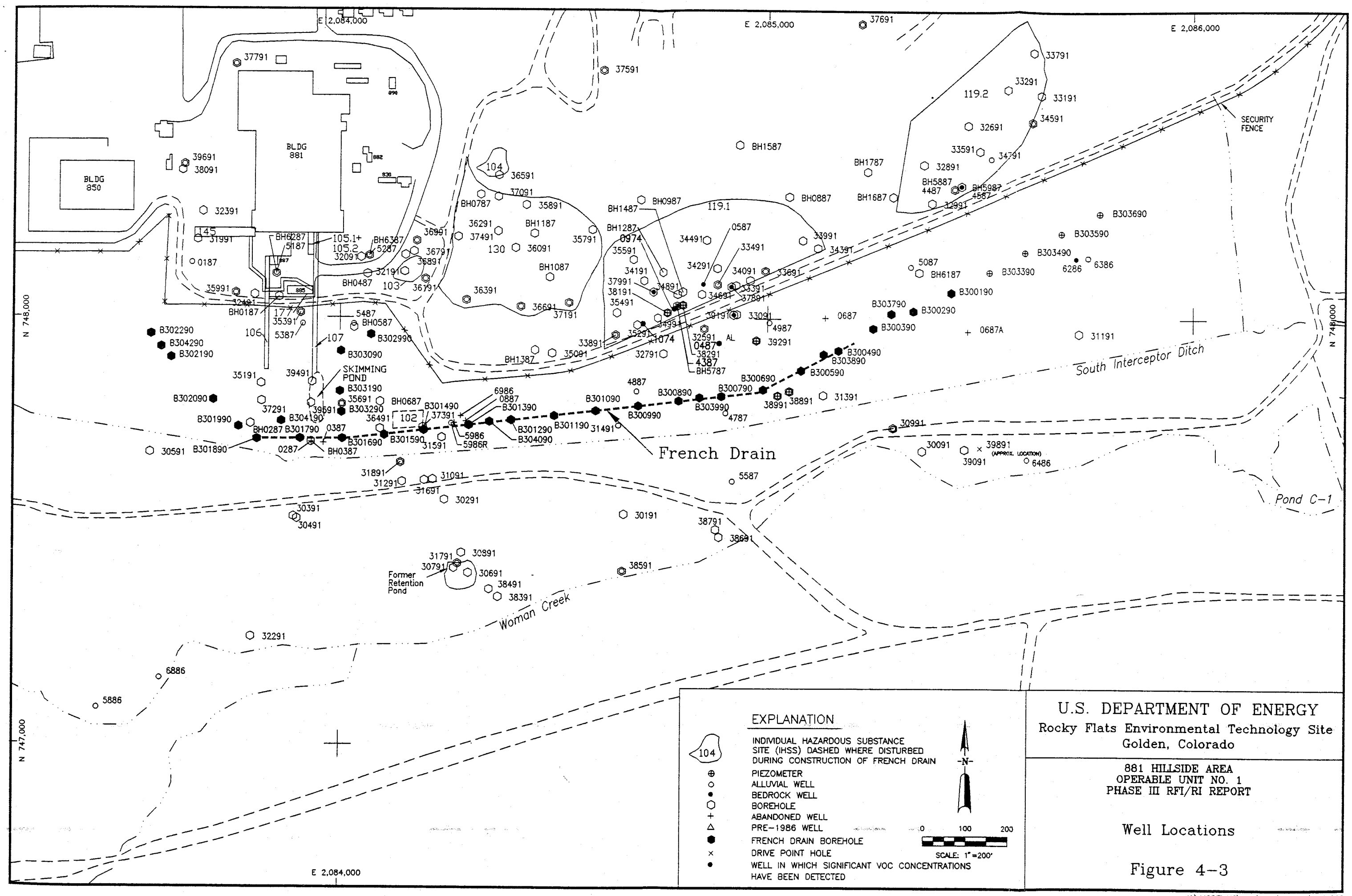
Surface Expression of Potential Groundwater Migration Pathways

Figure 4-1

25

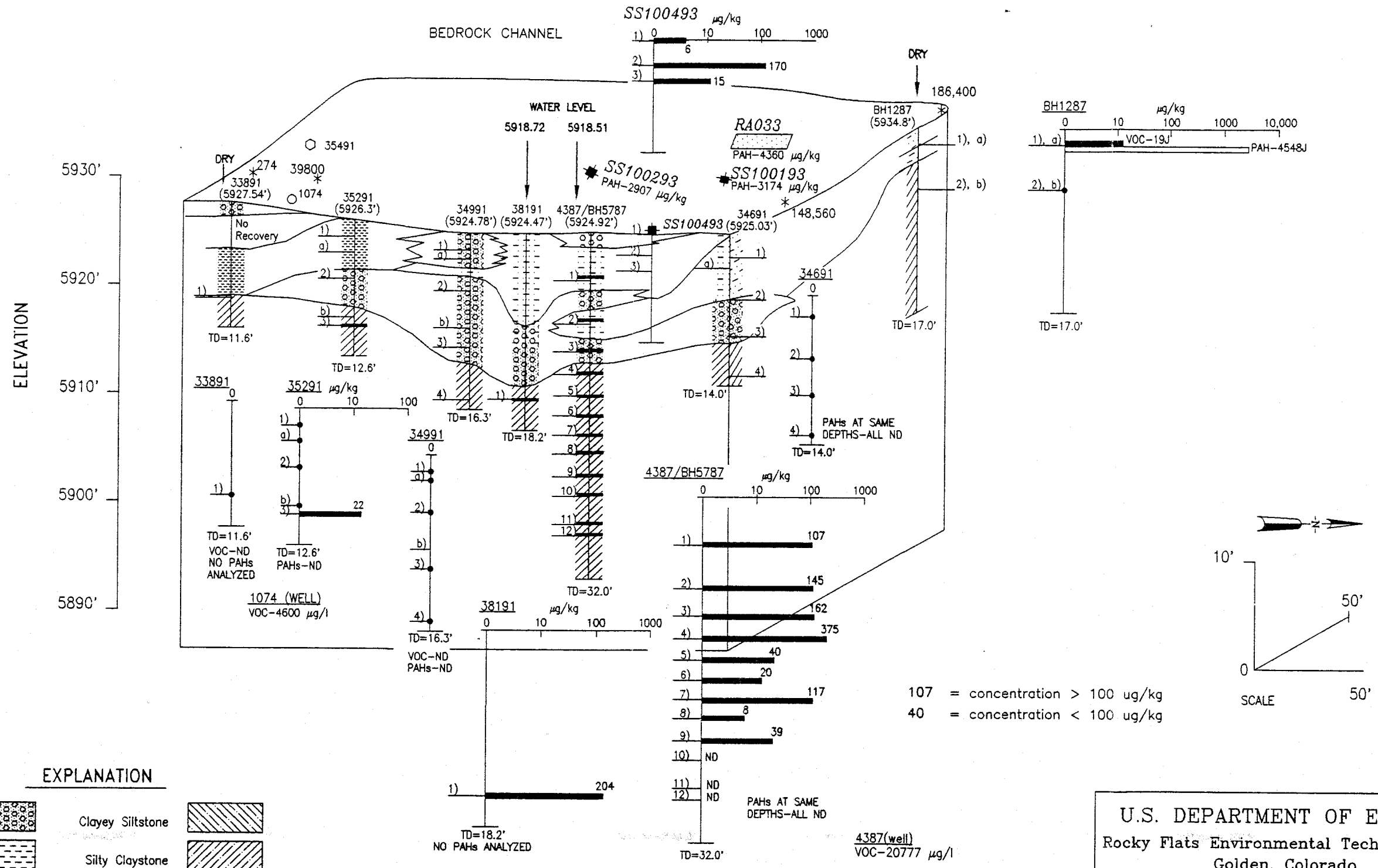

E 2,084,000
E 2,085,000
E 2,086,000
N 748,000
N 747,000
BLDG 881
BLDG 850
890
882
830
887
885
145
105.1+
105.2
177
106
107
SKIMMING POND
103
104
130
119.1
119.2
102
37991
Carbon Tetrachloride 0.2 0.2
Chloroform 4 9.3
Tetrachloroethene 0.4 1.6
Toluene ND 1.1
Trichloroethene 1.4 3.3
cis-1,2-Dichloroethene ND 0.23
0587
1,2-Dichloroethane ND 6
Carbon Tetrachloride ND 170
Chloroform ND 8
Trichloroethene ND 43
4587
1,2-Dichloroethane ND 5 J
Carbon Tetrachloride ND 5 J
Chloroform ND 18
Tetrachloroethene ND 0.07
Trichloroethene ND 0.1
37891
Chloroform ND 6.8
Tetrachloroethene 7.1 B 7.1 B
Trichloroethene 0.5 1.3
39191
Carbon Tetrachloride 0.4 0.4
Chloroform 1.1 1.8
Tetrachloroethene 0.5 0.5
Trichloroethene 5 6.8 B
SECURITY FENCE
South Interceptor Ditch
Pond C-1
0387
Carbon Tetrachloride NS 8
Tetrachloroethene NS 3 J
Trichloroethene NS 6
0887
1,1-Dichloroethene NS 1 J
Carbon Tetrachloride NS 130
Chloroform NS 3 J
Tetrachloroethene NS 20
Trichloroethene NS 35
Former Retention Pond
Woman Creek
NOTE: VOC CONTAMINANTS NOT LISTED, WERE ANALYZED FOR AND NOT DETECTED. AT LEAST ONE SAMPLE FROM EACH OF THE WELLS HAS BEEN ANALYZED FOR TCL VOLATILES.
EXPLANATION
104 INDIVIDUAL HAZARDOUS SUBSTANCE SITE (IHSS) Dashed where disturbed during construction of French Drain
ROCKY FLATS ALLUVIUM
COLLUVIUM
VALLEY FILL ALLUVIUM
WEATHERED CLAYSTONE
LARAMIE-ARAPAHOE BEDROCK
J ESTIMATED VALUE BELOW INSTRUMENT CALIBRATION RANGE
B ANALYTE DETECTED IN BLANK
NS = NOT SAMPLED
ND = NOT DETECTED
Well 31791 | 1st QTR 1992 | 1986-2nd QTR 1992
Tetrachloroethene | 0.24 | 130
Analyte | Concentrations in ug/l | Historical Maximum
Wells Completed in Weathered Claystone May Be Influenced by UHSU Groundwater
N
0 100 200
SCALE: 1"=200'
U.S. DEPARTMENT OF ENERGY
Rocky Flats Environmental Technology Site
Golden, Colorado
881 HILLSIDE AREA
OPERABLE UNIT NO. 1
PHASE III RFI/RI REPORT FIGURE 4-27
Organic Compounds Detected in Lower Hydrostratigraphic Unit Groundwater
Figure 4-2
K:\MODELING\RFP\OU1\NEWCM\R74129

26



K:\MODELING\RFP\OU1\NFWCM\R74010

27



U.S. DEPARTMENT OF ENERGY
Rocky Flats Environmental Technology Site
Golden, Colorado

881 HILLSIDE AREA
OPERABLE UNIT NO. 1
PHASE III RFI/RI REPORT FIGURE 4-34

Total VOC & PAH Detections in the Vicinity of IHSS 119.1

Figure 4-9

K:\ MODELING\RFP\OU1\NEWCM\R74268

34