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Evaluation of the Soil-Gas Survey at the Nonradioactive Dangerous Waste Landfill

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Prepared for the U.S. Department of Energy
Office of Environmental Restoration

Bechtel Hanford, Inc.
Richland, Washington

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EXECUTIVE SUMMARY

Soil-gas samples were collected from six shallow probes (1.8 m deep) and 33 deep probes (8.8 to 29.7 m deep) at the Nonradioactive Dangerous Waste Landfill (NRDWL) to (1) assess the current distribution and potential movement of volatile organic compounds (VOC) in the vadose zone and (2) reaffirm the current priority for closure of NRDWL. The sampling locations focused on the eastern half of NRDWL, where VOCs were detected in a 1993 soil-gas survey. Six VOCs were detected during the 1997 survey: 1,1,1-trichloroethane (TCA); 1,1-dichloroethane (DCA), tetrachloroethylene, trichloroethylene, carbon tetrachloride, and chloroform. Of these contaminants, TCA was the most widespread and detected in all but one of the samples from the deep probes at concentrations less than 1 part per million by volume (ppmv); however, TCA was not detected in the samples from the shallow probes. Carbon tetrachloride and chloroform were the only contaminants detected at concentrations exceeding 1 ppmv; in samples from two adjacent locations (one shallow and two deep probes), concentrations ranged from 20 to 46 ppmv. All of the same contaminants, except DCA, were detected in the 1993 survey. Evaluation of the 1997 soil-gas results indicates that the potential risk at NRDWL is low compared to the potential risks associated with other 200 Area waste sites and does not merit changing the current priorities for closure.

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1.0 INTRODUCTION

1.1 BACKGROUND

The Nonradioactive Dangerous Waste Landfill (NRDWL) is a *Resource Conservation and Recovery Act of 1976* (RCRA) land disposal unit assigned to the 200-IU-3 Operable Unit. The landfill was used to dispose nonradioactive dangerous waste and asbestos waste from 1975 to 1985. A closure and postclosure plan for NRDWL was submitted in August 1990 (DOE-RL 1990) that recommended that waste be left in place and that a final cover be placed for closure. Notice of deficiency comments from the Washington State Department of Ecology (Ecology) were provided in January 1994 and April 1997. In 1996, a 200 Area soil remediation strategy was developed that redefined and reprioritized operable units into waste site groups, integrated RCRA and *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) activities, and defined an integrated assessment process within the U.S. Department of Energy, Richland Operations Office (RL) Environmental Restoration (ER) program (DOE-RL 1996, DOE-RL 1997). The NRDWL was assigned to the ER program's Nonradioactive Landfills Waste Group, which was considered low on the priorities list. However, the Ecology Unit Manager for NRDWL identified concerns that the potential for NRDWL being a source of groundwater contamination may require closure of NRDWL earlier than the priority for the Nonradioactive Landfills Waste Group. Ecology and RL agreed that the 1997 soil-gas survey was needed to confirm the closure priority assigned to NRDWL by providing an assessment of the current distribution and potential movement of the contaminants of concern.

1.2 PURPOSE

Volatile organic compounds (VOC) were detected primarily within and south of the eastern third of the NRDWL trenches during a 1993 shallow, (1.5 to 1.8 m deep) soil-gas survey and have been detected during groundwater monitoring of wells near NRDWL since 1987 (Jacques 1993, Hartman and Dresel 1997). The purpose of the 1997 soil-gas investigation was to (1) collect deep soil-gas data to assess the vertical extent of VOC contamination and the potential impacts to groundwater and (2) resample selected shallow gas probes to assess changes in contaminant distribution that may indicate contaminant movement.

1.3 SAMPLING AND ANALYSIS OBJECTIVE

The contaminants of concern (COC) for NRDWL are 1,1,1-trichloroethane (TCA), tetrachloroethylene (PCE), trichloroethylene (TCE), carbon tetrachloride, and chloroform based on previous soil-gas data from NRDWL (Jacques 1993). Using the data quality objectives (DQO) process, the Environmental Restoration Contractor (ERC), RL, and Ecology defined the following specific objectives for this investigation (Smith 1997):

1. Are the COCs within NRDWL moving? This question will be addressed by comparing the VOC concentrations measured in 1997 to those measured in 1993.

2. Where are the COCs now? This question will be addressed by determining the distribution of VOC contaminants in the subsurface focusing on the vertical extent of VOCs.

3. Do the results of this sampling effort merit changing NRDWL's priority for closure? This question will be addressed by evaluating the levels of VOC concentrations in the vadose zone and the potential impact of the detected VOC on the underlying groundwater.

1.4 VADOSE ZONE CHARACTERISTICS

The vadose zone underlying NRDWL is 38.4 to 40.8 m thick and consists of surficial dune sand overlying flood-deposited silts, sands, and gravels of the Hanford formation (Weekes et al. 1987). The surficial dune sand layer is 0.9 to 1.2 m thick. Beneath the surface sand is a narrow horizontal silt layer approximately 7.6 to 10 cm thick that marks the top of the sand subunit of the Hanford formation. This silt layer was evident in open trenches of NRDWL and was encountered in the undisturbed areas of the site in 1993 during the surface geophysical survey and while installing the shallow soil-gas probe network (Mitchell et al. 1993, Jacques 1993). In contrast to the undisturbed areas, the closed disposal trenches represent large disturbed areas containing reworked soil and waste. The disturbed portions of the site contain medium- to coarse-grained sand.

Based on drilling at NRDWL, the vadose zone consists of an upper, unconsolidated sand subunit with occasional thin silt layers underlain by a gravel subunit consisting of pebbles and cobbles with a variable matrix of silt and sand (Weekes et al. 1987). The contact between the sand and gravel subunits through NRDWL averages 19.2 m (63 ft) below ground surface; in wells 699-25-34B and 699-25-34D at the southeast corner of NRDWL, the contact is 25.9 m (85 ft) below ground surface (Weekes et al. 1987, WHC 1993).

2.0 SAMPLING AND ANALYSIS PLAN

The strategy and methods used to sample and analyze the soil gas within the subsurface at NRDWL are described in the *Nonradioactive Dangerous Waste Landfill Sampling and Analysis Plan and Data Quality Objectives Process Summary Report* (Smith 1997). The Sampling and Analysis Plan includes the Field Sampling Plan and the Quality Assurance Project Plan.

The sampling design was developed by the ERC, RL, and Ecology based on historical soil-gas data, site geohydrology, budget limitations, and professional judgement. The selection of horizontal locations was made based on the historical soil-gas data, which shows contaminants generally associated with the chemical trenches in the eastern half of NRDWL and with some apparent tendency to move southeast outside of NRDWL. The selection of deep vertical locations at 9.1, 18.3, 27.4, and 36.6 m were considered reasonably close to each other to establish vertical concentration profiles and sufficiently deep to assess potential impacts on groundwater, but still cost-effective. A total of 27 existing shallow probes and 56 new deep probes (4 depths at each of 14 locations) were selected for sampling (Figures 1 and 2, respectively). The probes were prioritized into three phases: samples from Phase I and II probes had the highest priority and were considered necessary to delineate the extent of contamination to meet the DQOs; samples from Phase III probes had the lowest priority and were intended to supplement the coverage and density of the primary effort, as needed. In general, a higher priority was placed on deeper samples outside NRDWL and on shallower samples within NRDWL, based on the working model that any soil-gas migration from NRDWL would tend to occur vertically as well as horizontally.

3.0 RESULTS OF PROBE INSTALLATION

A total of 35 probes were installed from August 18, 1997, through August 27, 1997: 2 shallow probes and 33 deep probes. Probes were installed at all of the target depths at all of the Phase I and Phase II locations, except all 14 target depths of 36.6 m and two target depths of 27.4 m; installation of these probes was limited by resistance of the subsurface to further rod penetration, referred to as refusal. In addition, the final depths of four probes (three probes targeted for depths of 27.4 m and one probe targeted for a depth of 18.3 m) differ from their target depths by more than ± 3 m, the tolerance allowed in the Sampling and Analysis Plan. The actual depths achieved at each sampling location are compared to the target depths in Table 1.

Before probe installation, the 1993 geophysical survey data were reviewed to ensure that buried waste would not be encountered. Within the NRDWL trench area, horizontal probe locations were adjusted slightly (by 0 to 3 m) to locations where intersecting east-west and north-south geophysical survey lines indicated no disturbed soil that could potentially contain buried waste; intersections of perpendicular geophysical survey lines were considered to provide significantly more information for subsurface evaluation than single lines. The Sampling and Analysis Plan allowed horizontal adjustments of up to 15.2 m. No buried materials were encountered during probe installation.

Soil-gas probes were installed using a Geoprobe Model 5400™ hydraulic probe driver. Each sample point consists of a dedicated stainless steel screen implant connected to a length of 0.64 cm outside diameter polyethylene tubing (Figure 3).

Refusal was typically encountered at depths ranging from 19.5 to 29.7 m, which correspond to the average depth of the sand-gravel contact. The primary cause of refusal is believed to be pebbles or cobbles in the gravel subunit. However, refusal was encountered twice at 13.4 m and once at 3.7 m, presumably by the presence of cobbles within the sand subunit. As described in the Sampling and Analysis Plan, only one attempt was made to reach the target depth at each

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Geoprobe Model 5400 is a trademark of Geoprobe Systems, Salina, Kansas.

location, and no additional attempts were made to drive to that depth or deeper depths at that location. At each location, the deepest target depth was attempted first. In general, the resistance to probe installation increased at approximately 9 m below ground surface and again at 18 m.

During probe installation, eight initial attempts were abandoned (Table 2); at these locations, probes were successfully installed during later attempts. At one location, the installation was abandoned because of shallow refusal (3.7 m); at six locations, the installations were abandoned because of difficulties with the sample tip or screen placement. At three locations (D-8, D-9, and D-10), the rods broke in the subsurface and could be not be retrieved (at D-8, however, the sample probe was tested and found to be usable). The rod breakage was attributed primarily to metal fatigue, combined with installation at undisturbed locations. A total of 26.7 m of rod was left in place. New rods that were delayed in transit were received on the following workday and used for the remaining field work; no additional rod breakage was encountered.

4.0 RESULTS OF SOIL-GAS SAMPLING AND ANALYSIS

Soil-gas samples were collected and analyzed on September 2, 1997, and September 4, 1997, from all of the Phase I and II probes that were installed. The existing, shallow Phase III probes were not sampled due to the emphasis on analysis of samples from the deeper probes. Six VOCs were detected: TCA, 1,1-dichloroethane (DCA), PCE, TCE, carbon tetrachloride, and chloroform (Jacques 1997). Of these contaminants, TCA was the most widespread, detected in all but one of the samples from deep probes at concentrations less than 1 ppmv, but in none of the samples from the shallow probes. Carbon tetrachloride and chloroform were the only contaminants detected at concentrations exceeding 1 ppmv. In samples from three probes at two locations (two samples from S-4/1.8 m, one from D-3/8.8 m, and one from D-3/23.2 m), carbon tetrachloride concentrations ranged from 20 to 45 ppmv; concentrations exceeded the calibration range (0 to 23 ppmv) in samples from probes S-4/1.8 m and D-3/23.2 m. In the same samples from these probes, chloroform concentrations ranged from 22 to 46 ppmv; concentrations exceeded the calibration range (0 to 23 ppmv) in one sample from each probe. The actual values for concentrations that exceeded the calibration range are likely to be slightly higher (5 to 10%) because the slopes of the calibration curves decrease as the detector becomes more saturated with the contaminant. The VOC results for soil-gas and quality control samples are summarized in Table 3 (Jacques 1997).

Soil-gas samples were collected in the morning of each sampling day and analyzed on the same day in the afternoon. The VOC results were generated using a Photovac 10S Plus portable gas chromatograph. The gas chromatograph was calibrated using prepared calibration standards that had a concentration tolerance of ± 2%; three-point calibration curves were established for each analyte (Figure 4). The calibration for the 1 ppmv range, which contained the majority of the analyte concentrations, was checked each day that samples were analyzed. The minimum detection limits and practical quantitation limits were established for the analyses; the reporting limit was rounded to 0.10 ppmv for each analyte (Table 4). Additional details are described in Jacques (1997).

Soil-gas sample collection from five probes was difficult. During attempts to collect samples from probes at D-4/9.1 m, D-5/9.1 m, and D-6/9.1 m, the lower ends of the sample tubes contained water that prevented withdrawal of a full purge volume of vapor; the vapor sample collected for analysis consisted of the vapor present in the tube when sample extraction began (i.e., the purge gas). As extraction continued, the water appeared to fill the sample tube as it was drawn to the surface, implying that a readily available source of water (i.e., perched water) was present at the probe depth. These observations are consistent with the theoretically limiting depth (9.75 m) from which the sample pump could lift water; water samples were not collected. Because these three vapor samples are not representative of subsurface vapor, the analytical results were not included in the data evaluation; however, the results are included in Table 3 for completeness. Probe D-10/13.4 m was also difficult to sample due to the presence of moisture, but the sample tube was successfully purged before collecting the vapor sample. Vapor sample collection was also difficult at probe D-3/23.2 m. The samples from these two probes are considered suspect, but due to the significant concentration levels indicated in the analytical results from the D-3/23.2 m sample, they were included in the data evaluation.

The results of the 1997 soil-gas survey were consistent with results from past soil-gas sampling and analysis at NRDWL. All of the same VOCs detected in 1993 in samples from shallow probes at NRDWL were also detected in 1997 in samples from shallow and deep probes (Jacques 1993). In addition, analyses of five deep soil-gas samples collected during drilling of wells 699-25-34D and 699-26-34B in 1993 at the north and south boundaries of the eastern half of NRDWL indicated that the only VOC present at higher concentration at depth was carbon tetrachloride, detected at concentrations of 9 to 10 ppmv in two samples, one from 25 m depth at the southern well and one at 37.5 m depth at the northern well (WHC 1993). In 1997, carbon tetrachloride was also the only VOC detected at concentrations exceeding 1 ppmv in deep samples.

The analyses of the 1997 deep soil-gas samples provide a baseline for VOC concentrations at depth. TCA was detected in 29 of the 30 samples included for data evaluation from the deep probes at concentrations ranging from approximately 0.07 to 0.37 ppmv (Figure 5). TCA concentrations are higher within and south of the NRDWL trenches; concentrations between 0.2 and 0. 4 ppmv were generally detected in the deeper samples. DCA was detected in samples from only two probes, both at D-11, at concentrations ranging from approximately 0.09 to 0.10 ppmv. DCA (a degradation product of TCA) was detected in the samples that had higher concentrations of TCA. The results for DCA were not illustrated on plots because there were so few detections. PCE was detected at concentrations ranging from approximately 0.06 to 0.43 ppmv, and TCE was detected at concentrations ranging from approximately 0.05 to 0.25 ppmv, in samples from deep probes (Figures 6 and 7). PCE and TCE concentrations tend to be higher within and south of the NRDWL trenches. Carbon tetrachloride was detected at concentrations ranging from approximately 0.08 to approximately 42 ppmv, and chloroform was detected at concentrations ranging from approximately 0.08 to approximately 46 ppmv, in samples from deep probes (Figures 8 and 9). For both contaminants, concentrations exceeding 1 ppmv were detected in samples from two probes at location D-3 at the edge of chemical trench 34: D-3/8.8 m and D-3/23.2 m. Each detection of TCA, PCE, TCE, carbon tetrachloride, and chloroform are shown in relation to depth in Figure 10.

The analyses of the 1997 shallow, soil-gas samples can be compared to the 1993 analyses of samples from the same locations (Table 5). In 1997, TCA, DCA, and TCE were detected in none of the samples from the shallow probes. PCE was detected in samples from 4 of the 6 shallow probes at concentrations ranging from 0.05 to 0.60 ppmv. Carbon tetrachloride and chloroform were detected in samples from two adjacent shallow probes in chemical trenches 33 and 34: S-3 and S-4. In the two samples from probe S-4, carbon tetrachloride concentrations averaged approximately 43 ppmv, and chloroform concentrations averaged approximately 24 ppmv.

During the 1993 soil-gas survey, all of these contaminants, except DCA, were detected at shallow probes at NRDWL. The Photovac gas chromatograph used during the 1993 survey had a 10.6 eV lamp, which does not provide quantitation for some of the chlorinated hydrocarbon compounds as accurately as the 11.7 eV lamp currently in use. However, vapor samples were recollected from the chemical trenches in 1993 and analyzed using a Scentograph gas chromatograph, which provides more reliable results than the 10.6 eV lamp for TCA, carbon tetrachloride, and chloroform.

The 1993 results for the same six shallow probes that were sampled in 1997 indicate detections of TCA in samples from two of the probes, DCA in none of the samples, TCE in samples from five of the probes, and PCE in samples from five of the probes. Carbon tetrachloride and chloroform were detected in samples from probes S-3 and S-4, and chloroform was also detected in the sample from probe S-2. The 1993 results for PCE and TCE for all of the shallow probes are illustrated in Figures 11 and 12, respectively.

The maximum concentrations detected for each VOC during the 1993 and 1997 surveys at all locations are listed in Table 6. In general, for the shallow probes, the maximum detected concentrations of TCA, PCE, and TCE have decreased, and the maximum detected concentrations of carbon tetrachloride and chloroform have increased.

5.0 IMPLICATIONS FOR THE DQO QUESTIONS

The results of the soil-gas survey were used to address the three DQO questions.

1. Are the COCs within NRDWL moving?

In general, the 1993 and 1997 soil-gas samples were collected at different depths and over different areas, making comparison difficult. To evaluate migration within the deep zone, additional sampling and analysis would be required over time. However, limited comparison of analytical results for 1993 and 1997 soil-gas samples suggests that the contaminants within NRDWL have not migrated significantly. Comparison of the concentrations detected in shallow samples indicates that maximum carbon tetrachloride concentrations are still laterally within the chemical trenches at NRDWL. Comparison of the concentrations detected in deep samples suggests that vertical migration of carbon tetrachloride was directly beneath the chemical trenches within a narrow zone. In general, the same VOCs that were detected in 1993 were detected in 1997.

2. Where are the COCs now?

Based on the 1997 soil-gas survey results, the soil vapor contaminants tend to be distributed at low concentration levels within or south of the NRDWL trenches. Soil vapor concentrations of TCA tend to be higher with depth. Soil vapor concentrations of PCE generally tend to be lower with depth. The highest concentrations of carbon tetrachloride and chloroform are detected in shallow and deep samples within and beneath the chemical trenches and are very localized.

3. Do the results of this sampling effort merit changing NRDWL's priority for closure?

Low concentration levels of VOC (less than 1 ppmv) were detected within and south of the eastern half of NRDWL. Only carbon tetrachloride and chloroform were detected at concentrations exceeding 1 ppmv; these higher concentrations (approximately 20 to 46 ppmv) were detected within and beneath chemical trenches 33 and 34. Concentrations of the VOC contaminants detected during the soil-gas survey have been generally decreasing in the NRDWL groundwater wells (Figures 13 through 19).

The only VOC contaminant detected in the soil-gas of potential concern with regard to groundwater quality is carbon tetrachloride. Detections of carbon tetrachloride in groundwater between 1991 and 1996 were sporadic and difficult to attribute to a particular point source. Groundwater will continue to be monitored to assess concentration trends. This potential risk is low compared to the potential risks associated with other 200 Area waste sites and does not merit changing the current priorities for NRDWL as described in the Waste Site Grouping report (DOE-RL 1997).

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Table 1. Summary of NRDWL Soil-Gas Probe Installation. (Page 1 of 3)

Phase	Location Number "S" = Shallow "D" = Deep	Probe Target Depth (m)	Probe Actual Depth (m)	Borehole Identification Number	Date Installed
I	S-1	1.8	1.8	N/A	1993
I	S-2	1.8	1.8	B8167	8/18/97
I	S-3	1.8	1.8	B8166	8/18/97
I	S-4	1.8	1.8	N/A	1993
I	S-5	1.8	1.8	N/A	1993
I	S-6	1.8	1.8	N/A	1993
I	D-1	9.1	9.1	B8170	8/18/97
I		18.3	19.5	B8169	8/18/97
I		27.4	25.9*	B8168	8/18/97
I		36.6			
I	D-2	9.1	9.1	B8174	8/19/97
I		18.3	18.3	B8172	8/19/97
I		27.4	29.3*	B8171	8/19/97
I		36.6			
I	D-3	9.1	8.8*	B8176	8/19/97
I		18.3	18.3	B8177	8/19/97
I		27.4	23.2*	B8175	8/19/97
II		36.6			
I	D-4	9.1	9.1	B8179	8/20/97
I		18.3	18.3	B8178	8/20/97
II		27.4	27.1*	B8432	8/26/97
II		36.6			

Table 1. Summary of NRDWL Soil-Gas Probe Installation. (Page 2 of 3)

Phase	Location Number "S" = Shallow "D" = Deep	Probe Target Depth (m)	Probe Actual Depth (m)	Borehole Identification Number	Date Installed
II	D-5	9.1	9.1	B8430	8/26/97
II		18.3	18.3	B8429	8/26/97
II		27.4	26.8*	B8428	8/26/97
II		36.6			
I	D-6	9.1	9.1	B8183	8/20/97
I		18.3	18.3	B8181	8/20/97
I		27.4	22.6*	B8180	8/20/97
I		36.6			
I	D-7	9.1	9.1	B8187	8/21/97
I		18.3	18.3	B8188	8/21/97
I		27.4	26.4*	B8184	8/20/97
I		36.6			
I	D-8	18.3	18.3	B8190	8/21/97
I		27.4	29.7*	B8189	8/21/97
I		36.6			
I	D-9	18.3	19.5*	B8444	8/27/97
I		27.4			
I		36.6			
II	D-10	18.3	13.4*	B8194	8/22/97
I		27.4	25.1*	B8192	8/22/97
I		36.6			
II	D-11	18.3	18.3	B8427	8/25/97
I		27.4	26.2*	B8426	8/25/97
I		36.6			

Table 1. Summary of NRDWL Soil-Gas Probe Installation. (Page 3 of 3)

Phase	Location Number "S" = Shallow "D" = Deep	Probe Target Depth (m)	Probe Actual Depth (m)	Borehole Identification Number	Date Installed
II	D-12	18.3	18.6	B8195	8/25/97
II		27.4	13.4*	B8196	8/25/97
II		36.6			
II	D-13	18.3	18.3	B8434	8/27/97
II		27.4	26.2*	B8433	8/26/97
II		36.6			
II	D-14	18.3	19.5*	B8435	8/27/97
II		27.4			
II		36.6			

*Depth at refusal; actual probe depth generally paired with closest available target depth.

Table 2. NRDWL Abandoned Probe Installations.

Location Number	Depth of Installation (m)	Length of Rod Left in Ground (m)	Borehole Identification Number	Date Attempted	Reason for Abandonment
D-2	9.1	0	B8173	8/19/97	Tip would not release
D-6	3.7	0	B8182	8/20/97	Lost tip
D-7	10.4	0	B8185	8/21/97	Tip would not release
D-7	18.3	0	B8186	8/21/97	Could not set screen
D-8*	29.7	3.6	B8189	8/21/97	Joint broke at 25.9 m bgs during backpull; sample point usable
D-9	17.7	8.5	B8191	8/21/97	Rods broke at 9.1 m bgs
D-10	15.1	14.6	B8193	8/22/97	Could not thread sample screen past 12.2 m; top rod broke at joint during backpull
D-11	3.7	0	B8197	8/25/97	Refusal at 3.7 m bgs
D-4	2.4	0	B8431	8/26/97	Lost tip

*Probe installation not abandoned
bgs = below ground surface

Table 3. Analytical Results for Soil-Gas Samples Collected at NRDWL, September 1997.

Sample & Analysis Date	Probe Number	Depth (m)	Purge Volume (mL)	1,1,1-TCA (ppmv)	1,1-DCA (ppmv)	PCE (ppmv)	TCE (ppmv)	Carbon Tetrachloride (ppmv)	Chloroform (ppmv)	HEIS Number
9/2/97	Ambient Air	NA	900	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	BOLM21
9/2/97	Cal Check	NA	NA	0.93	0.91	0.92	0.92	0.95	0.89	BOLM42
9/2/97	Cal Check	NA	NA	0.96	0.99	0.94	0.98	0.98	0.98	BOLM43
9/2/97	Cal Standard	NA	NA	1.0	1.0	1.0	1.0	1.0	1.0	BOLM41
9/4/97	Ambient Air	NA	1000	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	BOLM44
9/4/97	Cal Check	NA	NA	0.96	0.95	0.94	0.96	0.91	0.90	BOLM69
9/4/97	Cal Check	NA	NA	0.97	0.97	0.93	0.96	0.99	1.0	BOLM70
9/4/97	Cal Standard	NA	NA	1.0	1.0	1.0	1.0	1.0	1.0	BOLM68
9/4/97	S-1	1.8	100	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	BOLM65
9/4/97	S-2	1.8	100	<0.10	<0.10	0.15	<0.10	<0.10	<0.10	BOLM56
9/4/97	S-3	1.8	100	<0.10	<0.10	0.068 j	<0.10	0.82	0.94	BOLM63
9/2/97	S-4	1.8	100	<0.10	<0.10	0.53	<0.10	41 e	22	BOLM40
9/4/97	S-4 replicate	1.8	100	<0.10	<0.10	0.60	<0.10	45 e	25 e	BOLM64
9/4/97	S-5	1.8	100	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	BOLM66
9/4/97	S-6	1.8	100	<0.10	<0.10	0.053 j	<0.10	<0.10	<0.10	BOLM67
9/4/97	D-1	9.1	450	0.098 j	<0.10	0.37	<0.10	<0.10	<0.10	BOLM57
9/4/97	D-1	19.5	960	0.20	<0.10	0.31	<0.10	<0.10	<0.10	BOLM58
9/4/97	D-1	25.9	1275	0.18	<0.10	0.27	<0.10	<0.10	<0.10	BOLM59
9/4/97	D-2	9.1	450	0.16	<0.10	0.35	<0.10	0.12	0.14	BOLM60
9/4/97	D-2	18.3	900	0.18	<0.10	0.30	<0.10	<0.10	0.14	BOLM61
9/4/97	D-2	29.3	1440	0.19	<0.10	0.20	<0.10	<0.10	<0.10	BOLM62
9/4/97	D-3	8.8	435	0.10	<0.10	<0.10	0.051 j	20	37 e	BOLM46
9/4/97	D-3	18.3	900	0.24	<0.10	0.43	0.068 j	0.45	1.6	BOLM47
9/4/97	D-3	23.2	500 b	<0.10	<0.10	0.21	<0.10	42 e	46 e	BOLM48
9/4/97	D-4	9.1	250 a,c	0.14	<0.10	0.087 j	<0.10	0.22	0.23	BOLM49
9/4/97	D-4	18.3	900	0.30	<0.10	0.37	0.071 j	0.13	0.31	BOLM50
9/4/97	D-4	27.1	1335	0.31	<0.10	0.22	0.063 j	0.099 j	0.26	BOLM51
9/4/97	D-5	9.1	250 a,c	<0.10	<0.10	<0.10	<0.10	<0.10	0.18	BOLM52
9/4/97	D-5	18.3	900	0.27	<0.10	0.32	<0.10	<0.10	0.11	BOLM53
9/4/97	D-5	26.8	1320	0.27	<0.10	0.23	<0.10	<0.10	0.11	BOLM54
9/4/97	D-5 Duplicate	26.8	1320	0.25	<0.10	0.28	<0.10	<0.10	0.12	BOLM55
9/4/97	D-6	9.1	250 a,c	0.057 j	<0.10	<0.10	<0.10	<0.10	<0.10	BOLM45
9/2/97	D-6	18.3	900	0.28	<0.10	<0.10	<0.10	<0.10	0.080 j	BOLM38
9/2/97	D-6	22.6	1110	0.19	<0.10	0.068 j	<0.10	0.087 j	0.12	BOLM39
9/2/97	D-7	9.1	450	0.10	<0.10	<0.10	<0.10	<0.10	<0.10	BOLM24
9/2/97	D-7	18.3	900	0.31	<0.10	<0.10	0.073 j	<0.10	<0.10	BOLM25
9/2/97	D-7	26.4	1320	0.32	<0.10	<0.10	0.077 j	<0.10	<0.10	BOLM26
9/2/97	D-8	18.3	900	0.37	<0.10	0.087 j	0.16	<0.10	<0.10	BOLM31
9/2/97	D-8	29.7	1460	0.31	<0.10	0.069 j	0.10	<0.10	<0.10	BOLM32
9/2/97	D-9	19.5	960	0.24	<0.10	<0.10	<0.10	<0.10	<0.10	BOLM20
9/2/97	D-10	13.4	660 a	.074 j	<0.10	<0.10	<0.10	<0.10	<0.10	BOLM22
9/2/97	D-10	25.1	1240	0.19	<0.10	<0.10	<0.10	<0.10	<0.10	BOLM23
9/2/97	D-11	18.3	900	0.35	0.10	0.095 j	0.25	<0.10	<0.10	BOLM33
9/2/97	D-11	26.2	1290	0.36	0.088 j	0.12	0.19	<0.10	<0.10	BOLM34
9/2/97	D-12	13.4	660	0.30	<0.10	0.060 j	0.059 j	0.11	0.15	BOLM35
9/2/97	D-12	18.6	915	0.34	<0.10	0.11	0.072 j	0.087 j	0.17	BOLM36
9/2/97	D-13	18.3	900	0.36	<0.10	0.070 j	0.19	<0.10	<0.10	BOLM29
9/2/97	D-13	26.2	1290	0.33	<0.10	0.074 j	0.13	<0.10	<0.10	BOLM30
9/2/97	D-14	19.5	960	0.22	<0.10	<0.10	0.078 j	<0.10	<0.10	BOLM27
9/2/97	D-14 Duplicate	19.5	NA	0.24	<0.10	<0.10	0.077 j	0.067 j	<0.10	BOLM28

a: Sample probe contained moisture and was difficult to sample

b: Sample probe was plugged or contained moisture and was difficult to sample

c: Low sample volume

e: Value exceeds calibration range

j: Value less than reporting limit

NA Not Applicable

Table 4. Minimum Detection Limits (MDL) and Practical Quantitation Limits (PQL).

Limit	1,1,1-TCA (ppmv)	1,1-DCA (ppmv)	PCE (ppmv)	TCE (ppmv)	Carbon Tetrachloride (ppmv)	Chloroform (ppmv)
MDL	0.027	0.028	0.031	0.027	0.026	0.024
PQL	0.082	0.083	0.093	0.080	0.077	0.072
Reporting	0.100	0.100	0.100	0.100	0.100	0.100

Table 5. VOC Concentrations Detected in Samples from Shallow Probes S-1 through S-6 in 1993.

Probe	1,1,1-TCA (ppmv)	PCE (ppmv)	TCE (ppmv)	Carbon Tetrachloride (ppmv)	Chloroform (ppmv)
Analyzed Using the Photovac 10S Plus with 10.6eV Lamp					
S-1	ND	0.017	ND	ND	ND
S-2	0.120	0.620	0.013	ND	ND
S-3	ND	0.390	0.018	4.500	3.000
S-4	ND	5.000	0.028	ND	ND
S-5	ND	<0.010	<0.010	ND	ND
S-6	ND	0.084	0.043	ND	ND
Analyzed Using the Scentograph Gas Chromatograph					
S-1	0.110	0.180	<0.010	ND	<0.010
S-2	ND	2.380	0.025	ND	0.065
S-3	ND	0.730	0.071	8.000	8.800
S-4	0.120	8.100	0.035	0.300	0.560
S-5	NS	NS	NS	NS	NS
S-6	NS	NS	NS	NS	NS

ND = Not Detected
NS = Not Sampled

Table 6. Maximum VOC Concentrations Detected in 1997 and 1993 Soil-Gas Surveys.

Year Depth	1,1,1-TCA (ppmv)	1,1-DCA (ppmv)	PCE (ppmv)	TCE (ppmv)	Carbon Tetrachloride (ppmv)	Chloroform (ppmv)
1997 Shallow	<0.10	<0.10	0.60	<0.10	45	25
1997 Deep	0.37	0.10	0.43	0.25	42	46
1993 Shallow*	8.7	ND	8.1	0.20	8	8.8
1993 Deep	ND	ND	ND	ND	9.7	ND

*Analyzed Using Scentograph Gas Chromatograph
ND = Not Detected

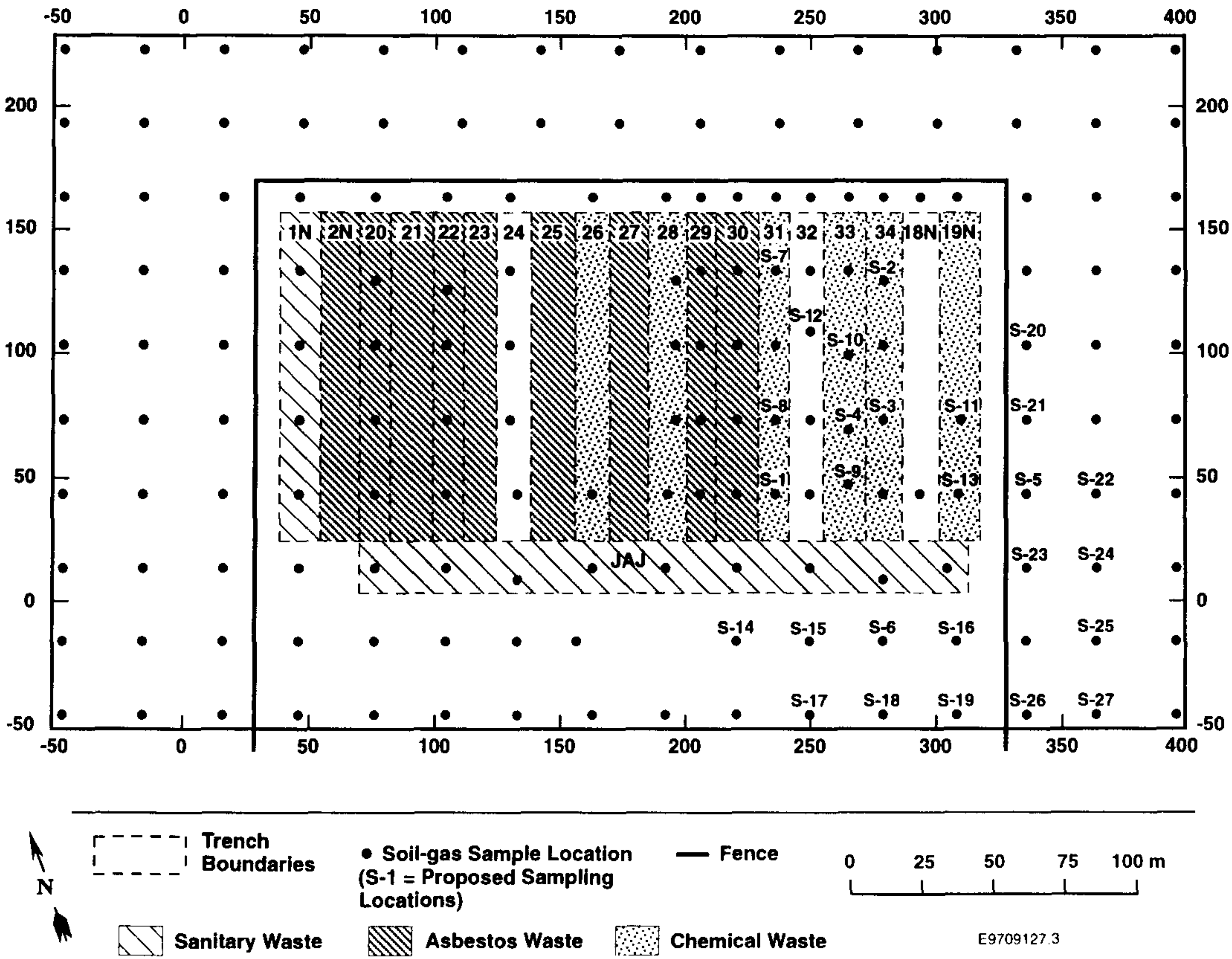


Figure 1. Proposed Shallow Soil-Gas Sampling Locations.

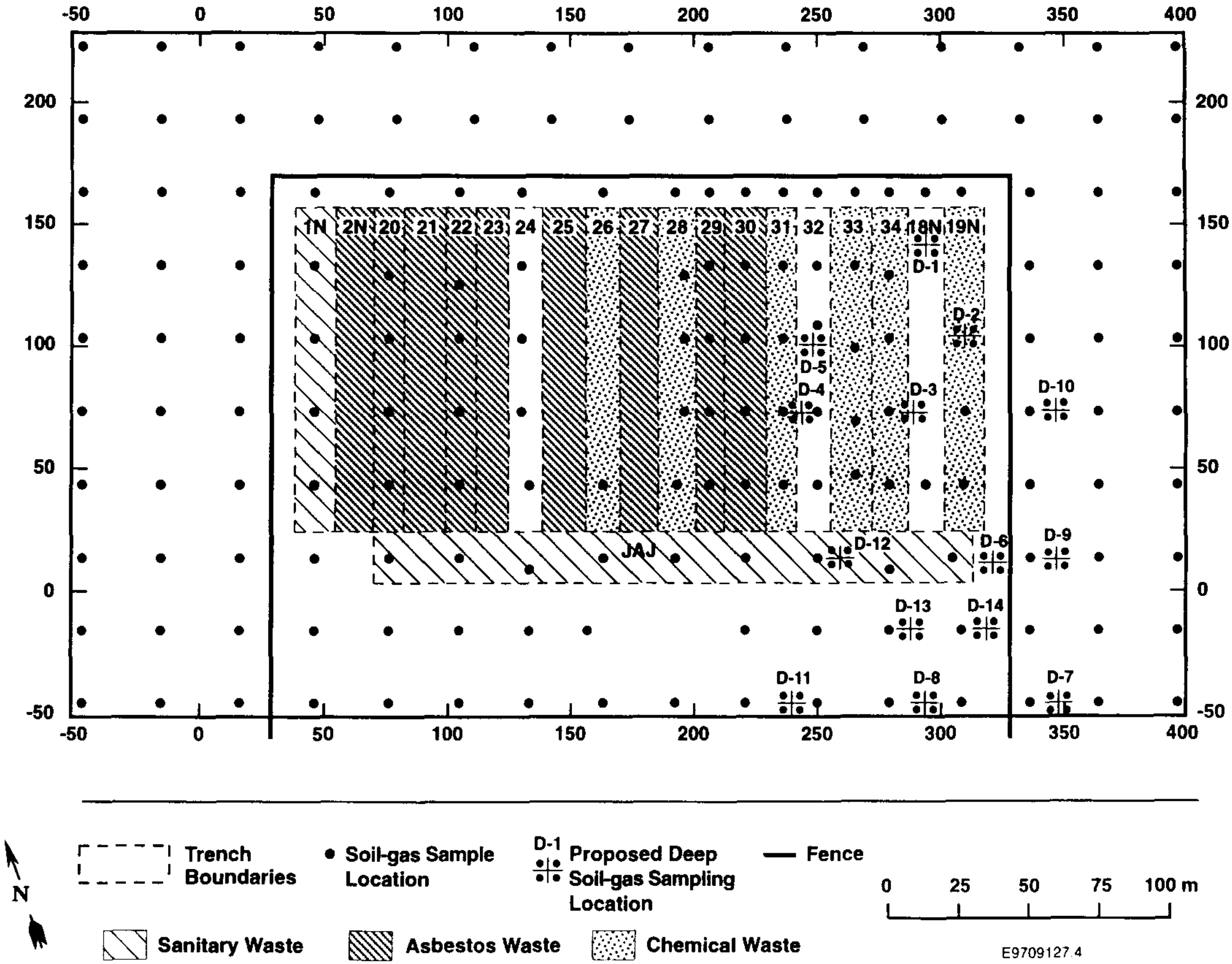


Figure 2. Proposed Deep Soil-Gas Sampling Locations.

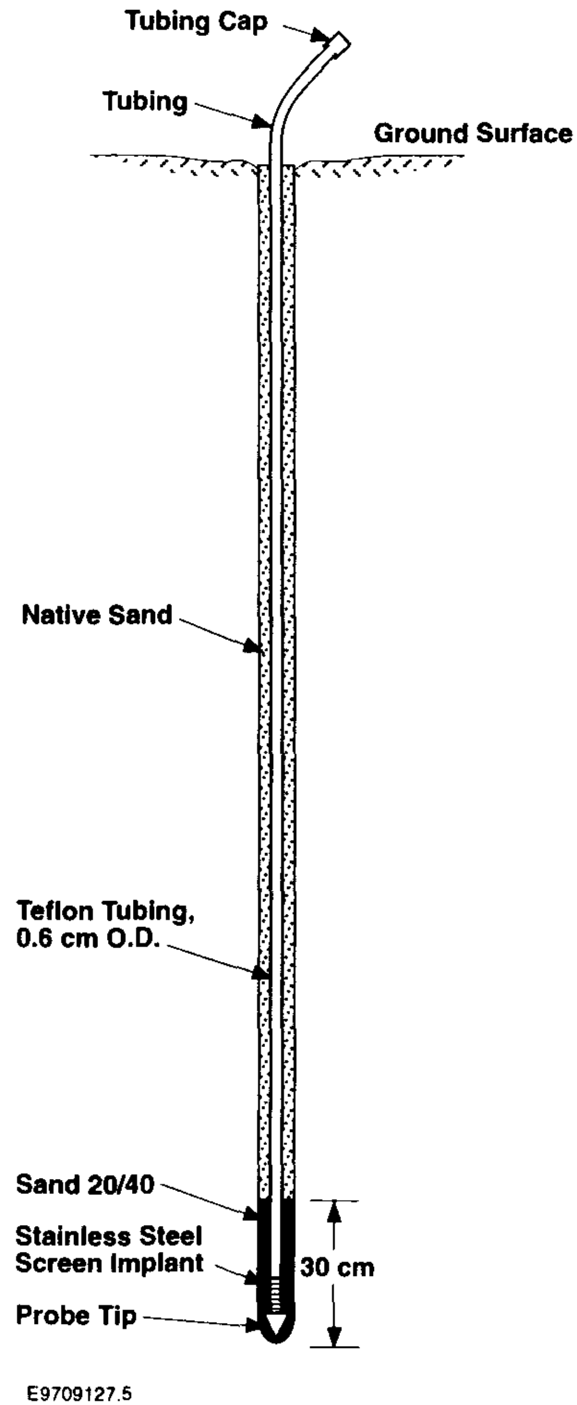
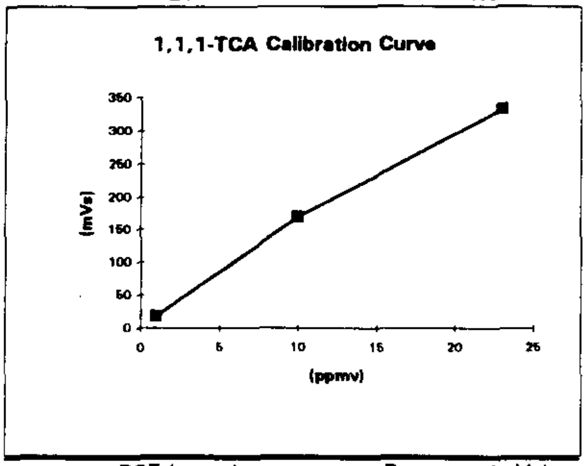


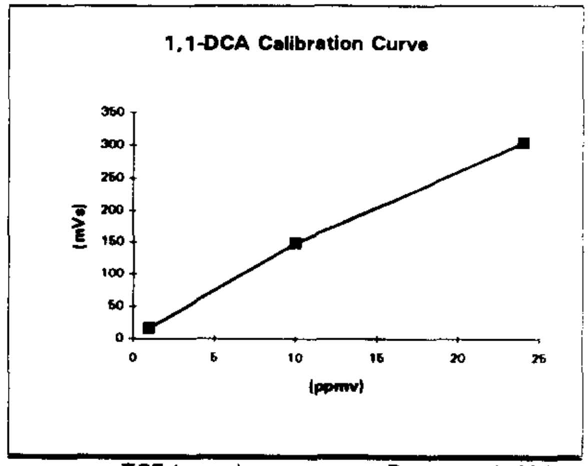
Figure 3. Typical NRDWL Soil-Gas Probe.

Figure 4. Calibration Curves for the NRDWL Soil-Gas Survey.

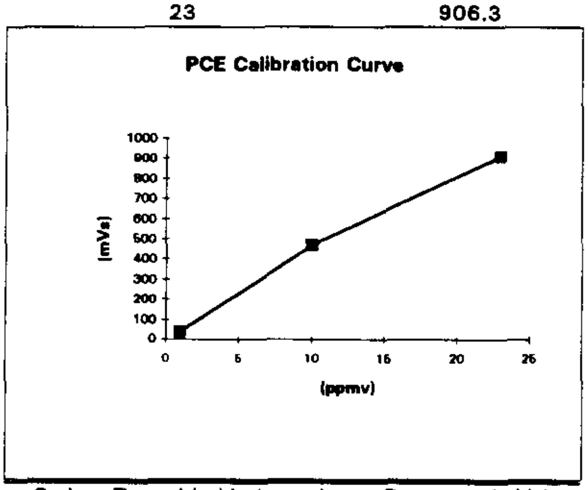
1,1,1-TCA (ppmv)	Response (mVs)
1.0	18.7
10	170.1
23	334.0



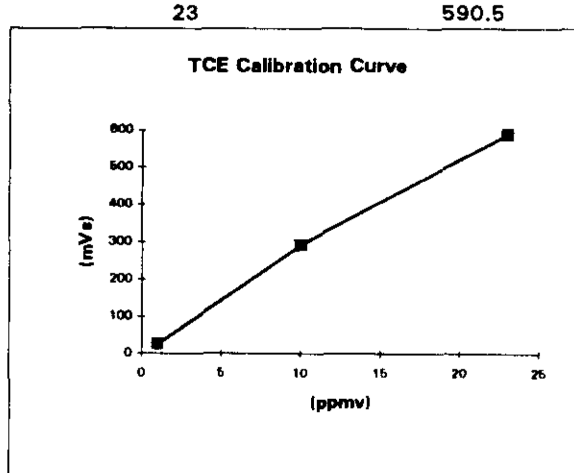
1,1-DCA (ppmv)	Response (mVs)
1.0	15.8
10	148.2
24	303.5



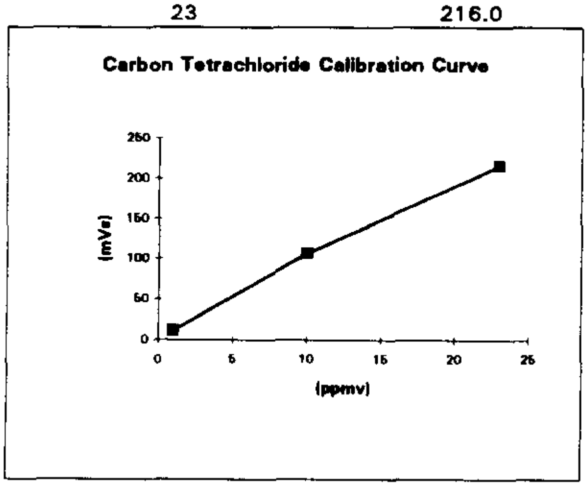
PCE (ppmv)	Response (mVs)
1.0	37.2
10	467.1
23	906.3



TCE (ppmv)	Response (mVs)
1.0	26.3
10	292.2
23	590.5



Carbon Tetrachloride (ppmv)	Response (mVs)
1.0	10.8
10	106.3
23	216.0



Chloroform (ppmv)	Response (mVs)
1.0	9.7
10	97.4
23	199.7

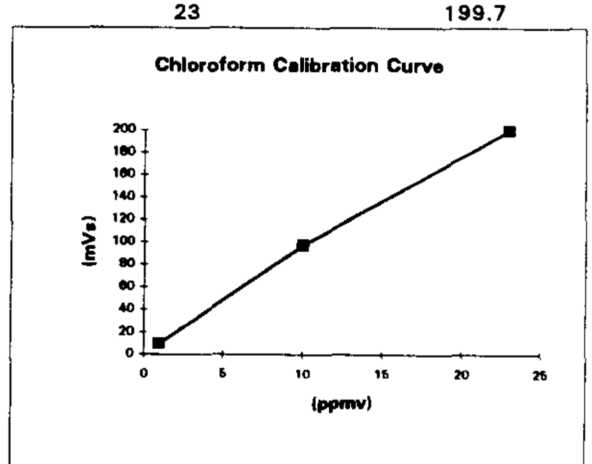


Figure 5. 1997 Soil-Gas Survey Results for TCA.

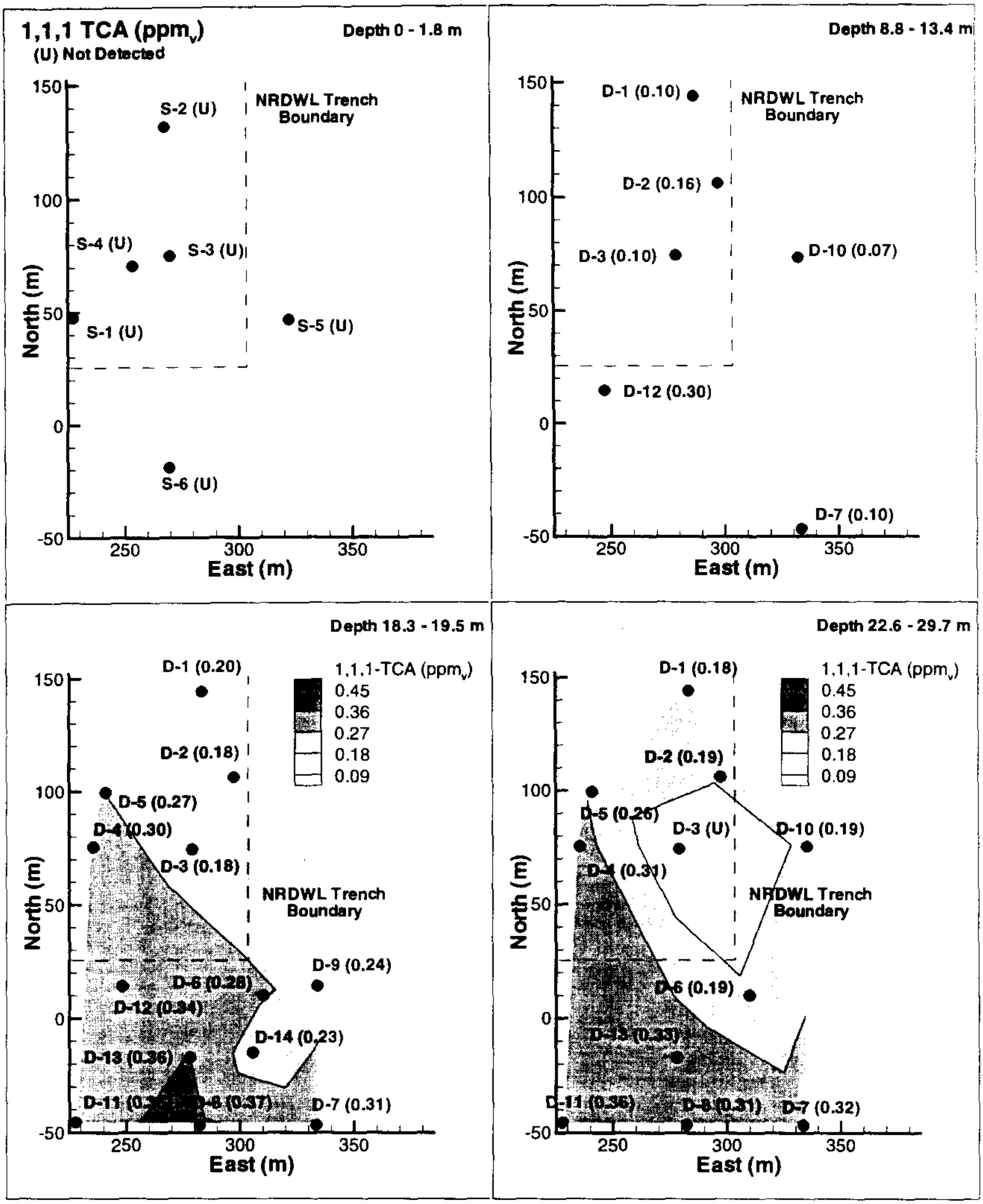


Figure 6. 1997 Soil-Gas Survey Results for PCE.

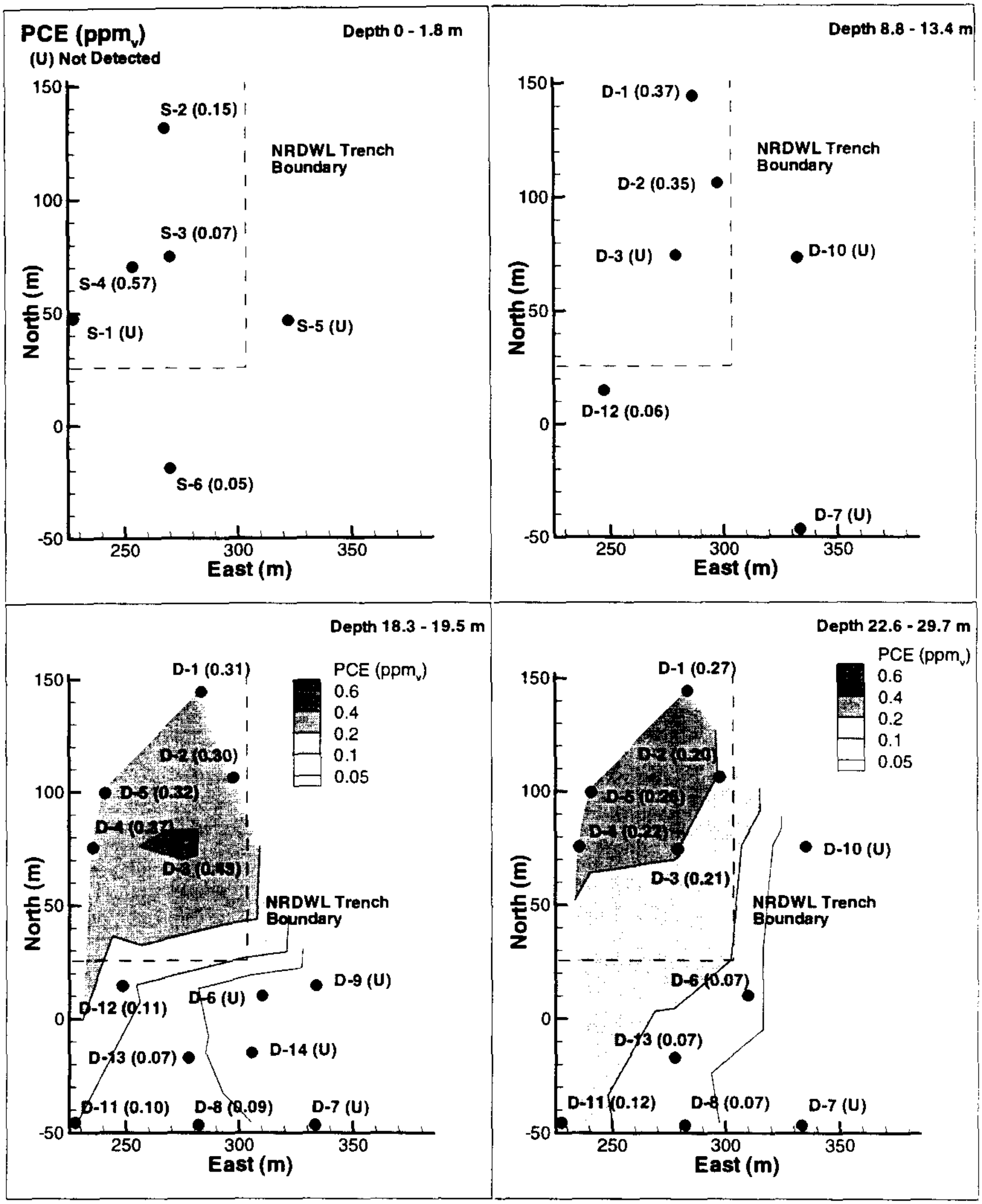


Figure 7. 1997 Soil-Gas Survey Results for TCE.

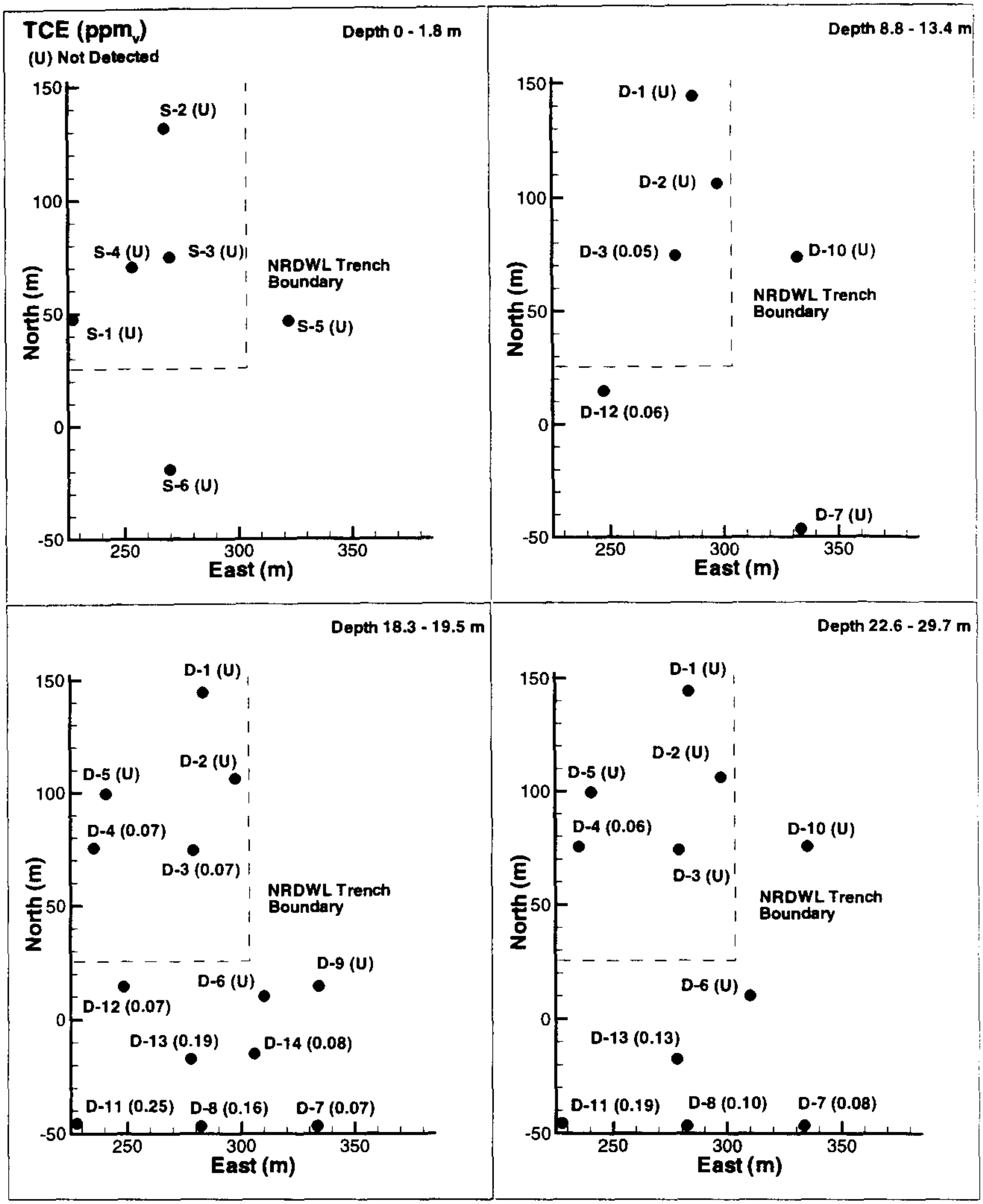


Figure 8. 1997 Soil-Gas Survey Results for Carbon Tetrachloride.

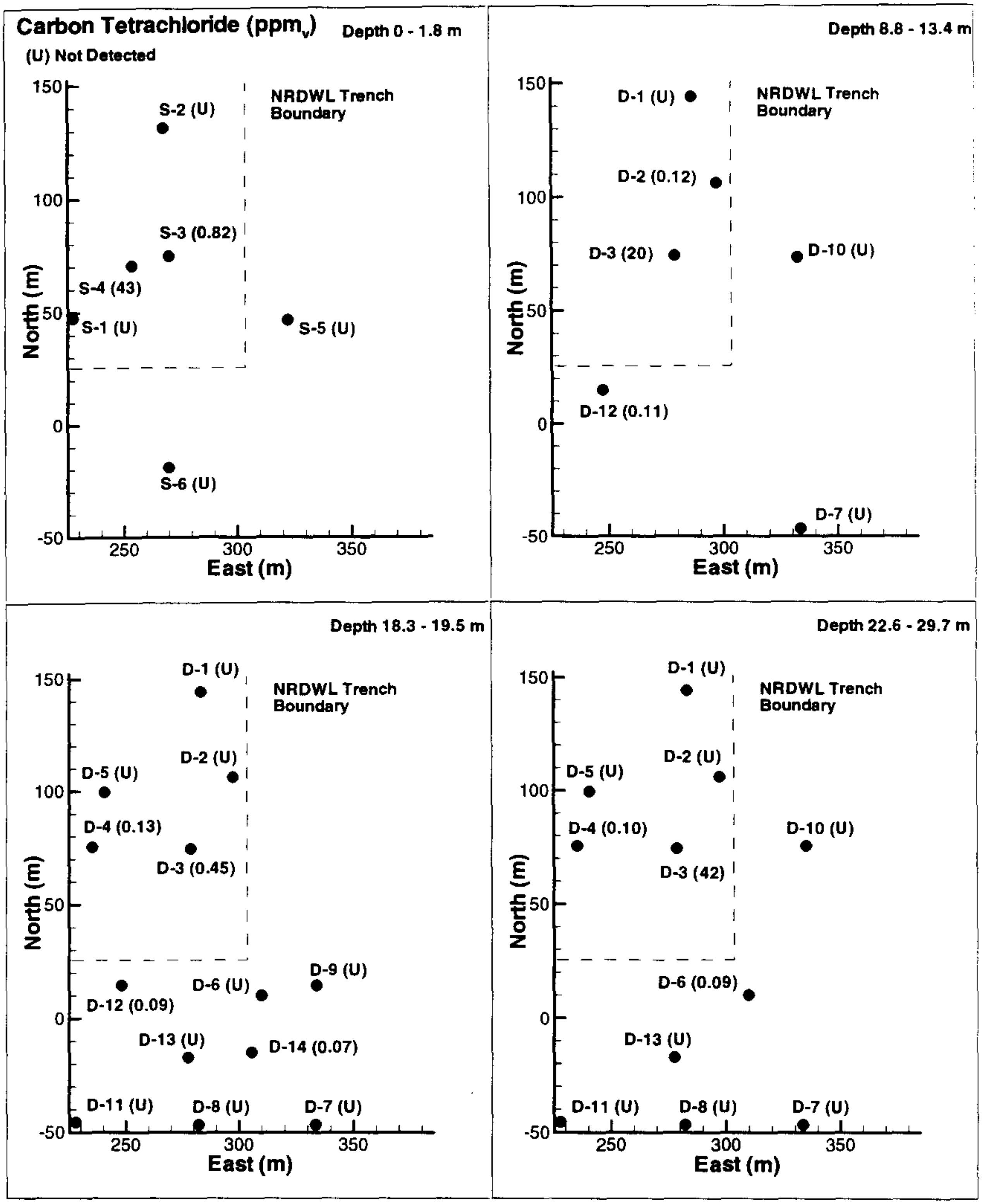


Figure 9. 1997 Soil-Gas Survey Results for Chloroform.

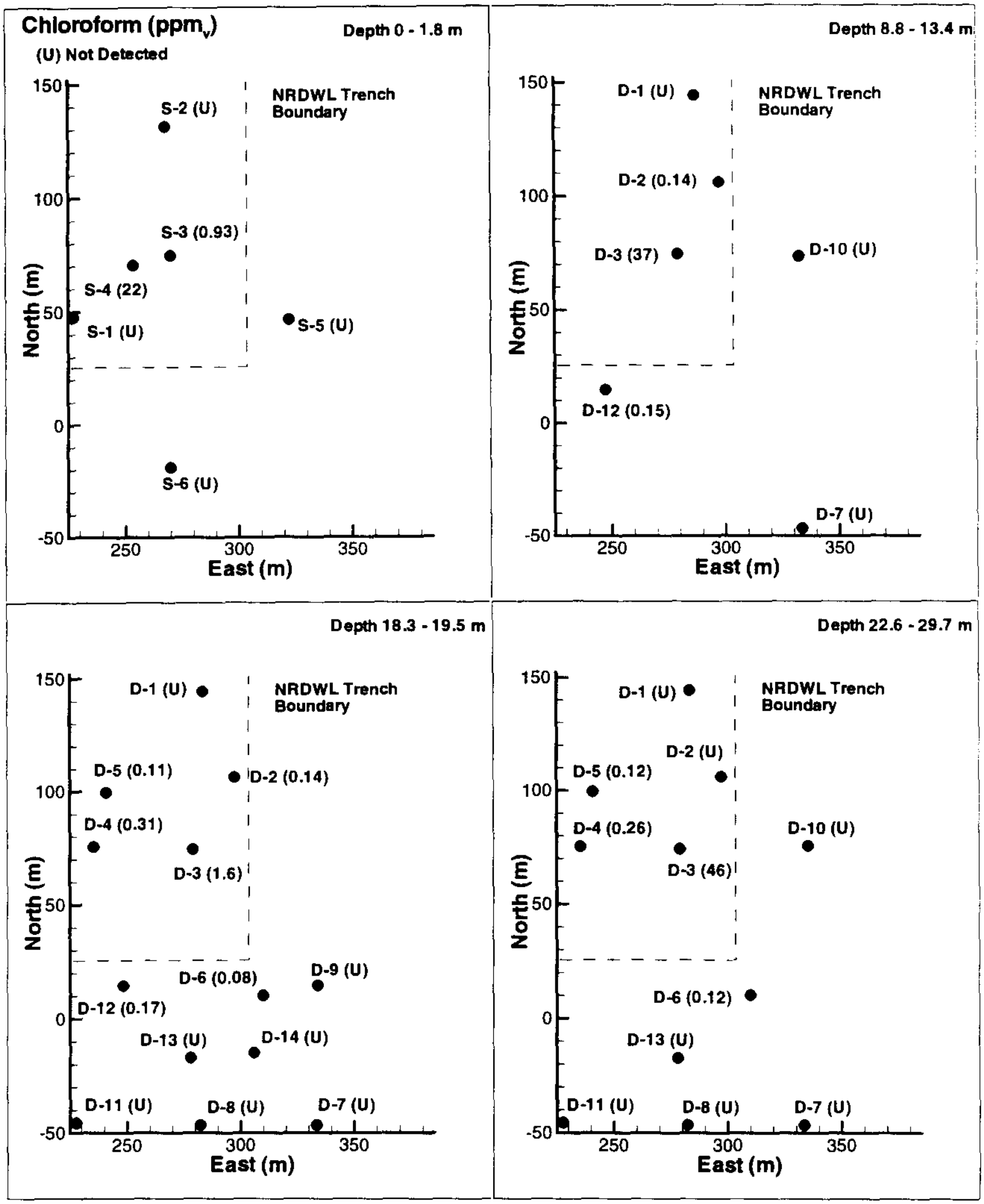
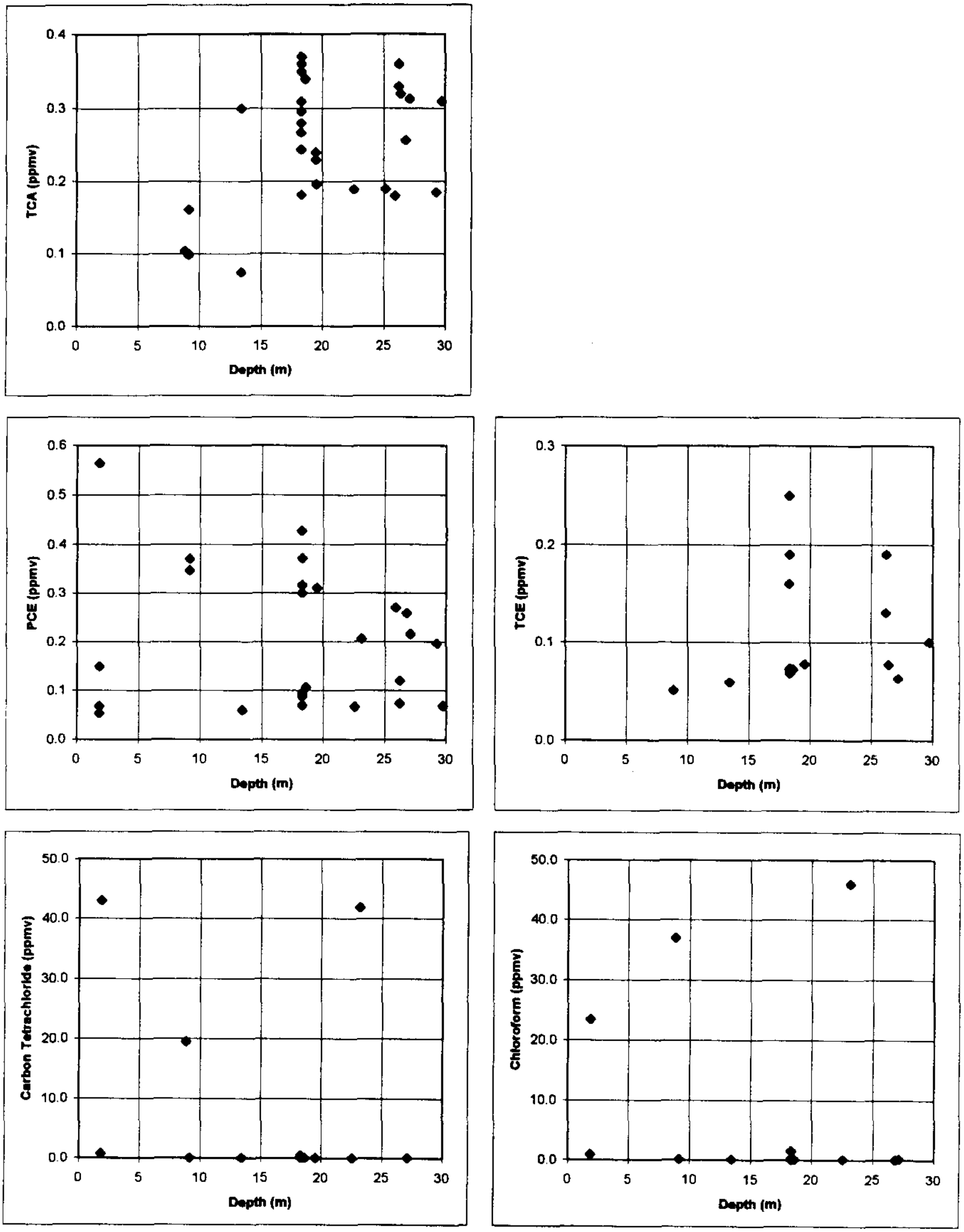


Figure 10. Relationship Between Concentrations of VOC Detected in 1997 Soil-Gas Survey and Depth.



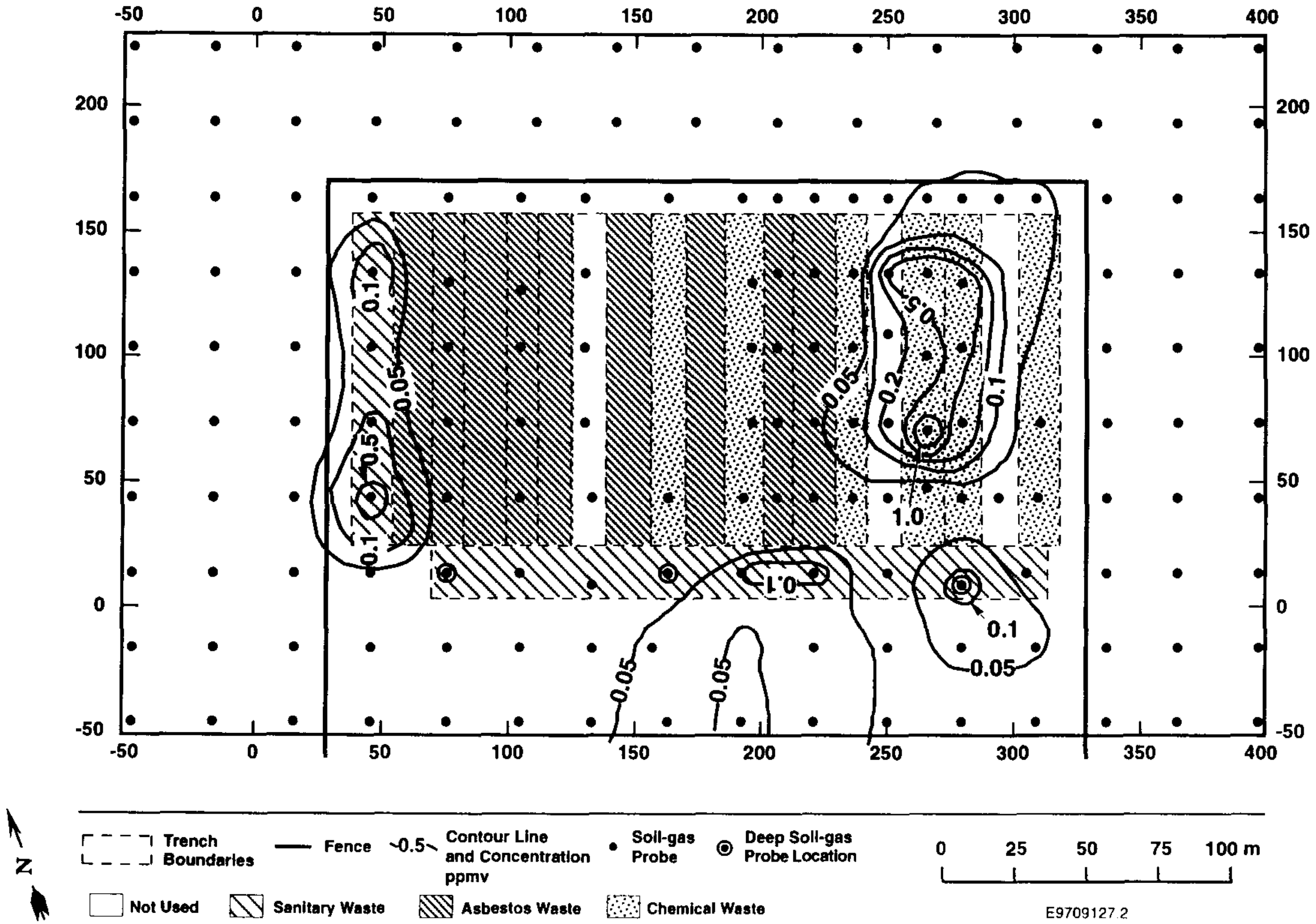


Figure 11. Soil-Gas Survey Results for PCE.

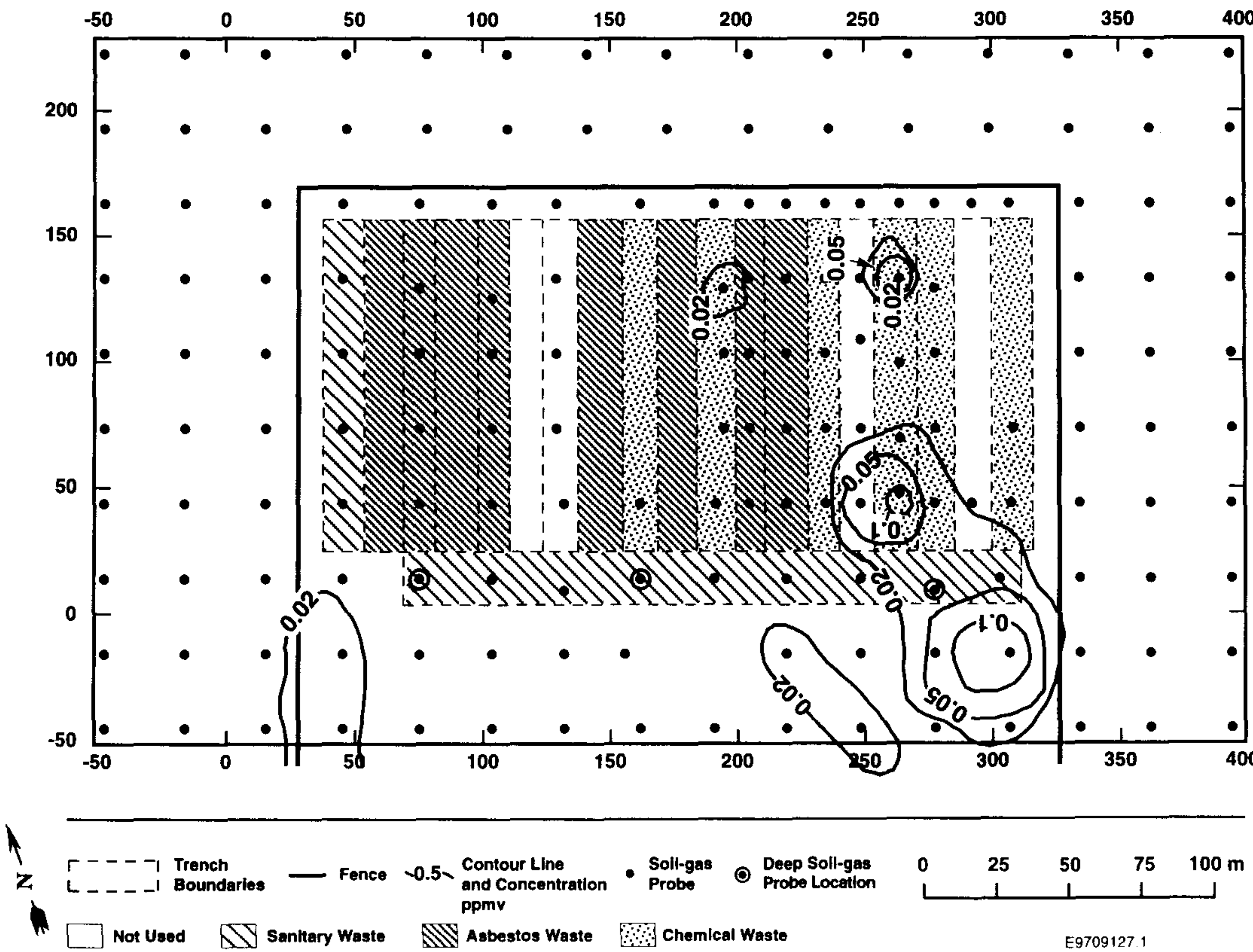


Figure 12. 1993 Soil-Gas Survey Results for TCE.

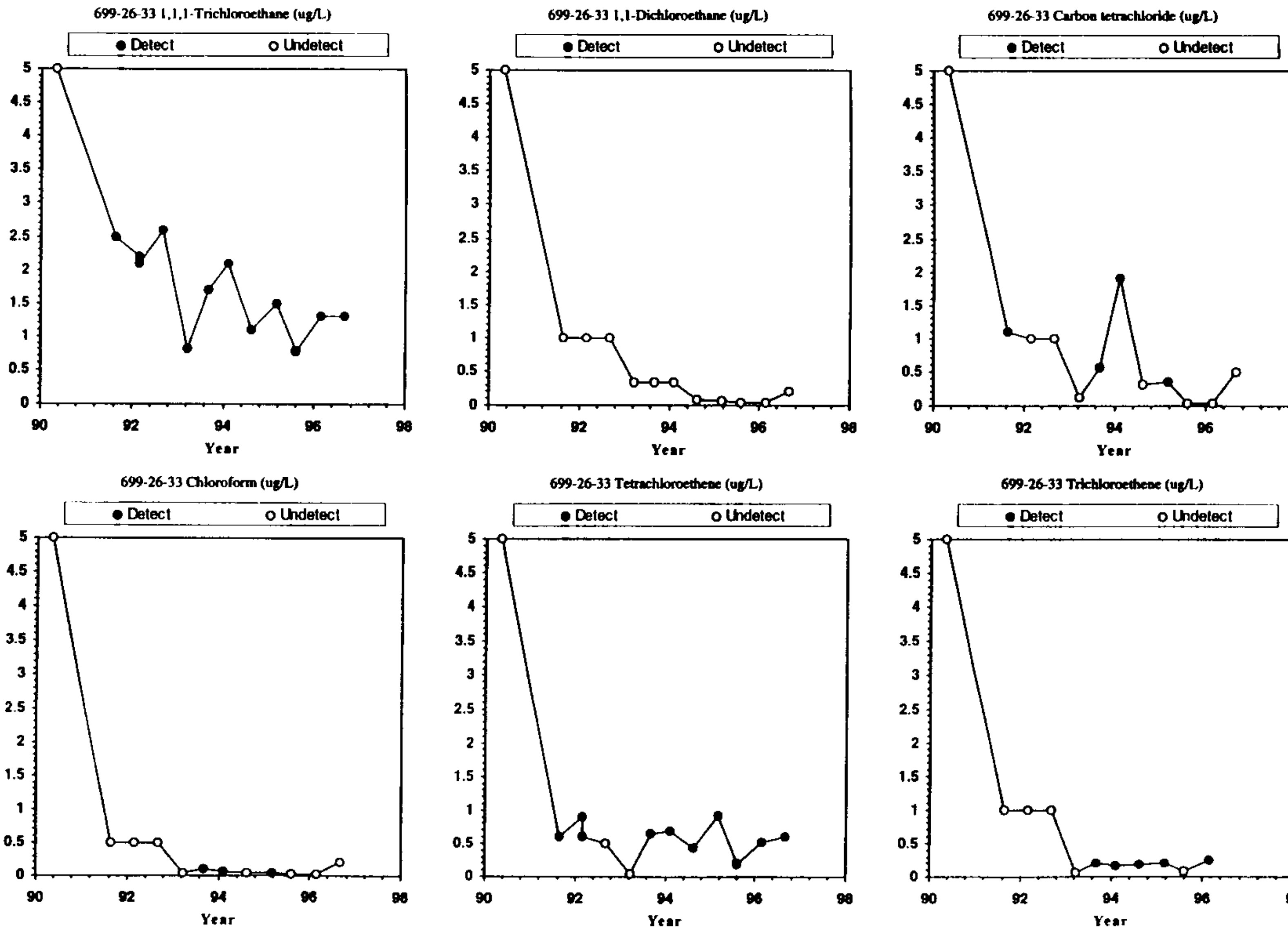


Figure 13. Groundwater Monitoring Results for Downgradient Well 699-26-33.

Figure 14. Groundwater Monitoring Results for Downgradient Well 699-25-34A.

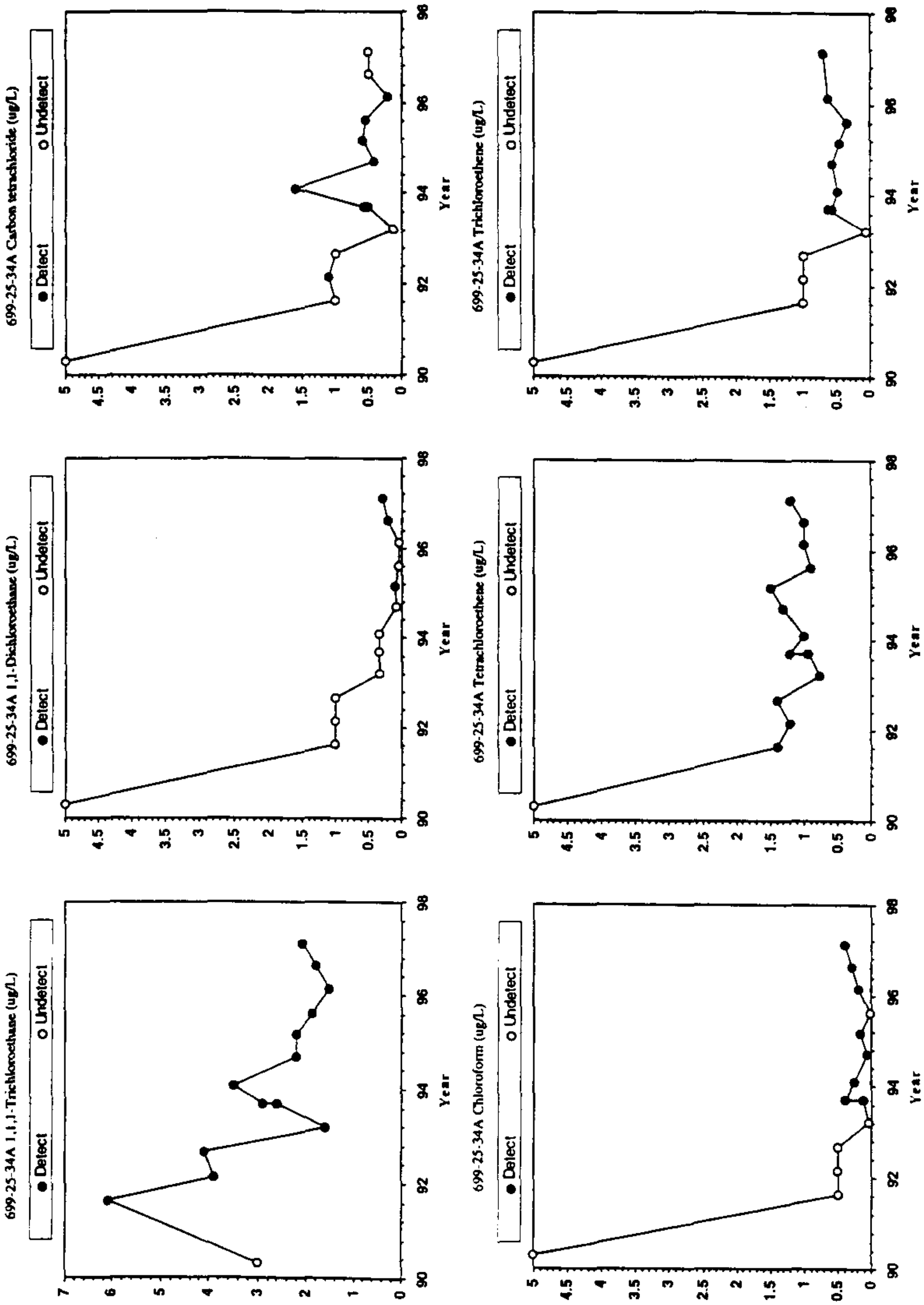


Figure 15. Groundwater Monitoring Results for Downgradient Well 699-25-34B.

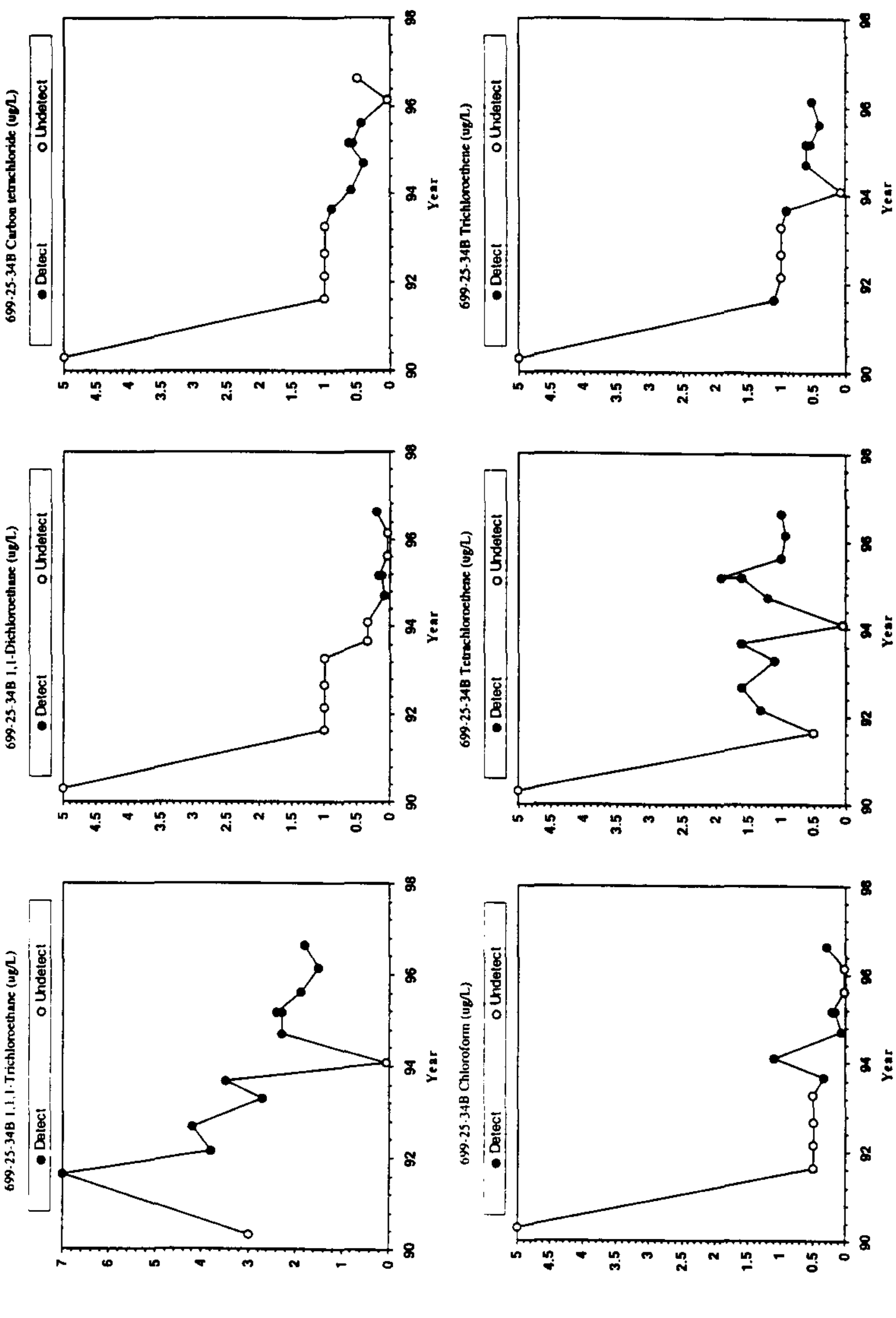
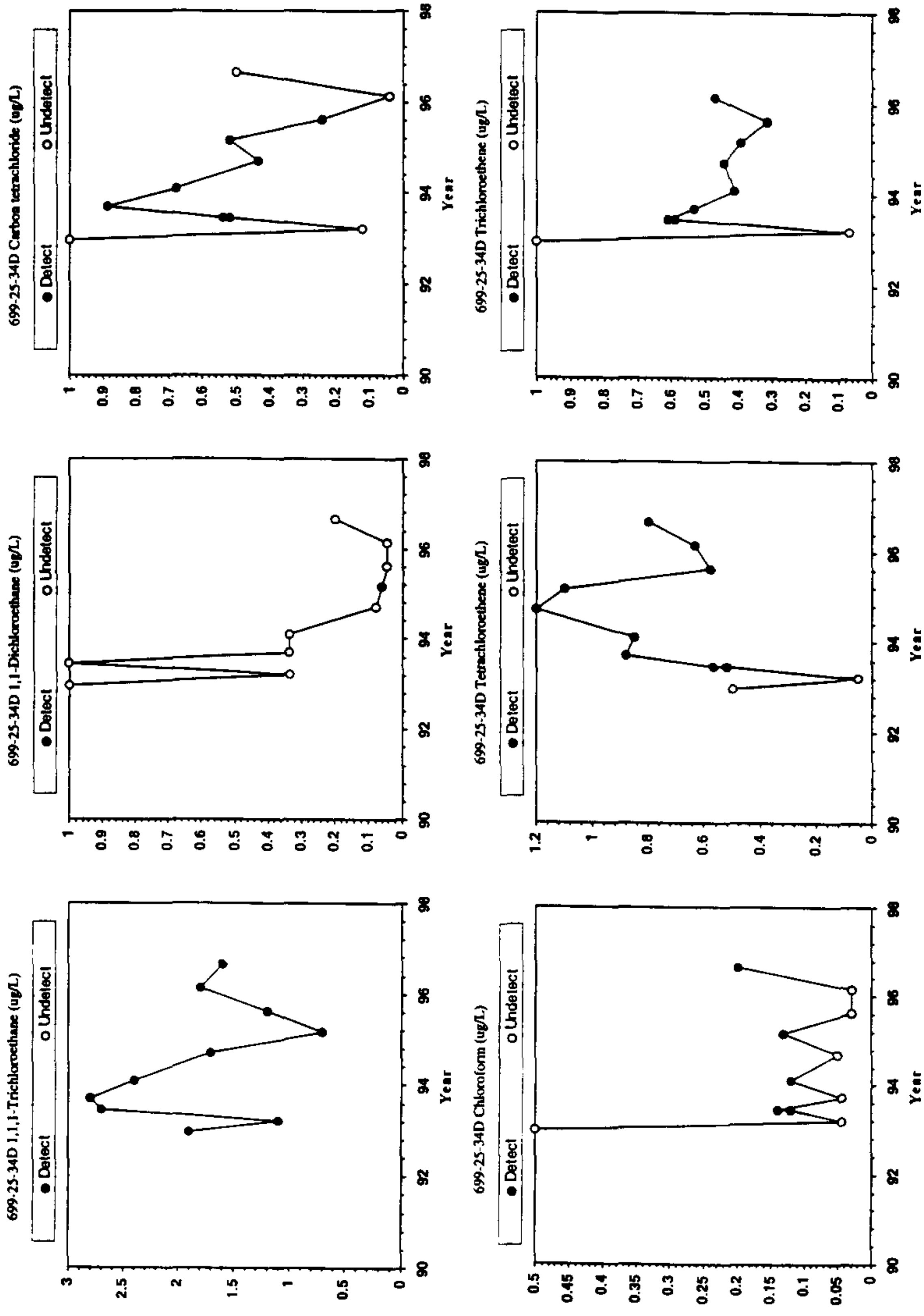


Figure 16. Groundwater Monitoring Results for Downgradient Well 699-25-34D.



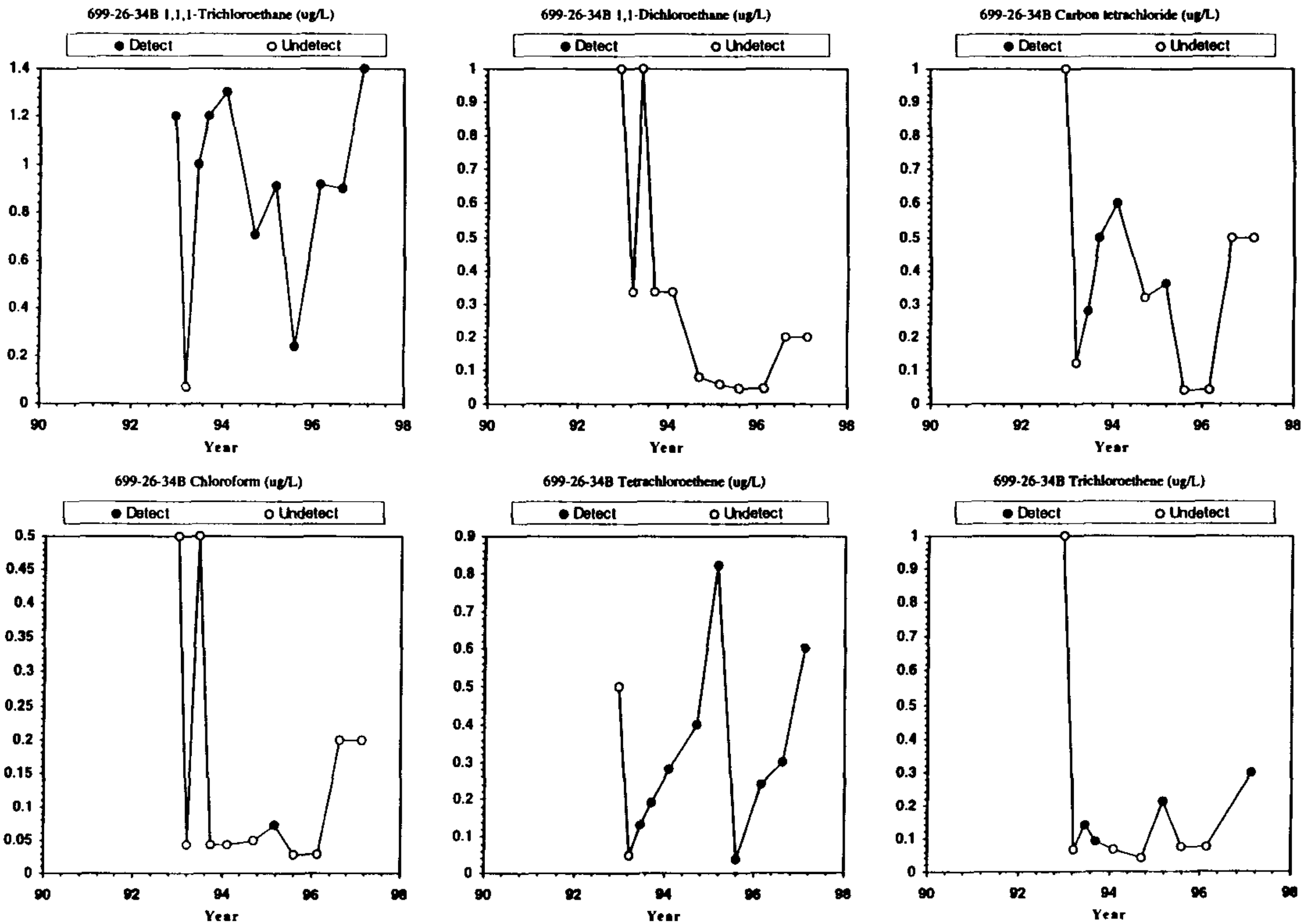
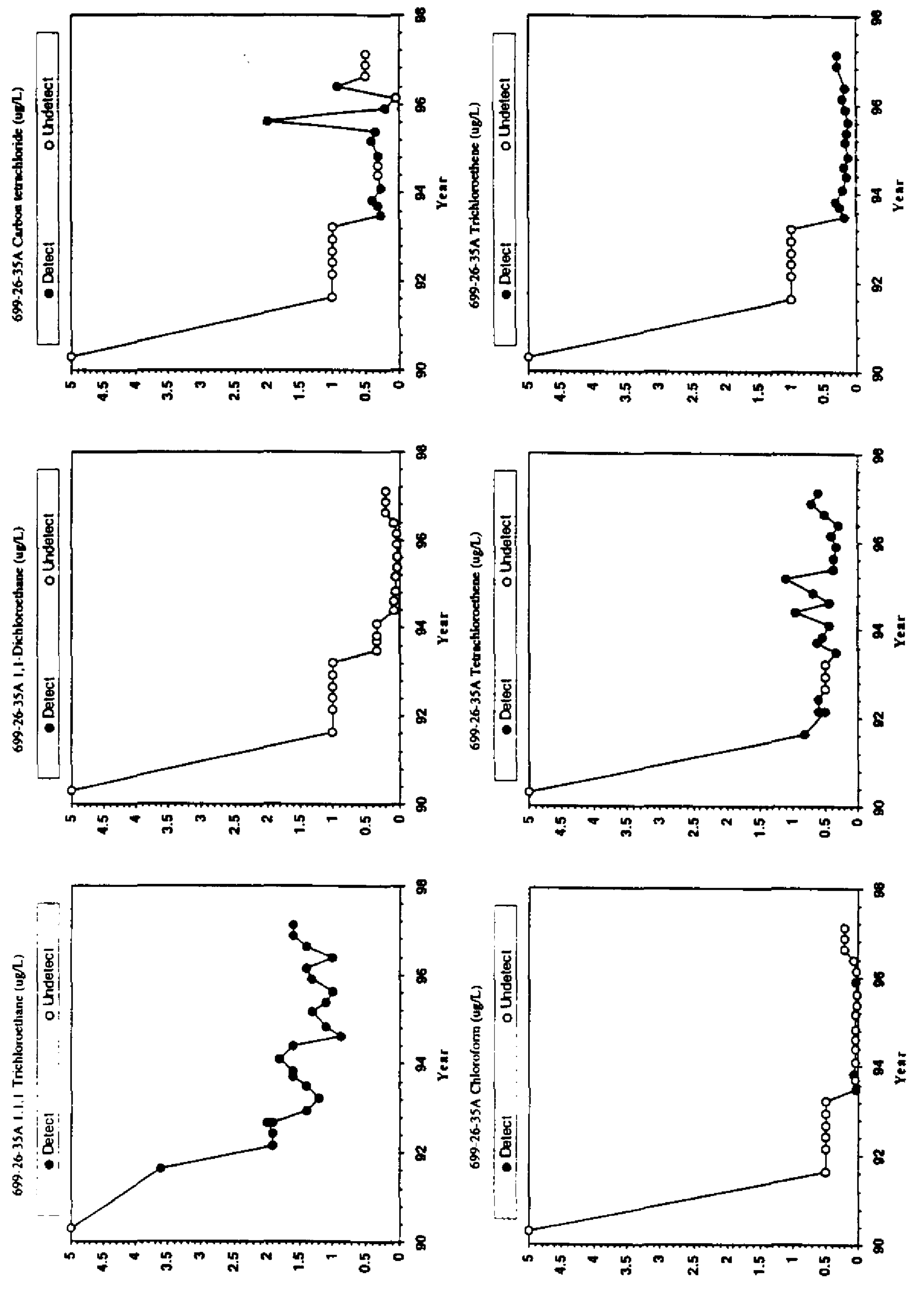


Figure 17. Groundwater Monitoring Results for Downgradient Well 699-26-34B.

Figure 18. Groundwater Monitoring Results for Upgradient Well 699-26-35A.



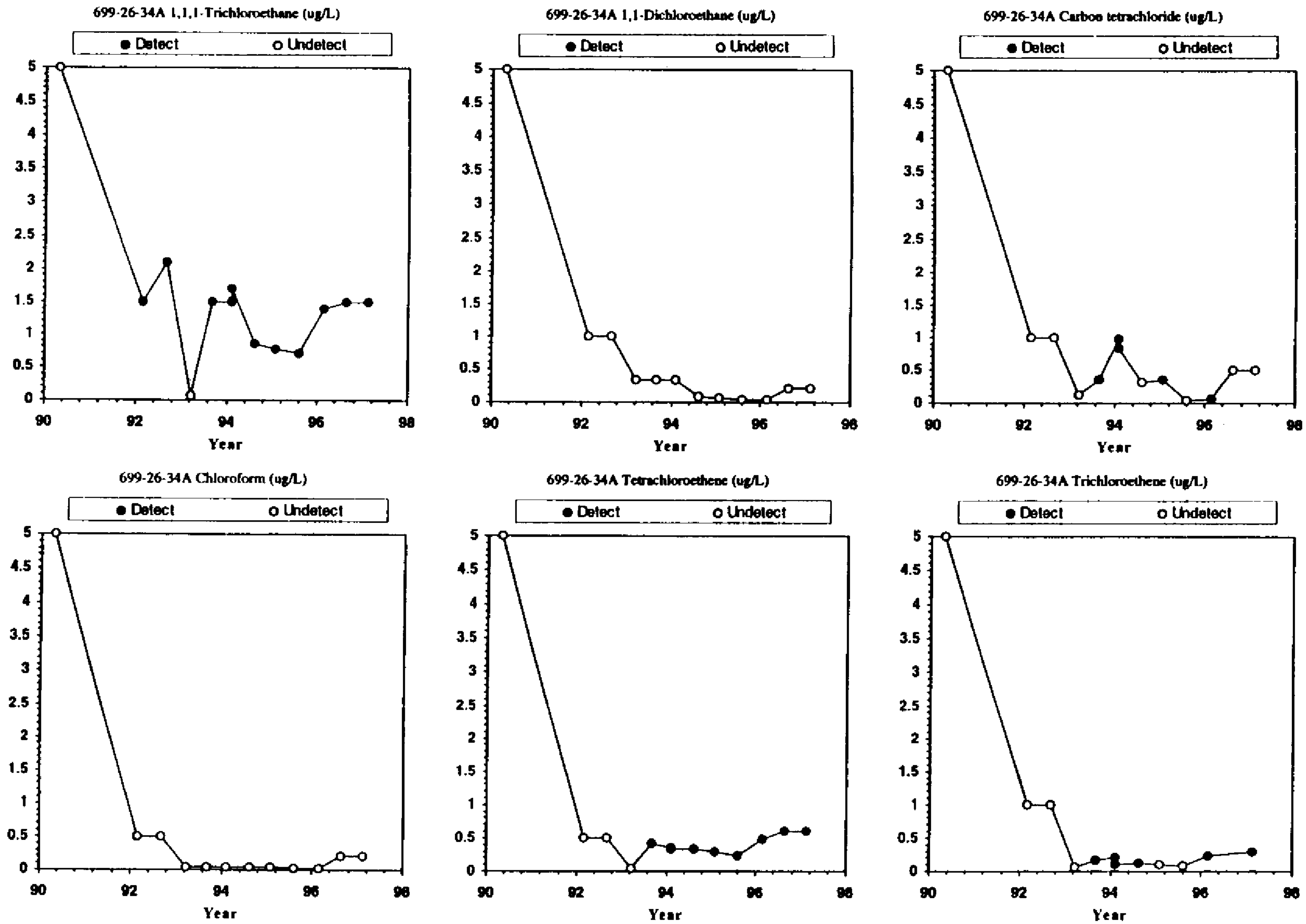


Figure 19. Groundwater Monitoring Results for Upgradient Well 699-26-34A.

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