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Corrective Action Plan for the Hanford Site Solid Waste Landfill

United States
Department of Energy
Richland, Washington

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Corrective Action Plan for the Hanford Site Solid Waste Landfill

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TERMS

11-DCA	1,1-dichloroethane
111-TCA	1,1,1-trichloroethane
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
Ecology	Washington State Department of Ecology
FY	fiscal year
GWQC	Washington State Ground Water Quality Criterion
NRDWL	Nonradioactive Dangerous Waste Landfill
PCE	tetrachloroethene
PNL	Pacific Northwest Laboratory
RCRA	Resource Conservation and Recovery Act of 1976
RL	U.S. Department of Energy, Richland Operations Office
SWL	Solid Waste Landfill
TCE	trichloroethene
TOX	total organic halogen
WAC	Washington Administrative Code

CORRECTIVE ACTION PLAN FOR THE HANFORD SITE SOLID WASTE LANDFILL

1.0 INTRODUCTION

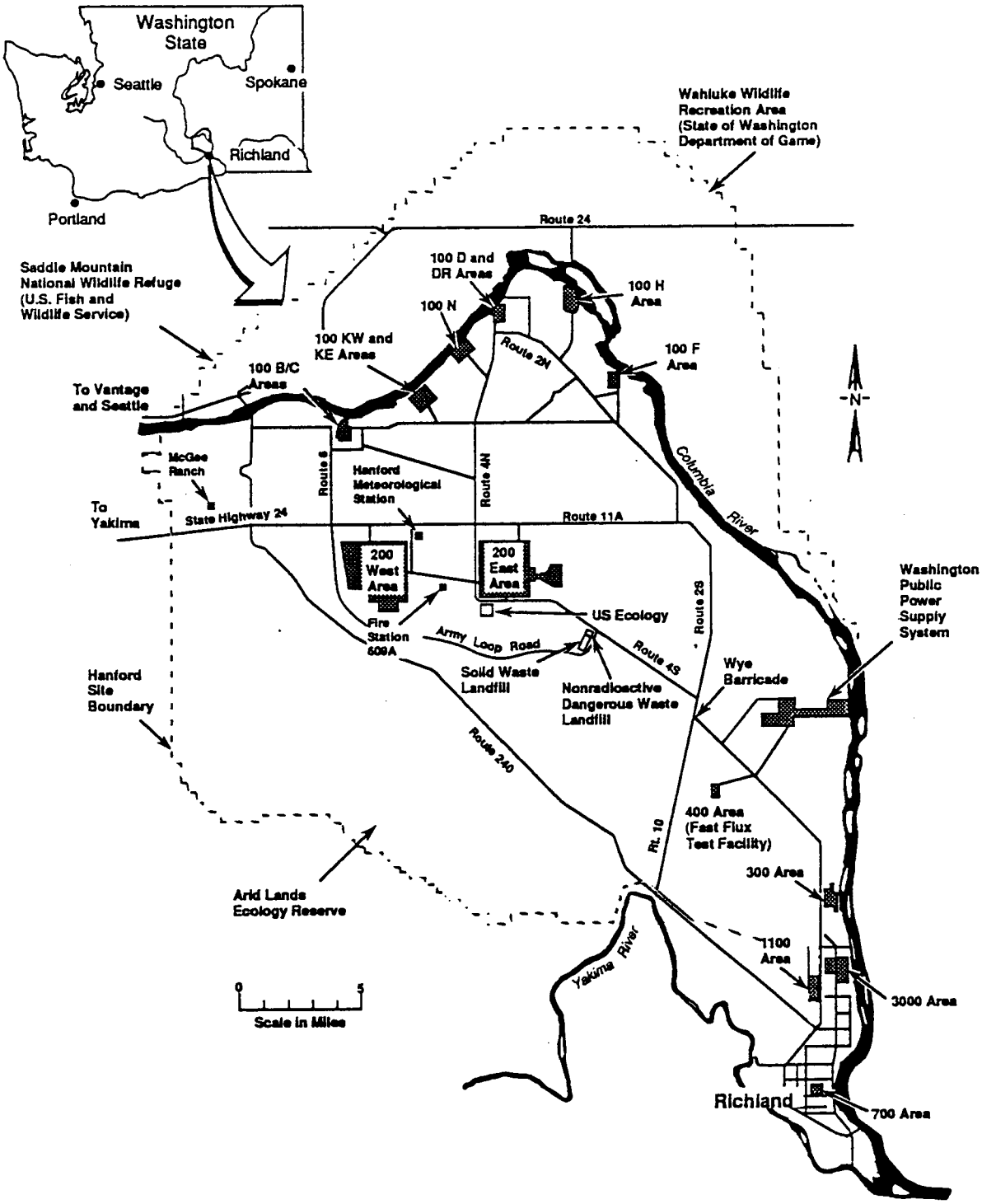
The Hanford Site Solid Waste Landfill (SWL), located southeast of the 200 East Area, shown in Figure 1, receives sanitary waste and construction debris from across the Hanford Site. It is part of the Hanford Site Central Landfill Complex, which also contains the Nonradioactive Dangerous Waste Landfill (NRDWL).

The SWL is regulated by Washington Administrative Code (WAC) 173-304, under which the regulatory authority is the Benton-Franklin Public Health Department. The U.S. Department of Energy, Richland Operations Office (RL) submitted a permit application for the SWL to the Benton-Franklin Public Health District in January of 1991 (DOE/RL 1991). The permit application was rejected and, as a result of subsequent negotiation between the Benton-Franklin Public Health Department and the Washington State Department of Ecology (Ecology), Ecology accepted responsibility for regulation of the SWL.

RL submitted a revised permit application to Ecology in 1993 (DOE/RL 1993). Ecology reviewed the revised permit application and issued a letter to RL requesting that a corrective action program be established for the SWL (Ma 1994). The letter further requested that a corrective action plan meeting the requirements of WAC 173-304-490(2)(j), be submitted to Ecology by September 30, 1994. RL subsequently requested a two-month extension, which moved the due date to November 30, 1994.

This corrective action plan was prepared in response to Ma (1994). It should be considered an addendum to the SWL permit application (DOE/RL 1994), which describes the site in more detail.

Figure 1. Map Showing Hanford Site and Location of the SWL.



2.0 DESCRIPTION OF SITE

The SWL, located approximately 5.6 km (3.5 mi) southeast of the 200 East Area, is a 27-ha (66-acre) solid waste disposal facility regulated under WAC 173-304. It received liquid waste between 1974 and 1987 and has received Hanford Site solid waste from 1973 to the present.

2.1 GEOLOGY AND HYDROLOGY

The geology and hydrology of the SWL are described in Fruland et al. (1989); however, none of the monitoring wells at the SWL has penetrated the full thickness of the Hanford formation. What is known about the deeper geology and hydrology beneath the SWL is inferred from characterization work at the adjacent NRDWL (Weekes et al. 1987).

The SWL, which lies on the southward-dipping flank of the Cold Creek syncline, is underlain by an estimated 183 m (600 ft) of suprabasalt sediments. The basalt is directly overlain by the fluvial and lacustrine deposits of the Ringold Formation, which is estimated to be 128 m (420 ft) thick at this location. The Ringold Formation is overlain by approximately 55 m (180 ft) of glacial flood deposits of the Hanford formation. The SWL site is mantled by a thin veneer of wind-blown sand. The deformation that produced the Cold Creek syncline was active during the deposition of the suprabasalt sediments and is probably continuing. Thus, any dip of sedimentary layers beneath the SWL is probably to the south toward the axis of the syncline.

The top of the unconfined aquifer (water table) beneath the SWL occurs within the Hanford formation, at a depth of approximately 37 m (120 ft). Thus, the entire vadose zone beneath the site is within the Hanford formation. The upper portion of the vadose zone is predominately sand with numerous thin, discontinuous silt layers. These silt layers contain up to 23 wt% water (Fruland et al. 1989). The lower portion of the vadose zone is dominated by gravels. Approximately 18 m (60 ft) of the Hanford formation is saturated, along with the entire thickness of the Ringold Formation. Characterization data for the site are insufficient to determine to what degree the aquifer in the lower portions of the Ringold Formation is isolated from the upper portions of the unconfined aquifer.

Groundwater flow in the upper portion of the unconfined aquifer is toward the southeast. The hydraulic gradient is low, (on the order of 5.0×10^{-5}). However, groundwater velocities, based on transport of tritium and nitrate from the 200 East Area, are on the order of 6 m/day (20 ft/day), apparently a result of the very high transmissivity within the Hanford formation.

2.2 DISPOSAL HISTORY

The SWL has received Hanford Site solid waste since 1973; this includes office waste, construction/demolition debris, and asbestos materials. In addition, the SWL received liquid waste from 1974 to 1987. The northernmost 5.7 ha (14 acres) was set aside for disposal of chemical and asbestos waste in 1975. This area, the NRDWL, has been inactive since 1988 and is regulated under WAC 173-303. The disposal history of the SWL is shown on the site map in Figure 2.

The SWL has been filled from north to south. The SWL was divided into five approximately equal panels (Figure 2); Operational Phase I, which consisted of filling the two northernmost panels, was completed in 1982. The first trench was the J. A. Jones (JAJ) trench along the northern boundary with the NRDWL. Phase II, which started in 1982, will fill the three southernmost panels; the Phase II north panel was finished in 1987 and the two remaining panels are currently being developed and filled.

Between 1974 and 1987 approximately 5.7×10^6 L (1.5×10^6 gal) of liquid waste were disposed of in trenches along the east and west boundaries of the SWL (Figure 2). This waste was principally sewage from septic tanks and chemical toilets; however, between 1985 and 1987 approximately 4×10^5 L (10^5 gal) of catch-tank wash water from the bus and heavy equipment garages was disposed of in three short trenches along the west side of the landfill. The catch-tank liquid contained chlorinated hydrocarbons.

2.3 GROUNDWATER MONITORING NETWORK

The groundwater monitoring network at the SWL (Figure 3) consists of seven downgradient monitoring wells and two upgradient monitoring wells. The initial monitoring network installed in 1987 (Fruland et al. 1989) consisted of one upgradient well (699-24-35) and five downgradient wells. Well 699-26-35A, an upgradient well for the adjacent NRDWL, was added to the SWL network in 1991 and two new downgradient wells were drilled at the south end of the SWL in 1993. All monitoring wells at the SWL monitor the top of the unconfined aquifer.

Figure 2. Map of SWL Showing Solid Waste Disposal Areas and Liquid Waste Disposal Trenches.

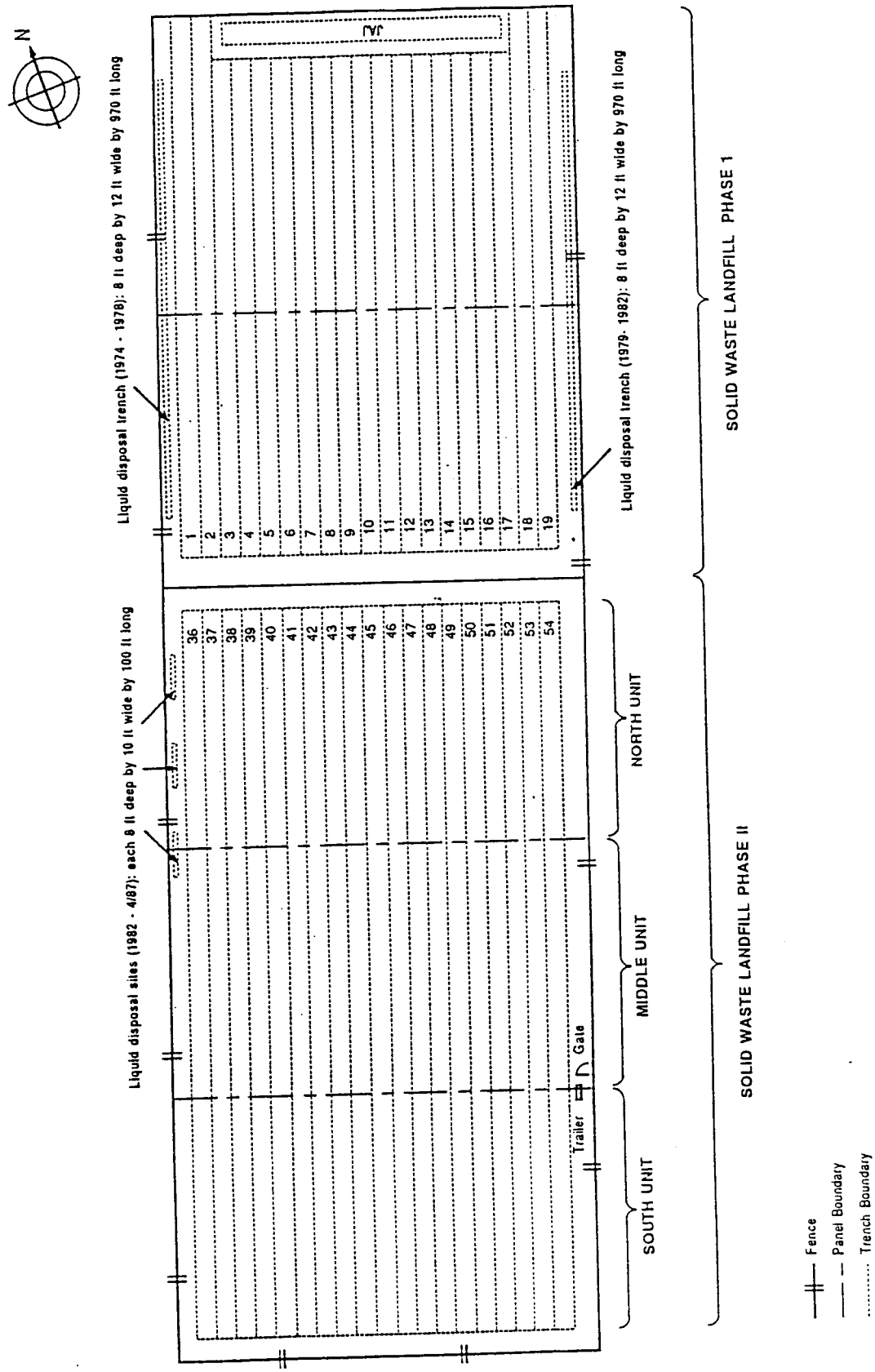
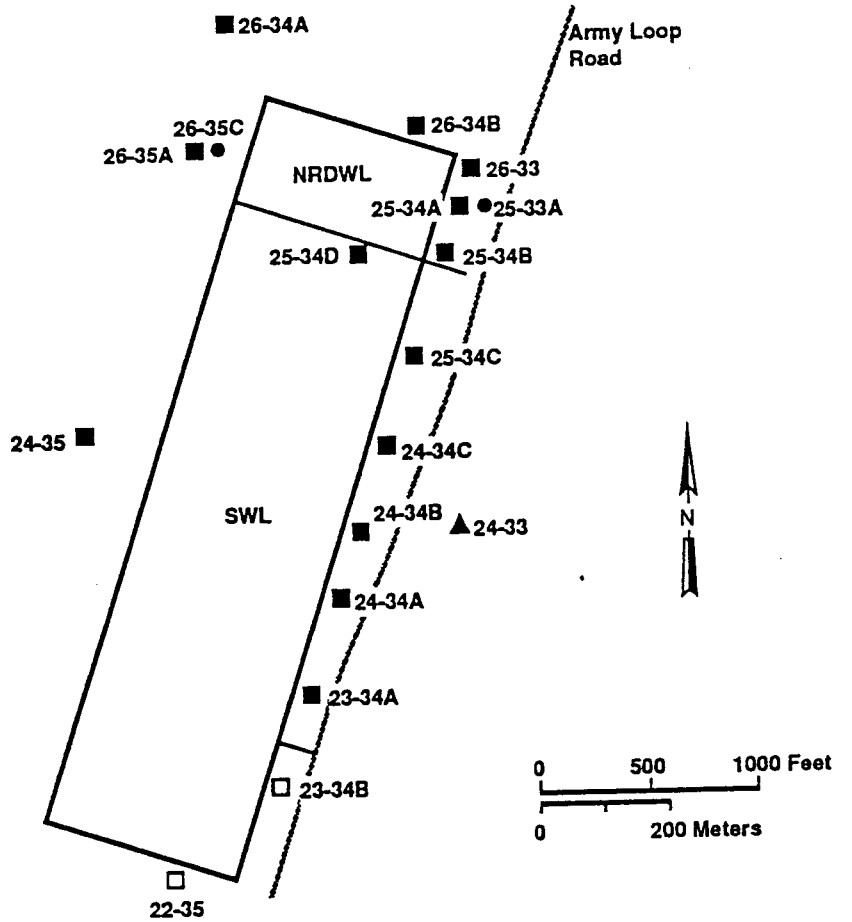


Figure 3. Map Showing Groundwater Monitoring Network at the SWL and NDWL.



■ Well completed at the top of the unconfined aquifer

● Well completed in the upper Ringold Formation

▲ Well not constructed to RCRA specifications

□ New RCRA wells completed in 1993.

NRDWL Nonradioactive Dangerous Waste Landfill

SWL Solid Waste Landfill

All wells prefixed by 699-

H9402008.24

3.0 EXTENT OF CONFIRMED CONTAMINATION

Contaminants at the SWL occur in the groundwater and within the vadose zone. The source of the contamination and the relationship between groundwater and vadose zone contamination are not clear.

3.1 GROUNDWATER CONTAMINATION

Chlorinated hydrocarbon contamination of groundwater at the SWL was first indicated in 1986 by Pacific Northwest Laboratory (PNL) sampling of non-Resource Conservation and Recovery Act of 1976 (RCRA) Well 699-24-33, located approximately 150 m (500 ft) east of the SWL. This contamination was confirmed when the downgradient monitoring well network at the SWL was installed in 1987 (Fruland et al. 1989). The contamination with chlorinated hydrocarbons is mirrored in determinations of total organic halogen (TOX), which consistently have been significantly above background values in the downgradient wells. Subsequent sampling has indicated a statistically significant increase in downgradient specific conductance values above background.

3.1.1 Chlorinated Hydrocarbons

The principal chlorinated hydrocarbon contaminants at the SWL are 1,1,1-trichloroethane (111-TCA), trichloroethene (TCE), tetrachloroethene (PCE), and 1,1-dichloroethane (11-DCA). A complete listing of all analytical data for four major chlorinated hydrocarbons at the SWL is presented in Tables 1 through 4. Minor constituents that are occasionally reported at concentrations above their detection levels include carbon tetrachloride, chloroform, and cis-1,2-dichloroethene.

1,1,1-TCA is the most abundant chlorinated hydrocarbon at the SWL; however, all reported concentrations are well below the Washington State Ground Water Quality Criterion (GWQC) of 200 ppb (WAC 173-200). However, if 11-DCA, which does exceed the GWQC, is a degradation product of 111-TCA, the presence of 111-TCA becomes more significant. Concentrations of 111-TCA have consistently been higher in monitoring wells near the south end of the landfill (Figures 4 and 5), a trend that was confirmed with the completion of two new monitoring wells (699-22-35 and 699-23-34B) at the south end of the landfill in 1993. The groundwater concentration pattern indicates that the center of the 111-TCA contamination source may have moved south of the SWL boundary.

Trichloroethene concentrations in groundwater downgradient to the SWL, particularly in the southernmost wells (Figures 6 and 7), have been below 10 ppb, but above the GWQC of 3 ppb. However, the concentrations have decreased with time; in 1993 and 1994 most measured concentrations have been below 3 ppb. The groundwater concentration pattern is similar to that of 111-TCA.

Table 1. Analytical Results for 1,1,1-Trichloroethane from Solid Waste Landfill Wells (ppb).

Sample Dates	26-35A	24-35	25-34C	24-34C	24-34B	24-34A	23-34A	23-34B	22-35
May 1987		5	3	24	56	43	52		
June 1987		3	4	25	40	41	49		
July/Aug 1987		3	3	28	46	42	54		
Oct/Nov 1987		3	*	35	64/61	42	47		
Jan/Feb 1988		4	5	28	58	44	60		
April 1988		3	4	24	41/41	32/32/29	37		
July/Aug 1988		3	5	23	35/34	26	30		
October 1988		<5	6	25	35	29	33		
January 1989		*	*	*	*	*	*		
March 1989		3.4	4.0	19	27	16	38		
May 1989		3.2	4.7	26	32	21	38		
August 1989		3.7/4.0	6.7	25	38	31	47		
October 1989		2.8/2.9	6.5/6.1	32/22	36	*	44/37/42		
January 1990		3.3	3.9	23	26	27	38		
April 1990		<5	5	21	28	19	49		
August 1991		6.8	3.6	23	25	26	34		
December 1991		*	*	16	17	15	32/33		
February 1992		4.0	1.9	8.8	15	20	22		
June 1992		3.9	1.9	7.8	13	11	26		
September 1992		<0.5	1.9	16	12	19	28		

Table 1. Analytical Results for 1,1,1-Trichloroethane from Solid Waste Landfill Wells (ppb).

Sample Dates	26-35A	24-35	25-34C	24-34C	24-34B	24-34A	23-34A	23-34B	22-35
December 1992		4.2	4.1	11	11	18	23		
March 1993		<0.5	<0.5	<0.5	10	16	27		
July 1993		2.9	3.4	8.0	9.4	16	26		
September 1993	1.6	6.5	3.9	14	13	20	19		
November 1993	1.6	6.4	3.9	11	10	17	27		
February 1994	1.8	3.2	3.8	4.8	13	17	28	30	38
June 1994	1.6	3.1	3.1	9.2	9.5	12	19	28	28
Aug/Sep 1994	0.88	2.5	2.6	7.3	7.7	10	16	27	29

Table 2. Analytical Results for Trichloroethene from Solid Waste Landfill Wells (ppb).

Sample Dates	26-35A	24-35	25-34C	24-34C	24-34B	24-34A	23-34A	23-34B	23-35
May 1987		<10	<10	<10	<10	<10			
June 1987		<10	<10	<10	<10	<10	<10		
July/Aug 1987		<10	<10	<4.6	<7.5	<6.7	<8.2		
Oct/Nov 1987		<5	*	<4	7/8	6	7		
Jan/Feb 1988		<5	<5	<3	8	7	9		
April 1988		<5	<5	<3	6	5/6	6		
July/Aug 1988		<5	<5	<3	5/6	5	5		
October 1988		<5	<5	<3	5	5	5		
January 1989		*	*	*	*	*	*		
March 1989		<1	<1	1.8	3.5	3.7	4.7		
May 1989		<1	<1	2.9	5.0	3.0	5.2		
August 1989		<1	<0.82	3.1	4.6	4.6	4.8		
October 1989		<1/<1	<0.5/<0.8	3.2/2.6	4.3	*	4.3/3.8/4.5		
January 1990		<1	<1	2.8	3.6	3.5	4.2		
April 1990		<5	<5	<3	<4	<3	7.0		
August 1991		<1	1.5	3.6	3.9	3.7	5.6		
December 1991		*	1.0	4.0	3.0	2.0	4.0		
February 1992	0.6	<1	<1	1.5	2.3	2.7	3.0		
June 1992	<1	<1	<1	1.4	2.1	1.9	3.6		
September 1992	<1	<1	1.1	2.6	2.0	2.9	4.1		

Table 2. Analytical Results for Trichloroethene from Solid Waste Landfill Wells (ppb).

Sample Dates	26-35A	24-35	25-34C	24-34C	24-34B	24-34A	23-34A	23-34B	23-35
December 1992	<1	<1	1.2	2.0	2.0	2.5	3.2		
March 1993	<1	<1	<1	1.9	1.8	2.3	3.4		
July 1993	0.19	0.23	0.75	1.2	1.6	2.6	3.0		
September 1993	0.24	0.49	1.3	2.7	2.7	3.7	2.4		
November 1993	0.31	0.34	0.9	2.1	2.0	2.3	2.5		
February 1994	0.21	0.11	0.94	1.3	1.8	1.9	2.2	2.6	4.3
June 1994	0.14	0.08/0.17	0.35	1.7	1.6	1.8	2.2	2.2	2.5
Aug/Sept 1994	0.19	0.30	0.78	1.7	1.8	1.7	2.3	2.0	2.2

Table 3. Analytical Results for Tetrachloroethene from Solid Waste Landfill Wells (ppb).

Sample Dates	26-35A	24-35	25-34C	24-34C	24-34B	24-34A	23-34A	23-34B	22-35
May 1987		<10	<10	<10	<10	<10	<10		
June 1987		<10	<10	<10	<10	<10	<10		
July/August 1987		<10	<10	<3.4	<4.7	<4.1	<6		
Oct/Nov 1987		<5	*	<4	8	6	7		
Jan/Feb 1988		<5	<5	<4	8	7	10		
April 1988		<5	<5	<4	8	6	8		
July/Aug 1988		<5	<5	5	7	5	7		
October 1988		<5	<5	6	7	6	7		
January 1989		*	*	*	*	*	*		
March 1989		<0.5	0.53	3.0	6.9	4.8	7.4		
May 1989		<0.5	0.8	5.4	9.1	5.0	8.7		
August 1989		0.67/0.6	1.4	6.1	9.1	7.7	7.8		
October 1989		0.5/0.5	1.3/1.3	6.5/4.9	8.9	*	6.4/7.2/7.9		
January 1990		0.62	1.0	6.5	7.4	7.5	8.2		
April 1990		<5	<5	7	11	6	12		
August 1991	0.8	1.4	2.5	9.5	9.6	8.2	5.2		
December 1991		*	1.5	7.8	6.3	4.6	*		
February 1992	0.6	1.3	1.4	3.6	6.1	6.5	4.8		
June 1992	0.6	1.1	1.1	4.3	6.6	3.7	4.3		
September 1992	<0.5	<0.5	1.7	5.9	4.2	3.8/3.9	4.6		

Table 3. Analytical Results for Tetrachloroethene from Solid Waste Landfill Wells (ppb).

Sample Dates	26-35A	24-35	25-34C	24-34C	24-34B	24-34A	23-34A	23-34B	22-35
December 1992	<0.5	0.5	1.0	3.7	3.2	3.4	2.7		
March 1993	<0.5	1.2	1.4	5.3	5.5	5.6	5.9		
July 1993	0.33	0.77	1.2	3.6	4.2	4.1	4.4		
September 1993	0.62	1.3	2.2	7.1	6.5	5.0	3.4		
November 1993	0.53	1.1	2.0	6.5	5.1	4.5	4.3		
February 1994	0.44	0.71	1.4	4.7	4.2	3.8	4.1	3.3	2.3
June 1994	0.95	1.1/1.5	1.7	4.9	4.4	3.8	4.1	3.3	2.7
August/Sept 1994	0.44	0.99	1.5	4.5	3.8	3.0	3.4	3.2	1.9

Table 4. Analytical Results for 1,1-Dichloroethane in Solid Waste Landfill Wells (ppb).

Sample Dates	26-35A	24-35	25-34C	24-34C	24-34B	24-34A	23-34A	23-34B	22-35
May 1987		<10	<10	<10	<10	<10	<10		
June 1987		<10	<10	<10	<10	<10	<10		
July/August 1987		<10	<10	<2.3	<5	<4.1	<4.6		
October/November 1987		<10	*	<10	<5	<4	<4		
January/February 1988		<10	<10	<10	<5	<5	<6		
April 1988		<10	<10	<10	<4	<4	<4		
July/August 1988		<10	<10	<10	<4	<3	<3		
October 1988		<10	<10	<10	<4	<4	<4		
January 1989		*	*	*	*	*	*		
March 1989		<1	<1	1.2	4.3	4.0	5.4		
May 1989		<1	<1	2.2	4.6	3.2	4.8		
August 1989		<1	<1	2.7	5.6	5.1	5.1		
October 1989		<1/<1	<1/<1	2.9/2.4	4.9	*	4.6/4.4/4.7		
January 1990		<1	<1	3.1	4.0	4.9	5.7		
April 1990		<5	<5	<3	6	5	7		
August 1991	<1	<1	<1	4.5	4.7	4.4	2.2		
December 1991		*	<1	4.0	3.0	3.0	*		
February 1992	<1	<1	<1	1.8	2.6	3.1	1.3		
June 1992	<1	<1	<1	2.1	2.8	2.1	1.6		
September 1992		<1	<1	4.0	2.3	2.5/2.8	1.4		
December 1992	<1	<1	<1	2.3	2.0	2.6	3.2		

Table 4. Analytical Results for 1,1-Dichloroethane in Solid Waste Landfill Wells (ppb).

Sample Dates	26-35A	24-35	25-34C	24-34C	24-34B	24-34A	23-34A	23-34B	22-35
March 1993	<1	<1	<1	2.3	1.7	2.3	3.2		
July 1993	<0.34	<0.34	0.35	1.6	1.6	2.1	3.6		
September 1993	<0.34	<0.34	<0.34	2.6	2.1	2.6	3.7		
November 1993	<0.34	<0.34	0.53	2.6	1.8	2.4	4.2		
February 1994	<0.34	<0.34	<0.34	1.7	1.8	2.8	4.3	5.4	5.5
June 1994	<0.08	<0.08	0.11	1.3	1.4	1.8	3.1	4.2	4.0
August 1994	<0.08	<0.08	0.12	1.7	1.5	1.8	3.0	4.9	5.3

Figure 4. Time Series Plot Showing Concentrations of 1,1,1-trichloroethane (ppb) in SWL Downgradient Wells.

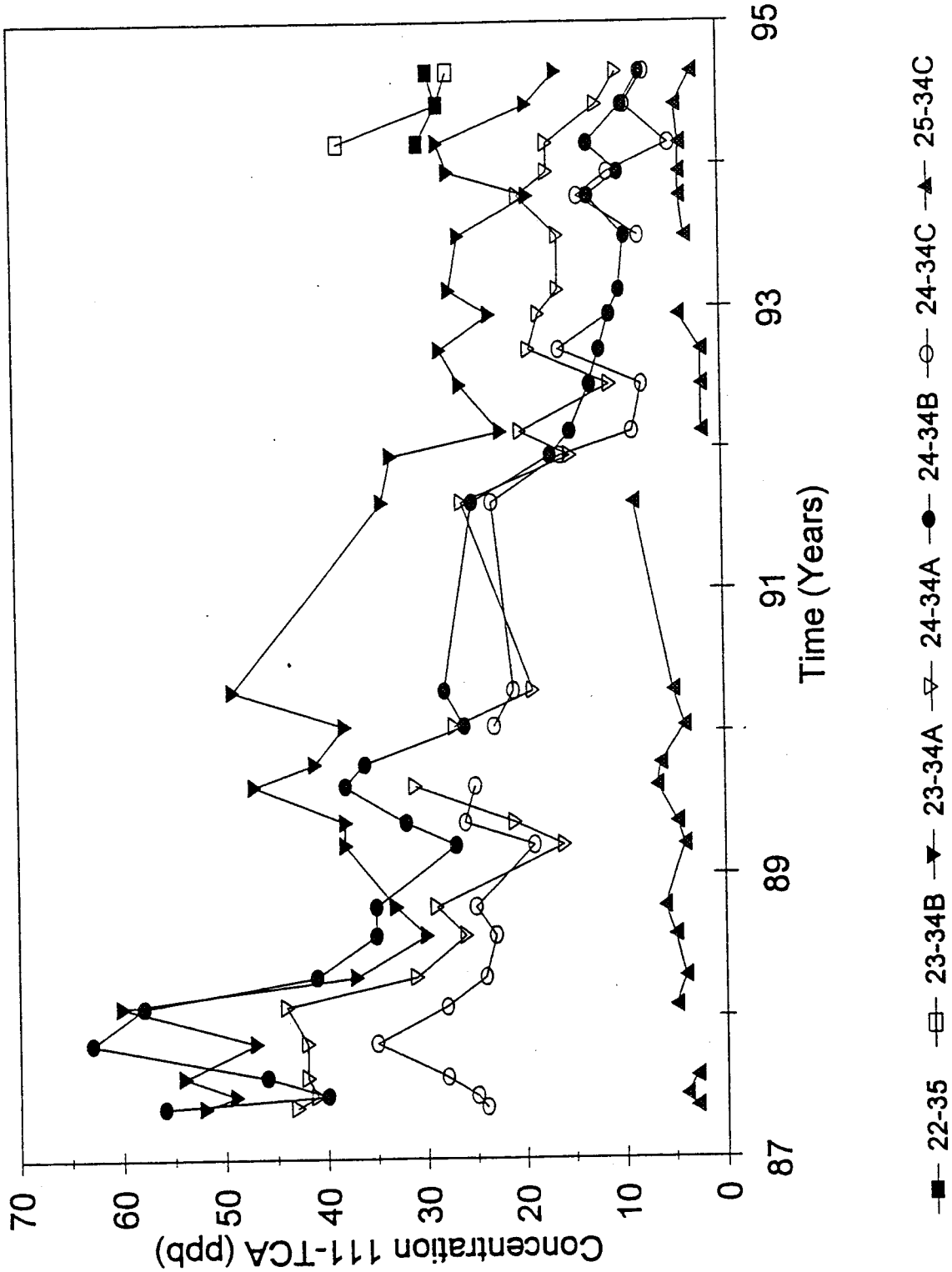


Figure 5. Plot Showing Spatial Distribution of 1,1,1-trichloroethane Concentrations (ppb) in Downgradient Wells at the SWL and NDWL. (Distance is in Meters from the Southeast Corner of the Landfill.)

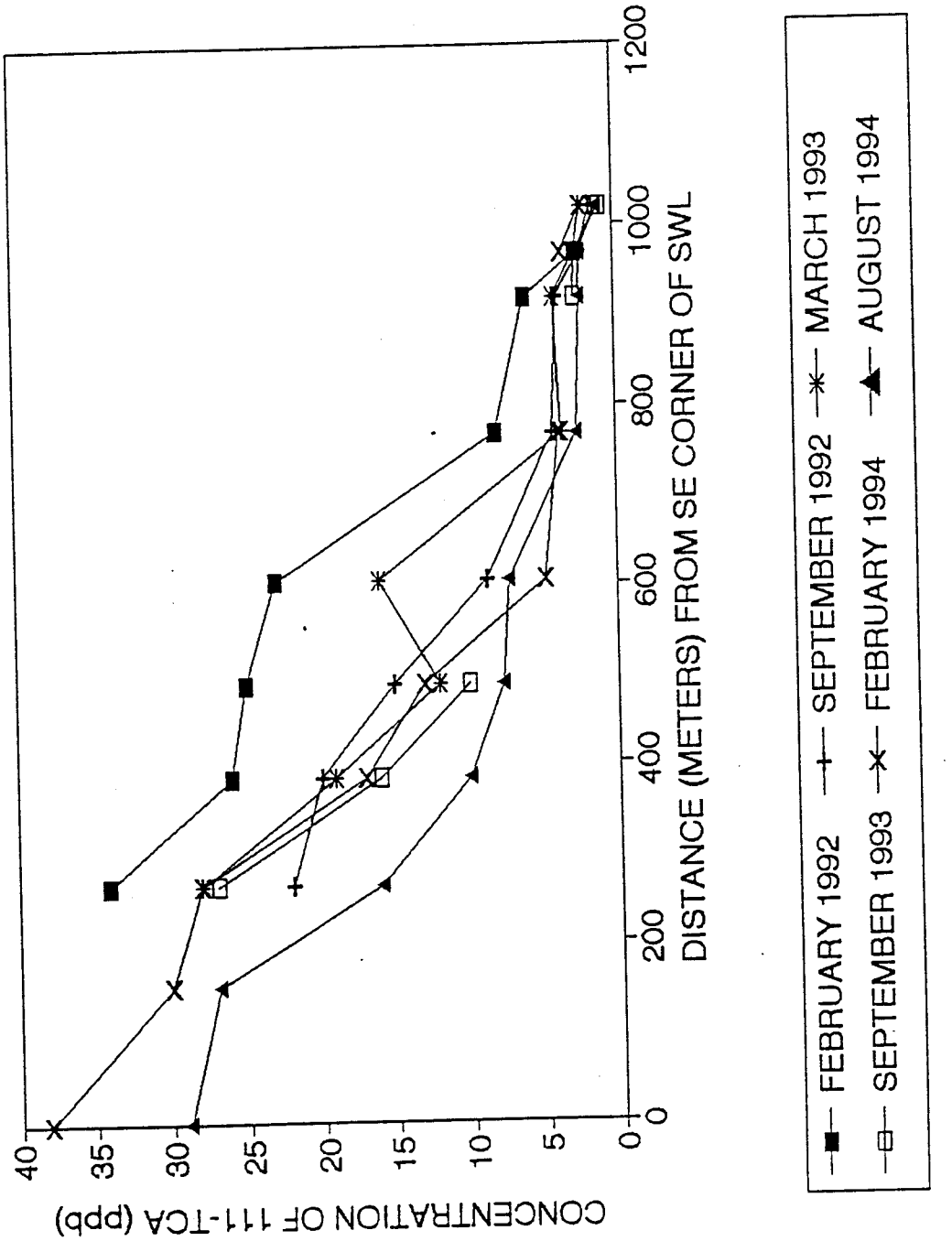


Figure 6. Time Series Plot Showing Concentrations of Trichloroethene (ppb) in SWL Downgradient Wells. (Distance is in Meters from the Southeast Corner of the Landfill.)

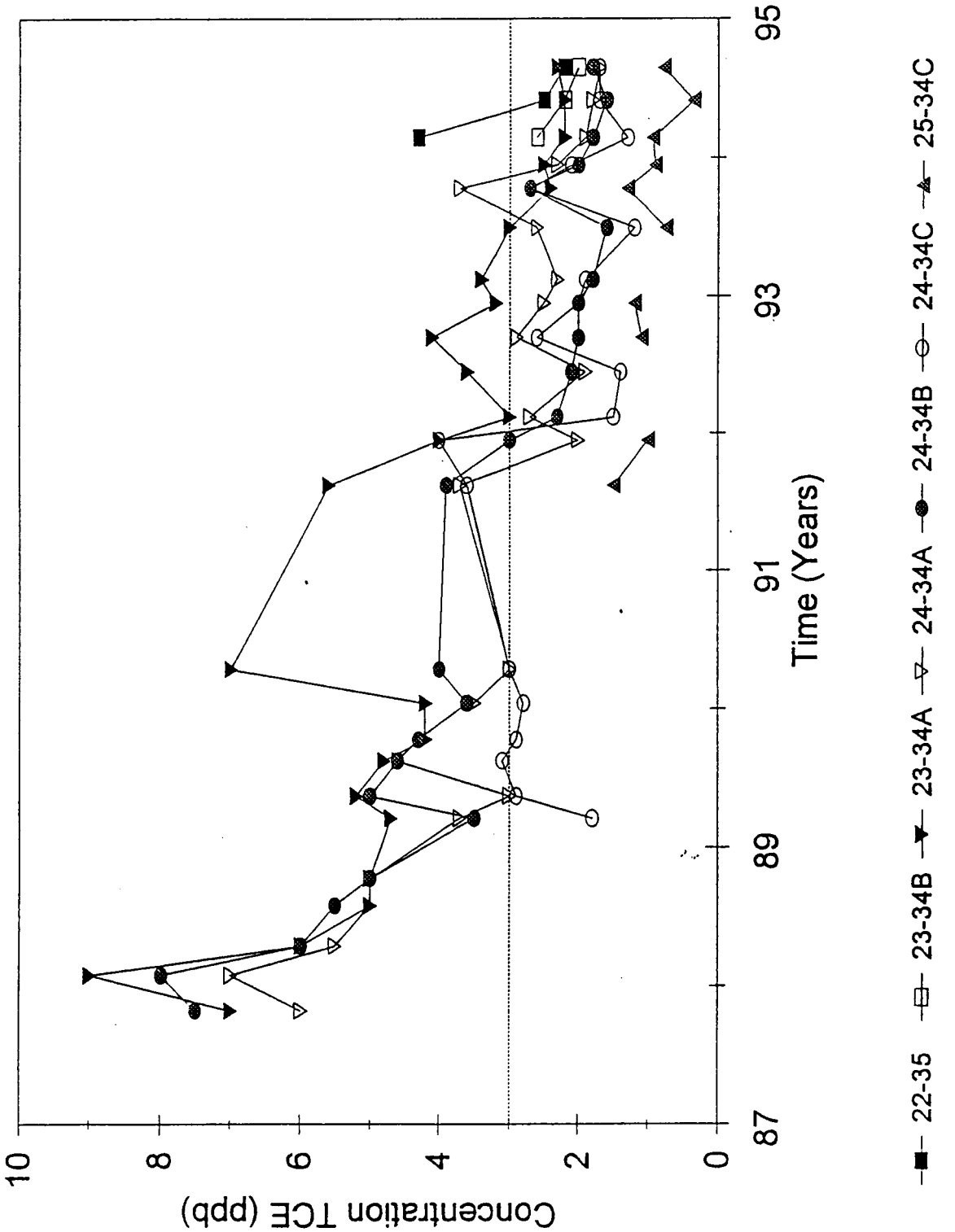
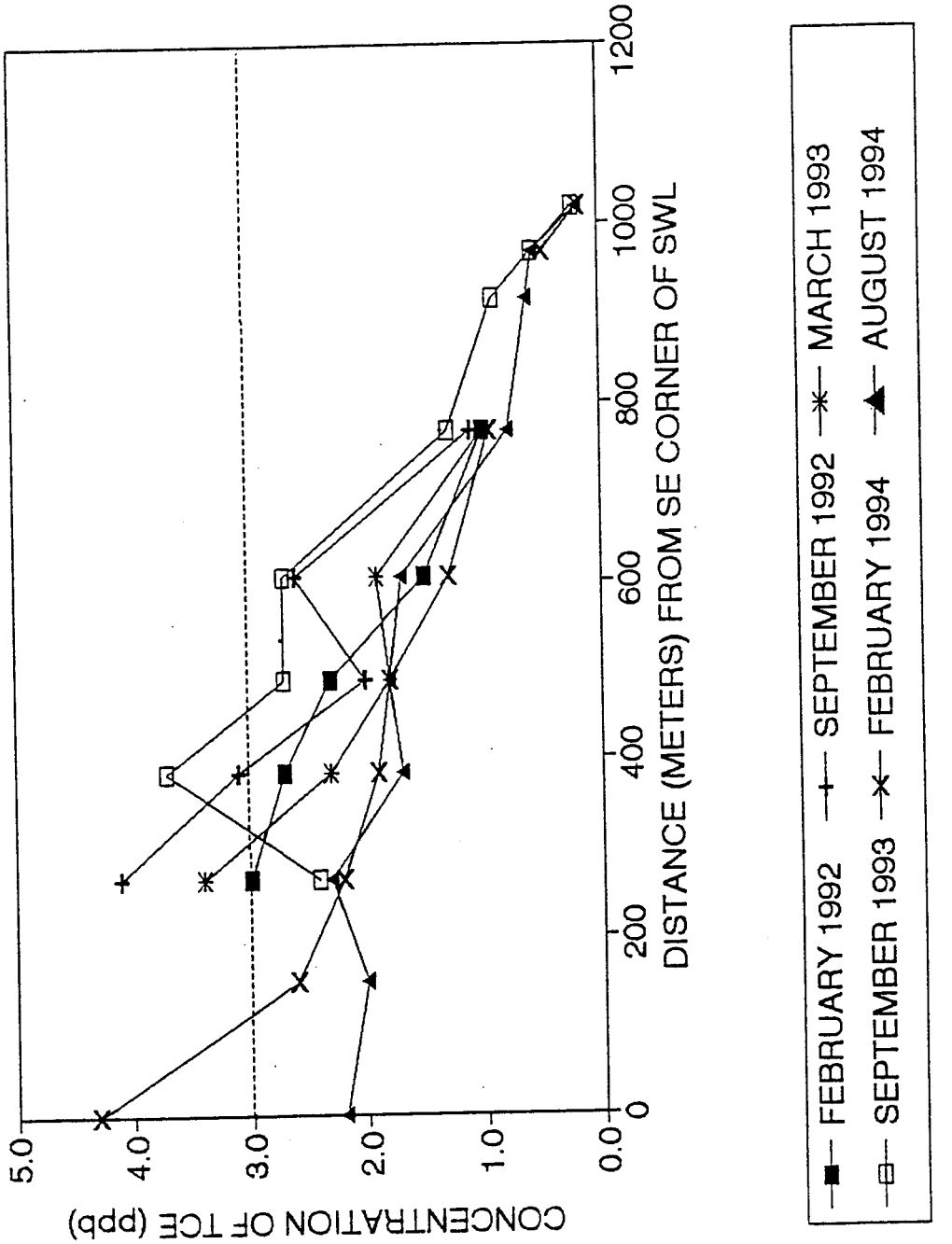


Figure 7. Plot Showing Spatial Distribution of Trichloroethene (ppb) in SWL and NDW. (Distance is in Meters from the Southeast Corner of the Landfill. The Dashed Line Represents the Groundwater Quality Criterion of 3 ppb.)



PCE concentrations in SWL downgradient wells have been less than 15 ppb, although they are consistently above the GWQC of 0.8 ppb. PCE concentrations have decreased slightly with time; however, they have shown little change since 1992 (Figures 8 and 9). The highest concentrations of PCE tend to occur in the southernmost wells; however, the concentrations in the two new wells at the southern end of the SWL are slightly lower than in the four southernmost older wells. This is unlike the concentration distribution for 111-TCA. The groundwater concentration pattern for PCE indicates that the source(s) of PCE in groundwater may still be beneath the SWL.

11-DCA occurs at concentrations well above the detection limit in the four southernmost downgradient wells of the original monitoring network and in the two new monitoring wells at the south end of the landfill. Recent analyses indicate very low concentrations (>> 1 ppb) in downgradient Well 699-35-34C. 11-DCA concentrations in the southern wells have been below 10 ppb, but have consistently been above the GWQC of 1 ppb (Figures 10 and 11). The concentrations of 11-DCA have shown a slight tendency to decrease over time and also to decrease from south to north along the landfill boundary. The groundwater concentration pattern for 11-DCA is quite similar to that of 111-TCA, which supports 11-DCA being a breakdown product of 111-TCA.

3.1.2 Specific Conductance

Except for Well 699-25-34C, specific conductance in downgradient monitoring wells consistently exceeds the background threshold value of 550 μmhos. These values, listed in Table 5, range up to 782 μmhos. The general tendency is for the values to increase from north to south along the line of downgradient wells; however, in many instances Well 699-24-34C has the highest specific conductance values in the network. The pattern of specific conductance values along the downgradient wells at the SWL is illustrated in Figure 12. The background threshold value was determined using quarterly data from upgradient Wells 699-24-35 and 699-26-35A.

3.2 VADOSE CONTAMINATION

A survey of shallow [2-m (6-ft)] vadose zone gases beneath the central portion of the SWL was reported by Evans et al. (1989). The survey found detectable concentrations of 111-TCA, TCE, PCE, 11-DCA, carbon tetrachloride, carbon dioxide, and methane. Methane was present at very low levels, with carbon dioxide concentrations exceeding methane concentrations by three or four orders of magnitude. Figure 13 indicates gas sampling sites used in the survey. Figures 14 through 17 show results of the gas analyses. It should be noted that methane and carbon dioxide were added to the analyte list after the survey had started and data for these constituents are not available for all

Table 5. Specific Conductance Values[a] for the Hanford Site Solid Waste Landfill (μmhos).

Sampling Date	22-35[b]	23-34A	23-34B	24-34A	24-34B	24-34C	25-34C	24-35[c]	26-35A[c,d]
January 1990		635[e]		552[e]	560[e]	554[e]	418	430	
April 1990		589[e]		538	551[e]	613[e]	410	433	
August 1991		619[e]		565[e]	589[e]	627[e]	520	470	400
December 1991		607[e]		590[e]	584[e]	622[e]	520	495	447
February 1992		551[e]		560[e]	578[e]	610[e]	460	414	360
June 1992		606[e]		676[e]	576[e]	782[e]	509	550	415
September 1992		626[e]		587[e]	597[e]	667[e]	526	472	427
December 1992		616[e]		647[e]	655[e]	751[e]	515	521	422
March 1993		608[e]		530	574[e]	670[e]	508	509	411
July 1993		651[e]		598[e]	674[e]	768[e]	525	569[e]	428
September 1993		641[e]		596[e]	608[e]	699[e]	544	491	430
November 1993		635[e]		592[e]	596[e]	686[e]	537	483	427
February 1994	697[e]	643[e]	667[e]	599[e]	615[e]	696[e]	550	506	445
June 1994	702[e]	644[e]	704[e]	595[e]	610[e]	747[e]	515	534	484

[a]Reported values are averages of replicate analyses.
[b]All well numbers are prefixed by 699-.
[c]Upgradient well.
[d]Also part of monitoring network of NRDWL.
[e]Value exceeds the background threshold value of 550 μmhos.

Figure 8. Time Series Plot Showing Concentrations of Tetrachloroethene (ppb) in SWL Downgradient Wells. (The Dashed Line Represents the Groundwater Quality Criterion of 3 ppb.)

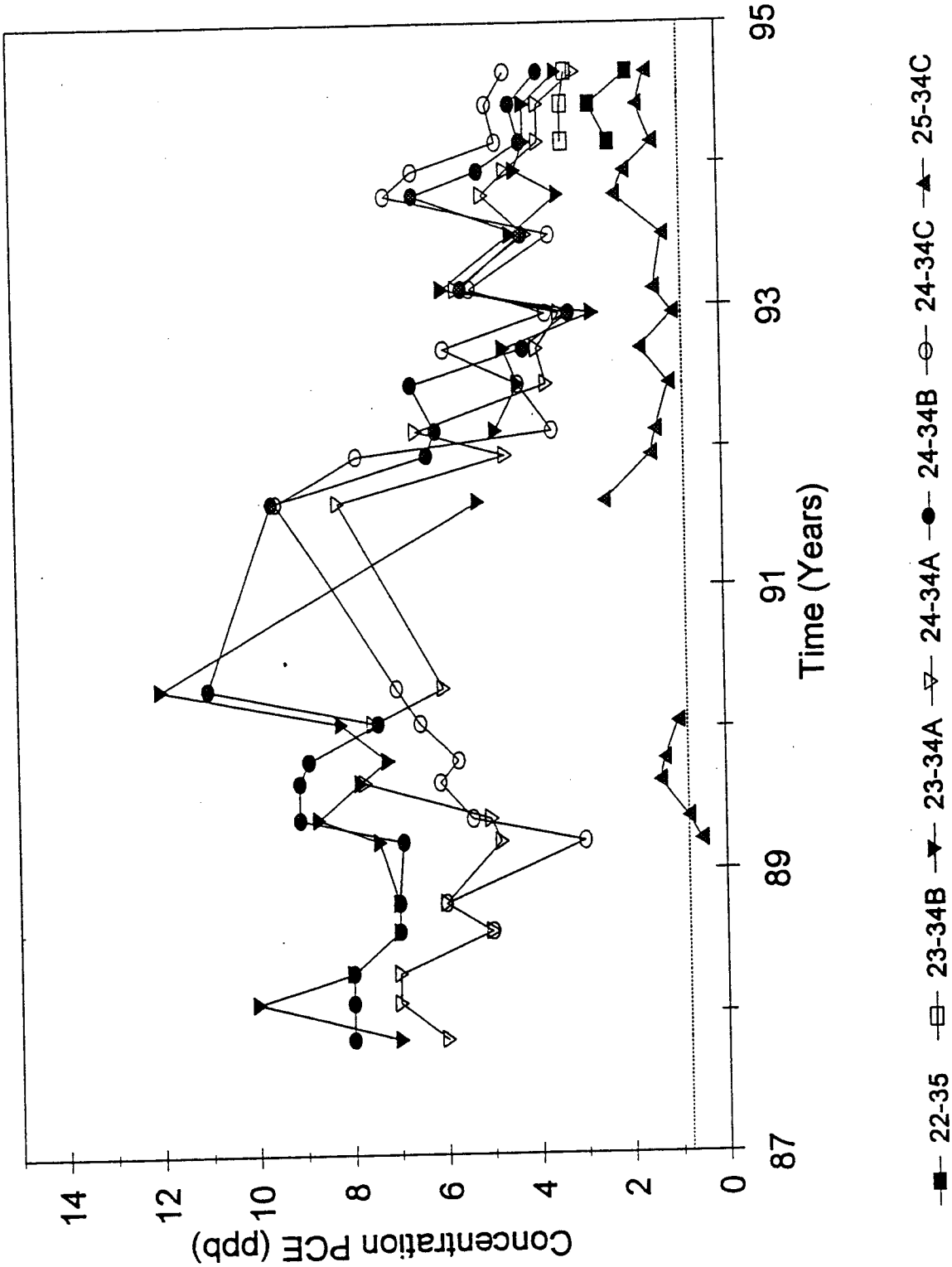


Figure 9. Plot Showing Spatial Distribution of Tetrachloroethene Concentrations (ppb) in Downgradient Wells at the SWL and NDWL. (Distance is in Meters from the Southeast Corner of the Landfill. The Dashed Line Represents the Groundwater Quality Criterion of 0.8 ppb.)

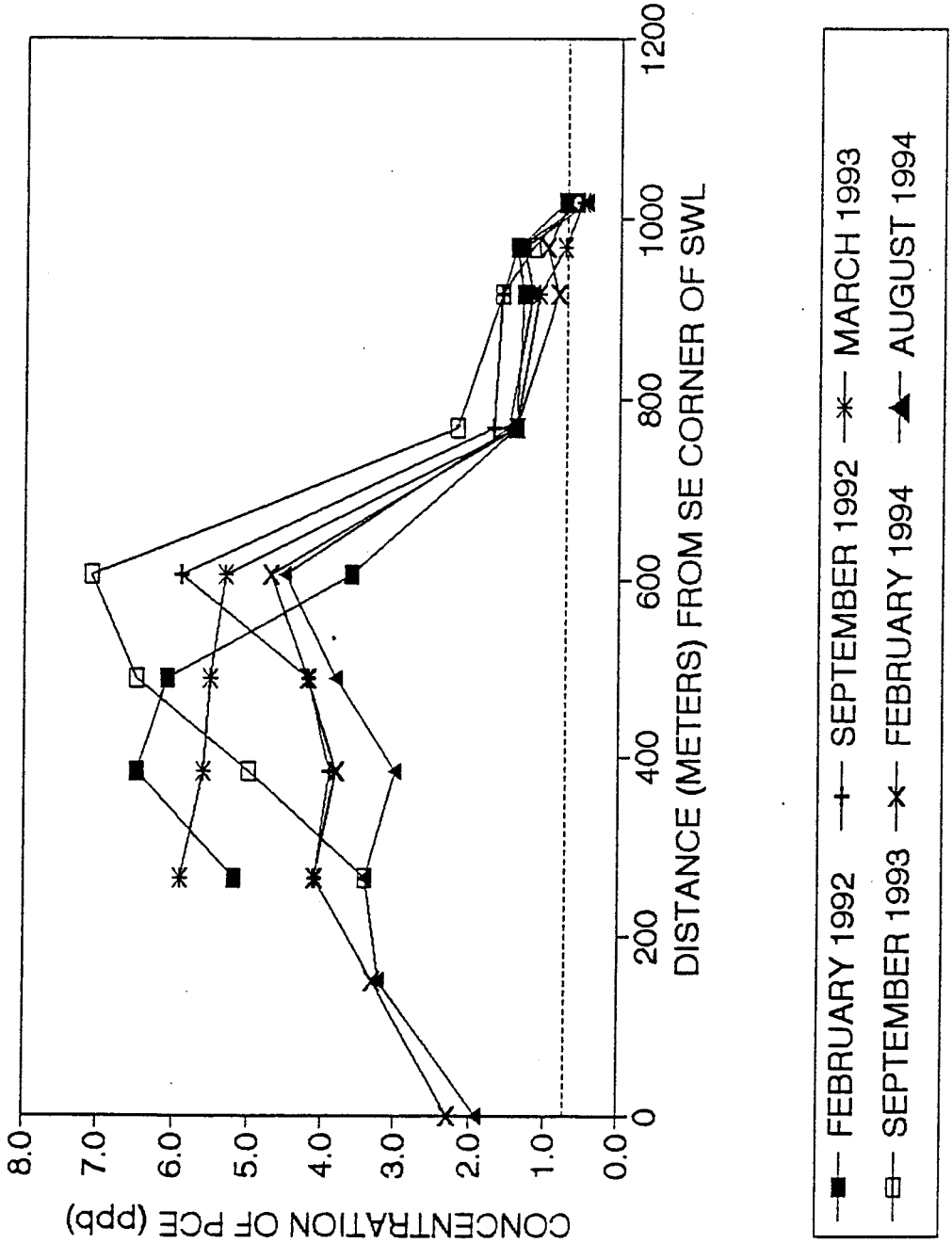


Figure 10. Time Series Plot Showing Concentrations of 1,1-dichloroethane (ppb) in SWL Downgradient Wells. (The Dashed Line Represents the Groundwater Quality Criterion of 1.0 ppb.)

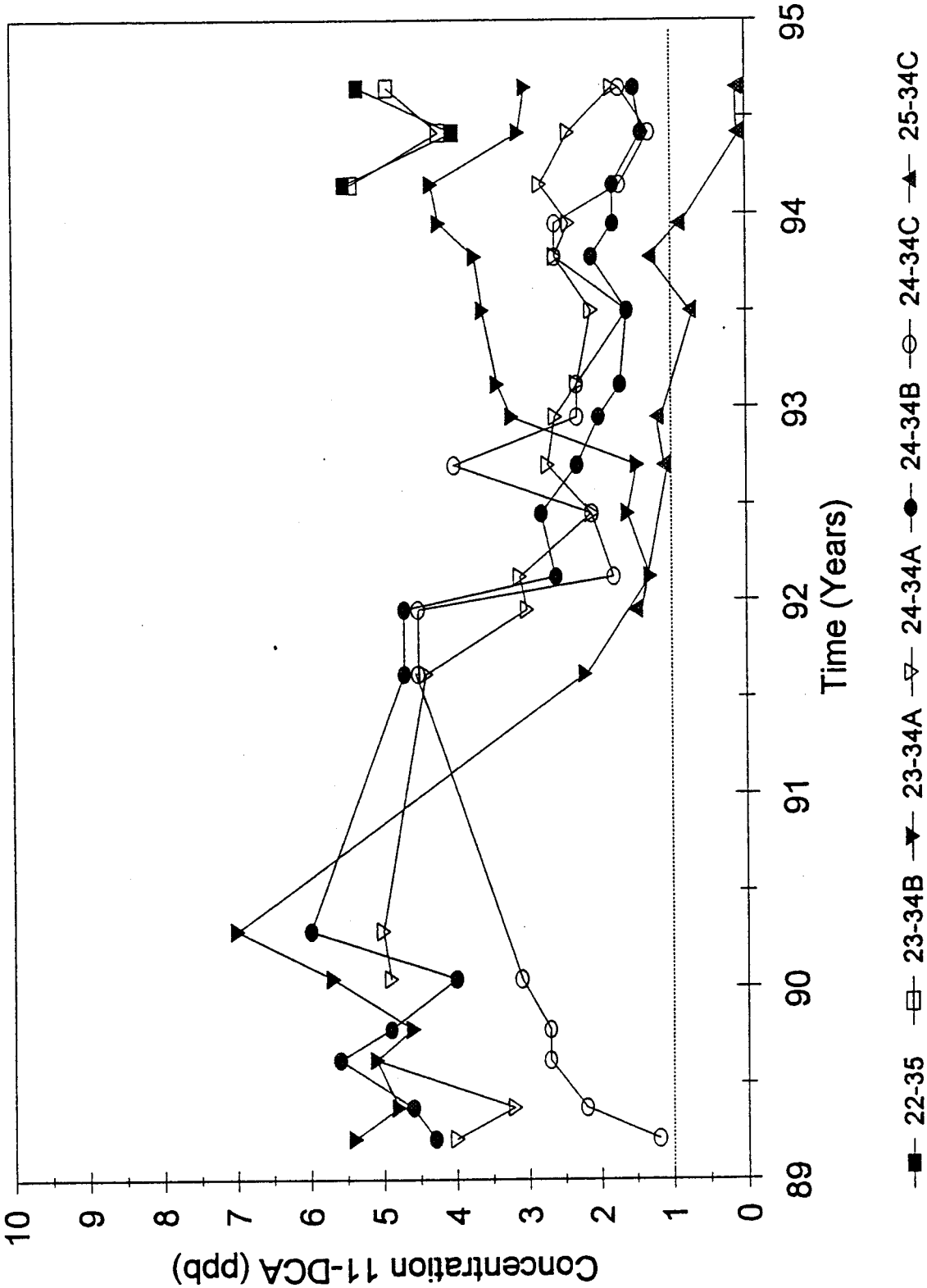


Figure 11. Plot Showing Spatial Distribution of 1,1-dichloroethene (ppb) Concentrations in Downgradient Wells at the SWL and NDWL. (Distance is in Meters from the Southeast Corner of the Landfill. The Dashed Line Represents the Groundwater Quality Criterion of 1.0 ppb.)

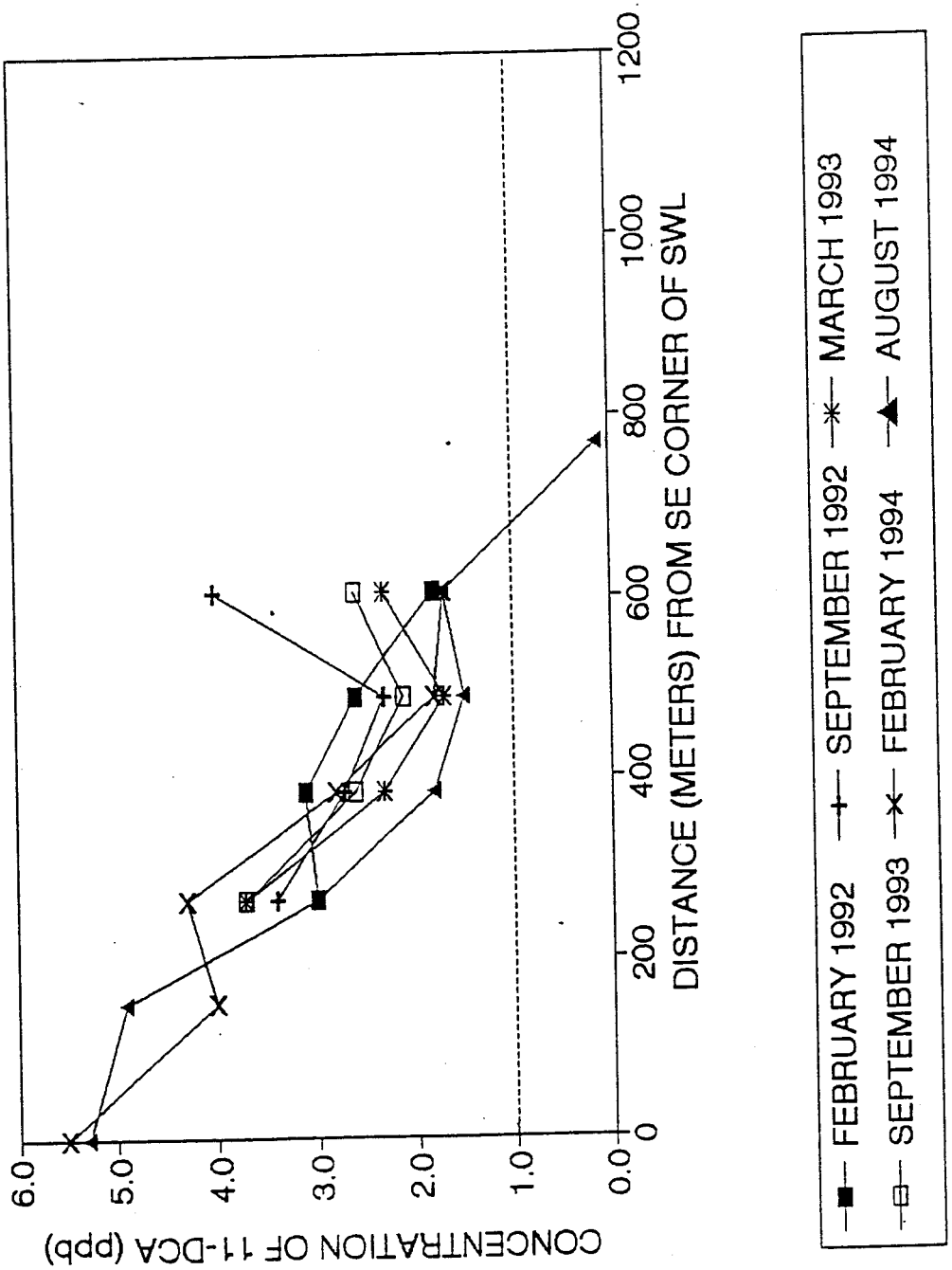


Figure 12. Plot Showing Spatial Distribution of Average Specific Conductance Values in Downgradient Wells at the SWL and NDWL. (Distance is in Meters from the Southeast Corner of the Landfill. The Dashed Line Represents the Background Threshold Value of 550 μmhos.)

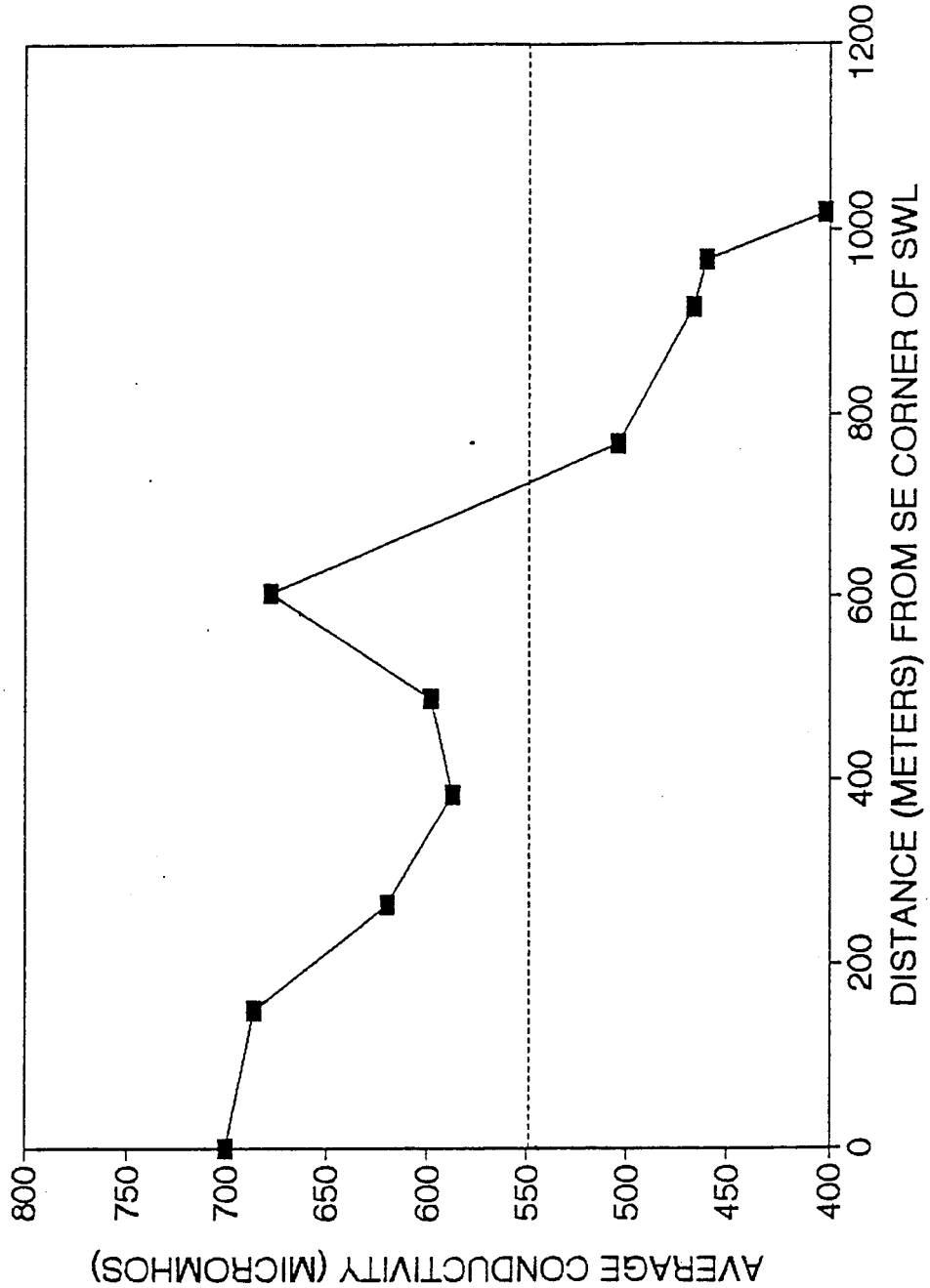


Figure 13. Map Showing Soil Gas Sampling Sites Used by Evans et al. (1989) for their Soil Gas Survey.

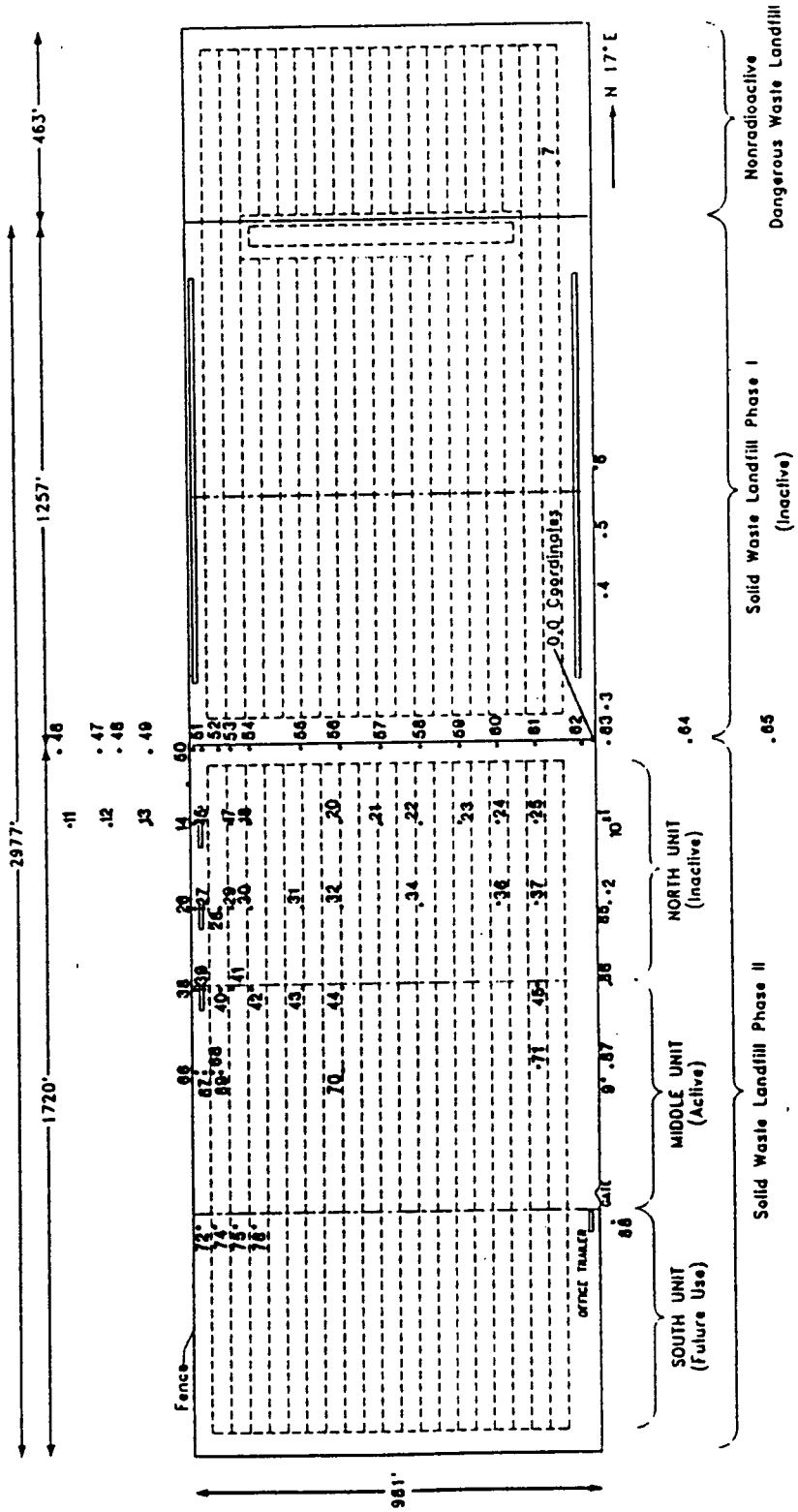


Figure 14. Soil Gas Results for 1,1,1-Trichloroethane (Evans et al. 1989). (Contours Represent Gas Concentrations in $\mu g/L$. Soil Gas Sampling Locations are Shown by Dots. Hatched Lines Indicate the Perimeter Fence Between Phase I and Phase II. The Dashed Lines Represent the Approximate Boundaries of Past, Present, and Planned Excavations.)

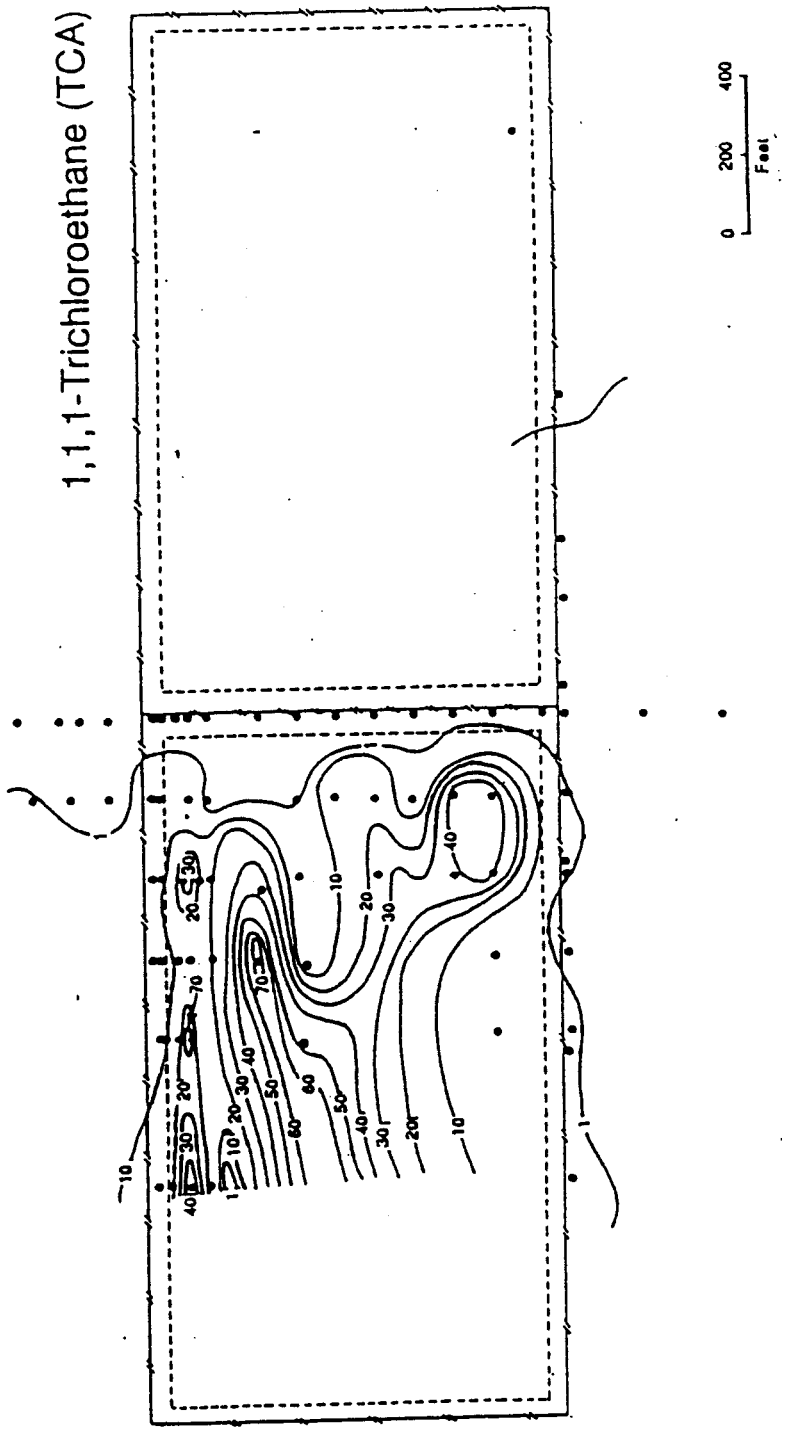


Figure 15. Soil Gas Results for Tetrachloroethene (Evans et al. 1989). (Contours Represent Gas Concentrations in μg/L. Soil Gas Sampling Locations are Shown by Dots. Hatched Lines Indicate the Perimeter Fence Between Phase I and Phase II. The Dashed Lines Represent the Approximate Boundaries of Past, Present, and Planned Excavations.)

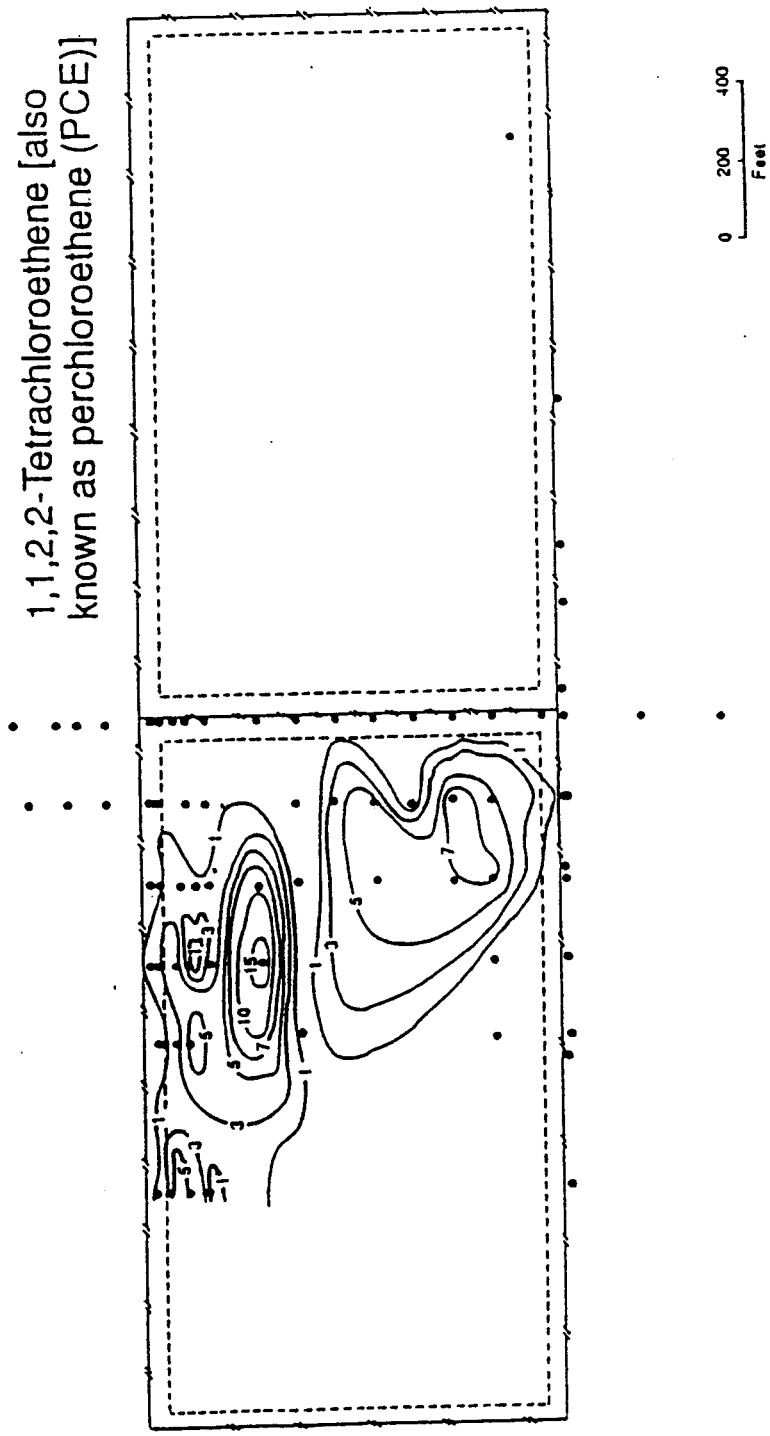


Figure 16. Soil Gas Results for Trichloroethene (Evans et al. 1989). (Contours Represent Gas Concentrations in µg/L. Soil Gas Sampling Locations are Shown by Dots. Hatched Lines Indicate the Perimeter Fence Between Phase I and Phase II. The Dashed Lines Represent the Approximate Boundaries of Past, Present, and Planned Excavations.)

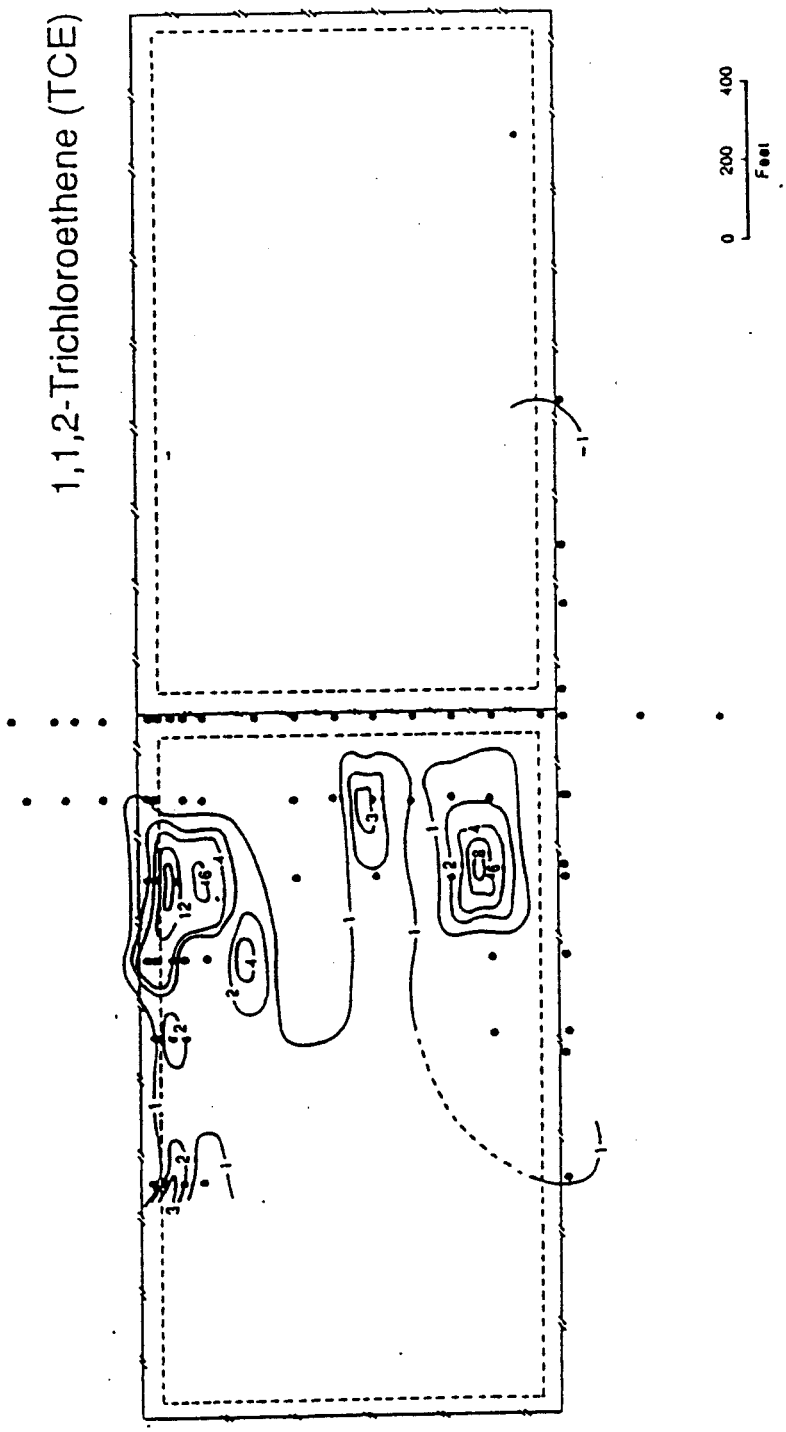
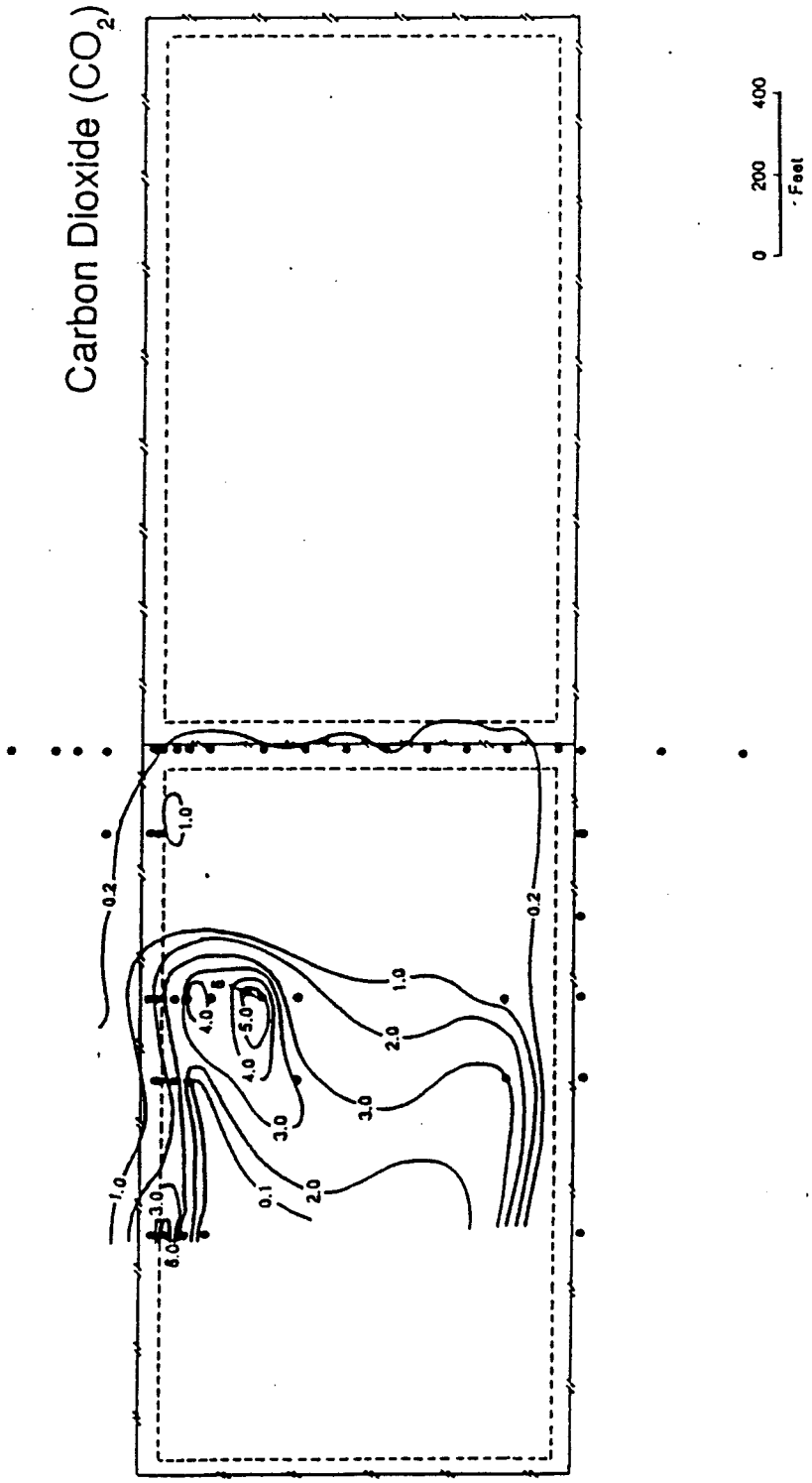


Figure 17. Soil Gas Results for Carbon Dioxide (Evans et al. 1989). (Contours Represent Gas Concentrations in μg/L. Soil Gas Sampling Locations are Shown by Dots. Hatched Lines Indicate the Perimeter Fence Between Phase I and Phase II. The Dashed Lines Represent the Approximate Boundaries of Past, Present, and Planned Excavations.)



sampling sites. 11-DCA was detected (0.5 to 7.4 μg/L) in several samples with relatively high 111-TCA concentrations; however, data were insufficient for contouring. Carbon tetrachloride was detected at very low levels (<0.1 μg/L) along the eastern boundary of landfill Phase I and the adjacent NRDWL.

Distribution patterns for 111-TCA and PCE are similar, with two areas of high concentration within the boundaries of the landfill. Neither zone of high 111-TCA and PCE corresponds directly to the three short trenches along the western boundary of the landfill used for disposal of catch-tank liquids. The distribution pattern for TCE shows less similarity to the distribution patterns of 111-TCA and PCE, particularly along the western landfill boundary where the highest TCE concentrations correspond more closely with the liquid disposal trenches. The distribution patterns for carbon dioxide and methane are similar to those of 111-TCA and PCE.

The carbon dioxide concentrations were determined using Drager tubes with a dynamic upper range of 6 volume%. During the survey, the maximum concentration for several samples actually exceeded 6 volume%; carbon dioxide concentrations are only known to exceed 6 volume% at those sampling points. Carbon dioxide vapor is denser than air and will tend to migrate downward under the influence of gravity. Therefore, a concentration as high as 6 volume%, at a depth of 2 m (6 ft), probably indicates much higher concentrations deeper within the vadose zone.

3.3 POTENTIAL SOURCES OF CHLORINATED HYDROCARBONS

Existing groundwater and vadose zone chemical data are consistent with several possible explanations of groundwater contamination at the SWL. Potential sources of contaminants at the SWL include the following:

- Chlorinated hydrocarbons dissolved in bus and heavy equipment wash water
- Chlorinated hydrocarbons migrating down dip from the NRDWL
- Chlorinated hydrocarbons included in sewage sludge
- Undocumented disposal of chlorinated hydrocarbons in solid waste trenches.

The following section discusses the evidence for and against each potential source. In this and the following sections it should be remembered that multiple sources for groundwater contamination may be present at the SWL.

3.3.1 1100 Area Catch-Tank Water

Between January 1985 and January 1987 approximately 3.8 x

10^5 L (10^5 gal) of catch-tank water from the bus garage and the heavy equipment garage were disposed of in three short trenches along the western boundary of the SWL. This was in addition to approximately 2.6 x 10^6 L (7 x 10^5 gal) of sewage waste disposed of in SWL trenches between 1982 and 1987.

Chemical analysis of catch-tank waters similar to those disposed of at the SWL indicates the presence of low levels of chlorinated hydrocarbons including carbon tetrachloride, 1,1,1-trichloroethane, and tetrachloroethene (DOE/RL 1993b, Appendix 4E). 1,1,1-Trichloroethane was the major component detected with lesser amounts of carbon tetrachloride and tetrachloroethene. Trichloroethene was below detection in the analyses.

The catch-tank water contained two of the principal contaminants of groundwater at the SWL; however, the following lines of evidence indicate that it is neither the only, nor the principal, source of groundwater contamination at the SWL.

- The concentration of contaminants in the catch-tank liquid is similar to that found in groundwater, while mixing with groundwater should produce a large degree of dilution.

- A conservative estimate of the quantity of 1,1,1-trichloroethane that has passed the downgradient wells indicates that at least three orders of magnitude more contaminant has moved downgradient than can be explained by the reported volume of catch-tank liquid and contaminant concentration (DOE/RL 1993b, Appendix 4F).

- A soil gas survey of the portion of the SWL adjacent to the three short trenches indicates very little correlation between high gas concentrations of chlorinated hydrocarbons and the disposal sites for catch-tank liquids. The soil gas highs are well within the body of the landfill (Evans et al. 1989).

- 1,1,1-Trichloroethane was detected in downgradient Well 699-24-33 in January 1986, one year after initiation of catch-tank water disposal at the SWL. In January 1986, the concentration in Well 699-24-33 was approximately 26 ppb, the highest reading from this well. Thus, if the catch-tank water is the source of groundwater contamination, the 1,1,1-trichloroethane must have traversed 30 m (100 ft) of vadose zone and approximately 460 m (1,500 ft) of unconfined aquifer in less than 1 year. This may be possible, but is considered highly unlikely.

It appears that the catch-tank water is, at most, a minor contributor to the groundwater contamination at the SWL.

3.3.2 Disposal Within the Solid Waste Landfill

Other than for the catch-tank liquid, no record exists of chlorinated hydrocarbons being disposed of at the SWL. There remains, however, a distinct possibility that the observed groundwater contamination is a result of unrecorded disposal activity at the SWL. The following evidence supports disposal of chlorinated hydrocarbons within the SWL.

- The soil gas survey (Evans et al. 1989) indicated concentration highs for chlorinated hydrocarbons within the body of the landfill, well removed from the liquid disposal trenches along the margins of the landfill (Figures 14 and 15).

- Groundwater monitoring data indicate that the main mass of contaminants (source) is located under the southern portion of the SWL or south of the SWL.

- Evidence from both the PNL soil gas survey and groundwater monitoring data (see Section 3.4) links the chlorinated hydrocarbon contamination with high carbon dioxide concentrations in the vadose zone; the high carbon dioxide concentrations apparently result from breakdown of sewage waste under oxidizing conditions.

- Relatively high values for chlorinated hydrocarbons and dissolved inorganic carbon are found in Well 699-24-34C, adjacent to the long liquid disposal trench along the east side of the landfill.

There is strong evidence for one or more sources of chlorinated hydrocarbons beneath the SWL. The chlorinated hydrocarbons, which are apparently migrating southward beneath the landfill, may be present as free liquid phases either in the vadose zone or within the aquifer. Alternatively they may exist as dissolved material in liquid that was disposed of in the sewage disposal trenches.

3.3.3 Migration from the Nonradioactive Dangerous Waste Landfill

Chlorinated hydrocarbon contaminants observed in groundwater and soil gas at the SWL may have originated in the adjacent NRDWL. Free-phase dense liquids, if they ever existed at the NRDWL, would have moved down dip toward the south either within the aquifer or along silt layers within the vadose zone. Factors indicating a potential NRDWL source include the following:

- The chlorinated hydrocarbon species observed at the SWL were disposed of at the NRDWL (DOE/RL 1990)

- The chlorinated hydrocarbon species observed at the SWL have been observed in the soil gas at the NRDWL (Jacques 1993, WHC 1993)

- Any dip in sedimentary structures at the site will be toward the south (toward the axis of the Cold Creek Syncline) and will result in contaminant migration under the SWL.

Factors indicating that the NRDWL is probably not a source include the following:

- The low impact of presently observed vadose zone contamination at the NRDWL on groundwater quality at the NRDWL indicate that the NRDWL is not presently a major source of contaminants, but does not rule out past contributions

- That reported quantities of chlorinated hydrocarbons disposed of at the SWL are probably insufficient to produce the observed effects at the SWL.

The NRDWL is probably not the source of the contaminants observed at the SWL; however, uncertainties about disposal at the NRDWL early in its operation and the lack of groundwater monitoring data during the first 12 years of operation leave open the possibility that the NRDWL contributed to the contamination at the SWL.

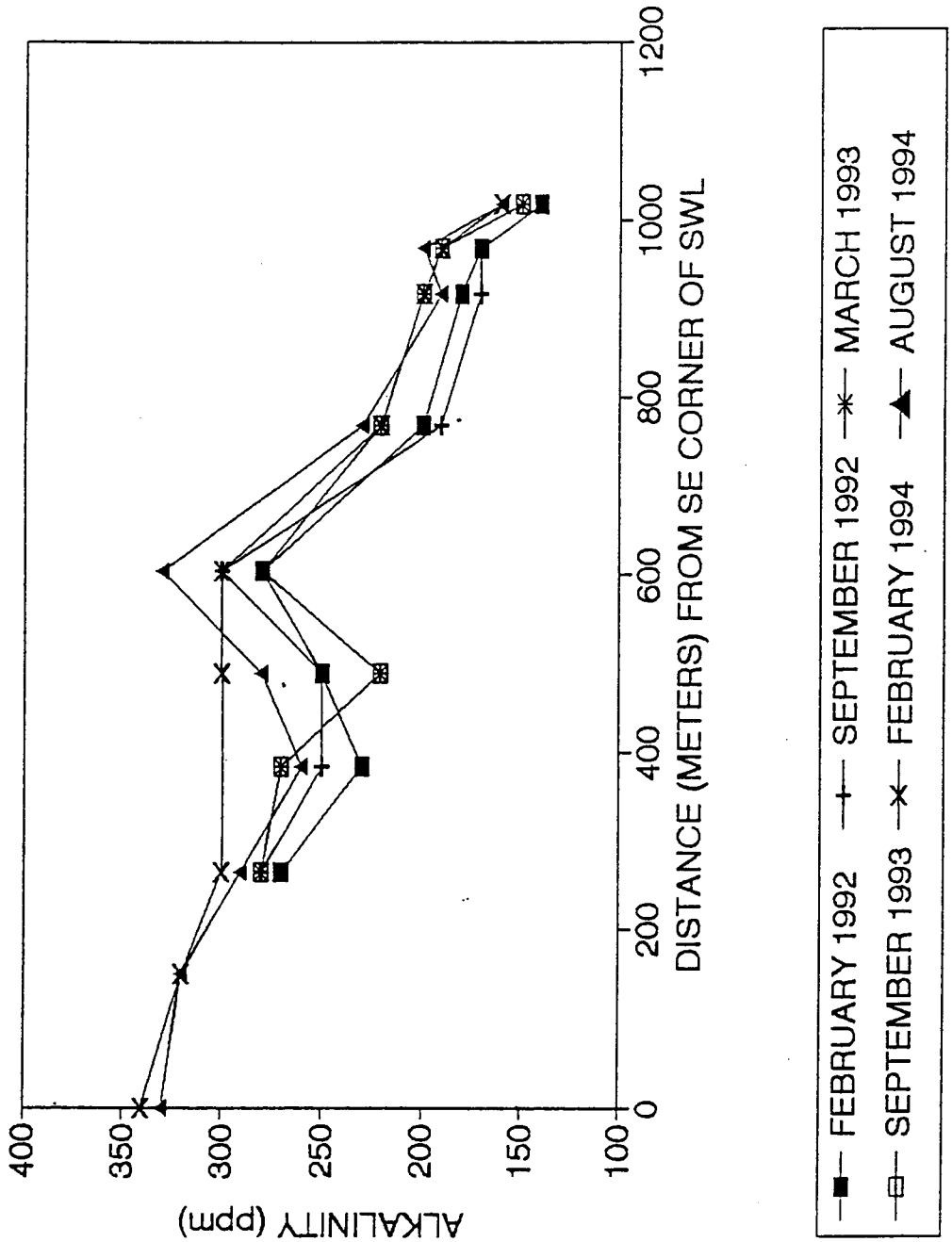
3.4 SOURCE OF ELEVATED SPECIFIC CONDUCTANCE VALUES

The elevated specific conductance values in downgradient wells at the SWL are associated with higher concentrations for alkalinity; total carbon; several cations including calcium, potassium, and barium; and slightly lower pH. The pattern of alkalinity values in downgradient wells at the SWL and adjacent NRDWL is shown in Figure 18, illustrating a southward increase in alkalinity values.

The higher alkalinity and higher total carbon in the downgradient groundwater indicate that the increased specific conductance is principally caused by an increased carbonate or bicarbonate concentration in the groundwater. This increased carbonate concentration is apparently the result of high concentrations of carbon dioxide in the vadose zone. Evans et al. (1989) reported high concentrations of carbon dioxide in vadose gas at the SWL and Jacques (1993) reported higher vadose concentrations of carbon dioxide in the northern portions of the SWL, relative to the NRDWL. The elevated carbon dioxide concentrations in the vadose zone at the SWL apparently result from the breakdown of sewage solids beneath the SWL under oxidizing conditions.

The solution of carbon dioxide in the groundwater lowers its pH by forming carbonic acid. The lowered pH causes an increased reaction between groundwater and aquifer solids, mostly silicates in this case. The reaction between groundwater and aquifer solids results in the removal of metal ions (bases) from the

Figure 18. Plot Showing Spatial Distribution of Alkalinity Values (ppm) in Downgradient Wells at the SWL and NDWL. (Distance is in Meters from the Southeast Corner of the Landfill.)



and a buffering of pH back toward higher values. This reaction explains the slightly increased metal concentrations and the slightly lower pH values in downgradient wells at the SWL.

3.5 CONCLUSIONS

The weight of evidence clearly indicates that chlorinated hydrocarbon sources exist beneath the SWL and probably in the area south of the landfill. However, the existing evidence is not sufficient for the source or nature of these sources to be determined.

The chlorinated hydrocarbon sources may exist as free liquids migrating either within the vadose zone or beneath the water table; however, the widespread occurrence of chlorinated hydrocarbons, including low concentrations in upgradient wells, indicates a strong vadose component. If the contaminant sources are within the vadose zone, the spatial correspondence between chlorinated hydrocarbons and high vadose carbon dioxide may indicate that the chlorinated hydrocarbons are dissolved in an aqueous sewage phase that is migrating southward within the vadose zone, probably along the tops of thin silt layers within the Hanford formation. If this is the case, the chlorinated hydrocarbons could have been disposed of along with the sewage waste or have mixed with it after disposal.

The elevated specific conductance in downgradient wells at the SWL is apparently caused by elevated bicarbonate concentrations in groundwater resulting from elevated vadose zone carbon dioxide concentrations beneath the SWL. The major effect is a slight increase in the hardness of the groundwater. The elevated specific conductance does not indicate a significant degradation of groundwater quality.

The SWL has two contaminant problems. The first, related to the presence of several chlorinated hydrocarbons in groundwater in excess of state groundwater quality criteria is addressed in Section 4. The second, related to increased specific conductance in downgradient monitoring wells is considered insignificant and is not addressed further.

4.0 CORRECTIVE ACTION CRITERIA

The characterization studies proposed here should provide sufficient information to decide if remediation is the proper option and, if it is, what techniques should be applied. If remediation is the preferred option, the best techniques for remediating groundwater contamination at the SWL depend largely on the location and form of the sources of the contaminants. Pump and treat may be appropriate if high concentrations of contaminant are found within the aquifer. In situ air stripping may be the appropriate remediation response if the contaminants exist as free or interstitial liquids within the vadose zone. Pumping coupled with air stripping may be the proper response if the contaminants are dissolved in an aqueous phase within the vadose zone.

Because the location and nature of the contamination sources are uncertain, the remediation of the site must follow a staged approach, starting with characterization and ending with implementation of a selected remediation technology. The approach that follows is similar, but not identical, to the remediation approach typically used for contaminated sites under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA). This similarity is a result of the logic of the situation and not of any attempt to follow CERCLA protocols. A schematic diagram showing the flow of the proposed corrective action program is presented in Figure 19.

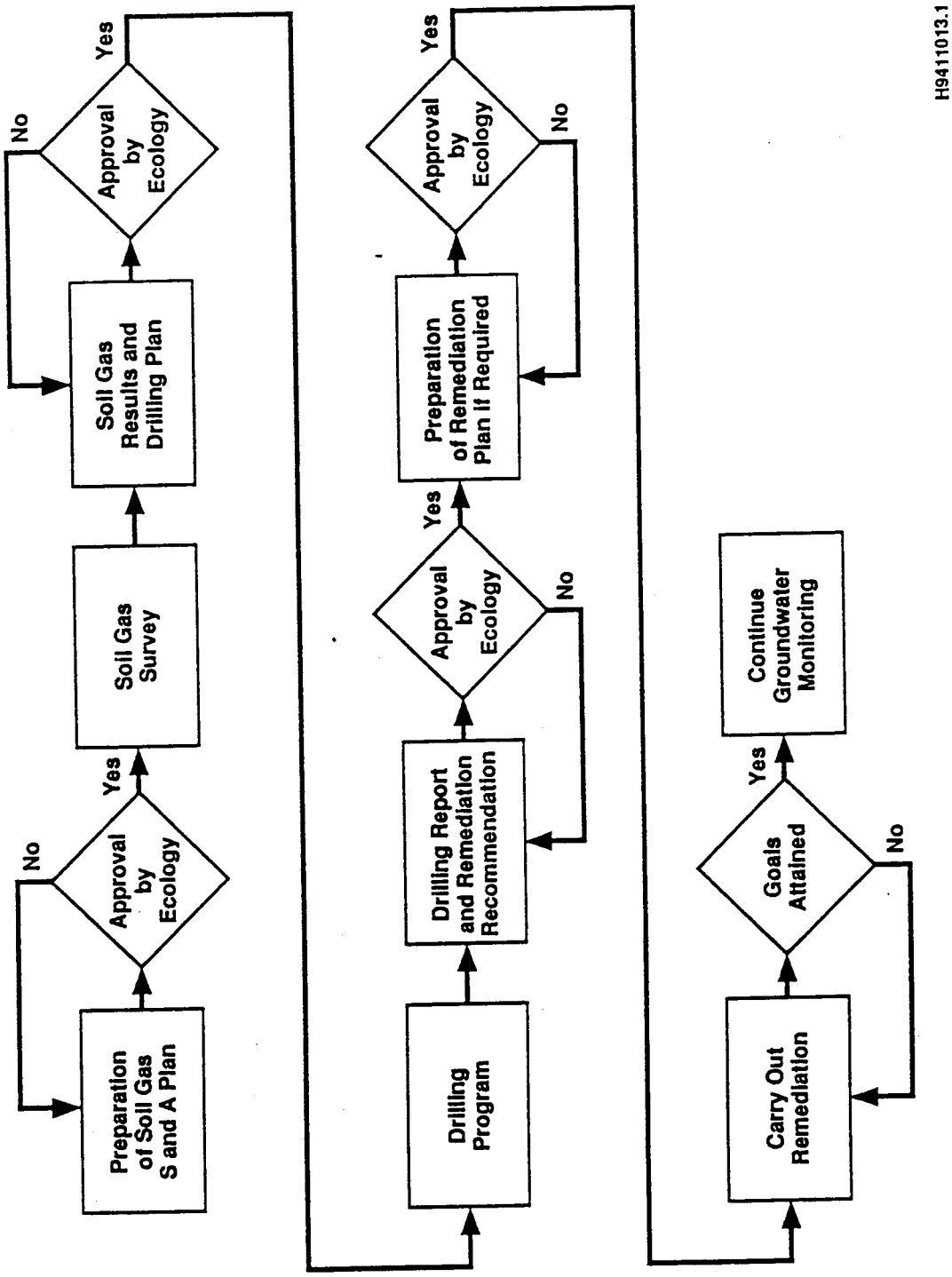
4.1 STAGED APPROACH

The staged approach will consist initially of a two-phased characterization stage. The two parts of the characterization stage are a comprehensive soil gas (vadose) survey, followed by a drilling program. The following stages will include data evaluation and selection of a remediation approach, implementation of the preferred approach, and evaluation of the effectiveness of the remediation. Each phase will be concluded with a report and/or plan for the next phase and work will continue only after it has been approved by Ecology.

4.2 VADOSE GAS CHARACTERIZATION

Vadose gas characterization offers a way to map the distribution of chlorinated hydrocarbon contaminants beneath the SWL and its surroundings. This technique is sensitive to contaminants within the vadose zone and/or the shallow portions of the unconfined aquifer; however, it is not effective in detecting contaminants within the deeper portions of the aquifer. This survey will expand on the work of Evans et al. (1989), which was developmental and covered only a relatively small portion of the landfill.

Figure 19. Diagram Illustrating Sequence of Proposed Actions at the SWL.



Vadose gas (soil gas) characterization at the SWL will consist of the analysis of shallow (nominal 2 m (6 ft) deep) gas samples over the entire solid waste landfill and the immediately surrounding areas, particularly to the south. If it appears feasible and funding is available, deeper gas samples may be collected in selected areas through the use of a cone penetrometer gas sampler (Jacques 1993).

Gas samples taken during the survey will be analyzed by gas chromatography for chlorinated hydrocarbons (VOAs), particularly those previously detected in SWL groundwater and soil gas surveys. In addition, the samples will be analyzed for carbon dioxide and methane to help determine the relationship between the hydrocarbon contaminants and sewage waste beneath the landfill.

A sampling and analysis plan for vadose gas sampling will be prepared and sampling will not begin until Ecology has reviewed and approved the plan. In addition, a report of sampling results will be prepared and sent to Ecology after sampling and analysis are complete. The final report of the gas sampling program will include an interpretation of sampling results and a recommendation for drilling activities.

4.3 DRILLING PROGRAM

The vadose gas survey provides a two-dimensional picture of contaminant distribution; however, it does not provide adequate information on depth distribution. Once vadose gas data analysis and interpretation are complete, a series of characterization wells will be drilled. These characterization wells will be drilled to sufficient depth to locate and characterize the contaminant sources and may extend into the aquifer.

If the vadose gas survey indicates significant contamination south of the landfill's boundary, additional groundwater monitoring wells may be needed. The new groundwater monitoring wells would include downgradient wells and possibly an additional upgradient well. These wells would be used to evaluate groundwater contamination in the area south of the landfill boundary.

A drilling plan, including provisions for sampling and analysis, will be prepared for review and approval by Ecology before drilling takes place. This plan will include a review of drilling options and will detail the drilling and sampling techniques to be used, analytical requirements, and data analysis. After drilling and sample analysis are complete, a final characterization report will be prepared for transmittal to Ecology.

4.4 REMEDIATION DECISION

If remediation is deemed desirable and feasible, the best technology to carry it out will depend on the location and form of the contaminant sources. On the basis of the characterization program, a recommendation for the best approach for remediation of contamination at the SWL will be included in the drilling program report.

4.5 REMEDIATION AND POST-REMEDIATION EVALUATION

Once Ecology approves the remediation approach, a final remediation plan will be prepared and submitted. Implementation of the final remediation plan will occur with the concurrence of Ecology. The plan submitted to Ecology will contain remediation goals and criteria for evaluating the remediation effort. The effectiveness of the remediation effort will be reported to Ecology periodically and at the end of the remediation effort. When the cleanup goals have been met, or it has been decided by Ecology that further effort is unnecessary, a final remediation report will be submitted indicating the state of contamination in groundwater at the SWL.

Groundwater monitoring at the SWL will be continued into the SWL post-closure period as specified in the site permit.

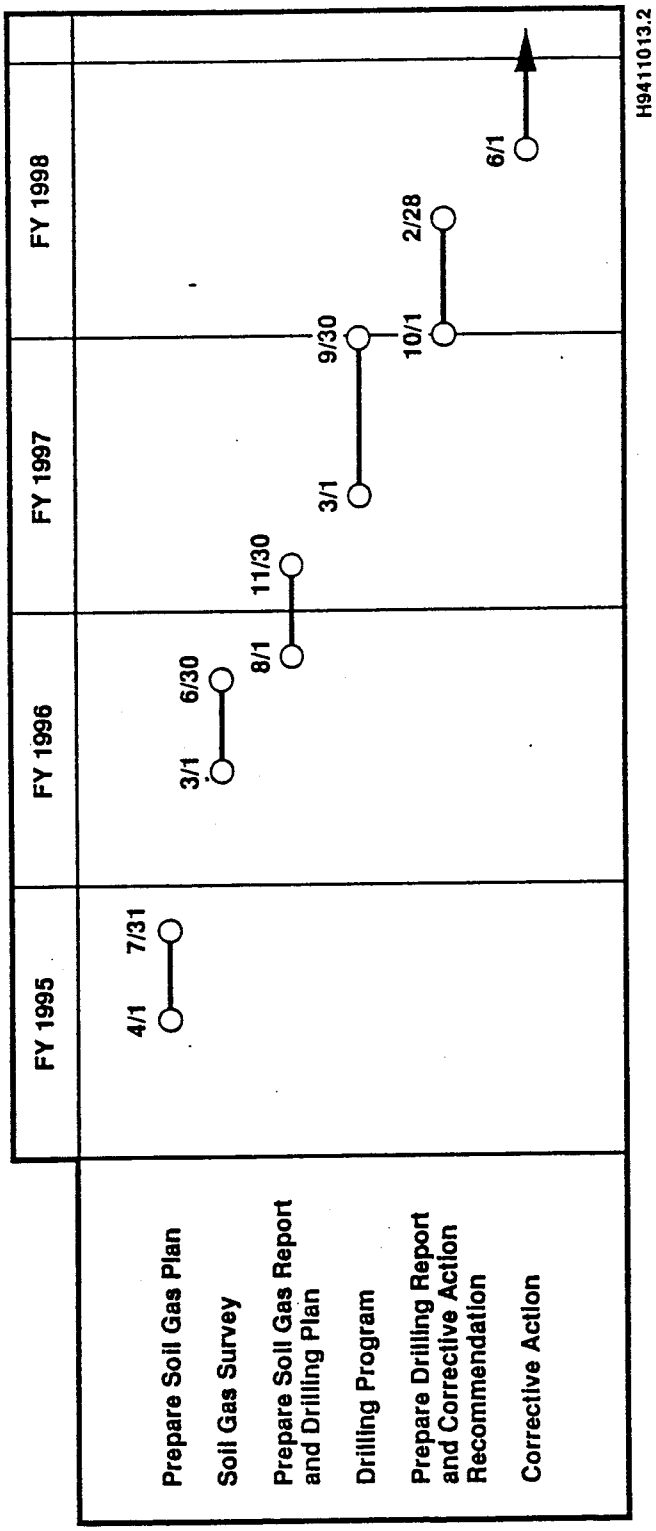
5.0 SCHEDULE AND COST

Schedule and cost for this remediation action are difficult to determine because the scope and nature of various parts remain to be determined.

Because of budget constraints, the soil gas survey probably cannot be started before fiscal year (FY) 1996. The actual cost will depend on the details of the sampling and analysis plan. Experience at the NRDWL indicates that the total cost is about $750 per sampling site. Assuming a survey on 30-m (100-ft) centers across the landfill (360 sampling points), an additional 100 points south of the landfill, and 50 points to increase analytical density in areas of high contaminant concentration, the total cost will be approximately $400,000.

The cost of drilling will depend on the drilling techniques used and the number of holes indicated by the soil gas survey. It may be possible to schedule and budget at least part of the drilling for the latter portion of FY 1996, with any remaining drilling funded for FY 1997. The cost of remediation will depend on the remediation technologies selected, the extent of the required remediation operations, and the time over which remediation operations must be carried out. The earliest that remediation operations can reasonably start is FY 1998. A tentative schedule for the Corrective Action Program is presented in Figure 20.

Figure 20. Tentative Schedule for Corrective Action Program at the SWL.



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