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Evaluation of Ground-Water Extraction Remedies: Phase II

Volume 2
Case Studies and Updates

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Volume 2 - Case Studies and Updates

Publication 9355.4-05A
February 1992

EVALUATION OF GROUND-WATER EXTRACTION REMEDIES: PHASE II

Volume 2
Case Studies

Office of Emergency and Remedial Response
U. S. Environmental Protection Agency
Washington, D.C.

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INTRODUCTION TO VOLUME 2

This volume was prepared as part of the second phase of a study to evaluate the effectiveness of the ground-water extraction systems being used to remediate ground-water contamination at hazardous waste sites.

Volume 2 includes updates of 17 of the 19 case studies originally written in the first phase of the evaluation and published by the U.S. Environmental Protection Agency in 1989 (U.S. EPA, 1989). For two of the sites in the original study, Case Study 5 and Case Study 19, no new information was available, so no update has been written. Also included in this volume are five new case studies for sites not addressed in the original evaluation. Volume 1 is a companion document summarizing the information on the 24 sites in both phases of the study and presenting general conclusions.

The 17 case-study updates presented in this volume are intended to be true updates rather than replacements of the original case studies. Enough information is given in the updates to make them stand-alone documents, but much of the detailed background information presented in the original case studies has not been repeated. For fullest understanding of the sites, both the original and the update should be read.

The case studies and updates are thought to represent site conditions and remedial activities accurately, on the basis of the site documents acquired in this project. The documents generally included site investigation and remedial design reports and periodic (usually quarterly or annual) monitoring reports for the operating ground-water remediation systems. The site documents were generally furnished by regulatory agency personnel associated with the sites or by the parties responsible for remediation. In addition, comments on drafts of each of the case studies and updates were solicited from individuals known to be familiar with the sites. Many helpful comments were received and were incorporated in the studies. Still, there is no way to ensure that significant facts have not been overlooked.

The case studies and updates are meant to be informative rather than definitive. They should not be considered authoritative source documents within the framework of enforcement actions or site negotiations. Under no circumstances are they to be interpreted as official statements of regulatory findings for the sites concerned.

Various interpretations and conclusions about site characteristics and remedial progress are presented in the case studies and updates. Many of the interpretations are taken directly from the site data and monitoring reports. In such cases, the source documents containing the interpretation are usually referenced. Conclusions drawn by the authors of the case studies generally are presented in the last two sections of each study, which are summaries of the remediation as a whole and of issues related to nonaqueous- phase liquid contaminants (NAPLs). Particularly in the "Summary of NAPL-Related Issues," the authors felt free to present tentative interpretations that are more or less speculative.

REFERENCE

U. S. Environmental Protection Agency (U.S. EPA). October 1989. *Evaluation of Ground-water Extraction Remedies: Volume 2. Case Studies 1-19.* EPA 9355.4-03.

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UPDATE OF CASE STUDY 1

Amphenol Corporation
Sidney, New York

Abstract

Monitoring data collected since 1988 show that the extraction system has continued to induce a zone of capture that encompasses the areas of known volatile organic compound (VOC) contamination. Concentrations of VOCs have decreased in some shallow wells indicating the ground-water quality in the shallow aquifer continues to improve as a result of remediation. However, VOC concentrations have stabilized at higher levels in some deeper wells.

Table of Background Data	
Date of Problem Identification	1983
Extraction Started	January 1987
Types of Contaminants	Tetrachloroethylene Trichloroethylene Chloroform
Primary Aquifer Materials	Fluvial and glacial silt, sand, and gravel
Maximum Number of Extraction Wells	2
Maximum Total Extraction Rate	260 gpm
Estimated Plume Area	9 acres
Estimated Plume Thickness	100 feet
Maximum Reported Concentrations	Total VOCs 329 ppb

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CASE STUDY UPDATE
AMPHENOL CORPORATION

BACKGROUND OF THE PROBLEM

INTRODUCTION

This report discusses events and progress in remediation at the Amphenol site from early 1989 through June 1990. It is an update of the original case study, which was based on data collected through the end of 1988 (U.S. EPA, 1989, Case Study 1).

The Amphenol site is a manufacturing facility located in the village of Sidney, New York (see Figure 1). Electroplating wastewater impounded in two waste treatment lagoons has contaminated soil and ground water at the site with volatile organic compounds (VOCs). This contamination is a potential threat to the water supply wells of the village of Sidney. The site is administered by the New York State Department of Environmental Conservation.

The problem was first discovered in 1983 when monitoring required by the EPA under the RCRA showed that soils and ground water beneath the treatment lagoons were contaminated by VOCs. The waste lagoons were taken out of operation in 1985. The ground-water extraction system began operation in January 1987 and has been operated almost continuously since startup.

The area is underlain by 100 to 200 feet of fluvial and glaciofluvial deposits of unconsolidated silt, sand, and gravel. Within these unconsolidated sediments are two transmissive zones referred to as the shallow and deep aquifer zones, respectively. The unconsolidated deposits are underlain by flat-lying shale bedrock.

The direction of ground-water flow is variable. It is influenced by the water level in the nearby Susquehanna River, the surface topography, and ground-water pumping from both the Sidney production wells and the extraction system. The most common flow pattern, which occurs when the river stage is high, is for ground water to flow to the southeast and southwest away from the river. When this occurs, ground water in the area of the two lagoons diverges and flows to both the southwest and southeast. When ground-water levels are high relative to the river stage, ground water flows to the northwest.

The primary contaminants of concern are trichloroethylene (TCE), chloroform, tetrachloroethylene, and other VOCs. The area of greatest contamination is immediately southwest of the two lagoons in the shallow aquifer zone. The shallow plume is divided into two lobes, one extending west from the lagoons parallel to the river and the other extending to the southeast. The deep plume is southeast of the lagoons and appears to turn to the east at its southern limit in response to ground-water pumping by the water supply wells of the village of Sidney.

UPDATE ON SITE CHARACTERISTICS

There have been no important changes in the site administration, or in the understanding of the hydrogeologic setting or waste characteristics since the time of the original case study.

REMEDIATION

Design and Operational Features of Remediation System

The objectives of remediation are to reduce total VOC concentrations to less than 5 ppb in the subsurface and to prevent contaminated ground water from reaching the Sidney water supply wells. The remediation system, as shown in Figure 2, consists of two extraction wells--RW-1, which is screened from 100 to 120 feet and designed to remediate the deep aquifer zone, and RW-2, which is 25 feet deep and designed to remediate the shallow zone. Both wells are close to the lagoons. Wells RW-1 and RW-2 are typically pumped at approximately 140 and 60 gpm, respectively.

The extraction system has not been modified since the end of 1988. However, a second production well for the village of Sidney, one located farther

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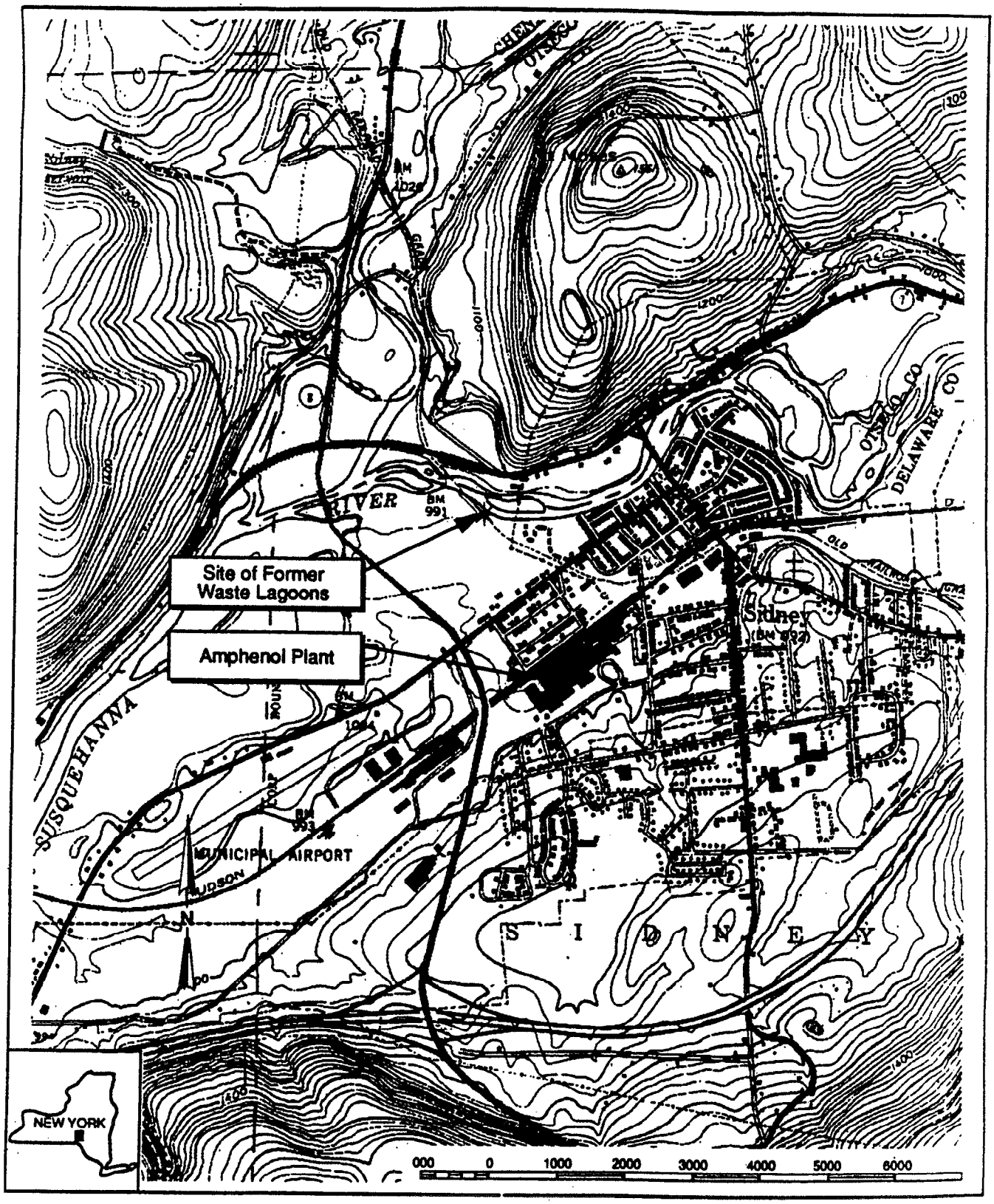

Source: USGS, 1982. Sidney Quadrangle, 7.5 Minute Topographic Series

1000 0 2000
scale in feet

Figure 1
SITE LOCATION MAP
AMPHENOL SITE

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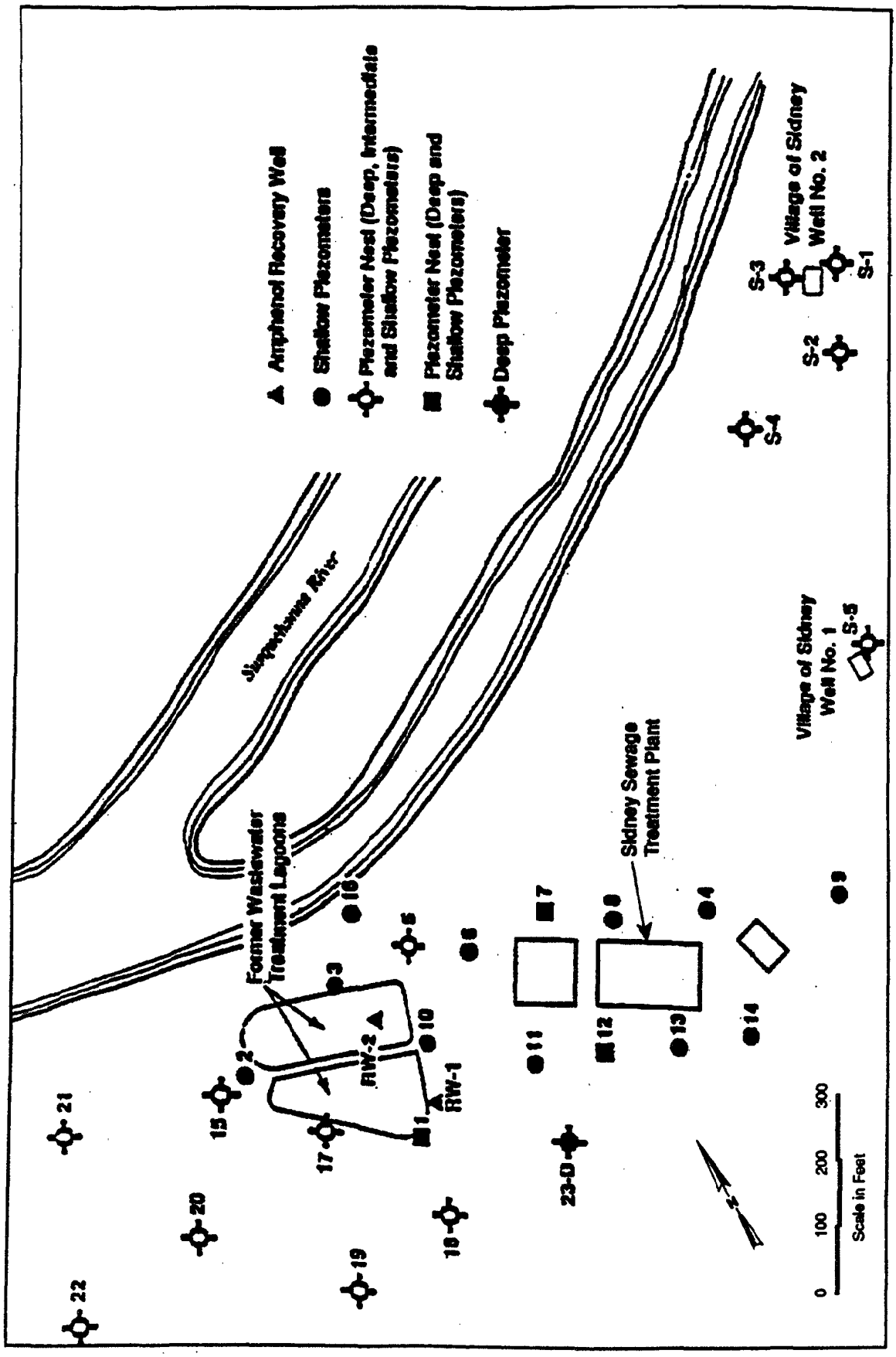

Figure 2
SITE PLAN WITH NESTED MONITORING WELLS, EXTRACTION WELLS, AND VILLAGE OF SIDNEY WELLS
AMPHENOL SITE

Source ERM, 1990a

Note The depth of an individual monitoring well within a well nest is designated as shallow (S) intermediate (I), or deep (D)

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northeast of the lagoons than Well No. 1, was put into operation on November 30, 1989. Although Well No. 1 is operational and is pumped intermittently for maintenance purposes, Sidney has generally used only Well No. 2 for its water supply since November 1989 (Woodyshek, 1991). Since 1989, Well No. 2 has been operated intermittently at 800 gpm, whereas prior to November 1989, Well No. 1 was operated continuously at 400 gpm. The change in pumping has caused a slight increase in the zone of capture of the water supply wells and a slight decrease in the zone of capture of the recovery wells.

EVALUATION OF PERFORMANCE

The two extraction wells appear to continue to capture the contaminant plume and prevent contamination from reaching the water supply wells, despite the addition of Well No. 2. Contaminant concentrations in wells 7-D and 12-D, the deep wells that are closest to the water supply wells, were found to be below detection limits when these wells were sampled in March 1990. Since sampling began in the mid-1980s, water supply well No. 1 has consistently contained 1 to 3 ppb of TCE and other volatiles and has not shown any decrease in concentrations in response to remediation. Contaminant concentrations have been consistently below detection limits in Well No. 2. Despite the persistence of contamination in Well No. 1, ground-water contour data suggest that the remedial objective of preventing the contaminant plume from migrating to the water supply wells has been met since the end of 1988.

Figures 3, 4, and 5 are time series graphs of total VOC concentrations in wells 1-S, 17-S, and 1-D, respectively. Wells 1-S and 1-D are paired wells located immediately south of the west lagoon, while well 17-S is located immediately west of the west lagoon. All three wells have been among the most contaminated wells at the site historically. Figures 3 and 4, both show that total VOC concentrations have continued to decrease gradually since the end of 1988, indicating that ground-water quality in the shallow aquifer zone continues to improve as a result of remediation.

Figure 5 shows that total VOC concentrations in deep well 1-D were stable from late 1988 through mid-1990. These results suggest that the remediation system has not significantly improved the water quality in the part of the deep aquifer zone adjacent to the deep extraction well since the end of 1988.

Table 1 shows a comparison of total VOC concentrations in 8 monitoring wells from 1986 through June 1990. The concentration of total VOCs has decreased substantially in all the contaminated shallow wells listed in Table 1 since 1986. However, the concentrations have been essentially stable in deep well 18-D since 1986. The overall decrease in VOC concentrations at the site are likely to be a result of remedial activities, including the drainage of the wastewater lagoons in mid-1985, the removal of contaminated soils in late 1986, and the startup of the extraction system in January, 1987.

SUMMARY OF REMEDIATION

The monitoring data collected since 1988 show that the extraction system has continued to induce a zone of capture that encompasses the areas of known contamination by VOCs and protects water supply wells, despite changes in water supply pumping. Continued gradual improvement in the water quality of the shallow aquifer zone is also evident. Monitoring data show that concentrations have stabilized in some deep wells, indicating that the extraction system may not be improving ground-water quality in the deep aquifer zone in some areas.

SUMMARY OF NAPL-RELATED ISSUES

The presence of contaminants in the form of nonaqueous phase liquids (NAPLs) has not been suggested in any of the information reviewed for the Amphenol site. Although the chlorinated organic solvents that are the primary contaminants of concern have the potential to remain in the aquifer as a dense nonaqueous phase, the historical means of contaminant deposition, the source removal actions at the site, and the observed distribution of ground-water contamination suggest that NAPLs, if present at all, probably do not exist in large quantities.

The VOCs from the Amphenol plant were apparently conveyed to the storage lagoons as a constituent of the plant's process waste water. It is not known to what extent the VOCs were

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Table 1
COMPARISON OF TOTAL VOC CONCENTRATIONS
1986 THROUGH JUNE 1990

	1986			1987			1988			1989			1990	
	Minimum	Maximum	Mean	Minimum	Maximum	Mean	Minimum	Maximum	Mean	Minimum	Maximum	Mean	3/19/90	6/12/90
1-S	91	179	119	47	61	54	38	50	45	23	39	29	22	17
1-D	60	154	102	53	74	64	20	47	29	27	32	30	24	25
3-S	5	172	72	*	*	1	ND	1	<1	ND	ND	ND	ND	ND
5-S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
15-S	8	100	50	2	22	12	ND	1	<1	ND	1	<1	ND	1
17-S	105	161	132	50	155	95	36	64	49	15	38	26	24	17
18-S	*	*	77	11	20	15	ND	16	8	10	11	11	9	NS
18-D	4	17	9	<1	16	8	6	12	9	8	13	10	12	7

Altered after ERM, 1990a

Notes:
ND = none detected
NS = not sampled
* = only one analysis available

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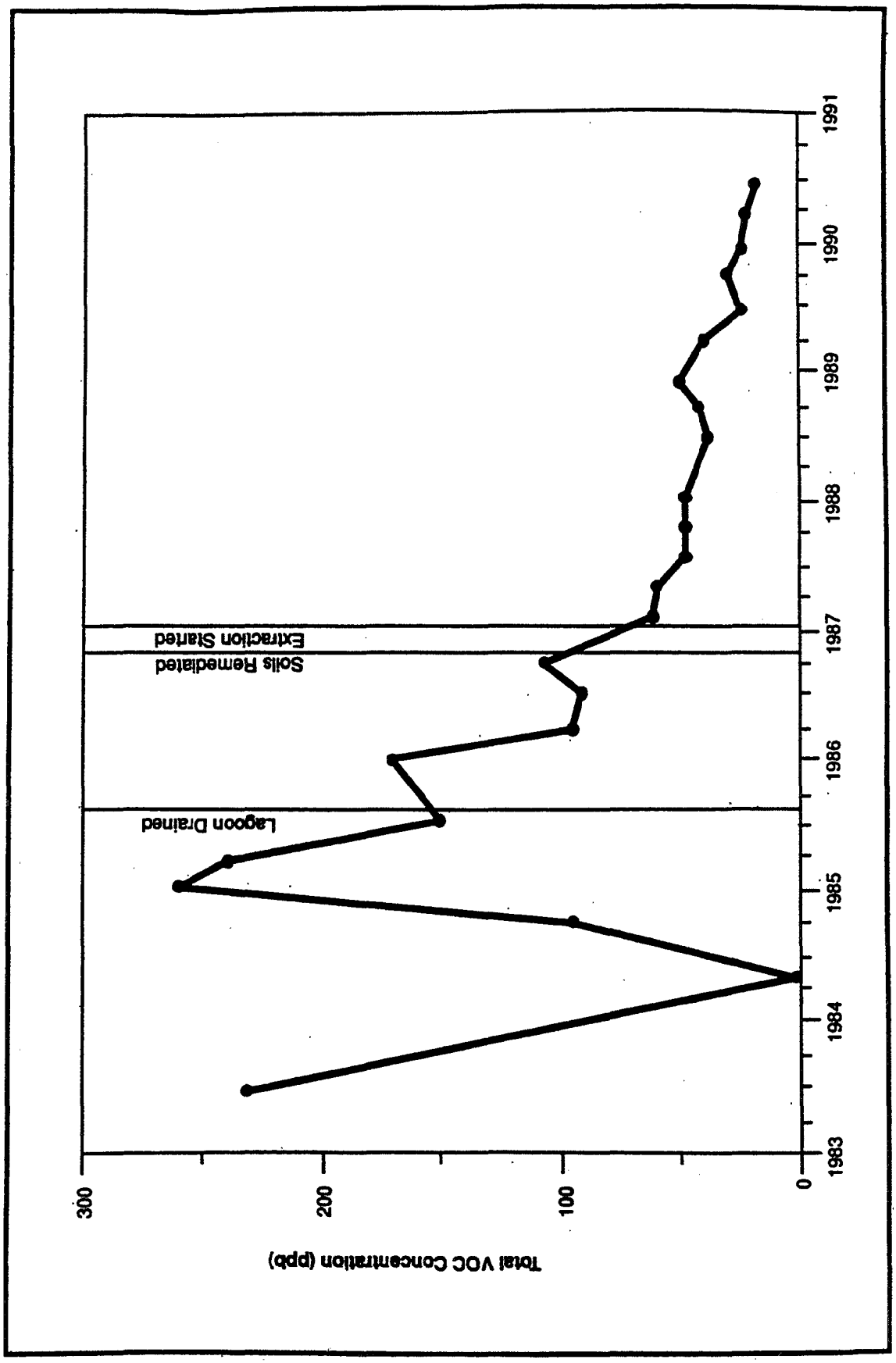

Figure 3
HISTORY OF TOTAL VOC CONCENTRATION IN MONITORING WELL 1-S, SHALLOW AQUIFER ZONE
AMPHENOL SITE

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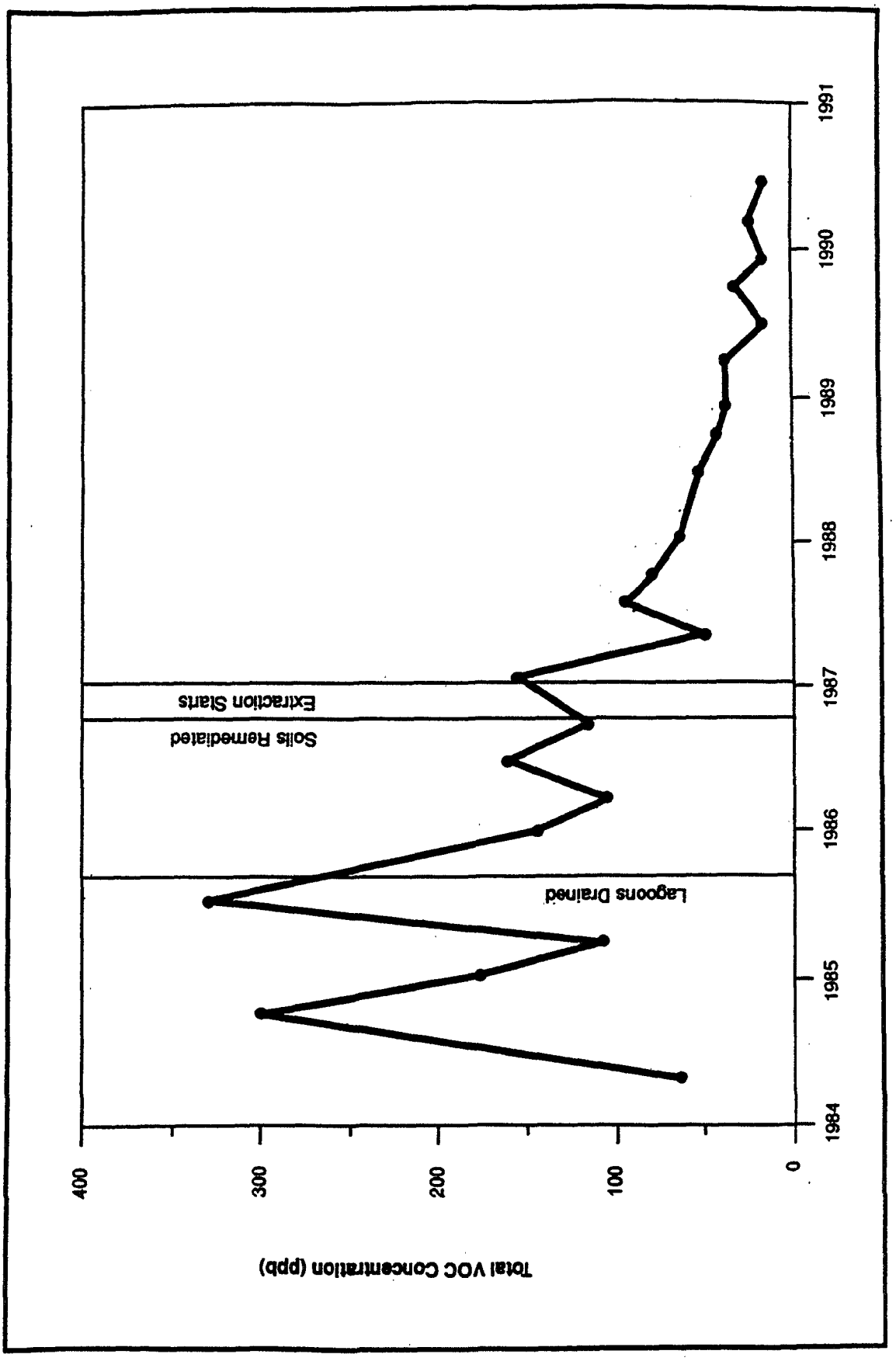

Figure 4
HISTORY OF TOTAL VOC CONCENTRATION IN MONITORING WELL 17-S, SHALLOW AQUIFER ZONE
AMPHENOL SITE

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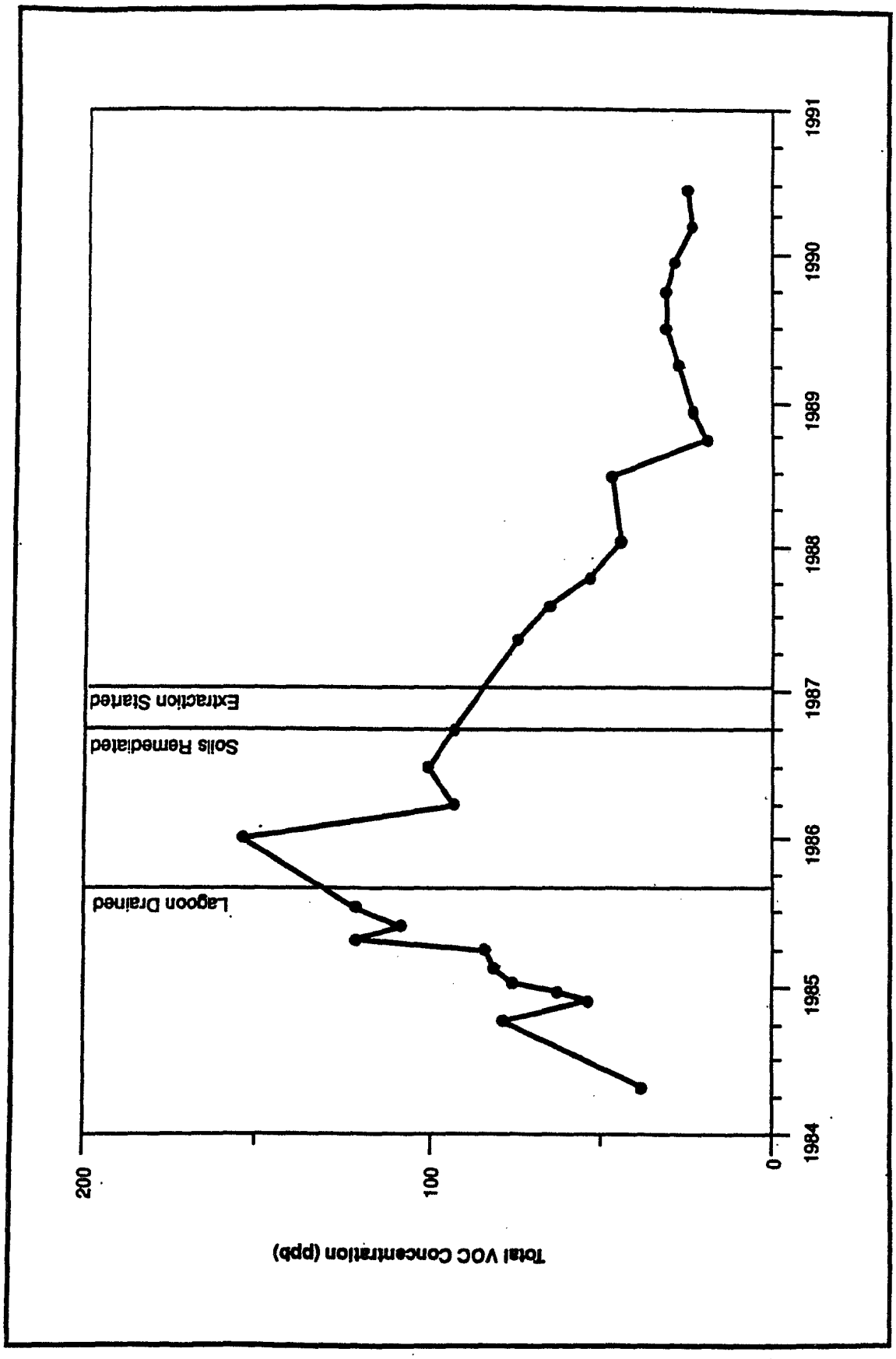
Total VOC Concentration (ppb)
200
100
0
1984
1985
1986
1987
1988
1989
1990
1991
Lagoon Drained
Soils Remediated
Extraction Started

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dissolved in this waste. The lagoons were lined with asphalt, which later became coated with metal hydroxide sludge due to precipitation from the metal plating waste. When the lagoons were taken out of service, it was found that the asphalt in the southern portion of the eastern lagoon had partially deteriorated. This could be the result of contact with chlorinated solvents, but there is no direct evidence of this.

An extensive program of soil sampling was conducted in the upper 5 to 6 feet of the soils beneath the lagoon. In most areas the VOC concentrations in the soils were less than 25 ppm. However, in the southern portion of the east lagoon, where the asphalt lining was damaged, field screening with a flame ionization detector showed VOC concentrations of more than 1,000 ppm in three locations. When samples taken from these hot spots were analyzed in the laboratory, the highest VOC reading was 32 ppm. If the soils were contaminated with NAPLs, concentrations on the order of hundreds or thousands of ppm would be expected. Because soil concentrations at these levels were detected by field screening in only 3 samples out of the approximately 200 samples taken, it can be concluded that NAPL contamination, if present, is not extensive. The levels of VOC contamination detected in ground water have been generally less than 300 ppb in the upper aquifer zone and less than 160 ppb in the lower zone. These levels are below the aqueous solubility of the major organic constituents present by a factor of 1,000 or more and would not normally raise suspicion of the presence of NAPLs.

UPDATE BIBLIOGRAPHY/ REFERENCES

Environmental Resources Management (ERM). February 20, 1990a. 1989 Annual Summary of the RCRA Ground-Water Monitoring. Letter to Henry Mitchell of Amphenol Corp.

ERM. February 20, 1990b. Letter to Henry Mitchell of Amphenol Corp., discussing monitoring in the fourth quarter of 1989.

ERM. June 12, 1990c. Letter to Henry Mitchell of Amphenol Corp., discussing monitoring in the first quarter of 1990.

ERM. September 20, 1990d. Letter to Henry Mitchell of Amphenol Corp., discussing monitoring in the second quarter of 1990.

U.S. Environmental Protection Agency (U.S. EPA). October 1989. *Evaluation of Ground-Water Extraction Remedies: Volume 2, Case Studies 1-19.* EPA/9355.4-03.

Woodyshek, John. January 3, 1991. Personal communication with John Woodyshek, Village of Sidney engineer.

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UPDATE OF CASE STUDY 2

Black and Decker
Brockport, New York

Abstract

The extraction system, which pumps from an enhanced fracture zone, has continued to meet the objective of plume containment since the end of 1988. Some contaminated ground water from formerly downgradient areas also continues to be captured. Concentrations in areas downgradient of and lateral to the fracture zone have generally decreased since 1988. Trends are stable or decreasing in upgradient areas. Concentrations of 5 percent of the aqueous solubility of TCE persist in the most contaminated well in the bedrock.

Table of Background Data	
Date of Problem Identification	1985
Extraction Started	May 1988
Types of Contaminants	Trichloroethylene 1,1,1-Trichloroethane 1,2-Dichloroethylene Vinyl Chloride
Primary Aquifer Materials	Glacial till over fractured sandstone
Maximum Number of Extraction Wells	1
Maximum Total Extraction Rate	10 - 15 gpm
Estimated Plume Area	11 acres
Estimated Plume Thickness	40 feet
Maximum Reported Concentrations	Trichloroethylene 86,000 ppb

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CASE STUDY UPDATE
BLACK & DECKER

BACKGROUND OF THE PROBLEM

INTRODUCTION

This report discusses events and progress at the Black & Decker site from the start of remediation in 1988 through early 1991. It is an update of the original case study, which was based on concentration data through November 1988 (U.S. EPA, 1989, Case Study 2).

The Black & Decker site is a former appliance manufacturing plant in Brockport, New York (see Figure 1). The ground water over much of the site has been contaminated by volatile organic compounds (VOCs) originating from metal-plating wastewater, sludge, and other sources. The site is under the jurisdiction of the U.S. EPA under RCRA and of the New York State Department of Environmental Conservation (NYSDEC).

The problem was discovered in 1985 when ground water in the area around the plant's waste management facility was sampled and found to be contaminated with VOCs. Operation of the waste management facility was terminated in 1986 and 1987. A pre-fracturing pumping test was conducted in March 1987, using a single extraction well, which proved to be ineffective, because it failed to capture ground water from a broad area of the fractured bedrock aquifer. In May 1987, an artificial fracture zone designed to enhance the effectiveness of the remediation system was created using explosives. The present remediation system, which consists of one extraction well centered within the artificial fracture zone, was operated intermittently from May to October 1988 and virtually continuously from October 1988 to early 1991.

There are three geologic units that underlie the Black & Decker site near the surface. The first is a 5- to 20-foot-thick deposit of unconsolidated glacial till that thickens to the north across the site. This till is underlain by a 50-foot-thick unit of fractured sandstone, known as the Medina sandstone. Underlying the Medina sandstone is the Queenston shale, which is several hundred feet thick at the Black & Decker site. There are two aquifers at the site--the overburden aquifer within the unconsolidated till and the bedrock aquifer within the fractured sandstone. Both aquifers are contaminated with VOCs. The horizontal direction of ground water flow within both aquifers is to the north-northwest. The vertical gradient was downward across most of the site in 1990.

The contaminants of concern are trichloroethylene (TCE), 1,2-dichloroethylene (1,2-DCE), 1,1,1-trichloroethane (TCA), and vinyl chloride. Most of the contaminant mass is within the upper half of the fractured bedrock aquifer. The contamination appears to have originated from the wastewater lagoons and the sludge-drying pits of the waste management area on the southeast border of the site. Some leakage from pipes may also have occurred.

UPDATE ON SITE CHARACTERISTICS

The information on the history, geology, hydrogeology, waste characteristics, and administration of the site reported in the original case study is still current. Additional information on site geology has been made available by NYSDEC. It has been reported that the bedding planes in the Medina sandstone dip 1 to 3 degrees to the south, away from the artificially induced fracture zone. Complete information on site characteristics can be found in the original case study.

REMEDIATION

The extraction system consists of one extraction well that pumps ground water from a 300-foot-long artificial fracture zone created to enhance flow within the fractured bedrock and increase the efficiency of remediation. The fracture zone is several feet wide and extends approximately 25 feet into the fractured sandstone bedrock. The extracted water is treated with an air stripper and then discharged to the Barge Canal that borders

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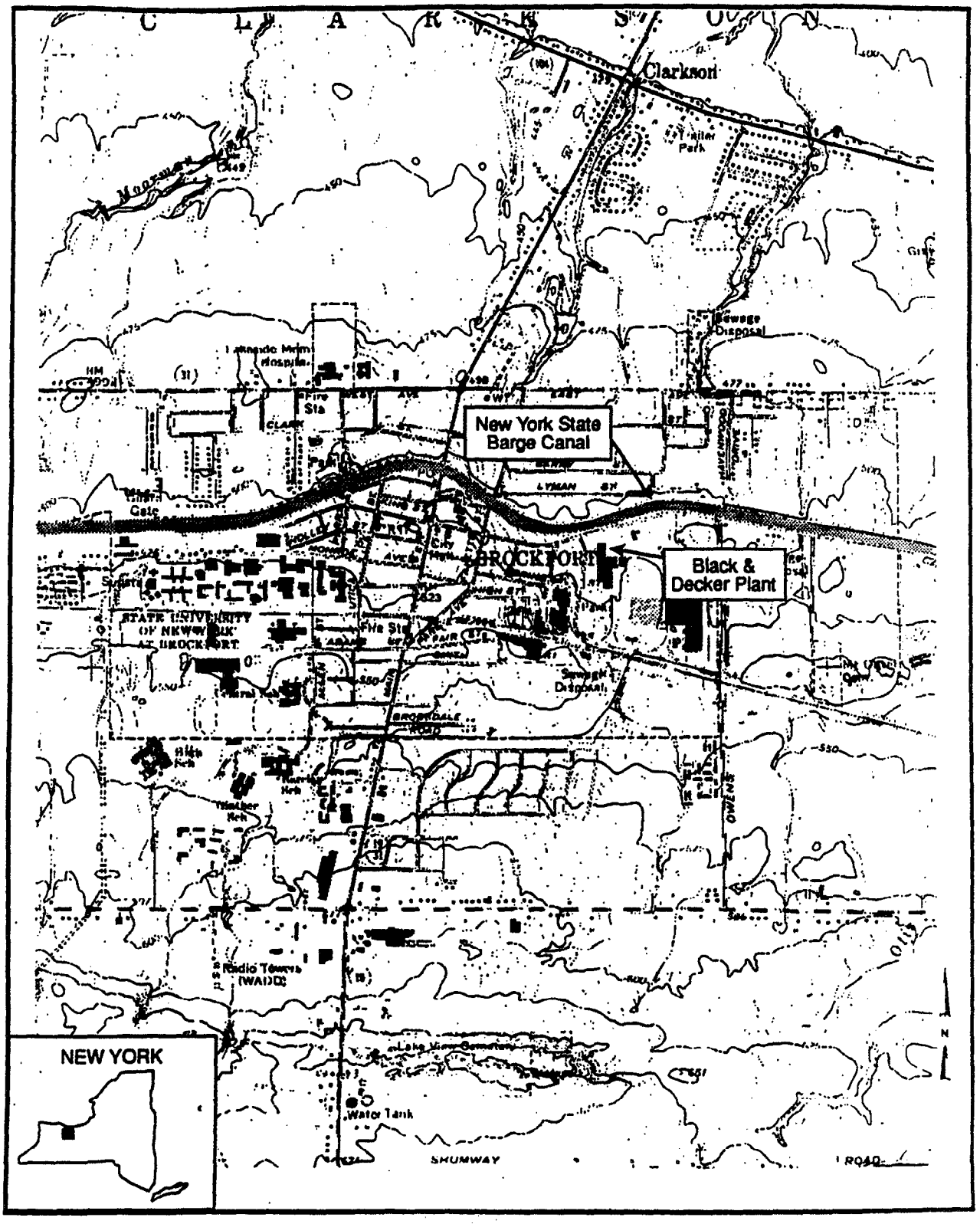

Source: USGS, 1978. Brockport Quadrangle, 7.5 Minute Topographic Series.

(Poor Quality Original)

0 1000 2000

Scale in Feet

Figure 1.
SITE LOCATION MAP
BLACK & DECKER SITE
BROCKPORT, NEW YORK

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the site on the north. The objective of remediation is not to clean up both aquifers to health-based levels as erroneously stated in the original case study. As stated by the site operators, the primary objectives of the ground-water extraction system are (1) to prevent the plume of VOCs from migrating further, and (2) to capture VOCs that have migrated downgradient of the artificially induced fracture zone. (General Electric Company, 1991). The monitoring well system consists of several wells installed in the overburden aquifer and a series of individual or clustered wells installed in the bedrock aquifer. The monitoring system is sampled quarterly.

No substantial changes have been made in the infrastructure of the remediation or monitoring systems since the end of 1988. The extraction system was operated nearly continuously from 1989 through early 1991. The average pumping rate during periods of operation in 1990 was approximately 12.4 gpm (Dunn Geosciences Corp., 1991). The system was shut down from February 27 to March 24, 1989, from December 15, 1989 to January 31, 1990, and from December 30, 1990 to January 10, 1991--in each case due to mechanical or maintenance problems.

The extraction system has continued to capture contaminated ground water from both the overburden and bedrock aquifers within the plant boundaries since the end of 1988. The extent of the capture zone within the overburden aquifer is difficult to assess, however, because of the limited number of wells installed in the overburden aquifer in the vicinity of the fracture zone. The potentiometric surface within the shallow bedrock aquifer in August 1990 is shown in Figure 2. Figure 2 shows that the capture zone within the shallow bedrock aquifer extended laterally to the east of the fracture zone approximately 200 feet in late 1990. Because of insufficient water-level data on the northeast boundary of the site, it is difficult to determine whether the ground water reported to flow northeast from the waste management area is being captured by the current extraction system.

In general, the extraction system appears to be effective in preventing the continued offsite migration of contamination. The capture zone created by the extraction system is most extensive in the intermediate and deep wells within the bedrock aquifer. This indicates that bedrock fractures are interconnected at the deepest intervals of the monitoring network and suggests that the capture zone extends vertically below the deepest wells of the monitoring system.

The operation of the extraction system since October 1988 has resulted in a decrease in contamination in monitoring wells located downgradient of and lateral to the fracture zone. Figures 3 and 4 are time-series plots of the concentration of TCE in overburden wells GEB-18S and GEB-23S, respectively, from early 1987 to late 1990. These two wells were designed to monitor ground water quality in the overburden aquifer along the centerline of the plume upgradient of the fracture zone. The concentration of TCE in well GEB-18S, the most contaminated overburden well, has generally decreased since 1987--from 38,000 ppb in January 1987 to 4,300 ppb in November 1990. The reason for the midyear peaks observed in 1988, 1989, and 1990 is unknown. The bedrock well, GEB-18B, that is paired with GEB-18S is one of the few wells in which the concentration of TCE has not decreased substantially. Since 1987 TCE concentrations in GEB-18B have decreased from 20,000 ppb in January 1987 to 12,000 ppb in November 1990, with fluctuations ranging between 8,600 ppb to 35,000 ppb.

Figure 4 shows that the concentration of TCE in GEB-23S fluctuated between 0 and 7 ppb from late 1987 to late 1990 but peaked to 25 ppb in the fourth quarter of 1988. The reason for the concentration peak in late 1988 is not known. Most of the contamination at this location is in the bedrock, as shown by concentrations in GEB-23B (see Figure 5).

Figure 5 shows the time-series trend of TCE concentration in bedrock well GEB-23B since the beginning of 1987. TCE concentrations increased from 62,000 in mid-1987 to 86,000 ppb in mid-1988, followed by a decrease through early 1989. The concentrations appear to have stabilized after early 1989.

The concentration of TCE in well GEB-30BI, located north of the fracture zone, from early 1987 through late 1989 is shown in Figure 6. This figure shows an abrupt decrease in TCE concentration from 280 ppb in October 1987 to 59

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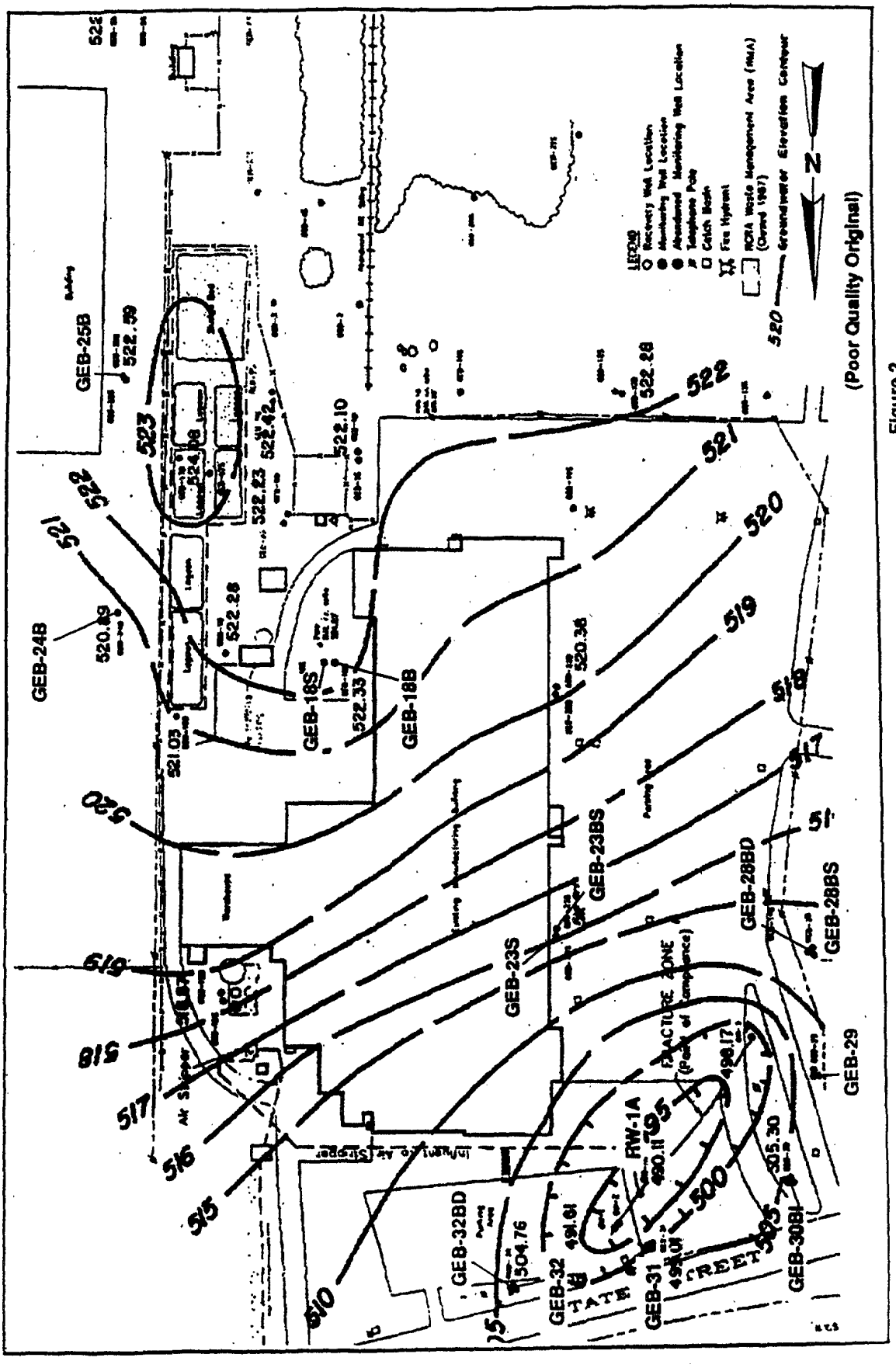

Figure 2
POTENTIOMETRIC SURFACE IN THE SHALLOW
BEDROCK AQUIFER, AUGUST 21, 1991
BLACK & DECKER SITE

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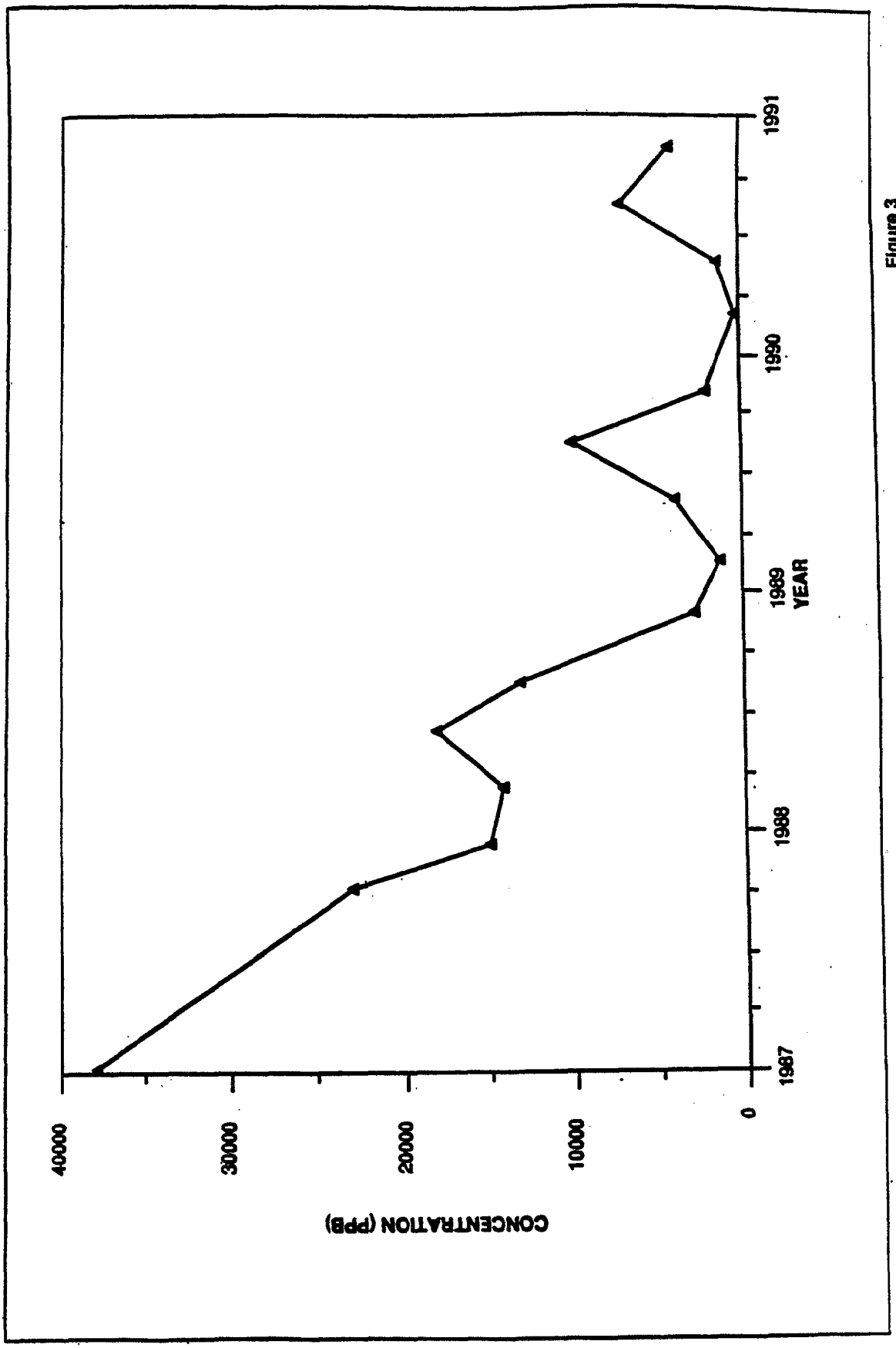

Figure 3
CONCENTRATION OF TCE IN MONITORING WELL GEB-18S
BLACK & DECKER SITE

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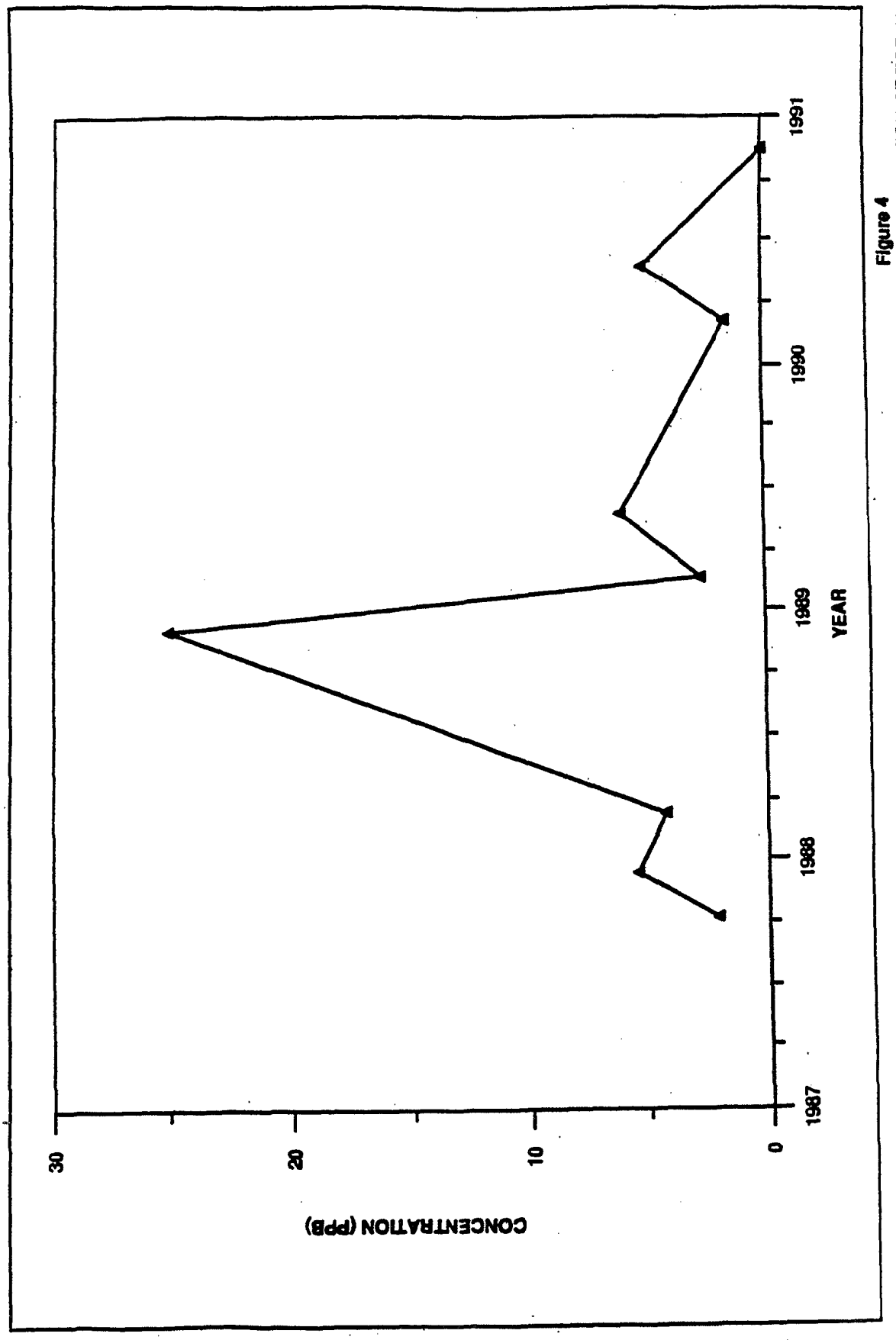

Figure 4
CONCENTRATION OF TCE IN MONITORING WELL GEB-23S
BLACK & DECKER SITE

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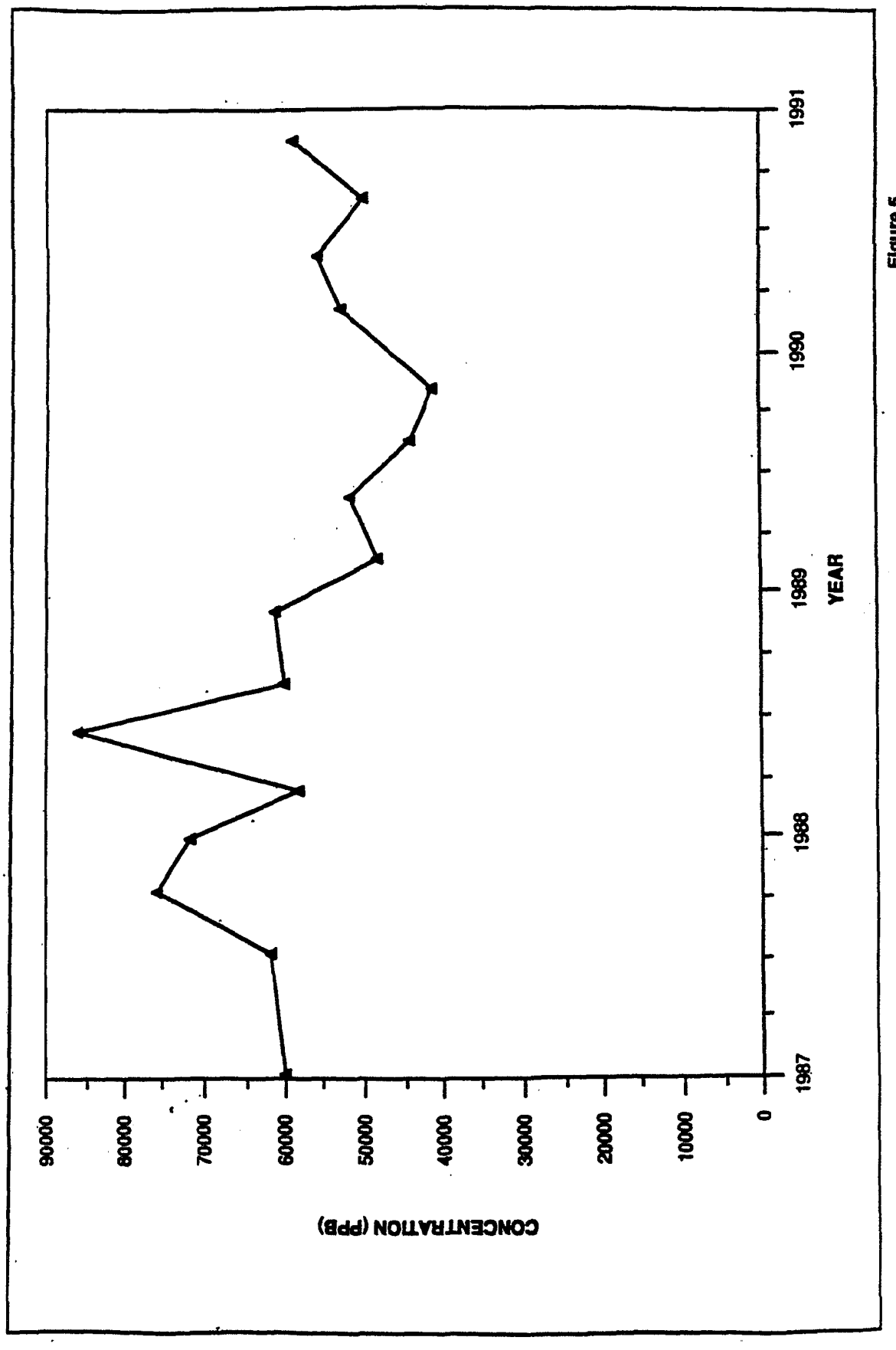

Figure 5
CONCENTRATION OF TCE IN MONITORING WELL GEB-23B
BLACK & DECKER SITE

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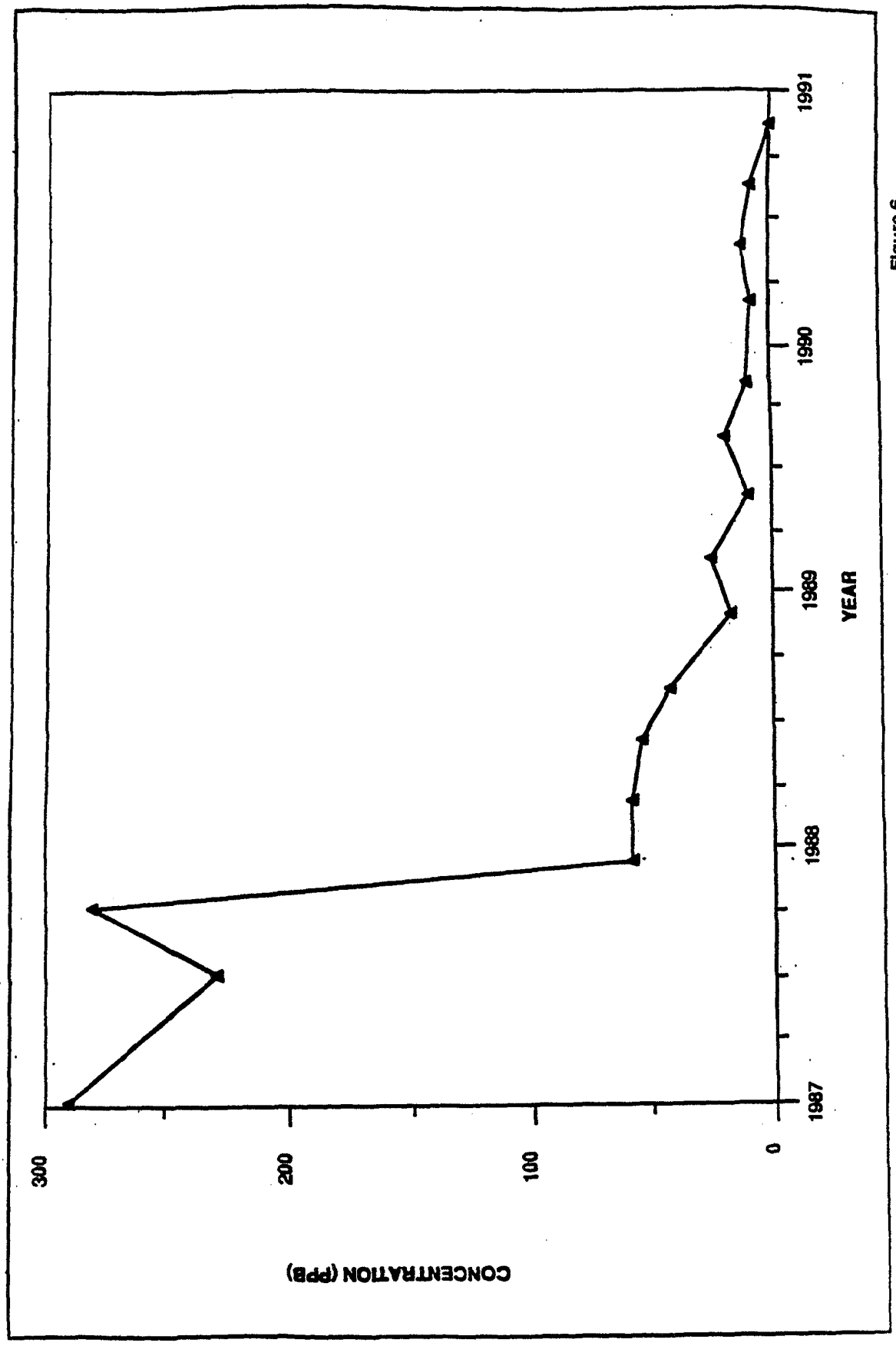

Figure 6
CONCENTRATION OF TCE IN
MONITORING WELL GEB-30BI
BLACK & DECKER SITE

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ppb in December 1987, followed by a gradual decrease in TCE concentration to less than 1 ppb in November 1990. The concentration of TCE in GEB-30BI in October 1986 was 39 ppb. The reason for the high TCE concentrations in 1987 is not known. The substantial reduction of TCE concentrations in GEB-30 BI is evidence that the extraction system has drawn back ground water from the formerly downgradient area near this well. The water levels shown in Figure 2 support this conclusion.

Figure 7 shows the concentration of TCE in the recovery well RW-1A from October 1987 through the end of 1989. These data show a substantial decrease in the concentration of TCE from October 1987 through November 1988, followed by a period of stable or slightly decreasing concentration through November 1989.

The concentration of VOCs in the ground-water monitoring system in general has decreased since ground-water extraction began in October 1988. An increase in the concentration of VOCs in mid-1987, at the time of artificial fracturing, was observed in several wells downgradient of and lateral to the fracture zone.

SUMMARY OF REMEDIATION

In the initial case study, it was reported that the remediation system captured contaminated ground water effectively through the end of 1988. Recent data demonstrate that the remediation system has continued to capture the ground water from most or all contaminated areas and, therefore, has continued to achieve its stated objective of plume containment. Concentration data collected through 1990 show that the concentration of VOCs has decreased or remained stable since 1987 in most of the wells in the monitoring system, indicating that the remediation system is also removing contaminants from the ground water. However, for site operators to terminate ground-water extraction, they must be in compliance with health-based standards as listed in the original case study and in the post-closure permit for the site (NYSDEC, 1991b). Concentrations of VOCs that are considerably greater than these target concentrations persist over much of the site, particularly along the centerline of the plume and in the bedrock.

SUMMARY OF NAPL-RELATED ISSUES

It is not known whether a residual source of ground water contamination in the form of a dense nonaqueous phase liquid (DNAPL) is present at the Black & Decker site. Persistent high concentrations of contaminants despite efficient extraction are one indication of DNAPLs. Data collected through the end of 1990 generally show a significant decrease in VOC concentrations. Although several wells show a stable or slightly declining trend in concentrations during 1989 and 1990, this type of asymptotic decline is typical of the concentration history of many non-DNAPL sites where ground-water extraction has been in progress for several years. The concentration trends to date at the Black & Decker site are not strongly indicative of DNAPL contamination. However, the concentration of TCE in GEB-23B in excess of 85,000 ppb in 1988 (approximately 8.5 percent of aqueous solubility) suggests that DNAPLS may be present in some areas of the site.

An increase in the concentration of contaminants following periods without ground-water pumping is another characteristic of sites contaminated with NAPLs. Increases in the concentrations of select contaminants were observed in wells GEB-29BD, GEB-30BD, GEB-32BS, and 32BD from February to May 1989. These increases may be related to the shutdown of the remediation system from February 27 to March 27, 1989; however, additional concentration data following subsequent shutdowns are needed to verify this relationship.

The presence of the artificial fracture zone may be a problem if DNAPLs are present at the site. The fact that the hydraulic capture is extensive in the bedrock, even at the deepest intervals of the monitoring network, suggests that the zone of good interconnection between fractures extends below the deeper wells in the sandstone bedrock. DNAPLs of VOCs are generally 30 to 80 percent more dense than water. As a result, they have a strong tendency to sink in the subsurface and are able to flow downward against hydraulic gradients. The creation of an artificial fracture zone may favor downward migration of DNAPLs, if present, below the vertical extent of ground-water capture, and thus establish a deep residual of contamination that cannot be remediated using the present extraction system. This is primarily true in the case of any DNAPLs that may be near the

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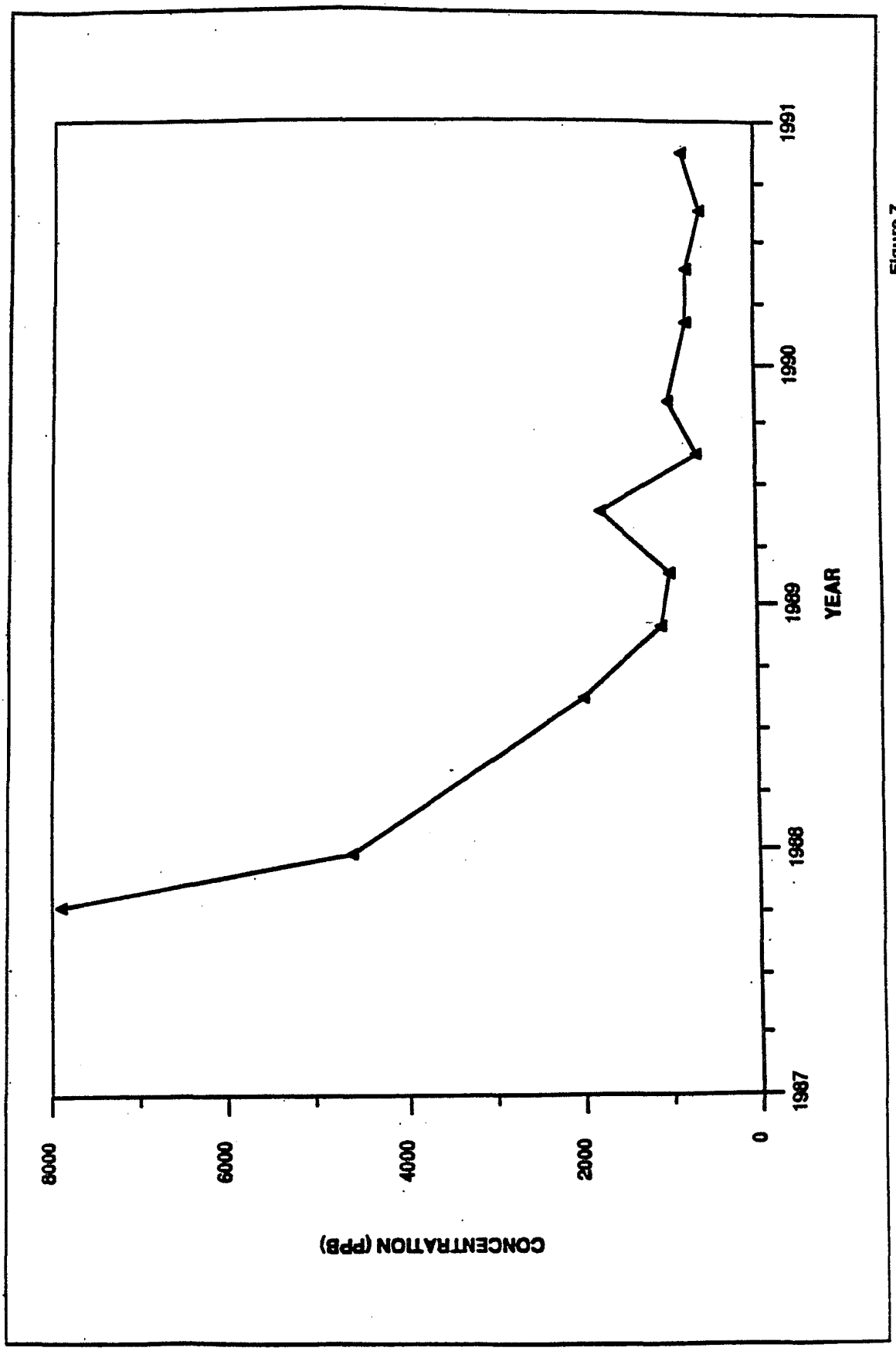

Figure 7
CONCENTRATION OF TCE IN RECOVERY WELL RW-1A
BLACK & DECKER SITE

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artificial fracture zone, where downward gravity flow might be enhanced by the artificial fracturing. Because the bedrock dips 1 to 3 degrees to the south away from the fracture zone, however, potential DNAPL sources near the existing plume center are expected to flow to the south. The fracture density and structure of the underlying Queenston shale has not been reported; therefore, it is difficult to predict the fate of any potential DNAPLs should they migrate below the sandstone.

UPDATE BIBLIOGRAPHY/ REFERENCES

Dunn Geosciences Corp. March 1988. *RCRA Annual Ground-Water Monitoring Report--1987 Black & Decker (U.S.), Inc., Housewares Group Brockport, New York.*

Dunn Geosciences Corp. March 1989. *RCRA Annual Ground-Water Monitoring Report--1988 Former Black & Decker Facility Brockport, New York.*

Dunn Geosciences Corp. March 1990. *RCRA Annual Ground-Water Monitoring Report--1989 Former Black & Decker Facility Brockport, New York.*

Dunn Geosciences Corp. March 1991. *RCRA Annual Ground-Water Monitoring Report--1990 Former Black & Decker Facility Brockport, New York.*

General Electric Company. May 29, 1991. Letter from Michael Ianniello, Remedial Project Engineer, GE Corporate Environmental Programs.

New York State Department of Environmental Conservation (NYSDEC). May 13, 1991a. Letter from Lawrence M. Thomas, Senior Engineering Geologist, Bureau of Hazardous Waste Facility Management.

NYSDEC. June 11, 1991b. Personal Communication with Lawrence M. Thomas, Senior Engineering Geologist, Bureau of Hazardous Waste Facility Management.

U.S. Environmental Protection Agency (U.S. EPA). October 1989. *Evaluation of Ground-Water Extraction Remedies: Volume 2. Case Studies 1-19, Interim Final.* EPA/9355.4-03.

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UPDATE OF CASE STUDY 3

Des Moines TCE
Des Moines, Iowa

Abstract

Since startup in December 1987, the extraction system has continued to create a hydraulic zone of capture in the areas of known ground-water contamination. Concentrations of VOCs in ground water have declined as a result of remediation. However, after initial sharp decreases in VOC levels at system startup, concentrations appear to have stabilized or have decreased at a slow rate in most wells and in the influent to the air stripper. From December 1987 through the end of 1989, the extraction system removed approximately 1,300 gallons of TCE from ground water.

Table of Background Data	
Date of Problem Identification	1974
Extraction Started	December 1987
Types of Contaminants	Trichloroethylene Trans-1,2-dichloroethylene Vinyl chloride
Primary Aquifer Materials	Silt, sand, clay, and gravel
Maximum Number of Extraction Wells	7
Maximum Total Extraction Rate	1,300 gpm
Estimated Plume Area	130 acres
Estimated Plume Thickness	50 feet
Maximum Reported Concentrations	Trichloroethylene 8,467 ppb

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CASE STUDY UPDATE
DES MOINES TCE

BACKGROUND OF THE PROBLEM

INTRODUCTION

This report describes events and progress in remediation at the Des Moines TCE site from late 1988 to early 1990. It is an update of the original case study, which was based on concentration data through September 1988 (U.S. EPA, 1989, Case Study 3).

The Des Moines TCE site is located in south central Des Moines, Iowa. The site is near the Des Moines Water Works (DMWW), the Raccoon River, and a manufacturing facility belonging to the DICO Corporation (see Figure 1). The primary contaminants are volatile organic compounds (VOCs). The site is administered by the EPA under the Superfund program.

The contamination problem was first discovered in 1974, when contaminants were detected in the ground water pumped by the DMWW. Remediation by ground-water extraction began on December 17, 1987, using a system of seven extraction wells on the DICO property.

The alluvial geology consists of 40 to 60 feet of unconsolidated silt, clay, sand and gravel overlying consolidated shale bedrock. The top 10 feet of the alluvial materials consist of silt and clay overbank deposits. A sandy aquifer extends from a depth of 10 feet to the top of bedrock. Water levels in the aquifer range from 10 to 25 feet below land surface. The predominant direction of ground-water flow on the DICO property was to the west prior to operation of the extraction system. This flow pattern was the result of long-term pumping from the north part of the infiltration gallery operated by the DMWW (see Figure 1). This part of the gallery was removed from service in 1984 because of ground-water contamination.

The contaminants of concern at the site are trichloroethylene (TCE), trans-1,2-dichloroethylene (Trans-1,2-DCE), and vinyl chloride. The main source of volatile organics was initially reported by DICO to be leaching from the contaminated soils west of the DICO plant. In past years, 100 to 200 gallons of waste solvent sludge were applied to these soils for dust control. However, the EPA suspects that there are other contaminant sources and has initiated further investigations to identify them.

UPDATE ON SITE CHARACTERISTICS

The consultant to DICO has changed names from AWARE, Inc., to Eckenfelder, Inc., since the initial case study was written. The site continues to be administered by EPA Region VII.

The original (Operable Unit 1) remedial investigation indicated that the bedrock surface is uneven and slopes to the northeast away from the river at the site (U.S. EPA, 1985). This bedrock slope may influence the direction of flow of any dense nonaqueous phase liquids (DNAPLs) that may be present.

DNAPLs are suspected because of the reported use of large quantities of potentially DNAPL-forming chlorinated solvents at the site. A remedial investigation concentrating on source identification and control (Operable Unit 2) is currently in progress. Extensive drilling and sampling in the bedrock have been completed but no DNAPLs have been found in the bedrock as of June 1991. Another remedial investigation designed to characterize the contamination in the north plume, thought to be the result of offsite sources, is also in progress (Operable Unit 3). Soil gas studies have been completed and several new monitoring wells and soil borings have been installed and sampled as a part of the Operable Unit 3 investigation.

Ongoing investigations seek to identify all of the contamination sources of the main DICO plume and of the north plume (Operable Units 2 and 3). Two large degreasing vats within the main DICO production building have been identified and are being investigated as possible sources of VOC contamination. Other potential sources of contamination on the DICO property identified since the initial case study include: (1) above-

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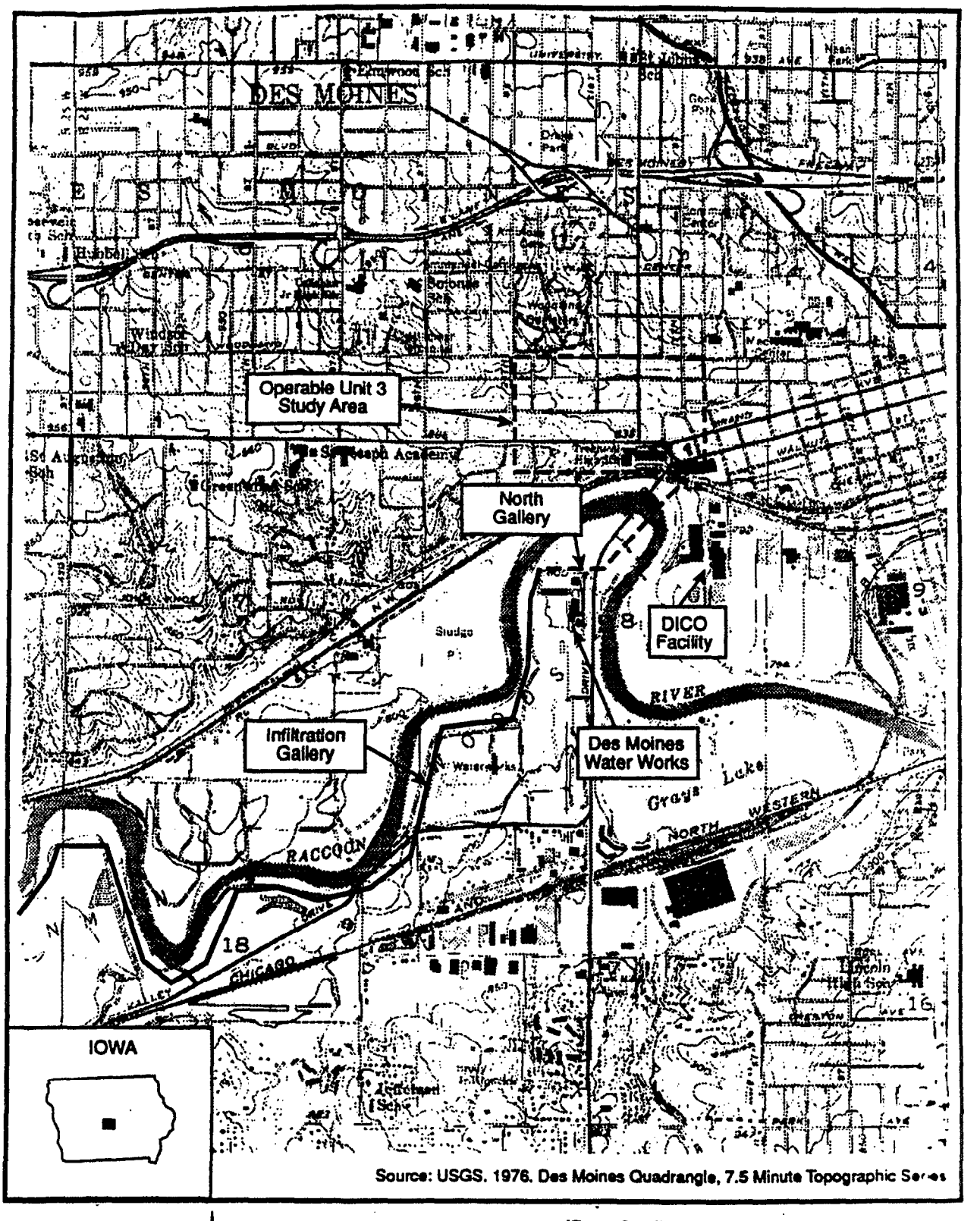

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Figure 1
SITE LOCATION MAP
DES MOINES TCE SITE
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ground solvent storage tanks southeast of the main DICO building; (2) an area near Well ERW-7 where used drums of solvent were cleaned; and (3) an area of construction debris south of the main building (Eckenfelder, 1989). These potential sources are shown in Figure 2.

Some potential sources of contamination outside the DICO property have also been identified, the most important of which is the VOC contamination that has migrated towards the extraction wells from the campus of Des Moines Tech, north of the DICO property.

The main source of contamination identified in the initial case study--waste sludge containing solvents that was applied to road surfaces--does not account for the contaminant mass found at the Des Moines TCE site. Even at a maximum reported concentration of 3,000,000 ppb of TCE, the maximum 200 gallons of sludge reported to have been spread onto road surfaces each year would have been equivalent to 0.6 gallons of pure TCE per year. Over the 12-year period from 1966 through 1978, during which the contaminated sludge was applied, this practice would have accounted for only 7.2 gallons of TCE, based on available estimates. By contrast, 750 gallons of TCE were removed by the air stripper from December 17, 1987, through September 1988, based on mass balance calculations of the air stripper influent and effluent. Over 1,300 gallons of TCE had been removed by the end of 1989 (Eckenfelder, 1990). These results suggest the need for more extensive source identification.

REMEDIATION

Design and Operational Features of Remediation System

The objective of remediation is to clean up the ground water to health-based standards. The recovery system in place as of September 1988 consisted of seven recovery wells, ERW-3 through ERW-9, oriented north-south between the DICO plant and the Raccoon River (see Figure 2).

Several changes were made in the operation of the extraction system since late 1988. Well ERW-9 was removed from service in September 1988 and was not operated in 1989 because of iron encrustation (ERM, 1990). Well ERW-4 was taken out of service from late March to early September 1989, because of corrosion problems. ERW-3 was also taken out of service for several months in 1989 because of corrosion problems. Pumping in Wells ERW-5 and ERW-6 was reduced from 225 gpm each to 130 and 160 gpm, respectively, during a drought in 1989. The overall pumping rate of the extraction system was reduced from approximately 1,300 gpm in 1988 to approximately 1,000 gpm in 1989.

EVALUATION OF PERFORMANCE

The original recovery network induced a zone of ground-water capture that extended horizontally beyond the known limits of contamination. A decrease in the zone of capture caused by reduced pumping in ERW-3, ERW-4, ERW-5, and ERW-6, and by the elimination of ERW-9 was observed in 1989. Despite the reduction in pumping, the extraction system has continued to capture ground water from all known areas of contamination since late 1988.

The extraction system has also continued to remove VOCs from the ground water at a significant rate. Figure 3 shows the concentration of TCE and Trans-1,2-DCE in the influent to the air stripper, from startup on December 17, 1987, through April 1990. The concentration of TCE was reduced dramatically in the first 6 months of operation. Since mid-1988, the concentration of TCE has decreased at a much lower rate, from an average concentration of approximately 950 ppb in mid-1988 to an average concentration of approximately 550 ppb at the end of March 1990. Approximately 1,300 gallons of TCE were removed by the air stripper from December 1987 through the end of 1989 (Eckenfelder, 1990). The concentration of Trans-1,2-DCE has been stable at approximately 90 ppb since the end of 1988.

The peak in TCE concentrations observed at the end of March 1989 was reportedly caused by the removal of ERW-3 and ERW-4 from the extraction system. Wells ERW-3 and ERW-4 are located at the north end of the line of extraction wells and extract ground water from the north plume, which consists primarily of Trans-1,2-DCE. Hence, their primary effect on the concentration of TCE in the influent is to dilute the composite sample and lower the concentration of TCE. However, no corresponding decrease in the influent concentration of TCE was observed in September 1989, when ERW-4 was restored to operation.

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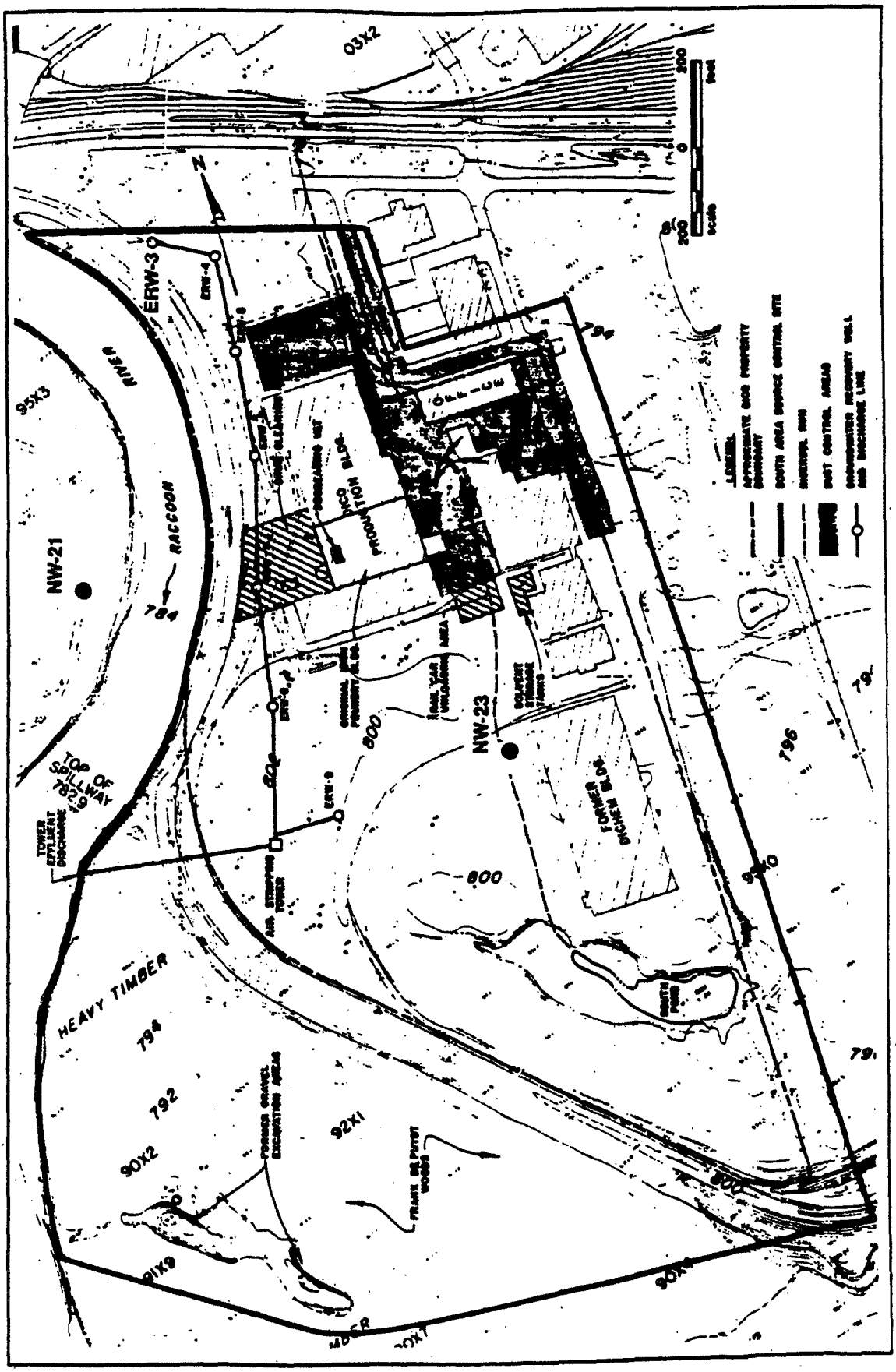

Figure 2
LOCATION OF POTENTIAL SOURCES OF CONTAMINATION
DES MOINES TCE SITE

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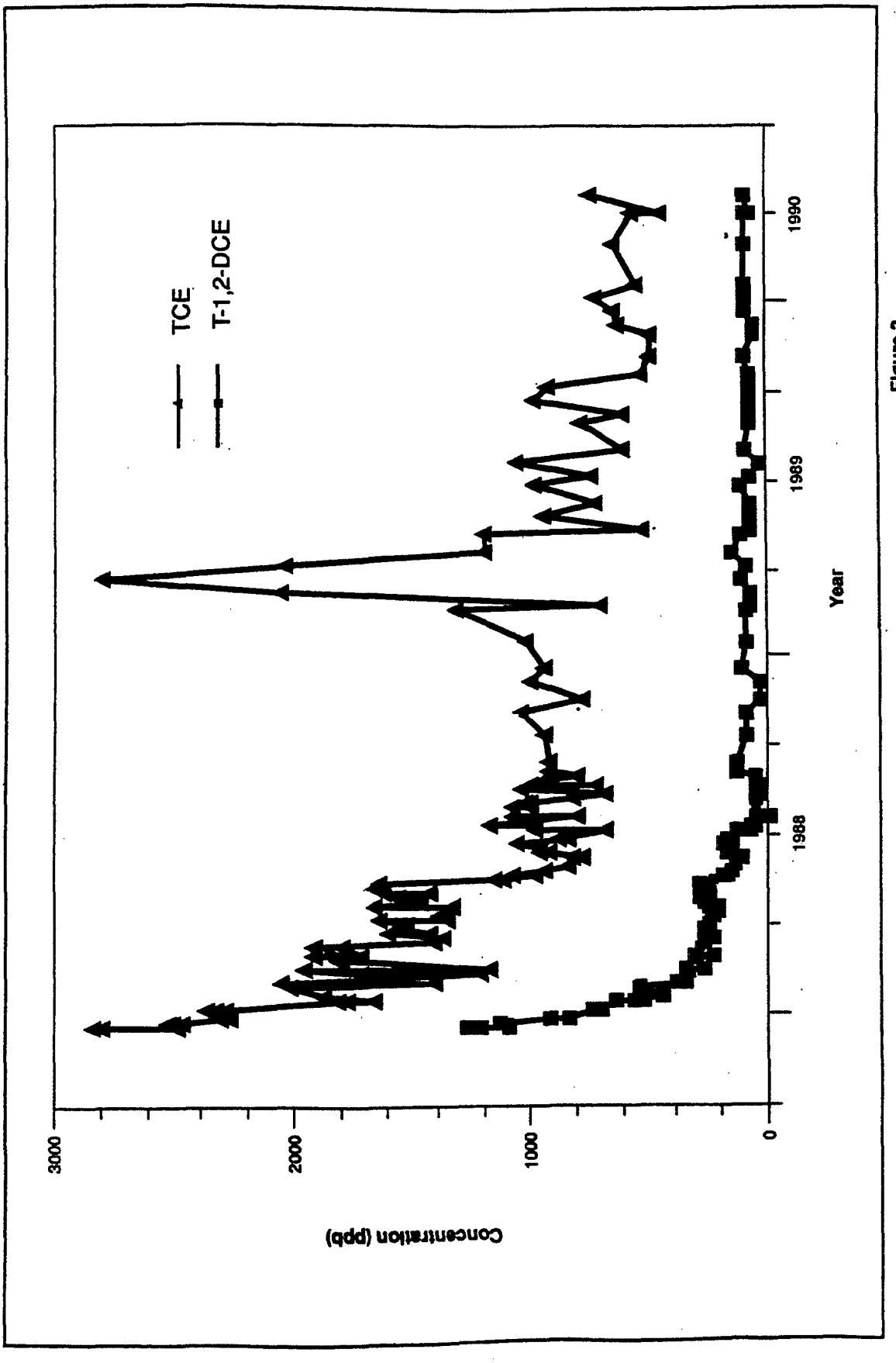

Figure 3
VOC CONCENTRATIONS IN THE INFLUENT TO THE AIR STRIPPER
DES MOINES TCE SITE

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Updated time series plots of contaminant concentrations in recovery Well ERW-8 and monitoring Wells NW-21 and NW-23 are shown in Figures 4, 5, and 6, respectively. The concentration of VOCs in ERW-8 declined rapidly from December 1987 through February 1988 and then more gradually from February to September 1988. From early 1989 through April 1990, the concentrations of TCE and Trans-1,2-DCE in ERW-8 were stable at approximately 40 and 30 ppb, respectively. The concentration of vinyl chloride in ERW-8 decreased to below the detection limits by mid-1989.

The concentrations of VOCs in NW-21, located west of the river and east of the north gallery (see Figure 2), have been erratic since startup, but have decreased gradually from December 1987 through April 1990. These data indicate that ground-water quality in this area is improving as a result of remediation.

The concentrations of VOCs in NW-23, located southeast of the extraction wells, declined significantly in the first 6 months of operation, but have stabilized since mid-1988; the concentration of Trans-1,2-DCE in NW-23, has remained at approximately 90 ppb since the beginning of 1989.

SUMMARY OF REMEDIATION

The hydraulic zone of capture created by the ground-water extraction system has consistently included the areas of known ground-water contamination since the system began pumping in December 1987. Approximately 1,300 gallons of TCE were removed by the extraction system from December 1987 through the end of 1989.

The concentrations of VOCs in ground-water have been reduced significantly as a result of remediation. After initial sharp declines, the concentrations of VOCs have continued to decline gradually in most wells and in the influent to the air stripper. More complete identification of the source and mass inventory of VOC contamination may help in guiding future remediation efforts.

SUMMARY OF NAPL-RELATED ISSUES

The presence of a residual source of ground-water contamination in the form of a DNAPL is suspected at the Des Moines TCE site. However, after a preliminary investigation of suspect bedrock surfaces, the presence of a DNAPL cannot yet be confirmed. The suspicion persists primarily because the quantity of contamination identified in the shallow contaminated soils seems to be insufficient to account for the scale of the known ground-water contamination. By the end of 1989 it was estimated that the quantity of TCE that had been removed by the extraction system was equivalent to approximately 1,300 gallons of the pure compound. The contamination problem was initially attributed by DICO to a relatively small amount of waste solvent in sludge used for dust control on the DICO property. Current site investigations are attempting to identify additional sources of the ground-water contamination.

The maximum concentration of TCE that has been detected in ground water at the site was 8,467 ppb. This is less than 1 percent of the aqueous solubility of TCE, and would not in itself be taken as an indication of the presence of DNAPL. Depth-specific soil sampling during the remedial investigation showed that VOCs were present at least as deep as the middle of the sand and gravel aquifer before startup of the ground-water remediation system. Only one sample was taken from the bottom of the aquifer, and it did not show contamination. However, no contamination was detected from the shallower samples taken from that deep boring either. More recently, soil sampling from the bottom of the aquifer and the underlying bedrock have failed to indicate the presence of NAPLs.

As shown in the time-series concentration plots, the ground-water concentrations have been reduced substantially since the beginning of remediation, but have generally stabilized at concentrations above health-based levels. This is consistent with the presence of a residual source that could be attributed to DNAPLs. However, it could also be explained by the gradual release of contaminants absorbed to soils in the less permeable parts of the aquifer or the vadose zone.

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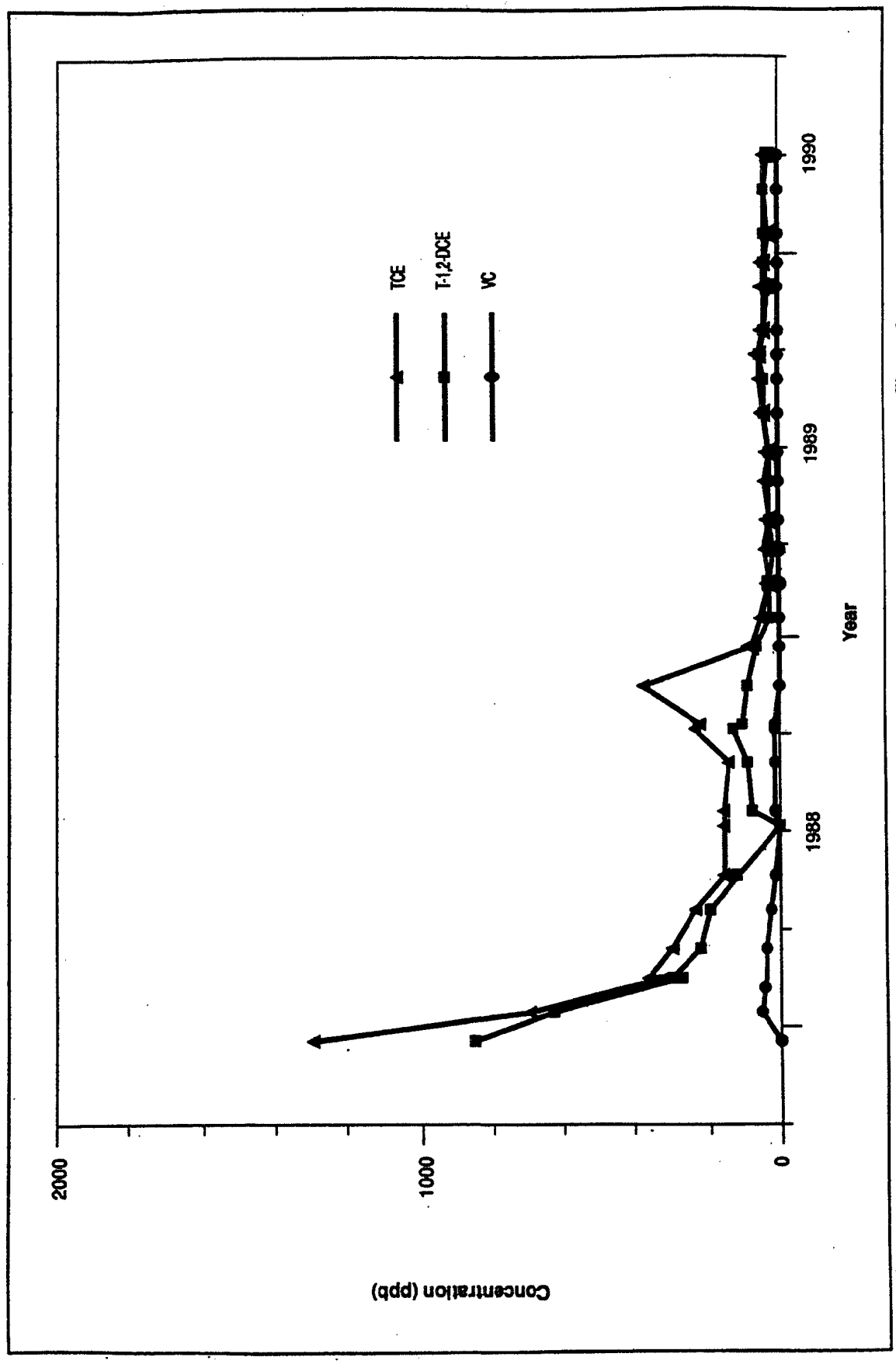

Figure 4
VOC CONCENTRATIONS IN EXTRACTION WELL ERW-8
DES MOINES TCE SITE

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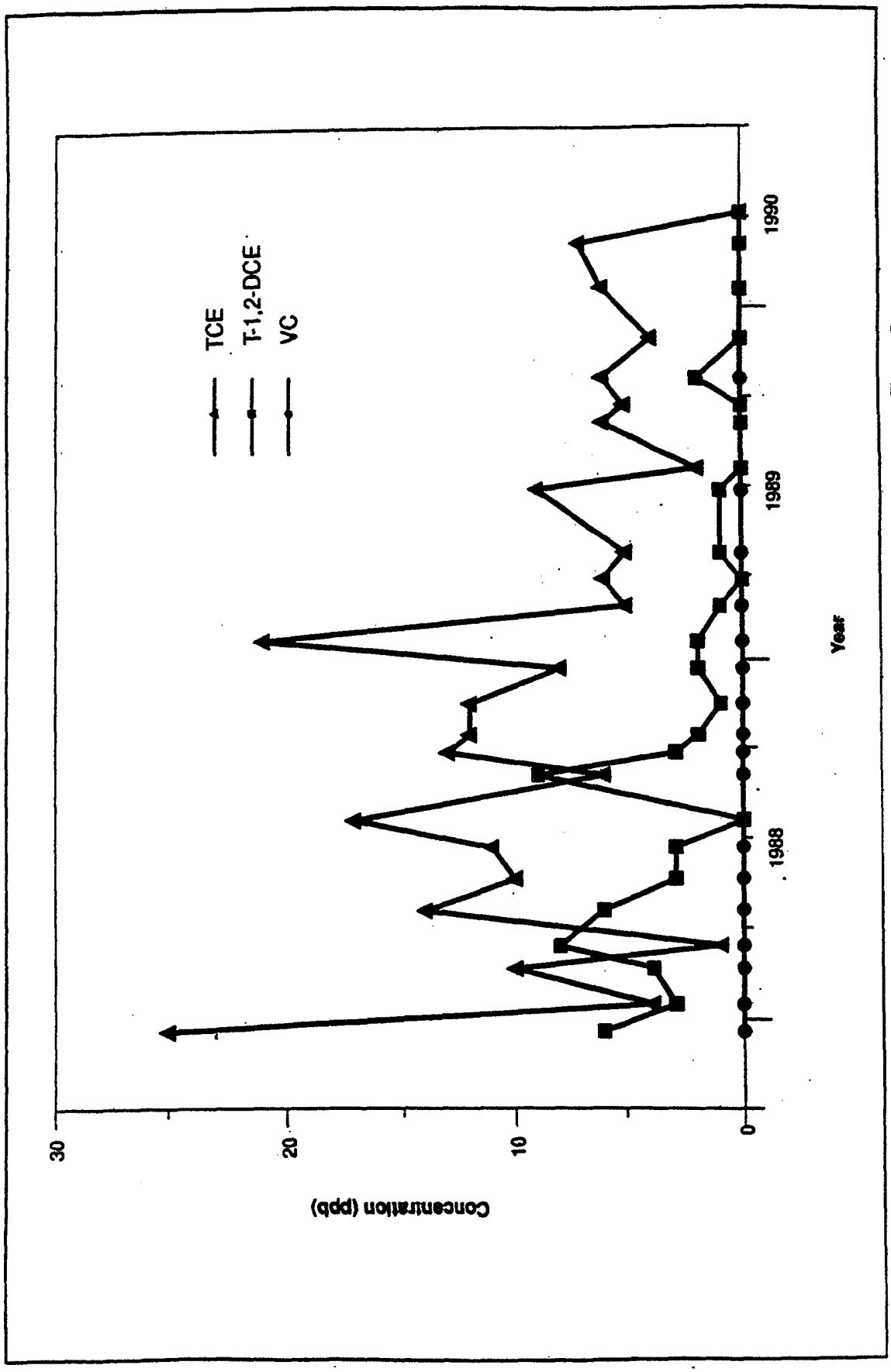

Figure 5
VOC CONCENTRATIONS IN MONITORING WELL NW-21
DES MOINES TCE SITE

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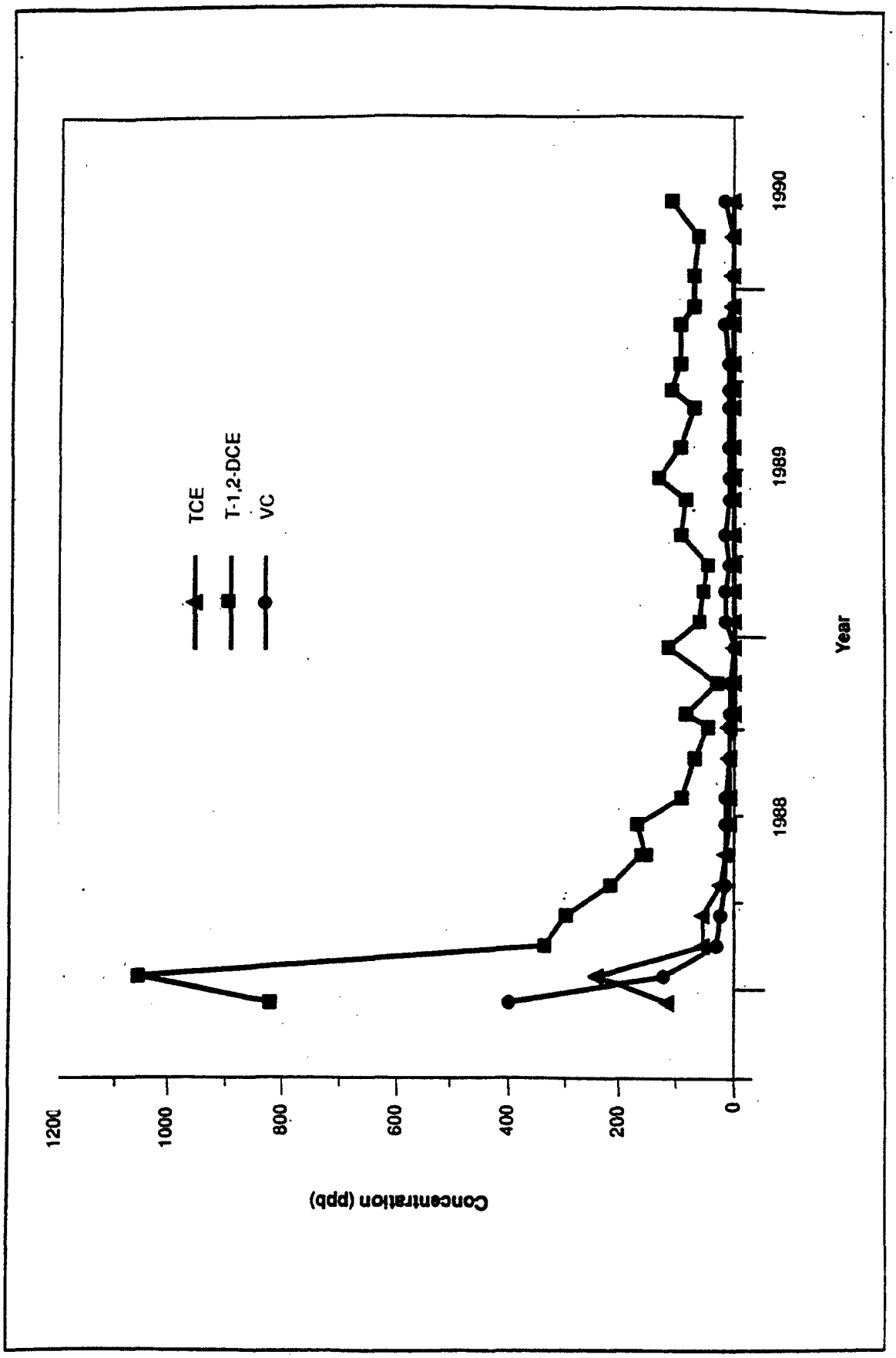

Figure 6
VOC CONCENTRATIONS IN MONITORING WELL NW-23
DES MOINES TCE SITE

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UPDATE BIBLIOGRAPHY/ REFERENCES

Eckenfelder, Inc. October 1989. *Des Moines South Area Source Control Operable Unit Sampling and Analysis Plan.*

Eckenfelder, Inc. February 1990. *Performance Evaluation Report No. 4 (January 1989 through December 1989) Groundwater Recovery and Treatment System, Des Moines TCE Site, Des Moines, Iowa.*

Eckenfelder, Inc. March 26, 1990. Progress Report for February 1990--letter to Mr. Glenn Curtis of EPA Region 7.

Eckenfelder, Inc. March 30, 1990. Progress Report for January 1990 letter to Mr. Glenn Curtis of EPA Region 7.

Eckenfelder, Inc. May 10, 1990. Progress Report for March 1990 letter to Mr. Glenn Curtis of EPA Region 7.

U.S. Environmental Protection Agency (U.S. EPA). December 17, 1985. *Final Remedial Investigation Report, Des Moines TCE Site, Des Moines, Iowa.*

U.S. EPA. October 1989. *Evaluation of Groundwater Extraction Remedies: Volume 2, Case Studies 1-19.* EPA/9355.4-03.

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UPDATE OF CASE STUDY 4

Du Pont-Mobile
Axis, Alabama

Abstract

Ground water in the unconfined sand aquifer is contaminated with volatile organics, base neutrals, and pesticides from a closed landfill. Since 1985, three extraction wells have been operating at the site boundary to prevent offsite migration of the contaminant plume. There have been no significant changes in the system since the original case study. The contaminant plume appears to be stable.

Table of Background Data		
Date of Problem Identification	1983	
Extraction Started	December 1985	
Types of Contaminants	VOCs, Pesticides	
Primary Aquifer Materials	Alluvial sand and clay	
Maximum Number of Extraction Wells	3	
Maximum Total Extraction Rate	180 gpm	
Estimated Plume Area	38 acres	
Estimated Plume Thickness	30 feet	
Maximum Reported Concentrations	Total Organic Halides	10,450 ppb
	Carbon Tetrachloride	5,815 ppb
	Trichloroethylene	3,940 ppb
	1,2,4-Trichlorobenzene	6,270 ppb

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CASE STUDY UPDATE
DU PONT-MOBILE SITE

BACKGROUND OF THE PROBLEM

INTRODUCTION

This report discusses progress in the remediation of the Du Pont-Mobile site from early 1989 through October 1990. It is an update of the original case study which was based on data collected through the end of 1988 (U.S. EPA, 1989, Case Study 4).

The Du Pont-Mobile site is an agricultural product manufacturing facility located in the town of Axis, Alabama, approximately 25 miles north of Mobile. Figure 1 shows the location of the site and the surrounding properties. Beginning in 1969, Shell Oil Company, then owner of the plant, disposed of sludges and drums of liquid wastes containing pesticides and VOCs in an onsite landfill consisting of three earthen pits. In addition, two surface impoundments called Six Acre-Foot Pond and Four Acre-Foot Pond were used for liquid wastes generated during insecticide production and for NPDES surge capacity.

Closure of the three waste management areas occurred during 1979 and 1980. The waste drums and approximately 4,000 cubic yards of contaminated soils were removed from the landfill area and disposed of offsite, followed by backfilling and regrading. The two surface impoundments were drained, excavated, and regraded.

Ground-water contamination originating from the former landfill area was first discovered in 1983 when sampling was performed by Shell Oil as part of an RCRA facility assessment. As a result, a ground-water extraction and monitoring system was installed to prevent further migration of the contaminants. Additional wells were added to this system in 1984 and 1985 to improve effectiveness. Through soil sampling and assessment of past waste-handling practices, the two former pond areas were judged not to pose a significant immediate threat of contamination to the ground water.

The site lies over three prominent stratigraphic units. The shallowest unit consists of 5 to 40 feet of surficial clay containing discontinuous silt and sand lenses covered with several feet of fill material. Directly beneath the clay is a layer of well-graded sand, ranging in thickness from 45 to 70 feet, containing clay lenses but thought to be hydraulically continuous. Finally, immediately beneath the sand layer lies a second layer of clay, extending vertically from approximately 90 to 600 feet below the ground surface.

Two aquifers exist beneath the site. The first is located in the sand layer, with the second located deep below the site under the lower layer of clay. Because of the thickness and impermeability of the lower clay layer, only the shallow sand aquifer is considered to be in immediate danger of contamination from the site. This shallow aquifer, referred to as the Alluvium Aquifer, has a predominantly eastward flow toward the Mobile River under natural conditions. However, long-term heavy industrial water-supply pumping at the neighboring Courtauld's North America property has created a prevailing northward flow in the central portion of the Du Pont site, with the Mobile River now serving as a source of recharge.

The primary contaminants of concern are VOCs and pesticides, along with some base-neutrals. While the exact nature and volume of wastes disposed of onsite is unknown, post-closure ground-water monitoring has detected the contaminants listed in Table 1.

UPDATE ON SITE CHARACTERISTICS

Since the time of the original case study, there have been no important changes in site administration or in the understanding of the hydrogeology, or waste characteristics. The site continues to operate under the provisions of a RCRA permit for operation of a hazardous waste storage facility that was issued in 1987. For the past 2 years, the monitoring and extraction wells have been sampled on a quarterly basis.

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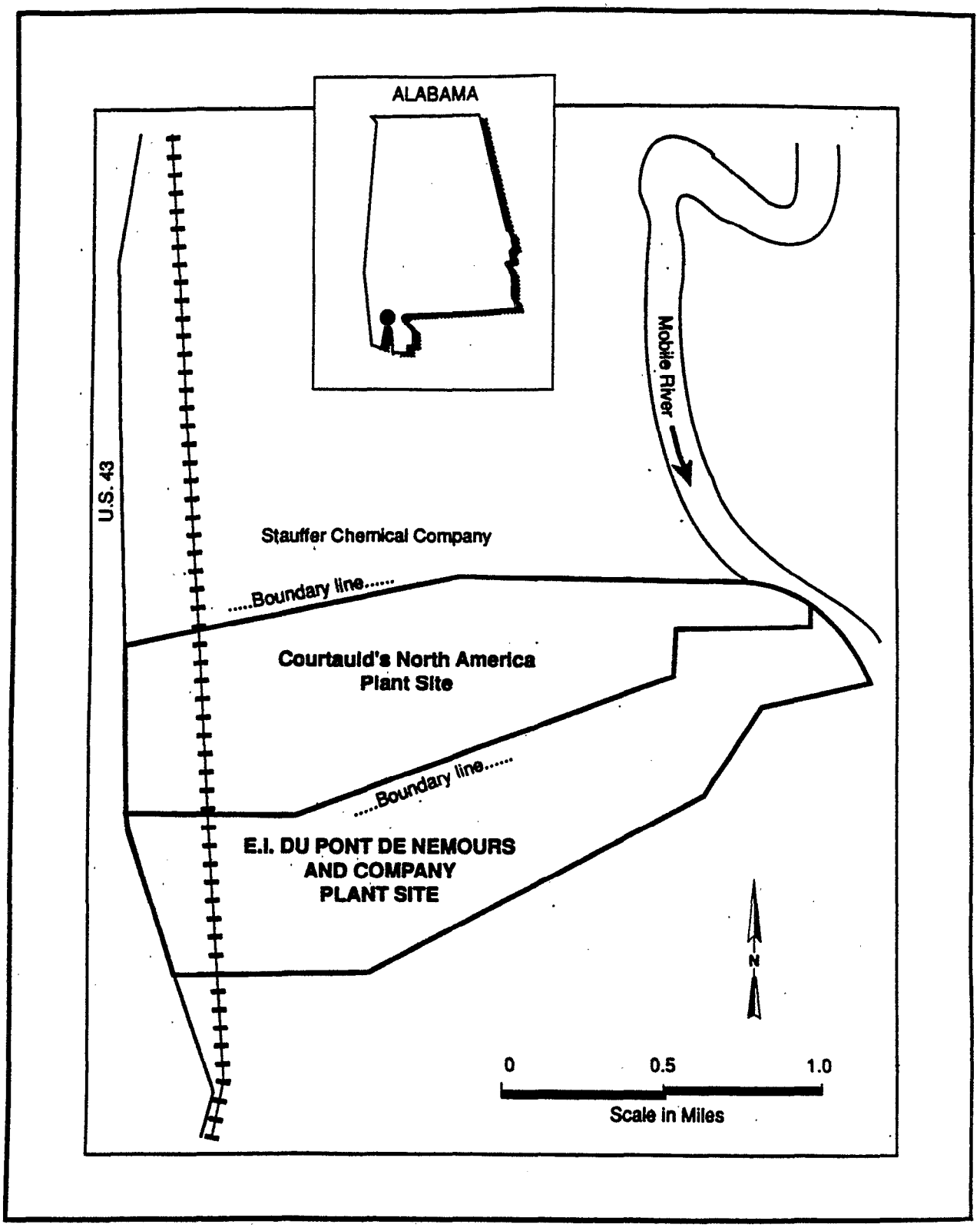

Figure 1
SITE LOCATION
DU PONT-MOBILE SITE
AXIS, ALABAMA

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Table 1
MAXIMUM CONCENTRATIONS OF CHEMICAL CONSTITUENTS OBSERVED IN GROUND-WATER MONITORING WELLS
1984 Through 1987

Ground-Water Chemical Constituent	Maximum Con. (ppb)	Monitoring Wells	Dates
Volatile Organics			
Acrolein	144	DW-2	09/84
Benzene	5	51	07/85
Carbon Tetrachloride (CBT)	5,815	52	06/87
Chloroform (CRF)	2,200	24	07/84
Chlorobenzene	42	22	12/87
Dibromochloropropane	3.2	27	11/84
Dichlorobromomethane	260	27	11/84
1,1-Dichloroethylene	10	23,51,52,53	03/87
Ethylbenzene	11.2	51	07/85
Methylene Chloride	63	27	11/84
Tetrachloroethylene	48.8	32	11/84
Toluene	12.8	51	07/85
1,2-Trans-dichloroethylene	42	24	08/86
1,1,1-Trichloroethane	42	27	11/84
Trichlorethylene (TCE)	3,940	24	09/84
1,2-Dichloroethane	3.24	E-2	09/86
1,1,2,2-Tetrachloroethane	73	32	06/87
1,1-Dichloroethane	13.9	23	09/86
Base Neutrals			
Isophorone	19	32	11/84
1,2,4-Trichlorobenzene (TCB)	6,270	32	11/84
Atrazine	179	25	06/87
Bladex	193	25	06/86
Rabon	2	18, R-1	07/84
Pydrin	4.4	32	12/87
Other Parameters			

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Table 1
MAXIMUM CONCENTRATIONS OF CHEMICAL CONSTITUENTS OBSERVED IN GROUND-WATER MONITORING WELLS
1984 Through 1987

Ground-Water Chemical Constituent	Maximum Con. (ppb)	Monitoring Wells	Dates
Chlorides	108 ppm	39	08/85
Sulfates	325 ppm	39	05/86
Cyanide	0.01	39	05/85

REMEDIATION

Design and Operation Features of Remediation System

The objective of the ground-water remediation at this site is to prevent off-site migration of contaminated ground water. The removal of contaminants from the aquifer is considered to be a secondary benefit of the remediation effort. Since the contaminated soils beneath the former landfill continue to be a source of ground-water contamination, no projections of time frame for aquifer restoration have been made.

The remediation system consists of three operating ground-water extraction wells located along the northern border of the site. Figure 2 shows the location of all monitoring and extraction wells at the Du Pont-Mobile site. The first two wells, E-1 and E-2, were initially drilled in late May 1985 to a depth of 75 feet, near the top of the shallow aquifer. After a failure in the casing of well E-2 in May 1986, well E-3 was installed 25 feet west of E-2. Extraction well E-4 was then added in December 1986 to increase the effectiveness of the extraction system. Currently, wells E-1, E-3, and E-4 remain in operation, each pumping at rates of 50 to 60 gpm. The extraction system has not been modified further since 1986.

The extracted water is treated in the plant's industrial biotreater and then released to the Mobile River as an NPDES-regulated discharge.

EVALUATION OF PERFORMANCE

Figures 3 and 4 show the total halogenated organic compound (TOX) concentrations in two monitoring wells located near the center of the plume and in the extraction wells as a function of time. The figures show that the TOX concentrations have not decreased steadily over time. Instead, the TOX concentrations have shown high variability. If any pattern can be discerned from these records over the past 4 years, it would appear to be a slight trend of increasing concentration.

The observation from Figure 3 that concentrations in well MW-32 are usually higher than in MW-24 is consistent with the idea that the landfill is continuing to release contaminants to the aquifer. Both wells are located between the landfill and the line of extraction wells, but MW-32 is closer to the landfill and to the probable centerline of the plume.

Figure 5 shows the measured TOX concentrations in the monitoring wells MW-50, MW-51, MW-52, and MW-53, located north of the line of extraction wells. Elevated concentrations of halogenated organic substances were measured in these wells, with the greatest levels found in MW-51 and MW-52. The detection of organics in these wells indicates that contaminants have moved north of the line of extraction wells at the site boundary. However, these contaminants may still be within the capture zone of the extraction wells. Because of the lack of water-level information to the north of this area, the extent of the capture zone cannot be accurately determined.

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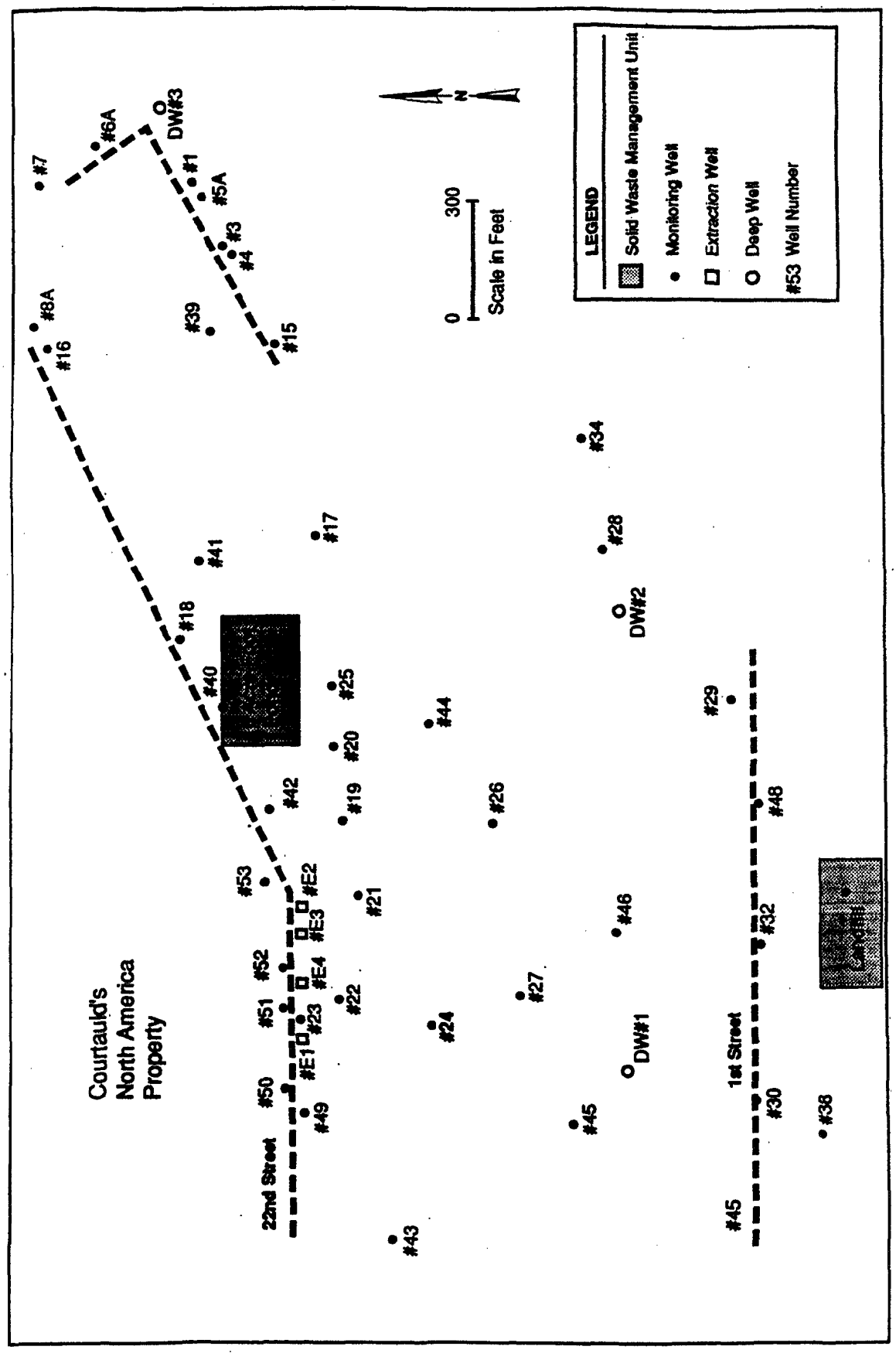

Figure 2
SITE PLAN SHOWING WASTE MANAGEMENT UNITS AND WELLS
DU PONT-MOBILE SITE

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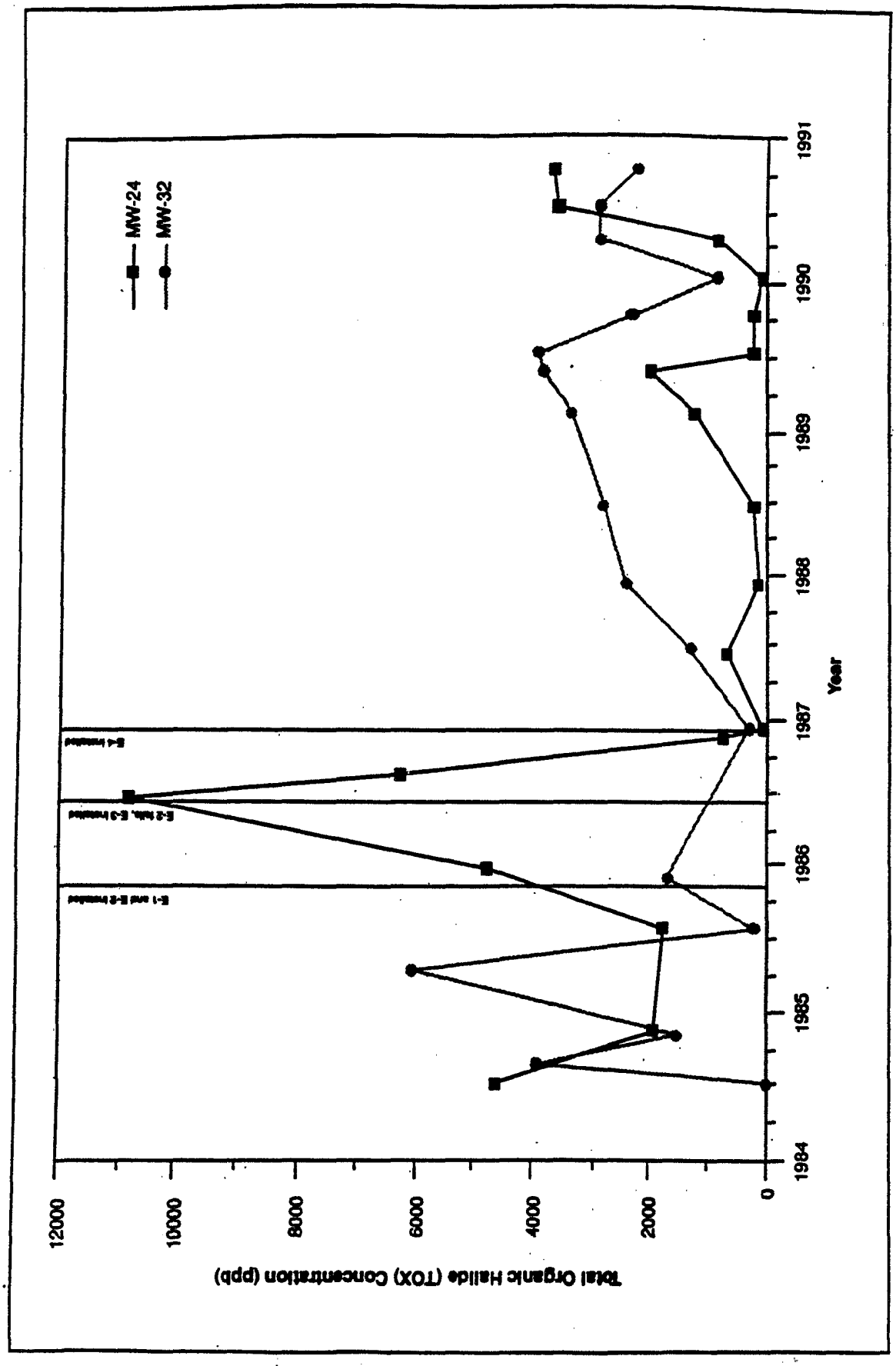

Figure 3
TOTAL ORGANIC HALIDE CONCENTRATIONS FOR TWO WELLS INSIDE THE PLUME
DU PONT - MOBILE SITE

Note: The two most recent data points were not validated.

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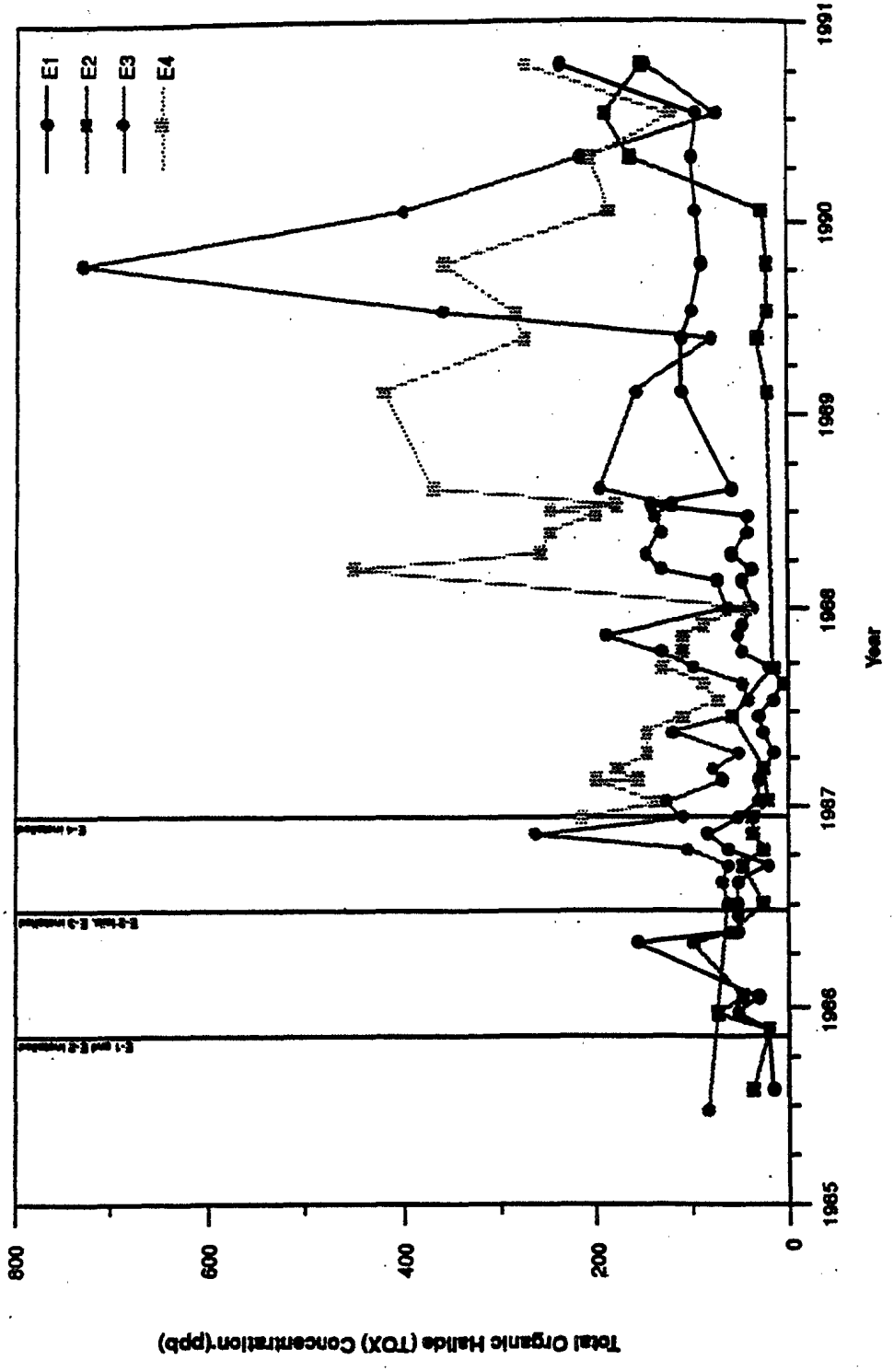

Figure 4
TOTAL ORGANIC HALIDE CONCENTRATIONS FOR FOUR EXTRACTION WELLS
DU PONT - MOBILE SITE

Note: The two most recent data points were not validated.

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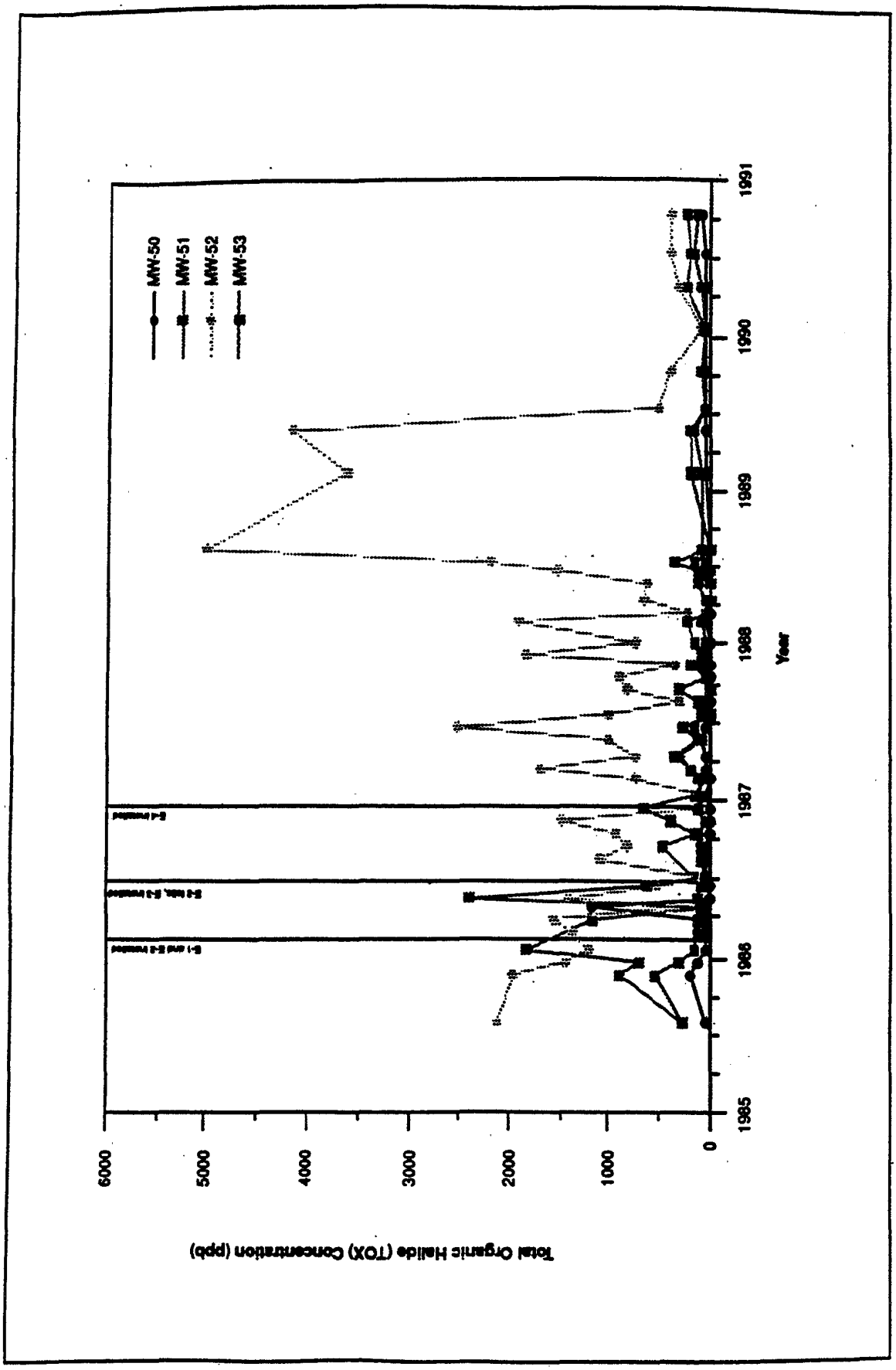

Figure 5
TOTAL ORGANIC HALIDE CONCENTRATIONS FOR FOUR MONITORING WELLS UPGRADIENT FROM EXTRACTION WELLS
DU PONT - MOBILE SITE

Note The two most recent data points were not validated.

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SUMMARY OF REMEDIATION

A ground-water extraction system consisting of four wells on the northern boundary of the site has been in continuous operation since the wells were installed in 1985 and 1986. Its objective is to prevent offsite migration of contaminants. In the original case study, some uncertainty was expressed concerning the degree of plume capture achieved by the extraction system. A time-averaged contour plot of the potentiometric surface under the influence of the extraction wells was presented in the original study, which suggested that the plume was being captured. This plot, however, was based mainly on water levels measured in the upper, and less permeable, part of the Alluvium Aquifer. There was also a general lack of information on water levels and contaminant concentrations north of the site boundary, which would be helpful in evaluating the effectiveness of the system. No new potentiometric surface maps have been made available since the original case study.

The TOX concentrations in the ground water have not shown a decline over the 6 years of monitoring but have instead been highly variable. Strong peaks of halogenated organics continue to occur, possibly due to slugs of free phase organics drawn into the extraction system, or to hydrologic fluctuations affecting leaching of contaminants from the source area.

SUMMARY OF NAPL-RELATED ISSUES

Certain characteristics observed at the Du Pont-Mobile site suggest that dense non-aqueous phase liquids (DNAPLs) may be present. As reflected by the soil and ground-water sampling and Shell Company records, the drums buried onsite likely included halogenated organic materials, such as trichloroethylene (TCE), that are potentially present as DNAPLs. If stored in their pure phase and allowed to leak from the drums into the soil, the DNAPLs could have penetrated the clay layer and the shallow aquifer, where they might be a persistent source of contamination. Such a scenario might explain the high variability in TOX concentrations in both the extraction wells and MW-24 and MW-32.

If DNAPLs were released, the complexity of the remediation necessary could increase significantly. Many DNAPLs have demonstrated the ability to quickly penetrate the vadose zone after release, even in low permeability clays. Once in the water table, these liquids often continue to migrate deeper, showing a tendency to follow gravity more than the established direction of ground-water flow. As a result, DNAPL contaminant concentrations should typically be higher in the lower reaches of the aquifer. Ground-water sampling at the Du Pont-Mobile site has not determined the extent of vertical distribution of contaminants within the plume. Further investigation would be necessary to determine whether DNAPLs are present in the lower reaches of the aquifer, and if so, whether the extraction well capture zone is adequate to prevent the further migration of aqueous contaminants originating from a deep DNAPL source.

UPDATE BIBLIOGRAPHY/ REFERENCES

E.I. Du Pont de Nemours and Co., Inc. November 1988. *Status Report for RCRA Facility Investigation, Solid Waste Management Units, Mobile Chemical Plant.*

E.I. Du Pont de Nemours and Co., Inc. April 16, 1990. Letter report on ground-water monitoring to Sue Robertson of the Alabama Department of Environmental Management.

E.I. Du Pont de Nemours and Co., Inc. January 28, 1991. Letter report on ground-water monitoring to Sue Robertson of the Alabama Department of Environmental Management.

U.S. Environmental Protection Agency (U.S. EPA). October 1989. *Evaluation of Ground-Water Extraction Remedies: Volume 2, Case Studies 1-19.* EPA/9355.4-03.

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CASE STUDY 5

Emerson Electric
Altamonte Springs, Florida

Abstract

The site is a former electrical component manufacturing and assembly plant that operated from January 1979 to the mid-1980s. From January 1980 to November 1981, wastewater from metal filming operations was discharged to a septic tank and tile drain on the southeast side of the main plant building. The discharge contained chlorinated and nonchlorinated solvents, xylene, ketones and other contaminants. From December 1984 to June 1987, a remediation system consisting of five extraction wells was operated. Concentrations of contaminants from composite samples decreased during this period. As a result, remediation is considered complete and the site has been removed from the State Action Site list. Because performance monitoring was limited to composite samples taken from the extraction wells, it is difficult to judge the completeness of aquifer restoration. Since the original case study was completed, monitoring has been discontinued. Because no new data have been generated, a case study update for the site was not written. See the original case study for more complete information on the site (U.S. EPA, 1989).

Table of Background Data	
Date of Problem Identification	1981
Extraction Started	December 1984
Types of Contaminants	VOCs
Primary Aquifer Materials	Sand
Maximum Number of Extraction Wells	5
Maximum Total Extraction Rate	30 gpm
Estimated Plume Area	3 acres
Estimated Plume Thickness	50 feet
Maximum Reported Concentrations	Methyl Isobutyl Ketone: 90,000 ppb

REFERENCE

U.S. Environmental Protection Agency (U.S. EPA). October 1989. *Evaluation of Ground-Water Extraction Remedies: Volume 2. Case Studies 1-19.* EPA 9355.4-03.

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UPDATE OF CASE STUDY 6

Fairchild Semiconductor
San Jose, California

Abstract

To date, the remediation system appears to be effective in containing ground-water contamination and has prevented the contamination of public drinking water supply wells. Since remediation began in 1982, VOC concentrations in ground water have decreased. In many offsite wells, VOC concentrations have decreased below cleanup levels. The slurry wall installed in Aquifers A and B continues to prevent offsite migration of contaminants and resaturation of remediated areas. In May 1990, pumping of onsite extraction wells ceased in accordance with the Remedial Actions Plan. Offsite pumping of ground water has continued. Beginning September 1990, treated ground water was to be reinjected to resaturate the onsite aquifer contained within the slurry wall.

Table of Background Data	
Date of Problem Identification	1981
Extraction Started	January 1982
Types of Contaminants	1,1,1-Trichloroethane 1,1-Dichloroethylene Freon
Primary Aquifer Materials	Alluvial sand and gravel with silt and clay layers
Maximum Number of Extraction Wells	36
Maximum Total Extraction Rate	9,200 gpm
Estimated Plume Area	75 acres
Estimated Plume Thickness	180 feet
Maximum Reported Concentrations	1,1,1-Trichloroethane 1,900,000 ppb

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CASE STUDY UPDATE
FAIRCHILD SEMICONDUCTOR CORPORATION SITE

BACKGROUND OF THE PROBLEM

INTRODUCTION

The original case study for the Fairchild Semiconductor Corporation site (*U.S. EPA, 1989*, Case Study 6) presented background information and data from ground-water monitoring and extraction systems through December 1988. The 22-acre Fairchild Semiconductor Corporation site, located at Bernal Road in the City of San Jose, California, is presently owned by the Schlumberger Technology Corporation. Figure 1 presents an overview of the site location. Fairchild first discovered chemical residues in the ground water in November 1981. Contamination was the result of a leaking underground waste solvent storage tank.

The site is included on the California Expenditure Plan for the Hazardous Waste Cleanup Bond Act of 1984 and was proposed for inclusion of the National Priorities List (NPL) under Superfund. Cooperative and enforcement agreements were entered into in May, 1985, between the U.S. EPA, the California Regional Water Quality Control Board (RWQCB), and the California Department of Health Services. The RWQCB has been acting as the lead agency overseeing cleanup of the site.

Operation of a ground-water extraction and treatment system began on January 16, 1982, as part of interim remedial measure (IRM) activities. To date, onsite IRM activities have consisted of underground storage tank removal, excavation of 3,389 cubic yards of soil, ground-water extraction and treatment, conduit sealing, in-situ soil vapor extraction, and slurry wall containment. Offsite IRM activities have included ground-water extraction, treatment, and monitoring. Remediation described in the Remedial Action Plan (RAP) prepared in October 1988, has also been implemented.

The Fairchild facility is located in a drainage basin that slopes northward into the nearby San Francisco Bay. The unit consists of a broad alluvial valley that is underlain by unconsolidated clays, silts, sands, and gravel. Sand and gravel layers interbedded with silt and silty clay layers combine to form four distinct underlying aquifers at the site. These aquifers are referred to as Aquifers A, B, C, and D. The aquifers are separated by silt and silty clay aquitards which range from several feet to 60 feet thick.

Aquifer A, which consists of alluvial sands and gravel, is located 10 to 20 feet below the ground surface and has a thickness of 15 to 40 feet. It is not continuous offsite and is currently dewatered onsite as a result of ground-water extraction activities. The aquifer is hydraulically connected with Aquifer B onsite in the vicinity of the former underground waste solvent storage tank. The highest solvent concentrations were detected prior to November 1982, within 50 feet of the former underground tank in Aquitard A/B.

Aquifer B consists of dense sands and gravels and is located between 60 and 120 feet below the ground surface. Water level data from April 1982, indicate ground water flow is to the northwest in this aquifer. Initially a confined aquifer, Aquifer B changed from confined to unconfined as a result of ground-water extraction in Aquifers A, B, and C.

Aquifer C consists of dense sands and gravels and is located between 150 to 190 feet below the ground surface. The aquifer has remained a confined system throughout the duration of the ground-water extraction activities. Water-level data from April 1982, indicate ground-water flow in this aquifer is to the northwest. The continuous 40-foot-thick B/C aquitard retards downward migration of contaminants into Aquifer C. Recent correspondence from Schlumberger (January, 1990) states that offsite contamination in the aquifer resulted from old agricultural wells screened in multiple aquifers and not from migration of contaminants vertically through Aquitard B/C.

Aquifer D, found at depths of 220 to 270 feet below the ground surface, is a discontinuous aquifer. There is an upward hydraulic gradient from Aquifer D to Aquifer C. No contamination has been detected in Aquifer D.

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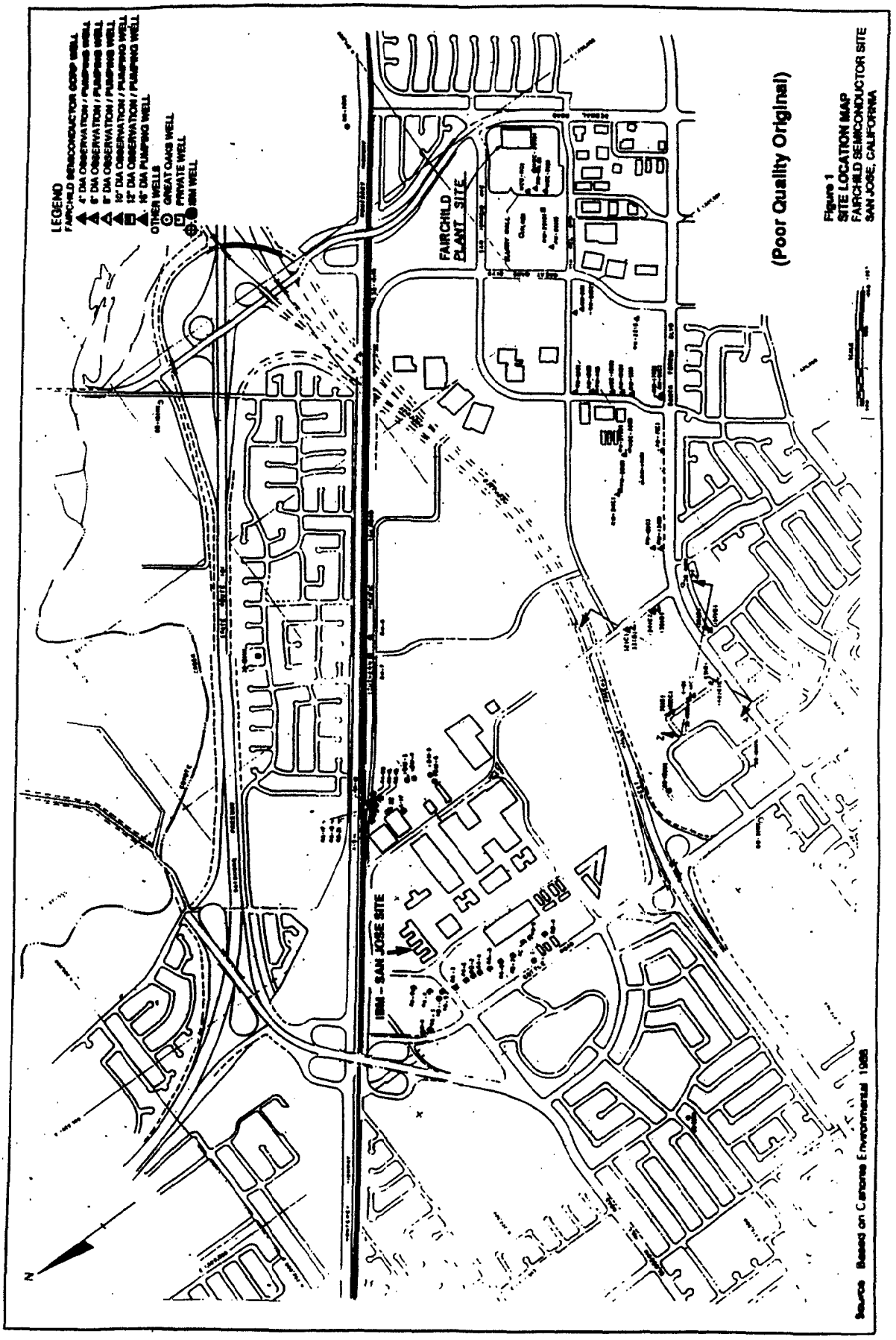

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Figure 1
SITE LOCATION MAP
FAIRCHILD SEMICONDUCTOR SITE
SAN JOSE, CALIFORNIA

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The primary contaminants found at the site were: chlorinated solvents, xylene, acetone, isopropyl-alcohol (IPA), and Freon-113. The highest concentrations of contaminants were found onsite in Aquifers A and B in the vicinity of the former underground waste solvent storage tank.

UPDATE ON SITE CHARACTERISTICS

The updated case study is based on 1989 and 1990 data obtained from the California Regional Water Quality Control Board (RWQCB). The data include annual, quarterly, and monthly reports submitted to RWQCB by Schlumberger and prepared by Schlumberger's consulting engineers, Canonie Environmental. These reports provide information on ground-water extraction rates, hydraulic controls, and contaminant concentrations.

The hydrogeologic information provided in the original case study is still current. No information has become available since 1988 that would change the description of basic site hydrogeology.

Aquifers A, B, and C are monitored on annual, quarterly, and bimonthly schedules to evaluate the concentrations of organic contaminants. Indicator compounds were selected due to their frequency of detection, concentrations, and spatial distributions. They include: 1,1,1-trichloroethane (TCA), 1,1-dichloroethylene (DCE), tetrachloroethylene (PCE), xylenes, acetone, isopropyl alcohol (IPA), and Freon-113. Since December 1988, TCA and 1,1-DCE have been the most prevalent contaminants throughout Aquifers A and B. The highest concentrations of TCA in Aquifers A and B in 1982 were 1,900,000 ppb and 670,000 ppb, respectively.

As noted in the original case study, prior to November 1982, maximum concentrations of several indicator compounds were higher than compound solubility levels, suggesting that contaminants in the ground water, and in the samples, were present as nonaqueous phase liquids (NAPLs).

REMEDIATION

Design and Operational Features of the Remediaton System

Site remediation goals are based on new criteria that were established by the RWQCB and adopted in January, 1989. These criteria specify that all offsite aquifers must meet Hazard Index criteria of less than 0.25. Hazard Index values are based on the combination of chemicals present rather than on absolute benchmark concentrations for individual chemicals. The Hazard Index (HI) for offsite ground water is calculated from the following equation:

$$HI = \frac{\text{Concentration of TCA (ppb)}}{200 \text{ ppb}} + \frac{\text{Concentration of 1,1-DCE (ppb)}}{6 \text{ ppb}}$$

where 200 ppb and 6 ppb are the onsite cleanup levels for TCA and 1,1-DCE, respectively.

The criteria also state that onsite wells must meet the California Department of Health Services drinking water action level or Maximum Contaminant Level (MCL), whichever is more stringent, for TCA, 1,1-DCE, Freon-113, and xylenes. The cleanup goal for PCE is 2 ppb based on the proposed state MCL. Cleanup goals for IPA and acetone are 3,500 ppb and 2,250 ppb, respectively, based on oral reference dose data in IRIS (U.S. EPA's Integrated Risk Management Information System).

Offsite remediation activities from 1982 to the present have focused on ground-water extraction and treatment to HI cleanup levels, and ground-water reuse and/or discharge.

The offsite B Aquifer was divided into three zones for the purpose of remediation evaluation (Refer to Figure 2). Zone boundaries were determined based on the estimated length of time required to remediate each zone to HI cleanup levels. Using this approach, ground-water extraction in each zone would be terminated when the B Aquifer in that zone was remediated to concentrations that correspond with HI cleanup criteria. With reference to the October 1988 RAP, the estimated time for remediation in each zone is 0 years, 2 years, and 5 years for zones 1, 2, and 3, respectively. The frame of reference for these

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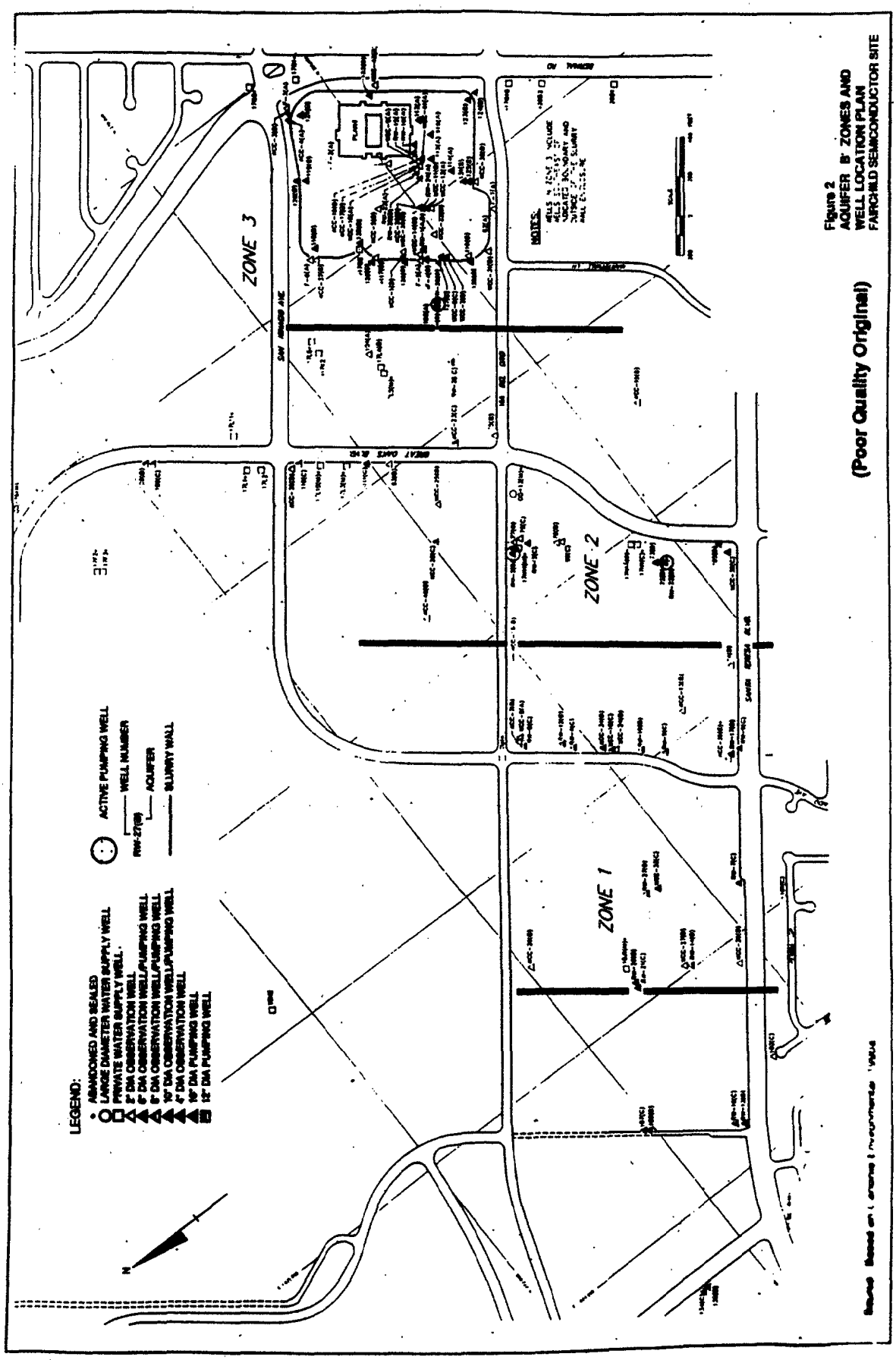

Figure 2
AQUIFER B' ZONES AND
WELL LOCATION PLAN
FAIRCHILD SEMICONDUCTOR SITE

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goals is January 1989, the date of RWQCB acceptance of the RAP.

During the interim remedial program, which started in 1982, Fairchild installed 40 ground-water recovery wells in onsite and offsite locations. Recovery wells were installed in Aquifers A, B,and C in downgradient areas west and northwest of the Fairchild plant. Recovery well locations were chosen using aquifer test results. Recovery wells were also placed parallel to local roadways to prevent further westward migration of the plume. Only 36 of the 40 initial recovery wells were ever operated, and only six recovery wells were operating as of the end of 1988.

Ground-water extraction was initiated on January 16, 1982, with the pumping of approximately 1,260 gpm from Well GO-13(M), an offsite water supply well. This rate was increased steadily until January 1983, when 9,600 gpm were being extracted. Since January 1983, the total flow rate has been gradually reduced. Before implementation of the operational plan to reduce ground-water extraction in February 1989, the pumping rate in Aquifer B was 960 gpm. As of September 1990, the only extraction wells operating were three wells in Aquifer B--RW-2(B), RW-22(B), and RW-25(B). These wells were operated at a total pumping rate of 655 gpm. The locations of these three wells are circled in Figure 2.

As of September 1990, pumping in offsite Aquifer B recovery Wells RW-2(B), RW-22(B), and RW-25(B) continued to maintain hydraulic control of contaminated ground water. The pumping of onsite extraction wells ceased in May 1990, in accordance with RAP activities. Ground-water extraction flow rates from January 1990, through September 1990, for both onsite and offsite wells averaged 656 gpm (Refer to Table 1). Offsite ground-water extraction between zones 2 and 3 maintained an average flow rate of 649 gpm following the termination of onsite pumping activities. Offsite ground-water extraction rates for zone 2 wells only averaged 221 gpm. Onsite Wells AE-1(B), AE-2(B), AE-3(B), AE-4(B), and RW-28(B) were reactivated in September 1990, to evaluate the application of the treatment and reinjection system. Reactivation of the system lowered the water table in Aquifer B by 4.71 feet to an average water-level elevation of 148.8 feet in September 1990.

In mid-1986, a 3-foot-thick slurry wall was installed through Aquifers A and B to enclose the onsite portion of the site. The slurry wall extends to the bottom of Aquifer B. The slurry wall acts to prevent resaturation of remediated areas from nearby percolation ponds and offsite migration of contamination.

The head differential across the slurry wall barrier has been measured on an annual, quarterly, and bimonthly basis to monitor the safety of the slurry wall system. A head differential of less than 24 feet was determined to represent an appropriate level of safety to prevent the loss of fine-grained soils from the slurry wall system. The slurry wall has been determined to be very effective in reducing onsite pumping requirements.

In June 1990, Schlumberger submitted a systems design plan for treating extracted ground water from onsite wells and offsite Well RW-25(B). The treatment system, which uses a Baltimore Air Coil (BAC) water cooling tower as the primary treatment system, has been designed to meet the instantaneous effluent limitations adopted by RWQCB. These limits are 5 ppb for TCA and 1,1-DCE each. While the tower was designed for cooling, it has been adapted for use at this site as an air stripper to accommodate the pumping and treatment of a large volume of ground water. Beginning in September 1990, treated ground water was to be reinjected into Aquifer B to resaturate the B Aquifer contained within the slurry wall to water levels even with those outside of the slurry wall system. Resaturation through reinjection of extracted groundwater is consistent with state water conservation initiatives. After the desired water level recovery inside the slurry wall has been achieved, pumping from some onsite wells may resume with continued treatment and reinjection.

In-situ soil vapor extraction, which began as a pilot study in October 1988, continues to be used to remove subsurface VOCs (including NAPLs) from the unsaturated soils in Aquifers A and B, and the A/B aquitard. Thirty-two air extraction wells and 5 ground-water recovery wells are used for the aeration process. The wells are located in the vicinity of the former underground storage tank. Eight air inlet wells were installed in areas not affected by the contamination to facilitate air flow through the affected soils. The extracted air is treated with granular activated carbon before emission to the atmosphere.

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Table 1
PUMPING SCHEDULE
FLOW READINGS (gpm)
1990

Well Number	01/03	01/01	01/17	01/24	01/31	02/07	02/14	02/21	02/28	03/07	03/14	03/21	03/28
RW-2(B)	202	209	202	205	209	205	205	205	205	205	208	202	205
RW-22(B)	261	261	254	254	261	261	254	254	244	248	254	261	254
RW-25(B)	261	261	254	254	261	261	254	254	244	248	254	261	254
RW-28(B)	21	20	16	13	13	13	13	13	12	13	12	13	14
AE-1(B)	9	9	9	8	8	7	8	7	--(a)	--(a)	--(a)	8	7
AE-2(B)	30	32	32	37	32	32	30	31	32	31	32	30	30
AE-3(B)	28	17	18	18	15	11	7	11	12	11	9	10	10
AE-4(B)	35	35	34	33	34	33	34	33	34	33	33	33	35
Total Flow	664	671	659	656	670	660	663	658	646	649	668	664	665

Source: Canonie Environmental, 1990c
Notes:
(a)Well AE-1(B) shut down for maintenance.

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Fairchild Semiconductor

Table 1
PUMPING SCHEDULE
FLOW READINGS (gpm)
1990

Well Number	04/04	04/11	04/18	04/25	05/02	05/09	05/16	05/23	05/30	06/06	06/13	06/19	06/26
RW-2(B)	205	205	202	205	202	199	202	183	170	195	195	195	192
RW-22(B)	254	254	254	270	267	254	267	244	238	254	254	260	323[b]
RW-25(B)	110	104	104	110	114	111	117	111	183	199	199	199	199
RW-28(B)	13	13	13	13	12	11	11	11	--[a]	--	--	--	--
AE-1(B)	8	8	8	7	7	7	7	8	--[a]	--	--	--	--
AE-2(B)	31	32	31	30	29	30	28	28	--[a]	--	--	--	--
AE-3(B)	9	10	10	10	10	10	9	10	--[a]	--	--	--	--
AE-4(B)	35	34	35	35	34	34	33	33	--[a]	--	--	--	--
Total Flow	665	660	657	680	675	656	674	628	591	648	648	654	714

Source: Canonie Environmental, 1990c
Notes:
(a) Terminated pumping on May 24, 1990, as approved by RWQCB.
(b) Increased flow rate due to irrigation.

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Fairchild Semiconductor

Table 1
PUMPING SCHEDULE
FLOW READINGS (gpm)
1990

Well Number	07/03	07/11	07/18	07/25	08/01	08/08	08/15	08/22	08/29	09/05	09/12	09/19	09/25
RW-2(B)	192	199	195	195	194	222	205	215	195	228	212	190	192
RW-22(B)	319[a]	205	205	209	176	238[a]	310[a]	205	192	261	199	195	189
RW-25(B)	199	199	199	202	199	199	199	199	199[b]	251[b]	274	287	284
Total Flow	710	603	599	606	569	659	714	619	586	740	685	672	665

Source: Canonie Environmental, 1990c
Notes:
(a) Increased flow rate due to irrigation use by Caltrans contractors.
(b) Increased flow rate to meet design demand for resaturation of the "B" aquifer.

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Fairchild Semiconductor

EVALUATION OF SYSTEM PERFORMANCE

Since December 1988, the last month covered by the original case study, the only chemicals detected outside the slurry wall enclosure in zone 3 of Aquifer B were TCA and 1,1-DCE. Some TCA concentrations were detected above cleanup levels.

Aquifer A, which was dewatered in 1984, remained dewatered in 1989 and 1990. Aquifer C has continued to meet offsite cleanup level criteria since it was remediated in late 1988. However, low TCA concentrations have been observed in Aquifer C. These detections are lower than the offsite cleanup criteria levels established for the combined effects of TCA and 1,1-DCE, and are within the range expected following the termination of pumping in Aquifer C.

Zone 1, the offsite area farthest from the Fairchild facility, attained cleanup criteria levels by December 1989. Ground-water monitoring data from 1990 confirm TCA and 1,1-DCE concentrations within cleanup criteria levels (Refer to Table 2). Zone 1 attained cleanup criteria levels in less than one year from the implementation of the RAP. This schedule meets the system performance goals set forth in the RAP.

In 1989, zone 2 and 3 ground-water extraction activities continued to provide hydraulic control of the chemical bearing ground-water plume in Aquifer B. The average total Aquifer B extraction rate for 1989 was 650 gpm. This represents quarterly averages of 840, 648, 563, and 545 gpm for the first, second, third, and fourth quarters, respectively. The decreasing rates were due to the shutoff of recovery wells RW-19(B) on February 7, 1989, and RW-27(B) on April 11, 1989. Shutoff of these recovery wells was scheduled as part of the operational plan to reduce ground-water extraction in Aquifer B.

By December 1988, ground-water levels in Aquifer B had declined 23 to 38 feet below April 1982 levels as a result of ground-water extraction activities. A program to reduce ground-water extraction in Aquifer B was initiated on February 7, 1989. This plan involved the shutoff of individual offsite wells. By September 1990, ground-water levels in B had risen 13.4 feet above February 1989 levels. By December 1988, ground-water levels in Aquifer C had declined 40 feet below April 1982 levels. A program to reduce ground-water extraction in Aquifer C was initiated on May 2, 1988. By December 1989, ground-water levels in Aquifer C had risen 25.5 feet above May 1988, levels. Ground-water levels in Aquifer C remained steady during 1989 and 1990. September 1990 water levels for Aquifers B and C are presented in Figures 3 and 4, respectively.

TCA concentrations at onsite Aquifer B wells have decreased from a maximum of 670,000 ppb in 1982, to a maximum of 2,000 ppb measured from Well WCC-17(B) on August 29, 1990. Figure 5 presents the distribution of TCA in Aquifer B on September 30, 1990, overlaid on contours of the TCA concentration on October 31, 1982, 9 months after extraction began. Figure 5 shows that offsite TCA concentrations have been reduced by as much as two orders of magnitude in some areas, and that the size of the 10-ppb plume has decreased to less then half of its original size.

Figures 6 and 7 show the contours of the Hazard Index of TCA and 1,1-DCE concentrations in September 1990, in Aquifers B and C, respectively. The figures show that a substantial offsite plume of contamination with a Hazard Index greater than the standard of 0.25 still existed in September 1990, in Aquifer B but was absent in Aquifer C.

Figures 8, 9, and 10 show the trend of TCA concentrations in three offsite recovery wells in Aquifer B--RW-2(B), RW-22(B), and RW-25(B). All three of the wells were operating recovery wells as of September 1990. These three plots confirm that TCA concentrations in these wells have decreased substantially from initial levels. TCA concentrations appear to have been reduced to stable levels of approximately 20 ppb in all three wells. Figure 11 shows that the TCA concentration in onsite Aquifer B recovery Well RW-28(B) decreased substantially from September 1989, to September 1990.

Initial startup of the in-situ soil vapor extraction system began in October 1988, with full operation beginning in January, 1989. The total mass of VOCs removed between October 1988, and September 1990, is estimated at 14,724 pounds, 2,724 pounds above the original projected recovery rates for the system. Table 3 presents a

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Table 2
WATER QUALITY DATA

Well Number	Most Recent Sampling Date	Concentrations (ppb)		Hazard Index Value	Hazard Index Target Cleanup Criteria
		TCA	1,1-DCE		
Zone 1: Offsite Wells					
RW-12(B)	9/14/90	0.5	0.5	0.00125	0.25
RW-14(B)	08/21/90	0.5	0.5	0.00125	0.25
RW-17(B)	08/21/90	0.5	0.5	0.00125	0.25
RW-19(B)	09/07/90	12.0	0.5	0.1433	0.25
RW-20(B)	08/23/90	1.4	0.5	0.0903	0.25
RW-27(B)	07/24/90	3.3	0.5	0.0165	0.25
WCC-7(B)	08/28/90	0.5	0.5	0.00125	0.25
WCC-13(B)	09/18/90	0.5	0.5	0.00125	0.25
WCC-19(B)	09/18/90	0.5	0.5	0.00125	0.25
WCC-26(B)	08/28/90	0.5	0.5	0.00125	0.25
WCC-27(B)	08/31/90	1.0	0.5	0.0883	0.25
74(B)	09/27/90	0.5	0.5	0.00125	0.25
Zone 2: Offsite Wells					
RW-2(B)*	09/19/90	11.0	1.9	0.3716	0.25
RW-22(B)*	09/19/90	12.0	1.9	0.3766	0.25
WCC-15(B)	04/24/90	0.5	0.5	0.00125	0.25
WCC-25(B)	08/31/90	0.5	0.5	0.00125	0.25
WCC-39(B)	08/31/90	0.5	0.5	0.00125	0.25
WCC-23(C)	09/14/90	1.0	0.5	0.0883	0.25
WCC-28(C)	05/31/89	0.5	0.5	0.00125	0.25
72(B)	09/19/90	25.0	4.3	0.8427	0.25
75(B)	07/25/90	19.0	1.9	0.4110	0.25
78(B)	08/31/90	29.0	4.5	0.895	0.25
83(B)	08/31/90	0.5	0.5	0.00125	0.25
105(B)	08/07/90	0.5	0.5	0.00125	0.25
108(B)	09/14/90	0.5	0.5	0.00125	0.25
111(C)	04/21/89	0.5	0.5	0.00125	0.25

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Table 2
WATER QUALITY DATA

Well Number	Most Recent Sampling Date	Concentrations (ppb)		Hazard Index Value	Hazard Index Target Cleanup Criteria
		TCA	1,1-DCE		
Zone 3: Offsite Wells					
120(B)	09/12/90	0.5	0.5	0.00125	0.25
126(B)	07/31/90	1.0	0.5	0.0883	0.25
127(B)	09/14/90	0.9	0.5	0.0875	0.25
128(B)	08/31/90	9.1	3.5	0.6288	0.25
129(B)	07/13/90	0.5	0.5	0.00125	0.25
WCC-37(B)	08/30/90	0.5	0.5	0.00125	0.25
WCC-38(B)	07/31/90	0.6	0.5	0.086	0.25
WCC-42(B)	09/19/90	0.5	0.5	0.00125	0.25
Onsite Wells					
				TCA Cleanup Level (ppb)	1,1-DCE Cleanup Level (ppb)
RW-28(B)	09/10/90	1,300.0	230.0	200.0	6
WCC-1(B)	09/27/90	660.0	25.0	200.0	6
WCC-2(B)	09/25/90	6.8	1.4	200.0	6
WCC-5(B)	09/19/90	18.0	1.0	200.0	6
WCC-16(B)	09/21/90	62.0	25.0	200.0	6
WCC-17(B)	09/21/90	330.0	50.0	200.0	6
WCC-20(B)	09/10/90	120.0	13.0	200.0	6
116(B)	09/07/90	1.1	0.5	200.0	6
122(B)	09/12/90	0.5	0.5	200.0	6

Source: Canonie Environmental, 1990c
*Wells remaining in operation

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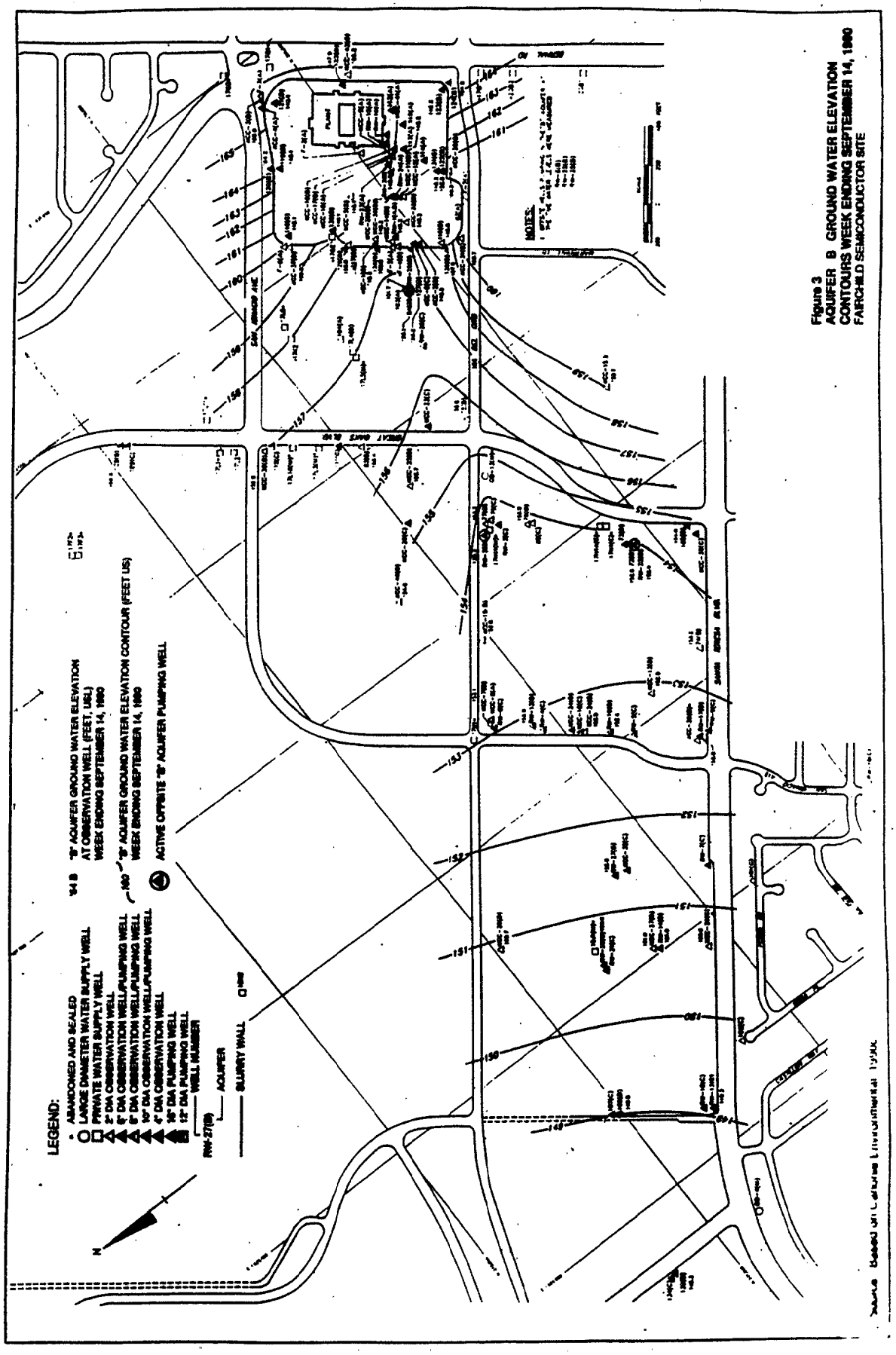
LEGEND:
ABANDONED AND SEALED
LARGE DIAMETER WATER SUPPLY WELL
PRIVATE WATER SUPPLY WELL
2" DIA OBSERVATION WELL
6" DIA OBSERVATION WELL/PUMPING WELL
8" DIA OBSERVATION WELL/PUMPING WELL
10" DIA OBSERVATION WELL/PUMPING WELL
4" DIA OBSERVATION WELL
16" DIA PUMPING WELL
12" DIA PUMPING WELL
WELL NUMBER
AQUIFER
SLURRY WALL
"B" AQUIFER GROUND WATER ELEVATION AT OBSERVATION WELL (FEET, USL) WEEK ENDING SEPTEMBER 14, 1990
"B" AQUIFER GROUND WATER ELEVATION CONTOUR (FEET US) WEEK ENDING SEPTEMBER 14, 1990
ACTIVE OFFSITE "B" AQUIFER PUMPING WELL
NOTES:
Figure 3
AQUIFER B GROUND WATER ELEVATION
CONTOURS WEEK ENDING SEPTEMBER 14, 1990
FAIRCHILD SEMICONDUCTOR SITE

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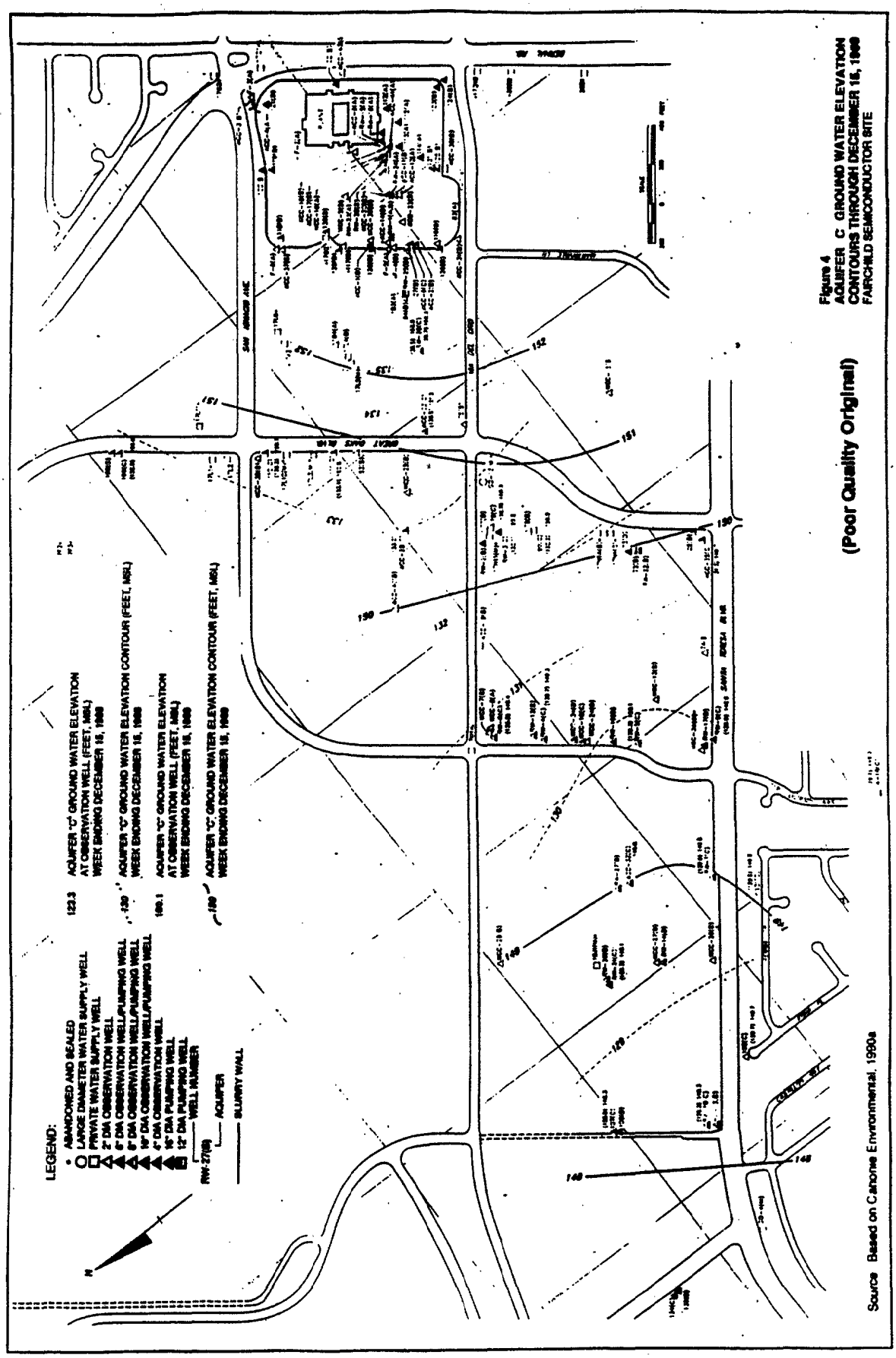

Figure 4
AQUIFER C GROUND WATER ELEVATION CONTOURS THROUGH DECEMBER 16, 1989
FAIRCHILD SEMICONDUCTOR SITE

(Poor Quality Original)

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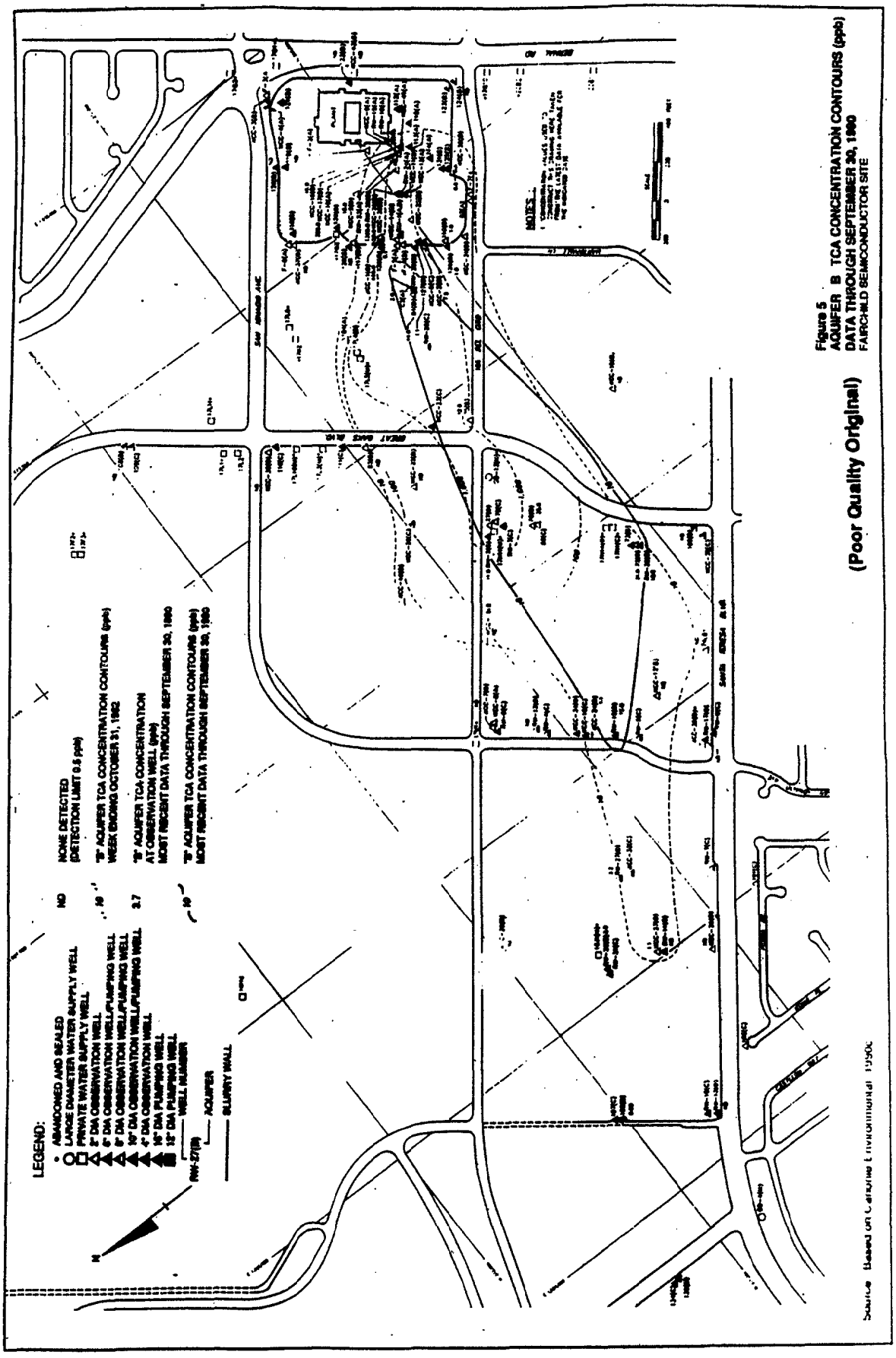

Figure 5
AQUIFER B TCA CONCENTRATION CONTOURS (ppb)
DATA THROUGH SEPTEMBER 30, 1990
FAIRCHILD SEMICONDUCTOR SITE

(Poor Quality Original)

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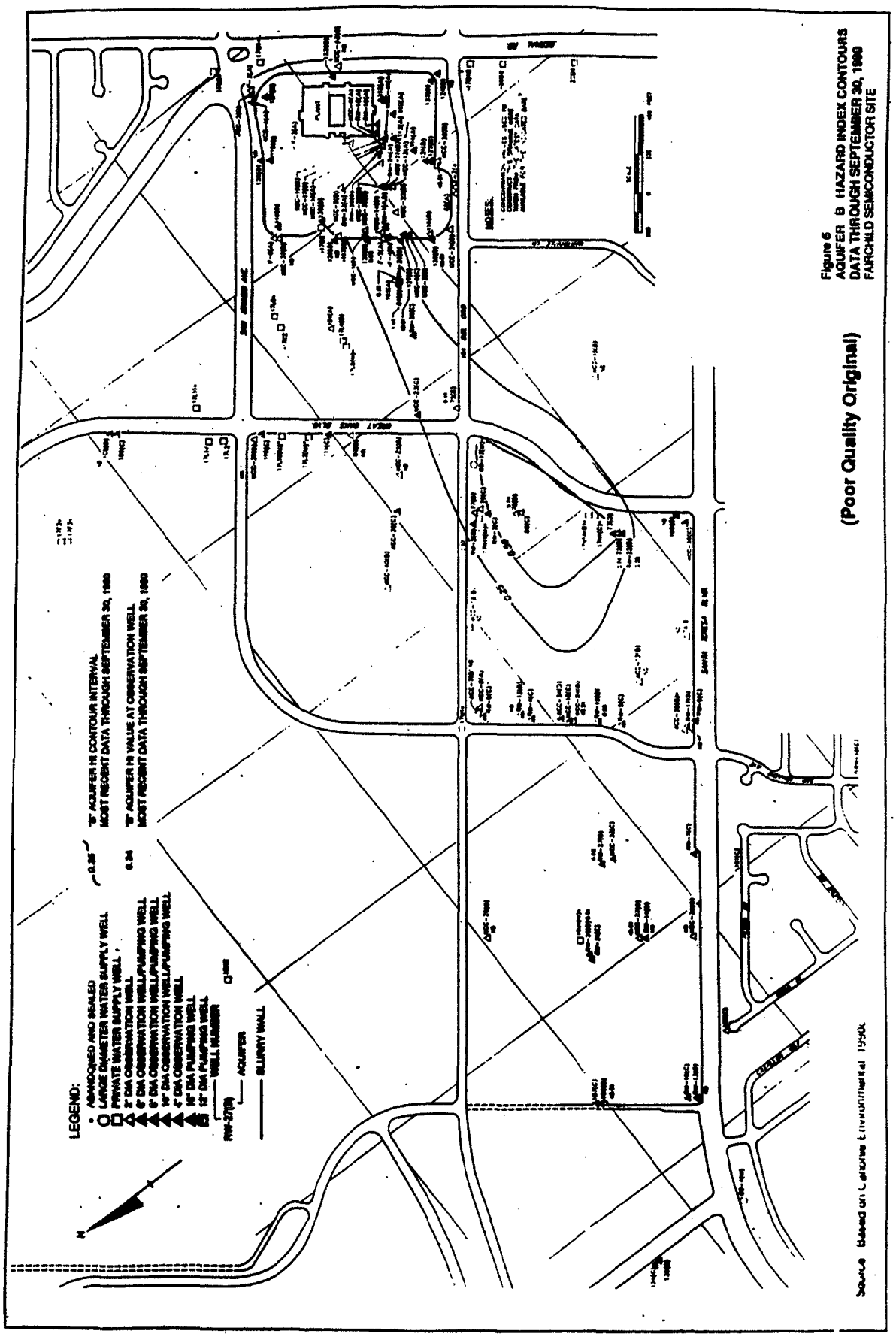

Figure 6
AQUIFER B HAZARD INDEX CONTOURS
DATA THROUGH SEPTEMBER 30, 1990
FAIRCHILD SEMICONDUCTOR SITE

(Poor Quality Original)

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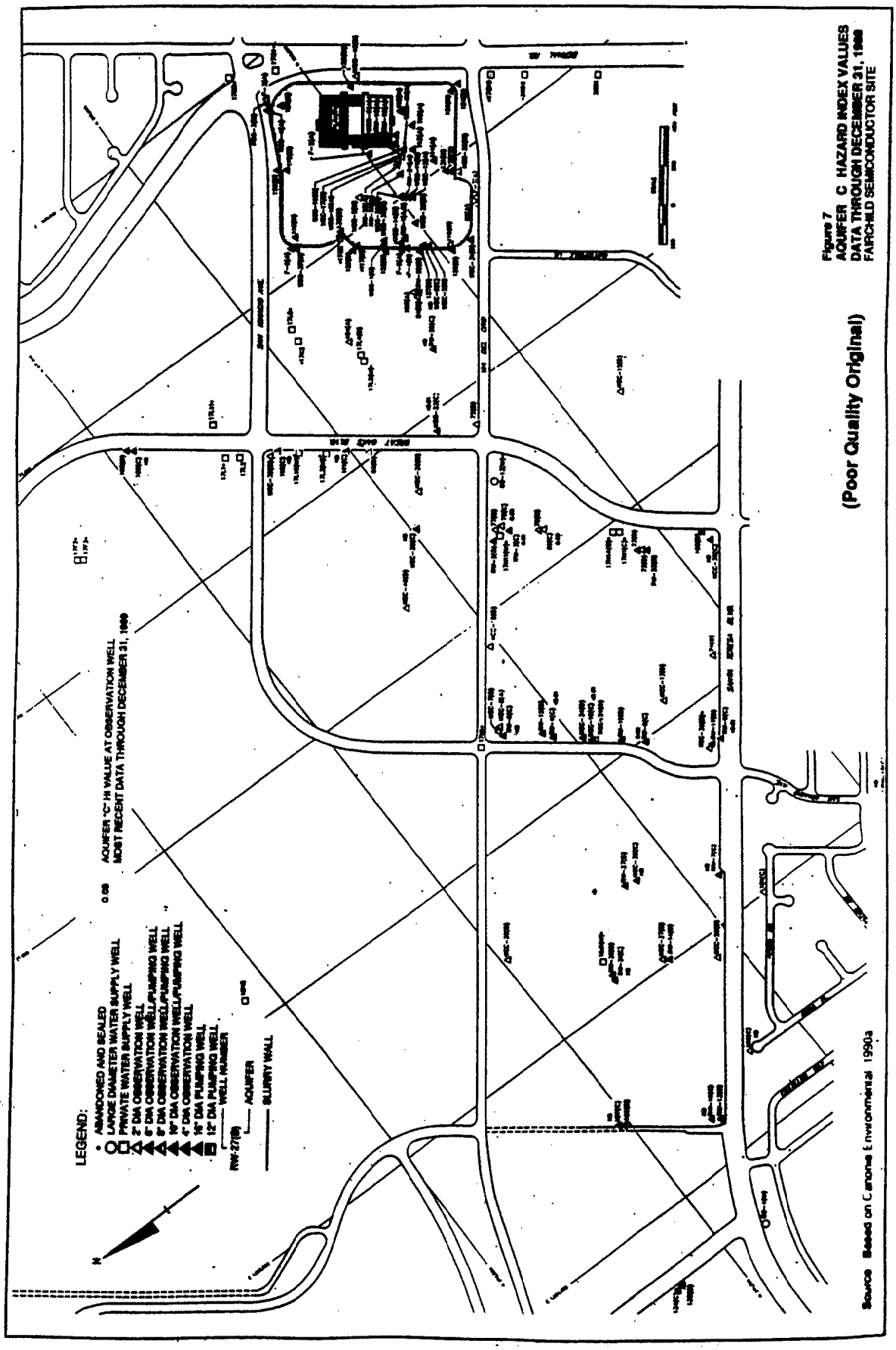

Figure 7
AQUIFER C HAZARD INDEX VALUES
DATA THROUGH DECEMBER 31, 1989
FAIRCHILD SEMICONDUCTOR SITE

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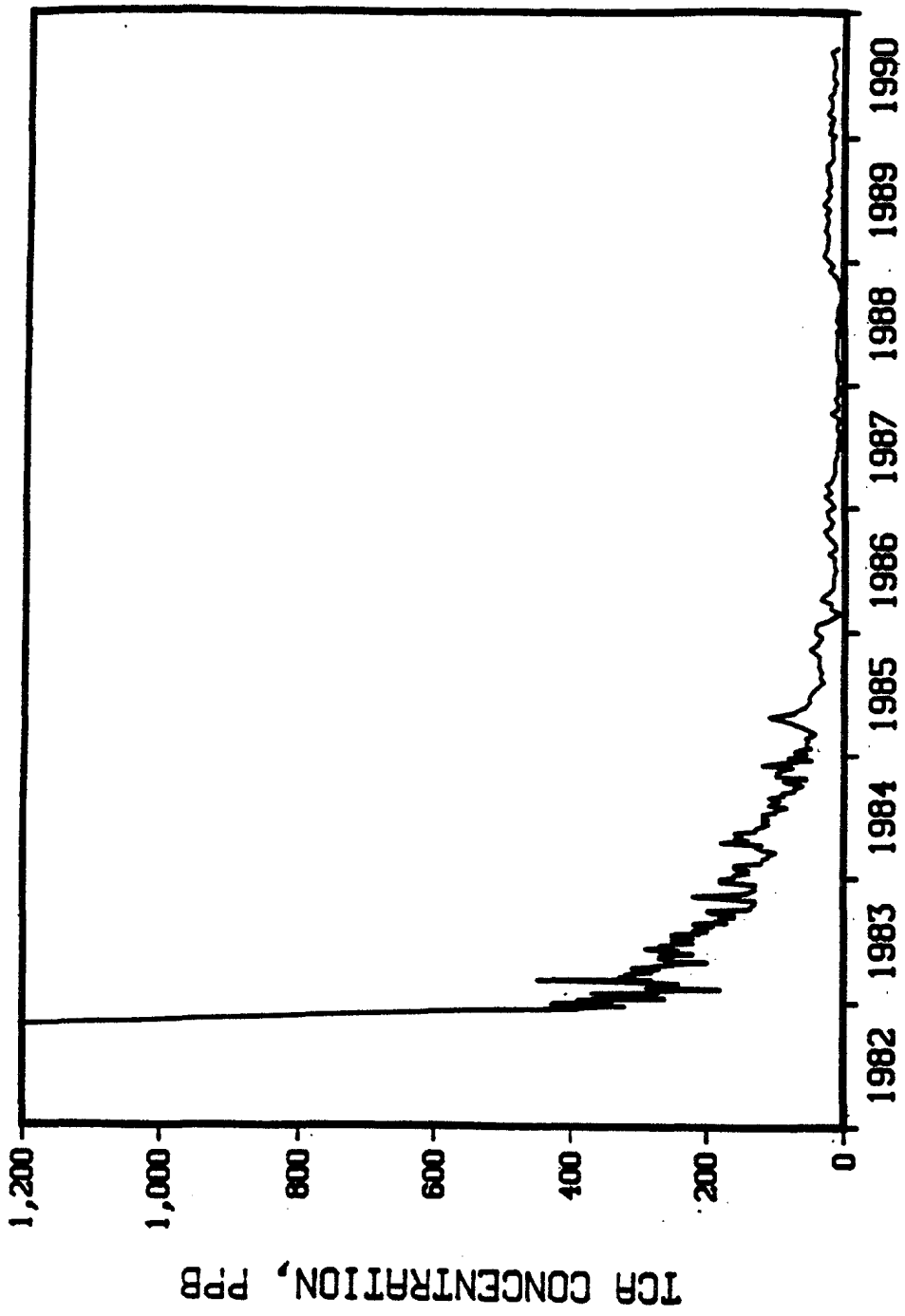

Figure 8
MULTIYEAR TCA CONCENTRATIONS
IN OFFSITE WELL RW-2 (B)
FAIRCHILD SEMICONDUCTOR SITE

Source: Based on Canonie Environmental, 1990c

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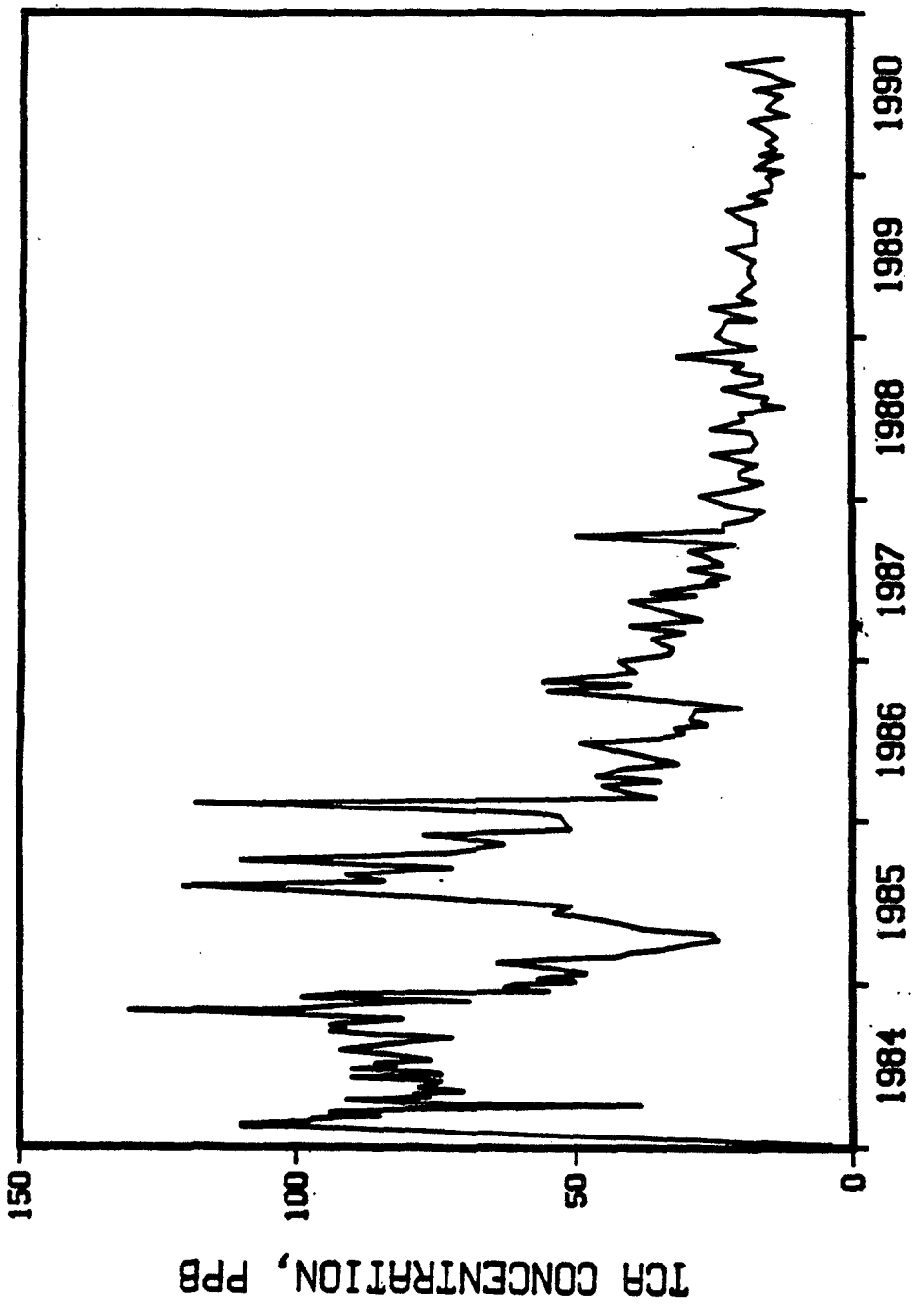

Source Based on Canonie Environmental, 1990c

Figure 9
MULTIYEAR TCA CONCENTRATIONS IN OFFSITE WELL RW-22 (B)
FAIRCHILD SEMICONDUCTOR SITE

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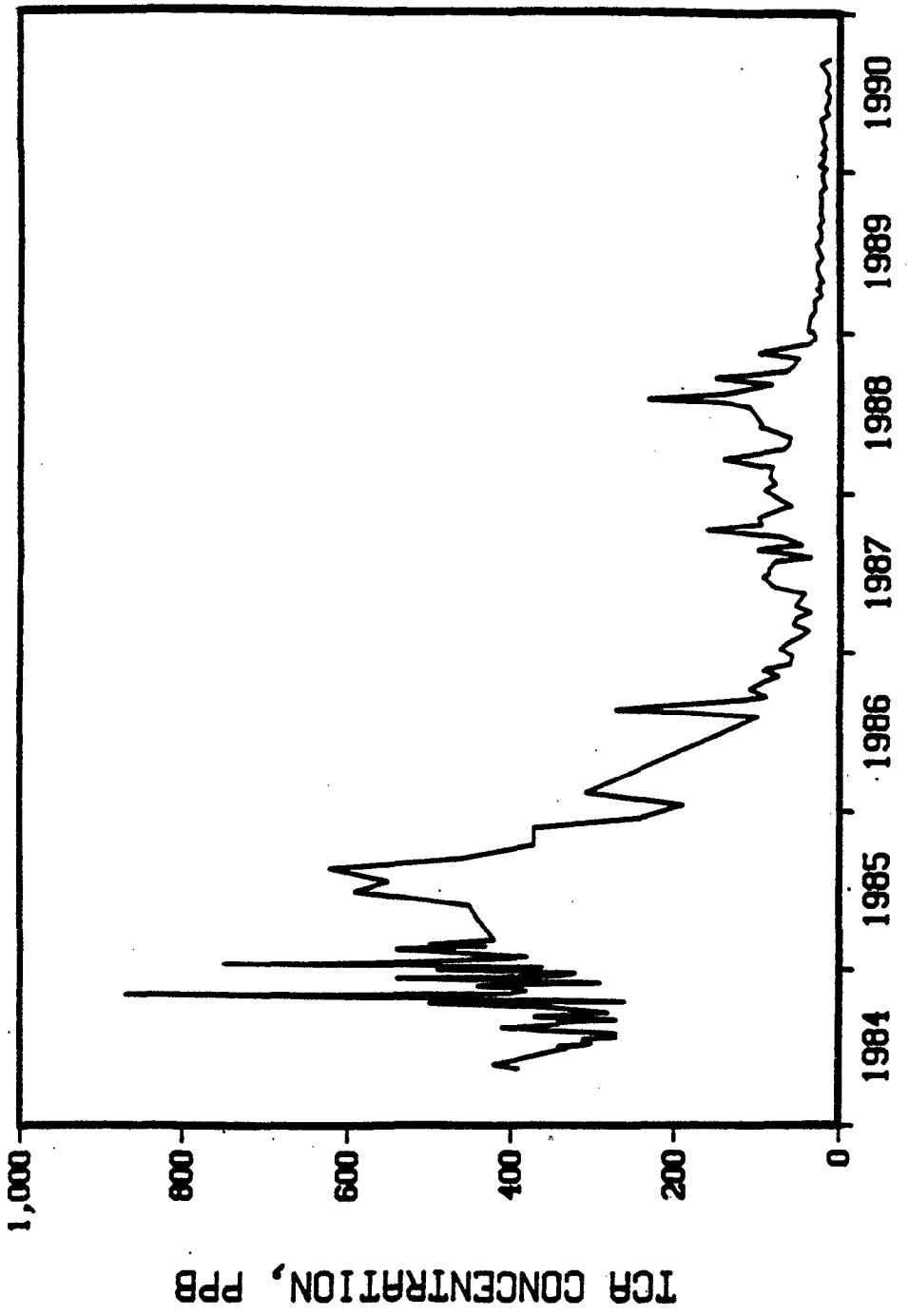

Figure 10
MULTIYEAR TCA CONCENTRATIONS
IN OFFSITE WELL RW-25 (B)
FAIRCHILD SEMICONDUCTOR SITE

Source: Based on Canonie Environmental, 1990c

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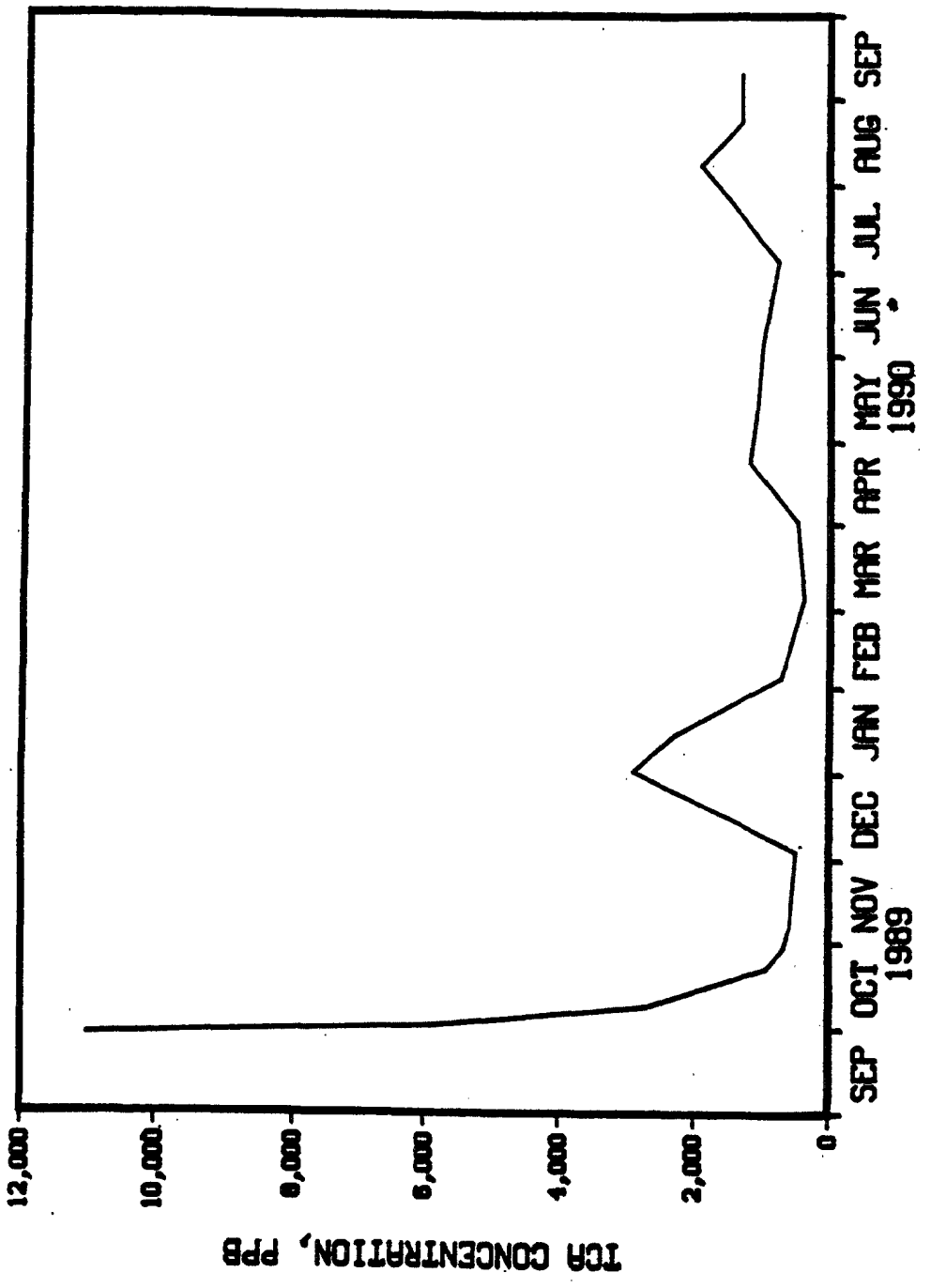

Figure 11
MULTIYEAR TCA CONCENTRATIONS
IN OFFSITE WELL RW-28 (B)
FAIRCHILD SEMICONDUCTOR SITE

Source Based on Canonie Environmental, 1990c

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Table 3
SOIL VAPOR EXTRACTION SYSTEM
ESTIMATE OF MASS REMOVED[a,b]

Well Number	1,1,1-TCA Removed (lbs)	1,1-DCE Removed (lbs)	PCE Removed (lbs)	Xylene Removed (lbs)	Freon-113 Removed (lbs)	Acetone Removed (lbs)	IPA Removed (lbs)	Period Total (lbs)
Aquitard A/B Wells								
AE-1A	21	3	0	2	0	1	0	26
AE-2A	50	6	0	5	0	4	0	66
AE-3A	15	1	0	1	0	429	113	559
AE-4A	34	5	0	1	0	2	0	41
AE-5A	62	5	0	1	0	8	0	77
AE-6A	18	2	0	1	0	429	143	592
AE-7A	17	3	0	0	0	1	0	22
AE-8A	79	10	0	10	0	1	0	101
AE-9A	71	5	0	11	0	2	0	89
AE-10A	93	8	0	6	0	444	47	598
AE-11A	29	7	0	3	0	0	0	39
AE-12A	1,618	46	0	5	2	320	17	2,010
AE-13A	337	23	1	24	1	1	0	386
AE-14A	1,166	88	2	10	2	30	0	1,298
AE-15A	79	11	0	15	0	230	20	355
AE-16A	211	16	1	34	1	916	195	1,374
AE-17A	204	14	0	25	0	275	96	614
AE-18A	376	15	1	38	0	186	9	623
AE-19A	15	1	0	0	0	225	76	317
AE/A1-18A	16	5	0	0	0	0	0	21
AE/A1-19A	18	4	0	1	0	0	0	23
AE/A1-20A	21	5	0	0	0	5	2	35
AE/A1-21A	1	0	0	0	0	0	0	2
AE/A1-22A	55	8	0	2	0	1	0	66
AE/A1-23A	6	2	0	0	0	17	0	26
AE/A1-24A	5	1	0	0	0	0	0	6
AE/A1-25A	5	1	0	1	0	0	0	6
Subtotals	4,622	294	7	196	8	3,526	720	
							Aquitard A/B Subtotal	9,373

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Table 3
SOIL VAPOR EXTRACTION SYSTEM
ESTIMATE OF MASS REMOVED[a,b]

Well Number	1,1,1-TCA Removed (lbs)	1,1-DCE Removed (lbs)	PCE Removed (lbs)	Xylene Removed (lbs)	Freon-113 Removed (lbs)	Acetone Removed (lbs)	IPA Removed (lbs)	Period Total (lbs)
Aquifer A Wells								
AE-20(A)	286	5	2	127	0	0	0	420
RW-15(A)	74	14	0	8	1	0	0	96
RW-16(A)	115	12	1	18	0	0	0	146
RW-23(A)	6	3	0	0	0	0	0	9
WCC-41(A)	2,301	34	5	162	2	545	22	3,071
Subtotals	2,782	68	8	314	3	546	22	
							Aquifer A Subtotal	3,742
Aquifer B Wells								
AE-1(B)	139	53	0	1	0	0	0	193
AE-2(B)	306	71	1	12	0	1	0	391
AE-3(B)	220	52	0	16	0	1	0	289
AE-4(B)	395	105	2	15	1	5	8	531
WCC-16(B)	3	0	0	0	0	1	0	4
WCC-17(B)	52	12	0	1	0	0	0	66
WCC-20(B)	95	34	2	4	0	0	0	135
Subtotals	1,210	328	5	49	2	7	9	
							Aquifer B Subtotal	1,609
Individual Totals of Chemicals Removed								
	8,614	689	19	559	13	4,079	751	
							Grand Total	14,724

Source: Canonie Environmental, 1990b
[a]All values are rounded and may not sum correctly.
[b]All values are current through March 31, 1990.

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breakdown of the mass of chemicals removed by each individual soil vapor extraction well. Approximately 59 percent of the mass of chemicals removed to date has been TCA.

SUMMARY OF REMEDIATION

To date, the remediation system appears to have been effective in containing ground-water contamination and has prevented the contamination of other public drinking water supply wells.

Water quality data from Aquifer B monitoring wells for September 1990, indicate that chemical concentrations in wells located in downgradient zone 1 have remained below cleanup levels. Parts of offsite zones 2 and 3 and some onsite monitoring wells are still above cleanup levels. Remediation activities for the onsite areas will continue until cleanup levels are achieved. These activities include: in-situ soil vapor extraction and the BAC treatment system.

The total amount of contaminants removed from onsite and offsite areas through September 1990, was 143,278 pounds--of which 38,000 pounds were removed from the soil; 90,500 pounds were removed through ground-water extraction; and 14,778 pounds were removed through in-situ soil vapor extraction (Canonie Environmental, 1991).

SUMMARY OF NAPL-RELATED ISSUES

The possibility that contaminants are present in the subsurface in the form of nonaqueous phase liquids (NAPLs) has not been addressed in any of the site documents reviewed. However, the high ground-water concentrations reported for TCA and xylene in the original study suggest that they may have been present in NAPL form.

The maximum concentrations reported for these contaminants in 1982 were 1,900,000 ppb for TCA and 76,000,000 for xylene. In both cases, the readings were for a sample taken from onsite well WCC-41(A), in Aquifer A. These reported concentrations are much higher than the aqueous solubility of either compound (950,000 ppb for TCA and 15,000 to 213,000 ppb for xylenes). The reporting of concentrations well above solubility indicates that the ground-water sample contained a greater mass of the contaminant than could be present in solution. The excess contaminant in the sample was probably in the form of colloidal-size globules of NAPL, indicating that the compounds were present as NAPLs in the aquifer also.

It has been reported that the contaminants originated from a leaking underground waste solvent storage tank. This suggests that the contamination was initially released in nonaqueous form. Pure TCA is a dense NAPL (DNAPL) and would be expected to sink rapidly through the aquifer. In this case, however, it was apparently not pure TCA, but a mixture containing a considerable proportion of xylene, a compound less dense than water, as well as several other constituents. It is not known whether this mixture would sink in the aquifer or float on the water table. In either case, it would be likely to migrate into the underlying formations because the water table was lowered into Aquifer B by the ground-water extraction system.

In 1987, the maximum concentrations of both TCA and xylene (100,000 ppb and 16,000 ppb, respectively) were measured in well WCC-17(B), which monitors Aquifer B directly below the area where the highest concentrations were found in Aquifer A 5 years earlier. This time the concentrations were approximately 10 percent of the solubility limits for each compound. These concentrations, although much lower than the maximum readings of 1982, were still high enough to be a strong indication that NAPLs were present in the aquifer. As noted previously, the overlying portions of Aquifer A were dewatered in 1987, and could not be sampled.

The highest TCA concentration measured in Aquifer B in 1990 was 2,000 ppb, again in well WCC-17(B). The corresponding xylene concentration was 100 ppb. These considerable reductions in concentration over the period of record may indicate that the reservoir of NAPL in Aquifer B is nearly exhausted. An alternative explanation may be that the contaminants never actually reached Aquifer B in NAPL form, but were retained in the A/B aquitard, from which they leached into Aquifer B, producing high concentrations. If so, the soil vapor extraction system operating in Aquifer A and in the A/B aquitard may be responsible for the reduction in contaminant levels.

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UPDATE BIBLIOGRAPHY/ REFERENCES

Canonie Environmental. October 1988. *Revised Draft Report, Remedial Action Plan.*

Canonie Environmental. February 1990a. *Annual Status Report January 1 through December 31, 1989, Fairchild Semiconductor Corporation, San Jose Facility.*

Canonie Environmental. June 1990b. *Detailed Design Waste 001 Treatment System, Fairchild Semiconductor Corporation, San Jose Facility.*

Canonie Environmental. November 1990c. *Quarterly Status Report July 1, Through September 30, 1990, Fairchild Semiconductor Corporation, San Jose Facility.*

Canonie Environmental. February 20, 1991. Fax from Mr. Dennis Curry, Project Manager Groundwater Extraction and Treatment Program, Fairchild Semiconductor Corporation, San Jose Facility.

Regional Water Quality Control Board. January 1989. Order Number 89-16, Site Cleanup Requirements for Fairchild Semiconductor Corporation and Schlumberger Technology Corporation, Santa Clara County.

Schlumberger Technology Corporation. February 1989. *Annual Status Report January 1, through December 31, 1988, Fairchild Semiconductor Corporation, San Jose Facility.*

Schlumberger Technology Corporation. June 1989. *Pilot Reinjection Study, Fairchild Semiconductor Corporation, San Jose Facility.*

Schlumberger Technology Corporation. February 1990a. *Annual Status Report January 1, through December 31, 1989, Fairchild Semiconductor Corporation, San Jose Facility.*

Schlumberger Technology Corporation. May 1990b. *Quarterly Status Report January 1, through March 31, 1990, Fairchild Semiconductor Corporation, San Jose Facility.*

Schlumberger Technology Corporation. August 1990c. *Quarterly Status Report April 1, through June 30, 1990, Fairchild Semiconductor Corporation, San Jose Facility.*

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UPDATE OF CASE STUDY 7

General Mills
Minneapolis, Minnesota

Abstract

The extraction system in both the shallow aquifer (five wells) and the underlying Carimona Member Aquifer continued to operate through 1989, despite some operational problems later in the year. The capture zone induced in the shallow aquifer since 1985 was maintained in 1989. TCE concentrations remained above cleanup standards in the shallow aquifer in some areas, and were considerably above standards and increasing in a broad area of the Carimona Member Aquifer. TCE concentrations in the Magnolia Member did not meet standards. A final decision to install an extraction system to remediate this contamination was made by the MNPCA in 1990. Residual sources such as DNAPLs are suspected by MNPCA regulators, but DNAPLs have not been observed directly.

Table of Background Data	
Date of Problem Identification	1981
Extraction Started	Late 1985
Types of Contaminants	Trichloroethylene Tetrachloroethylene 1,1,1-Trichloroethane
Primary Aquifer Materials	Glacial drift over fractured sedimentary rock
Maximum Number of Extraction Wells	6
Maximum Total Extraction Rate	390 gpm
Estimated Plume Area	110 acres
Estimated Plume Thickness	50 feet
Maximum Reported Concentrations	Trichloroethylene 2,300 ppb

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CASE STUDY UPDATE
GENERAL MILLS

BACKGROUND OF THE PROBLEM

INTRODUCTION

This report describes events and progress in remediation at the General Mills site through late 1989. It is an update of the original case study (U.S. EPA, 1989, Case Study 7), which presented background information and data from ground-water monitoring and extraction systems through 1988.

The General Mills site is located approximately 1 mile northeast of the Mississippi River on Hennepin Avenue on the outskirts of downtown Minneapolis. Figure 1 shows the site location. Site contamination is a result of disposal of chemical solvents in a soil adsorption pit located near the southeast corner of the former General Mills property. The disposal occurred between 1947 and 1962, when the site was owned by General Mills, Inc. In 1981, the Minnesota Pollution Control Agency (MNPCA) was apprised of site contamination.

General Mills, Inc., and MNPCA are jointly pursuing site cleanup under a 1984 Response Order by Consent. Operation of a ground-water extraction and treatment system began in 1985 and has functioned continuously since then, exclusive of routine maintenance and repair.

Four aquifers underlying the General Mills property are pertinent to aquifer remediation efforts at the site--the shallow aquifer, the Carimona and Magnolia Members of the Platteville Formation, and the St. Peter Sandstone.

The shallow unconsolidated aquifer (also known as the glacial drift aquifer) is unconfined and flows southwest toward the Mississippi River. A layer of glacial till and the Decorah Shale, when present, separate the glacial drift aquifer from the underlying bedrock aquifer. The layers impede, but do not prevent downward flow of ground water to lower aquifers.

The Carimona Member of the Platteville Formation underlies the glacial aquifer and consists of three to four feet of fractured and weathered micrite, a fine-grained limestone. The piezometric surface in the Carimona is relatively flat. The Carimona Member is separated from the underlying Magnolia Member by a thin bentonite layer that impedes downward flow. In the northern portion of the site, the hydraulic head in the Carimona Member is on average 4 to 5 feet higher than the head in the underlying Magnolia Member, thus indicating the potential for downward flow. However, there appears to be a net upward vertical gradient between the Magnolia Member and the overlying Carimona Member in the vicinity of wells ZZ and 13, and in the southern portion of the site.

The Magnolia Member of the Platteville Formation is approximately 8 feet thick. Ground water in the Magnolia Member flows to the northwest. Below this aquifer is a 22- to 27-foot thickness of alternating layers of shale, limestone, and dolomite that impedes the downward ground-water flow. The head difference between this aquifer and the underlying St. Peter Sandstone is 55 feet with a downward flow.

The primary ground-water contaminants at the site are chlorinated organic solvents, including trichloroethylene (TCE), tetrachloroethylene (PCE), 1,1,1-trichloroethane (TCA), and the degradation products of these compounds. The most prevalent compound detected was TCE.

Ground-water contamination is highest in the glacial drift and Carimona aquifers with respective maximum TCE concentrations of 1,300 ppb (Well B, 1986) and 2,300 ppb (Well WW, 1985). Lesser TCE concentrations were found in the Magnolia Member (440 ppb in Well ZZ, 1986), and in the St. Peter Sandstone (160 ppb in Well 200, 1987).

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(Poor Quality Original)

Source: USGS, 1972. St. Paul West Quadrangle, Minnesota, 7.5 Minute Series (Topographic)

Figure 1
SITE LOCATION MAP
GENERAL MILLS SITE, MINNEAPOLIS, MN

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UPDATE ON SITE CHARACTERISTICS

The updated case study is based on 1989 data obtained from the MNPCA, consisting of extraction well pumping rates, contaminant concentrations, and technical specifications for an additional pumping system. File correspondence between MNPCA and General Mills, and personal communications with MNPCA personnel supplemented the technical reports. The MNPCA continues to oversee remediation activities at the General Mills site.

Ground-water elevations were measured during April, July, and October 1989, for the following aquifers: Shallow Glacial Drift Aquifer, Carimona and Magnolia Members, St. Peter Sandstone, and the Prairie du Chien and Jordan formations. The April 1989 ground-water levels in the shallow aquifer, the Carimona Member, and the Magnolia Member are shown in Figures 2, 3, and 4. Ground-water levels in the these three aquifers remain consistent with those levels found in the original case study. The surface elevation monitoring data collected during 1989 also suggest hydraulic gradients similar to those identified in 1988.

During 1989, ground water at the General Mills site was tested to determine the concentration of both chlorinated and non-chlorinated volatile solvents. As identified in the original case study, TCE remains the most prevalent compound in the ground water.

TCE concentrations in the shallow aquifer, the Carimona Member, and the Magnolia Member remained above consent order threshold levels at several monitoring wells in 1989 (Barr, 1990). According to the original consent order, General Mills was required to install an extraction system in the Magnolia when TCE levels surpassed 27 ppb.

The detection of TCE above 27 ppb in upgradient Magnolia wells indicates that the General Mills site is not the only source of contamination in the Magnolia Member. Although the MNPCA determined the proposed Magnolia system would capture contaminated water in the Magnolia aquifer in the area of the former adsorption pit, the agency concluded that the Magnolia extraction system would capture only a small portion of the plume in the Magnolia Member. The MNPCA eventually decided to proceed with system expansion in October 1990, even though the source of contamination in the Magnolia Member remains unknown. The notification to proceed with the installation of the system was received by General Mills on January 15, 1991.

REMEDIATION

Design and Operational Features of Remediation System

The goals of remediation, as stated in the Consent Order, are to minimize further migration of volatile organics, particularly TCE, and to reduce TCE concentrations to less than 270 ppb in the shallow aquifer and to less than 27 ppb in the underlying Carimona and Magnolia Aquifers.

The remediation system at the General Mills site consists of two separate extraction systems--one onsite and one downgradient. Both systems began operating in November 1985. The onsite system includes three extraction wells--two in the shallow aquifer (Wells 109 and 110) and one in the Carimona Member (Well 108). Since operation began in 1985, the combined average withdrawal rate for 109 and 110 has been 70 gpm, and the extraction rate for the Carimona well has varied between 20 and 30 gpm. Three additional extraction wells are located downgradient from the site in the shallow aquifer system (Wells 111, 112, 113); the combined extraction rate has historically been about 300 gpm.

According to the water-level data from the original case study, pumping rates of about 50 gpm at each of the shallow-aquifer system wells (109, 110, 111, 112, 113) would result in a capture zone extending 100 feet on either side of the well. The earlier case study reported site data showing that the three shallow downgradient wells produced a wide capture zone, but the two shallow source-area wells produced limited capture zones. In a map of the plume distribution in the original case study, it appears that the 270-ppb TCE contour falls within the originally identified capture zone. Therefore, the wells appear to be limiting the extent of the plume. Data obtained from 1988 pumping tests in the Carimona indicate that a similar 50 gpm rate in the Carimona Member would produce a capture zone extending beyond the monitoring wells.

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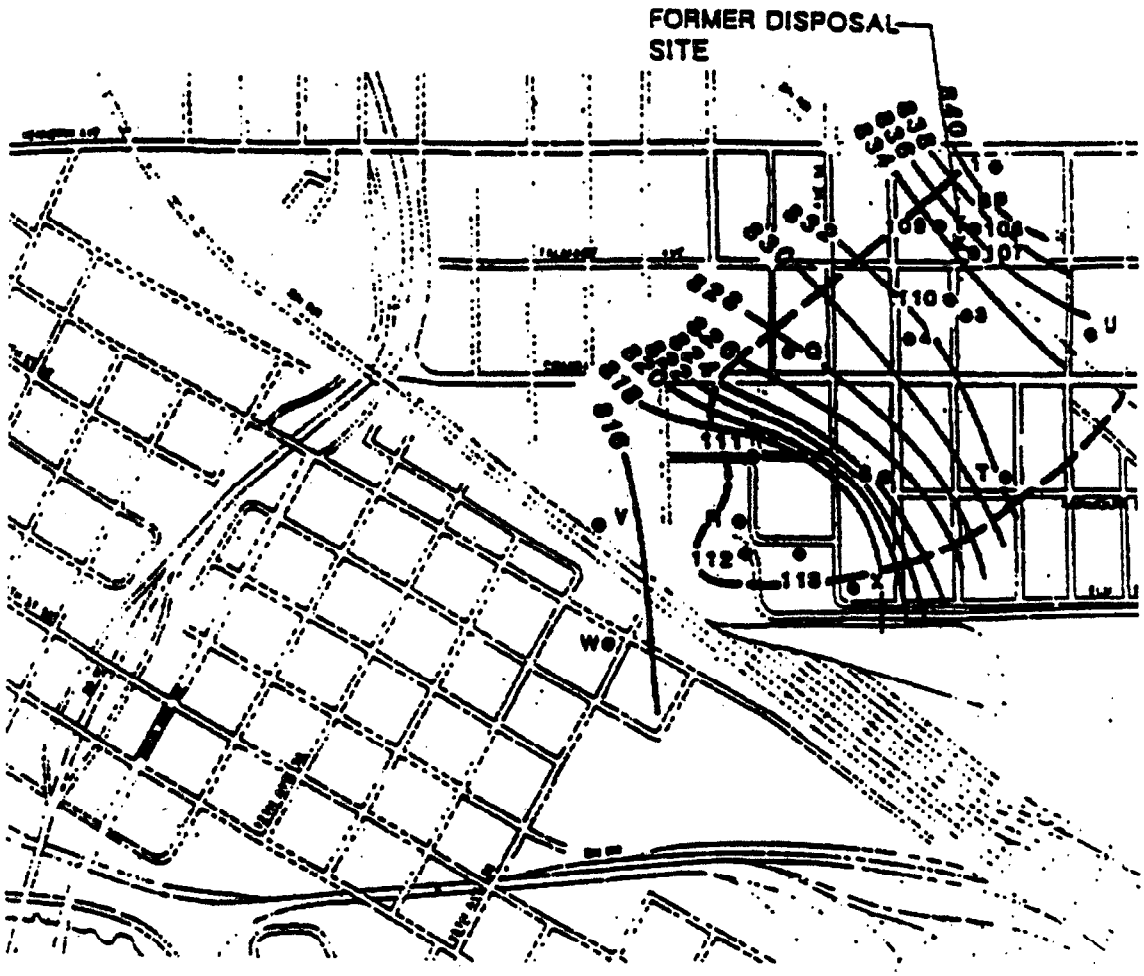

- Glacial drift monitoring well or site and downgradient pump-out well
- Water table contour (MSL)
- Estimated capture zone

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0 1000

Source: Barr, 1990

Figure 2
WELL LOCATIONS AND WATER LEVELS IN THE SHALLOW AQUIFER, APRIL 1989
GENERAL MILLS SITE

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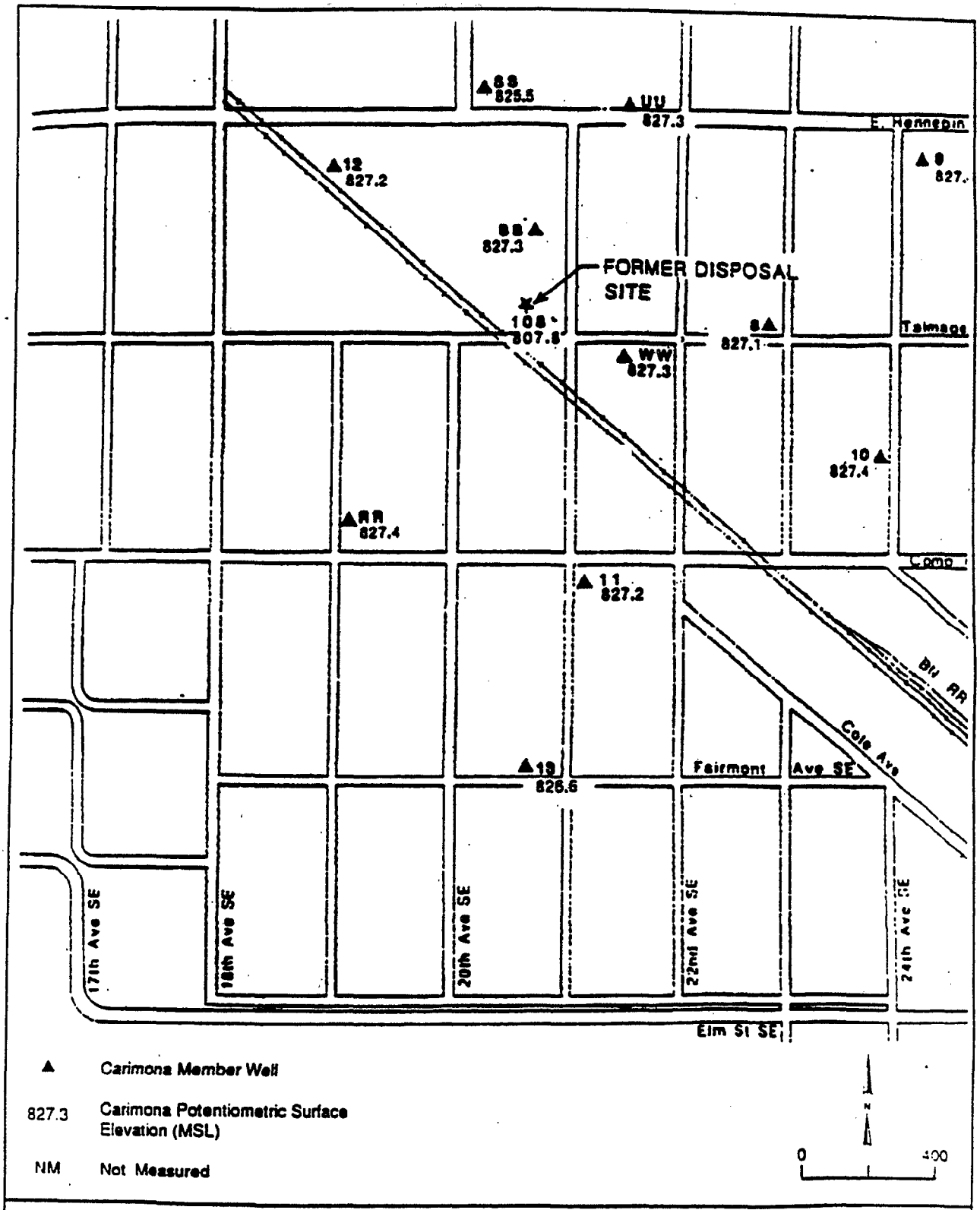

Source: Barr, 1990

Figure 3
WELL LOCATIONS AND WATER LEVELS IN THE CARIMONA MEMBER, APRIL 1989
GENERAL MILLS SITE

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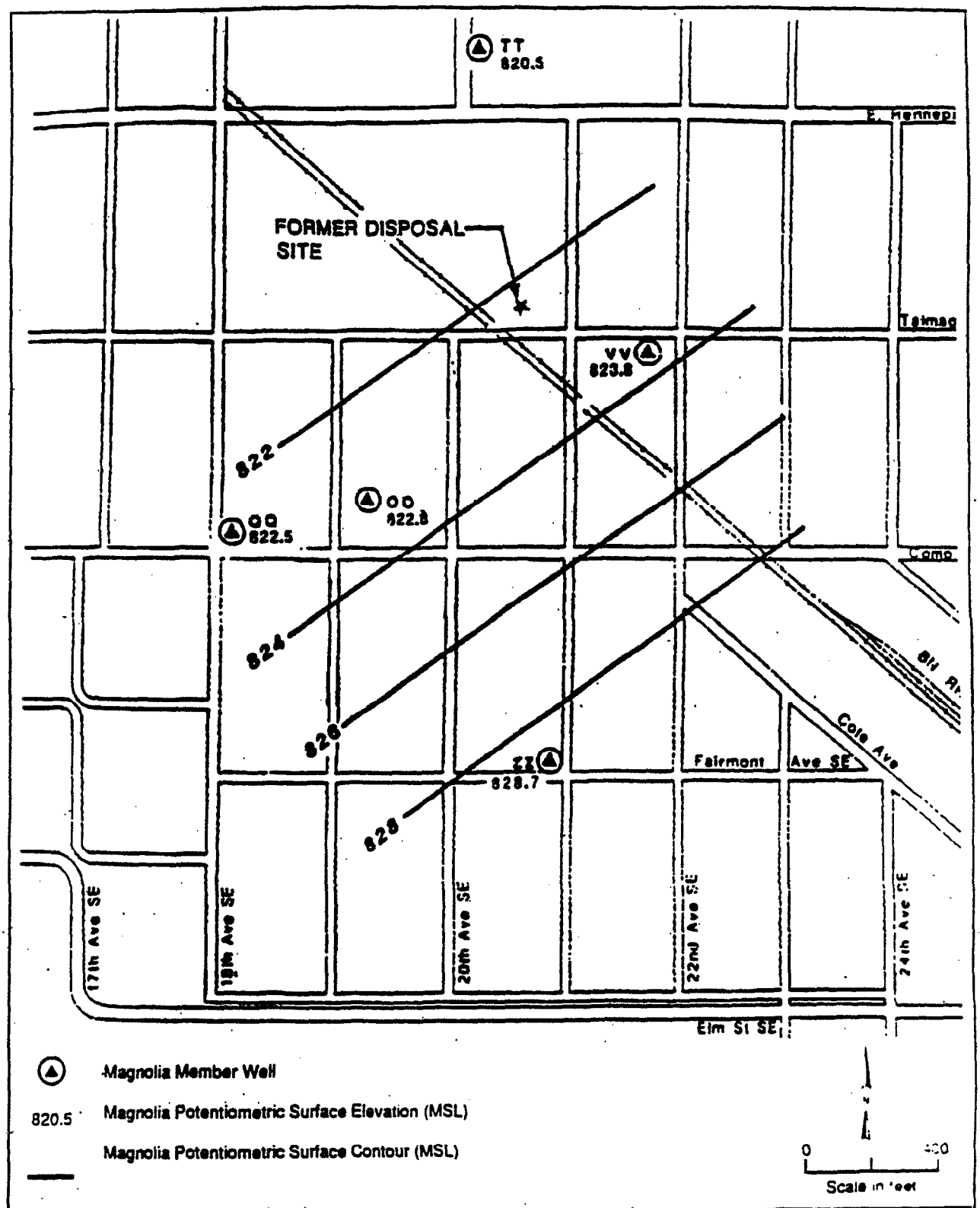

Source: Barr, 1990

Figure 4
WELL LOCATIONS AND WATER LEVELS IN THE MAGNOLIA MEMBER, APRIL 1989
GENERAL MILLS SITE

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The extraction rates in the five shallow extraction wells and in the one extraction well in the Carimona were reduced during parts of 1989 because of pump malfunctions. In the original case study, it was reported that the extraction wells for these systems operated continuously between 1985 and 1988, except for general maintenance downtime. The extraction-well systems continued to operate during 1989; however, electrical and mechanical problems with system pumps resulted in downtime and reduced extraction rates for both the shallow aquifer and Carimona Member.

The 1989 combined average monthly withdrawal rate of the shallow source-area Wells 109 and 110 was 75 gpm in 1989 (Barr 1990). Although the wells were operated at maximum sustainable yield during most of 1989, extraction rates decreased to 51 gpm during the last 3 months of 1989 because of pump failures in both wells.

The average extraction rate in 1989 for the downgradient wells (Nos. 111, 112, 113) was 290 gpm, with the average monthly rates for individual wells ranging from 90 to 107 gpm. The shallow downgradient system removed 150 million gallons of ground water in 1989. A total volume of 42 million gallons of ground water was removed from the shallow aquifer by the source-area wells (Nos. 109, 110) in 1989 (Barr 1990). Table 1 displays the average monthly pumping rates and downtime at individual wells.

In the Carimona Member, source-area Well 108 continues to withdraw water as part of site remediation. Its purpose is to contain and remediate ground water in the Carimona Member in areas where concentrations of TCE exceed 27 ppb. The average pumping rate for Well 108 was 16 gpm in 1989. A total volume of 8.7 million gallons of ground water was removed from the Carimona Member in 1989. This rate is reduced from 1988 yields due to mechanical and electrical problems associated with Well 108, which resulted in 46 days of downtime in the last 3 months of 1989.

No major modifications were made to the extraction system in 1989. In October 1989, the MNPCA decided to expand the extraction system into the Magnolia Member of the Platteville Formation. This decision was postponed, however, so that the MNPCA could review remedial-action alternatives to ground-water extraction (MNPCA Correspondence to General Mills, 1990). In the first three quarters of 1989, MNPCA personnel explored the possibility of soil removal, but determined that contamination had migrated from the soil profile into the ground water. In October 1990, the MNPCA approved implementation of the proposed Magnolia system as the remedial alternative which represented optimal use of remedial action funds (MNPCA, 1990b).

After the MNPCA selected ground-water extraction as the most feasible remedial alternative, General Mills submitted a work plan detailing the methodology used to collect the hydrologic data. The major analytical considerations in designing the Magnolia extraction system include aquifer tests and capture-zone design, both of which are still in the planning stage.

Two aquifer tests will be conducted in both the Carimona and Magnolia Members of the Platteville formation. The results will provide hydraulic data on: (a) the degree of hydraulic separation between the Carimona and Magnolia members, (b) storage coefficients and transmissivity of the Magnolia and Carimona members, (c) vertical hydraulic gradients between Magnolia and Carimona members, and (d) the location of recharge and discharge boundaries, if any (General Mills, 1989). The aquifer tests require construction of two wells to provide water-level data necessary to design an effective extraction system.

The extraction system, and its resulting capture zone, will be designed using an analytical ground-water model that will be calibrated with data obtained from the aquifer tests. Modeling will be conducted using the analytic element flow-code SLAEM (Strach, 1989). The model will be calibrated to the observed steady-state piezometric surface of the Magnolia Member. Model results are intended to provide data on: (a) the effectiveness of Well 108 in containing ground water in the Magnolia Member, (b) the optimum locations and pumping rates for the extraction wells, (c) the number of wells required for a Magnolia extraction system, and (d) the effects of pumping in the Magnolia member on the vertical hydraulic gradients between the Magnolia and Carimona members (General Mills, 1989).

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Table 1
1989 PUMPING RATES

	Glacial Drift Pump-Out Well Pumping Rate (Ave. GPM)					Carimona Pump-Out Well Pumping Rate (Ave. GPM)
	109	**110**	**111**	**112**	**113**	**108**
Jan 1989	41	29	91	101	92	22
Feb 1989	51	50	91	104	92	20
Mar 1989	47	55	91	105	92	20
Apr 1989	57	44	91	106[1]	91	20
May 1989	50	50	91	106[1]	92	21
Jun 1989	49	50	90	104	92	20
Jul 1989	48	50	90	105	92	19
Aug 1989	20[2]	51	90	107	92	18
Sep 1989	8.2[1]	51	90	104	92	19
Oct 1989	0.0[2]	44[2]	90	106	93	5.6[2]
Nov 1989	16[2]	25[2]	90	106	93	5.6[2]
Dec 1989	45[2]	23[2]	90	106	93	12[2]

Source: Barr, 1990.

[1]Flow meter malfunction.
[2]Wells not pumping full-time due to faulty motor control.

EVALUATION OF SYSTEM PERFORMANCE

Shallow Aquifer

Total VOC concentrations increased from April 1988 to April 1989, in four of the nine monitoring wells in the shallow aquifer. TCE contaminant levels did not meet cleanup standards in shallow monitoring Wells 3 and S in April 1989. Table 2 compares the total VOC/TCE concentrations for monitoring periods in 1984, 1987, 1988, and 1989. These data show that total VOC and TCE concentrations have generally decreased from 1984 to 1989 in most of the nine wells shown, but have increased in Wells S and W. Total VOCs have also increased in well 1, although TCE has decreased. In Well V, concentrations of total VOCs and TCE decreased only slightly. The increase in Well W suggests that the portion of the plume downgradient and beyond the zone of capture of the shallow extraction system may be migrating to the southwest across Well W. The time series trend of TCE concentrations in several monitoring wells, some of which are not listed in Table 2, are shown in Figures 5, 6, and 7.

Carimona Member

TCE and total VOC concentrations in the Carimona Member are also shown in Table 2. Data presented in the initial case study showed that TCE levels greater than 27 ppb extended at least 250 feet from source area in the north and 800 feet or more to the south and east in 1988. TCE concentrations increased from April 1988 to April 1989 in all the monitoring wells listed in Table 2, except BB and RR. These data show that

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Table 2
TOTAL VOC AND TCE CONCENTRATIONS (ppb)
SHALLOW AQUIFER AND CARIMONA MEMBER WELLS/1989 AND EARLIER

SHALLOW AQUIFER*				
Well	12/83 to 2/84 VOC/TCE	4-87 VOC/TCE	4-88 VOC/TCE	4-89 VOC/TCE
B	NA/1987	840/800	a360/330	270/250
Q	56/<1.3	101/2.6	6.2/0.86	13/1.1
S	850/770	710/650	520/460	910/860
T	BDL/<1.3	BDL/<0.2	BDL/<0.50	BDL/<0.50
V	100/78	180/160	180/160	140/130
W	11/7.5	34/24	67/43	86/57
1	NA/27	3.2/2.7	ND/<0.50	8.6/0.80
3	NA/800	810/740	480/440	350/320
4	NA/380	130/120	60/55	58/55
CARIMONA**				
Well	12-83/1-84 VOC/TCE	4-87 VOC/TCE	4-88 VOC/TCE	4-89 VOC/TCE
108	1300/1100	510/450	230/200	570/530
BB	NA/1400	1200/1100	580/530	390/340
RR	NA/33	120/110	240/220	220/180
SS	NA/<1.5	17/1.2	ND/<0.50	21/1.3
UU	NA/81	12/12	25/23	51/38
WW	NA/1700	310/290	360/320	540/530
8	NA/96	97/86	170/160	420/380
9	NA/<0.50	6.5/5.1	9.3/4.5	17/9.8
10	NA/2.6	130/120	62/56	170/160
11	NA/120	160/160	89/79	120/110
12	NA/1.5	BDL/<0.2	ND/<0.50	ND/<0.50
13	NA	150/140	1.2/<0.50	120/110

Source: General Mills, 1990; U.S. EPA, 1989; General Mills, 1991.

BDL=Below Detection Limits
NA - Not Available
*=TCE contaminant goal reduction level= <270 ppb
**=TCE contaminant goal reduction level= <27 ppb

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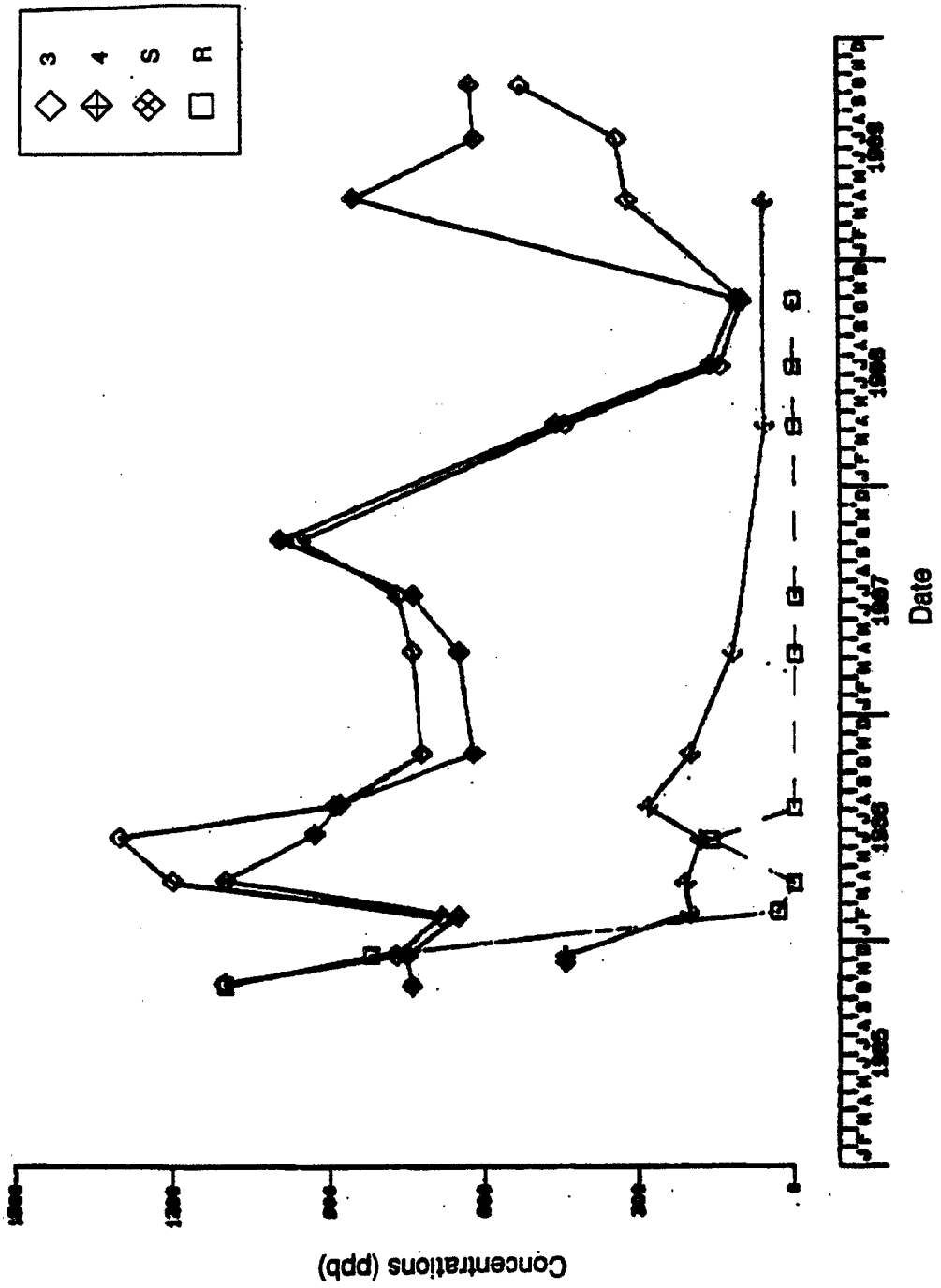

Figure 5
HISTORY OF TCE CONCENTRATION VARIATIONS IN SHALLOW AQUIFER WELLS 3,4,S AND R
GENERAL MILLS SITE

Source: Barr, 1990

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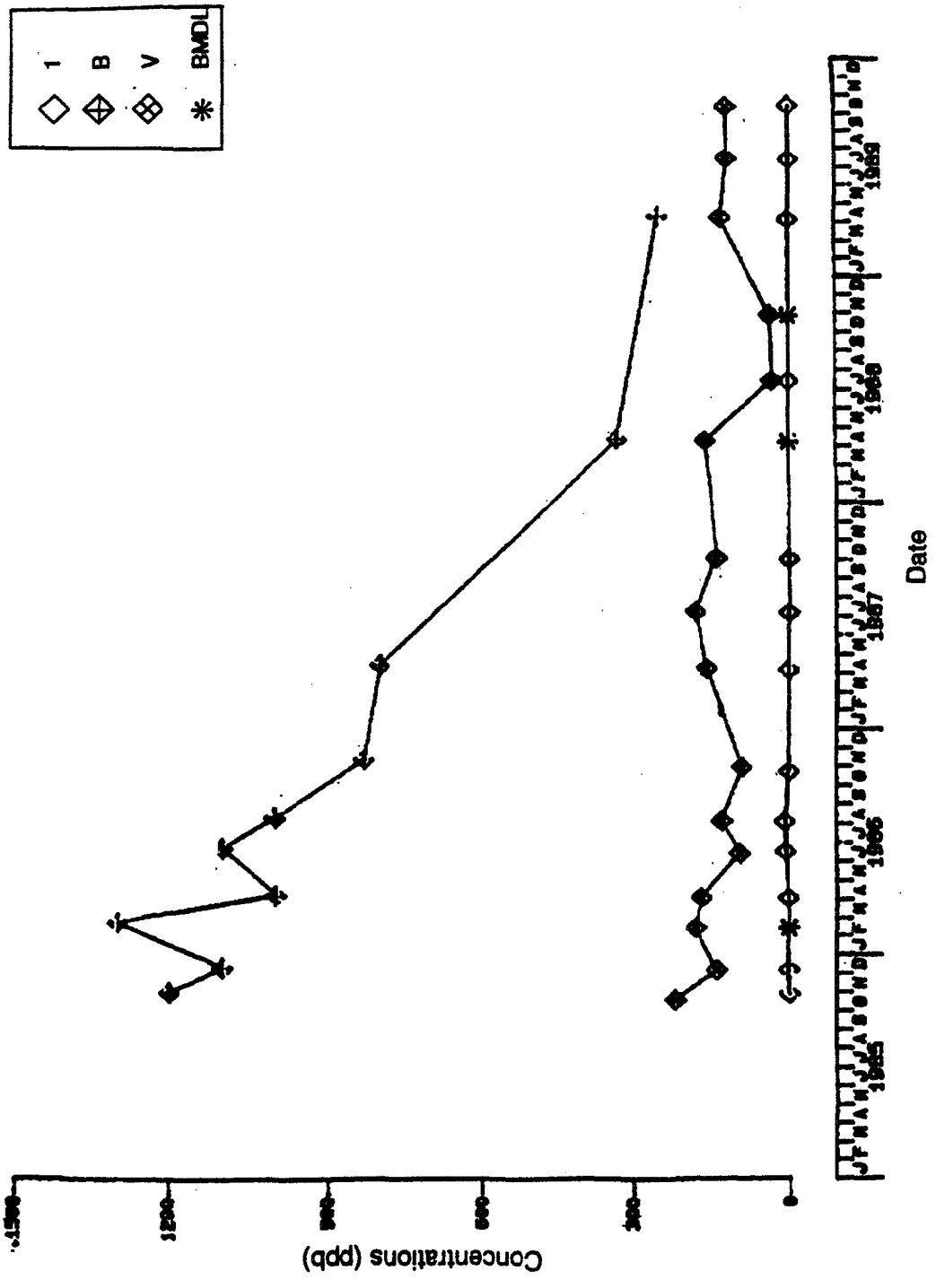

Source: Barr, 1990

Figure 6
HISTORY OF TCE CONCENTRATION VARIATIONS
IN SHALLOW AQUIFER WELLS 1, B, AND V.
GENERAL MILLS SITE

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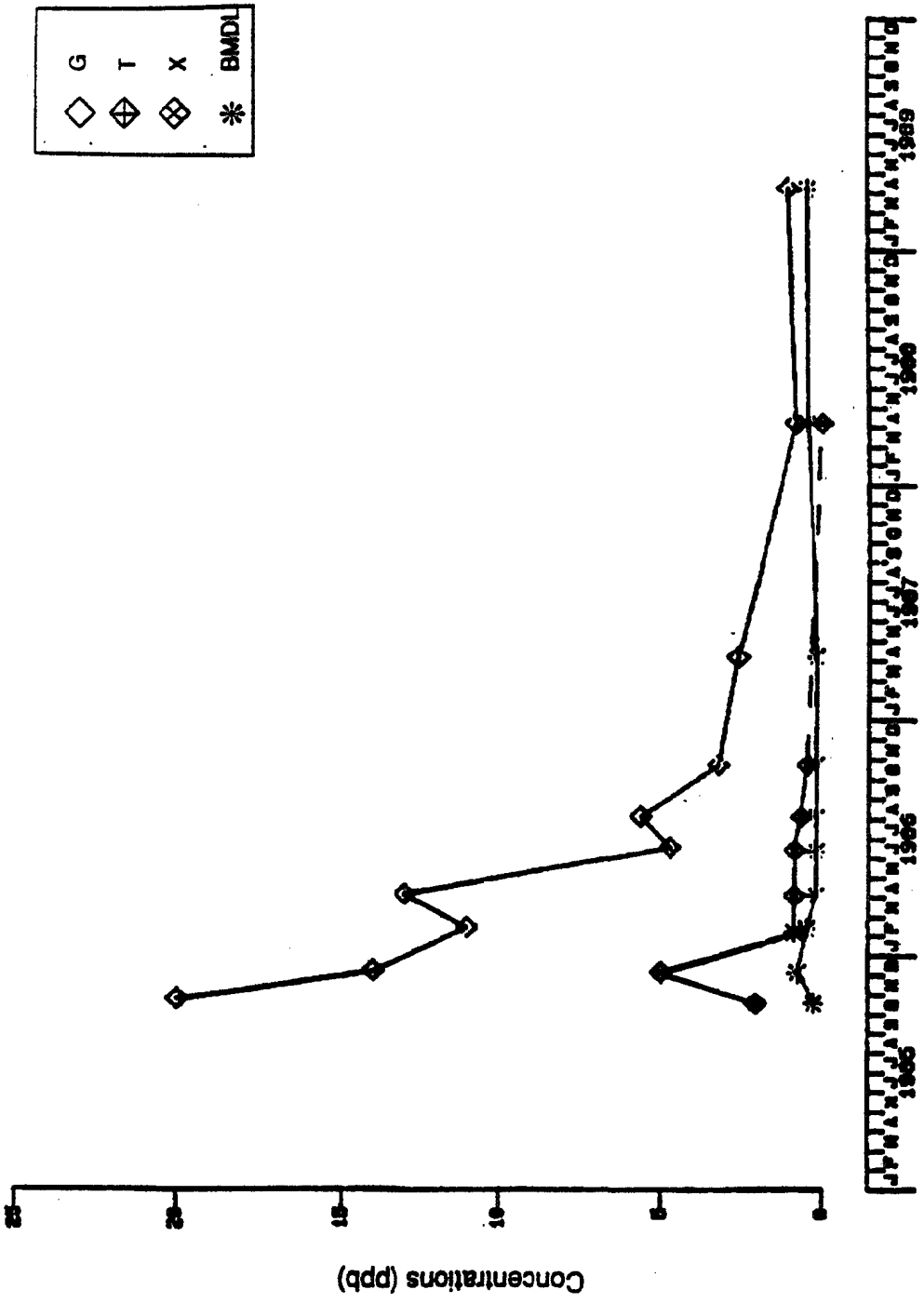

Source: Barr, 1990

FIGURE 7
HISTORY OF TCE CONCENTRATION VARIATIONS
IN SHALLOW AQUIFER WELLS G, T, AND X.
GENERAL MILLS SITE

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the area of the 27-ppb TCE plume in the Carimona Member appears to have increased considerably from 1988 to 1989.

According to the 1989 Annual Report for the site, the effectiveness of extraction in the Carimona Member is reflected by a 70 to 90 percent reduction in TCE concentrations in most of the Carimona monitoring wells since startup (Barr, 1990). Water levels in 1989 also showed that the capture zone established in 1985 continued to be successful in containing contaminated ground water through 1989 (General Mills, 1991). Time-series plots presented in Figures 8 and 9, however, show that while TCE concentrations continued to decline in monitoring Well BB from 1988 to 1989, contaminant levels increased in extraction Well 108 and monitoring well WW. In Well 108, TCE concentrations remained above the target goal of less than 27 ppb in 1989. TCE concentrations for Wells 10, 11, and 13 on the southeastern periphery of the plume also increased from April 1988 to April 1989. In April 1988, TCE levels in Well 13 were below the detection limit, but they increased to 110 ppb by April 1989. Because of problems in 1988 with laboratory quality-control equipment, results were too low and thus, incorrect (General Mills, 1991). If 1988 data are adjusted upward to correct these potential errors, some of the TCE concentrations would then appear to have been stable during 1988. Nonetheless, a comparison of 1987 and 1989 data in Table 2 shows that concentrations rose in several monitoring wells from 1987 to 1989. System operators contend that, despite these increased concentrations, the contaminant plume is being contained.

Table 3 lists the TCE concentrations detected in 1989 and early 1990 in the influent to effluent from the source-area treatment system. These data show that influent concentrations were stable during this period, except for December 1989 when influent levels decreased to below effluent levels (General Mills, 1991). In the first three quarters of 1989, the effluent released after treatment by air stripping was consistently below 27 ppb, a 96 percent average treatment efficiency for total VOCs. Due to electrical and mechanical failures in the Well 108 (Carimona Member) pump, system operators recorded 46 days of downtime in the last 3 months of 1989. Total VOC levels in the effluent rose from 20 ppb in the third quarter to 200 ppb in the fourth quarter. Additional sampling in January 1990 revealed 96 ppb TCE, which is still above the NPDES maximum allowable average of 50 ppb and only slightly below the daily 100 ppb allowable daily concentration.

Influent and effluent data are also displayed as a time-series plot in Figure 10. This figure shows that, although 1989 concentrations of TCE were higher than those in 1988, the TCE concentration of the influent continued to decline, especially compared to 1985 and 1986 concentrations. The December 1989 sampling event (Table 3), in which the concentrations in the effluent were higher than in the influent, is not included in this figure.

The Carimona extraction system was shut down in January 1990 because of elevated VOC concentrations. Inspection of the air stripper revealed calcium carbonate encrustation on the interior of the tower (Barr, 1990). The stripper tower was cleaned and the system resumed operation on April 19, 1990.

According to the 1989 Annual Report for the General Mills site, water-level data obtained for the Carimona Member cannot be used to assess the true capture zone of this system because of the low observed hydraulic gradients at the site and the absence of monitoring points away from the site.

Magnolia Member

TCE concentrations in the Magnolia Member fluctuated from 1985 to 1989. Figure 11 shows TCE contaminant levels ranging from more than 400 ppb to below the 27 ppb standard. Although TCE concentrations are still above the consent order standard of 27 ppb, they appear to have stabilized well below the levels first detected in 1985 and 1986. Sampling results from April, July, and October 1989, revealed an average TCE concentration of 73 ppb.

The capture zone in the Magnolia has yet to be determined, and will be estimated using the results of the aquifer tests in the Magnolia and Carimona aquifers, and the calibrated ground-water model that is based on the aquifer test results.

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Table 3
TOTAL VOC AND TCE CONCENTRATIONS (ppb) IN THE INFLUENT TO AND EFFLUENT FROM THE SOURCE-AREA TREATMENT SYSTEM IN 1989 AND EARLY 1990*

Influent				
1-89 VOC/TCE	**4-89 VOC/TCE**	**7-89 VOC/TCE**	**12-89 VOC/TCE**	**1-90 VOC/TCE**
390/390	480/440	380/380	150/140	380/380
Effluent				
1-89 VOC/TCE	**4-89 VOC/TCE**	**7-89 VOC/TCE**	**12-89 VOC/TCE**	**1-90 VOC/TCE**
9.8/9.8	18/13	20/20	200/190[1]	96/96[2]

Source: General Mills, 1990; U.S. EPA 1989.

TCE contaminant reduction level goal = <27 ppb
[1]Sample results received on January 15, 1990, indicated treatment system upset.
[2]Upset confirmation sample collected on January 16, 1990, and data received on January 19, 1990.
*Influent water is a composite of shallow extraction Wells 109 and 110 and deeper Carimona extraction Well 108.

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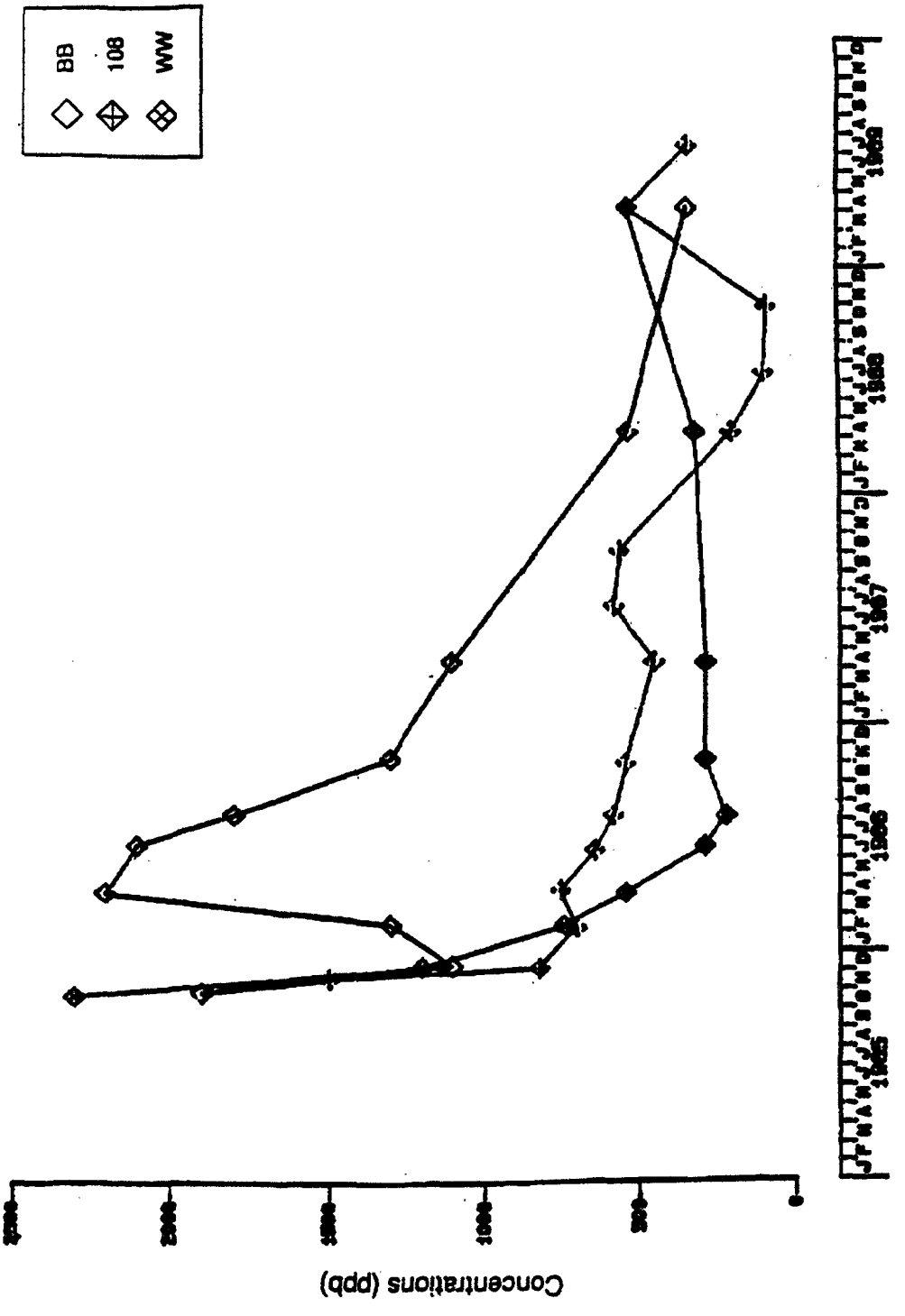

FIGURE 8
HISTORY OF TCE CONCENTRATION VARIATIONS IN CARIMONA MEMBER WELLS BB, 108, AND WW.
GENERAL MILLS SITE

Source: Barr, 1990

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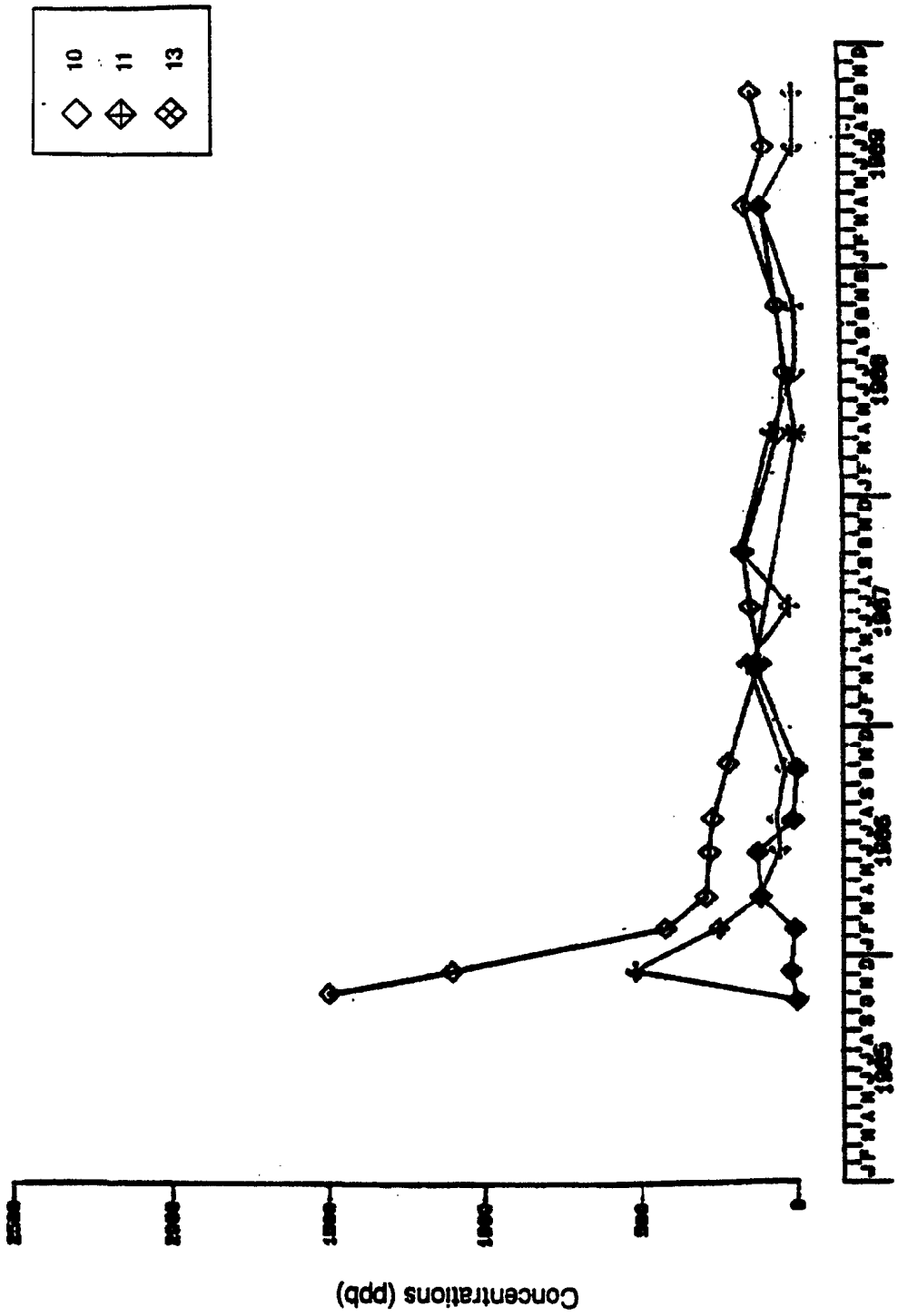

FIGURE 9
HISTORY OF TCE CONCENTRATION VARIATIONS IN CARIMONA MEMBER WELLS 10, 11, AND 13.
GENERAL MILLS SITE

Source: Barr, 1990

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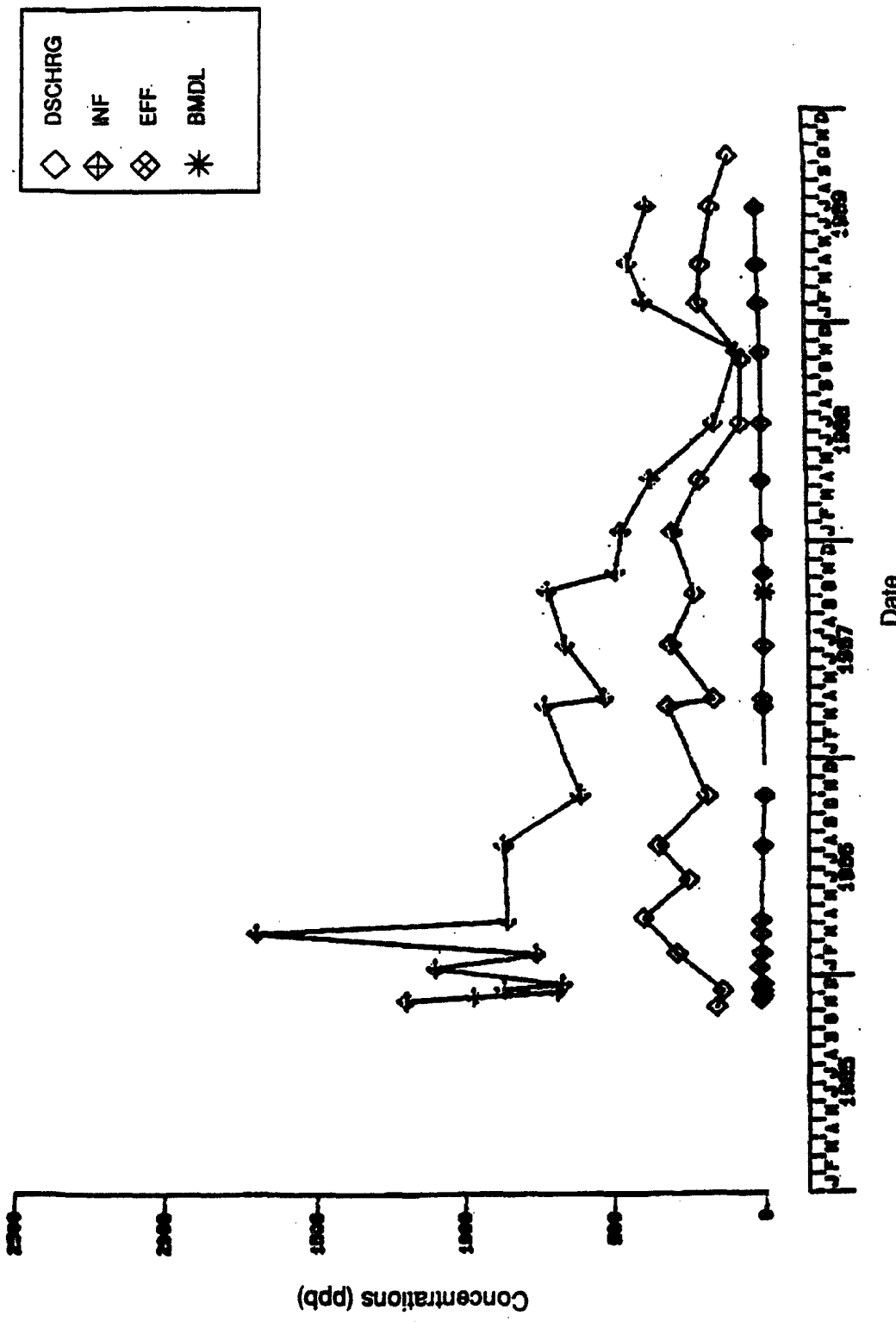

Source: Barr, 1990.

Figure 10
HISTORY OF TCE CONCENTRATION VARIATIONS IN THE SOURCE-AREA TREATMENT SYSTEM INFLUENT AND EFFLUENT
GENERAL MILLS SITE

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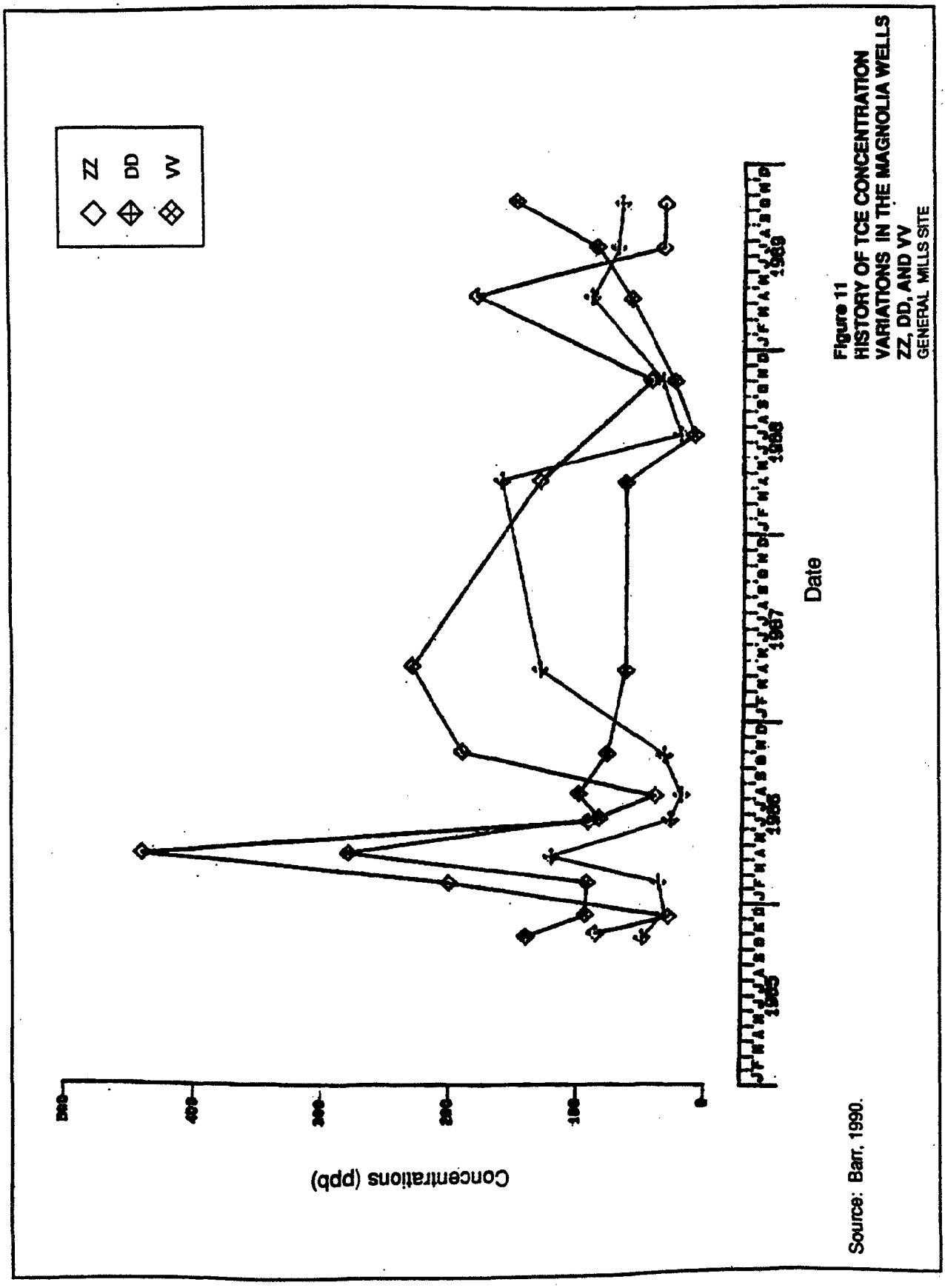

Figure 11
HISTORY OF TCE CONCENTRATION VARIATIONS IN THE MAGNOLIA WELLS ZZ, DD, AND VV
GENERAL MILLS SITE

Source: Barr, 1990.

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SUMMARY OF REMEDIATION

The two General Mills extraction systems continued to operate in 1989, but, in the fourth quarter extraction rates were reduced because of electrical and mechanical problems and elevated concentrations in the source-area treatment system. The construction of an extraction system in the Magnolia Member was required by the MNPCA in 1990.

During 1989, average extraction rates in the shallow-aquifer extraction system decreased due to electrical and mechanical malfunctions. Water levels in the shallow-aquifer source area wells are consistent with those identified in 1988, suggesting that the capture zone established in 1985 has been maintained through 1989. TCE concentrations in monitoring Well W downgradient of the extraction wells increased from 1984 to 1989, suggesting that the uncaptured downgradient portions of the plume may be migrating to the southwest.

Reduced pumping rates were also documented in the Carimona Member extraction system during 1989. The limited-radius capture zone identified in 1985-86 was maintained until the fourth quarter of 1989, when electrical and mechanical failures occurred in the extraction system, further reducing the limited capture-zone boundaries identified in the original case study. Limited capture is further indicated by substantial increases in TCE concentrations in peripheral monitoring wells in the Carimona from 1984 to 1989. These data suggest that the plume in the Carimona is getting larger, despite extraction.

No major changes were made in the remediation program; however, a decision was made in 1990 to construct an additional extraction system in the Magnolia Member because historical TCE concentrations did not meet the cleanup standard. High concentrations triggered renewed consideration of soil removal around the former disposal pit and an assessment of the sources of the Magnolia contamination. To date, the source of contamination in the Magnolia remains unknown. MNPCA staff are unsure how this will effect the remediation goals of restricting further contaminant migration and improving ground-water quality.

Residual contamination in the form of NAPLs and an adsorptive layer of peat beneath the disposal pit are still suspected by MNPCA staff to be potential sources of contamination. Because water contained in the aquifers is not used for a water supply and contaminant-removal costs are prohibitive, additional detection efforts and remedial actions are not planned for either type of suspected contamination.

Because of the continued suspicion that residual sources of contamination may be present at the site, it appears unlikely that cleanup goals will be achieved in the foreseeable future in any of the contaminated aquifers.

SUMMARY OF NAPL-RELATED ISSUES

The staff of the MNPCA suspect that DNAPLs are present at the General Mills site. This appears probable because of the nature and quantity of the waste materials, the reported means of disposal, and the persistence of the contaminant plume in spite of more than 5 years of remediation. However, direct observation of nonaqueous liquids in the subsurface has not been reported.

Chlorinated solvents, in quantities of up to 1,000 gallons per year, were poured into a small pit for approximately 15 years. If it were assumed that 10,000 gallons were disposed of in that period, the total mass of chlorinated solvents would be approximately 100,000 pounds. Figure 4 of the original case study (U.S. EPA, 1989) shows a map of the total dissolved VOC plume in the shallow aquifer as it was estimated from field data collected in March 1984, before the start of remediation. Assuming a retardation coefficient of 5 (reasonable for a sandy glacial drift), a porosity of 0.25, and a saturated thickness of 20 feet, this plume would contain approximately 3,000 pounds of dissolved and adsorbed VOCs. A substantial portion of the remaining 97,000 pounds of solvents may be present as a DNAPL.

Although no estimates of the mass of contaminants removed by the extraction wells have been presented in the data reports, a rough estimate based on reported pumping rates and concentrations would be 200 to 400 pounds per year. At this rate, the system would take more than 200 years to remove the total mass of contaminants thought to be present. It is not surprising, therefore, that ground-water monitoring at the site shows persistently high concentrations in some areas. The primary waste constituent, TCE, has an aqueous solubility of 1,100,000 ppm.

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This is much higher than the highest ground-water concentrations reported at the site (2,300 ppb). However, it is very common at sites known to have DNAPLs to find that the maximum ground-water concentrations are far less than the aqueous solubilities of the contaminants.

It should be noted that soil concentrations of up to 2,000 ppm were reported for TCE when the soils removed from around the disposal pit on the General Mills site were sampled. Although, the sorption properties of these soils have not been measured, it is likely that any ground water in contact with them would have solute concentrations near the solubility limit.

UPDATE BIBLIOGRAPHY/ REFERENCES

Barr Engineering Company. May 8, 1989a. Correspondence from Peter J. Sabee to Kathy Kramer, Minnesota Pollution Control Agency.

Barr Engineering Company. August 18, 1989b. Correspondence from Ray W. Wuolo to Mark Schmitt, Minnesota Pollution Control Agency, Saint Paul, Minnesota.

Barr Engineering Company. January 1990. *1989 Annual Report: General Mills East Hennepin Avenue Site*. Minneapolis, Minnesota.

U.S. Environmental Protection Agency (U.S. EPA). October 1989. *Evaluation of Ground-Water Extraction Remedies: Volume 2, Case Studies 1-19*. Document Number EPA/9355.4-03.

General Mills, Inc. 1989. *Magnolia Aquifer Testing Work Plan: 2010 East Hennepin Avenue Site*.

General Mills, Inc. May 30, 1991. Letter from Peter Sakee to Jennifer Sutler of the EPA.

Minnesota Pollution Control Agency (MNPCA). October 29, 1990a. Correspondence from Rodney E. Massey, Director, Ground Water and Solid Waste Division to William Taylor, General Mills, Inc.

Minnesota Pollution Control Agency, Ground Water and Solid Waste Division. October 29, 1990b. Internal Memorandum from Mark Schmitt, Re: Magnolia Aquifer Pump-And-Treat System.

Minnesota Pollution Control Agency. November 16, 1990c. Personal communication with Frederick Campbell, Hydrologist, Superfund Unit, Site Response Section.

Minnesota Pollution Control Agency. January 2, 1991. Personal communication with Mark Schmitt, General Mills Site Project Manager, Minnesota Pollution Control Agency, Ground Water and Solid Waste Division.

Strach, O. D. L. 1989. *Groundwater Mechanics*. Prentice Hall, Englewood Cliffs, New Jersey.

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UPDATE OF CASE STUDY 8

GenRad Corporation
Bolton, Massachusetts

Abstract

Ground-water extraction downgradient of the east plume has continued since late 1987 with a 3-month down period each winter. Contaminant concentrations over most of the east plume area have decreased since the extraction system began operating in 1987. Ground-water extraction has not been initiated in the highly contaminated north plume. The migration of the plume is limited because it discharges into Great Brook. Although concentrations of contaminants in the north plume have decreased, concentrations remain above drinking-water standards over most of the plume.

Table of Background Data	
Date of Problem Identification	1984
Extraction Started	Late 1987
Types of Contaminants	VOCs
Primary Aquifer Materials	Glacial sand, silt, and gravel
Maximum Number of Extraction Wells	2
Maximum Total Extraction Rate	40 gpm
Estimated Plume Area	10 acres
Estimated Plume Thickness	20 feet
Maximum Reported Concentrations	Trichloroethylene > 5,000 ppb

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CASE STUDY UPDATE
GENRAD CORPORATION

BACKGROUND OF THE PROBLEM

INTRODUCTION

This report describes events and progress in remediation at the GenRad Corporation site from December 1988 through November 1990. It is an update of the original case study, which was based on data from mid-1984 through late 1988 (U.S. EPA, 1989, Case Study 8).

The GenRad Corporation site is a manufacturing plant located in Bolton, Massachusetts, approximately 25 miles west of Boston (see Figure 1). Scientific and medical equipment are manufactured at the plant, resulting in the generation of waste sludge containing metal hydroxide and wastewater containing industrial solvents. Prior to 1984, these wastes were discharged directly to a sludge-drying bed and a surface impoundment. As a result of this practice, the soil and ground water at the site have been contaminated with volatile organic compounds (VOCs), principally trichloroethylene (TCE). The site remediation is administered by the Massachusetts Department of Environmental Protection (DEP).

The problem was first discovered in 1984 when a ground-water investigation performed to comply with RCRA requirements for closure of the waste management facility demonstrated that the ground water was contaminated with VOCs. The contamination was found in two separate areas--a western plume centered near the sludge-drying bed and an eastern plume emanating from the surface impoundment (see Figure 2). Beginning in 1984, contaminated soil and sludge were removed, underground storage tanks were excavated and the waste treatment facility was closed and demolished in an effort to remove the various sources of contamination. Further investigation revealed that the western plume had not migrated far, but that the eastern plume originating from the surface impoundment had migrated offsite approximately 600 feet. Operation of a long-term remediation system to extract and treat the contaminated ground water in this eastern plume began in late 1987.

The GenRad facility is underlain by unconsolidated glacial deposits and metamorphic bedrock. The thickness of the unconsolidated deposits is highly variable, but in general a 15- to 20-foot-thick unit of sand and gravel, present at the surface over most of the site, overlies approximately 11 feet of glacial till. In low-lying areas, several feet of organic sediments overlie the sand and gravel deposit at the surface. The bedrock that underlies the glacial till was not penetrated deeply during monitoring well installation at the site; however, it is known to be slightly to moderately fractured metamorphic rock. The bedrock surface is irregular and slopes to the northeast toward Great Brook. The slope of the bedrock surface northeast of Great Brook was not reported.

The permeable sand and gravel deposits act as an unconfined aquifer at the site. The transmissivity of these permeable sediments was measured and estimated to be between 350 and 10,000 ft^2/day. The transmissivity of the fractured bedrock was not reported in the original source documents but was estimated to be comparable to the transmissivity of the glacial till, that is, low in relation to the sands and gravel. However, some water-supply wells in the area are installed in the fractured bedrock. The depth to water ranges from 0 to 20 feet but is generally approximately 5 feet. The horizontal direction of ground-water flow is easterly, with flow to the east-northeast in the area of the former sludge-drying bed and to the southeast in the area of the former surface impoundment. The horizontal transport velocity of the ground water was estimated to be between 0.05 and 0.08 feet/day.

The two plumes of VOCs are oriented in the predominant directions of ground-water flow: that is, the north plume is oriented to the east-northeast and the east plume is oriented to the southeast. The primary contaminant of concern within the two plumes is trichloroethylene (TCE), but secondary contaminants include 1,1-dichloroethane, methylene chloride, 1,1-dichloroethylene, trans-1,2-dichloroethylene, 1,1,1-trichloroethane, tetrachloroethylene, and vinyl chloride.

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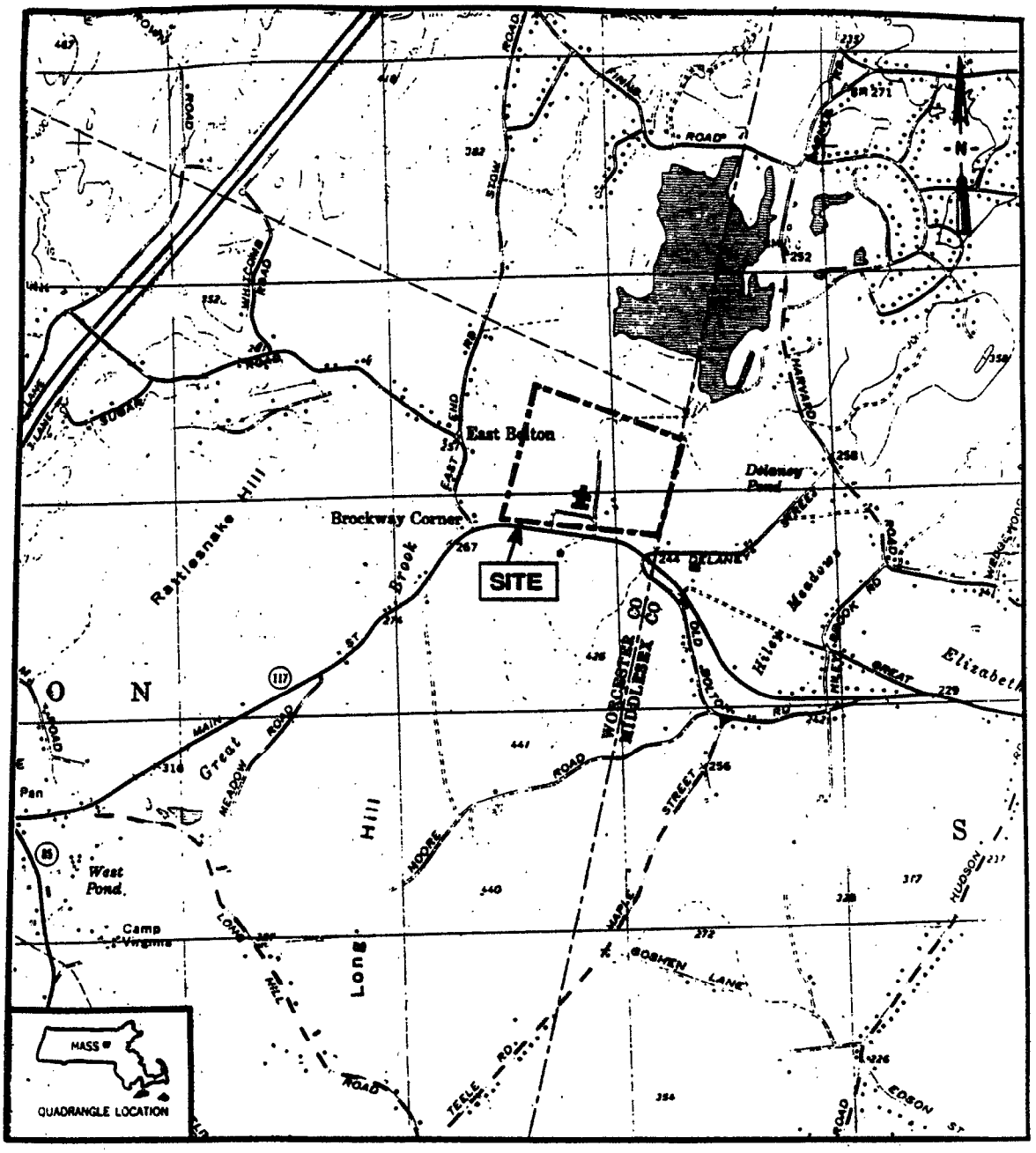

Source: USGS. 1986. Hudson, Massachusetts Quadrangle Map

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

Figure 1
SITE LOCATION MAP
GENRAD SITE, BOLTON, MASSACHUSETTS

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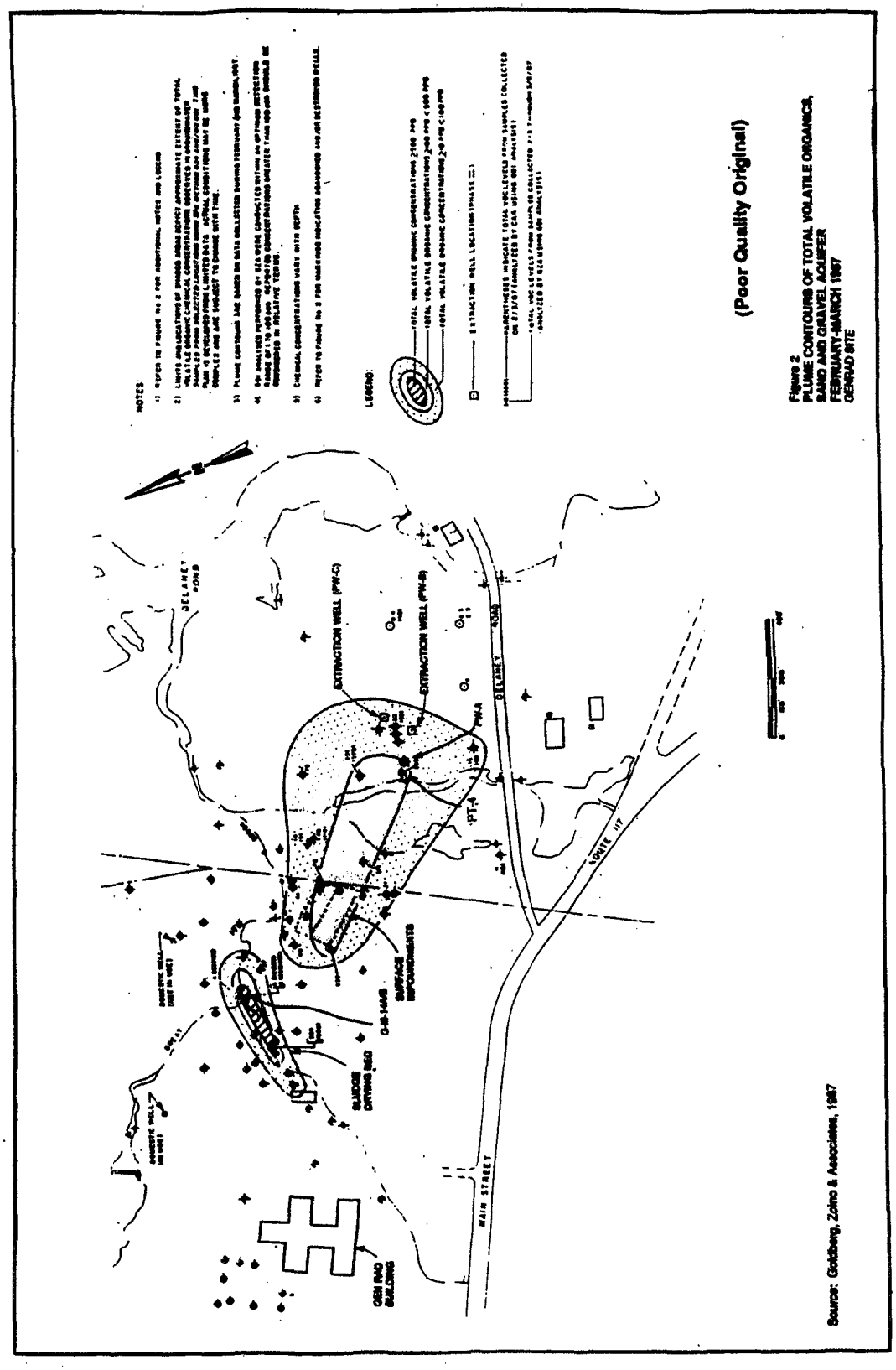

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Figure 2
PLUME CONTOURS OF TOTAL VOLATILE ORGANICS, SAND AND GRAVEL AQUIFER
FEBRUARY-MARCH 1987
GENRAD SITE

Source: Goldberg, Zoino & Associates, 1987

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One key characteristic of the north plume is that it appears to have migrated only a short distance from its original source location. The explanation for the lack of lateral migration reported by GenRad's consultant is that Great Brook acts as a hydraulic barrier to the northeastward migration of the north plume. Cross section A-A' in the original case study appeared to show that Great Brook was a gaining stream that would form a hydraulic barrier to ground-water flow by acting as a sink to contaminated ground water. However, concentration contours presented in the original case study show contamination northeast of Great Brook, indicating that Great Brook may not consistently act as a hydraulic barrier to ground-water flow, possibly because of seasonal lowering of the water table. Nonetheless, it appears that contaminated ground water from the north plume discharges to Great Brook at least part of the year and that Great Brook generally inhibits contaminant migration northeast of this drainage. Because of the lack of migration, there is no remediation system in place to extract contaminated ground water from the north plume.

In contrast to the north plume, the east plume had migrated substantially from its original source location by early 1987. This migration is further complicated by the fact that the plume has migrated offsite across both city and county boundaries. For this reason, ground-water extraction at the GenRad site has focused exclusively on remediating contaminated ground water in the east plume. The maximum concentrations of total VOCs in the north and east plumes in 1986 were approximately 5,000 ppb and 1,000 ppb, respectively.

UPDATE ON SITE CHARACTERISTICS

The information on site history, geology, hydrogeology, waste characteristics, and the administration of remediation presented in the original case study remains current in most respects. Some additional data about the geologic and hydrogeologic characteristics of the area near Great Brook have been gathered in a 1990 study of bedrock conditions (GZA, 1990b). One of the findings of this 1990 study was that Great Brook appears to follow a line of bedrock fractures as shown by regional fracture trace analysis. During the bedrock investigation, three deep bedrock wells and two associated shallow overburden wells, referred to as Series VI monitoring wells, were installed near Great Brook. Water level data collected from well pairs near Great Brook in 1990 showed that the vertical gradient was downward at well pair G-VI-1A/B at some distance from Great Brook, and upward at well pair G-VI-3A/B adjacent to Great Brook. This pattern of vertical gradients is consistent with the conclusion that Great Brook is a gaining stream that receives direct discharge from the area of the north plume. The hydraulic conductivity of the fractured bedrock was also measured in 1990. The conductivity was low, less than 0.02 feet/day, near G-VI-1B at a distance from Great Brook, but was low to moderate, 0.01 to 5.5 feet/day, near G-VI-2 and G-VI-3B, adjacent to Great Brook. The higher conductivity near Great Brook is consistent with the higher fracture densities expected in that area. More complete information on site characteristics can be found in the original case study.

REMEDIATION

Design and Operational Features of Remediation System

The objectives of remediation of the east plume were to prevent further offsite migration of contaminants and to clean up the contaminated ground water to drinking-water standards. No actions, beyond source removal, were taken to remediate the north plume because it was believed that "natural dilution" would remediate the ground water in this area without a significant degradation of the surface water quality in Great Brook. The east plume extraction system consists of two extraction wells (PW-B and PW-C) located approximately 100 feet apart near the eastern limit of the east plume. The well locations and pumping rates were chosen based on computer modeling and hydrodynamic response data gathered from testing a pilot extraction well, PW-A, installed as part of Phase I of the remediation. The total design pumping rate of the two existing Phase II extraction wells is 40 gpm (GZA, 1990a). The system was designed to be shut off for 3 months each year during the coldest period of the winter. The two extraction wells discharge to an air stripper treatment system. The effluent from the air stripper is discharged to two recharge trenches on the eastern boundary of the site, south of the east plume (GZA, 1990a). Each quarter, 16 monitoring wells are sampled to monitor the

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progress of remediation and the migration of the plume. The Phase II extraction system has been in operation since late 1987.

EVALUATION OF PERFORMANCE

The ground-water elevation contours at the GenRad site in November 1989 are shown in Figure 3. These data show that the two-well extraction system is effective in capturing ground water over a broad area of the sand and gravel aquifer. Specifically, it appears that contaminated ground water from the entire eastern plume is being captured by the existing extraction system. Ground water from the north plume is not captured. This result is consistent with the water-level data from an extraction period in October 1987 presented in the original case study (not shown). The practice of recharging treated ground water to two trenches south of the surface impoundments has changed the direction of flow near the surface impoundments from southeast before recharge began to northeast afterwards. This effect is probably due to ground-water mounding in the area of recharge. Water level contours suggest that this ground water turns southward and is captured by the extraction system over time.

The concentrations of total VOCs at the GenRad site in November 1989 are shown in Figure 4. Comparison of Figure 4 to the early 1987 data shown in Figure 2 shows that the concentrations of total VOCs in the east plume decreased from early 1987 to November 1989. The reduction of the size of the 100 to 500-ppb plume and its migration away from the surface impoundment from early 1987 to November 1989 are both indications of this reduction. Figure 4 also shows that the western two-thirds of the east plume migrated to the northeast, whereas the contaminated area south of the extraction wells migrated to the north. These patterns of plume migration are consistent with the directions of horizontal ground-water flow observed during periods of extraction in 1988 and 1989.

Three trends in the shape of the north plume are evident in comparing Figure 4 to the early 1987 data for total VOCs presented in Figure 2. From early 1987 to November 1989, it appears that: (1) the upgradient edge of the north plume migrated to the northeast away from the original source area, (2) the downgradient edge of the north plume continued to be limited by Great Brook, and (3) the north plume became wider. These three characteristics suggest that the contaminated ground water in the sand and gravel aquifer is dispersing laterally as it migrates to the northeast toward a discharge zone along Great Brook.

The results of the October 1990 sampling of the Series VI monitoring wells, consisting of three bedrock wells and two associated shallow wells, are shown in Table 1 and Figure 5. These results show that VOC contamination in the north plume was more extensive in the bedrock aquifer than in the sand and gravel aquifer in late 1990. Although only these three bedrock sampling points were available in late 1990, it is clear from comparison to Figure 4 that the contamination in the bedrock is more extensive both upgradient and downgradient of the existing plume in the sand and gravel aquifer. The concentration of total VOCs is greatest in G-VI-2, located 200 ft downgradient of the sludge-drying bed. This result is notable because vertical gradients are expected to be upward, not downward, at this location. Although all three existing bedrock wells show some contamination, the full extent of contamination in the bedrock has not been characterized to date.

Figure 6 shows the concentration of TCE in north plume wells G-III-14A and G-III-14B from mid-1984 through November 1990. This well pair is located on the south bank of Great Brook near bedrock well G-VI-2 at the downgradient eastern tip of the 500-ppb plume. The figure shows that the concentration of TCE in shallow well G-III-14A decreased steadily from the time of source removal in 1984 through early 1988, and then remained steady from early 1988 through late 1990. The overall decrease may be due to the relatively efficient discharge of the shallow ground water to Great Brook.

Figure 6 also shows that the concentration of TCE in deep well G-III-14B decreased from 1984 to early 1989, and then increased from early 1989 through late 1990. This later increase may be due to the migration of the highly contaminated center of the plume toward Great Brook. The increases seen in the spring sampling periods in 1988, 1989,

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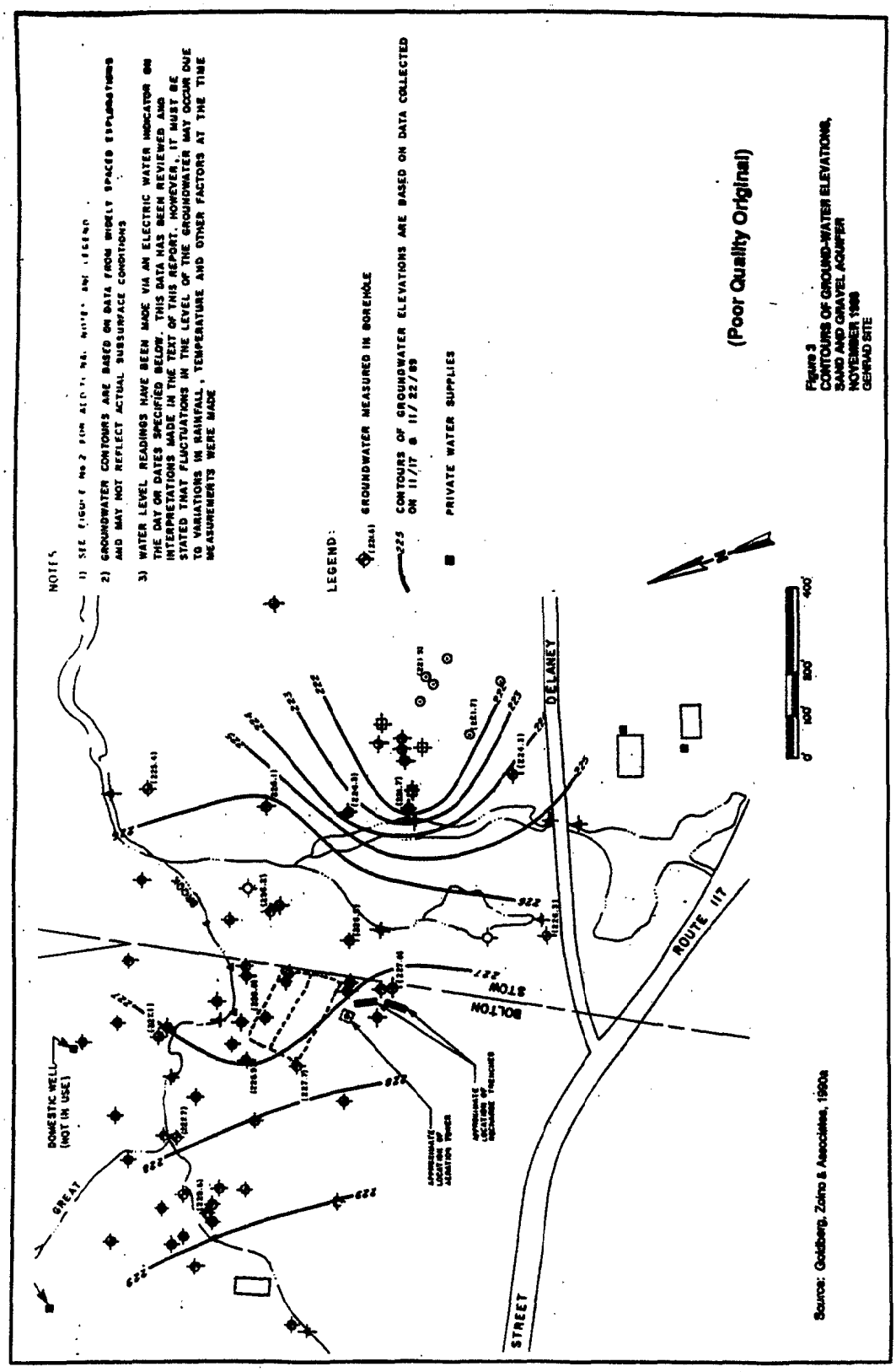

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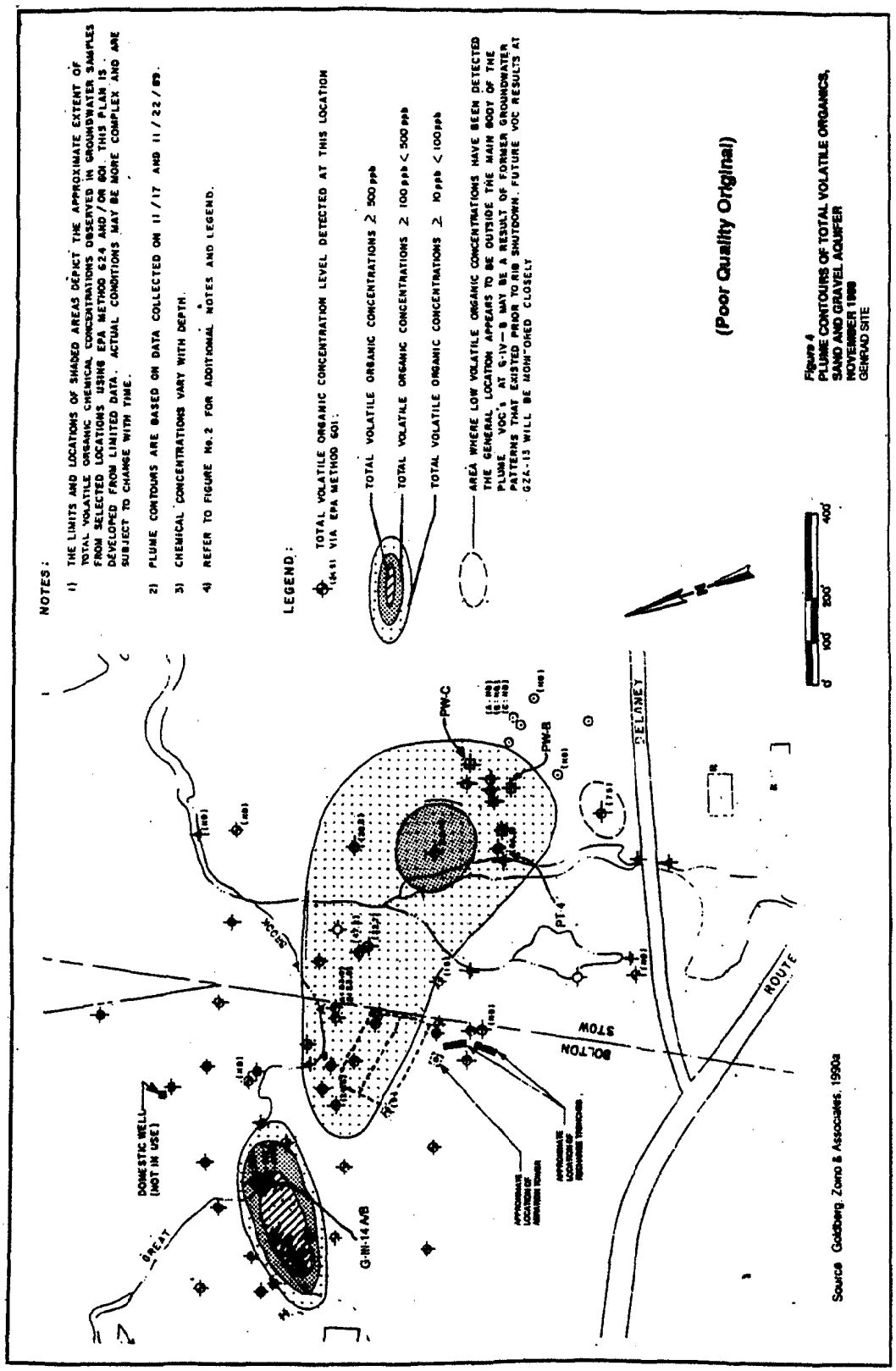
NOTES:
1) THE LIMITS AND LOCATIONS OF SHADED AREAS DEPICT THE APPROXIMATE EXTENT OF TOTAL VOLATILE ORGANIC CHEMICAL CONCENTRATIONS OBSERVED IN GROUNDWATER SAMPLES FROM SELECTED LOCATIONS USING EPA METHOD 624 AND/OR 601. THIS PLAN IS DEVELOPED FROM LIMITED DATA. ACTUAL CONDITIONS MAY BE MORE COMPLEX AND ARE SUBJECT TO CHANGE WITH TIME.
2) PLUME CONTOURS ARE BASED ON DATA COLLECTED ON 11/17 AND 11/22/89.
3) CHEMICAL CONCENTRATIONS VARY WITH DEPTH.
4) REFER TO FIGURE No.2 FOR ADDITIONAL NOTES AND LEGEND.
LEGEND:
TOTAL VOLATILE ORGANIC CONCENTRATION LEVEL DETECTED AT THIS LOCATION VIA EPA METHOD 601.
TOTAL VOLATILE ORGANIC CONCENTRATIONS ≥ 500 ppb
TOTAL VOLATILE ORGANIC CONCENTRATIONS ≥ 100 ppb < 500 ppb
TOTAL VOLATILE ORGANIC CONCENTRATIONS ≥ 10 ppb < 100 ppb
AREA WHERE LOW VOLATILE ORGANIC CONCENTRATIONS HAVE BEEN DETECTED THE GENERAL LOCATION APPEARS TO BE OUTSIDE THE MAIN BODY OF THE PLUME. VOC's AT G-IV-B MAY BE A RESULT OF FORMER GROUNDWATER PATTERNS THAT EXISTED PRIOR TO RIB SHUTDOWN. FUTURE VOC RESULTS AT GZA-13 WILL BE MONITORED CLOSELY
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0 100' 200' 400'
Figure 4
PLUME CONTOURS OF TOTAL VOLATILE ORGANICS, SAND AND GRAVEL AQUIFER
NOVEMBER 1989
GENRAD SITE
Source: Goldberg, Zoino & Associates, 1990a
DOMESTIC WELL (NOT IN USE)
GREAT
G-III-14 A/B
SCOTT
PW-C
PW-B
PT-4
BOLTON
STOW
DELANEY
ROUTE

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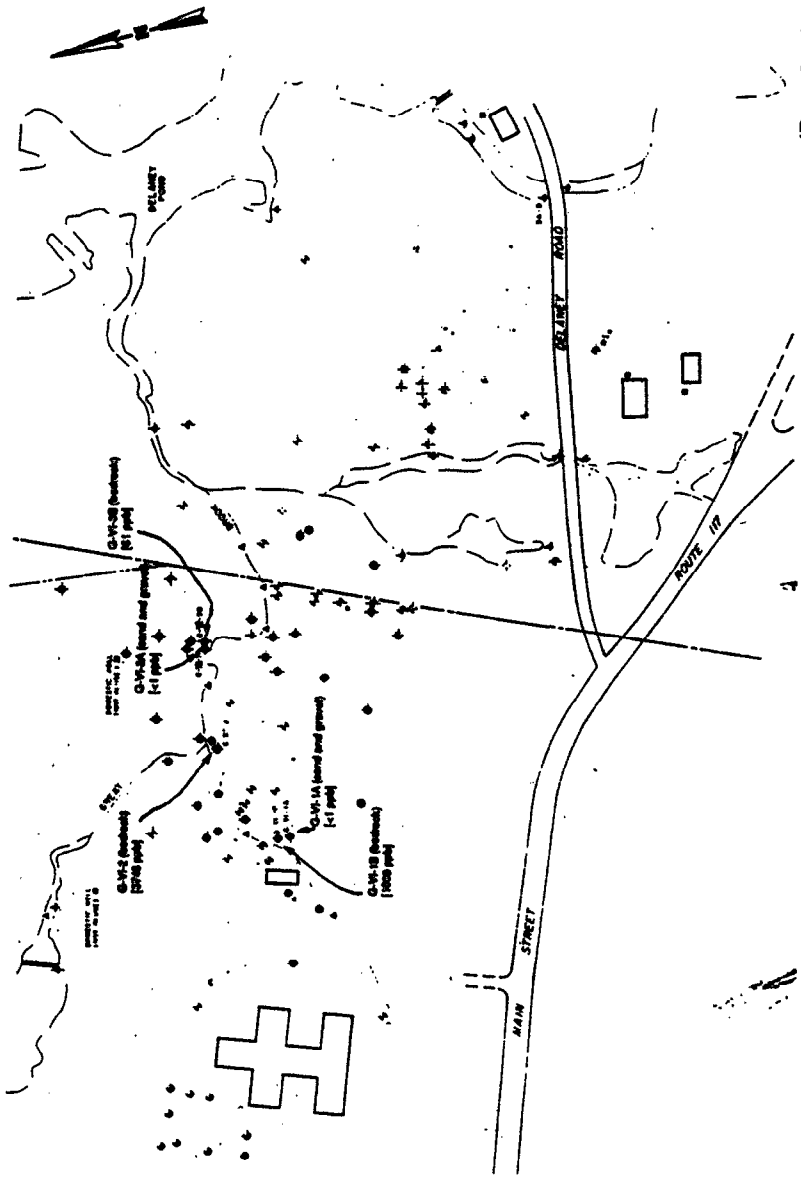

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Figure 6
CONCENTRATION OF TOTAL VOLATILE ORGANICS, IN SERIES VI MONITORING WELLS, OCTOBER 1989
GENRAD SITE

Source: Goldberg, Zoino & Associates, 1990b

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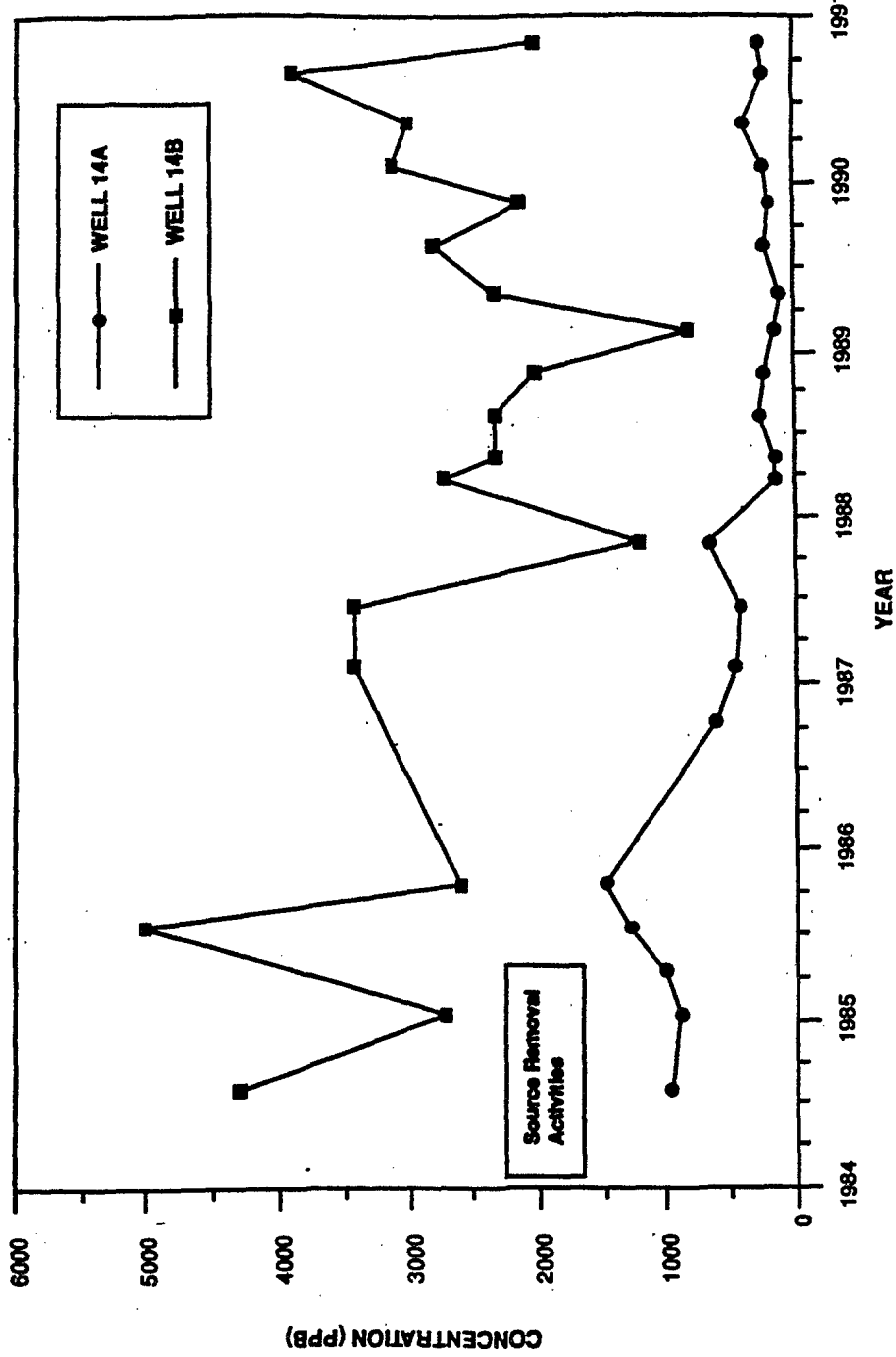

Figure 6
CONCENTRATION OF TCE IN G-III-14A AND G-III-14B (NORTH PLUME)
GENRAD SITE

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Table 1
TOTAL VOC CONCENTRATIONS IN SERIES VI MONITORING WELLS, OCTOBER 17, 1990

Well	Interval	TCE (ppb)	Total VOCs (ppb)
G-VI-1A	Upper Sand and Gravel	<1	<1
G-VI-1B	Fractured Bedrock Aquifer	960	1,009
G-VI-2	Fractured Bedrock Aquifer	3,700	3,748
G-VI-3A	Upper Sand and Gravel Aquifer	<1	<1
G-VI-3B	Fractured Bedrock Aquifer	25	61

and 1990 occurred after the system was shut down temporarily during the cold months. The concentration of TCE in the deeper interval of the sand and gravel aquifer remained high (2,000 ppb) at the end of 1990. The slower rate of discharge to Great Brook from deeper intervals of the aquifer may result in a slower rate of reduction of the TCE concentration than over shallower intervals; however, because of higher concentrations, the reductions in contaminant mass may still be significant.

Figure 7 shows the concentrations of TCE in east plume shallow well PT-4 from early 1987 through November 1990. Well PT-4 is located approximately 200 feet west of the south extraction well, PW-B. The figure shows that the concentration of TCE in PT-4 decreased substantially from 340 ppb in May 1988 to 110 ppb in November 1988, and then decreased slightly to 100 ppb through November 1990. This substantial initial reduction in TCE concentration was probably due to the startup of the nearby extraction system in late 1987.

Figure 8 shows the concentration of TCE in the influent to the air stripper from December 1987 through October 1989. The concentration decreased from 31 ppb in December 1987 to 5 ppb in December 1988, and then increased to 21 ppb at the end of October 1989. The concentration was highly variable over this entire period. The reason for the increase after December 1988 is unknown.

SUMMARY OF REMEDIATION

Ground-water extraction downgradient of the east plume has continued since late 1987 with a 3-month down period each winter. The east plume extraction system has continued to contain and capture contaminated ground water from the east plume since 1988, despite the winter down period. Concentrations over most of the east plume area have decreased since the extraction system began operating in late 1987. A considerable reduction in the size of the 100 to 500-ppb plume, probably due to the extraction system, has been observed since system startup. Some northeastern migration of the western two-thirds of the plume has been observed, but it is expected that this ground water will be captured in the future by the existing extraction system. It is expected that several more years will be necessary to clean up all of the east plume to drinking-water standards.

No extraction of ground water in the highly contaminated north plume has been initiated because of the limited migration of the north plume because of its direct discharge to Great Brook. The eastward migration of the north plume has continued to be limited by Great Brook since late 1988. The eastward migration of the upgradient edge of the plume and the widening of the plume both suggest that the contaminated ground water in the sand and gravel aquifer in this area continues to migrate away from its original source and toward Great Brook. Some decrease in overall concentrations has been observed; however,

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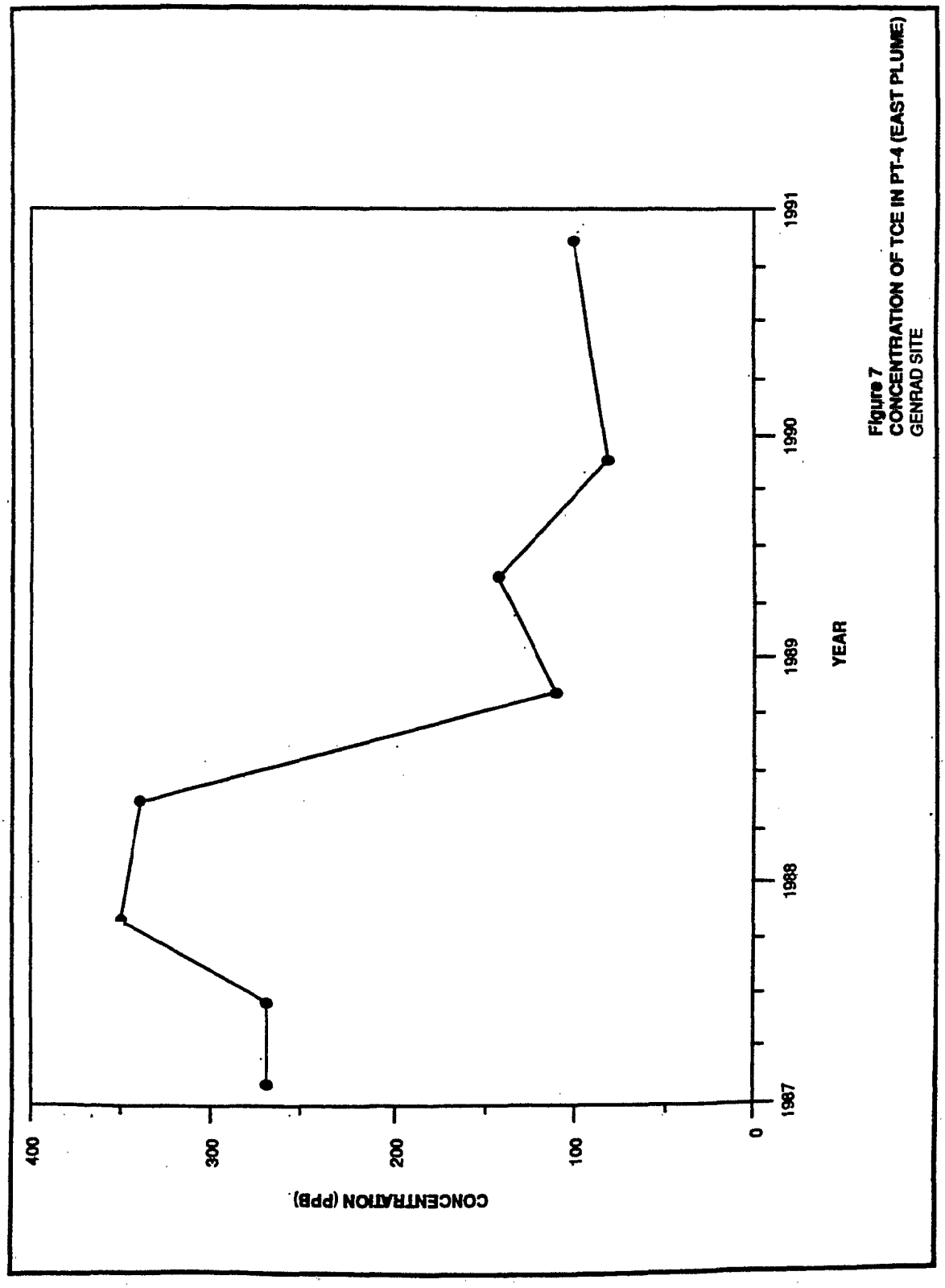

Figure 7
CONCENTRATION OF TCE IN PT-4 (EAST PLUME)
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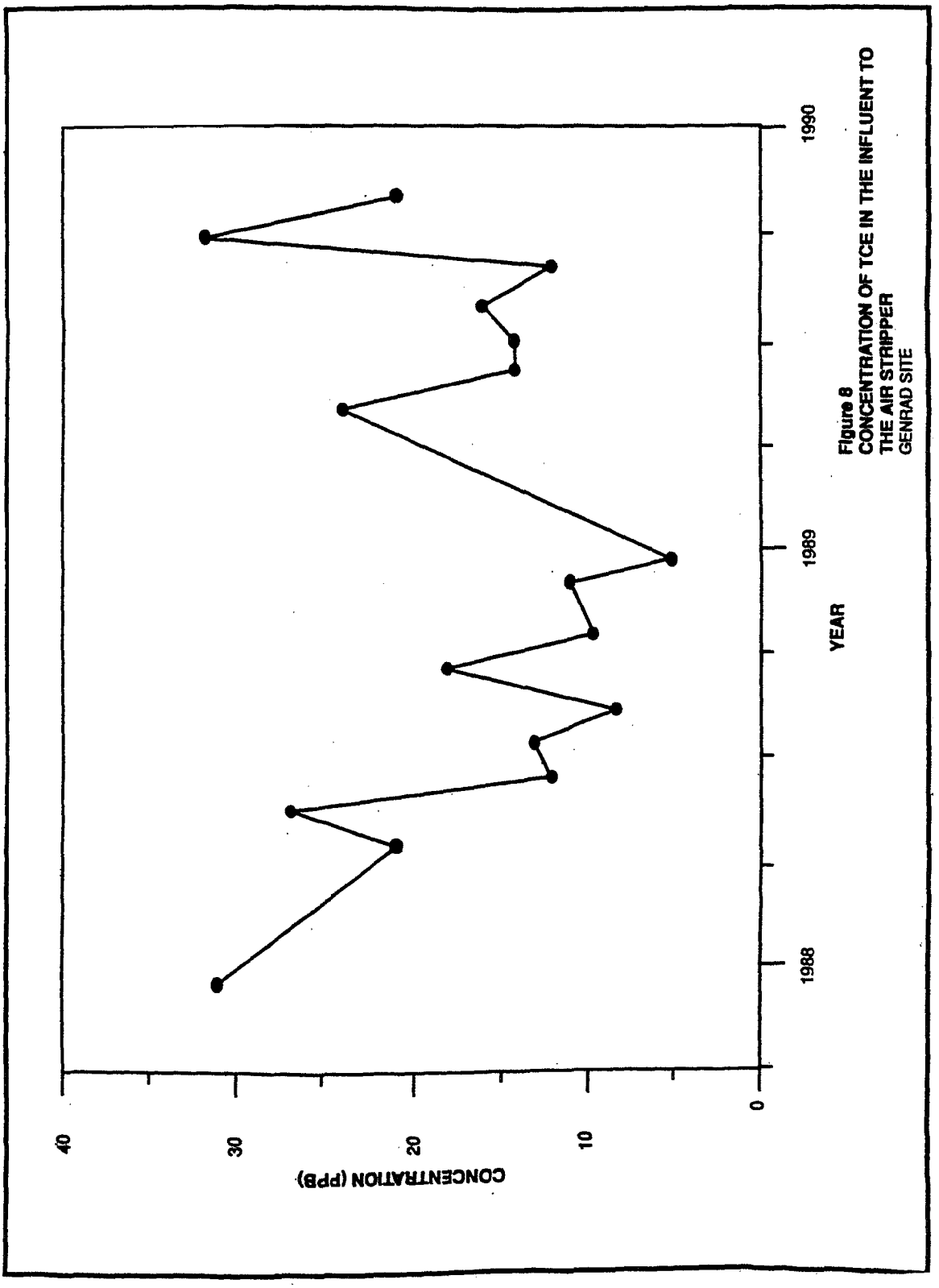

Figure 8
CONCENTRATION OF TCE IN THE INFLUENT TO THE AIR STRIPPER
GENRAD SITE

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concentrations of contaminants remain considerably above drinking-water standards over most of the north plume. Concentrations of VOCs were found to be significantly greater in the bedrock aquifer than in the sand and gravel aquifer during sampling in 1990. The natural cleanup of the north plume to drinking-water standards via ground-water discharge to Great Brook is expected to take many years, and may take decades.

SUMMARY OF NAPL-RELATED ISSUES

The presence of nonaqueous phase liquid (NAPL) contamination at the GenRad site has not been reported to date. The relatively low concentrations of contaminants in the east plume and the significant progress in concentration reduction from early 1987 to late 1989 suggest that this plume consists of dissolved VOC constituents that do not have a NAPL source.

There is a possibility of some dense NAPL (DNAPL) contamination in the north plume. The concentrations of total VOCs in the north plume are considerably higher than in the east plume, particularly at depth. The location of the highest concentration of contaminants in the lower part of the sand and gravel aquifer, as well as in the fractured bedrock that underlies it, may be an indication of some amount of DNAPL contamination. For example in well pair G-VI-3A/B, located adjacent to the sludge-drying bed, the concentration of total VOCs was less than 1 ppb at the top of the sand and gravel aquifer and 1,009 ppb within the underlying fractured bedrock aquifer in October 1990. This difference may be caused by a DNAPL lens of halogenated organics that has descended through the sand and gravel aquifer and pooled within the fractured bedrock. The highest concentration of total VOCs within the bedrock (3,748 ppb) was measured in G-VI-2, which is in a location where a high fracture density is expected. If DNAPLs are present, they would have the potential to migrate downward through the abundant fractures in this area, despite upward hydraulic gradients. Additional wells would need to be installed in the bedrock to investigate the extent of bedrock contamination before the possibility of DNAPL contamination can be confirmed.

The increases in VOC concentrations observed in spring of 1988, 1989, and 1990 occurred after the system had been temporarily shut down during the winter months. This increase may indicate that residual sources such as DNAPL are present in the area.

UPDATE BIBLIOGRAPHY/ REFERENCES

Goldberg, Zoino & Associates, Inc., (GZA). March 1987. File No. 3863.6.

GZA. February 14, 1990a. Letter to Massachusetts Department of Environmental Quality Engineering: Monthly Report November 1, 1989 to December 1, 1989.

GZA. November 29, 1990b. Letter to Massachusetts Department of Environmental Protection: GenRad Bolton Facility Bedrock Exploration Program.

U.S. Environmental Protection Agency (U.S. EPA). October 1989. *Evaluation of Ground-Water Extraction Remedies. Volume 2, Case Studies 1-19.* EPA/9355.4-03.

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UPDATE OF CASE STUDY 9

Harris Corporation
Palm Bay, Florida

Abstract

Remediation systems at the Harris facilities and General Development Utilities (GDU) continue to extract contaminated ground water. The introduction of extraction Well GS-131S in mid-1988 has enhanced the effectiveness of the shallow extraction system in the Harris south campus. However, some contaminated ground water still extends beyond the shallow zone of capture. The area of the deep plume has been reduced since system startup in 1985. Concentrations of total VOCs in the influent to both the Harris and GDU treatment systems decreased significantly after startup but have remained relatively stable in the last 3 to 4 years.

Table of Background Data	
Date of Problem Identification	1982
Extraction Started	April 1984
Types of Contaminants	VOCs
Primary Aquifer Materials	Sand and shell with clay layers
Maximum Number of Extraction Wells	24
Maximum Total Extraction Rate	310 gpm
Estimated Plume Area	60 acres
Estimated Plume Thickness	90 feet
Maximum Reported Concentrations	Total VOCs 37,120 ppb

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CASE STUDY UPDATE
HARRIS CORPORATION

BACKGROUND OF THE PROBLEM

INTRODUCTION

This report describes events and progress in remediation at the Harris Corporation site from early 1989 through January 1991. It is an update of the original case study, which was based on information from 1984 through February 1989 (U.S. EPA, 1989, Case Study 9).

The Harris Corporation site is located in the town of Palm Bay, Florida. The site encompasses three facilities: the Harris Semiconductor facility in the northern part of the site (the Harris north campus), the Harris Government Systems facility in the central part of the site (the Harris south campus), and the autonomous General Development Utilities (GDU) water and wastewater treatment facility in the southern part of the site (see Figure 1). The main activity of the north campus is the manufacture of electronic components, especially semiconductors and other microelectronic components. The activities of the south campus have varied since the facility was occupied by Harris in 1967, but have included electroplating, photoprocessing, painting, and computer hardware assembly. The GDU facility includes a water treatment plant that produces the drinking water for Palm Bay, a wastewater treatment plant, and several water supply wells.

Overall site remediation of the three facilities was administered by the Florida Department of Environmental Regulation (FDER), but is now administered by Region IV of the U.S. EPA (FDER, 1991).

Ground-water contamination was first discovered in March 1982 after samples collected from the finished water of the GDU water treatment plant were found to be contaminated with volatile organic compounds (VOCs). Subsequent actions at the GDU facility included: (1) sampling of all 18 water supply wells, leading to the termination of pumping in five contaminated wells in April 1982; (2) startup of a prototype air stripper treatment system at the GDU facility in November 1982, and of a permanent full-scale system in April 1984; and (3) restoration of four of the five wells to full production after the GDU treatment system began operation.

Following a period of site assessment and planning from 1982 through late 1984, a separate Harris ground-water extraction and air stripper treatment system was installed and began operation at the Harris south campus in two stages during 1985. In May 1985, four deep wells near the boundary with GDU (GS-123D, GS-124D, GS-125D, and GS-127D), a system of 10 shallow wellpoints near Building 5, and the Harris air stripper treatment system, began operation. In September 1985, three additional deep wells (GS-35D, GS-37D, and GS-43D) and three additional shallow wells (GS-35S, GS-37S, and GS-43S), all located in the area of highest contamination near Building 6, were added to the extraction and treatment system. Later changes to the system through 1988 included the replacement of the 10-wellpoint system with two conventional extraction wells (GS-44S and GS-18S) in mid-1987, and the addition of shallow extraction Well GS-131S to the three existing shallow extraction wells in June 1988.

Five main geologic units underlie the Harris/GDU study area. These five units, in order of increasing depth are: (1) a 42-foot thick unit of sand, silty sand, and sandy silt that contains shells in the bottom 5 to 10 feet; (2) a 22-foot-thick clay unit that acts as a leaky aquitard; (3) a permeable sand unit which occurs from depths of 65 to 95 feet; (4) the Hawthorne Formation, a low permeability, clay-confining unit with a thickness of 100 to 200 feet; and (5) the Floridan aquifer, a 1,000-foot unit of limestone and dolomite.

The two aquifer zones of concern are the shallow silty sand unit and the deeper permeable sand unit of the surficial aquifer (units 1 and 3 above). These two zones are referred to, respectively, as the shallow-aquifer zone and the deep-aquifer zone, and wells within these units are referred to as "shallow" and "deep." The general direction of horizontal ground-water flow is to the south-southeast in the shallow-aquifer zone and to the southeast in the deep-aquifer zone. A downward vertical head gradient exists between the two

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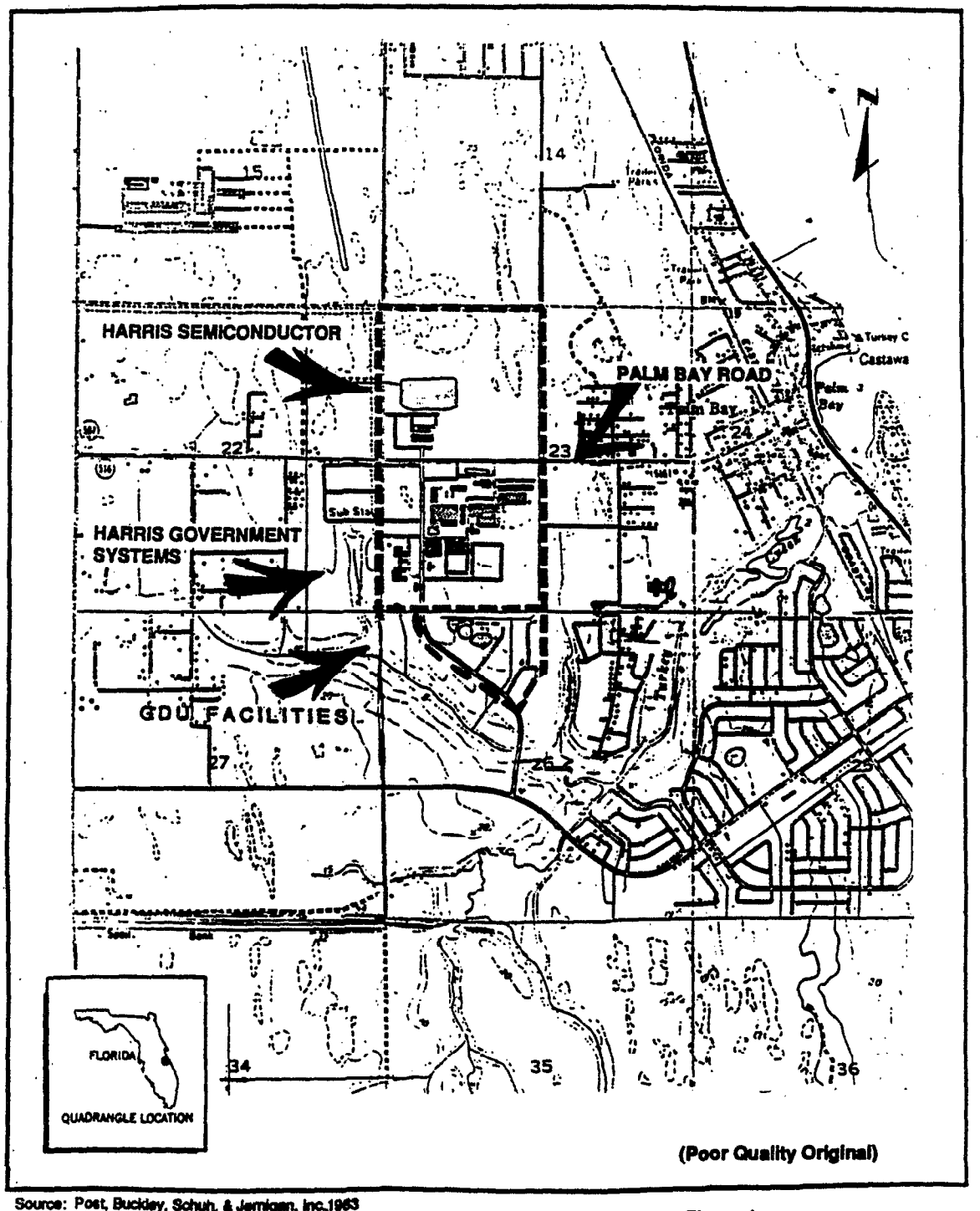

Source: Post, Buckley, Schuh, & Jernigan, Inc.,1963

Figure 1
GENERAL SITE LOCATION MAP
HARRIS CORPORATION SITE
PALM BAY, FLORIDA

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aquifer zones, especially in the vicinity of the extraction and production wells.

Volatile organic compounds are the main contaminants of concern. The VOC plume is made up of several constituents, including Trans-1,2-dichloroethylene (Trans-1,2-DCE), trichloroethylene (TCE), vinyl chloride, methylene chloride, and chlorobenzene. The main plume of total VOCs extends diagonally northwest-southeast across most of the south campus. The highest total VOC concentrations are found southeast of Building 6 in the east-central part of the south campus. Some of the potential, but unconfirmed, sources of ground-water contamination are corroded storm sewer lines, solvent sumps, leaking industrial pipelines, drum storage areas, drainage ditches, and several waste ponds and neutralization lagoons in both the north and south campuses.

UPDATE ON SITE CHARACTERISTICS

The information on early site history, geology, hydrogeology, administration of remediation, and waste characteristics and sources presented in the original case study is believed to be current. One minor change is that the south campus is now referred to as the Electronic Systems Sector (ESS) campus in some site documents. More complete information on site characteristics can be found in the original case study (U.S. EPA, 1989).

REMEDIATION

Design and Operational Features of Remediation System

When the initial case study was written, there were two separate extraction and treatment systems--one operated by Harris in the south campus, and a second operated by GDU. The objectives of the GDU remediation system are to provide drinkable water for public consumption and to prevent contamination from migrating to uncontaminated production wells. The GDU system consisted of four production wells (GDU-2B, GDU-3, GDU-5, and GDU-8) that discharged to an air stripper treatment system. Treated water from this system is blended with water from uncontaminated GDU production wells, and then treated again using conventional water treatment technology.

The objectives of the Harris remediation system are to clean up the aquifers underlying the Harris site to meet established standards and to prevent additional GDU production wells from becoming contaminated. Currently, the Harris south campus remediation system consists of 11 extraction wells and an air stripper treatment system. The extraction wells are located in 4 areas in the south campus. These are: (1) three deep barrier wells (GS-123D, GS-124D, and GS-125D) near the Harris/GDU property boundary, (2) two deep (GS-50D and GS-43D) and two shallow (GS-50S and GS-43S) wells near the main body of the plume southeast of Building 6, (3) one deep (GS-127D) and one shallow (GS-131S) well in the parking lot area between Building 6 and the Harris/GDU property boundary, and (4) two shallow wells (GS-18S and GS-44S) near the northeast plume near Building 5. Two former extraction wells, GS-37S and GS-37D, were taken out of production in August 1990, and replaced with GS-50S and GS-50D, which are located 200 feet west of the GS-37 wells. This change was made because of the low production of the GS-37 well cluster and was intended to improve plume capture to the west. The Harris remediation system in operation at the end of 1990 is shown in Figure 2. The shallow wells are screened near the bottom of the surficial silty sand unit from approximately 33 to 38 feet, and the deep wells are screened from 68 to 78 feet in the permeable sand unit underlying the clay aquitard. An extensive system of monitoring wells has been installed in both the north and south Harris campuses. Ground-water samples from a select number of these wells are collected and analyzed for VOCs each quarter.

The GDU remediation system has not been modified extensively since early 1989. In the original case study, it was reported that only four GDU production wells (GDU-2B, GDU-3, GDU-5, and GDU-8) were connected to the GDU treatment system. Recent documentation states that three additional wells (GDU-4, GDU-6, and GDU-7) were also discharging to the treatment system in early 1990 (GDU, January 16, 1990). The date of the addition of these three wells was not reported. The average pumping rate of the entire GDU production well network in December 1989 was 4.3 million gallons per day, or 3,000 gpm (GDU, 1989). The seven wells discharging to the GDU air stripper produced an average of 0.7 million gallons per day or 490 gpm during December 1989.

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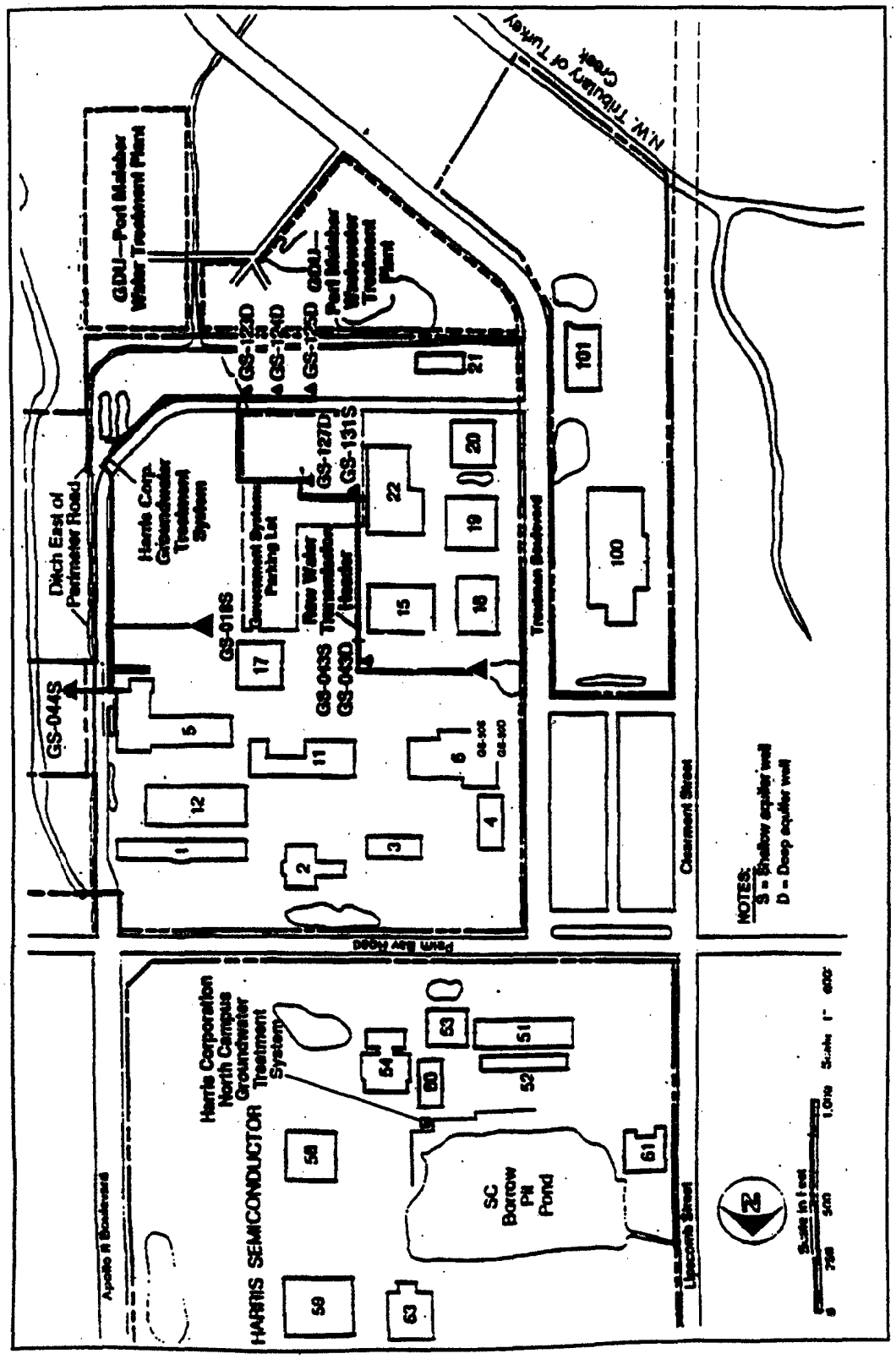

Figure 2
HARRIS CORPORATION REMEDIATION SYSTEM, LATE 1990
HARRIS CORPORATION SITE

Modified After CH2M HILL, 1986

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The configuration of the Harris south campus remediation system was changed in August 1990, with the replacement of GS-37S and GS-37D with extraction Wells GS-50S and GS-50D. The influent flow rate to the Harris air stripper in late 1990 was approximately 260 gpm, slightly less than the rate of 281 gpm in late-March 1987 reported in the original case study (Geraghty & Miller, January 25, 1991b). The Harris remediation did experience two interruptions of service in 1989 to provide for system maintenance. These periods of shutdown were from March 3 to April 21 (Harris, June 20, 1989), and for a 4-week period during May 1989 (Geraghty & Miller, November 30, 1989).

Other remedial activities at the Harris/GDU site were the installation and startup of a second Harris remediation system in the north campus area and preparations for additional extraction near Building 100, west of Troutman Boulevard. The north campus remediation system was completed in July 1990. It consists of 1 deep and 12 shallow extraction wells that discharge to a small air stripper. The treated water is discharged to the north campus industrial wastewater treatment plant. The extraction system borders the large north campus retention pond on the south and east, as shown in Figure 2. The combined extraction rate of the system was estimated to be approximately 25 gpm in late 1990 (Geraghty & Miller, 1991a). Total VOC concentrations in the influent to the north campus air stripper decreased from 1,430 ppb on June 28, 1990, to 637 ppb on October 31, 1990, probably as a result of the north campus extraction system.

Harris Corporation is currently preparing to initiate additional ground-water extraction near Building 100. The proposed system, described in a 1990 feasibility study/remedial action plan, is expected to consist of three wells that will extract ground water from the 40-foot zone near Building 100 (Geraghty & Miller, 1991b). Ground-water modeling simulations were performed to determine appropriate pumping rates and extraction well spacings for the system, which is expected to extract a total of 30 gpm. The water would be treated using the existing south campus air stripper. Two new monitoring wells were installed west of Clearmont Street southwest of Building 100 in January 1990. As of June 1991, construction of the proposed Building 100 extraction system was awaiting FDER approval.

EVALUATION OF PERFORMANCE

Figure 3 shows average 1990 total VOC concentrations in the shallow-aquifer zone superimposed on a contour map of the potentiometric surface of the shallow-aquifer zone on January 4, 1991. The capture zones associated with the three areas of shallow ground-water extraction are also shown. The extent of capture is similar to that of late March 1987, illustrated in the original case study, except that extraction Well GS-131S has extended the overall zone of capture considerably downgradient from Building 6. Comparison of the average 1990 total VOC isopleths to the approximate capture zone shows that almost all of the areas of ground-water contamination with greater than 50 ppb total VOCs were being captured by the existing system in December 1990. The 100 ppb plume southwest of Building 100 was not being captured in December 1990; however, planned extraction activities in this area are expected to rectify this deficiency. The distribution of ground-water contamination in areas with concentrations less than 50 ppb is not shown in Figure 3; however, some areas of ground-water contamination with concentrations of less than 50 ppb were probably outside the capture zone of the shallow extraction system in December 1990.

Figure 4 shows the average 1990 total VOC concentration isopleths in the deep-aquifer zone superimposed on a contour map of the potentiometric surface of the deep aquifer for December 1990. The approximate limit of the capture zone of the central control wells and the barrier wells is also shown. These data show that the most of the deep plume was being captured by the deep extraction wells in December 1989. The plume is generally narrower and smaller than the 1987 plume presented in the original case study, indicating progress in ground-water remediation. The areas of contaminated ground-water south of the barrier wells were apparently not being captured by the Harris remediation system in December 1990. This relationship was also shown by the 1987 isopleths of total VOCs presented in the original case study. As before, it is expected that the portion of the plume not captured by the Harris extraction system will be captured and treated by the GDU production well and treatment system. The distribution of ground-water contamination with concentrations less than 50 ppb is not shown in Figure 4. However, the capture zone shown in Figure 4 did not encompass the

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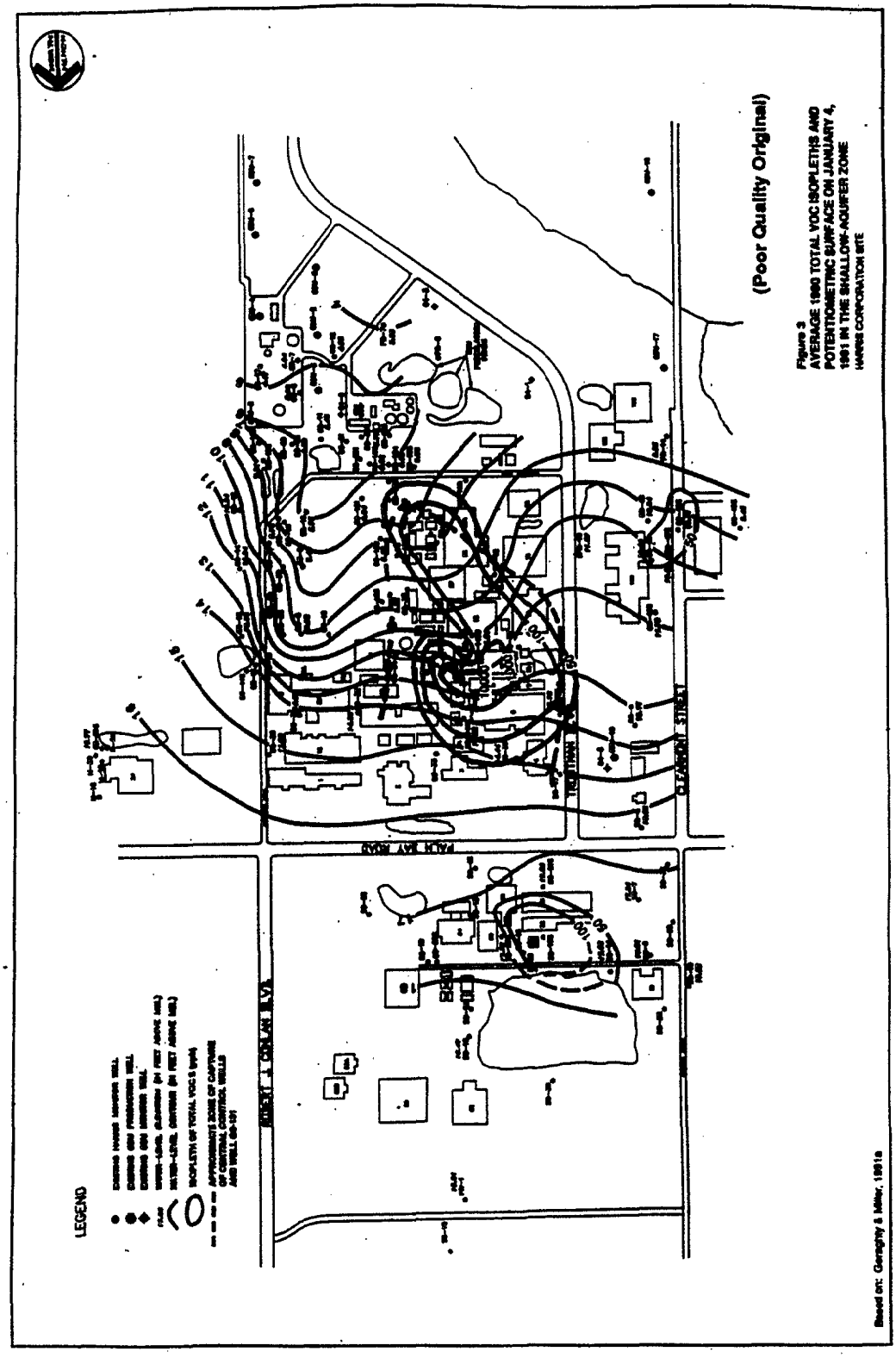

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Figure 3
AVERAGE 1990 TOTAL VOC ISOPLETHS AND POTENTIOMETRIC SURFACE ON JANUARY 4, 1991 IN THE SHALLOW-AQUIFER ZONE
HARRIS CORPORATION SITE

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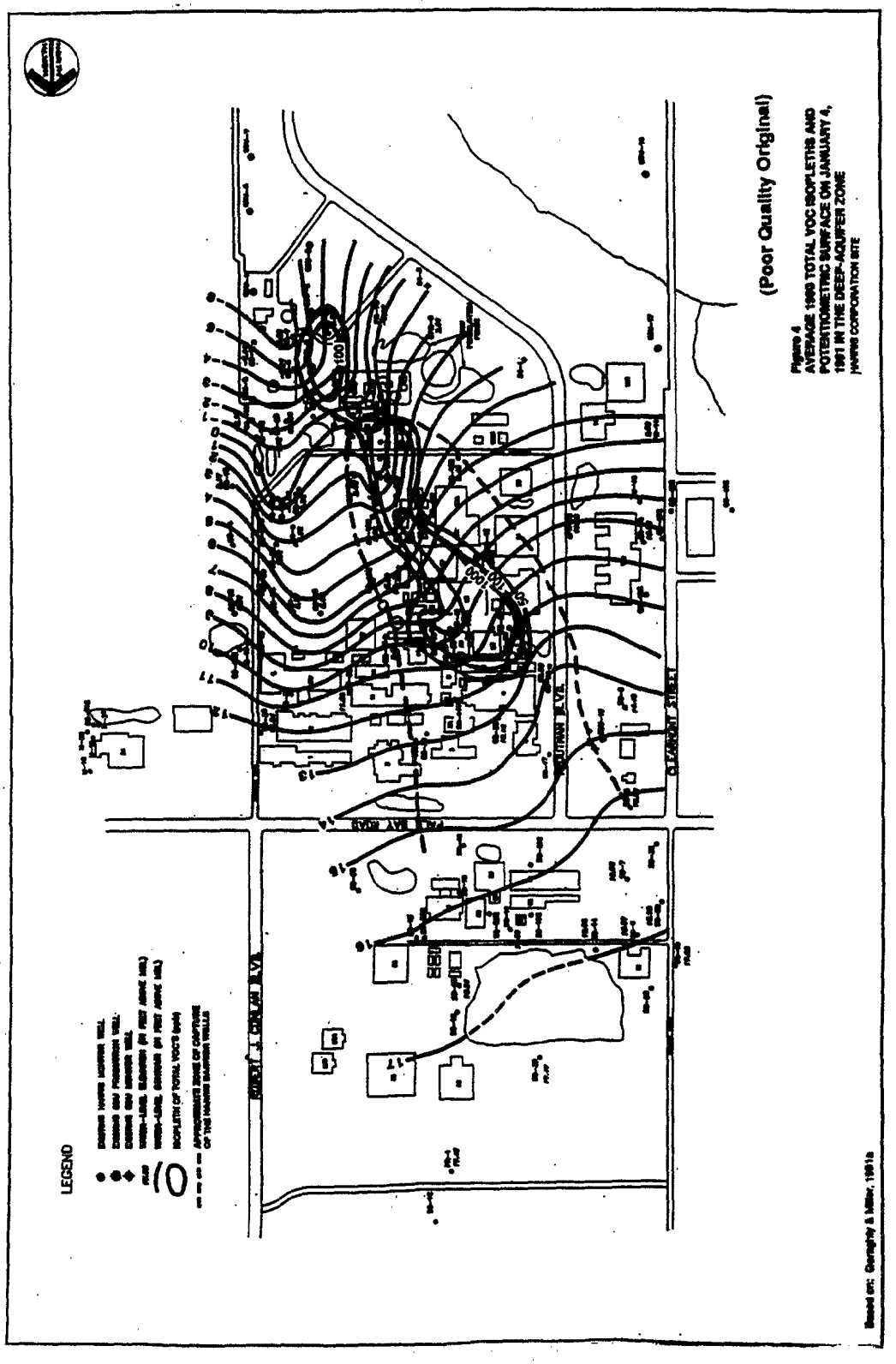
LEGEND
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Figure 4
AVERAGE 1990 TOTAL VOC ISOPLETHS AND POTENTIOMETRIC SURFACE ON JANUARY 4, 1991 IN THE DEEP-AQUIFER ZONE
HARRIS CORPORATION SITE

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1990 50 ppb isopleth, so it is expected that most or all of the low-concentration contamination upgradient of the barrier wells would also be contained by the Harris system.

Figure 5 is a time series plot of the concentrations of total VOCs in the influent to the Harris south campus air stripper from early May 1985 through October 1990. These data show a significant decrease in total VOC concentrations from 1985 to the end of 1988. Concentrations from early 1988 through late 1990 were essentially stable except for a concentration peak in mid-1989. Approximately 80 percent of the increase in total VOC loading in mid-1989 can be attributed to the central control wells (GS-37S, GS-37D, GS-43S, and GS-43D) but some increased loading was also observed in the barrier wells (Geraghty & Miller, November 30, 1989). This increase may have been caused by system shutdowns for a combined total of 2 1/2 months in March, April, and May 1989. The fact that little actual downgradient plume migration has occurred since startup, as shown by comparison of early plume maps (not shown) with Figures 3 and 4, suggests that the increase was not due to plume migration during shutdown. The repair of the pump in GS-43D in May 1989, after a period of minimal pumping of the highly contaminated central plume area, may have contributed to the increase.

The concentration of total VOCs in the influent to the GDU air stripper from April 1984, through January 2, 1991, is shown in Figure 6. The time series shows a significant initial decrease in total VOC concentrations followed by a period of stable concentrations of approximately 60 ppb during 1986. This was followed by a third period of stable concentrations in the range of 10-15 ppb from early 1987 through the end of 1990. It is not known when the three low concentration production wells were added to the influent stream.

SUMMARY OF REMEDIATION

Remediation systems at the GDU and Harris facilities continue to extract contaminated ground water. The effectiveness of the shallow extraction system in the Harris south campus was enhanced significantly by the introduction of GS-131S in mid-1988, as shown by comparison of data in the original case study with that of Figure 3. Some contaminated shallow ground water south of GS-131S in the main plume continued to be beyond the shallow capture zone in December 1990. Remediation of the north campus total VOC plume south of the retention pond began in mid-1990, and has shown some progress to date. The shallow plume southwest of Building 100, in the area west of the south campus, is not currently being captured. However, an extraction system designed to remediate this plume is expected to be approved by the FDER and constructed in 1991.

The size of the deep total VOC plume has been reduced by the extraction system since system startup in 1985. An area of contaminated ground water south of the barrier wells continues to be beyond the capture zone of the Harris extraction system, but within the capture zone of the GDU production wells that discharge to the GDU air stripper. Concentrations of total VOCs in the influent to both the Harris and GDU treatment systems decreased significantly after startup. However, influent concentrations in both systems have been relatively stable in the last 3 to 4 years.

SUMMARY OF NAPL-RELATED ISSUES

The presence of dense non-aqueous phase liquids (DNAPLs) at the Harris/GDU site is not currently suspected. However, some characteristics observed at the Harris/GDU site may suggest the possible presence of DNAPLs. One of the characteristics of DNAPL contamination is the persistence of high concentrations of contaminants over long periods despite efficient extraction rates. The persistence of total VOC concentrations of approximately 1,000 ppb in the influent to the Harris air stripper observed since early 1988 may be an indication of an abundant source of contaminants. This source of dissolved contaminants could be a DNAPL pool; however, the source could also be contaminants adsorbed onto soil particles in both the saturated and unsaturated zones. Significant increases in ground-water contamination after periods of no pumping are another indication of DNAPL contamination. A three-fold increase in the concentration of the composite of the four central control wells near Building 6 was observed from March 1 to July 26, 1989, after periods of system shutdown from March 3 to April 21 and for 4 weeks in May. Neither the persistence of high concentrations nor the observed concentration peak

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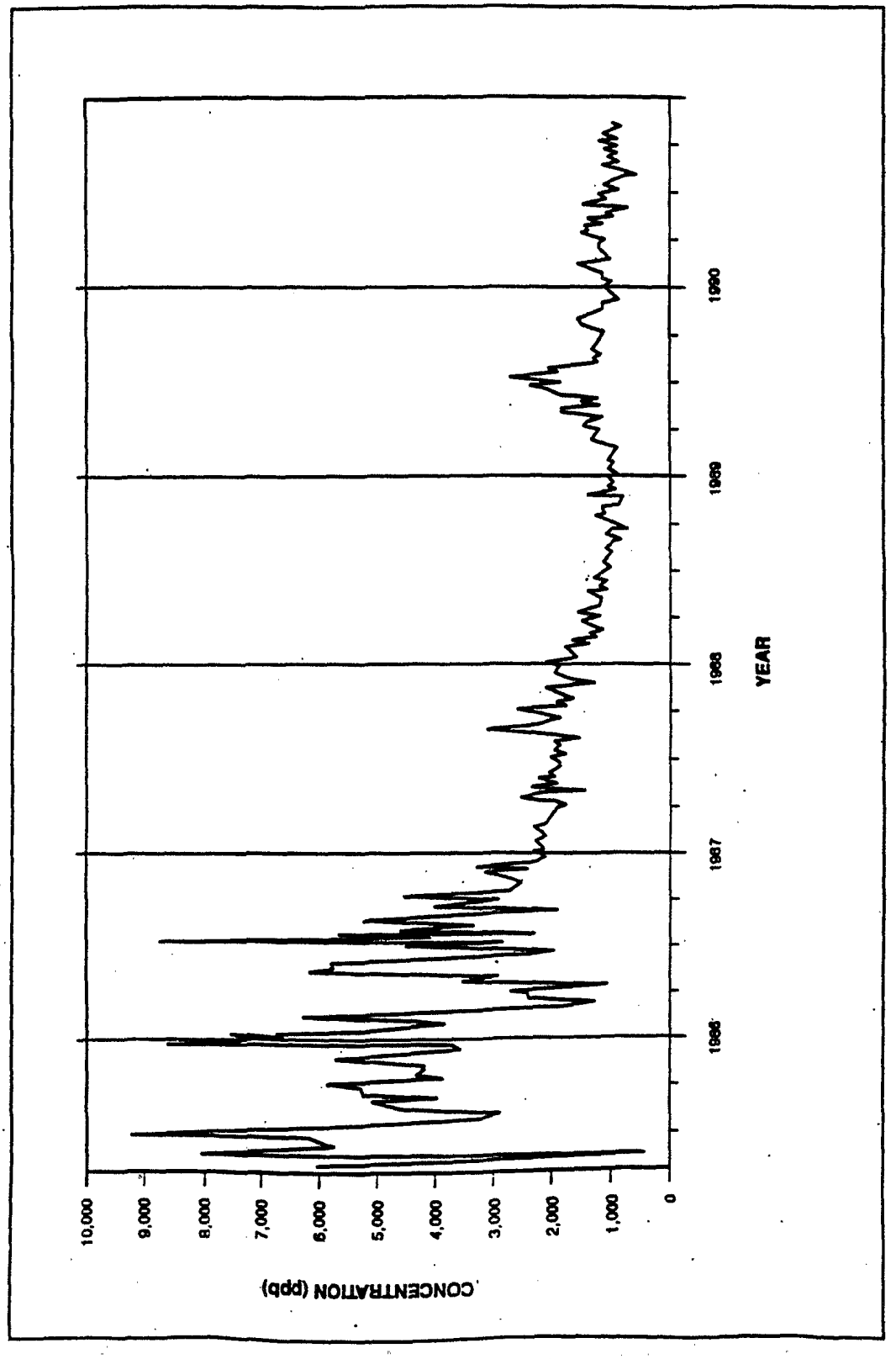

Figure 5
CONCENTRATIONS OF TOTAL VOCs IN THE INFLUENT TO THE HARRIS SOUTH CAMPUS AIR STRIPPER
HARRIS CORPORATION SITE

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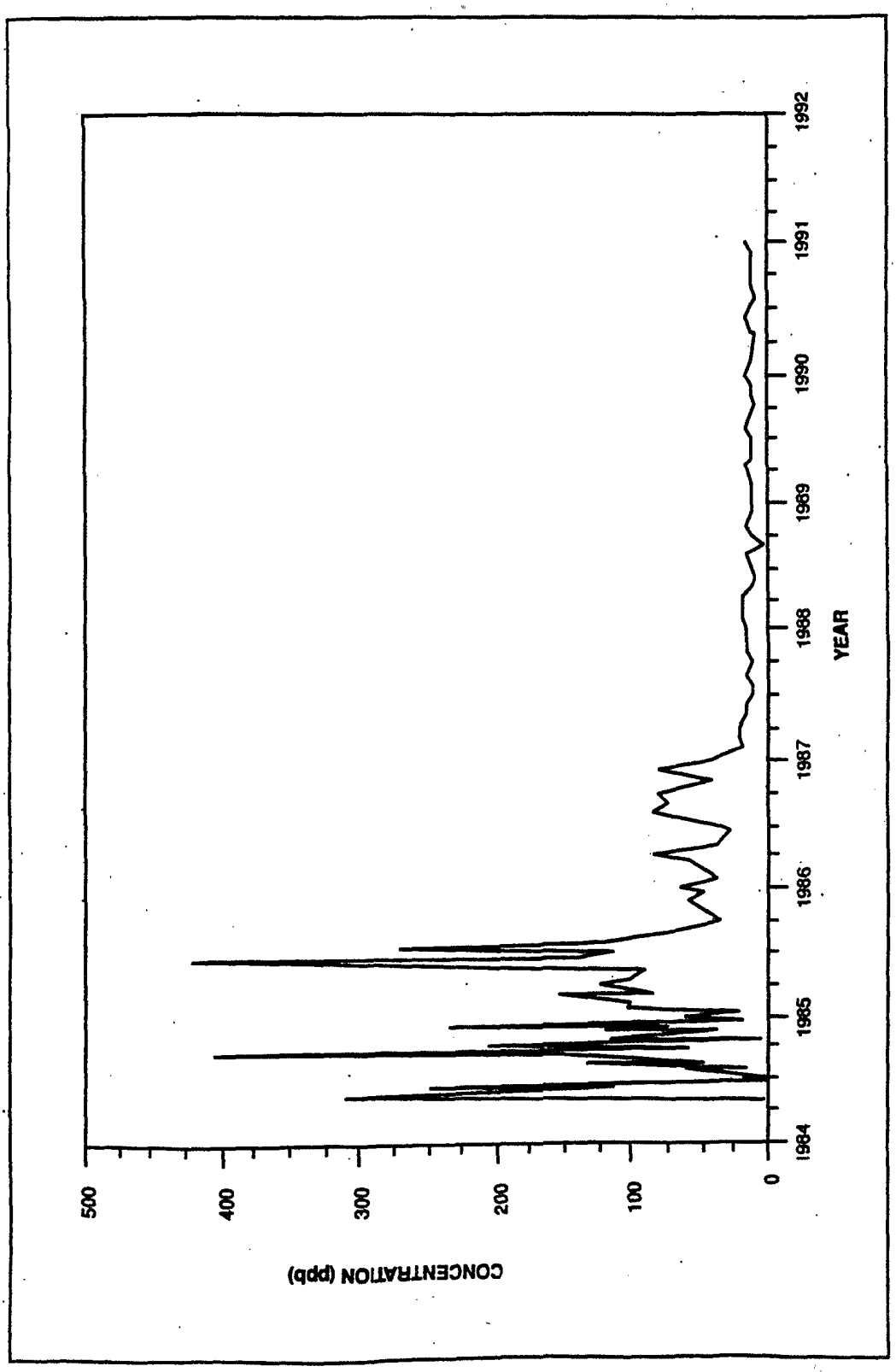

Figure 6
CONCENTRATIONS OF TOTAL VOCs IN THE INFLUENT TO THE GDU AIR STRIPPER
HARRIS CORPORATION SITE

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following a period of shutdown are proof of the presence of DNAPLs at the Harris/GDU site. A longer period of observation is necessary before the potential for DNAPL contamination at the Harris/GDU site can be assessed with greater confidence.

UPDATE BIBLIOGRAPHY/ REFERENCES

CH2M HILL. April 1986. *Assessment of the Harris Corporation Remediation Program.*

Florida Department of Environmental Regulations. May 22, 1991. Letter to Jennifer Sutter of the U.S. EPA.

General Development Utilities (GDU). December 1989. *Water Treatment Plant Operation Report.* December 1989.

GDU. January 16, 1990. Letter from Jose Peralta of GDU to Karen Knight of Ebasco, addressing request for 1989 operational data on GDU production wells.

Geraghty & Miller. November 30, 1989. Letter to Robert Sands, re: Response to GDU/CH2M HILL Letter Concerning the July 1989 Weekly Analysis Report.

Geraghty & Miller. January 1991a. *Harris Corporation Semiconductor Complex Remedial Action Report.*

Geraghty & Miller. January 25, 1991b. Letter to Robert Sands of Harris, re: FDER Review of Building 100 FS/RAP.

Harris Corporation. June 20, 1989. Monthly Status Report, April/May 1989, letter to FDER from Robert Stands.

Post, Buckley, Schuh, and Jernigan, Inc. December 1983. *Harris Corporation Task B-4 Hydrogeologic Study.*

U.S. Environmental Protection Agency (U.S. EPA). October 1989. *Evaluation of Ground-Water Extraction Remedies: Volume 2, Case Studies 1-19, Interim Final.* EPA/9355.4-03.

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UPDATE OF CASE STUDY 10

IBM-Dayton
Dayton, New Jersey

Abstract

Between 1978 and 1984, a system of up to 20 ground-water extraction wells was operated with the goal of aquifer remediation. After pumping was stopped in 1984, the plume of ground-water contamination began to reemerge. Residual dense nonaqueous-phase liquids (DNAPLs) were determined to be the cause, and a new system of wells for plume reduction and control was designed. The new system began operating in late 1990. As yet, not enough performance information is available for judging its effectiveness.

Background Data	
Date of Problem Identification	1977
Extraction Started	March 1978
Types of Contaminants	Volatile Organic Compounds
Primary Aquifer Materials	Sand and silt with clay layers
Maximum Number of Extraction Wells	21 (Original system) 4 (New system)
Maximum Total Extraction Rate	1,000 gpm (Original system) 100 gpm (New system)
Estimated Plume Area	60 acres
Estimated Plume Thickness	80 feet
Maximum Reported Concentrations	1,1,1-Trichloroethane 9,590 ppb Tetrachloroethylene 6,132 ppb

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CASE STUDY UPDATE
IBM-DAYTON

BACKGROUND OF THE PROBLEM

INTRODUCTION

This report discusses events and progress in the remediation of the IBM-Dayton facility from early 1989 through November 1990. The report is an update of the original case study, which was based on data collected through the end of 1988 (U.S. EPA, 1989, Case Study 10).

The IBM-Dayton site is in South Brunswick Township, New Jersey, just west of the town of Dayton (see Figure 1). Until 1985, IBM-Dayton was a manufacturing facility whose activities included producing computer punch cards and inked ribbons for printers. The facility is now used for administrative activities and repairing electronic equipment. Past site activities resulted in the contamination of local ground water by chlorinated organic solvents. Site remediation continues to be under the jurisdiction of the New Jersey Department of Environmental Protection (NJDEP).

The problem was first discovered in December 1977, when contaminants were detected in a South Brunswick Township production well (Well SB-11). The NJDEP determined that IBM-Dayton was one of the major contributors to ground-water contamination at SB-11. IBM determined that chemical-storage tanks near Building 001 (see Figure 2) were the likely sources of the contamination originating from the IBM site.

Operation of IBM's first ground-water extraction well began in March 1978. By 1984, the remediation system consisted of 14 onsite extraction wells and 7 offsite extraction wells. For a short period in 1982, nine onsite injection wells were also operated. In September 1984, pumping in the extraction wells stopped after the plume was reduced to the area around the source; the judgment was that additional pumping would not reduce the plume further. At that time, the ground-water remediation system was reduced to only a well head treatment system on water supply Well SB-11. Eight months after the onsite remediation system was terminated, water-quality monitoring showed renewed growth of the contaminant plume; by 1986, the plume had spread to the downgradient property boundary. In early 1989, the NJDEP approved IBM's long- term plan for ground-water extraction and monitoring to contain the contaminants near their onsite source, and final permits were obtained in September 1990. Well testing and intermittent start-up pumping of the three onsite wells began in October 1990, and continuous pumping of the new system began in November 1990.

The site is underlain by about 110 feet of unconsolidated deposits--primarily formations of silty sand, gravely sand, or clay--above bedrock. Two interconnected aquifers are involved in the ground-water contamination problem. They are (1) the shallow unconfined aquifer consisting of the Pensauken Formation (Pleistocene; silty sand with occasional zones of gravel) and the Old Bridge Sand member of the Magothy Formation (Cretaceous; silty sand); and (2) the lower semiconfined aquifer consisting of the Farrington member of the Raritan Formation (Cretaceous; sand with gravel). These two aquifers are separated by the Woodbridge Clay member of the Raritan Formation (Cretaceous; interbedded sand and clay); the Woodbridge Clay is locally absent under some parts of the site and the affected area (including at Well SB-11). The Brunswick Shale bedrock underlies the Farrington Sand.

The Woodbridge clay is absent in the vicinity of Well SB-11, so ground water withdrawn from Well SB-11 is derived from both aquifers. The direction of ground-water flow in both the shallow unconfined and the lower semiconfined aquifers is dominated by production Well SB-11 northeast of the site. There is also potential for downward vertical flow from the shallow aquifer to the lower aquifer through the intervening clay layer.

Estimates of local aquifer properties are limited to the shallow aquifer. Aquifer tests showed a range in horizontal hydraulic conductivity of 7×10^{-3} to 1.5×10^{-1} centimeters per second with no discernible pattern, indicating that there is significant areal and vertical heterogeneity in the

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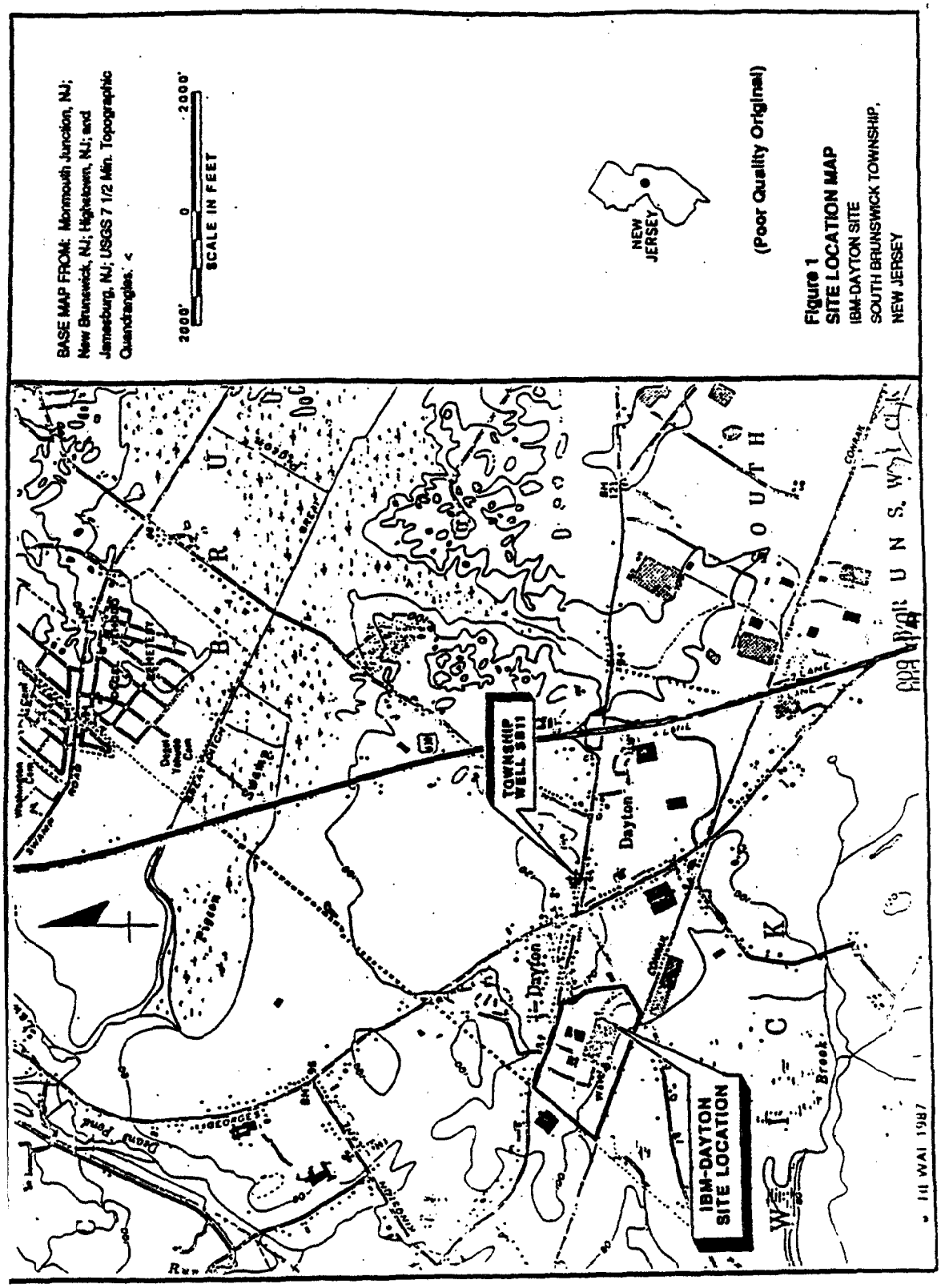

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Figure 1
SITE LOCATION MAP
IBM-DAYTON SITE
SOUTH BRUNSWICK TOWNSHIP,
NEW JERSEY

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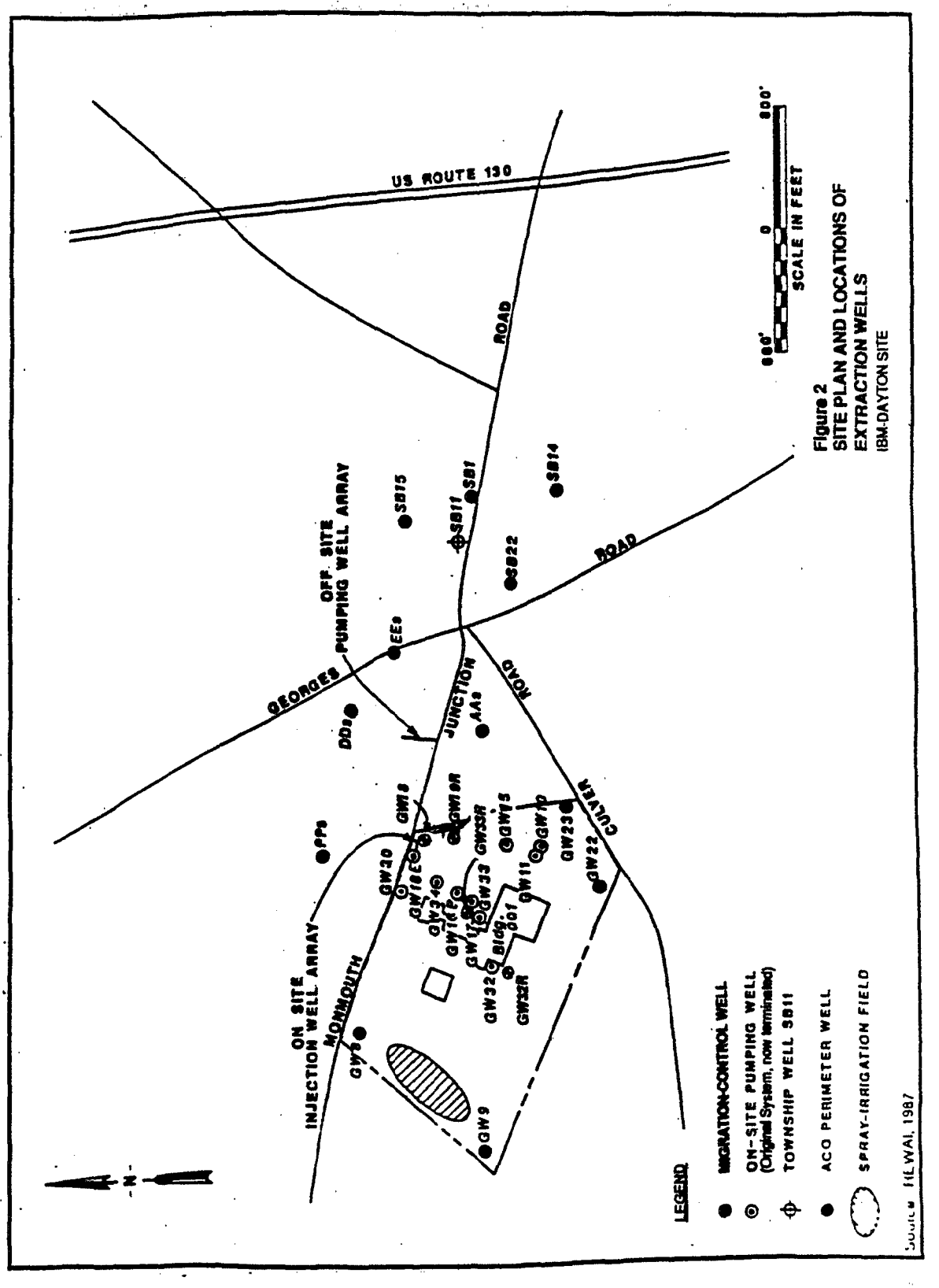

Figure 2
SITE PLAN AND LOCATIONS OF
EXTRACTION WELLS
IBM-DAYTON SITE

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shallow aquifer (REWAI, 1987). The average ground-water transport rate reported for theshallow aquifer at the IBM property is approximately 4 feet per day toward Well SB-11.

The primary contaminants of concern are the volatile organic compounds (VOCs) 1,1,1-trichloroethane (TCA) and tetrachloroethylene (PCE). Lower levels of trichloroethylene (TCE), 1,1-dichloroethylene (DCE), and 1,1-dichloroethane (DCA) were also identified. Initially, TCA was the dominant contaminant relative to PCE. With the termination of pumping in 1984, data indicate that PCE has become the dominant contaminant.

The change in relative concentrations between TCA and PCE may be related to the solubility of these two chemicals (Groundwater Sciences Corp., 1988a). TCA is more soluble and less readily sorbed to soil than PCE is. Therefore, pump-and-treat systems are more effective in removing TCA than PCE.

The suspected sources of the ground-water contamination originating from the IBM site are underground chemical-storage tanks that were removed in 1978, just after the onsite extraction system was started up. The VOC plume centers on the area of the tanks, and highest concentrations of total VOCs are found in the shallow aquifer. Concentrations of total VOCs in monitoring Well GW32 (GW32 is installed in the shallow aquifer in the vicinity of the original spill) decreased from about 15,000 ppb (1978) to 600 ppb (1984) while the extraction system was operating and then increased to about 6,000 ppb (1987) after the system was shut off. Much lower levels (less than 100 ppb in 1984) of total VOCs were found in the offsite plume, which extended in a lobe toward Well SB-11, in response to pumping from that well.

UPDATE ON SITE CHARACTERISTICS

Since the time of the original case study, there have been no significant changes in site administration or in the understanding of the hydrogeologic setting or of waste characteristics.

The densities of ground-water contaminants TCA, PCE, TCE, DCE, and DCA are greater than the density of water, so they have the potential to be present as dense nonaqueous-phase liquids (DNAPLs). The fact sheet for the New Jersey Pollutant Discharge Elimination System (NJPDES) permit (NJDEP, c. 1990) discusses an increase in the concentration of contamination in the ground water with depth near the source and relates this increase to the presence of DNAPL. The reappearance of elevated concentrations of the contaminants after the onsite ground-water extraction system was shut off and the absence of residual soil contamination near the ground surface have led to the conclusion that residual DNAPLs in one or both of the aquifers are the source of the ground-water contamination. IBM feels that the DNAPLs are limited to the shallow aquifer, but the NJDEP does not necessarily share this view.

REMEDIATION

Design and Operational Features of Remediation System

The objective of the ground-water remediation system installed in 1978 was to restore ground-water quality in both aquifers to levels that would be suitable for the municipal drinking water supply. In 1984, when NJDEP authorized the reduction of the remediation system to only wellhead treatment at Well SB-11, an action level of 100 ppb for TCA in any one of the 12 perimeter wells for two consecutive months was established as the point at which IBM was required to notify the NJDEP to determine the need for further remedial action (Groundwater Sciences Corporation, 1988b). Even though this criterion had not been exceeded, IBM decided in 1987 to initiate further remedial action to control the reemerging plume.

The system in place between 1978 and 1982 consisting of 13 onsite extraction wells in the shallow aquifer and 1 extraction well (GW-18E) in the deep aquifer (see Figure 2), operated intermittently in conjunction with Well SB-11. Ground water extracted from the onsite wells was treated by air stripping and then returned to the ground-water system by means of a spray-irrigation field located on the western part of the IBM site (see Figure 2). In 1982, an additional offsite pumping center was added to the system midway between the IBM site and Well SB-11. For a short time, the ground water extracted from the offsite wells was treated and then reinjected to a line of nine injection wells along the northern

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site boundary. The use of the injection wells was eventually stopped because their injection capacities were reduced by well deterioration. The effectiveness of the remediation program was monitored by testing the water quality and measuring the hydraulic performance of both aquifers in nearly 100 monitoring wells. By 1984, the determination was that continued pumping would not further reduce the concentrations in the ground water, so the system was shut down and the concentration of TCA was monitored to alert IBM and the NJDEP of the need for appropriate action.

The objectives of the long-term remediation program implemented in October 1990 are control of the boundary and source of the plume. The determination was that the residual source of the contaminants cannot effectively be removed by ground-water extraction. The remediation is focused on the shallow aquifer. Initially a three-step approach consisting of only boundary control (step 1), followed by combined boundary and source control (step 2), and ending with source control (step 3) was planned. Boundary control (step 1) was to be achieved by pumping Wells GWI-8 and GWI-9R (Figure 2) at 15 and 35 gpm, respectively. Step 2 (boundary and source control) of the remediation plan consisted of installing two new wells (GW32R and GW33R) in the same location as previous Wells GW32 and GW33 and pumping them at 25 gpm each. Concurrently, boundary control would be maintained by continuing to pump GWI-9R at 30 gpm. IBM anticipated that this phase (step 2) of the remediation plan would continue for a minimum of 2-1/2 years.

After concentrations were reduced to the point where boundary control was no longer necessary, step 3 (only source control) would be initiated. This phase of the remediation plan consists of pumping Wells GW32R and GW33R at 25 gpm indefinitely to control the source and prevent the reemergence of the chemical plume. Start-up was delayed during the permitting process and steps 1 and 2 were combined at the initiation of the program.

Currently, boundary-control Wells GWI-8 and GWI-9R and source-control Wells GW32R and GW33R (see Figure 2) are pumping. The rates are 15 gpm for Well GWI-8, 35 gpm for Well GWI-9R, and 25 gpm for Wells GW32R and GW33R (IBM, 1991b). All four of these wells are screened in the shallow aquifer.

The ground water is extracted, treated for metals, then run through an air stripper to remove VOCs before it is finally discharged to a spray field on the site. After the plume between the boundary and the source is reduced to permitted levels (10 ppb for PCE and 33 ppb for TCA), pumping at the boundary wells can be stopped, leaving source control as the final remedial procedure. The expectation is that a minimum of about a year and a half of combined source- and boundary-control pumping will be necessary before the system is reduced to only source control.

EVALUATION OF PERFORMANCE

At this time, there can be no in-depth evaluation of the performance of the new system since it was started in October 1990, and the data available for this report extend to only mid-November of 1990. Quarterly samples continue to be collected, and consultants for IBM Dayton are evaluating the effectiveness of the system. Their evaluation should be available in late 1991. Evaluation of the former system remains as described in the original case study.

Well testing and intermittent start-up pumping began in October 1990, and continuous pumping began in November 1990. Figures 3 and 4 show the water-level distributions in the shallow and deep aquifers that were measured in November 1990. According to IBM, however, the measurements used to construct these ground-water contour maps were collected after the wells were shut off for 12 hours. These ground-water elevations, therefore, do not reflect the response of the water table to pumping of the extraction wells. Well SB-11 was pumping and a distinct zone of influence can be seen around this well in both the upper and lower aquifer. Not known is whether other nearby wells also were exerting influence on the ground-water elevations at the same time.

Figure 5 shows the VOC plume in the shallow aquifer as it was observed in 1987, when the need for long-term migration control was becoming apparent. Total VOC concentrations of more than 1,000 ppb were measured in the onsite plume.

Figures 6 and 7 show the areal distribution of the summed TCA and PCE concentrations measured in the two aquifers in November 1990, shortly after the migration- control system began operating. The summed concentrations are not

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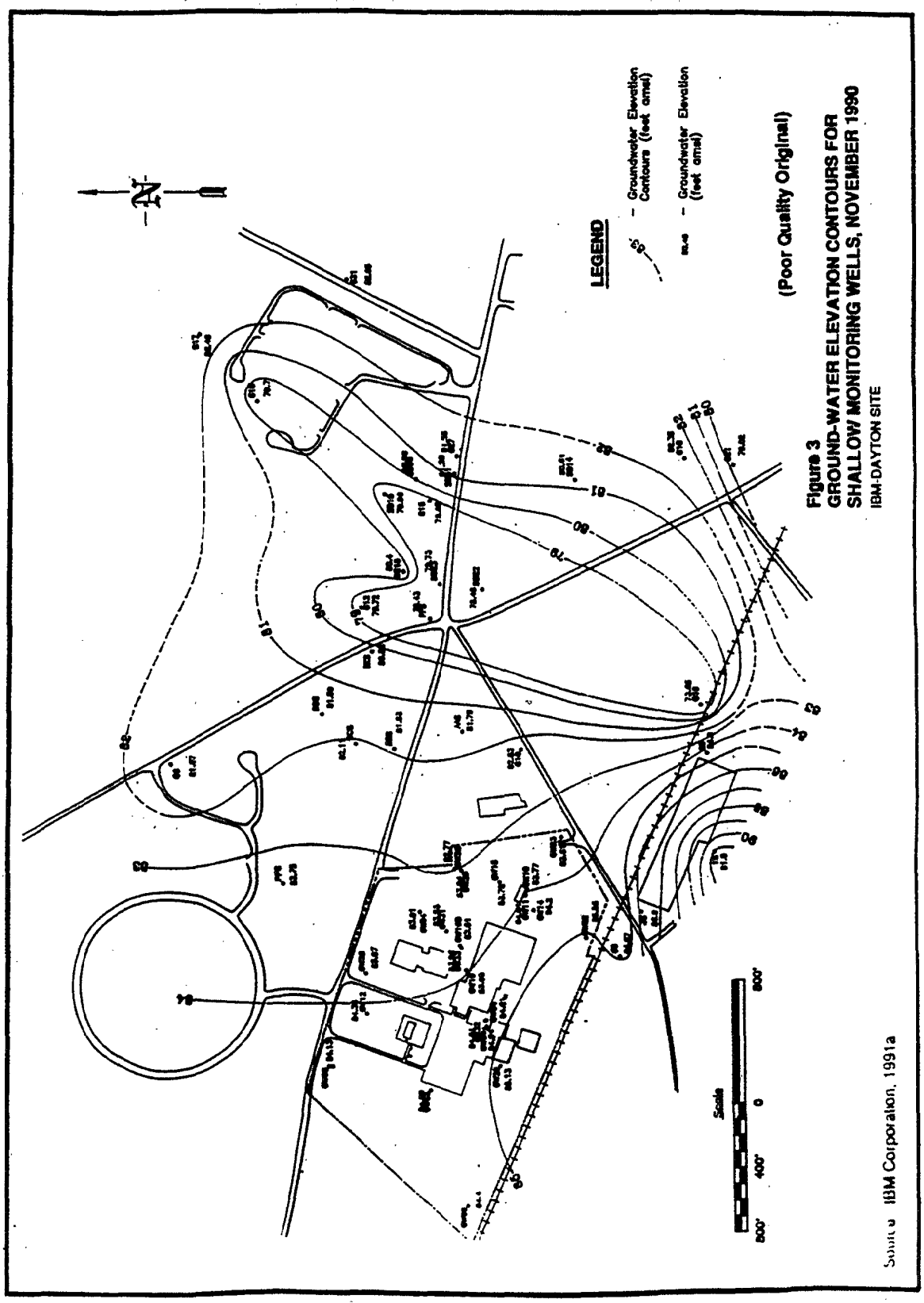

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Figure 3
GROUND-WATER ELEVATION CONTOURS FOR SHALLOW MONITORING WELLS, NOVEMBER 1990
IBM-DAYTON SITE

Source: IBM Corporation, 1991a

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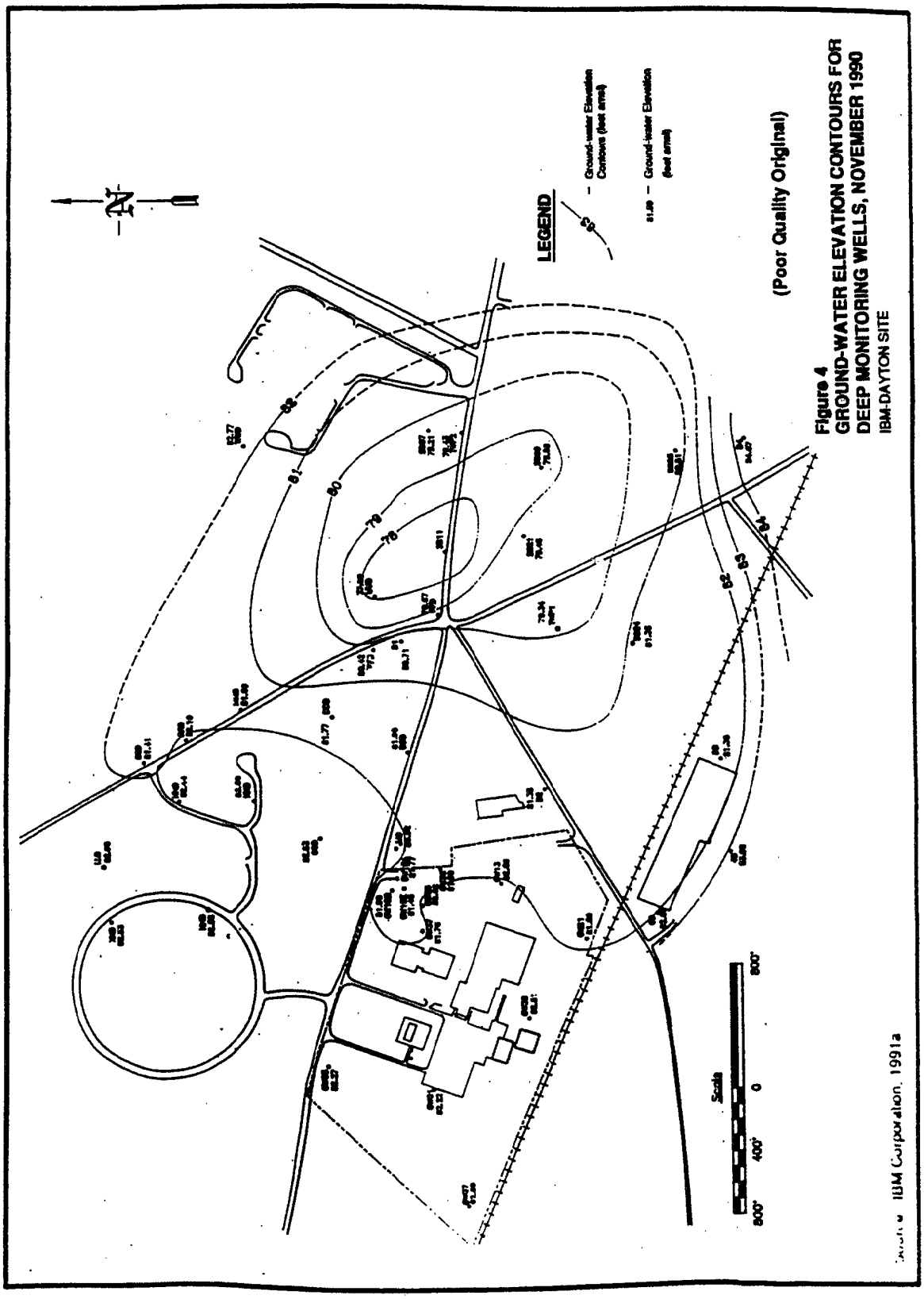

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Figure 4
GROUND-WATER ELEVATION CONTOURS FOR DEEP MONITORING WELLS, NOVEMBER 1990
IBM-DAYTON SITE

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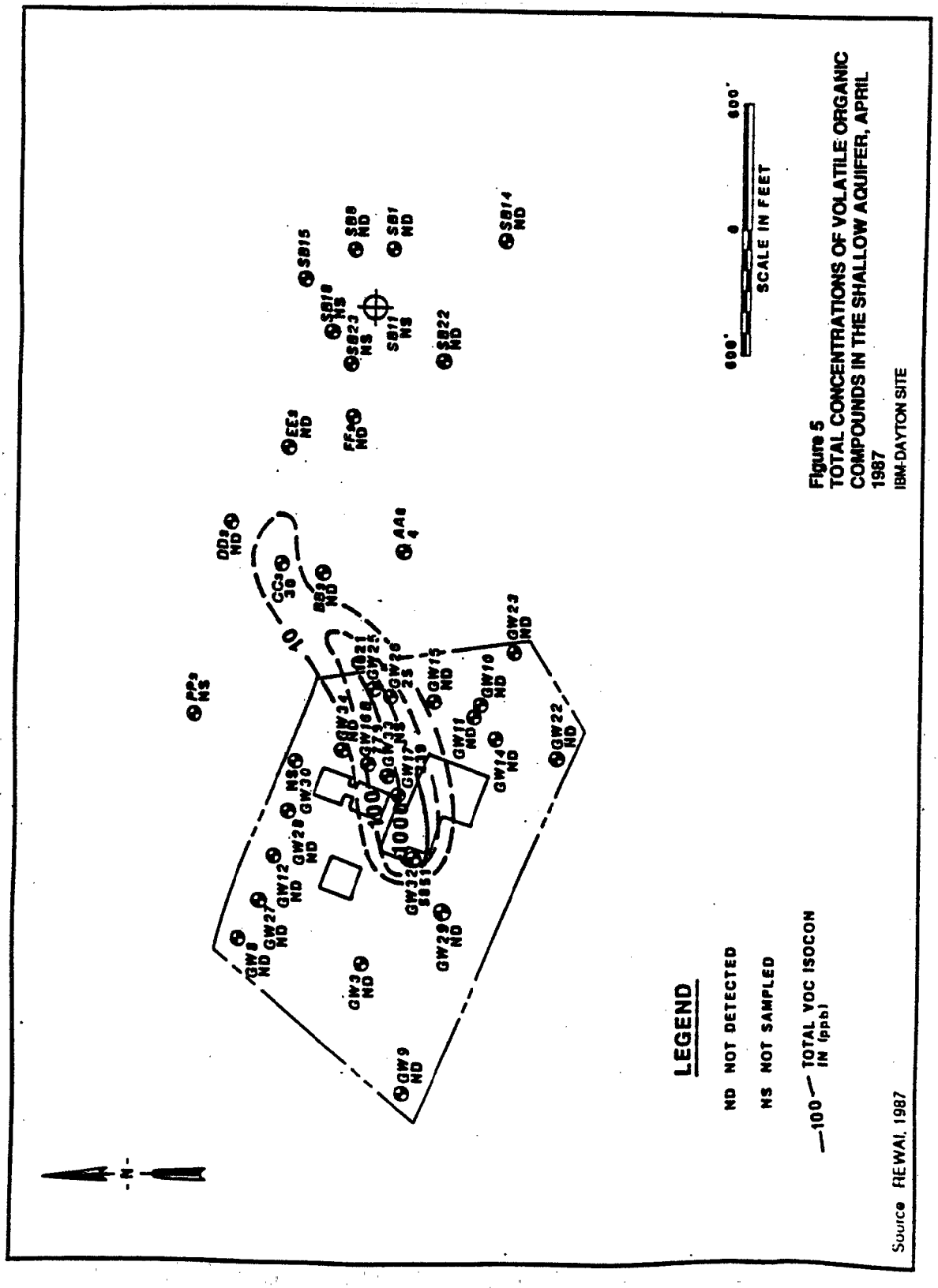

Figure 5
TOTAL CONCENTRATIONS OF VOLATILE ORGANIC COMPOUNDS IN THE SHALLOW AQUIFER, APRIL 1987
IBM-DAYTON SITE

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directly comparable to the total VOC readings shown in Figure 5, but TCA and PCE are the major constituents of the VOCs at the site, and the inference is that the November 1990 concentrations were generally lower than those of April 1987.

Figures 8, 9, and 10 show histories of TCA and PCE concentrations in three onsite wells in the central plume area. They show that PCE concentrations peaked in 1988 for Wells GW-16B and GW-32. A similar peak is shown in 1989 for Well GW-25, which is farther from the source area than the other two wells are. All three figures show that PCE concentrations were declining naturally before the migration-control system was started up in October 1990.

Figure 11 shows that the TCA and PCE concentrations at production Well SB-11 have remained fairly stable at between 20 and 40 ppb since 1985. It is too early to tell what effect the migration-control system will have on Well SB-11. The effect may not be dramatic because the NJDEP has determined that the IBM-Dayton facility is not the only source of the VOCs that contaminate this well.

SUMMARY OF REMEDIATION

Ground-water remediation began at the IBM Dayton site in 1978. Between 1978 and 1984, a system of as many as 21 extraction wells was operated in an attempt to restore the levels of ground-water quality to make the water suitable for a public water supply. In 1984, ground-water extraction was stopped with the expectation that natural attenuation processes would complete the restoration of the aquifer. However, it soon became apparent that VOC concentrations were rising again. By 1987, the maximum total VOC concentration in the reemergent plume was approximately 40 percent of the maximum measured in the 1978 plume.

The new plume was narrower and more sharply defined than the original, appearing to be influenced by the hydraulics of Well SB-11. This well was shut down from January to June 1978, in response to the discovery of ground-water contamination. During that period, ground-water contamination was relatively widespread on the IBM property. Well SB-11 was then restarted and has since been used to control the spread of the plume. Also possible is that additional minor pools or stringers of DNAPL may have been present at the site in 1978 and were cleaned up by the ground-water extraction system, leaving only the solvent-tank area as a distinct residual source of VOC contamination.

Hydrogeologic and water-quality appraisals of the site conducted in 1987 and 1988 led to the conclusion that the resurgence of VOC contamination was caused by residual DNAPL contamination (Groundwater Sciences Corp., 1988a and 1988b). Because of this conclusion, the determination was that the goal of aquifer restoration should be abandoned and that long-term migration control would be necessary instead. A permit for the migration-control system was issued in 1989, but complications in the permitting of the ground-water treatment facility delayed the start of pumping until October 1990. Since then, IBM has collected three rounds of ground-water data--in November 1990, February 1991, and May 1991. Data on ground-water elevation were collected while the extraction system was operating in May 1991. IBM states that this is the only set of data that shows the effect of pumping on ground-water elevations. The data are being studied by IBM's consultant and are not available for inclusion in this report.

SUMMARY OF NAPL-RELATED ISSUES

As noted previously, the reappearance of elevated concentrations after the onsite ground-water extraction system was shut off, coupled with the absence of residual soil contamination near the ground surface, suggested the presence of residual DNAPL as the source of the ground-water contamination (Groundwater Sciences Corporation, 1988b).

Well cluster GW42, among others, is located in the vicinity of a suspected source of ground-water contamination. It consists of a shallow, an intermediate, and a deep well within the shallow aquifer. The NJPDES permit for this facility notes that the water-quality data from this well show increases in contaminant concentrations with depth, and presents this as an indication that DNAPLs are present beneath this site. Table 1 shows the concentrations of TCA in these wells. Some other well clusters show similar patterns, but

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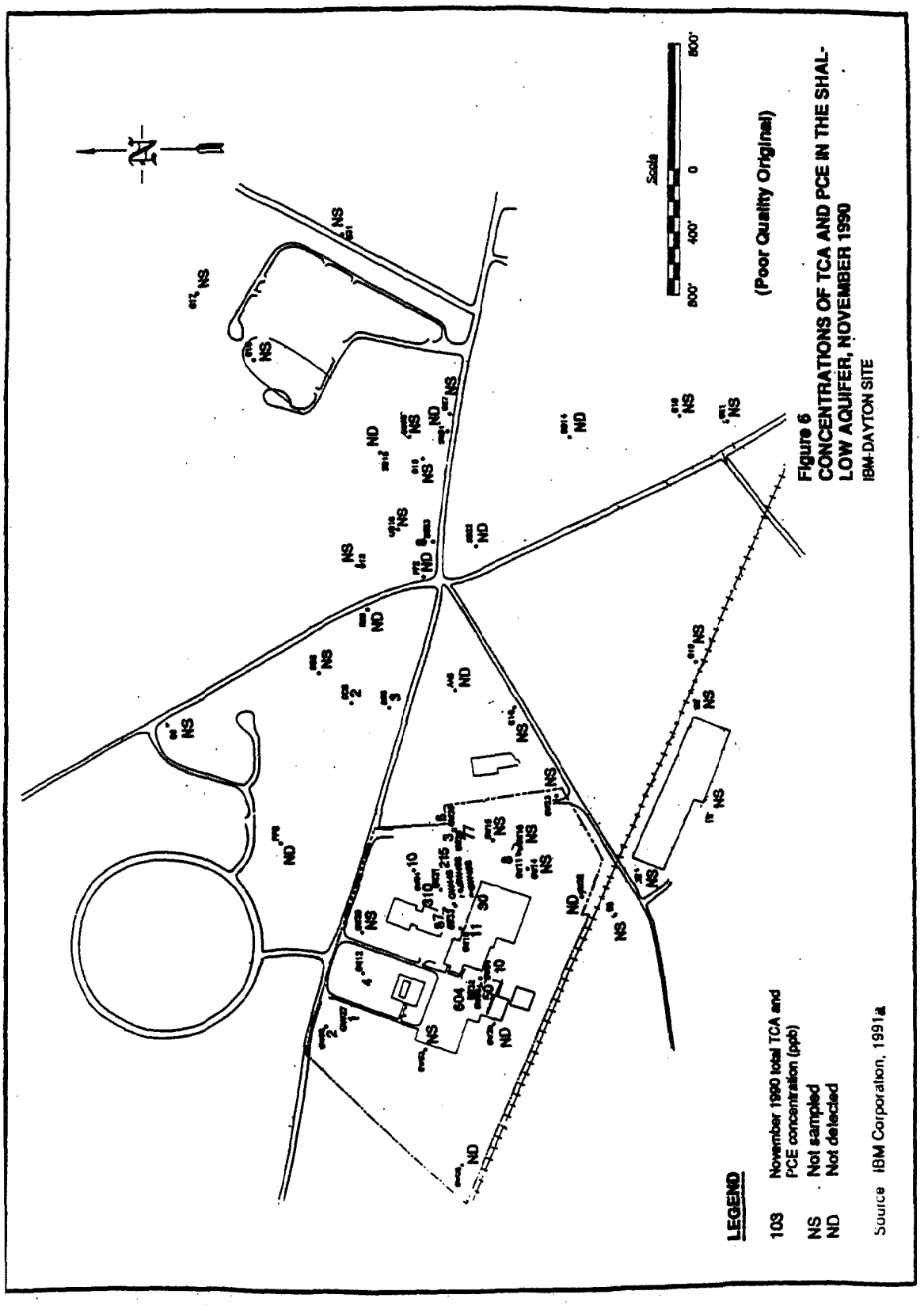

Figure 6
CONCENTRATIONS OF TCA AND PCE IN THE SHALLOW AQUIFER, NOVEMBER 1990
IBM-DAYTON SITE

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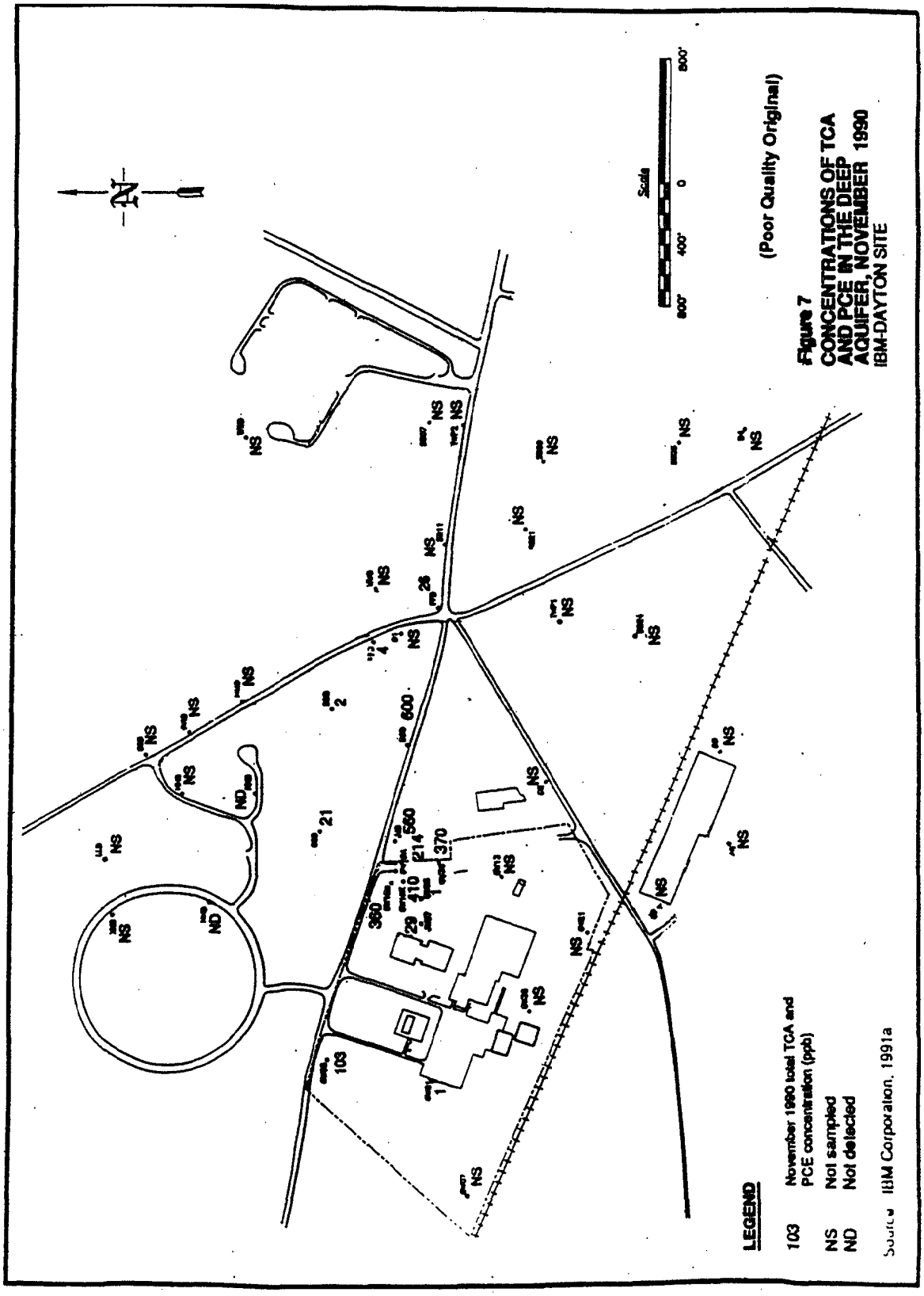
N
Scale
800'
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Figure 7
CONCENTRATIONS OF TCA
AND PCE IN THE DEEP
AQUIFER, NOVEMBER 1990
IBM-DAYTON SITE
LEGEND
103 November 1990 total TCA and PCE concentration (ppb)
NS Not sampled
ND Not detected
Source: IBM Corporation, 1991a

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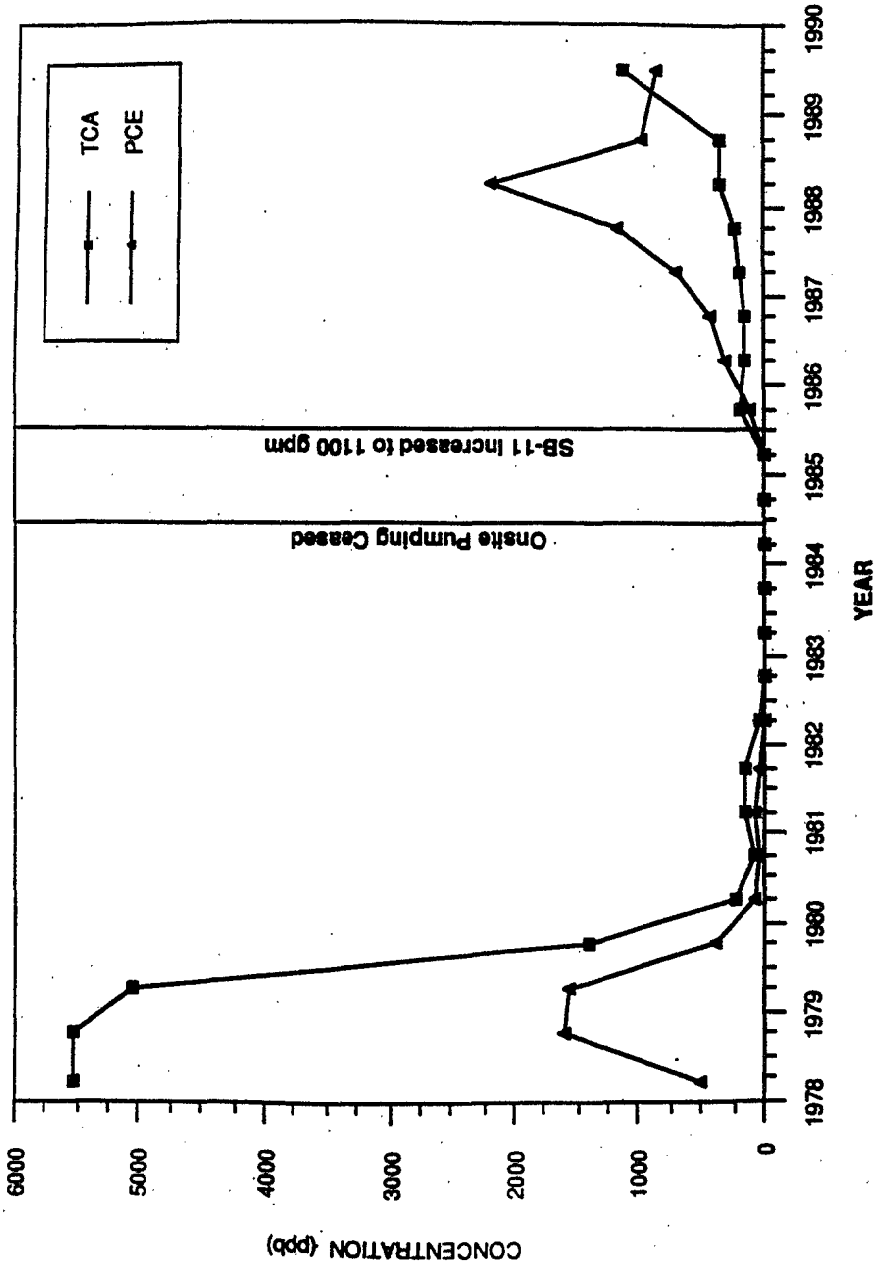

Figure 8
HISTORY OF TCA AND PCE VARIATIONS IN EXTRACTION WELL GW-16B
IBM-DAYTON SITE

Note
Data reported as 6-month average concentrations in ppb.
Data compiled from various sources.

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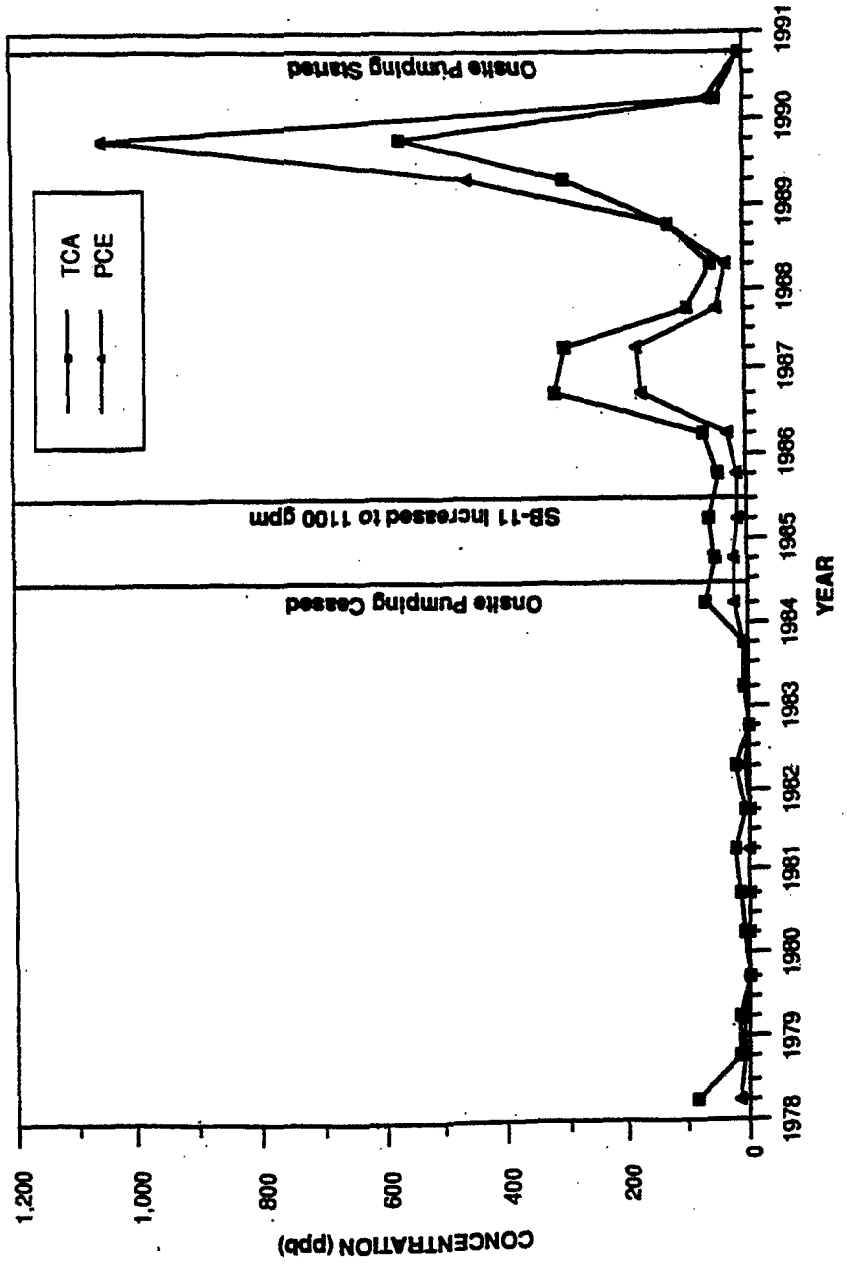

Figure 9:
HISTORY OF TCA AND PCE VARIATIONS IN MONITORING WELL GW-25
IBM-DAYTON SITE

Note
Data reported as 6-month average concentrations in ppb
Data compiled from various sources

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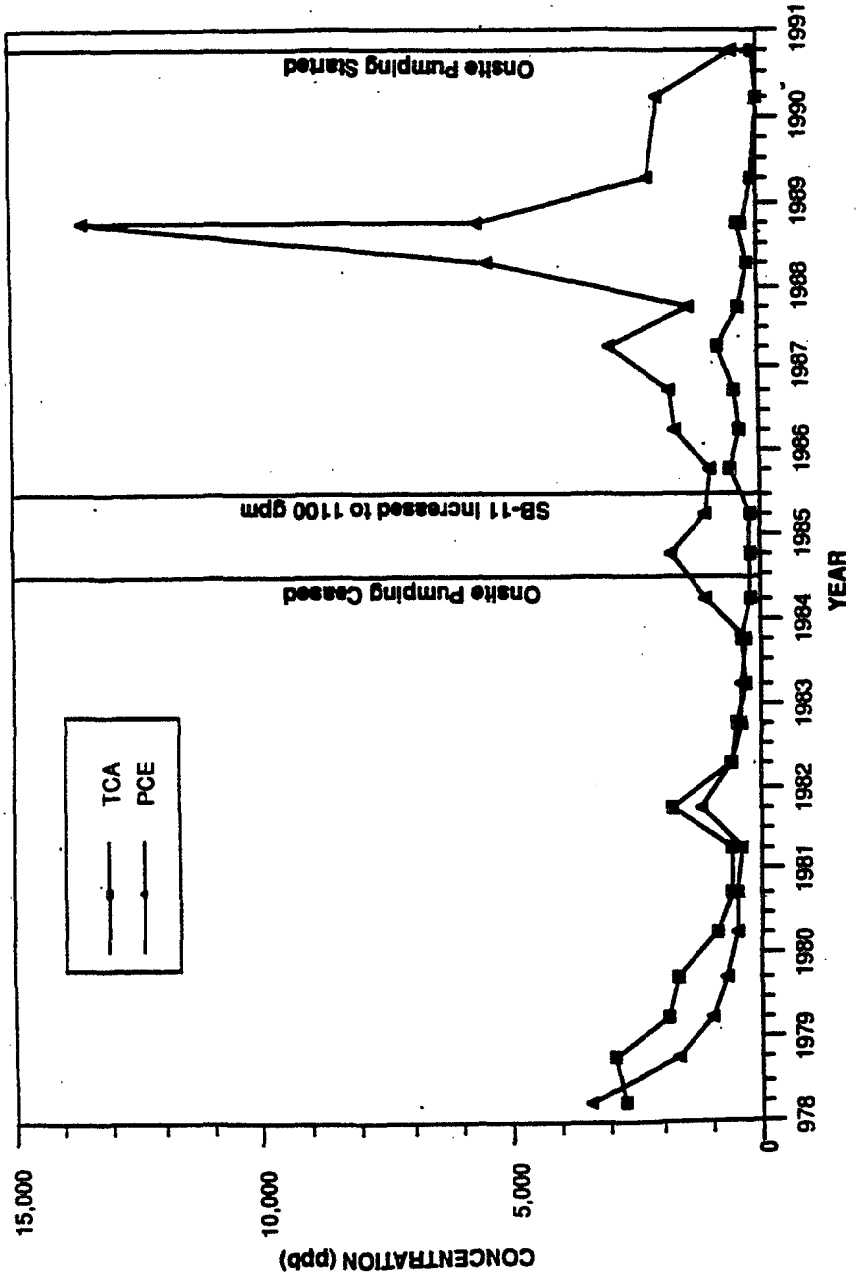

Figure 10
HISTORY OF TCA AND PCE VARIATIONS IN EXTRACTION WELL GW-32
IBM-DAYTON SITE

Note
Data reported as 6-month average concentrations in ppb.
Data compiled from various sources.

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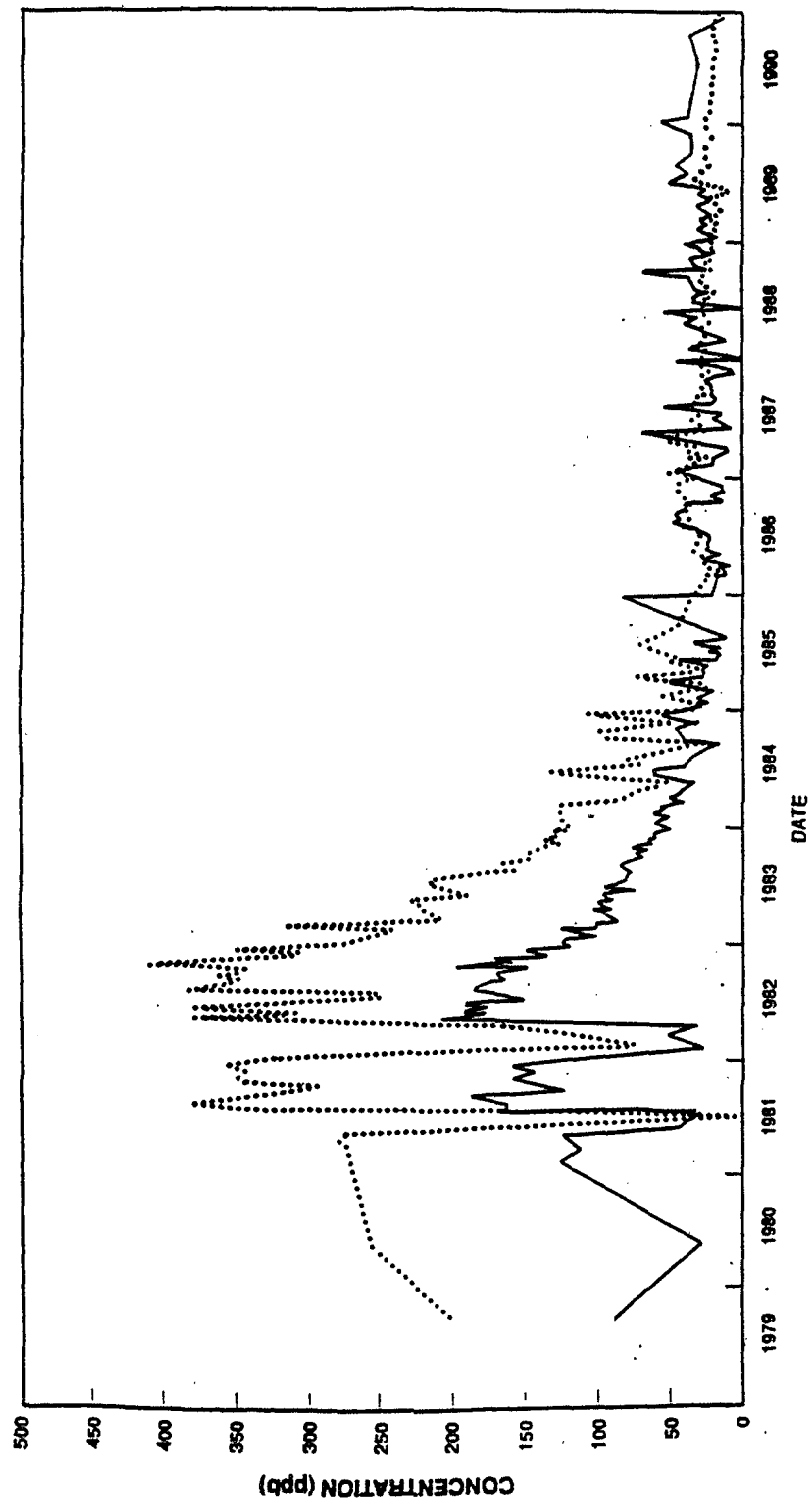

Figure 11
HISTORY OF TCA AND PCE VARIATION AT PRODUCTION WELL SB-11
IBM-DAYTON SITE

LEGEND
TCA .....
PCE ———

Compiled from various sources

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Table 1
SIX-MONTH AVERAGE CONCENTRATIONS OF TCA (ppb)

Well Number	JJ 1985	JD 1985	JJ 1986	JD 1986	JJ 1987	JD 1987
GW42D	3608	2809	3115	5146	5020	7362
GW42I	15	1	3	1	1	1
GW42S	6	4	60	130	53	44

JJ indicates June through July
JD indicates July through December

of important note is that this pattern is not necessarily the same for all the other contaminants or for all the other well clusters in the vicinity of the suspected source.

UPDATE BIBLIOGRAPHY/ REFERENCES

Groundwater Sciences Corporation. 1988a. *Groundwater Remediation Plan: IBM Dayton, New Jersey Facility.*

Groundwater Sciences Corporation, S. Feenstra, and J. Cherry. 1988b. *DNAPL Geochemistry and Remedial Feasibility; Farrington Sand Aquifer; Dayton, New Jersey.*

IBM Corporation. 1989-1990. *Bimonthly Amended Administrative Consent Order Reports for January 1989 to December 1990.*

IBM Corporation. 1990. *NJDPDES/DGW Monitoring Data Quarterly Reports for March through December 1990.*

IBM Corporation. 1991a. *NJDPDES/DGW Monitoring Data Report for November 1990, January 10, 1991.*

IBM Corporation. 1991b. Personal communication with Mr. Jeff Wilson. May 1991.

New Jersey Department Of Environmental Protection. Undated (c. 1990). NJPDES Permit to Discharge Into the Ground Waters of the State. Permit No. NJ0000426.

R.E. Wright Associates, Inc (REWAI). 1987. *Report on the Investigation of Chemical Reappearance in Groundwater at the IBM Dayton Site.*

U.S. Environmental Protection Agency (U.S. EPA). October 1989. *Evaluation of Ground-Water Extraction Remedies: Volume 2, Case Studies 1-19.* EPA/9355.4-03.

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UPDATE OF CASE STUDY 11

IBM-San Jose
San Jose, California

Abstract

The final ground-water extraction system includes 23 new and existing wells. Several of the wells in the new system began operating in October 1990. The remaining new extraction wells were scheduled to begin operating in early 1991. Between 1988 and 1990, little change was observed in the extent of the contaminant plumes. Previously, between startup and 1988, the size of the plume decreased. Freon 113 concentrations in the A aquifer decreased by 1 to 2 orders of magnitude between 1984 and 1990 except for the high concentration area near building 004.

Background Data	
Date of Problem Identification	1978
Extraction Started	May 1982
Types of Contaminants	Volatile Organic Compounds, Oil
Primary Aquifer Materials	Alluvial sand and gravel with silt and clay layers
Maximum Number of Extraction Wells	30
Maximum Total Extraction Rate	6,000 gpm
Estimated Plume Area	760 acres
Estimated Plume Thickness	250 feet
Maximum Reported Concentrations	Freon 113: 16,000 ppb

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CASE STUDY UPDATE
IBM-SAN JOSE

BACKGROUND OF THE PROBLEM

INTRODUCTION

The original case study for the IBM General Products Division site (U.S. EPA 1989, Case Study 11) summarized the remediation of ground-water contamination through May 1989. The IBM facility is located at 5600 Cottle Road in San Jose, California (Figure 1). Magnetic disks and heads for computer hardware are manufactured at this site, using a variety of process chemicals and materials. Ground-water contamination was first discovered at the site in 1978. The primary contaminants were Freon 113, 1,1,1-trichloroethane (TCA), 1,1-dichloroethylene (1,1-DCE), and trichloroethylene (TCE). In 1985, there was an onsite spill of hydrocarbon (Shell Sol 140) that caused additional ground-water contamination. Ground-water extraction in the onsite source areas first began in 1982. Extraction systems at the site boundary and in the midplume area offsite started operating in 1983. In 1984, an extraction system was installed offsite near the downgradient end of the plume. The cleanup is proceeding under the authority of the California Regional Water Quality Control Board.

The IBM facility is located in the Santa Teresa Basin in the southern part of the Santa Clara Valley. Bedrock underlies the Santa Teresa Basin and forms the surrounding mountains. Most of the bedrock consists of consolidated sandstones, shales, cherts, serpentinite, and ultrabasic rocks. The valley floor is underlain by Quaternary alluvium, consisting of unconsolidated clays, silts, sands, and gravels. The thickness of the alluvium ranges from zero in the surrounding highlands to approximately 400 feet near the center of the basin.

The monitored aquifer zones are referred to as the A, B, C, and D aquifers, in order of increasing depth. Deeper aquifers are in some areas, and the aquifers merge in some locations because of discontinuities in the aquitards. The B and C aquifers are coarser-grained than the A aquifer. The B aquifer generally consists of two or three sand or gravel units separated by silt or clay. Declining water levels from 1983 to 1988 had caused the B aquifer to become unconfined in much of the study area. Water levels have since recovered, and the B aquifer is confined once again. The C, D, and deeper aquifers remain confined.

The release of contaminants to soil and ground water may have been the result of surface spills and leaking underground piping. Contamination is found in all five aquifers and is found both onsite and offsite. Remedial measures have been taken only for the A, B, and C aquifers, although all five aquifers are monitored. Target remediation standards are specific for each aquifer. No extraction wells were installed below the C aquifer. Contamination of the A aquifer generally appears to be limited to areas within or near the site boundary. The B and C aquifers are contaminated both onsite and offsite. As reported in the initial case study, Freon 113 and TCA concentrations in the B aquifer were below target remediation standards in the fourth quarter of 1988.

In one area onsite, Shell Sol 140 was released accidentally in late November 1985. Shell Sol 140 is a light cutting oil with properties similar to those of kerosene. Shell Sol 140 contamination was limited to the A aquifer. In December 1985, product-recovery and hydraulic-control activities were implemented at the Shell Sol 140 release area including installing six A-aquifer extraction wells. Product-removal skimmers are used whenever recoverable amounts of free product accumulate in the wells (HLA, 1990d).

UPDATE OF SITE CHARACTERISTICS

This case-study update is based on ground-water monitoring data through September 1990, and additional field investigations conducted after 1988. Additional hydrogeologic information was collected during the predesign investigation for the A-aquifer extraction system (HLA, 1989b). The purpose of the hydrogeologic investigation was to find the most transmissive areas of the aquifer.

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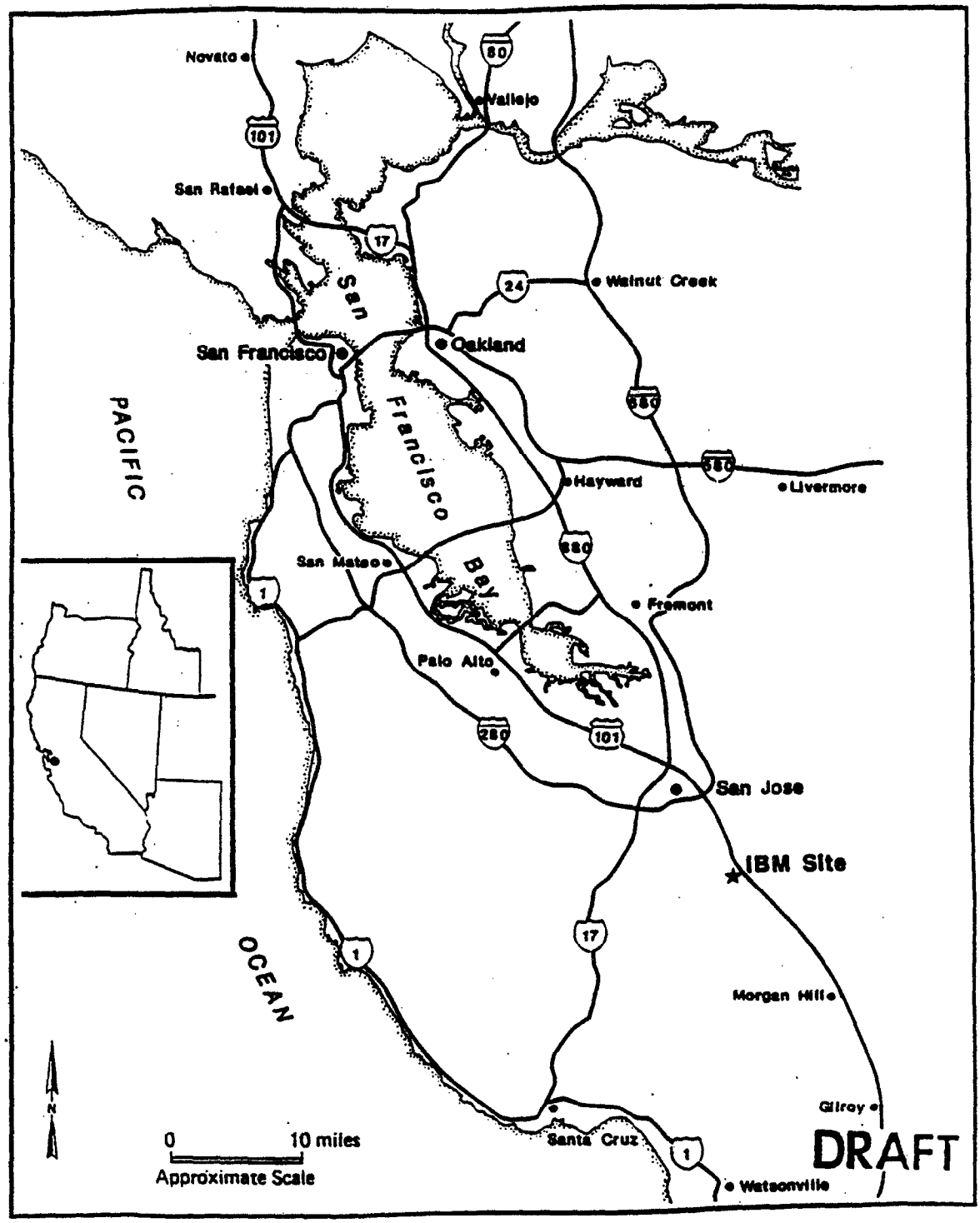

Source: HLA, 1987

Figure 1
REGIONAL MAP
IBM–SAN JOSE SITE
SAN JOSE, CALIFORNIA

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These areas would be the most favorable locations for extraction wells in the A aquifer.

The source areas are underlain by unconsolidated alluvial sediment composed of sand, gravel, silt, and clay. The A-aquifer zone is underlain by the A/B aquitard, which consists of a blue-gray clay. The A aquifer consists of point-bar and channel deposits that were deposited in a braided or meandering stream environment (HLA, 1989b). The point-bar deposits are composed primarily of fine-grained sand and silt and have relatively low transmissivity. The channel deposits are primarily mixtures of sand and gravel (HLA, 1989b).

Ground-water flow in the A aquifer is controlled by the deeper and more continuous channel deposits, particularly when water levels are low. The channel deposits are deepest in areas where the A/B aquitard is thinnest. These thin zones are also where contaminant migration from the A aquifer to the B aquifer is most likely to occur. A map of the high-conductivity channels is presented in Figure 2.

Since the fall of 1985, a general seasonal pattern of decline and recovery in water levels has been observed. However, water levels began a seasonal recovery in the fall of 1988 and continued to rise through the first quarter of 1990 in most B- and C-aquifer wells (HLA, 1990d). Water levels in many of the wells rose more than 20 feet between 1988 and March 1990. Water levels began a seasonal decline in most B- and C-aquifer wells in April 1990, and the decline continued through August 1990. Water levels began increasing again in September 1990 (HLA, 1990d). Water levels in approximately 40 percent of the monitoring wells in the A aquifer remain too low for obtaining representative ground-water samples (HLA, 1990d). Ground-water conservation is a concern and was a significant consideration in the remedial design.

Waste Characteristics

Freon 113, TCA, 1,1-DCE, TCE, 1,1-DCA, PCE, and chloroform are the contaminants of concern in the A aquifer. The primary contaminants in the B aquifer are Freon 113, TCA, and 1,1-DCE. Freon 113, TCA, and 1,1-DCE have been detected at low concentrations in the C aquifer.

Concentration-contour maps were presented for TCA and 1,1-DCE in the original case study because they were the contaminants of greatest concern. Freon 113, a much less toxic contaminant, is suspected to exist as a dense nonaqueous-phase liquid (DNAPL) near the Tank Farm 067 source area. Concentration contour maps for Freon 113 during the second quarters of 1984 and 1986 in the A, B, and C aquifers are presented in Figures 3, 4, and 5. The target remediation standard for Freon 113 is 1,200 ppb for the A aquifer, and 4,500 ppb for the B aquifer. The maximum Freon 113 concentrations observed in ground water in 1988 were well below target remediation goals.

Nonaqueous Shell Sol 140 has been observed since the 1985 spill. The areal extent of Shell Sol 140 free product during 1988 is shown in Figure 6. The area in which aqueous-phase Shell Sol 140 historically has been detected is also shown in Figure 6. The target remediation standard for Shell Sol 140 is 1,000 ppb.

REMEDIATION

Design and Operational Features of Remediation System

As reported in the original case study, three interim ground-water extraction systems consisting of 30 wells were installed at the site: (1) an onsite system near known source areas, (2) an onsite boundary system, and (3) an offsite system. The remedial measures at the site were considered an interim response, pending the approval of a final cleanup plan. In 1986, a long-term, comprehensive ground-water cleanup plan was submitted to the California Regional Water Quality Control Board, the Department of Health Services (DHS), and the EPA. In 1988, the long-term cleanup plan was approved by all three agencies.

As part of the long-term cleanup plan, new ground-water extraction systems were proposed. The predesign field investigation was conducted between September 1988 and February 1989. The areas selected for remediation were those with high aquifer transmissivity and pollutant concentrations that exceed target remediation goals. In the A aquifer, these areas generally correspond to the locations of the channel features.

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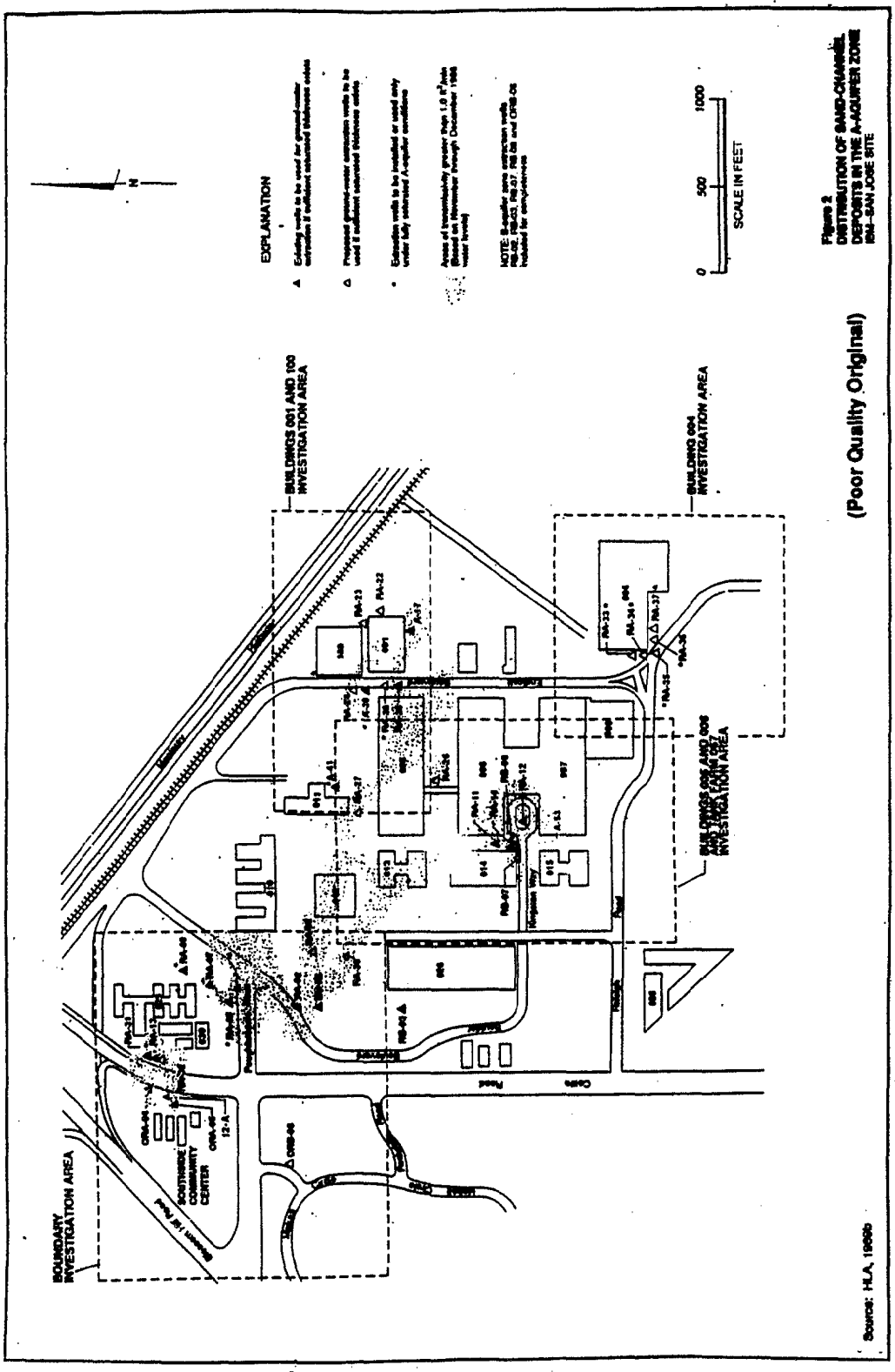

Figure 2
DISTRIBUTION OF SAND-CHANNEL DEPOSITS IN THE A-AQUIFER ZONE
IBM–SAN JOSE SITE

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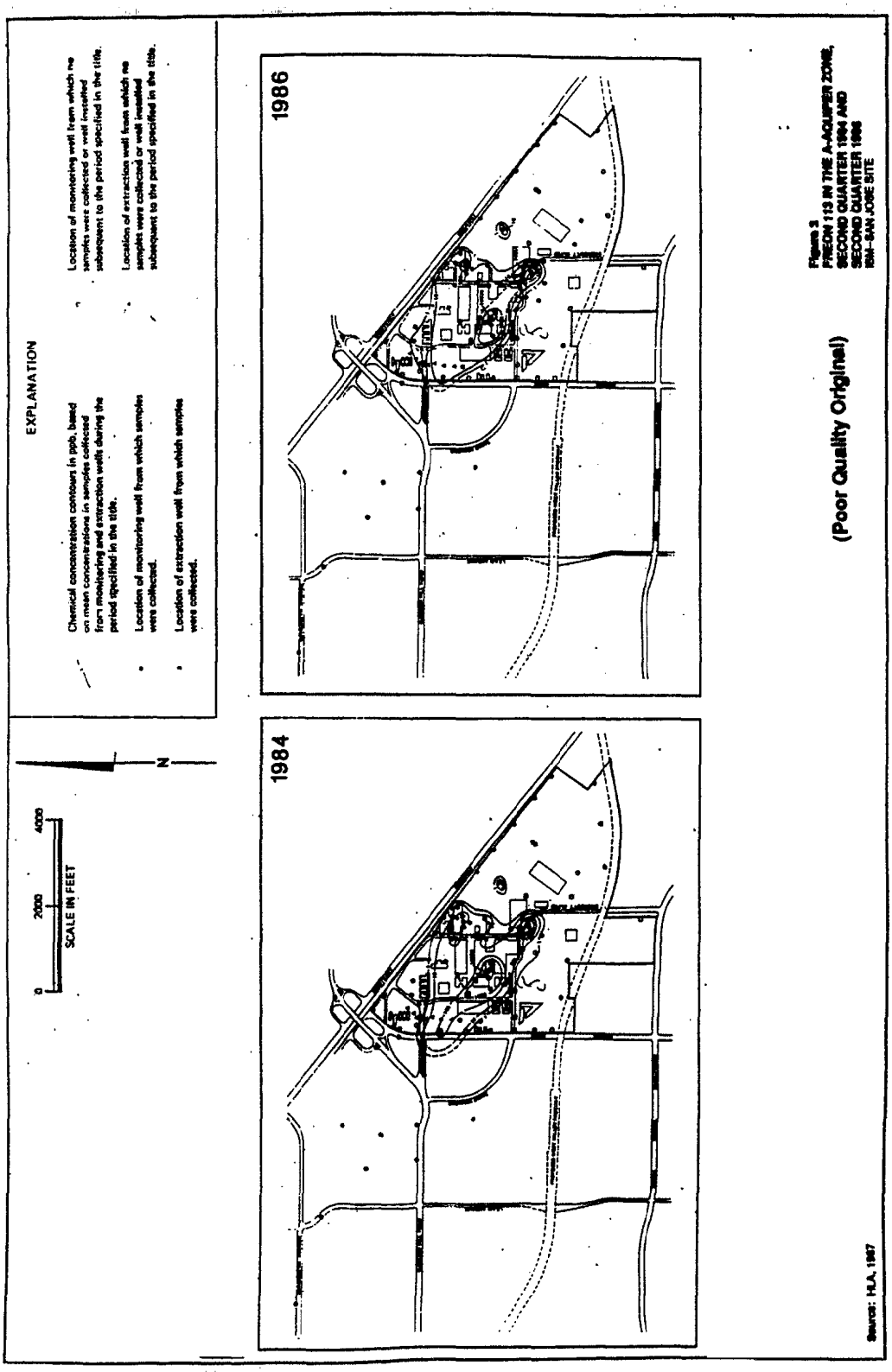

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Figure 3
FREON 113 IN THE A-AQUIFER ZONE,
SECOND QUARTER 1984 AND
SECOND QUARTER 1986
IBM–SAN JOSE SITE

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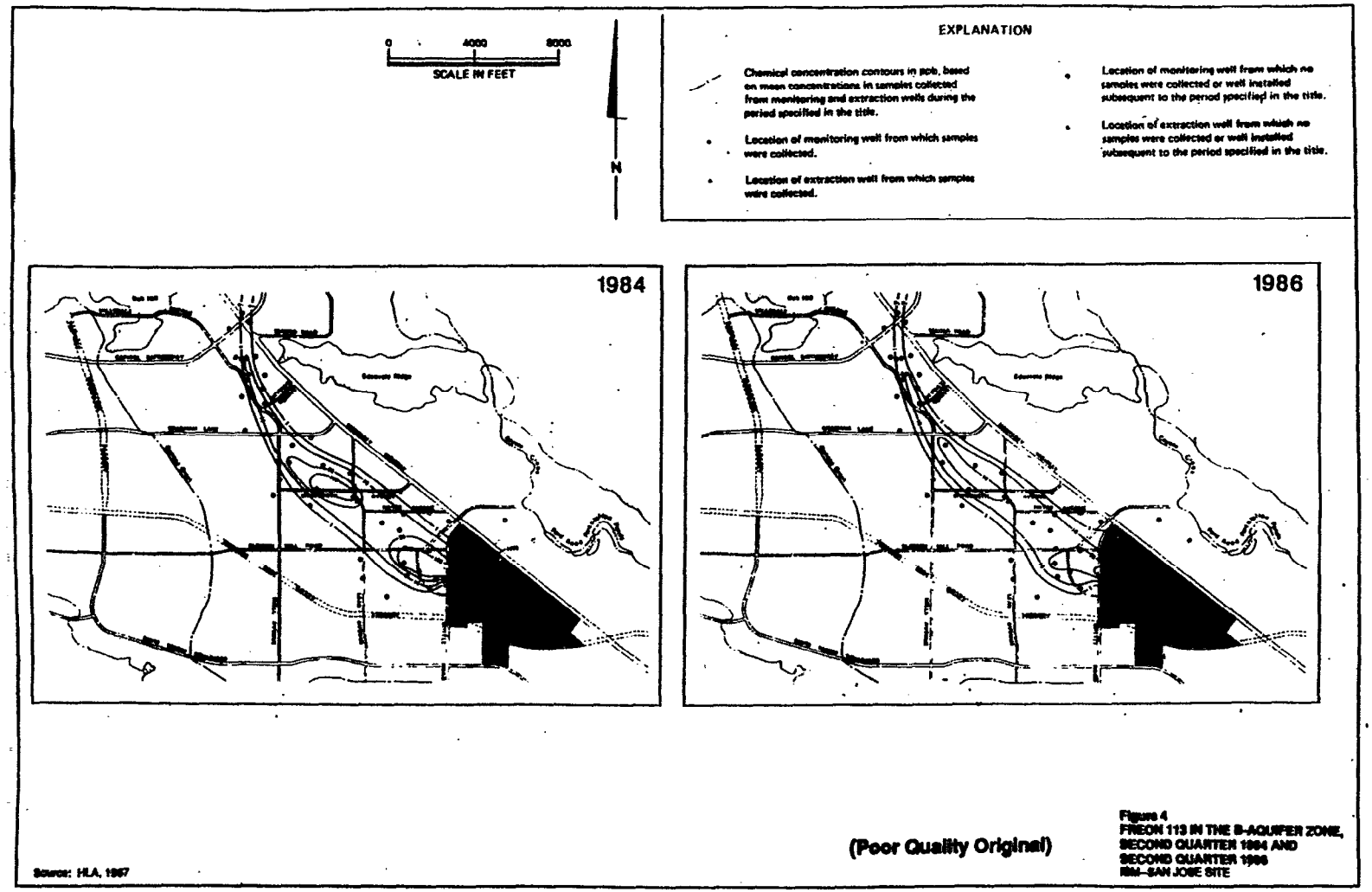

Source: HLA, 1987

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Figure 4
FREON 113 IN THE B-AQUIFER ZONE, SECOND QUARTER 1984 AND SECOND QUARTER 1986
IBM–SAN JOSE SITE

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IBM-San Jose

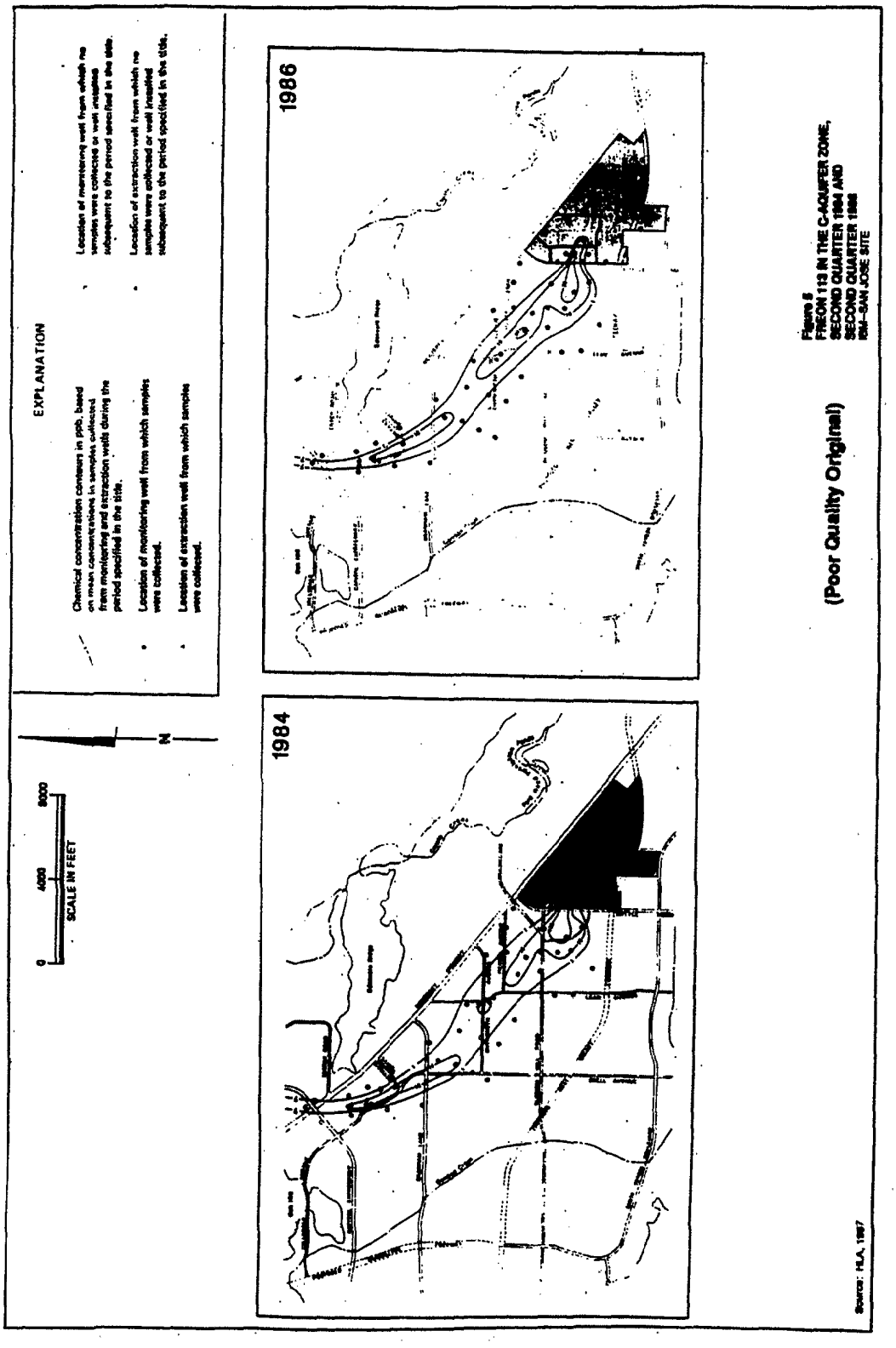

Figure 8
FREON 113 IN THE C-AQUIFER ZONE,
SECOND QUARTER 1984 AND
SECOND QUARTER 1986
IBM-SAN JOSE SITE

(Poor Quality Original)

SOURCE: HLA, 1987

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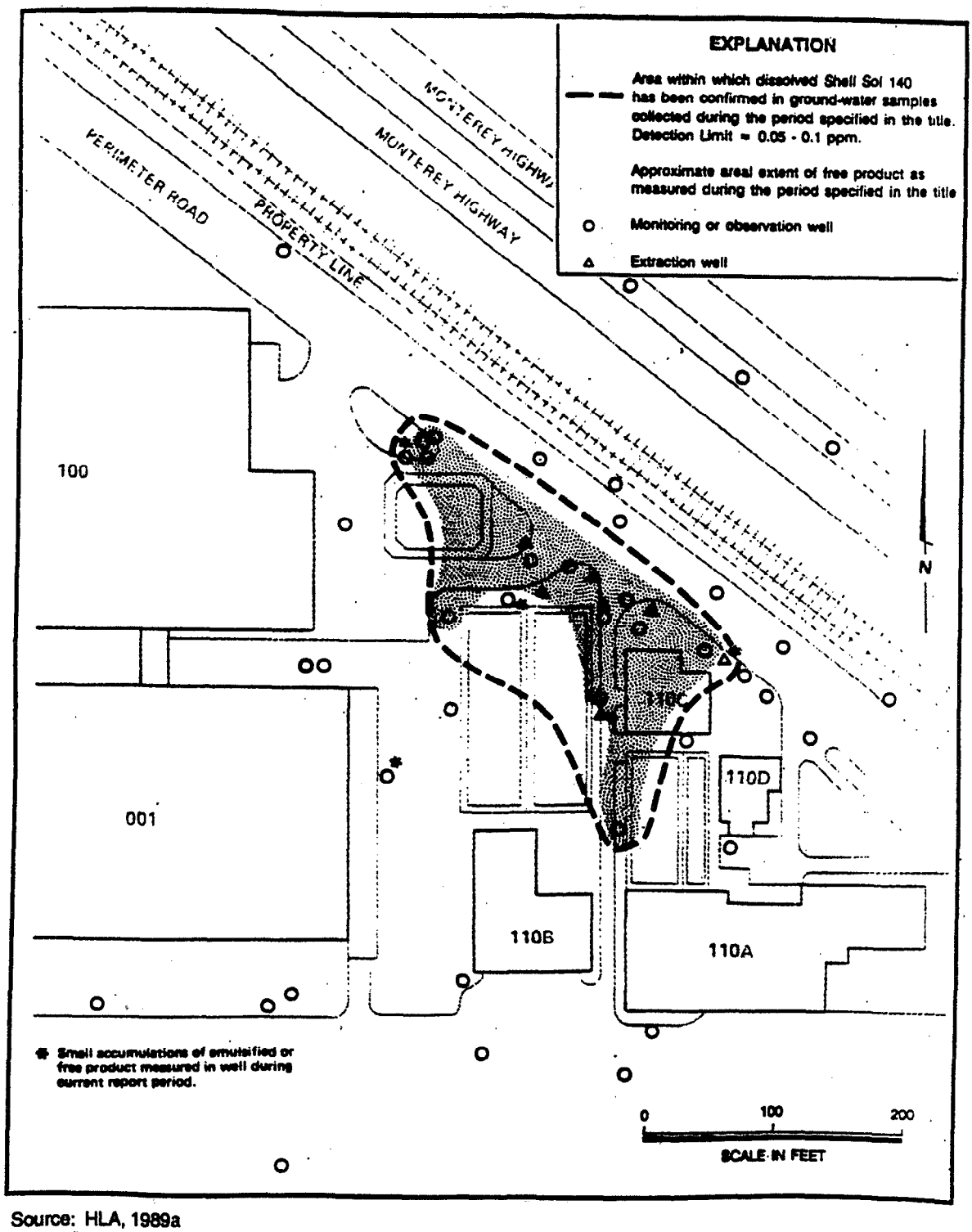

Source: HLA, 1989a

Figure 6
APPROXIMATE EXTENT OF SHELL SOL 140 IN THE A-AQUIFER FROM SEPTEMBER 26, 1988 TO DECEMBER 30, 1988
IBM–SAN JOSE SITE

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The final remedial ground-water extraction system was designed to minimize the potential for dewatering the B aquifer and deeper aquifers. The remedial action plan was developed on the basis of stable ground-water conditions and included contingencies for recovering and declining conditions (HLA, 1989c). An analysis of ground-water and hydrologic conditions showed that ground-water conditions were likely to be relatively stable; therefore, the remedial action plan was implemented without contingencies (HLA, 1989c).

Ground-water conservation is a concern because of steadily declining regional water levels, so alternatives for onsite ground-water reuse were explored. This led to the implementation of a pilot-scale ground-water recharge program, which is discussed later in this case-study update.

Design of Final Extraction System

The final extraction system consisted of wells installed as part of the interim remedial measures (IRM) program and new wells installed as specified in the plan for long-term cleanup. The three separate extraction systems are described below. The final system is expected to begin operating in 1991.

Onsite Extraction System. The interim onsite extraction system was centered on the A-aquifer source areas at Building 001, Tank Farm 067, and Building 006 (shown in Figure 2). The interim onsite system included 8 extraction wells, and the final extraction system includes 10 extraction wells. The A-aquifer well locations are shown in Figure 7. The onsite B-aquifer well locations are shown in Figure 8. The three areas selected for ground-water extraction and their corresponding extraction wells are listed below. The wells identified as existing were installed as part of the interim remedial work.

1. Tank Farm 067 area. (Four existing A-aquifer wells: RA-11, RA-12, RA-14, A-53. Two new B-aquifer wells: RB-7 and RB-8.)

2. Area around Building 005 and Building 006. (Two new A-aquifer wells: RA-26, RA-27.)

3. Building 001/100 area. (Conversion of existing A-aquifer monitoring well: A-17. Three new A-aquifer wells: RA-22, RA-234, and RA-25.)

Wells RA-25, RA-26, RA-27, RB-7, and RB-8 began operating in October 1990. The remaining extraction wells were scheduled to begin operating in early 1991.

Boundary Extraction Systems. The interim onsite boundary extraction system consisted of eight A-aquifer wells, seven B-aquifer wells, and two C-aquifer wells. All eight A-aquifer wells except RA-2 operated from June 1983 to late 1983 or to early 1984, when they were shut down because of low water levels (HLA, 1990b). Extraction Well RA-2 was pumped from June 1983 through October 1984. The pump was replaced with one of lower capacity, and pumping from RA-2 began again in September 1985. Well RA-2 is located in a deep part of the onsite sand-channel deposits (HLA, 1990b).

The final onsite A-aquifer boundary extraction system includes four new extraction wells (RA-29 through RA-32) and one existing well (RA-2) (Figure 7). A-aquifer ground-water extraction from Wells RA-29 and RA-30 began in October 1990 (HLA, 1990b). B-aquifer boundary wells also are in the final boundary extraction system; they include existing Well RB-2, which supplies water to the deionized water system and a new well, ORB-6, which is adjacent to the plant boundary (HLA, 1990b).

Offsite Extraction System. The interim offsite extraction system included three B-aquifer wells (ORB-1, ORBC-2, and ORBC-3) and one C-aquifer well (ORC-1). Wells ORC-1 and ORBC-2 were shut down in April 1988. Well ORBC-3 operated until July 1990. Well ORB-1 continued to operate in February 1991 (HLA, 1991). The final extraction system includes 5 wells: 2 new A-aquifer wells (ORA-04 and ORA-05), 1 converted A-aquifer monitoring well (12-A), and 2 new B-aquifer wells (ORB-6 and ORB-7). Well ORB-6 was installed in February 1990. Well ORB-7 was installed in November 1989. The locations of offsite monitoring and extraction wells in the B and C aquifers, respectively, are shown in Figures 9 and 10.

Ground-Water Extraction Rates. Most of the extraction wells in the interim and final extraction systems have not been operated continuously. Ground-water volumes extracted from each well in 1988, 1989, and 1990 are shown in Table 1.

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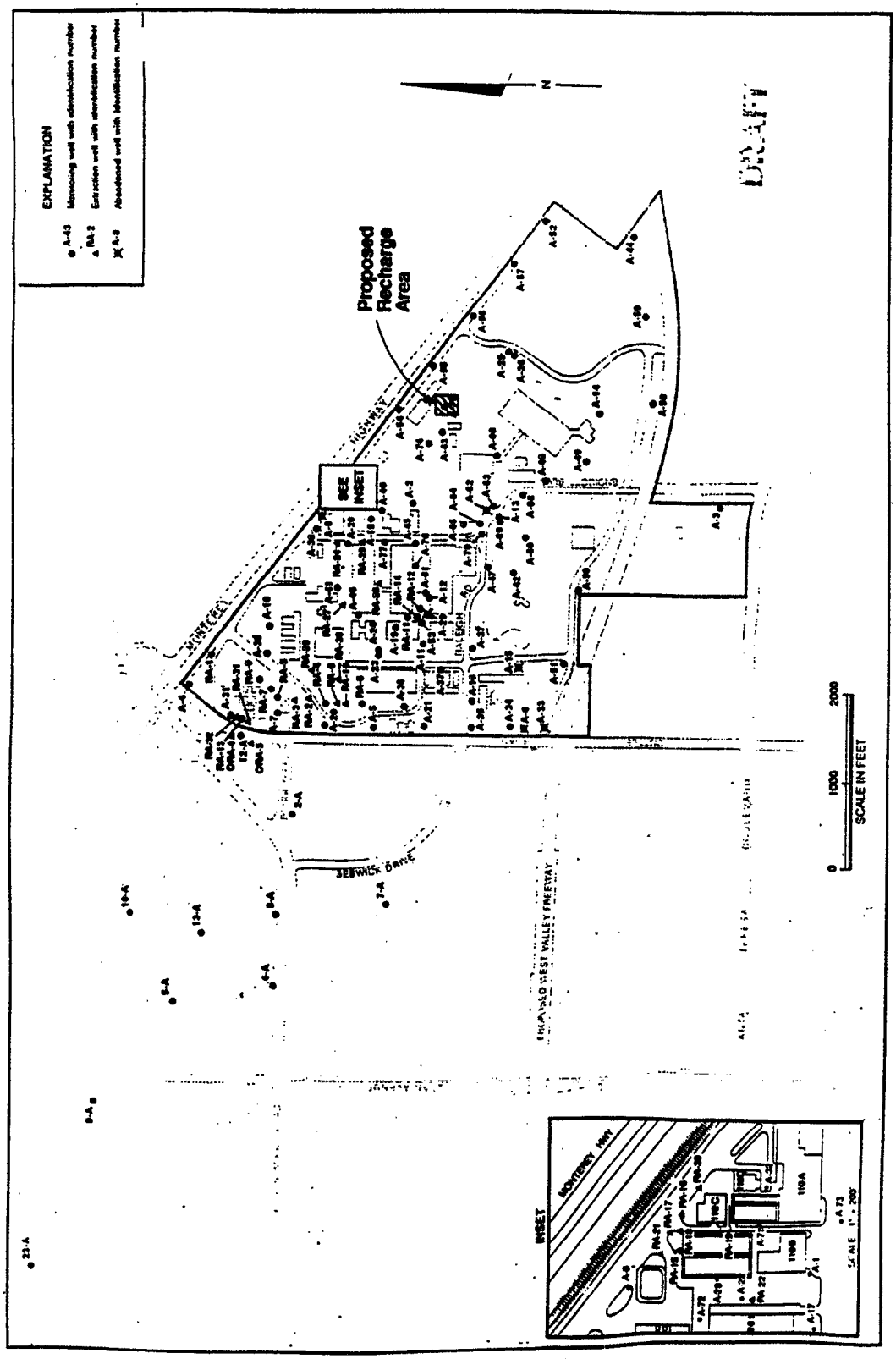

Source: HLA, 1991

Figure 7
MONITORING AND EXTRACTION WELLS IN THE A-AQUIFER ZONE
IBM-SAN JOSE SITE

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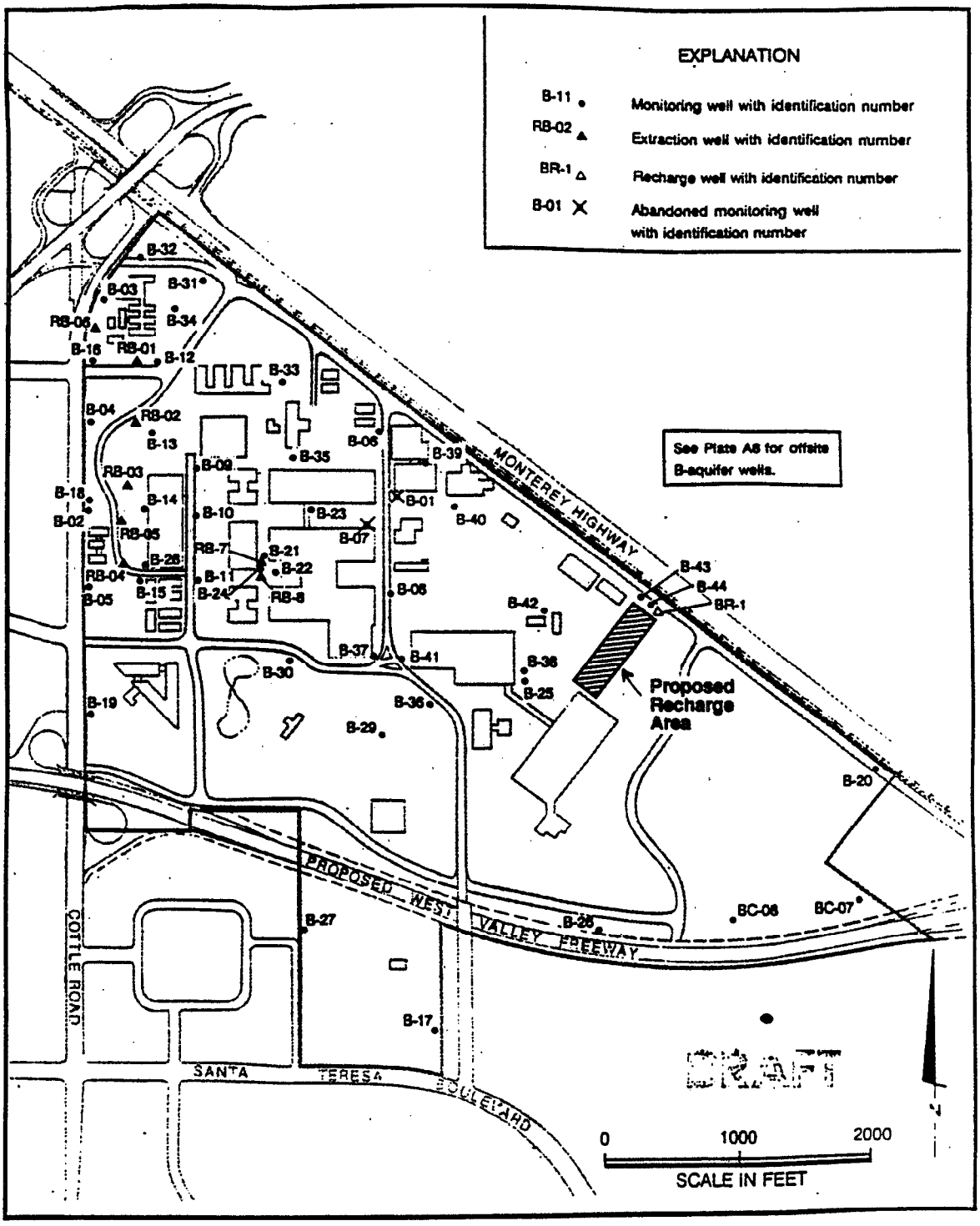

Source: HLA, 1991

Figure 8
MONITORING AND EXTRACTION WELLS IN THE ONSITE B-AQUIFER ZONE IBM–SAN JOSE SITE

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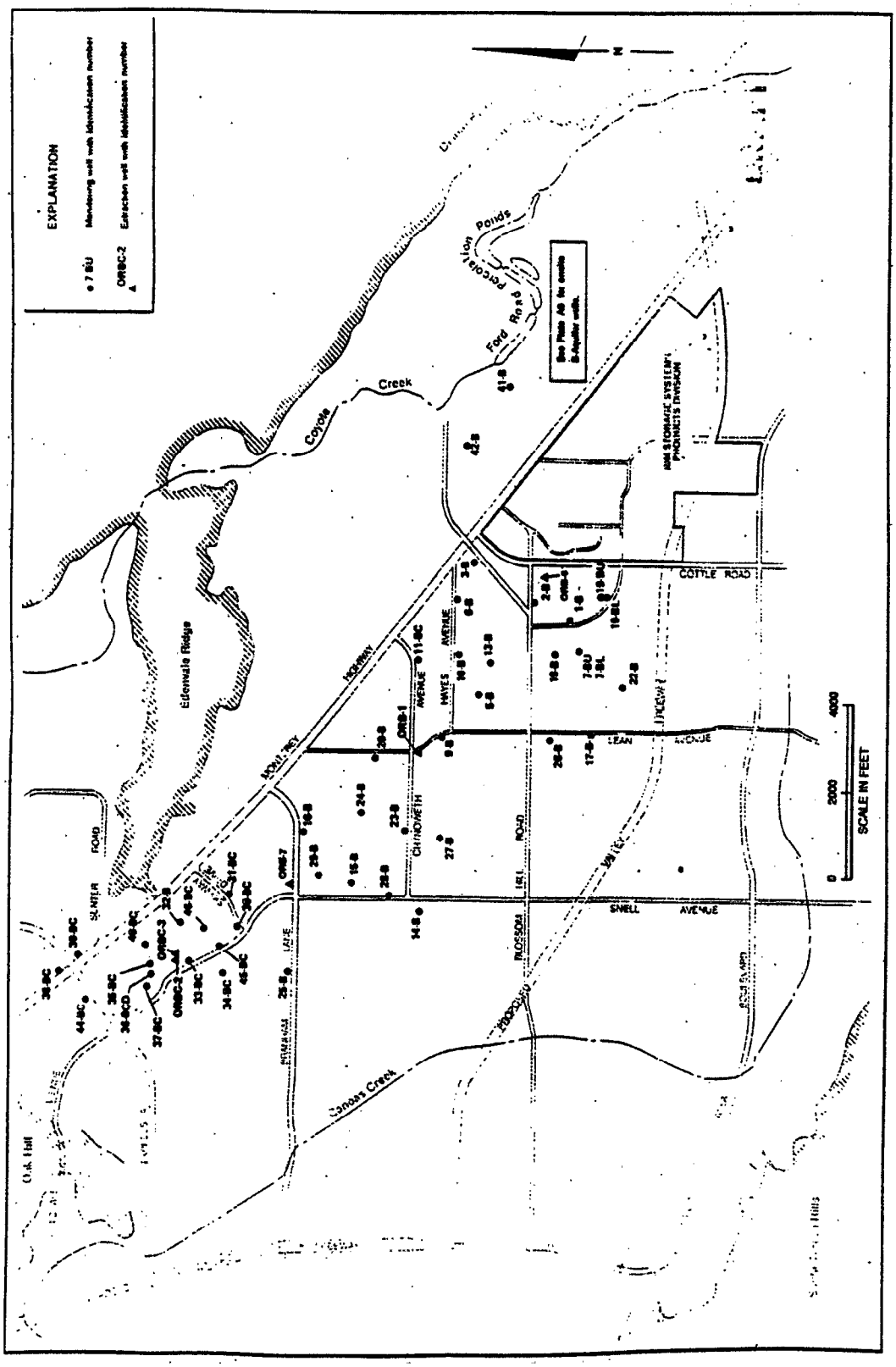

Source: HLA, 1991

Figure 9
MONITORING AND EXTRACTION WELLS IN THE OFFSITE B-AQUIFER ZONE
IBM--SAN JOSE SITE

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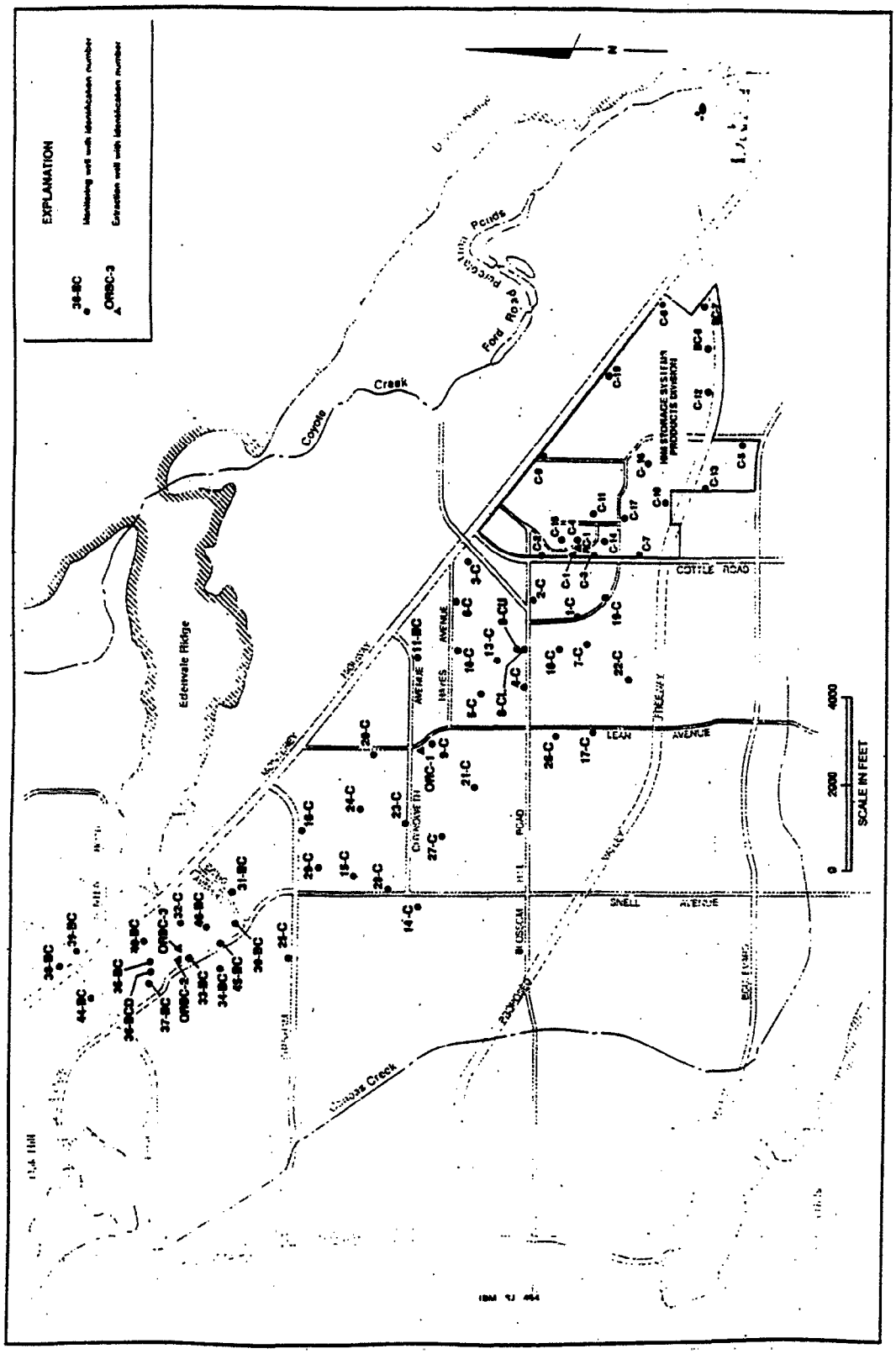

Source: IIIA, 1991

Figure 10
MONITORING AND EXTRACTION WELLS IN THE C-AQUIFER ZONE
IBM--SAN JOSE SITE

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Table 1
TOTAL VOLUME PUMPED FROM EXTRACTION WELLS
1988 - 1990
IBM-SAN JOSE SITE

Page 2 of 2

Year	Well Number	Volume Pumped (million gallons)
1990	RA-2	9.20
	A-53#	0.02
	RA-11#	0.02
	RA-12#	0.02
	RA-14#	0.02
	RA-24#	0.02
	RA-25#	0.66
	RA-27#	1.29
	RA-29#	0.24
	RA-30#	1.18
	RB-2	147.34
	RB-3††	74.41
	RB-7#	8.59
	RB-8#	8.54
	ORB-1	57.10
	ORB-6†	34.65
	ORB-7*	80.92
	ORBC-3††	97.92
TOTAL		522.14

Source: HLA, 1991

Wells on in: *May, †July, #Oct. - Dec.

††Wells off in July

Other unmetered low-flow wells: A-17, 12-A, RA-22, RA-26, RA-31, RA-32, ORA-4, ORA-5

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Table 1
TOTAL VOLUME PUMPED FROM EXTRACTION WELLS
1988 - 1990
IBM-SAN JOSE SITE

Page 1 of 2

Year	Well Number	Volume Pumped (million gallons)
1988	RA-2	14.31
	RB-1*	56.63
	RB-2	138.60
	RB-3	94.83
	RB-4*	4.12
	RB-5*	40.00
	RB-6*	59.74
	C-1*	22.82
	RC-1*	72.47
	ORB-1	29.29
	ORC-1*	47.20
	ORBC-2*	130.08
	ORBC-3	522.60
TOTAL		1232.69
*Wells off in April		
1989	RA-2	3.09
	RB-2	173.47
	RB-3	131.39
	ORB-1	38.27
	ORBC-3	237.36
TOTAL		583.58

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Operation from 1983 through 1990 represents interim ground-water extraction that continued during the construction of the final extraction and treatment systems. Flow rates were adjusted according to well-water levels. The ground-water treatment system was started up in late 1990. Before the new system was constructed, extracted ground water was discharged directly to storm drains with no pretreatment (HLA, 1991). Site operators have stated that the discharged water contained only very low concentrations of contaminants. During startup, extraction rates varied, depending on treatment plant capacity. After startup of the treatment plant is completed, and when either drought conditions no longer exist or a reuse is established for the entire flow, ground-water will be extracted from each well at or near the design flow rate (IBM, 1991). The design extraction rates for the final system are shown in Table 2. The total design ground-water extraction rate is 870 gpm. The final extraction and treatment system is expected to be operating in 1991 (IBM, 1991).

Ground-Water Recharge

Recharge of extracted ground water after treatment is being considered as an onsite ground-water use. Pilot testing for ground-water recharge began in late 1990. The pilot study is being conducted at one well to evaluate recharge rates, aquifer response, and well efficiency (McLaren, 1990). The proposed recharge areas for the A and B aquifers are shown in Figures 7 and 8. At the conclusions of the pilot recharge testing, the feasibility of full-scale recharge will be determined.

It is estimated that 20 gpm could be recharged through the proposed A-aquifer recharge area. However, cost analysis has shown that recharge to the A aquifer would not be a cost-effective means of reusing ground-water at such a low rate (HLA, 1990a). A-aquifer recharge is proposed only if the A-aquifer extraction system becomes ineffective because of low water levels.

The recharge areas were identified on the basis of hydrogeologic analyses. The areas are located upgradient of the chemical plumes to minimize the potential of spreading the plume and to enhance the extraction systems by flushing contaminated ground water through the aquifer zone. In the recharge area, the A aquifer consists of as much as 30 feet of permeable sand and gravel having a saturated thickness of 13 feet (HLA, 1990a). Water levels could rise quickly in a discontinuous sand and gravel lens; therefore, careful monitoring would be required. The B aquifer is better suited for recharge. It contains up to 45 feet of highly permeable sand and gravel that are relatively homogeneous and continuous over the site.

Soil-Vapor Extraction

Pilot-scale tests of soil-vapor extraction (SVE) are also being conducted. The intent of SVE is to reduce VOC concentrations in onsite source areas. The preliminary SVE areas are shown in Figure 11. The Shell Sol 140 spill area is one of the areas. Table 3 gives the estimated cumulative mass of contaminants removed by SVE through the third quarter of 1990. In the Building 004 area, 1,177 pounds of VOCs were removed in 340 hours of operation. In the Shell Sol 140 area, 8 pounds of petroleum hydrocarbons were removed in 56 hours of operation. IBM plans to install a full-scale SVE system.

EVALUATION OF PERFORMANCE

Hydraulic Control

Figure 12 shows that the water-level contours in the A aquifer in September 1990 were similar to those in June 1986, presented in the original case study. The effect of extraction well RA-2 (near Poughkeepsie Road) is apparent in both 1986 and 1990. No other A-aquifer extraction wells were operating in September 1990. Flow in the A-aquifer zone is to the southwest over much of the site but is northeast to northwest in the western part of the site.

In September 1990, flow in the B-aquifer zone at the site was to the northwest, as shown in Figure 13. Extraction wells operating in September 1990 include RB-2, ORB-1, ORB-6, and ORB-7. These wells do not appear to have a significant effect on ground-water flow in the B-aquifer zone. In 1986, however, the cones of depression around extraction wells ORBC-2, ORBC-3, ORB-1, and RB-3 were evident. The extraction rate from the B aquiferwas 1,550 gpm in 1986 and 400 gpm in September 1990. The final design extraction rate for the onsite and offsite B-aquifer wells is approximately 800 gpm.

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Table 2
ESTIMATED FINAL SYSTEM EXTRACTION RATES
IBM--SAN JOSE SITE

Well	Flow Rate Final Conditions (gpm)
12A	2
A-17	6.0
A-53	3.8
ORA-04	2
ORA-5	2
ORB-06	195
RA-2	33.5
RA-11	3.8
RA-12	3.8
RA-14	3.8
RA-22	1.8
RA-24	8.5
RA-23	5
RA-25	13.5
RA-26	3
RA-27	41
RA-29	33.5
RA-30	22
RA-31	7.5
RA-32	10
RB-02	260
RB-07	105
RB-08	1-5
TOTAL	872

Source: Kennedy, Jenks, Chilton, 1989.

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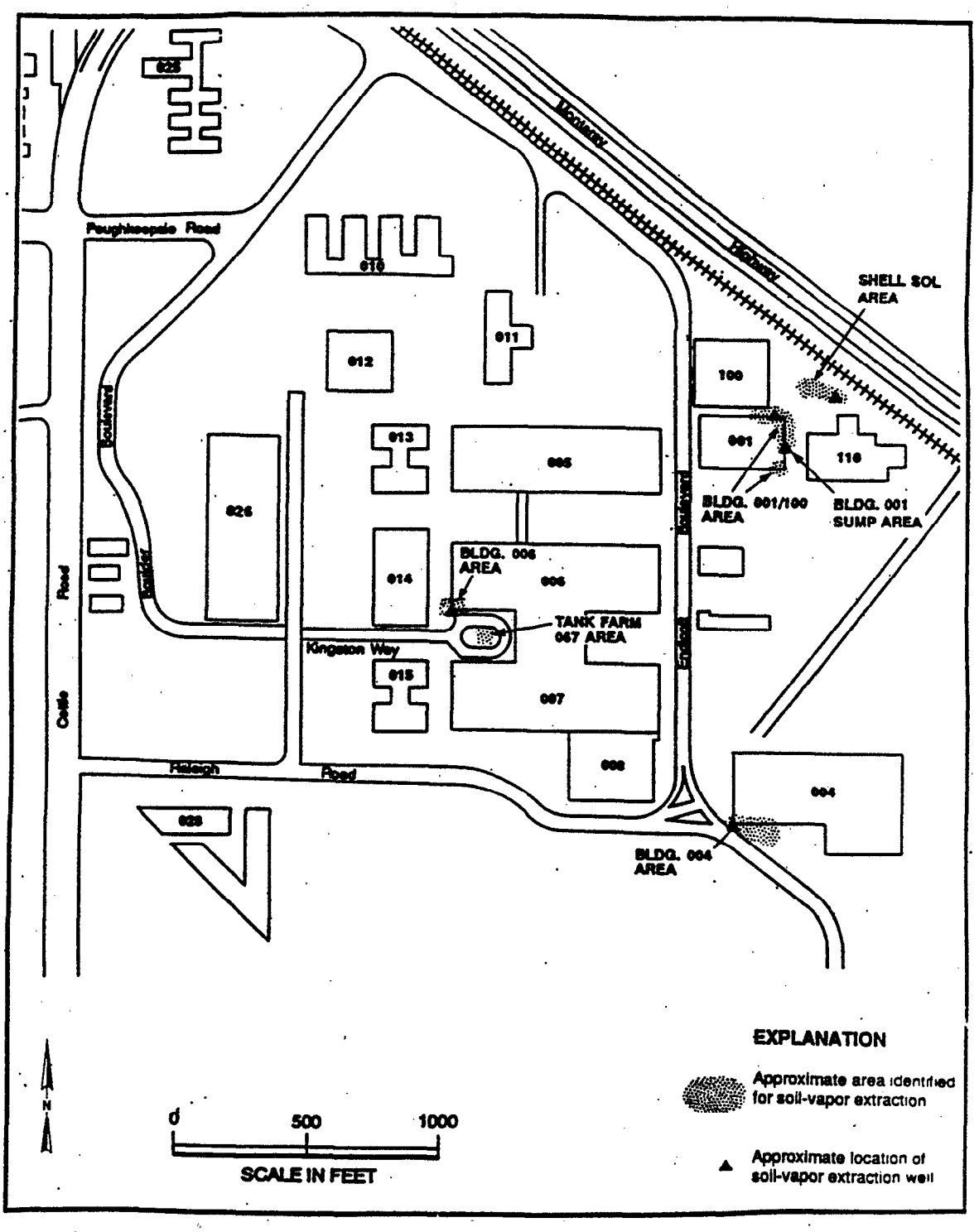

Source: HLA, 1990d

Figure 11
PRELIMINARY AREAS FOR SOIL-VAPOR EXTRACTION
IBM–SAN JOSE SITE

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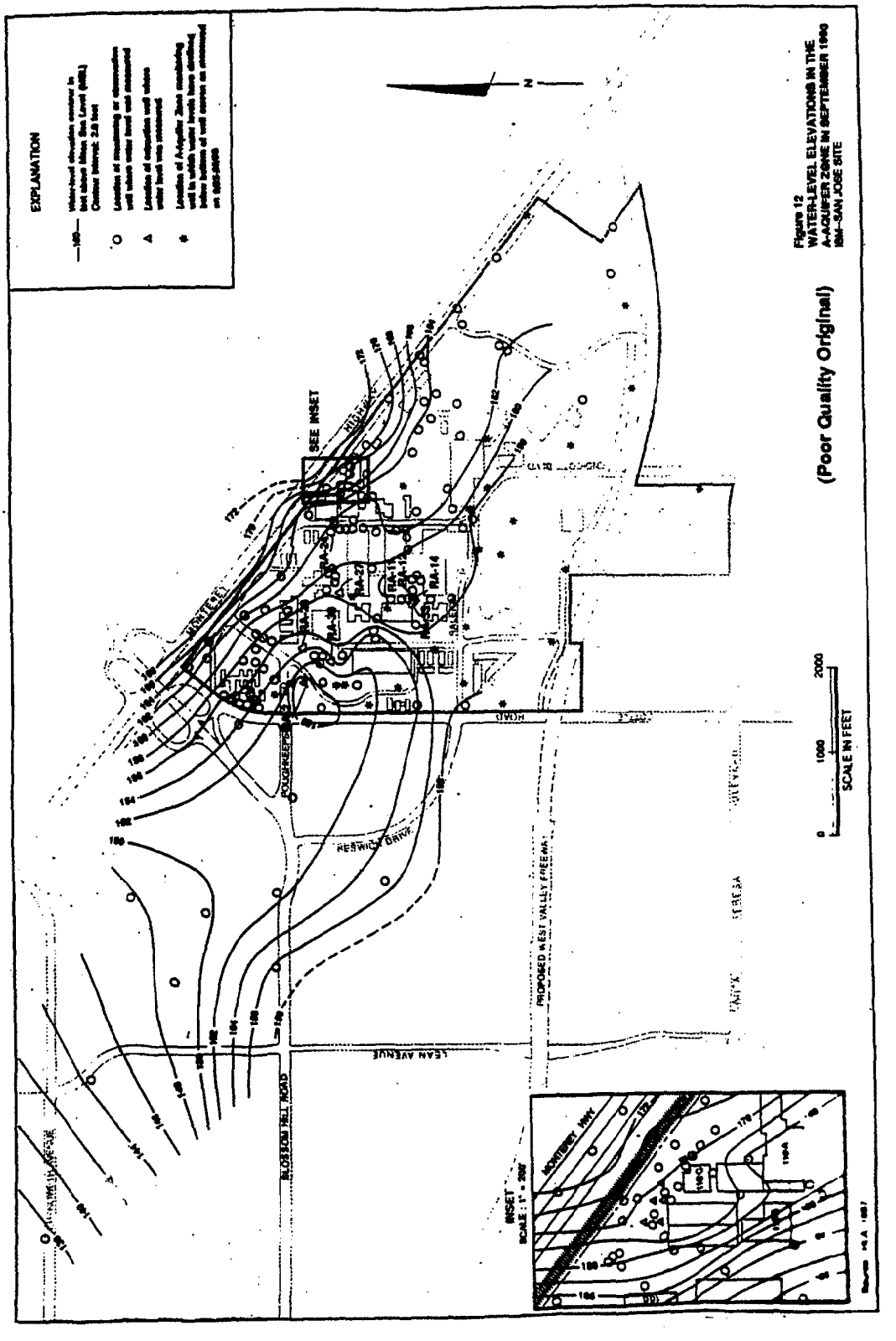

Figure 12
WATER-LEVEL ELEVATIONS IN THE
A-AQUIFER ZONE IN SEPTEMBER 1990
IBM-SAN JOSE SITE

(Poor Quality Original)

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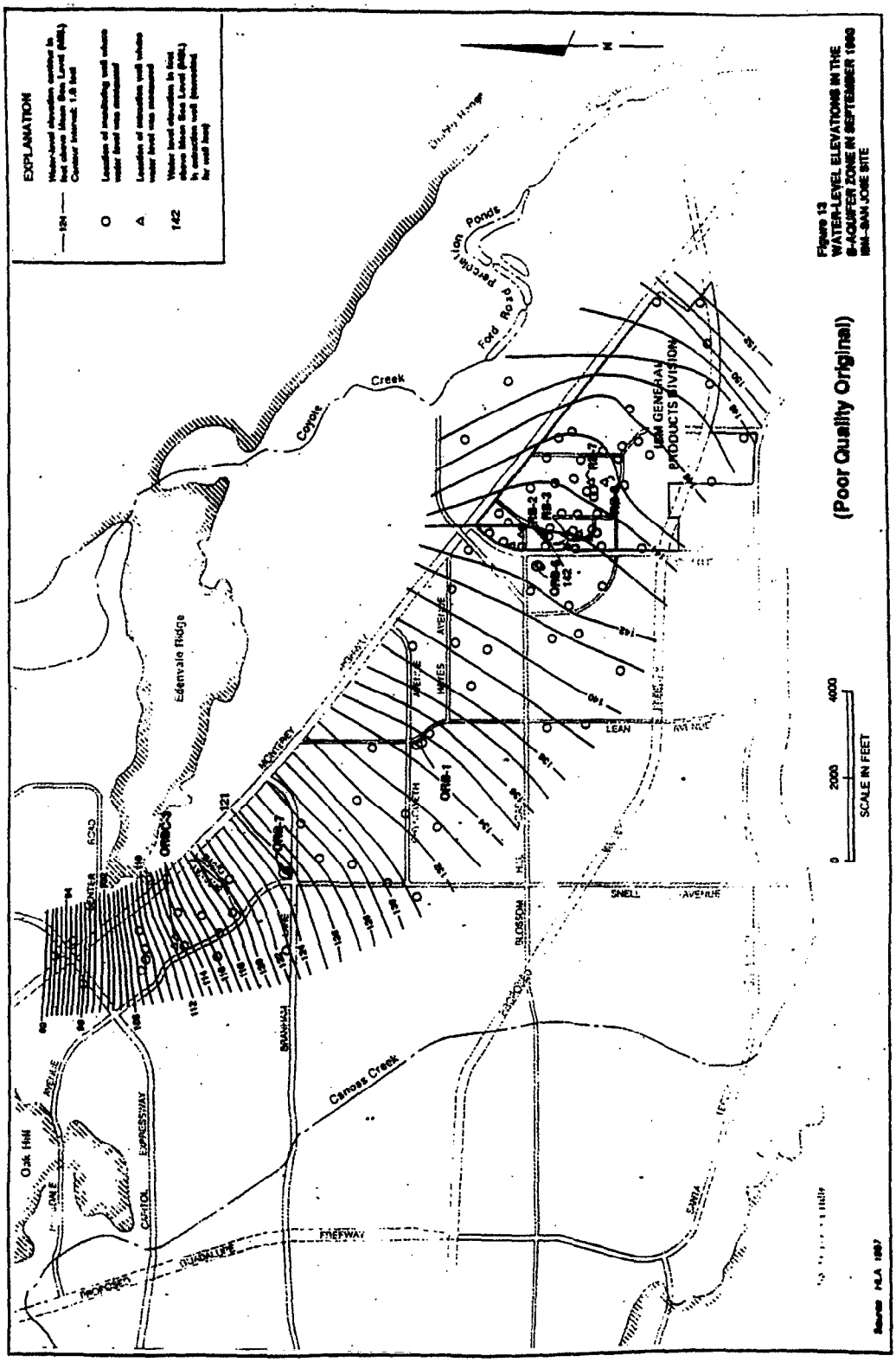

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Figure 13
WATER-LEVEL ELEVATIONS IN THE B-AQUIFER ZONE IN SEPTEMBER 1990
IBM-SAN JOSE SITE

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Table 3
SUMMARY OF PRELIMINARY SOIL-VAPOR EXTRACTION
THIRD QUARTER 1990
IBM-SAN JOSE SITE

	Area				
	Building 004	Shell Sol 140	Building 001/100	Building 006, Tank Farm 067	Building 001 Sump
Estimated Cumulative Mass Removal (lbs)					
VOCs	1177	0	15.2	69	262
Petroleum Hydrocarbons	0	7.8	280	0	69
Total Operating Time (hrs)	340	56	277	16.3	339
Average Extraction Rate (cfm)	154.4	119	105	120	22
Estimated Mass Removal Rate (lb/day)					
VOCs	83	0	1.3	110	18.5
Petroleum Hydrocarbons	0	3.3	24	0	4.9

Source: HLA, November 1990

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Ground-water extraction from the C aquifer has not occurred since April 1988. September 1990 water levels in the C-aquifer zone are shown in Figure 14. Ground-water flow in the C-aquifer zone at the site is to the northwest.

Reductions in Mass and Concentrations of Contaminants

Monitoring-well data from September 1989, to September 1990, indicate little change in the areal extent and concentration of most of the contaminant plumes in the A, B, and C aquifers in comparison to what is shown in 1988 data. Figures 15, 16, and 17 present the September 1989 to September 1990 mean concentration-contour maps of Freon 113, TCA, and 1,1-DCE in the A aquifer. In the A aquifer, Freon 113 and TCA concentrations remained below the target remediation standards of 18,000 ppb and 200 ppb, respectively. The maximum concentrations observed during the fourth quarter of 1990 were 9,500 ppb for Freon 113 and 100 ppb for TCA (HLA, 1990d). The maximum 1,1-DCE concentration during the fourth quarter of 1990 in the A aquifer was 33 ppb, which exceeds the target remediation standard of 6 ppb (HLA, 1990d). This standard was exceeded in parts of the onsite area in 1989 and 1990, as shown in Figure 17.

The only contaminant plume that showed significant change was Freon 113 in the A aquifer. Some decrease in Freon 113 concentrations was observed. Figures 3 and 15 present concentration-contour maps for Freon 113 in 1984, 1986, and 1990. Freon concentrations in the northern and western parts of the site have been reduced by 1 to 2 orders of magnitude. However, the high-concentration area in the southeast has not been affected significantly.

B-aquifer concentration-contour maps of Freon 113, TCA, and 1,1-DCE are presented in figures 18, 19, and 20. The maximum detected concentrations were 1,100 ppb for Freon 113, 26 ppb for TCA, and 8.2 ppb for 1,1-DCE (HLA, 1990d). The areas of greatest Freon 113 contamination in the B aquifer are the same as those in the A aquifer, suggesting downward migration of Freon 113 from the A aquifer to the B aquifer. In the B aquifer, TCA concentrations were below the target remediation standard (50 ppb) in 1990; however, 1,1-DCE was detected at 8.2 ppb in one monitoring well, which exceeds the 1.5 ppb standard (HLA, 1990d). TCE was detected at 8.4 ppb, which exceeds the 3.1 ppb target remediation standard (HLA, 1990d).

Figures 21, 22, and 23 present C-aquifer concentration-contour maps for Freon 113, TCA, and 1,1-DCE. Contaminant concentrations in the C aquifer are significantly lower than in the A and B aquifers. The maximum concentrations observed were 90 ppb for Freon 113, 9.8 ppb for TCA, and 0.7 ppb for 1,1-DCE (HLA, 1990d). All pollutant concentrations were below target remediation standards in the C aquifer during 1990 (HLA, 1990d).

Although ground-water concentrations for most pollutants have not been reduced significantly by the extraction system since 1988, the system is recovering pollutants. Table 4 lists the estimated mass of Freon 113, TCA, TCE, and 1,1-DCE recovered during 1990. The estimates are based on average 1990 extraction-well concentrations and the total ground-water volume extracted from each well. Most of the contaminants were recovered from the B aquifer, where the extraction rates were highest.

Since the startup of a Shell Sol 140 recovery system in 1989, approximately 2,500 gallons of product have been recovered (HLA, 1991). The free product is recovered from skimming pumps installed in wells throughout the plume. The water table is depressed in the plume area to facilitate the recovery of free product. Figure 24 shows the extent of the nonaqueous and dissolved plumes of Shell Sol 140 in 1990. The extent of the free-product plume decreased somewhat from 1988 to 1990. Since 1990, concentrations of Shell Sol 140 in ground-water samples taken from wells with no free product have decreased from 1 ppb or less to below detection limits (IBM, 1991).

SUMMARY OF REMEDIATION

Between 1988 and 1990, little change was observed in the areal extent of the contaminant plumes. Previously, between startup and 1988, there had been some reduction in the plume. The Freon 113 concentrations in the A aquifer decreased by 1 to 2 orders of magnitude between 1984 and 1990 except for the high-concentration area near Building 004. Although no significant reductions in concentration have been observed for the other primary contaminants since 1988,

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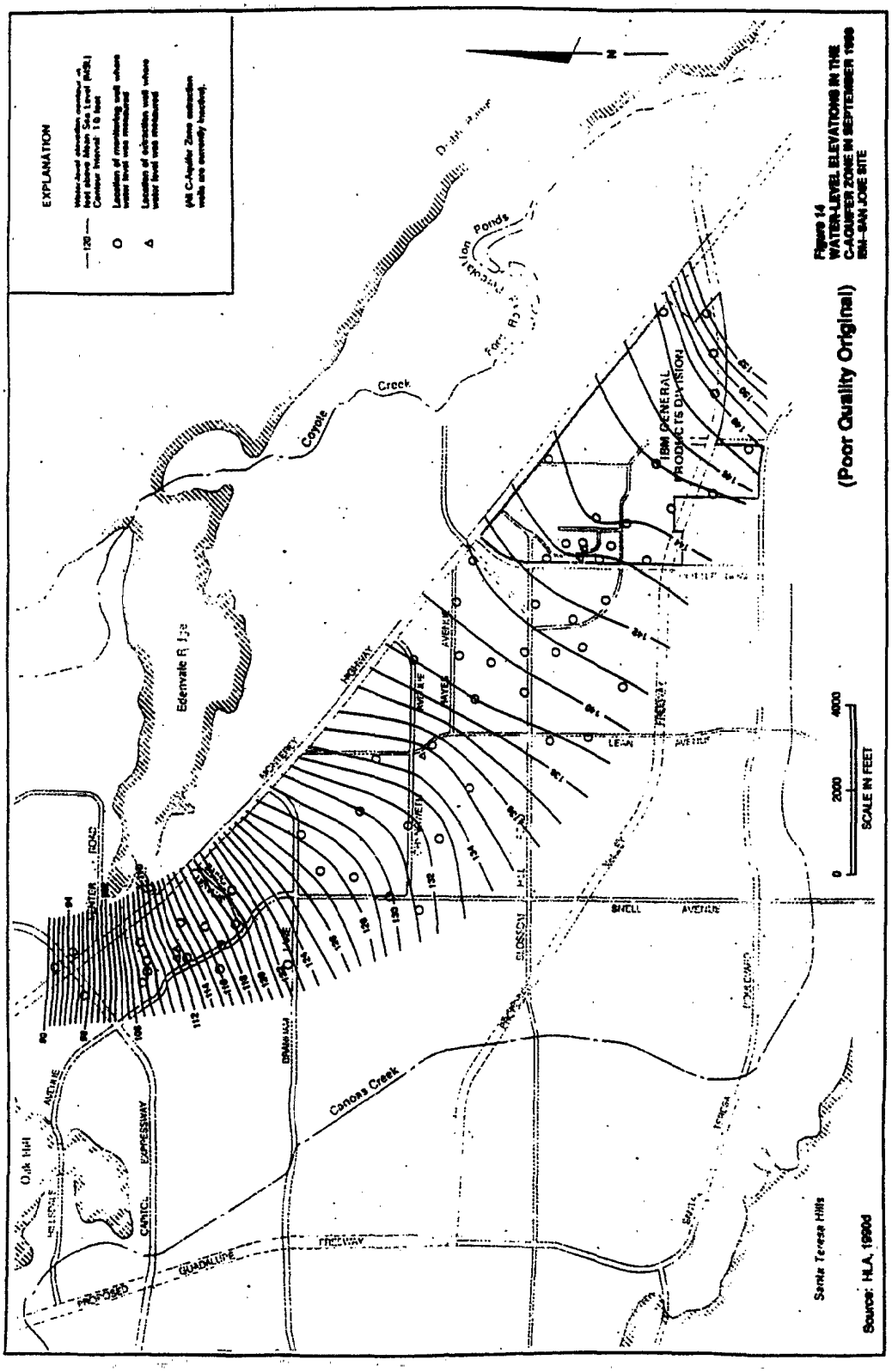

Figure 14
WATER-LEVEL ELEVATIONS IN THE C-AQUIFER ZONE IN SEPTEMBER 1990
IBM-SAN JOSE SITE

(Poor Quality Original)

Source: HLA, 1990d

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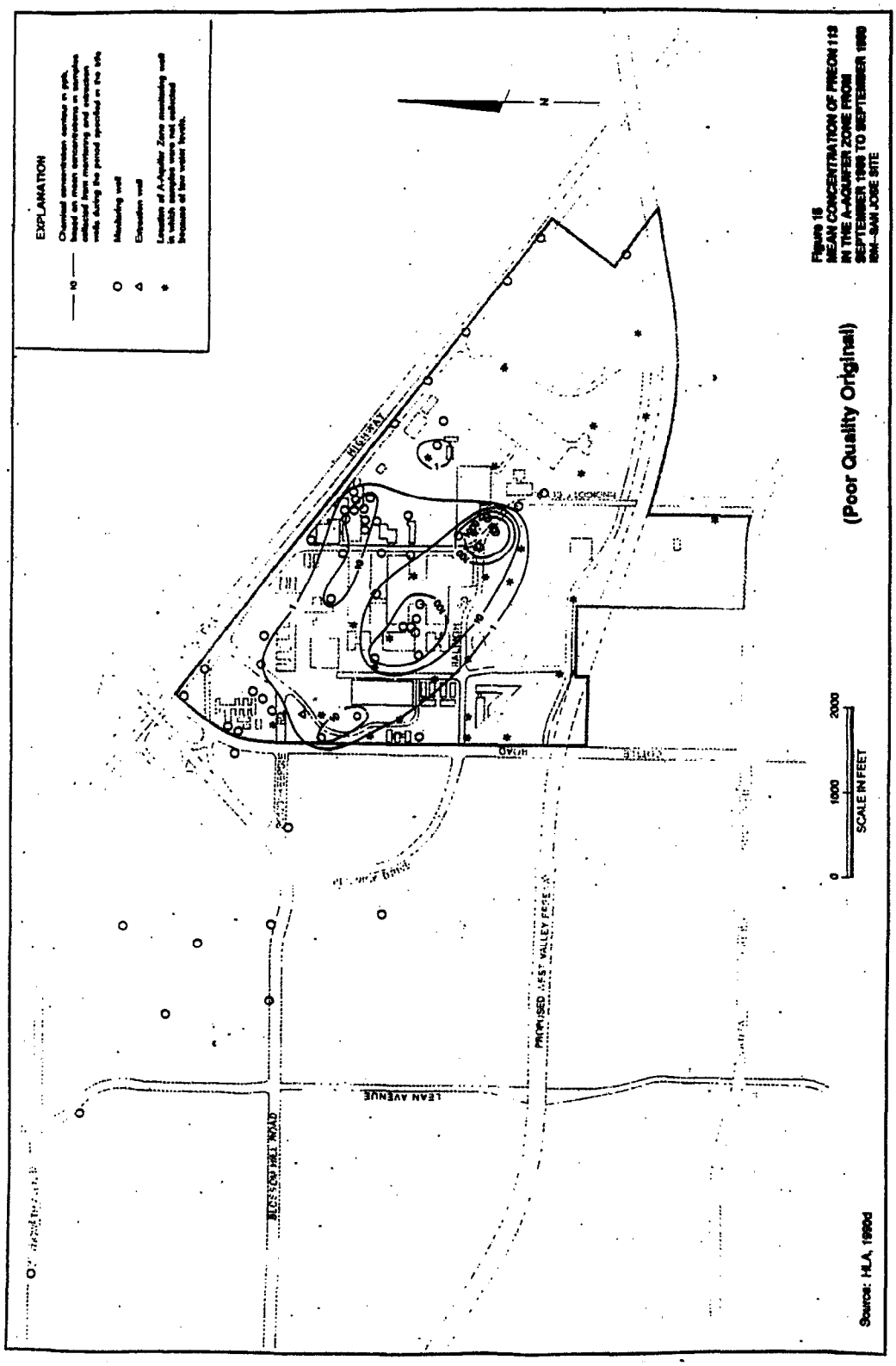

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Figure 15
MEAN CONCENTRATION OF PRECON 113
IN THE A-AQUIFER ZONE FROM
SEPTEMBER 1986 TO SEPTEMBER 1989
IBM-SAN JOSE SITE

Source: HLA, 1990d

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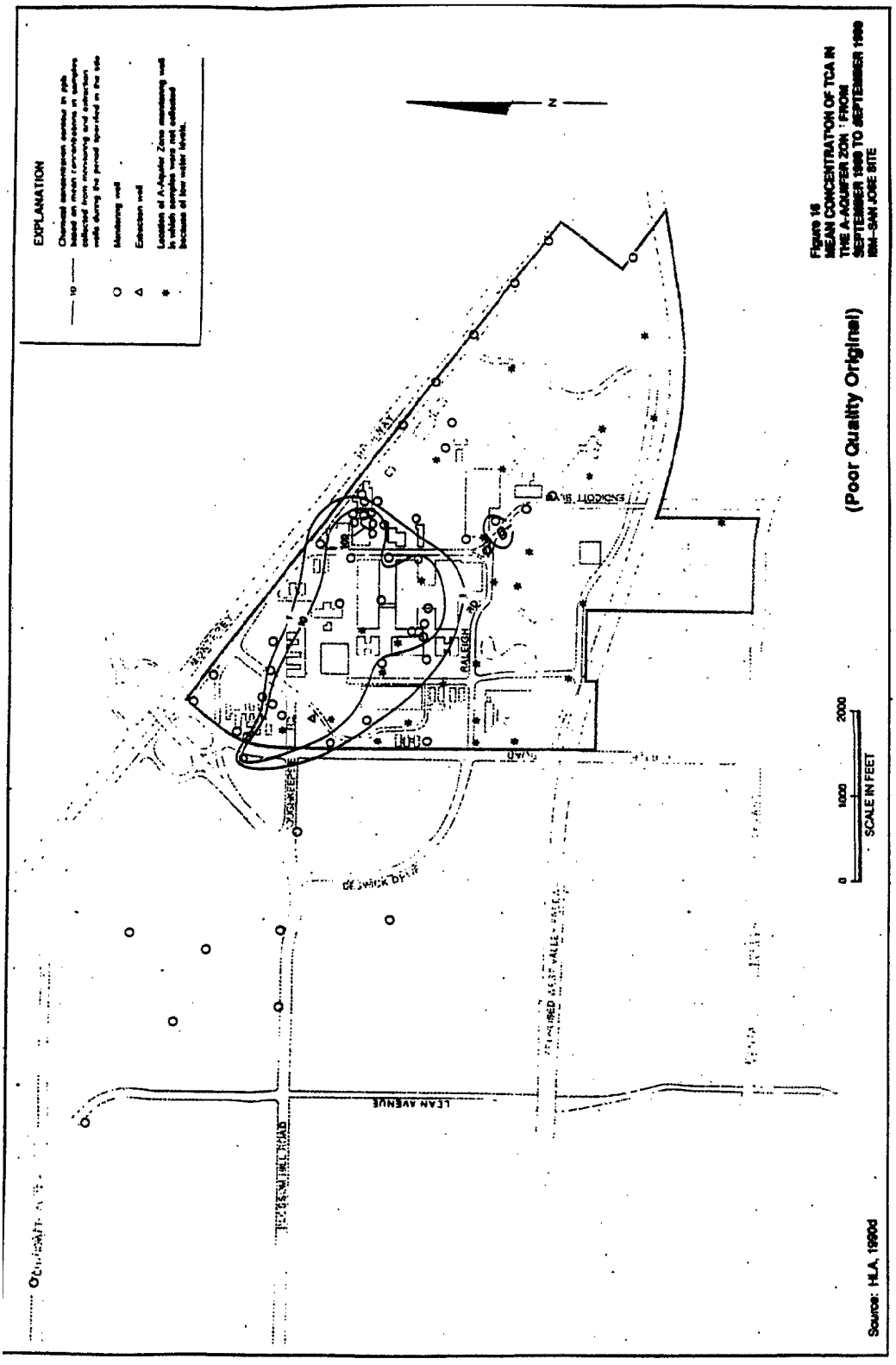

Figure 16
MEAN CONCENTRATION OF TCA IN THE A-AQUIFER ZONE FROM SEPTEMBER 1989 TO SEPTEMBER 1990
IBM–SAN JOSE SITE

(Poor Quality Original)

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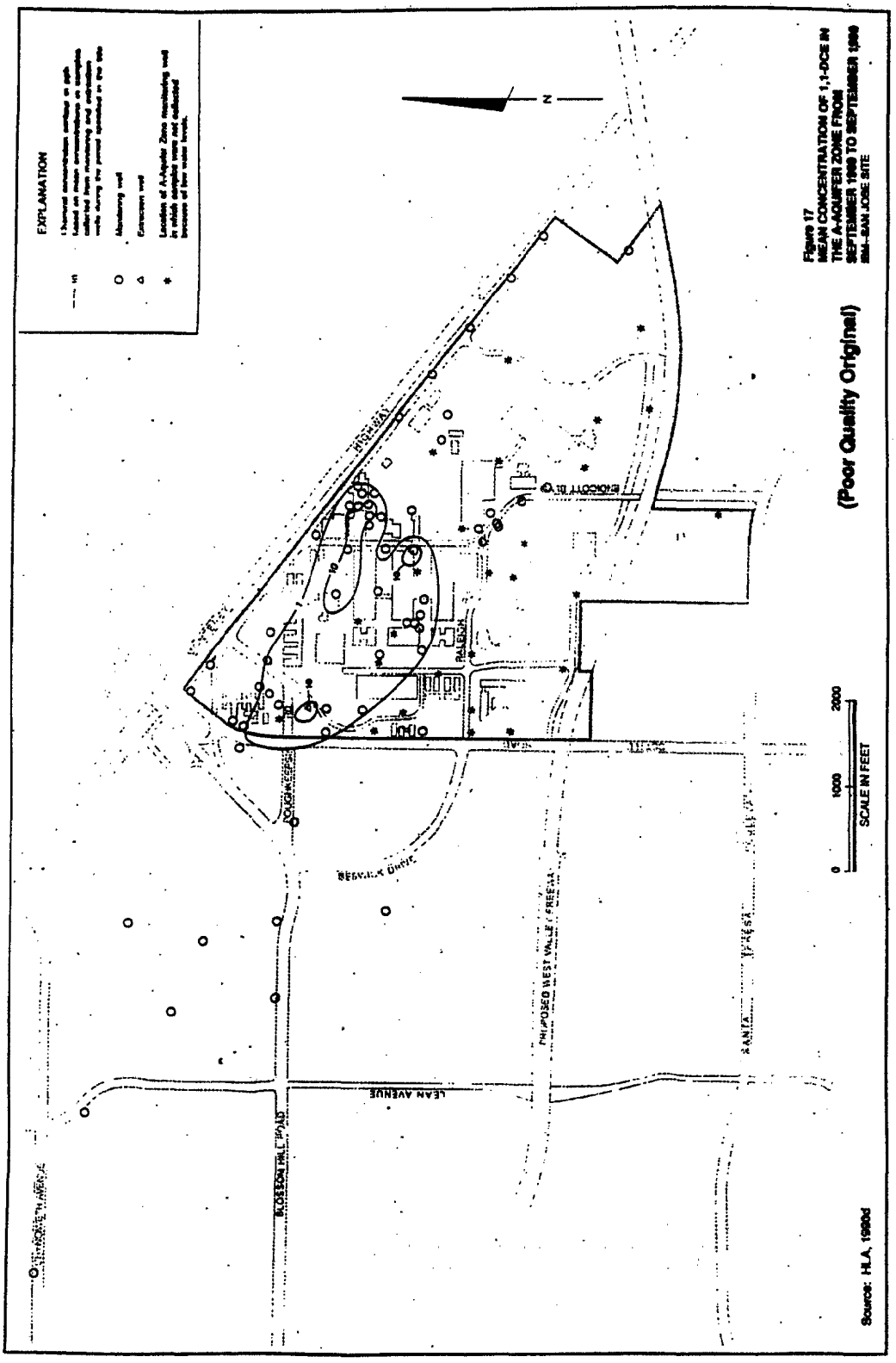

Figure 17
MEAN CONCENTRATION OF 1,1-DCE IN THE A-AQUIFER ZONE FROM SEPTEMBER 1989 TO SEPTEMBER 1990
IBM—SAN JOSE SITE

(Poor Quality Original)

Source: HLA, 1990d

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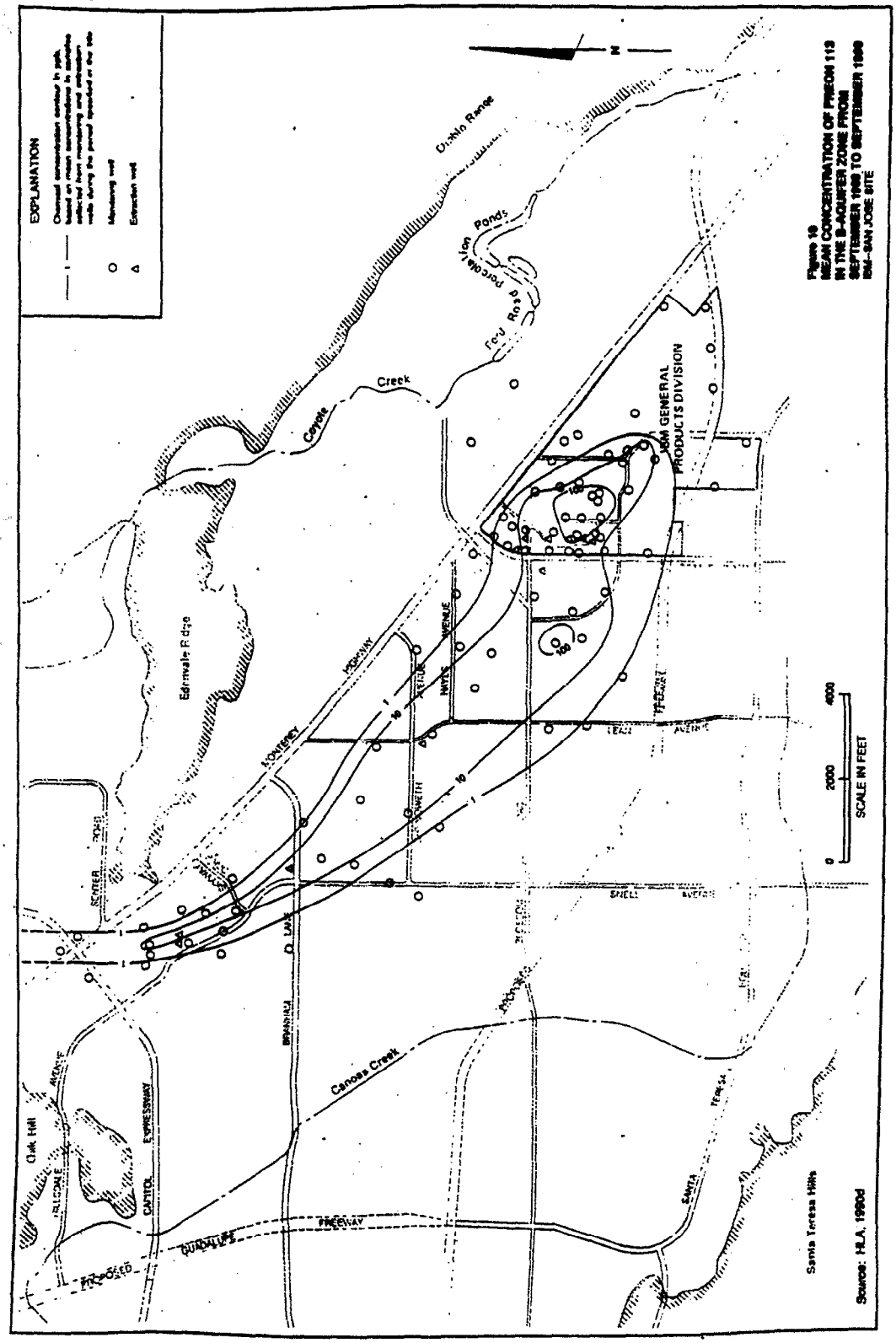

Figure 10
MEAN CONCENTRATION OF PRECON 113
IN THE B-AQUIFER ZONE FROM
SEPTEMBER 1988 TO SEPTEMBER 1989
IBM-SAN JOSE SITE

Source: HLA, 1990d

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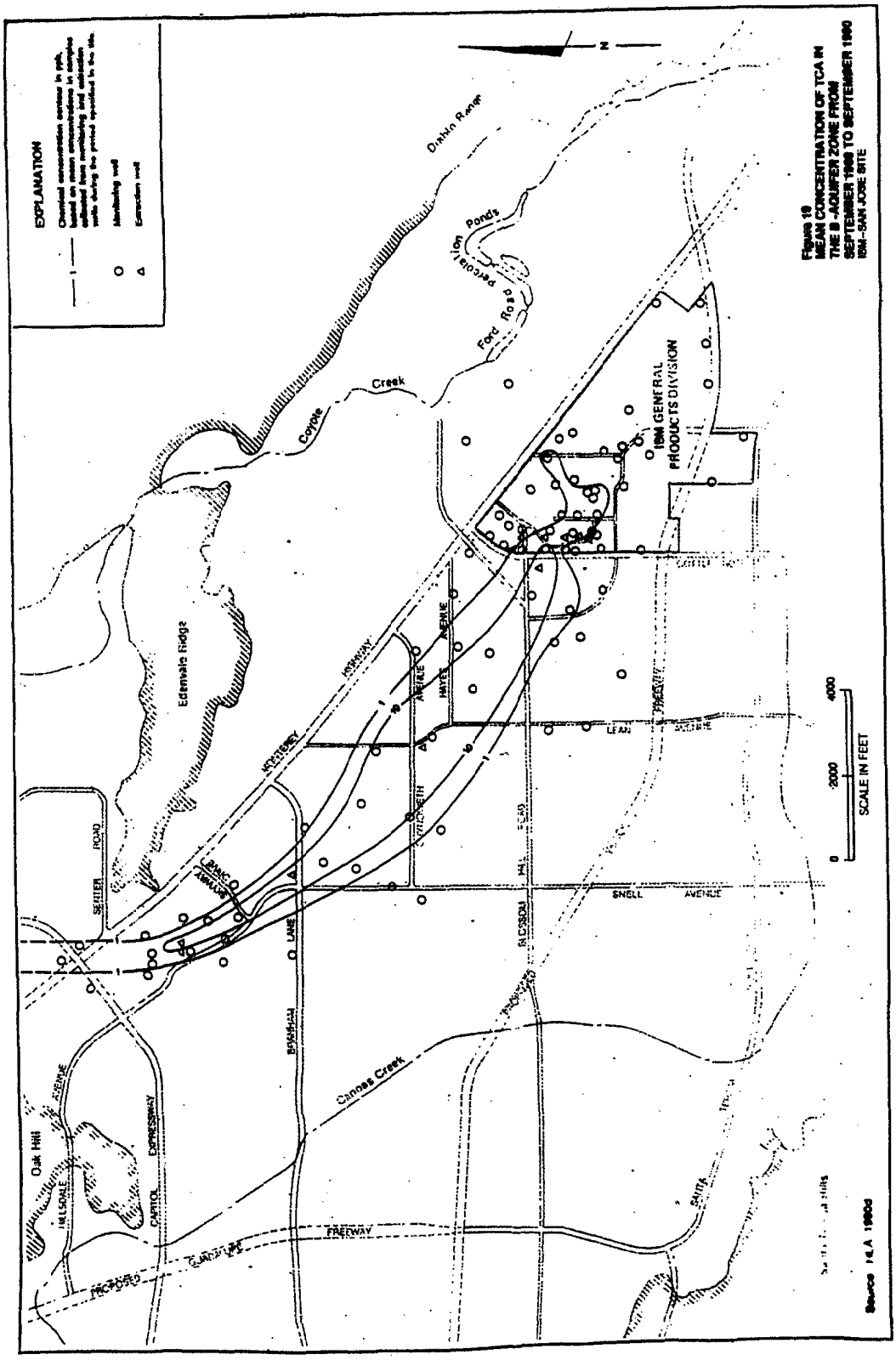

Figure 19
MEAN CONCENTRATION OF TCA IN THE B-AQUIFER ZONE FROM SEPTEMBER 1989 TO SEPTEMBER 1990
IBM-SAN JOSE SITE

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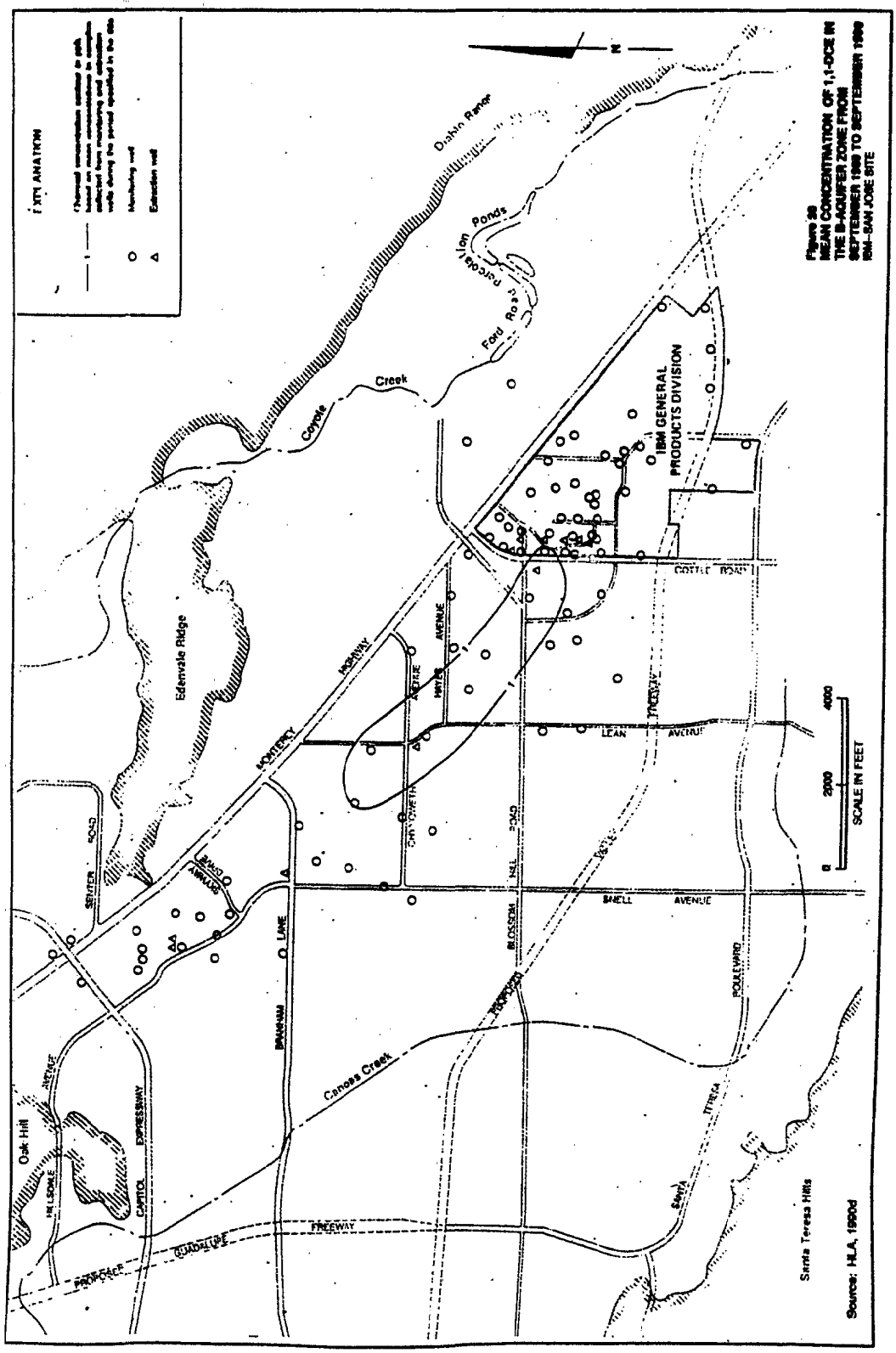

Figure 20
MEAN CONCENTRATION OF 1,1-DCE IN THE B-AQUIFER ZONE FROM SEPTEMBER 1989 TO SEPTEMBER 1990
IBM-SAN JOSE SITE

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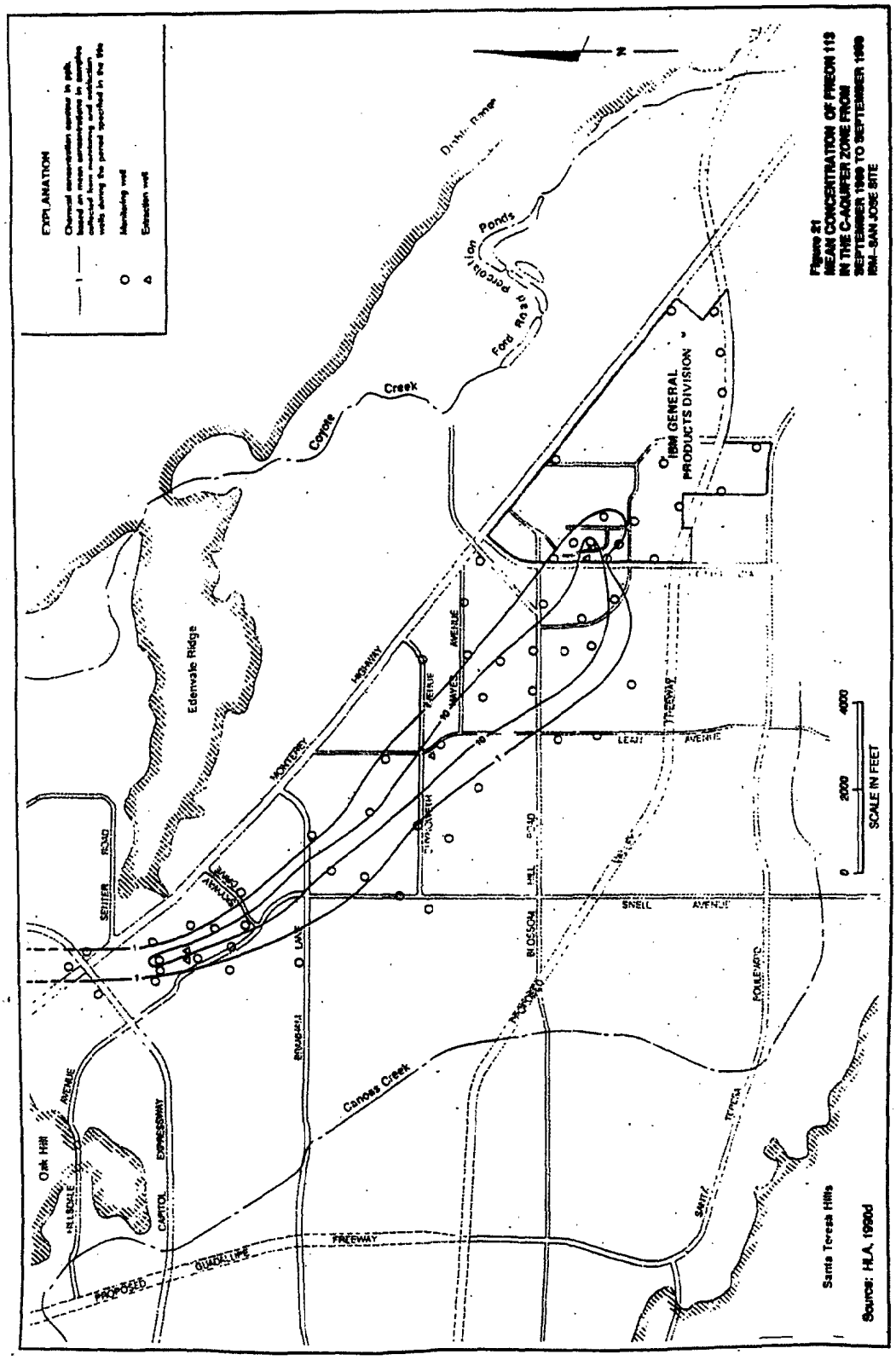

Figure 21
MEAN CONCENTRATION OF FREON 113
IN THE C-AQUIFER ZONE FROM
SEPTEMBER 1989 TO SEPTEMBER 1990
IBM-SAN JOSE SITE

Source: HLA, 1990d

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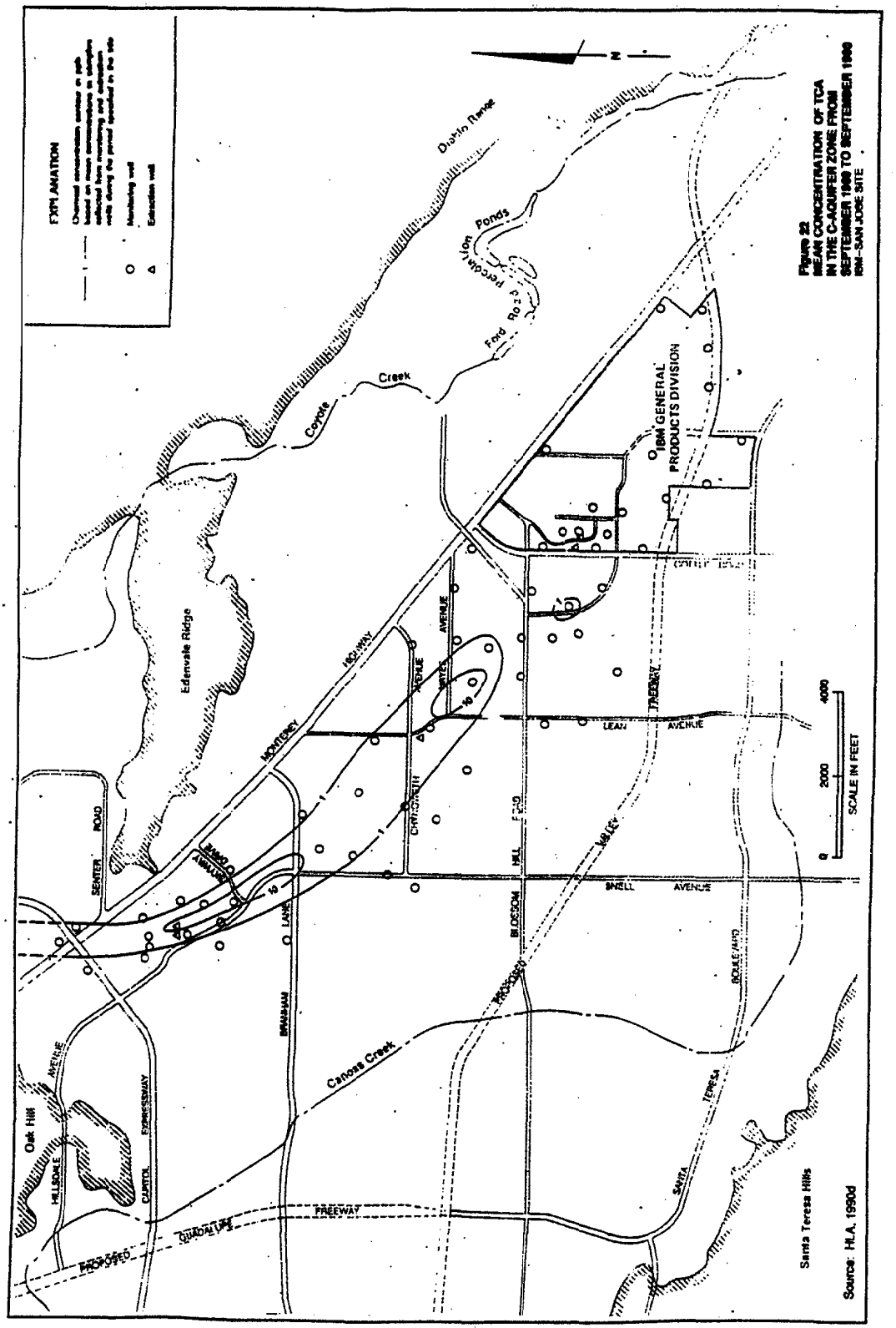

Figure 22
MEAN CONCENTRATION OF TCA
IN THE C-AQUIFER ZONE FROM
SEPTEMBER 1988 TO SEPTEMBER 1990
IBM-SAN JOSE SITE

Source: HLA, 1990d

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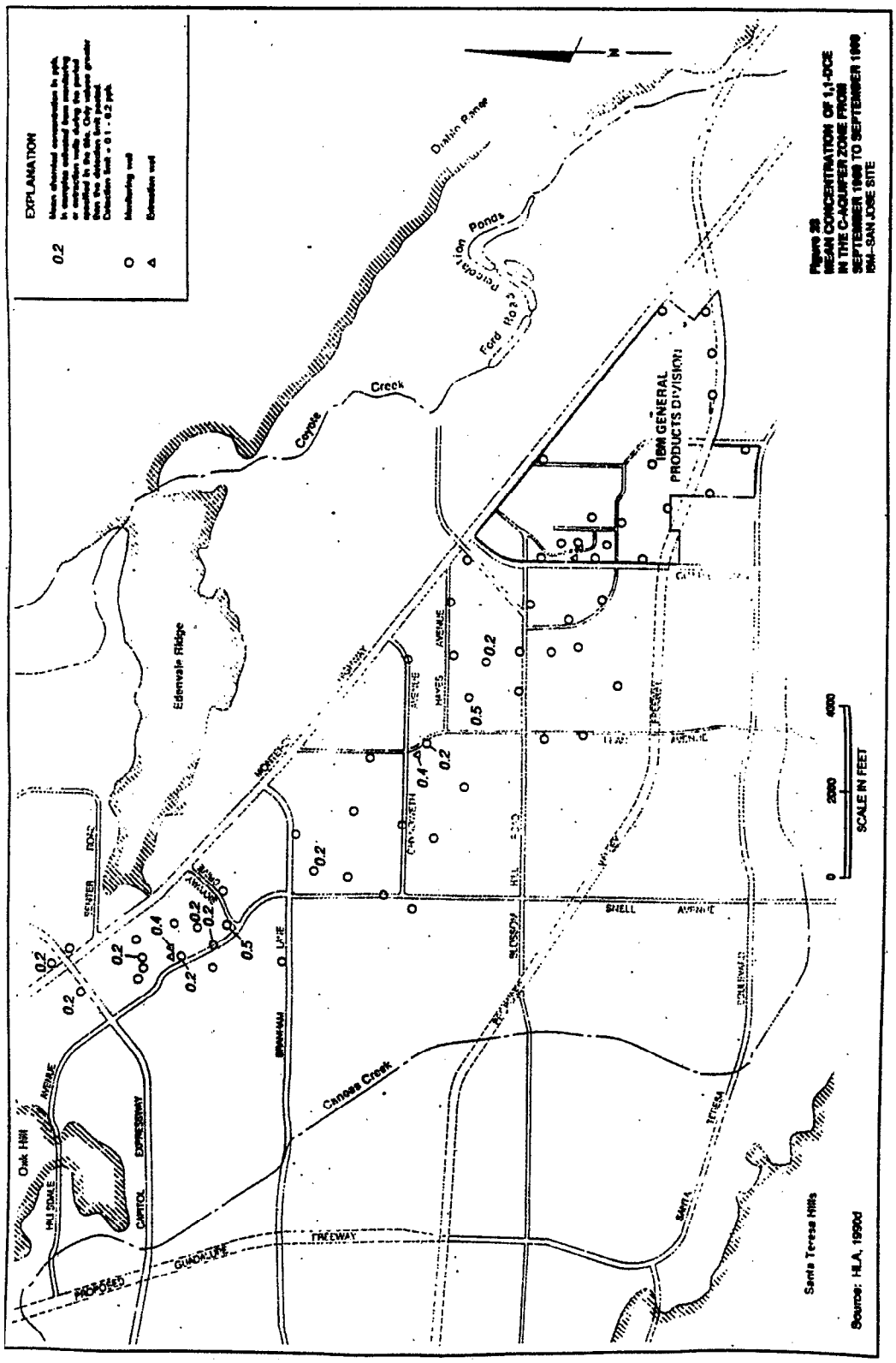

Figure 28
MEAN CONCENTRATION OF 1,1-DCE IN THE C-AQUIFER ZONE FROM SEPTEMBER 1988 TO SEPTEMBER 1990
IBM-SAN JOSE SITE

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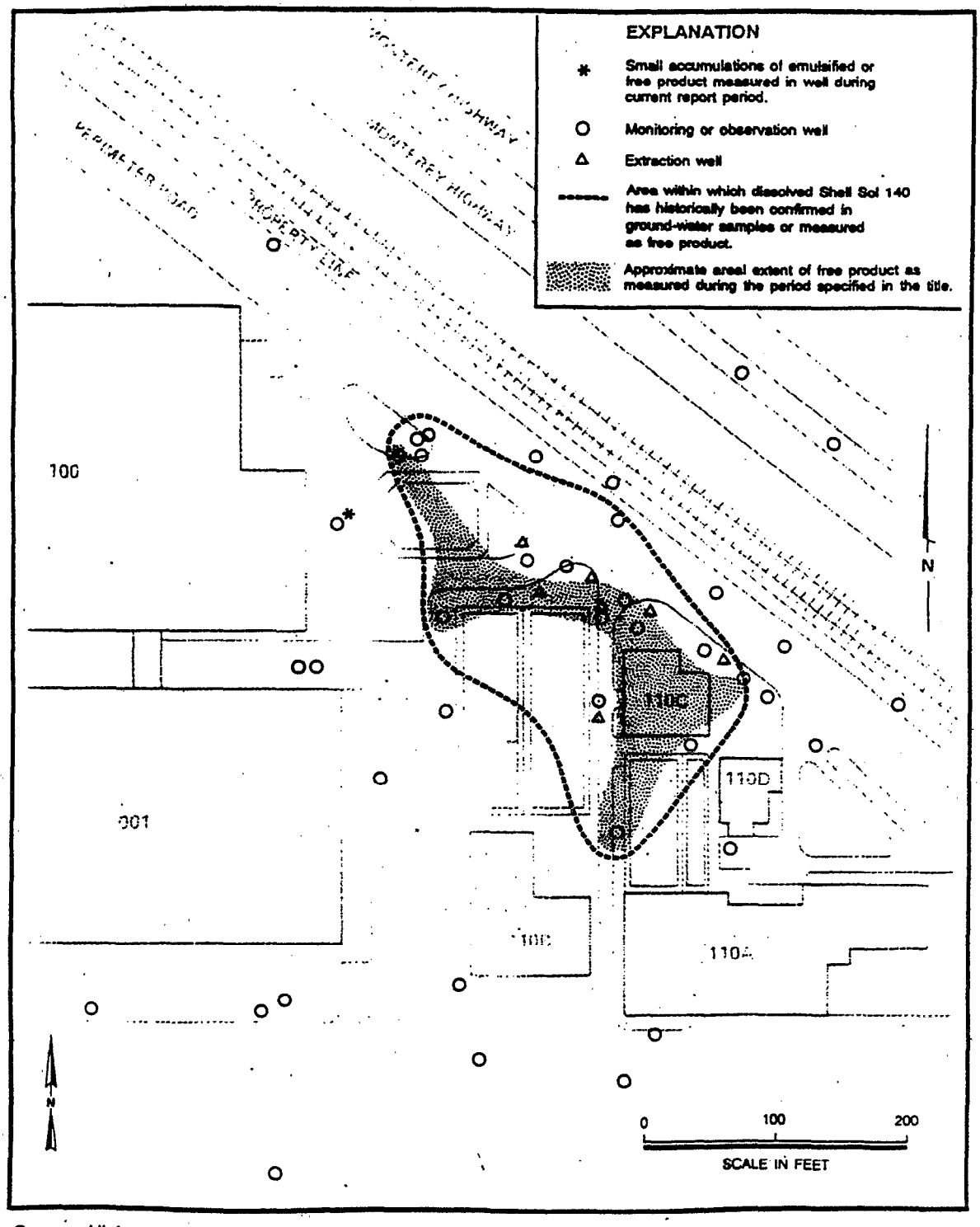

Source: HLA, 1990d

Figure 24
APPROXIMATE EXTENT OF SHELL SOL 140 IN THE A-AQUIFER FROM JUNE 25, 1990 TO SEPTEMBER 28, 1990
IBM–SAN JOSE SITE

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Table 4
MASS OF POLLUTANTS RECOVERED FROM GROUNDWATER EXTRACTION WELLS IN 1990

Pollutant	Estimated Mass Recovered (lbs)
Freon 113	300
TCA	60
1,1-DCE	6
TCE	1.5
Source: HLA, 1991	

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significant masses of contaminants were recovered by extraction wells. The concentration of Freon 113, TCA, TCE, and 1,1-DCE exceeded target remediation standards for the A aquifer in the third quarter of 1990. TCE was the only contaminant that exceeded the remediation standard for the B aquifer during the third quarter of 1990. 1,1-DCE and TCE were detected at concentrations as high as 10 ppb and 8 ppb, respectively. It is expected that recovery of pollutants will be slow at such low concentrations.

SUMMARY OF NAPL-RELATED ISSUES

Two types of nonaqueous phase liquids (NAPLs) are known or suspected to be present at the IBM San Jose site; light NAPLs and dense NAPLS (DNAPLs). The spill of approximately 8,100 gallons of Shell Sol 140 in November 1985, produced a floating layer of nonaqueous, or free-phase, hydrocarbon, as shown in Figure 6. Subsurface leaks of Freon 113 and chlorinated solvents from storage tanks and pipe lines may have also resulted in parts of the A aquifer being contaminated with DNAPLs. The areas of suspected and known NAPL contamination correspond approximately to the areas of preliminary soil-vapor extraction shown in Figure 11.

NAPLs in the Shell Sol spill area are being remediated by a combination of SVE and free-product skimming from recovery wells. So far, approximately 2,500 gallons of free product have been recovered from the system. The combination of recovery techniques appears to have the potential to remediate the Shell Sol problem, according to experience with other hydrocarbon spills. Comparison of the NAPL-contaminated areas in Figures 6 and 24 indicates that the area of the floating NAPL layer was reduced considerably between 1988 and 1990.

The suspected DNAPLs consist primarily of Freon 113, TCA, and 1,1-DCE. The areas most heavily contaminated with Freon 113 are in the A aquifer around Tank Farm 067 and the southwest corner of Building 004. The solubility of Freon in water is approximately 170,000 ppb, and its specific gravity is about 1.48. Concentrations of Freon 113 near 10 percent of its solubility have been detected in ground-water samples taken from the A aquifer in the Tank Farm 067 area, suggesting that DNAPL Freon may be present in this area. Freon concentrations greater than solubility have been detected in ground water from borings in this area (HLA, 1987).

Comparison of Figures 3 and 15 indicates that there has been a considerable decrease in the extent of the Freon 113 plume over the course of the remediation and that the maximum ground-water concentration of the Tank Farm 067 area has decreased. However, there has been no significant decrease in the concentrations around Building 004. In 1990, the highest concentration of Freon in a ground-water sample was 9,500 ppb, measured in A-aquifer well A-69. Freon concentrations in the B aquifer also have always been highest in the Tank Farm 067 area. This is directly below the parts of the A aquifer that initially had the highest concentrations. This may be indicative of the downward migration of DNAPLs through the A/B aquitard in this area; however, hydraulic gradients are also downward in this area, so downward advection of dissolved constituents is also possible. The highest Freon concentration in the B aquifer in 1990 was 1,100 ppb, measured in Well B-22. Likewise, the highest concentrations in the C aquifer are the vicinity of Tank Farm 067.

The highest concentrations of TCA and 1,1-DCE have consistently been in the A aquifer near Building 001. The high concentrations in that area have been persistent over the 6-year period of record, indicating that these compounds may be present as DNAPLs.

Freon 113 concentrations in the Tank Farm 067 area of the A aquifer, where DNAPLs are suspected, have declined substantially since 1986. A possible explanation for the decline is that the potential DNAPL has penetrated the A/B aquitard in this area, leaving the relatively thin part of the A aquifer below the water table with Freon at no more than residual saturation. Because Freon is volatile, it might not persist long above the water table.

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UPDATE BIBLIOGRAPHY/ REFERENCES

Harding Lawson Associates (HLA). June 1987. *Appendix B: Summary of Hydrologic Studies, Draft Comprehensive Plan, IBM Groundwater Restoration Program.*

HLA. January 1989a. *Quarterly Report - Fourth Quarter 1988, Groundwater Monitoring Program, IBM Storage Systems Products Division, San Jose, California.*

HLA. June 30, 1989b. *Predesign Field Investigation: A-Aquifer Zone Extraction System, Cottle Road Boundary Area.*

HLA. August 15, 1989c. *Criteria for Decision Analysis of Final Plan Implementation and Contingency Proposal, IBM Groundwater Protection Program, San Jose, California.*

HLA. January 18, 1990a. *Recharge Evaluation and Proposed Pilot Study, IBM General Products Division, San Jose, California.*

HLA. April 13, 1990b. *A-Aquifer Zone Boundary and Offsite Extraction System, IBM General Products Division, San Jose California.*

HLA. May 14, 1990c. *Quarterly Report--First Quarter 1990, Groundwater Monitoring Program, IBM Storage Systems Products Division, San Jose, California.*

HLA. November 2, 1990d. *Quarterly Report--Third Quarter 1990, Groundwater Monitoring Program, IBM Storage Systems Products Division, San Jose, California.*

HLA. June 19, 1991. Personal communication with Steven Walker, engineering geologist, HLA.

IBM. February 1991. Personal communication with Marian Duncan of IBM.

Kennedy, Jenks, and Chilton. August 1989. *IBM Groundwater Protection Program, Onsite Groundwater Utilization, IBM General Products Division, San Jose, California.*

McLaren Environmental Engineering. March 20, 1989. *Preliminary Design Report, International Business Machines.*

McLaren Hart. October 1, 1990. *Groundwater Recharge Pilot Study and Sampling Plan, IBM Storage Systems Products Division, San Jose, California.*

U.S. Environmental Protection Agency (U.S. EPA). October 1989. *Evaluation of Ground-Water Extraction Remedies: Volume 2, Case Studies 1-19.* Document Number: EPA/9355.4-03.

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UPDATE OF CASE STUDY 12

Nichols Engineering
Hillsborough Township, New Jersey

Abstract

During 1990 and 1991, ground-water extraction has continued at the site. Since the system startup in January 1988, CCl_4 concentration in ground water has been reduced by 80 to 90 percent in some wells. As of June 1991, site operators were in negotiations with NJDEP to cease ground-water recovery operations at the site.

Table of Background Data	
Date of Problem Identification	1987
Extraction Started	January 1988
Types of Contaminants	VOCs
Primary Aquifer Materials	Fractured shale, siltstone, sandstone, and conglomerate
Maximum Number of Extraction Wells	4
Maximum Total Extraction Rate	65 gpm
Estimated Plume Area	2 acres
Estimated Plume Thickness	100 feet
Maximum Reported Concentrations	Carbon Tetrachloride 980 ppb

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CASE STUDY UPDATE
NICHOLS ENGINEERING AND RESEARCH CORPORATION

BACKGROUND OF THE PROBLEM

INTRODUCTION

The original case study for the Nichols Engineering and Research Corporation (NERC) site (U.S. EPA, 1989, Case Study 12) was based on monitoring data through October 6, 1988. This update is based on additional progress reports that present monitoring data collected through April 4, 1990. Ground water at the site occurs in a fractured rock aquifer and has elevated levels of volatile organic compounds (VOCs). Administration of site cleanup is being conducted in accordance with the New Jersey Department of Environmental Protection's (NJDEP) Environmental Clean-up and Responsibility Act (ECRA).
The NERC site is located at the southwest corner of the intersection of Willow and Hillsborough Roads in Hillsborough Township, Somerset County, New Jersey (see Figure 1). Figure 2 shows the site layout and the location of the 12 original onsite monitoring wells.

The NERC facility was involved in combustion research from the early 1970s to 1983. Ground-water sampling beneath the NERC site performed in 1986 and early 1987 revealed contamination with VOCs near a subsurface wastewater settling basin adjacent to the west side of the pilot plant (see Figure 2). The basin is suspected of being the source of the ground-water contamination beneath the site. Results of water quality analyses from the ground-water sampling program indicate that three contaminant plumes of the VOCs carbon tetrachloride (CCl_4), chloroform ($CHCl_3$), and tetrachloroethylene (PCE) are centered near wells MW-1 and MW-2, with the CCl_4 plume being the most extensive. The dashed outline in Figure 2 indicates the approximate extent of the plume in 1988.

Remediation began in January 1988 with the installation of a ground-water recovery system. The original system consisted of one extraction well at MW-3. This well was selected because of its central location in the contaminant plume and because aquifer test results suggested that it would provide the necessary capture zone. Subsequent revisions to the extraction system are discussed below.

Based on an analysis of pump test data, Storch Engineers, the environmental consultants for Nichols, postulated a complex aquifer system composed of two marginally independent fractured-rock aquifers. The uppermost water-table aquifer, exhibiting delayed yield behavior, is separated from the lower high transmissivity, semi-unconfined zone by a 10- to 20-foot-thick stratum of poorly fractured sedimentary rocks. The confining layer is penetrated by a number of vertical or nearly vertical fractures. The transmissivity tensor for the lower zone is anisotropic, with the major axis parallel to the long axis of the contaminant plume in a southeast to northwest orientation.

The water table ranges from 20 to 40 feet below the ground surface across the NERC site. The natural direction of ground-water flow is generally toward the northwest. However, during certain times of the year there is a ground-water divide near well MW-4 (see Figure 2), and water southeast of this divide flows toward Royce Brook. Estimates of the natural hydraulic gradient vary between 0.034 and 0.007 depending on which wells are used. This indicates nonuniform flow, which is typical of fractured-rock aquifers.

UPDATE ON SITE CHARACTERISTICS

Despite the addition of two new deep monitoring wells at the NERC site (MW-10D and MW-2D), in January 1989 and January 1990, respectively (see Figure 3), the description for the hydrogeology of the site has not been revised. The new wells are 100 feet deep, with steel casing from the ground surface down to a depth of 61 feet and open, unscreened well bores from a depth of 61 to 100 feet (Storch Engineers, 1990). Well MW-10D is 200 feet downgradient from the suspected contaminant source, and MW-2D is immediately downgradient. The addition of the two new wells brings the total number of monitoring wells at the site to 14. No core

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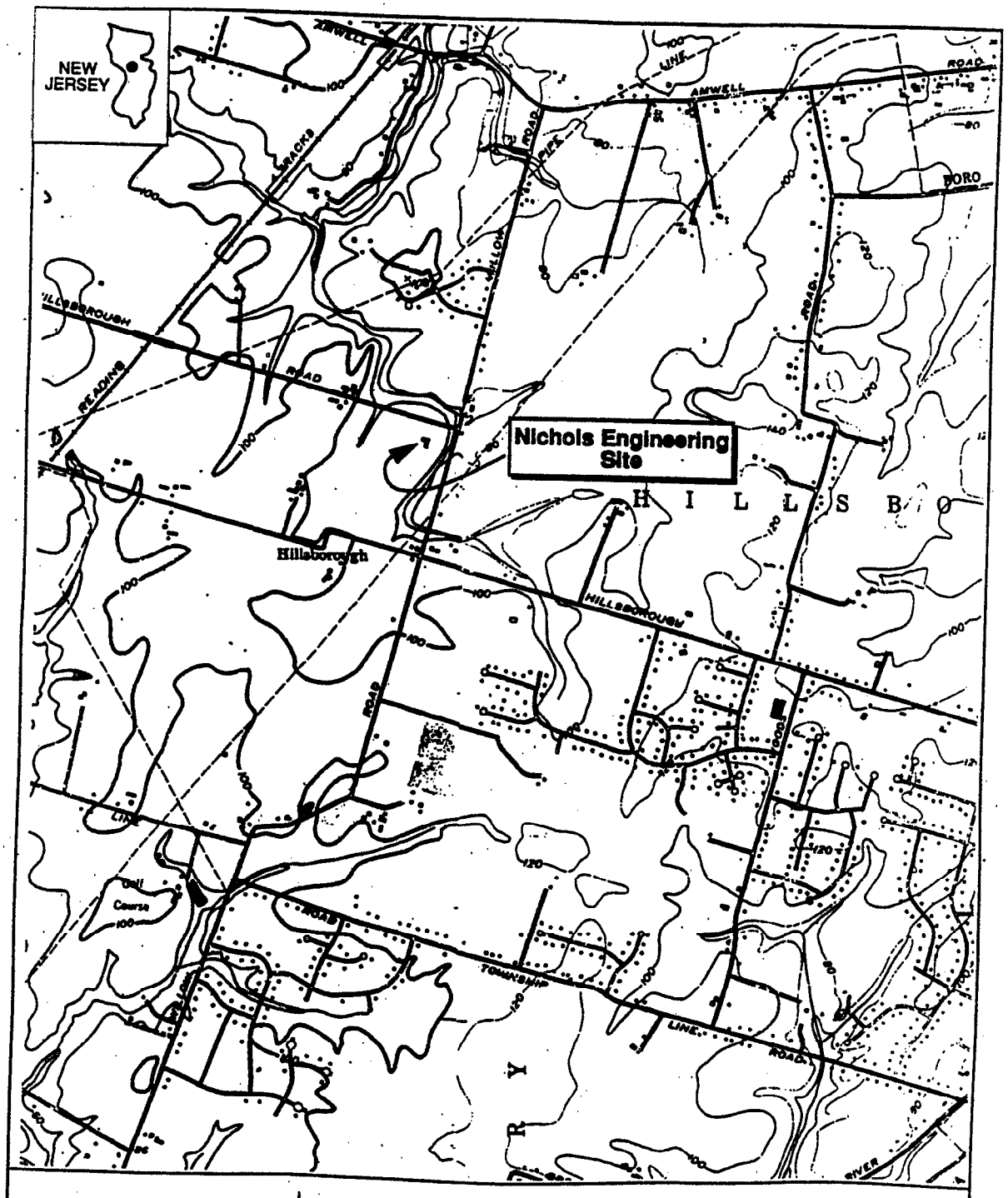

Figure 1
SITE LOCATION MAP
NICHOLS ENGINEERING SITE
HILLSBOROUGH TOWNSHIP, NEW JERSEY

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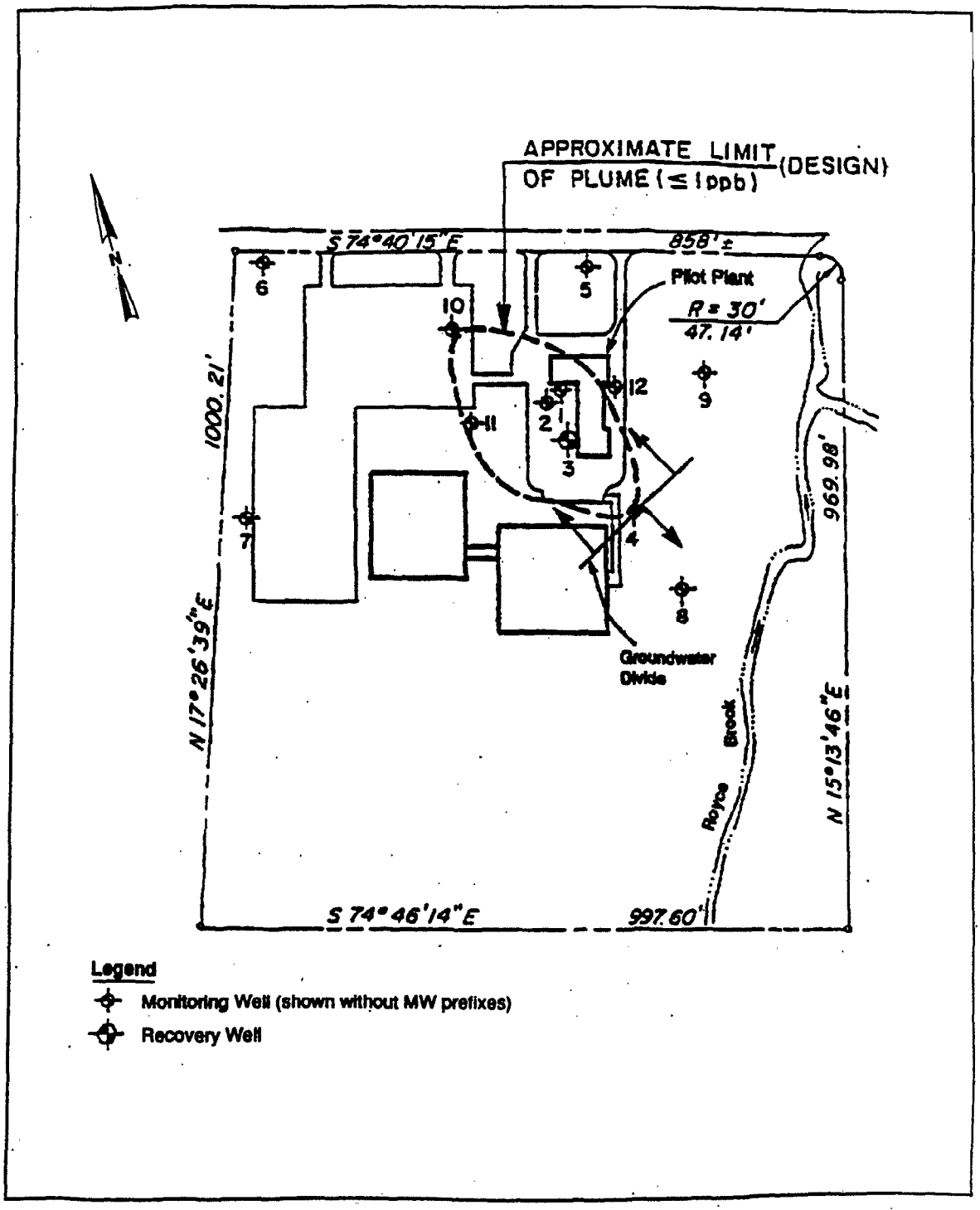

Source: Storch Engineers, 1988b

Figure 2
INITIAL MONITORING AND RECOVERY WELL LOCATION MAP SHOWING GROUND-WATER DIVIDE NICHOLS ENGINEERING SITE

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samples were collected during drilling. Therefore, the exact depth of different hydrogeologic layers is unknown. All of the wells are open-bore rock wells, with a depth of between 50 feet and 100 feet. Table 1 gives the well depths and estimated casing depth for all wells (Storch Engineers, 1991).

In their June 1989 progress report, Storch Engineers asserts that evidence from the continued sampling of all wells and discrete sampling of wells MW-3, MW-11, and MW-12, and from the site history indicate that the contaminants that have been detected are present as a dissolved phase near the top of the water-table aquifer, not as a dense nonaqueous phase liquid (DNAPL).

The evidence used by system operators to rule out the presence of DNAPLs includes the relatively low concentrations encountered compared to concentrations expected if the pure product were present, the higher concentrations near the surface of the water table, and the decreasing concentration resulting from ground-water extraction. According to system operators, evaluation of trends in contaminant concentration over time indicates that the primary contaminant source is located in the vadose zone rather than at depth where the pure product (DNAPLs) of the primary site contaminants would sink because they are denser than water. However, Storch Engineers acknowledges the possibility that DNAPLs might be present in fractures deep beneath the site. Rock fractures at the site are believed to extend considerably below the deepest monitoring well currently installed (Storch Engineers, 1991).

Continued monitoring at the site revealed the presence of additional possible ground-water contaminants: carbon disulfide (CS_2), trichloroethylene (TCE), toluene, 2-butanone (MEK), and methylene chloride (DCM). However, the predominant ground-water pollutants are CCl_4, $CHCl_3$, and PCE.

CS_2 was found in the two new deep wells at increasingly greater concentrations following its initial detection in MW-10D in April 1989. Site operators suggest that the data are indicative of a plume of CS_2 in a dissolved phase at depth below the water table. No evidence is offered for the presence of CS_2 as a nonaqueous phase liquid (NAPL).
occasion at 160 ppb in MW-5. Storch Engineers is investigating whether the TCE detected in samples taken from wells other than MW-5 is a ground-water contaminant or a laboratory contaminant. The high TCE levels in well MW-5, along with the discovery of other VOCs in that well, have been attributed to other pollutant sources and will not be discussed in this case study update.

Storch Engineers attributes the presence of toluene, ethylbenzene, and xylene in MW-10 and MW-10D to exhaust fumes from the sampling van, generator, or traffic within the immediate vicinity. These two wells are located in a parking lot. NJDEP does not dispute this possible explanation (NJDEP, 1990).

MEK contamination of MW-1, MW-2, and MW-11, was attributed to the introduction of contaminants into the ground-water during the installation of new recovery pumps in these monitoring wells. Specifically, the suspected source of MEK is the glue used to join segments of the sampling tubes introduced into these wells. MEK was no longer detected after removal of the sampling tubes.

DCM is suspected of being a laboratory contaminant.

REMEDIATION

Design and Operational Features of Remediation System

The recovery system has been operating continuously since January 22, 1988. The initial system consisted of one pumping well (MW-3). Modifications to the recovery system undertaken in December 1988 and January 1989 included the installation of submersible pumps in MW-1, MW-2, and MW-11 (depths for these wells are shown in Table 1). Figure 3 shows the modified system. The total pumping rate of the four recovery wells was maintained during the first half of 1989 at the same rate of approximately 60 gpm as that drawn from MW-3 initially. The individual wells were pumped at a rate of 30 gpm (MW-3 and MW-11), 2 gpm (MW-2), and 1 gpm (MW-1). Thereafter, the total pumping rate was reduced to

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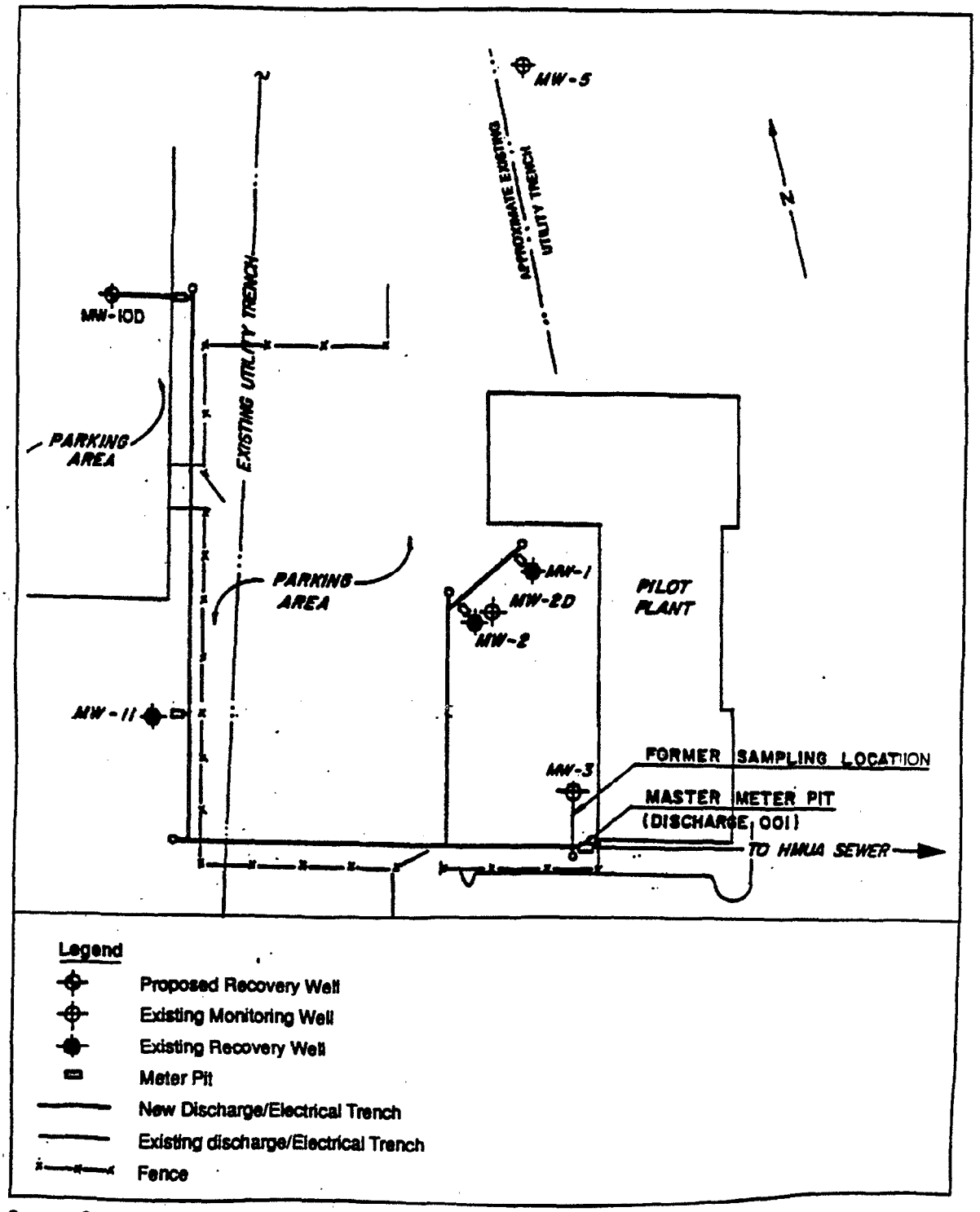

Source: Storch Engineers, 1990

Note: This map indicates the site condition as of Jan. 31, 1990.

Figure 3
LAYOUT OF MODIFIED GROUND-WATER MONITORING AND RECOVERY SYSTEM NICHOLS ENGINEERING SITE

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Table 1
MONITORING WELL DATA FOR NICHOLS ENGINEERING SITE

Well No.	Well Depth (ft)	Approximate Casing Depth (ft)
MW-1	60	15-20
MW-2	60	15-20
MW-2D	100	61
MW-3	100	15-20
MW-4	65	15-20
MW-5	60	15-20
MW-6	60	15-20
MW-7	60	15-20
MW-8	50	15-20
MW-9	55	15-20
MW-10	60	15-20
MW-10D	100	61
MW-11	100	15-20
MW-12	100	15-20

between 36 and 42 gpm. As of May 9, 1990, TCE was found intermittently at levels below the reporting limit in wells MW-1, MW-2, MW-10, and MW-11, and on one 53,700,000 gallons of ground water had been recovered and discharged into the Hillsborough Municipal Utility Authority sanitary sewer system.

The reason for adding new wells to the extraction system was to expedite ground-water remediation by increasing the rate of VOC reduction per unit of ground water removed. The selection of the three additional recovery wells was based on the observation that well MW-11 was not showing any significant decrease in contaminant concentration. Also, all three of the new wells are outside the estimated zone of capture of well MW-3 in the lower geologic stratum.

The original extraction system design analysis incorporated average hydraulic properties and assumed that the aquifer behaves as a single homogeneous medium (see Figure 3 in original case study). Capture-zone analyses conducted separately for the upper and lower hydrogeologic strata show that wells MW-11, MW-1, and MW-2 lie within the capture zone of recovery well MW-3 within the upper low transmissivity stratum but is located beyond the capture zone that theoretically develops in the lower high transmissivity stratum (see Figures 4 and 5). The capture-zone analyses are based on the capture-zone type curves developed by Javandel and Tsang (1986). These type curves assume a homogeneous and isotropic porous medium with uniform natural flow of ground water. The technique was applied separately to three separate estimates of the regional ground-water gradient within each hydrogeologic layer and the resulting capture

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zones were composited using best professional judgement (Storch Engineers, 1991).

EVALUATION OF PERFORMANCE

Figure 6 shows a comparison of the cone of depression for the integrated potentiometric surface (recall that monitoring wells are open throughout their length below the water table) associated with the initial recovery system pumping at 60 gpm on January 3, 1989, the modified recovery system pumping at 60 gpm on July 13, 1989, and the modified system pumping at 36 gpm on June 21, 1990. Storch Engineers has asked the NJDEP to authorize further modification of the system by relocating the MW-3 recovery pump to MW-10D and by pumping the recovery wells intermittently. The relocation of a recovery pump to MW-10D is intended to reduce the CS_2 level, which has been detected in MW-10D and MW-2D. The intermittent pumping schedule was proposed because it may improve the efficiency of contaminant recovery from the vadose zone by allowing the water table to rise and saturate some of the unsaturated zone. Table 2 lists the results of ground-water sampling in the monitoring wells since the start of remediation (Storch Engineers, 1990).

Monitoring wells MW-1 and MW-2 have historically exhibited the highest VOC concentrations. Figures 7 and 8 present the concentrations of CCl_4 detected in target wells MW-1, MW-2, MW-10, and MW-11. Isopleths for CCl_4 and $CHCl_3$, which are shown in Figures 9 and 10, provide a comparison between the size and configuration of the contaminant plume on January 6, 1988, and April 4, 1990.

Based upon the results of the January 29-30, 1990, and April 4, 1990, sampling rounds, CCl_4 concentrations in monitoring Wells MW-1 and MW-2 have been reduced by 92.3 percent and 86.9 percent, respectively, since January 22, 1988. The target cleanup level of 5 ppb for individual VOCs (10 ppb for total VOCs) would require a 99.5 percent reduction of the original concentration of CCl_4 in MW-1 and a 99.2 percent reduction in monitoring Well MW-2. Figures 9 and 10 show that the current recovery system has been effective at lowering the peak contaminant levels within the plume and reducing the volume of ground water in which the VOC concentration exceeds the target cleanup level. However, the rate of decline of CCl_4 in MW-1, MW-2, and MW-11 decreased during 1989 and 1990. In each of their successive progress reports, Storch Engineers re-estimated the time required to reach cleanup levels based on best-fit curves of VOC concentrations over time. Because of the decreasing removal rates, this estimate increased from 950 days in June 1989 to 1,400 days in August of 1989, to as much as 150 years in July of 1990 (Storch Engineers, 1989a, 1989e, and 1990).

Storch Engineers (1990) postulates a number of physical and chemical factors that could have reduced the efficiency of the recovery system being used at the NERC facility. Heterogeneities in the aquifer can result in advective dispersion that yields extremely long flow paths for portions of the contaminant plume. Strataof reactive clays or high organic content can retard portions of the contaminant plume in relation to the main body. Precipitation may also result in flushing of residual contamination from the unsaturated zone at extremely slow rates. Free-phase product may be pooled in small, poorly connected fractures in the unsaturated zone, providing a continuous contaminant source.

Although clear evidence of the effects of heterogeneity and chemical retardation have not been provided, Storch Engineers has shown a potential correlation between high precipitation levels and increased concentrations of VOCs in ground water at the NERC site (Figure 11). Though the evidence is not without its ambiguities because of the periodic nature of the ground-water sampling data versus the continuous nature of the precipitation records, the pattern of fluctuation of contaminant concentration indicates a contaminant source in the unsaturated zone (Storch Engineers, 1990). Storch Engineers (1990) postulates that VOCs in the unsaturated zone are being mobilized by infiltrating precipitation, which carries dissolved contaminants into the saturated zone. However, NJDEP does not agree that the evidence for this correlation is conclusive enough to justify experimenting with an induced infiltration system (NJDEP, 1990).

SUMMARY OF REMEDIATION

The NERC site has reported elevated levels of VOCs (mainly CCl_4) in the ground water. A ground-water recovery well has been in continuous

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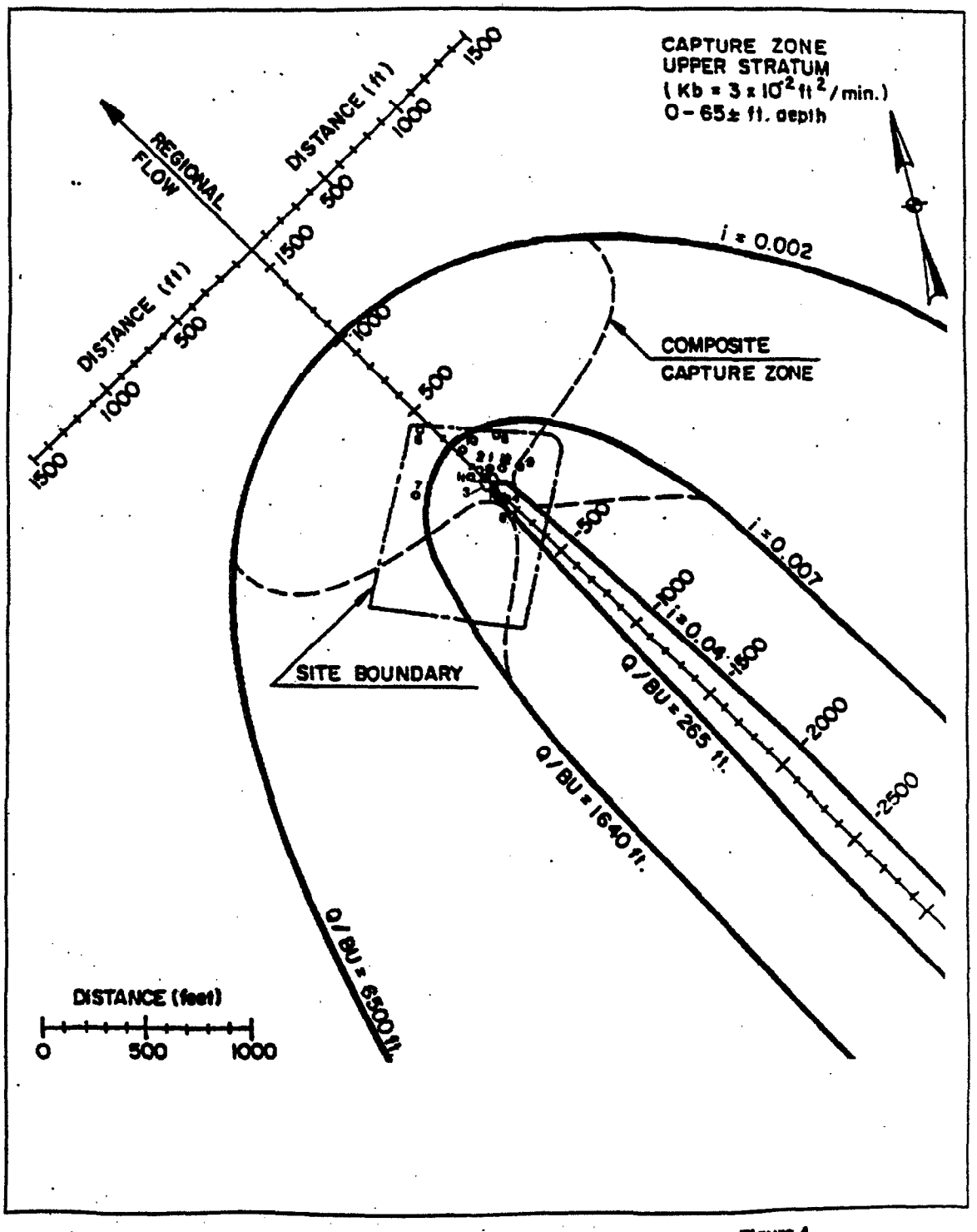

Source: Storch Engineers, 1988b

Note: Wells shown without MW prefixes

Figure 4
CAPTURE ZONE (MW-3)
UPPER STRATUM
NICHOLS ENGINEERING

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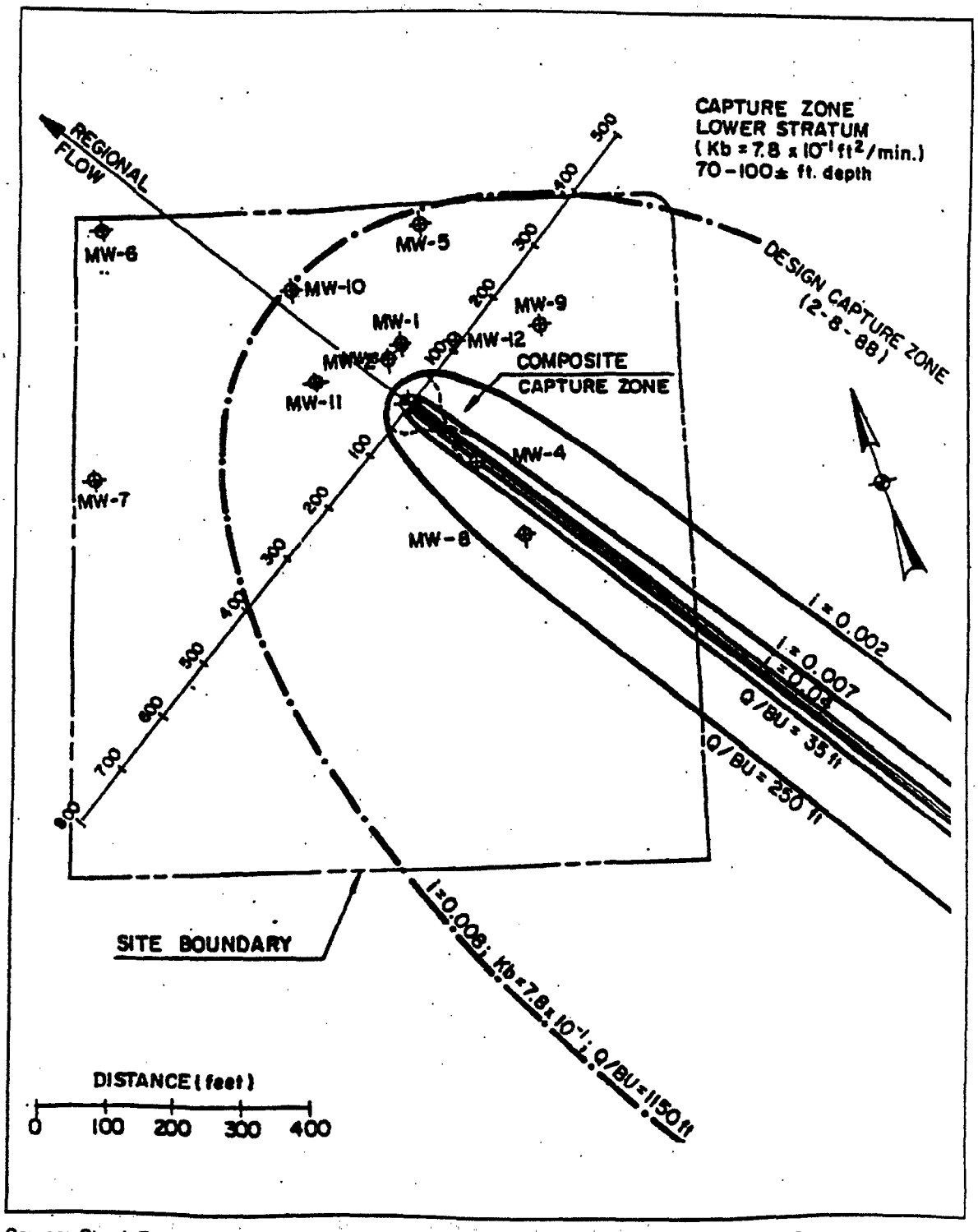

Source: Storch Engineers, 1988b

Figure 5
CAPTURE ZONE (MW-3)
LOWER STRATUM
NICHOLS ENGINEERING

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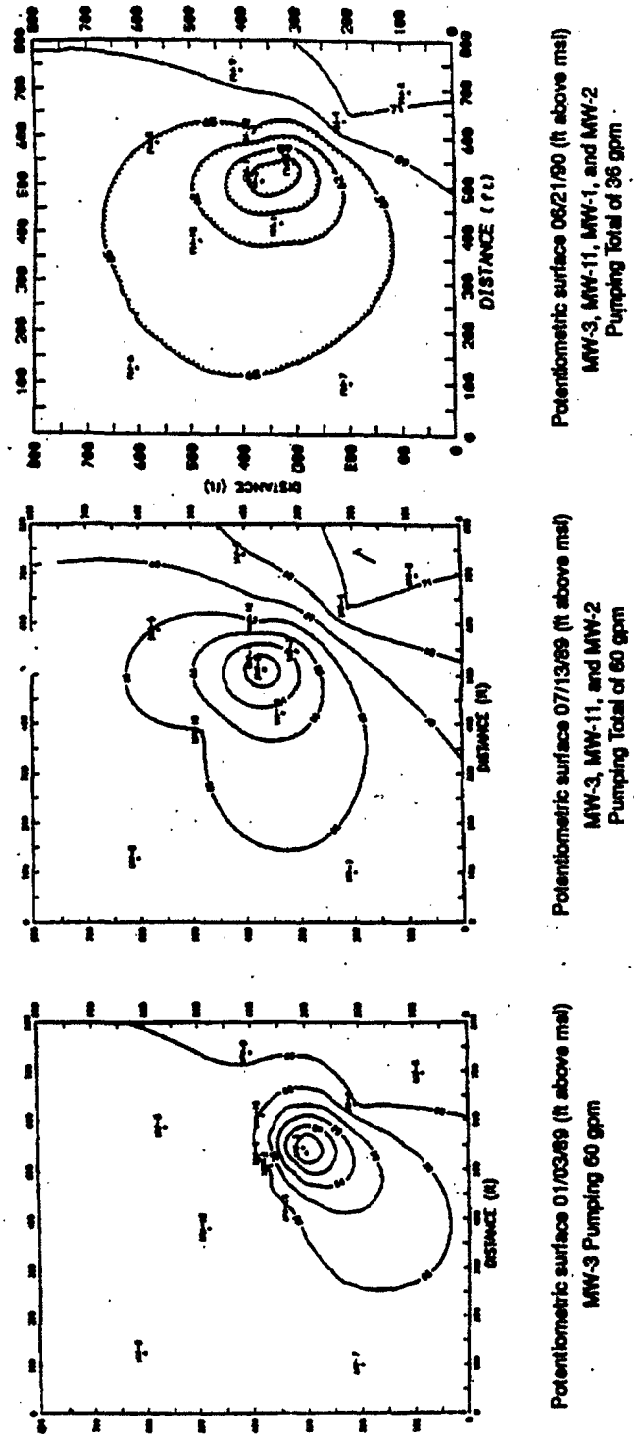

Source Storch Engineers, 1990

Figure 6
POTENTIOMETRIC SURFACE IN RESPONSE TO DIFFERENT PUMPING CONFIGURATIONS
NICHOLS ENGINEERING SITE

(Poor Quality Original)

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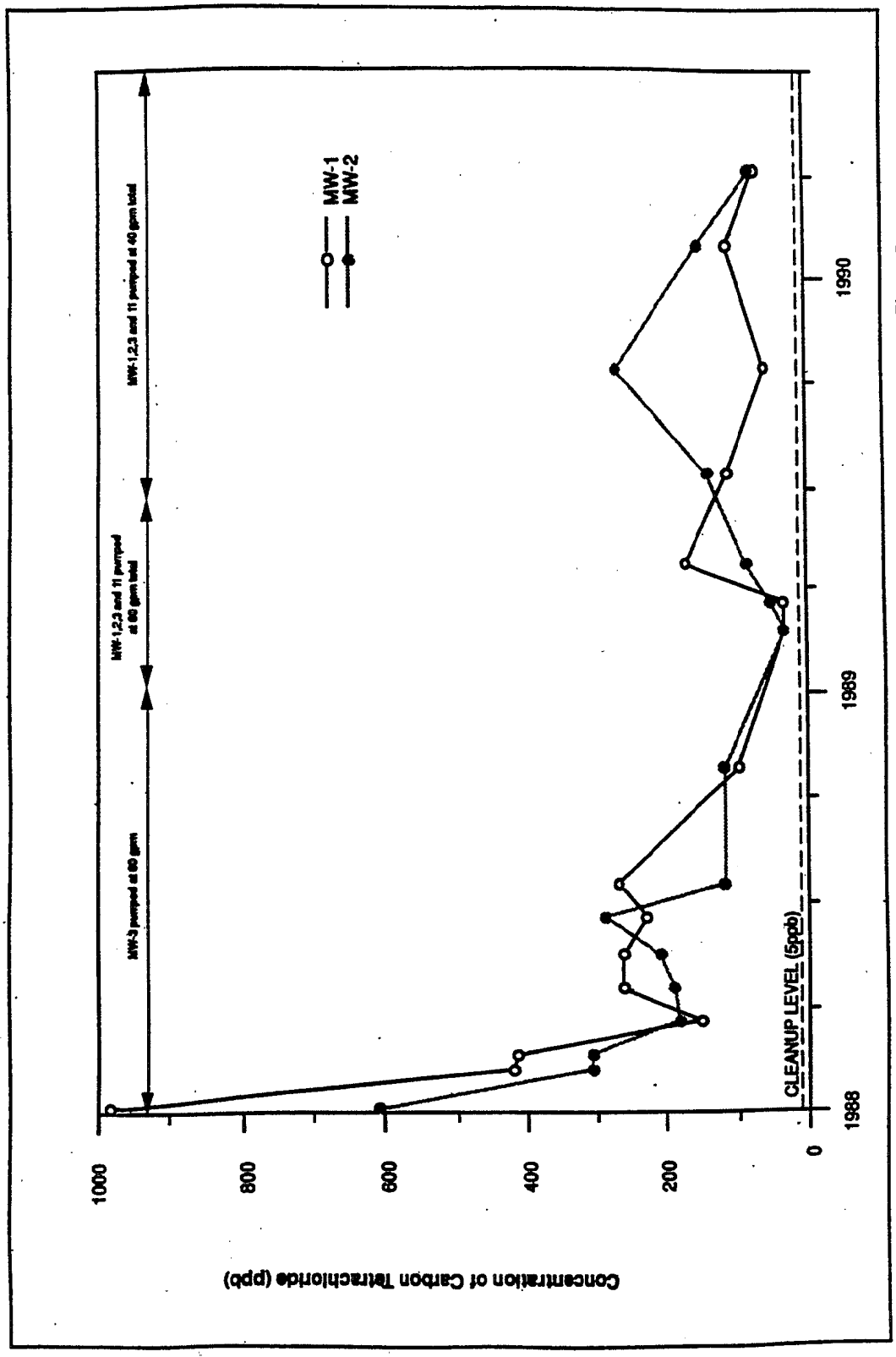

Source: Data in Table 1 in Storch Engineers, 1990

Figure 7
CCl_4 CONCENTRATION OVER TIME
IN MW-1 AND MW-2
NICHOLS ENGINEERING SITE

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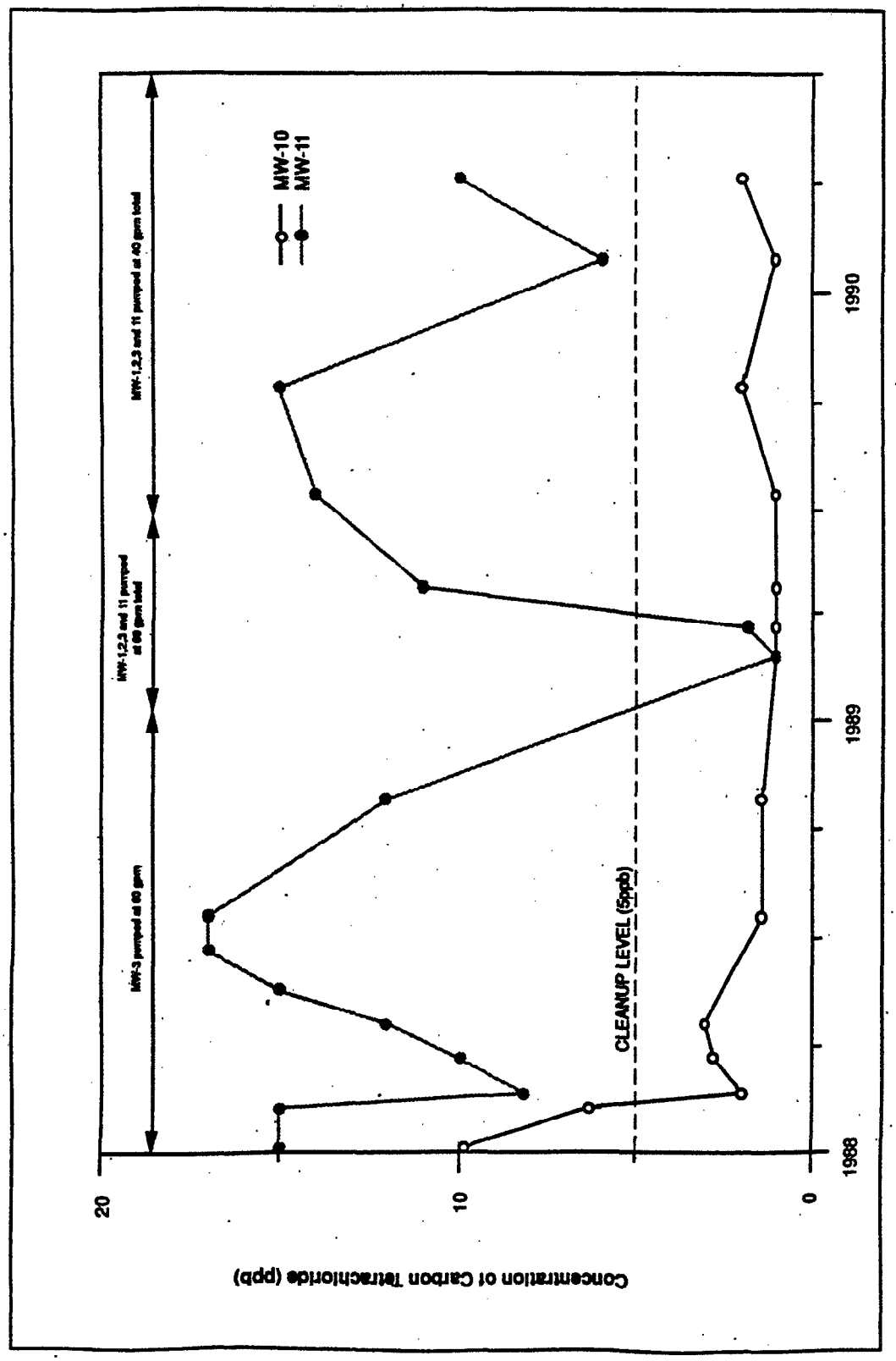

Source Data in Table 1 in Storch Engineers, 1990

Figure 8
CCl_4 CONCENTRATION OVER TIME IN MW-11 AND MW-10
NICHOLS ENGINEERING SITE

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TABLE 2. SAMPLING RESULTS (JANUARY 1988-APRIL 1990): NICHOLS ENGINEERING AND RESEARCH CORPORATION

(concentration in ppb)

MW-1

Parameter	1/6/88-1/7/88	2/8/88	2/22/88	3/21/88	4/19/88	5/19/88	6/21/88	7/21/88-7/22/88	10/26/88	2/23/89	3/22/89	4/26/89-4/27/89	7/12/89-7/13/89	10/12/89-10/13/89	1/29/90-1/30/90	4/4/90
Chloroform	ND	17	19	6.8	10	12	9.3	12	5.6	ND	1.1 *	10	8.9	4.0 *	10	5.3
Toluene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Methylene Chloride	ND	ND	1.8 z	1.4 z	37 @	ND	3.8 *	32	2.9 z	ND	6.5 z	ND	11 *	ND	2.7 z	5.0 *
Carbon Tetrachloride	980	420	410	150	260	260	230	270	98	35	30	170	110	57	110	75
Trichloroethene	ND	1.7 *	1.6 *	1.5 *	ND	ND	ND	ND	ND	ND	ND	ND	3.0 *	1.4 *	1.3 *	ND
Tetrachloroethene	ND	14	13	5.1	9.8 *	7.7	7.3	7.2 *	3 *	ND	ND	6.6	6.2	3.0 *	7.9	3.6 *
1,1,1-Trichloroethene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Vinyl Acetate	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Carbon Disulfide	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2-Butanone	ND	ND	ND	ND	ND	ND	ND	ND	ND	1100	ND	ND	ND	ND	ND	ND
Benzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chloromethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.2 *

MW-2

Parameter	1/6/88-1/7/88	2/8/88	2/22/88	3/21/88	4/19/88	5/19/88	6/21/88	7/21/88-7/22/88	10/26/88	2/23/89	3/22/89	4/26/89-4/27/89	7/12/89-7/13/89	10/12/89-10/13/89	1/29/90-1/30/90	4/4/90
Chloroform	21	17	15	9	9.3	14	13	7.3 *	7.7	2 *	1.9 *	3.6 *	8.4	12	9.6	4.3
Toluene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Methylene Chloride	ND	ND	3.9 z	ND	1.7 z	ND	3.2 *	32	ND	3.9 *	6.1 z	5.9 *	10 *@	5.4 *@	3.7 z	6.6
Carbon Tetrachloride	610	310	310	180	190	210	290	120	120	34	50	87	140	270	150	80
Trichloroethene	ND	1.7 *	1.9 *	ND	1.1 *	ND	1.4 *	ND	ND	ND	ND	ND	3.3 *	ND	1.5 *	ND
Tetrachloroethene	ND	11	9.4	4.7	5.5	8.7	9.4	ND	4.5 *	ND	ND	ND	4.9 *	7.8 *	5.7	2.9 *
1,1,1-Trichloroethene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Vinyl Acetate	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Carbon Disulfide	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2-Butanone	ND	ND	ND	ND	ND	ND	ND	ND	ND	88	59	ND	ND	ND	ND	ND
Benzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chloromethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.3 *

MW-2D

Parameter	1/6/88-1/7/88	2/8/88	2/22/88	3/21/88	4/19/88	5/19/88	6/21/88	7/21/88-7/22/88	10/26/88	2/23/89	3/22/89	4/26/89-4/27/89	7/12/89-7/13/89	10/12/89-10/13/89	1/29/90-1/30/90	4/4/90
Chloroform	--	--	--	--	--	--	--	--	--	--	--	--	--	--	ND	ND
Toluene	--	--	--	--	--	--	--	--	--	--	--	--	--	--	ND	ND
Methylene Chloride	--	--	--	--	--	--	--	--	--	--	--	--	--	--	2.0 z	4.7 *
Carbon Tetrachloride	--	--	--	--	--	--	--	--	--	--	--	--	--	--	ND	ND
Trichloroethene	--	--	--	--	--	--	--	--	--	--	--	--	--	--	ND	ND
Tetrachloroethene	--	--	--	--	--	--	--	--	--	--	--	--	--	--	ND	ND
1,1,1-Trichloroethene	--	--	--	--	--	--	--	--	--	--	--	--	--	--	ND	ND
Vinyl Acetate	--	--	--	--	--	--	--	--	--	--	--	--	--	--	ND	ND
Carbon Disulfide	--	--	--	--	--	--	--	--	--	--	--	--	--	--	6.9	1.6 *
2-Butanone	--	--	--	--	--	--	--	--	--	--	--	--	--	--	ND	ND
Benzene	--	--	--	--	--	--	--	--	--	--	--	--	--	--	ND	ND
Chloromethane	--	--	--	--	--	--	--	--	--	--	--	--	--	--	ND	1.4 *
Xylenes (total)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	ND	2.2 *

Source Storch Engineers, 1990

-- = Not Analyzed
ND = Not Detected
* = Trace concentrations below the reporting limit
@ = Analyte also detected in Erco Procedural Blank

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TABLE 2. SAMPLING RESULTS (JANUARY 1988-APRIL 1990): NICHOLS ENGINEERING AND RESEARCH CORPORATION

MW-3

Parameter	1/6/88-1/7/88	2/8/88	2/22/88	3/21/88	4/19/88	5/19/88	6/21/88	7/21/88-7/22/88	10/26/88	2/23/89	3/22/89	4/26/89-4/27/89	7/12/89-7/13/89	10/12/89-10/13/89	1/29/90-1/30/90	4/4/90
Chloroform	1.6	ND	ND	ND	ND	ND	ND	ND	ND	--	--	--	--	--	--	--
Toluene	1.7	ND	ND	ND	ND	ND	ND	ND	ND	--	--	--	--	--	--	--
Methylene Chloride	2.4	1.5 @	12	ND	1.3 z	ND	3.6 *	5.8	4.6 z	--	--	--	--	--	--	--
Carbon Tetrachloride	1.8	ND	ND	ND	ND	ND	ND	ND	ND	--	--	--	--	--	--	--
Trichloroethene	ND	ND	ND	ND	ND	ND	ND	ND	ND	--	--	--	--	--	--	--
Tetrachloroethene	ND	ND	ND	ND	ND	ND	ND	ND	ND	--	--	--	--	--	--	--
1,1,1-Trichloroethene	ND	ND	ND	ND	ND	ND	ND	ND	ND	--	--	--	--	--	--	--
Vinyl Acetate	ND	ND	ND	ND	ND	ND	ND	ND	ND	--	--	--	--	--	--	--
Carbon Disulfide	ND	ND	ND	ND	ND	ND	ND	ND	ND	--	--	--	--	--	--	--
2-Butanone	ND	ND	ND	ND	ND	ND	ND	ND	ND	--	--	--	--	--	--	--
Benzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	--	--	--	--	--	--	--

MW-4

Parameter	1/6/88-1/7/88	2/8/88	2/22/88	3/21/88	4/19/88	5/19/88	6/21/88	7/21/88-7/22/88	10/26/88	2/23/89	3/22/89	4/26/89-4/27/89	7/12/89-7/13/89	10/12/89-10/13/89	1/29/90-1/30/90	4/4/90
Chloroform	ND	ND	ND	ND	--	--	--	ND	--	--	--	ND	--	--	ND	--
Toluene	9.1	ND	ND	ND	--	--	--	ND	--	--	--	ND	--	--	ND	--
Methylene Chloride	ND	2.9 @	9.4	1.4 *	1.3 z	--	--	10 @	--	--	--	4.0 *	--	--	ND	--
Carbon Tetrachloride	2.6	1 *	ND	1.9 *	1.3 *	--	--	ND	--	--	--	ND	--	--	ND	--
Trichloroethene	ND	ND	ND	ND	ND	--	--	ND	--	--	--	ND	--	--	ND	--
Tetrachloroethene	ND	ND	ND	ND	ND	--	--	ND	--	--	--	ND	--	--	ND	--
1,1,1-Trichloroethene	ND	ND	ND	ND	ND	--	--	ND	--	--	--	ND	--	--	ND	--
Vinyl Acetate	ND	ND	ND	ND	ND	--	--	ND	--	--	--	ND	--	--	ND	--
Carbon Disulfide	ND	ND	ND	ND	ND	--	--	ND	--	--	--	ND	--	--	ND	--
2-Butanone	ND	ND	ND	ND	ND	--	--	ND	--	--	--	ND	--	--	ND	--
Benzene	ND	ND	ND	ND	ND	--	--	ND	--	--	--	ND	--	--	ND	--

MW-5

Parameter	1/6/88-1/7/88	2/8/88	2/22/88	3/21/88	4/19/88	5/19/88	6/21/88	7/21/88-7/22/88	10/26/88	2/23/89	3/22/89	4/26/89-4/27/89	7/12/89-7/13/89	10/12/89-10/13/89	1/29/90-1/30/90	4/4/90
Chloroform	ND	--	--	--	--	--	--	ND	ND	ND	ND	ND	ND	ND	ND	ND
Toluene	8.2	--	--	--	--	--	--	ND	ND	ND	ND	ND	ND	93 *	ND	ND
Methylene Chloride	1.4 *	--	--	--	--	--	--	1.1 z	7.2 z	2.3 *	12 z	16	3.4 * @	ND	3.4 z	8.9
Carbon Tetrachloride	1.6 *	--	--	--	--	--	--	7.4	7	1.9 *	ND	ND	ND	ND	ND	ND
Trichloroethene	ND	--	--	--	--	--	--	ND	ND	ND	ND	ND	ND	160	ND	ND
Tetrachloroethene	ND	--	--	--	--	--	--	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,1-Trichloroethene	ND	--	--	--	--	--	--	ND	ND	ND	ND	ND	ND	24 *	ND	ND
Vinyl Acetate	ND	--	--	--	--	--	--	ND	ND	ND	ND	ND	ND	ND	ND	ND
Carbon Disulfide	ND	--	--	--	--	--	--	ND	ND	ND	ND	ND	ND	ND	ND	2.1 *
2-Butanone	ND	--	--	--	--	--	--	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzene	ND	--	--	--	--	--	--	ND	ND	ND	ND	ND	ND	ND	ND	ND

Source: Storch Engineers, 1990

-- = Not Analyzed
ND = Not Detected
* = Trace concentrations below the reporting limit
@ = Analyte also detected in Erco Procedural Blank
z = Both trace concentrations detected below the reporting limit and analyte detected in Erco Procedural Blank.

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TABLE 2. SAMPLING RESULTS (JANUARY 1988-APRIL 1990): NICHOLS ENGINEERING AND RESEARCH CORPORATION

MW-6

Parameter	1/5/88-1/7/88	2/8/88	2/22/88	3/21/88	4/19/88	5/19/88	6/21/88	7/21/88-7/22/88	10/26/88	2/23/89	3/22/89	4/26/89-4/27/89	7/12/89-7/13/89	10/12/89-10/13/89	1/29/90-1/30/90	4/4/90
Chloroform	ND	ND	ND	ND	ND	--	--	ND	--	--	--	ND	--	--	ND	--
Toluene	ND	ND	ND	ND	ND	--	--	ND	--	--	--	ND	--	--	ND	--
Methylene Chloride	3.5 *	8.8 ●	1.2 z	ND	1.5 z	--	--	10 z	--	--	--	7.9 z	--	--	1.7 z	--
Carbon Tetrachloride	ND	ND	ND	ND	ND	--	--	ND	--	--	--	ND	--	--	ND	--
Trichloroethene	2.4	ND	ND	ND	ND	--	--	ND	--	--	--	ND	--	--	ND	--
Tetrachloroethene	ND	ND	ND	ND	ND	--	--	ND	--	--	--	ND	--	--	ND	--
1,1,1-Trichloroethene	ND	ND	ND	ND	ND	--	--	ND	--	--	--	ND	--	--	ND	--
Vinyl Acetate	ND	ND	ND	ND	2.5 ●	--	--	ND	--	--	--	ND	--	--	ND	--
Carbon Disulfide	ND	ND	ND	ND	ND	--	--	ND	--	--	--	ND	--	--	ND	--
2-Butanone	ND	ND	ND	ND	ND	--	--	ND	--	--	--	ND	--	--	ND	--
Chloromethane	ND	ND	ND	ND	ND	--	--	ND	--	--	--	1.2 *	--	--	ND	--
Benzene	ND	ND	ND	ND	ND	--	--	ND	--	--	--	ND	--	--	ND	--

MW-7

Parameter	1/5/88-1/7/88	2/8/88	2/22/88	3/21/88	4/19/88	5/19/88	6/21/88	7/21/88-7/22/88	10/26/88	2/23/89	3/22/89	4/26/89-4/27/89	7/12/89-7/13/89	10/12/89-10/13/89	1/29/90-1/30/90	4/4/90
Chloroform	ND	--	--	--	--	--	--	ND	--	--	--	ND	--	--	ND	--
Toluene	1.6 *	--	--	--	--	--	--	ND	--	--	--	ND	--	--	ND	--
Methylene Chloride	2.4 *	--	--	--	--	--	--	16 z	--	--	--	3.6 z	--	--	3.5 z	--
Carbon Tetrachloride	ND	--	--	--	--	--	--	ND	--	--	--	ND	--	--	ND	--
Trichloroethene	ND	--	--	--	--	--	--	ND	--	--	--	ND	--	--	ND	--
Tetrachloroethene	ND	--	--	--	--	--	--	ND	--	--	--	ND	--	--	ND	--
1,1,1-Trichloroethene	ND	--	--	--	--	--	--	ND	--	--	--	ND	--	--	ND	--
Vinyl Acetate	ND	--	--	--	--	--	--	ND	--	--	--	ND	--	--	ND	--
Carbon Disulfide	ND	--	--	--	--	--	--	ND	--	--	--	ND	--	--	ND	--
2-Butanone	ND	--	--	--	--	--	--	ND	--	--	--	ND	--	--	ND	--
Benzene	ND	--	--	--	--	--	--	ND	--	--	--	ND	--	--	ND	--

MW-8

Parameter	1/5/88-1/7/88	2/8/88	2/22/88	3/21/88	4/19/88	5/19/88	6/21/88	7/21/88-7/22/88	10/26/88	2/23/89	3/22/89	4/26/89-4/27/89	7/12/89-7/13/89	10/12/89-10/13/89	1/29/90-1/30/90	4/4/90
Chloroform	ND	--	--	--	--	--	--	ND	--	--	--	ND	--	--	ND	--
Toluene	ND	--	--	--	--	--	--	ND	--	--	--	ND	--	--	ND	--
Methylene Chloride	2.5 *	--	--	--	--	--	--	3 z	--	--	--	2.6 *	--	--	ND	--
Carbon Tetrachloride	ND	--	--	--	--	--	--	ND	--	--	--	ND	--	--	ND	--
Trichloroethene	ND	--	--	--	--	--	--	ND	--	--	--	ND	--	--	ND	--
Tetrachloroethene	ND	--	--	--	--	--	--	ND	--	--	--	ND	--	--	ND	--
1,1,1-Trichloroethene	ND	--	--	--	--	--	--	ND	--	--	--	ND	--	--	ND	--
Vinyl Acetate	ND	--	--	--	--	--	--	ND	--	--	--	ND	--	--	ND	--
Carbon Disulfide	ND	--	--	--	--	--	--	ND	--	--	--	ND	--	--	ND	--
2-Butanone	ND	--	--	--	--	--	--	ND	--	--	--	ND	--	--	ND	--
Benzene	ND	--	--	--	--	--	--	ND	--	--	--	ND	--	--	ND	--

Source: Storch Engineers, 1990

-- = Not Analyzed
ND = Not Detected
* = Trace concentrations below the reporting limit
● = Analyte also detected in Erco Procedural Blank
z = Both trace concentrations detected below the reporting limit and analyte detected in Erco Procedural Blank.

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TABLE 2. SAMPLING RESULTS (JANUARY 1986-APRIL 1990): NICHOLS ENGINEERING AND RESEARCH CORPORATION

MW-9

Parameter	1/6/86-1/7/86	2/6/86	2/22/86	3/21/86	4/19/86	5/19/86	6/21/86	7/21/86-7/22/86	10/26/86	2/23/89	3/22/89	4/26/89-4/27/89	7/12/89-7/13/89	10/12/89-10/13/89	1/29/90-1/30/90	4/4/90
Chloroform	ND	--	--	--	--	--	--	ND	--	--	--	ND	--	--	ND	--
Toluene	ND	--	--	--	--	--	--	ND	--	--	--	ND	--	--	ND	--
Methylene Chloride	ND-	--	--	--	--	--	--	2.4 z	--	--	--	7.9 @	--	--	ND	--
Carbon Tetrachloride	ND	--	--	--	--	--	--	ND	--	--	--	ND	--	--	ND	--
Trichloroethene	ND	--	--	--	--	--	--	ND	--	--	--	ND	--	--	ND	--
Tetrachloroethene	ND	--	--	--	--	--	--	ND	--	--	--	ND	--	--	ND	--
1,1,1-Trichloroethene	ND	--	--	--	--	--	--	ND	--	--	--	ND	--	--	ND	--
Vinyl Acetate	ND	--	--	--	--	--	--	ND	--	--	--	ND	--	--	ND	--
Carbon Disulfide	ND	--	--	--	--	--	--	ND	--	--	--	ND	--	--	ND	--
2-Butanone	ND	--	--	--	--	--	--	ND	--	--	--	ND	--	--	ND	--
Chloromethane	ND	--	--	--	--	--	--	ND	--	--	--	1.0 *	--	--	ND	--
Benzene	ND	--	--	--	--	--	--	ND	--	--	--	ND	--	--	ND	--

MW-10

Parameter	1/6/86-1/7/86	2/6/86	2/22/86	3/21/86	4/19/86	5/19/86	6/21/86	7/21/86-7/22/86	10/26/86	2/23/89	3/22/89	4/26/89-4/27/89	7/12/89-7/13/89	10/12/89-10/13/89	1/29/90-1/30/90	4/4/90
Chloroform	1.7 *	1.6 *	1.4 *	ND	ND	--	--	ND	ND	ND	ND	ND	ND	ND	ND	ND
Toluene	4.2	ND	ND	ND	ND	--	--	ND	ND	ND	ND	ND	ND	1.4 *	ND	ND
Methylene Chloride	1.8 *	2.4 *	7.4	ND	ND	--	--	1.1 *	ND	4.6 *	6.6 z	21	7.6 *@	ND	ND	2.9 *
Carbon Tetrachloride	9.6	ND	ND	2.8	3	--	--	1.4 *	1.4 *	ND	ND	ND	ND	1.9 *	ND	1.9 *
Trichloroethene	ND	ND	ND	ND	ND	--	--	ND	ND	ND	ND	ND	ND	ND	1.9 *	3.4 *
Tetrachloroethene	ND	ND	ND	ND	ND	--	--	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,1-Trichloroethene	ND	ND	ND	ND	ND	--	--	ND	ND	ND	ND	ND	ND	ND	ND	ND
Vinyl Acetate	ND	ND	ND	ND	ND	--	--	ND	ND	ND	ND	ND	ND	ND	ND	ND
Carbon Disulfide	ND	ND	ND	ND	ND	--	--	ND	ND	ND	ND	ND	ND	ND	1.9 *	ND
2-Butanone	ND	ND	ND	ND	ND	--	--	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzene	ND	ND	ND	ND	ND	--	--	ND	ND	ND	ND	ND	ND	ND	ND	ND
Ethylbenzene	ND	ND	ND	ND	ND	--	--	ND	ND	ND	ND	ND	ND	1.3 *@	ND	ND
Chloromethane	ND	ND	ND	ND	ND	--	--	ND	ND	ND	ND	ND	ND	ND	ND	1.2 *

MW-10D

Parameter	1/6/86-1/7/86	2/6/86	2/22/86	3/21/86	4/19/86	5/19/86	6/21/86	7/21/86-7/22/86	10/26/86	2/23/89	3/22/89	4/26/89-4/27/89	7/12/89-7/13/89	10/12/89-10/13/89	1/29/90-1/30/90	4/4/90
Chloroform	--	--	--	--	--	--	--	--	--	ND	ND	ND	ND	ND	ND	ND
Toluene	--	--	--	--	--	--	--	--	--	ND	ND	ND	ND	ND	ND	ND
Methylene Chloride	--	--	--	--	--	--	--	--	--	4.3 *	11 z	11	9.1 *@	ND	ND	8.7
Carbon Tetrachloride	--	--	--	--	--	--	--	--	--	ND	ND	ND	ND	ND	ND	ND
Trichloroethene	--	--	--	--	--	--	--	--	--	ND	ND	ND	ND	ND	ND	ND
Tetrachloroethene	--	--	--	--	--	--	--	--	--	ND	ND	ND	ND	ND	ND	ND
1,1,1-Trichloroethene	--	--	--	--	--	--	--	--	--	ND	ND	ND	ND	ND	ND	ND
Vinyl Acetate	--	--	--	--	--	--	--	--	--	ND	ND	ND	ND	ND	ND	ND
Carbon Disulfide	--	--	--	--	--	--	--	--	--	2.1 *	5.9	14	19	ND	23	20
2-Butanone	--	--	--	--	--	--	--	--	--	ND	ND	ND	ND	ND	ND	ND
Benzene	--	--	--	--	--	--	--	--	--	ND	ND	ND	ND	ND	ND	ND
EthylBenzene	--	--	--	--	--	--	--	--	--	ND	ND	ND	ND	2.3 *@	ND	ND
Xylenes (total)	--	--	--	--	--	--	--	--	--	ND	ND	ND	ND	1.6 *	ND	ND

Source Storch Engineers, 1990

-- = Not Analyzed
ND = Not Detected
* = Trace concentrations below the reporting limit
@ = Ahalyte also detected in Erco Procedural Blank
z = Both trace concentrations detected below the reporting limit and analyte detected in Erco Procedural Blank.

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TABLE 2. SAMPLING RESULTS (JANUARY 1986-APRIL 1990): NICHOLS ENGINEERING AND RESEARCH CORPORATION

MW-11

Parameter	1/6/86-1/7/86	2/6/86	2/22/86	3/21/86	4/19/86	5/19/86	6/21/86	7/21/86-7/22/86	10/26/86	2/23/89	3/22/89	4/26/89-4/27/89	7/12/89-7/13/89	10/12/89-10/13/89	1/29/90-1/30/90	4/4/90
Chloroform	3.6	5.4	2.6	3.8	4.4	2.9	5	4.2	4.6 *	ND	ND	3.3 *	5.2	4.5 *	2.9 *	3.3 *
Toluene	6.7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Methylene Chloride	1.5 *	ND	3.9 *	1.5 *	1.8 z	1.9	2.4	3 *	5.7 z	57 z	3 z	7.5 *	7.8 *@	ND	2.6 z	9
Carbon Tetrachloride	15	15	8.1	10	12	15	17	17	12	ND	1.8 *	11	14	15	5.9	10
Trichloroethene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	5.4	ND	ND	5.1	1.0 *	ND
Tetrachloroethene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.1 *	ND	ND	ND
1,1,1-Trichloroethene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Vinyl Acetate	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Carbon Disulfide	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	4 *	ND	ND	ND	ND	ND
2-Butanone	ND	ND	ND	ND	ND	ND	ND	ND	ND	3200	140	ND	ND	ND	ND	ND
Benzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

MW-12

Parameter	1/6/86-1/7/86	2/6/86	2/22/86	3/21/86	4/19/86	5/19/86	6/21/86	7/21/86-7/22/86	10/26/86	2/23/89	3/22/89	4/26/89-4/27/89	7/12/89-7/13/89	10/12/89-10/13/89	1/29/90-1/30/90	4/4/90
Chloroform	ND	--	--	--	--	--	--	ND	--	--	--	ND	--	--	ND	--
Toluene	3.2	--	--	--	--	--	--	ND	--	--	--	ND	--	--	ND	--
Methylene Chloride	3 *	--	--	--	--	--	--	ND	--	--	--	12 *	--	--	4.0 z	--
Carbon Tetrachloride	ND	--	--	--	--	--	--	ND	--	--	--	ND	--	--	ND	--
Trichloroethene	ND	--	--	--	--	--	--	ND	--	--	--	ND	--	--	ND	--
Tetrachloroethene	ND	--	--	--	--	--	--	ND	--	--	--	ND	--	--	ND	--
1,1,1-Trichloroethene	ND	--	--	--	--	--	--	ND	--	--	--	ND	--	--	ND	--
Vinyl Acetate	ND	--	--	--	--	--	--	ND	--	--	--	ND	--	--	ND	--
Carbon Disulfide	ND	--	--	--	--	--	--	ND	--	--	--	2.5 *	--	--	ND	--
2-Butanone	ND	--	--	--	--	--	--	ND	--	--	--	ND	--	--	ND	--
Benzene	ND	--	--	--	--	--	--	ND	--	--	--	ND	--	--	ND	--

MSP-1(MMP)

Parameter	1/6/86-1/7/86	2/6/86	2/22/86	3/21/86	4/19/86	5/19/86	6/21/86	7/21/86-7/22/86	10/26/86	2/23/89	3/22/89	4/26/89-4/27/89	7/12/89-7/13/89	10/12/89-10/13/89	1/29/90-1/30/90	4/4/90
Chloroform	--	--	--	--	--	--	--	--	--	ND	ND	ND	1.9 *	ND	ND	ND
Toluene	--	--	--	--	--	--	--	--	--	ND	ND	ND	ND	ND	ND	ND
Methylene Chloride	--	--	--	--	--	--	--	--	--	2.7 *	4 z	ND	10 *@	ND	2.4 z	5.5
Carbon Tetrachloride	--	--	--	--	--	--	--	--	--	ND	3.3 *	ND	7.2	3.2 *	ND	1.4 *
Trichloroethene	--	--	--	--	--	--	--	--	--	1.4 *	7.2	6.3	3.6 *	ND	1.7 *	1.0 *
Tetrachloroethene	--	--	--	--	--	--	--	--	--	ND	ND	ND	ND	ND	ND	ND
1,1,1-Trichloroethene	--	--	--	--	--	--	--	--	--	ND	ND	ND	ND	ND	ND	ND
Vinyl Acetate	--	--	--	--	--	--	--	--	--	ND	ND	ND	ND	ND	ND	ND
Carbon Disulfide	--	--	--	--	--	--	--	--	--	ND	ND	ND	ND	ND	ND	ND
2-Butanone	--	--	--	--	--	--	--	--	--	ND	52	ND	ND	ND	ND	ND
Benzene	--	--	--	--	--	--	--	--	--	ND	ND	ND	2.5	ND	ND	ND

Source: Storch Engineers, 1990

-- = Not Analyzed
ND = Not Detected
z = Trace concentrations below the reporting limit
@ = Analyte also detected in Trip Procedural Blank
* = [illegible]

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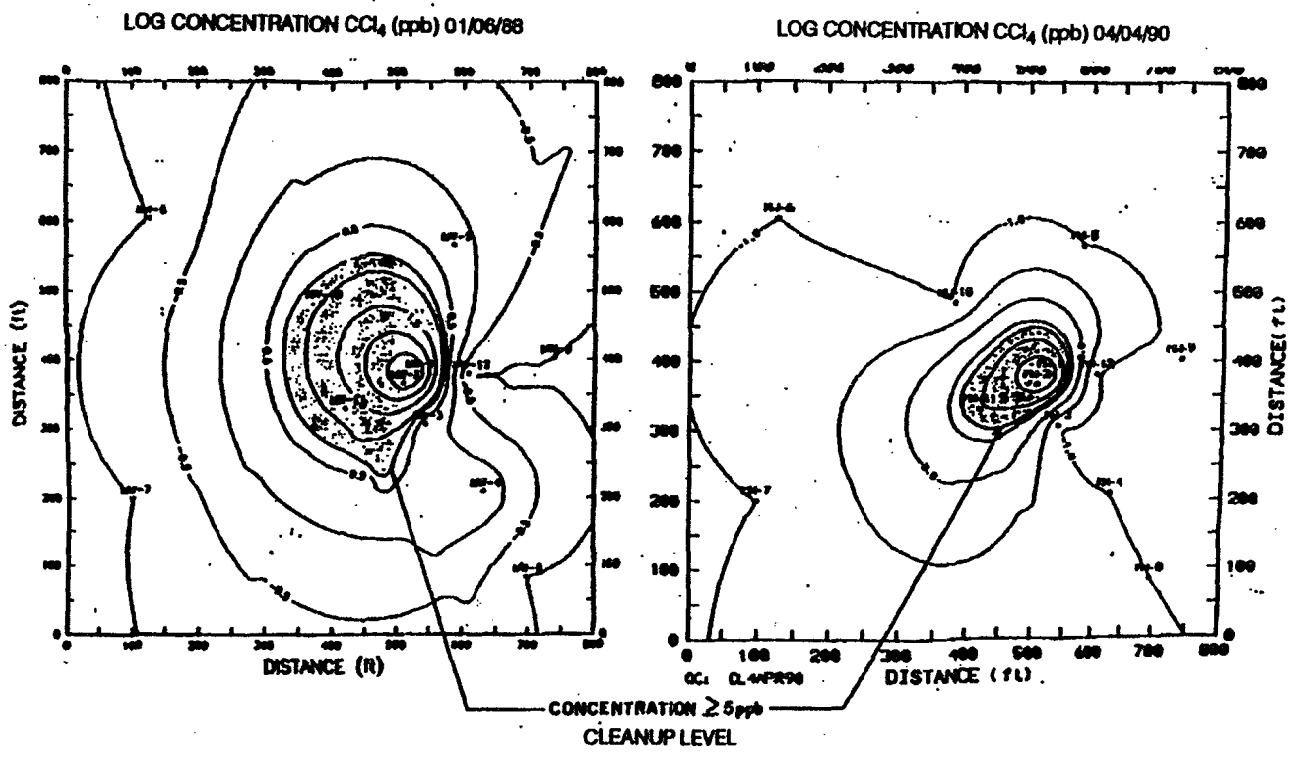

Source Storch Engineers, 1990

(Poor Quality Original)

Figure 9
CCl_4 ISOPLETH
NICHOLS ENGINEERING SITE

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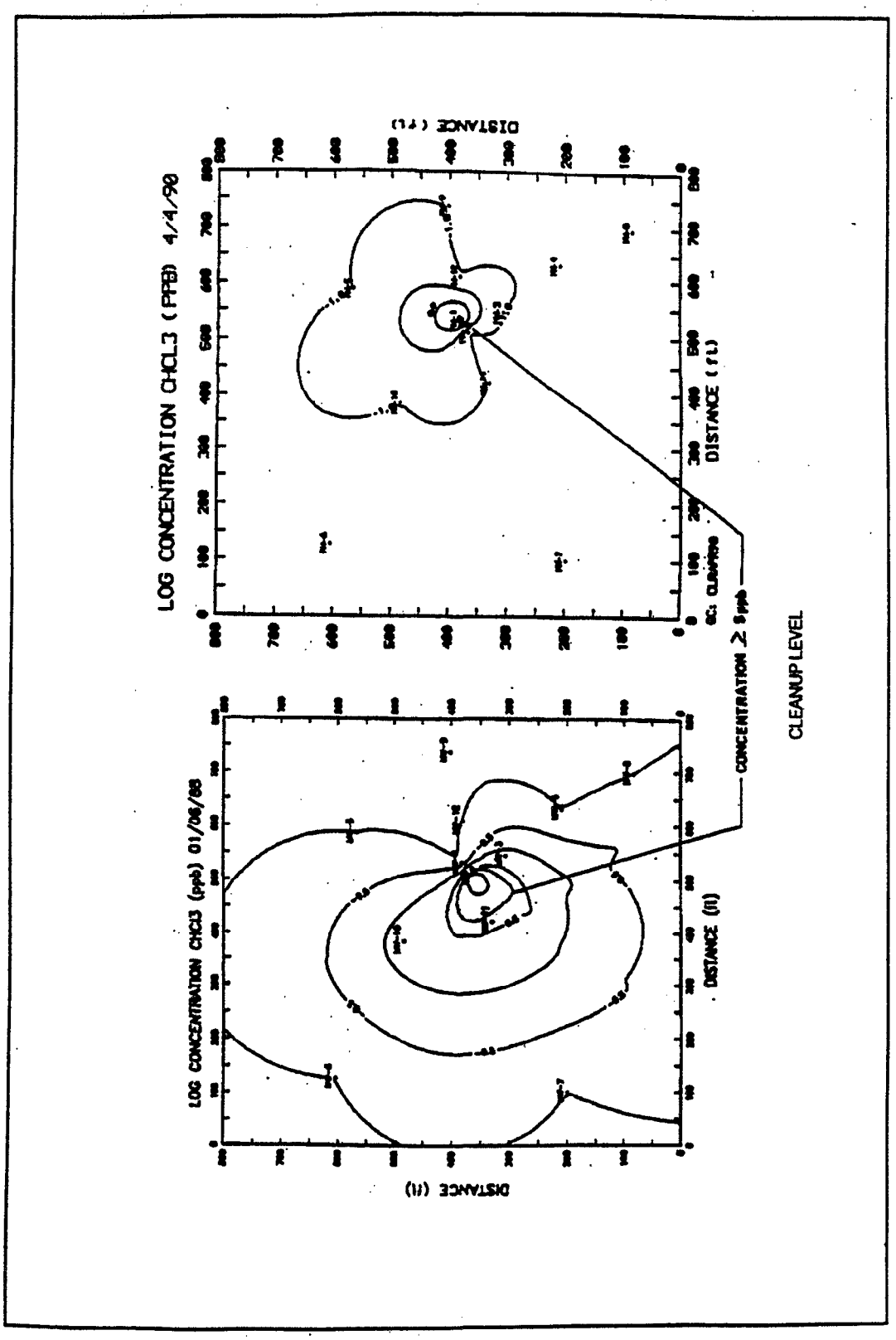

Source Storch Engineers, 1990

(Poor Quality Original)

Figure 10
$CHCl_3$ ISOPLETH
NICHOLS ENGINEERING SITE

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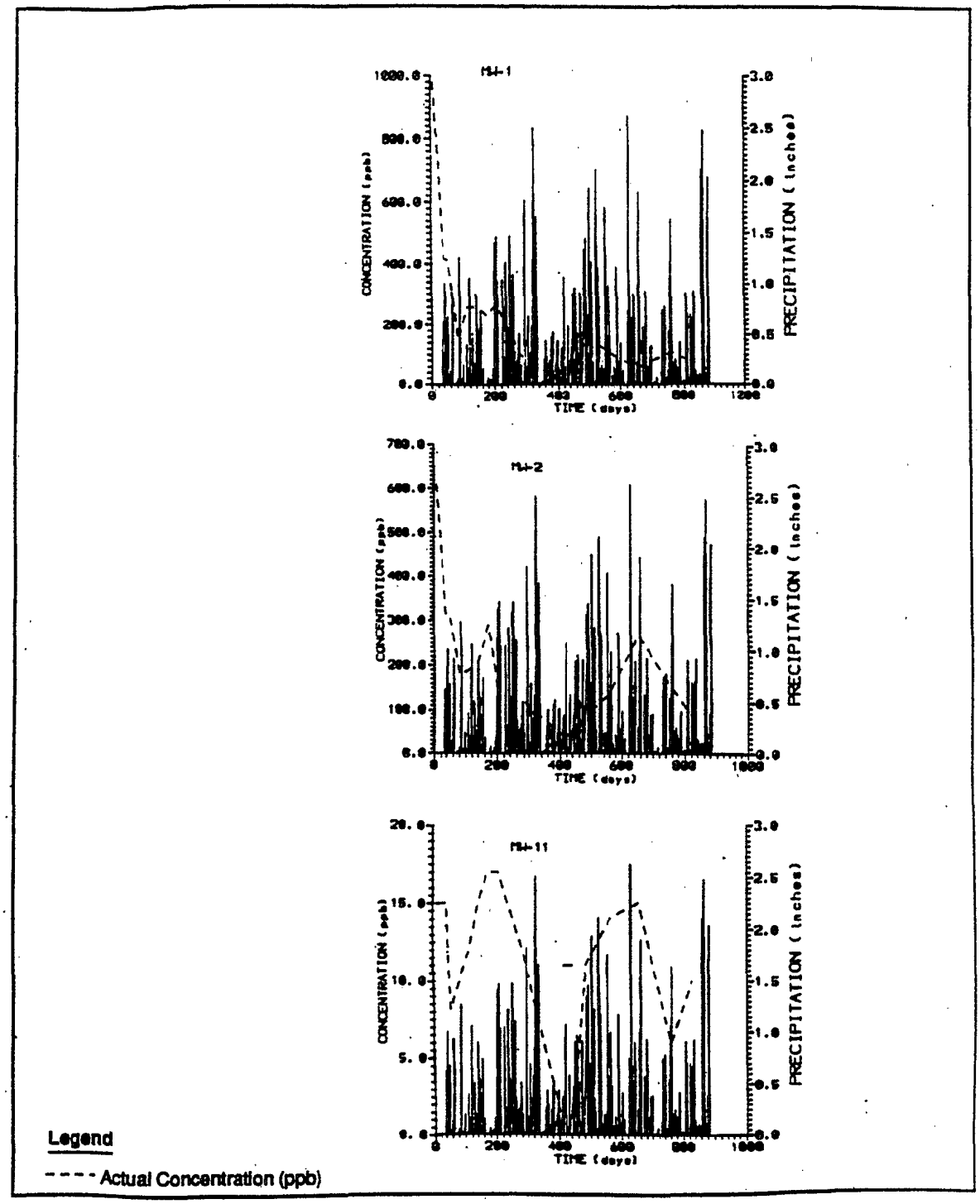

Source: Storch Engineers, 1990

Figure 11
CCl_4 CONCENTRATION VS PRECIPITATION IN MW-1, MW-2, MW-11
NICHOLS ENGINEERING

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operation since January 22, 1988, and as a result the CCl_4 concentration has been reduced by 80 to 90 percent in some wells. The rate of CCl_4 removal has decreased significantly during the course of operation. Furthermore, the addition of three additional extraction wells to the system in January 1989 has not significantly accelerated the ground-water cleanup.

The presence of CCl_4 within the unsaturated zone is of primary concern. Although CCl_4 was not observed in the unsaturated zone in initial soil surveys (U.S. EPA, 1989), CCl_4 contamination in the ground water may be attributed to the leaching of CCl_4 from the soil. There seems to be a correlation between increased precipitation and increased concentration of CCl_4 in monitoring wells. The method of storing wastewater in settling basins at the site might have contributed to contamination in the unsaturated zone.

The unsaturated zone at NERC can logically be seen as two different zones. The first zone is the part of the unsaturated zone that occurs naturally in the absence of pumping. This natural unsaturated zone is bounded by the ground surface and water-table surface, which occurs 20 to 40 feet below the ground surface. The second, or induced, unsaturated zone is that part of the zone created by the drawdown of the operating recovery well.

A technique that currently is being considered and that may improve the recovery rate of CCl_4 within the induced unsaturated zone is intermittent pumping. By shutting off the recovery wells and allowing the water table to resume its natural position, the induced unsaturated zone will become inundated and some dissolution of CCl_4 into the ground water will occur. Continued pumping can then remove the CCl_4 captured by this process. Intermittent operation of the recovery well(s) would increase the removal of CCl_4 from the induced unsaturated zone to some degree, but CCl_4 in the natural unsaturated zone would not be affected.

The CCl_4 in the natural unsaturated zone will not be affected by ground-water extraction unless other actions are taken. Although the displacement of ground water by intermittent pumping will create air flow through this zone, the impact this air flow has on the removal of CCl_4 is probably minimal. Implementation of a soil vapor extraction system does, however, have the potential to significantly affect the removal of CCl_4 from this zone. Alternatively, the treated ground water could be recharged to the surface of the site to infiltrate through the unsaturated zone and leach out the CCl_4. The apparent correlation between precipitation and elevated levels of CCl_4 in the ground-water suggests that this would be effective.

As of June 1991, site operators were in negotiations with NJDEP to cease ground-water recovery operations at the site. If approved, ground-water monitoirng will continue at the site. The system would then be restarted should concentrations of contaminants exceed the threshold levels that have yet to be specified.

SUMMARY OF NAPL-RELATED ISSUES

The possibility that contaminants may be present in NAPL form at the NERC site has been considered by Storch Engineers. No direct evidence of NAPLs has been found in the field. The ground-water concentrations that have been detected in monitoring wells are well below the aqueous solubilities of the compounds, but this does not rule out the presence of NAPLs because of the great dilution potential associated with ground-water sampling. Storch Engineers acknowledges the possibility of NAPL presence. However, evaluation of concentration variations with depth and the apparent correlation of increased concentration with rainfall have led them to suspect that the source of residual contamination is in the vadose zone. It is unclear whether the vadose zone contamination is in the form of NAPLs or is limited to adsorbed contaminants.

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UPDATE BIBLIOGRAPHY/ REFERENCES

New Jersey Department of Environmental Protection (NJDEP). December 20, 1990. Personal communication with Steven Kehayes.

Javandel, I., and C.F. Tsang. 1986. Capture-Zone Type Curves: A Tool for Aquifer Cleanup. *Ground-water*. 24(5): 616-625.

Storch Engineers. June 2, 1987a. *NERC Report on Ground-water Sampling Analysis, Assessment, and Conceptual Cleanup Plan.*

Storch Engineers. September 28, 1987b. *NERC Ground-water Contaminant Recovery and Treatment System Design: Interim Progress Report.*

Storch Engineers. February 8, 1988a. *NERC Ground-water Cleanup Plan.*

Storch Engineers. September 28, 1988b. *NERC Ground-water Cleanup Progress Report--July 1988.*

Storch Engineers. November 28, 1988c. Letter to Mr. Steven Kehayes describing progress of ground-water recovery activities.

Storch Engineers. February 1989a. Letter to Mr. Steven Kehayes describing progress of ground-water recovery activities.

Storch Engineers. March 1989b. Letter to Mr. Steven Kehayes describing progress of ground-water recovery activities.

Storch Engineers. April 1989c. Letter to Mr. Steven Kehayes describing progress of ground-water recovery activities.

Storch Engineers. June 1989d. Letter to Mr. Steven Kehayes describing progress of ground-water recovery activities.

Storch Engineers. December 1989e. Letter to Mr. Steven Kehayes describing progress of ground-water recovery activities.

Storch Engineers. July 1990. Letter to Mr. Steven Kehayes describing progress of ground-water recovery activities.

Storch Engineers. January 4, 1991. Personal communication with Keith Ryan.

U.S. Environmental Protection Agency (U.S. EPA). October 1989. *Evaluation of Ground-water Extraction Remedies: Volume 2, Case Studies 1-19*. EPA/9355.4-03.

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UPDATE OF CASE STUDY 13

Olin Corporation
Brandenburg, Kentucky

Abstract

Five new pumping wells have been installed since 1988 near the three Ranney wells and along the river to enhance containment and site cleanup. Most of the plume is contained by this system. Despite substantial total pumping, the concentrations in the three Ranney wells have stabilized at high levels through 1989 and 1990 after decreasing in the early 1980s. Trends are also generally stable in the five new pumpings wells, but are decreasing in some monitoring wells near the pumping wells.

Table of Background Data	
Date of Problem Identification	Early 1970s
Extraction Started	1974
Types of Contaminants	Dichloroethyl ether Dichloroisopropyl ether
Primary Aquifer Materials	Silt and sand with interbedded clay
Maximum Number of Extraction Wells	10
Maximum Total Extraction Rate	6,200 gpm
Estimated Plume Area	240 acres
Estimated Plume Thickness	80 feet
Maximum Reported Concentrations	Dichloroethyl ether 48,000 ppb Dichloroisopropyl ether 632,000 ppb

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CASE STUDY UPDATE
OLIN CORPORATION

BACKGROUND OF THE PROBLEM

INTRODUCTION

The original case study for Olin Chemical Corporation (U.S. EPA, 1989, Case Study 13) evaluated ground-water remediation activities through October 1988 at the Doe Run Facility in Brandenburg, Kentucky. The site location is shown in Figure 1. Olin Chemical has used ground water from three wells since 1952 in its manufacturing process and as a coolant. In the early 1970s, ground-water contamination by ether compounds caused by onsite disposal practices was identified. These practices included thermal destruction in open burning pits and the use of settling basins as receptacles for processing wastes. The Kentucky Division of Waste Management oversees the present remedial activities. Ground-water pumping from the Ranney wells that are now a component of the remediation system began in 1952 with plant startup. Identification of the ether contamination and the development of a monitoring and management program for the contaminated ground water began in 1974.

The site is situated within the Ohio River alluvial valley, which is the natural discharge area for the region. The valley is divided into two terraces. The lower portion is a flood plain subject to frequent overflows of the Ohio River. The upper section is where most of the Olin facility is located. The upper 20 to 30 feet of material near the river is predominantly fine-grained silt and sand with interbedded layers of clay. A thick sequence of sand and gravel underlies the upper sand layer. The bedrock below these layers is comprised of low porosity/low permeability limestone. Ground water at the site generally exists under unconfined conditions. Recharge to the aquifer is received from precipitation, leakage from the bedrock valley walls, and leakage from unlined ditches and streams that cross the flood plain. The natural ground-water flow at the site is north toward the Ohio River; however, at high river levels, the Ohio River is also a source of recharge to the aquifer.

Contaminants of concern are chloroethers, primarily dichloroethyl ether (DCEE) and dichloroisopropyl ether (DCIPE). An estimated 18,000 tons of propylene dichloride, DCEE, and DCIPE were disposed of in a burning pit between 1952 and 1974. Additional wastes were discharged to a settling lagoon and to the burner area, which incinerated an estimated 10 tons of off-gas. When ground-water contamination was identified and monitoring began in 1974, concentrations of DCEE ranged from 50 ppb to approximately 3,000 ppb, and DCIPE concentrations ranged from 100 ppb to 32,000 ppb.

UPDATE ON SITE CHARACTERISTICS

This updated case study is based on 1989 and 1990 data provided by Olin Corporation. The information includes monitoring-well sampling results, a summary of ground-water extraction rates, and average ether concentrations for the Ranney Wells and new wells. Personal communication with staff from the Olin Corporation supplemented the documentation. Olin Corporation continues to operate the remediation system, with oversight from the Kentucky Division of Waste Management.

REMEDIATION

Design and Operational Features of Remediation System

The goal of remediation at the time of the original case study was to prevent contaminant migration beyond the region currently affected. Aquifer restoration is not a component of remedial objectives. Human health standards based on a 10^{-6} excess lifetime cancer risk would be 0.03 ppb for DCEE and 34.7 ppb for DCIPE (U.S. EPA, 1980). These standards, however, are not remedial objectives at this site.

The remediation system used to implement these goals includes three radial wells constructed in the early 1950s (Ranney Wells 1, 2, and 3) and two vertical wells installed in 1978 (Collector Wells 4

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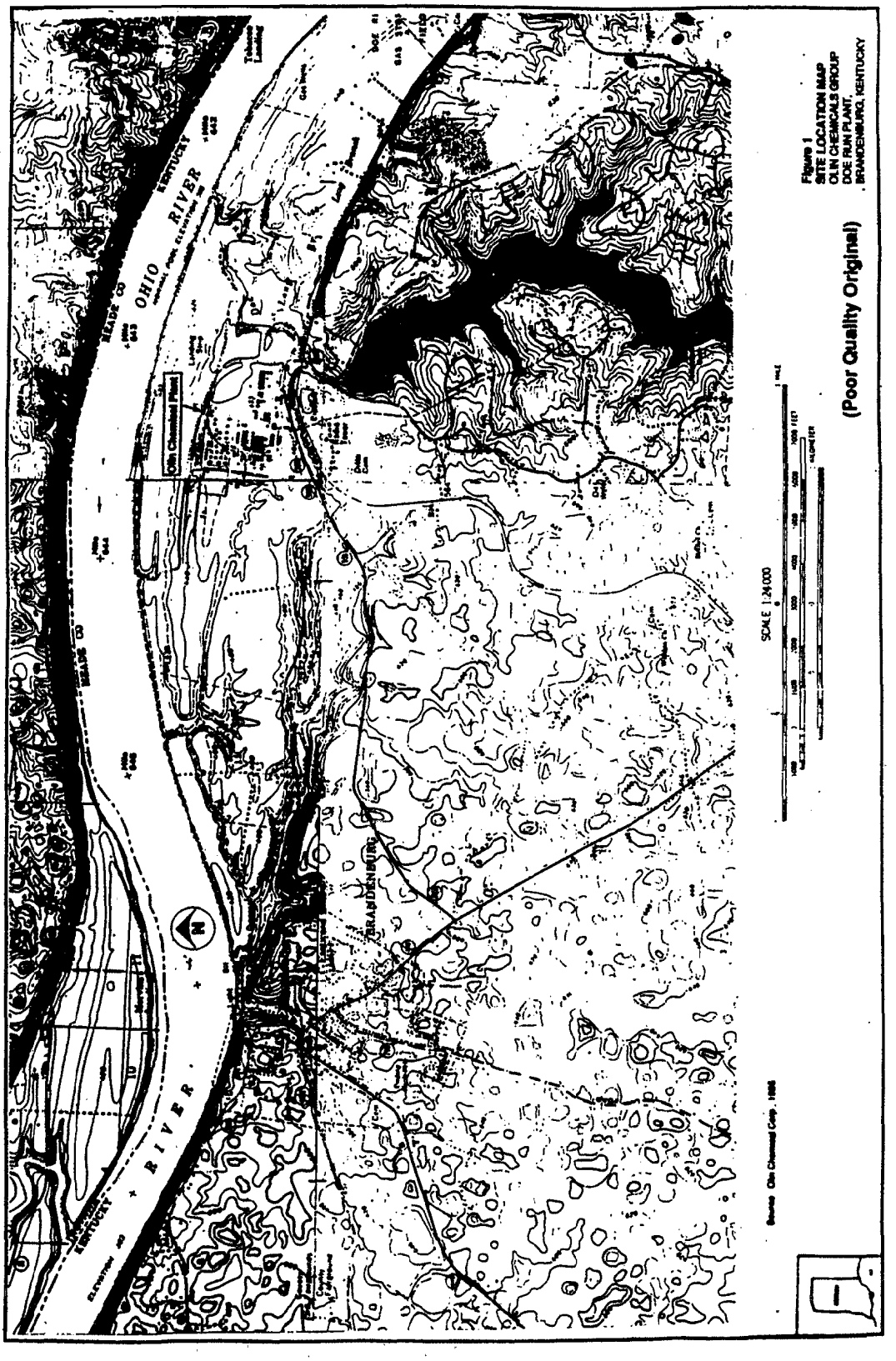

Figure 1
SITE LOCATION MAP
OLIN CHEMICALS GROUP
DOE RUN PLANT,
BRANDENBURG, KENTUCKY

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and 5). The three Ranney wells were installed and operating prior to identification of an ether contamination problem. The two vertical wells installed in 1978 were installed to increase the water supply of the manufacturing plant and were not intended to contain the contamination.

After studies had been conducted to determine the sources and the extent of contamination and to characterize site geology and hydrogeology, the responsible parties developed a management plan in 1984 to contain the contaminant plumes. After it was determined that contamination could be contained onsite by the existing pumping wells, optimum remedial pumping rates were established in 1984. Ranney Well 3 is designed for rates between 1,000 and 1,500 gpm. The combined pumping rate of Ranney Wells 1 and 2 are maintained at 100 gpm higher than that of Well 3, and Well 1 is operated at a minimum rate of 500 gpm between July and October. The original case study concluded that, under the above pumping conditions, the ground-water flow beneath all solid-waste management units is intercepted by the Ranney and collector wells.

Thirty-three monitoring wells are onsite to evaluate remedial progress. Three of the monitoring wells (MW-7, BH-1, and MW-2) are located in the contaminant plume and were used in the original case study to indicate the progress of remediation. Figure 2 shows the location of the Ranney wells, the Collector wells, and the plume indicator wells in relation to the source areas at the Doe Run facility.

In the two years since the original case study was published, the pumping rates for the Ranney wells have not changed significantly. During 1989 and 1990, Ranney Well 3 was operated at or slightly below its minimum design rate.

Major modifications to the system during 1989 and 1990 include the installation of five new pumping wells (IW-1, IW-2, IW-3, IW-4, and IW-5) that began operation in July and August 1989. Figure 2 shows the locations of these wells. The wells provide additional water for plant needs, help clean up the contamination in the Ranney wells, and provide further assurance that contaminated ground water does not migrate offsite. Table 1 presents the pumping rates of all the Olin wells. The new wells, particularly IW-3, did not operate continuously during 1989 and 1990. This downtime is due to National Pollutant Discharge Elimination System (NPDES) permitting restrictions which limit the discharge of ethers to the river. To avoid discharging quantities of ethers above the permitted limits, certain wells have needed to be shut down temporarily. Typically, Well IW-3 is a swing well. If ether concentrations approach the permit limits, then the well (or wells) is taken offline.

EVALUATION OF SYSTEM PERFORMANCE

Ground water was tested at the Doe Run facility throughout 1989 and 1990 to determine the concentrations of DCEE and DCIPE. Figures 3, 4, and 5 provide the time-series concentrations of DCIPE and DCEE for the plume-indicator wells (MW-7, BH-1, and MW-2) from 1984 to 1990.

DCIPE concentrations in ground-water samples from Well MW-7, which is located directly downgradient from the off-gas burners, have decreased from an October 1986 high of almost 3,000 ppb to below detection levels by October 1990. DCEE concentrations have continued to stabilize at or near the low levels achieved in 1987. The continuation of low detection levels in MW-7 suggests that the contaminant plume reached and passed this well.

In Well BH-1, DCIPE levels decreased from concentrations of more than 6,000 ppb identified in the earlier case study to 2 ppb in October 1989 and below detection levels in October 1990. The reduced concentrations of both DCIPE and DCEE during 1989 and 1990 are part of a contaminant-reduction trend that began in 1986.
MW-2, which is located between Ranney Wells 2 and 3, has also undergone intermittent fluctuations in concentration levels since the system began operation. DCEE concentrations were as high as 6,000 ppb in 1985, and DCIPE levels were greater than 1,000 ppb. Concentrations of both contaminants, however, were markedly reduced by October 1988 and were below detection levels by October 1990.

Contaminant concentrations in the Ranney wells have also decreased from levels identified in the first case study. Ranney Well 1, which registered the highest levels of DCIPE in the early 1980s (15,000 to 30,000 ppb), has exhibited a decrease in both DCIPE and DCEE since 1988. The highest concentration detected during the 1989-1990 period was 9,160 ppb of DCIPE in September

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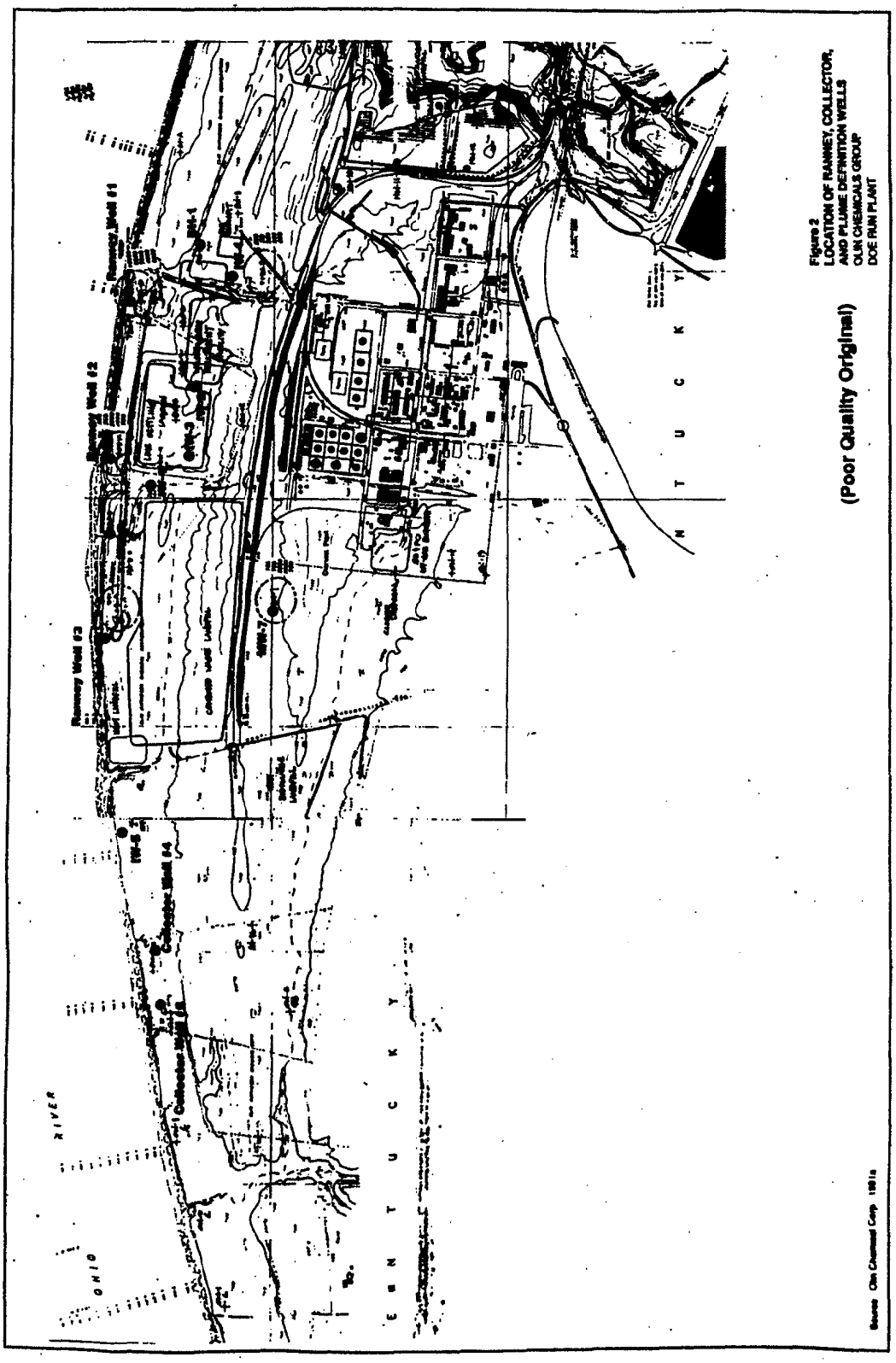

Figure 2
LOCATION OF RANNEY, COLLECTOR, AND PLUME DEFINITION WELLS
OLIN CHEMICALS GROUP
DOE RUN PLANT

(Poor Quality Original)

Source: Olin Chemical Corp. 1981c

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Table 1
OLIN CHEMICAL CORPORATION, DOE RUN PLANT
AVERAGE PUMPING RATES FOR RANNEY, COLLECTOR, AND NEW WELLS
1989-1990

Well	Pumping Rate (gpm)
Ranney Well 1*	1000-1200
Ranney Well 2*	1000-1200
Ranney Well 3	800-1000
Collector Well 4	1500
Collector Well 5	1000
IW-1	300-400
IW-2	200-400
IW-3	Normally Offline
IW-4	200-400
IW-5	300

Source: Olin Chemical Corp., 1991a
* = Ranney Wells 1 and 2 are alternated.

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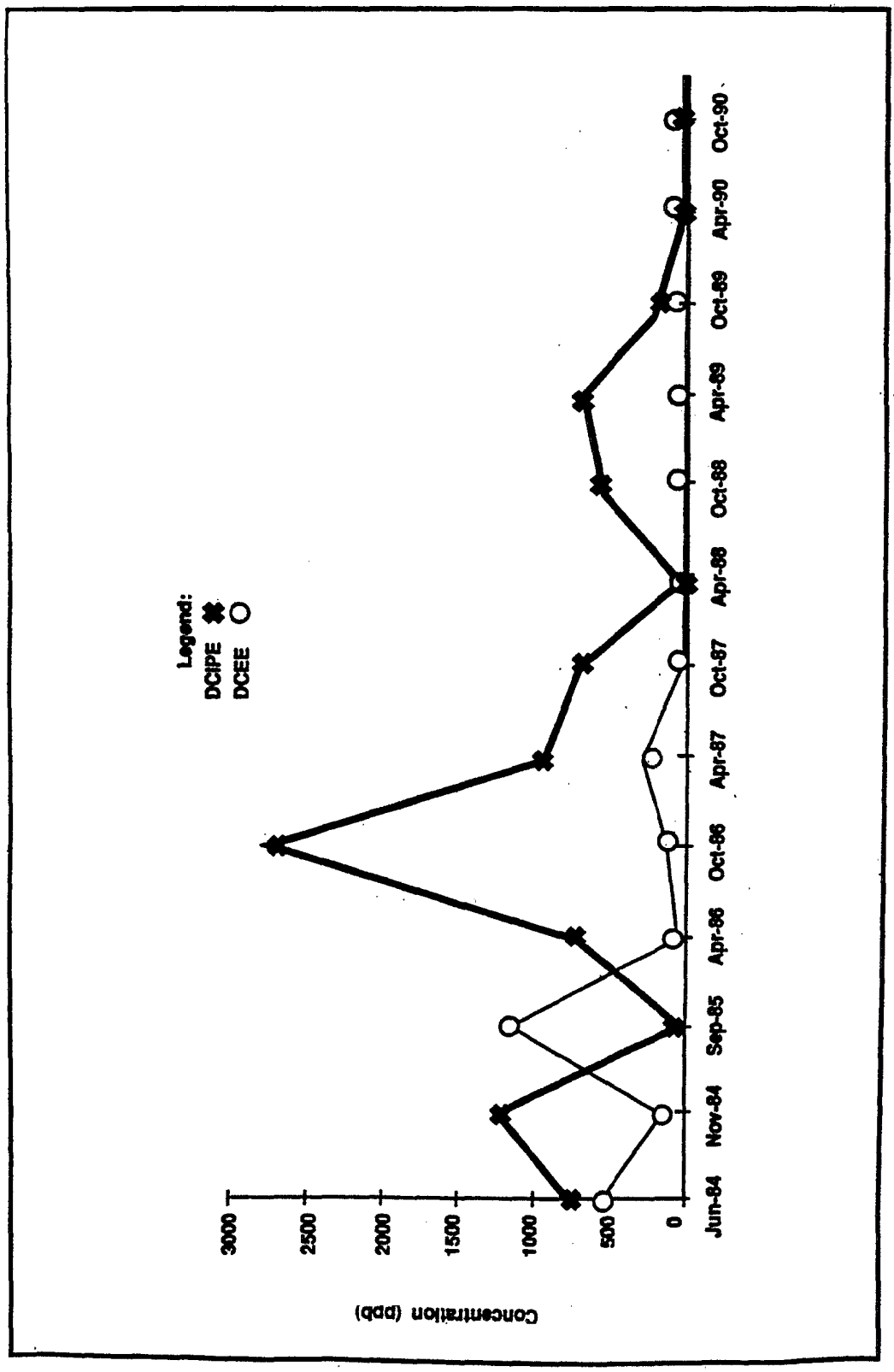

Source: EPA, 1989; Olin Chemical Corp., 1991a

Figure 3
ETHER CONCENTRATIONS IN MW-7
OLIN CHEMICALS GROUP
DOE RUN PLANT

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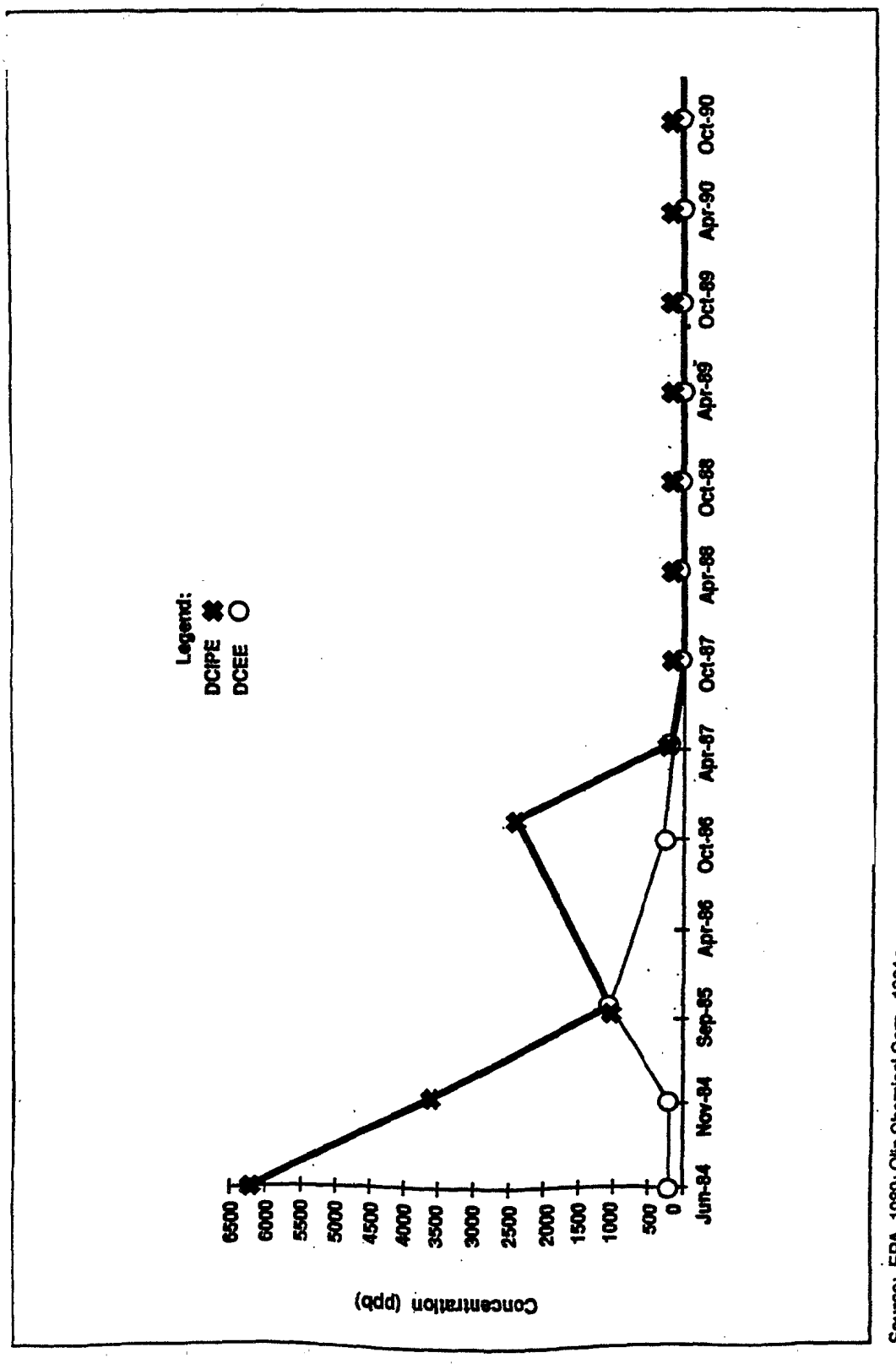

Source: EPA, 1989; Olin Chemical Corp., 1991a

Figure 4
ETHER CONCENTRATIONS IN BH-1
OLIN CHEMICALS GROUP
DOE RUN PLANT

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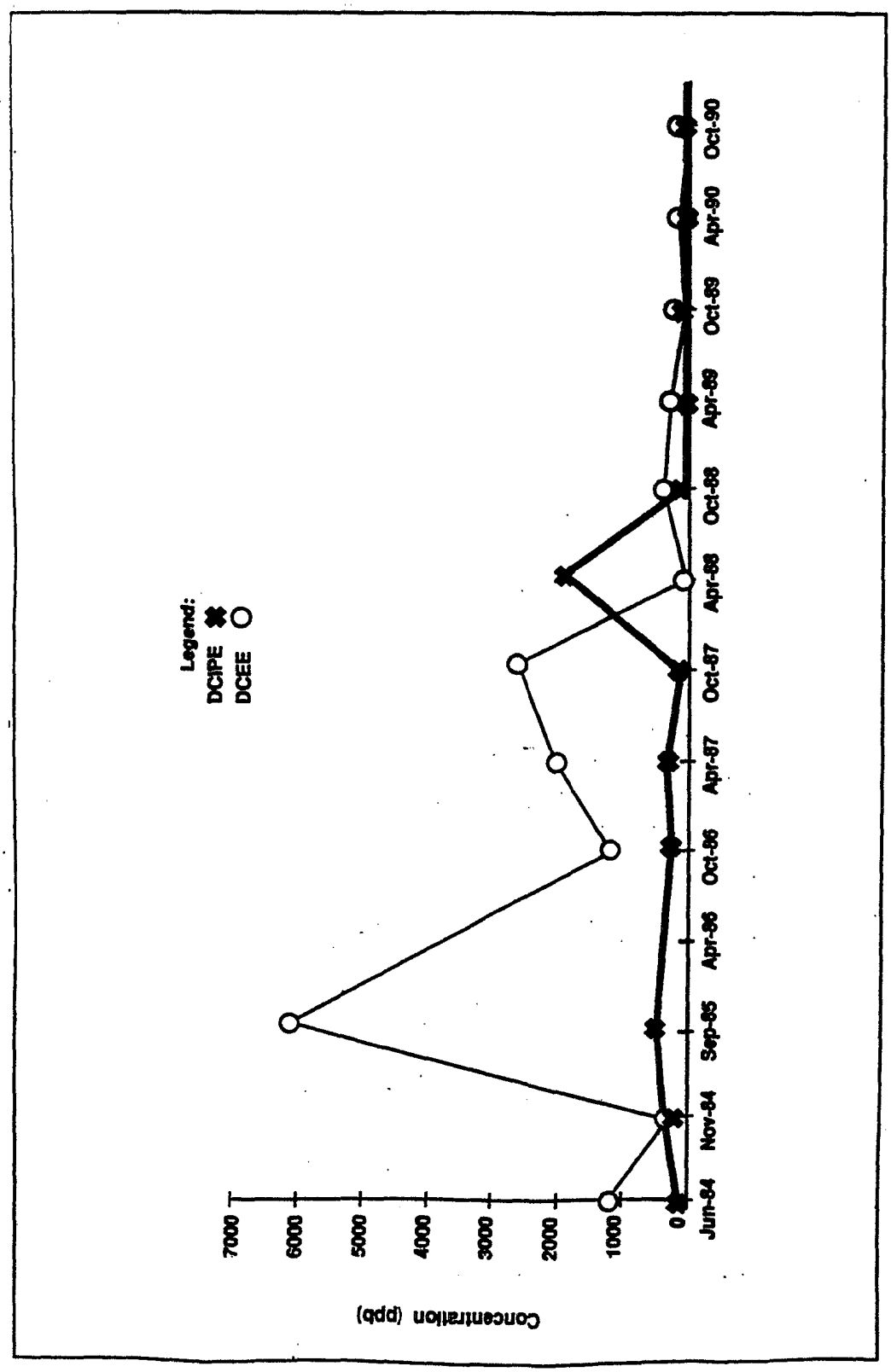

Source: EPA, 1989; Olin Chemical Corp., 1991a

Figure 5
ETHER CONCENTRATIONS IN MW-2
OLIN CHEMICALS GROUP
DOE RUN PLANT

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1989. The average monthly concentration of DCIPE for the 2-year period since publication of the first case study was approximately 5,000 ppb.

The concentrations for DCEE and DCIPE in Ranney Wells 2 and 3 are generally below those levels detected in Ranney 1. Table 2 provides the average concentrations of DCIPE and DCEE for each of the Ranney Wells for 1989 and 1990 and shows that although average concentrations have declined from levels detected in the early 1980s, no significant reductions have occurred during 1989 and 1990. Both DCIPE and DCEE are in excess of health-based standards.

Table 3 provides the DCEE and DCIPE concentrations for the new wells for 1989 and 1990. DCEE and DCIPE concentrations in these wells also register above health-based standards. DCIPE concentrations are greatest in IW-1 (21,350 ppb), but DCEE levels as high as 3,980 ppb have been detected in IW-3.

SUMMARY OF REMEDIATION

Remediation objectives have not changed since publication of the first case study; the goal at Olin's Doe Run facility is to control further migration of the plume. Although health-based standards have been set for primary site contaminants, these cleanup parameters have not been incorporated into remedial goals.

Concentrations of DCIPE and DCEE continue to decline from the elevated levels registered before remediation began. In the three plume-definition wells, concentrations are below or slightly above detection levels. The high pumping rates established at the start of remedial activities are still in effect and continue to contribute to the containment of site contamination.

Although contaminant concentrations have been reduced in the Ranney wells since the early 1980s, no significant declines have occurred during 1989 and 1990, and concentrations remain above established health standards.

In the interim since the initial case study, five new wells have been installed to provide additional water for plant use, to accelerate cleanup of the Ranney wells, and to ensure that contamination is contained onsite. Contaminant concentrations in these wells are in excess of the levels identified in the monitoring and Ranney wells.

SUMMARY OF NAPL-RELATED ISSUES

Efforts to determine the presence or absence of nonaqueous phase liquids (NAPLs) at the Olin site have not been undertaken since remediation began in 1974. Plans, however, are pending to initiate such investigations. Although contaminant concentrations have been reduced in almost 20 years of recovery-system operation, concentrations in Ranney Wells 1 and 3 appear to have stabilized at levels 2 to 3 orders of magnitude higher than health-based criteria. In addition, ground-water samples from the new wells, which are located south of Ranney Wells 1 and 2, show contaminant concentrations above those detected in the Ranney, Collector, and plume-definition monitoring wells. The presence of a NAPL in the aquifer could prevent aqueous concentrations of ethers from decreasing further, despite remediation.

The primary waste constituents at the site, DCIPE and DCEE, have respective aqueous solubilities of 1,700,000 ppb and 10,200,000 ppb. Their specific gravities are 1.103 and 1.22, respectively. To date, the highest concentrations of contaminants were recorded in a monitoring well during the 1975 annual sampling. Concentrations were analyzed at 632,000 ppb for DCIPE (37 percent of solubility) and 48,000 ppb for DCEE (0.5 percent of solubility). Concentrations above 1 to 10 percent of solubility suggest that NAPLs might be present in the aquifer. Although the concentrations in Ranney Well 1 are less than 1 percent of solubility, the Ranney Collector would be expected to dilute the sample due to its geographical reach and subsequent extensive recovery area.

Source characteristics of contaminants also suggest that a NAPL may exist. Approximately 18,000 pounds of chloroethers were disposed of in a burning pit between 1952 and the early 1970s in the area of Ranney Well 1.

Site operators acknowledge that ether contamination could be caused by NAPLs. At present, they do not believe NAPLs exist due to decreasing contaminant concentrations in the ground water. However, system operators intend to conduct geologic and hydrogeological studies to determine the extent of vertical contamination. Once these studies have been completed, they plan to explore alternative remedial technologies.

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Table 2
OLIN CHEMICAL CORPORATION, DOE RUN FACILITY
AVERAGE CONCENTRATION (ppm) OF
CHLOROETHERS IN RANNEY WELLS*
1989-1990

Month/Year	Ranney Well No. 1		Ranney Well No. 2		Ranney Well No. 3	
	DCEE	DCIPE	DCEE	DCIPE	DCEE	DCIPE
Jan. 1989	Not Running		0.12	2.83	0.22	0.22
Feb. 1989	Not Running		0.112	3.10	0.092	0.088
Mar. 1989	Not Running		0.051	1.99	0.043	0.081
Apr. 1989	0.05	4.01	Not Running		0.41	0.31
May 1989	0.14	5.77	Not Running		0.32	0.23
June 1989	Not Running		0.14	3.33	0.21	0.26
July 1989	0.24	6.87	0.06	2.01	0.18	0.19
Aug. 1989	Not Running		0.16	2.04	0.19	0.22
Sept.1989	0.03	9.16	Not Running		0.03	0.05
Oct. 1989	0.02	2.37	Not Running		0.07	0.11
Nov. 1989	0.009	2.684	0.025	2.01	0.238	0.306
Dec. 1989	0.08	5.699	Not Running		1.09	1.83
Jan. 1990	0.08	4.35	0.042	1.448	0.176	0.503
Feb. 1990	Not Running		0.036	1.81	0.27	0.13
Mar. 1990	0.04	1.10	0.32	2.08	0.33	0.45
Apr. 1990	0.08	3.88	Not Running		0.15	0.20
May 1990	0.17	5.38	Not Running		0.17	0.33
June 1990	0.52	4.24	0.32	1.54	0.18	0.29
July 1990	0.08	3.67	Not Running		0.16	0.25
Aug. 1990	0.12	4.89	Not Running		0.26	0.29
Sept.1990	0.06	5.53	Not Running		0.13	0.21
Oct. 1990	0.04	5.24	Not Running		0.13	0.21
Nov. 1990	0.28	6.96	Not Running		0.14	0.30
Dec. 1990	0.20	6.65	Not Running		0.17	0.27

Source: Olin Chemical Corp., 1991
*Operating practice of these wells: Combined flow of RW-1 and RW-2 will exceed RW-3 flow.

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Table 3
OLIN CHEMICAL CORPORATION DOE RUN FACILITY
NEW WELL CHLOROETHER CONCENTRATIONS (ppm)
1989-1990

Month/Yr.	IW-1		IW-2		IW-3		IW-4		IW-5	
	DCIPE	DCEE	DCIPE	DCEE	DCIPE	DCEE	DCIPE	DCEE	DCIPE	DCEE
8/89	21.35	0.35	0.15	0.03	0.09	0.03	0.03	0.03	1.46	0.47
9/89	9.26	0.09	0.14	0.03	0.12	0.15	0.04	0.21	1.79	0.03
10/89	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
11/89	6.24	0.09	NS	NS	0.36	1.12	0.10	0.64	NS	NS
12/89	6.66	0.16	NS	NS	0.32	1.12	0.27	0.42	1.36	1.34
1/90	4.20	0.07	0.09	0.02	NS	NS	0.08	0.44	NS	NS
2/90	6.75	0.07	0.08	0.04	NS	NS	0.13	0.49	NS	NS
3/90	13.96	0.16	0.25	0.12	NS	NS	0.57	0.91	1.60	0.26
4/90	6.17	0.06	0.37	0.04	0.80	0.70	0.19	0.89	0.80	0.19
5/90	5.23	0.05	0.36	0.09	NS	NS	0.22	1.10	0.52	0.15
6/90	6.84	0.04	0.35	0.07	NS	NS	0.14	1.03	0.41	0.10
7/90	2.98	0.03	0.24	0.04	0.21	0.05	0.14	1.07	0.29	0.06
8/90	3.30	0.05	0.23	0.08	1.17	2.66	0.22	1.01	0.31	0.08
9/90	4.75	0.02	0.34	0.10	0.32	3.98	0.44	1.63	0.44	0.08
10/90	4.24	0.03	0.32	0.06	NS	NS	0.48	0.95	0.44	0.07
11/90	5.57	0.03	0.37	0.17	NS	NS	0.49	1.16	0.33	0.08
12/90	5.73	0.02	0.38	0.20	NS	NS	0.50	1.30	0.29	0.18

Source: Olin Chemical Corp., 1991
NS = Not sampled.

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UPDATE BIBLIOGRAPHY/ REFERENCES

Olin Chemical Corp. September 1986. *A Ground-Water Assessment of Olin Chemicals Group Doe Run Plant, Brandenburg, Kentucky.*

Olin Chemical Corp. March 7, 1991a. Correspondence from Danny M. Henderson, Environmental Specialist, Olin Chemicals, Charleston, Tennessee.

Olin Chemical Corp. February 1991b; March 28, 1991c. Personal communication with Danny M. Henderson, Environmental Specialist, Olin Chemicals, Charleston, Tennessee.

U.S. Environmental Protection Agency (U.S. EPA). October 1989. *Evaluation of Ground-Water Extraction Remedies: Volume 1, Case Studies 1-19.* EPA/9355.4-03.

U.S. EPA. November 28, 1980. *Federal Register.* 45(231):793330.

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UPDATE OF CASE STUDY 14

Ponders Corner
Tacoma, Washington

Abstract

Pumping and wellhead treatment at water-supply Wells H1 and H2 have continued since 1984. The system has continued to meet its primary objective of providing treated water for public consumption. The zone of capture of H1 and H2 has continued to include areas of contamination, except for a small part of the plume that escaped before 1984. PCE concentrations in H1 and H2 and monitoring wells downgradient of the source area have been stable since the end of 1985. This persistence of contamination is believed to be caused by a residual source.

Table of Background Data	
Date of Problem Identification	1981
Extraction Started	September 1984
Types of Contaminants	Tetrachloroethylene Trichloroethylene Trans-1,2-Dichloroethylene
Primary Aquifer Materials	Glacial sand, silt, gravel, and clay
Maximum Number of Extraction Wells	2
Maximum Total Extraction Rate	2,000 gpm
Estimated Plume Area	23 acres
Estimated Plume Thickness	80 feet
Maximum Reported Concentrations	Tetrachloroethylene 4,866 ppb

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CASE STUDY UPDATE
PONDERS CORNER (LAKEWOOD)

BACKGROUND OF THE PROBLEM

INTRODUCTION

This case study update discusses recent developments and progress in the ground-water remediation at the Ponders Corner site (also known as the Lakewood site) in Tacoma, Washington. The original case study for this site (U.S. EPA, 1989, Case Study 14) presented background information and data from the site ground-water monitoring and remediation systems that were current through March 1989.

The location of the Ponders Corner Site is shown in Figure 1. It includes the property of Plaza Cleaners and two water supply Wells, H1 and H2, belonging to the Lakewood Water District. In 1981, it was discovered that disposal of waste solvents from the dry cleaning operations at Plaza Cleaners had resulted in contamination of the two water supply wells. In August 1981, Wells H1 and H2 were taken out of service temporarily while monitoring wells were installed and contaminated surficial soil in the source area was excavated. By September 26, 1984, air strippers had been installed to treat the water produced from the contaminated wells, and pumping was resumed. Remedial activities at the Ponders Corner site were conducted under the U. S. EPA's Superfund program.

The Ponders Corner site is underlain by glacial deposits of sand, gravel, silt, clay, and till. The four major geologic units underlying the site are, in order of increasing depth: (1) the Steilacoom gravel, a unit of sand and gravel, (2) the Vashon till, consisting of low-permeability sediments, (3) the Advance Outwash aquifer, an important regional aquifer, and (4) the Colvos sand, a unit consisting of silt, clay, and fine silty sand. Wells H1 and H2 are completed in the Advance Outwash aquifer at a depth of approximately 110 feet. The Advance Outwash is a highly permeable semi-confined to confined aquifer. The natural direction of ground-water flow is west-northwest toward nearby Gravelly Lake. However, at the Ponders Corner site, ground water in the Advance Outwash flows to the south under the influence of pumping from Wells H1 and H2.

The main contaminants of concern are tetrachloroethylene (PCE), trichloroethylene (TCE), and trans-1,2-dichloroethylene, all of which are solvents or by-products of solvents used in dry cleaning. The dry cleaning wastes at Plaza Cleaners were discharged to a septic tank system consisting of three buried tanks with a total volume of 4,250 gallons. The wastes were flushed through the tanks to the septic system drain field by 15,000 to 20,000 gallons of laundry wastewater per day. Solvent-contaminated wastewater and sludge was also poured onto the ground outside the Plaza Cleaners building. These discharges resulted in soil contamination in both the unsaturated Steilacoom gravel and in the underlying Vashon till, and represent a continuing source of contaminant leaching to the ground water.

When water supply Wells H1 and H2 are in operation, the contaminated ground water from the site is hydraulically contained, removed, and treated. However, during the three years when the wells were out of operation, a part of the contaminant plume in the Advance Outwash aquifer was transported away from the site to the west-northwest. This isolated contaminant plume, with PCE concentrations of less than 10 ppb, escaped the capture zone of the wells and continued to move toward Gravelly Lake after pumping resumed.

UPDATE ON SITE CHARACTERISTICS

The Ponders Corner site continues to be administered by the EPA. However, after completion of the ongoing soil remediation study in the first quarter of 1991, the Washington State Department of Ecology is expected to take over operations and maintenance activities at the site, including ground-water monitoring.

No new information about the hydrogeologic characteristics of the site has been generated since the original case study. However, the operational results of a soil vapor extraction system at Plaza

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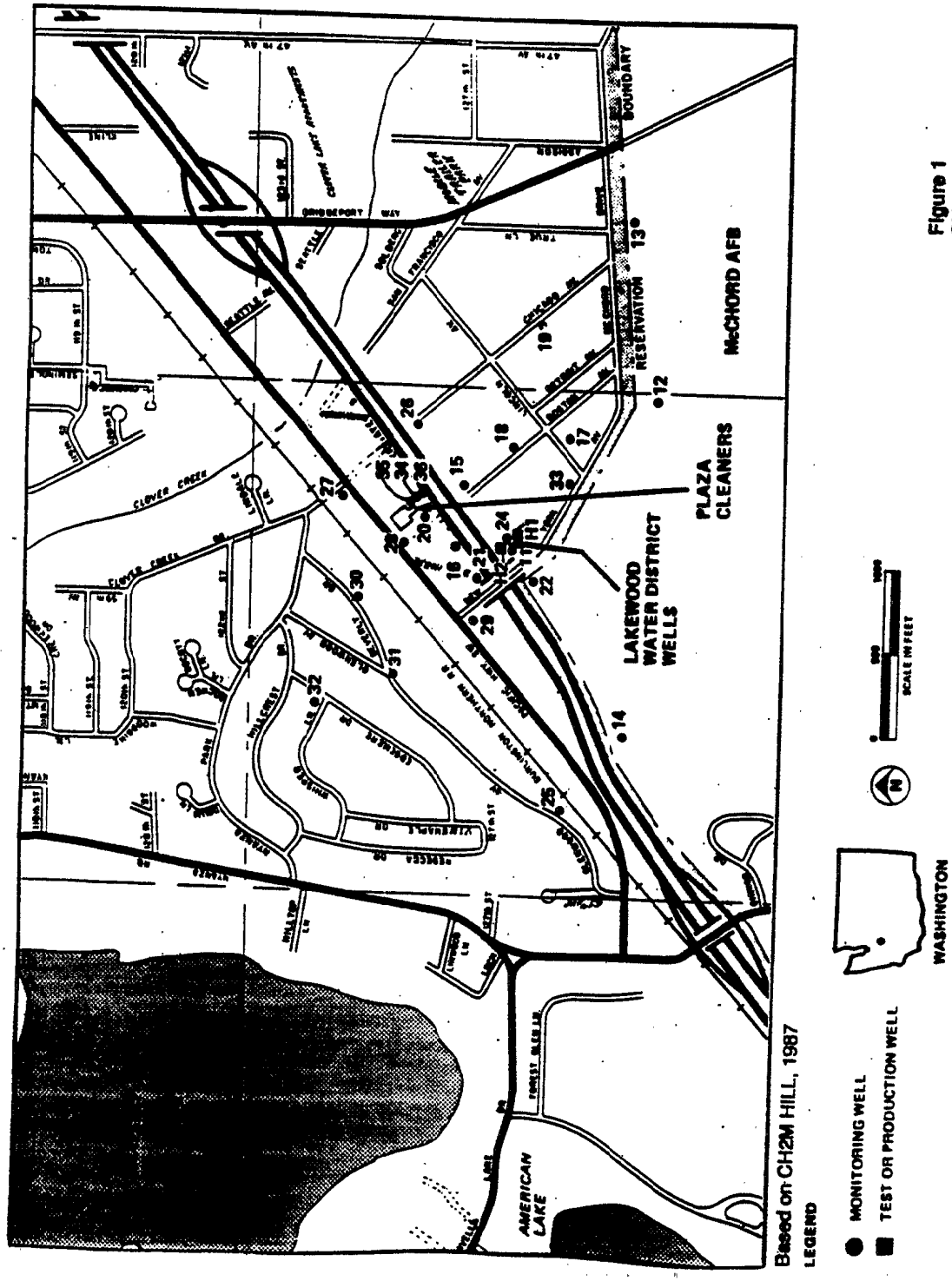

Figure 1
SITE LOCATION MAP
PONDERS CORNER SITE
TACOMA, WASHINGTON

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Cleaners has shown that the quantity of PCE contamination in the unsaturated Steilacoom gravel was much greater than had been expected during the design stage.

It was initially estimated that the contaminated soils in the upper portions of Steilacoom gravel at Plaza cleaners contained approximately 4 to 5 pounds of PCE (U.S. EPA, 1985). (This in not to be confused with the estimate of 10 pounds of PCE in the saturated portions of the Steilacoom gravel listed in Table 1 of the original case study.) The 5-pound estimate was based on analysis of 82 soil samples collected from seven soil borings and six shallow test pits installed on the Plaza Cleaners property during the remedial investigation. Beginning in March 1988, a soil vapor extraction system was operated at Plaza Cleaners to accelerate the cleanup of the unsaturated Steilacoom gravel in that area. In approximately 1 year of intermittent operation an estimated 775 pounds of PCE were removed by soil vapor extraction (CH2M HILL, 1989a). No explanation for this discrepancy has been given.

REMEDIATION

Design and Operational Features of the Remediation System

The primary objective of the wellhead treatment system is to capture the plume of ground-water contamination while providing potable water from production Wells H1 and H2. In addition, it is expected that continued operation of the system will lead to eventual restoration of ground-water quality to health-based levels.

The ground-water remediation system consists of continued pumping from water supply Wells H1 and H2 at a combined rate of approximately 2,000 gpm. There have been no significant changes in the wellhead treatment system since it started operating in 1984. However, the ground-water monitoring system at the site has been modified, and soil vapor extraction has been used to remediate contaminated soils in the source area. A study of final remedial actions is currently taking place to determine whether additional soil remediation activities are needed.

As described in the original case study, a total of 36 ground-water monitoring wells were installed by the time the remedial investigation was completed. In February 1987, six more wells were installed, one in the area of the uncaptured plume northwest of the site and five along the perimeter of McChord Air Force Base. In April 1989, an inventory of the site monitoring wells was conducted to determine which ones needed repair or abandonment. By that time, there were 51 monitoring wells at the site. As a result of the inventory, it was recommended that 17 wells be repaired, and that 23 be abandoned. Most of the wells were found to be damaged or to have deficiencies in surface completion that would make them possible conduits for further contamination of the subsurface. Much of the damage was caused by vandalism (CH2M HILL, 1990b).

The soil vapor extraction system was installed around the former septic tank and its associated drain field system at Plaza Cleaners in December 1987. It consisted of ten 2-inch wells installed to depths of approximately 18 feet, and three horizontal vapor extraction headers installed within the three abandoned septic tanks. The vapor extraction system was equipped with activated carbon filters large enough to adsorb an estimated total of 40 pounds of PCE at the expected vapor phase concentration of 25 ppm. The system was put into operation on March 22, 1988, and extracted vapor containing up to 170 ppm of PCE on the first day. After one month of operation the average vapor concentrations had been reduced to about 14 ppm. An estimated 360 pounds of PCE had been removed during the first month of operation. Operation of the system continued intermittently, with interruptions for replacement of the activated carbon, until April 1989. During this time, an estimated total of 775 pounds of PCE was removed.

EVALUATION OF PERFORMANCE

Six rounds of ground-water samples have been collected from the network of monitoring wells since July 1987, the date of the last sampling reported in the original case study. The most recent reported sampling occurred in April 1990. Table 1 lists a cumulative summary of the PCE concentrations measured in the monitoring wells since 1985. The locations of the monitoring wells are shown in Figure 2. In general, the concentrations in contaminated wells that do not lie between the source area and the production wells have declined over the period of record. Wells that are located between Plaza Cleaners and

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Table 1
PCE CONCENTRATIONS MEASURED IN MONITORING WELLS
PONDERS CORNER SITE

Well No.	2/12/85 Through 2/14/85	3/18/85 Through 3/22/85	4/25/85	5/16/85 Through 5/20/85	6/17/85 Through 6/21/85	8/20/85 Through 8/23/85[a]	11/5/85 Through 11/7/85[a]	8/25/86 Through 8/28/86	12/16/86 Through 12/17/87	3/17/87 Through 3/20/87	7/7/87	10/5/87 Through 10/6/87	1/28/88 Through 1/29/88	4/25/88 Through 4/26/88	10/7/88 Through 11/28/88	5/22/89 Through 5/25/89	4/23/90 Through 4/24/90
11A	6.2	5.6	NM	6.1	2.7	4.3	2	1.4	NM	NM	NM	NM	NM	NM	NM	NM	
11B	NM	NM	NM	NM	NM	2.4	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	
12	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NM	NM	
13A	ND	ND	ND	ND	ND	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	
13B	NM	NM	NM	NM	NM	ND	ND	ND	ND	ND	ND	ND	J	ND	NM	NM	
14	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	
15A	NM	0.5	NM	ND	ND	ND	ND	ND	NM	NM	NM	NM	NM	NM	NM	NM	
15B	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	
16A	110	70	NM	46	33	12/11[b]	19	16	17	49	NM	8	NM	7.3-8.0	NM	5(16)	74
16B	NM	15	NM	13	5	NM	4[c]	4.5	NM	NM	NM	NM	NM	NM	NM	NM	
17A	ND	ND	NM	ND	ND	ND	ND	NM	NM	NM	NM	NM	NM	NM	NM	NM	
17B	NM	ND	NM	ND	ND	ND	ND	NM	NM	NM	NM	NM	NM	NM	NM	NM	
18	ND	ND	NM	ND	ND	D	ND	ND	NM	NM	NM	NM	NM	NM	NM	NM	
19A	ND	ND	NM	ND	ND	ND	ND	ND	NM	ND	ND	ND	J	ND	ND	ND	ND
19B	NM	ND	NM	ND	ND	ND	ND	ND	NM	NM	NM	NM	NM	NM	NM	NM	
19C												NM	J	ND	NM	NM	
20A	NM	5.1	NM	NM	2.8	4.0	ND	2.1	1.5	ND	NM	ND	NM	1.2	NM	ND	0.6J
20B	NM	4,856	2,200	570	1,220	1,060	350	745	NM	NM	NM	ND	NM	NM	NM	1,100 (880)	550 (1,300)
21	27	2.2	NM	13	11	10	ND	ND	4.6	4	NM	6	NM	4.0	NM	2 J	3
22	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	
24A	8.5	1.5	NM	7.2	4.4	16	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	
24B	NM	9.5	NM	0.9	4.0	4.9	ND	2.9	NM	NM	NM	NM	NM	NM	NM	NM	
25	ND	ND	NM	ND	ND	ND	13	ND	NM	NM	NM	NM	NM	NM	NM	NM	
26	ND	ND	NM	NM	ND	ND	9	ND	NM	NM	NM	NM	NM	NM	NM	NM	
27	ND	NM	NM	NM	ND	ND	ND	ND	NM	NM	NM	NM	NM	NM	NM	NM	
28A	ND	0.7	NM	ND	ND	NM	ND	ND	NM	NM	NM	NM	NM	NM	NM	NM	
29	5.8	0.9	NM	5.4	1.1	3.4	ND	2	2.8	ND	NM	ND	NM	1.8	ND	1J	0.8J
30	38	24.1	NM	17.2	13	NM	10	5.3	2.2	ND	NM	5	NM	3.8-4.7	3J	NM	
31	ND	ND	NM	ND	ND	ND	ND	ND	NM	NM	NM	NM	NM	NM	NM	NM	
32	ND	4.3	5	6.9	3.3	3.7	ND	2	1.5	2	NM	ND	NM	D	ND	1J	1

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Ponders Corner

Table 1
PCE CONCENTRATIONS MEASURED IN MONITORING WELLS
PONDERS CORNER SITE

Well No.	2/12/85 Through 2/14/85	3/18/85 Through 3/22/85	4/25/85	5/16/85 Through 5/20/85	6/17/85 Through 6/21/85	8/20/85 Through 8/23/85[a]	11/5/85 Through 11/7/85[a]	8/25/86 Through 8/28/86	12/16/86 Through 12/17/87	3/17/87 Through 3/20/87	7/7/87	10/5/87 Through 10/6/87	1/28/88 Through 1/29/88	4/25/88 Through 4/26/88	10/7/88 Through 11/28/88	5/22/89 Through 5/25/89	4/23/90 Through 4/24/90
33	ND	ND	NM	ND	ND	ND	ND	ND	NM	NM	NM	NM	NM	NM	NM	NM	
34	83	NM	NM	NM	NM	1.2	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	
35	ND	ND	NM	ND	ND	ND	ND	ND	NM	NM	NM	NM	NM	NM	NM	NM	
36	139	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	
37[d]										ND	ND	ND	J	ND	ND	ND	
38[d]										ND	ND	NM	NM	NM	NM	NM	
39A[d]										ND	ND	ND	J	D	ND	NM	
39B[d]										ND	ND	NM	NM	J	ND	ND	
39C												NM	NM	ND	NM	NM	
40[d]										ND	ND	ND	J	ND	ND	ND	ND
41[d]										ND	ND	NM	NM	NM	NM	ND	ND

[a]Exceeded acceptable holding time.
[b]Duplicate analysis.
[c]Estimated value. Compound present but at less than the specified detection limit.
[d]Wells constructed 2/87 through 3/87.

Notes: Units in ppb.
NM = Not measured.
ND = Not detected.
D = Detected, not quantified.
J = Estimated value. Value not accurate.

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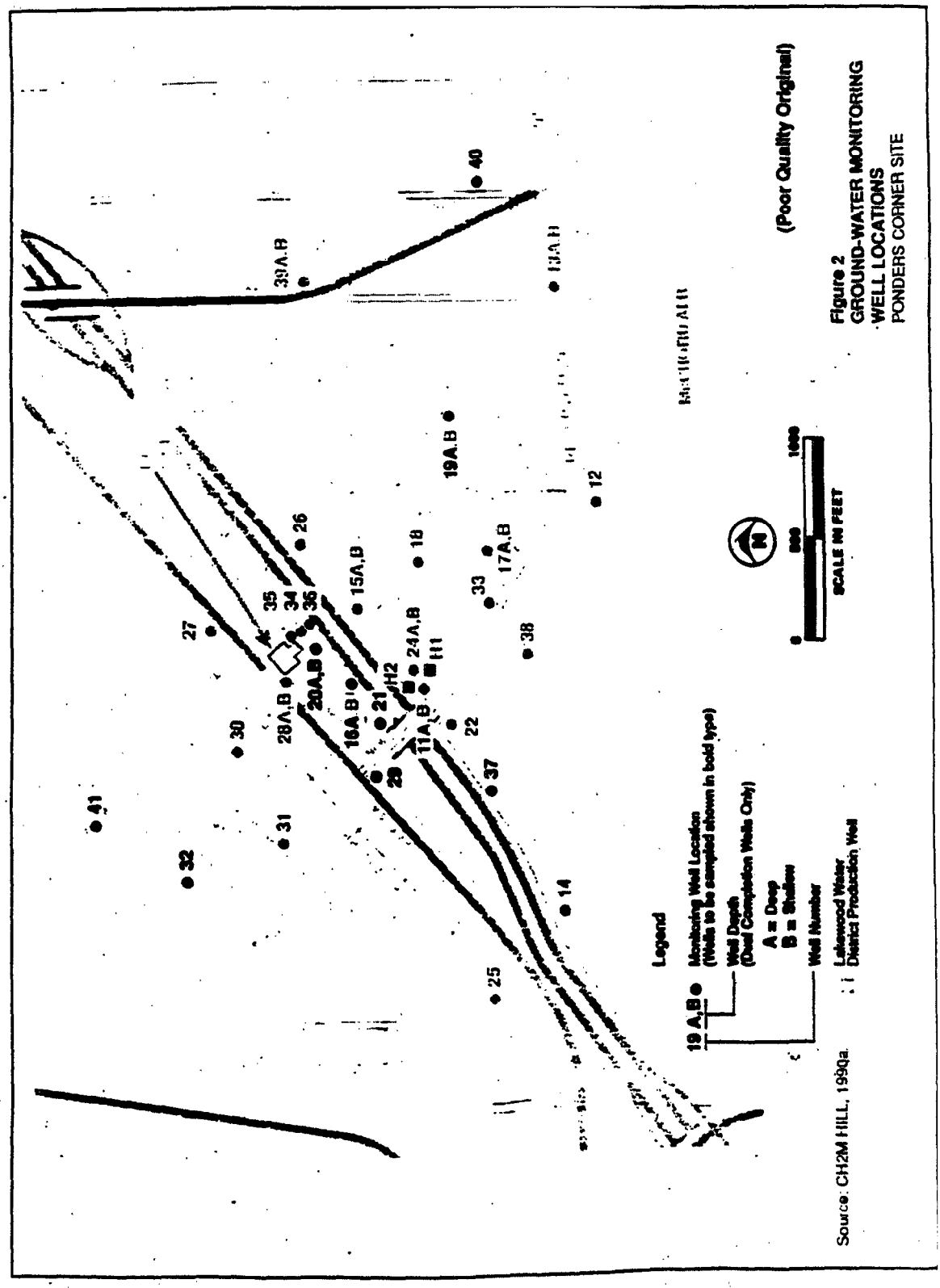
Ponders Corner



(Poor Quality Original)

Figure 2
GROUND-WATER MONITORING WELL LOCATIONS
PONDERS CORNER SITE

Source: CH2M HILL, 1990a.

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the production wells include wells 20A, 20B, 16A, 16B, 24A, and 24B. All of these wells, except 20B, monitor the Advance Outwash aquifer. Well 20B is screened in the Vashon till, and the concentrations measured in it are notably higher than in the other wells. The concentrations in these wells generally declined markedly only during the early days of ground-water remediation. In Well 20B, for instance, the latest measured PCE concentrations are approximately the same as those found in the well in mid-1985. (Two concentrations are given for the same date when split or duplicate analyses were run.)

Figures 3 and 4 are time-series graphs of the PCE and TCE concentrations measured in flows from production Wells H1 and H2. Figure 3 shows that the PCE concentration in well H2 peaked at 492 ppb in September 1984 and that, after an initial sharp decrease, it has remained fairly stable at between 30 and 100 ppb since early 1985. The PCE concentration appears to have risen slightly during 1989 and to have decreased slightly in 1990. This may have been due to increased recharge during the rainy season of late 1989 and early 1990. The PCE concentration in Well H1 seems to show a similar rise and fall during late 1989 and early 1990.

Figure 4 shows that the TCE concentration in both wells has been consistently near or below detection limits since late 1985. Small peaks in the TCE concentration were observed in the first quarters of 1988, 1989, and 1990.

SUMMARY OF REMEDIATION

The ground-water remediation system continues to meet its primary goal of treating the water produced from Wells H1 and H2 to levels suitable for public consumption. The zone of capture created by the two production wells encompasses the areas of known contamination except for a small portion of the plume that escaped before the wellhead treatment system was put into operation. The PCE concentrations in the production wells and in the monitoring wells downgradient of the source area have been essentially stable since the end of 1985. This persistence of the PCE contamination appears to confirm the conclusion that a residual source of ground-water contamination is impeding aquifer restoration. This continuing source of PCE can probably be attributed to adsorbed contaminants in the Vashon till near the Plaza Cleaners, and perhaps also to PCE that is present as a separate nonaqueous phase liquid (NAPL) in that vicinity.

SUMMARY OF NAPL-RELATED ISSUES

The possibility that PCE or TCE may be present in the subsurface as NAPLs at the Ponders Corner site has not been mentioned in any of the site-related documents. It has been generally concluded that a residual source is present in the vicinity of Plaza Cleaners that continues to leach contamination into the Advance Outwash aquifer. The source has been attributed to contaminants adsorbed to the soil particles in the Vashon till. However, if NAPLs were present in the Vashon till, they would also represent a source of continued leaching, and would have a similar prolonging effect on the ground-water remediation.

Site records indicate that wastes were discharged to the ground at Plaza Cleaners in two different ways. The greatest volume was discharged to the septic disposal system, which consisted of three septic tanks and the associated drain field. It is not clear whether the liquids discharged to the septic tanks contained nonaqueous solvents or only dissolved solvents. During the remedial investigation, both the supernatant liquids in the septic tanks and the sludges were sampled. The maximum PCE concentrations detected were 550 ppb in the supernatant and 483 ppm in the sludge. The aqueous solubility of PCE is approximately 200 ppm. It was not mentioned that NAPLs were found in the tanks. However, it was suggested that the bottoms of the tanks may not have been impermeable. If no NAPLs were found, it could be because they had already leaked through the bottoms of the tanks.

The second means of waste disposal at Plaza Cleaners was to pour solvent-contaminated sludges and process waste water on the ground outside the back door of the plant. Approximately 30 gallons of liquid waste containing up to 100 ppm of chlorinated solvents were poured on the ground per week (U.S. EPA, 1984). Again, it is not clear whether these wastes included nonaqueous solvents, but it is likely that at least small amounts were in NAPL form. It was reported in the record of decision that a soil sample collected in the dumping area had a PCE concentration of 3,460 ppm, which suggests that nonaqueous phase

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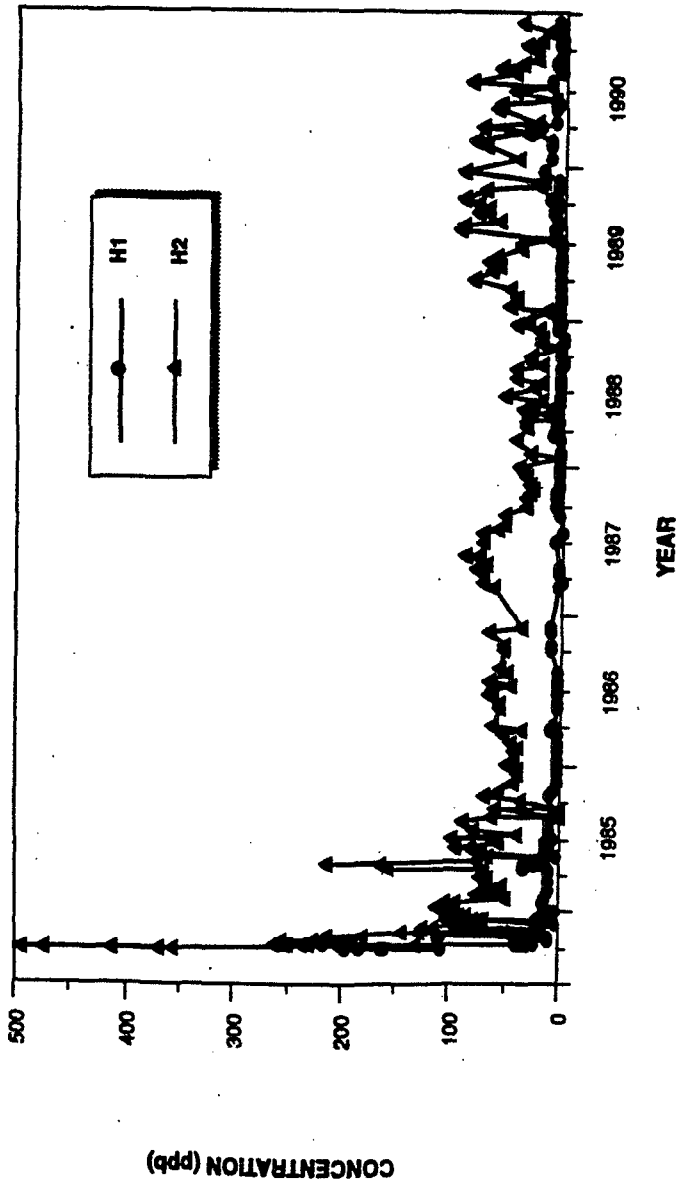

Figure 3
PCE CONCENTRATION IN WELLS H1 AND H2
PONDERS CORNER SITE

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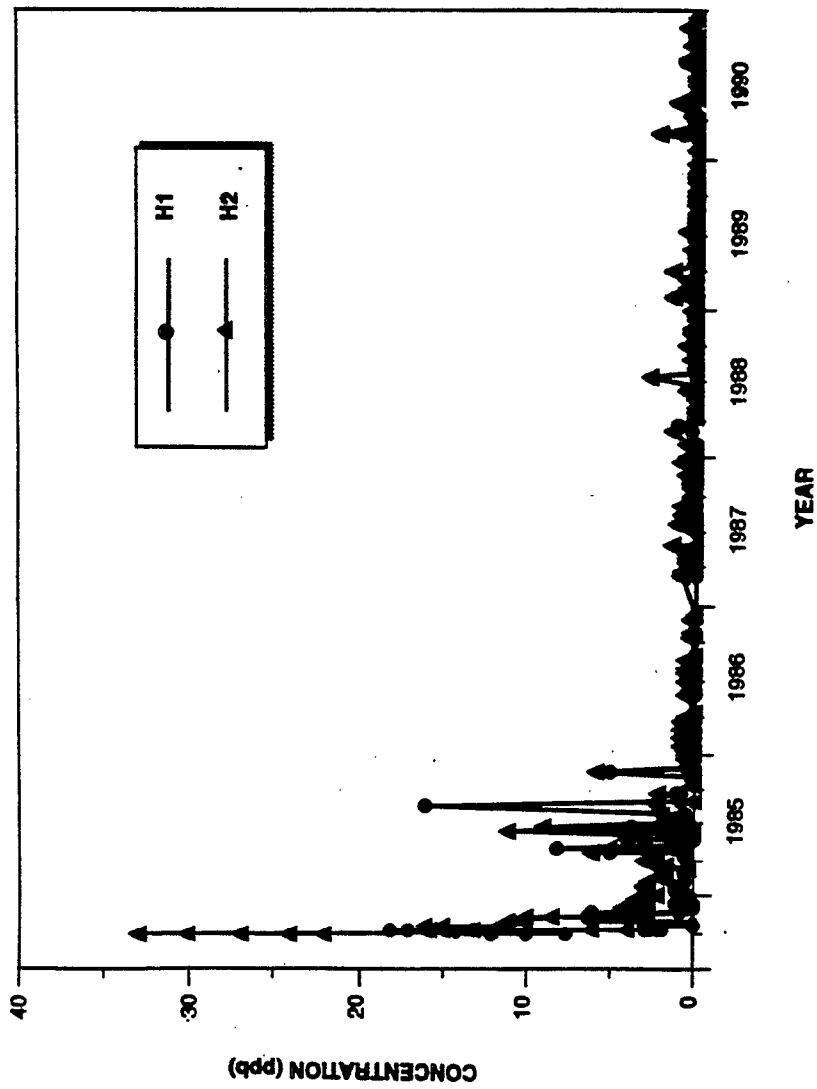

Figure 4
TCE CONCENTRATION IN WELLS H1 AND H2
PONDERS CORNER SITE

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liquids were present in the soil. However, the maximum soil concentration reported from soil borings and test pits in the area was 3,880 ppb of PCE (CH2M HILL, 1989b). This level of soil contamination is somewhat more ambiguous regarding the likelihood of NAPLs.

The unexpectedly large quantity of PCE recovered during operation of the soil vapor extraction system indicates that reliance on soil sampling in the Steilacoom gravel underestimates the presence of contaminant. This could be because considerable quantities of solvents passed through the unsaturated Steilacoom gravel as dense NAPLS and collected either within lenses of fine sediments in the Steilacoom or in the underlying Vashon till. Because the upper portion of the Vashon till is also unsaturated in this area, solvents in either fine sediments in the Steilacoom gravel or in the Vashon till could have contributed vapor to the soil vapor extraction system. However, the same could be said for solvents that were simply adsorbed to the soil matrix in either unit and had never been present as NAPLs.

Whether the residual source at Ponders Corner includes NAPLs or is limited to adsorbed contaminants, the result is to prolong the time needed for aquifer remediation.

UPDATE BIBLIOGRAPHY/ REFERENCES

CH2M HILL. April 1987. *Predesign Report.* EPA-62-ON22.

CH2M HILL. April 25, 1989a. Draft Memorandum to Janet O'Hara, EPA Region X, on Lakewood SVES Summary.

CH2M HILL. December 1989b. *Remedial Action Work Plan, Lakewood RA, Pierce County Washington.*

CH2M HILL. April 1990a. *Sampling and Analysis Plan, Remedial Action, Lakewood RA.*

CH2M HILL. May 21, 1990b. Memorandum to Ann Williamson, EPA Region X, on Lakewood RA Monitoring Well Inventory.

CH2M HILL. August 30, 1990c. Memorandum to Ann Williamson, EPA Region X, on Groundwater Sampling at Lakewood.

U.S. Environmental Protection Agency (U.S. EPA). June 1984. *Superfund Record of Decision, Ponders Corner Site, WA (IRM),* EPA/ROD/R10-84/002.

U.S. EPA. September 30, 1985. *Record of Decision, Remedial Alternative Selection, Ponders Corner Site.*

U.S. EPA. October 1989. *Evaluation of Ground-Water Extraction Remedies: Volume 2, Case Studies 1-19.* EPA/9355.4-03.

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UPDATE OF CASE STUDY 15

Savannah River Site
Aiken, South Carolina

Abstract

Remedial activities since the initial case study include: 1) an increase in the extraction rate of the existing system; 2) hydrogeologic investigations and the installation of two new extraction systems near the Savannah River Lab, and south of the main M-Area plume; 3) the installation of a soil vapor extraction system in the M-Area; and 4) further plume characterization. Since the last case study, the concentration of TCE in the water table aquifer and parts of the Upper Congaree has decreased, but increases have occurred in the Lower Congaree and the deepest aquifer, the Black Creek. An additional 28,000 pounds of solvents were removed in 1990. DNAPLs were identified in 1991. Some areas of the plume remain beyond the capture zone.

Background Data	
Date of Problem Identification	1981
Extraction Started	September 1985
Types of Contaminants	Tetrachloroethylene Trichloroethylene 1,1,1-Trichloroethane
Primary Aquifer Materials	Layered sand, silt, and clay
Maximum Number of Extraction Wells	12
Maximum Total Extraction Rate	550 gpm
Estimated Plume Area	1,030 acres
Estimated Plume Thickness	150 feet
Maximum Reported Concentrations	Trichloroethylene 223,000 ppb

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CASE STUDY UPDATE
SAVANNAH RIVER SITE

BACKGROUND OF THE PROBLEM

INTRODUCTION

The original case study of the U.S. Department of Energy's (U.S. DOE) Savannah River Nuclear Weapons Facility in Aiken, South Carolina (U.S. EPA 1989, Case Study 15) described remedial actions addressing contamination of an aquifer system under the site's manufacturing (M-area) and administrative areas (A-area) through December 1988. Figure 1 shows the location of these areas at the Savannah River site. The Savannah River site (SRS) is part of a network of weapons plants that conducts research and manufactures products in support of the nuclear weapons industry. Contamination was caused by the disposal of approximately 2.1 million pounds of volatile organic degreasing solvents into an onsite settling basin between 1958 and 1982. Contamination was first identified in June 1981. Discharges to the settling basin were discontinued in July 1985 and remedial action began in September 1985. The plant is operated by Westinghouse Savannah River Company under contract to U.S. DOE. Remediation is regulated by the South Carolina Department of Health and Environmental Control (SCDHEC).

The formations of interest that underlie the site are in order of increasing depth, the Barnwell Group, the McBean Formation, the Congaree Formation, the Ellenton Formation, and the Black Creek Formation. Before remediation began, the water table was between 60 and 120 feet below the land surface within the Barnwell Group and the McBean Formation.

The Barnwell Group is composed of the Upland Unit, the Tobacco Road Formation, and the Dry Branch Formation. The Upland Unit is a poorly-sorted mix of sand, cobbles, silt, and clay with a thickness of approximately 57 feet. The Tobacco Road Formation is a moderate- to well-sorted, fine-to-medium sand containing some silt, pebbles, and clay. The Tobacco Road Formation is up to 97 feet thick. The Dry Branch Formation is a moderate- to well-sorted, medium sand containing some clay. It is from 30 to 55 feet thick.

The McBean Formation is between 16 and 34 feet thick, and characterized by moderate- to well-sorted, fine sand with additional clay and silt layers. Ground water in the McBean Formation flows radially outward.

The Congaree Formation is divided into Upper and Lower units by a clayey intermediate zone. The Upper level is approximately 60 feet of fine to medium sand and clay beds. Under natural conditions, the A/M areas overlie a ground-water ridge from which ground water flows away to the east, west, and south. The Lower stratum ranges from four to 44 feet of moderate- to well-sorted sand. Ground water in the lower zone flows in an easterly and southerly direction.

The Ellenton Formation varies in thickness from 32 to 95 feet and is composed of two major clay layers separated by poorly-sorted sand. The bottom layer ranges from 10 to 56 feet thick and is the principal confining unit for the underlying Black Creek Formation. The direction of water flow in the Ellenton is to the southeast.

The Black Creek Formation is composed of poor- to well-sorted, medium to coarse sands and ranges from 150 to 180 feet thick. The upper section is an important production zone for water-supply wells in the M-area.

Of the 2.1 million pounds of solvents discharged to the HWMF, some fraction volatilized to the atmosphere, but a substantial amount is believed to have percolated downward to the saturated zone. Using volume-averaging of concentration information from monitoring wells, the total initial amount of dissolved organic solvents in the aquifer was estimated at 260,000 to 450,000 pounds, of which 75 percent is 1,1,2-trichloroethylene (TCE). Other major VOCs are tetrachloroethylene (PCE) and 1,1,1-trichloroethane (TCA).

Before remediation began at Savannah River, TCE levels as high as 223,000 ppb were detected in

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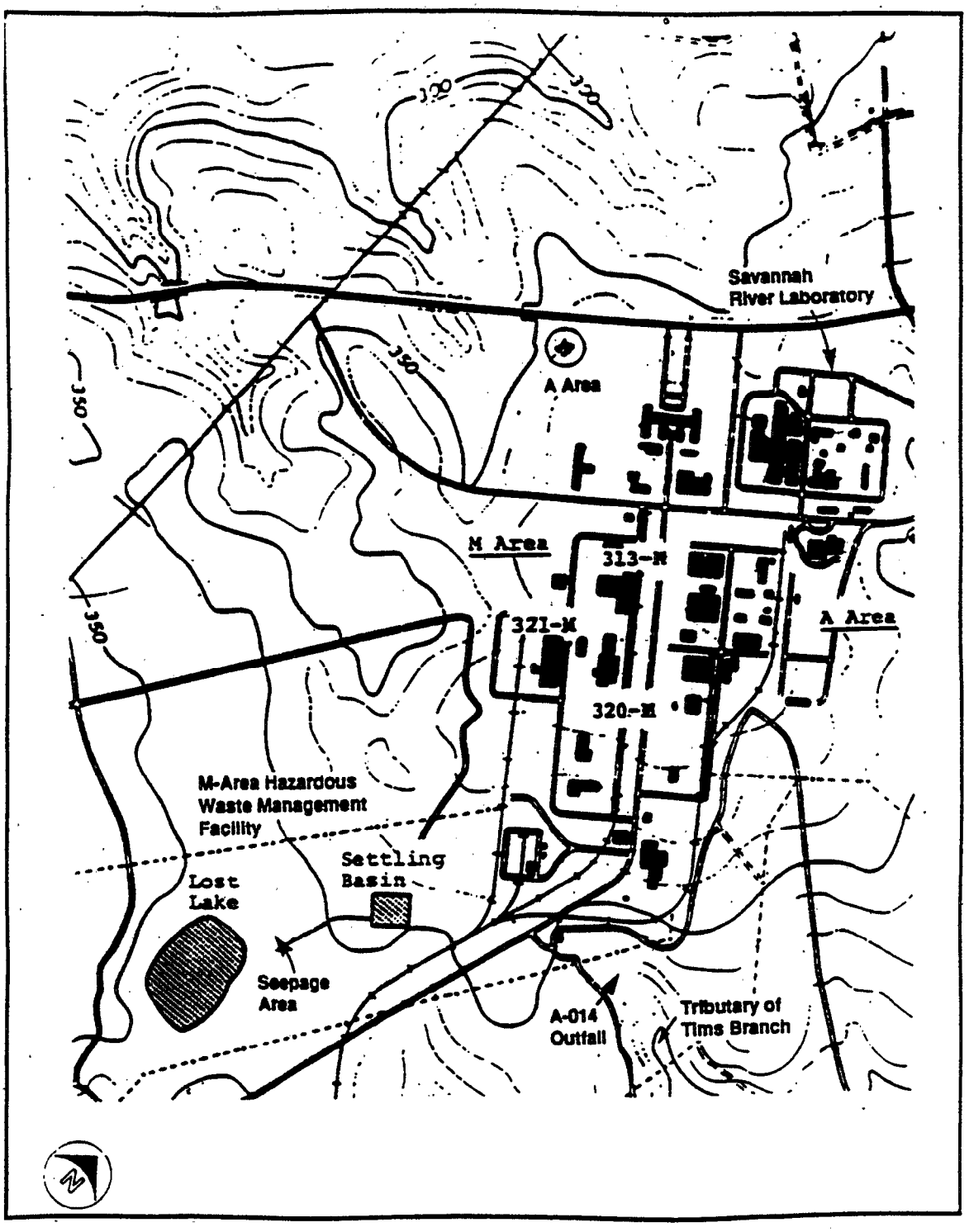

Source: U.S. DOE, 1986

Figure 1
MAP OF A/M-AREA
SRS A/M-AREA SITE
AIKEN, SOUTH CAROLINA

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ground water in the M-Area. TCE concentrations above 100,000 ppb were also observed in the A-014 outfall and the settling basin. Contamination was centralized in the McBean and Congaree Formations with the Ellenton clay layers forming a partial barrier to downward migration of contaminants. TCE levels of 756 ppb had also been detected in the Black Creek Formation.

A contaminant plume beneath the settling basin in the M-Area is migrating downward. Separate plumes have been detected in the vicinity of the Savannah River Laboratory (SRL) and in the southern sector near the A-014 outfall (U.S. DOE, 1991).

UPDATE ON SITE CHARACTERISTICS

The update of the case study is based on data obtained from Westinghouse Savannah River Company. Data obtained include 1990 permit modifications to the M-Area Basin, the 1989 and 1990 Annual Corrective Action Reports, a 1990 third quarter summary, air-stripper summaries, and internal memoranda summarizing site activity since publication of the original case study. The basic understanding of site characteristics remains as described in the original case study.

At the time of the initial case study, site contamination was not evaluated according to health-based standards. Since that time, however, Ground Water Protection Standards (GWPS) were outlined in the M-Area Modification/Part B Permit (U.S. DOE, 1990b). These goals, which are based on EPA's maximum contaminant levels (MCLs) for organic contaminants, are 5 ppb for TCE and PCE and 200 ppb for TCA.

REMEDIATION

Design and Operational Features of the Remediation System

At the time of the original case study, the stated contamination cleanup objectives at the A/M Areas were to minimize horizontal and vertical migration of contaminated ground water away from source areas and to remove 99 percent of the contamination in the aquifer over a 30-year period (U.S. DOE, 1987). Current SRS operators explain that this 99 percent figure has never been used as the basis for a cleanup criterion. The criterion of removal of 99 percent in 30 years was derived mathematically to provide a removal curve that is used as the basis of comparison of each year's removal data (Westinghouse Savannah River Company, 1991).

The full-scale remediation system that began operation in September 1985 consisted of 236 monitoring wells, 11 recovery wells, and a large-production air stripper near the M-Area buildings. The locations of the recovery wells and the air stripper are shown in Figure 2.

The monitoring wells are used to assess the extent of the contamination and to monitor the effectiveness of the remediation. These wells are screened at different depths to track trends in the potentiometric head and contaminant concentrations throughout the entire multi-aquifer system. During 1988, 165 monitoring wells were sampled.

Four of the recovery wells (RWM-3, RWM-5, RWM-9, RWM-11) were designed to be pumped at 55 gpm while the remaining seven were designed to be pumped at 25 gpm. As of December 1988, the average total withdrawal from the recovery well system was 436 gpm. The initial case study concluded that this rate could increase to 725 gpm if the pumps were modified to operate at full-formation capacity and that pumping rates were limited only by the capacity of the air-stripper discharge pump.

Since the original case study was presented, both minor and major modifications to the remediation system have been proposed and elements of the proposals have been implemented. Minor modifications consist of increasing the flow of influent to the air stripper. SRS system operators have explained that the initial case-study statement that extraction-well pumping rates were limited by the capacity of the air-stripper discharge pump was incorrect; they identify permit restrictions as the factor responsible for not increasing flow to the air stripper (Westinghouse Savannah River Company, 1991).

In December 1989, a performance test on the air stripper system was conducted. System operators determined that the air stripper could operate effectively at 500 gpm (U.S. DOE 1990a). In March 1990, the SCHEDC approved a permit application allowing Savannah River site operators to increase flow to the air stripper to as much as

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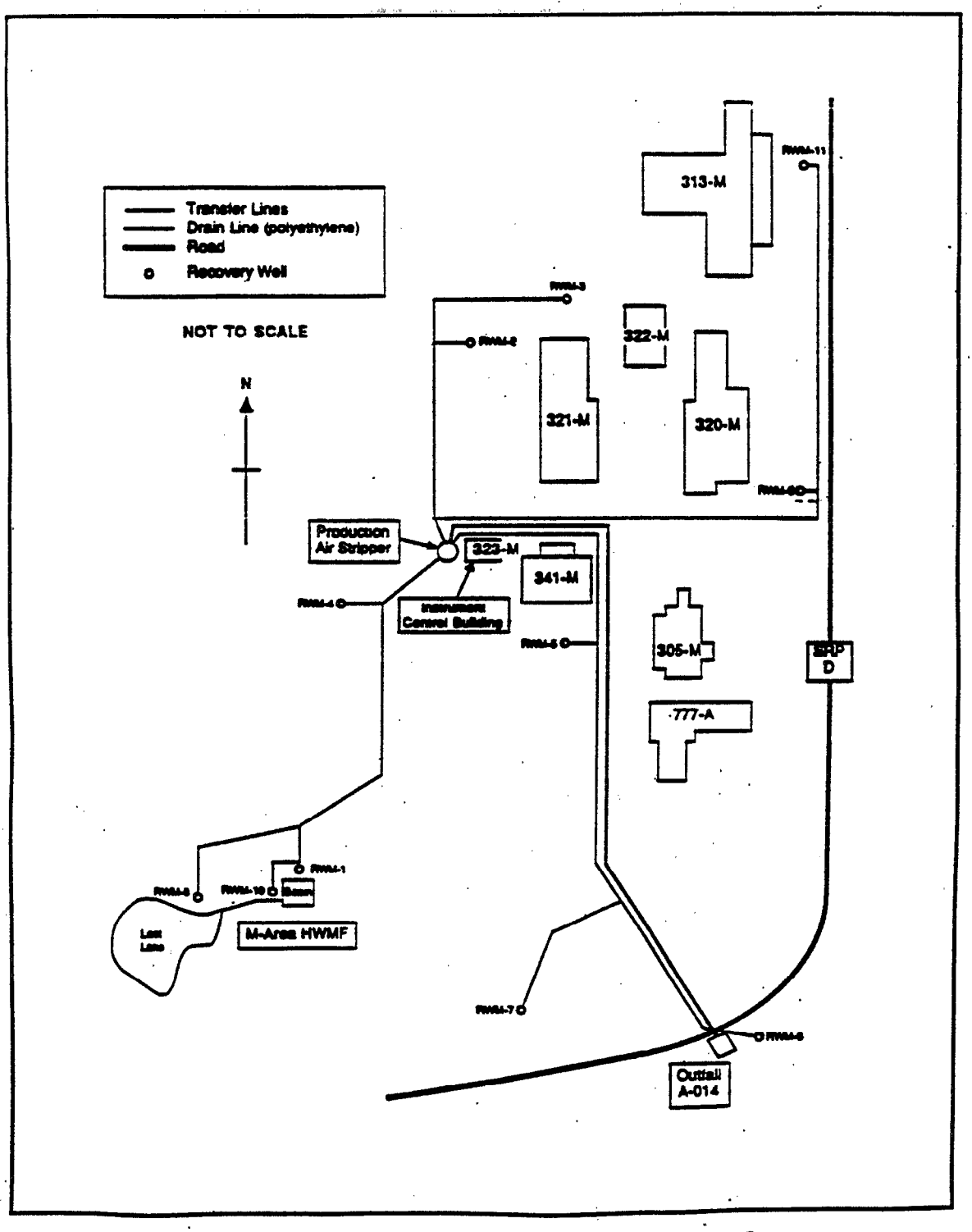

Source: U.S. DOE, 1990a

Figure 2
RECOVERY WELL LOCATIONS
SEPTEMBER 1989
SRS A/M-AREA SITE

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610 gpm. The revised flow was intended to increase the removal rate of the central plume in the M-Area. System operators project that increasing flows to this rate would result in an atmospheric discharge rate of 6.7 lbs/hr (29.5 tons/year), which does not exceed the permitted atmospheric-discharge limit. Minor design changes to the system would be necessary to achieve increased flow rates, including redesigning distributor trays and improving packing materials. During 1990, the air stripper removed approximately 28,000 pounds of solvent from the ground water. Since September 1985, the system has removed approximately 203,762 pounds of solvent. The average inlet water feed rate to the air stripper in 1990 was 454 gpm (U.S. DOE, 1991). In the third quarter of 1990, the air stripper logged 446.9 hours of downtime due to stripper upgrade, repair, and general maintenance. The air stripper was sampled about once a week for TCE and PCE.

Of the four recovery wells designed to be pumped at 55 gpm, three operated below capacity at an average monthly flow during July, August, and September 1990 of 46 gpm each (RWM 3, RWM 5, RWM 9), and one operated in excess of design capacity at an average of 65 gpm (RWM 11).

Major modifications include: (1) installation of a ground-water corrective-action system in the area of the SRL, (2) further assessment of the geologic and hydrogeologic conditions in the southern sector of the M-Area in anticipation of the need for a remediation system, (3) implementation of a vadose-zone remediation program, (4) implementation and completion of the Phase IV Well Drilling Program, and (5) RCRA closure of the M-Area Hazardous Waste Management Facility (HWMF), completed during 1990.

Corrective Action System at SRL

Since the first case study, a separate contaminant plume in the vicinity of the SRL in the northeastern A/M Area was identified. This plume may have been caused by spills or leaks from solvent storage tanks. In 1990, the facility conducted an investigation to define the extent of contamination and institute a remedial system to remove and treat contaminated ground water from the SRL complex. Program elements include source identification, plume definition, and a remediation system. Source identification consists of personnel interviews to identify former use patterns involving degreasing solvents. Plume definition is contingent on monitoring well data to define the vertical and horizontal extent of the plume.

The proposed system is expected to consist of 14 monitoring wells, two recovery wells, and an air stripper that will discharge treated effluent to the A-001 outfall. By mid-1990, the 14 monitoring wells and one recovery well had been installed, and by November 1990, the SRS had received a construction permit to install a treatment facility in the vicinity of the Savannah River Laboratory. The system was scheduled to begin extraction at a rate of 70 gpm in June 1991.

Southern Sector of M-Area

Plans are underway to conduct hydrogeological studies of the southern boundary of the M-Area in anticipation of additional remedial actions. The 30-year capture zone encompasses the north, east, and western boundaries of the M-Area plume, while the southern area remains outside the influence of the existing recovery system. The investigation will consist of hydrogeologic investigation (including well installation, geologic interpretation, and aquifer characterization), and remedial action design (including consideration of alternative technologies). The data derived from these investigations will be used to implement a remedial action plan in the southern sector of the M-Area. The plan will address recovery well locations, screen intervals, flow rates, treatment technology, and disposal methods (U.S. DOE, 1990b). In mid-1990, a recovery well was installed in the southern sector. In March 1991, plant operators conducted a 72-hour pump test. The results of this test will be used to determine the design requirements of the remediation system in the area (Westinghouse Savannah River Company, 1991).

Vacuum-Extraction in the Vadose-Zone

Based on a pilot program that resulted in the removal of 1,500 pounds of solvents over a period of three weeks, SRS proposed a full-scale vacuum-extraction system to SCDHEC; however, it has not yet received approval on the RCRA permit modification (Westinghouse Savannah River Company, 1991). The remediation plan consists of five parts: (1) site characterization, (2) well drilling and installation, (3) system operation, (4)

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performance evaluation, and (5) permitting. Throughout 1990, vacuum-extraction technologies were implemented to reduce contaminant levels in the vadose zone in the A/M Areas. As of December 1990, 14 soil borings had been drilled, monitoring wells had been installed in two of these borings, and two clusters of vadose-zone monitoring wells and four vadose zone vapor-extraction wells had been installed.

Phase IV Well Drilling

On September 25, 1989, drilling of the Phase IV monitoring wells was initiated. The purpose of the drilling program was to complement the existing well system in delineating the vertical and horizontal extent of ground-water contamination and to determine the potential need for additional remedial measures. The project was completed in May 1991. A total of 71 monitoring wells and two recovery wells were installed (Westinghouse Savannah River Company, 1991). Figure 3 shows the location of the Phase II, III, and IV wells.

EVALUATION OF PERFORMANCE

Changes in water quality since the first case study are evident from a trend analysis of data from 40 monitoring and 11 recovery wells that were tested during the fourth quarter of 1990. Of the 40 monitoring wells tested, 14 concentrations exhibited no trend, 24 showed an upward trend, and 12 displayed a decreasing trend (U.S. DOE, 1991).

Based on analysis of samples from monitoring wells, TCE is still the most prevalent onsite contaminant. Both TCE and PCE contaminant concentrations exceeded the GWPS in 1990. Contaminant concentrations of TCE increased by 23 percent in the Lower Congaree between the original case study and the third quarter of 1990. TCE levels in the Black Creek showed an increasing trend, averaging 583 ppb between the last quarter of 1989 and the third quarter of 1990. TCE concentrations as high as 20,000 ppb were also detected in a new plume definition well located west of the M-Area Facilities in the Upper Congaree. PCE distribution is similar to that of TCE, but concentrations are generally lower than those of TCE.

Table 1 lists the concentrations of TCE, TCA, and PCE for the point-of-compliance (POC) monitoring wells from the last quarter of 1989 to the third quarter of 1990. The point-of-compliance is a vertical surface located at the hydraulically downgradient limit of the waste management area and extends down into the uppermost aquifer; however, the POC wells are screened in the Congaree. A comparison of these data shows continued high levels of TCE and PCE in the water table unit (7,450 ppb TCE and 19,500 ppb PCE). Although the concentrations of TCE and PCE in the POC wells continue to decline since the start of remediation in 1985, in most of the POC wells, including the two in the Congaree, concentrations in excess of the health-based goals were detected.

In the fourth quarter of 1990, TCE was detected in monitoring wells in the water table unit at a maximum concentration of 57,000 ppb, in the Upper Congaree at a maximum of 50,000 ppb, and in the Lower Congaree at a maximum of 3,290 ppb. Although the Ellenton clay layer generally impedes movement into the lower units, TCE continues to migrate into the Black Creek Formation where maximum concentrations in 1990 (1,980 ppb) were more than double what they were when remediation began in 1985. These data are displayed in Figures 4, 5, and 6.

Figure 7 displays the concentrations of TCE and PCE in the air stripper influent from September 1985 to December 1990. Since system startup, plots of PCE and TCE concentrations show decreasing trends. A review of the average monthly chlorocarbon concentrations for the fourth quarter of 1990 in the individual recovery wells in Table 2 illustrates that the average monthly TCE and PCE concentrations were highest in the vicinity of the M-Area buildings (RWM-2 and RWM-3) and the settling basin (RWM-1).

The expected 30-year zone of capture has not changed since the original case study was published. Analysis of monitoring well data from 1990, however, revealed TCE levels as high as 18,300 ppb west of the acknowledged plume boundary. Based on data from additional wells in the vicinity of the SRL, the plume in this area is greater than that identified in the original case.

The SRL plume extends into the Upper Congaree where TCE levels as great as 14,800 ppb in this area have been detected. Figure 8 shows the location of the suspected source near the SRL and the predominant ground-water flows from that source to the southeast through the A/M Areas (U.S. DOE 1990c). Because remedial action is

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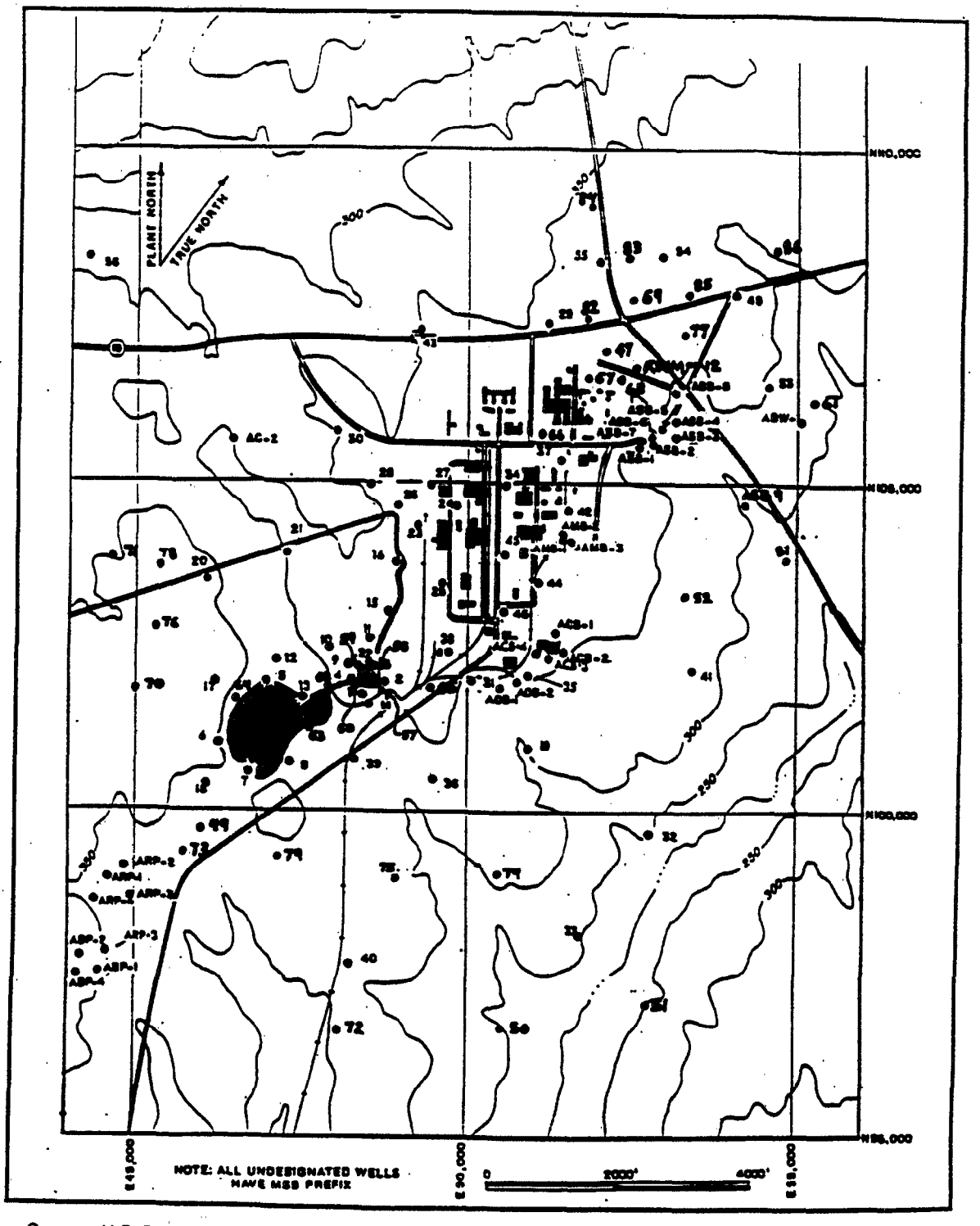

Source: U.S. DOE, 1990a

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Figure 3
PHASE II, III, AND IV MONITOR-WELL CLUSTERS
SRS A/M-AREA SITE

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Table 1
COMPARATIVE PARAMETERS FOR CONTAMINANTS OF CONCERN–SAVANNAH RIVER POINT OF COMPLIANCE WELLS (ppb)

		Trichloroethylene (TCE)					Trichloroethane (TCA)					Tetrachloroethylene (PCE)				
Well MSB:	Unit Screened	4Q89	1Q90	2Q90	3Q90	4Q90	4Q89	1Q90	2Q90	3Q90	4Q90	4Q89	1Q90	2Q90	3Q90	4Q90
1A	Water Table	DW				110	DW				<10.0	DW				170
2A	Water Table	458	292	220	314	190	20	32	26	22	8	1010	850	910	1340	530
3A	Water Table	DW				DW	DW					DW				
4A	Water Table	DW				DW	DW					DW				
5A	Water Table	8	15	20	44	61	4	3	3	4	5	15	15	19	29	24
6A	Water Table	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	q<1.0	<1.0	<1.0	<1 0
7A	Water Table	10	4	5	3	3	<1.0	<1.0	<1.0	<1.0	<5.0	23	10	13	8	9
8	Water Table	54	50	42	49	DW	<5.0	<5.0	<1.0	1	DW	201	140	140	184	DW
13A	Lower Congaree	<5.0	<1.0	<1.0	<1.0	13	<5.0	<1.0	<1.0	<1.0	<1.0	<5.0	<1.0	<1.0	<1.0	<1.0
13B	Upper Congaree	15	30	22	30	24	<2.0	2	2	2	2	17	46	57	59	38
13C	Water Table	14	15	*	*	*	5	5	*	*	*	15	24	*	*	*
22	Water Table	11	7450	DW		DW	<5.0	<1.0	DW		DW	17	19,500	DW		DW

Source: U.S. DOE, 1990 and U.S. DOE, 1991
* Well bailed dry, only VOCs and select constituents could be analyzed 3Q89 and 4Q89.
DW = Dry Well.

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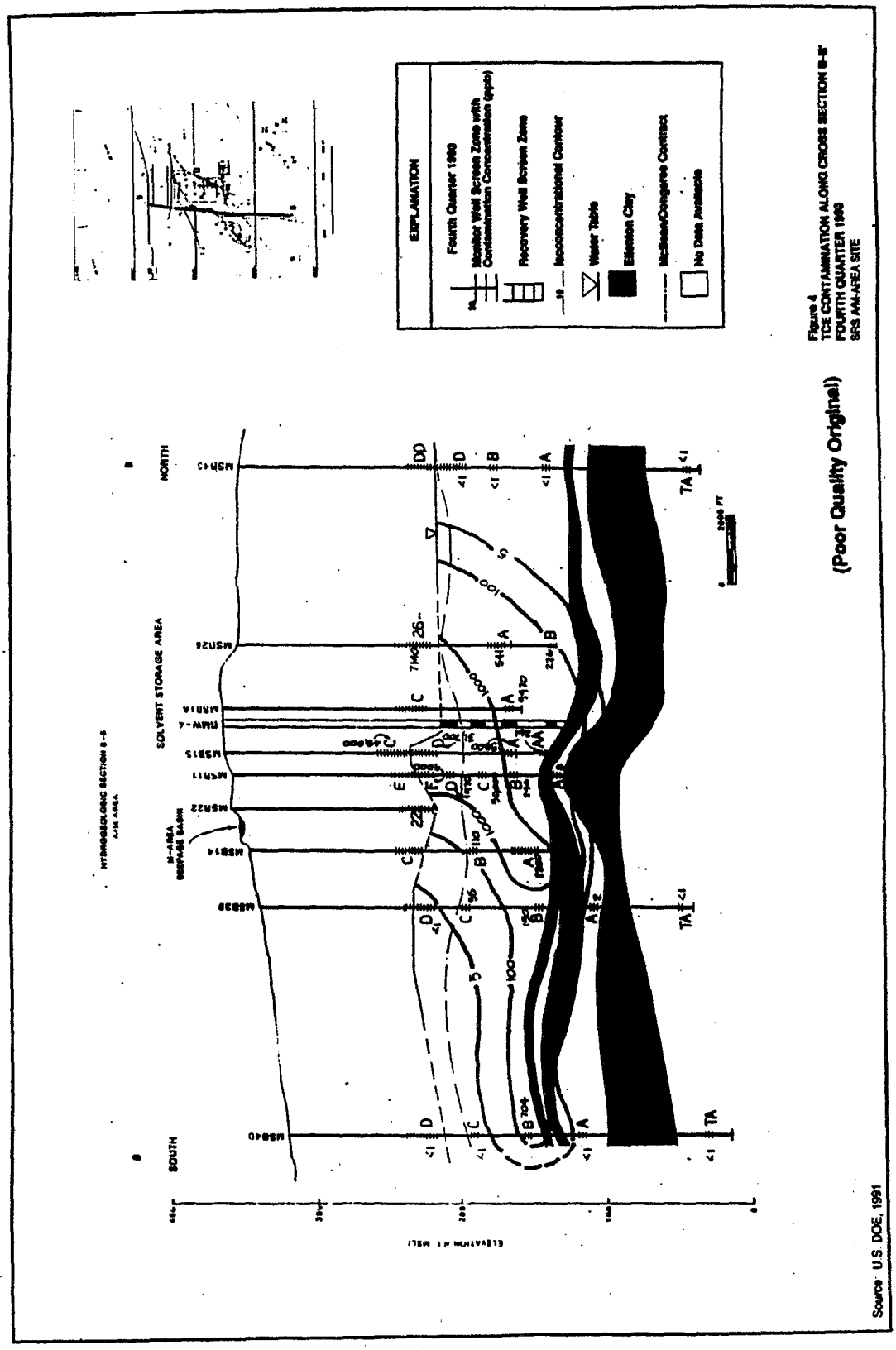

Figure 4
TCE CONTAMINATION ALONG CROSS SECTION B-B'
FOURTH QUARTER 1990
SRS AM-AREA SITE

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Source: U.S. DOE, 1991

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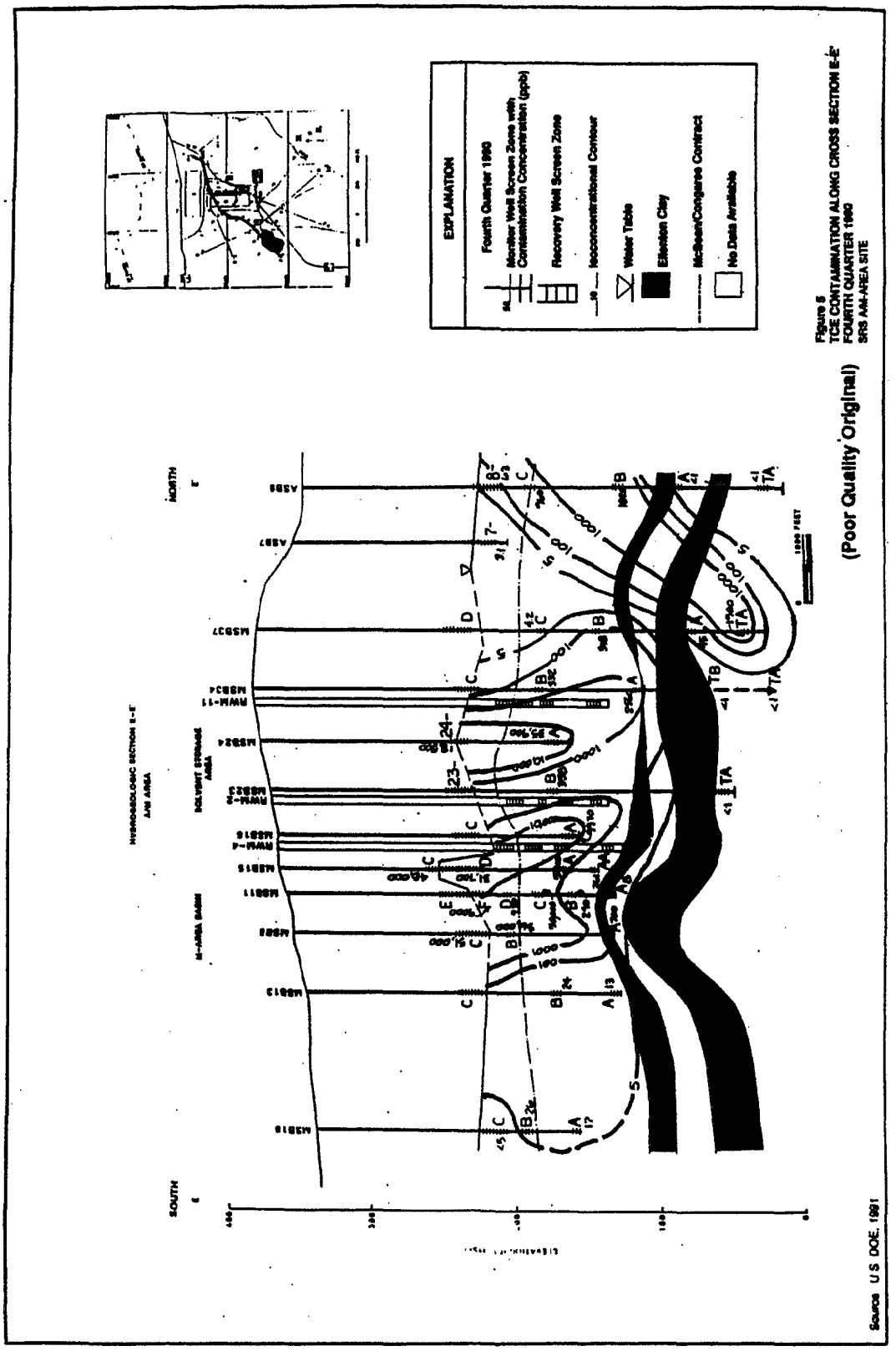

Figure 6
TCE CONTAMINATION ALONG CROSS SECTION E-E'
FOURTH QUARTER 1990
SRS A/M-AREA SITE

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Source: U.S. DOE, 1991

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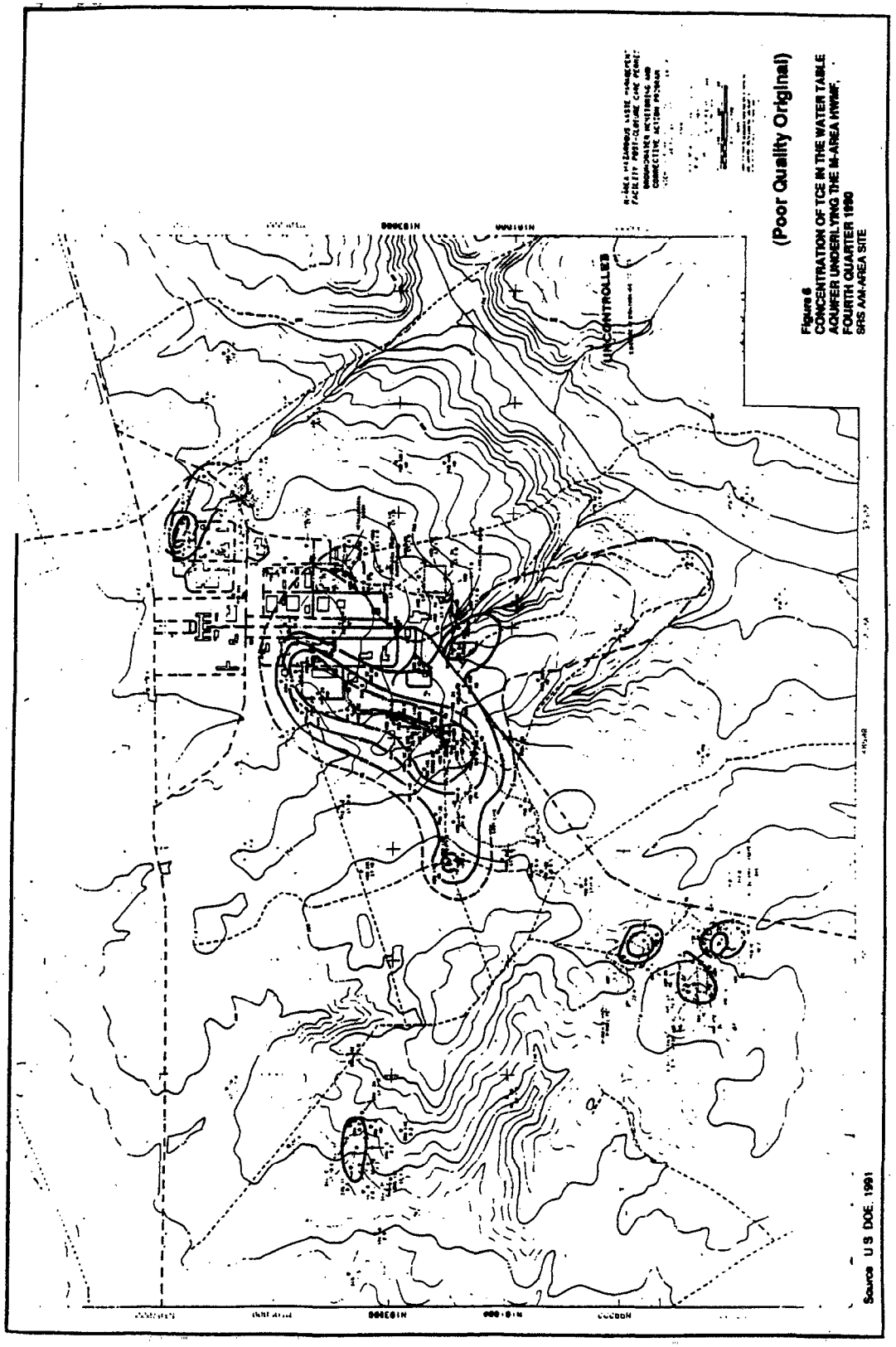

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Figure 6
CONCENTRATION OF TCE IN THE WATER TABLE AQUIFER UNDERLYING THE M-AREA HWMF, FOURTH QUARTER 1990
SRS AM-AREA SITE

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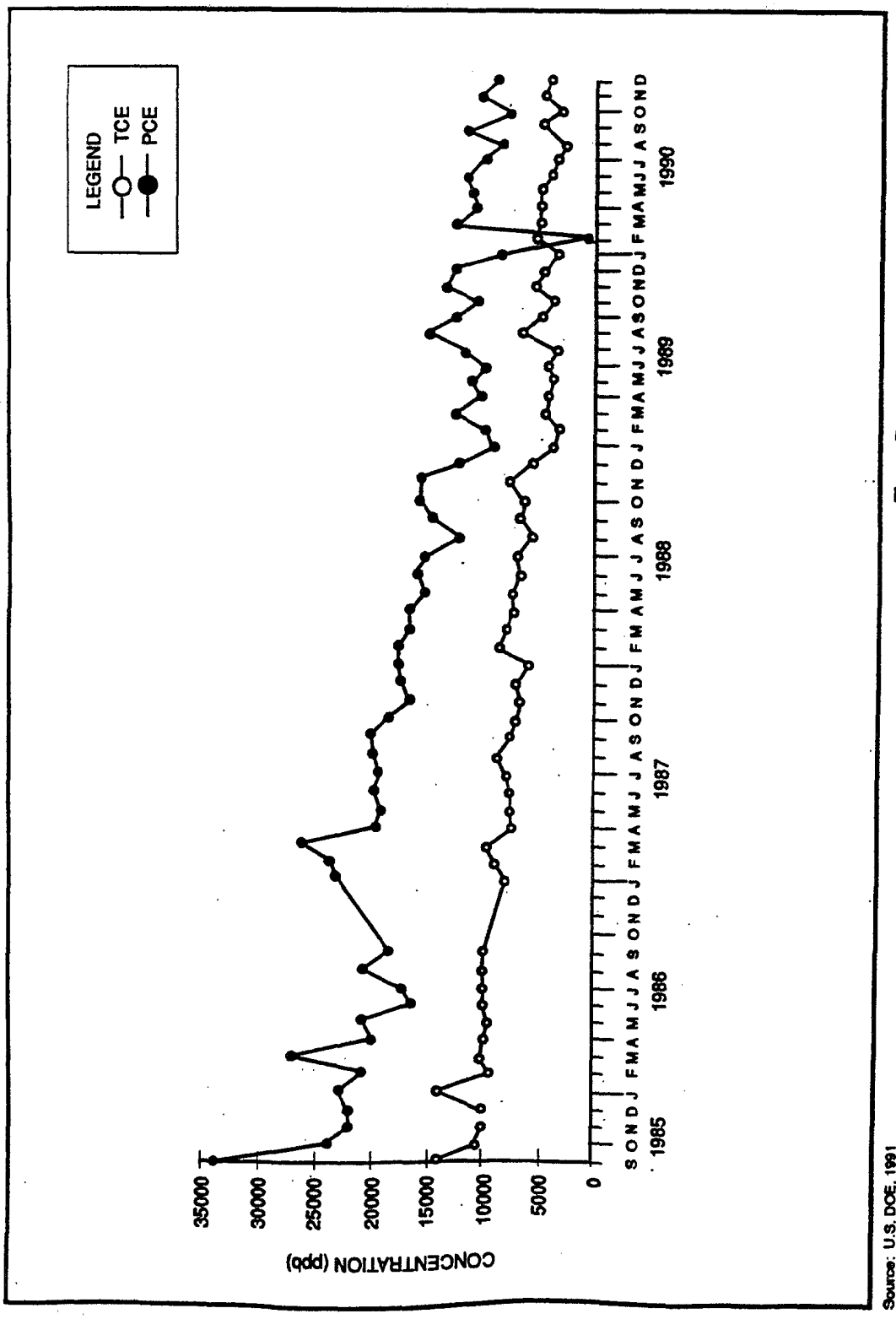

Source: U.S. DOE, 1991

Figure 7
TIME SERIES PLOT OF TCE AND PCE CONCENTRATIONS IN THE AIR STRIPPER INFLUENT, SEPTEMBER 1985 TO DECEMBER 1990
SRS A/M-AREA SITE

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Table 2
RECOVERY WELLS AVERAGE MONTHLY CHLOROCARBON CONCENTRATIONS (ppb)
FOURTH QUARTER 1990

	October Degreaser Solvent Concentrations			November Degreaser Solvent Concentrations			December Degreaser Solvent Concentrations		
Well Number	TCE (ppb)	PCE (ppb)	Total (ppb)	TCE (ppb)	PCE (ppb)	Total (ppb)	TCE (ppb)	PCE (ppb)	Total (ppb)
RWM-1	41,100	18,800	59,900	42,000	20,300	62,300	44,700	21,800	66,500
RWM-2	25,300	9,040	34,340	27,100	10,600	37,700	26,200	8,770	34,970
RWM-3	17,700	4,300	22,000	17,600	5,130	22,370	19,400	4,310	23,710
RWM-4	6,210	686	6,896	6,840	847	7,687	6,370	587	6,957
RWM-5	1,740	1,230	2,970	1,980	1,370	3,350	1,830	1,130	2,960
RWM-6	8,160	7,040	15,200	7,550	5,850	13,400	8,540	6,550	15,090
RWM-7	4,170	4,890	9,060	4,040	4,440	8,480	4,420	5,810	10,230
RWM-8	344	164	508	361	157	518	416	189	605
RWM-9	143	59	202	171	23	194	162	11	173
RWM-10	6,310	15,300	21,610	3,410	5,610	9,020	2,930	5,310	8,240
RWM-11	4,790	512	5,302	4,910	660	5,570	4,380	329	4,709

Source: U.S. DOE, 1991
TCE = Trichloroethylene
PCE = Tetrachloroethylene

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still in the construction stage, it is too early to assess the effectiveness of remediation in the vicinity of the SRL. Developing a remediation program to address this area is important due to continued contaminant migration into the Black Creek Formation.

Since September 1985, the system has removed approximately 203,762 pounds of solvent. An estimate of mass of solvent contaminants present in the aquifers has been calculated using concentration data for each year from startup through the end of 1989. (To date, an estimate was not made for 1990 due to the extensive number of wells.) Estimated mass removed is calculated as the difference between the estimate of total mass present in the aquifer in 1989 from that which was estimated at startup. The total estimated mass removed through the fourth quarter of 1989 was approximately 92,000 pounds. The actual amount removed by the air stripper through the fourth quarter of 1989 was 175,400 pounds. The amount actually removed is nearly twice the estimate of mass reduction. This discrepancy could be caused by inaccuracy in volume averaging of the monitoring well data or by the presence of DNAPLs that were not accounted for in the calculations.

SUMMARY OF REMEDIATION

Since the original case study, changes at the Savannah River site include research into alternative remediation technologies, exploratory efforts to define the actual extent of site contamination, and reductions of contaminant concentrations. System operators acknowledge the need to assess more completely the actual extent of site contamination. During 1989 and 1990, actions were initiated to evaluate the remedial needs in the SRL and southern sector of the M-Area. To date, preliminary construction has begun, but it is too early to assess the effectiveness of these efforts. It is clear from preliminary data that the plume extends beyond the zone of influence of the existing M-Area remediation system.

Since the last case study, efforts, such as the Phase IV drilling program, were initiated to provide a better definition of the extent of ground-water contamination at the site. Alternative in situ techniques, such as soil vacuum extraction, are being pursued to supplement the recovery rates of the extraction wells. These efforts are in various stages of completion and any evaluation of their effectiveness at this time is premature.

Although such actions begin to address continued high levels of contamination and insufficient definition of the plume, significant progress toward remedial objectives has not been made since the original case study. Some reduction in contaminant concentrations is evident, particularly in the Upper Congaree, but the contaminant trends identified in 1988 were still evident in 1990. Although contaminants appear to be decreasing in the water table unit of the Solvent Storage area, in all other units total concentrations are stabilized at or increasing from 1988 levels. Plume concentrations continue to migrate to the Black Creek formation.

TCE concentrations in air-stripper influent decreased significantly from approximately 9,000 ppb to below 2,000 ppb between January 1990 and February 1990. The reason for this decrease was unknown. TCE concentrations increased in March 1990 above 12,000 ppb and then decreased and stabilized to approximately 9,000 ppb by the end of 1990. PCE influent concentrations stabilized near 4,000 ppb during 1990. Since the first case study, the total mass of solvents has decreased. The mass-inventory reduction total, however, is below that projected by the 30-year removal schedule.

System operators defined zones of capture for the 11 recovery wells as that volume of aquifer that contains all the ground-water flow paths with travel times of 30 years or less. The original case study concluded that the actual capture zone would be smaller than projected due to retardation caused by partitioning between solid and liquid phases. In addition, even if the projected capture zone were achieved, it would still fail to capture contaminated ground water in the area southeast of the A/M Area.

Given the low pumping rates, the distance between wells, and the detection of contamination outside the expected zone of capture, it is unlikely that contaminant concentrations will be reduced to below health-based levels in a 30-year period.

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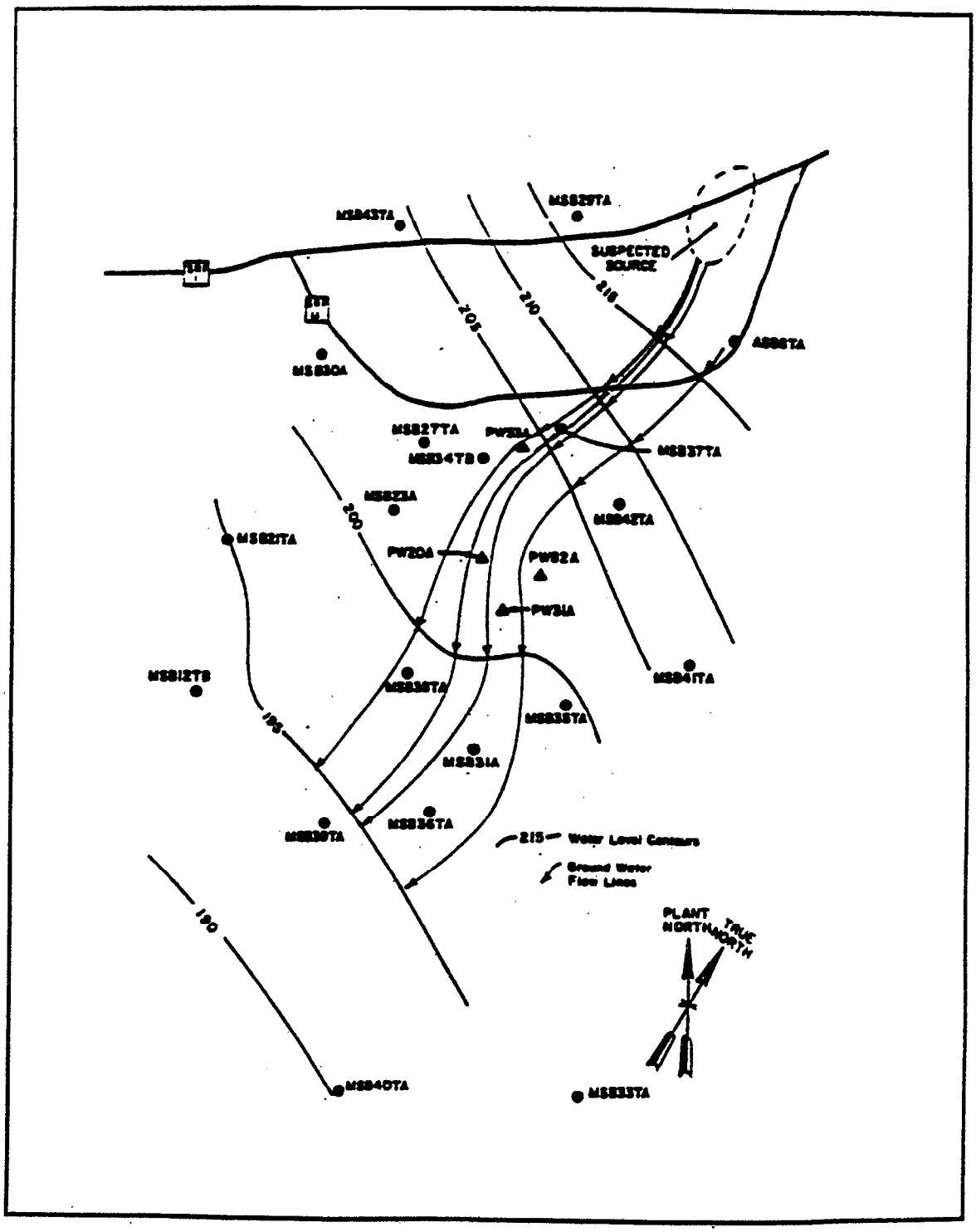

Source: U.S. DOE, 1990a

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Figure 8
SUSPECTED SOURCE NEAR THE SRL COMPLEX, 1989
SRS A/M-AREA SITE

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SUMMARY OF NAPL-RELATED ISSUES

In April 1991, SRS operators confirmed the presence of a DNAPL in one monitoring well, MSB-3D, near the closed M-Area HWMF (DOE, 1991). The well is located near an abandoned settling basin where solvents and electroplating sludges had been discharged. Preliminary organics analysis indicates that the DNAPL consists of 58 percent PCE, 2 percent TCE, and minor amounts of chlorobenzene and 1,2-dichlorobenzene (Westinghouse Savannah River Company, 1991).

The well was installed in September 1990, to replace the Point of Compliance well, MSB-3A, which had been dry since 1986. MSB-3D is from 128 to 148 feet deep, near the bottom of the water table aquifer. In this area, the top of the water table is at a depth of 130 feet, and a clay aquitard is at a depth of 150 feet. It is possible that DNAPLs might be pooling on this clay unit.

During sampling events prior to the discovery of the DNAPL, maximum recorded concentrations of 570,000 ppb PCE and 160,000 ppb TCE were measured in bulk ground-water samples from well MSB-3D (Westinghouse Savannah River Company, 1991).

In addition to the direct observation of DNAPLs at the site, other factors, such as the source characteristics, the existence of contaminant concentrations in ground water exceeding 1 to 10 percent of aqueous solubility, and the persistence of high concentrations despite remediation, all indicated the potential for DNAPL contamination.

The highest solvent concentrations in ground water are found in wells near the M-Area Basin, where degreaser solvents were discharged in wastewater, and in wells near the SRL complex, where tank leaks are suspected (Westinghouse Savannah River Company, 1991). From these sources, it is possible that a separate DNAPL phase could have migrated into the aquifer.

While concentrations of PCE and TCE have decreased in the water table aquifer since system startup, they remained high during 1990. In the fourth quarter of 1990, the maximum concentration of PCE was 96,000 ppb (64 percent of solubility). Maximum TCE levels were measured at 57,000 ppb (5.1 percent of solubility). Both maximums were recorded near the M-Area Basin in monitoring well MSB-31C. Concentrations exceeding 10 percent of solubility are another indication that DNAPLs probably exist near the M-Area Basin.

In the fourth quarter of 1990, concentrations of contaminants were lower in aquifers beneath the water table unit. In the Upper Congaree unit, a maximum of 50,000 ppb TCE was reported (4.5 percent of solubility). The high concentration of TCE suggests that DNAPL might have migrated to this unit. Concentrations of TCE decrease with depth. In 1990, maximum reported concentrations of TCE were 3,290 ppb in the Lower Congaree unit, 1,820 ppb in the Ellenton Unit, and 1,980 ppb in the Black Creek unit.

Concentrations of TCE in the Black Creek Unit have been increasing since monitoring began. In 1990, the maximum concentration was 1980 ppb in well MSB-37. If DNAPLs migrate into this unit, remediation of the site will become more difficult. The SRL area has been suggested as the source of contamination of the Black Creek (U.S. DOE, 1991).

The SRS has formed a team to address the recent discovery of DNAPLs at the site. The plan of action developed by the team is based on three elements: (1) confirmation of DNAPLs at suspect locations, (2) development of a system to recover DNAPLs, and (3) development of a method to treat or dispose of reclaimed solvents (Westinghouse Savannah River Company, 1991).

Because of the occurrence of DNAPLs, and the extent of the contaminant plume, system operators acknowledge that remediation will be more extensive than originally estimated.

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UPDATE BIBLIOGRAPHY/ REFERENCES

Litherland, Susan T., and David W. Anderson. November 1990. The Trouble with DNAPLs. In *Hazardous Materials Control Research Institute, Proceedings of the 11th National Conference.*

Mercer, J. W., and R. M. Cohen. February 1990 in-press. Transport of Immiscible Fluid in the Subsurface. *Journal of Contam. Hydrol.*

Schwille, F. 1984. Migration Organic Fluids Immiscible with Water in the Unsaturated Zone, Pollutants in Porous Media. In *The Unsaturated Zone Between Soil Surface and Ground Water.* New York: Springer-Verlag.

U.S. Department of Energy (U.S. DOE). July 1986. Application for a Post-Closure Permit, A/M Area Hazardous Waste Management Facility, Volume III, Revision No. 1, Savannah River Plant.

U.S. DOE. February 1987. *Effectiveness of the M-Area Ground-Water Remedial Action Program: September 1985-September 1986, Savannah River Plant.*

U.S. DOE. March 1990a. *Savannah River Project. M-Area Hazardous Waste Management Facility Post-Closure Care Permit, Ground-Water Monitoring and Corrective Action Program, 1989 Annual Report.*

U.S. DOE. September 1990b. *Savannah River Project. Modification of M-Area Basin and Vicinity Hazardous Waste Management Facility Post-Closure Care Part B Permit Application.*

U.S. DOE. November 1990c. *Savannah River Project. M-Area Hazardous Waste Management Facility Post-Closure Care Permit, Ground-Water Monitoring and Corrective Action Program, 1990 Third Quarter Report.*

U.S. DOE. March 1991. *Savannah River-Project. M-Area Hazardous Waste Management Facility, Post-Closure Permit, Groundwater Monitoring and Corrective Action Program. 1990 Annual Report.*

U.S. Environmental Protection Agency (U.S. EPA). October 1989a. *Evaluation of Ground-Water Extraction Remedies: Volume 2, Case Studies 1-19.* EPA/9355.4-03.

U.S. EPA. May 1989b. Dense Nonaqueous Phase Liquids. Paper presented at Regional Superfund Ground-Water Forum, Superfund Forum Issue.

Westinghouse Savannah River Company. December 14, 1990; January 2, 1991; February 5, 1991; June 4, 1991; June 5, 1991. Personal communication with Chris Bergren, Hydrogeologist, Savannah River Plant, Aiken, South Carolina.

Westinghouse Savannah River Company. May 13, 1991; May 24, 1991. Letters from Chris Bergren, Hydrogeologist, Savannah River Plant, Aiken, South Carolina.

Westinghouse Savannah River Company. January 7, 1991. Update memorandum on A/M Area Corrective Action Program from Charles C. Sherman, Manager, Environmental Restoration and Groundwater Section, Environmental Protection Department.

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UPDATE OF CASE STUDY 16

Site A
South Florida

Abstract

During 1990 and 1991, extraction and air stripping of ground water has continued at the site. Vinyl chloride, now the primary contaminant of concern, has remained at levels exceeding health-based standards. In early 1991, the EPA initiated a remedial investigation that included soil borings, the installation of additional monitoring wells along the southern boundary of the site, and the sampling of all wells at the site.

Table of Background Data	
Date of Problem Identification	1985
Extraction Started	August 29, 1988
Types of Contaminants	Benzene, chlorobenzene, 1,4-dichlorobenzene, trans-1,2-DCE, and vinyl chloride
Primary Aquifer Materials	Sand, limestone
Maximum Number of Extraction Wells	1
Maximum Total Extraction Rate	50 gpm estimated, actual rates have been around 38 gpm
Estimated Plume Area	0.7 acres
Estimated Plume Thickness	15-25 feet
Maximum Reported Concentrations	benzene 36.0 ppb chlorobenzene 370.0 ppb vinyl chloride 86.0 ppb 1,4-dichlorobenzene 170.0 ppb trans-1,2-DCE 7200.0 ppb

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CASE STUDY UPDATE
SITE A

BACKGROUND OF THE PROBLEM

INTRODUCTION

The original case study of Site A[1] in south Florida (U.S. EPA, 1989, Case Study 16), presented data about the onsite ground-water extraction system through March 1989. The company at the site has produced industrial cleaning compounds since 1958. A map of the site is shown in Figure 1. Contamination is caused by chlorinated organics and aromatic compounds that are concentrated in the south-central area of the site. Investigation into the extent of contamination began in 1985, and the extraction system began operating in August 1988. The site is managed by a potentially responsible party (PRP), with administrative oversight from the local county government.

Underlying Site A is the Biscayne Aquifer, the sole source of potable water for the county. The aquifer lies below a one-foot thickness of sandy organic topsoil and is composed of four geologic units. The first is a 15- to 25-foot-thick layer of sandy oolitic limestone with high vertical and horizontal conductivity from solution openings. Below the limestone is a 20-foot layer of fine to medium grained quartz sand. Underneath the sand is the Fort Thompson Formation, a 45-foot thick unit of limestone, which is the most productive layer in the Biscayne aquifer. The base unit of the aquifer is the Tamiami Formation, a regional confining unit comprising sand, silt, clay, and shell. Beneath the Biscayne aquifer lies the Floridan aquifer, which in this area contains brackish water.

The site is contaminated by the organic compounds benzene, chlorobenzene, 1,4-dichlorobenzene, trans-1,2-dichloroethylene (trans-1,2-DCE), and vinyl chloride. Figure 2 shows the location of the monitoring wells and the contaminant plume as originally designated by the PRP. The PRP contended that contamination was confined to the upper 15 to 25 feet of the Biscayne Aquifer and extended no more than 100 feet in any direction from the extraction well. However, the original case study identified two monitoring wells (MWT-32 and MWS-09) outside the boundaries of the designated plume that had contaminant concentrations above the aquifer remediation goals.

As of March 1989, concentrations of benzene, chlorobenzene, and vinyl chloride were still above cleanup standards in the contaminant plume identified by the PRP and in two monitoring wells outside the northern boundary of the designated plume.

The PRP also asserted that contamination is limited to the upper 15 to 20 feet of the Biscayne aquifer. Contamination levels above allowable standards, however, were detected at depths of 55 feet in monitoring well CDM-03 located within the designated plume.

UPDATE ON SITE CHARACTERISTICS

Site data for this update included 1990 monthly progress reports for the temporary air stripper and monitoring wells. Personal communication with the county oversight agency and EPA regional staff supplemented the technical status reports. In the interim since the initial case study, the PRP remained responsible for site cleanup, while the county agency continued to exercise oversight of cleanup progress. In addition, the state District Court granted a request from the EPA to conduct a remedial investigation at the site.

As reported in the original case study, concentrations of benzene were still higher than the cleanup goal of 1 ppb in monitoring Wells CDM-02 and MWS-11 in mid-March 1989. Since that date, ground-water sampling has been reported for only five monitoring wells: CDM-02, MWS-06, MWS-11, DERM-05, and DERM-06. All of these wells are approximately 20 feet deep, except Well DERM-05, which is only 10 feet deep. All of the sampling results reported for these wells since March 1989 have shown benzene concentrations below the cleanup standard.

Vinyl chloride was detected at concentrations above the 1 ppb cleanup goal in Wells CDM-02,

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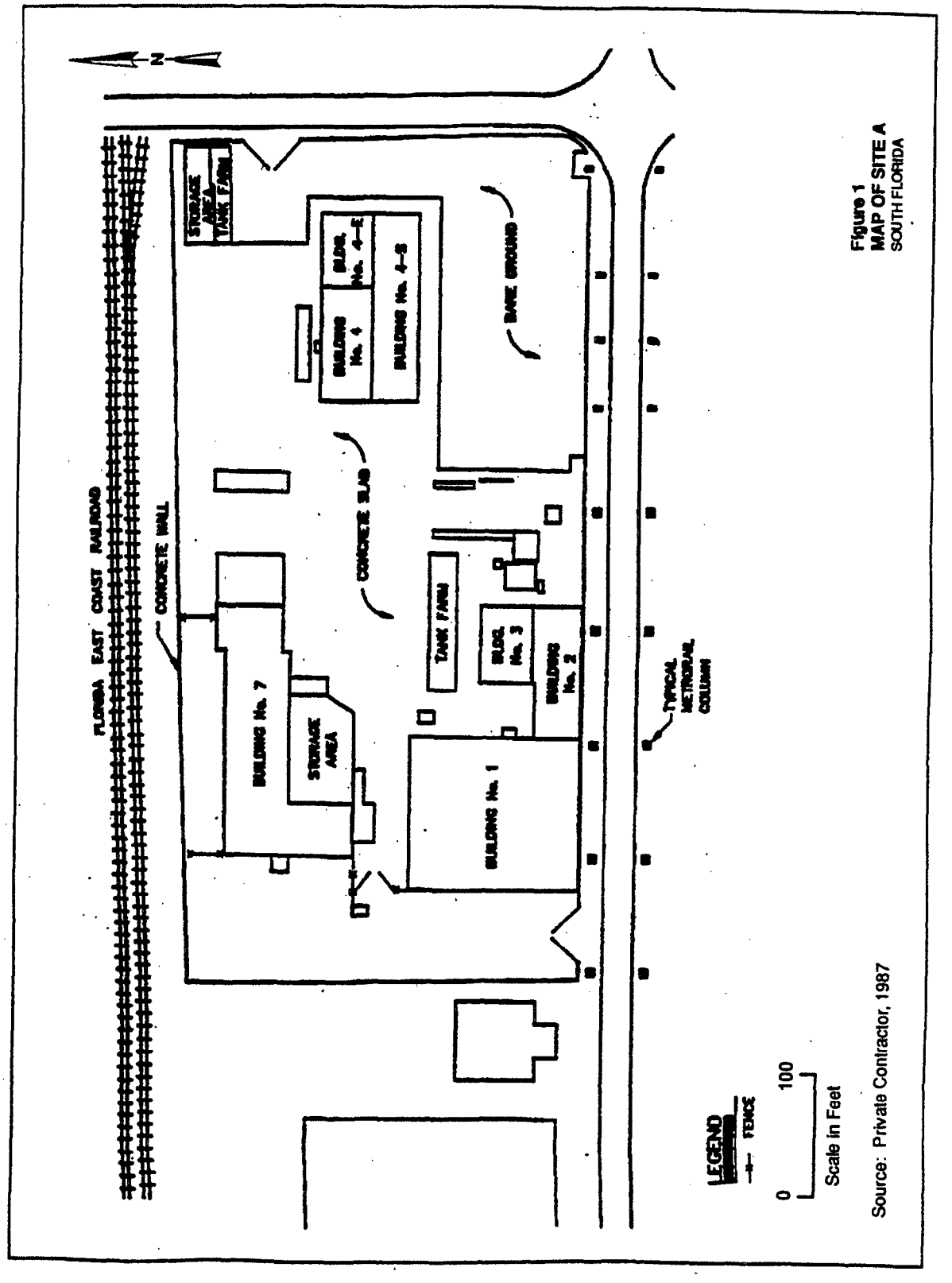

Source: Private Contractor, 1987

Figure 1
MAP OF SITE A
SOUTH FLORIDA

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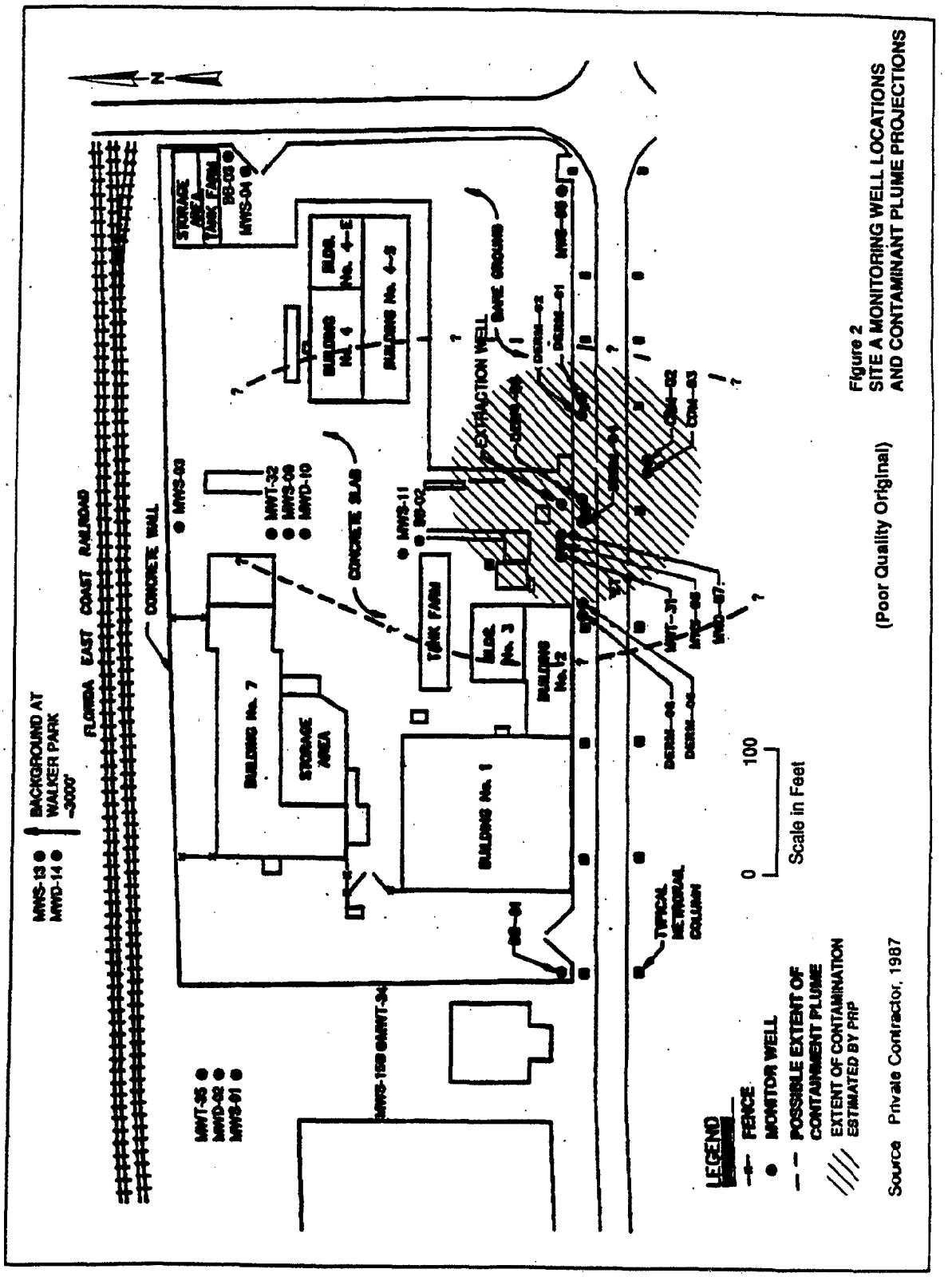

Figure 2
SITE A MONITORING WELL LOCATIONS
AND CONTAMINANT PLUME PROJECTIONS

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DERM-05, and DERM-06 in three of the four sampling rounds reported in 1990. Concentration levels were greatest in two monitoring wells (DERM-05 and DERM-06) adjacent to the extraction well. Table 1 lists the vinyl chloride concentrations in these wells since the extraction system began operation. The PRP believes that the vinyl chloride in these wells is migrating from offsite sources (Private Contractor, 1990a).

It should be noted that the ground-water sampling has been conducted without regulatory oversight.

REMEDIATION

Design and Operational Features of the Remediation System

The original goal of remedial actions at Site A was to reduce the concentrations of VOCs in the south-central area of the site to levels meeting health-based standards within 60 days. The remediation system consists of monitoring wells, a single extraction well in the center of the contaminated area, and an air stripper that discharges to the city sewer system.

During the first three quarters of 1990, pump malfunctions and maintenance of the air stripper caused minor disruptions in remediation. The air stripper was out of service several times between January and October 1990. The first time occurred between February 22 and March 23 when the well pump and motor failed after the air stripper underwent a routine cleaning. This resulted in 674 inoperable hours during which the air stripper influent and effluent were not tested (Private Contractor, 1990a). A second shutdown of 111 hours occurred between April 7 and April 11, 1990, and was caused by an inoperable pump motor (Private Contractor, 1990c). Additional shutdowns, lasting less than 8 hours each, occurred in July and September, when the packing media in the stripping tower were cleaned.

Having recently received authority to enter the site, the EPA has initiated a new remedial investigation that will include soil borings at documented onsite seepage pits, and the installation of additional monitoring wells along the southern boundary of the site (U.S. EPA, 1991b). The results of these field activities will be used to determine the actual extent of the contaminant plume, and the presence or absence of dense nonaqueous phase liquids (DNAPLs) (U.S. EPA, 1991a). As of May 1991, the data from the studies had not been released. These studies may result in future modifications to the remedial system.

EVALUATION OF SYSTEM PERFORMANCE

No water-level measurements have been reported for this site that could be used to judge the effectiveness of the extraction well in capturing the contaminant plume. As mentioned in the original case study, the extraction system operators reported that the onset of pumping produced "no measurable differences of water levels" in the monitoring wells. No further information on the hydraulic effectiveness of the extraction well has been given in the periodic status reports submitted by the operators.

All contaminants except for vinyl chlorine have reached clean-up goals as measured in the influent to the air stripper. During 1990, the concentrations of benzene and chlorobenzene that were detected in three monitoring wells in 1989 were brought within health-based standards. Contaminant levels of vinyl chloride, however, continue to appear in three of the five monitoring wells in the area of the extraction well. Despite substantial declines in concentrations since 1988, vinyl chloride continues to be detected in levels higher than the cleanup-goal of 1 ppb.

The air stripper continues to function effectively in removing VOCs present in influent. Table 2 lists the cumulative volume of ground water treated in the first three quarters of 1990. Since system start-up, the air stripper has removed approximately 15 pounds of VOCs.

Figure 3 shows the variation in concentrations of the five principle contaminants measured at the influent sampling point of the air stripper over the period of remediation.

In the original case study, total VOCs in air stripper influent were reported to be at concentrations above 10,000 ppb for the first 10 days after start-up. The highest total VOCs concentration, 24,001 ppb, was recorded on

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Table 1
CONCENTRATIONS OF VINYL CHLORIDE IN THREE SITE A MONITORING WELLS (ppb)

		Monitoring Wells		
Date	**Days after Startup**	**CDM-02**	**DERM-05**	**DERM-06**
8-29-88	0	6.70	100.00	19.00
9-28-88	30	13.00	94.00	7.50
10-28-88	60	12.00	8.70	5.00
11-27-88	90	19.00	14.00	3.60
12-27-88	120	6.00	5.00	11.00
1-26-89	150	BCG	27.00	8.70
2-25-89	180	BCG	18.00	6.20
3-27-89	210	1.10	BCG	BCG
4-26-89	240	BCG	15.00	29.00
5-26-89	270	BCG	27.00	12.00
6-25-89	300	BCG	44.00	29.00
7-25-89	330	BCG	28.00	28.00
9-26-89	393	BCG	NS	NS
2-28-90	548	BCG	32.00	25.00
6-20-90	660	5.80	BCG	BCG
7-26-90	696	6.40	6.10	5.70
10-17-90	779	1.40	8.30	7.80

Vinyl chloride contaminant goal reduction level = 1 ppb.
BCG = Below cleanup goals.
NS = Not sampled.

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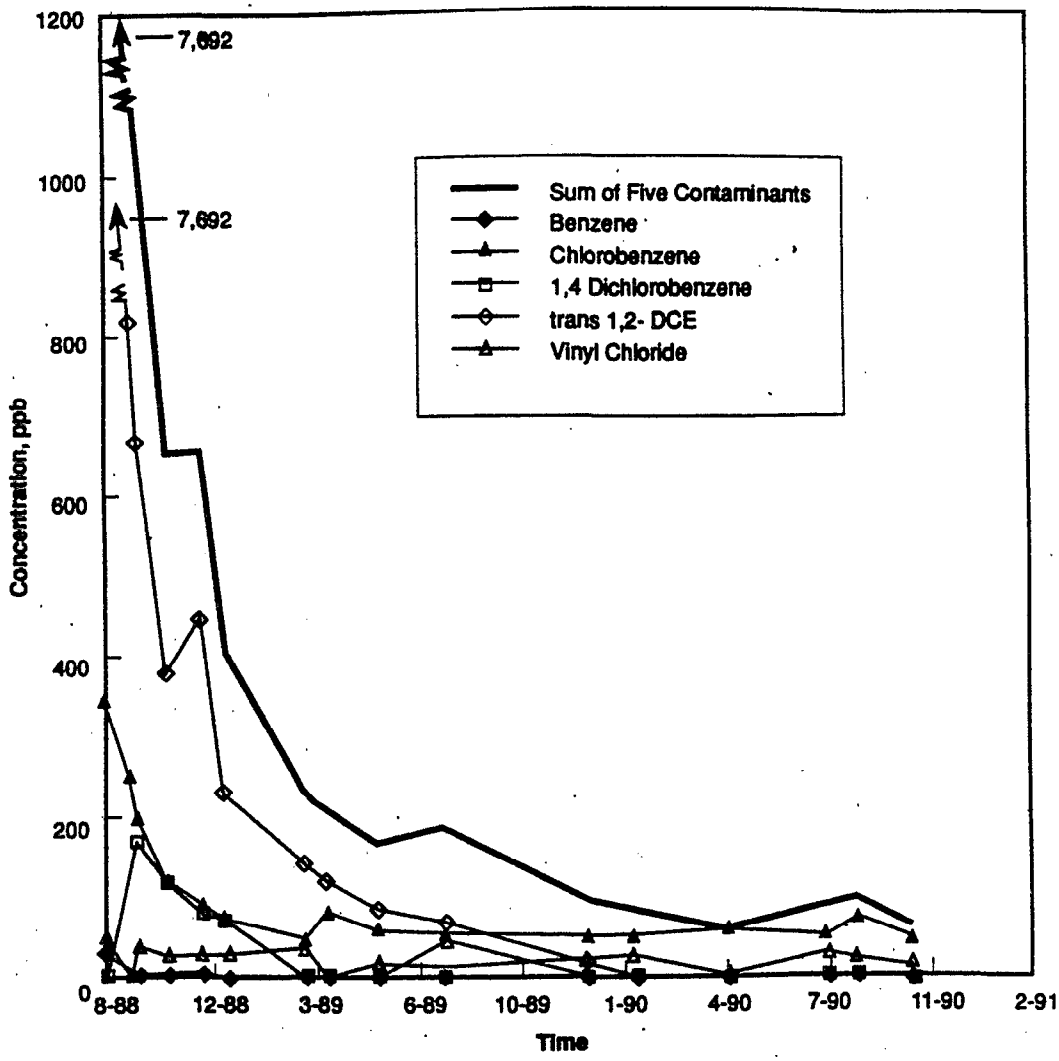

Source: Private Contractor, 1990e

Figure 3
TEMPORARY AIR STRIPPER INFLUENT CONTAMINANT CONCENTRATIONS AT SITE A FROM AUGUST 1988 TO OCTOBER 17, 1990

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Table 2 TEMPORARY AIR STRIPPER DATA				
	3-90	**4-90**	**7-90**	**10-90**
Water Treated (Cum. Gallons)	25,872,800	27,062,500	32,319,979	36,860,670
Treatment Rate (gpm)	37.5	38.1	38.5	37.7
Well Discharge Pressure (psig)	43	43	36	44
Blower Discharge Static Pressure (in. of water)	3.5	3.9	6.9	5.6
Source: Private Contractor, October 1990e				

August 29, 1988, the date of start-up. However, in more recent tables of contaminant concentrations at the air stripper, total VOCs were indicated to be the sum of only 5 VOCs, and total VOCs concentration at start-up was reported at just 7,692 ppb. No explanation has been given for this change in the reported startup concentration. However, examination of the early monitoring records shows that the total VOC concentrations were typically more than three times higher than the sum of the concentrations for the five VOC compounds listed individually. This seems to indicate that other unidentified compounds were present. In the more recent reports, the total VOC concentrations listed are simply the sum of the five compounds of concern.

As of October 1990, the concentrations of all contaminants except benzene and vinyl chloride had fallen below cleanup goals in the stripper influent. The October benzene and vinyl chloride concentrations were 2 ppb and 13 ppb, respectively.

SUMMARY OF REMEDIATION

As of October 1990, the extraction system had been in operation for approximately 800 days, and reduction of vinyl chloride concentrations to the cleanup goal had not been achieved. For other site contaminants, the process of decreasing concentrations to acceptable levels has taken as much as 9 months since system startup. The extraction system designers had expected to remediate the site in 60 days using a model-based pumping rate of 30 gpm. After startup, the pumping rate was increased to 50 gpm because the model had shown that cleanup goals could be achieved faster with higher pumping rates.

Ground-water restoration goals were not achieved in the projected 60-day period. However, after more than 2 years of extraction, the concentrations of four of the five contaminants of concern have apparently been reduced to meet cleanup goals in the five monitoring wells being sampled. Vinyl chloride was still above the cleanup goal in three of the wells.

SUMMARY OF NAPL-RELATED ISSUES

After further field investigations in the spring of 1991, the U.S. EPA has not confirmed the presence of a DNAPL phase at the site. Recent soil borings have identified on-site seepage pits as a possible source of contamination (U.S. EPA Staff, May 10, 1991b).

During earlier site investigations, the presence of compounds such as TCE and trans-1,2-DCE indicated the potential for DNAPLs. However, the groundwater concentrations of these compounds have been reduced to health-based standards during 1989 and 1990.

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The EPA, however, speculates that these reductions may be caused by dilution of contaminated water with uncontaminated water, and that decreases in contaminant levels do not indicate that future remedial actions should not include an assessment of DNAPLs (U.S. EPA Staff, May 10, 1991b). The EPA has begun preliminary fieldwork at Site A that will culminate in a remedial investigation/feasibility study characterizing the type and extent of contamination in the source area, including possible remedial actions that address DNAPLs. No data from the study has been released as of May 1991.

UPDATE BIBLIOGRAPHY/ REFERENCES

County Environmental Agency Staff. November 1990. Personal communication.

Private Contractor. September 1987. *Provisional Remedial Action Plan, Site A.*

Private Contractor. March 26, 1990a. *Site A Temporary Air Stripper Monthly Status Report.*

Private Contractor. April 16, 1990b. *Site A Temporary Air Stripper Monthly Status Report.*

Private Contractor. April 27, 1990c. *Site A Temporary Air Stripper Monthly Status Report.*

Private Contractor. August 16 1990d. *Site A Temporary Air Stripper Monthly Status Report.*

Private Contractor. October 31, 1990e. *Site A Temporary Air Stripper Monthly Status Report.*

U.S. Environmental Protection Agency (U.S. EPA). October 1989. *Evaluation of Groundwater Extraction Remedies: Volume 2, Case Studies 1-19.* Document Number EPA/9355.4-03.

U.S. EPA Staff (Region IV). February 19, 1991a. Personal communication.

U.S. EPA Staff (Region IV). May 10, 1991b. Personal communication.

1.The true identification of Site A will remain confidential because of continuing controversy regarding site-management responsibility and its inclusion on the National Priorities List (NPL).

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UPDATE OF CASE STUDY 17

Utah Power & Light
Idaho Falls, Idaho

Abstract

Since the original case study, pumping and treatment of ground water at the site has continued. Concentration of PAHs in the influent to the treatment system has decreased substantially since remediation began. However, because of the presence of free phase creosote, it is unlikely that the aquifer will be restored to health-based levels in the foreseeable future using the current extraction system.

Table of Background Data	
Date of Problem Identification	1983
Extraction Started	October 1985
Types of Contaminants	Creosote
Primary Aquifer Materials	Alluvium and fractured basalt
Maximum Number of Extraction Wells	17
Maximum Total Extraction Rate	200 gpm
Estimated Plume Area	8-10 acres
Estimated Plume Thickness	175 feet
Maximum Reported Concentrations	Mean maximum concentrations Pyrene 1,776 ppb Naphthalene 8,600 ppb Phenanthrene 4,522 ppb

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CASE STUDY UPDATE
UTAH POWER & LIGHT POLE TREATMENT YARD

BACKGROUND OF THE PROBLEM

INTRODUCTION

This report describes progress in ground-water remediation at the Utah Power & Light (UP&L) site from March 1989 to March 1990. It is an update of the original case study of site remediation, which was based on information through March 1989 (U.S. EPA, 1989, Case Study 17).

The UP&L pole treatment yard is located in Idaho Falls, Idaho, near the east bank of the Snake River (see Figure 1). The facility was used to treat wooden poles with creosote from the early 1920s through mid-1983. As a result of creosote leaks from underground piping, the soil and bedrock underlying the facility have become contaminated. The site is administered by the Idaho Department of Health and Welfare, Hazardous Materials Bureau, now that Idaho has become an RCRA-authorized state.

The contamination was first detected in July 1983 when a creosote leak was found in the underground piping between the treatment and storage vats at the facility. In response to this discovery, soil and rock were excavated from a large pit down to the surface of the basalt bedrock to a depth of approximately 25 feet. However, borings into the bedrock showed that the bedrock was contaminated with free-phase creosote below the bottom of the pit. The pit was backfilled with compacted clay and clean gravel in 1984 and 1985, and was later classified as an RCRA hazardous waste management facility (HWMF). Additional soil and rock borings were drilled and 15 ground-water monitoring wells were installed in 1984 and 1985 to further assess the lateral and vertical extent of the site contamination.

A preliminary pilot-scale ground-water extraction and treatment system was operated at the site from October 1985 through April 1986. More than expected free-phase creosote was produced from pumping the monitoring and recovery wells during this first pilot test. As a result, starting in February 1987, a second pilot test was conducted that used an improved treatment system and wells specifically designed for extraction. Since then, the ground-water extraction and treatment system has been operated continuously.

The site is near the eastern edge of the Snake River Plain in a geologic region characterized by basalt lava flows. The surface soils consist of 3 to 5 feet of loess underlain by 20 to 30 feet of sand and gravel. These deposits are underlain by a series of basalt lava flows separated by interflow deposits of clay, gravel, and cinders. The thickness of these basalt flows is known to exceed 1,600 feet near the site; however, borings extend to a maximum depth of only 400 feet at the site itself. The basalt flows at the site are referred to as Basalt A through Basalt E in the site documentation.

The three aquifer zones at the site occur within interflow zones and within fractures in the basalt. The uppermost aquifer zone at the site is Aquifer No. 1, which occurs between depths of approximately 110 to 160 feet below land surface, and is most permeable between the water table and 160 feet. The transmissivity of Aquifer No. 1 has been measured at between 1,100 and 950,000 gallons per day per foot (gpd/ft). The hydraulic properties of the aquifer are highly direction-dependent and spatially non-uniform. Aquifer No. 1 is unconfined.

Aquifer No. 2 is a confined aquifer that occurs within the weathered basalt and interflow zone near the bottom of Basalt B and the top of Basalt C, between approximately 240 and 260 feet below land surface. The transmissivity of Aquifer No. 2 has been measured at between 20,400 and 30,400 gpd/ft. Hydraulic properties are spatially and directionally more uniform in Aquifer No. 2 than in Aquifer No. 1. Aquifer No. 3 is within interflow and fracture zones occurring at depths of 360 to 400 feet. The original case study reported that Aquifer No. 3 was expected to be highly transmissive, based on specific capacity results.

The water table is over 100 feet below land surface. The water table elevation fluctuates seasonally with an amplitude of approximately

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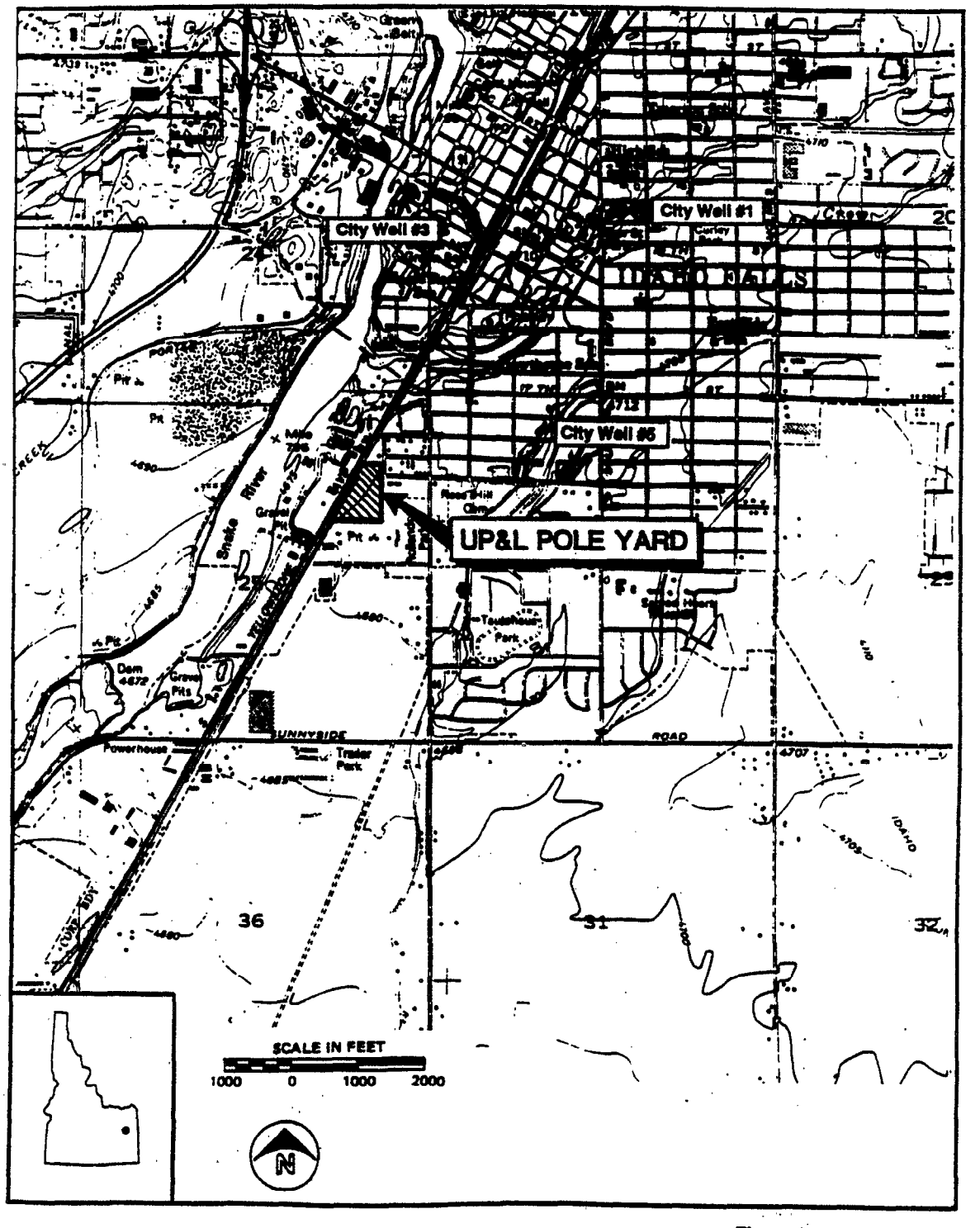

Source: CH2M HILL, 1987

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Figure 1
SITE LOCATION
UTAH POWER & LIGHT SITE
IDAHO FALLS, IDAHO

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25 feet. The hydraulic head in Aquifer No. 1 is approximately 2 to 3 feet greater than the head in Aquifer No. 2, which, in turn, is approximately 2 feet greater than the head in Aquifer No. 3. The average downward seepage velocity between Aquifer Nos. 1 and 2 has been estimated at approximately 20 feet per year, based on an effective porosity of 0.1. Within Aquifer Nos. 1 and 2, horizontal flow is generally towards the southwest.

Creosote is the contaminant of concern at the UP&L site. Creosote is a distillate of coal tar that has been shown to contain up to 400 individual compounds, most of which are classified as polycyclic aromatic hydrocarbons (PAHs). The viscosity of creosote is 50 to 70 times greater than water. Most of its individual components have a low solubility in water and a low mobility in solution.

The contamination at the site is in the form of both dissolved constituents and free-phase creosote. Creosote was found in several borings through the bedrock at the base of the pit excavated in 1983. No creosote was found in the surficial gravel overlying the bedrock. In general, creosote contamination has been observed in wells south and southwest of the former excavated pit. Monitoring Wells MW-7, MW-8, and MW-13, and recovery Wells R-4, R-5, and R-6 were considered to be within the plume of contaminated ground water in Aquifer No. 1 in 1986. Monitoring Well MW-9 and recovery Well R-7 were near or within the contaminant plume in Aquifer No. 2 in 1986. No contamination was found within Aquifer No. 3 in 1986.

UPDATE ON SITE CHARACTERISTICS

The information on the history, geology, waste characteristics, and administration of the site presented in the original case study remains current. More specific estimates of the transmissivity of Aquifer No. 3 are now available. These estimates range from 1,500,000 to 11,200,000 gpd/ft based on aquifer pump tests and an assumed aquifer thickness of 300 feet (Dames & Moore, 1988). More complete information on site characteristics can be found in the original case study.

REMEDIATION

Design and Operational Features of the Remediation System

The main objective of the UP&L remediation system is to contain the contaminated ground water vertically and horizontally using a system of extraction wells. The system of monitoring and recovery wells in place in March 1989 is shown in Figure 2. A secondary objective is to remove free-phase creosote where practical. The extraction system was designed on the basis of numerical modeling results and onsite performance experience, and consists of 11 extraction wells in Aquifer No. 1, and 6 extraction wells in Aquifer No. 2. Each of the monitoring and recovery wells in the extraction system has been operated during select periods since late 1985. The selection of pumping wells and the total rate of extraction is constrained by limitations in the productivity of Aquifer No. 1, and the desire to limit the downward gradient induced by pumping in Aquifer No. 2.

The record of recovery well operation from late 1985 through March 1990 is shown in Figure 3. Figure 3 shows that 7 recovery wells in Aquifer Nos. 1 and 6 recovery wells in Aquifer No. 2 have operated intermittently since March 1989. One change in the extraction system is in the operation of recovery well RW-11, which was installed before March 1989, but did not operate until July 1989. No other system changes were reported since the original case study. The extraction system is currently in operation; however, no specific operational data were available for March 1990 through June 1991.

Figure 4 shows the combined average monthly pumping rate of the extraction system from January 1988 through March 1990. Since March 1989, the system has been pumped at an average rate of approximately 139 gpm or 200,000 gallons per day. The operational mix of individual wells that made up the total pumping rate of 139 gpm was quite variable during that period, as shown in Figure 3. The selection of individual pumping rates was based on initial computer modeling results and the constraints mentioned above.

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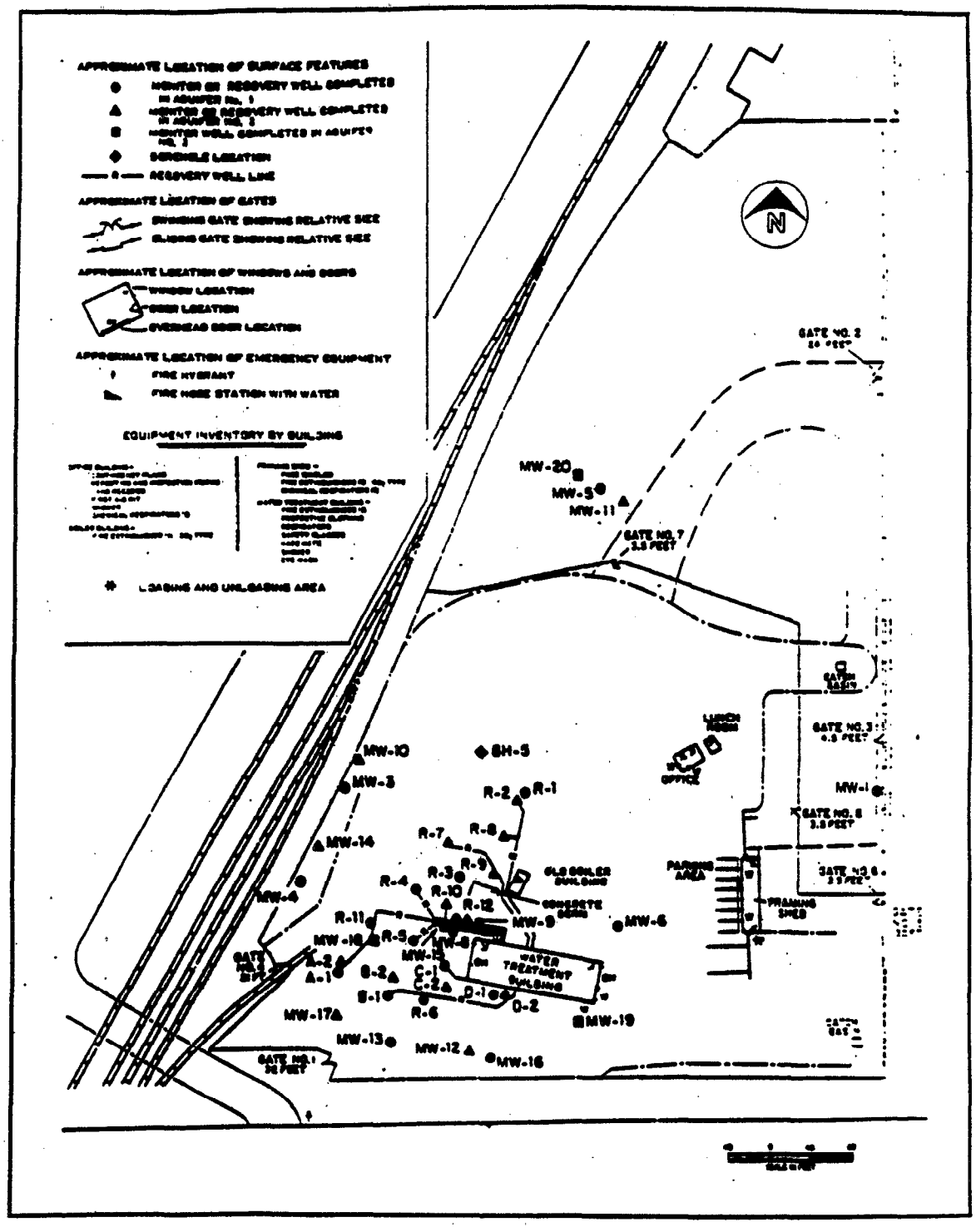

Source: Dames & Moore, 1989a

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Figure 2
EXTRACTION AND MONITORING WELL SYSTEM, MARCH 1989
UTAH POWER & LIGHT SITE

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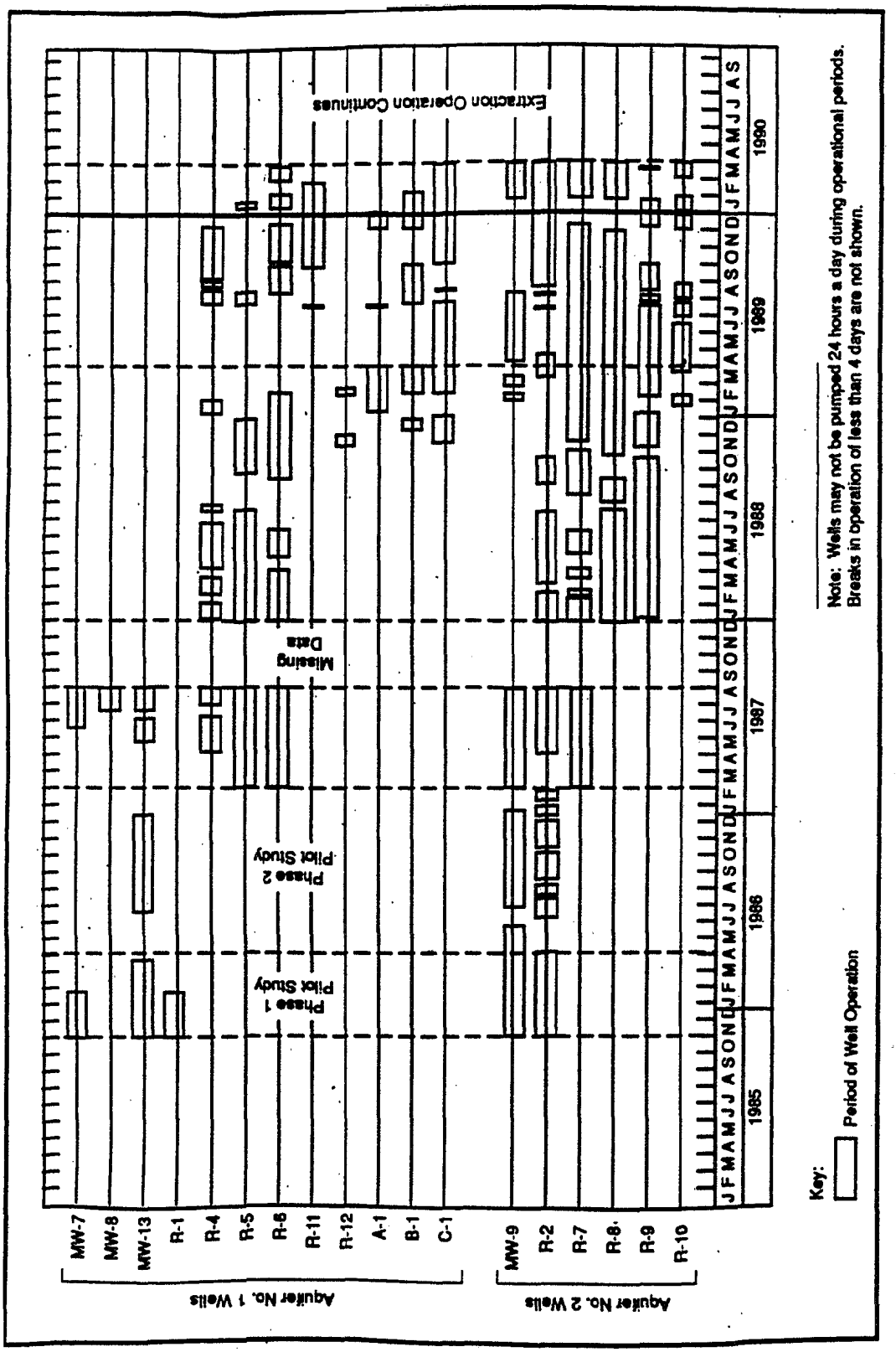

Figure 3
RECORD OF RECOVERY WELL OPERATION
NOVEMBER 1985 THROUGH MARCH 1990
UTAH POWER & LIGHT SITE

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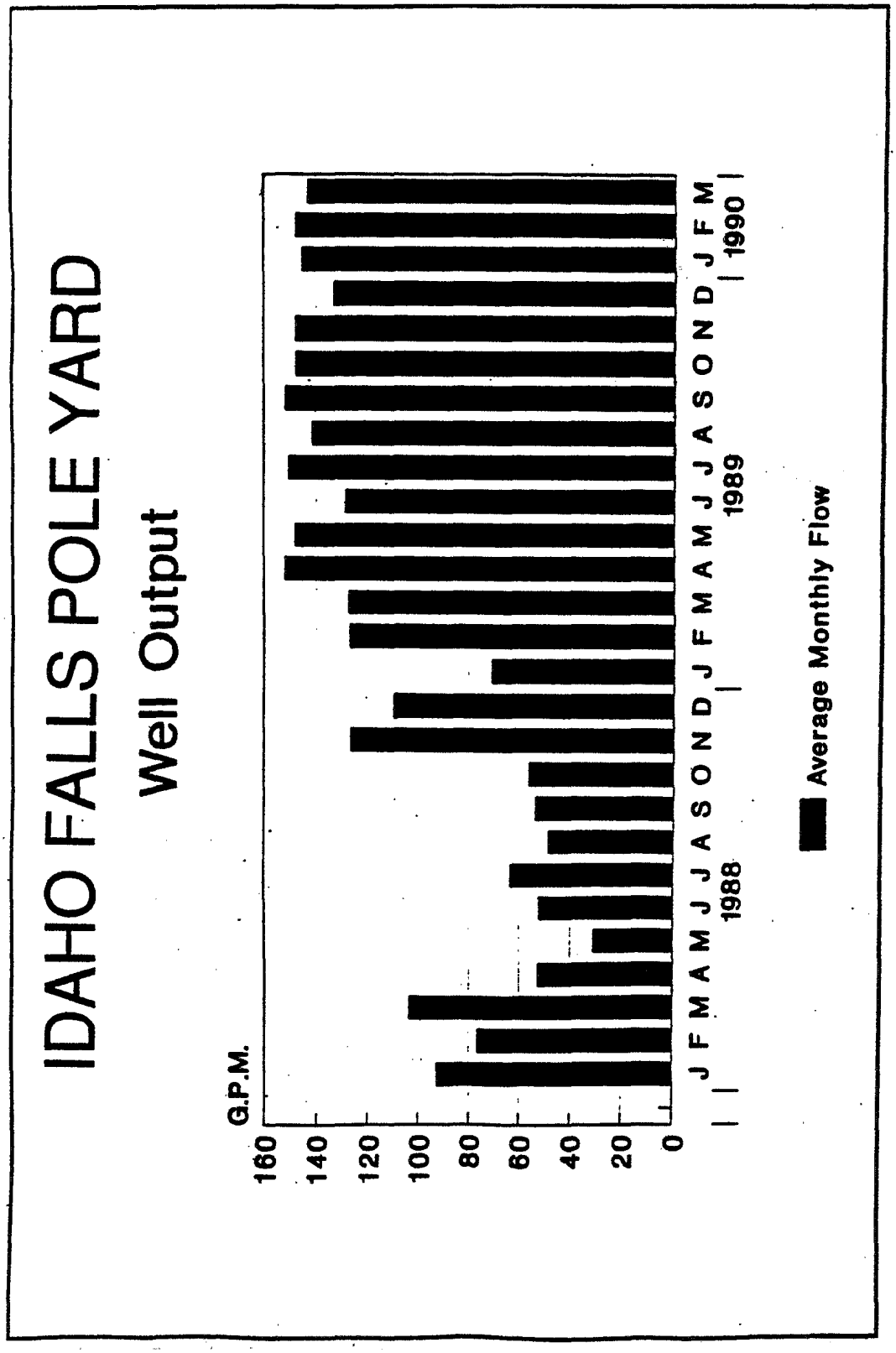

Figure 4
COMBINED AVERAGE MONTHLY PUMPING
RATE OF EXTRACTION SYSTEM
JANUARY 1988 TO MARCH 1990
UTAH POWER AND LIGHT SITE

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EVALUATION OF PERFORMANCE

Since system startup in late 1985, the zones of hydraulic capture within Aquifer No. 1 and Aquifer No. 2 have varied because of changes in the pumping rate and well locations. Figure 5 shows the potentiometric surface in Aquifer No. 1 on May 22, 1990. This figure shows a change in the overall pattern of horizontal flow from that in the original case study (not shown), but the limits of the zone of capture do not appear to differ substantially. The system did appear to capture ground water on the southern boundary of the site near MW-16 more effectively in May 1990 than in January 1989. Data on the distribution of contamination in May 1990 were not available for comparison to the zone of capture. Only four wells in Aquifer No. 1 were sampled in the first quarter of 1990 (C-1, R-5, R-6, and R-11). All were within the zone of capture. Only R-5 and R-11 were found to be contaminated.

Figure 6 shows the potentiometric surface in Aquifer No. 2 on May 22, 1990. This figure does not show a substantial change in the limits of the zone of capture created by the extraction well network from that in the original case study (not shown). Water level data in Figure 6 suggest some increase in the rate of ground-water flow to the extraction wells, but the increase may be due to variations in the graphical contouring of the data. All the wells found to be contaminated in the first quarter of 1990 were within the zone of capture in Aquifer No. 2. However, the available concentration data are from wells close to the HWMF, so the extent to which the extraction system captures all the contaminated ground water cannot be estimated.

Figure 7 shows the time series concentration of total PAHs in the influent to the treatment system from February 1988 through March 1990. This figure shows that influent concentrations have decreased substantially since early 1989. Concentration peaks, believed to be the result of extracting slugs of free-product creosote, have been less than 300 ppb since early 1989, in contrast with peaks of greater than 50,000 ppb in early 1986. The magnitude and variability of the concentrations of total PAHs have decreased substantially since the start of remediation in late 1985. The magnitude and variability of the concentrations of total phenols (not shown) have also been reduced.

SUMMARY OF REMEDIATION

As stated in the original case study, it is difficult to evaluate the effectiveness of the remediation system because of the complex fractured rock aquifer system and the presence of free-product creosote. In fractured rock aquifers, aquifer properties such as hydraulic conductivity tend to be anisotropic, making flow difficult to analyze. The full extent of the plume is also difficult to assess because of the limited number of offsite monitoring wells. Piezometric surface maps of Aquifer Nos. 1 and 2 suggest that dissolved contaminants from the areas of known ground-water contamination were being captured by the extraction network in Aquifer Nos. 1 and 2 in mid-1990. However, hydraulic gradients may not influence the movement of dense free-product creosote. Pumping operations aimed at minimizing downward flow gradients have not been entirely successful. Creosote may tend to migrate downward through bedrock fractures because of its high density, even if hydraulic gradients favor upward flow.

Since remediation began in 1985, the concentration of total PAHs in the influent to the treatment system has decreased substantially. There are still strong concentration peaks of total PAHs, believed to be caused by slugs of free-product creosote being drawn into the extraction system, but the magnitude of these peaks has decreased substantially since remediation began. The remediation system is clearly removing both dissolved constituents and free-product creosote from the subsurface. However, because of the presence of creosote, it appears unlikely that the aquifer can be restored to health-based levels with the current system. Because of the density of creosote, it may also be difficult to achieve vertical containment of the contamination.

SUMMARY OF NAPL-RELATED ISSUES

The presence of dense nonaqueous phase liquid (DNAPL) creosote at the UP&L site has been proven by direct observation. During the drilling, drilling rods smeared with creosote were pulled from several boreholes. Slugs of creosote have also been observed in wells. The total mass of

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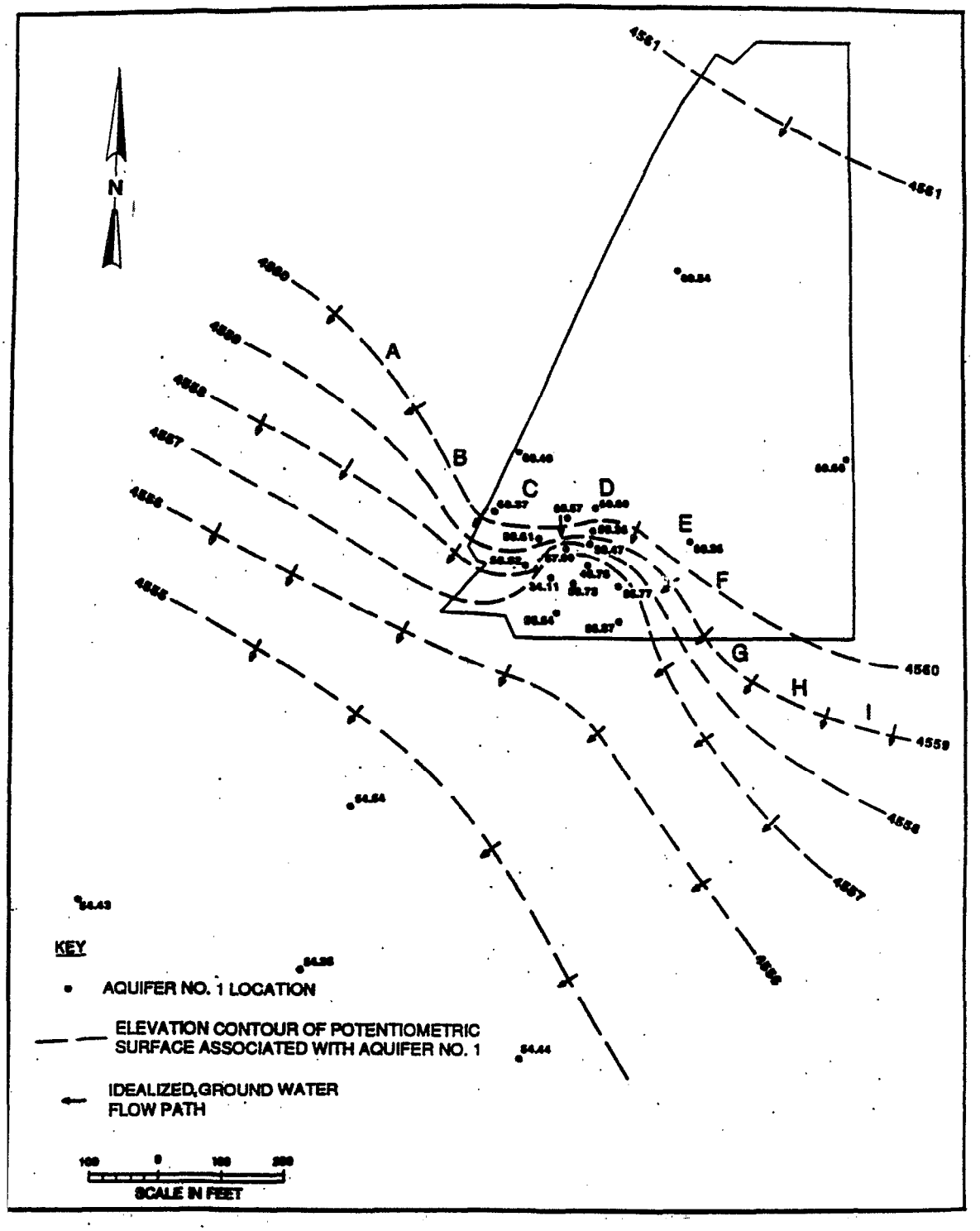

Source: Dames & Moore, 1990

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Figure 5
POTENTIOMETRIC SURFACE IN AQUIFER NO. 1 ON MAY 22, 1990
UTAH POWER & LIGHT SITE

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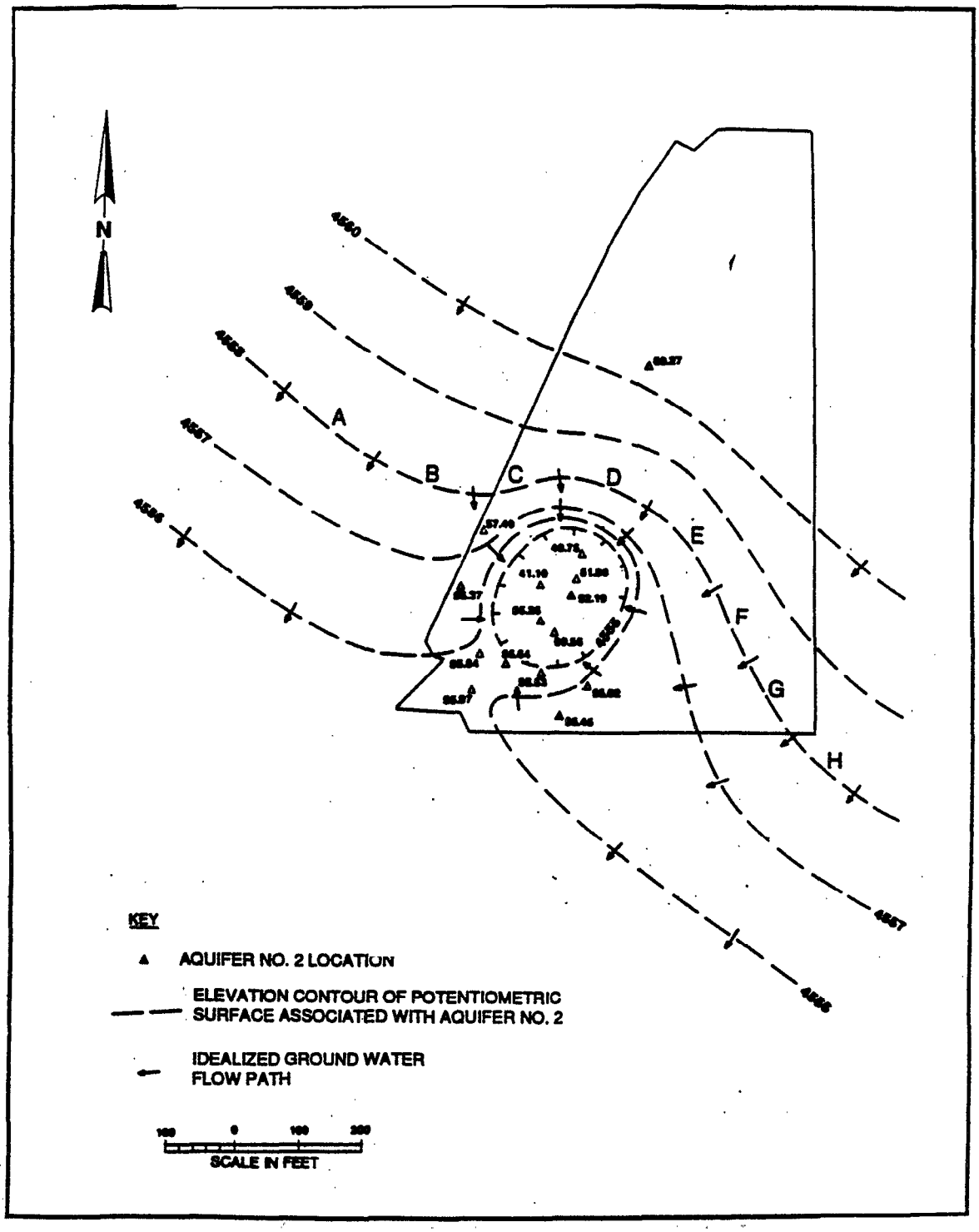

Source: Dames & Moore, 1990

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Figure 6
POTENTIOMETRIC SURFACE IN AQUIFER NO. 2 ON MAY 22, 1990
UTAH POWER & LIGHT SITE

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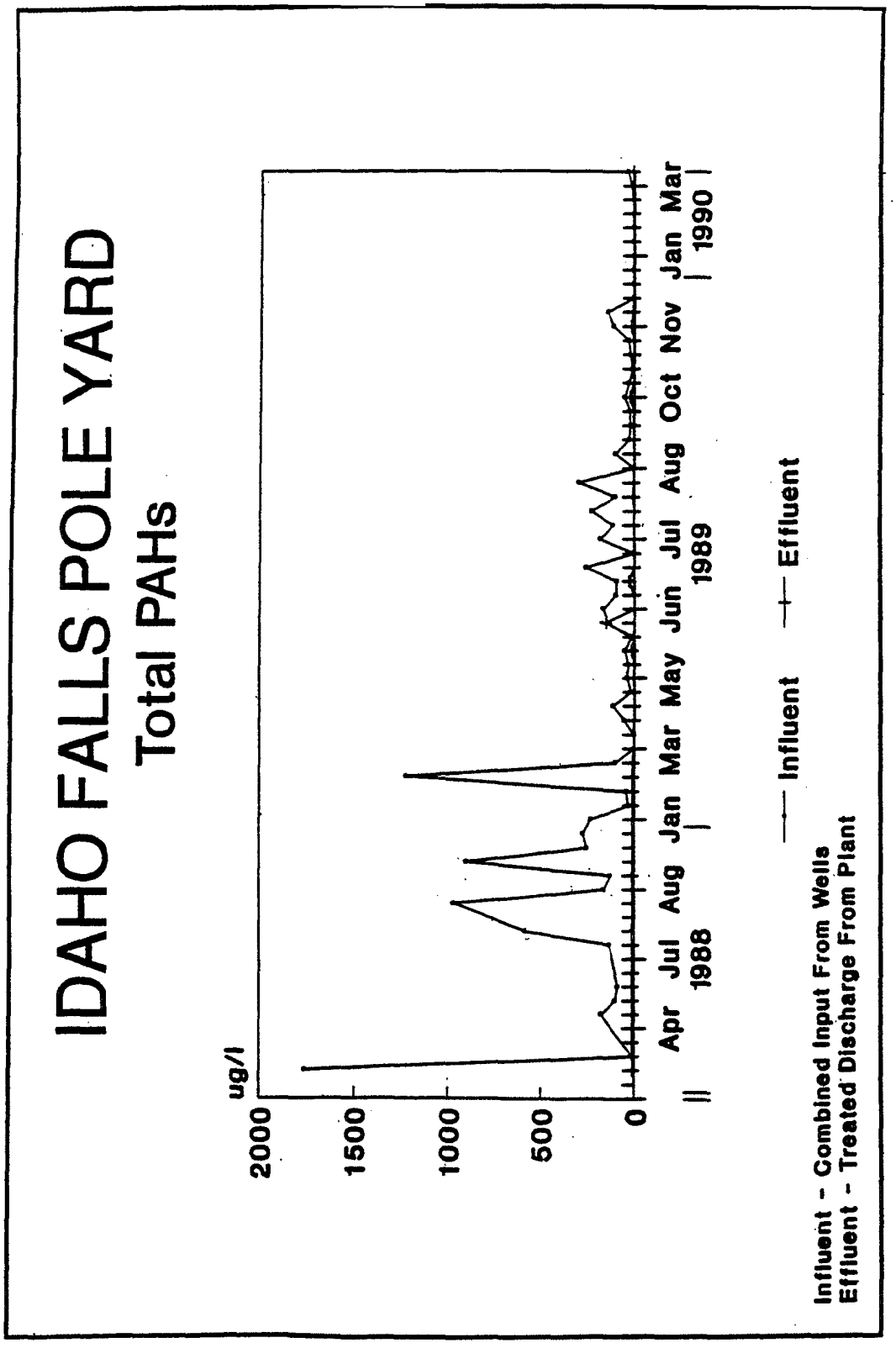

Figure 7
CONCENTRATIN OF TOTAL PAHs IN THE INFLUENT TO THE TREATMENT SYSTEM FROM FEBRUARY 1988 TO MARCH 1990
UTAH POWER & LIGHT SITE

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creosote that was released to the subsurface through the leak in the underground pipe and from other sources is not known. Some residual contamination was removed during excavation of the soils overlying the bedrock, but it is possible that a substantial portion of the total mass of creosote is still present in the vadose zone and the fractured rock. Because creosote is slightly denser than water (its specific gravity is 1.05 to 1.09), it is expected to sink into the subsurface. Because capillary forces are reduced in fractures, where the surface area to volume ratio is low, DNAPLs tend not to adsorb onto fracture surfaces. Therefore, most of the total mass of creosote probably would not be left as a residual on the fracture surfaces through which the creosote has migrated. This lack of a loss of mass as the creosote migrates would favor more distant migration. The high viscosity of creosote would impede its migration, but it would also make extraction of free-product creosote more difficult. The physical properties of creosote and the complexity of the fractured subsurface both suggest that the final remediation of the site to health-based standards may not be achievable in the foreseeable future using the current remediation system.

UPDATE BIBLIOGRAPHY/ REFERENCES

CH2M HILL. October 1987. *Groundwater Treatment Phase 2 Interim Report, UP&L Pole Treatment Yard, Idaho Falls, Idaho.*

Dames & Moore. January 1988. *Installation of Aquifer No. 3 Monitoring Wells, Pole Treatment Yard, Idaho Falls, Idaho, for Utah Power & Light Company.*

Dames & Moore. March 7, 1989. Report of Quarterly Ground Water Flow Rate and Direction Calculations for Aquifer No. 3. Pole Treatment Yard, Idaho Falls, Idaho. Letter from George Condrat to L. E. Newland of Utah Power & Light.

Dames & Moore. May 1989a. *Utah Power & Light/Pacific Power & Light, Idaho Falls Pole Yard, RCRA Post-closure Semi-annual Report for October 1988 through March* 1989.

Dames & Moore. November 1989b. *Utah Power & Light/Pacific Power & Light Idaho Falls Pole Yard, RCRA Post-closure Semi-annual Report for April through September* 1989.

Dames & Moore. June 1990. *Utah Power & Light/Pacific Power & Light Idaho Falls Pole Yard, RCRA Post-closure Semi-annual Report for October 1989 through March 1990.*

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UPDATE OF CASE STUDY 18

Verona Well Field
Battle Creek, Michigan

Abstract

Ground-water remediation systems are operating in two separate parts of the Verona Well Field project area. The barrier well system continues to control plume migration into the well field. Since its implementation, high concentration regions have been reduce laterally, but contamination remains high along the plume's centerline. The second system, a combination of ground-water extraction and soil vapor extraction, has continued to remediate VOC contamination at the TSRR facility. Ground-water contaminant levels remain above clean-up goals at the facility. Remediation of the two remaining source areas, the Thomas Solvent Annex and the GTWRR Paint Shop area, has not begun, although a remedial investigation and a feasibility study for those areas have been completed.

Table of Background Data	
Date of Problem Identification	1981
Extraction Started	May 1984
Types of Contaminants	VOCs
Primary Aquifer Materials	Glacial sand and gravel over fractured sandstone
Maximum Number of Extraction Wells	(TSRR) 9 (Blocking Wells) 6
Maximum Total Extraction Rate	(TSRR) 400 gpm (Blocking Wells) 2,000 gpm
Estimated Plume Area	125 acres
Estimated Plume Thickness	120 feet
Maximum Reported Concentrations	Total VOCs 85,960 ppb

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CASE STUDY UPDATE
VERONA WELL FIELD

BACKGROUND OF THE PROBLEM

INTRODUCTION

The original case study for the Verona Well Field Superfund site presented background information and described the remedial progress made through mid-1988 (U.S. EPA, 1989, Case Study 18). This update discusses more recent developments at the site and the progress that has been made through early 1991.

Verona Well Field is located on both sides of the Battle Creek River, approximately 3.5 miles northeast of downtown Battle Creek, Michigan. The location of the well field with respect to the river and the contaminant source areas, is shown in Figure 1. In 1981, routine sampling of the municipal water supply led to the discovery that the well field was contaminated with volatile organic compounds (VOCs), principally chlorinated solvents. Further investigation showed that the primary sources of the contamination were the Thomas Solvent Company's Raymond Road (TSRR) facility, the Thomas Solvent Annex on Emmett Street, and the Grand Trunk Western Railroad (GTWRR) marshalling yard (see Figure 1).

Verona Well Field was listed by the EPA as a Superfund site in 1982. In May 1984, the EPA issued a record of decision (ROD) specifying an Interim Remedial Measure (IRM) for the well field. The IRM consisted of the installation of three new wells in the uncontaminated northern portion of the well field and the conversion of several existing wells into a blocking system that would halt the spread of the contaminant plume. The IRM was implemented in 1984.

In 1985, a second ROD was signed for remediation of the most heavily contaminated of the three source areas, the Thomas Solvent Raymond Road (TSRR) facility. The TSRR remediation system included ground-water extraction wells and a soil vapor extraction system. The ground-water extraction system began operating in March 1987. A pilot vapor extraction system was also installed in 1987, and testing began in November of that year. Construction of the final system was initiated in January 1988. Full-scale operation of the system began in March 1988.

The geologic units of concern at the site are the unconsolidated glacial till deposits and the underlying sandstone of the Marshall Formation. The thickness of the glacial deposits range from a few feet to 100 feet. Near the TSRR facility, the thickness is approximately 45 feet. The glacial deposits consist primarily of stratified and inter-layered sand and gravel, with clay or clay-rich glacial till layers occurring locally. The underlying Marshall Formation consists of very fine to medium sandstone with layers of shaley sandstone. In the area of the well field, it is approximately 150 feet thick. Both vertical and horizontal fractures are frequent in the upper 60 to 80 feet as well as from 100 to 135 feet in the sandstone. In its lower reaches, it is interbedded with siltstone, shale, and limestone. The sandstone is underlain by a shale layer that appears to be an effective aquiclude.

Both the sandstone and the glacial deposits function as aquifers, and in most areas there appears to be little or no hydraulic separation between the two zones. The water table in the vicinity of the TSRR facility is 16 to 25 feet below ground surface. The natural flow of ground water is toward the Battle Creek River. Superimposed on the natural hydraulic gradients are those imposed by pumping in the well field. At the TSRR facility, the effects of the well field reinforce the natural gradients, which produce ground-water flow to the north-northwest.

Ground-water quality investigations conducted since the discovery of contamination at Verona Well Field have identified two plumes of VOCs approaching the well field from the south and southeast. The southern plume originates from the TSRR facility and the Thomas Solvent Annex. The smaller and more easterly plume comes primarily from the paint shop in the Railroad Car Department next to the GTWRR marshalling yard.

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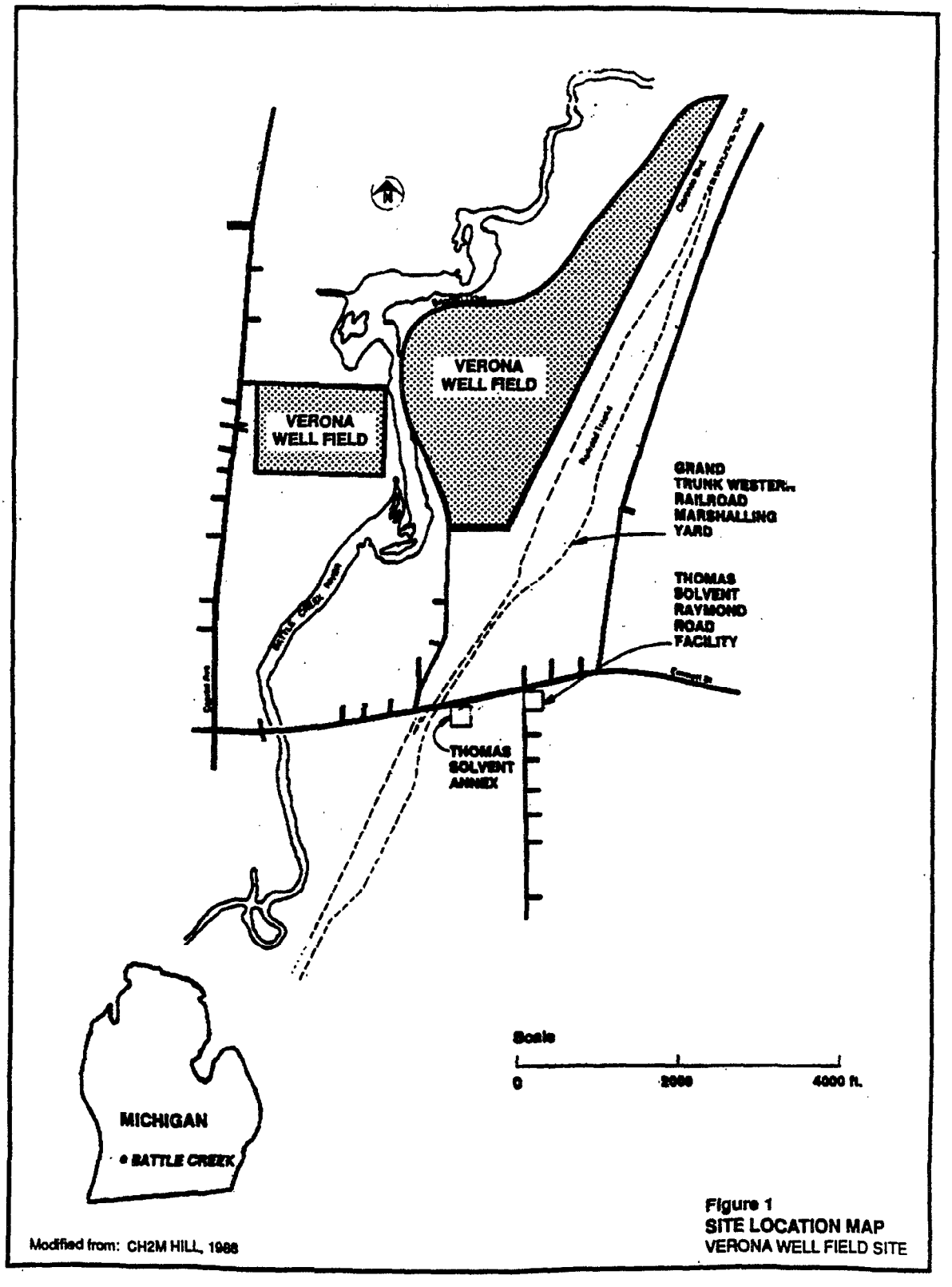

Modified from: CH2M HILL, 1988

Figure 1
SITE LOCATION MAP
VERONA WELL FIELD SITE

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The contaminants that have been regularly detected in groundwater sampling at the well field are:

- Tetrachloroethylene (PCE)
- Trichloroethylene (TCE)
- 1,2-Dichloroethylene (1,2-DCE) (cis and trans)
- 1,1-Dichloroethylene (1,1-DCE)
- 1,1,1-Trichloroethane (1,1,1-TCA)
- 1,2-Dichloroethane (1,2-DCA)
- 1,1-Dichloroethane (1,1-DCA)

At the TSRR facility, the contaminants found in the ground water include all of the above plus chloroform, methylene chloride, and the characteristic constituents of petroleum hydrocarbons, toluene, xylene, and ethylbenzene.

UPDATE ON SITE CHARACTERISTICS

The remediation at Verona Well Field continues to be administered by the EPA under the Superfund program. The operation of the blocking wells in the well field continues as specified in the 1984 ROD. At the TSRR facility, the remediation is proceeding as established by the 1985 ROD. In 1990, a remedial investigation was completed for the remaining primary source areas at the Thomas Solvent Annex and the GTWRR Paint Shop (U.S. EPA, 1990). This investigation included data collected from the entire site, but focused on the two remaining source areas. This was followed, in 1991, by a feasibility study of remedial alternatives addressing the two remaining source areas (U.S. EPA, 1991).

New information gathered in the site investigations since mid-1988 has added some detail, but has not significantly altered the description of site hydrogeology given in the original case study.

The site-wide data collected during the remedial investigation in 1989 show that the highest concentrations of VOCs are still found in the three primary source areas. The highest total VOC concentrations detected in ground-water samples from each of the three areas in 1989 were:

- TSRR Facility: Well B18 - 85,960 ppb
- Thomas Solvent Annex: Well B8 - 49,800 ppb
- GTWRR Paint Shop: Well CH106I 64,510 ppb

In each case, these maximum VOC concentrations were found in ground-water samples taken at or near the water table. It was noted that the contaminants are generally found at or near the water table in the source areas and in the middle and lower portions of the aquifer as the plumes approach the well field. High pumping rates in the well field produce strong vertical gradients, which appear to pull the contamination downward through the sandstone aquifer.

Thomas Solvent Annex Source Area: The Thomas Solvent Annex property is owned by the GTWRR, and was leased to Thomas Solvent Company from 1939 to the mid-1980s. The site was used as a railroad siding for shipping the chemicals handled by the company, primarily solvents and fuels. The site facilities included a solvent pumping and transfer station for loading and unloading railroad cars, two underground storage tanks, and one aboveground storage tank. Soil and ground-water contamination at the annex is thought to have arisen from leaking drums and surface spills.

Table 1 lists the maximum concentrations of the primary contaminants found in ground-water samples taken from the Thomas Solvent Annex during the 1989 remedial investigation. The listed concentrations were not all detected in the same well. The PCE concentration of 2,100 ppb is approximately 1 percent of the aqueous solubility of that compound. The concentration of 7,900 ppb listed for ethylbenzene is about 5 percent of solubility. These relatively high concentrations provide some indication that VOCs may be present as nonaqueous phase liquids (NAPLs).

A much stronger indication of NAPLs was obtained from the program of soil sampling conducted during the remedial investigation. Three soil samples were taken from each of 16 borings drilled at the Thomas Solvent Annex. Each of the top two samples taken from every boring was a composite representing average conditions over a 6-foot interval. The third sample was composited over whatever interval remained from a depth of 12 feet down to the water table, which was generally located between 14 and 18 feet below ground. Table 2 provides a summary of the analytical results for the resulting 48 samples. The most prevalent contaminant found above the water table was PCE. The maximum PCE concentration of 42,000,000 ppb was detected in a composite sample taken from

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just above the water table. Because the aqueous solubility of PCE is approximately 150,000 ppb, this high concentration indicates that the sample contained more PCE than could be held in the dissolved and adsorbed phases alone. It is a strong indication that NAPLs were also present.

GTWRR Paint Shop Area: The paint shop and other maintenance shops of the GTWRR Railroad Car Department used solvent chemicals for degreasing and cleaning from the mid-1960s until the 1980s. Until the late 1970s, spent solvents were disposed of on the ground outside the shops or in a pit adjacent to the paint shop (U.S. EPA, 1990).

A summary of the maximum concentrations of the primary VOCs found in ground-water samples taken from the paint shop area in 1989 is given in Table 1. The highest concentration found, both in absolute terms and relative to aqueous solubility, was the 32,000 ppb detected for PCE. This is approximately 21 percent of the solubility limit for that compound.

Ten soil borings were drilled in the paint shop area, with composite samples again being collected over 6-foot intervals. The water table at this site was below the top of the consolidated sandstone unit, so the borings were terminated at the sandstone rather than at the water table. The thickness of the glacial deposits in this area was between 12 and 22 feet, so three samples were obtained from some of the borings and four from others. The total number of samples was 34. The analytical results for the soil samples are listed in Table 3. Again, PCE was detected most frequently and in the highest concentrations.

Thomas Solvent Raymond Road Facility: The Thomas Solvent Company conducted business under various names at the Raymond Road location between 1939 and 1984. The activities at the site over these years included purchasing, storing, blending, and selling virgin industrial solvents. Used solvents were also accepted and stored before being transported offsite for disposal or recycling.

Figure 2 shows the site plan of the TSRR facility in its current configuration. The warehouse and loading dock, shown cross-hatched in the figure were demolished during the installation of the ground-water extraction system.

Also shown in Figure 2 are the locations of 21 underground storage tanks, which were removed from the site in January 1991. In 1984, each of the tanks was tested for leakage. The tank sizes, contents, and leakage test results are listed in Table 4. The tank contents and leakage rates give some indication of the kinds of soil and ground-water contaminants that might be expected, but do not provide an estimate of the total contaminant mass. In addition to leakage from some of the tanks, direct discharge of solvents to the ground during cleaning of tanks and drums has been reported.

The maximum concentrations of the primary contaminants detected in ground-water samples taken from the TSRR facility in 1989 are listed in Table 1. Toluene was the compound found in highest concentration. TCE and PCE concentrations were also quite high.

Table 5 gives a summary of the soil concentrations detected at the TSRR facility in 1989. A total of 75 soil samples were taken from 25 borings. Again, PCE was the most frequently detected contaminant and had the highest mean concentration. A greater variety of compounds was detected in this source area than in the two others. In general, the concentrations in soils were higher than at the GTWRR paint shop, but not as high as at the Thomas Solvent Annex. However, it should be pointed out that both ground-water and soil vapor extraction systems had been operating at the TSRR facility for approximately two years at the time these samples were taken whereas, at the other two source areas, there had not yet been any remediation.

A floating NAPL layer had been observed at the TSRR site. The NAPL was first detected in monitoring Well B-18 in 1984. The thickness of the free product layer in the well was reported to be 2.5 to 3.5 feet. The NAPL was sampled and found to have a specific gravity of 0.93.

The NAPL consisted primarily of petroleum hydrocarbon products and hexanes which contained lesser amounts of trichloroethane, trichloroethylene, and tetrachloroethylene. Analytical results are shown in Table 6 for a NAPL sample taken from Well B-18, and water samples taken from Wells B-18 and B-18I. Well

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Table 1 MAXIMUM 1989 CONCENTRATIONS IN SOURCE AREA GROUND-WATER SAMPLES (Concentrations in ppb)			
Compound	Thomas Solvent Annex	GTWRR Paint Shop	TSSR Facility
1,2-DCE	13,000	17,000	3,700
1,1,1-TCA	12,000	13,000	6,900
TCE	970	280	17,000
PCE	2,100	32,000	17,000
Toluene	4,200	4,900	34,000
Ethylbenzene	7,900	11,000	2,000
Total Xylene	24,000	28,000	660
Note: The maximum concentrations were not all measured in the same monitoring well.			

B-18 is screened at the water table, and B-18I is screened below it at the top of the sandstone. The NAPL layer has not been observed since October 1988 (CH2M HILL, 1991b).

REMEDIATION

Design and Operational Features of the Remediation Systems

The design and operational features of the active remediation systems at the Verona Well Field site have not changed substantially since the original case study. Three remediation systems have been implemented: the barrier system in the well field itself, and the ground-water and soil vapor extraction systems at the TSRR facility.

Barrier Well System: As stated in the original case study, wells of the 20-series, in the south-central portion of the well field, have been designated as blocking wells. The objectives of the blocking system are to intercept the contaminant plume and to protect the water supply wells in the northern part of the well field. Operation of the blocking system started in May 1984 using Wells V-20, V-22, V-25, V-27, and V-28. Since that time, the blocking wells have continued to operate, sometimes with five and sometimes with six wells pumping. As of 1990, six of the 20-series wells (V-22, V-24, V-25, V-26, V-27, V-28) were being used, with a total extraction rate of 1,500 gallons per minute (gpm). The selection of the wells to be pumped and the pumping rates were guided by water level and water quality monitoring in the well field. The water pumped from the blocking wells is combined with the discharge of the TSRR extraction system, which is pumped to the well field through a force main from the TSRR facility. The combined flows are then treated by air stripping and discharged to the Battle Creek River.

TSRR Remediation Systems: As reported in the original case study, the remedial activities at the TSRR facility include both ground-water extraction and soil vapor extraction.

The ground-water extraction system consists of nine extraction wells screened in the glacial deposits on the TSRR site and directly downgradient from it. The locations of the extraction wells are shown in Figure 3. All of the wells, except Well EW-8, are 8 inches in diameter. From startup until October 1988, Well EW-8 had been used as a free product recovery well. The well has a diameter of 24 inches and had been provided with both a standard well pump and a skimmer pump for the floating NAPL. However, after free product had not been observed in the well for several months, the skimmer pump was

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Table 2
SUMMARY OF CHEMCIALS DETECTED IN ANNEX SUBSURFACE SOIL BORINGS

Chemical	Number of Detections	Detection Frequency (%)	Mean Concentration (μg/kg)[a]	SD[a]	95% UCL	Range of Detected Concentrations
Bis(2-ethylhexylphthalate)	2	67	61.5	9.2	71.9	55-68
1,2-Dichloroethane	3	6	191	407	306	260-2,400
1,2-Dichloroethene	7	15	212	427	333	150-2,700
Ethylbenzene	5	10	31,641	216,457	92,880	180-1,500,000
Methylene Chloride	3	6	161	283	241	650-1,400
Tetrachloroethene	47	98	949,393	6,061,021	2,664,000	140-42,000,000
Toluene	14	29	71,160	490,700	210,000	140-3,400,000
1,1,1-Trichloroethane	6	13	37,761	259,769	111,300	210-1,800,000
Trichloroethene	28	58	120,308	679,107	312,400	160-4,600,000
Xylenes (mixed)	7	15	250,250	1,732,014	740,200	380-12,000,000

[a]Calculation using ½ the detection limit for samples where compound was undetected.
SD = Standard deviation.
UCL = Upper confidence limits.

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Table 3
SUMMARY OF CHEMICALS DETECTED IN PAINT SHOP SUBSURFACE SOIL BORINGS

Chemical	Number of Detections	Detection Frequency (%)	Mean Concentration (µg/kg)[a]	SD[a]	95% UCL	Range of Detected Concentrations
Bis(2-ethylhexylphthalate)	2	67	216	232	479	52-380
Bromodichloromethane	2	6	284	774	534	440-630
Tetrachloroethene	28	82	3,376	6,364	5,515	150-35,000
Toluene	6	18	294	767	552	77-430
1,1,1-Trichloroethane	5	15	294	770	553	150-620

[a]Calculation using ½ the detection limit for samples where compound was undetected.
SD = Standard deviation.
UCL = Upper confidence limits.

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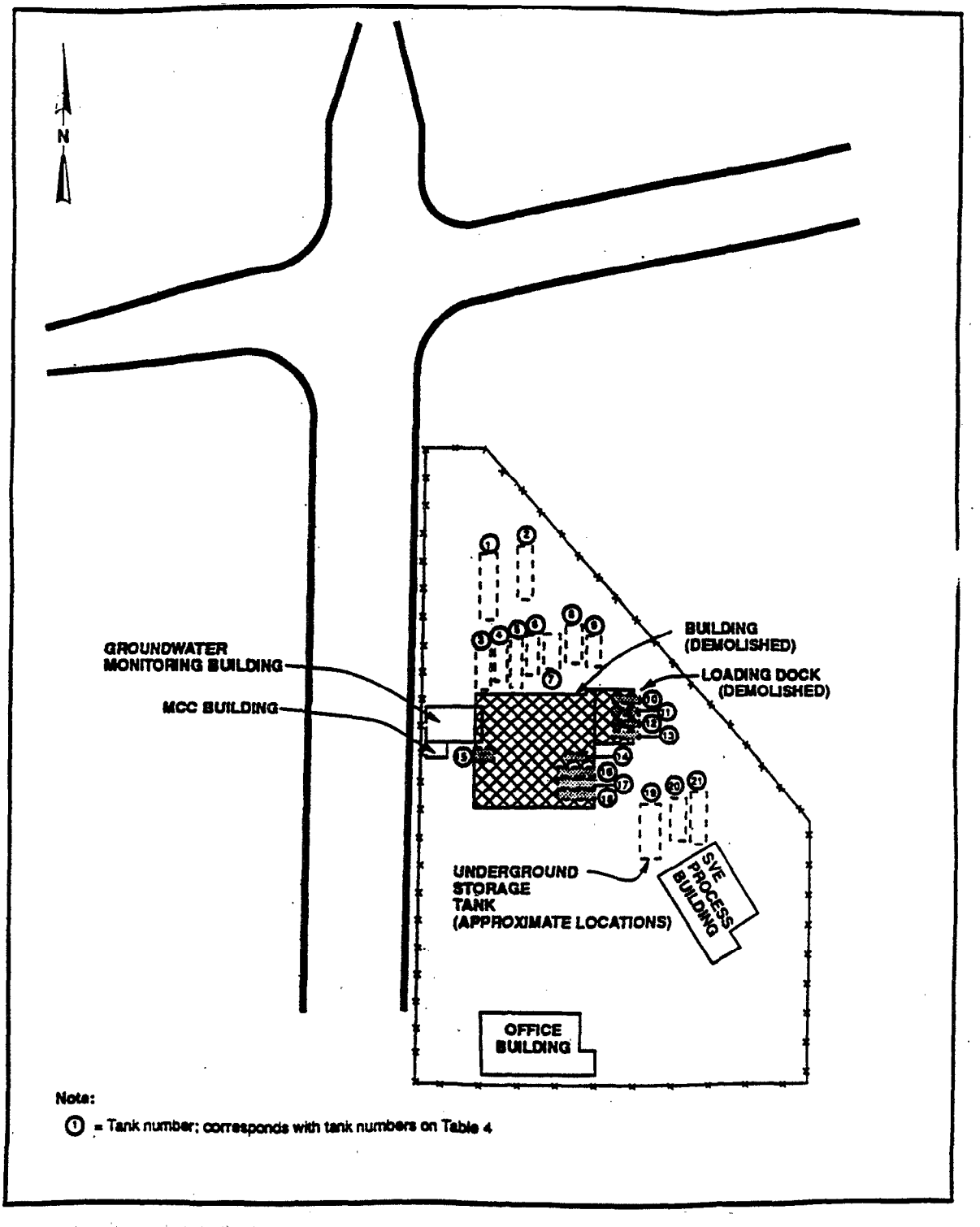

Source: CH2M HILL, 1991a

Figure 2
TSRR SITE PLAN SHOWING BURIED SOLVENT TANKS
VERONA WELL FIELD SITE

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Table 4
UNDERGROUND STORAGE TANKS
THOMAS SOLVENT RAYMOND ROAD SITE

Tank Number[a]	Contents[b]	Tank Volume (gallons)	Leakage Rate[c] (gal/hr)
1	Hi-purity hexane	15,000	0.556
2	99 percent ethyl acetate	6,000	0.179
3	Xylene	8,000	<0.053
4	Acetone	8,000	<0.05
5	Toluene	10,000	0.073
6	Trichloroethylene (TCE)	6,000	0.067
7	Perchloroethylene (PCE)	4,000	<0.05
8	1,1,1-trichloroethane	6,000	0.232
9	TS-100 solvent	4,000	<0.05
10	Methyl ethyl ketone	4,000	<0.05
11	Methanol	4,000	0.069
12	VMP naptha	4,000	<0.05
13	310-66 mineral spirits	4,000	<0.05
14	Ethyl alcohol 903-200	4,000	<0.05
15	140 F solvent	4,000	<0.05
16	Active thinner (Heptane)	6,000	0.066
17	N-propyl acetate	6,000	<0.05
18	#300 mineral spirits (isopropyl alcohol 99%)	6,000	0.086
19	Mineral spirits	15,000	<0.05
20	Diesel fuel	6,000	0.181
21	Reclaimed acetone	12,000	<0.05

[a]Tank number corresponds to tank numbers shown in Figure 2.
[b]Reflects contents at time of testing.
[c]Tank tests by Horner Creative Metals, Inc., for Thomas Solvent Company. Rates under test conditions may or may not be representative of leakage rates under actual conditions.

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Table 5
SUMMARY OF CHEMICALS DETECTED IN RAYMOND ROAD SUBSURFACE SOIL BORINGS

Chemical	Number of Detections	Detection Frequency (%)	Mean Concentration (µg/kg)[a]	SD[a]	95% UCL	Range of Detected Concentrations
Volatiles						
Acetone	11	15	743	4,052	1,660	120-32,000
Benzene	6	8	14.8	8.1	16.6	8-72
Bromomethane	4	5	29.2	14.9	32.6	16-130
2-Butanone	5	7	35.6	33.6	43.2	98-200
Carbon Disulfide	5	7	35	31	96	4-71
Carbon Tetrachloride	4	5	24.5	95.5	46.1	6-840
Chlorobenzene	9	12	22.4	32.4	29.7	13-180
Chloroform	16	21	20.2	20.6	24.9	14-140
1,1-Dichloroethane	4	5	16.6	16.9	20.4	12-130
1,1-Dichloroethene	9	12	87.6	545	211	5-4,700
1,2-Dichloroethene	4	5	19.1	31.9	26.3	6-230
Ethylbenzene	34	45	2,713	20,774	7,415	6-180,000
Methylene Chloride	36	48	3,048	5,940	4,392	77-21,000
Tetrachloroethene	63	84	9,607	62,042	23,650	40-530,000
Toluene	67	89	7,855	52,346	19,700	160-450,000
1,1,1-Trichloroethane	22	29	235	1,174	501	7-9,300
Trichloroethene	36	48	1,193	5,661	2,474	4-43,000
Xylene	41	55	13,483	97,036	35,440	10-840,000

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Table 5
SUMMARY OF CHEMICALS DETECTED IN RAYMOND ROAD SUBSURFACE SOIL BORINGS

Chemical	Number of Detections	Detection Frequency (%)	Mean Concentration (µg/kg)[a]	SD[a]	95% UCL	Range of Detected Concentrations
Semivolatiles						
Benzoic Acid	2	8	882	297	1,001	37-690
Benzylbutylphthalate	2	8	173	49.8	193	43-72
Bis(2-ethylhexyl)phthalate	10	42	983	2,034	1,197	40-9,300
Di-n-butylphthalate	6	25	200	142	257	35-770
Naphthalene	4	17	518	988	913	120-4,000
Tetrahydrofuran	12	16	145	101	343	30-300

[a]Calculation using ½ the detection limit for samples where compound was undetected.
SD = Standard deviation.
UCL = Upper confidence limits.

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Table 6
CONTAMINANT ANALYSIS FOR WELLS B-18 AND B-18I
THOMAS SOLVENT RAYMOND ROAD SITE

Volatile Organic	B-18 (Water)	B-18 (NAPL)	B-18I
Acrolein			
Acrylonitrile			
Benzene		1,000,000	
Carbon Tetrachloride		600,000	
Chlorobenzene			
1,2-Dichloroethane	5,000	1,300,000	
1,1,1-Trichloroethane	29,000	3,200,000	
1,1-Dichloroethane		42,000	4
1,1,2,2-Tetrachloroethane			
Chloroethane			
Chloroform		60,000	
1,1-Dichloroethene		1,400,000	
1,2-Dichloroethene		280,000	
1,2-Dichloropropane			
Trans-1,3-Dichloropropene			
Cis-1,3-Dichloropropene			
Ethylbenzene	LT	3,000,000	4
Methylene Chloride	6,000	600,000	13
Chloromethane			
Bromomethane			
Bromoform			
Bromodichloromethane			
Fluorotrichloromethane			
Chlorodibromomethane			
Tetrachloroethene	27,000	6,500,000	93
Toluene	40,000	44,000,000	7
Trichloroethene	45,000	12,000,000	11
Vinyl Chloride			
Acetone	1,000,000		27
2-Butanone			
Carbon Disulfide			
2-Hexanone			
4-Methyl-2-Pentanone		LT	
Styrene			
Vinyl Acetate			
O-Xylene	8,000	5,000,000	13
Total Volatiles	1,160,000	78,982,000	172

Notes: All values in ppb.
B-18 is a shallow well screened at the water table.
B-18I is an intermediate well screened at the sandstone surface.
LT = less than detection limit.
Samples collected in 1984.

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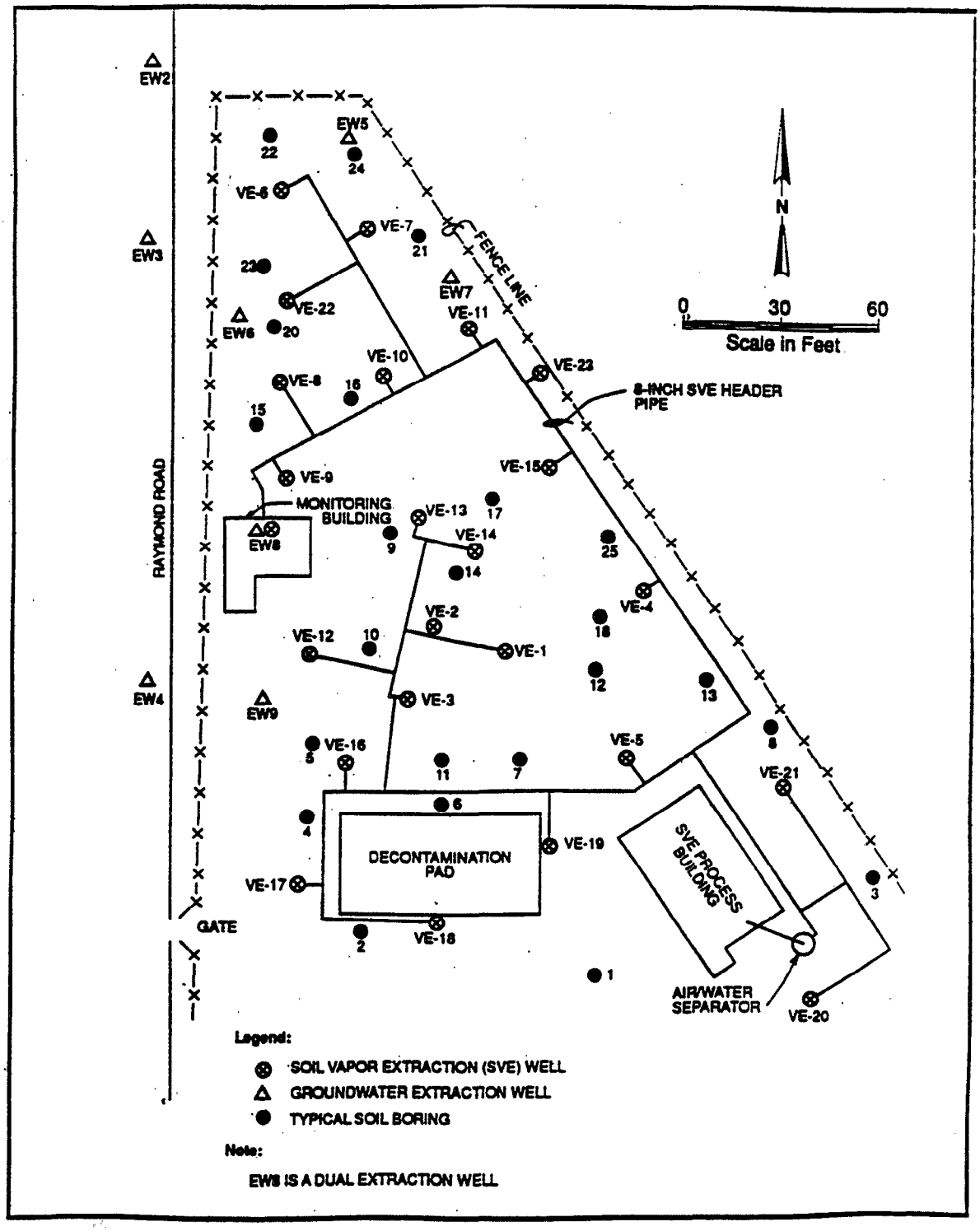

Source: CH2M HILL, 1991a

Figure 3
TSRR SITE MAP SHOWING REMEDIATION SYSTEMS
VERONA WELL FIELD SITE

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removed in October 1988. No floating NAPLs have been observed in the wells at the site since this time.

Extraction Wells EW-2 through EW-9 typically produce between 30 and 70 gpm each. Well EW-1 was never able to produce more than 5 to 7 gpm, and in 1989 it was removed from service. The total flow rate of the ground-water extraction system ranges between 300 and 350 gpm. It is estimated (CH2M HILL, 1991a) that the system directly affects approximately the top 20 feet of the saturated zone over an area of 65,000 square feet. This represents a saturated pore volume of approximately 260,000 cubic feet. The extraction system is estimated to remove one pore volume approximately every 4 days.

There have been no major modifications in the operation of the extraction system. However, it has been found that continuous pumping of the wells caused well-screen fouling with iron-related and sulfur-related bacteria. To keep the productivity of the wells up to design standards it was necessary to institute a program of regular well chlorination. This process required one of the wells to be shut down for chlorine treatment nearly every working day, so that every well could be treated two or three times a month. In May 1990, the practice of chlorinating wells was discontinued. Since then, site operators have reported that there has been no bacteria buildup on well screens and that well productivity has not decreased.

The objective of the ground-water extraction system is to reduce the concentrations of VOCs in the ground water to specified health-based levels. In the initial case study it was reported that the target cleanup levels corresponded to the EPA's maximum contaminant levels (MCLs) and that MCLs had only been established for three of the compounds of concern. In the 1991 feasibility study (U.S. EPA, 1991), a more comprehensive set of compound-specific remedial objectives was established for the proposed remedial actions at the two remaining source areas. These cleanup goals have also been adopted for the TSRR remediation. Table 7 lists the new remediation goals together with the constituent concentrations measured in the active extraction wells in March 1990.

To enhance the effectiveness of the ground-water extraction system, a soil vapor extraction system has also been operating at the TSRR facility since 1988. The original vapor extraction network consisted of 23 PVC wells of 2- and 4-inch diameter. The well locations of the original system are shown in Figure 3. The wells were screened from approximately 5 feet below ground to 3 feet below the water table. It was estimated that this system directly affected the full 20-foot thickness of the vadose zone over an area of approximately 36,000 square feet. The volume of gas-filled pores affected was approximately 144,000 cubic feet. At the typical system flow rate of 1,400 cubic feet per minute, approximately 14 pore volumes of vapor were removed per day.

In January 1991, 21 underground storage tanks and part of the SVE system were removed from the site. A new system, consisting of 21 wells instead of 23, was installed in February 1991. The wells are screened in the lower 6 feet of the vadose zone, approximately 14 to 20 feet below the land surface. Well screens are approximately 10 feet in length. The new system (not shown) covers the same general area as the old system. Flow rates of the new system are approximately the same as for those of the previous system (CH2M HILL, 1991b).

Both activated carbon adsorption and catalytic oxidation have been used to treat extracted vapor before it has been released to the atmosphere. Carbon adsorption system was used from system startup through December 1989, and from February 1991 to the present. During 1990, the carbon adsorption system was replaced with a catalytic oxidation unit, which oxidized the VOCs in the soil vapor at temperatures of 780 to 820 degrees Fahrenheit in the presence of a catalyst. The catalytic oxidation system was used at the time because it had been determined to be more cost effective than the carbon system. However, when the new SVE system was installed in 1991, operators switched back to carbon adsorption, which proved to be the more economical method.

In the original case study, the performance objectives for the vapor extraction system were described as reduction of total VOC concentrations in the soil to less than 1 mg/kg. However, the 1991 feasibility study has set more stringent soil cleanup criteria for the Thomas Solvent Annex and GTWRR Paint Shop areas. These new soil remediation objectives are considered to be applicable to the TSRR site also. Table 8 lists the new criteria along with some representative VOC concentrations remaining in the soil at the TSRR location.

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Table 7
GROUND-WATER CONCENTRATIONS AND CLEANUP OBJECTIVES
THOMAS SOLVENT RAYMOND ROAD SITE
BATTLE CREEK, MICHIGAN

Contaminant	Extraction Well (3/15/90 data)								Remedial Objective[a]
	2	3	4	5	6	7	8	9	
Acetone									3,500
Benzene	48	8					11		1
Chlorobenzene									100
Chloroform					27				6
1,1-Dichloroethane	1.6								0.33
1,2-Dichloroethane					11				0.33
1,1-Dichloroethene		99			18		35		0.058
1,2-Dichloroethene (cis)	15	170			380		99		1
1,2-Dichloroethene (trans)									100
Ethylbenzene	2.5	66			33		100		30
Methylene Chloride									5
Tetrachloroethene	29	410	6.5		430		400	25	0.7
Toluene	59	830			380		310	17	40
1,1,1-Trichloroethane	1.6	310			200		470	3.1	200
1,1,2-Trichloroethane									0.6
Trichloroethene	1.9	500	1.4		370	1.1	420	10	3
Vinyl Chloride									0.015
Xylene	22	290			390		380	2.3	20

Notes: EW-1 is not operated.
All units in ppb.
Blank spaces indicate that the compound was not detected.
Extraction well concentrations represent contaminant levels averaged over the entire screened zone of the aquifer.
[a]Remedial objectives for the site are developed in the feasibility study for the other two source areas (U.S. EPA, 1991).

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Table 8
SOIL-CLEANUP OBJECTIVES
THOMAS SOLVENT RAYMOND ROAD SITE
BATTLE CREEK, MICHIGAN

Contaminant	Average Soil Concentration in August 1988 (µg/kg)	Estimated Soil Concentration in January 1991[a] (µg/kg)	Remedial Objective[b] (µg/kg)
1,1-Dichloroethane	3	--	6.6
1,1-Dichloroethene	70	10	1.2
1,2-Dichloroethane	1	--	6.6
1,2-Dichloroethene (cis)	6	--	20
1,2-Dichlorethene (trans)	6	--	2,000
Ethylbenzene	2,800	420	600
Methylene Chloride	2,700	200	100
Tetrachloroethene	12,000	1,800	14
Toluene	8,000	1,200	800
1,1,1-Trichloroethane	570	90	4,000
Trichloroethene	1,400	210	60
Xylenes	7,500	1,100	400

[a]Based on an 85 percent contaminant removal since August 1988. This assumes identical rates of contaminant removal from the vadose zone.
[b]Remedial objectives for the site are developed in the feasibility study for the other two source areas (U.S. EPA, 1991).

Notes: -- indicates not detected.

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EVALUATION OF PERFORMANCE

Barrier Well System: In the original case study it was stated that, as of mid-1988, the barrier well system was successful in blocking plume migration to the water supply wells in the northern part of the well field. More recent performance information indicates that the system continues to capture both of the contaminant plumes that approach the well field from the south and southeast.

Figures 4 and 5 show water level contours in the glacial deposits and in the underlying sandstone, based on measurements taken in April 1989. In the glacial overburden aquifer, the hydraulic effects of the 20-series blocking wells are quite clearly seen. In the sandstone aquifer, the influence of the blocking wells is combined with that of the operating water supply wells farther north in the well field. However, the ground-water flow pattern is well defined by the water level contours, and the blocking wells are located between the contaminant source areas and the production wells. The northernmost wells, V-50 through V-53, were installed as part of the IRM to replace the production capacity lost when the 20-series wells were converted for plume control.

The contaminant plumes in the glacial overburden and sandstone aquifers are shown in Figures 6 and 7. The total VOC concentration contours are based on ground-water samples taken during the remedial investigation in April 1989. Comparison of these plume maps with the 1984 plume map presented in the original case study shows that the plumes have been stabilized and that migration into the northern part of the well field has been cut off. There has been a general reduction in the extent of the high concentration regions around the source areas. Concentrations in the area between the TSRR facility and the Thomas Solvent Annex have been reduced by approximately two orders of magnitude. However, total VOC concentrations of more than 1000 ppb persist around, and immediately downgradient of, all three source areas.

Figure 8 shows contours of total VOC concentration in a vertical cross section taken through the main body of the contaminant plume originating at the TSRR facility. It shows that the highest concentrations in the TSRR source area are found near the water table, but farther downgradient they are deeper in the sandstone. Comparison with a similar cross sectional plot in the original case study shows that there has been little change in concentrations along the centerline of the plume since 1984.

TSRR Remediation Systems: Through December 1990, approximately 645 million gallons of ground water containing approximately 14,000 pounds of VOCs had been removed by the ground-water extraction system at the TSRR facility.

Figure 9 shows the historical record of total VOC concentrations in Well EW-8, which is of particular interest because it is located in the central part of the floating NAPL layer. After approximately the first 500 days of operation, the concentrations in this well have been relatively stable in the 4,000 to 5,000 ppb range, with an apparent slow declining trend. In addition to ground-water extraction, Well EW-8 is also a free product recovery well. Between March 1987 and October 1988, more than 150 gallons, or roughly 1,200 pounds, of free product were skimmed from the well. The NAPL layer has not been recorded at the site since October 1988.

Figure 10 shows the record of total VOC concentrations in the combined flow stream from the extraction well system. The concentrations, which were originally as high as 19,000 ppb, showed a rapid decline in the first half of the year and have stabilized at less than 3,000 ppb. Over the last two years a very slow declining trend can be observed.

Approximately 45,000 pounds of VOCs have been removed by the soil vapor extraction system since it began operating in November 1987. Figure 11 shows the record of cumulative VOC removal for the vapor extraction system. Approximately 95 percent of the contaminant removal was achieved during the first 200 days of the 400-day operating record shown. During the second half of 1990 the system's production rate was consistently less than 10 pounds per day. This is in contrast to the first half year of system operation, when production rates were commonly between 600 and 1000 pounds per day. In late 1990, it was estimated that approximately 1000 pounds of VOC remained in the vadose zone soils.

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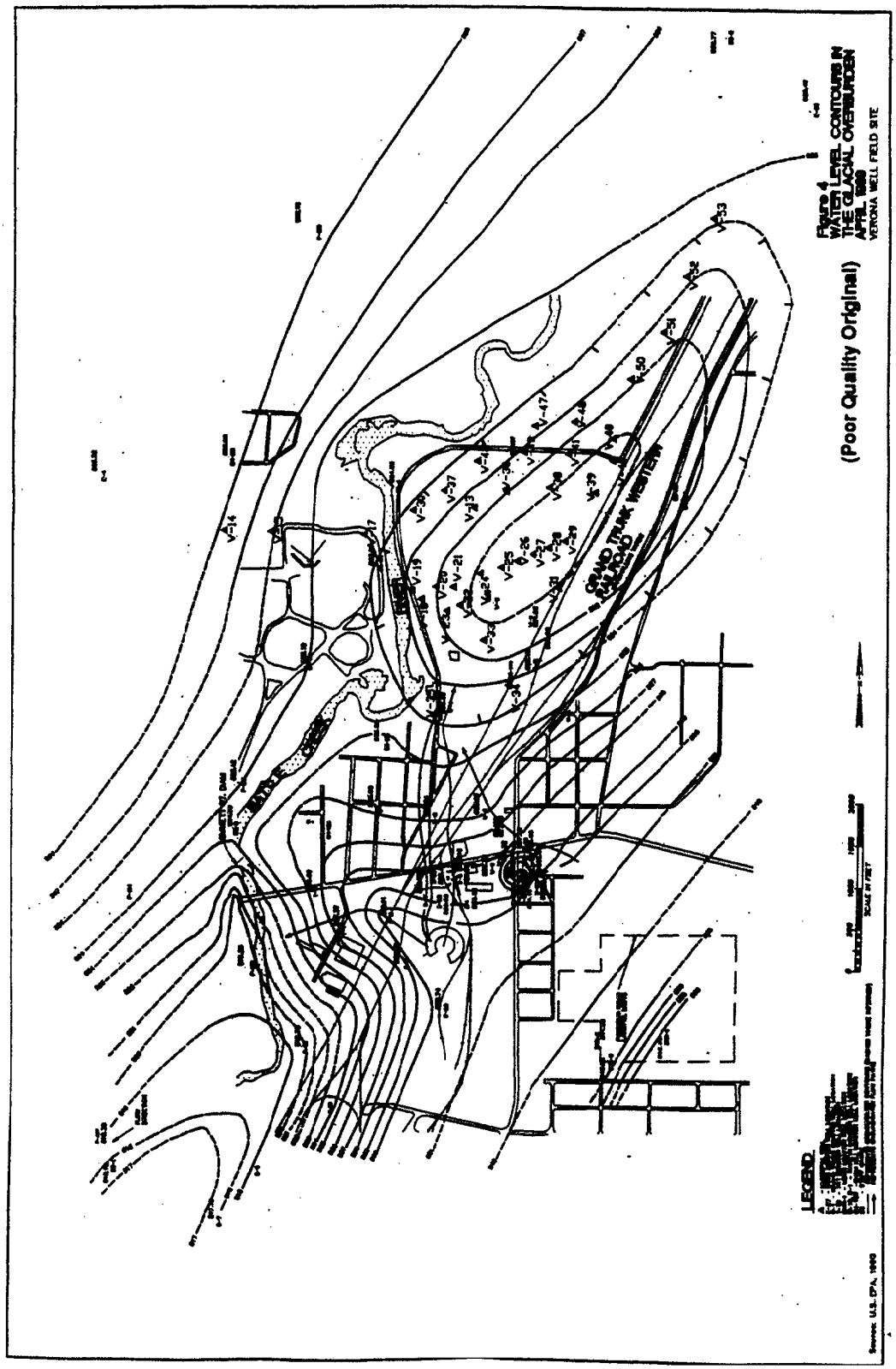
Figure 4
WATER LEVEL CONTOURS IN
THE GLACIAL OVERBURDEN
APRIL 1989
VERONA WELL FIELD SITE
(Poor Quality Original)
GRAND TRUNK WESTERN
RAILROAD
LEGEND
SCALE IN FEET
Source: U.S. EPA, 1990

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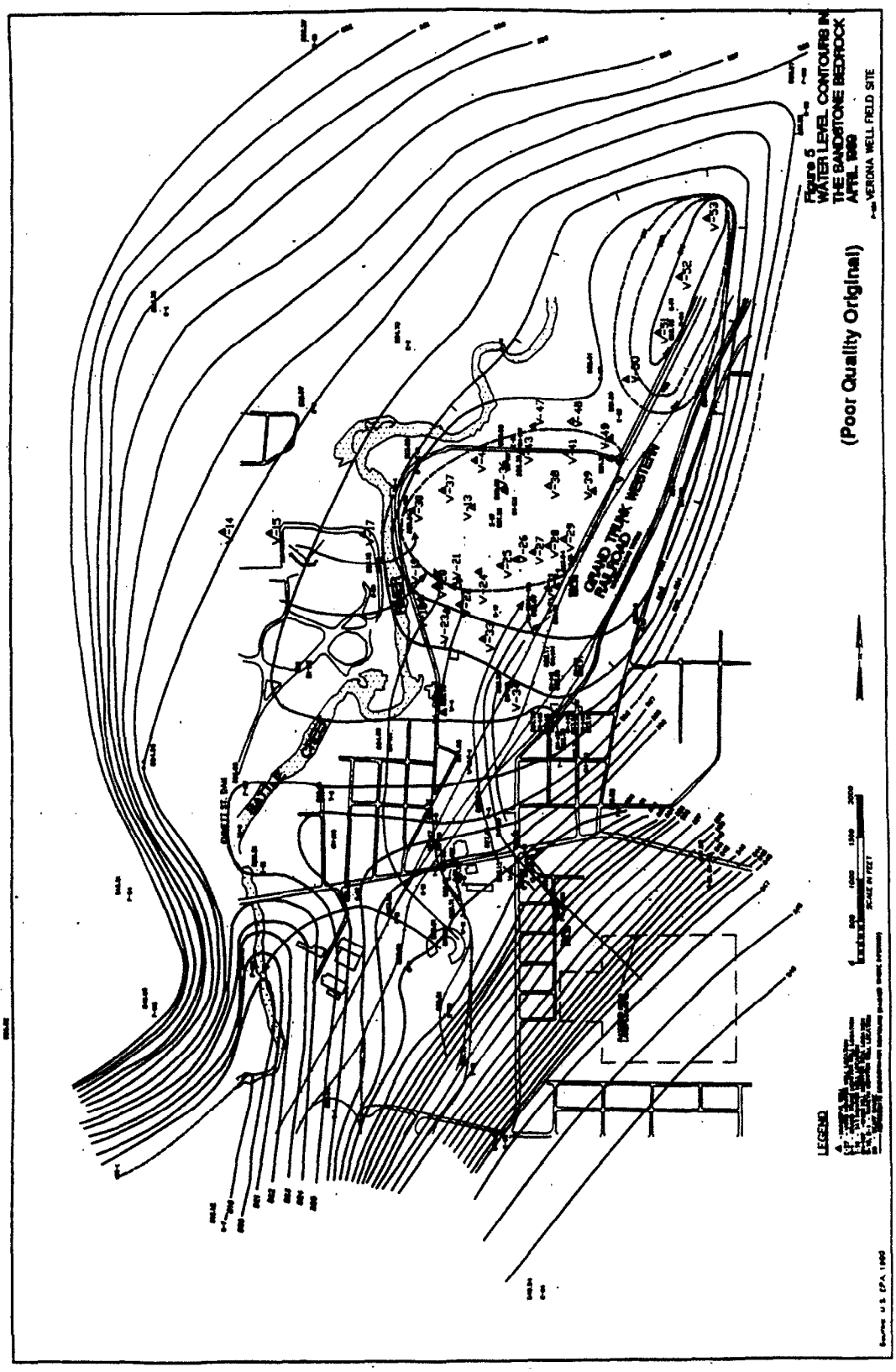
Figure 5
WATER LEVEL CONTOURS IN
THE SANDSTONE BEDROCK
APRIL 1989
VERONA WELL FIELD SITE
(Poor Quality Original)
GRAND TRUNK WESTERN RAILROAD
LEGEND
SCALE IN FEET
Source: U.S. EPA, 1990

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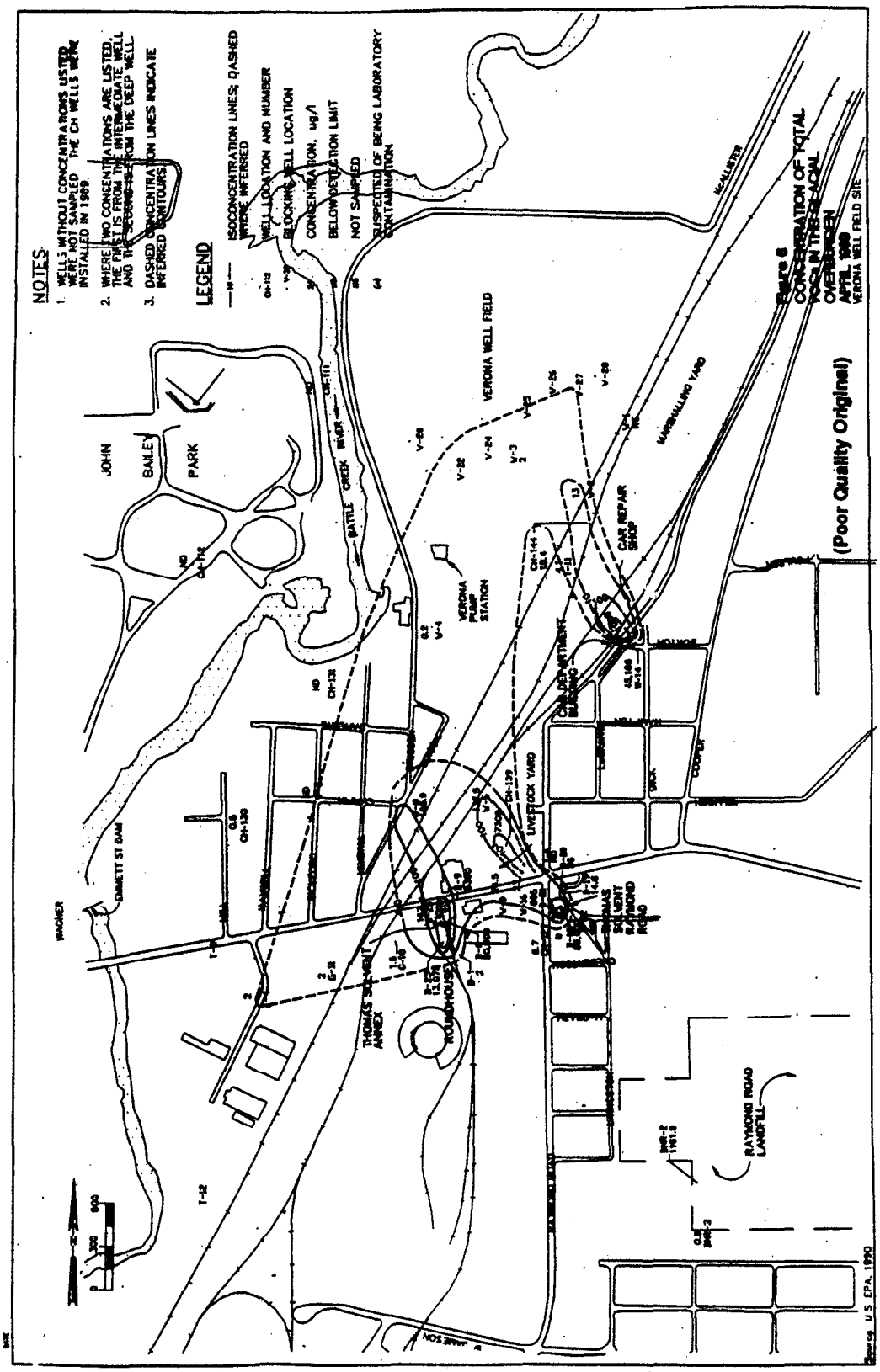
NOTES
1. WELLS WITHOUT CONCENTRATIONS LISTED WERE NOT SAMPLED. THE CH WELLS WERE INSTALLED IN 1989.
2. WHERE TWO CONCENTRATIONS ARE LISTED, THE FIRST IS FROM THE INTERMEDIATE WELL AND THE SECOND IS FROM THE DEEP WELL.
3. DASHED CONCENTRATION LINES INDICATE INFERRED CONTOURS.
LEGEND
ISOCONCENTRATION LINES; DASHED WHERE INFERRED
WELL LOCATION AND NUMBER
BLOCKING WELL LOCATION
CONCENTRATION, ug/l
BELOW DETECTION LIMIT
NOT SAMPLED
SUSPECTED OF BEING LABORATORY CONTAMINATION
JOHN BAILEY PARK
VERONA WELL FIELD
BATTLE CREEK RIVER
VERONA PUMP STATION
CAR REPAIR SHOP
MARSHALLING YARD
LIVESTOCK YARD
THOMAS SOLVENT ANNEX
ROUNDHOUSE
THOMAS SOLVENT RAYMOND ROAD
RAYMOND ROAD LANDFILL
EMMETT ST DAM
WAGNER
McALLISTER
Figure 6
CONCENTRATION OF TOTAL VOCs IN THE ALLUVIAL OVERBURDEN
APRIL 1989
VERONA WELL FIELD SITE
(Poor Quality Original)
Source: U.S. EPA, 1990

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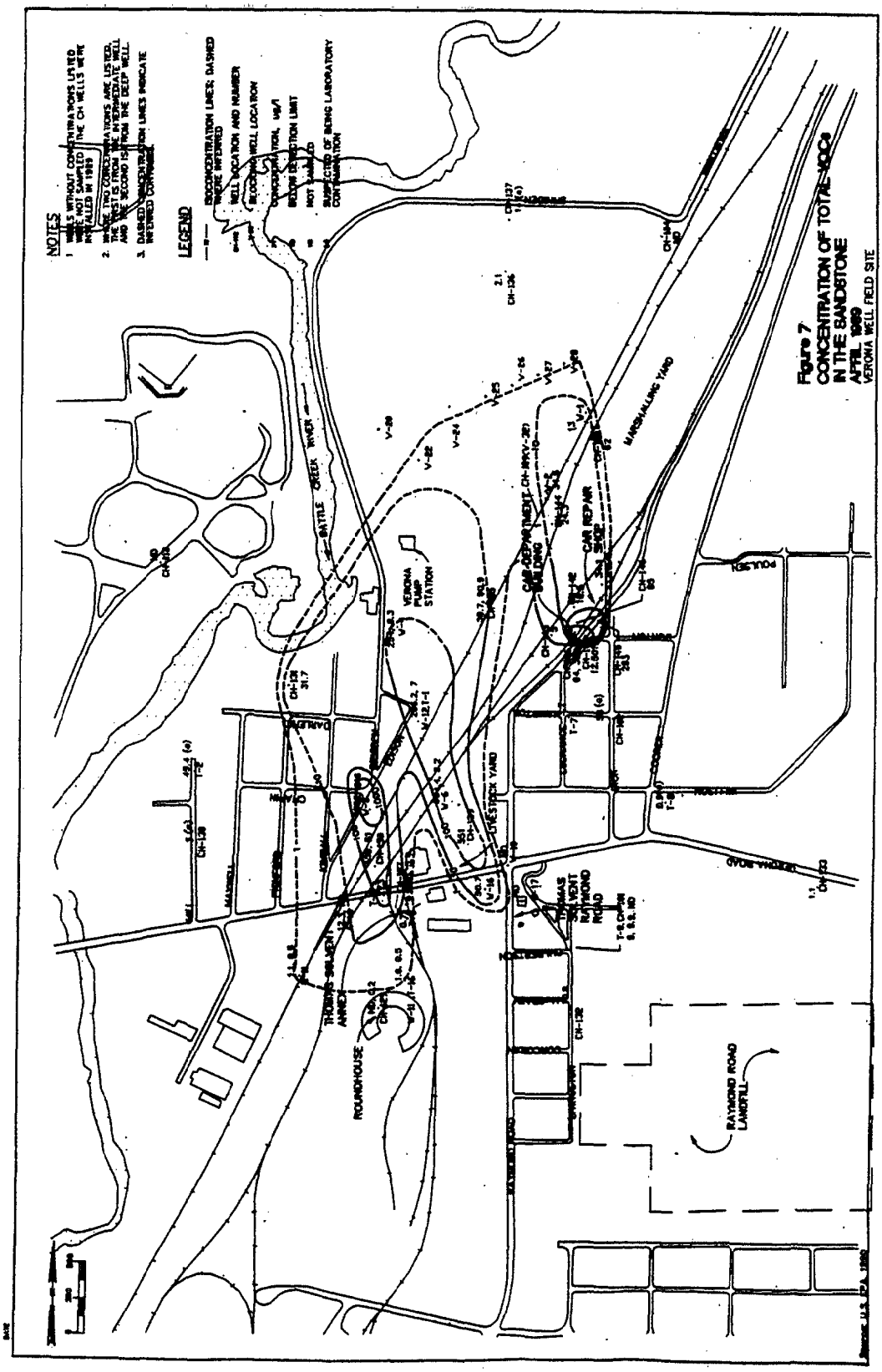

(Poor Quality Original)

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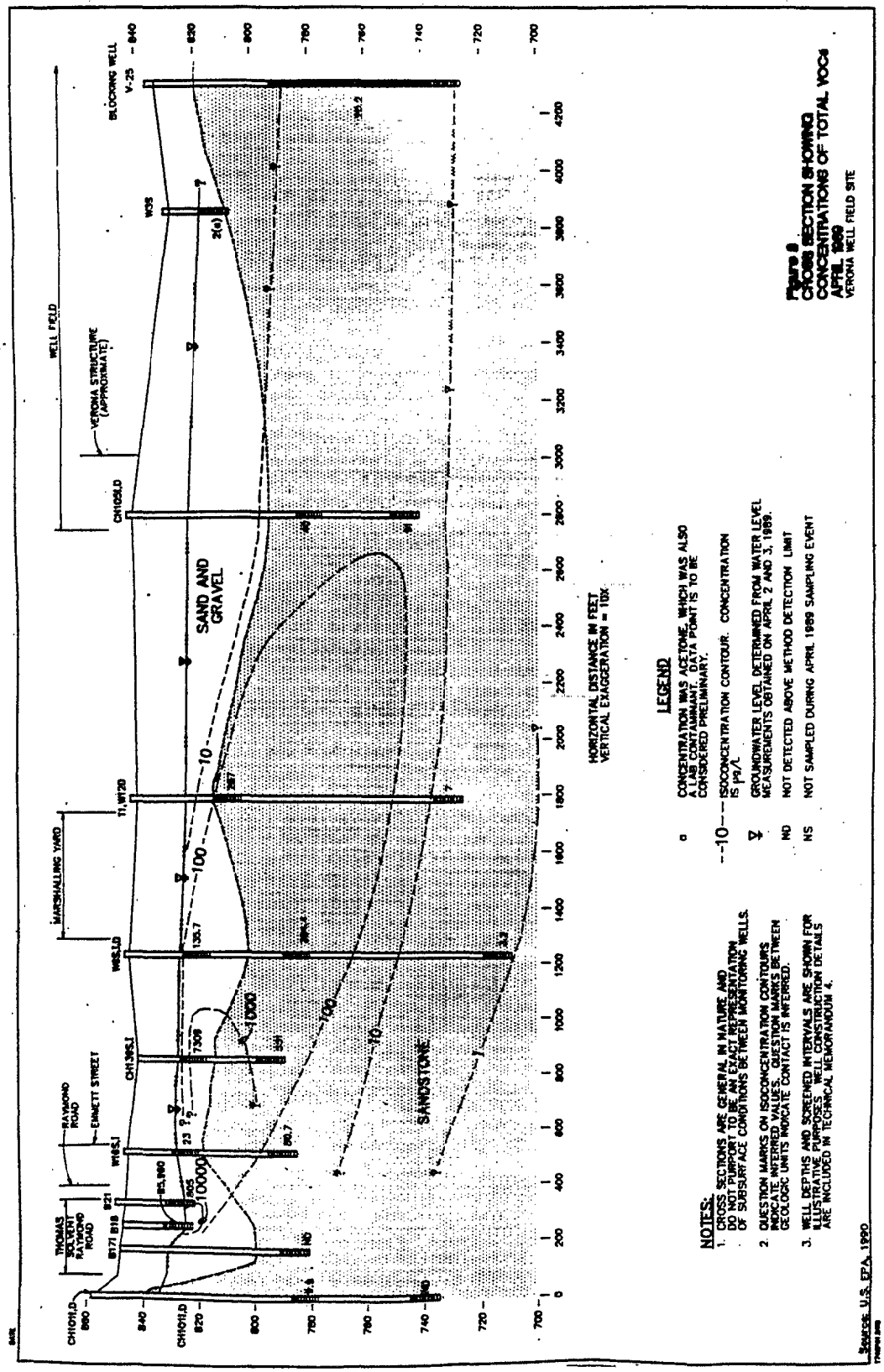
WELL FIELD
VERONA STRUCTURE (APPROXIMATE)
MARSHALLING YARD
THOMAS SOLVENT RAYMOND ROAD
RAYMOND ROAD
EMMETT STREET
BLOCKING WELL
SAND AND GRAVEL
SANDSTONE
HORIZONTAL DISTANCE IN FEET
VERTICAL EXAGGERATION = 10X
LEGEND
CONCENTRATION WAS ACETONE, WHICH WAS ALSO A LAB CONTAMINANT. DATA POINT IS TO BE CONSIDERED PRELIMINARY.
ISOCONCENTRATION CONTOUR. CONCENTRATION IS µg/L
GROUNDWATER LEVEL DETERMINED FROM WATER LEVEL MEASUREMENTS OBTAINED ON APRIL 2 AND 3, 1989.
ND NOT DETECTED ABOVE METHOD DETECTION LIMIT
NS NOT SAMPLED DURING APRIL 1989 SAMPLING EVENT
NOTES:
1. CROSS SECTIONS ARE GENERAL IN NATURE AND DO NOT PURPORT TO BE AN EXACT REPRESENTATION OF SUBSURFACE CONDITIONS BETWEEN MONITORING WELLS.
2. QUESTION MARKS ON ISOCONCENTRATION CONTOURS INDICATE INFERRED VALUES. QUESTION MARKS BETWEEN GEOLOGIC UNITS INDICATE CONTACT IS INFERRED.
3. WELL DEPTHS AND SCREENED INTERVALS ARE SHOWN FOR ILLUSTRATIVE PURPOSES. WELL CONSTRUCTION DETAILS ARE INCLUDED IN TECHNICAL MEMORANDUM 4.
Figure 8
CROSS SECTION SHOWING CONCENTRATIONS OF TOTAL VOCs
APRIL 1989
VERONA WELL FIELD SITE
Source: U.S. EPA, 1990

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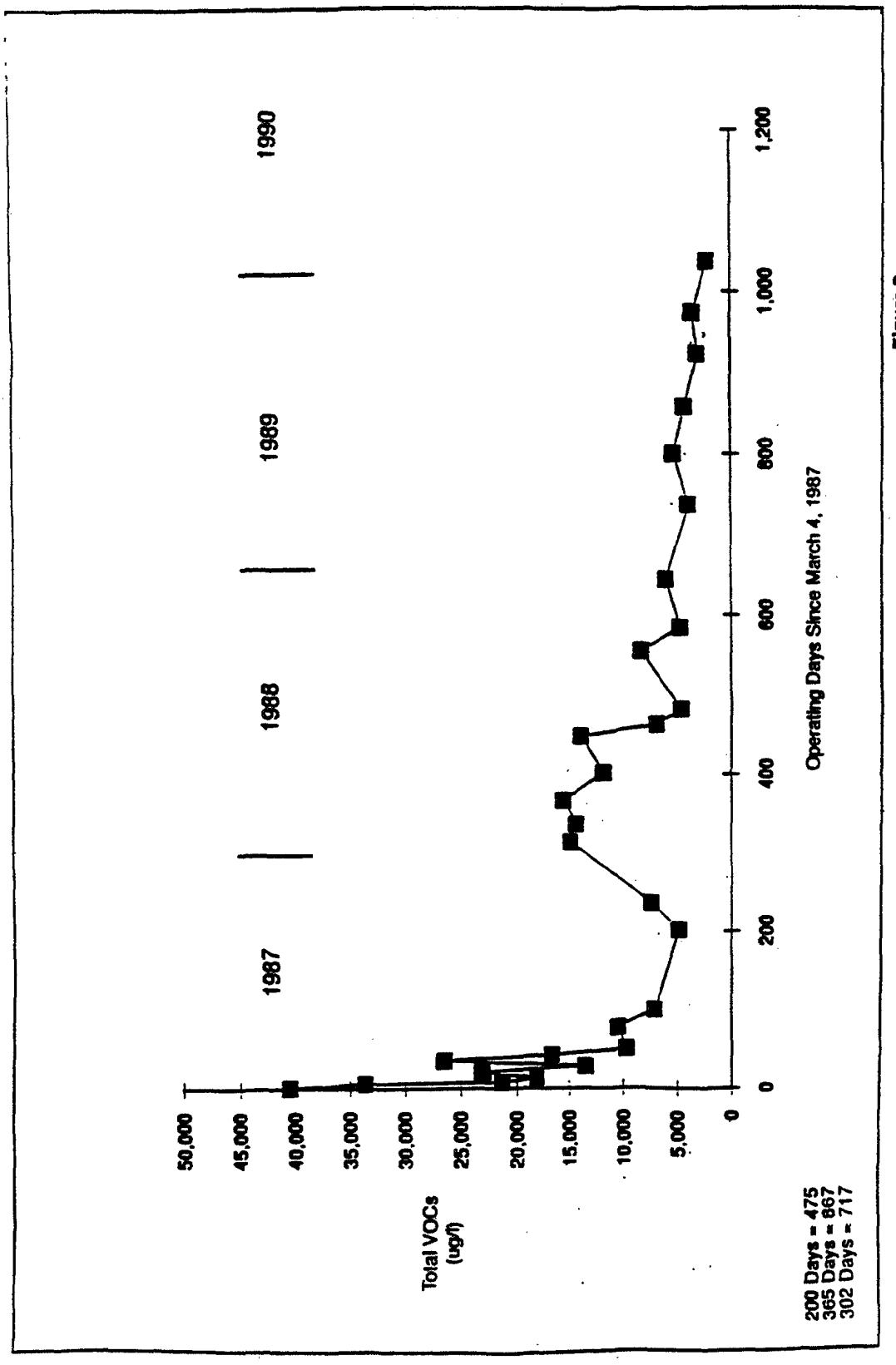

Figure 9
RECORD OF TOTAL VOC CONCENTRATIONS IN EXTRACTION WELL EW-8
VERONA WELL FIELD SITE

Source: CH2M HILL, 1991a

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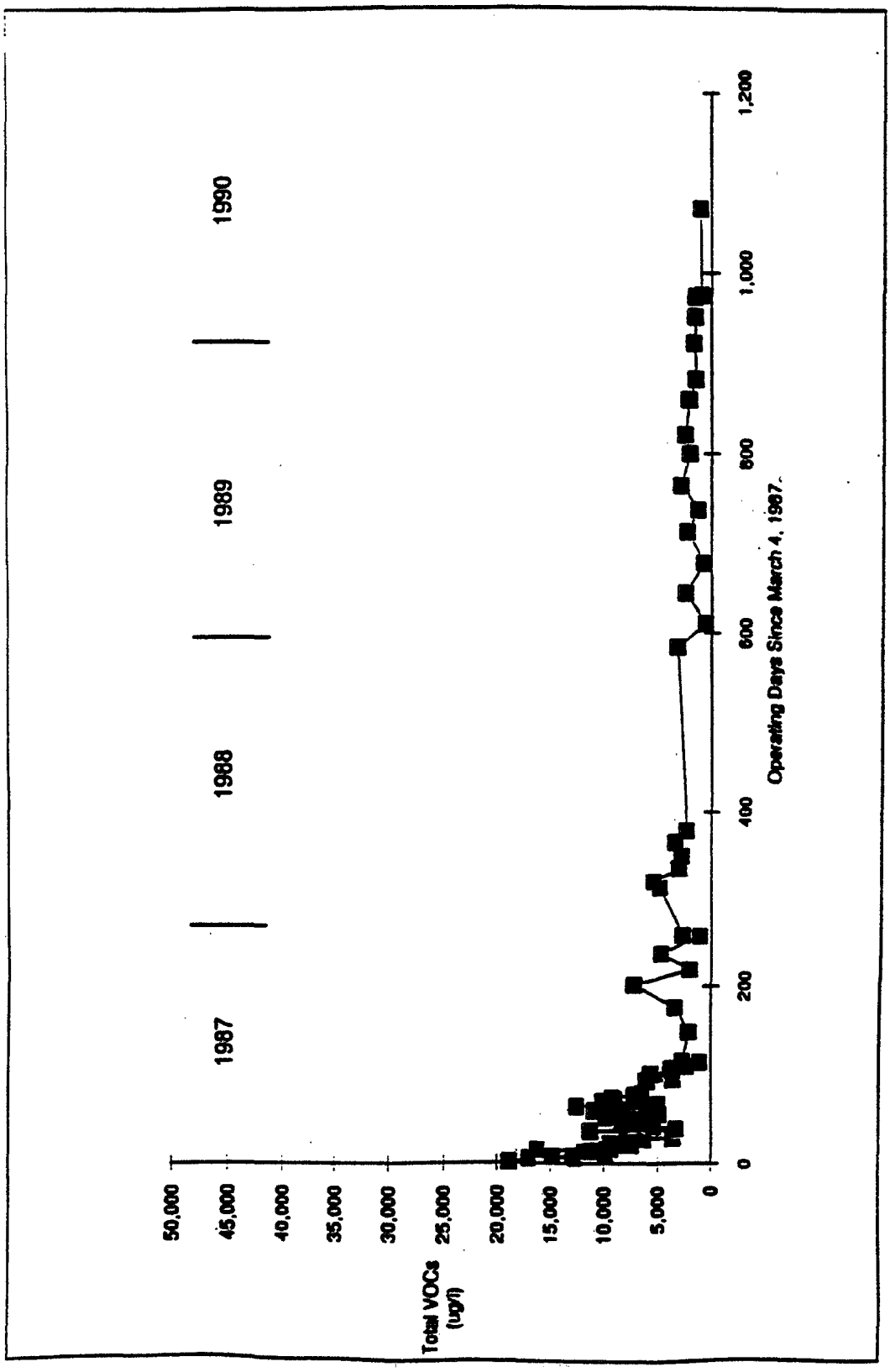

Source: CH2M HILL, 1991a

Figure 10
RECORD OF TOTAL VOC CONCENTRATIONS IN COMBINED EXTRACTION WELL FLOW
VERONA WELL FIELD SITE

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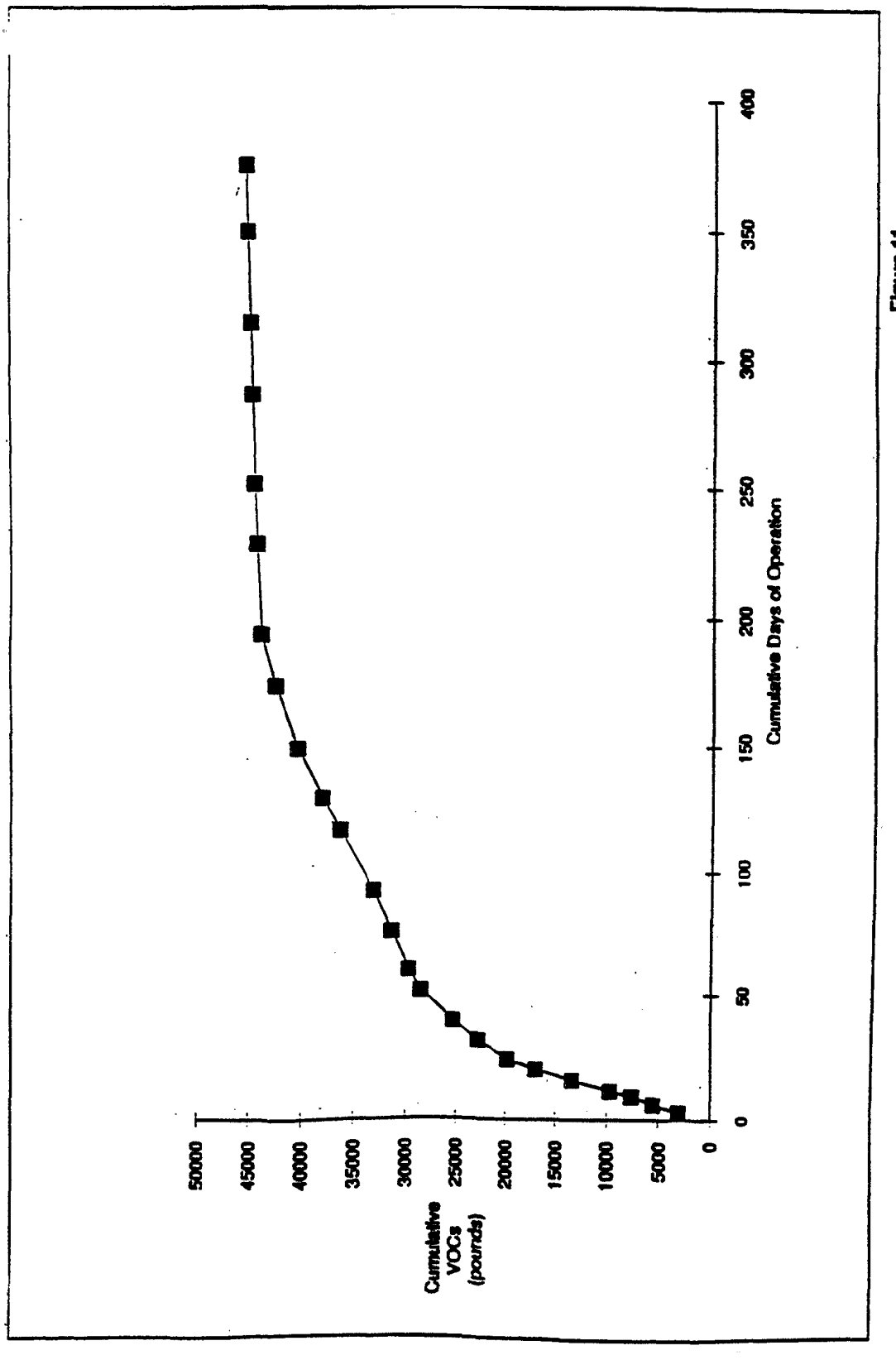

Figure 11
RECORD OF CUMULATIVE VOC REMOVAL BY THE SOIL VAPOR EXTRACTION SYSTEM
VERONA WELL FIELD SITE

Source: CH2M HILL, 1991a

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SUMMARY OF REMEDIATION

Ground-water remediations are in progress in two separate parts of the Verona Well Field project area. The first system to go into operation was the barrier well system, which is intended to control plume migration in the well field. In addition, a combination of ground-water extraction and soil vapor extraction are being used to remediate VOC contamination at the TSRR facility. The TSRR facility is one of three primary contaminant source areas that are jointly responsible for most of the well field contamination. Remediation of the two remaining source areas, the Thomas Solvent Annex and the GTWRR Paint Shop area, has not yet begun, although a remedial investigation and a feasibility study for those areas have been completed.

The barrier well system is protecting the remaining production wells in the Verona Well Field from the contaminant plumes emanating from the three primary source areas. However, VOCs have been detected in the first row of wells behind the barrier wells. In August 1988 and periodically during 1989 and 1990, VOC concentrations ranging from 0.5 ppb to 7 ppb have been measured in several of those wells. Detections are sporadic, usually appearing in nonconsecutive sampling rounds (Public Works Department, City of Battle Creek, Michigan, 1991). The contaminant plumes themselves have remained fairly stable since the barrier system began operating in 1984. The high concentration regions of the plumes have been reduced somewhat in lateral extent, but there has been little reduction along the centerlines of the individual plumes. Continued operation of the barrier well system will probably be necessary for a long time.

At the TSRR facility, the ground-water and soil vapor extraction systems continue to operate. Approximately 19,000 pounds of VOCs have been removed by ground-water extraction and 45,000 pounds by soil vapor extraction. An additional 1,200 pounds have been removed by free product skimming in the NAPL recovery well. However, the production rates have declined, in all three categories, to such low levels that further remedial progress is expected to be very slow. Contaminant concentrations are still well above the health-based cleanup goals.

SUMMARY OF NAPL-RELATED ISSUES

A layer of NAPL was discovered floating on the water table at the TSRR facility in 1984. The NAPL was tested and found to be a mixture consisting mainly of chlorinated solvents and BTX (benzene, toluene, and xylene) compounds. Even though the chlorinated solvents were stored at the site in separate leaking underground tanks, extensive monitoring has not shown evidence of independent dense NAPL (DNAPL) plumes. Instead, the dense chlorinated solvents seem to be present only near the water table in conjunction with the floating NAPL mixture. The NAPL has not been observed since October 1988.

The remediation systems have addressed the NAPL problem at the TSRR facility in conjunction with the ground-water and soil contamination problems. Most of the contaminant mass has been recovered in the vapor phase by the soil vapor extraction system and in the dissolved phase by the ground-water extraction system. Less than 2 percent of the contaminant mass that has been removed was recovered as a NAPL by the free product skimming system.

The recovery rates of both the ground-water and the soil vapor extraction systems have fallen off greatly with continued operation, even though a substantial mass of contamination is thought to remain in the subsurface. Studies suggest that a portion of the NAPL might have been retained in the soil pore space and is contributing to the contamination at the site (CH2M HILL, 1991b).

Subsurface investigations at the Thomas Solvent Annex and the GTWRR paint shop have provided information suggesting that NAPLs may be present in those source areas also. The evidence at the Thomas Solvent Annex is particularly strong, with several soil samples showing extremely high concentrations of chlorinated solvents. Contaminants have not been directly observed at these sites in nonaqueous phase. This is not surprising because the dense chlorinated solvents are potentially present as DNAPLs, which are considerably more elusive than floating NAPLs.

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UPDATE BIBLIOGRAPHY/ REFERENCES

CH2M HILL. May 1988. *Verona Well Field Final RI/FS Work Plan.*

CH2M HILL. January 1990. Technical memorandum 5, Verona Well Field, Remedial Investigation/Feasibility Study.

McCann, Michael, Paul M. Boersma and Patricia V. Cline. May 1991. Effects of Nonaqueous Phase Liquids on a Superfund Remediation. *Proceedings from HAZTECH International, Pittsburgh, Pennsylvania.*

CH2M HILL. January 1991a. *Draft Performance Evaluation Report, Thomas Solvent Raymond Road Operable Unit, Verona Well Field Site.*

CH2M HILL. June 13, 1991b. Personal communication with Mike McCann, Project Manager.

Public Works Department, City of Battle Creek, Michigan. June 18, 1991. Personal communication with John F. O'Brien, Public Utilities Manager.

U.S. Environmental Protection Agency (U.S. EPA). October 1989. *Evaluation of Ground-Water Extraction Remedies: Volume 2, Case Studies 1-19.* Document Number EPA/9355.4-03.

U.S. EPA. August 1990. *Remedial Investigation Report, Verona Well Field, Volume 1.*

U.S. EPA. February 1991. *Public Comment Draft Feasibility Study, Verona Well Field.*

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CASE STUDY 19

Ville Mercier
Quebec, Canada

Abstract

The Ville Mercier site is located along the south shore of the St. Lawrence River, 20 km southwest of Montreal, Quebec. From 1968 to 1972, a waste-oil carrier disposed of an estimated 40,000 m^3 of liquid petroleum and petrochemical wastes in an abandoned gravel pit near Ville Mercier. By 1972, removal of liquid wastes and remediation by incineration was initiated. Through 1975, most liquid wastes had been removed and incinerated. Removal and incineration of sludges did not begin until 1981.

By 1981, it was estimated that ground-water contamination extended over an area of 30 km^2. Following a 1982 feasibility study, pumping and treatment of the most heavily contaminated zones was chosen as the site remedy. The system consists of three extraction wells within a combined extraction rate of 47 l/sec. As of 1988, only a minimal amount of contaminants (20 tons) had been extracted from the ground water. Dense nonaqueous phase liquids (DNAPLs) have been observed at the site. Site operators have had to address clogging problems in the treatment system caused by bacteria fouling, precipitation of metals, and DNAPLs. Pumping and treatment is expected to extend some time into the future. An update of this case study was not written because new data were not available. See the original case study for more complete information on the site (U.S. EPA, 1989).

Table of Background Data	
Date of Problem Identification	Early 1970s
Extraction Started	1983
Types of Contaminants	Organics
Primary Aquifer Materials	Glacial sand, gravel, and clay over fractured sandstone
Maximum Number of Extraction Wells	3
Maximum Total Extraction Rate	750 gpm
Estimated Plume Area	7,600 acres
Estimated Plume Thickness	80 feet
Maximum Reported Concentrations	Not given

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CASE STUDY 20

Mid-South Wood Products
Mana, Arkansas

Abstract

Soils and ground water have been contaminated at the Mid-South Woods site as a result of spills of wood treatment liquids and onsite disposal of wastes into unlined ponds. The contamination has been remediated using a system of French drains and drilled recovery wells. An interim 3-well system was operated from early 1985 to mid-1989. The full 15-well recovery system has been operated since mid-1989. Available data from 1984, 1985, 1989, and 1990 show that concentrations in ground water decreased significantly from 1985 to 1989. In addition to the operation of the remediation system, this reduction may also be due to natural attenuation and downward lateral migration of contaminants. Both LNAPLS and DNAPLS have been observed at the site. There is evidence of DNAPLS down to 172 feet in one well.

Table of Background Data	
Date of Problem Identification	1976
Extraction Started	early 1985
Types of Contaminants	pentachlorophenol (PCP) chromium arsenic polynuclear aromatic hydrocarbons (PANs)
Primary Aquifer Materials	Fractured sandstone and shale
Maximum Number of Extraction Wells	15 (most with French drains)
Maximum Total Extraction Rate	approximately 42 gpm
Estimated Plume Area	10-20 acres
Estimated Plume Thickness	as much as 172 feet
Maximum Reported Concentrations	40,000,000 PCP

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CASE STUDY
MID-SOUTH WOOD PRODUCTS SITE

BACKGROUND OF THE PROBLEM

This case study summarizes ground-water remediation efforts at the Mid-South Wood Products Superfund site in Mena, Arkansas. The site is a 57-acre wood-treating facility located in western Arkansas, a short distance north of Highway 71. Figure 1 shows the site location. The site is divided into two areas--the abandoned plant area, where pentachlorophenol (PCP) and creosote formerly were used to pressure-treat wood, and the currently active wood treatment facility, where chromated copper arsenate (CCA) is used.

The abandoned plant area includes an old treatment plant, two waste ponds, a landfill, the north and south landfarms, and Clear Lake. Figure 2 shows the location of these features. The active treatment plant, located near the old plant in the northeastern quadrant of the site, consists of a pressure-treating cylinder, several elevated storage tanks for treatment solution, a concrete drip pad, and a wood-drying kiln.

The ground water at the site is contaminated with PCP, chromium, arsenic, and derivatives of creosote, primarily polynuclear aromatic hydrocarbons (PAHs). The current plant owner, Mid-South Wood Products, and the previous owner, Hines Lumber Company, are the two potentially responsible parties (PRPs) at the site. The U.S. EPA oversees site remediation activities under the Superfund program.

SITE HISTORY

The plant site was originally developed in the 1930s to produce untreated wood posts. The production of creosote-treated timber began at the site in 1955. In 1967, Hines Lumber Company purchased the plant and continued to operate it as a wood treatment plant using both creosote and PCP in carrier oils as treatment liquids (U.S. EPA, 1986b). These treatment liquids were used until 1977, when the old PCP and creosote treatment areas were abandoned and Hines converted the facility to a chromated copper arsenate (CCA) treating plant (U.S. EPA, 1984). Mid-South Wood Products purchased the plant in September 1978 and continued using the CCA wood treatment process. In 1978, Mid-South attempted to close the Old Pond by spraying the liquid and sludge from Old Pond onto the north and south landfarm areas, mixing these wastes into the soil at the landfarms, and then filling up Old Pond with part of the resulting sludge-soil mixture.

The contamination problem was first discovered in 1976, when a large fishkill in a nearby river was traced to the site. In 1980, an oily material was detected in a stream, approximately 1,000 feet west-northwest of the two waste ponds (B&F Engineering, 1990c). A landowner adjacent to the site also complained about contamination in runoff from the landfill in 1980. In response to this complaint, ground water samples were collected in late 1980. These samples revealed low levels of PCP, arsenic, and chromium in the ground water west and northwest of the site (U.S. EPA, 1986c).

The Mid-South Wood site was added to the Superfund National Priorities List in 1982. Between 1980 and 1986, the Arkansas Department of Pollution Control and Ecology (ADPCE), the EPA, and Hine's consultants (B&F Engineering and Law Engineering) conducted a series of remedial investigations to characterize the type and extent of contamination at the Mid-South site. Activities included collecting and analyzing samples of surface water, ground water, surface soils, and sediments. These investigations showed contamination by semivolatile organics (PCP and primary creosote compounds) and metals (arsenic and chromium) both onsite and offsite. The record of decision (ROD) specifying the approach to remediation of the site was signed by the EPA in 1986. A temporary ground-water extraction and treatment system consisting of Wells RW-1, RW-2, RW-3, and their associated French drains was constructed in late 1984 and began operating in early 1985. The ground-water recovery system specified in the ROD began operating in the summer of 1989.

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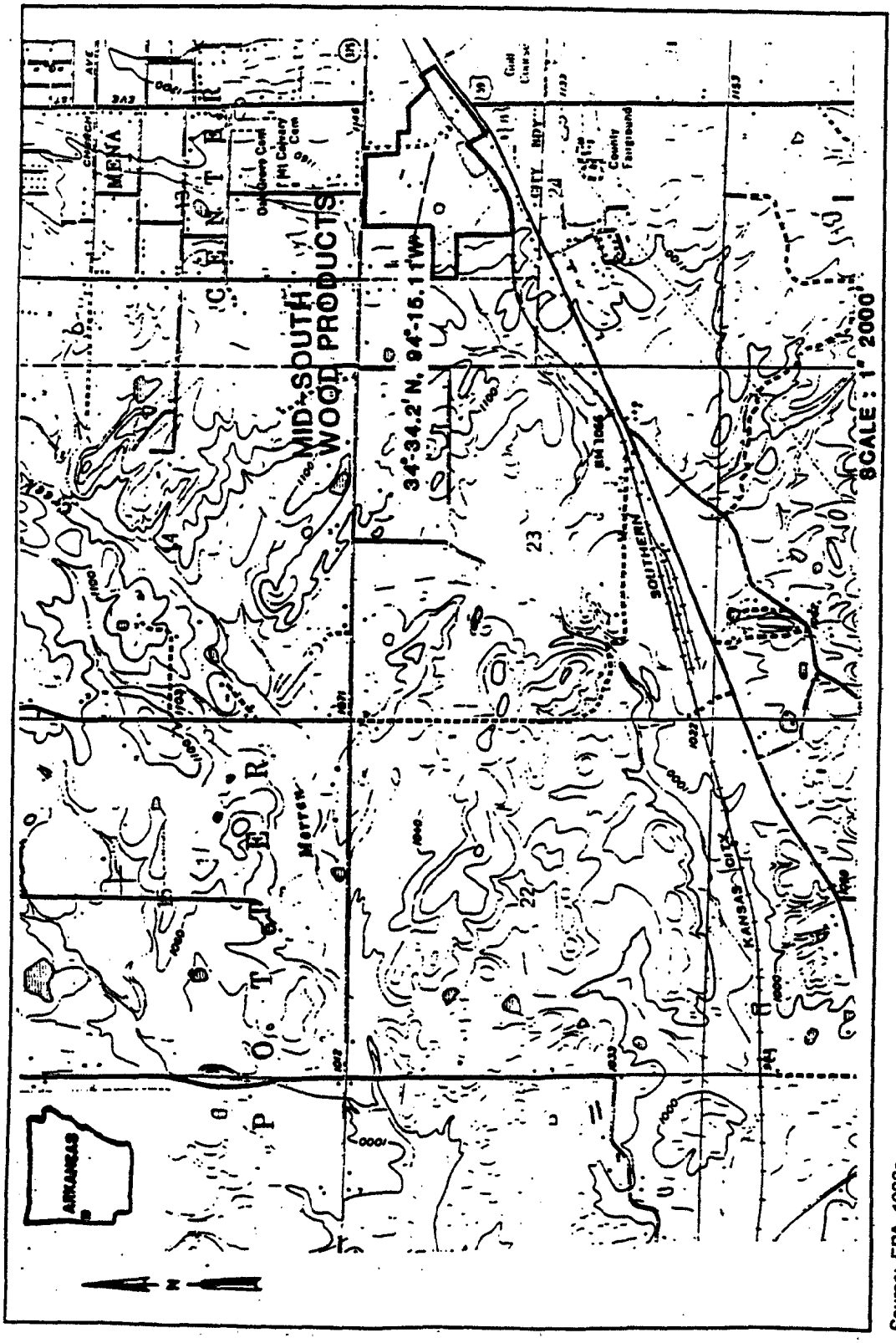

Source: EPA, 1986c

Figure 1
LOCATION OF MID-SOUTH WOOD SITE
IN RELATION TO MENA, ARKANSAS
MID-SOUTH WOOD, MENA, ARKANSAS

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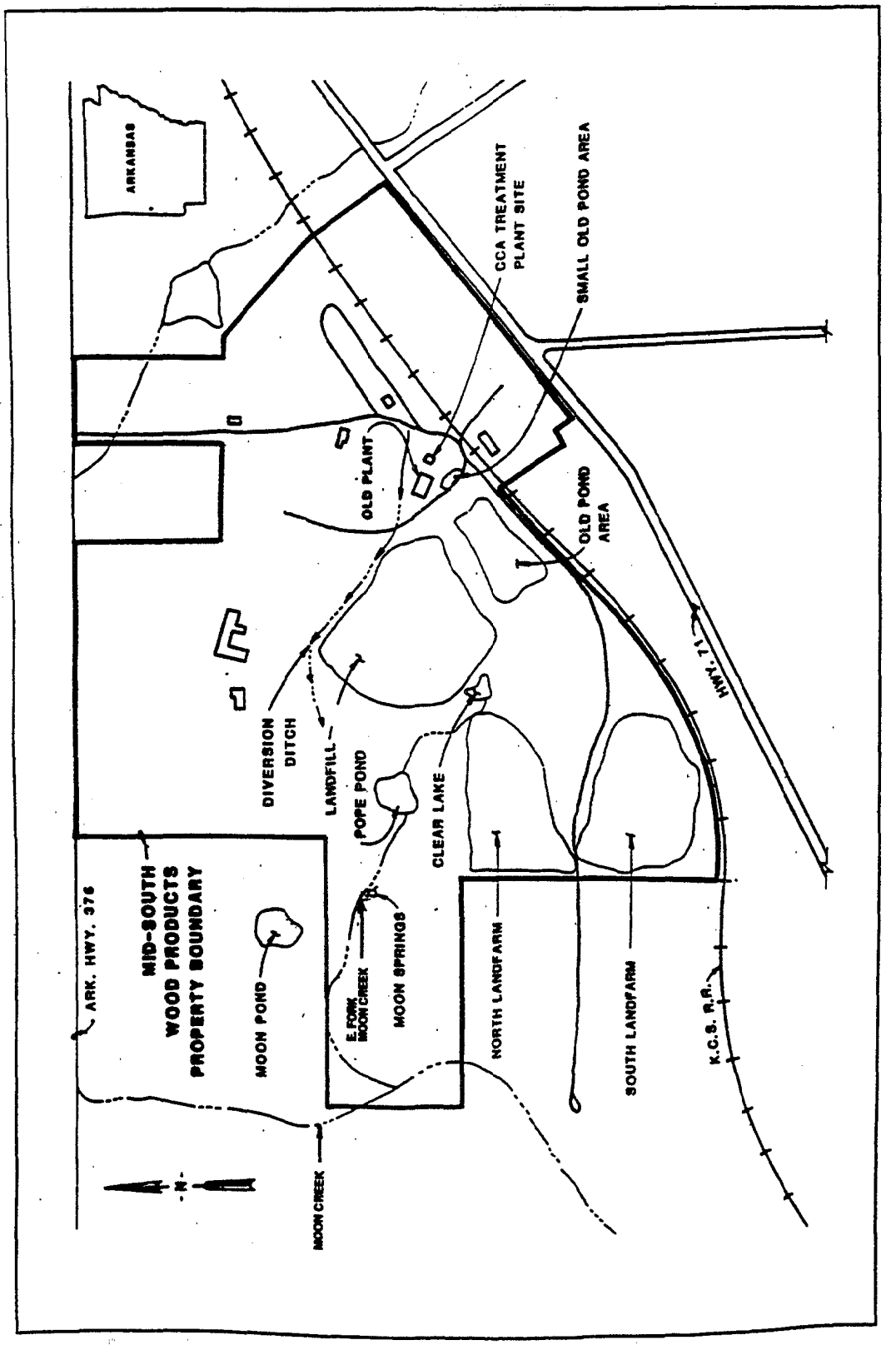

Figure 2
MID-SOUTH WOOD SITE MAP
MID-SOUTH WOOD PRODUCTS SITE

Source: U.S. EPA, 1986c

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GEOLOGY

The Mid-South Wood site is located in the Ouachita Mountains physiographic province in an area of consolidated sedimentary rocks. It is situated on the northern flank of a syncline of shale and sandstone beds that dips to the southwest. A broad anticline forms the mountains north of the site. A fault zone passes through the site underneath the Old Pond area. The zone runs west to east along the east fork of Moon Creek. This fault zone is characterized by highly fractured shales.

The stratigraphic units at the site are the Mississippian age Stanley Group and Jackfork Group and consist of sandstone, shale, and sandstone interbedded with shales. The sandstone contains hairline fractures dipping at angles of 30 to 70 degrees. The fractures in the shale are both horizontal and vertical but are more abundant along the bedding plane surfaces. The interbedded sandstone and shale unit is fractured also. Figure 3 illustrates the site geology, including the fault zone and the bedding structure.

The soils overlying the rock consist of weathered rock, residual soils, and fill material. The residual soil cover on the site is thin and consists of clayey sands, clayey silts, and silty to sandy clay with gravel. The gravel consists primarily of angular rock fragments. The average soil depth is 3 feet, and soil depth ranges from less than 2 feet to 6 feet deep.

HYDROGEOLOGY

The ground water at the site is unconfined and occurs primarily within the weathered surface and the deep fractures of the sandstone and shale bedrock. The depth to water ranges from 3 to 30 feet below land surface and is generally shallowest along topographic highs. The saturated zone within the soil and weathered rock is 1 to 9 feet thick above the bedrock. The primary porosity of the sandstone and shale is limited; most of the ground water occurs in secondary openings such as joints, fractures, and bedding planes.

Ground-water flow at the site generally follows the surface topography. The general direction of horizontal ground-water flow is to the southeast in the eastern third of the site and to the west and southwest in the western two-thirds of the site. In general, hydraulic head decreases with depth over most of the site, indicating that there is the potential for downward ground-water flow. The actual direction of flow within fractures is a function of both the orientation of the fracture and the direction of the prevailing hydraulic gradient.

The ground-water elevation contours are illustrated in Figure 4, which shows that ground-water divides occur along a north-south line near the old plant and along an east-west line between the north and south landfarms. Water level data shown in Figure 4 also suggest that the east fork of Moon Creek is a gaining stream that receives direct ground-water discharge. Although shallow ground-water gradients and flow directions within the weathered rock are believed to mimic the slope of the surface topography, the direction of ground-water flow is controlled by the orientation of the fractures within the unweathered rock.

Ground-water recharge is controlled by the thickness of the soil cover and the abundance of bedrock fractures; areas with thin soil cover and highly fractured rocks respond quickly to precipitation and account for most of the ground-water recharge.

Soils at the site have a lower hydraulic conductivity than the fractured bedrock. Ground-water velocities are approximately 20 feet per year along the fault zone paralleling the east fork of Moon Creek, 30 feet per year along the railroad tracks, and 30 to 60 feet per year along slopes. The average ground-water flow velocity is 35 feet per year.

WASTE CHARACTERISTICS AND POTENTIAL SOURCES

The site is contaminated with organic and inorganic wastes associated with wood-treating processes. The organic wastes consist of PCP and a suite of creosote compounds, most of which are PAHs. Inorganic contaminants include arsenic and chromium.

Onsite contamination was evident during early investigations both in the old areas and at the currently operating CCA plant. In 1984, the highest concentrations of contaminants were in the surface soils and stream sediments (0 to 12 inches) and in the subsurface soils (see Table 1). However, substantial contamination was also found

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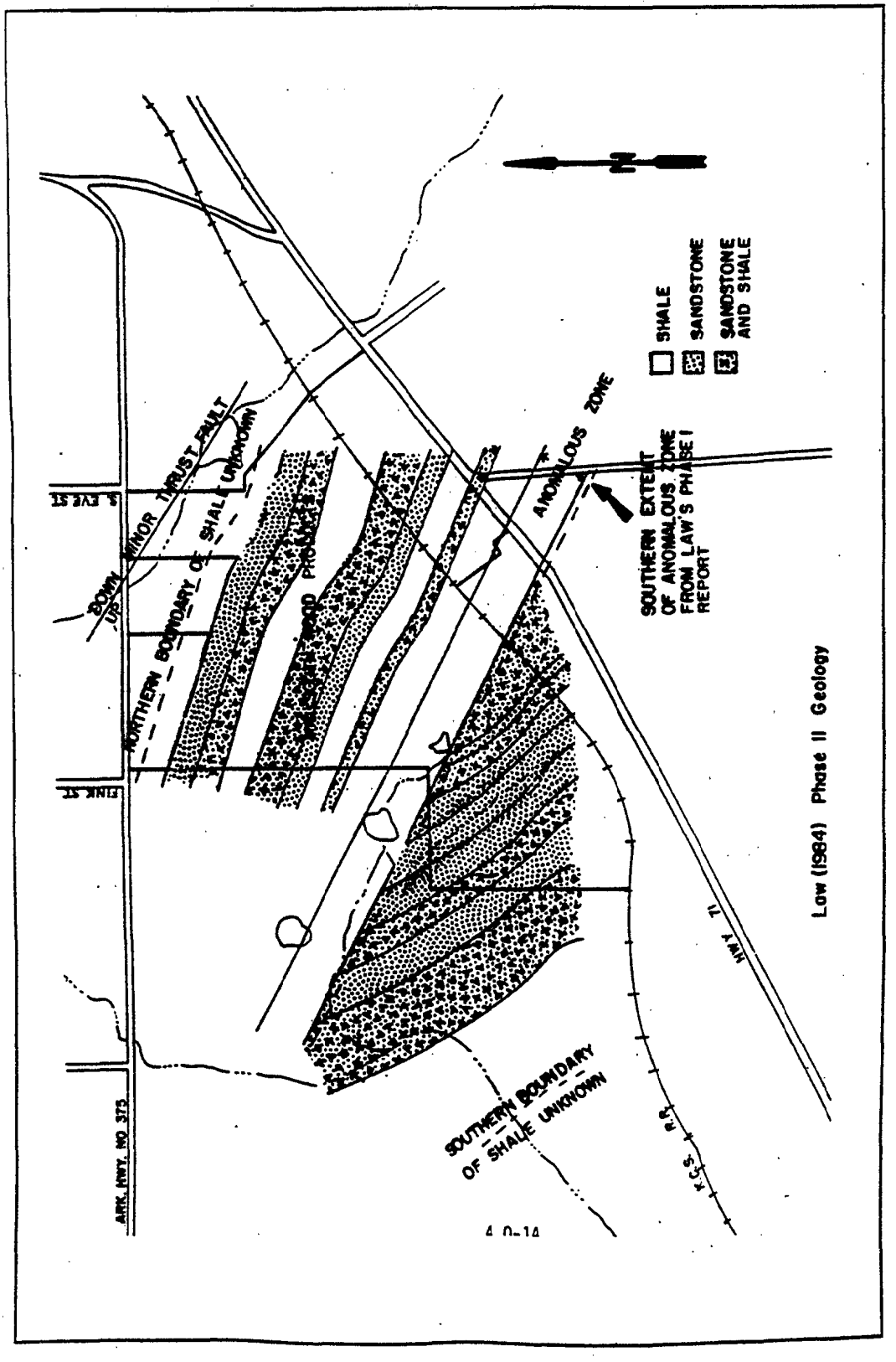

Source: U.S. EPA, 1986b

(Anomalous Zone = Fault Line)

Figure 3
SITE GEOLOGY
MID-SOUTH WOOD PRODUCTS SITE

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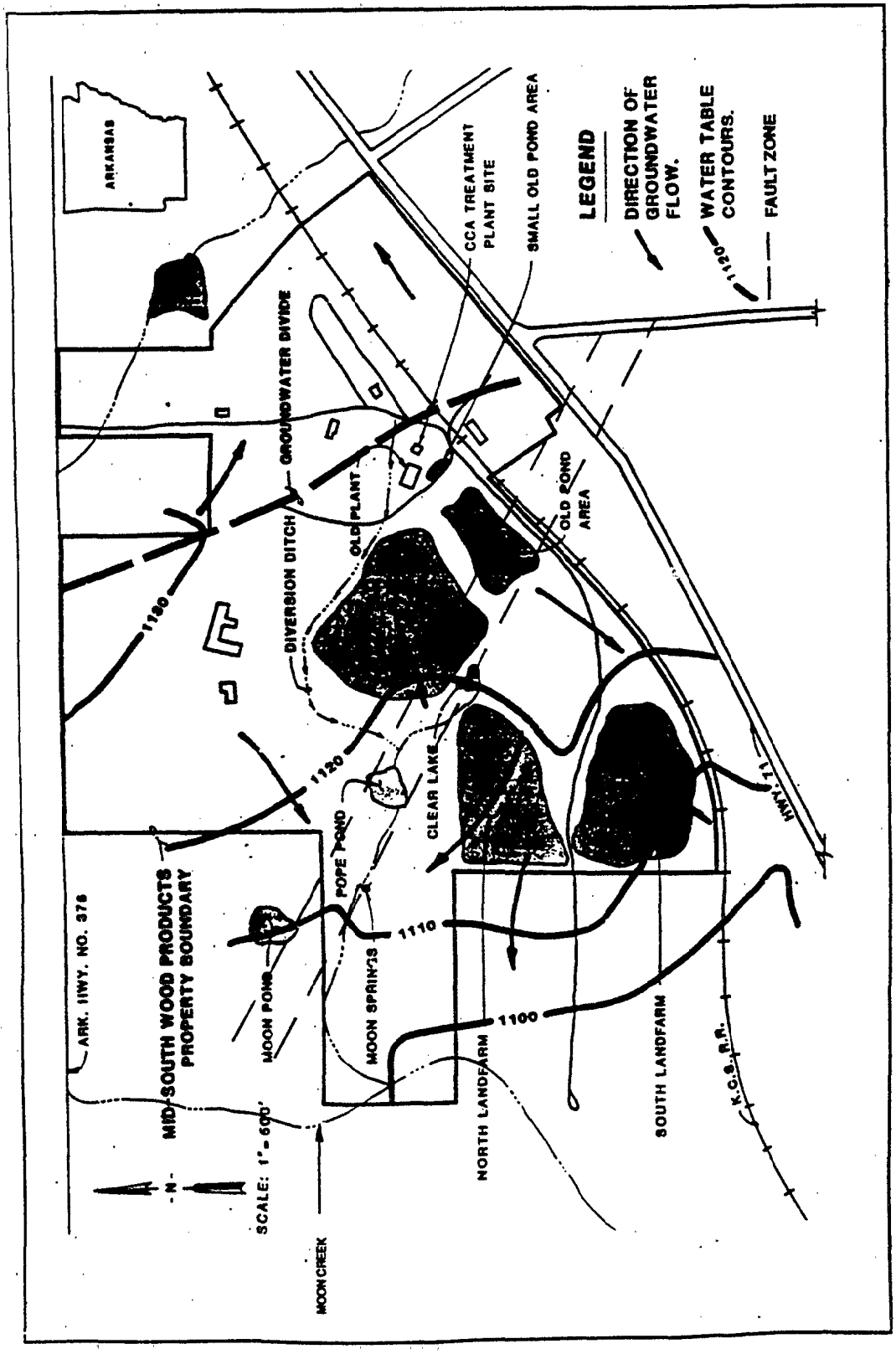

Figure 4
GROUND-WATER CONTOURS AND FLOW DIRECTION PRIOR TO GROUND-WATER RECOVERY
MID-SOUTH WOOD PRODUCTS SITE

Source: U.S. EPA, 1986a

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Table 1
ARITHMETIC MEAN CONCENTRATIONS OF CONTAMINANTS IN VARIOUS MEDIA IN 1984 PRIOR TO REMEDIATION (ppb)

	Surface Water		Ground Water		Surface Soils (0 to 12")		Subsurface Soils		Stream Sediments	
	Onsite	Offsite	Onsite	Offsite	Onsite	Offsite	Onsite	Offsite	Onsite	Offsite
Arsenic	124	28	26*	7	5,450	3,290	3,360	3,880*	16,300	20,300*
Chromium, Total	341	14	27*	8	18,100	11,400	12,000	200*	22,900	24,600*
Fluoranthene	11	358	2,400	3	1,310,000	4,500	126,000	1,350	189,000	4,310
Pentachlorophenol	267	260	3,240	195	2,820,000	417	155,000	211	116,000	3,040
Pyrene	7	231	2,000	3	1,010,000	5,170	96,100	967	146,000	4,660
Acenaphthene	7	149	3,410	6	514,000	100	91,500	314	27,800	313
Acenaphthylene	ND	Tr	Tr	9	21,000	Tr	2,740	ND	48	20
Anthracene	ND	129	2,670	Tr	239,000	467	42,000	157	15,500	301
Benzo(a)anthracene	1	57	445	Tr	221,000	867	18,600	306	29,400	981
Benzo(a)pyrene	ND	Tr	ND	ND	23,500	Tr	Tr	49	905	264
Benzo(b)fluoranthene	2	38	259	Tr	180,000	1,100	9,360	189	37,200	1,180
Benzo(k)fluoranthene	2	38	1	Tr	180,000	317	9,400	89	35,600	761
Chrysene	1	56	429	Tr	231,000	1,580	16,400	343	39,700	1,080
Dibenzofuran	ND	94	905	2	125,000	ND	75,200	343	662	51
Fluorene	ND	185	2,870	3	336,000	Tr	94,600	183	13,700	103
2-Methylnaphthalene	ND	2	5,480	2	3,000	ND	109,000	2,320	824	879
Naphthalene	ND	ND	9,140	2	4,500	ND	188,000	31	1,290	24
Phenanthrene	ND	514	6,130	6	1,140,000	333	251,000	1,550	59,100	1,080

Source: U.S. EPA, 1986c
Data do not include As and Cr samples from the vicinity of the CCA plant.
*Median value
ND - Not detected
Tr - Trace amount

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in the ground water during 1984. The distributions of PCP, arsenic, chromium, and PAH compounds in onsite soils during initial investigations are shown in Figures 5, 6, 7, and 8, respectively. Some amount of the contaminant mass is believed to remain as pools or residuals of free phase liquid contaminants in the soil, the soil/sludge mixture, and the ground water.

The old plant, the two old ponds, and the two landfarms are the primary areas of contamination in the abandoned area. The geologic materials underlying the old plant and the small old pond were, and may still be, heavily contaminated with PCP, several creosote constituents, chromium, and arsenic. Waste oils appear to have migrated from these areas to Moon Springs via the geologic fault. Concentrations of PCP ranging from 260 to 4,200 ppb, and concentrations of several PAH constituents as high as 17,000 ppb were detected in surface water at or near Moon Creek. Analysis of soil samples in the Moon Creek area also revealed elevated concentrations of chromium (118,000 ppb) and arsenic (7,600 ppb).

Before remediation began, PCP levels in the old plant and old waste pond source areas ranged from 200,000 to 11,000,000 ppb in the soil and from 2,000 to 40,000 ppb in the shallow ground water. Chromium levels ranging from 8,000 to 15,000 ppb and arsenic levels from 2,000 to 8,000 ppb were detected in the soil in most areas of the site before remediation began; however, chromium levels as high as 450,000 ppb and arsenic levels as high as 270,000 ppb have been found in the soils in the small old pond area. Concentrations of arsenic and chromium in surface water in the area of the old plant and the two waste ponds ranged from 10,000 to 20,000 ppb. No arsenic and chromium were detected in water samples collected from test pits excavated in the source area. The 1984 arithmetic means of organic and inorganic contaminant concentrations in the old plant and waste pond areas are presented in Table 1.

Contamination in the area of the CCA plant was detected on the surface, in subsurface soils, and in ground water. The soils within 200 feet of the CCA plant contain the highest concentrations of chromium and arsenic contamination of the onsite soils and are a substantial source of these contaminant metals. Arsenic concentrations as high as 1,435,000 ppb have been detected in soils in the CCA plant area. Shallow soils are more contaminated than deeper soils, particularly with copper, chromium, and arsenic. The 1985 arithmetic means of organic and inorganic contaminant concentrations in the vicinity of the CCA plant are presented in Table 2. Both Tables 1 and 2 confirm that contamination of onsite ground water, particularly with organic compounds, was substantial in 1984 and 1985. The concentration of organic contaminants in soils decreases with depth from the ground surface to the water table.

Table 3 lists the chemical properties of several contaminants found at the Mid-South Wood site. All constituents listed in Table 3 have pure phase densities that are greater than water; however, PCP is typically dissolved in light carrier oils as part of the wood treatment process. The aqueous solubility of these constituents is below 20 ppb with the exceptions of PCP, which has a solubility of 14,000 ppb (U.S. EPA, 1982). Reference to Table 1 shows that the average onsite ground-water concentrations of chrysene (429 ppb), benzo(b) fluoranthene (259 ppb), and benzo(a) anthracene (445 ppb) were considerably greater than the solubility in water of these contaminants. Average onsite ground-water concentrations of PCP and benzo(k) fluoranthene were both 23 percent of solubility. These 1984 concentrations were extremely high, especially considering that the in situ concentrations may be even higher due to sample dilution over the 10-foot screen length. Table 1 provides strong evidence that nonaqueous phase liquid contamination existed at the site in 1984.

The CCA stormwater sump, which collects surface water that flows from the CCA plant working area, is a second source of inorganic contaminants. The sump is unlined, allowing contaminated water from the sump to infiltrate directly into the shallow subsurface. Samples of sump water revealed concentrations of copper (2,320 ppb), chromium (29,600 ppb), and arsenic (18,220 ppb) (U.S. EPA, 1986).

Offsite contamination was found during initial investigations in an area 75 to 100 feet in diameter southwest of the railroad tracks at the site's southern border. Contaminant levels of benzo(a) pyrene, were detected in soils at concentrations as high as 1,700 ppb. This offsite soil contamination is thought to be the result of ground-water discharge to the surface. Nonaqueous phase liquids (NAPLs) were observed in the drainage

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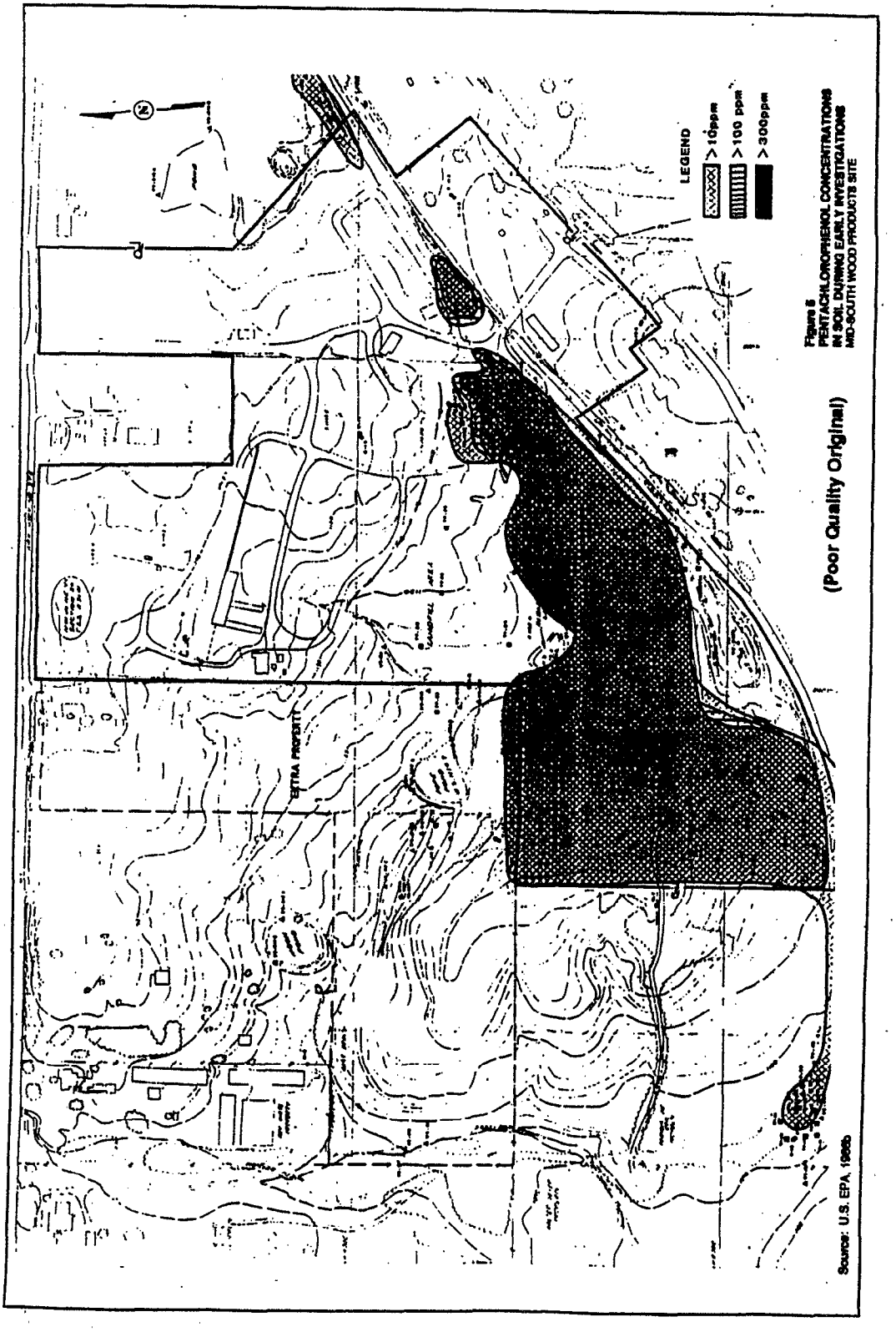

Figure 8
PENTACHLOROPHENOL CONCENTRATIONS IN SOIL DURING EARLY INVESTIGATIONS
MID-SOUTH WOOD PRODUCTS SITE

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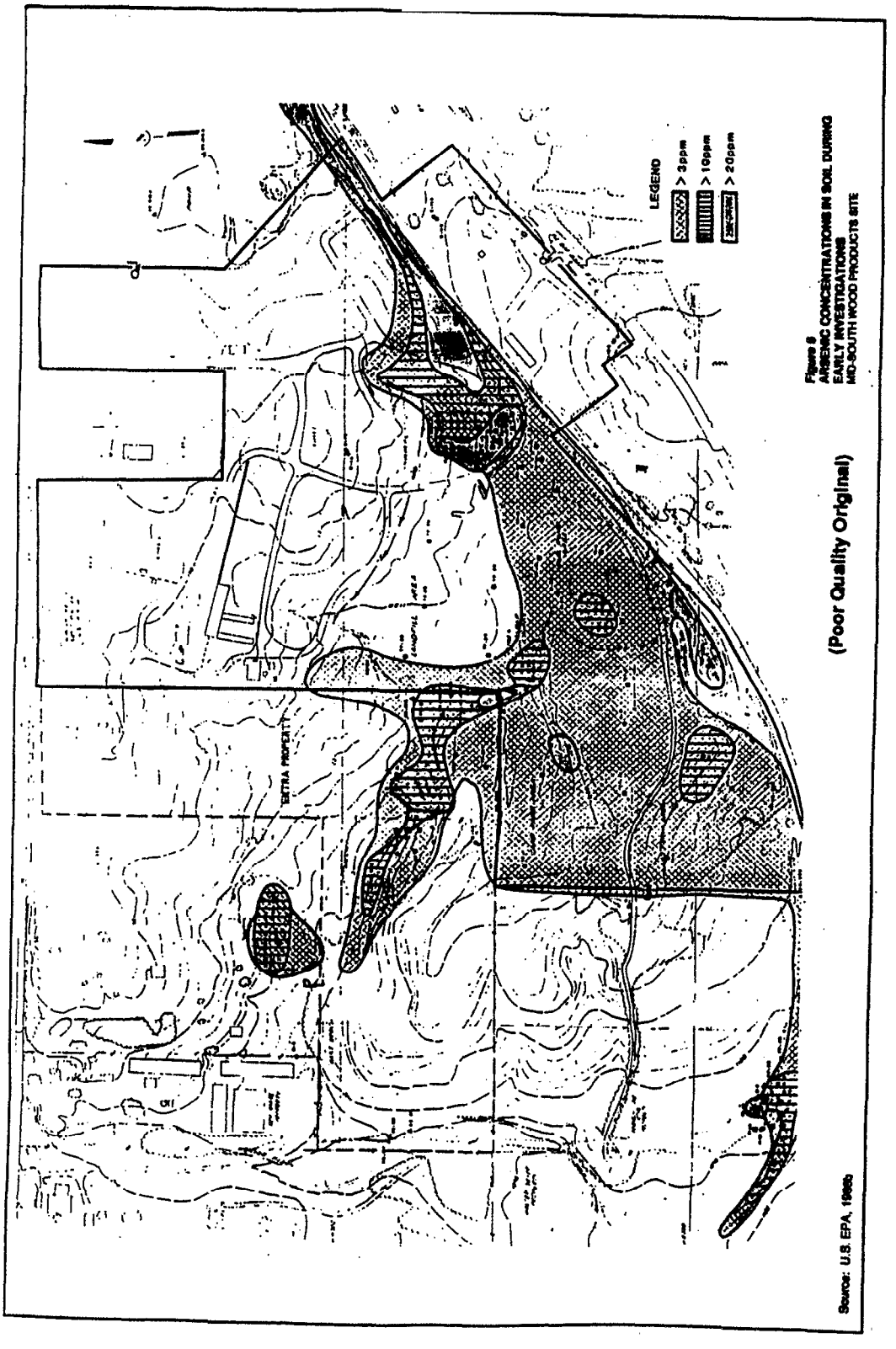
LEGEND
> 3ppm
> 10ppm
> 20ppm
Figure 8
ARSENIC CONCENTRATIONS IN SOIL DURING
EARLY INVESTIGATIONS
MID-SOUTH WOOD PRODUCTS SITE
(Poor Quality Original)
Source: U.S. EPA, 1989

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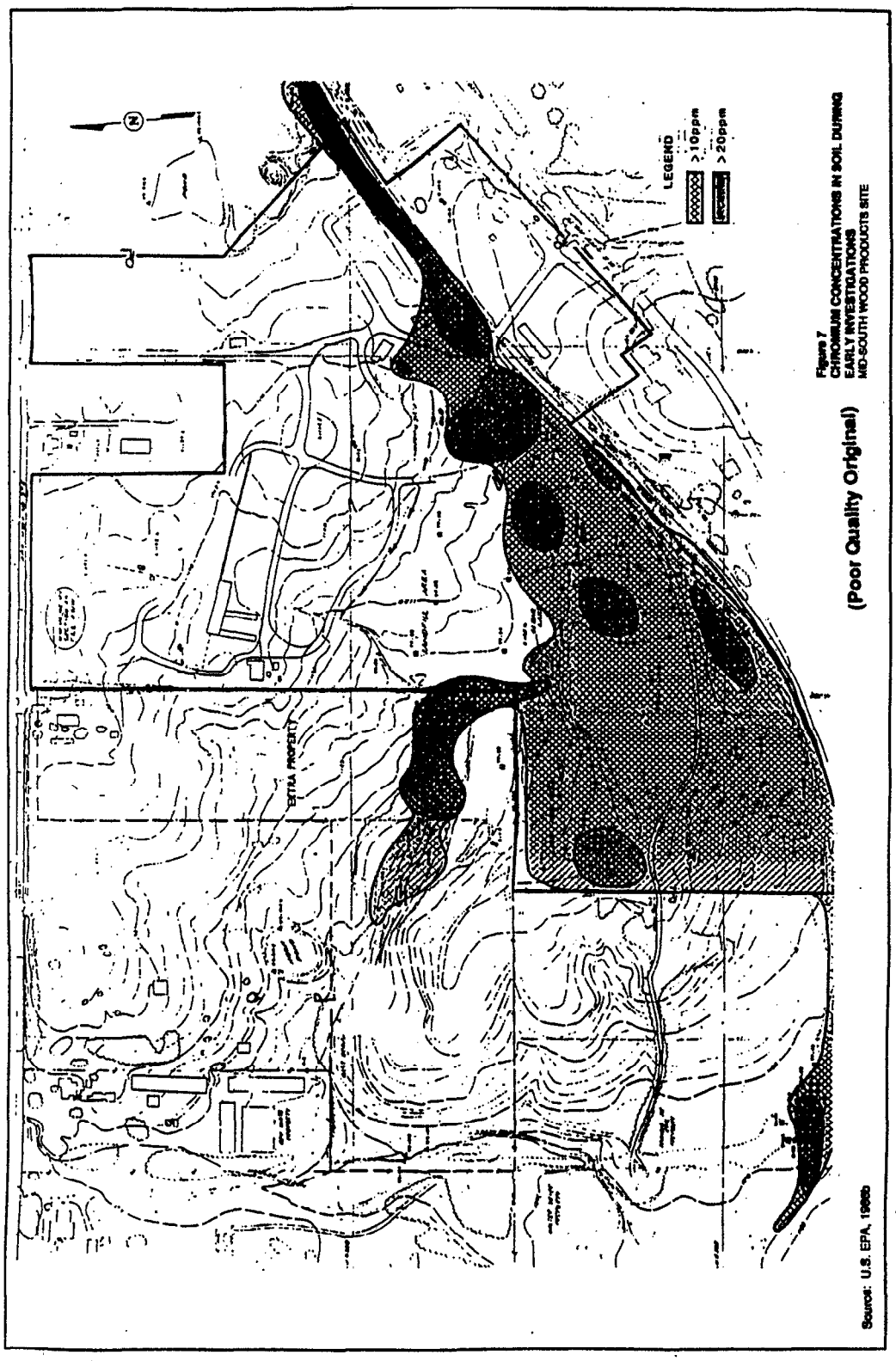

Figure 7
CHROMIUM CONCENTRATIONS IN SOIL DURING
EARLY INVESTIGATIONS
MID-SOUTH WOOD PRODUCTS SITE

(Poor Quality Original)

Source: U.S. EPA, 1986b

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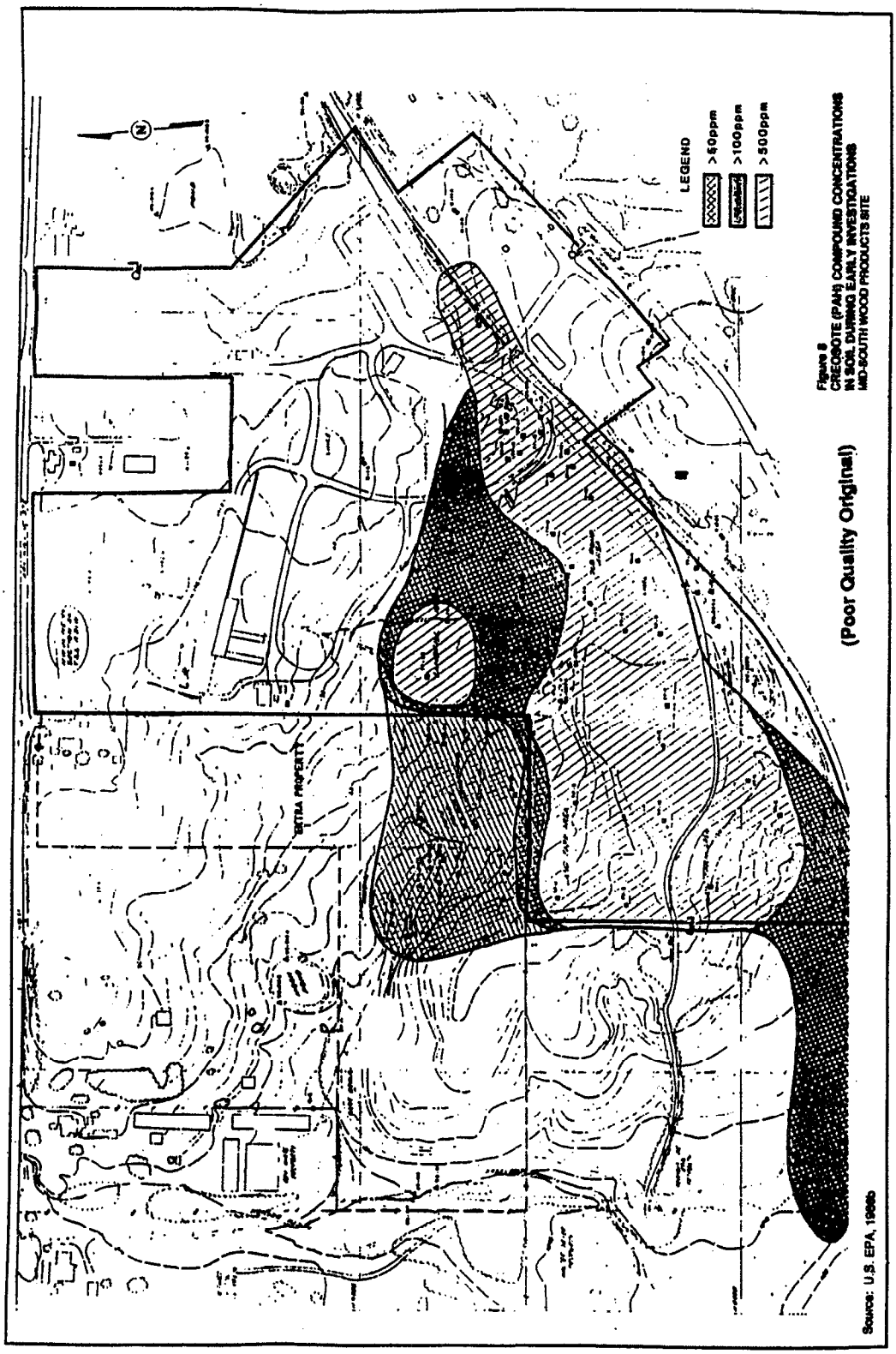

Figure 8
CREOSOTE (PAH) COMPOUND CONCENTRATIONS IN SOIL DURING EARLY INVESTIGATIONS MID-SOUTH WOOD PRODUCTS SITE

Source: U.S. EPA, 1986b

(Poor Quality Original)

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Table 2
ARITHMETIC MEANS OF CONTAMINANT CONCENTRATIONS (ppb)
CCA PLANT SITE AREA, 1985 SAMPLES
MID-SOUTH WOOD PRODUCTS SITE

	Ground Water Well M-14, M-15, M-16, M-17	Surface Soils (0 to 12")	Subsurface Soils (>12")
Arsenic	18	198	2
Chromium, Total	183	22	104
Fluoranthene	263	33,513	20,439
Pentachlorophenol	10,230	187,627	47,387
Pyrene	194	29,078	14,545
Acenaphthene	437	5,136	23,511
Acenaphthylene	ND	ND	ND
Benzo(a)anthracene	35	3,372	2,602
Benzo(b)pyrene	ND	1,215	786
Benzo(b)fluoranthene	ND	10,579	941
Benzo(k)fluoranthene	ND	1,801	770
Chrysene	37	5,527	2,985
Dibenzofuran	300	3,709	17,410
Fluorene	280	4,845	18,488
2-Methylnaphthalene	730	12,091	33,953
Naphthalene	2,585	2,200	44,912
Phenanthrene	617	10,007	38,264
Anthracene	127	1,462	9,187

Source: U.S. EPA, 1986c
ND - Not detected

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Table 3
CHEMICAL PROPERTIES OF SELECT CONTAMINANTS
MID-SOUTH WOOD SITE

	Density (g/cm^3)	Solubility in Water (ppb)	Sediment-Water Partition Constant, K_{oc}
Creosote*	1.05	-	-
PCP	2.0	14,000	5.3×10^4
Polynuclear Aromatic Hydrocarbons (PAHs)			
Benzo(a) Anthracene	1.17	5.7	2.0×10^5
Benzo(b) Fluoranthene	-	14	5.5×10^5
Benzo(k) Fluoranthene	-	4.3	5.5×10^5
Benzo(a) Pyrene	1.35	3.8	5.5×10^6
Chrysene	1.27	1.8	2.0×10^5

Source: U.S. EPA, 1982

*Creosote is a complex mix of 300 to 400 individual chemical constituents, most of which are PAHs.

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ditch in this area. PCP concentrations ranging from 1,000 to 4,000 ppb were identified in both soil and water samples. Although metals were not detected in water samples, chromium (10,000 to 25,000 ppb) and arsenic (1,000 to 5,000 ppb) were detected in soils.

REMEDIATION

Selection and Design of the Remedy

Objectives of Remediation

The objective of remedial activities at the Mid-South Wood site is to reduce potential health risks so that the threat to human health and the environment is decreased to acceptable levels. System designers assumed that exposure of humans to contaminants by wind or erosion would be eliminated by capping contaminated soils. The remaining pathways of potential contaminant migration are: 1) surface-water flows to ground-water supplies, and 2) direct infiltration from source areas down to the water table; therefore, cleanup goals were based on potential ingestion of contaminated ground water.

Standards for total carcinogenic PAHs and for metals were set by estimating the excess cancer risk that would result from consumption of the contaminated water over a lifetime. Because most carcinogens do not have a simple concentration promulgated as a standard, EPA selected a cleanup level for PAHs relative to a specified excess lifetime cancer-risk level. Using a model to calculate the excess risk, the EPA and Hines Lumber Company negotiated a 1×10^{-5} risk level for total PAH compounds of 3,000 ppb (U.S. EPA, 1986c). The cleanup level for PCP was not specified. The action levels for cleanup of arsenic and chromium were established as the upper limit of the range of naturally occurring background levels of these metals. Using this criterion, the cleanup standard for soils is 5,600 ppb for arsenic and 19,400 ppb for chromium (U.S. EPA, 1986c).

National Pollutant Discharge Elimination System (NPDES) permits were also required to discharge treated ground water to surface drains. Daily maximum discharge levels were set for arsenic (50 ppb), chromium (50 ppb), and for two of the PAH compounds (naphthalene, 2,300 ppb; fluoranthene, 3,980 ppb).

System Configuration

Remedial actions at the Mid-South Wood site consist of a combination of technologies, including soil excavation and capping, ground-water recovery and treatment, and ground-water monitoring. Ground-water recovery is accomplished using a system of French drains and extraction wells. Figure 9 illustrates the major components of the current remediation and monitoring system, which began operating in the summer of 1989. An earlier remediation system, consisting of extraction Wells RW-1, RW-2, and RW-3, installed in three French drains, was constructed in late 1984 and began operating in early 1985.

Contaminated soils from the old pond, the small old pond, and the old plant areas were excavated, stabilized, and consolidated in the old pond. All other contaminated soils were consolidated in the north landform area (B&F Engineering 1991b).The old pond and the north landfarm were then capped with clay, sand, and topsoil to prevent further contamination of ground water.

The final ground-water recovery system, which began operating in the summer of 1989, was designed to remove contaminated ground water from several locations throughout the site and treat the contaminated water to NPDES permit concentrations. To recover contaminated ground water, eight French drains and 15 recovery wells were installed. Nine of the recovery wells are within the sumps of the French drains, and six others are isolated, deep extraction wells. French drains were chosen to recover contaminated ground water because the fractured nature of the bedrock below the site would result in low yields from a system composed only of drilled extraction wells. The French drains are located at the CCA plant, around the tanks and pressure chamber of the old plant, along the perimeter of the old pond, and in line with the northwest-southeast fault zone. The French drain trenches were excavated to the depth of backhoe refusal at the top of the bedrock--a depth of approximately 15 feet. The system was designed to collect contaminated ground water from shallow depths where flow and contaminant concentrations were expected to be greatest. Figure 10 is a cross section of a typical drain.

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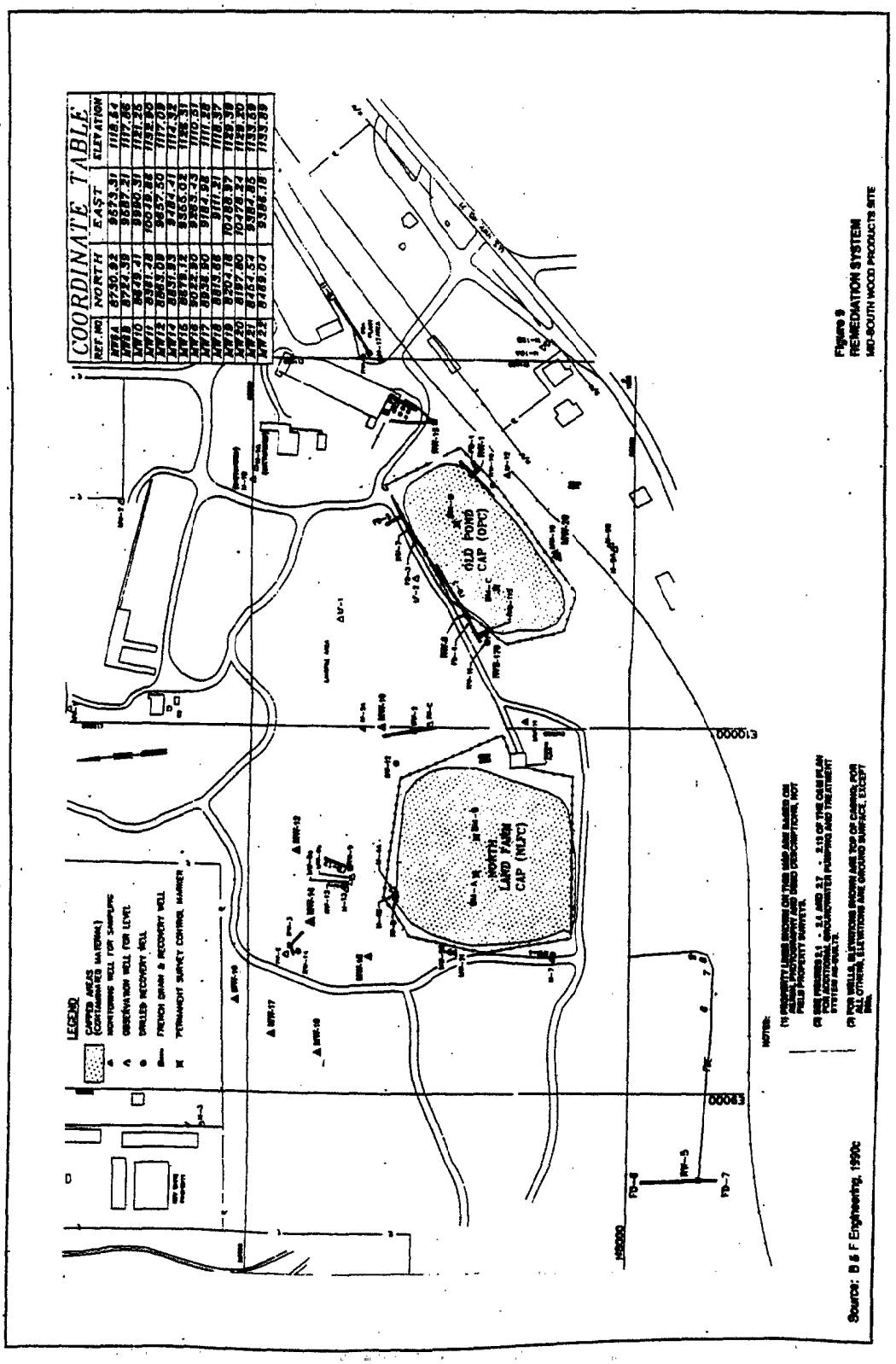
COORDINATE TABLE
REF. NO. | NORTH | EAST | ELEVATION
MW9A | 8730.92 | 9573.31 | 1118.64
MW9B | 8724.39 | 9587.21 | 1117.86
MW10 | 8649.41 | 9590.31 | 1121.25
MW11 | 8361.48 | 9657.50 | 1132.90
MW12 | 8863.09 | 9657.50 | 1117.09
MW14 | 8831.93 | 9484.41 | 1114.32
MW15 | 8679.12 | 9365.02 | 1126.31
MW16 | 9022.90 | 9263.43 | 1110.51
MW17 | 8936.90 | 9184.96 | 1111.28
MW18 | 8813.66 | 9181.21 | 1118.37
MW19 | 8204.18 | 10488.97 | 1129.39
MW20 | 8197.80 | 10478.24 | 1129.20
MW21 | 8454.54 | 9384.85 | 1133.59
MW22 | 8469.04 | 9386.18 | 1133.89
LEGEND
CAPPED AREAS (CONTAMINATED MATERIAL)
MONITORING WELL FOR SAMPLING
OBSERVATION WELL FOR LEVEL
DRILLED RECOVERY WELL
FRENCH DRAIN & RECOVERY WELL
PERMANENT SURVEY CONTROL MARKER
OLD POND CAP (OPC)
NORTH LAND FARM CAP (NLFC)
E10000
E9000
N8000
NOTES:
Source: B & F Engineering, 1990c
Figure 9
REMEDIATION SYSTEM
MID-SOUTH WOOD PRODUCTS SITE

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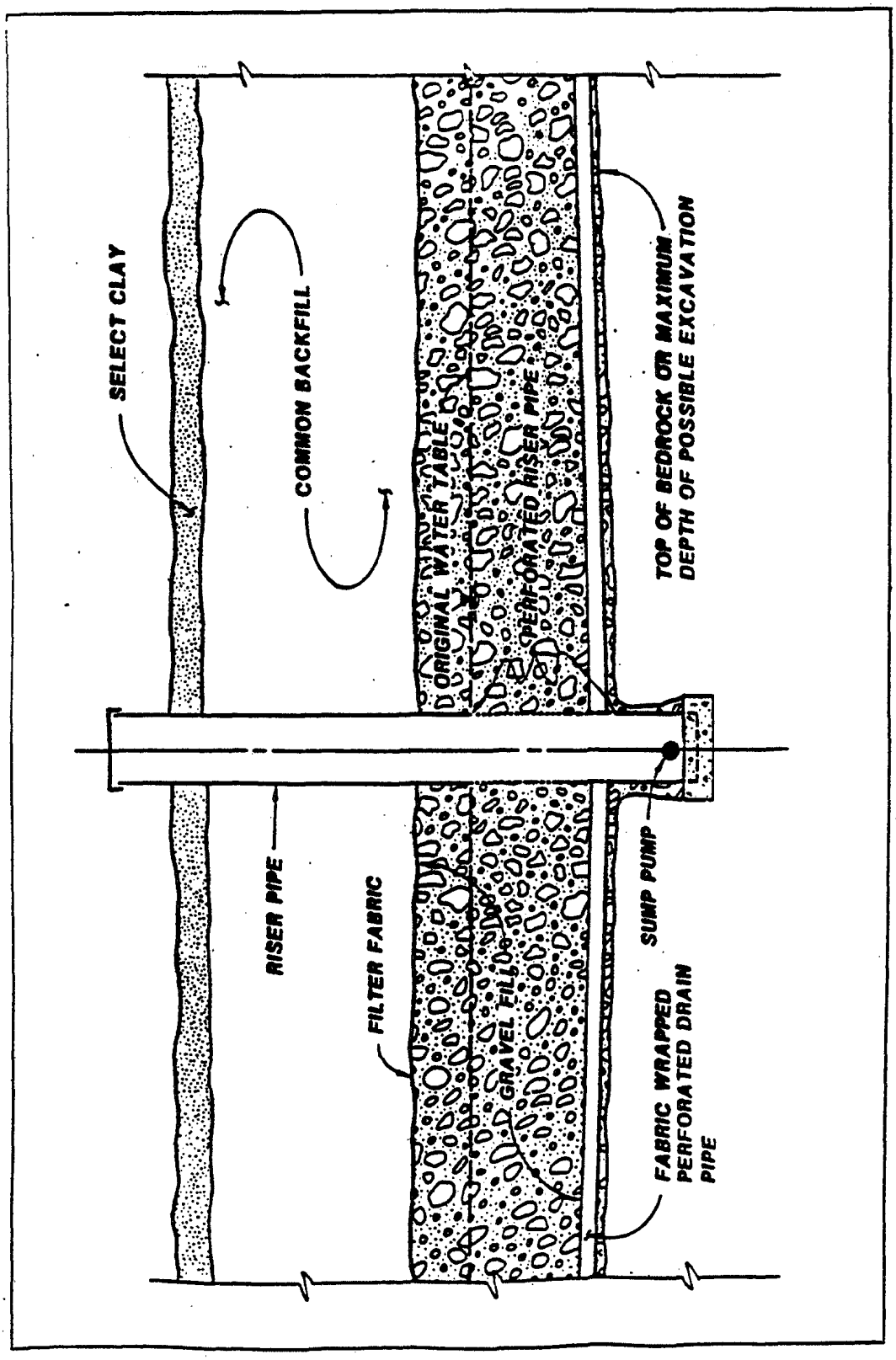

Source: U.S. EPA, 1986c

Figure 10
CROSS SECTION OF GROUND-WATER RECOVERY SYSTEM
MID-SOUTH WOOD PRODUCTS SITE

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After the contaminated ground water has been intercepted by French drains, it is collected by the recovery-well system. The annual average flow rate from the recovery wells is estimated to be about 30 gpm, with an average peak weekly flow of 42 gpm. If the flow from the wells does not contain NAPLs, it is pumped through force mains to a storage tank and is later treated by carbon adsorption to remove organics (B&F Engineering, 1991b). Once treated, effluent is discharged to surface drains.

If the water from the recovery wells contains NAPLs, it is channeled through the oil/water separator to remove oils or sludges prior to carbon treatment. Figure 11 illustrates the oil-recovery system. Ground water contaminated with NAPLs is removed from the recovery well by installing a recirculation pipe to break up the phasing in the well. Oils and sludges are then pumped into a retention tank above the oil/water separator. After NAPLs have been transferred to the retention tank, the recovery well is removed from service for 1 week before it resumes a normal operating schedule. The NAPLs remain in the retention tank for the same period of time and are then drained into the separator, where the free oils are recovered and disposed of in compliance with current Federal and state regulations. According to the Operations and Maintenance (O&M) plan for Mid-South Wood (B&F Engineering, 1990c), the expected amount of free oils and sludges is estimated to be less than 50 gallons per year.

Monitoring wells were installed at three onsite areas--along the perimeter of the two capped areas, near the various French drains, and along the geologic fault zone--to assess contaminant movement and evaluate the effectiveness of contaminant recovery. Most of the monitoring wells were installed to depths betweem 30 and 60 feet; however, one Well--IWB-170--was drilled to 172 feet (B&F Engineering, 1989). Figure 9 shows the location of the monitoring wells.

EVALUATION OF PERFORMANCE

The final ground-water extraction and treatment system at the Mid-South Wood site has been operating since the summer of 1989; a smaller temporary system began operating in early 1985. The monitoring system has been sampled quarterly since the system began operation. Tables 4 and 5 show contaminant concentrations in nine monitoring wells and in 15 recovery wells over four quarterly sampling events beginning in the fourth quarter of 1989 and ending in the third quarter of 1990. Most of the monitoring wells are located near Moon Spring and are north-northwest of the north landfarm. MW-10 is between the north landfarm and the old pond, and MW-20 and IWB-170 are along the western border of the old pond area. The recovery wells are distributed throughout the site. The ground water in the Moon Springs area is downgradient of the north landfarm and the old pond. Ground water is believed to flow relatively efficiently from the main old plant/old pond area to the Moon Springs area along the fracture zone.

In general terms, the concentrations in the recovery and monitoring wells listed in Tables 4 and 5 are considerably lower than the concentrations in onsite monitoring wells measured in 1984 and 1985. None of the wells had any of the three listed PAH compounds at concentrations above detection limits during the four quarterly sampling events in 1989 and 1990. However, the aqueous solubility of benzo(a) anthracene and benzo(a) pyrene is below the detection limit, and the aqueous solubility of benzo(b&k) fluoranthene is only slightly higher than the detection limit, so the data of Tables 4 and 5 should not be inferred as precluding the existence of these contaminants in either dissolved or DNAPL form. These three PAH compounds are not necessarily the most abundant of the PAHs present at the site, and their total mass relative to all PAHs is unknown. The combined concentration of PAHs was not reported, so a comparison of PAH contamination to the cancer-related cleanup standard of 3,000 ppb of total PAHs established for the site is not possible.

The concentration of PCP generally has decreased since 1984 and 1985. The concentration of PCP in the nine monitoring wells was below detection in all wells except for MW-15, located northwest of the north landfarm, and in MW-20 and IWB-170 on the western boundary of the old pond. Ground water in MW-15 is downgradient of the north landfarm and may have been contaminated by the wastes deposited there; however, the PCP concentrations in MW-15 were only slightly higher than the detection limit. Concentrations of PCP in MW-20 (110 to 4,400 ppb) and in IWB-170 (140 to 1,900 ppb) are quite high and are quite variable over time. Concentrations increased after remediation began, but did decrease in the third

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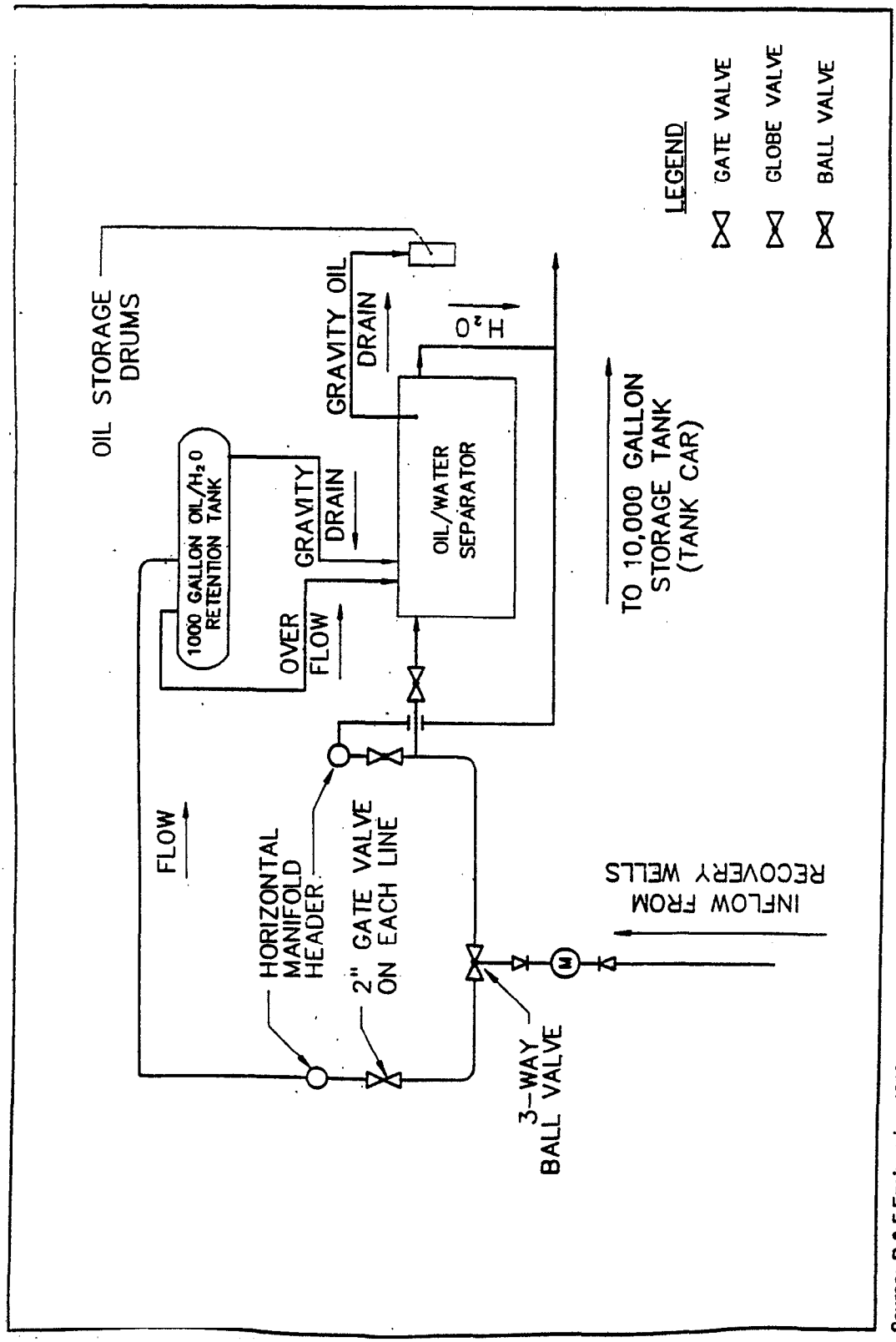

Figure 11
OIL RECOVERY SYSTEM
MID-SOUTH WOOD PRODUCTS SITE

Source: B & F Engineering, 1990

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Table 4
CONCENTRATIONS OF CONTAMINANTS IN MONITORING WELLS
FOURTH QUARTER 1989 TO THIRD QUARTER 1990
MID-SOUTH WOODS SITE

	Arsenic (ppb)				Chromium (ppb)				PCP (ppb)			
	4Q89	1Q90	2Q90	3Q90	4Q89	1Q90	2Q90	3Q90	4Q89	1Q90	2Q90	3Q90
MW-10	<2	9.3	7.4	6.9	<50	<50	<50	<50	<1	<1	<1	<1
MW-12	2.1	<2	2.5	<2	<50	<50	<50	<50	<1	<1	<1	<1
MW-14	<2	<2	<2	<2	<50	<50	52	<50	<1	<1	<1	<1
MW-15	<2	2.4	2.7	2.1	<50	<50	80	<50	2.2	<1	<1	2.1
MW-16	<2	3.2	<2	<2	<50	<50	<50	<50	<1	<1	<1	<1
MW-17	4.8	5.9	3.6	2.4	<50	<50	<50	<50	<1	<1	<1	<1
MW-18	10	16	9.6	7.7	<50	<50	<50	<50	<1	<1	<1	<1
MW-20	5.1	2.7	6.2	11	<50	<50	<50	<50	110	320	4,400	<1
IWB-170	<2	3.3	3.0	<2	<50	<50	<50	<50	140	1,700	1,900	370

Sources: B&F Engineering, 1989, 1990a, 1990b, 1990d, 1990e

Screened intervals (ft): MW-10, 29 to 39; MW-12, 47 to 57; MW-14, 48 to 58; MW-15, 49 to 59; MW-16, 25 to 35; MW-17, 25 to 35; MW-18, 26 to 36; MW-20, 30 to 40; IWB-170, 162 to 172

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Table 4
CONCENTRATIONS OF CONTAMINANTS IN MONITORING WELLS
FOURTH QUARTER 1989 TO THIRD QUARTER 1990
MID-SOUTH WOODS SITE

	Benzo(a)anthracene (ppb)				Benzo(b & k)fluoranthene (ppb)				Benzo(a)pyrene (ppb)			
	4Q89	1Q90	2Q90	3Q90	4Q89	1Q90	2Q90	3Q90	4Q89	1Q90	2Q90	3Q90
MW-10	<10	<10	<10	<10	<20	<20	<10	<10	<10	<10	<10	<10
MW-12	<10	<10	<10	<10	<20	<20	<10	<10	<10	<10	<10	<10
MW-14	<10	<10	<10	<10	<20	<20	<10	<10	<10	<10	<10	<10
MW-15	<10	<10	<10	<10	<20	<20	<10	<10	<10	<10	<10	<10
MW-16	<10	<10	<10	<10	<20	<20	<10	<10	<10	<10	<10	<10
MW-17	<10	<10	<10	<10	<20	<20	<10	<10	<10	<10	<10	<10
MW-18	<10	<10	<10	<10	<20	<20	<10	<10	<10	<10	<10	<10
MW-20	<10	<100	<10	<10	<20	<200	<10	<10	<10	<100	<10	<10
IWB-170	<100	<10	<100	<100	<200	<20	<100	<100	<100	<10	<100	<100

Sources: B&F Engineering, 1990a, 1990b, 1990d, 1990e

Screened intervals (ft): MW-10, 29 to 39; MW-12, 47 to 57; MW-14, 48 to 58; MW-15, 49 to 59; MW-16, 25 to 35; MW-17, 25 to 35; MW-18, 26 to 36; MW-20, 30 to 40; IWB-170, 162 to 172

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Table 5
MID-SOUTH WOOD RECOVERY SYSTEM: CONTAMINANT CONCENTRATIONS IN RECOVERY WELLS
FOURTH QUARTER 1989 TO THIRD QUARTER 1990

	PCP (ppb)				Arsenic (ppb)				Chromium (ppb)			
	4Q89	1Q90	2Q90	3Q90	4Q89	1Q90	2Q90	3Q90	4Q89	1Q90	2Q90	3Q90
RW-1	NS	820	900	1,300	NS	17	32	36	NS	<50	<50	<50
RW-2	17	6.7	2	2.1	3.7	3.6	5.2	6.5	<50	<50	<50	<50
RW-3	NS	700	280	NS	NS	<2	5.8	NS	NS	<50	<50	NS
RW-4	<1	1.8	1.7	NS	<2	<2	<2	NS	<50	<50	<50	NS
RW-5	160	380	360	NS	<2	<2	2.7	NS	<50	<50	<50	NS
RW-6	26	NS	2.1*	NS	6.6	NS	3.5	NS	<50	NS	<50	NS
RW-7	27	280	88	2.5	16	6.2	50	31	<50	<50	<50	<50
RW-8	2,500	1,700	2,100	10,000	11	5.3	8	94	<50	<50	<50	<50
RW-9	NS	1,500	1,500	NS	NS	<2	4.6	4.6	NS	NS	<50	<50
RW-10	280	120	350	5.7	30	4.2	2.6	16	<50	<50	<50	<50
RW-11	NS	370	39	66	NS	<2	<2	<2	NS	<50	<50	<50
RW-12	<1	4	39	NS	<2	3.8	2.7	NS	<50	<50	<50	<50
RW-13	38	200	190	NS	<2	6.5	6.8	NS	<50	<50	<50	NS
RW-14	<1	1,300	16	NS	<2	2.9	6	NS	<50	<50	<50	NS
RW-15	15,000	65,000	5,800	3,700	410	16,000	3	2,200	840	25,000	620	200

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Table 5
MID-SOUTH WOOD RECOVERY SYSTEM: CONTAMINANT CONCENTRATIONS IN RECOVERY WELLS
FOURTH QUARTER 1989 TO THIRD QUARTER 1990

	Benzo(a)anthracene (ppb)				Benzo(b+k)fluoranthene (ppb)				Benzo(a)pyrene (ppb)			
	4Q89	1Q90	2Q90	3Q90	4Q89	1Q90	2Q90	3Q90	4Q89	1Q90	2Q90	3Q90
RW-1	NS	<10	<10	<100	NS	<20	<10	<100	NS	<10	<10	<100
RW-2	<10	<10	<10	<10	<20	<20	<10	<10	<10	<10	<10	<10
RW-3	NS	<10	<10	NS	NS	<20	<10	NS	NS	<10	<10	NS
RW-4	<10	<10	<10	NS	<20	<20	<10	NS	<10	<10	<10	NS
RW-5	<10	<10	<10	NS	<20	<20	<10	NS	<10	<10	<10	NS
RW-6	<10	NS	<10	NS	<20	NS	<10	NS	<10	NS	<10	NS
RW-7	<10	<10	<10	<1,000	<20	<20	<10	<1,000	<10	<10	<10	<1,000
RW-8	<10	<10	<20	<1,000	<20	<20	<20	1,000	<10	<10	<20	<1,000
RW-9	NS	<10	<10	NS	NS	<20	<10	NS	NS	<10	<10	NS
RW-10	<10	<10	<10	<10	<20	<20	<10	<10	<10	<10	<10	<10
RW-11	NS	<10	<10	<200	NS	<20	<10	<200	NS	<10	<10	<200
RW-12	<10	<10	<10	NS	<20	<20	<10	NS	<10	<10	<10	NS
RW-13	<10	<10	<10	NS	<20	<20	<10	NS	<10	<10	<10	NS
RW-14	<10	<10	<10	NS	<20	<20	<10	NS	<10	<10	<10	NS
RW-15	<10	<1,000	<100	<100	<20	<2,000	<100	<100	<10	<1,000	<100	<100

Source: B&F Engineering, 1990a; 1990b; 1990d; and 1990e
NS = Not sampled during that quarter
*RW-6, 2Q90 data from 4/12/90 sample

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quarter of 1990. The contamination in IWB-170 is especially significant because it demonstrates that contamination exists at depths of at least 172 feet in the northwest corner of the old pond. The extent of deep contamination is not known. Additional study of the deep contamination was considered too costly considering the complexity of the site geology. The high variability and high concentrations relative to the aqueous solubility of PCP in Wells MW-20 and IWB-170 suggest that the ground-water contamination in these wells may be the result of dense, nonaqueous phase liquidcontamination, especially considering the depth of IWB-170.

PCP and arsenic contamination was detected also in the recovery wells shown in Table 5. Consistently high concentrations of PCP and arsenic were detected in RW-1, RW-8, and RW-15, which pump from French drain systems in the old plant and old pond areas. The liquids collected in these drain systems include ground water contaminated with dissolved constituents and possibly some carrier oil contaminated with PCP. The arsenic and chromium contamination in RW-15--16,000 ppb and 25,000 ppb, respectively, in the first quarter of 1990--was probably the result of the CCA plant northeast of the French drain pumped by RW-15. Chromium concentrations in all recovery wells except RW-15 were below detection limits during each of the four sampling periods. PAHs were below detection in all recovery wells.

The standards at which soil removal action would be required for both arsenic and chromium are based on background soil. Although chromium and arsenic occur naturally in some soils in concentrations as high as 5,000 ppb and 3,000 ppb, respectively, they were not found at this site in background water samples. However, because these metals are treated and discharged, they are subject to compliance with NPDES daily maximum discharge standards. The discharge water standards are 50 ppb for both metals. Arsenic and chromium concentrations comply with this effluent standard even before treatment at all monitoring and recovery well locations, with the exception of RW-15, which is located in the vicinity of the CCA treatment plant.

One of the factors that probably caused the decrease in contaminant concentrations in ground water from 1985 to the fourth quarter of 1989 was the operation of the interim three-well recovery system from early 1985 to mid-1989. Natural attenuation and downward and lateral migration of the contaminant are other factors. The operation of the full-scale 15-well recovery system starting in mid-1989 also probably contributed to the reductions observed by the fourth quarter of 1989.

It is difficult to assess the lateral extent of the improvement in ground-water quality. Because of the complex fracture system and the potentially limited interconnection between fractures, it is possible that the improvements in water quality are not laterally extensive and that substantial pockets of contamination remain. Also, because the French drains were excavated to relatively shallow depths, the remediation system addresses only shallow ground-water contamination and the removal of LNAPLs. The system does not address contamination by the dense, nonaqueous phase liquids that are believed to exist at the site.

SUMMARY OF REMEDIATION

The Mid-South Wood site has been contaminated by spills of wood treatment chemicals and by disposal of these materials in open ponds. Contamination occurred both onsite and offsite in soils, surface water, and ground water. Contaminants of concern for ground water are PCP, a suite of creosote compounds (PAHs), arsenic, and chromium. None of these is known to be native at detectable levels in ground water. The primary sources of PCP and creosote contamination were the old plant and the old pond. The main source of metals contamination was the CCA treatment facility.

Remedial action was initiated to address both the soil and ground-water contamination at the site. Action included consolidating and capping contaminated soils in the landfarms and implementing a French drain and drilled well recovery system for contaminated ground water. An interim system of three French drains with recovery Wells (RW-1, RW-2, and RW-3) began operating in early 1985. The current system of 8 French drains and 15 recovery wells began operating in the summer of 1989.

Monitoring- and recovery-well data from the first four quarters of operation in 1989 and 1990, when compared to data from 1984 and 1985, provided the basis for the evaluation of the system. Drawing definitive conclusions from the limited

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data would be premature. In general, however, the data show that concentrations were significantly lower in 1989 and 1990 than in 1984 and 1985. The PAH compounds that were analyzed--chrysene, benzo(a)anthracene, benzo (b+k) fluoranthene, and benzo(a)pyrene--were not found in 1989 and 1990 in concentrations that exceed health-based standards in any of the wells sampled. Arsenic and chromium were also near or below detection limits in all wells, with the exception of recovery Well RW-15, in 1989 and 1990. The arsenic and chromium in RW-15 are believed to be the result of contamination originating from the CCA treatment plant.

Significant concentrations of PCP were found in two monitoring wells (MW-20 and IWB-170) and in several recovery wells in 1989 and 1990. The PCP found in MW-20 and in the recovery wells is probably due to the dissolution of PCP from sources in the waste ponds and landfarms, and the interception of light free-phase carrier oils containing PCP. LNAPL contamination by oils has been observed within the French drain recovery system (U.S. EPA, 1991b). The presence of high concentrations of PCP in IWB-170 at a depth of 172 feet is a strong indication of dense free-phase (DNAPL) contamination. Evidence of free-phase contamination was observed directly in fractures in core samples taken from the deepest intervals of IWB-170 (U.S. EPA, 1991b). The limits of the depth of contamination in other areas was reported to be 60 feet (B&F Engineering, 1991b); however, no other wells were deeper than 59 feet as of the end of 1989 (B&F Engineering, 1989). Because of the high cost of investigating deep DNAPL contamination in fractured rock, and the fact that the deep aquifer was not used as a water supply, additional investigations were not considered cost-effective.

The general reduction in contaminant concentrations observed in ground water from 1985 to 1990 can be attributed in part to the ground-water recovery system. The operation of the 3-well extraction system from early 1985 to mid-1989 and of the 15-well system from mid-1989 to the fourth quarter of 1989 probably decreased concentrations to some degree; however, it is also possible that the contaminants were attenuated naturally from 1985 to 1989 or migrated laterally or downward because of ground-water gradients or contaminant density. Because of the complex fracture system and the possibility that the fractures intercepted by the recovery system may not be connected to other highly contaminated fractures nearby, it is difficult to draw conclusions about overall ground-water cleanup at the site. The fracture system is highly heterogeneous; as a result, adjacent sampling points may contain significantly different concentrations of contaminants. This heterogeneity in contaminant distribution is compounded by the presence of LNAPL and DNAPL contamination.

The data shown in Tables 4 and 5 suggest that there is little evidence of residual creosote contamination at the site. However, the lack of detectable concentrations of creosote in the form of three PAHs in 1989 and 1990 may be a result of the placement of the recovery and monitoring system at shallow depths. The aqueous solubility of PAHs is also generally below the detection limits shown in these tables, which means that it would be possible to have nearby DNAPL pools without exceeding the detection limits. Creosote has a tendency to exist as a DNAPL because of its density of approximately 1.05 g/cm^3 and its viscosity, which is 50 to 70 times that of water. The absence of creosote contamination in recent ground-water samples despite the use of creosote as a wood treatment liquid from approximately 1955 to 1977 may be due to the downward migration of most of the creosote contamination below the monitoring and recovery system. Therefore, it is possible that DNAPL creosote contamination exists at depth and is undetected by the existing system. The evidence for the existence of PCP, a treatment compound used from 1967 to 1977, in DNAPL at depths of at least 172 feet is strong because of the high concentrations of dissolved PCP found (14% of aqueous solubility). DNAPL observed in fractures down to 172 feet may consist of both PCP and creosote; however, only PCP was detected in the deep ground-water samples.

Pathways for potential migration of dissolved constituents are primarily to the west from the old plant and small pond areas, although some contamination may migrate east from the old plant. Some of the contaminants that originated in the source areas appear to be migrating directly to Moon Spring along the fault zone. These contaminants are at relatively shallow depths due to vertical upward gradients in the fault zone. Contamination is also suspected at the railroad tracks to the south. Downward migration by

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DNAPLs is another potential contaminant migration pathway.

SUMMARY OF NAPL-RELATED ISSUES

The presence of LNAPL contamination by carrier oils at the Mid-South Wood site has been observed directly. LNAPL and shallow, dissolved contamination have been the focus of site investigations and remediation to date. However, it is also known that some onsite DNAPL contamination exists, particularly along the fault line. Although preliminary analytical results from ground-water sampling revealed that levels of onsite contaminants, including PCP and PAHs, were generally reduced, these concentrations cannot be interpreted to preclude the possibility that DNAPLs eventually will be detected in ground-water samples from the current monitoring network. The presence of several PAHs and PCP at concentrations greater than their aqueous solubility in 1984 and 1985 suggests that DNAPLs were present at that time. DNAPLs were observed to depths of 172 ft during deep drilling.

Free oil containing creosote compounds and/or PCP, was disposed of onsite in the old plant and old pond areas over a period of more than two decades. Some free phase creosote was also disposed of during this period. Creosote and PCP have chemical properties that tend to favor their accumulation and migration as DNAPLs. For example, PCP and the PAH compounds have densities greater than that of water, which favors their downward migration in the saturated zone. The density of PCP is 2.0 g/cm^3, and the density of most of the PAH compounds is approximately 1.2 g/cm^3. Free phase compounds with these densities can migrate downward readily, regardless of hydraulic gradients.

The high viscosity of creosote inhibits its recovery, particularly in gravity flow systems such as French drains. Creosote's high viscosity greatly decreases its mobility in response to hydraulic gradients and may account for the failure to detect PAHs in 1989 and 1990 (see Tables 3 and 4). The principal migration direction of creosote is expected to be downward through the complex fracture network rather than lateral in response to hydraulic gradients.

DNAPL migration is affected by the geologic structure of the site. The fault zone at Mid-South Wood is characterized by highly fractured rocks that may provide an effective pathway for downward DNAPL migration. At the time of the remedial investigation, there was evidence of migration into the underlying shale and residual contamination in the fracture zone. Even if capping the contaminated soils inhibited additional migration of contaminants dissolved in ground water, DNAPL contaminants may continue to migrate downward into the fractured rock. Site investigations also revealed that, due to the fractured bedrock in the remedial areas, not all contamination can be collected by the ground-water recovery and treatment system (U.S. EPA, 1986b). Obtaining comprehensive data about DNAPL migration in fractured-rock systems, however, is technologically complex, and in this case was considered economically prohibitive.

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BIBLIOGRAPHY/REFERENCES

B&F Engineering, Inc. September 8, 1986. *Proposed Remedial Action Plan, Mid-South Wood Products Superfund Site, Mena, Arkansas.*

B&F Engineering, Inc. May 15, 1987. *Free Oils Investigation, Mid-South Wood Products, Mena, Arkansas.*

B&F Engineering, Inc. September 26, 1989. *Monitoring Well Sampling and Analysis Plan, Mid-South Superfund Site, Mena, Arkansas.*

B&F Engineering, Inc. February 1990a. *Fourth Quarter 1989 Ground Water Monitoring Report, Mid-South Superfund Site.*

B&F Engineering, Inc. May 3, 1990b. *First Quarter 1990 Ground Water Monitoring Report, Mid-South Superfund Site.*

B&F Engineering, Inc. May 1990c. *Operation and Maintenance Manual, Superfund Remediation, Mid-South Wood Products Site, Mena, Arkansas.*

B&F Engineering, Inc. May 31, 1990d. *Second Quarter 1990 Ground Water Monitoring Report, Mid-South Superfund Site.*

B&F Engineering, Inc. November 29, 1990e. *Third Quarter 1990 Ground Water Monitoring Report, Mid-South Superfund Site.*

B&F Engineering, Inc. March 21, 1991(a). Personal Communication with William Fletcher, President.

B&F Engineering, Inc. June 4, 1991(b). Letter from Bill Fletcher to Jennifer Sutter of EPA Headquarters.

U.S. Environmental Protection Agency (U.S. EPA). December 1982. *Aquatic Fate Process Data for Organic Priority Pollutants*, EPA-440/4-81-014.

U.S. EPA, Region VI. October 24, 1984. *Remedial Investigation Report, Mid-South Wood Products, Mena, Arkansas, Volume I.*

U.S. EPA, Region VI. March 13, 1986a. *Supplemental Remedial Investigation, CCA Plant, Mid-South Wood Products Site, Mena, Arkansas.*

U.S. EPA, Region VI. April 1986b. *Feasibility Study, Mid-South Wood Products Site, Mena, Arkansas.*

U.S. EPA, Region VI. November 14, 1986c. *Record of Decision, Mid-South Wood Products Site, Mena, Arkansas.*

U.S. EPA, February 20, 1991a. Personal communication with Cathy D. Gilmore, Remedial Project Manager, Environmental Protection Agency, Region VI.

U.S. EPA, Region VI. April 16, 1991b. Personal communication with Lou Barinka.

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CASE STUDY 21

Occidental Chemical
Lathrop, California

Abstract

The soils and ground water underlying the Occidental Chemical site have been contaminated with pesticides as a result of past handling and disposal practices. The primary contaminant of concern at the site is dibromochloropropane (DBCP), because of its high mobility and known sterilizing effect on humans. The extraction system, which consists of six extraction wells, began operation in 1982. The system appears to capture most of the existing contaminant plume. Concentrations of pesticides have decreased substantially since extraction began. The installation of two additional extraction wells, EW-6 and EW-7, is planned for 1991.

Background Data	
Date of Problem Identification	1977
Extraction Started	June 1982
Types of Contaminants	Pesticides
Primary Aquifer Materials	Interbedded alluvial sand, silt, and clay
Maximum Number of Extraction Wells	6
Maximum Total Extraction Rate	600 gpm
Estimated Plume Area	770 acres
Estimated Plume Thickness	190 feet
Maximum Reported Concentrations	Dibromochloro-propane: 4,200 ppb

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CASE STUDY
OCCIDENTAL CHEMICAL SITE

BACKGROUND OF THE PROBLEM

The Occidental Chemical site is located in Lathrop, California, approximately 60 miles east of Oakland, in California's Central Valley (see Figure 1). A pesticide and fertilizer plant was operated at the site by Occidental Chemical from 1953 to 1983. Past handling and disposal practices at the site have resulted in contamination of the soil and ground water underlying the area. The site is on the southern limit of the town of Lathrop in an area of light commercial and industrial activity. The primary contaminants of concern at the site are dibromochloro-propane (DBCP) and ethylene dibromide (EDB), both of which are fumigant pesticides. Site remediation is administered by the State of California and the U.S. EPA (EPA) National Enforcement Investigation Center. Because the initial site investigation began before the Superfund legislation was passed in 1980, the remedial action is driven by a 1981 consent decree rather than by Superfund.

SITE HISTORY

The Occidental Chemical plant began operating in 1953 and began producing pesticides as early as 1957. A contamination problem was first discovered in 1977 when it was found that a substantial percentage of the plant workers were sterile--possibly as a result of exposure to DBCP. Concern over possible ground-water contamination led to a cease and desist order by the California Central Valley Regional Water Quality Control Board on April 27, 1979, which required the contamination to be characterized (CDM, 1983). In mid-1979, the EPA conducted an extensive environmental audit of post-disposal practices. In December 1979, the U.S. and the State of California filed suit against Occidental (U.S. EPA, January 1991a).

In response to the legal actions taken in 1979, a large-scale investigation of the contamination of soils and ground water at and near the site was conducted in 1980. This investigation included the installation and sampling of 43 onsite and offsite monitoring wells, the sampling of 31 nearby water-supply wells, extensive soil sampling, and the excavation of several trenches in the western third of the site to identify buried wastes. Monitoring wells at locations PW-1 through PW-14 shown in Figure 2 were installed during 1980.

These initial samples revealed low concentrations of DBCP in several offsite watersupply wells, and extensive onsite contamination of ground water and soils. A total of 21 pesticides were detected in the 43 onsite monitoring wells. The excavation work in the western storage area intercepted four major disposal trenches and a number of smaller disposal pits. Many of the disposal pits and trenches were found to contain bottles and other product containers, some of which were filled with liquid pesticides. Some wastes in these disposal areas were below the water table (Canonie Environmental, 1981). A report summarizing the results of this Phase I investigation was submitted by Occidental Chemical in December 1980 (Canonie Environmental, 1980).

On February 6, 1981, a consent decree was signed which established the framework for future site investigations and remediation. The plan called for excavation and offsite disposal of source material from the disposal pits and contaminated soils from several areas of the site. The offsite disposal of the wastes from the pits was completed in 1981. Some source areas on site were capped instead of being removed. Additional monitoring wells and a ground-water extraction, treatment, and reinjection system were also installed. The remediation system, consisting of five extraction wells, two injection wells, and a carbon adsorption treatment system, began operating on June 22, 1982.

Other remedial activities or administrative actions since the startup of the remediation system include: (1) the sale of the Occidental property to the J. R. Simplot Company in January 1983, (with responsibility for remediation retained by Occidental), (2) the demolition of the DBCP plant and excavation of soils in its vicinity in late 1983, (3) the addition of six monitoring wells in 1986, (4) the discovery, assessment, and excavation of an area of high pesticide contamination in soils

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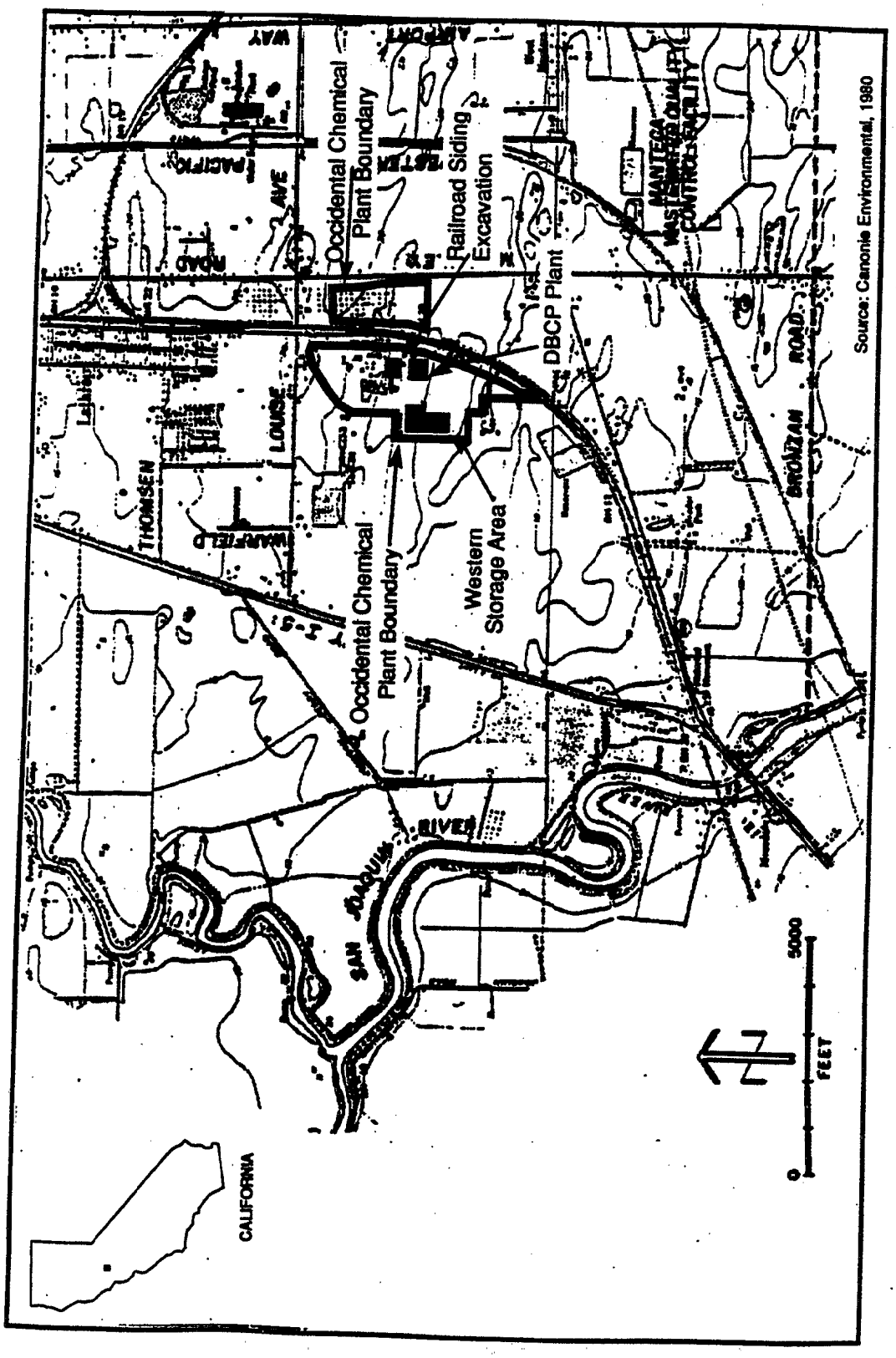

Source: Canonie Environmental, 1980

Figure 1
VICINITY MAP
OCCIDENTAL CHEMICAL SITE

(Poor Quality Original)

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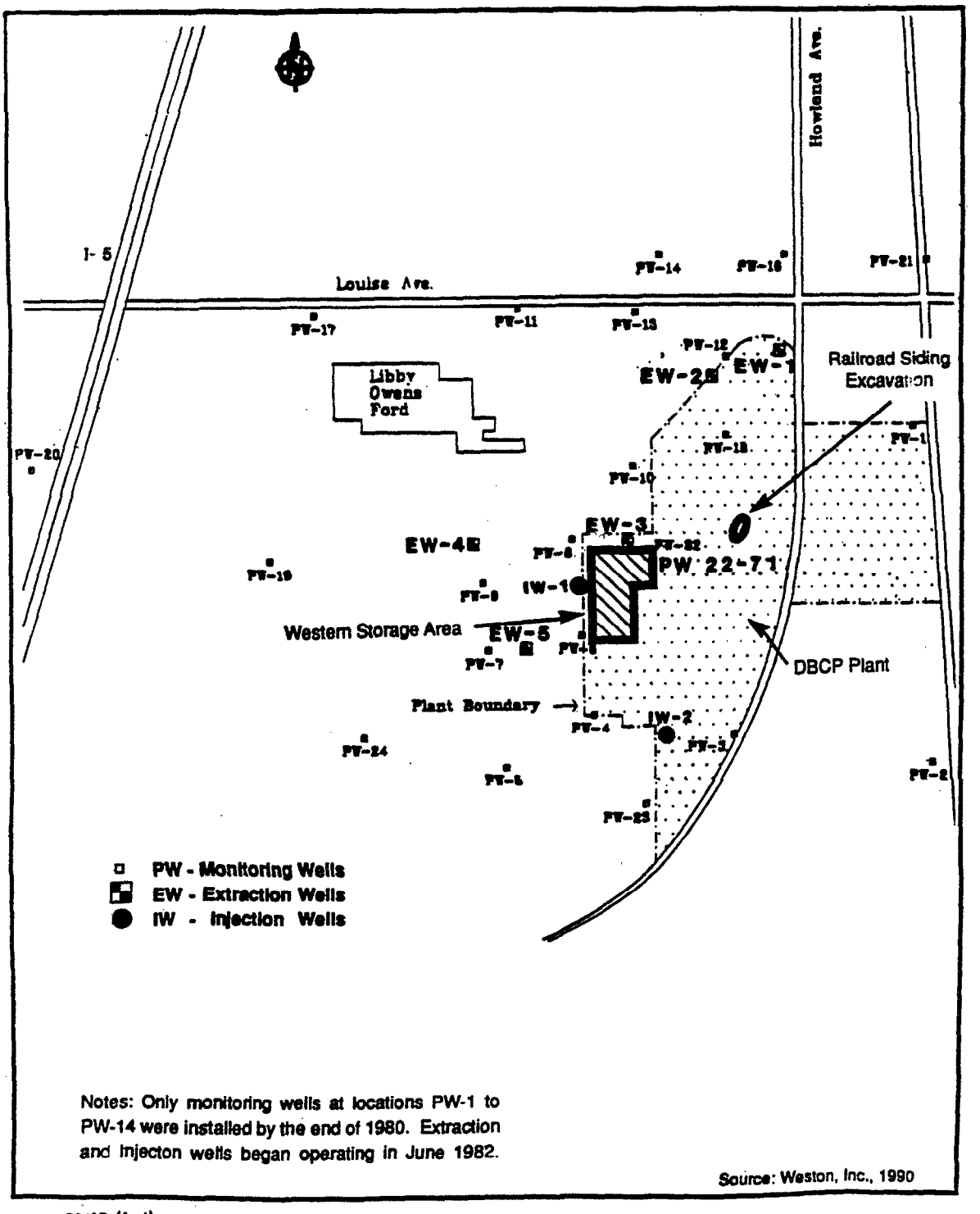

Notes: Only monitoring wells at locations PW-1 to PW-14 were installed by the end of 1980. Extraction and Injecton wells began operating in June 1982.

Source: Weston, Inc., 1990

SCALE (feet)

Figure 2
WELL LOCATION MAP, 1989
OCCIDENTAL CHEMICAL SITE

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underlying a railroad siding in the southeast part of the site from 1986 through 1988 (Weston, 1987a, 1988b, 1989a), and (5) the addition of monitoring Well PW-22-71 to the extraction system in December 1989. Other routine maintenance work on the injection and extraction wells was performed in 1989 and 1990. The installation of two additional extraction wells, EW-6 and EW-7, is planned in 1991 (U.S. EPA, May 14,1991).

GEOLOGY

The Occidental Chemical site is located in the center of the Central Valley, approximately half way between the Sierra Nevada mountains on the east and the Coast Range mountains on the west. The western boundary of the site is approximately two miles east of the San Joaquin River.

The site is underlain by several hundred feet of unconsolidated alluvial and marine sediments of Tertiary and Quaternary age. These sediments consist of interbedded sands, clays, and silts, with occasional gravels. Individual strata vary in thickness from 1 to 100 feet and are commonly discontinuous. Figure 3 is an east-west cross section across the Central Valley along a transect approximately 2 miles south of the site. This figure shows the complex stratigraphy of discontinuous and intergraded beds that characterizes the geology of the region.

Geologic logs recorded during drilling at the site show that its stratigraphy consists of interbedded and discontinuous beds of sand and clay similar to the stratigraphy shown in Figure 3. Two important differences are: (1) that sand and gravel beds appear to constitute approximately 40 percent of the sediment thickness of the upper aquifer on site, and (2) the Corcoran clay member is continuous across the site (Canonie Environmental, 1980). The thickness of the Corcoran clay is approximately 50 feet. A cross section of the stratigraphy along the western boundary of the plant, from PW-7 to PW-12, is shown in Figure 4.

HYDROGEOLOGY

The sediments underlying the Occidental Chemical site can be divided into three distinct hydrogeologic units--a 250-foot-thick upper aquifer, the 50-foot-thick Corcoran clay confining unit, and a 200-foot-thick lower aquifer. The upper aquifer is an important regional water-supply aquifer. It is generally unconfined with the exception of a few areas that are confined by overlying impermeable sediments. The lower aquifer is confined and contains brackish ground water with high chloride concentrations. As shown in Figure 4, these zones can only be loosely correlated across the site.

The upper aquifer is divided into three partially coupled permeable zones. These three zones consist of a shallow zone from 31 to 83 feet, an intermediate zone from 84 to 150 feet, and a deep zone from 151 to 218 feet. These three zones can only be loosely correlated across the site, as shown in Figure 4. The top of the Corcoran clay is approximately 250 feet below land surface but is deeper in some areas. There is a downward gradient of approximately 1 foot per 50 vertical feet within the upper aquifer (Canonie Environmental, 1980).

Ground water has been used extensively for irrigation over a period of several decades in the region surrounding the site. The site is at the edge of a broad cone of depression centered around the city of Stockton eight miles north of the plant. Water levels on site depend on a complex pattern of agricultural and industrial pumping in the vicinity of the site; however, the direction of horizontal ground-water flow is generally to the west or northwest towards the San Joaquin River. During periods of high pumping, ground water flows to the north in the northern third of the site. The response to pumping is greatest in the deep zone of the upper aquifer. Horizontal gradients are generally 1/1000 to 5/1000 ft/ft at the site.

A 25-hour aquifer test of a production well screened from 210 to 270 feet in the deep zone of the upper aquifer was performed in August 1980. The results of this test showed that the regional aquifer has a transmissivity of 21,000 gallons per day per foot, a hydraulic conductivity of 2×10^{-2} cm/sec, and a storage coefficient of 7×10^{-5}. The low storage coefficient demonstrates that the deep zone of the upper aquifer is confined in the vicinity of this production well. The 1980 aquifer test also showed that the vertical hydraulic conductivity of the clay aquitard overlying the production zone is estimated to be 1×10^{-6} cm/sec. A second aquifer test was performed at the site in November, 1985 (Weston, 1986); however, the results of this test were not available.

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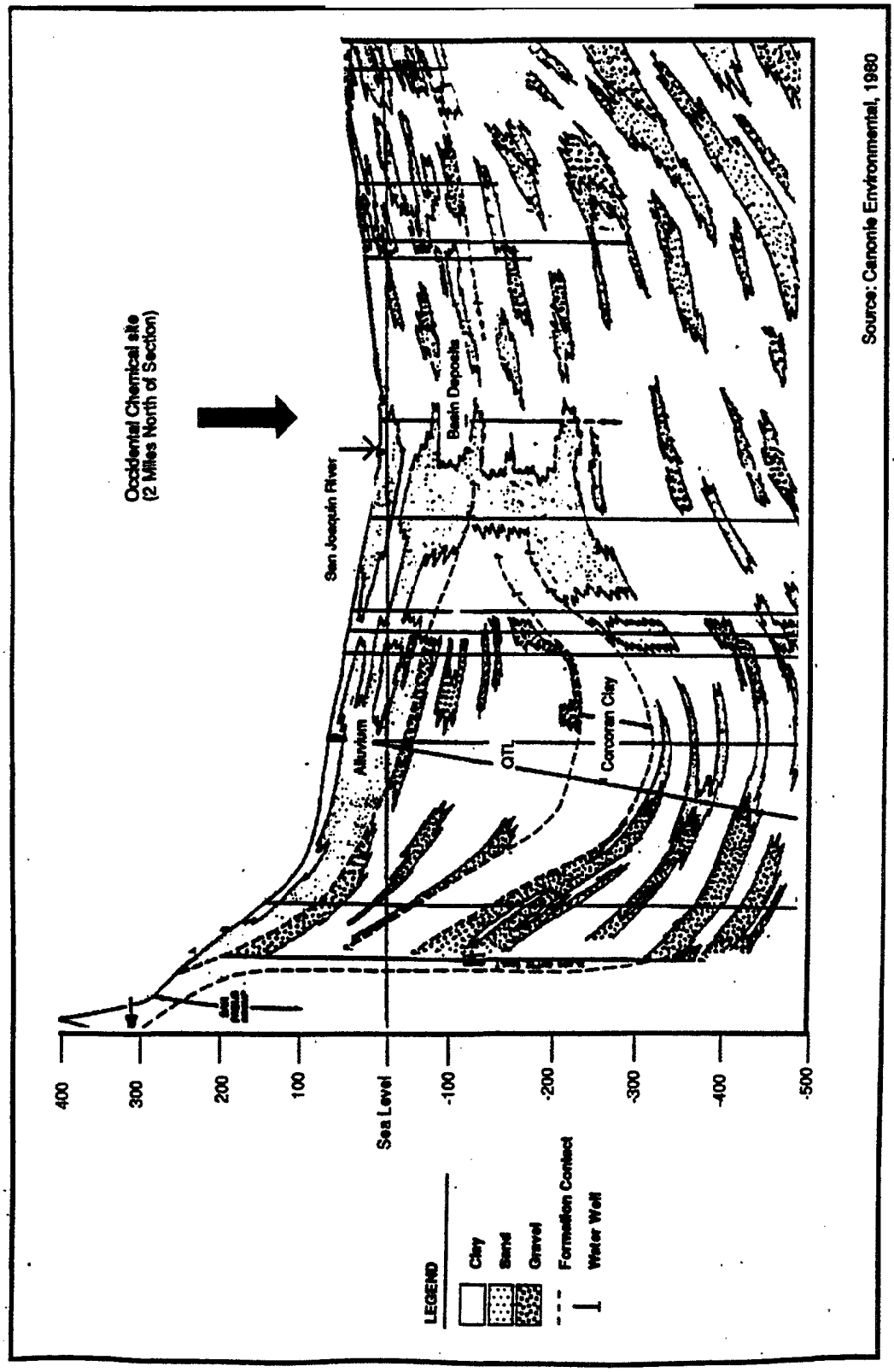

Source: Canonie Environmental, 1980

Figure 3
EAST-WEST CROSS SECTION THROUGH THE CENTRAL VALLEY TWO MILES SOUTH OF THE SITE
OCCIDENTAL CHEMICAL SITE

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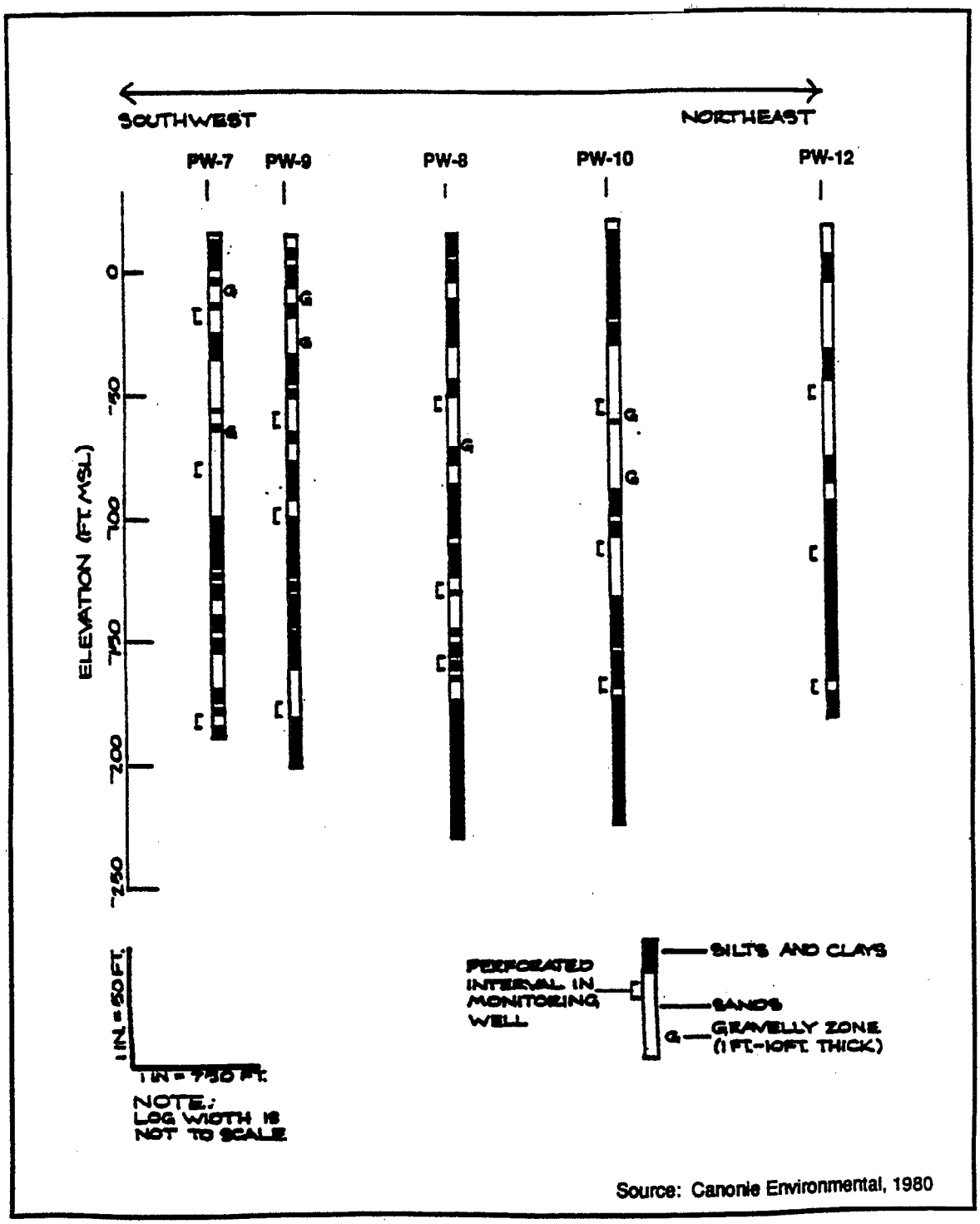

Source: Canonie Environmental, 1980

Figure 4
SITE GEOLOGICAL CROSS SECTION
ALONG WESTERN PLANT BOUNDARY
OCCIDENTAL CHEMICAL SITE

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WASTE CHARACTERISTICS AND POTENTIAL SOURCES

The ground water underlying the Occidental Chemical site has been heavily contaminated with a number of pesticides as a result of past disposal practices. During initial sampling of 43 monitoring wells in 1980, 21 different pesticides were detected. Table 1 lists these 21 pesticides. The pesticides dibromochloropropane (DBCP) and ethylene dibromide (EDB) are the primary contaminants of concern. Only DBCP was found in a majority of the monitoring wells. Both compounds are nematocidal fumigant pesticides. The isomers of the pesticide BHC, including lindane, were also common.

DBCP is a highly toxic pesticide that is known to have a sterilizing effect upon exposure. DBCP is highly mobile and has a high solubility in water (1,230,000 ppb). Because of its high toxicity and its high mobility and persistence in soil and ground water, the EPA phased out the use of DBCP from 1977 to 1979. The current Proposed Maximum Contaminant Level (PMCL) for DBCP is 0.2 ppb. EDB is also highly soluble (4,310,000 ppb) and mobile in water (U.S. EPA, 1987). It is known to be a potent carcinogen in rats. The current proposed MCL for EDB is 0.05 ppb. The use of EDB was banned by the EPA in 1983.

The environmental audit of the Occidental Chemical plant conducted in the late 1970's showed that past liquid and solid waste disposal led to the contamination of soil and ground water at the site. Until at least 1970, waste pesticide solids and concentrated liquids were disposed of onsite in shallow trenches in the western storage area shown in Figure 1. A number of these trenches were excavated in 1980 and found to contain bottles and other containers of pesticides. Liquid wastes were also disposed of in unlined ditches and ponds in permeable soils until at least 1976. Several separate source areas have been capped, or excavated and removed, since remedial activities began in 1980.

DBCP was found at a maximum concentration of 1,200 ppb in one 200-foot-deep well during early sampling. It was also detected at a concentration of 4 ppb in a private well 0.5 miles north of the Occidental Chemical plant (U.S. EPA, 1985). Contamination by DBCP was distributed widely throughout the site in 1980, but was generally highest at PW-6 near the western storage area. EDB contamination was also widespread in the western third of the site and in adjacent offsite areas in 1980. Remediation efforts have focussed on DBCP because it is the most mobile of the contaminants of concern.

Figures 5, 6, and 7 show the distribution of DBCP in the shallow, intermediate, and deep zones, respectively, in October 1982, shortly after remediation began. These figures show that DBCP contamination is greatest along the western boundary of the plant and offsite to the west. Contamination extended slightly farther to the west in the intermediate and deep zones than in the shallow zone in October 1982.

REMEDIATION

Selection and Design of the Remedy

The stated objectives of the remediation system at the Occidental Chemical site are to contain the contaminant plume in the upper aquifer by ground-water extraction, and to treat the extracted ground water to an effluent DBCP concentration of 1 ppb, or less, before injecting it into the lower aquifer (Weston, 1990). Aquifer restoration is also an objective of remediation, as stated in the consent decree, according to the EPA, NEIC (1991c). Steps taken to improve ground-water cleanup have included redistribution of pumping to high concentration areas, conversion of PW-22 to an extraction well, and an increase in treatment system capacity (EPA, NEIC, 1991a.)

The remediation system consists of six extraction wells and two injection wells. The two injection wells are used to inject the treated effluent water into the brackish aquifer that underlies the Corcoran clay at a depth of 300 to 500 feet. A system of 69 monitoring wells is used to monitor the progress of remediation and to check on the integrity of the clay layer separating the two aquifers. Sixty-five of these wells are installed in the upper aquifer, primarily in groups of three wells, each of which is installed in one of the three zones of the upper aquifer. Eight of the 69 wells are used to monitor the hydraulic separation between the upper and lower aquifers.

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Table 1
PESTICIDES DETECTED IN INITIAL 1980 MONITORING WELL SAMPLING
OCCIDENTAL CHEMICAL SITE

(Total Number of Wells = 42)

Chemical	Number of Wells Where Detected	Detection Limit (ppb)	Range (ppb)	Median (ppb)	MCL/ PMCL
DBCP	33	0.1	0.13-1240	168	-/0.2
Lindane	21	0.05	0.06-14.85'	2.3	4/0.2
α-BHC	19	0.05	0.08-9.15	1.7	-
Δ-BHC	13	0.05	0.09-5.6	2.65	-
EDB	11	1.0	1.0-49.4	7.4	-/0.05
2,4-D	8	2.0	1.8-4	3	100/70
Disyston	6	1.0	2.0-6.2	3.2	-
Delnav	5	1.0	1.8-25.2	6.5	-
Dimethoate	4	1.0	1.8-15.2	11.2	-
Dieldrin	3	0.05	0.05-0.3	0.05	-
Sevin	3	30	30-80	70	-
2,4,5-T	3	0.5	1.0-1.4	1.4	10/50
Thiodan I	2	0.05	-	0.05	-
HCB	2	0.05	-	0.05	-
p,p'-DDT	1	0.05	-	0.90	-
Toxaphene	1	5	-	8.2	5/5
Chlordane	1	0.5	-	0.53	-/2
DDE	1	0.05	-	0.59	-
Ethyl Parathion	1	1.0	-	3.3	-
DEF	1	1.0	-	1.7	-
Methyl Parathion	1	1.0	-	2.5	-

Source: Canonie Environmental, 1980
MCL= Maximum Contaminant Level, Safe Drinking Water Act (SDWA)
PMCL= Proposed Maximum Contaminant Level
"-" = No standard or standard not known

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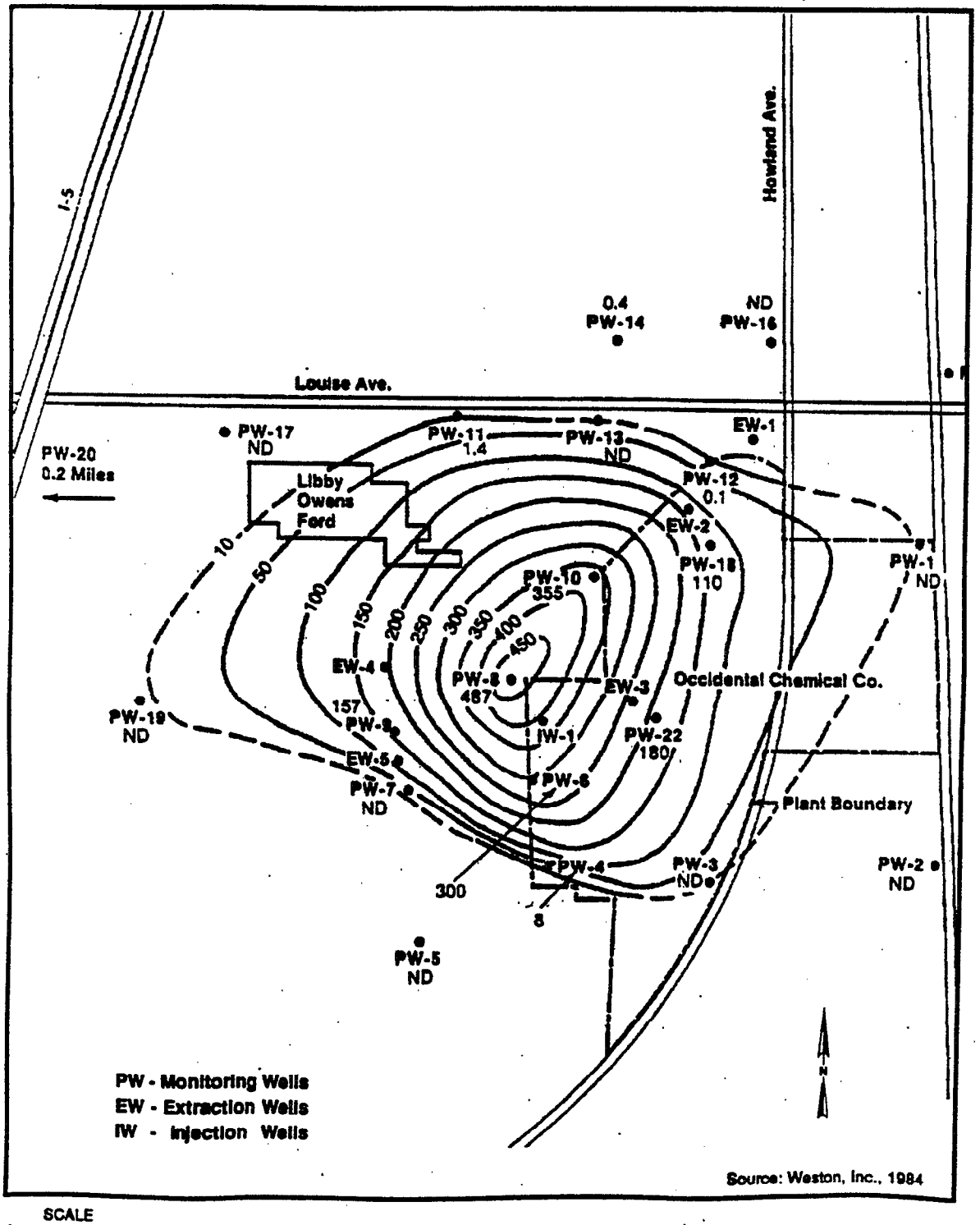

SCALE
0 1,375
1" = 1,375'

Figure 5
DISTRIBUTION OF DBCP (ppb) IN THE SHALLOW ZONE, 31-63 FOOT LEVEL-OCTOBER 1982
OCCIDENTAL CHEMICAL SITE

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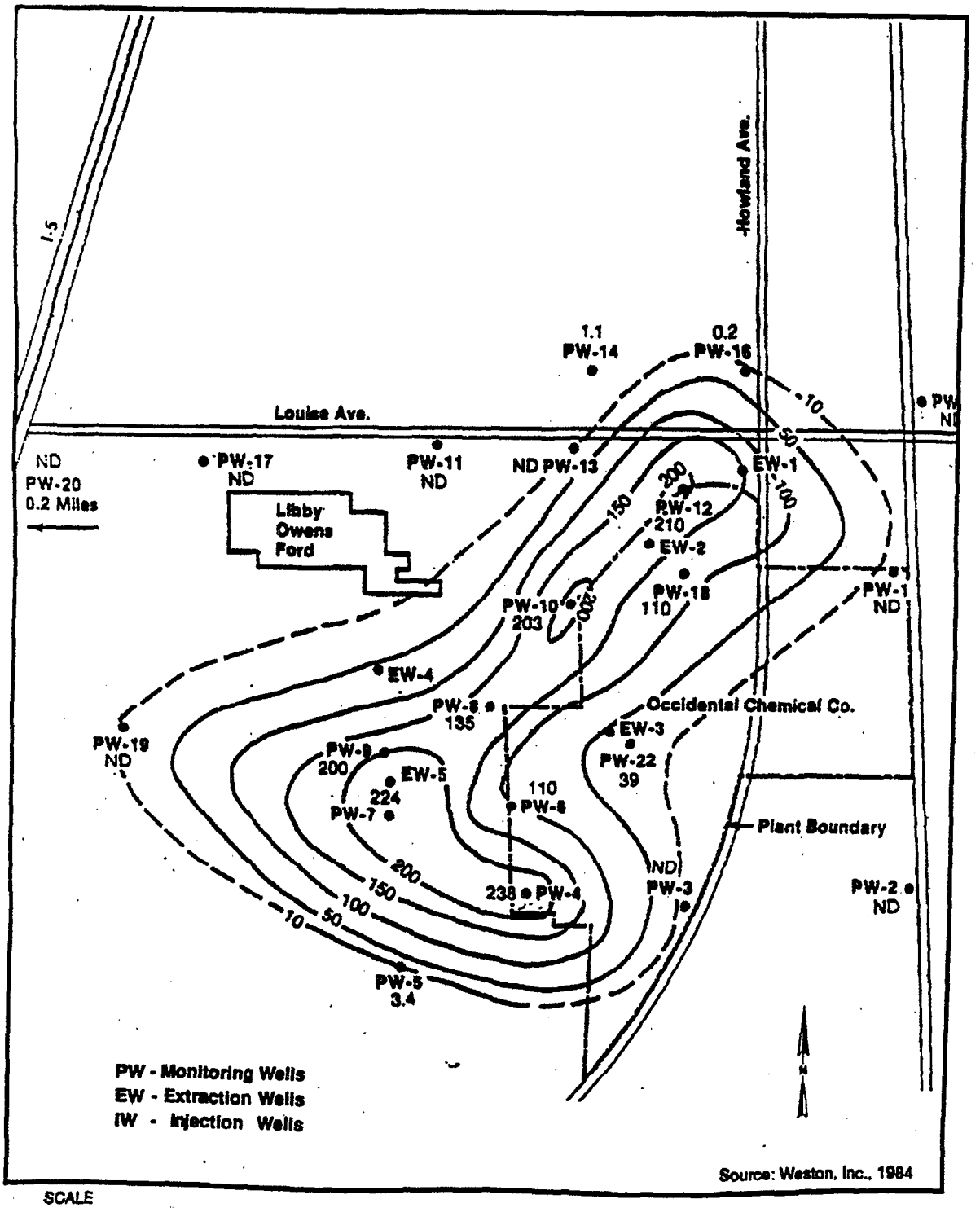

SCALE
0 1,375
1" = 1,375'

Figure 6
DISTRIBUTION OF DBCP (ppb)
IN THE INTERMEDIATE ZONE,
80-150 FOOT LEVEL-OCTOBER 1982
OCCIDENTAL CHEMICAL SITE

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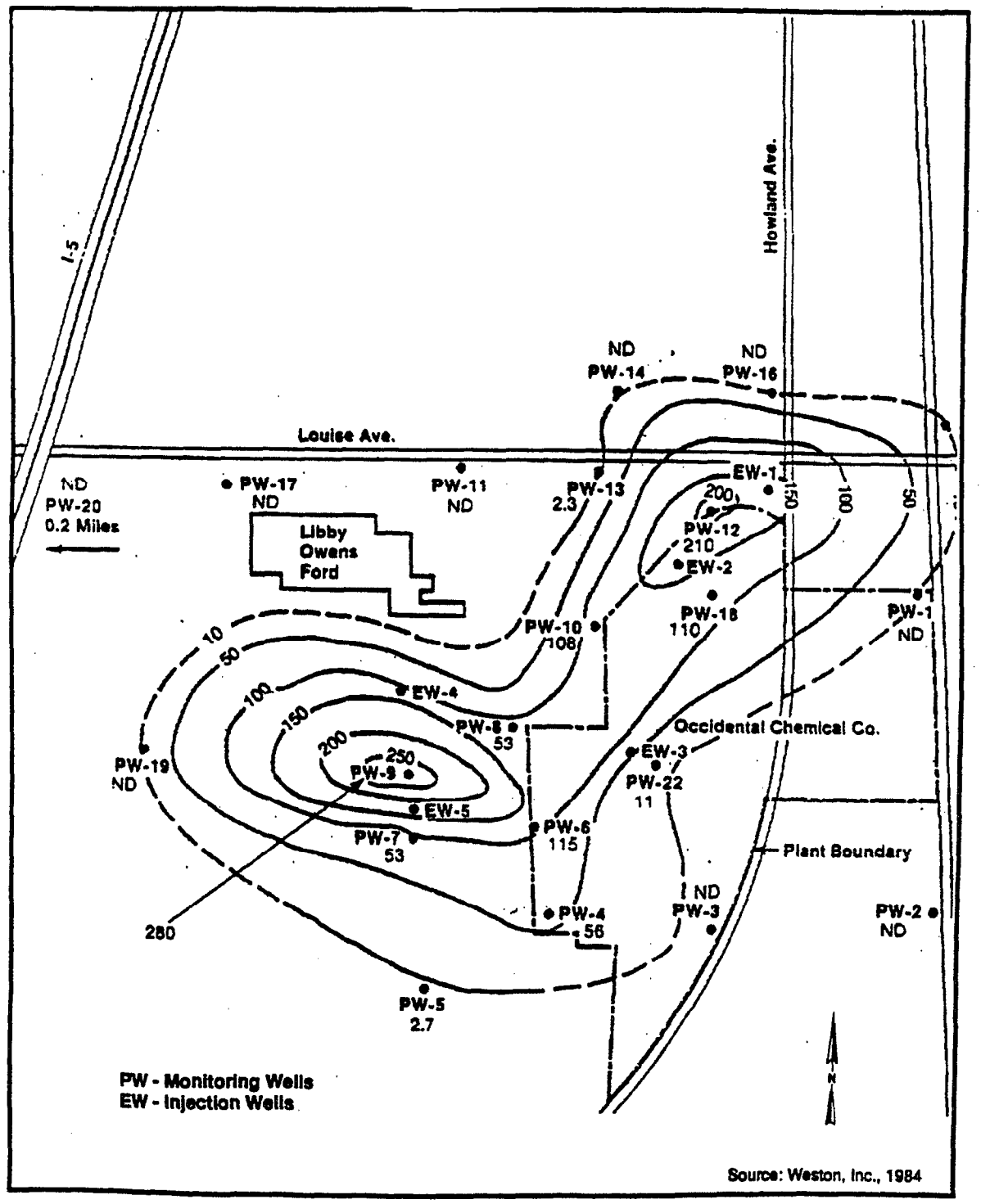

SCALE
0 1,375
1" = 1,375'

Figure 7
DISTRIBUTION OF DBCP (ppb) IN THE DEEP ZONE, 150-218 FOOT LEVEL-OCTOBER 1982
OCCIDENTAL CHEMICAL SITE

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Figure 2 shows the remediation system as it has existed since 1989. The five main extraction wells are designated EW-1 through EW-5. EW-1 and EW-2 are north of the plant, EW-3 is north of the western storage area, and EW-4 and EW-5 are offsite to the west of the plant. The placement and pumping rates of the five extraction wells were chosen using computer modeling completed in 1981. The system is designed to intercept the prevailing offsite ground-water flow to the north and west. These five extraction wells began pumping at approximately 500 gpm on June 22, 1982. Their combined pumping rate in January 1991, was 600 gpm (U.S. EPA, 1991a).

Monitoring Well PW-22-71 (PW-22, shallow zone) was converted to an extraction well in December 1989, and is pumped intermittently at an average rate of approximately 0.56 gpm. The pumping history and screened interval of the five main extraction wells is shown in Table 2. EW-1 is screened over part of both the intermediate and the deep zone, EW-2 is screened over the deep zone only, and EW-3, EW-4, and EW-5 are screened over all three zones. The pumping program was changed from a seasonal to year-round in October 1985, to enhance hydraulic control in the western part of the site. The addition of two more extraction wells, EW-6 near PW-10 and EW-7 near EW-5, has been proposed to increase the rate of contaminant recovery, but these wells had not been installed as of May 1991. Installation is planned by the end of 1991.

The extracted ground water is treated by carbon adsorption before being injected into the brackish lower aquifer that underlies the Corcoran clay. The carbon adsorption system is fairly effective in removing most of the contaminant pesticides; however, the solvent sulfolane, which was used in a past manufacturing process, is not removed. Sulfolane is found throughout the site; however, it is of less concern than DBCP because it is believed to have a low toxicity. (U.S. EPA, 1991b).

The monitoring well system is sampled three times a year--in February, June, and October. Wells from the Lathrop water district are sampled six times a year. The analytical parameters used in the ground-water sampling program are shown in Table 3. The ground-water samples are analyzed for inorganics, pesticides, herbicides, BHC isomers, sulfolane, and radiologic parameters.

EVALUATION OF PERFORMANCE

The extraction system at the Occidental Chemical site has generally been effective in controlling the contaminant plume in all three zones since the system began operating in June 1982. The general pattern of ground-water flow in the area of the plant has varied since startup because of periodic changes in nearby water-supply pumping and in the distribution of natural and artificial recharge.

Despite seasonal variations in pumping, the piezometric surface in all three zones has been drawn down by the extraction wells to create a northeast-southwest trending trough that transects the northern third of the plant area. Ground water north of the plant generally flows southeast toward the trough and then turns to flow southwest in the area underlying the northern third of the site. Ground water in the southern two-thirds of the site generally flows northwest toward the trough and then turns to flow southwest in the area west of the plant boundary.

Figures 8, 9, and 10 are contour plots of the water levels in the shallow, intermediate, and deep zones of the upper aquifer, respectively, during June 1989, October 1989, and February 1990. These figures illustrate the trough in the piezometric surface at each depth along an axis connecting extraction Wells EW-1 and EW-2 north of the plant, EW-3 in the center of the site, and EW-4 west of the plant during 1989 and 1990. Contaminated ground water flowing inward towards the trough of depression in the area east of EW-4 appears to be captured by the extraction network. Contaminated ground water in the area west of EW-4 does not appear to be captured by the existing extraction system.

Hydraulic control was not achieved in the deep zone underlying the area northwest of the site in June 1989. This lack of control was reported to be the result of high-volume pumping north of the site during the summer. Some intermittent periods of ineffective hydraulic control in the south and southwest from 1983 through 1987 were also reported (Weston, 1984, 1985a, 1986, 1987, 1988a). Hydraulic control was achieved in these areas in 1988 and 1989 as a result of improvements in the extraction system in 1987 and 1988 (Weston, 1989b, 1990). In general, the extraction system has created a trough of depression that appears to have captured the bulk

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Table 2
EXTRACTION WELL DATA

Well	Depth (ft)	Screen Interval	Pumping Rate Prior to 10/85 (gpm)	Pumping Rate After 10/85 (gpm)	Pumping Rate After 10/88 (gpm)
EW-1	220	135 to 210	150 summer 100 winter	100	100
EW-2	220	150 to 210	150 summer 100 winter	100	100
EW-3	210	60 to 94 134 to 200	200 summer 150 winter	150	180
EW-4	200	70 to 120 170 to 190	0 summer 75 winter	75	50
EW-5	170	70 to 160	0 summer 75 winter	75	75

Source: Weston, 1990

of the contaminant plume since startup in 1982, despite anomalous periods of ineffective control in some areas. Some contaminated ground water in areas west of EW-4 may have flowed beyond the limits of the capture zone since 1982.

The size and concentration of the pesticide plume has decreased substantially since the extraction system began operation in June 1982. Figure 11 shows concentration isopleths and trend surface contour plots of the DBCP distribution in the shallow, intermediate, and deep zones in February 1990. Trend surface analysis is a statistical averaging technique that shows overall trends in the concentration data, while reducing the weighting of anomalously high values. Reference to the corresponding contour plot of the concentration of DBCP in the shallow zone in October 1982 (Figure 5) shows that DBCP concentrations have been reduced to less than 1/10 of their earlier levels in the shallow zone over most of the site. For example, the concentration of DBCP in the shallow zone decreased from 355 ppb to 12 ppb in PW-10, and from 487 ppb to 1.2 ppb in PW-8 from October 1982 to February 1990.

The concentration of DBCP in the shallow well at PW-22 was higher in February 1990 (290 ppb) than in October 1982 (180 ppb); however, the decrease in DBCP concentrations observed in nearby wells suggests that the high concentration in PW-22 may be quite localized. The concentration of DBCP in the shallow well at PW-22 was 10.1 ppb in June 1989 suggesting that the concentration in this well may also be quite variable.

A comparison of October 1982 concentrations shown in Figures 6 and 7 to February 1990 concentrations shown in Figure 11 demonstrates that the concentration of DBCP has also decreased substantially in the intermediate and deep zones of the upper aquifer. Intermediate zone concentrations decreased from 135 to 2 ppb in PW-8, from 224 to 15 ppb in PW-7, from 203 to 0.1 ppb in PW-10, and from 210 to 0.5 ppb in PW-12. Similar reductions were observed in the deep zone. However, the concentrations varied substantially between sampling events in some cases.

Figure 12 is a three-dimensional plot of the trend surface of DBCP concentrations in the three zones from October 1982 to February 1990. This figure clearly shows that the concentration of DBCP has decreased substantially since 1982. Note that the vertical scale used for the February 1990 data is twice that used in the other two plots, so reductions are even greater than they appear.

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Table 3
SAMPLING AND ANALYTICAL SCHEDULE, PERMANENT MONITORING (PW), AND LATHROP DISTRICT WELLS

PERMANENT MONITORING WELL OPERATIONS

Sampling

Frequency: 3 times yearly - Feb., June, and Oct.
Location: All PW wells

Analysis Required

Parameter	Frequency
DBCP/EDB	All sampling periods
Sulfolane	All sampling periods
Inorganics[1]	All sampling periods
Nitrate	October only
BHC Isomers[6]	October only
Radiological[5]	Every other October*
Uranium only	Every other October*

*Odd number years

LATHROP WATER DISTRICT WELL OPERATIONS

Sampling

Frequency: 6 times yearly - Feb., April, June, Aug., Oct., and Dec.
Location: All operating wells

Analysis Required

Parameter	Frequency
DBCP/EDB	All sampling periods
Sulfolane	All sampling periods
Inorganics[1]	All sampling periods
Nitrate	October only
Uranium only	All sampling periods
Organochlorine[2]	October only
Organophosphorous[3]	October only
BHC Isomers[6]	October only
Herbicides[4]	October only
Radiological[5]	October only

LEGEND:

1. Inorganics
   pH, Conductivity, SO_4, Cl

2. Organochloride Scan
   Aldrin, DDT, Chlordane, Dieldrin, DDD, Heptachlor, DDE, Toxaphene

3. Organophosphorous Scan
   DEF, Ethyl Parathion, Delnav, Methyl Parathion, Dimethoate, Disyston

4. Herbicides
   2,4-D
   2,4,5-T

5. Radiological
   Gross Alpha, Total Uranium, Radium 226, Gross Beta

6. BHC Isomers
   A-BHC, D-BHC, B-BHC, G-BHC

Source: Weston, 1990

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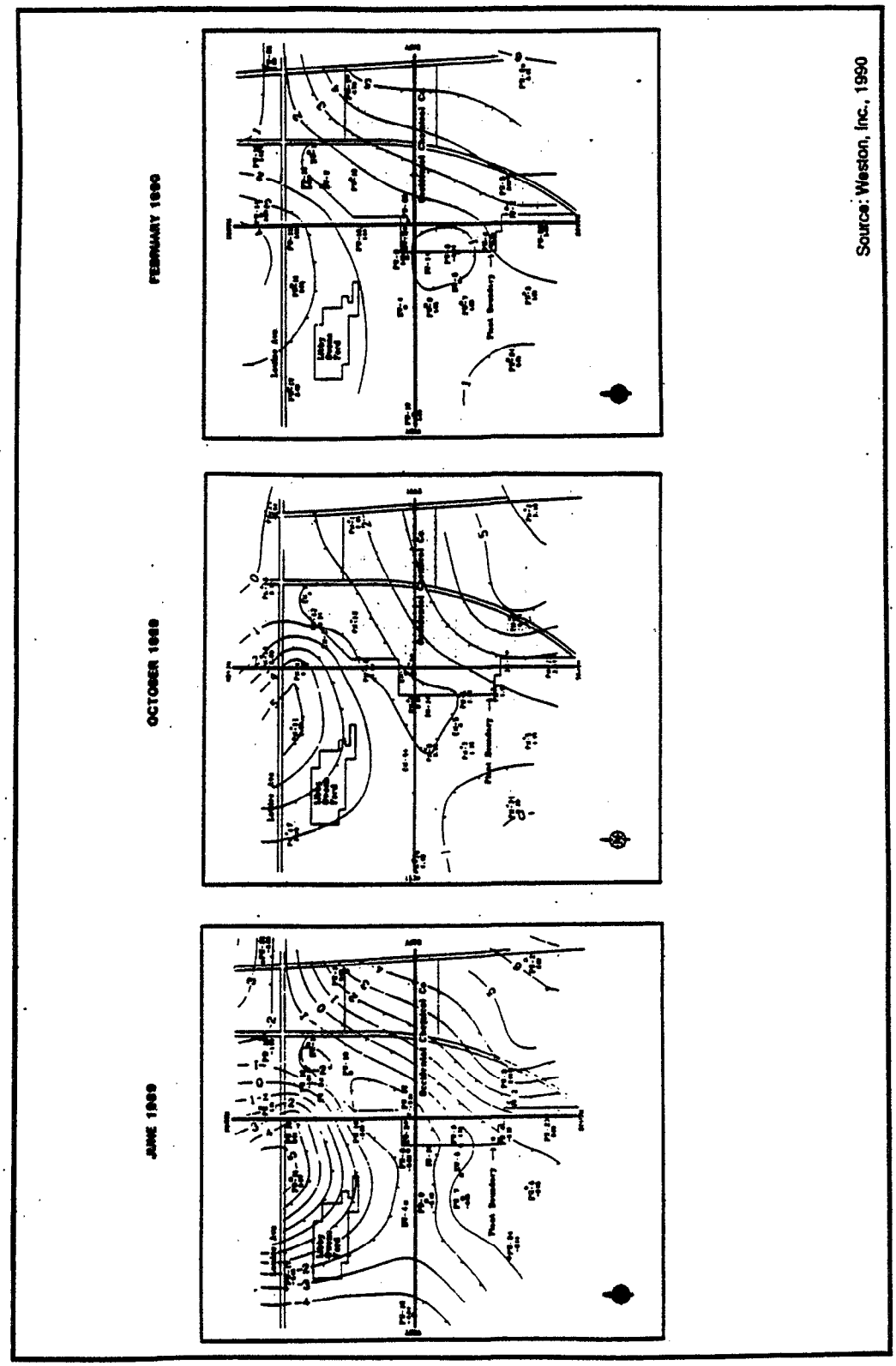

Figure 8
CONTOUR PLOTS OF WATER LEVEL ELEVATIONS IN THE SHALLOW ZONE, 1989 AND 1990
OCCIDENTAL CHEMICAL SITE

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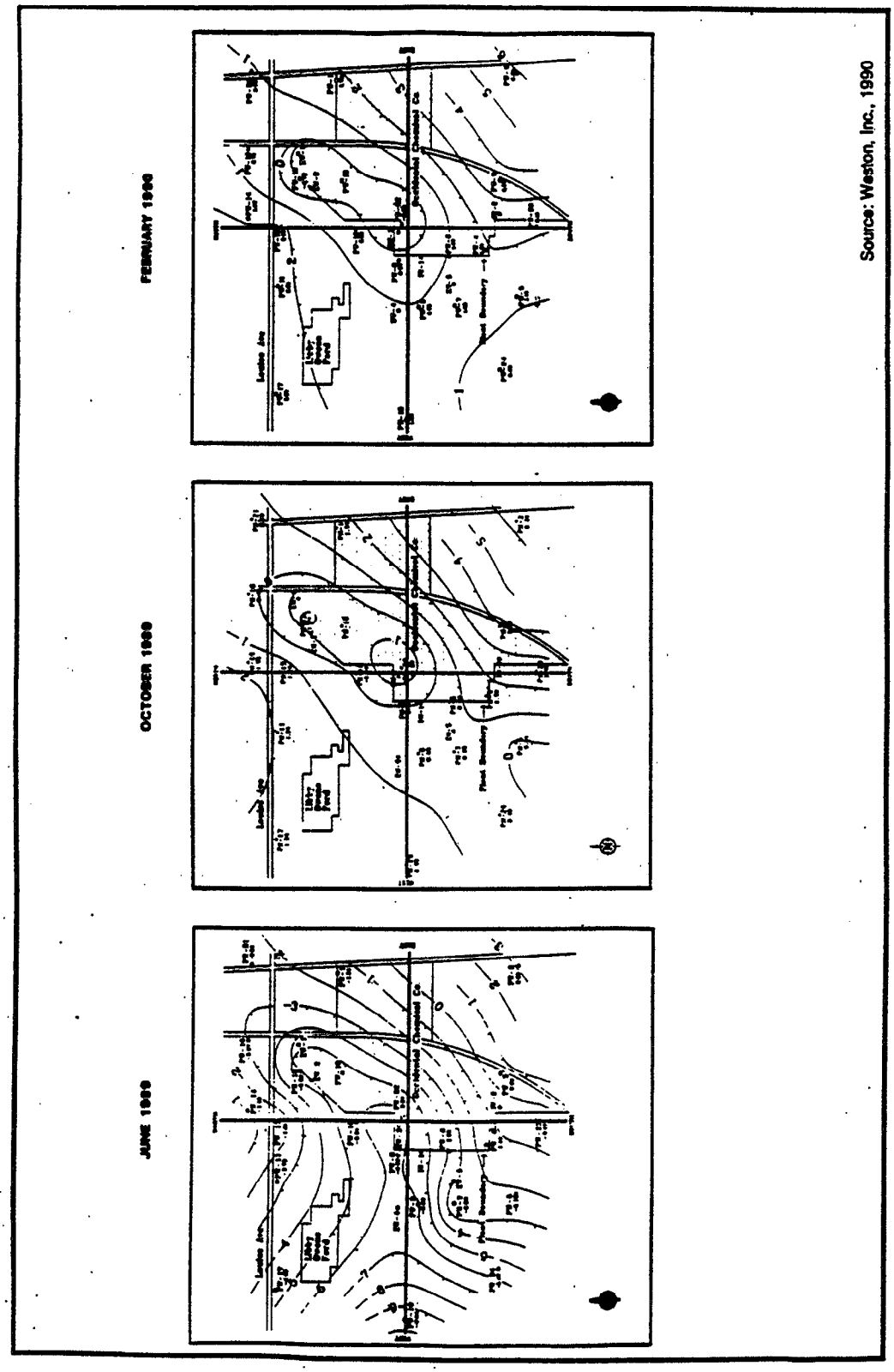

Source: Weston, Inc., 1990

Figure 9
CONTOUR PLOTS OF WATER LEVEL ELEVATIONS IN THE INTERMEDIATE ZONE, 1989 AND 1990
OCCIDENTAL CHEMICAL SITE

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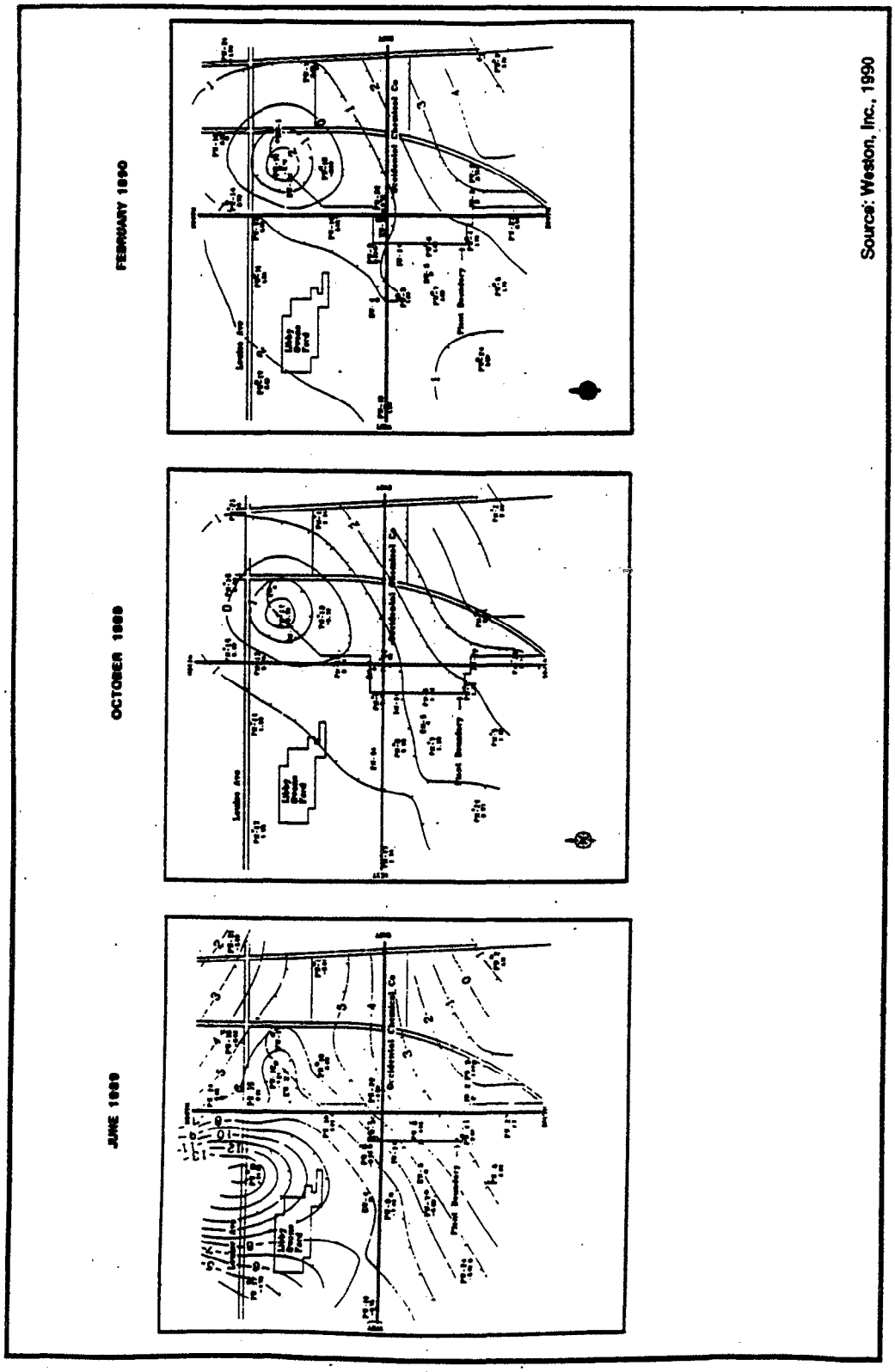

Figure 10
CONTOUR PLOTS OF WATER LEVEL ELEVATIONS
IN THE DEEP ZONE, 1989 AND 1990
OCCIDENTAL CHEMICAL SITE

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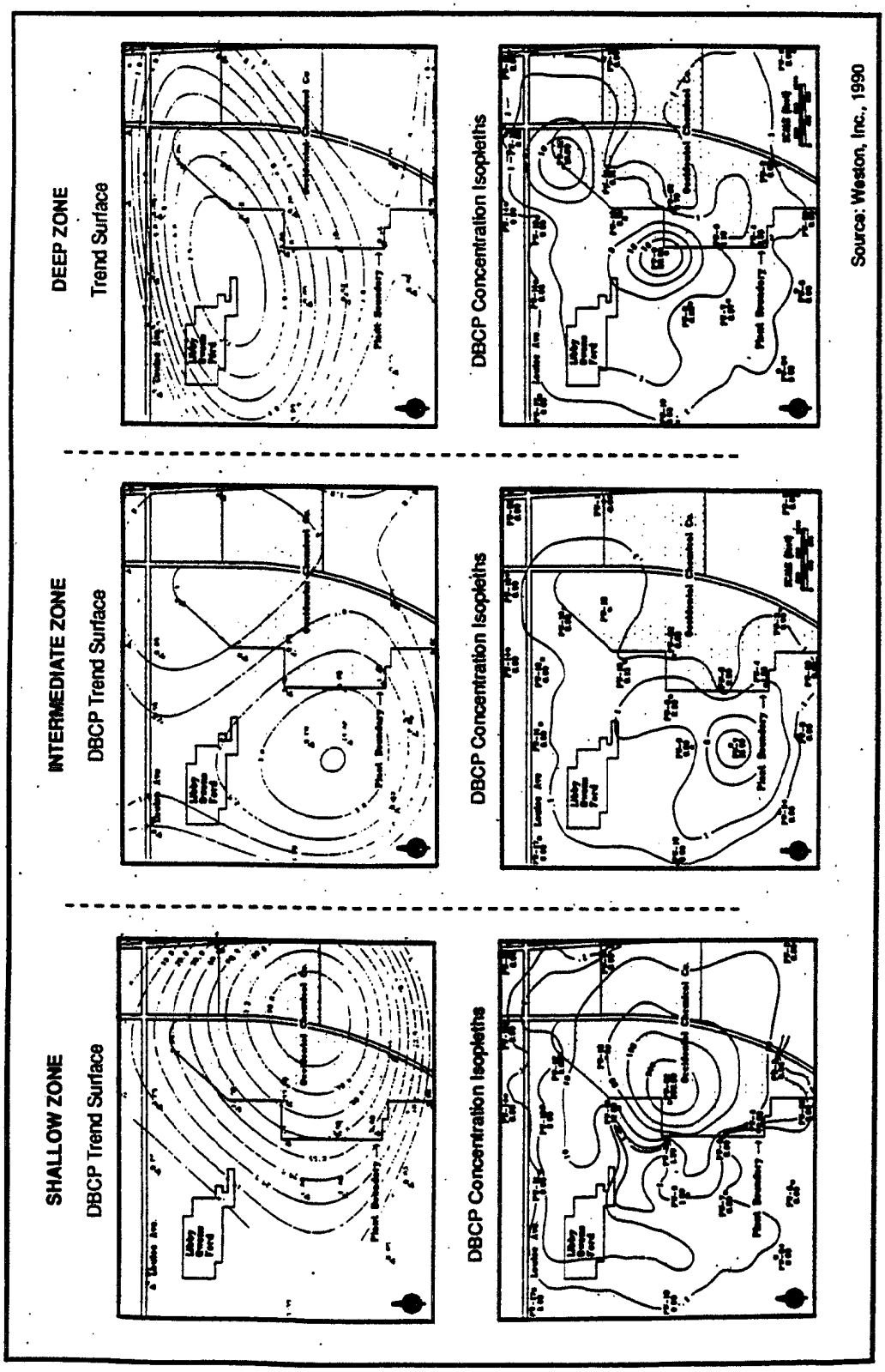

Figure 11
TREND SURFACE AND CONCENTRATION ISOPLETTHS OF DBCP CONCENTRATIONS IN THE SHALLOW, INTERMEDIATE, AND DEEP ZONES FEBRUARY, 1990 (ppb)
OCCIDENTAL CHEMICAL SITE

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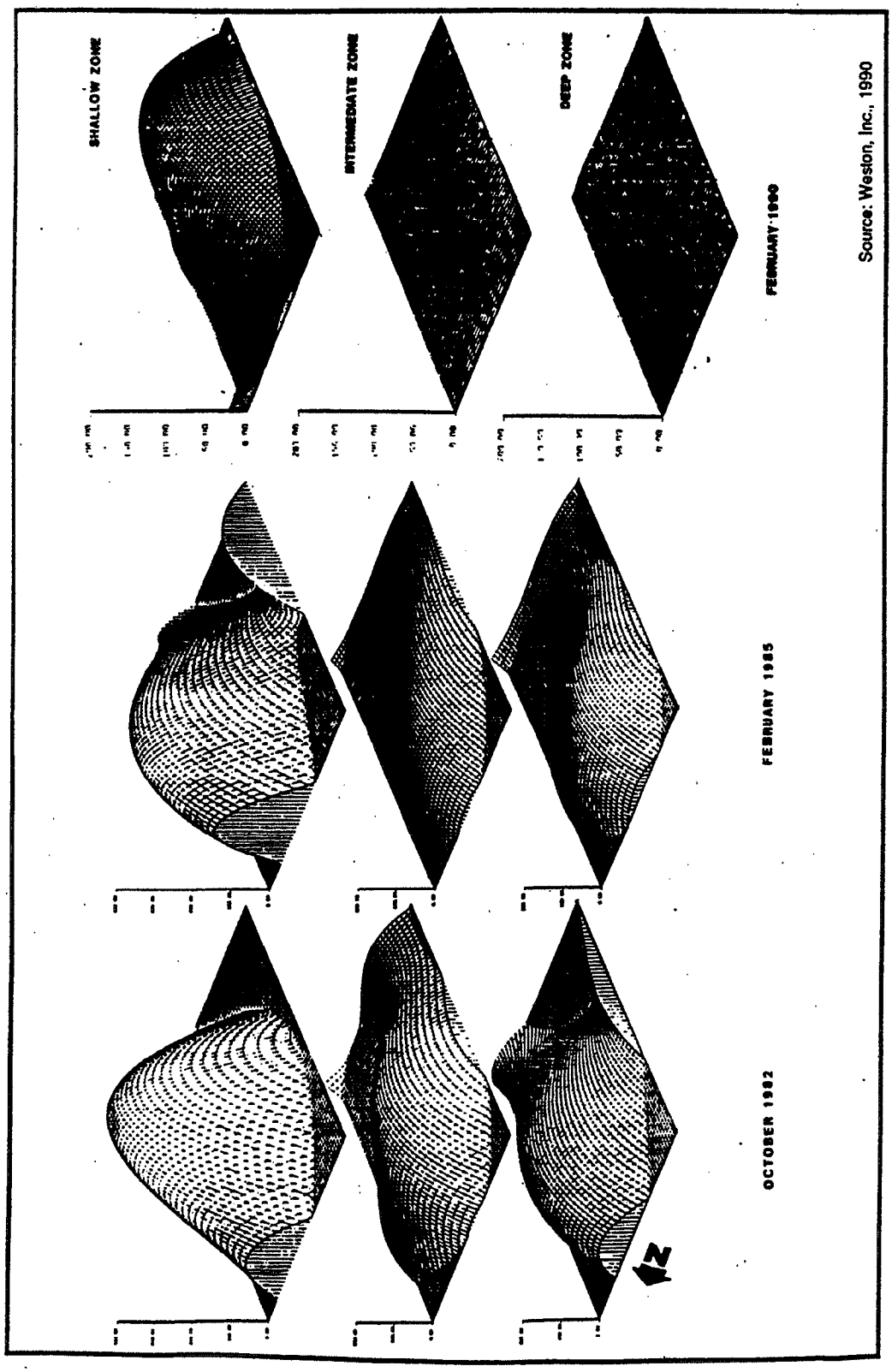

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Figure 12
TREND SURFACE OF DBCP CONCENTRATIONS IN THE CENTER OF THE SITE, OCTOBER 1982 TO FEBRUARY 1990
OCCIDENTAL CHEMICAL SITE

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These plots also suggest that the DBCP plume has not migrated substantially since 1982, despite the fact that DBCP is known to be highly mobile in ground water.

Figures 13, 14, and 15 show the trend in DBCP concentrations from October 1982 to February 1990 in monitoring Wells PW-6-197, PW-8-150, and PW-22-71, respectively. Well PW-6-197 is the deep zone monitoring well at PW-6, located along the western boundary of the plant. Figure 13 shows a steep initial drop in DBCP concentrations followed by a steady decrease through the end of 1986. Concentrations in PW-6-197 appear to have stabilized at approximately 10-15 ppb since the end of 1986. This pattern of steep initial decreases followed by more gradual reductions was observed in many of the monitoring wells. The concentrations of DBCP in several cells decreased to below detection limits by the end of 1986.

Other wells have shown a more gradual decrease and greater variability in DBCP concentrations since 1982 than PW-6-197. An example of this trend is the data from PW-8-150 shown in Figure 14. PW-8-150 is the intermediate zone monitoring well at PW-8, located on the northwest corner of the former Western Storage area. The DBCP concentration in PW-8-150 decreased from approximately 150 ppb in early 1983 to approximately 30 ppb at the end of 1989. The reason for the sharp increases and decreases seen in the concentration trend is not known. However, the increases and decreases appear to be seasonal. Overall, the plots display general decreasing groundwater contamination levels.

The concentration trend in PW-22-71 has been extremely variable since late 1982, as shown in Figure 15. PW-22-71 is the high-concentration monitoring well that was converted to use as an intermittent extraction well in December 1989. The reason for the high variability and long term stability in DBCP concentrations is not clear, however, the proximity of this well to the Western Storage area suggests that the stability and variability may be the result of a residual source of DBCP in the soil.

Figure 16 is a time series plot of the monthly average concentration of DBCP in the influent to the treatment system from mid-1982 to early 1990. This plot shows that the composite concentration of DBCP in ground water extracted by the remediation system has decreased substantially over the 7-1/2 years of system operation--from approximately 4000 ppb in October 1982 to approximately 20 in mid-1989. The influent concentration appears to have stabilized since mid-1989.

Site operations have calculated that the rate of decrease in DBCP contamination is slowing (Weston, Inc., 1990). The recently expanded extraction system is intended to accelerate the rate at which contaminants are removed from the ground water. It is uncertain if the additional extraction wells will affect DBCP concentrations.

SUMMARY OF REMEDIATION

The soils and ground water underlying the Occidental Chemical site have been contaminated with a variety of pesticides as a result of past disposal practices. The most critical of these pesticides is DBCP because of its high mobility and known sterilizing effect on humans. All three zones of the 250-foot-thick upper aquifer have been contaminated with pesticides. Ground-water contamination is greatest in the shallow zone along, and to the west of, the western boundary of the plant; however, low-level contamination has also been detected offsite to the north. Contamination in the intermediate and deep zones of the upper aquifer extends farther offsite to the west than in the shallow zone. Several source removal actions have occurred since cleanup began in 1981.

The site is being remediated using a system of five extraction wells located north and west of the plant, and along its western boundary and one intermittent extraction well in a high concentration area in the western part of the plant. The extraction system, which pumps from all of the three upper aquifer zones, began operating at approximately 500 gpm on June 22, 1982, and has operated continuously since then. The extracted ground water is treated and reinjected into the brackish lower aquifer that underlies the Corcoran clay confining unit at a depth of 300 to 500 feet.

The extraction system has created a drawdown trough that trends northeast-southwest along the northern boundary of the plant. This trough controls offsite ground-water flow to the north and west and appears to capture most or all of the existing contaminant plume, despite occasional periods of ineffective control caused by high-volume water-supply pumping in the area.

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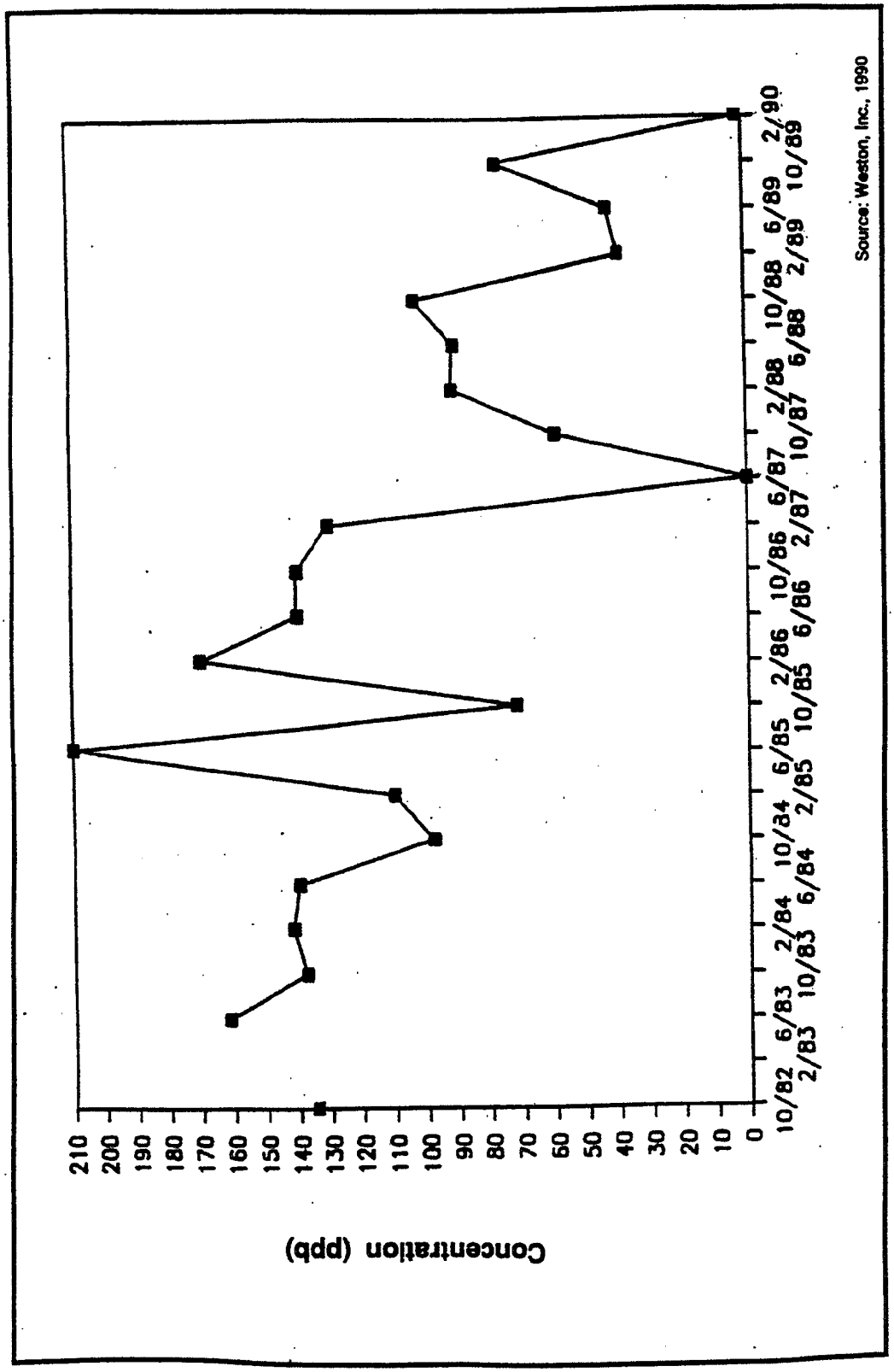

Figure 13
CONCENTRATION OF DBCP IN PW-6-197,
OCTOBER 1982 TO FEBRUARY 1990
OCCIDENTAL CHEMICAL SITE

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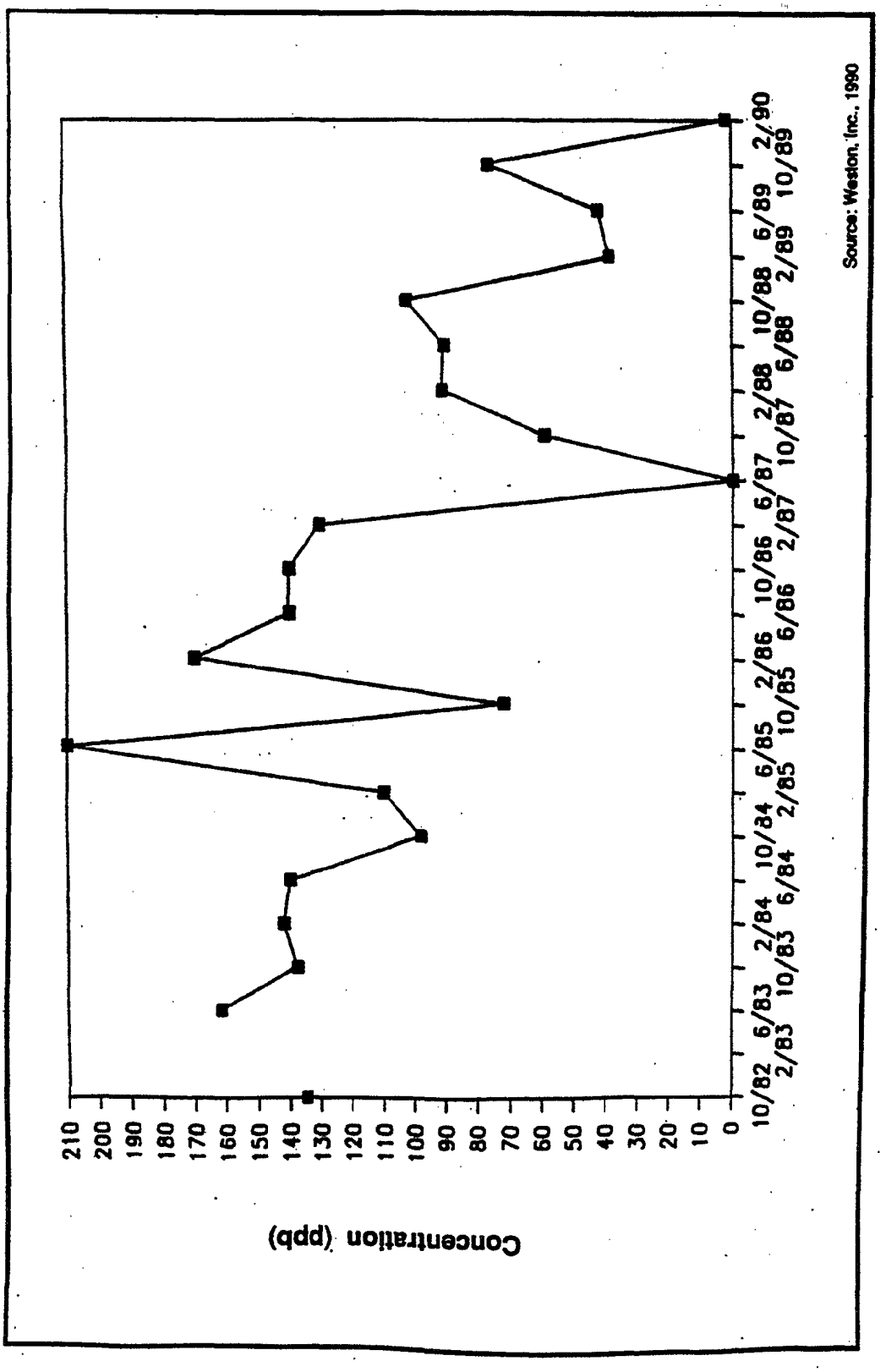

Figure 14
CONCENTRATION OF DBCP IN PW-8-150, OCTOBER 1982 TO FEBRUARY 1990
OCCIDENTAL CHEMICAL SITE

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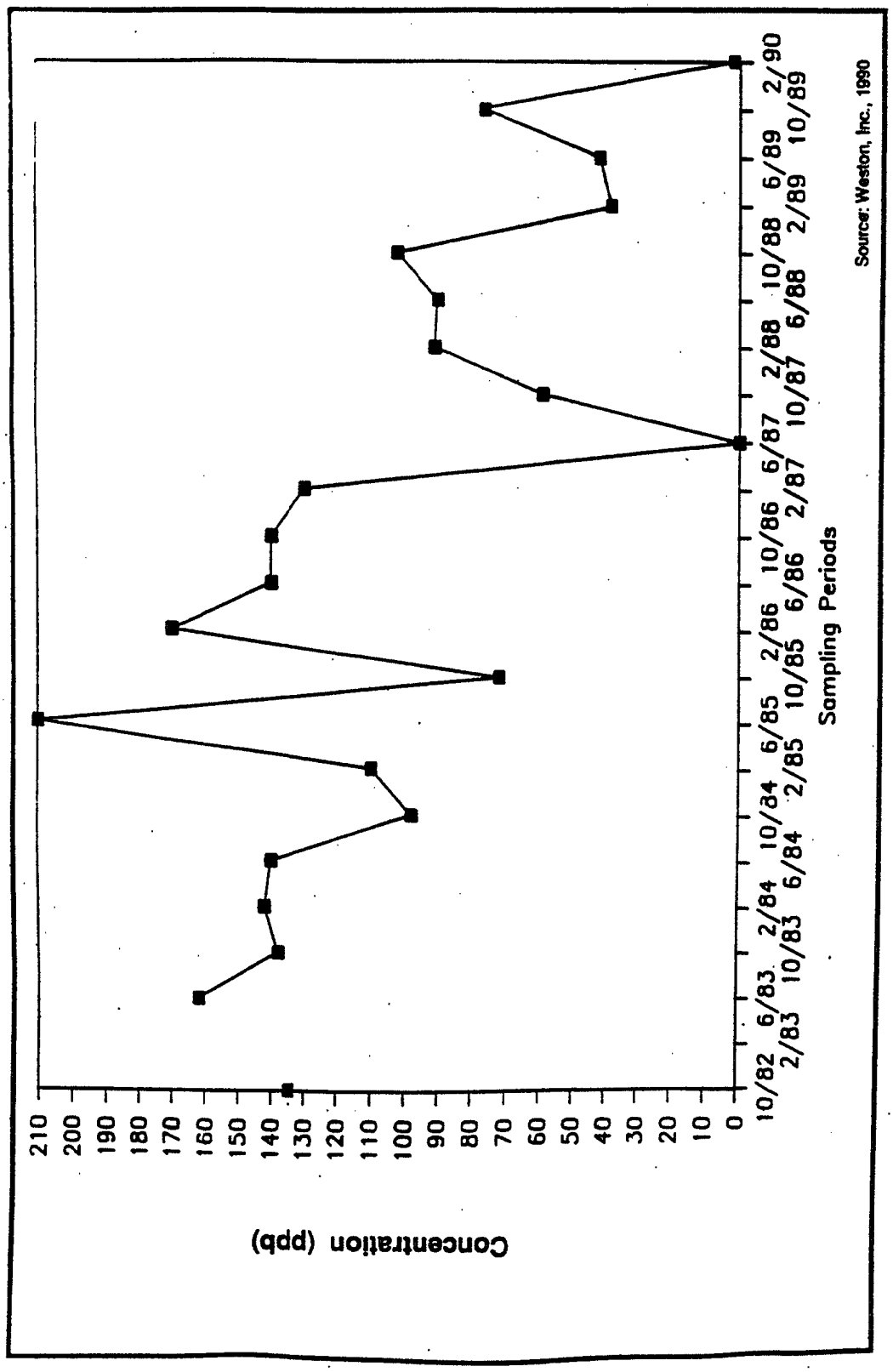

Figure 15
CONCENTRATION OF DBCP IN PW-22-71
OCTOBER 1982 TO FEBRUARY 1990
OCCIDENTAL CHEMICAL SITE

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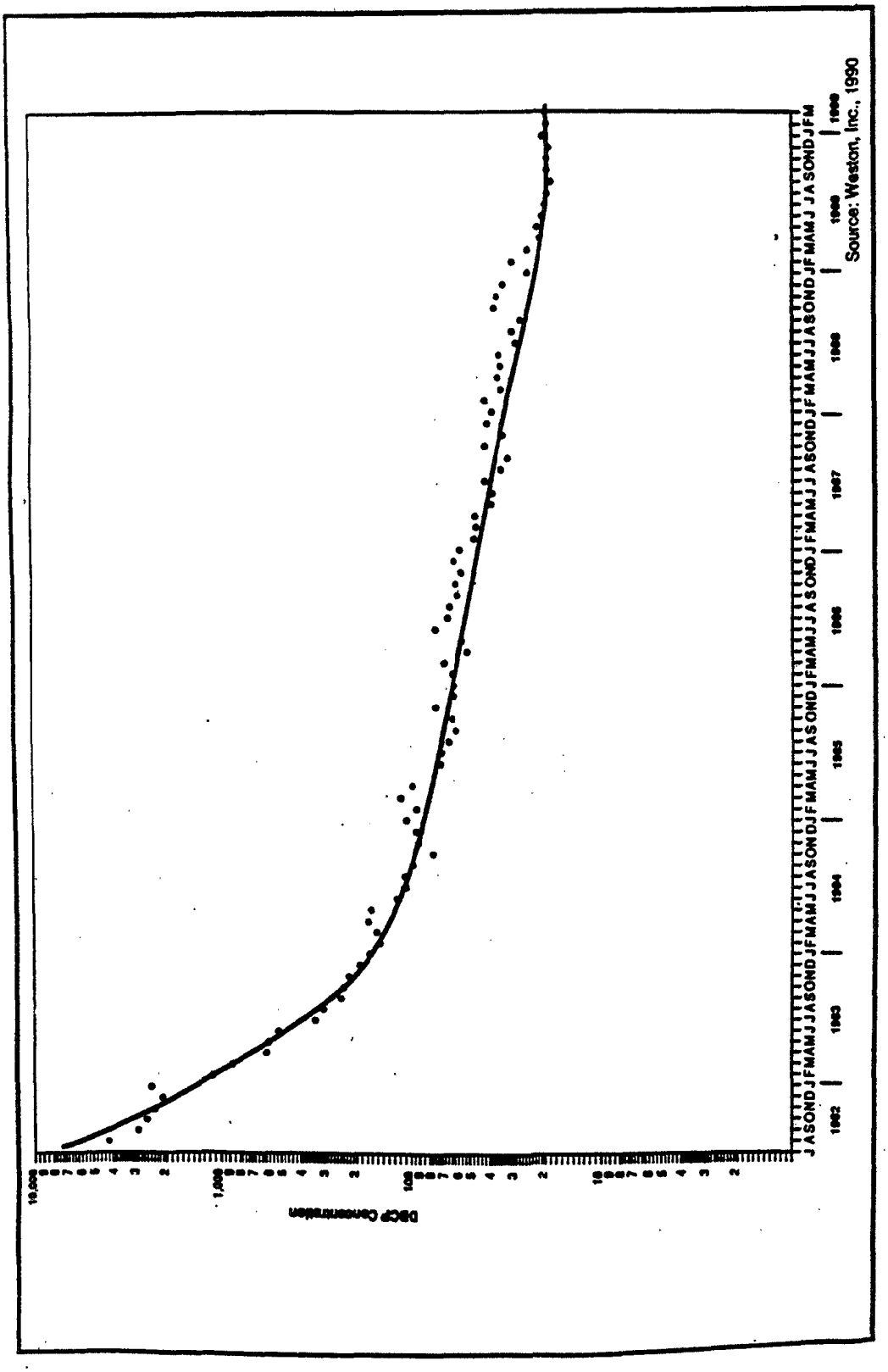

Figure 16
MONTHLY AVERAGE CONCENTRATION OF DBCP (ppb)
IN THE TREATMENT PLANT INFLUENT,
1982 TO MARCH 1990
OCCIDENTAL CHEMICAL SITE

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The concentrations of pesticides have decreased substantially in all three zones of the upper aquifer since extraction began in 1982. Contaminant concentrations in the upper aquifer are commonly less than 10 percent of their original levels, although high concentrations persist at the shallow well at PW-22. Significant reductions in nearby wells suggest that this area of high onsite contamination is not laterally extensive. DBCP concentrations are still up to three orders of magnitude higher than the drinking water standard of 0.2 ppb DBCP in some areas. The concentration of DBCP in the influent to the treatment system has decreased to less than 1 percent of its original concentration in the 7 1/2 years of operation.

SUMMARY OF NAPL-RELATED ISSUES

Contamination by non-aqueous phase liquids (NAPLs) is not suspected at the Occidental Chemical site. Some signs of contamination by NAPLs would include: (1) contaminant concentrations greater than 1 to 10 percent of aqueous solubility, (2) persistence of the contamination despite efficient extraction, (3) significant increases in contaminant concentrations following periods without pumping, (4) the existence of cross-gradient or upgradient contamination caused by slopes in the surface of impermeable layers, (5) high variability in contaminant concentrations, and (6) direct observation of NAPLs. None of these characteristics are present at the Occidental Chemical site.

Indications of possible NAPL contamination can be attributed to other factors. The stable trend, for example, in the influent concentration of DBCP since mid-1989, could be due to operational factors. Moreover, even if the existence of buried containers of pure product in the trenches can be taken as an indication that a NAPL source was released near the water table surface, this does not necessarily suggest that these contaminants remained in NAPL form after migrating some distance from their source.

Considerable variability in pesticide concentrations was observed between sampling events at a few individual locations in the monitoring network, notably in the shallow well at PW-22. Other examples of variable concentrations, especially along the western border of the site, can be seen in the 1989/1990 data presented in Figures 7, 8, and 9. Some of these changes were order of magnitude increases and decreases in concentrations. This variability was recognized early in the site monitoring program and was part of the justification for using trend surface analysis to smooth the data and make interpretation easier. The reason for the variability is not known. It is possible that the variability could be an indication of NAPL contamination, particularly at PW-22 where concentrations have historically been the highest observed at the site. A more complete analysis of the historical data would be necessary to add strength to this hypothesis.

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BIBLIOGRAPHY/REFERENCES

Camp, Dresser & McKee (CDM). May 3, 1983. 1982 *Annual Report, Occidental Chemical Company, Lathrop, California, Section IV: Recalibration of the Ground-water Flow Model in the Vicinity of the Occidental Chemical Facility, Lathrop, California.*

Canonie Environmental Services Corp. December 1980. *Groundwater and Soil Analysis Program Near Lathrop, California, Phase I Study.*

Canonie Environmental Services Corp. July 1981. *Soil Mitigation Measures, Western Storage Area, Occidental Chemical Company, Lathrop, California, Final Report.*

Luhdorff and Scalmanini Consulting Engineers. April 1983. *1982 Annual Report, Occidental Chemical Company, Lathrop, California, Sections I, II, and III.*

U.S. EPA, NEIC. June 1991c. Comments by Tom Dahl on the draft case study of the Occidental Chemical site.

U.S. Environmental Protection Agency (U.S. EPA), Tom Dahl. November 1985. Occidental Chemical Company at Lathrop, California, A Groundwater/Soil Contamination Problem and a Solution, paper presented at the *First International TNO Conference on Contaminated Soil, Utrecht, the Netherlands.*

U.S. EPA, Office of Drinking Water. March 31, 1987. *Health Advisories for 16 Pesticides, PB 87-200176.*

U.S. EPA, Tom Dahl. 1991a. Occidental Chemical Company at Lathrop, California, A Groundwater/Soil Contamination Problem and a Long-term Solution. Paper presented at the *Instituto Per L'Ambiente conference on The Reclamation of Contaminated Soils, Milan, Italy.*

U.S. EPA, National Enforcement Investigation Center (NEIC). May 14, 1991b. Personal communication with Tom Dahl, Consent Decree Coordinator for the Occidental Chemical-Lathrop site.

Weston, Inc. 1984. *Occidental Chemical Corporation, 1983 Annual Report, Groundwater Remedial Program, Lathrop, California.*

Weston, Inc. 1985a. *Occidental Chemical Corporation, 1984 Annual Report, Groundwater Remedial Program, Lathrop, California.*

Weston, Inc. 1985b. *Trend Surface Analysis of DBCP Concentrations in Groundwater at the Facility in Lathrop, California.*

Weston, Inc. 1986. *Occidental Chemical Corporation, 1985 Annual Report, Groundwater Remedial Program, Lathrop, California.*

Weston, Inc. 1987a. *Occidental Chemical Corporation, 1986 Annual Report, Groundwater Remedial Program, Lathrop, California.*

Weston, Inc. August 21, 1987b. *Site Investigation Report, J. R. Simplot Company Facility, Lathrop, California.*

Weston, Inc. 1988a. *Occidental Chemical Corporation, 1987 Annual Report, Groundwater Remedial Program, Lathrop, California.*

Weston, Inc. June 2, 1988b. *Proposed Remedial Excavation Plan, J. R. Simplot Company Facility, Lathrop, California.*

Weston, Inc. January 9, 1989a. *Remedial Excavation Project Report, J. R. Simplot Company Facility, Lathrop, California.*

Weston, Inc. 1989b. *Occidental Chemical Corporation, 1988 Annual Report, Groundwater Remedial Program, Lathrop, California.*

Weston, Inc. 1990. *Occidental Chemical Corporation, 1989 Annual Report, Groundwater Remedial Program, Lathrop, California.*

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CASE STUDY 22

Sylvester/Gilson Road
Nashua, New Hampshire

Abstract

Ground water at this 20-acre site is contaminated primarily with volatile organic compounds in a fractured bedrock aquifer and in the unconsolidated overburden. The site has been capped and enclosed within a slurry wall. Ground water within the slurry wall is extracted, treated, and reinjected. A portion of the treated water is injected outside the slurry wall to maintain inward gradients. Concentrations of the more soluble compounds have decreased substantially over the nine years of remediation. However, toluene concentrations have not been reduced, leading to the suspicion that toluene may be present in nonaqueous phase.

Background Data	
Date of Problem Identification	1970
Extraction Started	December 1981
Types of Contaminants	Arsenic, metals, semivolatile and volatile organic compounds
Primary Aquifer Materials	Glacial sand, gravel, and till over fractured schist
Maximum Number of Extraction Wells	8
Maximum Total Extraction Rate	300 gpm
Estimated Plume Area	16 acres
Estimated Plume Thickness	110 feet
Maximum Reported Concentrations	Tetrahydrofuran (THF): 1,000,000 ppb Methylene Chloride: 122,500 ppb Methyl Ethyl Ketone: 80,000 ppb Toluene: 140,000 ppb Chloroform: 81,000 ppb

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CASE STUDY
SYLVESTER/GILSON ROAD SITE

BACKGROUND OF THE PROBLEM

This case study summarizes the remediation of ground-water contamination at the Sylvester/Gilson Road site, located in the City of Nashua, New Hampshire. A location map is presented in Figure 1 and a site plan is presented in Figure 2.

SITE HISTORY

Approximately six acres of the site was used as a sand borrow pit for an undetermined number of years. The operator of the facility began using the pit for waste disposal in the late 1960s. Wastes in the pit include household refuse, demolition material, chemical sludges and hazardous liquid chemicals. The refuse and demolition material were usually buried and the sludges and liquids were either mixed with trash or allowed to percolate into the ground adjacent to the old sand pit. Drums containing hazardous liquids were buried or placed on the ground surface.

Dumping at the site was discovered by the State of New Hampshire in late 1970 and a court injunction was issued in 1976 ordering the removal of all materials from the site. The operator did not comply with the injunction and illegal dumping of hazardous wastes continued. In 1978, state officials observed drums stored at the site. A court order was issued in October 1979 prohibiting all further disposal of hazardous wastes at the site. Documents show that over 800,000 gallons of hazardous wastes were disposed at the site during ten months of 1979. In June 1980 1,314 drums containing primarily toluene, xylene, and benzene were removed from the site.

The initial site investigation, begun in April 1980, revealed high concentrations of heavy metals and volatile and semivolatile organics in ground water. The contaminant plume moved from the site northward toward Lyle Reed Brook (Figure 2). Volatile hazardous compounds that reached the creek were volatilized into the atmosphere resulting in ambient air concentrations above acceptable public health limits. The initial investigation indicated that if the plume migration was not mitigated, water quality criteria for arsenic, methylene chloride, chloroform, 1,1-dichloroethane (1,1-DCA), trichloroethylene (TCE), and benzene could potentially be exceeded in the Lyle Reed Brook and the Nashua River.

In December 1981, the EPA initiated emergency containment action at the site and a ground-water recirculation system was installed. The purpose of this system was only to control the offsite migration of contamination; no ground-water treatment was included at that time. Four extraction wells were installed to remove contaminated ground water from an area downgradient of the disposal area and discharge it to recharge trenches upgradient of the disposal area (Figure 2).

A remediation feasibility study was completed in May 1982, and a record of decision (ROD) was issued by the EPA in 1982. The ROD called for a slurry wall to be installed around the 19.2-acre site and a synthetic cap to be placed over the area. This containment system was installed by December 1982. Pilot plant studies for treatment of extracted ground water were conducted in early 1983. A supplemental ROD concerning ground-water extraction and treatment was issued in September 1983. The existing ground-water pumping/recharge system began operation in September 1984 with no treatment. The ground-water treatment plant for removal of metals and volatile organic compounds (VOCs) began operation in April 1986.

GEOLOGY

The site is underlain by fractured bedrock mantled with 20 to 100 feet of unconsolidated sediments. These sediments consist of a thin low-permeability glacial till covered by a high-permeability sand and gravel outwash deposit (Figure 3). The glacial till ranges in thickness from 0 to over 20 feet and appears to be absent in the vicinity of Wells LIM-40, M-21, FIM-5, and GZ-5 (Figure 2).

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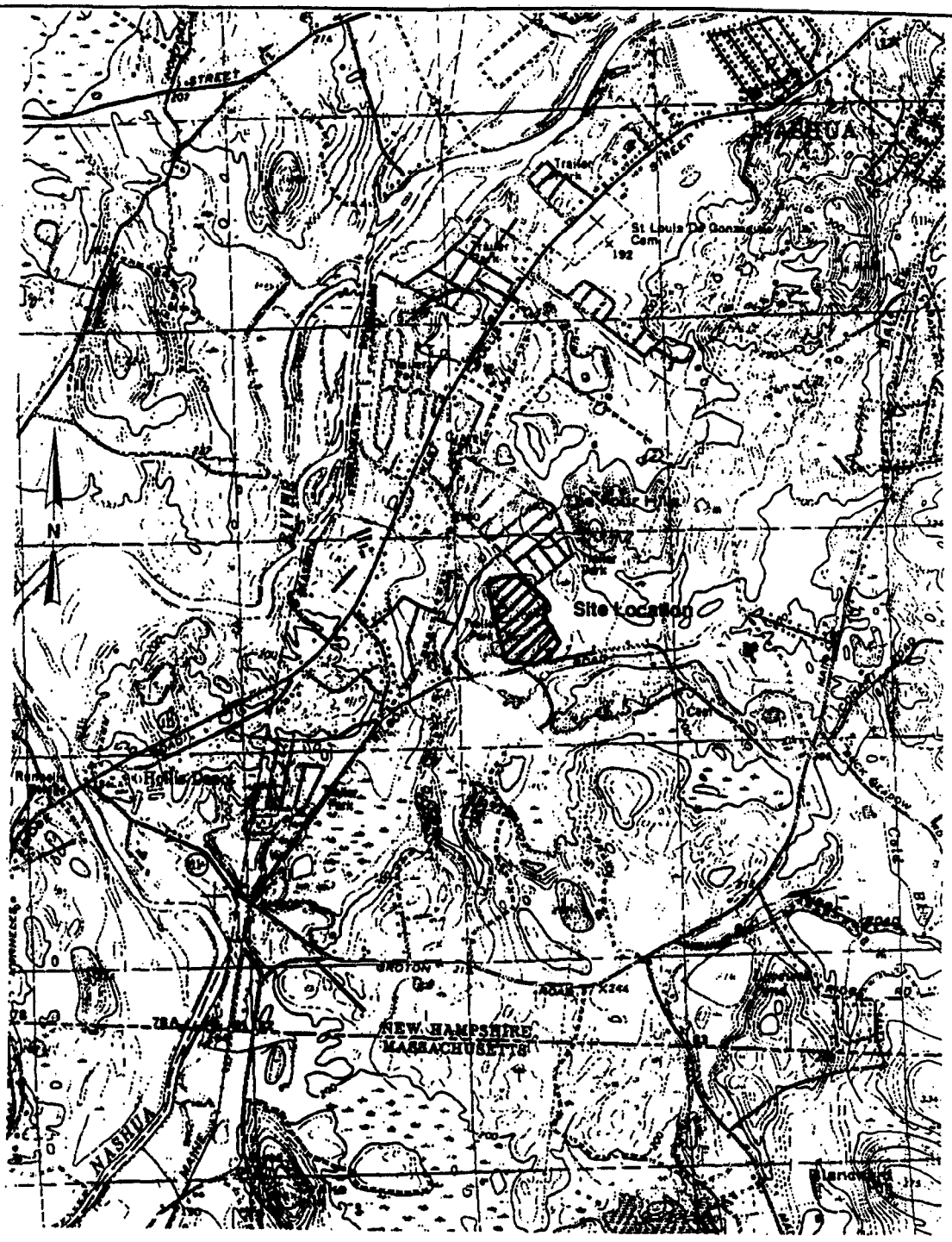

0 1000 2000
Scale in Feet

Source: USGS, Pepperell Quadrangle, 1979

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Figure 1
SITE LOCATION MAP
SYLVESTER/GILSON ROAD SITE
NASHUA, NEW HAMPSHIRE

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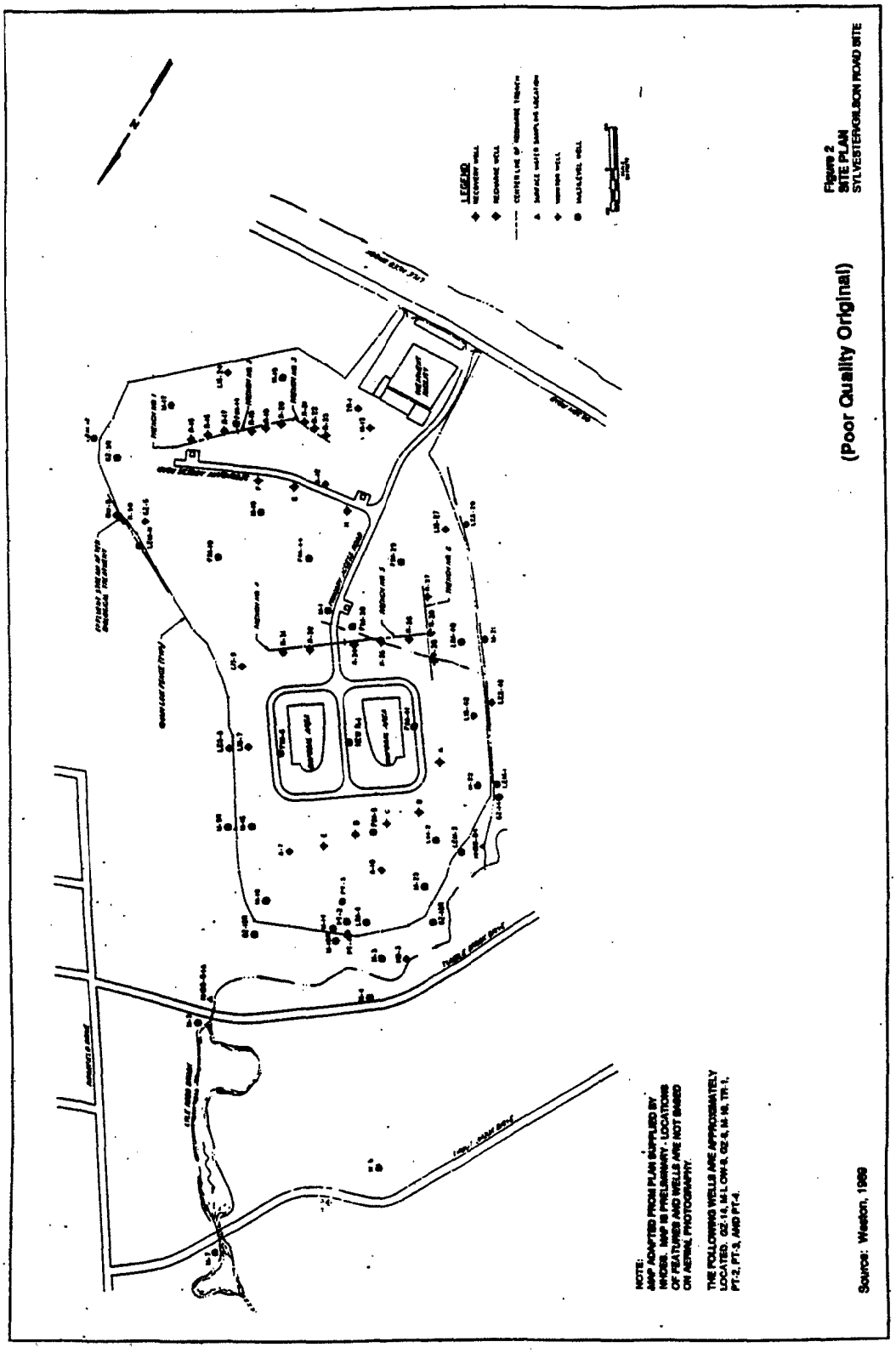

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Figure 2
SITE PLAN
SYLVESTER/GILSON ROAD SITE

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The bedrock unit reportedly consists of a biotite schist of the Merrimack Group and igneous rocks. It is differentially weathered and fractured and is characterized by northeast and north-trending ridges and valleys. As Figure 3 shows, the top of the bedrock surface is irregular, with variation in relief of more than 70 feet. Unconsolidated deposits are in the valleys in the bedrock surface and are thickest where bedrock elevations are the lowest (Figures 3 and 4).

HYDROGEOLOGY

The site is located within the Lyle Reed Brook watershed. Lyle Reed Brook flows from the east to within 50 to 1,000 feet of the site around the southern, western, and northwestern boundaries, eventually discharging into the Nashua River.

Two major aquifer systems within this watershed underlie the site. One is the sand and gravel stratified drift aquifer, and the other is the fractured bedrock aquifer. A discontinuous silt, sand, and gravel till layer of varying thickness and permeability separates the two aquifers. In general, the till has a lower hydraulic conductivity than the overlying stratified drift and, in some places, may act as a confining layer. Where the till is absent, the stratified drift and fractured bedrock aquifers are in direct hydrogeologic communication.

Ground water in the stratified drift occurs under water table conditions, while ground water within the fractured bedrock probably occurs under semiconfined conditions (Weston, 1989). Aquifer tests in the stratified drift yielded a range of hydraulic conductivity between 20 and 200 ft/day and a range of transmissivities between 700 and 6,600 ft^2/day (Weston, 1989). Transmissivity for the fractured bedrock is reported as 6,500 ft^2/day (Weston, 1989). However, Weston (1989) reports that pumping rates in the bedrock wells range from 2 to 100 gpm. This suggests that there is a significant range of hydraulic conductivity in the bedrock (see Table 1).

On the basis of this data, Weston (1982) concluded that the overburden and bedrock aquifers are hydrogeologically similar and respond in a similar manner to regional hydraulic influences. As a result, Weston (1982) expected that without active gradient control there would be considerable underflow from the slurry wall containment area.

Ground-water elevations measured in the stratified drift in January 1982, 1 month after the start-up of the ground-water recirculation system, ranged from 167 to 174 feet above MSL and showed ground water flowing across the site in a northwesterly direction toward Lyle Brook (Figure 5). Weston (1982) calculated ground-water flow velocities to be 0.8 to 1.6 feet/day and reported that Goldberg, Zoino, and Associates estimated the hydraulic gradient to be 0.003 to 0.004 feet/foot. The water level contours shown in Figure 5 show no obvious hydraulic effect produced by the interim recirculation system that began operating in December 1981.

WASTE CHARACTERISTICS AND POTENTIAL SOURCES

Ground water is contaminated with numerous organic compounds and selenium. The maximum ground-water concentrations of these compounds in 1981 and the cleanup goals are presented in Table 2. Note that only validated data are presented here. Some samples that were not validated showed higher concentrations than the maximum values listed. The cleanup goals, known as alternate concentration levels (ACLs), were based on extensive research and are levels deemed necessary to adequately protect human health and the environment (U.S. EPA, 1990).

Table 2 shows that there has been a significant decrease in the concentrations of contaminants on this site. However, two contaminants (toluene and 1,1 dichlorethane) show significant increases in concentration in some samples.

Figure 6 presents a contour map of total VOC concentration for December 1980. The high-concentration area of the plume extended in an elliptical shape from the area of historical liquid waste disposal near the current location of trench 3 to monitoring point FIM-41. Tetrahydrofuran (THF) was found in concentrations exceeding 1,000,000 ppb. Toluene, methylene chloride, and methyl isobutyl ketone occurred at concentrations one to two orders of magnitude lower. In the vertical column, the contaminants were distributed relatively uniformly in the overburden with slight decreases in concentration with greater depth. VOC concentrations were elevated in bedrock near monitoring point M-1, suggesting hydraulic connection between the overburden and the bedrock.

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Table 1
ESTIMATES OF AQUIFER CHARACTERISTICS
SYLVESTER/GILSON ROAD SITE

Parameter/Flow Zone	Basinwide Estimates	Site-Specific Measure ments	Earlier Modeling Studies	Current Modeling Studies
Hydraulic Conductivity (ft/day) Overburden/Stratified Drift	30-100	20-200	'50	30
Transmissivity (ft^2/day) Overburden/Stratified Drift Bedrock	2,000-8,000 ---	700-6,600 6,500	3,500 6,500	2,500 1,190
Saturated Thickness (ft) Overburden/Stratified Drift	10-80	30-90	50	30-80
Horizontal Hydraulic Gradient (ft) Overburden/Stratified Drift Bedrock	0.006 ---	--- ---	0.004 0.004	0.004-0.006 0.004-0.006
Porosity (%) Overburden/Stratified Drift	30-32	---	---	---
Effective Porosity/Specific Yield (%) Overburden/Stratified Drift	14-32	---	25	25
Vertical Hydraulic Conductivity (ft/day) Till Layer	---	5	5	5
Regional Groundwater Recharge (in/yr)	24	---	42	18

Source: Weston, 1989

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Table 2
GROUNDWATER QUALITY IN 1981 AND 1988
SYLVESTER/GILSON ROAD SITE

ACL Compounds	Maximum Concentration in Groundwater (1981)	Alternate Concentration Level (ACL)	Maximum Concentration in Groundwater (1988)	Number of Samples That Exceeded ACLs	Number of Samples
Vinyl Chloride	950	95	300	1	65
Benzene	3400	340	1100	2	65
Chloroform	81000	1505	5	0	65
1,1,2 Trichloroethane	17	1.7	5 U	0	65
Tetrachloroethene	570	57	10	0	65
Trichloroethylene	15000	1500	3	0	65
Methyl Ethyl Ketone	80000	8000	7400 J	0	65
Chlorobenzene	1100	110	800	7	65
Methylene Chloride	122500	12250	39	0	65
Toluene	29000	2900	31000	3	65
1,1 Dichloroethane	15	1.5	2200	18	65
Trans-1,2 Dichloroethylene	18000	1800	9200	1	65
1,1,1 Trichloroethane	2000	200	38	0	65
Methyl Methacrylate	3500	350	ND	ND	0
Selenium	NA	2.6	5 U	0	10
Phenols	NA	400	2274	3	25

Source: Weston, 1989

Note: All concentrations in ppb.
ND denotes No Data.
NA denotes Not Available.
Sampling points with multiple occurrences include FIM 29-2 and FIM 44-3.
No data is available for Methyl metacrylate.
Only validated data are presented.
J= estimated value
U = below quantification limit

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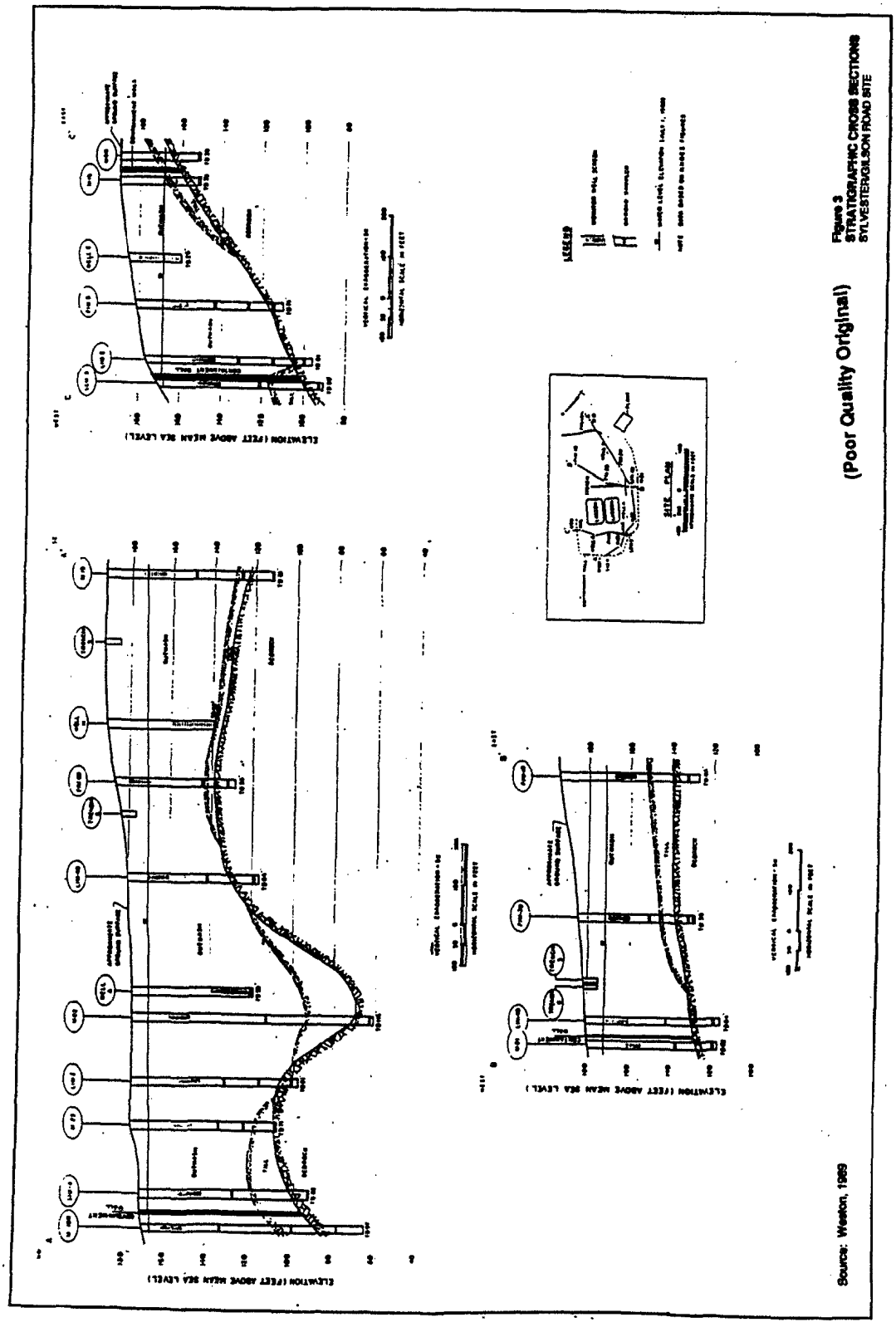

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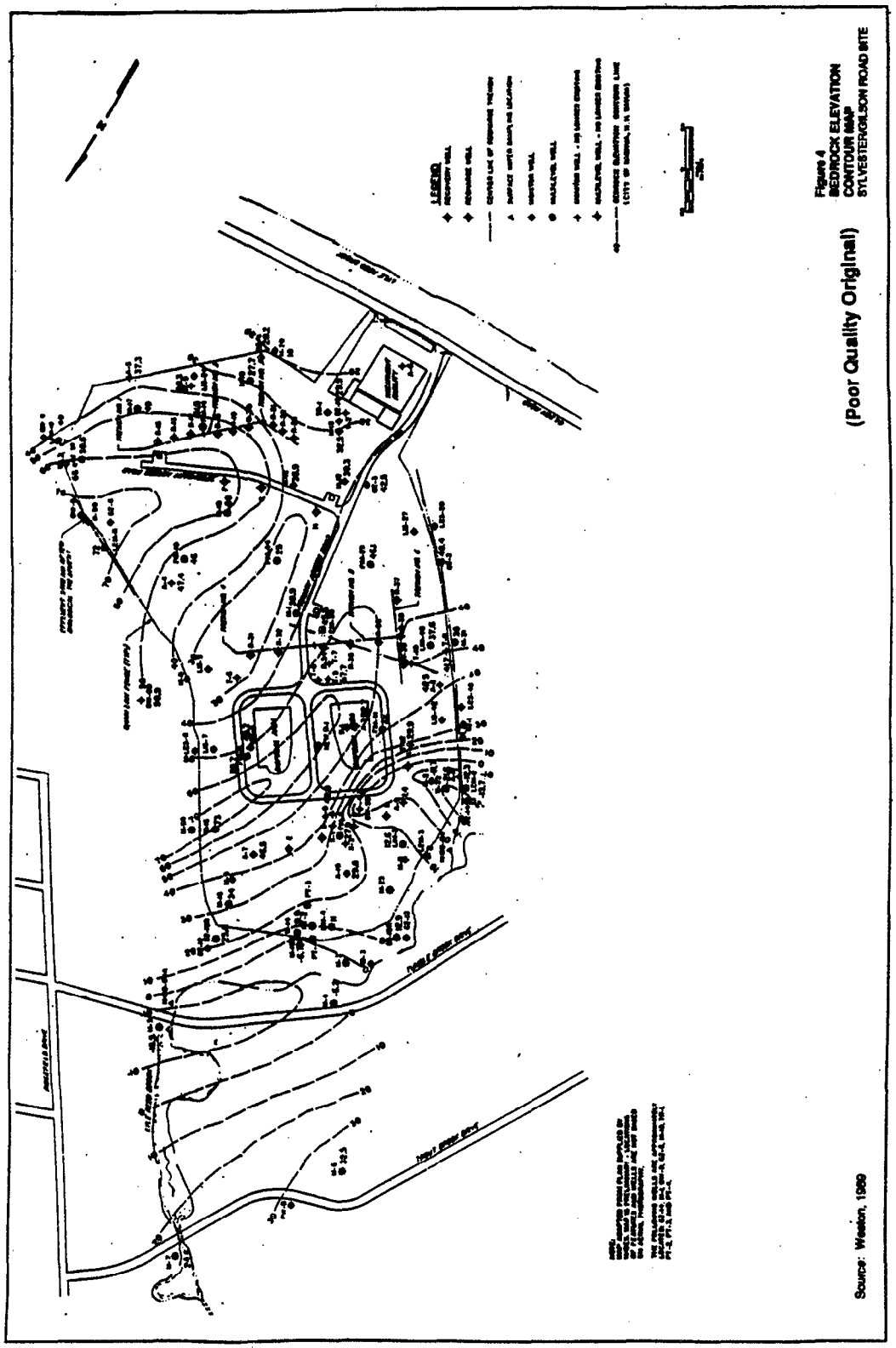
LEGEND
Figure 4
BEDROCK ELEVATION
CONTOUR MAP
SYLVESTER/GILSON ROAD SITE
(Poor Quality Original)
Source: Weston, 1989

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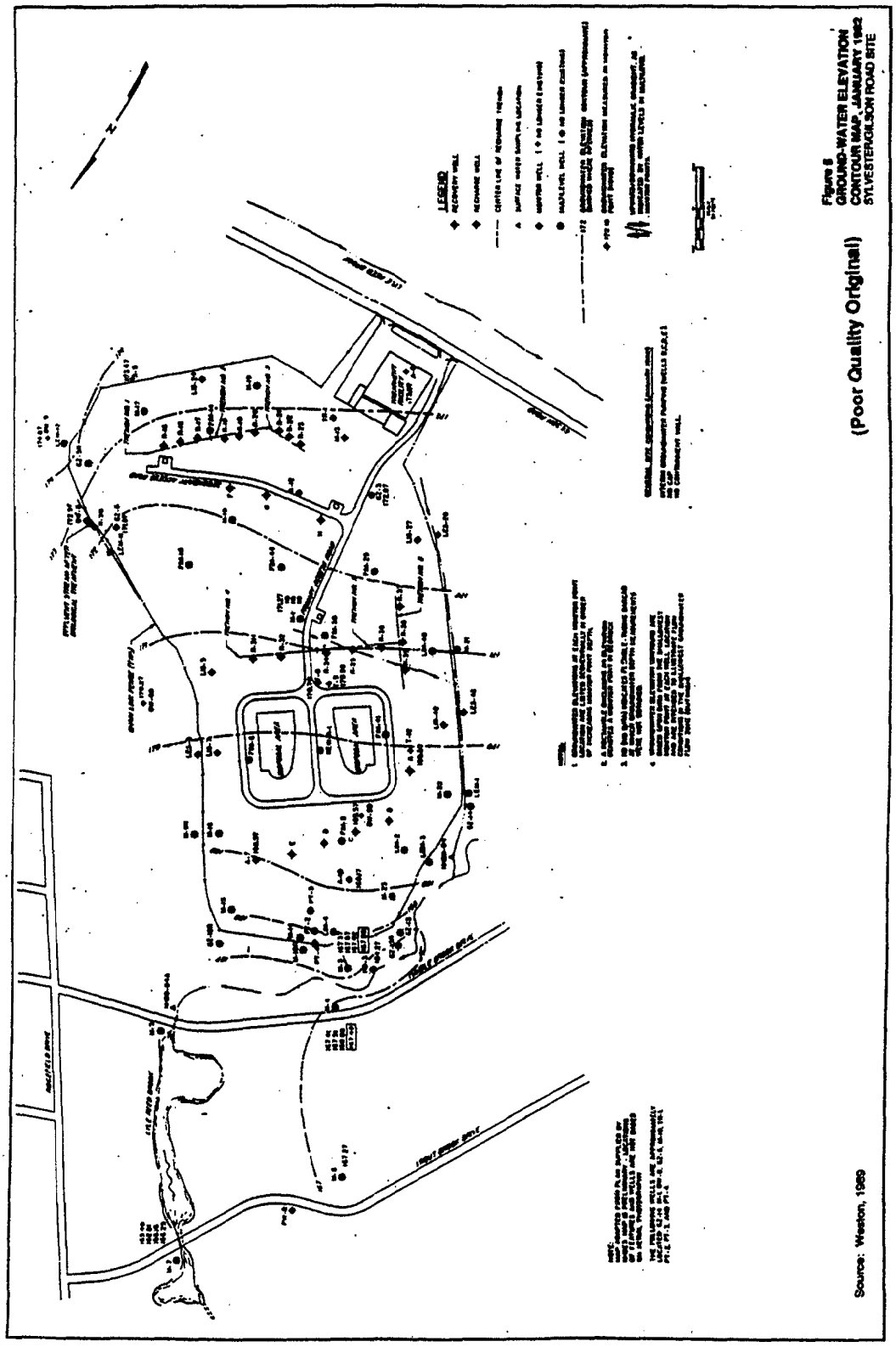
LEGEND
Source: Weston, 1989
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Figure 8
GROUND-WATER ELEVATION
CONTOUR MAP, JANUARY 1992
SYLVESTER/GILSON ROAD SITE

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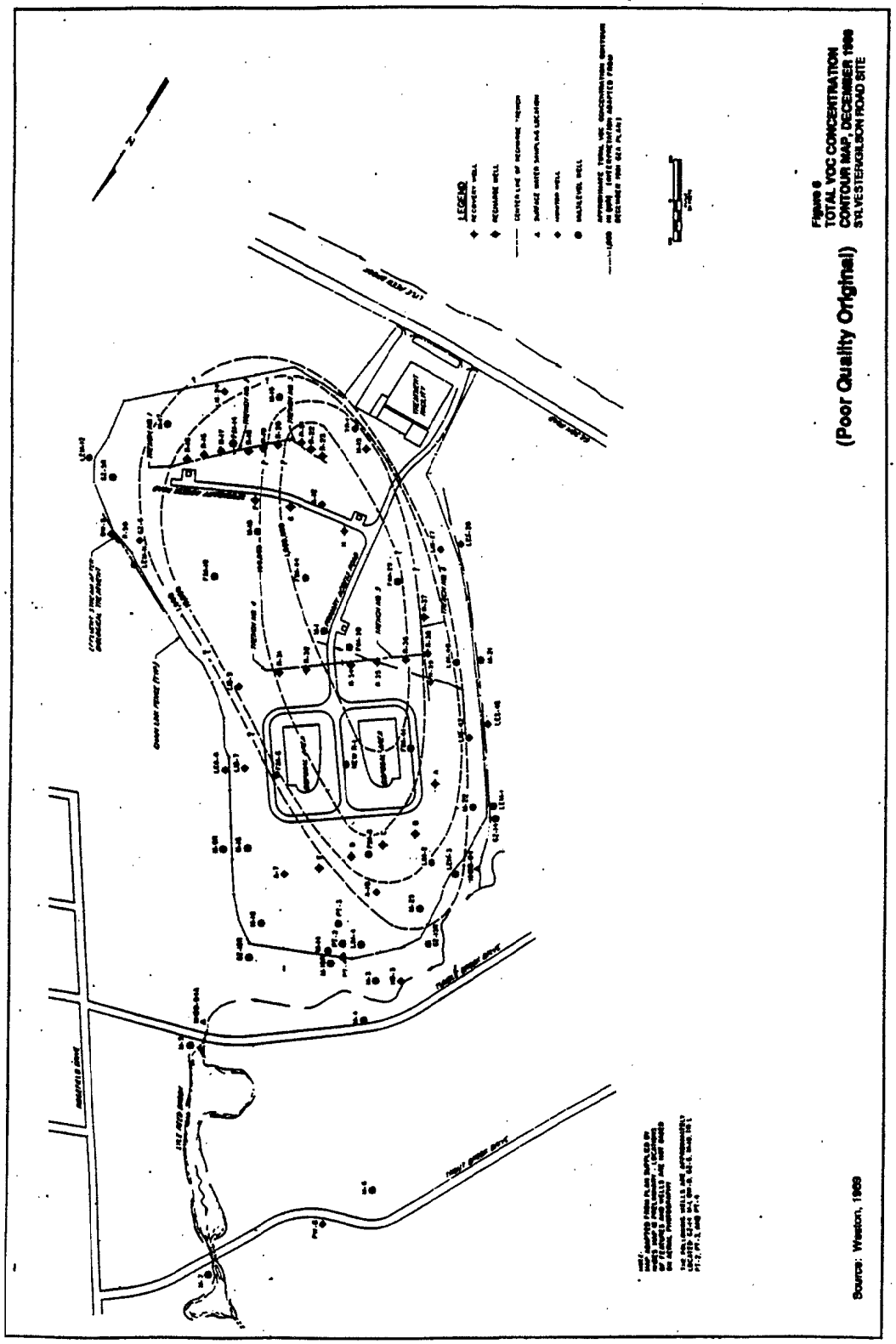
LEGEND
Figure 6
TOTAL VOC CONCENTRATION
CONTOUR MAP, DECEMBER 1989
SYLVESTER/GILSON ROAD SITE
(Poor Quality Original)
Source: Weston, 1989

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REMEDIATION

Selection and Design of the Remedy

As a result of the initial ROD, a synthetic cap and containment wall were constructed to minimize infiltration and limit contaminant migration. The containment wall, shown in Figure 7, corresponds approximately to the location of the perimeter fence shown in the other site maps. It was constructed of bentonite slurry with a design hydraulic conductivity of 10^{-7} cm/sec. The slurry wall is approximately 4 feet wide, 4,000 feet in perimeter length, and as deep as 100 feet in some locations (Weston, 1989). Approximately 20 acres are enclosed by the wall and covered by the cap.

The existing remedial system also includes eight ground-water extraction wells (A through H) and seven recharge trenches (1 through 7). The purpose of the system is to isolate contaminated ground water, recover and treat ground water in the isolated system, and induce uniform flushing of the isolated upper saturated zone. Ground water is extracted, treated, then recharged through trenches. The maximum pumping rate for each of the eight wells is 40 to 50 gallons per minute (gpm) (Weston, 1989). The ground-water treatment system design flow rate is 300 gpm (U.S. EPA, 1990).

The extraction well and recharge trench locations are shown in Figure 2. Three of the trenches (1, 2, 3) are located at the upgradient end of the site, three trenches (4, 5, 6) are located in the middle of the site, and one trench (7) is located just outside the containment wall on the northeast side of the site. Recharge to trench 7 is intended to maintain greater pumping rates than recharge rates in the containment area to induce inward rather than outward flow through the fractured bedrock under the slurry wall.

Table 3 lists the 1988 average extraction rates for wells and the average recharge rates for the trenches. The average total extraction rate was 260 gpm. Approximately 50 gpm of the treated ground water is recharged to trench 7, exterior to the wall. The majority of the treated ground water, averaging 105 gpm, is recharged to trench 4. The recharge rates to trenches 1, 2, and 3 are variable. Recharge to trenches 5 and 6 has been minimal. The preferential recharge to trench 4 results in mounding of the ground-water surface in the area of trench 4 (see Figure 8).

The ground-water treatment system includes chemical precipitation for removal of inorganic constituents, high temperature air stripping for volatile organics removal, and extended aeration activated sludge treatment for the portion of the waste stream that is to be discharged offsite (in trench 7). Sludge produced by the treatment plant is deposited in the disposal areas shown near the center of the site on the site maps. These disposal areas are constructed above the cap that covers the site inside the slurry wall and are provided with a leachate collection system. The treatment system began operating in 1986. Prior to that time, the ground-water extraction system was operated solely to recirculate ground water within the confines of the slurry wall, and there was no offsite discharge.

EVALUATION OF PERFORMANCE

Hydraulic Control

A ground-water elevation contour map for the stratified drift aquifer in July 1988 is presented in Figure 8. This map shows that water elevations across the site were slightly higher in 1988 than in 1982 (Figure 5), and the major ground-water flow at the site continued to be to the northwest and west. Mounding is evident around trenches 2 and 4; however, cones of depression are not apparent around the extraction wells. In addition, the gradient across the slurry wall was not consistently inward (Figure 8). These observations suggest that pumping rates are insufficient to effectively control ground-water flow, especially at the northwest and southwest ends of the site.

There have been some problems with clogging of the recharge trenches, which may have limited the rates of ground-water recirculation. Before 1986, recharge of untreated water to the onsite trenches led to fouling by iron precipitation. Now that metals are removed at the treatment plant before the ground water is recharged, iron precipitation is no longer a problem. However, the fouled trenches still need to be rehabilitated. Biological encrustation has been a problem in the offsite recharge trench, but periodic treatment with hydrogen peroxide seems to be effective in keeping this trench in operation.

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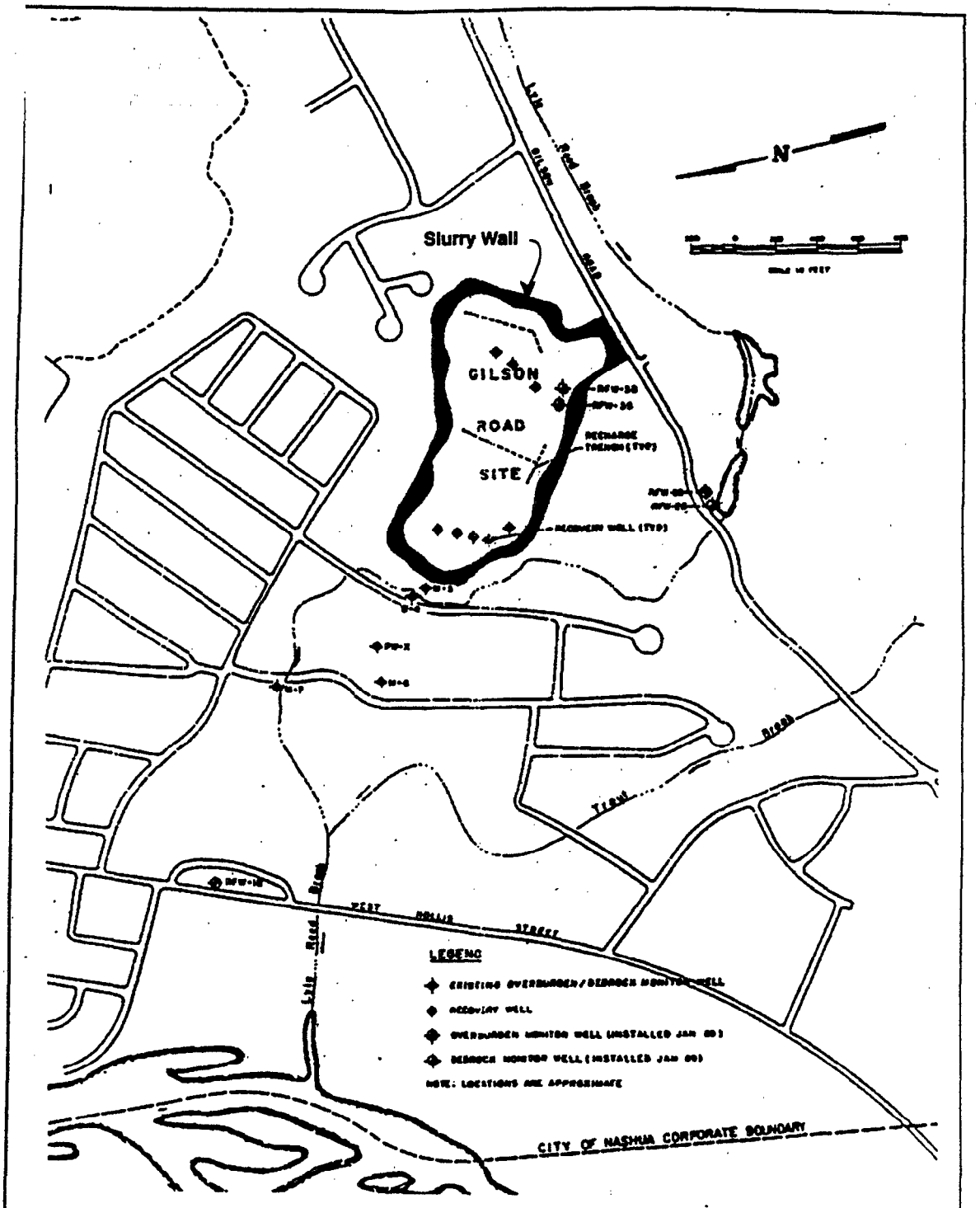

Source: Weston, 1989

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Figure 7
SLURRY WALL
SYLVESTER/GILSON ROAD SITE

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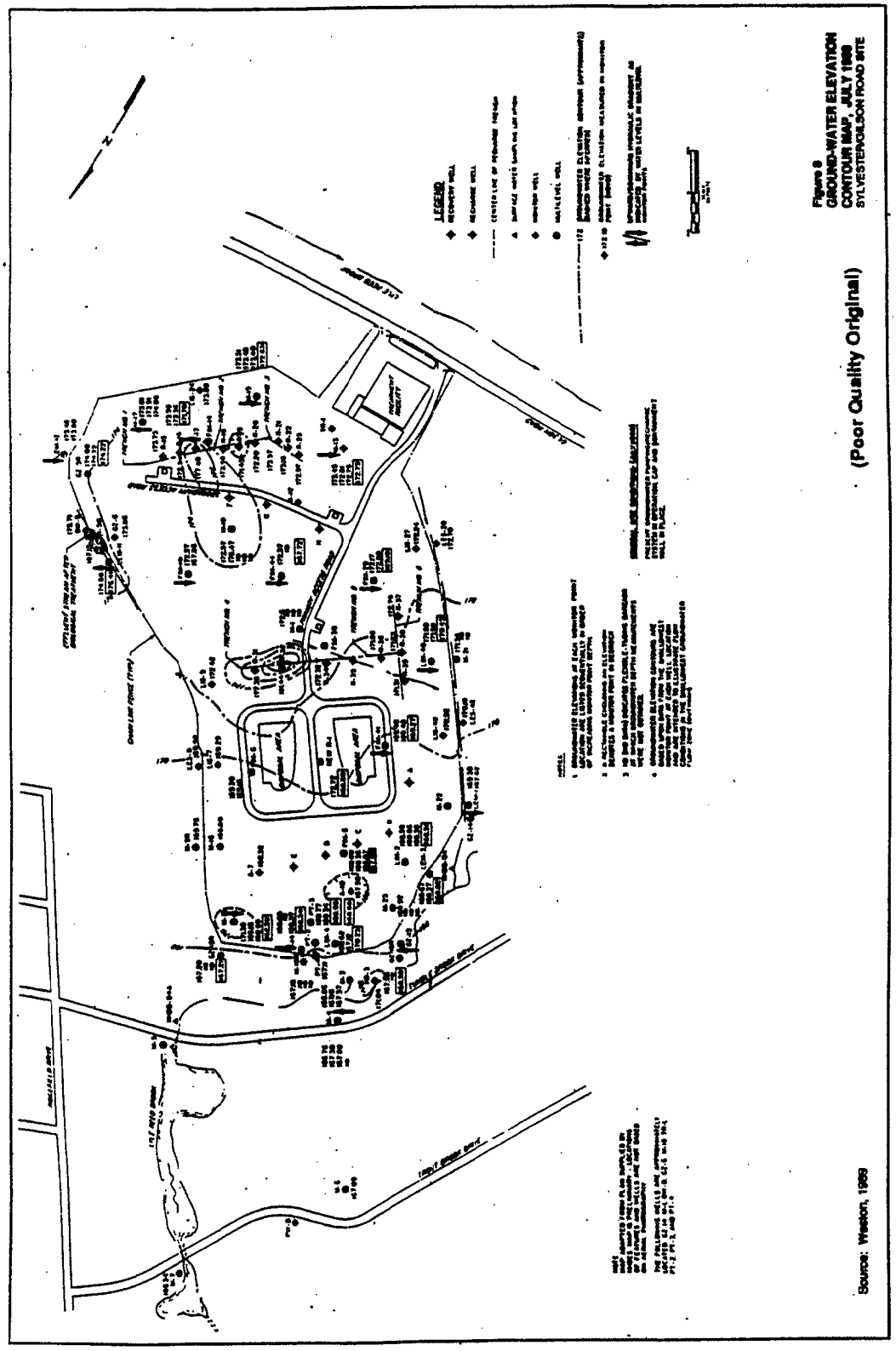
LEGEND
Figure 8
GROUND-WATER ELEVATION
CONTOUR MAP, JULY 1989
SYLVESTER/GILSON ROAD SITE
(Poor Quality Original)
Source: Weston, 1989

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Table 3
1988 EXTRACTION AND RECHARGE RATES
SYLVESTER/GILSON ROAD SITE

Wells (A-H) and Trenches (1-7)	Extraction/Recharge (gpm)	
	Plant Records	Estimated Average
A	30 - 38	33
B	0 - 38	30
C	0	0
D	38 - 47	42
E	38 - 50	45
F	0 - 45	25
G	0 - 45	40
H	35 - 50	45
1	5 - 20	10
2	5 - 35	35
3	5 - 65	60
4	5 - 80+	105
5	0 - 15	0
6	0 - 10	0
7	50	50

Source: Weston, 1989

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A new operating mode was proposed in 1989 to increase ground-water capture. Pumping and recharge rates would be preferentially redistributed toward areas of high residual contamination without significantly reducing the overall capture zone. The proposed new extraction and recharge rates are shown in Table 4. The intent is to increase pumping in areas of high contamination (wells A, H, G, and F), increase recharge in areas of high contamination (trenches 2 and 3), and decrease recharge to trench 4. The rates were selected on the basis of contaminant concentrations and the capabilities of individual wells and trenches (Weston, 1989). The new total extraction rate is 300 gpm.

Six new extraction wells in areas of greatest residual contamination were planned for installation in the fall of 1990 (U.S. EPA, 1990). Additional flow modeling was conducted to optimize the locations and pumping rates of the wells. Rebuilding recharge trenches to maintain design recharge rates was planned for the summer of 1990.

Multilevel monitoring points show downward ground-water gradients across much of the site, indicating that the contaminant plume may be escaping downward from the stratified drift into the fractured bedrock zone in areas were the till is absent. In view of this, consideration is being given to increasing the recharge rate to trench 7 to 100 gpm (U.S. EPA, February 13, 1991).

Reductions in Mass and Concentration of Contaminants

Treatment Plant Influent Data. Figure 9 presents plots of VOC concentrations in treatment plant influent for selected compounds (toluene, THF, chloroform, chlorobenzene) over time. The plots show decreasing concentrations for THF, methyl ethyl ketone (MEK), and chloroform with stable toluene concentrations. Toluene concentrations remained relatively constant although high removal efficiencies were observed in the treatment plant (Weston, 1989).

Ground-water Quality Data. Data collected in May 1988 showed decreases in pollutant concentrations since treatment plant startup in 1986 ranging from 58 to 100 percent for all ACL compounds except toluene and 1,1-dichloroethane (1,1-DCA). The maximum concentration of ACL compounds detected in 1988 are given in Table 2. For eight of the 16 ACL compounds, all of the samples collected had concentrations less than the ACLs. Ground-water quality data were collected after May 1988, but according to Region 1 EPA staff, the data are not available at this time as a result of pending litigation.

Because there are many contaminants in the ground water, three indicator compounds were selected to monitor water quality conditions: toluene, THF, and 1,1-DCA. Toluene and THF have historically been dominant contaminants. Toluene and THF are both less dense than water and 1,1-DCA is more dense than water.

Contour maps of total VOC concentrations at various depths across the site in May 1988 is shown in Figures 10A through 10C. Cross-sections of total VOC concentrations are shown in Figure 11. VOC concentrations exceeding 10,000 ppb occur along the west side in the shallow overburden and in the bedrock. VOC concentrations greater than 100,000 ppb are found at the southern end of the site in the overburden aquifer.

A comparison of total VOC concentrations in 1988 with those of 1980 (Figure 6) shows an order of magnitude reduction. It is also evident that the plume has been split by recharge trenches 4 and 5 in the middle of the site. The bedrock concentrations are higher under trenches 4 and 5 than around extraction wells C, D, and E. The opposite trend is observed in the overburden.

Contour maps of toluene concentrations at various depths in May 1988 are presented in Figures 12A through 12C. Cross-sections of toluene concentrations are shown in Figure 13. Toluene concentrations in the overburden range from over 100,000 ppb at the southeastern end of the site to 10 ppb at the northwestern end. Toluene concentrations in the bedrock exceed 1,000 ppb along the southeastern end and west side of the site.

The sustained elevated toluene concentrations in both treatment plant influent and ground-water monitoring wells may indicate the presence of toluene floating on the ground water and/or at residual saturation in the vadose zone as a nonaqueous phase liquid (NAPL). Other VOCs may be in solution with the nonaqueous phase

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Table 4
PROPOSED NEW EXTRACTION AND RECHARGE RATES
SYLVESTER/GILSON ROAD SITE

Well/Trench	Extraction/Recharge (gpm)
A	40
B	40
C	47
D	0
E	23
F	50
G	50
H	50
1	60
2	75
3	75
4	55
5	10
6	10
7	50

Source: Weston, 1989

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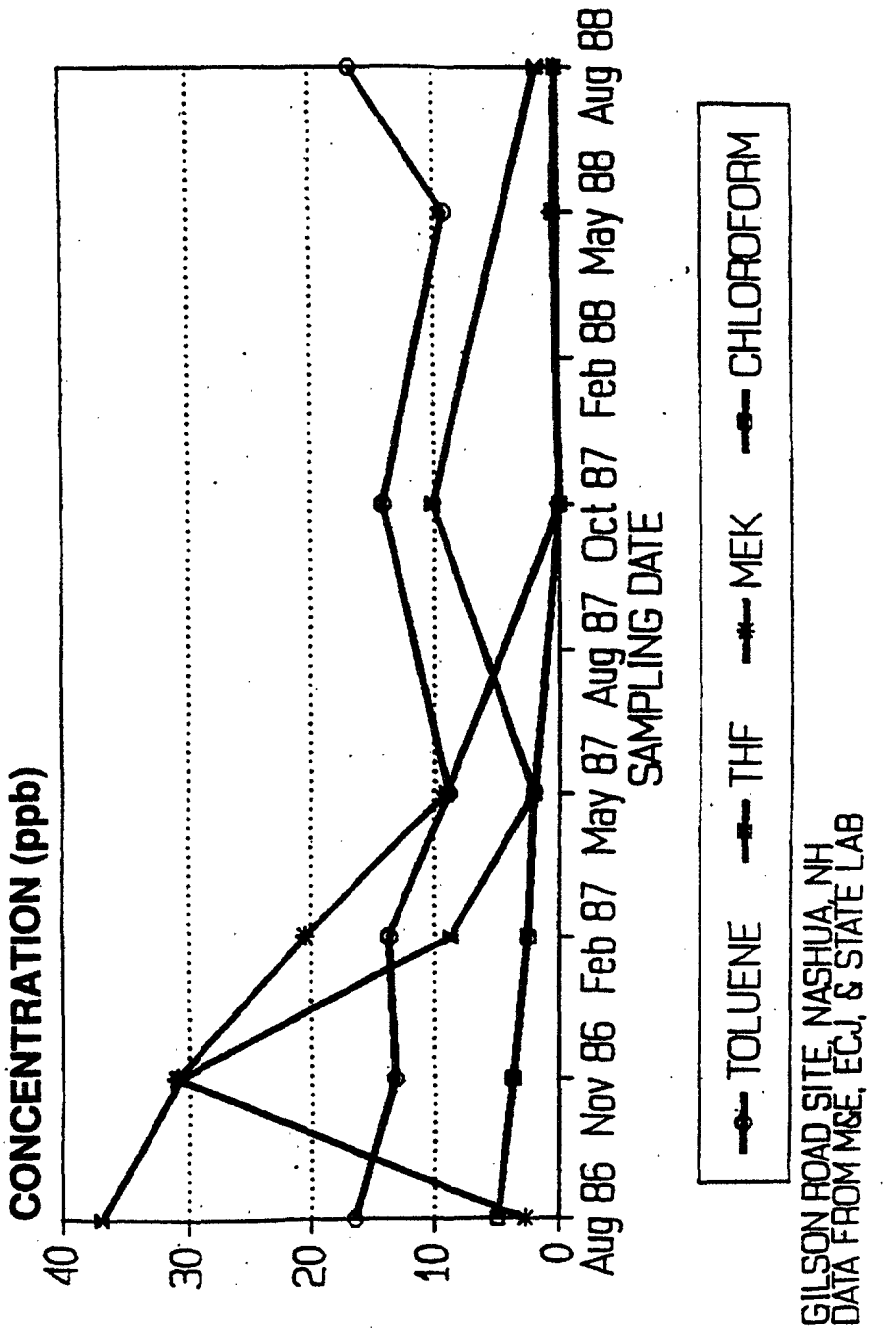

Source: Weston, 1989

Figure 9
SELECTED VOCs IN TREATMENT PLANT INFLUENT
SYLVESTER/GILSON ROAD SITE

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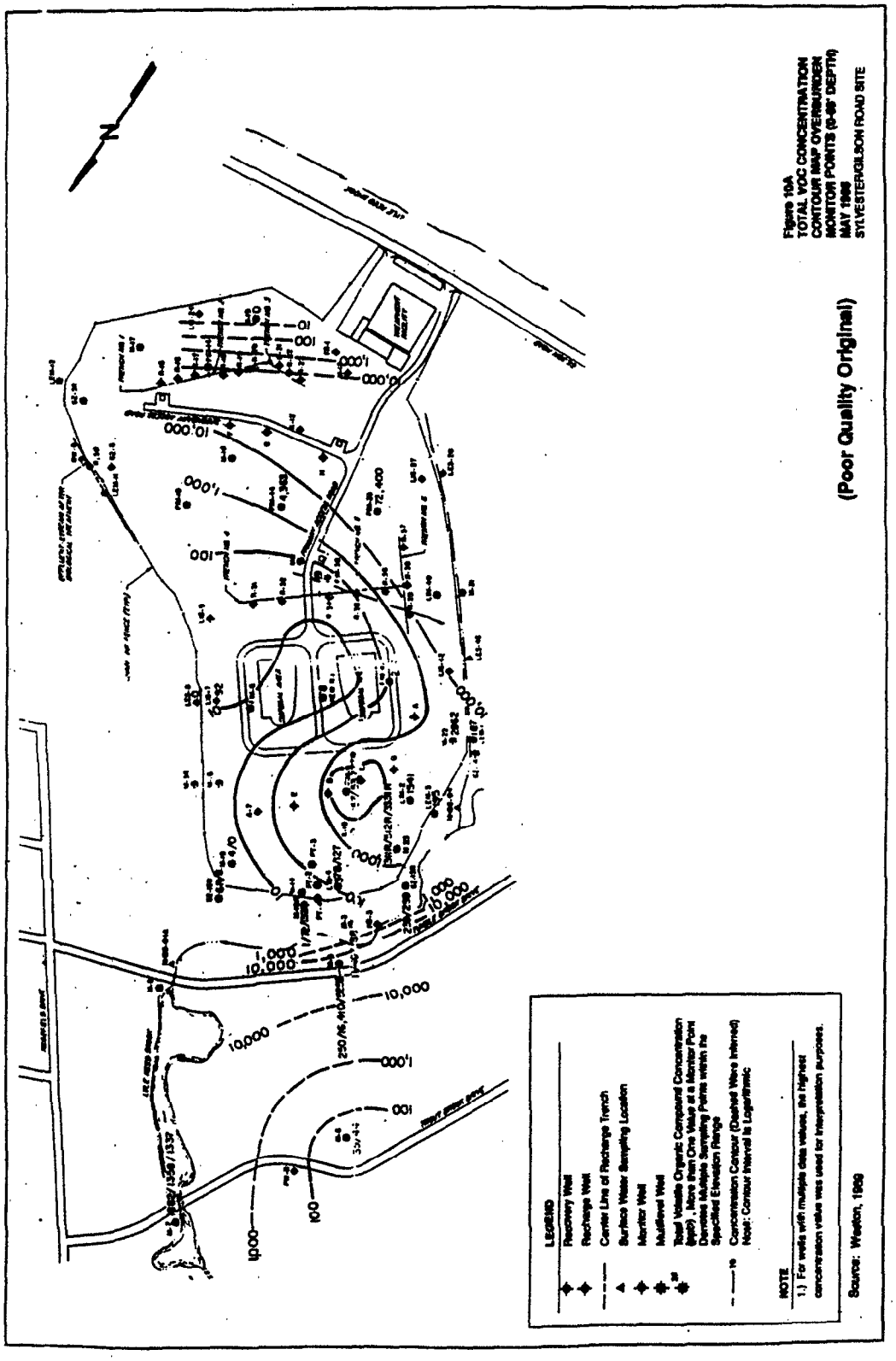

Figure 10A
TOTAL VOC CONCENTRATION
CONTOUR MAP OVERBURDEN
MONITOR POINTS (8-9' DEPTH)
MAY 1989
SYLVESTER/GILSON ROAD SITE

(Poor Quality Original)

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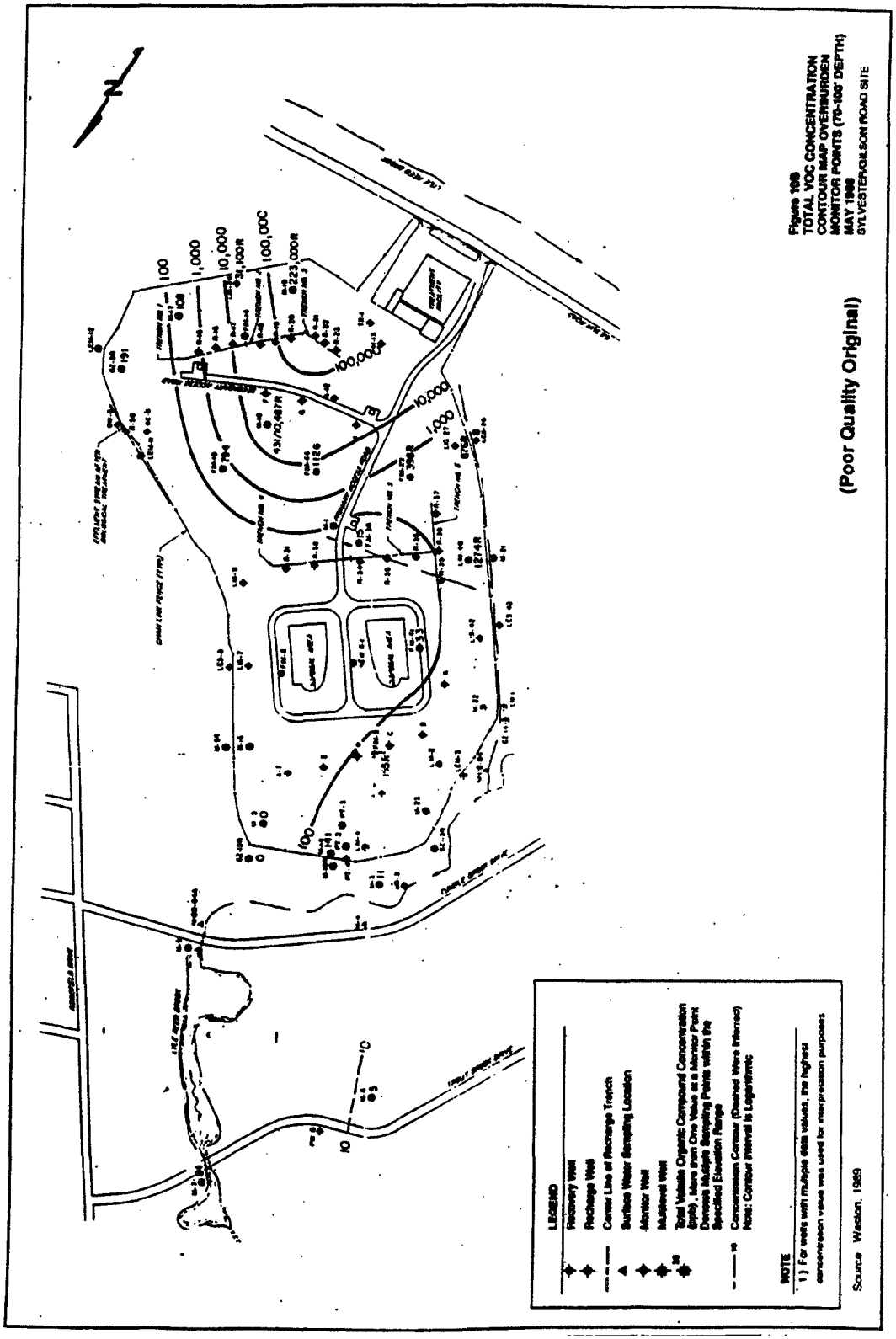
Figure 10B
TOTAL VOC CONCENTRATION
CONTOUR MAP OVERBURDEN
MONITOR POINTS (70-100' DEPTH)
MAY 1989
SYLVESTER/GILSON ROAD SITE
(Poor Quality Original)
LEGEND
Recovery Well
Recharge Well
Center Line of Recharge Trench
Surface Water Sampling Location
Monitor Well
Multiwell Well
Total Volatile Organic Compound Concentration (ppb). More than One Value at a Monitor Point Denotes Multiple Sampling Points within the Specified Elevation Range
Concentration Contour (Dashed Were Inferred)
Note: Contour Interval Is Logarithmic
NOTE
1) For wells with multiple data values, the highest concentration value was used for interpolation purposes.
Source Weston, 1989
100
1,000
10,000
100,000
10

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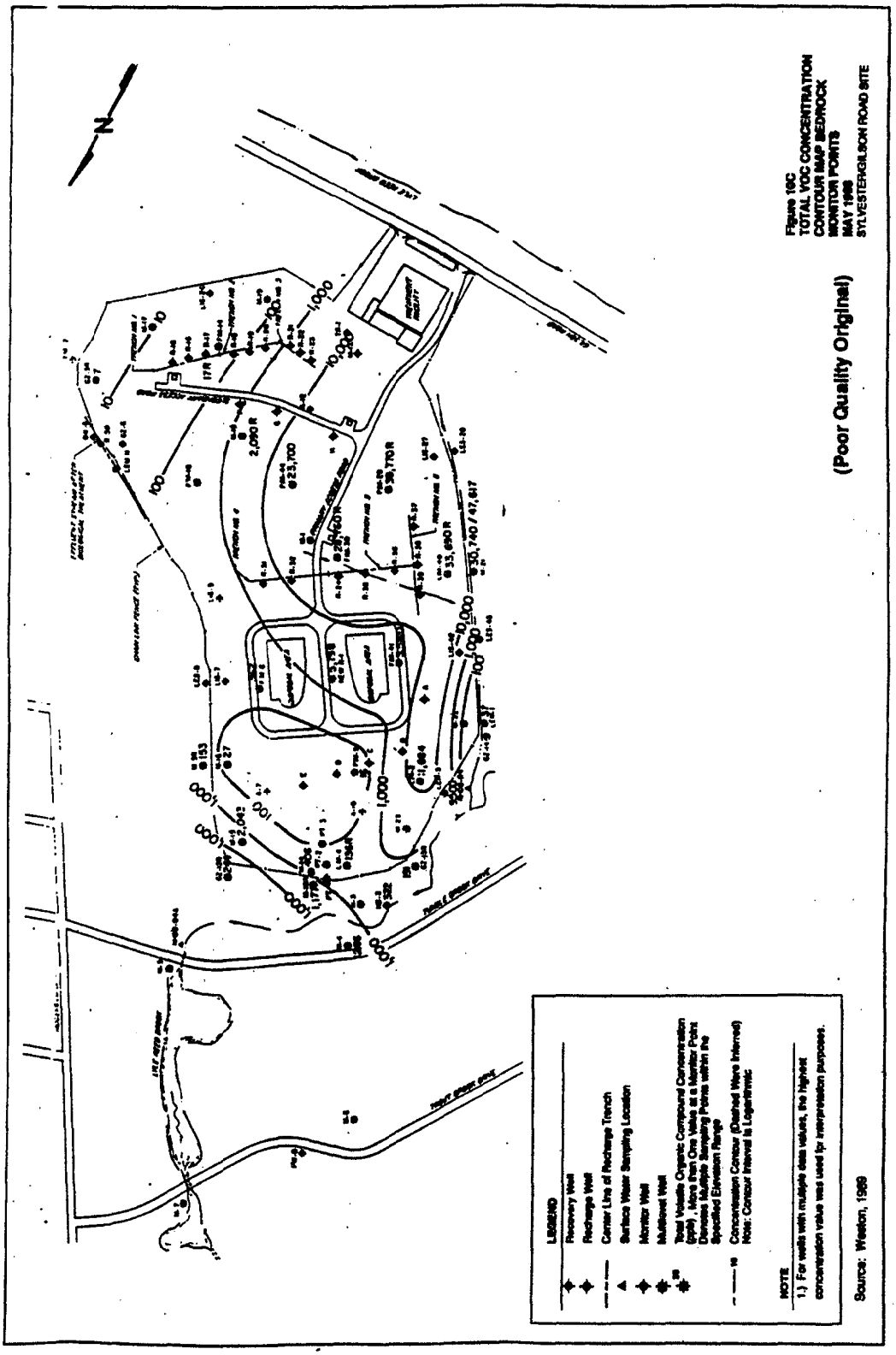
N
LEGEND
Recovery Well
Recharge Well
Center Line of Recharge Trench
Surface Water Sampling Location
Monitor Well
Multiwell Well
Total Volatile Organic Compound Concentration (ppb). More than One Value at a Monitor Point Denotes Multiple Sampling Points within the Specified Elevation Range
Concentration Contour (Dashed Were Inferred) Note: Contour Interval is Logarithmic
NOTE
1.) For wells with multiple data values, the highest concentration value was used for interpretation purposes.
Source: Weston, 1988
(Poor Quality Original)
Figure 16C
TOTAL VOC CONCENTRATION
CONTOUR MAP BEDROCK
MONITOR POINTS
MAY 1988
SYLVESTER/GILSON ROAD SITE

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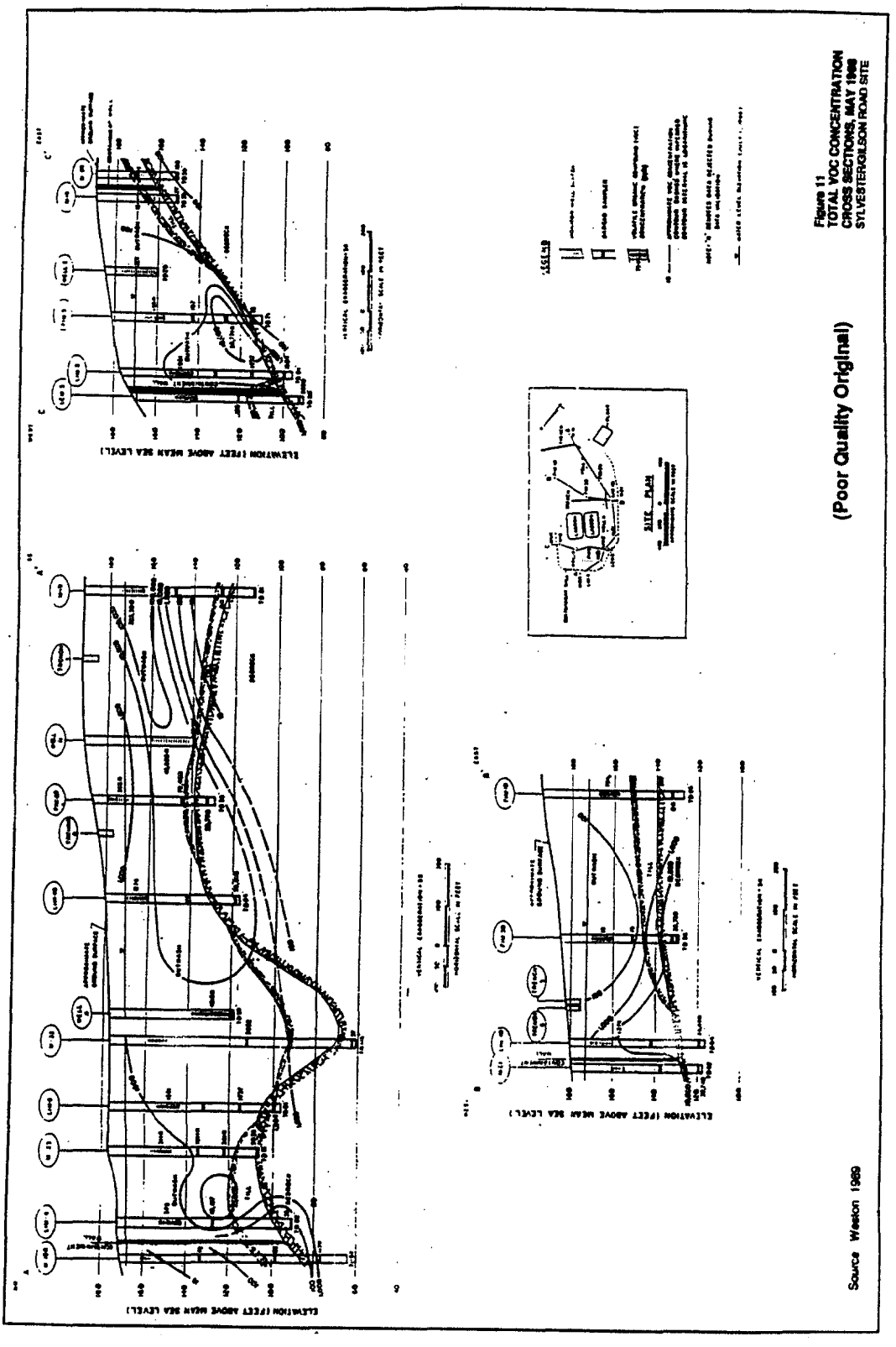

Figure 11
TOTAL VOC CONCENTRATION
CROSS SECTIONS, MAY 1988
SYLVESTER/GILSON ROAD SITE

(Poor Quality Original)

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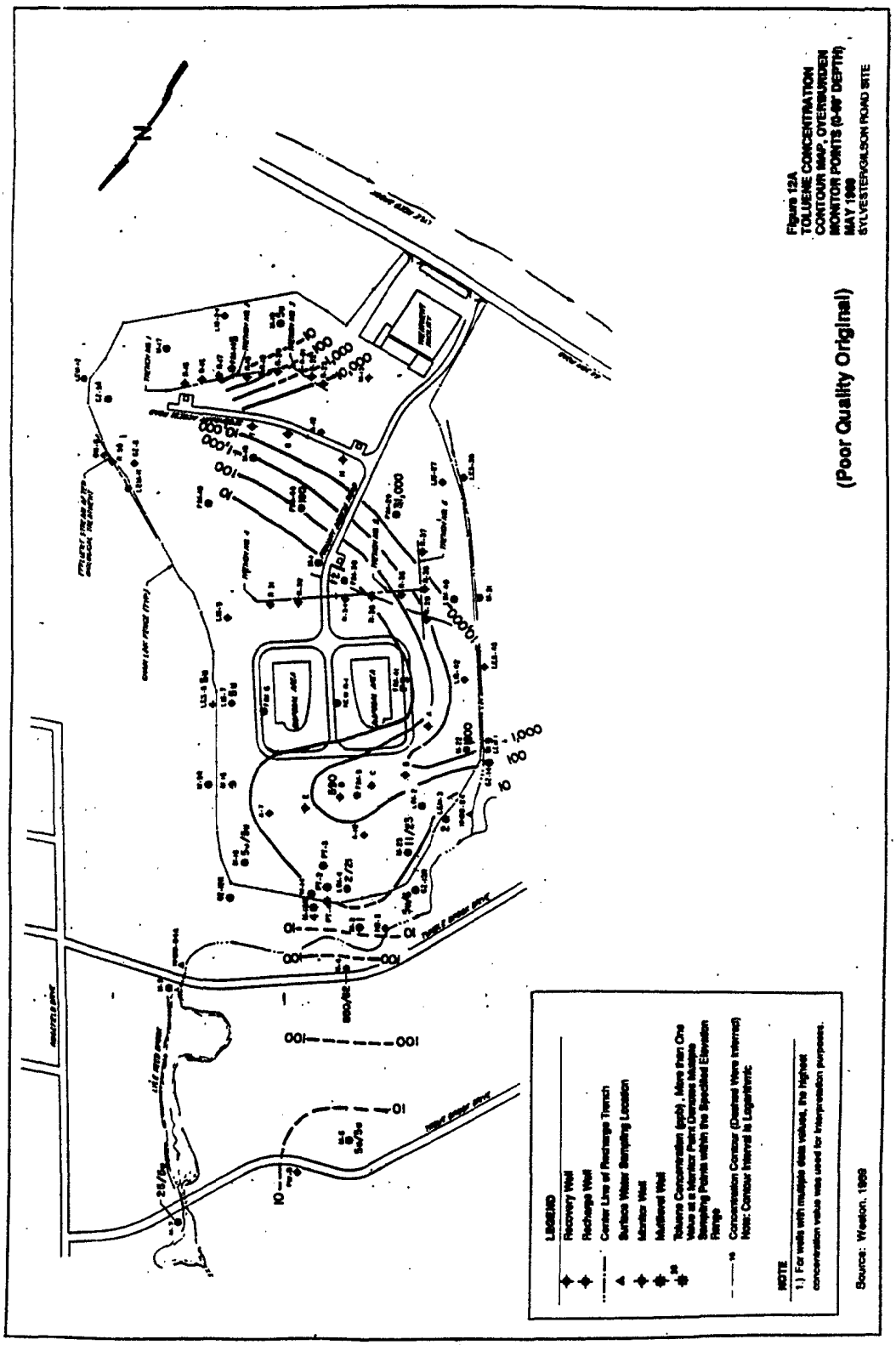
LEGEND
Recovery Well
Recharge Well
Center Line of Recharge Trench
Surface Water Sampling Location
Monitor Well
Multilevel Well
Toluene Concentration (ppb), More than One Value at a Monitor Point Denotes Multiple Sampling Points within the Specified Elevation Range
Concentration Contour (Dashed Were Inferred)
Note: Contour Interval is Logarithmic
NOTE
1.) For wells with multiple data values, the highest concentration value was used for interpretation purposes.
Source: Weston, 1992
(Poor Quality Original)
Figure 12A
TOLUENE CONCENTRATION
CONTOUR MAP, OVERBURDEN
MONITOR POINTS (0-60' DEPTH)
MAY 1990
SYLVESTER/GILSON ROAD SITE

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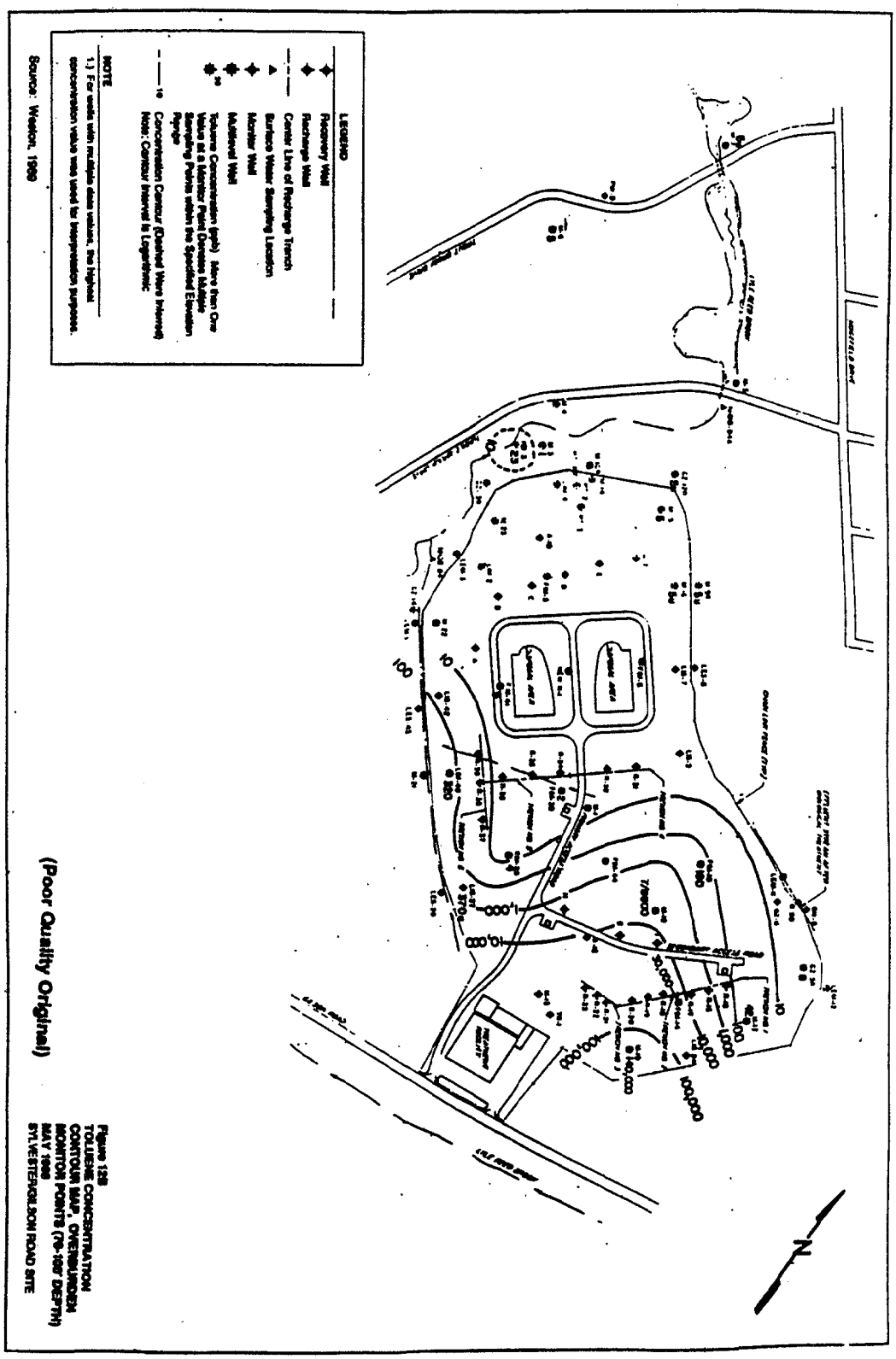

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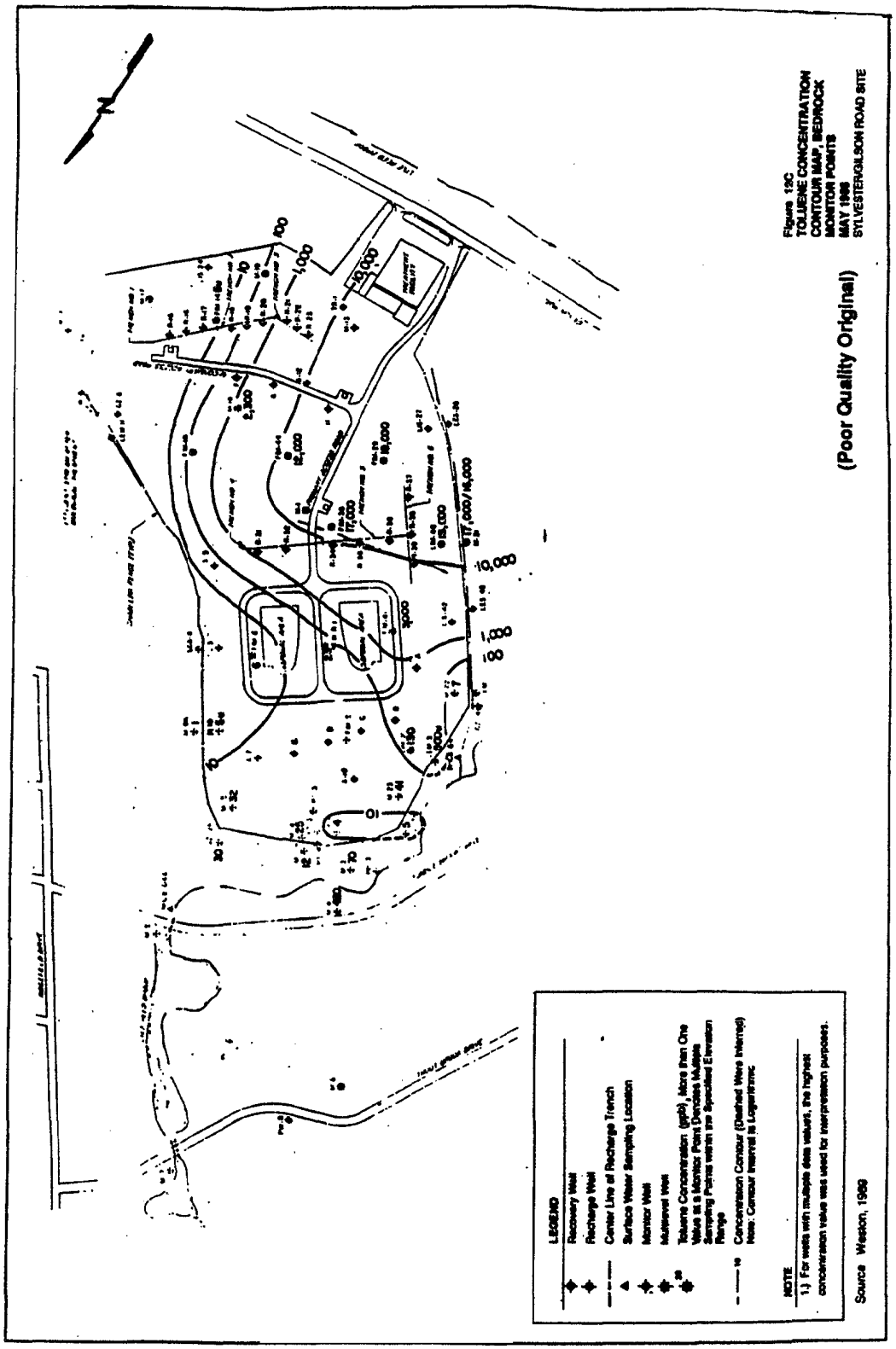
LEGEND
Recovery Well
Recharge Well
Center Line of Recharge Trench
Surface Water Sampling Location
Monitor Well
Multilevel Well
Toluene Concentration (ppb), More than One Value is a Monitor Point Denotes Multiple Sampling Points within one Specified Elevation Range
Concentration Contour (Dashed Were Inferred)
Note: Contour Interval is Logarithmic
NOTE
1.) For wells with multiple data values, the highest concentration value was used for interpretation purposes.
Source Weston, 1989
(Poor Quality Original)
Figure 12C
TOLUENE CONCENTRATION
CONTOUR MAP, BEDROCK
MONITOR POINTS
MAY 1989
SYLVESTER/GILSON ROAD SITE

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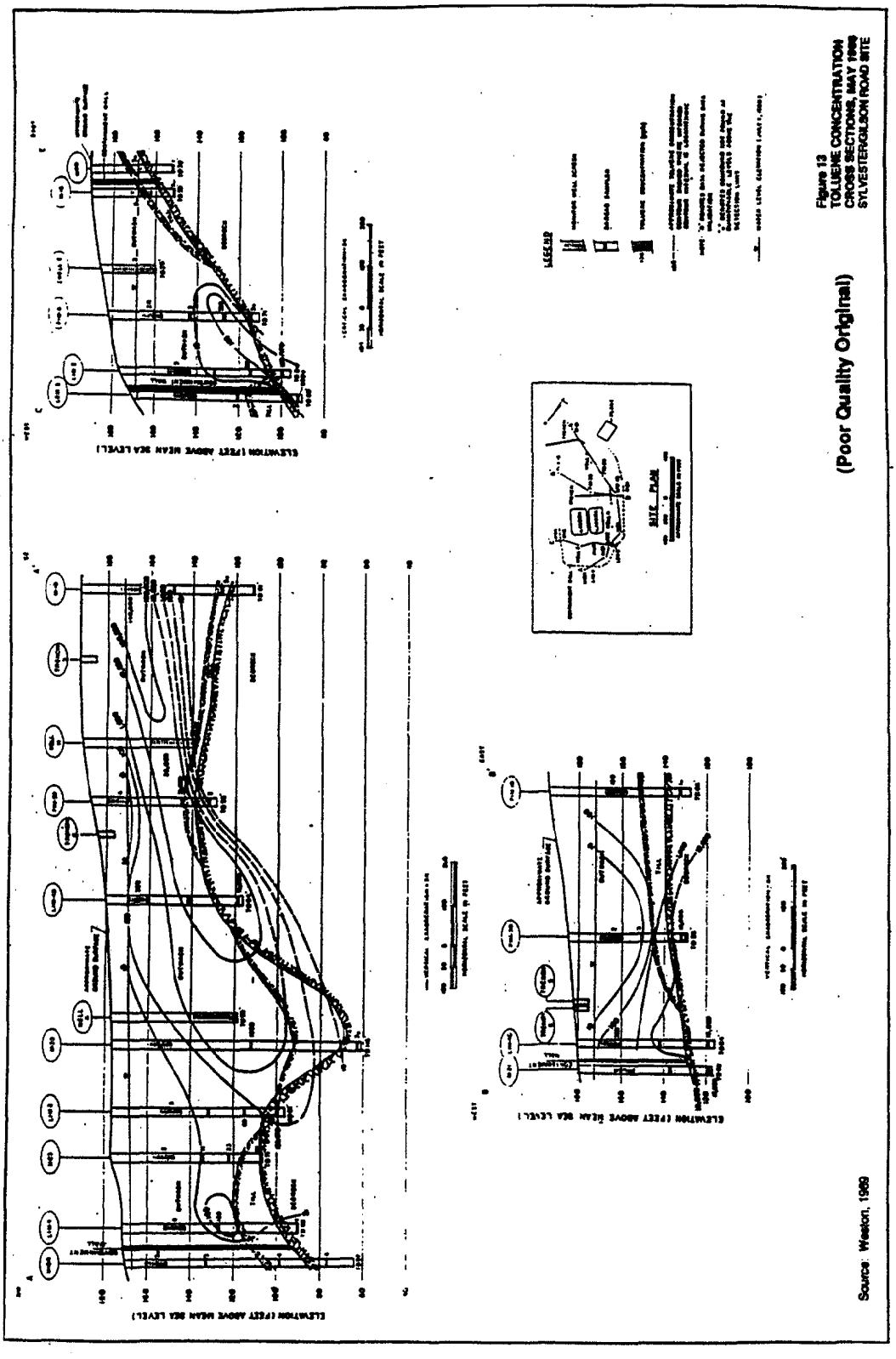

Figure 13
TOLUENE CONCENTRATION
CROSS SECTIONS, MAY 1989
SYLVESTER/GILSON ROAD SITE

(Poor Quality Original)

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toluene. Additional investigations, such as soil gas studies, borings and sampling, and excavation beneath the cap, are underway to locate and develop a remedial action for the source of nonaqueous toluene. The investigation and design of a toluene recovery system is scheduled to be completed in April 1991. Free product recovery measures will involve depressing the water table in the source area and skimming the toluene (U.S. EPA, February 13, 1991).

Contour maps of THF concentrations and 1,1-DCA concentrations in May 1988 are presented in Figures 14A, 14B, 15A, and 15B. Cross-sections of THF concentrations are presented in Figure 16. Areas with high THF concentrations do not correspond to areas with high VOC concentrations in 1988 as they did in 1980. THF is no longer the dominant plume contaminant. Areas of high 1,1-DCA concentration appear to correspond with areas of high toluene concentrations. Both 1,1-DCA and toluene have relatively low water solubility.

THF, a relatively mobile and low-toxicity compound, has moved into the northwestern end of the site, where its is not within the capture zone of the existing extraction wells. Toluene and some other persistent VOCs have moved into lower flow zones at the base of the overburden and in upper bedrock, where they are less likely to be captured by relatively shallow recovery wells operating at the site. This may be a result of preferential recharge to trench 4, which is causing mounding of hydraulic heads, and may be setting up deeper circulation flow paths that radiate outward below the intakes of the extraction wells (Weston, 1989).

Overall contaminant concentrations were an order of magnitude lower in August 1987 than December 1980. During this period the plume migrated downgradient. In May 1988, the bedrock zone remained contaminated across the site and offsite to the northwest, west, and southwest. Offsite contamination is probably a result of downward circulation and advection of contaminants induced by the pumping/recharge operation (Weston, 1989). Natural underflow through the upper fractured bedrock flow zone may have also contributed to offsite migration of contaminants (Weston, 1989).

SUMMARY OF REMEDIATION

The remediation of the Sylvester/Gilson Road site is summarized as follows:

- There are two aquifer zones beneath the facility that are contaminated primarily with volatile organics. Contamination in both zones has extended offsite to the downgradient Lyle Reed Brook.

- A bentonite slurry wall was installed around the perimeter of the site and a synthetic cap was placed over the entire site.

- A ground-water extraction/recharge system was installed including eight extraction wells inside the slurry wall and seven recharge trenches. The system began operating in 1984. A 300 gpm treatment plant began operating in 1986. Since then, ground water has been extracted, treated, and then recharged through trenches located both inside and outside the slurry wall.

- From May 1986 to May 1988, 40 to 100 percent reduction in concentration was observed for all ACL compounds except 1,1-DCA and toluene. 1,1-DCA concentrations exceeded the ACL in 18 of 65 samples collected in 1988. No decrease was observed in toluene concentrations suggesting that there may be a nonaqueous source of toluene at the southeastern (upgradient) portion of the site. Additional site investigations are planned to locate the toluene source.

- Water level monitoring does not show that inward gradients are being maintained across the slurry wall. Contaminants appear to be escaping from the site by flowing under the wall in the bedrock aquifer. Also, some redistribution of contamination has occurred in areas that are not effectively captured by the extraction wells. Contaminant levels exceeding ACLs were observed in these areas. Six additional extraction wells were planned to more effectively control plume migration.

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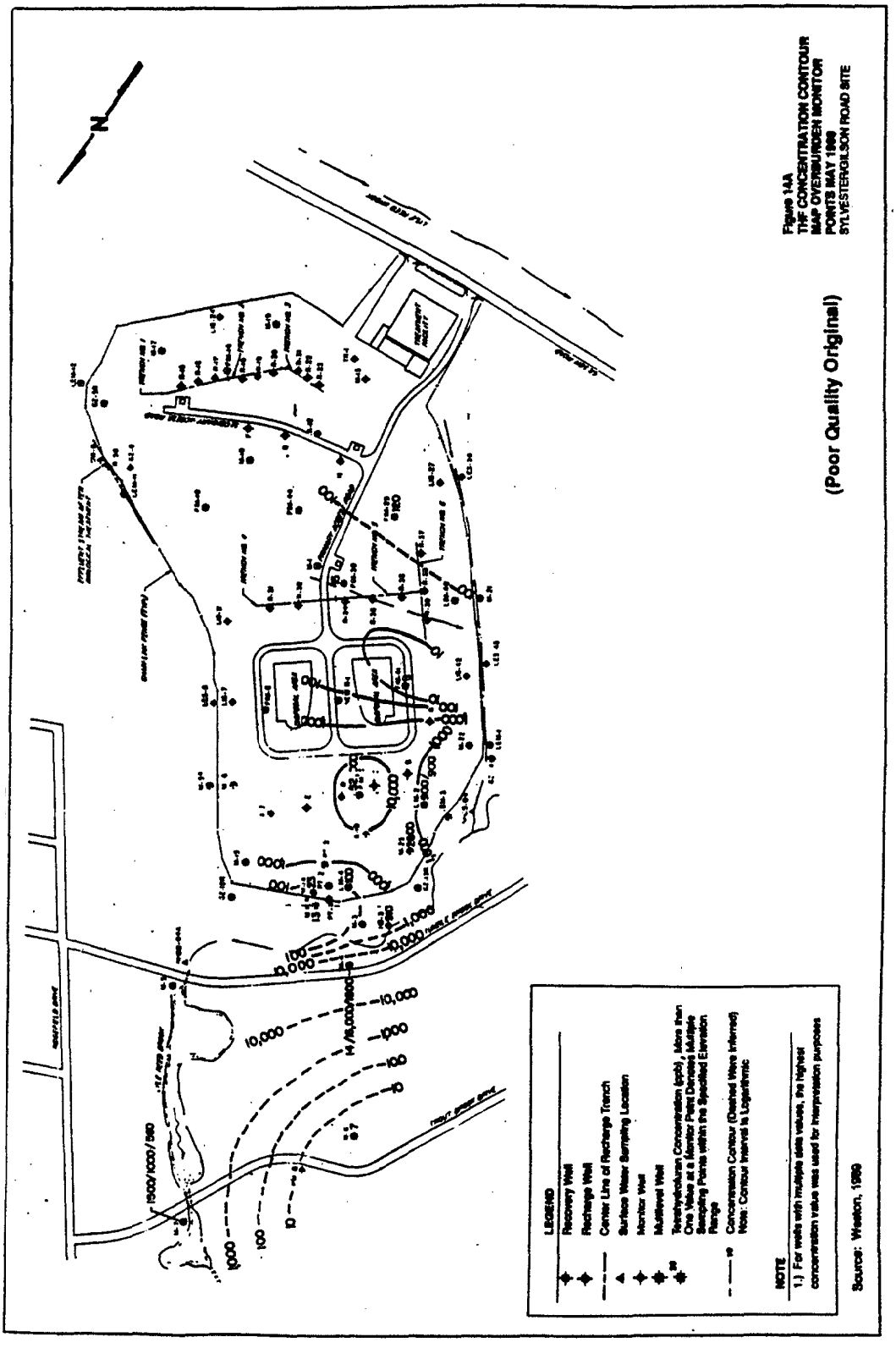

Figure 14A
THF CONCENTRATION CONTOUR
MAP OVERBURDEN MONITOR
POINTS MAY 1990
SYLVESTER/GILSON ROAD SITE

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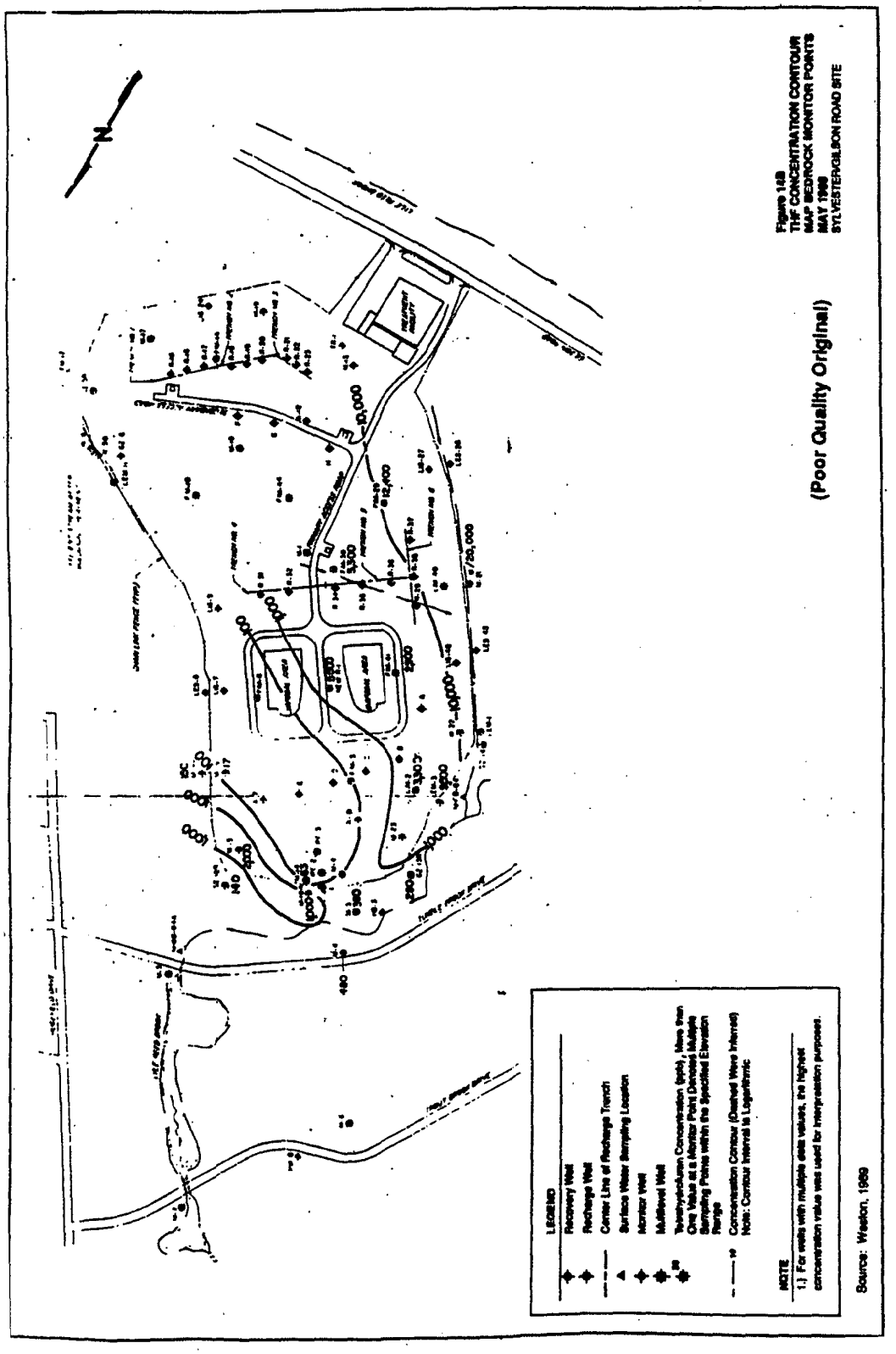

Figure 14B
THF CONCENTRATION CONTOUR
MAP BEDROCK MONITOR POINTS
MAY 1989
SYLVESTER/GILSON ROAD SITE

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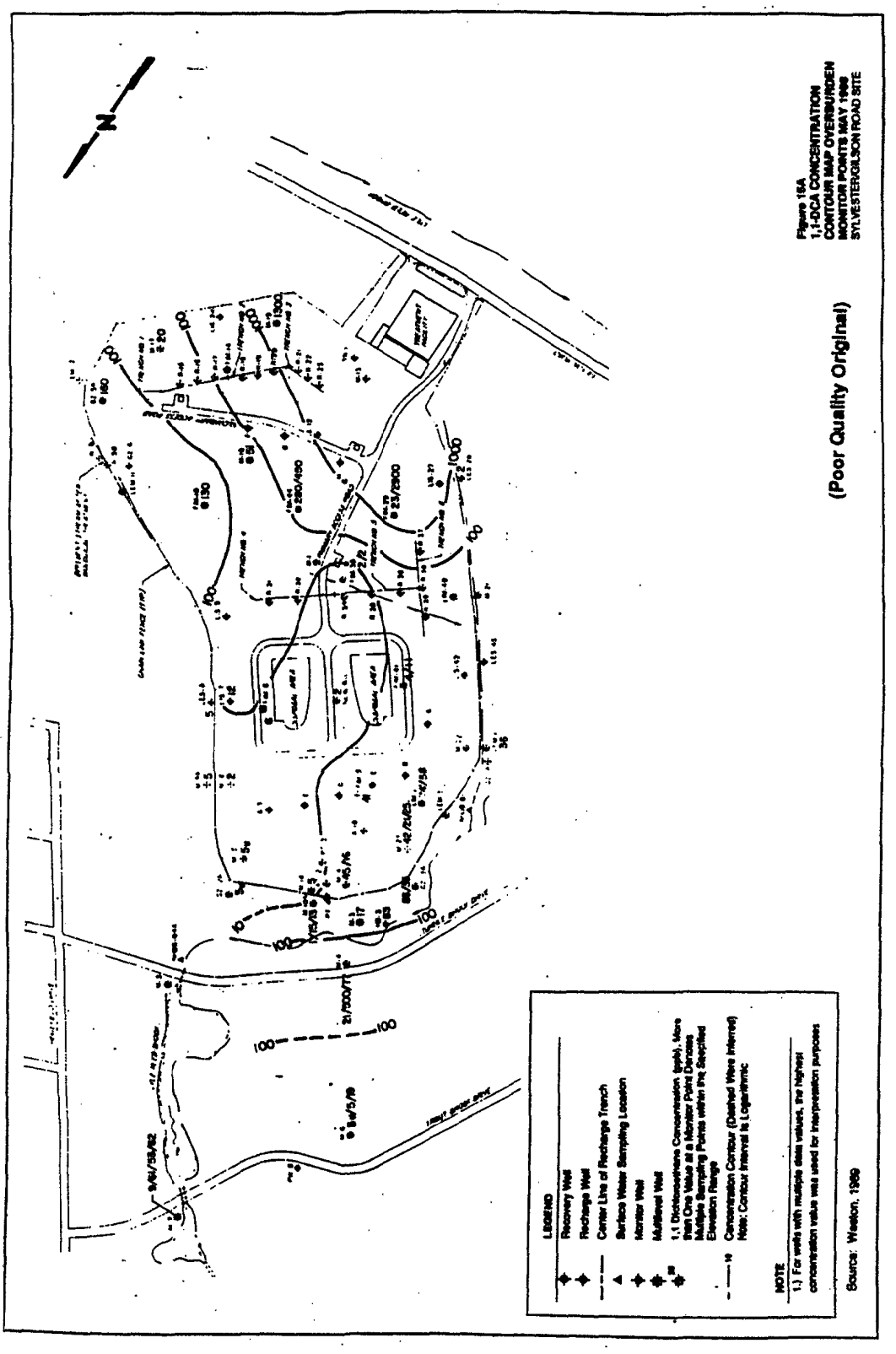
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Figure 18A
1,1-DCA CONCENTRATION
CONTOUR MAP OVERBURDEN
MONITOR PORTS MAY 1986
SYLVESTER/GILSON ROAD SITE
LEGEND
Recovery Well
Recharge Well
Center Line of Recharge Trench
Surface Water Sampling Location
Monitor Well
Multilevel Well
1,1 Dichloroethane Concentration (ppb), More
than One Value at a Monitor Point Denotes
Multiple Sampling Points within the Specified
Elevation Range
Concentration Contour (Dashed Where Inferred)
Note: Contour Interval is Logarithmic
NOTE
1.) For wells with multiple data values, the highest
concentration value was used for interpretation purposes
Source: Weston, 1986
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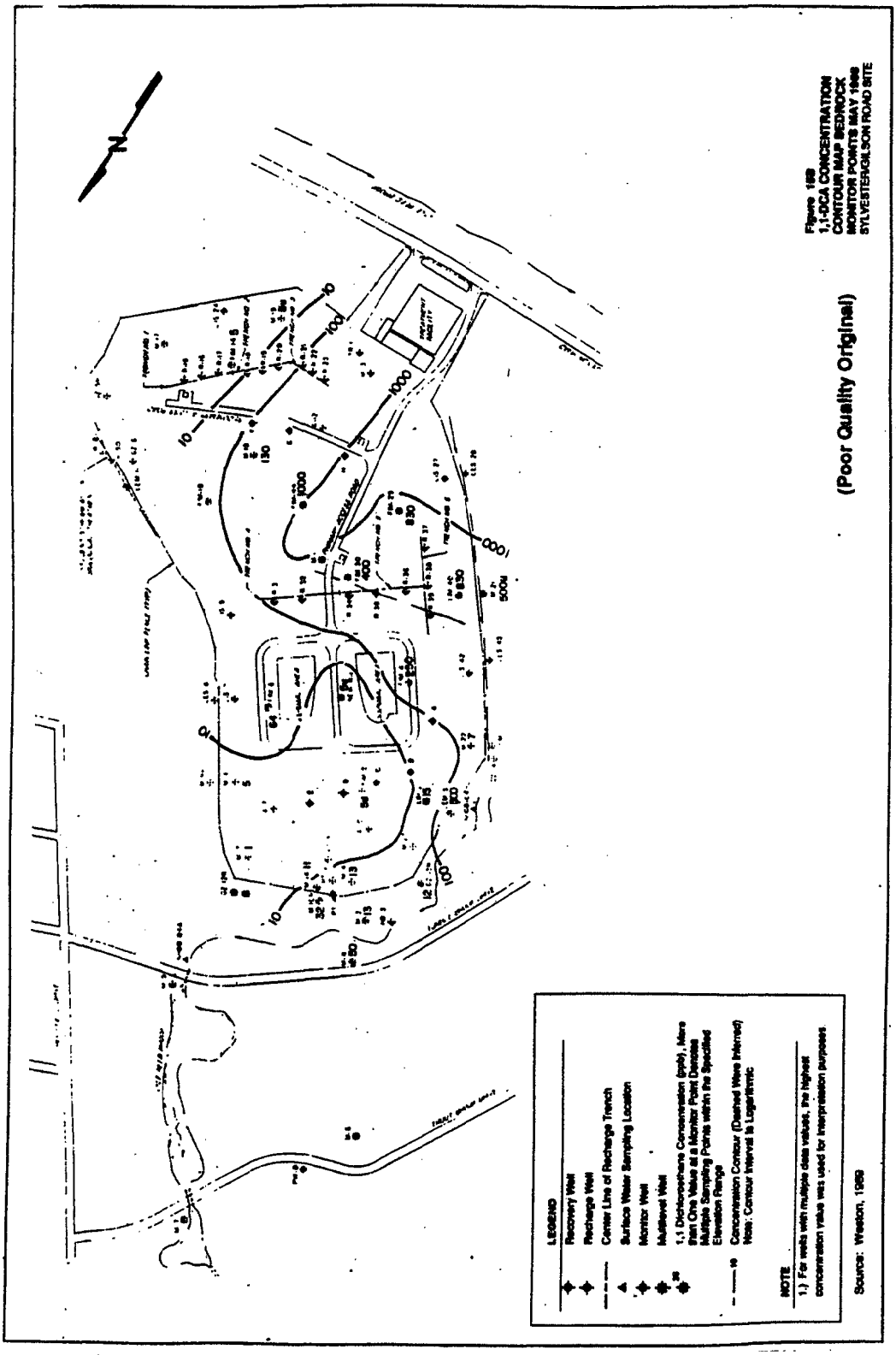

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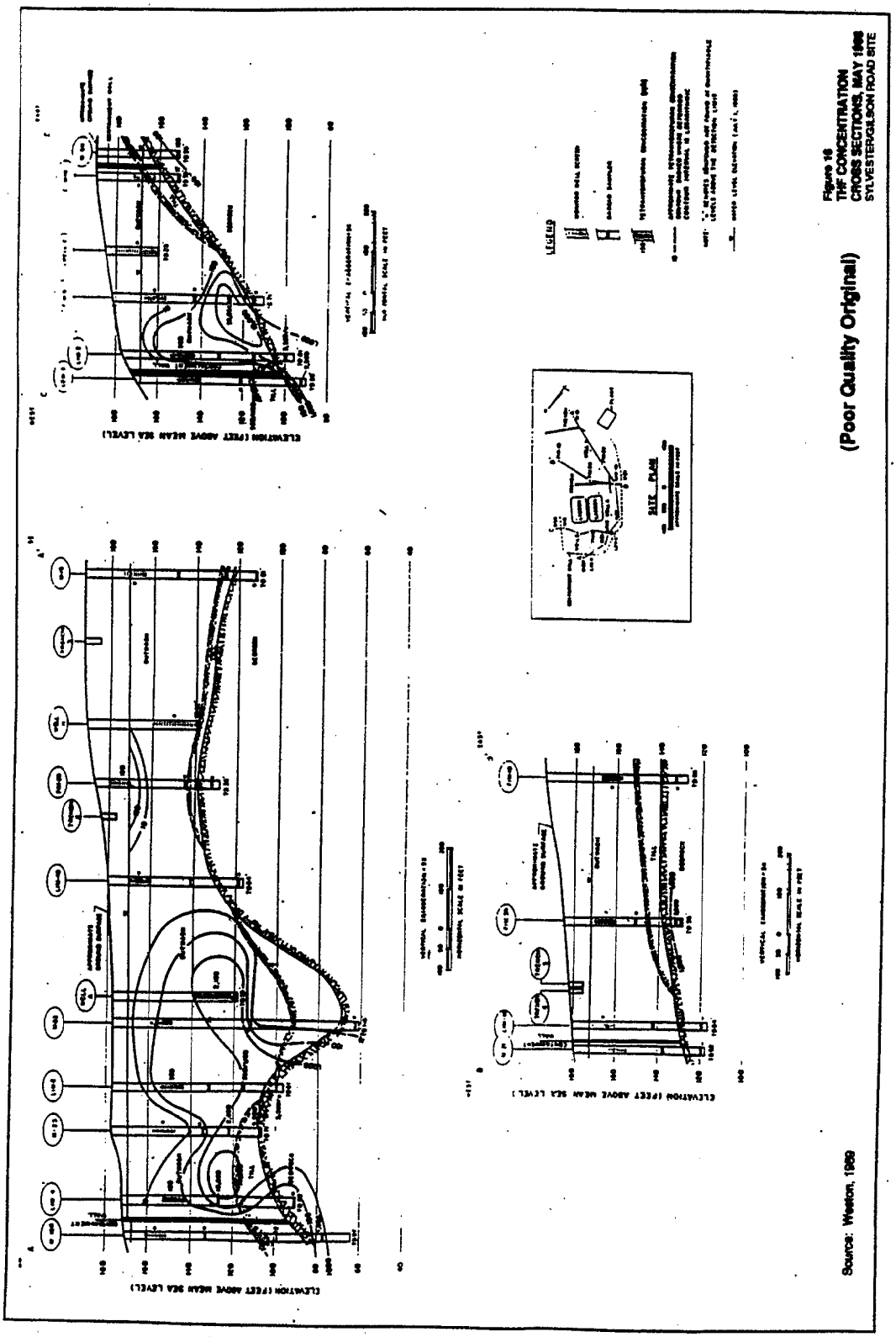

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Figure 16
THF CONCENTRATION
CROSS SECTIONS, MAY 1989
SYLVESTER/GILSON ROAD SITE

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SUMMARY OF NAPL-RELATED ISSUES

Nonaqueous toluene is thought to be floating on the water table at the southern end of the site near monitoring well M-19. This is suspected because toluene concentrations in the ground water in this area have remained high in spite of more than seven years of ground-water recirculation and two years of treatment. The toluene concentration measured in ground water sampled from well M-19 in May 1988 was 140,000 ppb. This is approximately 26 percent of the aqueous solubility of toluene (534,800 ppb). Such a high concentration, relative to solubility, is in itself a very strong indication that the compound is present as a NAPL. Furthermore, as shown in Figure 9, the toluene concentration in the treatment plant influent was remarkably stable throughout the available two years of record. In spite of these strong indications of NAPL presence, free-phase toluene has not been observed in any of the monitoring wells (U.S. EPA, 1991).

Another contaminant of importance at the site is 1,1-DCA. The maximum concentration measured in May 1988 was 2,900 ppb in well FIM-29. This is less than 1 percent of the solubility of this compound. However, the maximum concentrations have not been decreasing over the period of record. Also, as shown in Figure 15A, the areal distribution of 1,1-DCA is similar to that of toluene. This leads to the supposition that nonaqueous 1,1-DCA, and potentially several other compounds, may be dissolved in the floating NAPL layer.

Tetrahydrofuran, the contaminant with the highest initial ground-water concentrations is miscible in water. It is, therefore, unlikely to be present as a NAPL. The relatively rapid reduction in THF concentrations and the marked change in the shape of the THF plume between 1981 and 1988 can be contrasted to the toluene plume's stability and resistance to remediation efforts. Unless specialized techniques are used to remediate the assumed floating NAPL layer, it is unlikely that the ground-water extraction and recirculation system will be very effective in cleaning up the site.

A program is presently under way at the site to investigate the NAPL problem and design a recovery system for it. However, because of the sensitivity of ongoing negotiations, no detailed information has been made available on these efforts.

BIBLIOGRAPHY/REFERENCES

Roy F. Weston, Inc. (Weston). January 1982. *Final Report, Sylvester Hazardous Waste Dump Site Containment and Cleanup Assessment.*

Roy F. Weston, Inc. (Weston). February 1989. *Remedial Program Evaluation Gilson Road Site, Nashua, New Hampshire.*

U.S. Environmental Protection Agency (U.S. EPA). July 1982. *Superfund Record of Decision, Remedial Alternative Selection, Sylvester Site, Nashua, New Hampshire.*

U.S. EPA. September 1983. *Supplemental Record of Decision, Groundwater Treatment Alternative Section, Sylvester Site, Nashua New Hampshire.*

U.S. EPA. July 1990. *Explanation of Significant Differences, Sylvester/Gilson Road Hazardous Waste Site, Nashua, New Hampshire.*

U.S. EPA. Region I. February 13, 1991. Personal Communication with Chester Janowski.

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CASE STUDY 23

Tyson's Dump
King of Prussia, Pennsylvania

Abstract

Disposal of waste liquids into unlined lagoons during the 1960s has led to considerable contamination of the onsite disposal area and the offsite fractured bedrock. DNAPL contamination has been observed south of the Schuylkill River and is suspected under parts of Barbadoes Island. DNAPLs have migrated north along bedding planes in the fractured rock. Aqueous phase contamination, derived from the DNAPLs, extends to the north side of the river and has discharged to the river in at least some areas, threatening downstream users. A seven well interim extraction system, in operation since November 1988, has generally controlled the central part of the dissolved plume south of the river. Lateral areas have not been completely captured, but construction of a final system is almost complete.

Background Data	
Date of Problem Identification	1973
Extraction Started	November 1988
Types of Contaminants	VOCs, especially 1,2,3-Trichloropropane (TCP), xylene, toluene, and ethylbenzene
Primary Aquifer Materials	Thin layer of sand and clay over fractured sandstone and siltstone
Maximum Number of Extraction Wells	7
Maximum Total Extraction Rate	120 gpm
Estimated Plume Area	65 acres
Estimated Plume Thickness	365 feet
Maximum Reported Concentrations	1,2,3-Trichloropropane 1,400,000 ppb

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CASE STUDY
TYSON'S DUMP SITE

BACKGROUND OF THE PROBLEM

The Tyson's Dump site is in King of Prussia, Pennsylvania approximately 15 miles northwest of central Philadelphia (see Figure 1). The 4-acre site is located at an abandoned sandstone quarry that is bordered on the north by a Conrail railroad shipping yard and the Schuylkill River, on the south by the high wall of the former quarry and on the east and west by streams (see Figure 2). Residential and industrial areas surround the site on the south and west. Tyson's Dump was operated as a disposal facility for septic and chemical wastes from 1960 to 1970. The soil and ground water underlying the site have been heavily contaminated with volatile organic compounds (VOCs) as a result of past dumping into unlined lagoons. The primary contaminants of concern at the site are 1,2,3-trichloropropane, xylene, toluene, and ethylbenzene. Dense non-aqueous phase liquid (DNAPL) contamination is known to exist at the site. Tyson's Dump is a Superfund site that is ranked number 25 on the EPA's National Priorities List. The remediation of the site is administered by the EPA and the Pennsylvania Department of Environmental Resources (PADER).

SITE HISTORY

Tyson's Dump was operated as a disposal site by companies owned by Franklin P. Tyson and Fast Pollution Treatment Inc., between 1960 and 1970. During this time, various septic and chemical wastes were brought onsite in tanker trucks and disposed of in unlined lagoons. As each lagoon filled up with waste, it was covered, and a new lagoon was begun. The Ciba-Geigy Corporation, Smith-Kline Beckman, Wyeth Laboratories, and the Essex Group all used the dump to dispose of wastes during this period; all are considered to be potentially responsible parties (PRPs). In 1969, General Devices, Inc., acquired the property from Franklin Tyson.

In 1973, the Pennsylvania Department of Environmental Resources (PADER) ordered the site owners to close the Tyson's Dump site. By this time, most of the 4-acre site contained lagoons, and contamination was spread throughout the site as a result of spills and overflows during operations. The closure order directed that the lagoons be drained, excavated, backfilled with clean soil, and revegetated, and the contents of the lagoons shipped offsite. In response to PADERs closure order, General Devices, Inc., reportedly emptied the lagoons of standing water, then backfilled and vegetated the lagoons (ERM, 1991b).

The investigation of the Tyson's Dump site has historically concentrated on two separate administrative components--the "onsite" area, in or near the area used for disposal, and the "offsite" area, north of the disposal areas (see Figure 2). The onsite area was investigated primarily between January 1983 and August 1985, whereas detailed investigation of offsite areas began in early 1986 and has continued through 1991.

The investigation of contamination at the Tyson's Dump site began in January 1983, when the EPA received a complaint about conditions at the site from an anonymous citizen. In response to this complaint, the EPA and its contractors conducted an initial survey of the site and sampled soil, air, and ground water in and near the former disposal area. This initial field investigation, which was conducted between January and June 1983, showed that the onsite soil and ground water were contaminated with high levels of volatile organic compounds (VOCs).

Based on early findings during the initial survey in 1983, the EPA determined that immediate action was required to limit public exposure to uncontrolled chemical odors and liquid wastes at the site. In March 1983, the EPA began addressing the immediate threat posed by onsite contamination, by instituting several emergency remedial measures. These included: (1) construction of a soil cap over the suspected lagoon areas and regrading of the site to control drainage, (2) construction of a leachate collection system and an air stripper/activated carbon

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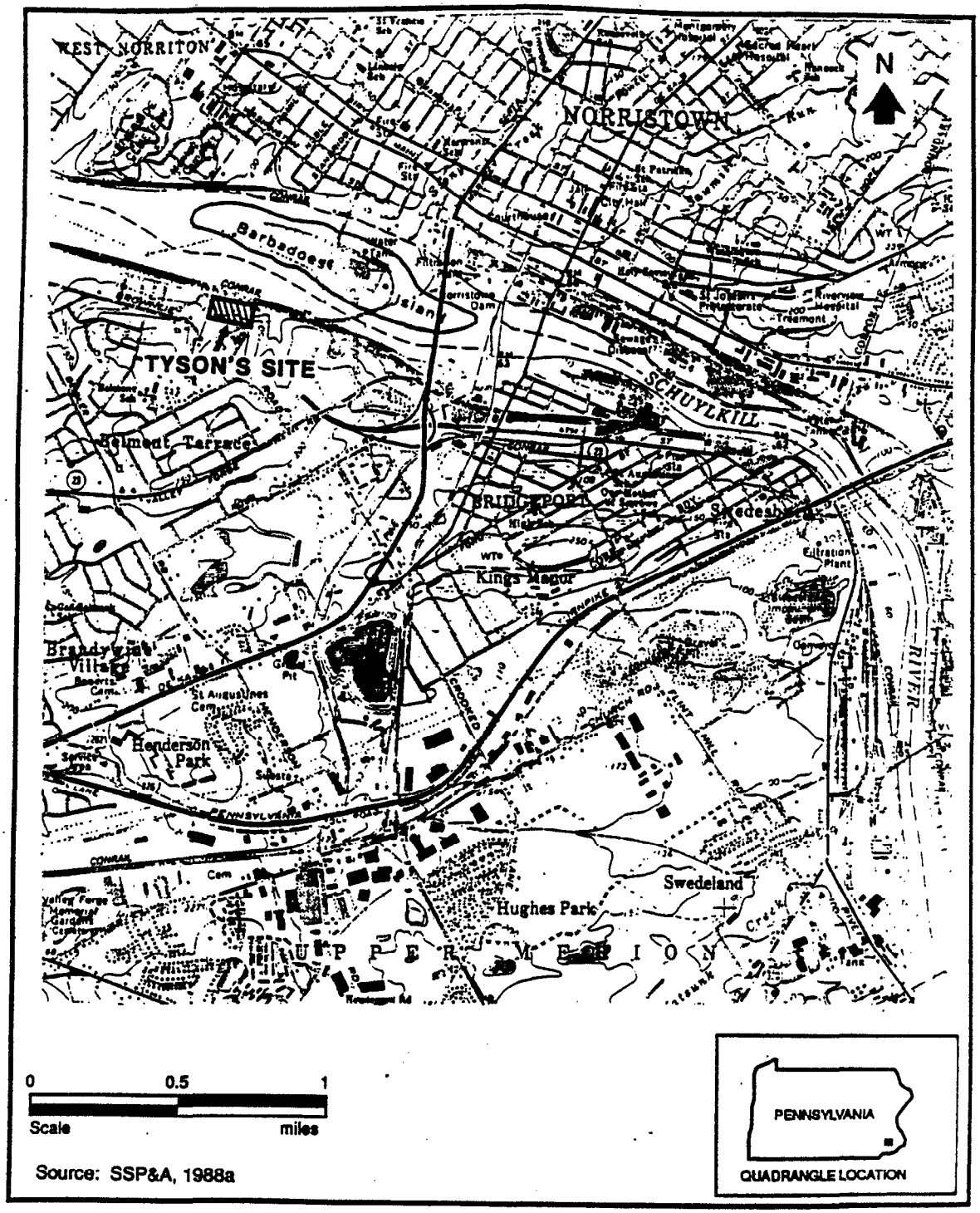

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Figure 1
SITE LOCATION
TYSON'S DUMP SITE
KING OF PRUSSIA, PENNSYLVANIA

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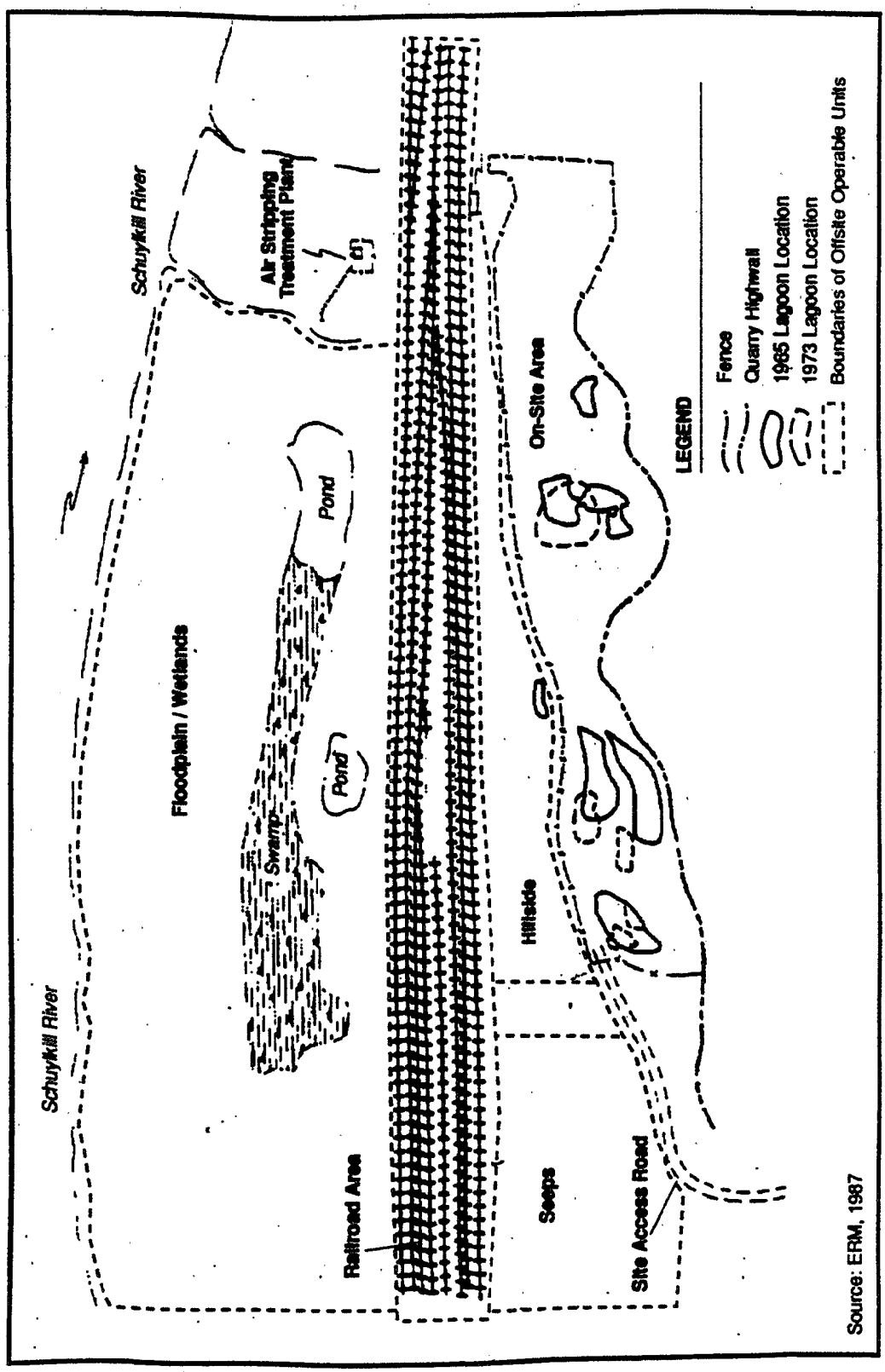

Figure 2
SITE MAP
TYSON'S DUMP SITE

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leachate treatment system, and (3) construction of a security fence to limit unauthorized access to the site. Additional investigation of the extent of contamination, both on and offsite, was also specified. The onsite area was defined as the 4-acre area within and immediately adjacent to the security fence.

In September 1983, a plan for a full remedial investigation and feasibility study (RI/FS) of onsite contamination was approved. Between December 1983 and March 1984, the EPA and its contractors conducted an intensive field investigation of the onsite area. This investigation was primarily concerned with characterizing surficial and shallow contamination contained in the unconsolidated onsite soils. The report on the remedial investigation of the onsite area was completed in August 1984.

Based on the results of the investigations conducted in 1983 and 1984, the EPA issued an Operable Unit record of decision (ROD) in December 1984, for the onsite area. The ROD recommended the following actions:

1. Excavation and offsite disposal of contaminated soils in a RCRA-permitted landfill.

2. Upgrading the existing air-stripping facility to treat leachate, shallow ground water, and surface run-on encountered during excavation.

3. Excavation and offsite disposal of contaminated sediments in the gully west of the treatment plant that receives effluent from the existing air stripper (see Figure 2).

Between January and August 1985, the EPA began to implement these remedial measures by installing soil borings and conducting magnetometer surveys throughout the site to determine the depth to bedrock, the extent of waste materials, the volume of soil to be removed, and the presence or absence of metallic debris.

In the fall of 1985, Ciba-Geigy agreed to conduct additional investigations of the offsite area. Five separate offsite operable units were identified for study: (1) the deep (bedrock) aquifer, (2) the hillside area, (3) the railroad area, (4) the floodplain and wetlands area, and (5) the seep area (see Figure 2). In March 1986, a work plan was prepared and in May 1986, an Administrative Consent Order governing the offsite operable unit RI/FS was signed by the EPA and Ciba-Geigy.

In November 1986, Ciba-Geigy began pilot-scale feasibility tests for using soil vapor extraction (SVE) to clean up the lagoon area, instead of the excavation and disposal method specified in the December 1984 ROD. Tests showed SVE would be an effective method of reducing VOCs in contaminated soils. This reorientation of the onsite cleanup was necessary because SVE had not been a viable technology at the time of the original 1984 ROD. Moreover, the findings of the ongoing offsite RI showed that most of the contamination had migrated to the bedrock; hence, excavation and disposal for source control would no longer be effective. In March 1988, in response to a July 1987 proposal by Ciba-Geigy and the three other PRPs, the EPA issued a revised ROD, authorizing the use of soil vapor extraction to remediate the onsite lagoon soils.

The results of offsite investigations begun early in 1986 were reported in December 1986, in the draft Offsite RI and Environmental Assessment reports. These documents covered investigations originally detailed in the initial March 1986 work plan, and in a July 1986 addendum. In the draft RI, it was proposed that remedial measures be selected for the railroad, seep, hillside, and floodplain/wetlands operable units, and for the deep aquifer operable unit in the area south of the river. Additional study of the deep aquifer north of the south bank of the river was proposed. These plans were detailed further in the March 1987 second addendum to the original March 1986 offsite RI/FS workplan.

The offsite RI report, which included investigations north of the river specified in addendum No. 2, was submitted to the EPA in July 1987. These investigations showed that: (1) some of the contamination was present as dense non-aqueous phase liquids (DNAPLs), (2) the majority of the aqueous-phase contamination in the deep bedrock aquifer was a result of DNAPL dissolution (an estimated 97 percent), and (3) some of the ground water contaminated with dissolved-phase was discharging to the Schuylkill River. To decrease the volume of ground-water discharge to the Schuylkill River, the PRP's consultant, ERM, recommended in June 1987 that a ground-water extraction system be installed. A Partial Consent Decree was issued on February 19, 1988 requiring

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the PRPs to install and operate a ground-water extraction system. In 1988, S.S. Papadopulos & Associates (SSP&A) was retained to design and install the recommended system along the south bank of the Schuylkill River.

In August 1988, on behalf of Ciba-Geigy, ERM submitted a draft offsite operable unit FS to the EPA proposing the selection of the no-action alternative for all the offsite operable units except the deep aquifer operable unit. This selection of the no-action alternative for four of the five offsite operable units was authorized by the EPA in a third ROD in September 1988. This ROD also specified that a system of extraction wells be installed along the south bank of the Schuylkill River, and the ground water be treated using steam stripping and carbon adsorption.

The interim extraction system, consisting of seven extraction wells, was brought on line on November 21, 1988. Six of the seven wells began operation on this date. The soil vapor extraction system in the onsite lagoon area also began operating in November 1988 (ERM Enviroclean, 1988).

ERM continued to investigate the extent of DNAPL and dissolved phase contamination in the ground water from 1989 through 1991, focusing primarily on ground water in the deep aquifer under the Schuylkill River, Barbadoes Island, and along the north bank of the river, as detailed in addenda Nos. 3 (June 1989) and 4 (1991) of the original RI/FS work plan. As part of the addendum No. 3 investigation, the interim ground-water recovery system was shut down during part of February 1990, to evaluate the degree of hydraulic interconnection between the pumping wells and monitoring wells installed near the Schuylkill River. A fourth site ROD (EPA, 1984, 1988a, 1988b, 1990), which required the expansion of the extraction system south of the river and on Barbadoes Island, as well as further study of the hydrogeologic conditions north of the river, was issued by the EPA on September 28, 1990.

GEOLOGY

The Tyson's Dump is located in an abandoned sandstone quarry in the Triassic lowlands province of Pennsylvania. The site is underlain by a relatively thin veneer of colluvium, fill and floodplain deposits that overlie the middle and lower sandstone and siltstone members of the Stockton Formation. Figure 3 is a north-south cross section across the site from the Schuylkill River to the high area south of the site. An east-west cross section along the river is shown in Figure 4. These two cross sections show several monitoring well clusters with open intervals at up to four levels within the bedrock.

Unconsolidated material on and in the vicinity of Tyson's Dump consists of undisturbed colluvial deposits at the base of the quarry high wall, fill material placed in the former lagoon area during initial remediation activities, construction debris and fill material in the seep area, and floodplain deposits from the base of the bedrock outcrop just north of the former lagoon area to the south bank of the Schuylkill River. The onsite colluvium, fill and the floodplain deposits are not contiguous, as shown in Figure 3. The depth to bedrock from south to north across the floodplain varies from 3 to 10 feet at the base of the embankment south of the railroad tracks to more than 20 feet on the north side of the tracks (EPA, 1988b).

The floodplain deposits can be divided into three subunits. The uppermost unit consists of a 1- to 2-foot-thick organic-rich silty clay. This is underlain by 10 to 15 feet of brownish red sandy clay with trace gravel and cobbles. This clay unit is underlain by a basal unit of sand and gravel with cobbles. The basal unit is 10 feet thick at the river's edge, but pinches out to the south and is absent at the railroad tracks.

The bedrock aquifer underlying the site consists of three units of the Stockton Formation: an upper red siltstone and fine sandstone unit, a middle purple arkosic sandstone, and a lower green arkosic sandstone. These lower two units are interbedded with occasional thin layers of siltstone. The red and purple units are more resistant to chemical weathering than the green unit and tend to be the ridge-formers in this area.

The Stockton Formation dips to the north-northwest at approximately 12 degrees regionally. The data collected during the offsite RI were found to agree with this regional trend (ERM, May 1990). The area contains several lineaments, and several east-west high-angle faults were identified during drilling (ERM, 1990a). High-angle joints 15 to 30 degrees from vertical were observed in almost all bedrock wells. The predominant orientation of the in situ joints measured in the

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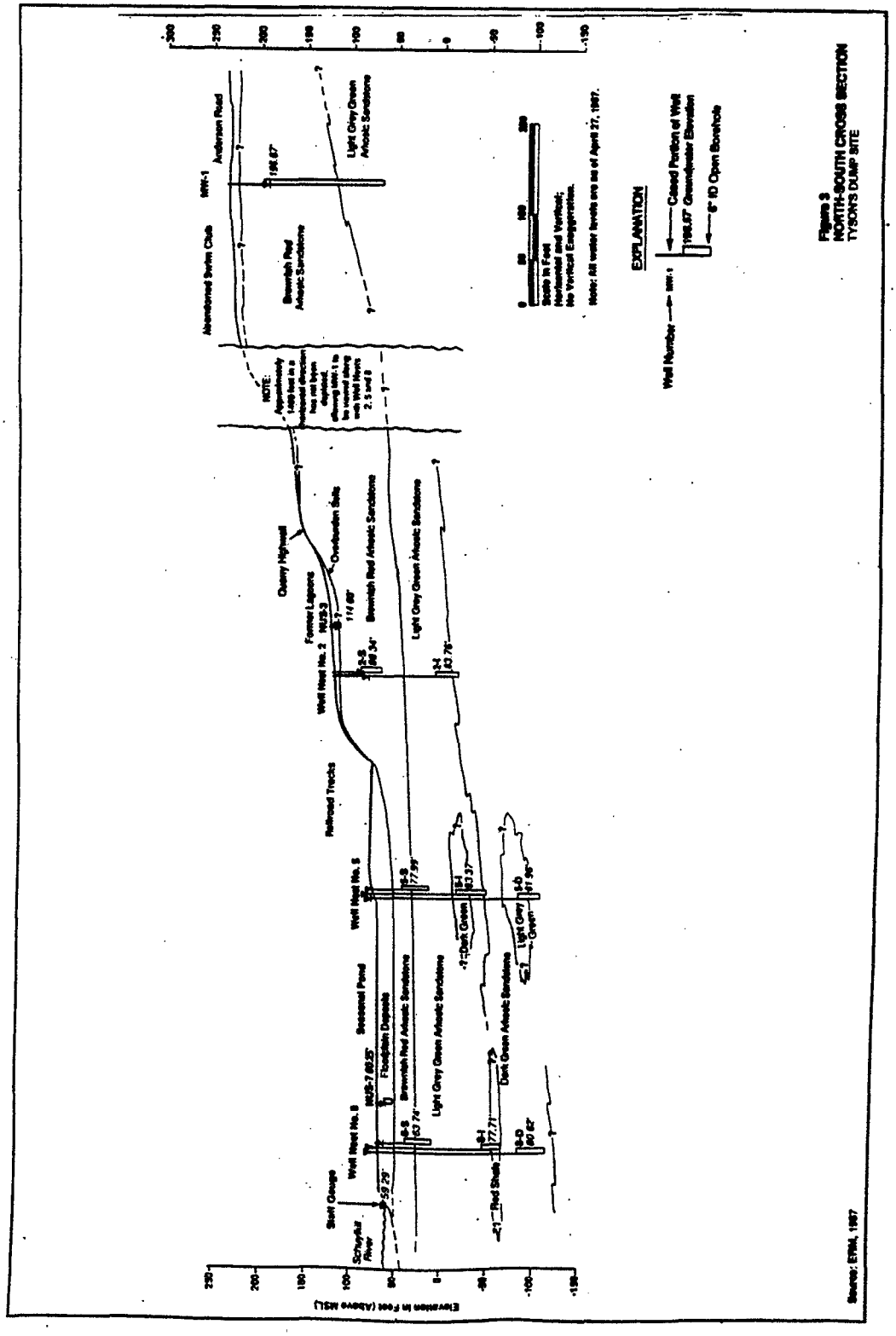
Elevation in Feet (Above MSL)
Staff Gauge
Schuylkill River
Well Nest No. 8
Seasonal Pond
Floodplain Deposits
Brownish Red Arkosic Sandstone
Light Grey Green Arkosic Sandstone
Dark Green Arkosic Sandstone
Red Shale
Railroad Tracks
Well Nest No. 5
Well Nest No. 2
Former Lagoons
Quarry Highwall
Overburden Soils
Light Grey Green Arkosic Sandstone
Brownish Red Arkosic Sandstone
Abandoned Swim Club
Anderson Road
Light Grey Green Arkosic Sandstone
Brownish Red Arkosic Sandstone
EXPLANATION
Well Number
Cased Portion of Well
Groundwater Elevation
6" ID Open Borehole
Figure 3
NORTH-SOUTH CROSS SECTION
TYSON'S DUMP SITE
Source: EPRA, 1987

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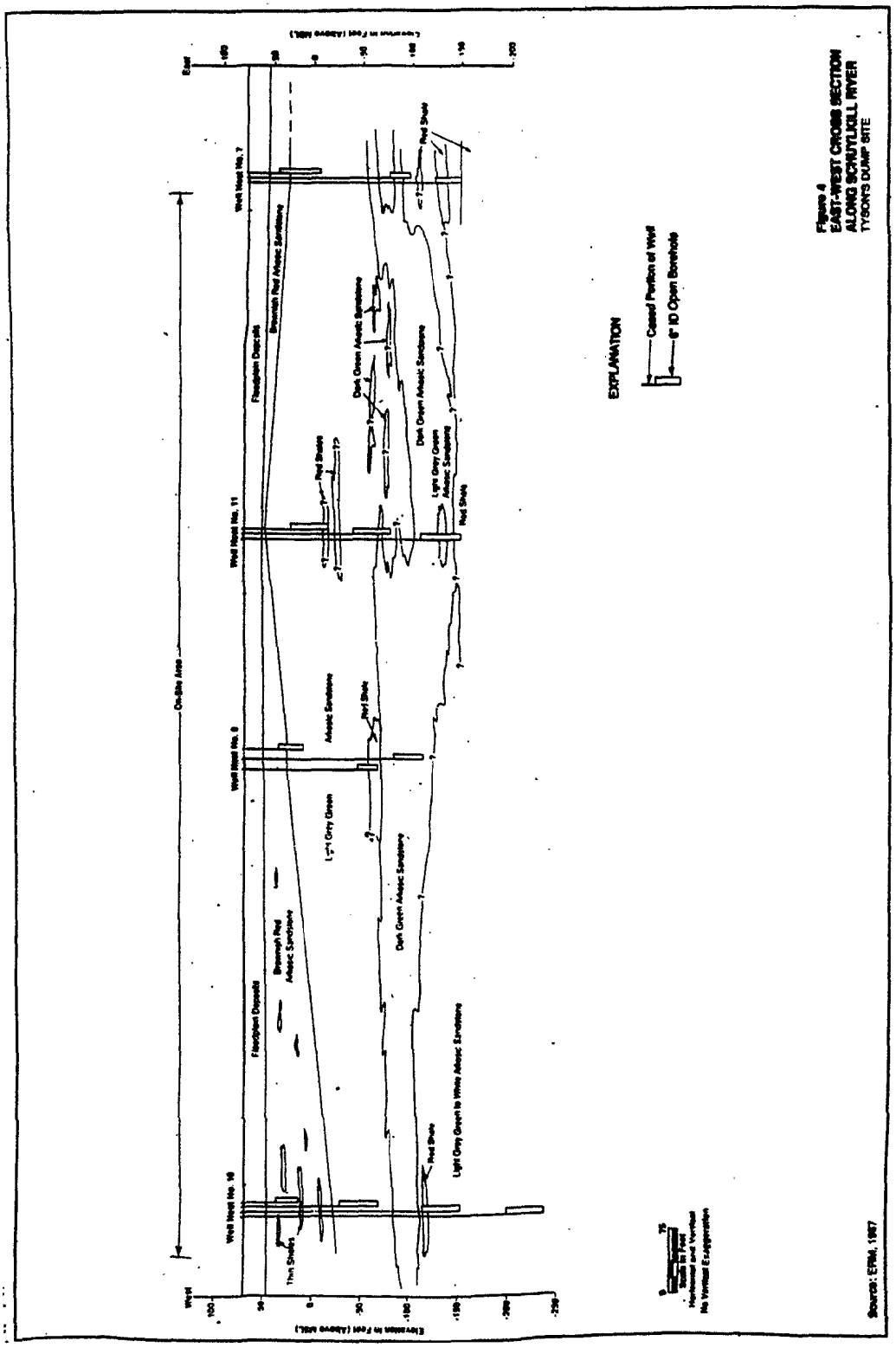
Figure 4
EAST-WEST CROSS SECTION
ALONG SCHUYLKILL RIVER
TYSON'S DUMP SITE
EXPLANATION
Cased Portion of Well
6" ID Open Borehole
Well West No. 10
Well West No. 8
Well West No. 11
Well West No. 7
Floodplain Deposits
Brownish Red Arkosic Sandstone
Dark Green Arkosic Sandstone
Light Grey Green Arkosic Sandstone
Red Shale
Thin Shales
On-Site Area
West
East
Source: EPA, 1987

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quarry high wall was to the north-northeast (ERM, 1990a). The bedrock is also believed to be strongly fractured along the bedding planes.

HYDROGEOLOGY

Ground water occurs both in the unconsolidated deposits and the bedrock aquifer. Ground water in the bedrock aquifer occurs both within primary intergranular spaces and secondary porosity features such as fractures. The permeability of the bedrock aquifer is highly anisotropic. Modeling studies of contaminant concentrations in the river suggest that the permeability along the bedding planes may be 10 times the permeability perpendicular to bedding (EPA, 1990). Hydraulic conductivity tends to be greatest in the uppermost 50 feet of the bedrock aquifer and decreases with depth (SSP&A, 1988a). The hydraulic conductivity of the bedrock was measured at between nearly zero and 11 feet per day at several intervals within well clusters south of the river (ERM, 1987).

The direction of ground-water flow from the site both in the unconsolidated materials and the bedrock aquifer is radially northward toward the river. The potentiometric surfaces in the shallow, intermediate, and deep zones of the bedrock aquifer on October 13, 1988, before extraction began, are shown in Figures 5, 6, and 7, respectively. These figures show that flow is northward toward the river in all three zones of the bedrock aquifer. A comparison of these three potentiometric surfaces shows that the vertical gradient was upward in some areas of the floodplain south of the river even before pumping began. Ground-water elevation data indicate that groundwater in the shallow bedrock discharges to the floodplain deposits in some areas south of the Schuylkill River. However, ERM's evaluation of ground-water flow in this area concludes that the volume of ground-water discharge to the floodplain deposits is not likely to be significant (ERM, 1990b). Horizontal gradients within the intermediate and deep zones of the bedrock aquifer south of the Schuylkill River were estimated to be 0.032 to 0.073 ft/ft in October 1988, before extraction began (ERM, 1990a).

Water levels and hydraulic gradients in and near the river generally suggest that a portion of the ground water discharges to the Schuylkill River. Water levels in wells along both banks of the river are generally equal to or higher than the water level in the river, indicating the potential for horizontal flow to the river. Some ground water is also believed to flow north underneath the river. Vertical gradients were upward between some of the intervals in well clusters along both the north and south bank of the river during extraction on April 17, 1990. In particular, upward gradients were observed in the central portion of the site south of the river (ERM, 1990a). The vertical gradient between some intervals in well clusters on Barbadoes Island was also slightly upward on that date. However, on the same date, downward gradients were observed in well nests 7 and 12 south of the river and between certain intervals within well clusters on both sides of the river and on Barbadoes Island (ERM, 1990a). Vertical gradients are spatially variable, especially with depth and conclusions based on available data are difficult to make.

Water levels near the river are strongly influenced by river stage. Long-term water level measurements of well cluster 10 south of the river and CW-4 (Figure 8) on Barbadoes Island in 1989 and 1990 showed that ground-water levels respond almost immediately to changes in river stage. The influence of the river can be attributed to two factors: hydraulic loading effects of the water in the river, and direct hydraulic connection between the river and the bedrock aquifer. The relative influence of these two factors varies depending on location.

In February 1990, a recovery test designed to measure the interconnection of the areas north and south of the river was performed by turning off the ground-water extraction system for several days. Wells south of the river, especially those close to the pumping wells, generally recovered quickly, while water levels in wells on Barbadoes Island decreased rather than increased in response to the recovery test (see Figure 8). Well CW-4, on the island, was found to respond strongly to changes in barometric pressure. The immediate response to hydraulic loading and barometric pressure changes suggests that portions of the bedrock aquifer are confined.

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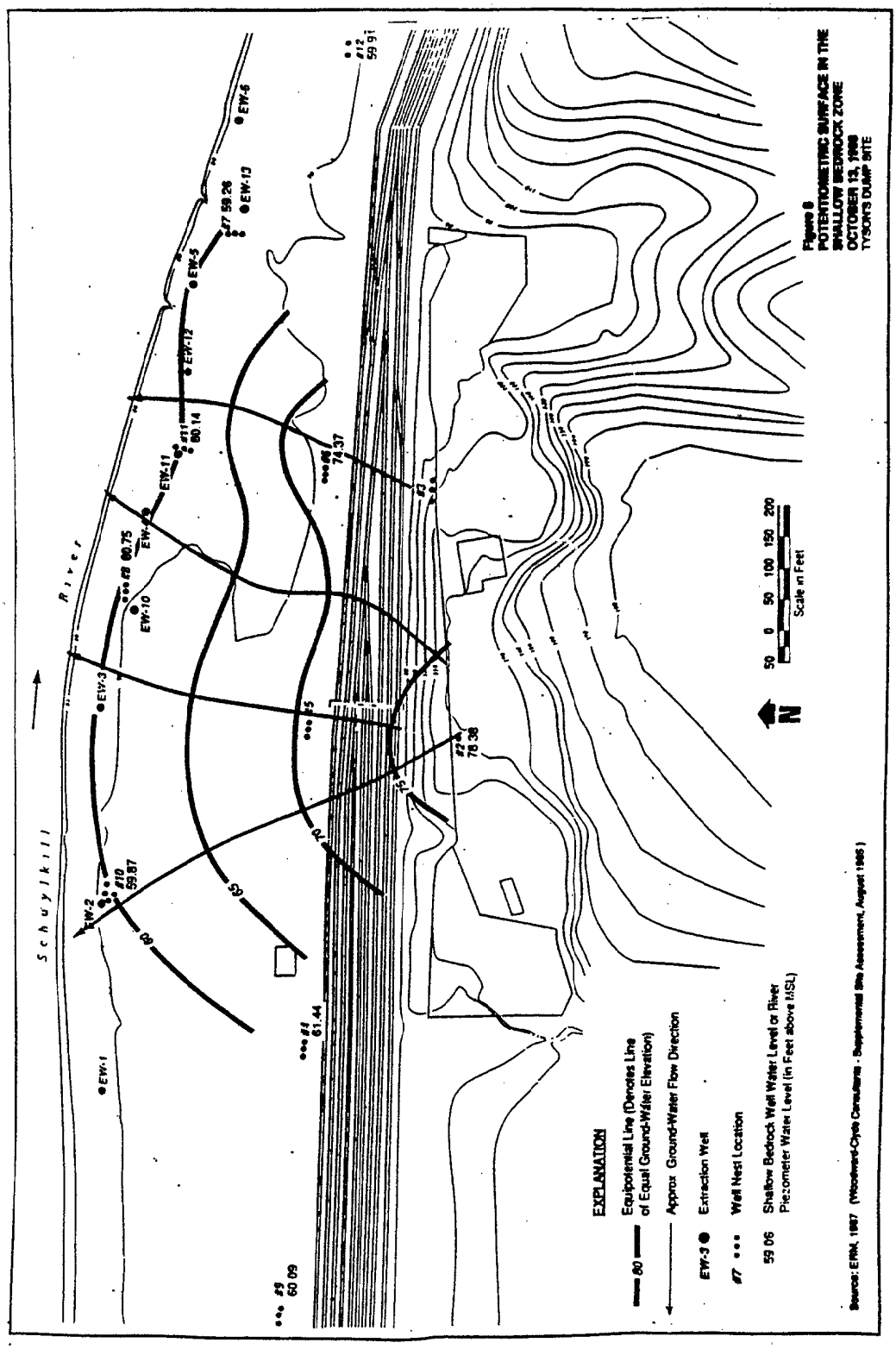
Schuylkill River
EW-1
EW-2
EW-3
EW-5
EW-6
EW-10
EW-11
EW-12
EW-13
#10 59.87
#8 60.75
#11 60.14
#7 59.26
#12 59.91
#4 61.44
#5 60.09
#2 78.38
#6 74.37
#3
60
65
70
75
N
50 0 50 100 150 200
Scale in Feet
EXPLANATION
80 Equipotential Line (Denotes Line of Equal Ground-Water Elevation)
Approx Ground-Water Flow Direction
EW-3 Extraction Well
#7 Well Nest Location
59.06 Shallow Bedrock Well Water Level or River Piezometer Water Level (in Feet above MSL)
Source: ERM, 1987 (Woodward-Clyde Consultants - Supplemental Site Assessment, August 1985)
Figure 8
POTENTIOMETRIC SURFACE IN THE SHALLOW BEDROCK ZONE
OCTOBER 13, 1986
TYSON'S DUMP SITE

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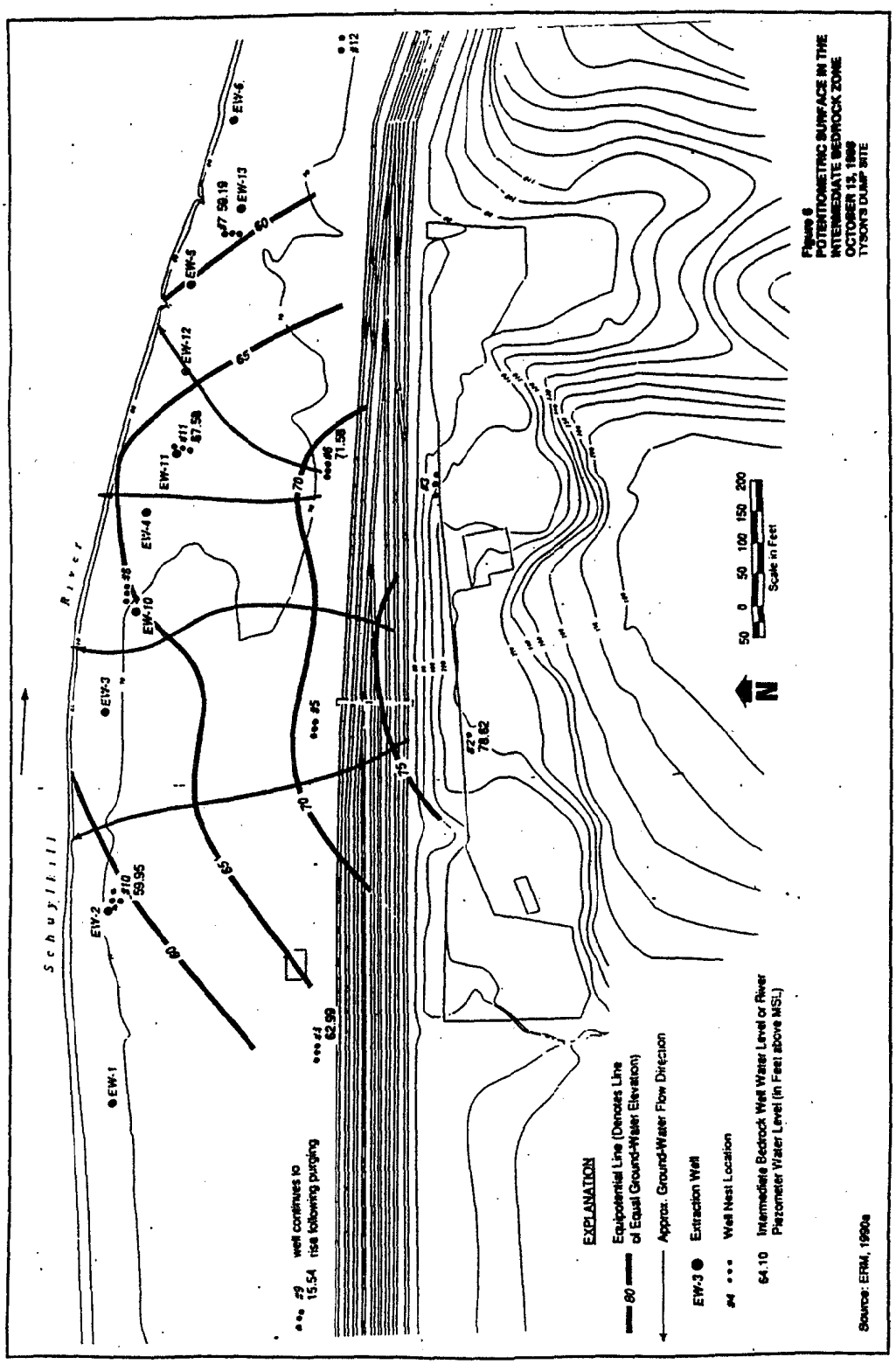

Figure 6
POTENTIOMETRIC SURFACE IN THE INTERMEDIATE BEDROCK ZONE
OCTOBER 13, 1988
TYSON'S DUMP SITE

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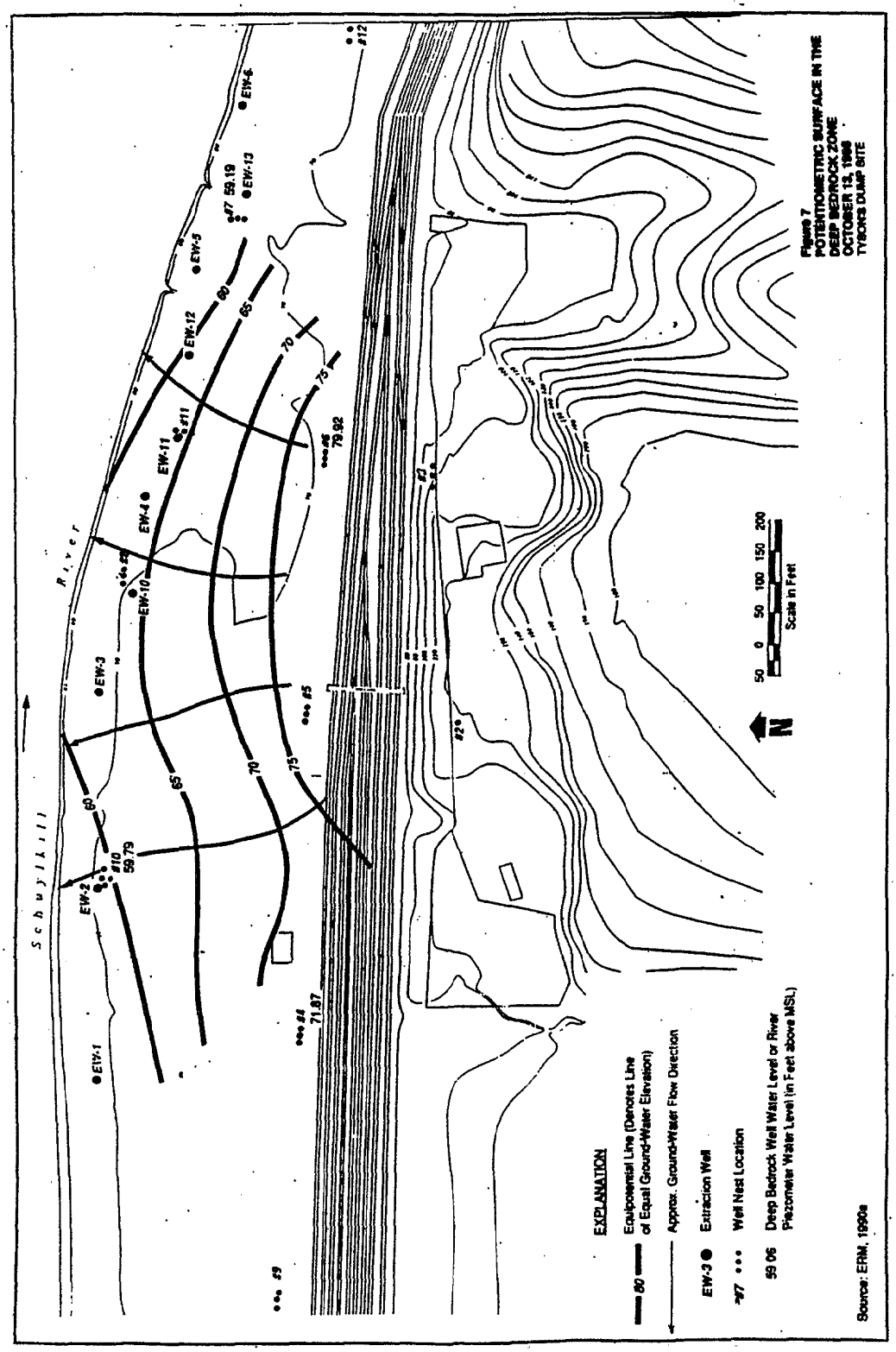
Figure 7
POTENTIOMETRIC SURFACE IN THE
DEEP BEDROCK ZONE
OCTOBER 13, 1988
TYSON'S DUMP SITE
Schuylkill River
EW-1
EW-2
EW-3
EW-4
EW-5
EW-6
EW-10
EW-11
EW-12
EW-13
#1 71.87
#2
#3
#4
#5
#6 79.92
#7 59.19
#8
#9
#10 59.79
#11
#12
60
65
70
75
N
50 0 50 100 150 200
Scale in Feet
EXPLANATION
60 Equipotential Line (Denotes Line of Equal Ground-Water Elevation)
Approx. Ground-Water Flow Direction
EW-3 Extraction Well
#7 Well Nest Location
59.06 Deep Bedrock Well Water Level or River Piezometer Water Level (in Feet above MSL)
Source: ERM, 1990a

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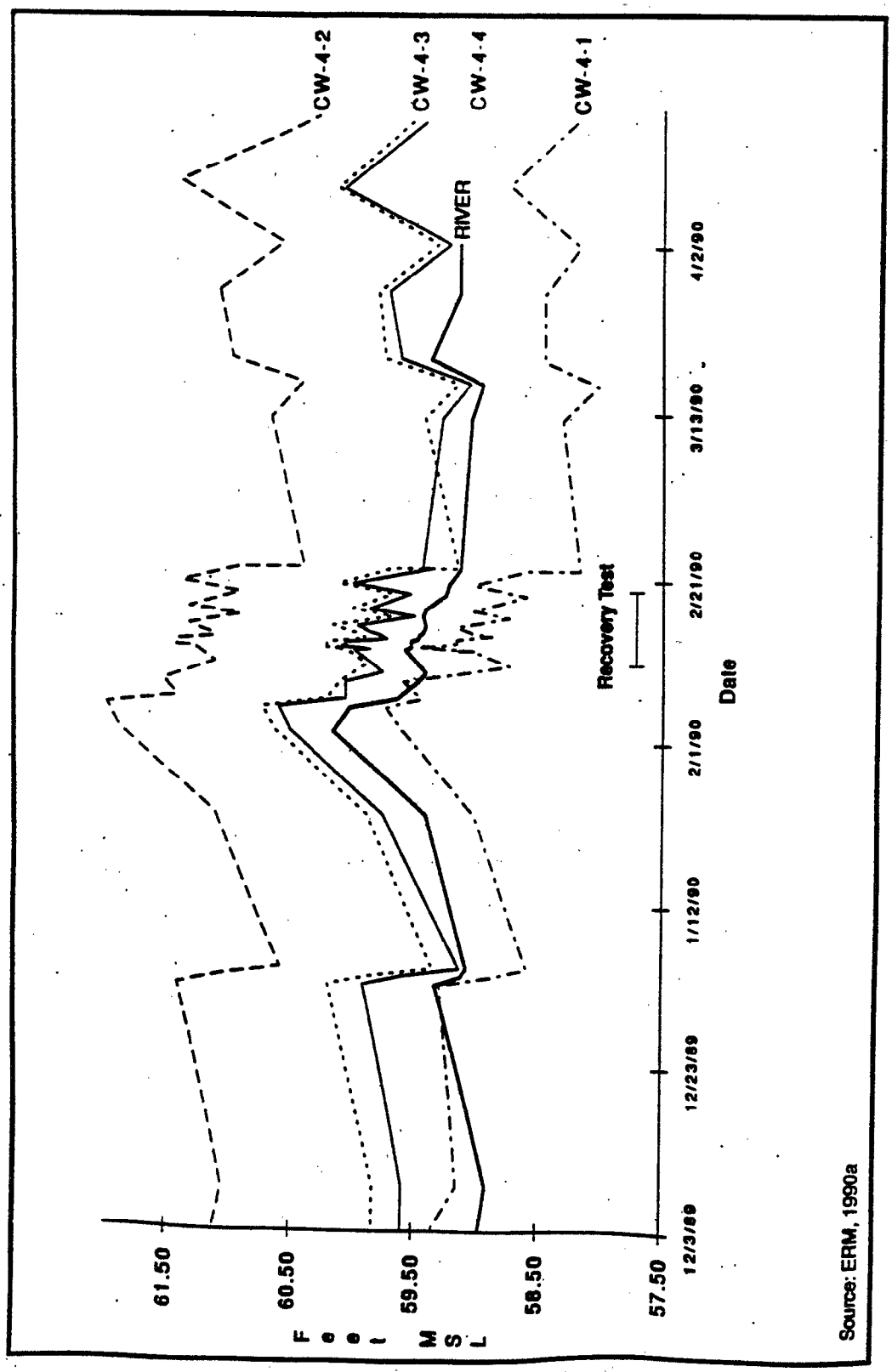

Figure 8
RESPONSE OF WELL CLUSTER CW-4 TO CHANGES IN RIVER LEVEL AND TO THE FEBRUARY 1990 RECOVERY TEST
TYSON'S DUMP SITE

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WASTE CHARACTERISTICS AND POTENTIAL SOURCES

Organic compounds originating from the Tyson's Dump onsite area have contaminated ground water underlying the disposal area and as far north as the north side of the Schuylkill River. These contaminants are known to be present both as DNAPLs and as dissolved constituents. Both the unconsolidated deposits and the fractured bedrock are contaminated. Dissolved contaminants, particularly 1,2,3-trichloropropane, were also found in water samples collected at downstream local water supply intakes (typically 0.5 to 1.5 ppb) and in river bottom sediments. Even after treatment, 1,2,3-trichloropropane persisted at the part per trillion level in finished drinking water. 1,2,3-trichloropropane was not detected in river samples collected upstream from the Tyson's Dump site.

The contamination consists of both volatile and semivolatile organic compounds. The primary contaminants are the VOCs 1,2,3-trichloropropane, toluene, ethylbenzene, and xylenes, but other volatile and semivolatile organics are also present (ERM, 1987). The composition of DNAPLs taken from two intermediate bedrock wells south of the river is listed in Table 1. Both samples contained substantial percentages of these four main contaminants.

DNAPLs were introduced into the ground water via infiltration through unlined lagoons located at the Tyson's Dump and are believed to have migrated downward by gravity flow to the bedrock surface. At that point, the DNAPLs are believed to have migrated directly into the bedrock and possibly flowed along the bedrock surface. Once in the bedrock, the DNAPLs are likely to have migrated downward through vertical joints and along bedding planes, coating the walls of the bedrock openings and pooling in low areas. A schematic representation of this flow path is illustrated in Figure 9. DNAPLs have been observed in samples of the bedrock ground water collected from as deep as 135 feet in monitoring Well 8-I located adjacent to the south bank of the Schuylkill River.

The distribution of 1,2,3-trichloropropane (1,2,3-TCP) in May 1986 in ground water in the unconsolidated sediments is illustrated in Figure 10. This figure shows that 1,2;3-TCP concentrations were as high as 690 mg/l (690,000 ppb) in wells in the east-central part of the onsite area and as high as 220,000 ppb in the west-central part of the onsite area in May 1986. Concentrations were less than 1/1,000 of these amounts in wells at the east and west ends of the onsite area. In the two wells in the floodplain deposits shown in Figure 10, 1,2,3-TCP concentrations were 730 and 22 ppb, despite the discharge of ground water from the shallow bedrock aquifer to the floodplain. More recently, Terra Vac has completed more than 200 borings in the onsite area. These data, which were not available for incorporation into this case study, provide a clearer understanding of the shape of the bedrock surface and the distribution of contamination onsite near the former lagoons (ERM, 1991b).

The distribution of 1,2,3-TCP in the shallow, intermediate, and deep bedrock zones in 1986 is shown in Figures 11, 12, and 13, respectively. The concentration of both total xylenes and toluene within these zones was approximately one order of magnitude less than the concentration of 1,2,3-TCP in 1986 and the overall shape of the xylene and toluene plumes was similar, hence only TCP will be shown graphically. Figures 11 to 13 show that the highest concentrations of 1,2,3-TCP were found in well clusters 3 (810,000 ppb), 6 (1,200,000 ppb), and 11 (980,000 ppb) located north-northeast of the former eastern lagoons and in well cluster 10 (400,000 ppb) northwest of the former western lagoons. Concentrations were generally highest in the intermediate zone but were also quite high in the shallow zone, particularly at 11-S (980,000 ppb). Although the investigations did not extend to the north side of the river in May 1986, Figures 11 to 13 show that the plume extended to the river along a broad front. As of February 1990, ground-water concentrations of 1,2,3-TCP were greatest (1,400,000 ppb) in 3I, a well located south of the Schuylkill River at intermediate depth (75-99 feet) (ERM, 1990a).
Studies of DNAPL behavior and calculations by ERM (1987) showed that a very large hydraulic gradient may be required to move the DNAPL by ground-water flow because of its density (see Table 1). This gradient does not exist in the aquifers underlying this site. Although the DNAPLs may not respond to the hydraulic gradients, dissolved contaminants originating from the DNAPL source are advected with the flow of ground water. The gradient in the deep aquifer underlying the floodplain in some areas is upward toward the river. Therefore, the contamination in

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Table 1
DNAPL COMPOSITION AND PROPERTIES

	% by Weight	
	Well 3-I	**Well 8-I**
1,2,3,-Trichloropropane	23.0	73.0
Xylenes	17.0	5.8
Ethyl benzene	3.8	0.9
Toluene	4.2	0.9
Total	**48.0%***	**80.6%****
Brookfield Viscosity	3. cps	7. cps
Specific Gravity	1.125 gm/cm^3	1.30 gm/cm^3

Source: ERM, 1987

* The balance of the sample composition were compounds eluting later than xylenes, but not in an elution pattern identifiable as petroleum distillates.

** The balance of sample composition was typical of unidentified petroleum distillates. Petroleum distillates can be identified as a general class of compounds because of the characteristic hydrocarbon envelope that is obtained during gas chromatographic analysis of samples containing these analytes.

the Schuylkill River is likely the result of baseflow with dissolved contaminants discharging to the river rather than the direct discharge of DNAPLs. According to ERM, the presence of site-specific compounds in the river may also be due to runoff from the drainageways discharging through the offsite area (ERM, 1987).

ERM (1987) found the solubility of 1,2,3-trichloropropane to be approximately 1,900,000 ppb; therefore, because the trichloropropane is the predominant solvent measured in the DNAPL sample collected at the site, a DNAPL solubility of 1,900,000 ppb was thought to be a reasonable estimate of the actual solubility of the DNAPL. Concentrations of dissolved DNAPL greater than 190,000 ppb were interpreted as indicating a nearby DNAPL source (ERM, 1987). DNAPLs were found in Wells 2-S, 3-S, 3-I, 5-S, 6-S, 6-I, and 8-I in 1986. Efforts to effectively recover DNAPL were unsuccessful (ERM, 1987).

REMEDIATION

Selection and Design of the Remedy

Initial remedial efforts conducted by the EPA and their contractors focused on the onsite unconsolidated material and consisted of soil removal and leachate collection and treatment. A soil vapor extraction system designed to treat the onsite soil was installed in 1988, and began operating in November 1988.

The investigations of the offsite area conducted by ERM showed that the deep bedrock aquifer has been extensively contaminated with DNAPLs. Based on the offsite investigation, ERM concluded that the DNAPLs trapped in the bedrock aquifer could not be effectively recovered and would continue to act as a source of dissolved contaminants in the ground water.

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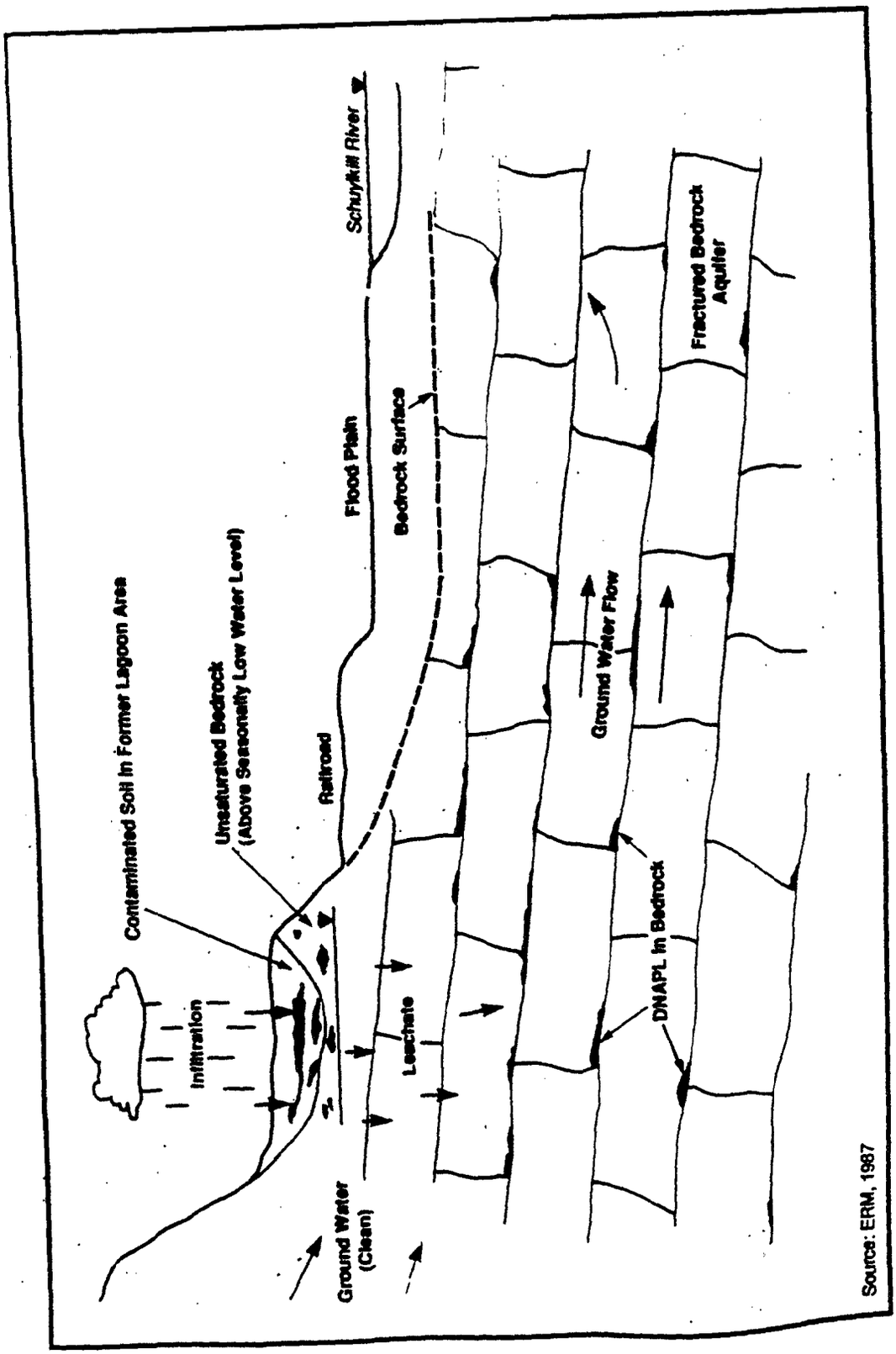

Source: ERM, 1987

Figure 9
SCHEMATIC OF POTENTIAL CONTAMINANT PATHWAY
TYSON'S DUMP SITE

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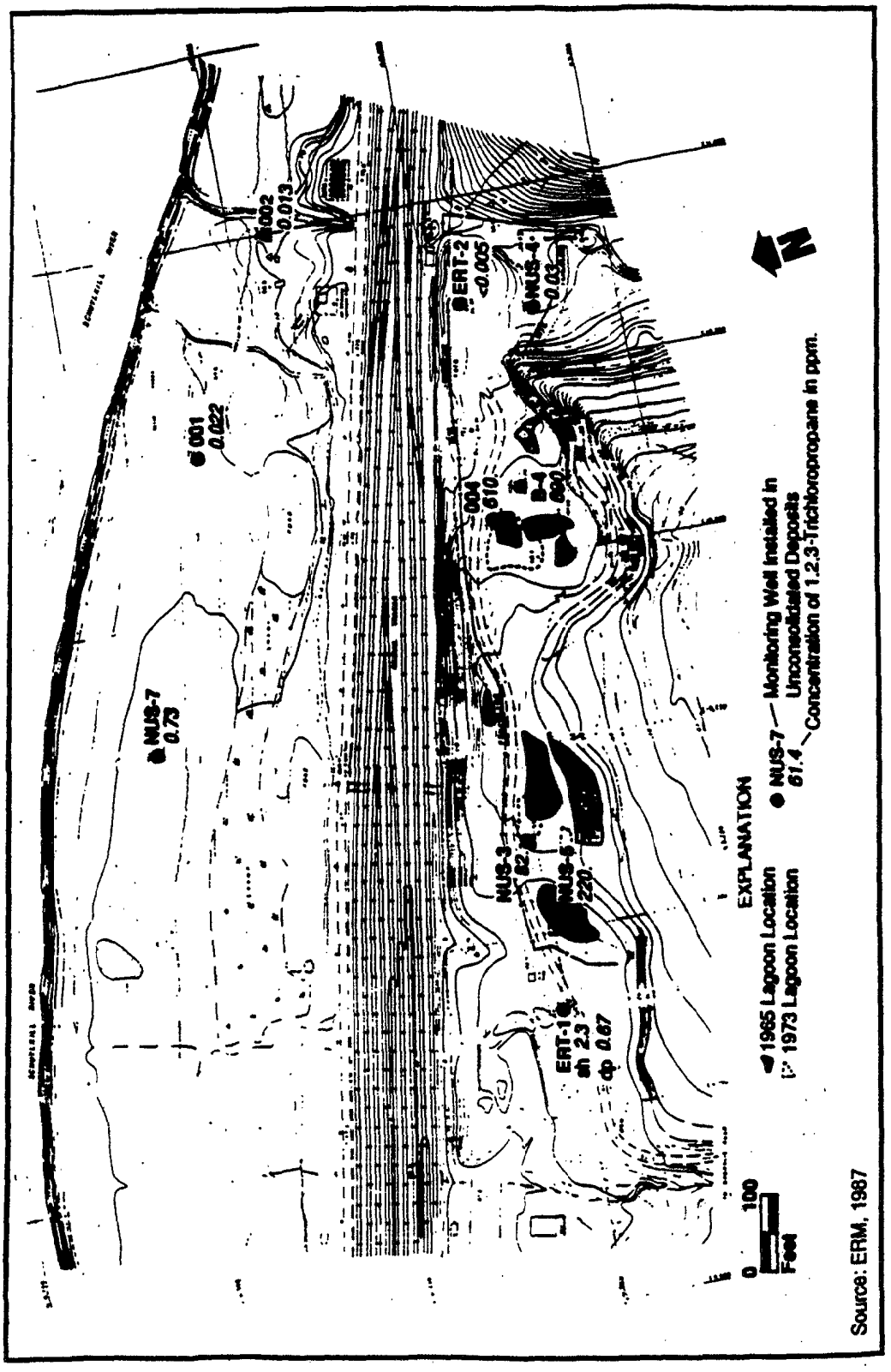

Figure 10
DISTRIBUTION OF 1,2,3,-TRICHLOROPROPANE
IN UNCONSOLIDATED DEPOSITS, MAY 1986
TYSON'S DUMP SITE

(Poor Quality Original)

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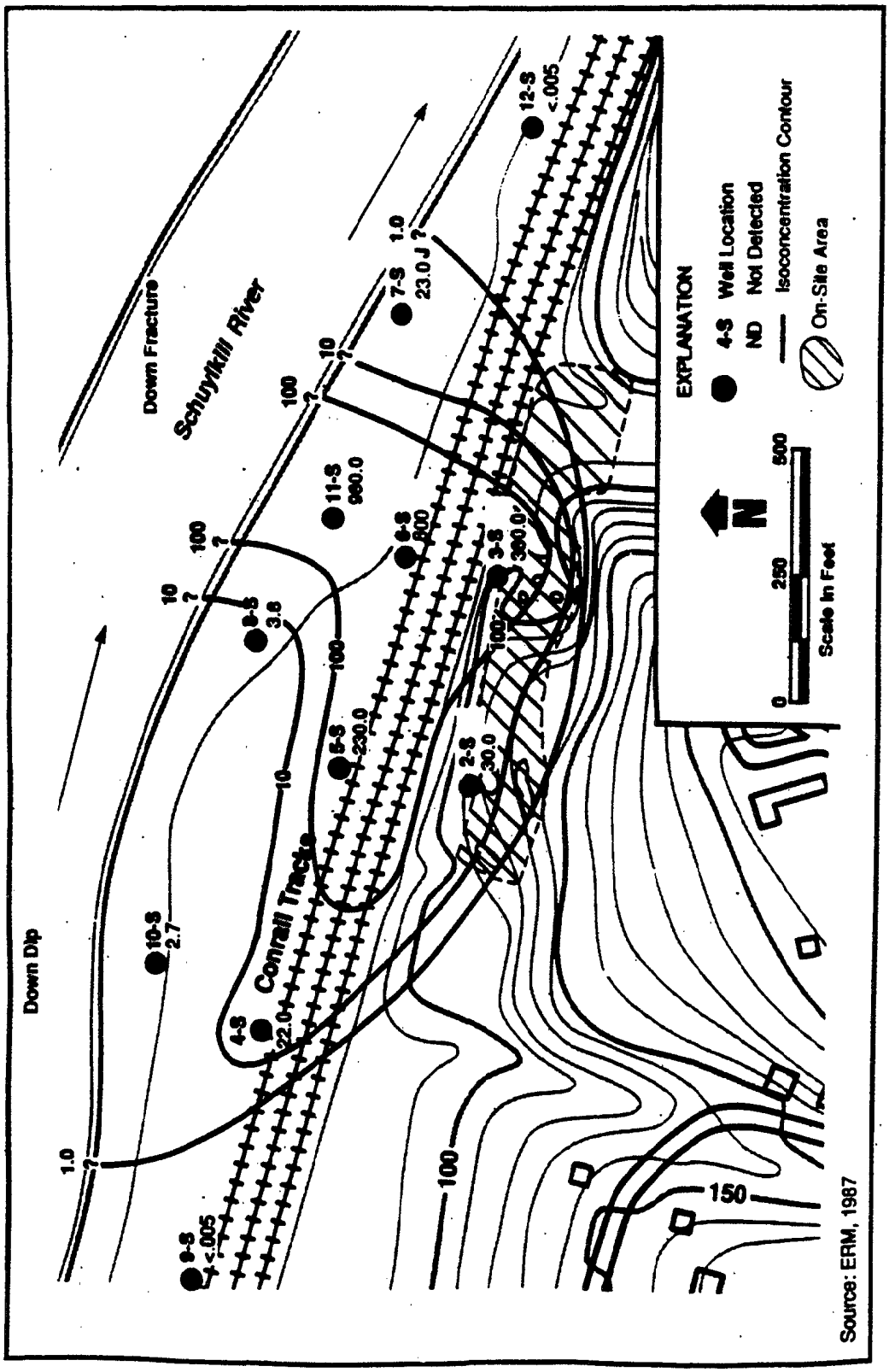

Figure 11
DISTRIBUTION OF 1,2,3,-TRICHLOROPROPANE (ppm)
IN THE SHALLOW BEDROCK ZONE, 1986
TYSON'S DUMP SITE

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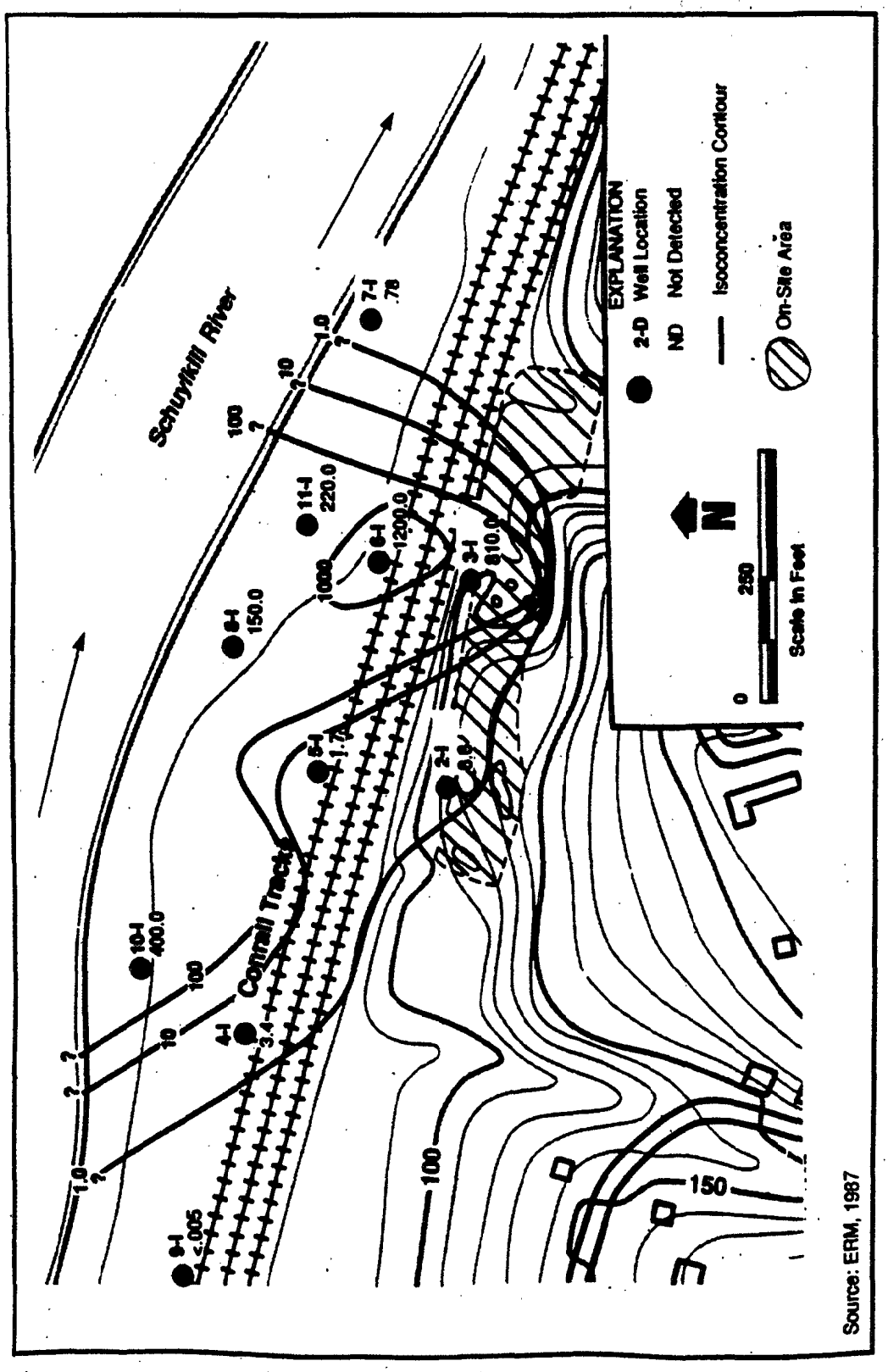

Figure 12
DISTRIBUTION OF 1,2,3,-TRICHLOROPROPANE (ppm)
IN THE INTERMEDIATE BEDROCK ZONE, 1986
TYSON'S DUMP SITE

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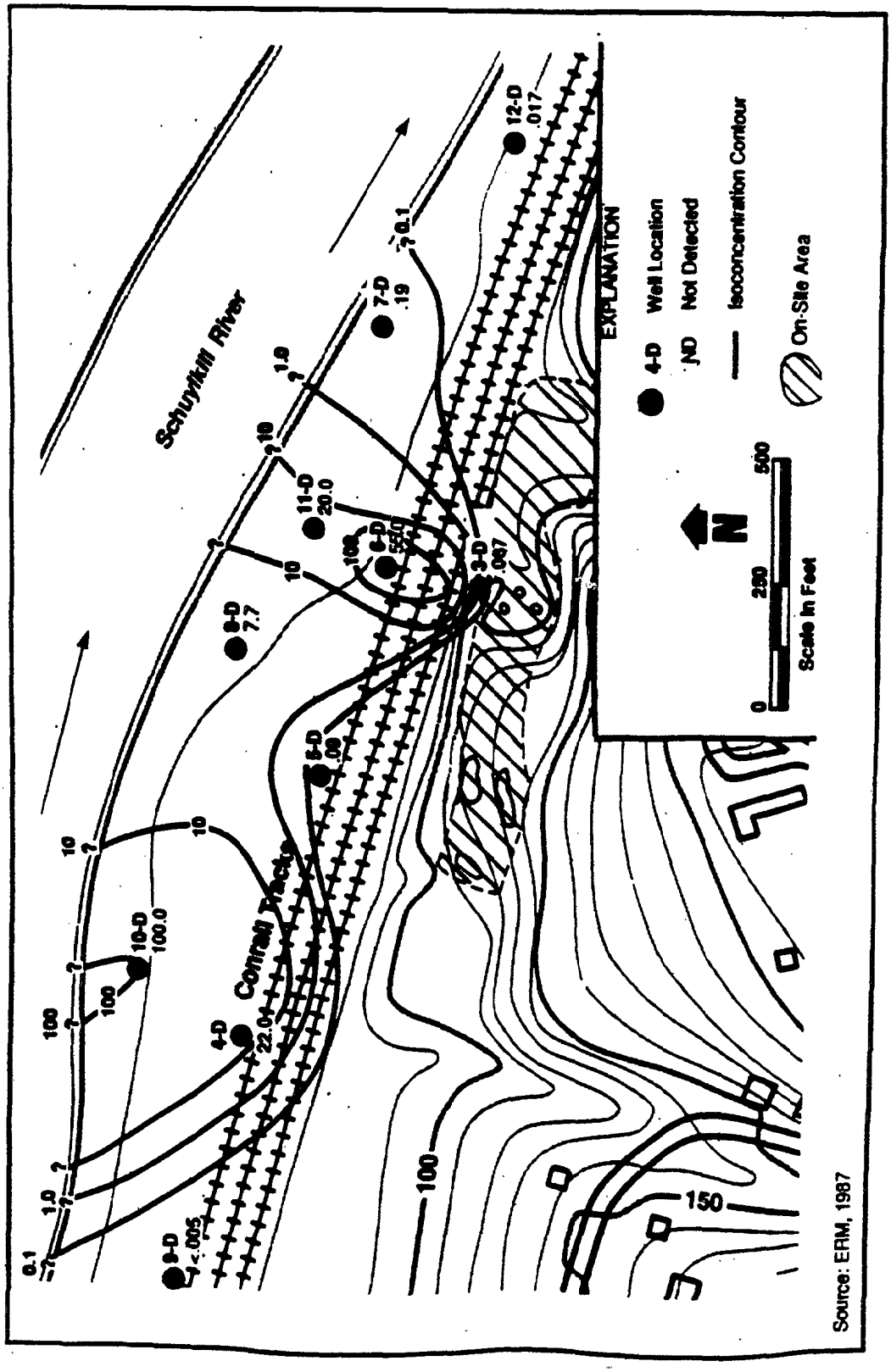

Figure 13
DISTRIBUTION OF 1,2,3,-TRICHLOROPROPANE (ppm)
IN THE DEEP BEDROCK ZONE, 1986
TYSON'S DUMP SITE

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A number of hydrogeologic tests and a round of ground-water sampling were conducted to determine the hydraulic properties of the bedrock and the distribution of contamination at various depths. These data were used to develop a three-dimensional numerical model of ground-water flow in the bedrock aquifer along the south bank of the river (SSP&A, 1988a). A particle tracking model was also used by SSP&A to simulate contaminant transport.

As a result of this investigation, two ground-water recovery systems, one interim and one final, were proposed to intercept baseflow to the Schuylkill River (SSP&A, 1988a). SSP&A designed an interim system of seven extraction wells--four 50-foot wells and three 180-foot wells to be installed in a line along the Schuylkill River. Modeling indicated that this system would be capable of extracting 200 gpm. The interim system was proposed because it could be brought online quickly. SSP&A predicted that this system would be capable of intercepting the most contaminated ground water in the upper 50 feet of the bedrock and eliminating most, if not all, of the contaminated ground-water discharge to the Schuylkill River. Figure 14 shows the simulated potentiometric surface and ground-water flowlines produced by the 7-well interim extraction system, with a pump rate of 200 gpm. Figures 15 and 16 show the horizontal and vertical zones of capture of the proposed 7-well interim extraction system.

Six 180-foot-deep test wells, EW-1 through EW-6, were installed in the bedrock in a line parallel to and 50 feet from the river bank from November 1987, to March 1988 (SSP&A, 1988a). EW-3, EW-4, and EW-5 were later completed as recovery wells as part of the interim extraction system. In October 1988, recovery Wells EW-10 through EW-13 were installed (ERM Enviroclean, 1988). Six of the interim extraction wells, EW-3, EW-4, EW-5, EW-10, EW-11, and EW-12, began operating on November 21, 1988. The proposed depth of installation of the pumps in the first three wells was 120 to 125 feet, whereas the pumps in The full-scale ground-water recovery system proposed by SSP&A consisted of thirteen 180-foot-deep recovery wells installed in a line along the Schuylkill River. The projected horizontal capture zone of the final 13-well system pumped at 350 gpm is shown in Figure 17. This system was to be installed after the interim system was in place. As of June 1991, the final system of extraction wells had been installed, but the system had not begun operating, pending EPA construction of the header system (EPA, 1991b).

EVALUATION OF PERFORMANCE

Hydraulic Control

Figure 18 shows the potentiometric surface elevations in the shallow bedrock zone on September 5, 1990. Extraction Wells EW-3, EW-4, EW-5, EW-10, and EW-12 were operating on that date, with a combined pumping rate of approximately 100 gpm (SSP&A, 1990). This figure shows that the potentiometric surface around the operating extraction wells had been lowered to an elevation of 50 feet or less and that elevations in non-pumping extraction wells and monitoring wells had been lowered to less than 60 feet. S.S. Papadopulos (1990) reports that the average elevation of the Schuylkill River is normally between 59 and 60 feet MSL. Based on the potentiometric surface elevations shown on Figure 18, it appears that the interim ground-water extraction system is effectively capturing most ground-water flow along the riverfront between EW-3 and EW-13. Comparing Figure 5 with 18, it appears that the capture zone created by the operating extraction wells may extend laterally as far as EW-2 on the west and EW-6 on the east. Flow is also induced from the Schuylkill River to the extraction wells when the drawdown is sufficient, a reversal of natural gradients. The highest concentrations of 1,2,3-TCP in the shallow bedrock have historically been observed in monitoring well clusters 3, 6, and 11. The interim ground-water extraction system, pumping at a rate of 100 gpm, appears to be effective at capturing shallow ground-water flow migrating from the vicinity of these well clusters.

Another area of high concentration during the RI was at monitoring well cluster 10 located considerably west of EW-3. Contaminated ground water in this area was not expected to be captured by the interim extraction system but is expected to be captured by the final system. However, based the remaining four wells were to be installed at approximately 65 to 70 feet (SSP&A, 1988b). The objectives of the ground-water extraction system are to contain the ground water south of the river and to stop, or at least limit, the baseflow of contaminated ground water to the river. on the potentiometric surface shown in Figure 18, it appears that the hydraulic gradient between well cluster 10 and the river may have been reduced, or

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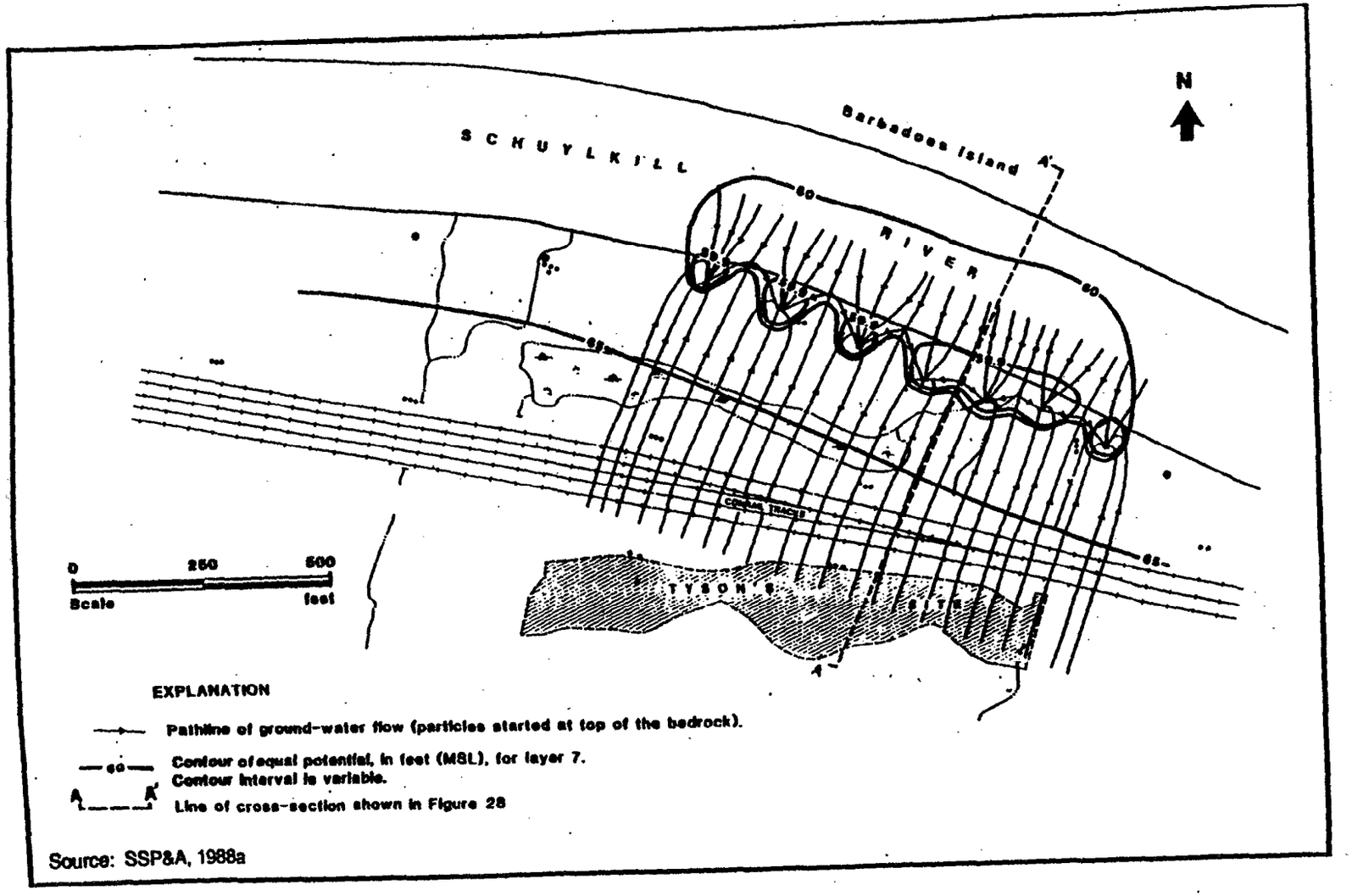

Source: SSP&A, 1988a

Figure 14
SIMULATED POTENTIOMETRIC SURFACE AND ISOTROPIC STREAMLINES FOR THE 7-WELL INITIAL RECOVERY SYSTEM
TYSON'S DUMP SITE

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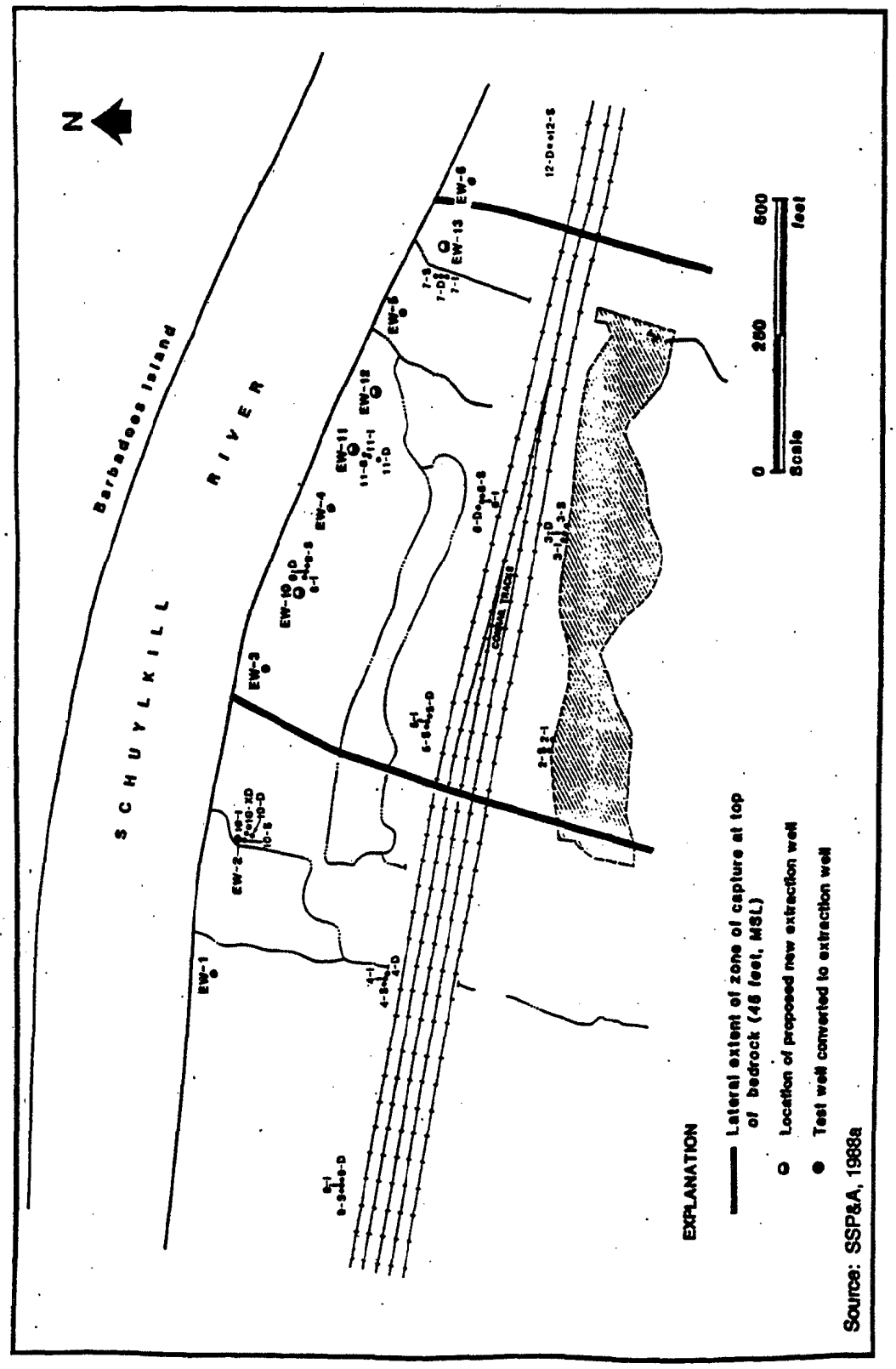

Figure 15
ZONE OF CAPTURE FOR 7-WELL INITIAL RECOVERY SYSTEM, 200 GPM
TYSON'S DUMP SITE

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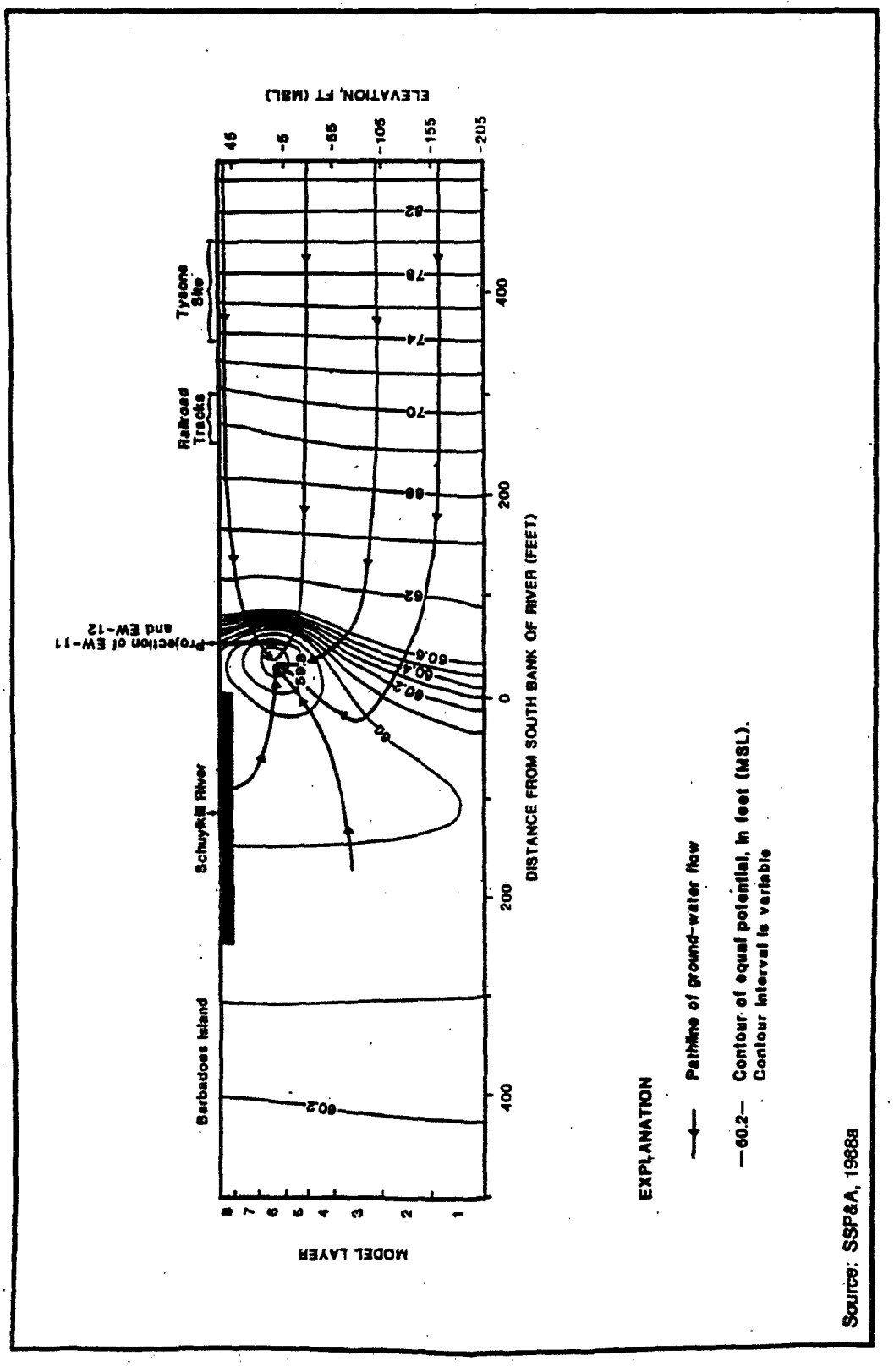

Figure 16
CROSS-SECTIONAL VIEW OF COMPUTED GROUND-WATER POTENTIALS AND ISOTROPIC STREAMLINES FOR THE 7-WELL INITIAL RECOVERY SYSTEM
TYSON'S DUMP SITE

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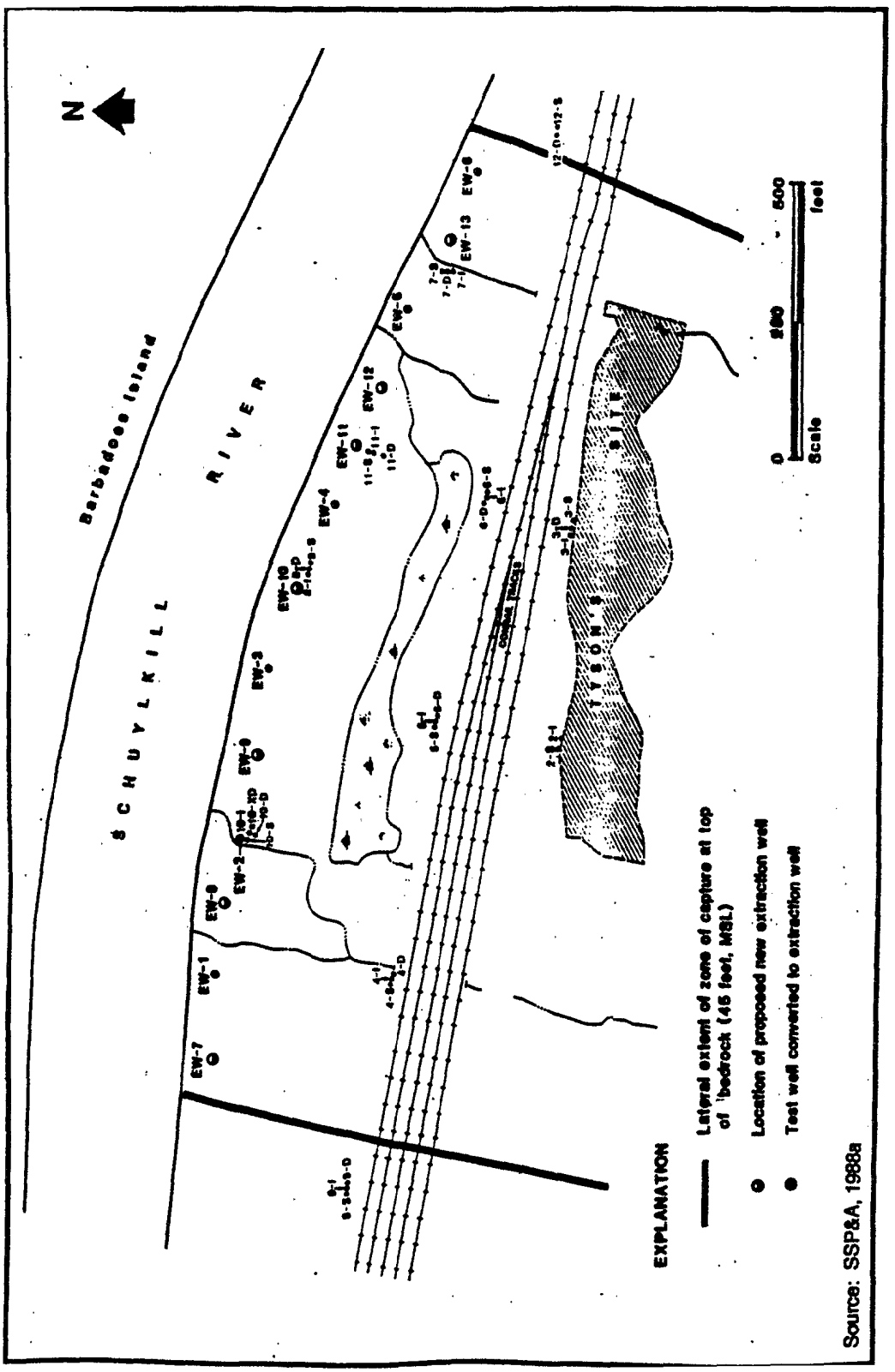

Figure 17
ZONE OF CAPTURE FOR 13-WELL RECOVERY SYSTEM, 350 GPM
TYSON'S DUMP SITE

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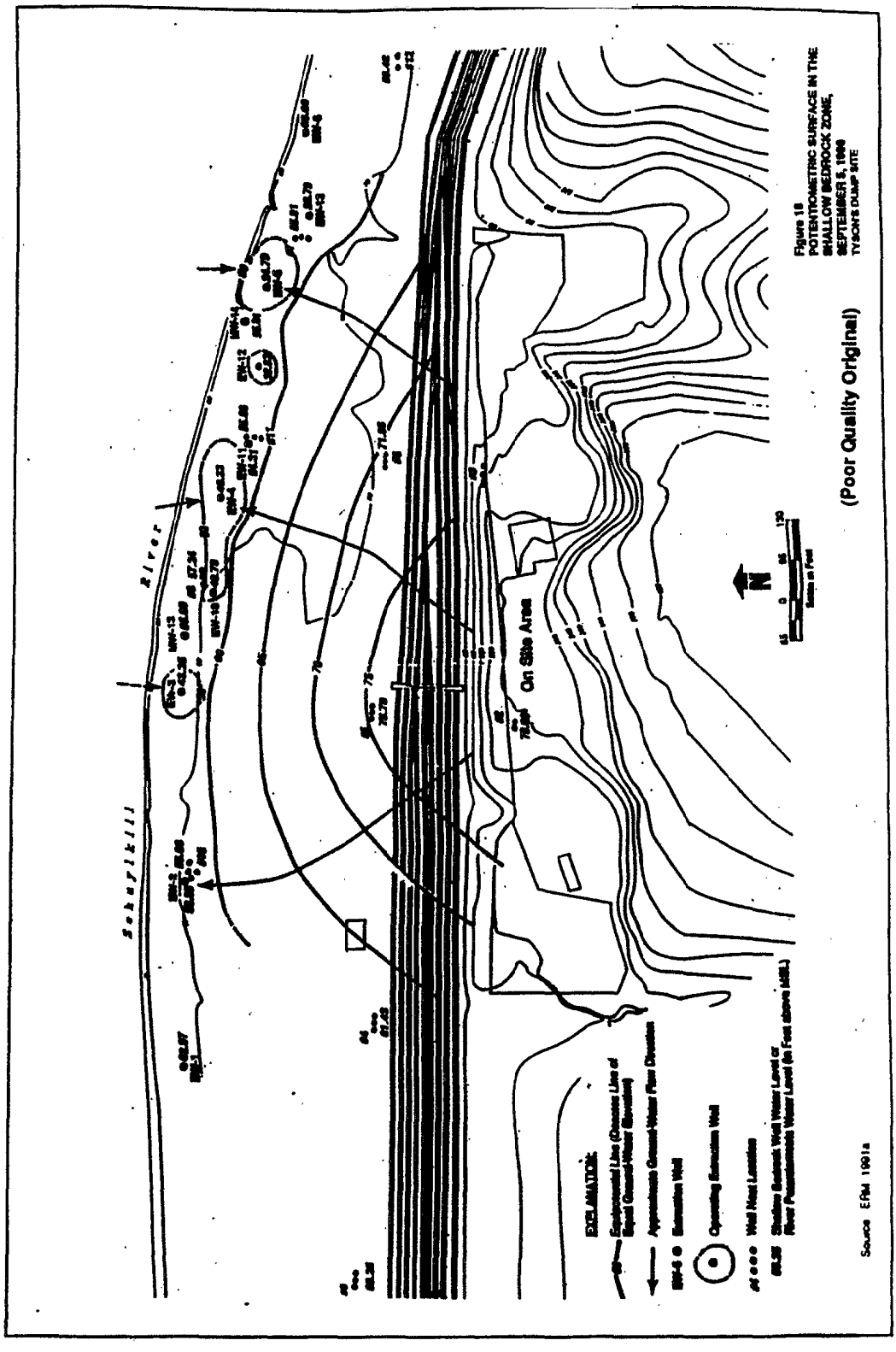
Figure 18
POTENTIOMETRIC SURFACE IN THE
SHALLOW BEDROCK ZONE,
SEPTEMBER 5, 1990
TYSON'S DUMP SITE
(Poor Quality Original)
Source ERM 1991a
On Site Area
Sekuyikill
River
EXPLANATION:
Equipotential Line (Denotes Line of Equal Ground-Water Elevation)
Approximate Ground-Water Flow Direction
Extraction Well
Operating Extraction Well
Well Nest Location
Shallow Bedrock Well Water Level or River Potentiometric Water Level (in Feet above MSL)
Scale in Feet

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at times reversed, depending on the elevation of the river stage. Although the interim system was not designed to capture contaminated ground water in this area, it appears that shallow base flow to the river from this area has been reduced.

The effect of extraction has been a decrease in the occurrence of site-specific contaminants in the river water. Samples of river water at public water supply intakes downstream have been taken weekly to monthly since startup. Thirty-seven of the 40 samples collected at the Pennsylvania American Water Company's crib intake since the start of extraction in November 1988, have not shown detectable levels of 1,2,3-TCP (ERM, 1990a). Of the three remaining samples, only two were detected above the quantitative detection limit of 0.5 ppb. By contrast, in the 15 months before startup, site-related compounds were detected in 12 out of 37 samples (ERM, 1990a). These results are shown in Table 2. These data suggest that the extraction system has reduced the baseflow of contaminated ground water to the river.

Concentration Reduction

The distribution of total VOCs (in ppm) in the shallow, intermediate, and deep zones of the bedrock aquifer in February 1990, is shown in Figures 19, 20, and 21. Corresponding total VOC concentrations in wells north of the river and on Barbadoes Island in December 1989, are also shown in brackets, where available. These figures show that the total VOC plume extends under Barbadoes Island and the north bank of the river within the bedrock aquifer. The concentration of contaminants also clearly increases with depth. Based on the criterion that concentrations over 190,000 ppb are indicative of a nearby DNAPL source, it appears that DNAPLs were present as far as Barbadoes Island within the intermediate and deep zones of the bedrock aquifer in early 1990.

A comparison to the corresponding December 1989, total VOC concentrations suggests that total VOC concentrations on Barbadoes Island and north of the river are increasing over time; however, ERM (1991) believes that the apparent increase of VOCs was artificially created by the introduction of potable water to the borehole during coring. The drilling fluids were believed to have temporarily diluted the concentration of VOCs in the vicinity of the well and this dilution was reflected in artificially low results from the first round of samples. Furthermore, ERM (1991) argues, based on experimental data, that the low viscosity, high density DNAPL would have migrated quickly to a meta-stable equilibrium point and stopped shortly after the lagoons were closed almost 20 years ago. Therefore, on the basis of these two rounds, it is not known whether concentrations were actually increasing; even if they were, it is unlikely that increases in dissolved contamination were the result of ongoing DNAPL movement.

Table 3 shows the concentration of total VOCs and 1,2,3-trichloropropane in select monitoring wells since the offsite RI began in 1986. Table 3 includes the cored wells that were installed north of the south bank of the river starting in 1987. In general, these data show that concentrations have decreased at most of the monitoring wells south of the river. The exceptions to this are some of the intermediate and deep zone wells, including 3I, 4D, 8I, 8D, 10XD, and 11I. The reasons for these increased concentrations from September 1986, to September 1990, are unknown; nor is it clear that the increase is part of a trend. Some possible explanations for the differences are: (1) dilution of the early sample, (2) errors in sampling or handling, (3) remobilization of DNAPLs during drilling, (4) the effect of pumping, and (5) the inherent variability in concentrations in areas near DNAPL sources.

The concentrations of 1,2,3-TCP in the seven extraction wells from September 1988, to May 1990, are illustrated in Figure 22. All seven wells show a significant downward trend following the startup of the extraction system in November 1988. These data suggest that the concentration of 1,2,3-TCP along the river front is decreasing and that any potential horizontal baseflow to the river is less contaminated than before remediation. However, ERM suggested that this apparent reduction is caused by dilution of the ground water with river water drawn in by the extraction system and reduced time for dissolution of DNAPLs into ground water during pumping (ERM, 1991b). A sharp increase in the 1,2,3-TCP concentration in Wells EW-3, EW-11, and EW-12 was observed in the last quarter of 1989. The reason for the increase at these three broadly distributed locations along the river is unknown; however, ERM reports that increased VOC concentrations have been

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Table 2
CONCENTRATION OF 1,2,3-TRICHLOROPROPANE IN THE SCHUYLKILL RIVER (ppb)
TYSON'S DUMP SITE

Date	Concentration in River Crib	Date	Concentration in River Crib
9/2/87	0.42 B	08/24/88*	0.28 B
9/10/87	0.24 B	09/07/88*	0.55 B
9/16/87	ND	09/21/88*	0.14 J
9/23/87	0.32 B#	10/05/88*	ND
9/30/87	0.25 J#	10/19/88*	ND
10/07/87	0.83 B	11/02/88*	ND
10/14/87	ND	11/16/88	ND
10/21/87	1.1	11/30/88	0.18 J
10/28/87	1.3	12/07/88*	ND
11/11/87	0.88	12/14/88*	ND
12/02/87	0.56 B	12/20/88*	ND
12/09/87	0.69	12/28/88*	ND
12/16/87	1.8	01/04/89*	ND
12/23/87	1.3	01/11/89*	ND
12/30/87	NA	01/18/89*	ND
01/13/88	NS	01/25/89*	ND
02/02/88	1.8	02/01/89*	0.8 J
02/17/88*	0.87	02/08/89*	ND
03/03/88	0.30 B	02/15/89*	ND
03/16/88	0.67	02/22/89*	ND
03/30/88	0.54 B	03/02/89*	ND
04/13/88*	1.4	03/08/89*	0.24 B
04/27/88*	1.2	03/15/89*	ND
05/11/88*	1.0	03/22/89*	ND
05/25/88	0.32 B	03/29/89*	ND
06/09/88	0.64 B	04/04/89*	ND
06/22/88	0.44 J	04/10/89*	ND
07/13/88*	ND	04/19/89*	ND
7/27/88*	0.34 B	04/26/89*	ND
08/10/88*	0.12 J	05/03/89*	ND

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Table 2
CONCENTRATION OF 1,2,3-TRICHLOROPROPANE IN THE SCHUYLKILL RIVER (ppb)
TYSON'S DUMP SITE

Date	Concentration in River Crib	Date	Concentration in River Crib
05/10/89*	0.6	01/03/90*	ND
05/24/89*	0.1 B	02/07/90*	ND
06/07/89*	ND	03/07/90*	ND
06/21/89*	0.3 J	05/09/90*	2.2 B
07/05/89*	ND	06/06/90*	ND
07/19/89*	ND	07/05/90*	ND
08/02/89*	ND	08/09/90*	ND
08/16/89*	ND	09/05/90*	ND
09/11/89*	ND	10/02/90*	ND
09/20/89*	ND	11/06/90*	ND
10/04/89*	ND	12/04/90*	0.5
10/18/89*	ND	01/03/91*	ND
11/02/89*	ND	02/14/91	ND
11/15/89*	ND	03/06/91	ND
12/01/89*	ND		

Source: ERM, 1991a

Qualifier Codes:

Analyzed according to modified EPA Method 601 with a quantitation limit of 0.50 ppb.
B - This result is qualitatively invalid since this compound was also detected in a blank at a similar concentration.
J - This result is a quantitative estimate.
ND - Not detected.
NS - Not sampled.
NA - Not analyzed; all vials were frozen and broken in laboratory refrigerator.
- Sample vial contained bubbles upon receipt. The actual concentration/detection limit may be slightly higher than reported.
*Analyzed using a DB-624 fused silica megabore capillary column. All other analyses performed using an SP1000 on Carbopack B packed column.
**Only the River Crib-E will be sampled in the future starting May 25, 1988.

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Table 3
CONCENTRATION OF TOTAL VOC AND 1,2,3-TRICHLOROPROPANE IN MONITORING WELLS SINCE 1986 RI
(ppb)
TYSON'S DUMP SITE

		WELL ID NUMBERS																
DATE		2S	2I	3S	3I	3D	4S	4I	4D	5S	5I	5D	6S	6I	6D	7S	7I	7D
September 1986	Total VOCs	32,200	6,690	509,200	905,300	1,619	22,320	3,411	22,790	285,700	1,713	20,690	938,900	1,256,800	58,466	230	797	218
	TCP	30,000	6,600	380,000	810,000	67	22,000	3,400	22,000	230,000	1,700	90	800,000	1,200,000	55,000	230	780	190
August 1987	Total VOCs																	
	TCP																	
August 1987	Total VOCs																	
	TCP																	
September 1988	Total VOCs															830		
	TCP															830		
September 1989	Total VOCs															320		
	TCP																	
December 1989	Total VOCs																	
	TCP																	
February 1990	Total VOCs		1,912		1,515,940	298		2,514	110,290		292	423		1,152,200	6,871		483	47
	TCP		1,900		1,400,000	140		2,500	110,000		290	ND		1,100,000	6,400	320	480	44
September 1990	TCP															240		

Compiled from ERM, May 1990, Appendix I; ERM, March 1991; ERM, June 18, 1991e
Total VOC concentrations include all constituents except those detected in associated blanks

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Tyson's Dump

Table 3
CONCENTRATION OF TOTAL VOC AND 1,2,3-TRICHLOROPROPANE IN
MONITORING WELLS SINCE 1986 RI
(ppb)
TYSON'S DUMP SITE

		WELL ID NUMBERS																
DATE		8S	8I	8D	9S	9I	9D	10S	10I	10D	10XD	11S	11I	11D	12S	12D	13	14
September 1986	Total VOCs	3,860	156,500	8,800	ND	14	11	3,383	432,500	103,720	69,270	1,050,400	249,700	35,150	1,462	17		
	TCP	3,800	150,000	7,700	ND	ND	ND	2,700	400,000	100,000	69,000	980,000	220,000	20,000	ND	17		
August 1987	Total VOCs																	
	TCP																	
August 1987	Total VOCs																	
	TCP																	
September 1988	Total VOCs	6,536				ND	93	6,835				1,060,074			1,038			
	TCP	6,300				ND	0	6,000				1,000,000			ND			
September 1989	Total VOCs	1,300						583				760,000			880		297	16,750
	TCP														4			
December 1989	Total VOCs																	
	TCP																	
February 1990	Total VOCs		661,765	15,082					485,259	21,515	124,652		524,905	7,110				
	TCP	1,300	640,000	15,000				160	480,000	20,000	120,000		490,000	6,700				
September 1990	TCP	2,900						520				920,000			2		730	1,100

Compiled from ERM, May 1990, Appendix I; ERM, March 1991; ERM, June 18, 1991e
Total VOC concentrations include all constituents except those detected in associated blanks

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Tyson's Dump

Table 3
CONCENTRATION OF TOTAL VOC AND 1,2,3-TRICHLOROPROPANE IN
MONITORING WELLS SINCE 1986 RI
(ppb)
TYSON'S DUMP SITE

		Cored Well 1				Cored Well 2				Cored Well 3				Cored Well 4				Cored Well 5		
DATE		CW1-1 223-250	CW1-2 175-201	CW1-3 132-155	CW1-4 87-105	CW2-1 XD	CW2-2 183-203	CW2-3 127-147	CW2-4 88-110	CW3-1 170-190	CW3-2 127-150	CW3-3 77-112	CW3-4 Shallow	CW4-1 170-199	CW4-2 87-121	CW4-3 65-78	CW4-4 37-58	CW5-1 169-201	CW5-2 98-130	CW5-3 35-79
September 1986	Total VOCs																			
	TCP																			
August 1987	Total VOCs	2,907	790	155	17	2	7	6	1											
	TCP	2,900	780	150	16	ND	ND	ND	ND											
August 1987	Total VOCs	4,605	1,911	189	3															
	TCP	4,600	1,900	180	2															
September 1988	Total VOCs																			
	TCP																			
September 1989	Total VOCs																			
	TCP																	ND	ND	ND
December 1989	Total VOCs	2,840	2,123	443	33		9	8	3	1	2	11		182,833	94,480	30,180	60	ND	ND	ND
	TCP	2,800	2,100	430	27		ND	ND	ND	ND	ND	ND		180,000	94,000	30,000	57			
February 1990	Total VOCs	6,000		2,900	33		2	9	3	4	2	39		1,223,020	250,480	91,090	340	5	6	ND
	TCP						ND	ND	ND	ND	ND	ND		1,200,000	250,000	90,000	340	ND	ND	ND
September 1990	TCP																			

Compiled from ERM, May 1990, Appendix I; and ERM, March 1991
Total VOC concentrations include all constituents except those detected in associated blanks

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Tyson's Dump

Table 3
CONCENTRATION OF TOTAL VOC AND 1,2,3-TRICHLOROPROPANE IN
MONITORING WELLS SINCE 1986 RI
(ppb)
TYSON'S DUMP SITE

		Cored Well 7				Cored Well 8					
DATE		CW7-4	CW7-3	CW7-2	CW7-1	CW8-4	CW8-3	CW8-2	CW8-1	DB-1	DB-2
September 1986	Total VOCs										
	TCP										
August 1987	Total VOCs										
	TCP										
August 1987	Total VOCs										
	TCP										
September 1988	Total VOCs										
	TCP										
September 1989											
December 1989	Total VOCs										ND
	TCP										
February 1990	Total VOCs	37	56	36	8	13		2	25	3	127
	TCP	ND	ND	ND	ND	ND		ND	ND	ND	120
September 1990											

Compiled from ERM, May 1990, Appendix I; and ERM, March 1991
Total VOC concentrations include all constituents except those detected in associated blanks.

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Tyson's Dump

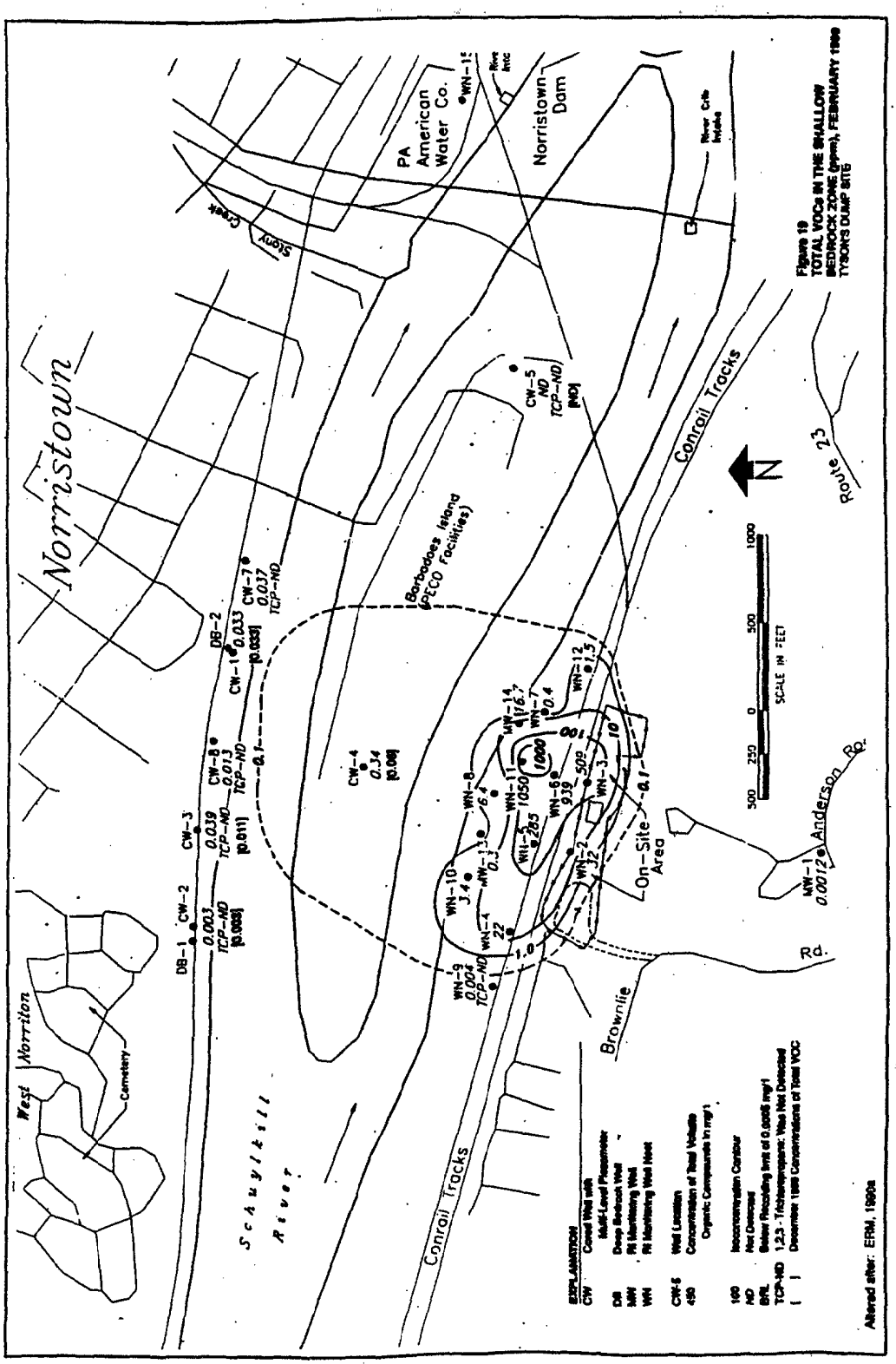
Figure 19
TOTAL VOCs IN THE SHALLOW BEDROCK ZONE (ppm), FEBRUARY 1988
TYSON'S DUMP SITE
Norristown
West Norriton
Cemetery
Schuylkill River
Conrail Tracks
Stony Creek
PA American Water Co.
Norristown Dam
River Crib Intake
Barbadoes Island (PECO Facilities)
Route 23
Anderson Rd.
Brownlie Rd.
On-Site Area
SCALE IN FEET
EXPLANATION
Altered after: ERM, 1990a

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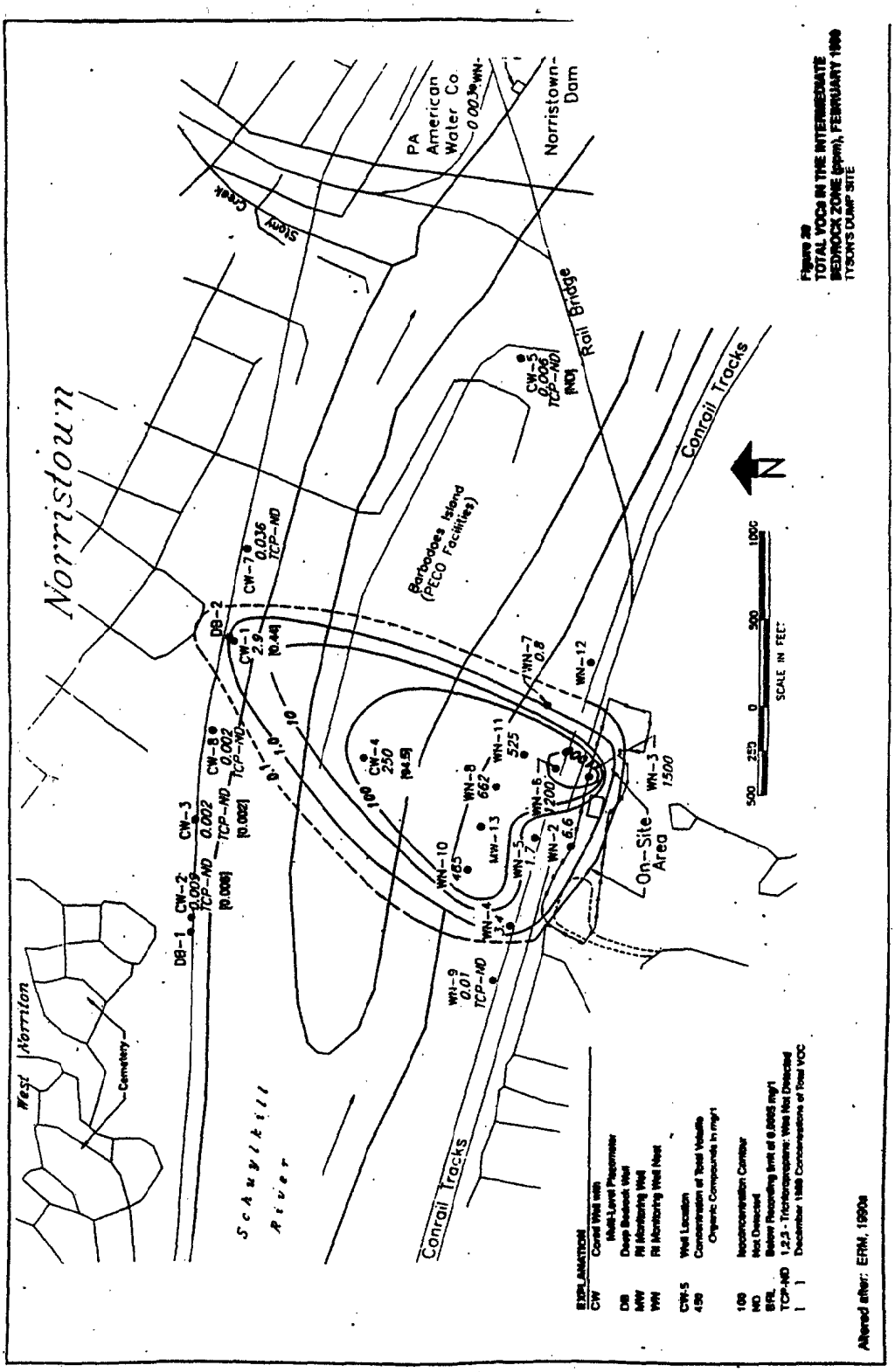

Figure 29
TOTAL VOCs IN THE INTERMEDIATE BEDROCK ZONE (ppm), FEBRUARY 1990
TYSON'S DUMP SITE

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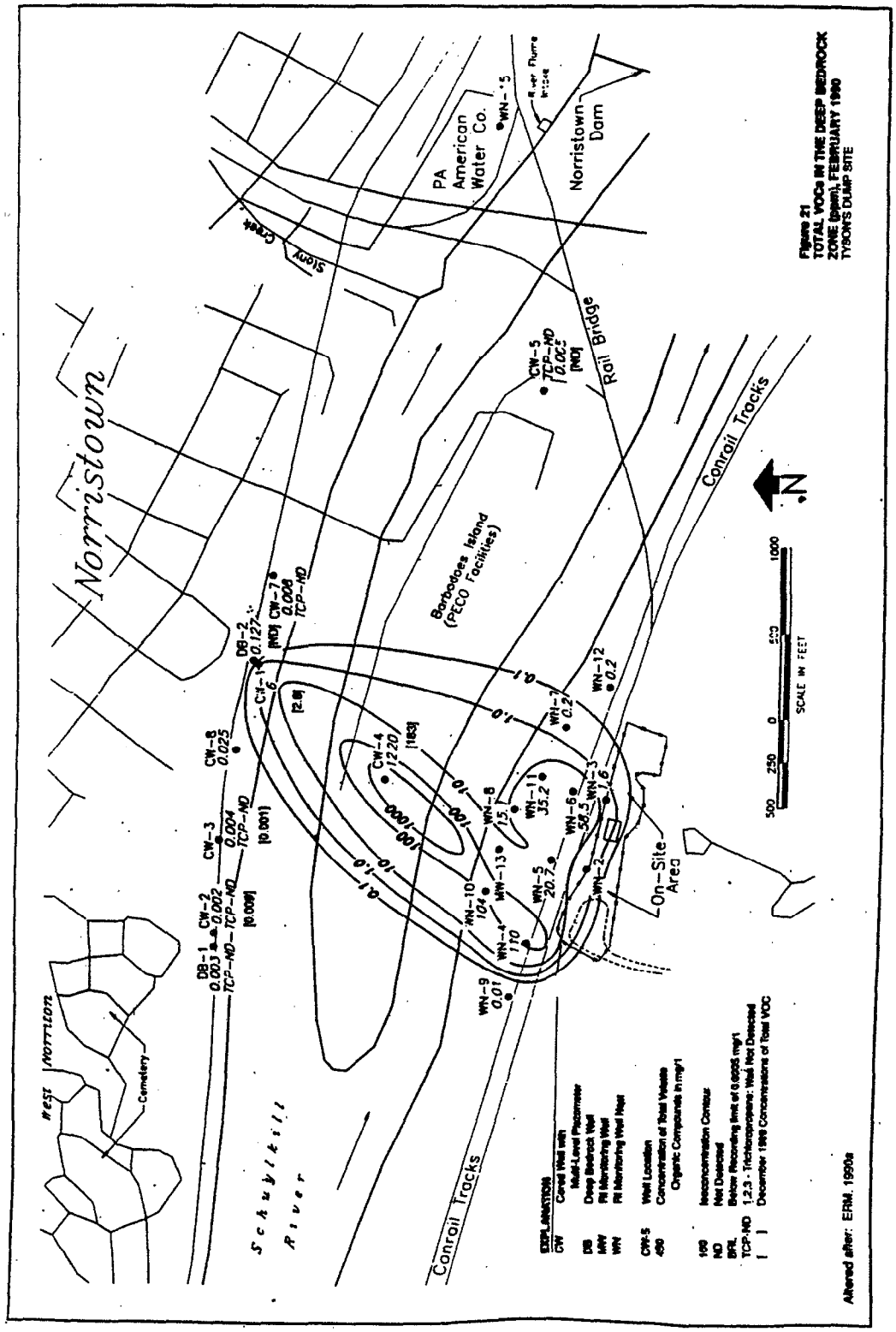

Figure 21
TOTAL VOCs IN THE DEEP BEDROCK ZONE (ppm), FEBRUARY 1990
TYSON'S DUMP SITE

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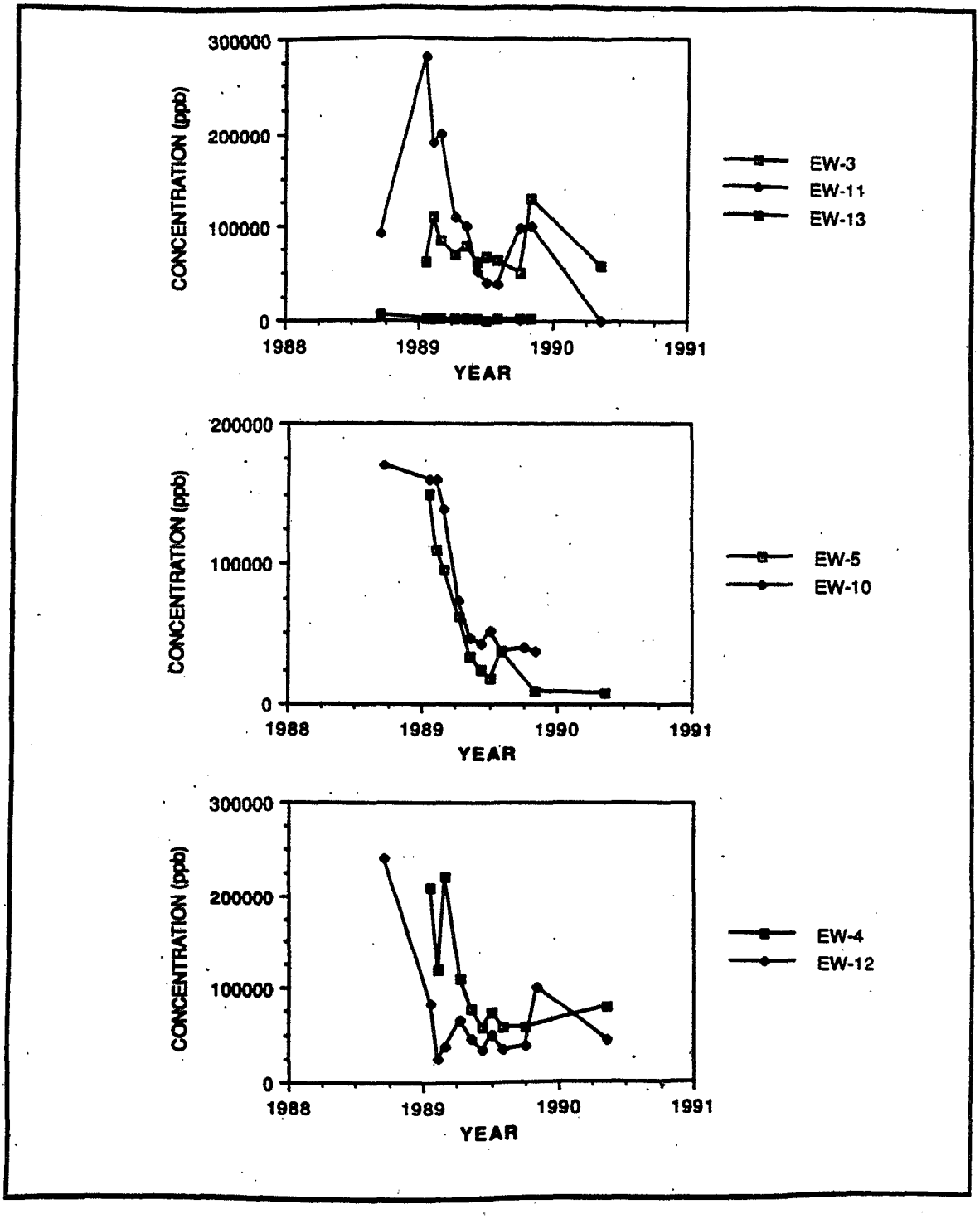

Figure 22
CONCENTRATION OF 1,2,3 -TRICHLOROPROPANE IN THE SEVEN EXTRACTION WELLS TYSON'S DUMP SITE

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observed after even brief shutdown of the extraction system (ERM, 1991b). The concentrations of 1,2,3-TCP in the influent to the ground-water treatment system shown in Figure 23 also shows that the concentration of 1,2,3-TCP entering the extraction system along the river front has decreased since startup.

SUMMARY OF REMEDIATION

The soil and ground water at the Tyson's dump site have been heavily contaminated with organic compounds, principally 1,2,3-trichloropropane and other VOCs, as a result of the disposal of waste liquids into unlined lagoons in the onsite area in the 1960s. A substantial fraction of the contaminants are thought to be present as dense non-aqueous phase liquids (DNAPLs). Investigations have further shown that contamination in the bedrock aquifer extends from the onsite area to the north side of the Schuylkill River, and that contaminated ground water discharges to the river, potentially threatening downstream water users. DNAPL contamination within the bedrock aquifer is believed to extend to a depth of at least 135 feet south of the river, and to a depth of at least 200 feet under Barbadoes Island. These DNAPLs are believed to have migrated northward from the disposal area by gravity flow along bedding planes in the sandstone bedrock, which dips north-northwest at approximately 12 degrees.

The direction of horizontal ground-water flow is radially northward from the disposal area to the river. Upward vertical gradients in the bedrock aquifer in the central portion of the site south of the river, and contamination in the river water indicate that ground water contaminated with VOCs discharges to the river from the bedrock aquifer. DNAPLs are not expected to discharge to the river because of their depth and density. However, the DNAPLs in the bedrock are believed to act as a long-term source of contamination to the river via the upward flow of dissolved constituents. The restoration of the aquifer was deemed to be unattainable in the immediate vicinity of the DNAPL, because the DNAPL acts as a continuous source of the solute plume.

In order to limit baseflow of contaminated ground water to the Schuylkill River from the area south of the river, a ground-water extraction system was installed along the south bank of the river. An interim system of seven extraction wells began operating in November 1988. A larger system of 13 extraction wells was proposed to supplement the interim system and increase the zone of capture of the extraction network. This final system had been installed, but was not operational as of June 1991.

The extraction system has been partially successful in its objectives of containing the plume of dissolved constituents south of the river and limiting the baseflow of contaminated ground water. Limited available data on the hydraulic response to pumping suggests that part of the plume has been captured by the system since startup in November 1988. However, February 1990, data show that the plume is not captured by the system between EW-11 and EW-5 and east of EW-5 when extraction Wells EW-10, EW-12, and EW-13 are not operated. Information on the capture zone that is produced during periods when all seven wells are operated was not available for review. More complete information on pumping history is needed to judge whether the central part of the contaminant plume has been captured as effectively as projected. However, it is known that a substantial portion of the plume east of EW-3 and west of EW-13 has not been, and was not expected to be, captured by the interim system.

The system has decreased the frequency with which site-specific contaminants are detected in the river water downstream of the site. Only two of the 40 samples collected near the intake of a downstream water supplier have contained 1,2,3-TCP above detection limits since extraction began, versus 12 out of 37 samples collected before startup. Therefore, the system does appear to have reduced the threat to the health of downstream water users caused by contamination at the Tyson's site. The concentration of 1,2,3-TCP in the extraction wells and in the influent to the treatment system have decreased substantially since remediation began. However, ERM believes that concentrations in the extraction wells and the influent are only lowered as a result of dilution effects during pumping; if the extraction system were shut off, dissolved-phase VOC concentrations would be expected to return to historically high levels as a result of DNAPL dissolution (ERM, 1991b). Future extraction of ground water underlying Barbadoes Island has been prescribed by the EPA in a September 1990, ROD. This extraction is intended to control the dissolved plume near the DNAPLs in this area.

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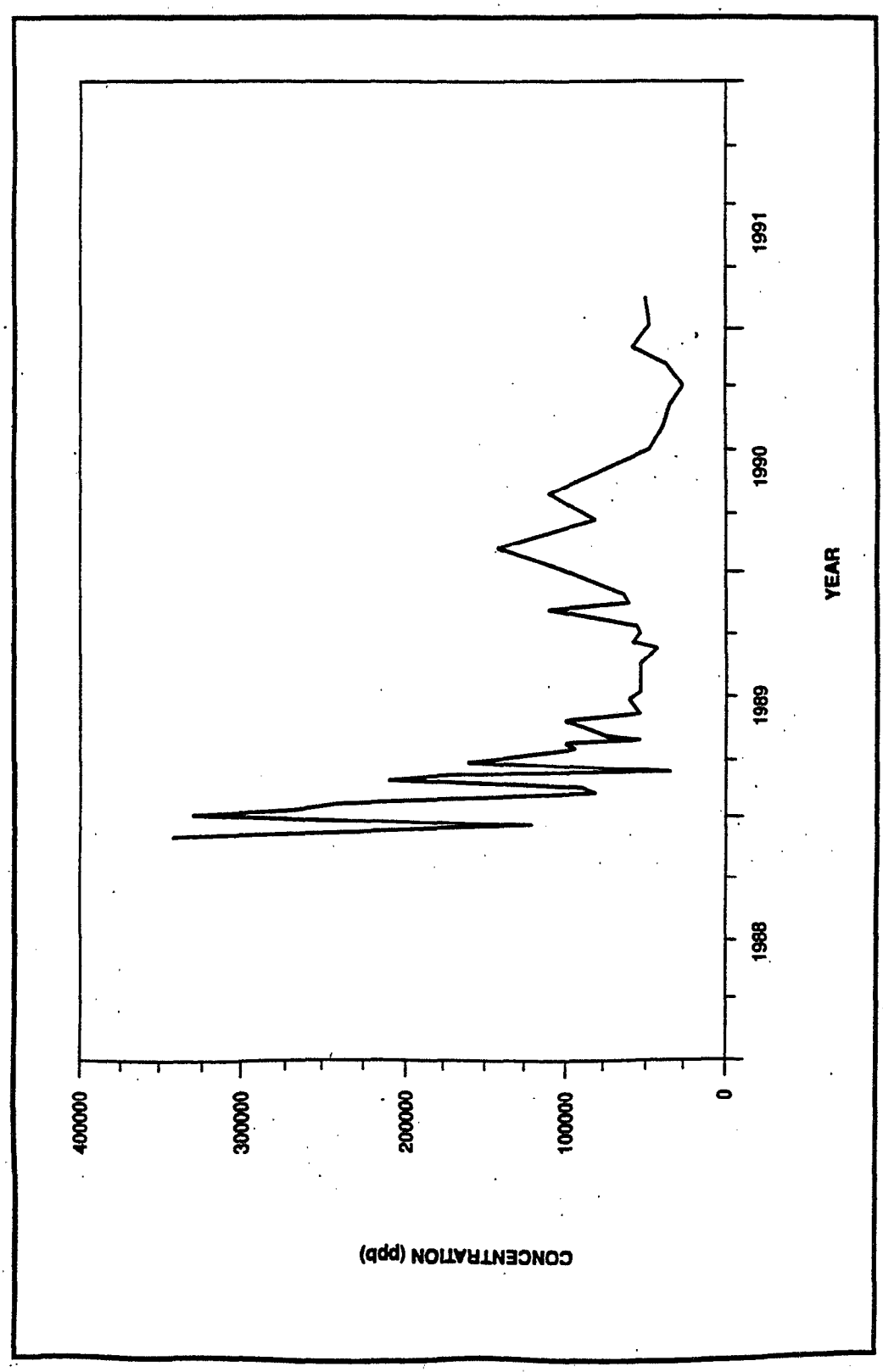

Figure 23
CONCENTRATION OF 1,2,3-TRICHLOROPROPANE
IN THE INFLUENT TO THE GROUND-WATER
TREATMENT SYSTEM
TYSON'S DUMP SITE

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SUMMARY OF NAPL-RELATED ISSUES

Dense non-aqueous phase liquids (DNAPL) have been found in several bedrock wells south of the Schuylkill River at the Tyson's Dump site. These DNAPLs are believed to have migrated downward from the unlined disposal lagoons into the bedrock aquifer, where further migration was facilitated by vertical and horizontal fractures. Northward migration of DNAPLs towards the river was favored by prevailing northward hydraulic gradients, vertical high angle joints, the northward slope of the bedrock surface, and the 12 degree north-northwestward regional dip of the bedrock strata. DNAPLs have been directly observed to a depth of 135 feet in monitoring Well 8-I on the south bank of the river.

ERM has estimated the solubility of the DNAPL to be approximately 1,900,000 ppb and has interpreted concentrations over 190,000 ppb to indicate a nearby DNAPL source. Based on this criterion, the concentration of 1,220,000 ppb of total VOCs observed in the deep interval of monitoring Well CW-4 on Barbadoes Island in February 1990, suggests that DNAPLs had migrated to a depth of 200 feet beneath Barbadoes Island by early 1990. The maximum concentration north of the river in February 1990, was 6,000 ppb, which suggests that DNAPLs may not have reached the north side of the river by that time.

BIBLIOGRAPHY/REFERENCES

ERM. July 29, 1987. *Tyson's Site, Montgomery County, Pennsylvania, Off-Site Operable Unit Remedial Investigation Report, Volume 1.*

ERM. May 31, 1990a. *Draft Tyson's Site Third Addendum Investigation Report.*

ERM. June 1990b. *Off-site Operable Units Feasibility Study.*

ERM. March 6, 1991a. *1990 Annual Monitoring Well Report, Tyson's Site.*

ERM. June 17, 1991b. Letter from Mr. Joe Ferry to Steven Brown of CH2M HILL, Re: Review of Draft Case Study of the Tyson's Site, File: 272-23-01-01.

ERM. June 18, 1991c. Personal communication with Mr. Joe Ferry.

ERM. March 29, 1991d. Letter to Mrs. Karline Tierney of Ciba-Geigy Regarding Monthly Progress Report for the Remedial Investigation/ Feasibility Study (RI/FS) of the Tyson's Site Off-Site Operable Units RI/FS, March 1991.

ERM Enviroclean. November 1988. *Ciba-Geigy Corporation, Tyson's Site, Progress Report for October 1988.*

ERM Enviroclean. December 1988. *Ciba-Geigy Corporation, Tyson's Site, Progress Report for November 1988.*

S.S. Papadopulos & Associates, Inc (SSP&A). August 1988a. *Installation and Hydrogeologic Evaluation of Test Wells and Design of a Ground-Water Recovery System, Tyson's Site, Montgomery County, Pennsylvania.*

SSP&A. October 21, 1988b. Letter to Mr. Joe Ferry of ERM.

SSP&A. October 22, 1990. Letter to Ms. Karline Tierney of Ciba-Geigy Corporation.

U.S. Environmental Protection Agency (U.S. EPA). December 1984. *Superfund Record of Decision: Tyson's Dump Site, PA, EPA/ROD/R03-84/008.*

U.S. EPA. March 1988a. *Revised Superfund Record of Decision: Tyson's Dump Sit, PA.* EPA/ROD/R03-88/045.

U.S. EPA. September 1988b. *Superfund Record of Decision: Tyson's Dump Site, PA.* EPA/ROD/R03-88/068.

U.S. EPA. September 1990. *Superfund Record of Decision: Tyson's Dump Site, PA.* Operable Unit 3.

U.S. EPA. June 10, 1991a. Personal communication with Kathy Davies, Regional Hydrogeologist, Region III.

U.S. EPA. June 24, 1991b. Personal communication with Kathy Davies, Regional Hydrogeologist, Region III.

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CASE STUDY 24

Western Processing
Kent, Washington

Abstract

Western Processing is a former waste recycler and storage facility. The site was closed in 1983. In July 1984, site cleanup began with the removal of waste from the area and the installation of a slurry wall around the facility. In July 1988, a ground-water extraction and treatment system began operation. The extraction system consists of 206 well points in the shallow ground-water zone, each designed to recover 1 gpm. An inward head gradient is maintained across the slurry wall. Data collected from well points in 1990 indicate reduction in concentrations for only a few contaminants. Plumes of most metals and organics remained stable or increased in concentration between 1988 and 1990. However, the data indicate that metals and organics are being recovered by the well point extraction system. An LNAPL, consisting of diesel motor oil and solvents, has been observed in two well points.

Background Data	
Date of Problem Identification	1983
Extraction Started	July 1988
Types of Contaminants	Metals, Organics
Primary Aquifer Materials	Interbedded sand, silt, and clay over medium silty sand
Maximum Number of Extraction Wells	206
Maximum Total Extraction Rate	220 gpm
Estimated Plume Area	14 acres
Estimated Plume Thickness	65 feet
Maximum Reported Concentrations	Trans-1,2-Dichloroethene 390,000 ppb Toluene: 180,000 ppb Zinc: 510,000 ppb Nickel: 280,000 ppb

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CASE STUDY
WESTERN PROCESSING

BACKGROUND OF THE PROBLEM

This case study summarizes the remediation of ground-water contamination at the Western Processing site located at 7215 South 196th Street in Kent, Washington. Ground water at the site is contaminated with numerous metals and organics. A site location map is presented in Figure 1.

SITE HISTORY

From 1952 to 1961 the site was leased to the U.S. Army for use as an anti-aircraft artillery battery. In 1961 the site was turned over to the owner without removal of general support facilities and sold to Western Processing Company, Inc. From 1961 to early 1983 various chemical reclamation and industrial waste processing and storage activities were conducted on 11 of the 13 acres. The remainder of the site was used for residential purposes.

The principal wastes received by Western Processing include: electroplating solutions and sludges, pesticides and herbicides, spent acid and caustic solutions, waste oils and solvents, battery mud, flue dust from secondary smelters, aluminum slag, and galvanization skimmings.

After the site was closed in early 1983, emergency removal was conducted by the U.S. EPA. Hundreds of thousands of gallons of hazardous chemicals, paint sludges, and wastewater from ponds and tanks were removed from the site. The Washington State Department of Ecology installed stormwater control measures in late 1983.

In July 1984, site cleanup began. This included removing liquid, solid, and demolition waste from the site. A slurry wall was installed around a 16.5-acre area to mitigate ground-water migration and additional stormwater measures were implemented. In July 1988, a ground-water extraction and treatment system began operating.

GEOLOGY

Western Processing is located near the north-south axis of the Duwamish (Kent) Valley, a former embayment of Puget Sound. The edges of the valley can be seen at the east and west margins of Figure 1. The valley has been partly filled with Recent deposits. The east and west margins of the Duwamish Valley are defined by a dissected glacial drift plain with elevations approximately 350 to 600 feet above the valley floor (CH2M HILL, 1984).

Consolidated rock in the area is exposed only where there are small outcrops of Tertiary extrusive and intrusive igneous rocks at the northern end of the valley. The uplands bordering the valley are composed of Pleistocene glacial and interglacial deposits. The valley fill is primarily a sequence of Recent alluvial and lacustrine deposits. Recent sediments are typically fine- to medium-grained sands, silts, peaty silt, and clay. The total depth of valley fill apparently exceeds 500 feet (CH2M HILL, 1985).

The White River alluvium underlies the Western Processing site. The alluvium consists of a complex sequence of discontinuous interbedded silt, sand, and clay lenses to approximately 40 feet below the ground surface. A fairlycontinuous fine to medium sand with intermittent silty zones exists below 40 feet. A deep well south of the site showed that sand and silt extend to a depth of approximately 150 feet. Beyond this depth, dense clay and silt were found to extend to at least 365 feet below grade (CH2M HILL, 1985). Figure 2 presents a schematic geologic column showing the three major hydrogeologic units that underlie the site.

HYDROGEOLOGY

The Western Processing site is bordered by Mill Creek on the west. Mill Creek is a tributary of the Green River, which drains to Puget Sound.

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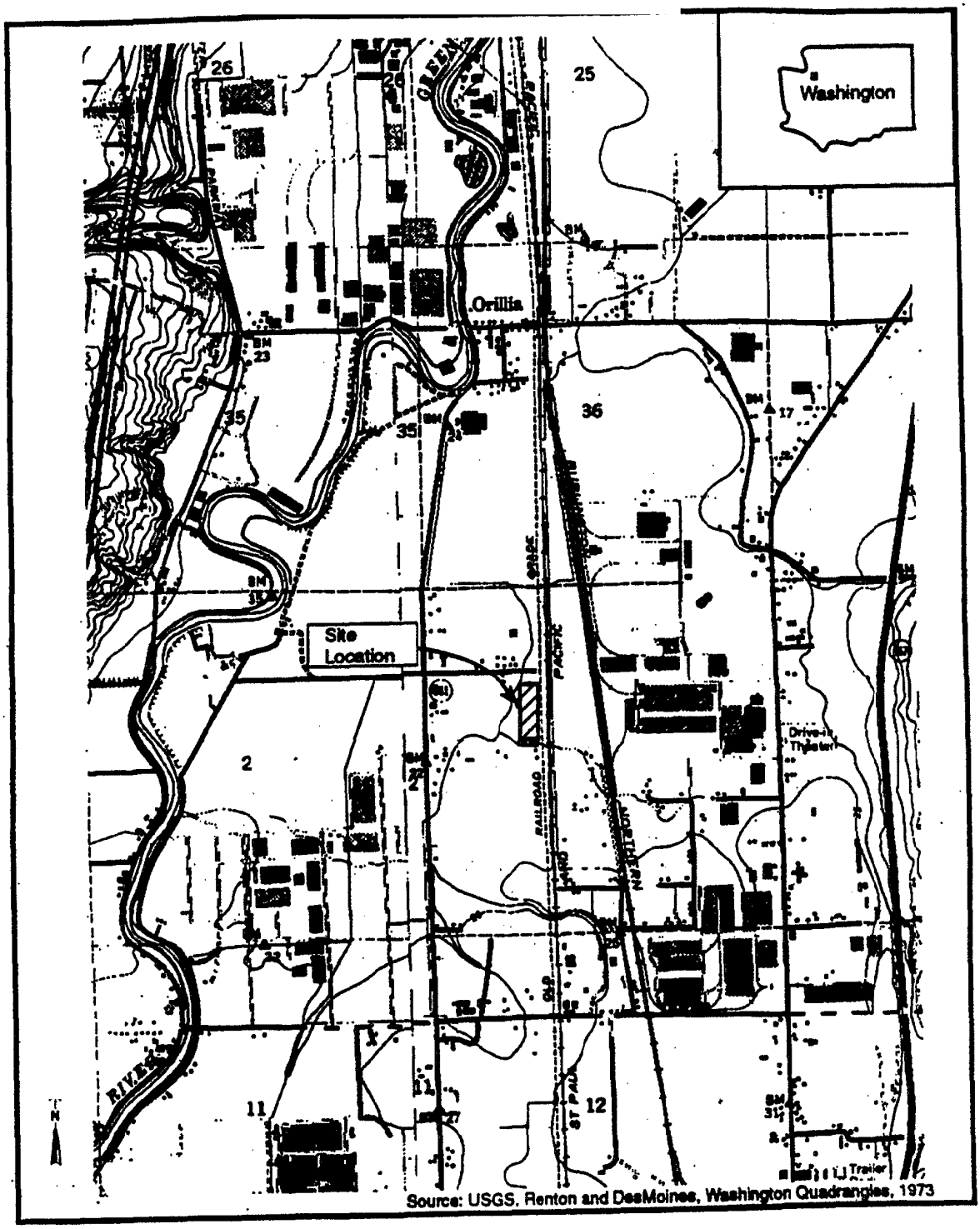

0 1000 2000
Scale in Feet

(Poor Quality Original)

Figure 1
SITE LOCATION MAP
WESTERN PROCESSING SITE
KENT, WASHINGTON

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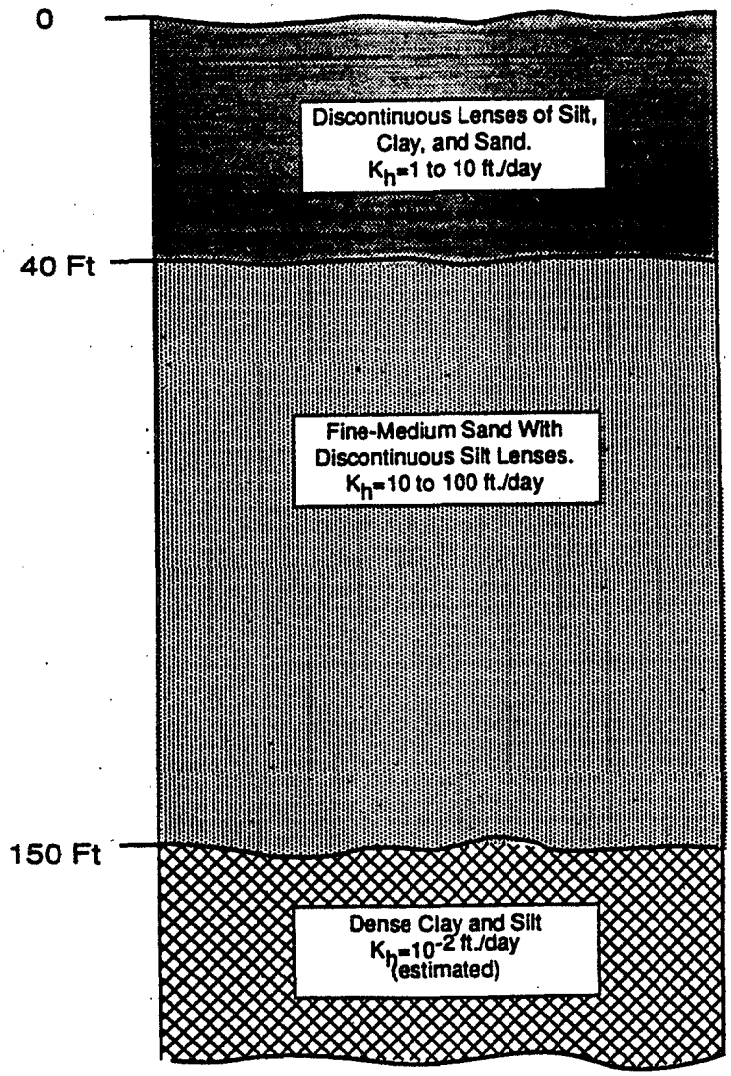

Source: CH2M HILL, 1985

Figure 2
SCHEMATIC GEOLOGIC SECTION
WESTERN PROCESSING SITE

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Ground water in the area occurs primarily in unconsolidated fluvial, marine, lacustrine, and glacial deposits. The most productive aquifers are outwash deposits of the glacial drift that comprise the uplands. Ground water in the valley floor is typically very shallow, with an average depth to water of less than 10 feet. The ground may become completely saturated in low areas during wet periods (CH2M HILL, 1984).

Confined ground water occurs frequently in the area as a result of the complex stratigraphy and generally fine grained sediments. A flowing artesian system, meeting part of the City of Kent's water needs, occurs at depths of less than 300 feet near the east and west valley margins (CH2M HILL, 1984).

Ground water in the area is recharged primarily by precipitation in the uplands bordering the Duwamish Valley. Ground-water flow is toward the valley axis and northward toward Puget Sound. Ground-water losses include discharge to stream channels and Puget Sound, spring discharges, and, to a much smaller extent, discharges as a result of pumping wells and evapotranspiration (CH2M HILL, 1984).

Deposits underlying Western Processing exhibit complex small-scale stratigraphy. Sediments are generally fine-grained sands, silts, and clays. Silty sands and sandy silts are the most commonly encountered sediments. Portions of the site have been filled with a variety of materials. Battery fragments and black cinders have been reported. The depth of fill is highly variable across the site (CH2M HILL, 1984).

Ground water at the site occurs at an average depth of 6 feet. A ground-water elevation contour map for the shallow flow zone in August 1984, before installation of the slurry wall, is shown in Figure 3. Ground-water movement is affected by four primary factors: (1) regional ground-water flow toward the Green River, which has an upward flow component, (2) ground-water recharge and mounding onsite, which has a downward flow component, (3) discharge to Mill Creek and the east drain, and (4) variations in hydraulic conductivity. Local ground-water flow patterns in the upper 100 feet are complicated by discontinuous silt and clay lenses in the upper 40 feet (CH2M HILL, 1984).

Ponded surface water, high precipitation infiltration, and/or variations in hydraulic conductivity of the soil caused a ground-water mound to form near the center of the site in excess of the mound that would naturally exist between two discharge areas such as Mill Creek and the east drain (CH2M HILL, 1985). The horizontal flow gradient is radial from the center of the site.

Vertical gradients also strongly influence the local ground-water flow. Figure 4 presents a schematic cross section that illustrates the vertical gradients. The downward gradients are strongest in the middle of the site. Downward ground-water flow becomes less pronounced near the site boundary; flow eventually reverses and is upward at the two drainages. At the north end of the site, horizontal flow predominates at depths below 70 feet (CH2M HILL, 1985).

WASTE CHARACTERISTICS AND POTENTIAL SOURCES

Fifty-seven EPA priority pollutants were identified in ground-water samples collected in 1984 from onsite and offsite wells (CH2M HILL, 1984). Eighteen priority pollutants, six metals and twelve organics, were selected as indicator contaminants. These indicator contaminants are listed in Table 1. The average concentrations of compounds detected in ground water in 1984 by area of the site are given in Table 2. The site areas are shown in Figure 5.

Figure 6 shows a 1984 map of total indicator metals concentrations measured in ground water at various depths. Metals in ground water were most pronounced in shallow wells located on the northern half of the site. Total indicator metals in these wells often exceeded 100,000 ppb. Ground water is Shallow wells on the south end of the site, where metals in soils were highest, contain considerably lower concentrations of indicator metals, usually less than 10,000 ppb. Table 3 lists the maximum concentration detected for each indicator metal.

Indicator metals exceeded 100,000 ppb in two onsite intermediate wells in the central and north central sections of the site. Indicator metals were above 10,000 ppb in one well on the southern half of the site. Indicator metals in deep wells were highest in one onsite location at the northeastern corner of the site with concentrations slightly

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Table 1
SELECTED INDICATOR CONTAMINANTS
WESTERN PROCESSING SITE

Organics	Inorganics
Volatile Organics:	Metals:
1,1,1-Trichloroethane	Cadmium
Trans-1,2-Dichloroethene	Chromium
Tetrachloroethene	Copper
Trichloroethene	Nickel
Toluene	Lead
Chloroform	Zinc
Acid Extractable Compounds:	
2,4-Dimethylphenol	
Phenol	
Base/Neutral Compounds:	
Total PAHs[a]	
Total Phthalates	
Other Organics:	
PCBs	
Oxazolidone	

Source: CH2M HILL, 1984

[a]Total priority pollutant polycyclic aromatic hydrocarbons (PAHs).

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Table 2
AVERAGE CONTAMINANT CONCENTRATIONS
WESTERN PROCESSING SITE

Page 1 of 3

Area	Contaminant	Average Groundwater Concentration 6-15 ft. (ppb)	Average Groundwater Concentration 15-30 ft. (ppb)
I/II	**Volatiles**		
	Phenol	108,583	1,490
	Methylene chlorine	56,872	48,971
	Trans 1,2-dichloroethene	20,297	154
	Chloroform	2,378	2,012
	Trichloroethene	29,508	7,244
	1,1,1-Trichloroethane	21,609	1,014
	Toluene	1,633	314
	Tetrachloroethene	109	0
	Ethylbenzene	2	0
	BN/AE		
	Naphthalene	2	23
	Phenanthrene	0	0
	PCB	0	0
	Pyrene	0	0
	Fluoranthene	0	0
	Benzo(a)anthrancene	0.3	0
	Bis(2-ethylhexyl)phthalate	0	0
	Metals		
	Nickel	15,129	14,250
	Cadmium	2,391	964
	Zinc	126,447	117,687
	Chromium	5,249	313
	Arsenic	14	12
	Copper	1,333	757
	Lead	340	263

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Table 2
AVERAGE CONTAMINANT CONCENTRATIONS
WESTERN PROCESSING SITE

Area	Contaminant	Average Groundwater Concentration 6-15 ft. (ppb)	Average Groundwater Concentration 15-30 ft. (ppb)
V	**Volatiles**		
	Phenol	745,954	39
	Methylene chlorine	40,603	122
	Trans 1,2-dichloroethene	147,005	0
	Chloroform	1,213	3,787
	Trichloroethene	89,535	8,310
	1,1,1-Trichloroethane	3,620	0
	Toluene	1	44
	Tetrachloroethene	183	0
	Ethylbenzene	0	0
	BN/AE		
	Naphthalene	0	23
	Phenanthrene	0	0
	PCB	0	0
	Pyrene	0	0
	Fluoranthene	0	0
	Benzo(a)anthrancene	0	0
	Bis(2-ethylhexyl)phthalate	0	0
	Metals		
	Nickel	1,327	461
	Cadmium	68	119
	Zinc	18,284	30,876
	Chromium	66	80
	Arsenic	5	15
	Copper	42	24
	Lead	29	21

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Table 2
AVERAGE CONTAMINANT CONCENTRATIONS
WESTERN PROCESSING SITE

Area	Contaminant	Average Groundwater Concentration 6-15 ft. (ppb)	Average Groundwater Concentration 15-30 ft. (ppb)
IX	**Volatiles**		
	Phenol	0	0
	Methylene chlorine	20	5
	Trans 1,2-dichloroethene	118	18
	Chloroform	0.3	0
	Trichloroethene	106	46
	1,1,1-Trichloroethane	10	7
	Toluene	0.1	0
	Tetrachloroethene	0	0
	Ethylbenzene	0	0
	BN/AE		
	Naphthalene	0	0
	Phenanthrene	0	0
	PCB	0	0
	Pyrene	0	0
	Fluoranthene	0	0
	Benzo(a)anthrancene	0	0
	Bis(2-ethylhexyl)phthalate	0	0
	Metals		
	Nickel	540	0
	Cadmium	94	0
	Chromium	7	0
	Arsenic	0	0
	Copper	3	0
	Lead	0	0

Source: CH2M HILL, 1984
Note: Undetected constituents listed as 0

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Table 3
MAXIMUM INDICATOR METALS IN SHALLOW GROUND WATER
WESTERN PROCESSING SITE

Compound	Depth (feet)	Concentration (ppb)
Cadmium	13	60,000
Chromium	13	65,000
Copper	10	13,000
Lead	10	3,300
Nickel	13	280,000
Zinc	10	510,000

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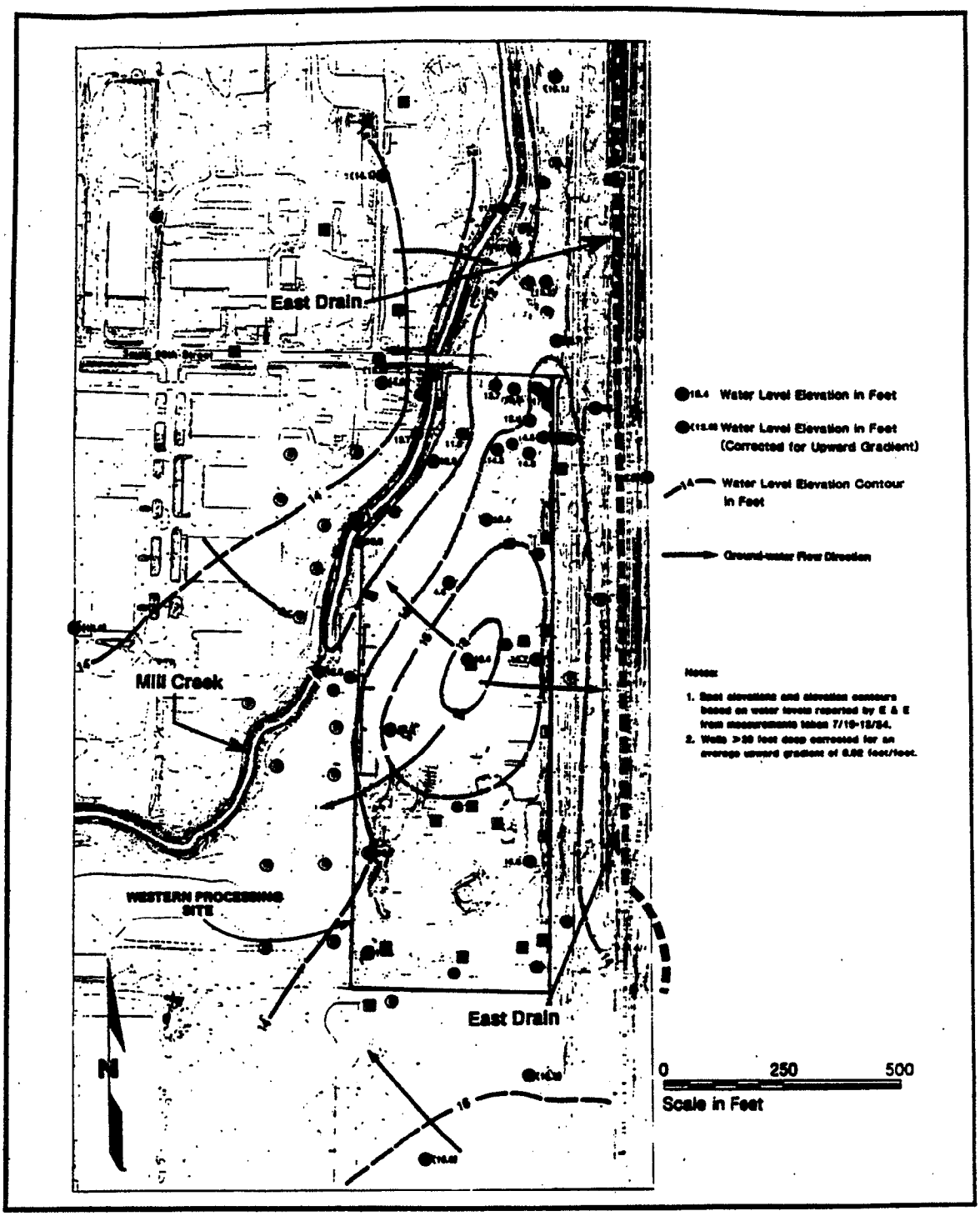

Source: CH2M HILL, 1985

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Figure 3
SHALLOW GROUND-WATER ELEVATION CONTOURS
WESTERN PROCESSING SITE

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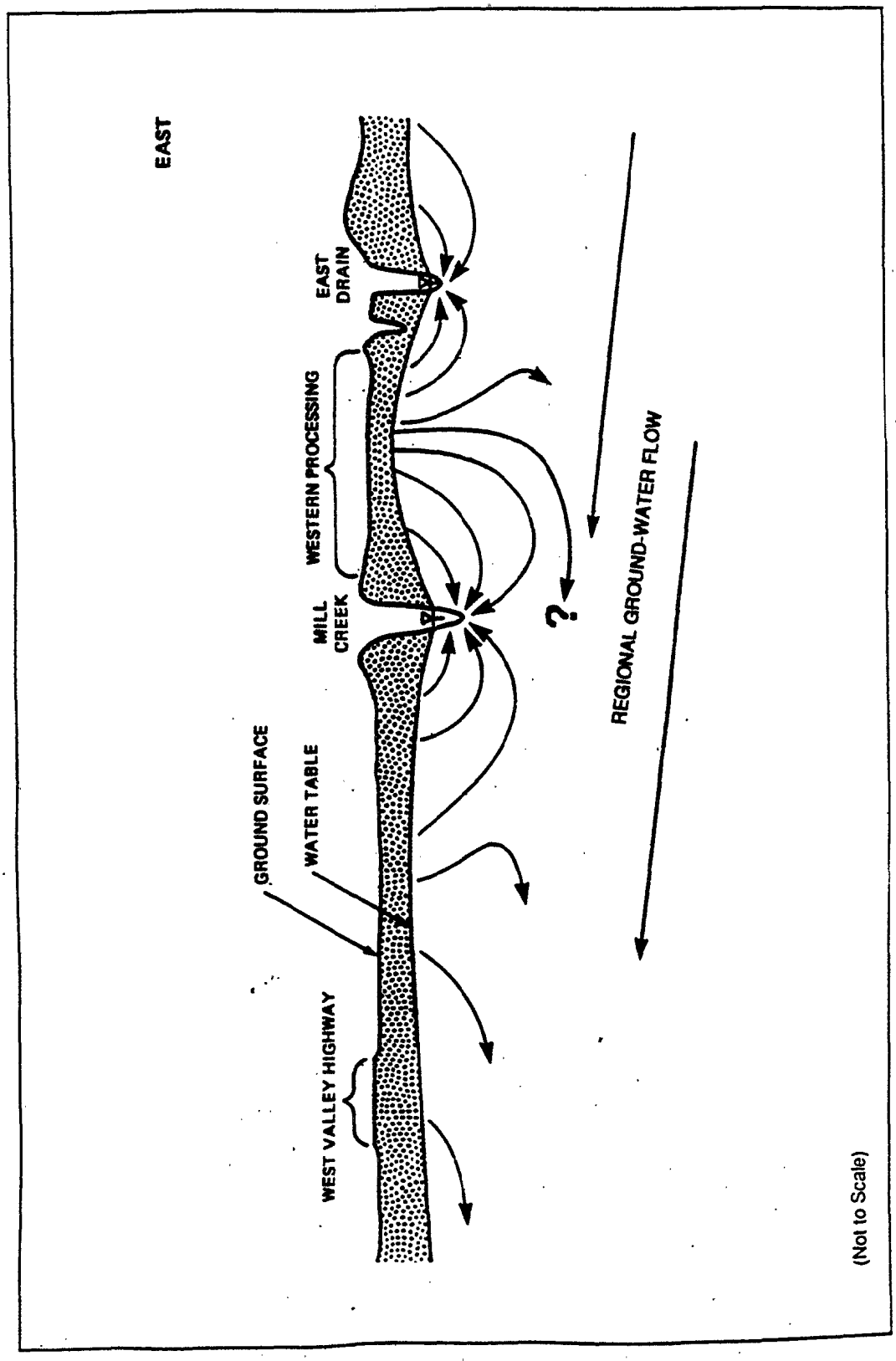

Figure 4
SCHEMATIC REPRESENTATION OF LOCAL GROUND-WATER FLOW SYSTEM
WESTERN PROCESSING SITE

Source: CH2M HILL, 1985

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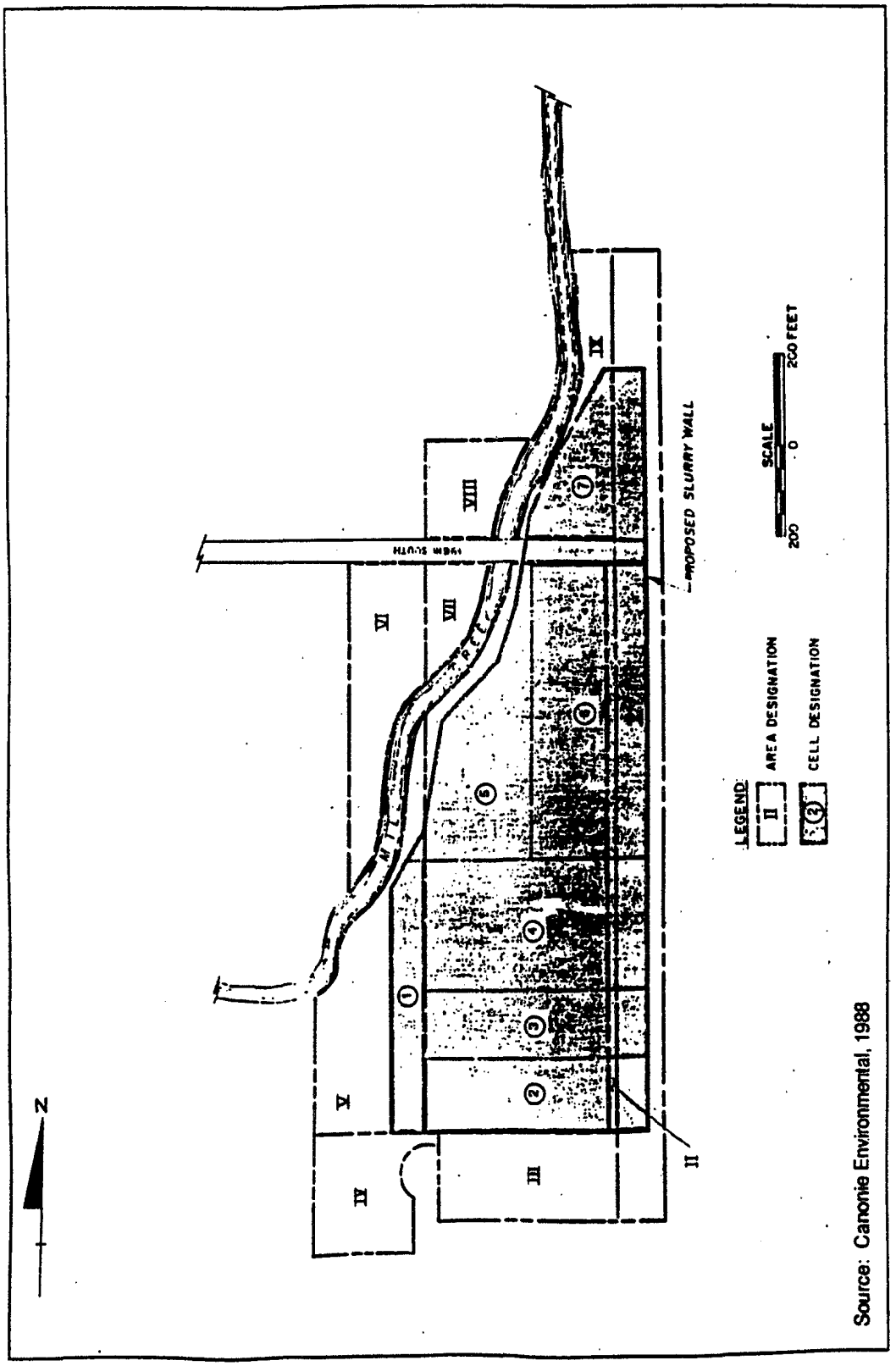

Source: Canonie Environmental, 1988

Figure 5
AREA AND CELL DESIGNATION
WESTERN PROCESSING SITE

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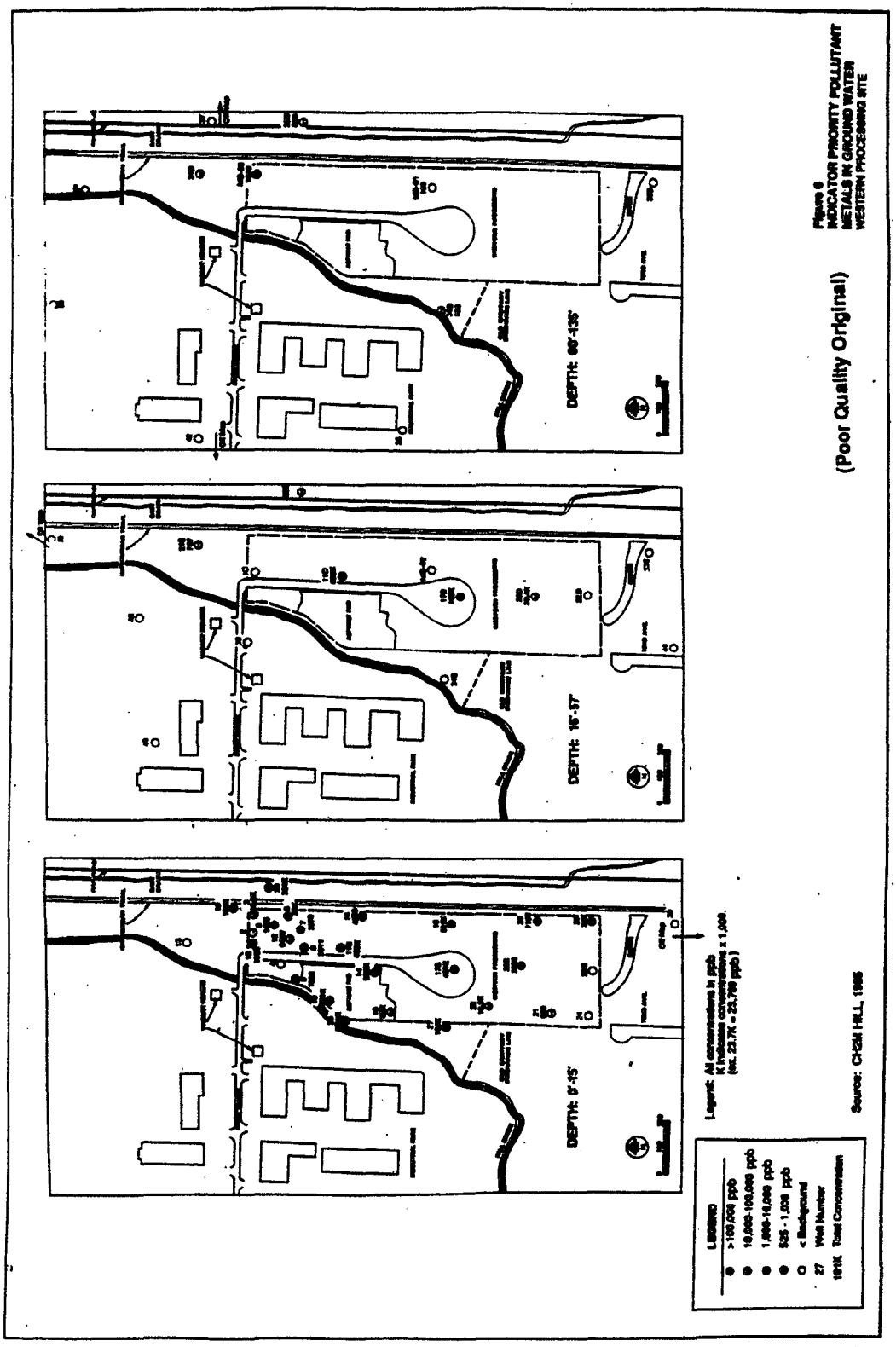

Figure 6
INDICATOR PRIORITY POLLUTANT
METALS IN GROUND WATER
WESTERN PROCESSING SITE

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above 1,000 ppb. All other intermediate and deep wells had concentrations only slightly above background.

Volatile organic compounds (VOCs) in ground water were at highest concentrations in shallow onsite wells in the central and northern half of the site. Figure 7 presents a 1984 map of total VOC concentrations at various depths. The highest total VOC concentrations detected were 1,346,000 ppb and 660,000 ppb. Total VOCs in intermediate depth wells are the highest in onsite wells.

Volatile organics were found in several wells in concentrations much greater than those found elsewhere. Methylene chloride was highest in Wells 15 and 9, trichloroethene (TCE) in Wells 15, 21, 11S, and 17S, 1,1,1-TCA in Wells 15 and 11S, and trans-1,2-dichloroethene in Well 21. These wells were considered potential source areas from which volatile organics could migrate.

Table 4 lists the concentrations of volatile organics in wells having more than 100,000 ppb total volatiles. Concentrations of TCE as high as 20 percent of solubility were observed, which strongly suggests the presence of a nonaqueous phase. Trans-1,2-DCE was observed at 390,000 ppb. This is 65 percent of solubility (600,000 ppb), most likely indicating the presence of nonaqueous product.

Semivolatile organics concentrations exceeding 10,000 ppb were only detected in shallow ground water. The maximum concentration of total acid-extractables detected was 5,400,000 ppb in Well 27. The northern half of the site exhibited the highest levels of contamination. The most frequently detected acid extractables were phenol and 2,4-dimethylphenol. Base/neutral compounds were detected infrequently. Concentrations of base/neutrals were considerably lower than other contaminants with concentrations generally lower than 20 ppb.

REMEDIATION

Selection and Design of the Remedy

The objectives of ground-water remediation are to allow no further contamination of shallow ground water and reduce ground-water contaminant concentrations to levels that will protect the aquatic organisms in Mill Creek. The first phase of the remediation involved surface cleanup. The second phase included installation of a containment wall and a ground-water extraction system, which was expected to operate for at least five years.

The containment wall, shown in Figure 8, is constructed of soil-bentonite slurry with a hydraulic conductivity of 10^{-7} cm/sec. The slurry wall is 3 feet wide and extends 46 feet below grade (Landau Associates, 1987).

The extraction system, also shown in Figure 8, includes 206 shallow well points, approximately 30 feet deep. The extraction system includes onsite, barrier, and trans-1,2-DCE extraction (referred to as "trans") well systems. The trans wells are specifically for the mitigation of the offsite plume of trans-1,2-DCE.

Six well points are located in Area V outside the slurry wall and 200 are located inside the wall. The wells are completed with 2-inch diameter polyvinyl chloride casing with slotted screen sections at least 5 feet long. A 1-inch diameter suction tube is suspended inside the casing from a well cap. The suction tubing extends to the perforation zone, which is about 10 to 15 feet below the projected water table depth. Water is drawn from the wells by centrifugal vacuum pumps. Each well point withdraws approximately 1 gpm. The extraction system is designed to withdraw between 100 and 200 gpm.

There are seven cells, shown in Figure 5, which contain 16 to 60 well points each. The well points in each cell are connected by a common header. Extraction rates are controlled by the number of wells operating at a time. The flow rates for each cell based on total extraction flow rate desired are given in Table 5.

The well point system includes infiltration trenches which run parallel to the well point headers. The trenches are shown by dashed lines in Figure 8. Infiltration is intended to supplement precipitation in washing the near-surface soils. Infiltration is limited to less than 75 percent of the extraction flow to maintain an inward ground-water gradient across the slurry wall. The gradient is monitored weekly using 18 piezometer pairs (shown in Figure 8). The extraction and infiltration rates are as high as possible while still maintaining an

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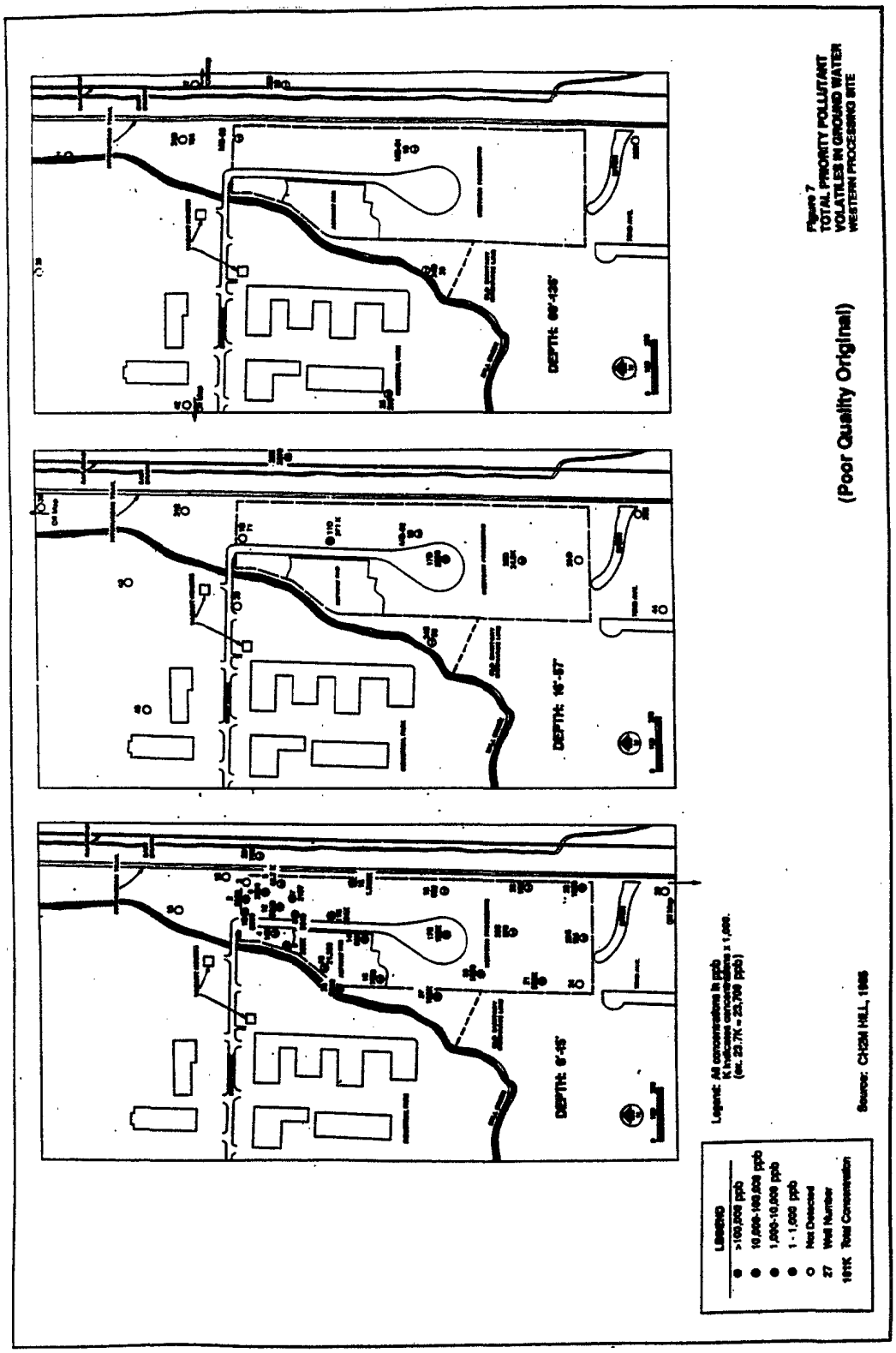

Figure 7
TOTAL PRIORITY POLLUTANT
VOLATILES IN GROUND WATER
WESTERN PROCESSING SITE

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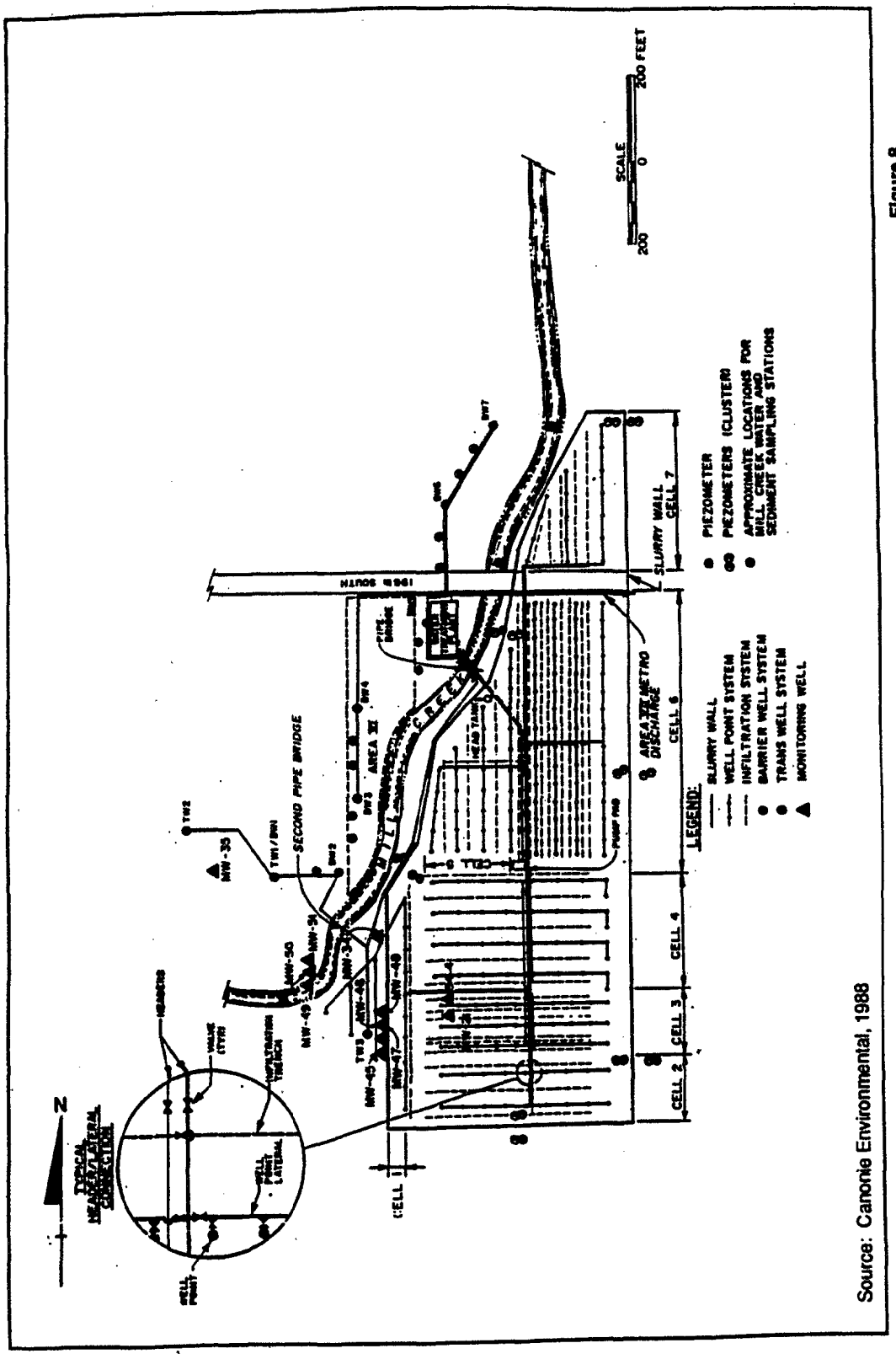

Source: Canonie Environmental, 1988

Figure 8
SITE LAYOUT
WESTERN PROCESSING SITE

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Table 4
VOLATILE ORGANICS IN WELLS
HAVING MORE THAN 100,000 ppb TOTAL VOLATILES
WESTERN PROCESSING SITE

Well Number	Depth (feet)	Compound	Concentration (ppb)
Onsite Wells			
15	14.5	Methylene Chloride	720,000
		1,1,1-Trichloroethane	340,000
		Trichloroethene	210,000
		1,1-Dichloroethane	33,000
		Chloroform	27,000
		1,2-Dichloroethane	16,000
		Toluene	5M[a]
TOTAL			1,346,005
21	13	Trans-1,2-Dichloroethene	390,000
		Trichloroethene	170,000
		Methylene Chloride	100,000
		Vinyl Chloride	360
TOTAL			660,360
9	13	Methylene Chloride	220,000
		Trichloroethene	17,000
		1,1,1-Trichloroethane	5,500
		Trans-1,2-Dichloroethene	4,600
		Toluene	2,400
TOTAL			249,500
11S	10.5	Trichloroethene	80,000
		1,1,1-Trichloroethane	73,000
		Methylene Chloride	46,000
		Toluene	2,800
		1,1-Dichloroethane	2,100
TOTAL			203,900

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Table 4
VOLATILE ORGANICS IN WELLS
HAVING MORE THAN 100,000 ppb TOTAL VOLATILES
WESTERN PROCESSING SITE

Page 2 of 2

Well Number	Depth (feet)	Compound	Concentration (ppb)
11D	27.5	Methylene Chloride	250,000
		Trichloroethene	14,000
		1,1,1-Trichloroethane	5,200
		Toluene	1,100
		Trans-1,2-Dichloroethene	780
TOTAL			271,080
17	13.5	Trichloroethene	42,000
		Methylene Chloride	42,000
		Toluene	22,000
		Chloroform	12,000
		Benzene	2,200
		1,1,1-Trichloroethane	1,700
		Fluorotrichloromethane	920
TOTAL			122,820
Off-Property Wells			
27	10	Trichloroethene	140,000
		1,1,1-Trichloroethane	20,000
		Methylene Chloride	16,000
		Chloroform	6,700
		Toluene	5M[a]
TOTAL			182,705

Source: CH2M HILL, 1985

[a]M indicates compound detected but not quantified.

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Table 5
WELL POINT EXTRACTION SYSTEM EXAMPLE PERFORMANCE NORMAL CELL FLOW DISTRIBUTIONS AT VARIED TOTAL FLOW RATES (AREA I)

		Cell Flow Distribution (gpm)			
Cell No.	Well Count	200 gpm Total	150 gpm Total	100 gpm Total	50 gpm Total
1	10	10	7.5	5	2.5
2	18	18	13.5	9	4.5
3	30	30	22.5	15	7.5
4	36	36	27	18	9
5	30	30	22.5	15	7.5
6	60	60	45	30	15
7	16	16	12	8	4

Source: Canonie Environmental, 1988

inward gradient and not exceeding the treatment plant capacity. Precipitation is a factor in determining extraction and infiltration rates (Canonie Environmental, 1988).

The infiltration system was not operated during the first two months of ground-water extraction to collect data on aquifer drawdown. Once the infiltration system was started, infiltration was adjusted to produce at least a one foot drop in the water table across the slurry wall.

Extracted water is treated in a pretreatment plant, where metals are precipitated out of solution and volatile organics are removed by an air stripper. A portion of the treated water is used in the infiltration system, and the remainder is discharge to the Seattle Metropolitan Sewer System.

EVALUATION OF PERFORMANCE

Hydraulic Control

Figure 9 is a ground-water elevation contour map showing the shallow flow zone in November 1989. Flow at the southern portion of the site is radially inward. Flow in the northern portion is to the northwest. An inward ground-water flow gradient has apparently not been maintained at the northern end of the site.

Data collected from the piezometer pairs in November 1990, indicate that inward gradients exist across the slurry wall ranging from -0.02 feet/foot, at several locations at the northern end of the site to 17 feet/foot. During November 1990, the average head difference across the wall at the 18 monitoring points was 4.8 feet (Ecology and Environment, 1988 through 1990).

Reductions in Mass Concentration of Contaminants

Figure 10 presents concentration contour maps for cadmium in shallow ground water in 1988 and 1990. The 1988 data in Figure 10 were collected from the extraction well points soon after installation of the system. The maximum cadmium contamination occurs in the center of the site. The maximum cadmium concentration observed in 1988 was greater than 8,000 ppb. The maximum cadmium concentration observed in

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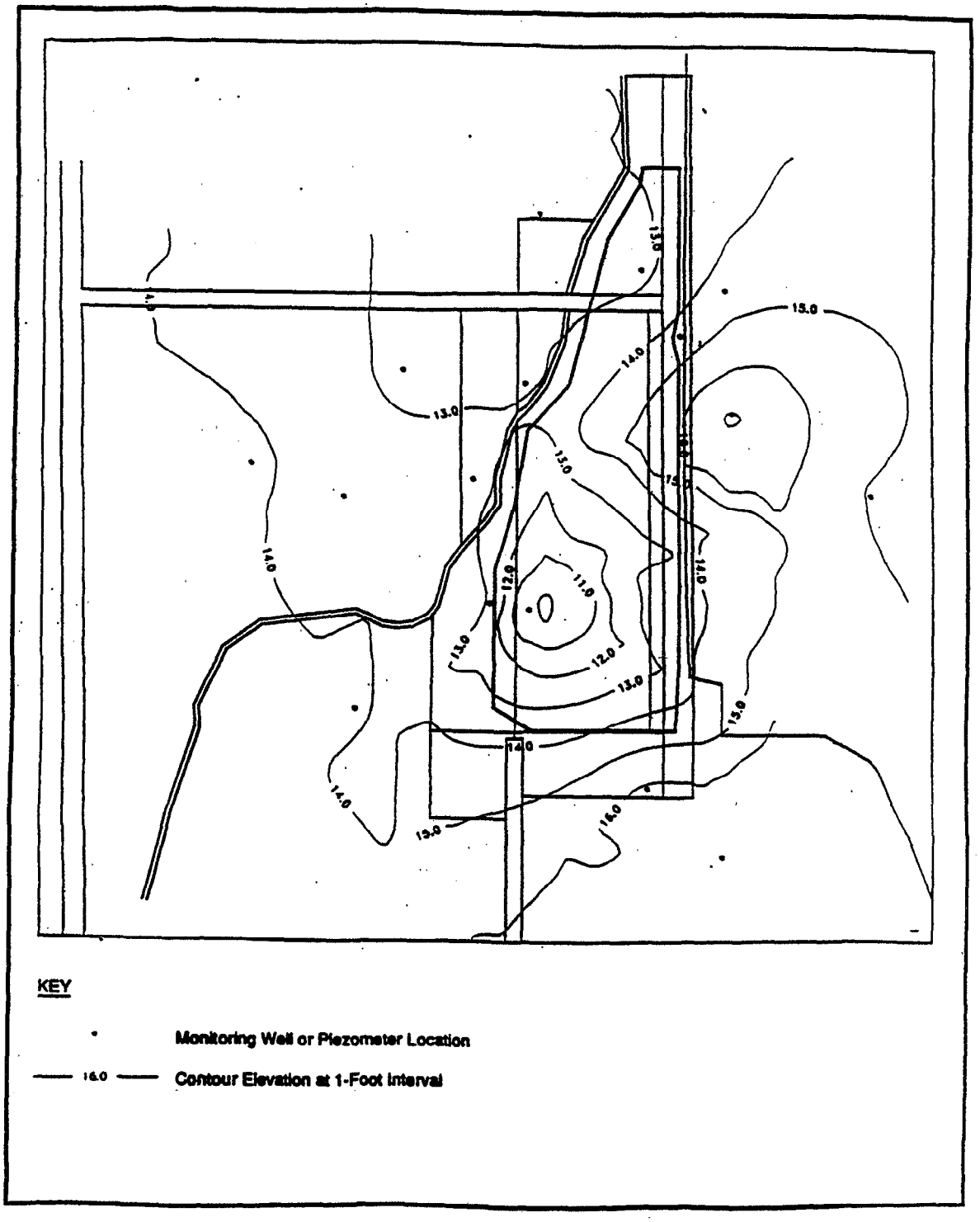

Source: Landau Associates, 1991a

Figure 9
GROUND-WATER ELEVATION CONTOURS FOR THE SHALLOW ZONE NOVEMBER 1989
WESTERN PROCESSING SITE

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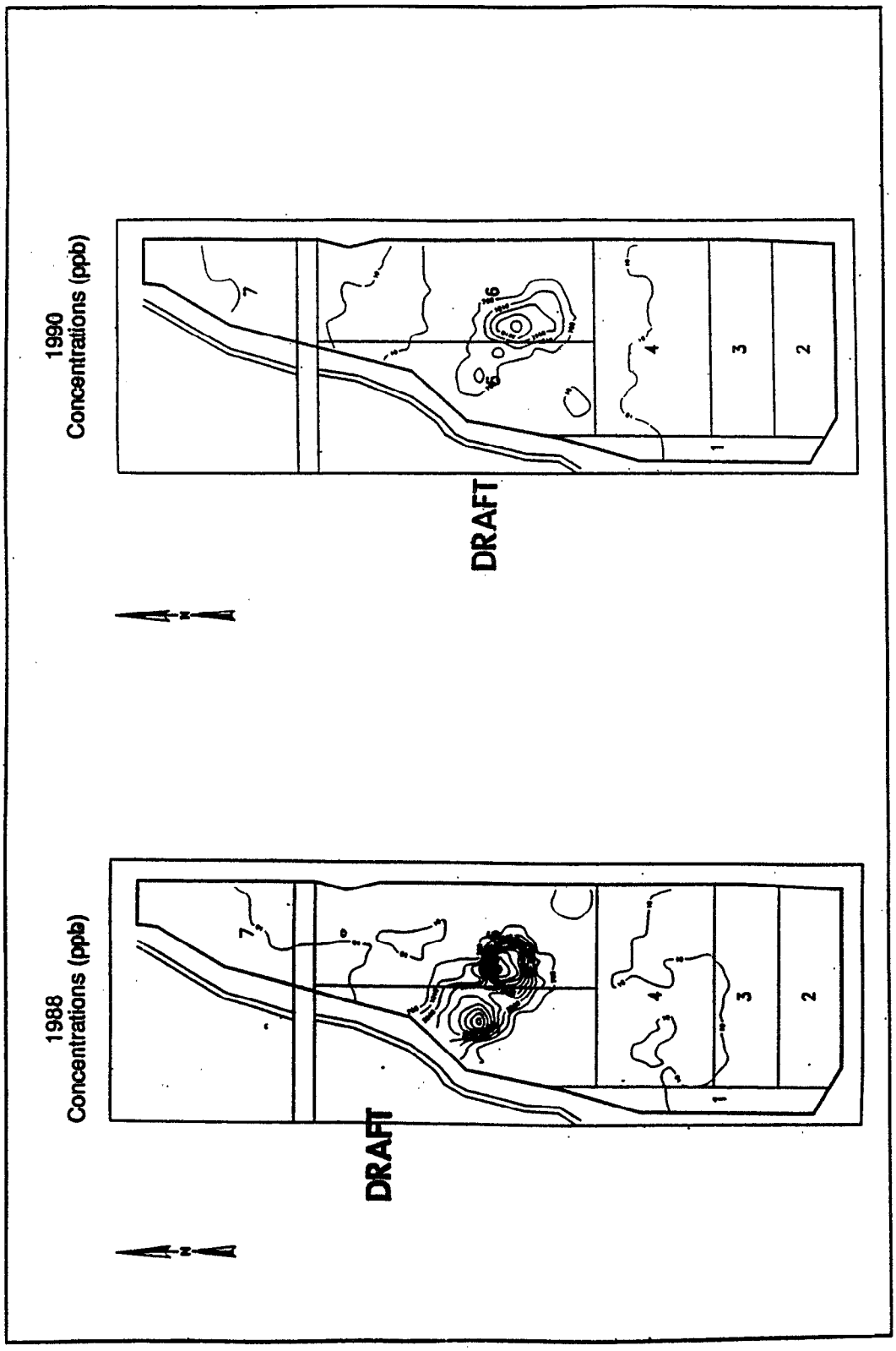

Source Landau Associates, 1991b

Figure 10
CADIUM WELLPOINT CONCENTRATION CONTOUR MAPS FOR 1988 AND 1990
WESTERN PROCESSING SITE

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1990 was about 4,000 ppb, considerably less than 1984 or 1988. The extent of the plume in 1990 is similar to that in 1988, but the concentration gradient is much smaller.

Well point concentration contour maps for chloroform in shallow ground water in 1988 and 1990 are shown in Figure 11. In 1988, the chloroform plume extended from the central portion of the site through the southern portion. Chloroform concentrations greater than 9,000 ppb were observed in the center of the site. In 1990, concentrations as high as 10,500 ppb were observed in the center of the site. The plume in the center of the site appears to have migrated south. Concentrations as high as 12,000 ppb were observed in the southeastern portion of the site in 1990 compared to 6,000 ppb in 1988. Chloroform has a specific gravity of 1.49, and has a high aqueous solubility (8,000 mg/l) compared to most other indicator organics.

Figure 12 shows well point concentration maps for toluene in 1988 and 1990. In 1988, the toluene plume extended throughout the central portion of the site with a maximum concentration of 12,000 ppb. No concentrations in excess of 1,000 ppb were observed at the northern end of the site as they had been in 1984. In 1990, considerably higher concentrations were observed in the central site with a maximum of 180,000 ppb. Toluene has a specific gravity of 0.87 and lower aqueous solubility (515 mg/l) than most indicator organics.

Well-point concentration contour maps for vinyl chloride in 1988 and 1990 are shown in Figure 13. In 1988, vinyl chloride contamination was evident throughout the southern end of the site with a maximum concentration of 19,000 ppb. Vinyl chloride contamination is also evident in a smaller area in the upper central area of the site. The 1990 well point concentration map indicates a significant reduction in vinyl chloride contamination in both plumes. The maximum 1990 concentration was 3,600 ppb.

Samples of extracted ground water in well point cell headers have been analyzed for indicator compounds since the extraction system began operating. Plots of concentrations versus time are presented in Figure 14 for total 1,2-DCE, chloroform, methylene chloride, and TCE. Figure 14 presents data from Cells 5 and 6, which are two of the most highly contaminated cells. The plots show highly variable, but declining, methylene chloride and TCE concentrations from late 1988 to late 1990. Figure 15 presents well point cell header concentrations for benzene and toluene over time in Cells 5 and 6. In Cell 5, a small declining trend in benzene concentration is evident; however, no long-term trend is evident in the toluene plot. In Cell 6, there is a significant decline in toluene concentrations from October 1988 to July 1989, but no long-term trend is evident.

The severity of cadmium concentration was reduced somewhat from 1988 to 1990. Chromium and nickel also showed reductions in concentrations during the same period. Metals with stable or increasing concentrations between 1988 and 1990 included aluminum, iron, lead, and zinc.

Vinyl chloride contamination was reduced considerably from 1988 to 1990. Other organics that exhibited reductions in contamination included 1,1-DCA, 1,1-DCE, methylene chloride, and TCE. Benzene, chloroform, cis- and trans-1,2-DCE, tetrachloroethane, toluene, 1,1-TCA showed stable or increasing concentrations from 1988 to 1990.

SUMMARY OF REMEDIATION

The remedial measures implemented at the Western Processing site are summarized as follows:

- The three aquifer zones beneath the site are contaminated with numerous metals and organics. The shallow aquifer zone is contaminated most extensively.

- A slurry wall and well point extraction system were constructed at the site. The extraction system includes 206 well points in the shallow ground-water flow zone each, designed to recover 1 gpm. Contaminant extraction is enhanced by an infiltration system which consists of trenches parallel to the well point headers.

- The extraction and infiltration systems are controlled to maintain an inward ground-water flow gradient. Water elevation data for the shallow ground-water zone in 1989 showed that an inward gradient was maintained throughout the central and

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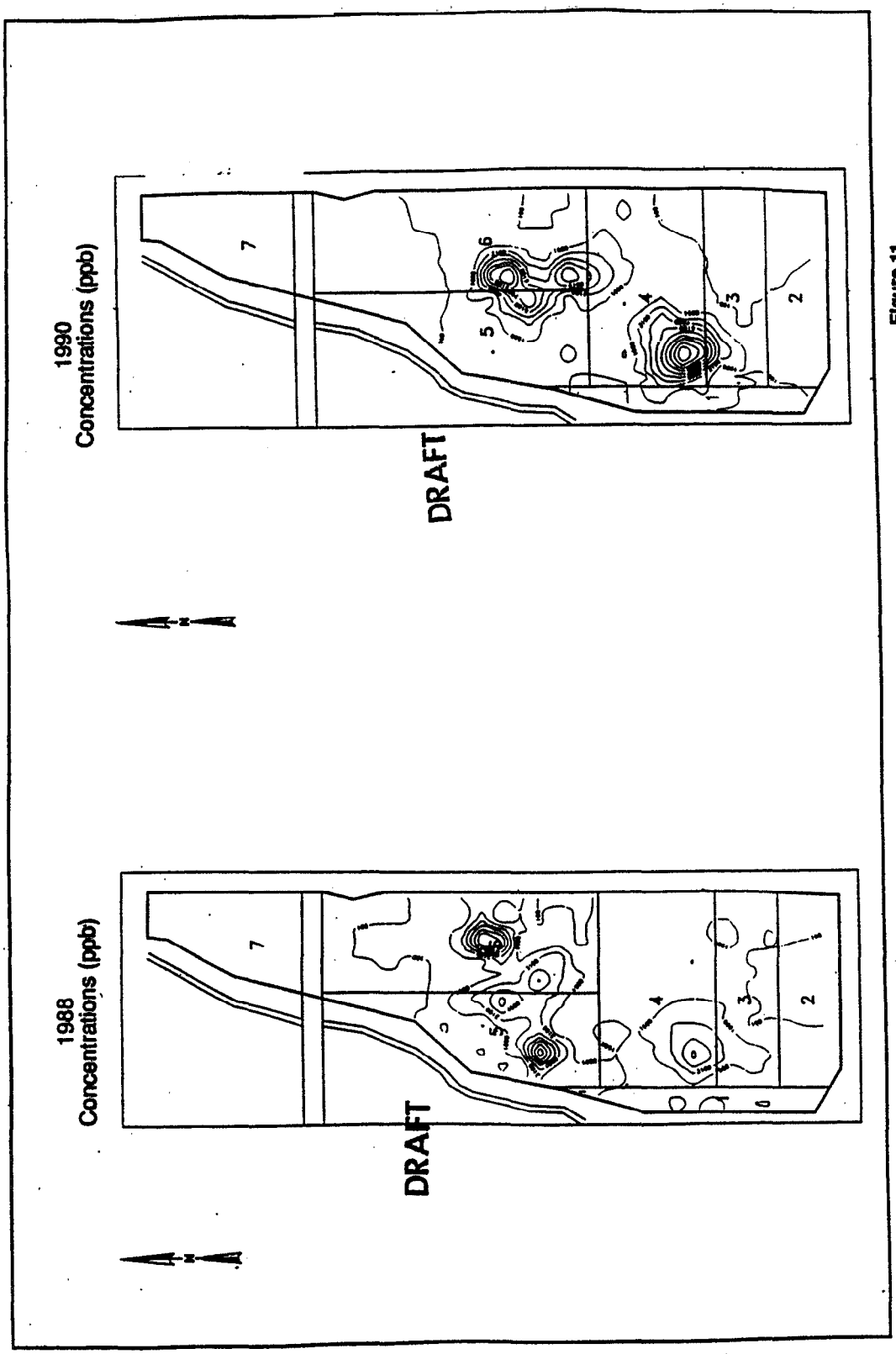

Source: Landau Associates, 1991b

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Figure 11
CHLOROFORM WELL POINT CONCENTRATION CONTOUR MAPS
1988 AND 1990
WESTERN PROCESSING SITE

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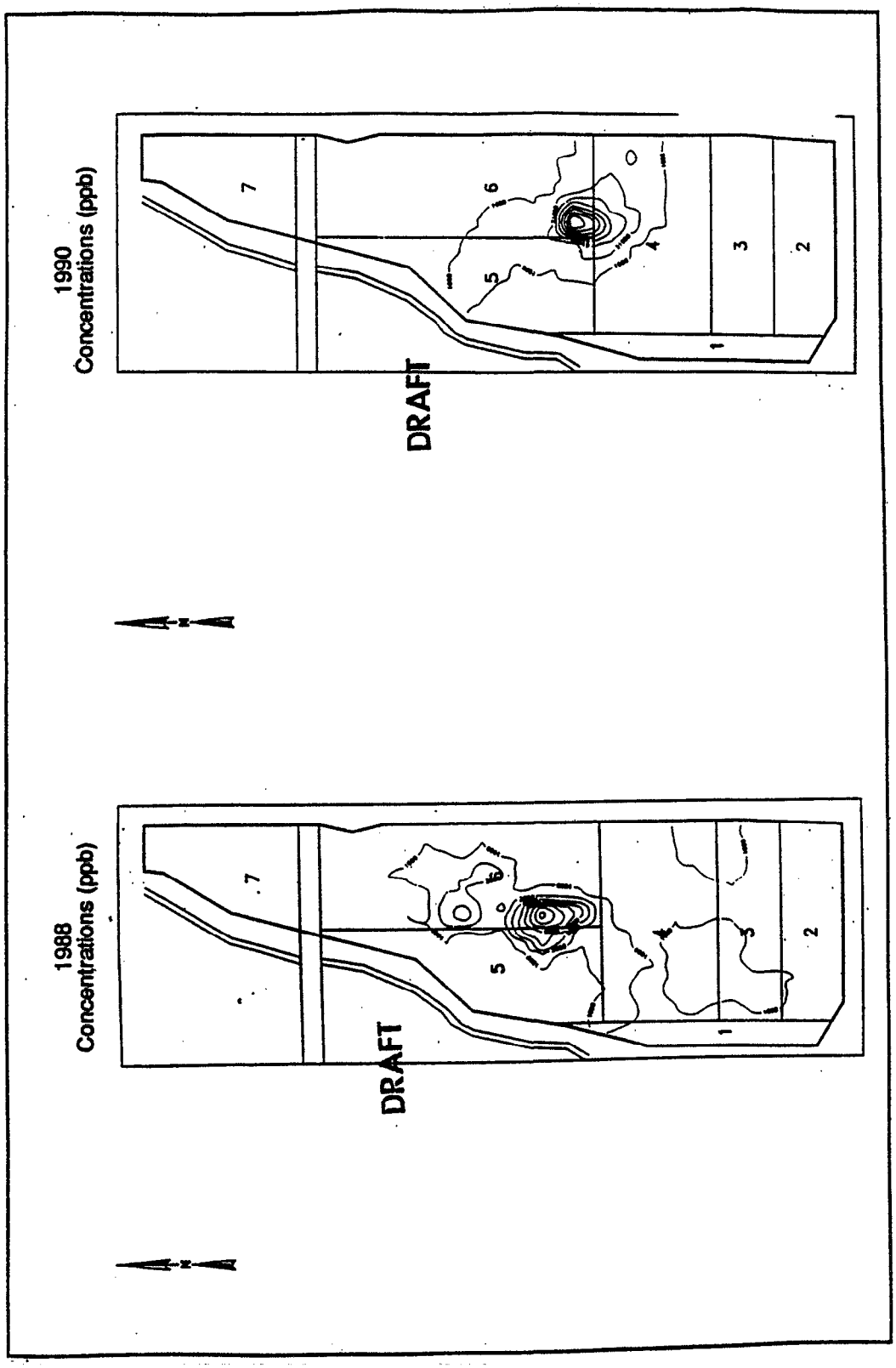

Source Landau Associates, 1991b

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Figure 12
TOLUENE WELL POINT
CONCENTRATION CONTOUR MAPS
1988 AND 1990
WESTERN PROCESSING SITE

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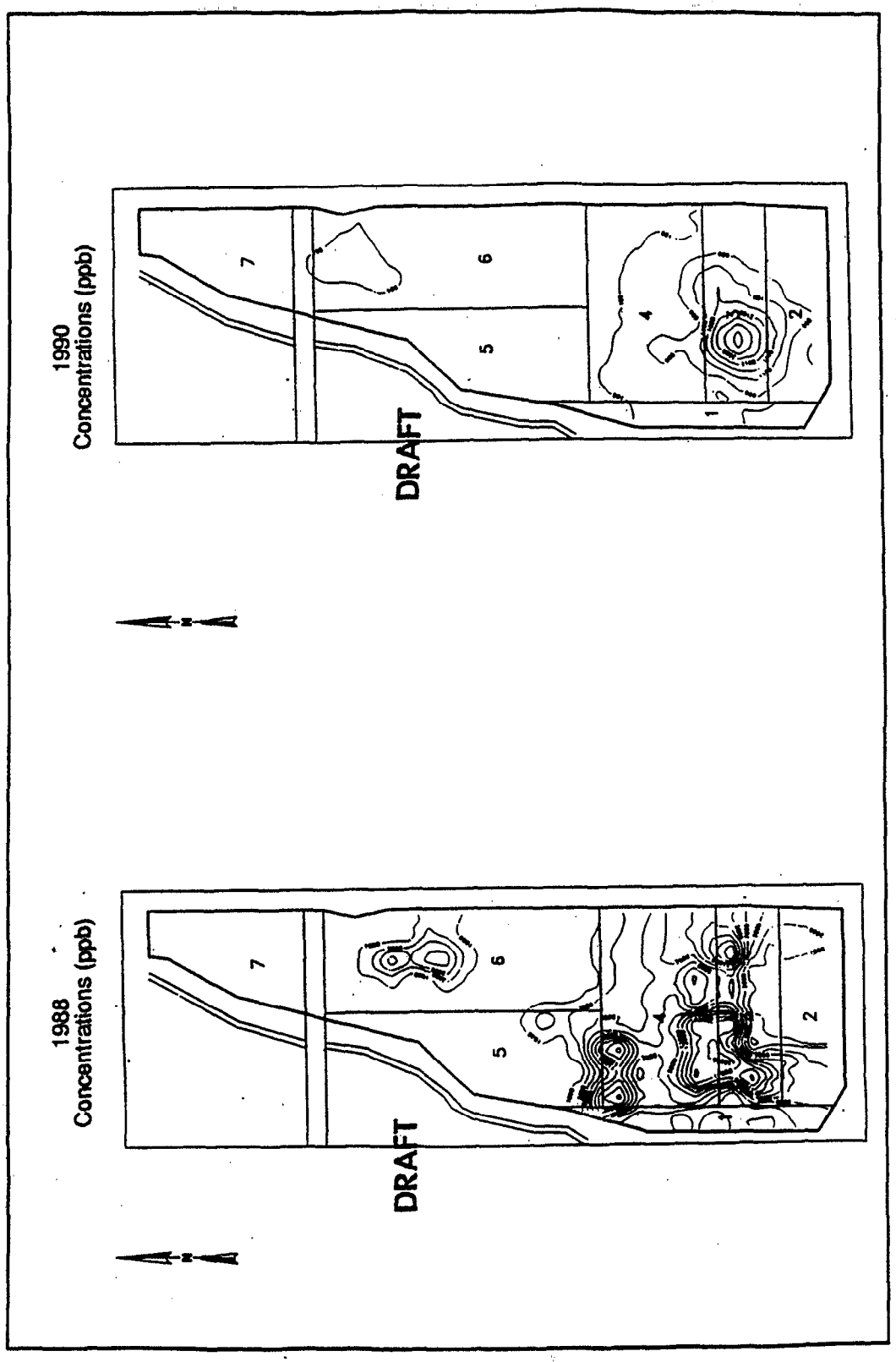

Source Landau Associates, 1991b

Figure 13
VINYL CHLORIDE WELL POINT CONCENTRATION CONTOUR MAPS
1988 AND 1990
WESTERN PROCESSING SITE

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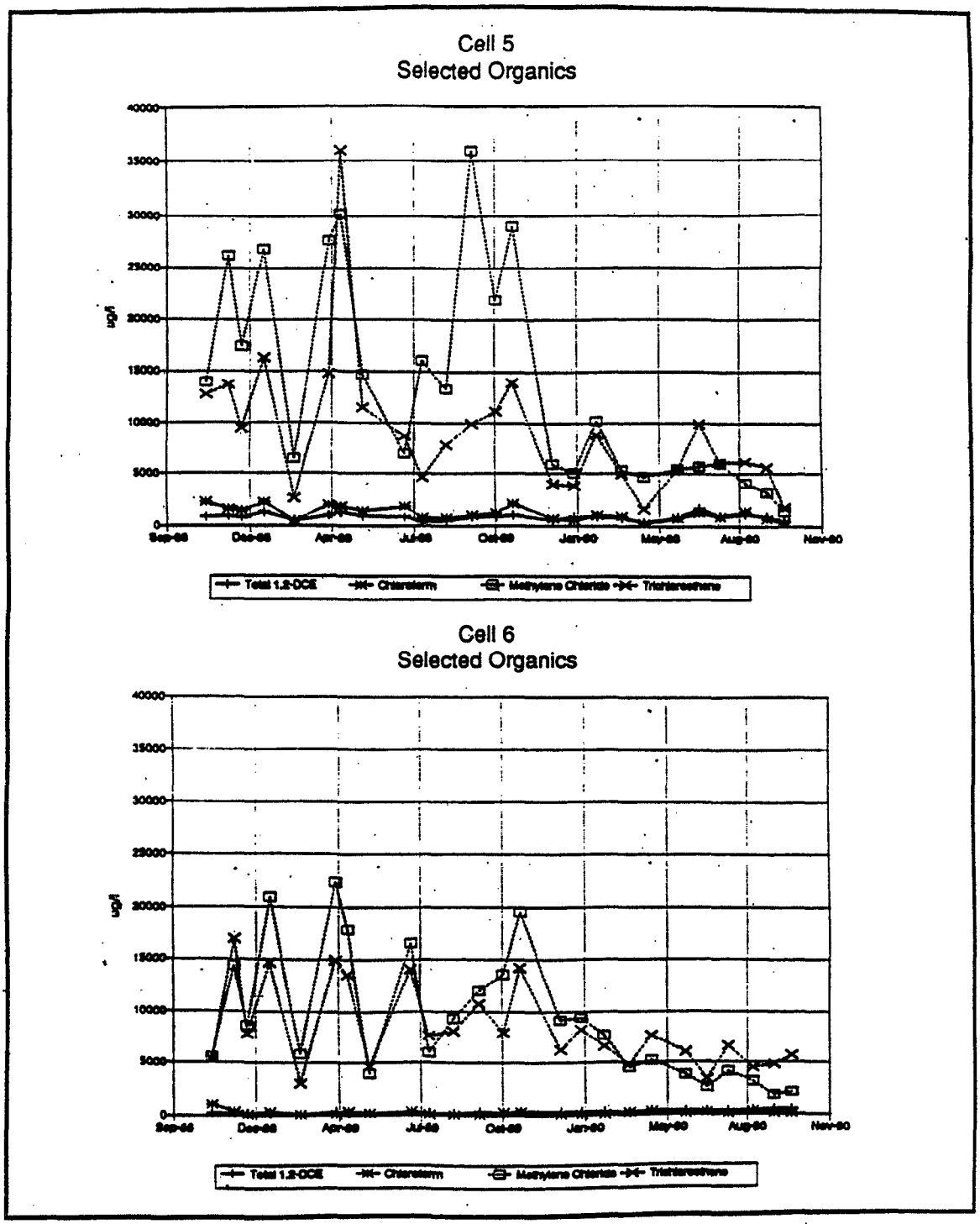

Source: Landau Associates, 1991b

Figure 14
SELECTED ORGANICS CONCENTRATIONS IN GROUND WATER EXTRACTED FROM CELLS 5 AND 6
WESTERN PROCESSING SITE

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southern portions of the site, but there was offsite ground-water migration at the northern end of the site.

- Data collected from well points in 1990 indicate reduction in concentrations for only a few contaminants. Plumes of most metals and organics remained stable or worsened between 1988 and 1990. However, the data indicate that metals and organics are being recovered by the well point extraction system.

- The lack of significant reduction in levels of pollution could be a result of additional contaminants being flushed from the soil by the infiltration system. The persistent contamination may also be explained by the relatively short time the extraction system has been operating.

SUMMARY OF NAPL-RELATED ISSUES

Nonaqueous phase liquids (NAPLs) have not yet been recognized as part of the remediation problem at the Western Processing Site. In 1988 site operators first observed a floating NAPL (LNAPL) in two non-adjacent well points (U.S. EPA, 1991). It is suggested that LNAPLs are located above the water table and well screens. Preliminary analysis of the LNAPL revealed that it consisted of diesel motor oil and solvents (U.S. EPA, 1991). High ground-water concentration of several organic compounds relative to their aqueous solubilities suggests that there may be other NAPLs at the site.

Ground-water concentrations of toluene were not particularly high when measured during the remedial investigation in 1984. In 1990, however, after two years of ground-water remediation, concentrations as high as 180,000 ppb were recorded. This is approximately 34 percent of the aqueous solubility of toluene. High toluene concentrations were not measured in the early ground-water samples possibly because the monitoring wells were screened below the water table, which was only a few feet below the ground surface. When the water table was drawn down by extraction from the well points, a floating layer of toluene would be drawn down with it, and higher concentrations might be measured. The records of blended toluene concentrations for Cells 5 and 6, shown in Figure 15, show little or no systematic decline over the two-year period since the beginning of extraction. This behavior also tends to suggest that nonaqueous toluene may be present.

Other organics that are potentially present as NAPLs are methylene chloride, TCE, 1,1,1-TCA, and trans-1,2-DCE. Each of these compounds was detected at ground-water concentrations of more than 5 percent of solubility. TCE and 1,1,1-TCA were found at 20 and 36 percent of solubility, respectively. Trans-1,2-DCE has been detected at 65 percent of solubility. Such high concentrations can be taken as strong indications that some, or all, of these compounds may be present as dense NAPLs (DNAPLs).

If DNAPLs were present in large quantities, the implications for the success of ground-water remediation would be serious. Because the confining slurry wall is not underlain by a continuous layer of low hydraulic conductivity, the DNAPLs would not be prevented from sinking into the fine to medium sand aquifer at depths of 40 feet and below. However, if the quantities of DNAPL are relatively small, the interbedding of silts and clays in the shallow soils would tend to spread the DNAPLs laterally. Under these circumstances, a considerable volume of DNAPL could be present at residual saturation without penetrating to great depth.

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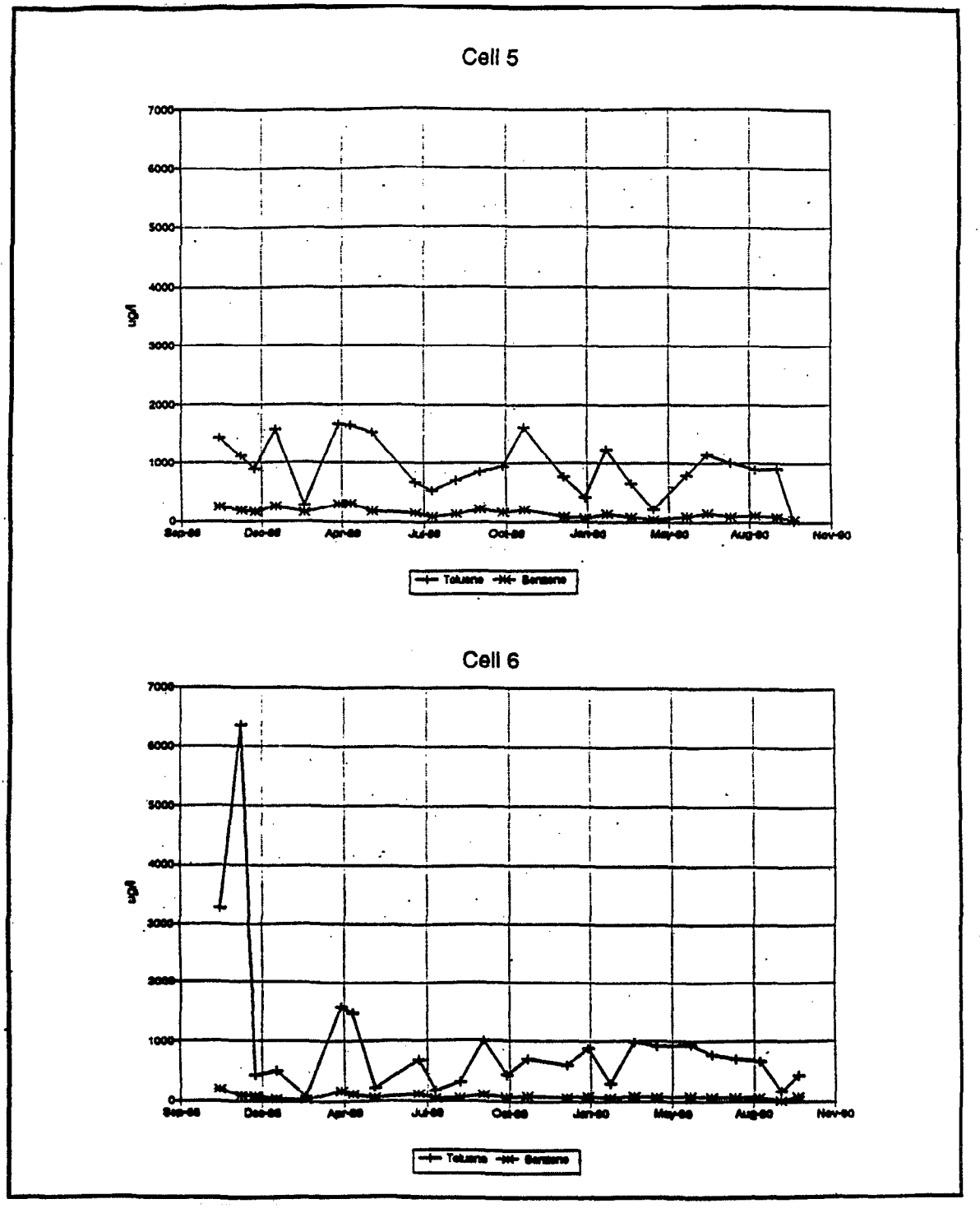

Source: Landau Associates, 1991b

Figure 15
BENZENE AND TOLUENE CONCENTRATIONS IN GROUND WATER EXTRACTED FROM CELLS 5 AND 6 WESTERN PROCESSING SITE

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BIBLIOGRAPHY/REFERENCES

Canonie Environmental. June 17, 1988. *Well Point Extraction System Operations and Maintenance Manual (O&M Manual).*

CH2M HILL and Ecology and Environment. December 17, 1984. *Remedial Investigation, Western Processing, Kent, Washington.*

CH2M HILL and Ecology and Environment. March 6, 1985. *Feasibility Study for Subsurface Cleanup, Western Processing, Kent, Washington.*

Ecology and Environment. 1988 through 1990. Operations Data for the Well Point Extraction System.

Landau Associates, Inc. April 10, 1987. *Supplemental Feasibility Assessment for Flushing Enhancement Slurry Wall, Western Processing, Kent, Washington.*

Landau Associates, Inc. November 1990. *Quarterly Interpretive Report: First Quarter 1989, Western Processing.*

Landau Associates, Inc. February 13, 1991a. *Quarterly Interpretive Report: Fourth Quarter 1989. Western Processing.*

Landau Associates, Inc. 1991b. Draft graphics of 1990 data.

U.S. Environmental Protection Agency (U.S. EPA). September 1985. *Superfund Record of Decision, Remedial Alternative Selection, Western Processing Company, Inc., Kent, Washington.*

U.S. EPA. June 20, 1991. Personal communication with Mr. Bernard Zavalas, Environmental Services Division.

* U.S. G.P.O.:1992-311-893:60677