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Case Studies 1-23:

Remedial Response at Hazardous Waste Sites

EPA-540/2 84-002b
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CASE STUDIES 1-23:
REMEDIAL RESPONSE AT
HAZARDOUS WASTE SITES

MUNICIPAL ENVIRONMENTAL RESEARCH LABORATORY
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OFFICE OF EMERGENCY AND REMEDIAL RESPONSE
U.S. ENVIRONMENTAL PROTECTION AGENCY
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NOTICE

The information in this document has been funded wholly or in part by the United States Environmental Protection Agency under Contract Number 68-03-3113, Task 39-3 and Cooperative Agreement number CR809392 to JRB Associates and the Environmental Law Institute. It has been subject to the Agency's peer and administrative review, and it has been approved for publication as an EPA document.

ABSTRACT

In response to the threat to human health and the environment posed by numerous uncontrolled hazardous waste sites across the country, new remedial action technologies are evolving and known technologies are being retrofitted and adapted for use in cleaning up these sites. This report identifies and assesses the various types of site response activities which have been implemented, are in progress, or have been proposed to date at uncontrolled hazardous waste sites across the United States. This was accomplished through the combined efforts of JRB Associates (JRB) and the Environmental Law Institute (ELI). A nationwide survey was conducted in which 395 uncontrolled hazardous waste sites across the U.S. were identified where some form of remedial action was planned, was presently ongoing, or has been completed. Each of these sites was assessed and the results are presented here-in. Based on these survey findings, JRB and ELI selected a total of 23 sites for which detailed case study investigations have been conducted. Case study reports for each of the 23 sites are presented. These reports include extensive discussions of the remedial responses at each of the 23 sites with respect to technology, cost, and institutional framework. JRB and ELI maintained a specific focus for each of these parameters. JRB's primary focus in these investigations was to assess site response activities from a geotechnical and engineering perspective, while ELI's main objective was to assess these remedial actions from a cost and institutional perspective. Additionally, technological, cost, and institutional data for the 23 case study sites are summarized in several user guidance indices.

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LIST OF ABBREVIATIONS AND SYMBOLS

ABBREVIATIONS

ASTM	- American Society for Testing and Materials
BTU/lb	- British Thermal Units - per pound
^oC	- degrees Centigrade
cm	- centimeters
cm^3	- cubic centimeters
COD	- chemical oxygen demand
EP toxic	- Extraction Procedure toxic
gpd	- gallons per day
gpl	- gallon per liter
gpm	- gallon per minute
ha	- hectares
kg	- kilograms
kg/m^3	- kilograms per cubic meters
kwh	- kilowatt hours
kwh/year	- kilowatt hours per year
l	- liters
LL	- Liquid limit
m	- meters
m^2	- square meters
m^3	- cubic meters
mg	- milligrams
mg/l	- miligrams per liter
ml	- milliliters
mt.	- metric tons
NaPEG	- sodium polyethylene glycol
NCP	- National Contingency Plan
NPDES	- National Pollution DIscharge Elimination System
Pa	- Pascals
pcf	- pounds per cubic foot
PL	- plastic limits
POTW	- publicly owned treatment works
ppb	- parts per billion
ppm	- parts per million
psi	- pounds per square inch
RCRA	- Resource Conservation and Recovery Act
STP	- sewage treatment plant
TCDD	- tetrachlorodibenzodioxin (referred to as dioxin)
TICH	- total identifiable chlorinated hydrocarbons
TOC	- total organic carbon
TSCA	- Toxic Substances Control Act
TSS	- total suspended solids
ug	- micrograms
ug/g	- micrograms per gram
ug/l	- micrograms per liter

SYMBOLS

$Ca(OH)_2$	- calcium hydroxide
CaO	- calcium oxide
$Ca\ CO_3$	- calcium carbonate
	greater than
	less than

ACKNOWLEDGMENTS

JRB Associates and the Environmental Law Institute (ELI) prepared this report for EPA's Office of Research and Development, Municipal Environmental Research Laboratory, Solid and Hazardous Waste Research Division. This report was prepared through the coordinated efforts and guidance of S. Robert Cochran, JRB Project Manager, and Dr. Edward Yang, ELI Project Manager. The following persons from JRB and ELI all played major roles in conducting the nationwide survey, case study site selection, case study site visits, and report preparation: Hal Bryson, Roger Dower, Christine Edmunds, Mark Evans, Claudia Furman, Nurhan Giampaolo, Susan Green, Marjorie Kaplan, Mark Menefee, Eric Nagle, Edward Repa, Paul Rogoshewski, Mary Snowber, Holly Stallworth, Tim Van Epp, Kathleen Wagner, James Werner, and Roger Wetzel.

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USER GUIDANCE INDICES

This section contains two guidance indices developed to aid the use of this document in locating specific information relative to each case study. The two indices are a technology guidance index and a National Contingency Plan (NCP) reference index. Each consists of a set of tables that are organized so that the reader can quickly locate specific page numbers relative to their topic of interest. The following discussions provide specific instructions on the use of these indices and the information contained within them.

TECHNOLOGY INDEX

The 23 case studies provide examples of over 35 different remedial action technologies and also provide comparative examples of over 25 of these technologies being implemented at different sites under varying circumstances. Comparison of both technologies and site-specific conditions will allow for the evaluation of specific technologies based on actual performance as recorded in the case studies with respect to anticipated or known conditions of future sites. Finally, the technology indices provide a method for research into the various implementation problems associated with the remedial actions.

The Technology Index presents the 23 case studies on the left side margin with the entire list of technologies employed at these sites across the top of the page. By cross referencing the technologies with case studies one can quickly find the page number in the case study discussing the various aspects of that particular technology employed at the site. This process eliminates excessive review of the case studies in order to obtain data on specific issues surrounding the use of technologies in a wide range of implementation scenarios.

NCP REFERENCE INDEX

The NCP Reference Index presents information regarding the references to provisions of the National Contingency Plan (NCP) that appear in the right margin of each case study. These references consist of a citation to a section of the NCP along with some key works from that section, and are intended to correlate the text of the case studies with the NCP. The references do not imply that the NCP legally applied to the activities discussed in the case study, nor that the NCP ahould have been followed by the response managers. Most of the 23 responses covered by this research were concluded before the revised NCP became final.

The NCP Reference Index presents informantion in much the same manner as the technology index with the exception that the 23 case studies appear along the top of the page and the NCP references are listed along the left side margin. The NCP reference index is used in the same way as the technology index. By cross referencing the NCP references with case studies on can easily locate the pages in the case studies where NCP references have been cited.

The NCP references are designed to note actual examples of some of the issues covered by the NCP. For example, if a decision maker is concerned with whether and what type of source control remedial action should be undertaken at a site pursuant to section 300.(e)(2) of the NCP, he can lookup that section in the NCP Reference Index and find references to numerous case studies where the parties, both private and publiv, had to deal with this issue. Thus , the user can find concrete examples where, e.g., the population at risk (section 300.68(e)(2)(1)(A)) or hydrogeological factors (section 300.68 (e)(2)(1)(D)) were issues affecting decisions about source control measures.

The researchers have sought to reference the NCP in a consistent and through manner. However, since this requires correlating the broad provisions of the NCP with the narrow facts of particular case studies, the users of this index may perceive different correlations. Netherless, it is hoped that this index will help the user relate the NCP to actual response actions.

TECHNOLOGY INDEX

REMEDIAL RESPONSE TECHNOLOGY / CASE STUDY SITE	Activated Carbon Adsorption	Aeration	Aquifer Recharge	Barrier Wall-ASPEMIX	Barrier-Wall-Clay	Barrier Wall-Slurry	Capping-Asphalt	Capping-Clay	Contaminated Materials-Drumming	Contaminated Materials-Excavation	Contaminated Materials-Removal	Dewatering	Dike	Disposal Off-site	Disposal On-Site	Drainage System	Dredging	Drum Excavation
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*Case Study Reports prepared by ELI only

All numbers indicate pages in individual studies where the response action is first described.

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NCP REFERENCE INDEX (CONT'D)

	Anonymous A	Anonymous B	Anonymous C	Biocraft	Chemical Metals Industries	Chemical Recovery Systems	College Point	Fairchild Republic	General Electric	Gallup	Goose Farm
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300.68(i)(2)(B) distribution of costs over time	1-40										
300.68(i)(2)(C) constructability											
300.68(i)(2)(E) adverse effects											
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300.68(k) fund balancing											11-25
300.70(b)(1)(i) air emissions control											
300.70(b)(1)(ii)(A) surface seals		2-23							9-47		

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NCP REFERENCE INDEX (CONT'D)

	H & M Drum Company	Houston Chemical	Howe, Inc.	Marty's GMC	N.W. Mauthe	Occidental Chemical	PP&L - Stroudsburg	Quanta Resources	Richmond Sanitary	Trammell Crow	University of Idaho	Vertac Chemical
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300.68(i)(2)(E) adverse effects												
300.68(j) extent of remedy			14-21		16-19				20-15	21-15		
300.68(i) fund balancing	12-14											
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	Anonymous A	Anonymous B	Anonymous C	Biocraft	Chemical Metals Industries	Chemical Recovery Systems	College Point	Fairchild Republic	General Electric	Gallup	Goose Farm
300.70(b)(1)(ii) surface water controls									9-33		
300.70(b)(1)(ii)(B) surface water diversion and collection systems			3-16						9-36		
300.70(b)(1)(ii) (B)(1) dikes and berms											
300.70(b)(1)(ii) (B)(2) ditches, diversions, waterways									9-36		
300.70(b)(1)(ii)(C) grading									9-36		
300.70(b)(1)(ii)(D) revegetation		2-23							9-36		
300.70(b)(1)(iii)(A) impermeable barriers	1-2/ 1-38	2-16		4-18		6-14					

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NCP REFERENCE INDEX (CONT'D)

	H & M Drum Company	Houston Chemical	Howe, Inc.	Marty's GMC	N.W. Mauche	Occidental Chemical	PP&L - Stroudsburg	Quanta Resources	Richmond Sanitary	Trammell Crow	University of Idaho	Vertac Chemical
300.70(b)(1)(ii) surface water controls					16-18		18-19					23-37/ 23-39
300.70(b)(1)(ii)(B) surface water diversion and collection systems					16-22							23-32
300.70(b)(1)(ii) (B)(1) dikes and berms		13-21	14-4					19-9	20-2/ 20-17			23-32
300.70(b)(1)(ii) (B)(2) ditches, diversions, waterways					16-3/ 16-24		18-19					
300.70(b)(1)(ii)(C) grading						17-26				21-33		
300.70(b)(1)(ii)(D) revegetation										21-33		23-33/ 23-39
300.70(b)(1)(iii)(A) impermeable barriers					16-24				20-2/ 20-16			23-33/ 23-49

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NCP REFERENCE INDEX (CONT'D)

	Anonymous A	Anonymous B	Anonymous C	Biocraft	Chemical Metals Industries	Chemical Recovery Systems	College Point	Fairchild Republic	General Electric	Gallup	Goose Farm
300.70(b)(1)(iii) (A)(1) slurry walls											
300.70(b)(1)(iii) (A)(2) grout curtains											
300.70(b)(1)(iii) (C) ground water pumping		2-16/ 2-17		4-4/ 4-18/ 4-44					9-32/ 9-37		11-15
300.70(b)(1)(iii) (C)(2) plume containment									9-37		11-15
300.70(b)(1)(iii) (D)(1) subsurface drains		2-16/ 2-17/ 2-26	3-3/ 3-14/ 3-19	4-3/ 4-18/ 4-27		6-11			9-2/ 9-47		
300.70(b)(1)(iii) (D)(3) liners											
300.70(b)(1)(iv) contaminated water and sewer lines		2-22		4-3/ 4-17							

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NCP REFERENCE INDEX (CONT'D)

	H & M Drum Company	Houston Chemical	Howe, Inc.	Marty's GMC	N.W. Mauthe	Occidental Chemical	PP&L - Stroudsburg	Quanta Resources	Richmond Sanitary	Trammell Crow	University of Idaho	Vertac Chemical
300.70(b)(1)(iii) (A)(1) slurry walls					16-24		18-24					
300.70(b)(1)(iii) (A)(2) grout curtains							18-30					
300.70(b)(1)(iii) (C) ground water pumping			14-5/ 14-16				18-22/ 18-35					
300.70(b)(1)(iii) (C)(2) plume containment												
300.70(b)(1)(iii) (D)(1) subsurface drains					16-3/ 16-18							23-49
300.70(b)(1)(iii) (D)(3) liners												
300.70(b)(1)(iv) contaminated water and sewer lines												

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NCP REFERENCE INDEX (CONT'D)

	Anonymous A	Anonymous B	Anonymous C	Biocraft	Chemical Metals Industries	Chemical Recovery Systems	College Point	Fairchild Republic	General Electric	Gallup	Goose Farm
300.70(b)(2)(i) gaseous emissions treatment											
300.70(b)(2)(ii) direct waste treatment methods			3-14	4-20					9-41/ 9-47		11-19
300.70(b)(2)(ii)(A) biological methods											
300.70(b)(2)(ii) (A)(1) conventional wastewater treatment											
300.70(b)(2)(ii) (A)(2) aerated lagoon											
300.70(b)(2)(ii) (A)(3) biological reactors				4-4/ 4-17/ 4-18							
300.70(b)(2)(ii)(B) chemical methods				4-19					9-31		

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NCP REFERENCE INDEX (CONT'D)

	H & M Drum Company	Houston Chemical	Howe, Inc.	Marty's GMC	N.W. Mauthe	Occidental Chemical	PP&L - Stroudsburg	Quanta Resources	Richmond Sanitary	Trammell Crow	University of Idaho	Vertac Chemical
300.70(b)(2)(i) gaseous emissions treatment												23-31
300.70(b)(2)(ii) direct waste treatment methods												23-34/ 23-44
300.70(b)(2)(ii)(A) biological methods												
300.70(b)(2)(ii) (A)(1) conventional wastewater treatment												23-33
300.70(b)(2)(ii) (A)(2) aerated lagoon		13-22										
300.70(b)(2)(ii) (A)(3) biological reactors												
300.70(b)(2)(ii)(B) chemical methods												

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NCP REFERENCE INDEX (CONT'D)

	Anonymous A	Anonymous B	Anonymous C	Biocraft	Chemical Metals Industries	Chemical Recovery Systems	College Point	Fairchild Republic	General Electric	Gallup	Goose Farm
300.70(b)(2)(ii) (B)(3) neutralization		2-17									
300.70(b)(2)(ii) (B)(4) equalization											
300.70(b)(2)(ii) (C)(1) air stripping									9-21		
300.70(b)(2)(ii) (C)(2) carbon absorption		2-17							9-19		
300.70(b)(2)(iii)(C) solidification											
300.70(b)(2)(iii)(E) in situ soil treatment											
300.70(b)(2)(iii) (E)(1) solution mining									9-31		11-18

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NCP REFERENCE INDEX (CONT'D)

	H & M Drum Company	Houston Chemical	Howe, Inc.	Marty's GMC	N.W. Mauthe	Occidental Chemical	PP&L - Stroudsburg	Quanta Resources	Richmond Sanitary	Trammell Crow	University of Idaho	Vertac Chemical
300.70(b)(2)(ii)(B)(3) neutralization												23-44
300.70(b)(2)(ii)(B)(4) equalization												23-44
300.70(b)(2)(ii)(C)(1) air stripping												
300.70(b)(2)(ii)(C)(2) carbon absorption						17-2/ 17-35						
300.70(b)(2)(iii)(C) solidification										21-30		23-44
300.70(b)(2)(iii)(E) in situ soil treatment												
300.70(b)(2)(iii)(E)(1) solution mining												

(continued)

NCP REFERENCE INDEX (CONT'D)

	Anonymous A	Anonymous B	Anonymous C	Biocraft	Chemical Metals Industries	Chemical Recovery Systems	College Point	Fairchild Republic	General Electric	Gallup	Goose Farm
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300.70(c) off-site transport						6-12					11-24
300.70(c)(1) off-site transport for destruction						6-11					
300.70(c)(1)(ii) off-site transport; capacity to manage hazardous wastes	1-2										
300.70(c)(2)(i) removal of contaminated soil and sediments			3-14	4-18		6-10/ 6-11					11-22

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NCP REFERENCE INDEX (CONT'D)

	H & M Drum Company	Houston Chemical	Howe, Inc.	Marty's GMC	N.W. Mauthe	Occidental Chemical	PP&L - Stroudsburg	Quanta Resources	Richmond Sanitary	Trammell Crow	University of Idaho	Vertac Chemical
300.70(b)(2)(iii)(E)(2) neutralization												
300.70(b)(2)(iii)(E)(3) microbiological degradation			14-33									
300.70(c) off-site transport			14-33									23-27/ 23-50
300.70(c)(1) off-site transport for destruction							18-23					
300.70(c)(1)(ii) off-site transport; capacity to manage hazardous wastes			14-32									
300.70(c)(2)(i) removal of contaminated soil and sediments					16-3/ 16-24	17-2/ 17-33	18-34					23-43

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NCP REFERENCE INDEX (CONT'D)

	Anonymous A	Anonymous B	Anonymous C	Biocraft	Chemical Metals Industries	Chemical Recovery Systems	College Point	Fairchild Republic	General Electric	Gallup	Goose Farm
300.70(d)(2) provision of alternative water supply											
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NCP REFERENCE INDEX (CONT'D)

	H & M Drum Company	Houston Chemical	Howe, Inc.	Marty's GMC	N.W. Mauthe	Occidental Chemical	PP&L - Stroudsburg	Quanta Resources	Richmond Sanitary	Trammell Crow	University of Idaho	Vertac Chemical
300.70(d)(2) provision of alternative water supply			14-4			17-31/ 17-36						
300.71 worker health and safety									20-16			

CASE STUDY REPORTS

ANONYMOUS SITE A

NORTH-CENTRAL CALIFORNIA

INTRODUCTION — NCP Reference

Approximately 100 acres (40 ha) of surface impoundments containing pesticide and fertilizer wastewater is located on the property of a large agricultural chemical products manufacturer, which will be referred to as "Anon A" in the following case study. The site is underlain by relatively impervious (10^{-7} cm/sec) Bay Mud, which prevents downward migration of wastes, but seepage and overflow through the dikes occurred several times since the facility opened in the early 1950's. During a heavy 100-year rainstorm in February 1980, about 3.5 million gallons (1.3×10^{-7}l) of fertilizer waste water containing 2,400 mg/l ammonia was discharged into a slough leading to the nearby Bay to prevent overtopping of the dikes and feared dike failure.

Background

The existing 100 acre (40 ha) pond system was built primarily in the late 1950's and early 1960's. There are about 56 acres (23 ha) of pesticide waste-water ponds and 32 acres (13 ha) of fertilizer wastewater. Seepage through the dikes and overflow of the ponds occurred several times during subsequent years because of cracks in the dikes and heavy winter rainstorms. During the early 1970's in response to these problems, Anon A repaired and upgraded the dikes by widening and adding clay covers to various sections of the dikes to increase their structural strength and prevent slumping and seepage. These modifications were not intended to increase overall capacity. Until 1980, most of the releases of waste water were small volumes, under 100 galllons (379 l) and were reported to the California Regional Water Quality Board (WQCB).

In February 1980 a heavy, 100-year rainstorm filled the ponds close to their capacity. A representative of Anon A called the WQCB on February 20, 1980, reported that the waste ponds were on the verge of overtopping the dikes, and requested permission to discharge some waste water to relieve the pressure on the dikes. The

300.65(a)(3) notification by permit holder alternatives were to; (1) allow overtopping of all ponds which might have resulted in a 40 million gallon (1.5×10^{10} l) discharge from complete dike failure, (2) discharge to the sewer system or (3) discharge the least hazardous wastewater to provide additional pond capacity into which one of the more toxic wastes could be transferred. WQCB believed the latter alternative to be the most desirable and it allowed the company to lower the pond level of the Fertilizer Pond by releasing 3.5 million gallons (1.3×10^{7} l) to the adjacent slough which emptied into the Bay. Following the discharge, a Cease and Desist Order was issued to Anon A to prevent future releases.

300.68(e)(2)(iv) environmental effects

Synopsis of Site Response

Anon A undertook two major site response actions following the February 1980 release and subsequent Cease and Desist Order to increase the capacity and integrity of its pond system:

300.68(c) responsible party clean-up

- About 75 million gallons (2.8×10^{10} l) of wastewater were pumped out of the fertilizer and pesticide ponds and trucked to approved Class I and Class II-1 landfills; and

300.70(c)(1)(2) offsite transport

- The dikes were reinforced by increasing their thickness and height, and an ASPEMIX cut-off wall was installed along the northern, western and southern dikes of West Pond in 1980, and around the Fertilizer Pond and Pond 2 in 1982.

300.70(b)(iii)(A) impermeable barrier

This report will focus on the ASPEMIX cut-off wall because of its innovative design and unique cost components.

The ASPEMIX cut-off wall is an underground wall composed of asphalt emulsion, sand, concrete and water. The ASPEMIX material is installed much like a grout curtain, with side by side injections, however, a vibrating beam on a 80-ton crane is used, similar to a pile driving operation. After vibrating a specially designed I-beam, approximately 17 feet (5m) long, into the ground and through the Bay Mud below, ASPEMIX is injected while the beam is withdrawn. Two-thirds of the dike perimeter cut-off wall have been finished. The final third is anticipated to be completed in 1983.

SITE DESCRIPTION

The Anon A site is located in northern California. The chemical manufacturing facility occupies about 140 acres (56 ha) and can be divided into two general areas that are separated by Street X (see Figure 1). The area southeast of Street consists of chemical manufacturing and storage facilities; and office facilities and occupies approximately 40 acres (16 ha). The remainder of the facility property is to the northwest of Street X and is occupied by a solar evaporation and wastewater treatment pond system and a fertilizer plant.

Surface Characteristics

The county in which Anon A is located can be divided into four geomorphic units based on differences in landform. These units are: (1) hilly to very steep uplands within the Coastal Range, (2) terraces, fans, and flood plains in the valleys, (3) river channels and delta overflow land and (4) tidal flats of the bays. The site property lies within the latter of these units, in what was once a tidal marsh, where the ground surface is approximately the same elevation as mean high water. Surface drainage in the vicinity of the site is west towards a bay which merges with the larger Bay. The smaller bay will be referred to as "the bay" in this report.

Historically, the evaporation pond area was dissected by numerous natural sloughs and man-made ditches through which surface runoff passed from the east to the bay. The main slough with which the other drainageways connected was located just north of the present-day fertilizer plant. Many of these former sloughs and drainage ditches influenced the layout and configuration of the 16 existing dikes. With the development of the fertilizer plant and the evaporation pond system, offsite surface drainage across the site has been diverted into constructed ditches that direct flow to Creek X which then drains into the bay.

300.68(e)(2)(i) extent of danger to public

The bay area is used by both city residents and the the wildlife inhabiting the area. It is used for recreation, navigation, and as an industrial water supply. In In addition, it is the habitat and resting area for waterfowl and migratory birds, a habitat for shellfish and part of numerous fish species' migration routes.

300.68(e)(2)(i)(E) climate

The local climate of the county is strongly influenced by both topography and its proximity to San Francisco Bay. The area adjacent to the bay, in which the site is located, is characterized by cool summers and mild winters. The influence of marine air is reflected in the moderate average July temperature of 62°F (16.7°C). The month of September brings slightly higher temperatures, with an average of 65°F (18.3°C). During the winter

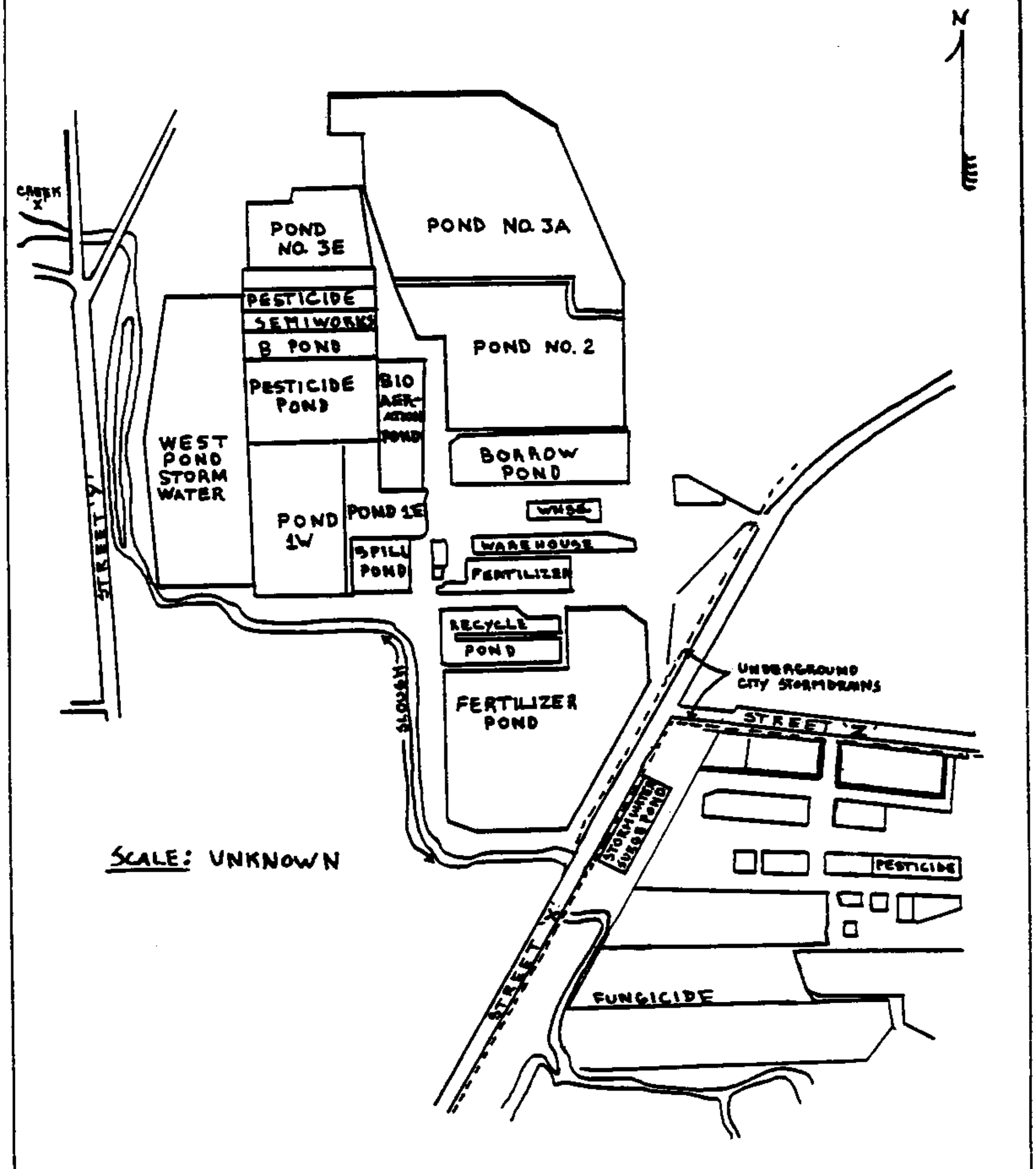

Figure 1. Anon A Facility Pond Locations

(Source: Anon A Facility, CA)

months, temperatures will average 50°F (10°C). The annual average temperature is approximately 58°F (14.4°C).

Late in the spring and through the summer season, coastal fog is common in the early morning hours in areas adjacent to the bay, usually clearing by midday. Winds are steady and generally prevail from a south-southwesterly direction, at velocities between 15 and 25 knots (24-40 km/hr) during daylight hours and decreasing to 10 knots (16 km/hr) or less in the evenings. The humidity during winter months averages about 90 percent at night and 70 percent in the afternoons. During the period from July to September the humidity is much less, averaging about 55 percent.

Precipitation in the area is highly variable, ranging from .05 inches (0.13 cm) during August to more than 5 inches (12.7 cm) in December. The average annual precipitation in the area is approximately 22 inches (56 cm) per year. It has been calculated that 1 year out of 25, the average rainfall will be 34 inches (86 cm) and 1 year out of 100, the rainfall will average 40 inches (1 m). This information is important in later discussions concerning wastewater pond capacity. Precipitation in the form of snowfall, rarely occurs in the lowland areas which include the tidal flats where the site area is located.

300.68(e)(2) (i)(D) hydrogeological factors

The soils in the site area are members of the Reyes series and are characterized as silty clays. The Reyes series typically consists of very poorly drained soils in saltwater marshes or tidal areas where there is regular inundation by high tides. The depth from the surface of a typical profile, is approximately 5 feet (1.5 m). The Reyes series soils are more commonly known as Bay Mud. Except for the pond locations on site, the Bay Mud in the area is overlaid by a placed fill material which ranges in thickness between 3 and 10 feet (.9 and .3 m). West of Street X the uppermost soil unit beneath the treatment and evaporation ponds is a dark gray silty clay that is rich with organic matter and is highly pervious. The thickness of the Bay Mud, which underlies the organic silty clay, in the area west of Street X, ranges from 2.5 (.76 m) feet below the east side of the Fertilization Pond, to 34 feet (10 m) below the south end of the site. The Bay Mud is not present east of Street X. In this area, the fill, instead, is directly underlain by alluvium and the soil-type is described as urban land.

Below the Bay Mud, there lies what is known as Older Bay Mud which is darker in color and stiffer in texture than the Younger Bay Mud. The thickness of the Older Bay Mud ranges between 2 and 6 feet (.61 and 1.8 m). The elevation in the vicinity of the site is at or near sea level and the slope is less than 1 percent. The soil is extremely moist and has a permeability between 1.4 10^{-4} cm/sec and 4.5 10^{-5} cm/sec.

The site is situated on the outskirts of a city's northwest boundary, with numerous other industrial facilities. The bay shore areas to the southwest and those that surround the the city have been used for industrial purposes for at least 80 years. Directly to the northwest of the site, Creek X is fed by another creek and the marshy areas to the north before entering the bay (see Figure 1).

Hydrogeology

The site is located along the eastern shore of a bay. The entire bay area is a drowned river valley within a northwest trending structural trough formed in Franciscan bedrock. The bay was formed when a block of bedrock, was tilted towards the east; the uplifted western edge of the block forming hills and the downdropped eastern edge creating the depression which is now Bay X. Subsequent to the downdropping of the block, material eroded from the eastern hills and was deposited in alluvial fans to form the gently sloping plain that borders the eastern shoreline of the bay where the site is located.

300.68(e)(2)
(i)(D)
hydrogeological
factors

There are four major geologic units that occur beneath the site area and they are listed below according to relative age, the youngest appearing first:

- Younger Bay Mud - clayey sandy silt and silty clay with organic matter and shells

- Old Bay Mud - stiff silty clay with sand and fine gravel

- Estuary deposits and alluvium - interfingering estuary and alluvial fan deposits of varying ages; silty and sandy clays with interbedded clayey gravels and gravel lenses

- Franciscan bedrock - sandstones and siltstones of the Franciscan formation.

Because the site is located near an inundated zone, in an area that is nearly level, the underlying subsurface conditions reflect even minor fluctuations that occurred in the bay water level in the way of extensive interfingering of alluvial material (sediments from the surrounding hills) and estuarine or marine sediments. The Bay

Muds are the most recent deposits in this alluvial-estuarine sequence. The Bay Mud units were described in the previous section on soils and will not be discussed again in this section. The following discussion concentrates on the alluvium and estuary deposits and Franciscan bedrock that lie below the Bay Mud.

The texture of the alluvium is variable, ranging from brown and grayish-brown silty clays to silty sands with fine gravel lenses. This variability reflects two processes that have taken place during the formation of the alluvial fans in the site area. The first process reflects the gradual erosion of the hills and slow deposition of the eroded sediments in a series of poorly sorted sheet wash deposits. Deposition of the coarser gravel and sands generally occurs in the upper part of the fan while the silts and clays are deposited along the fans' outer most flat-lying portions. The second process involves run-off flowing through channels across the fan surface transporting and sorting sediments, and storms carrying coarse sediment onto the fan's distal section.

The estuary deposits consist of brownish-gray to gray silty clays and clayey silts deposited in the quiet, shallow marine environment of the early bay. These clays are often calcareous and contain shell fragments. The estuary sediments at the site may also contain an alluvial component due to the site's proximity to present and past bay shorelines. Generally, a shallow, near-shore environment receives a large influx of alluvial sands and silts, which are reworked by tidal currents and benthic organisms.

The bedrock material underlying the alluvial-estuarine sequence consists of sandstones and siltstones of the Franciscan formation. It occurs at a depth of approximately 273 feet (83 m) at the northeast corner of the Fertilizer Pond, increasing in depth towards the northwest and the bay.

The alluvial deposits, consisting primarily of sands and silts with occasional gravel, constitute the principal shallow water-bearing strata. The estuarine deposits consist mainly of clays and organic clays and silts that have low to very low permeabilities. Therefore, potential ground water development for drinking water sources or industrial uses within the site area is limited. Presently, within the site area, there is only one deep well that was completed in the sand and gravel zones between depths of 100 and 170 feet (30.5 and 52 m) and is used for industrial purposes. Within a 2-mile (3 km) radius of the site, there are only two privately owned wells registered for domestic use. Both wells are located northeast of the site and were completed in sands and gravels at depths between 175 and 240 feet (53 and 73 m).

The site location can be hydrologically characterized as a regional discharge area. The principal source of recharge in the area are the hills to the southeast of the site. The predominant direction of ground water flow at the site is from the southeast to the northwest.

The water table is generally shallow over the site area, ranging between 2 and 8 feet (.61 and 2.4 m) below the ground surface. The height of the ground water table within the site area is greatly affected by the established network of drainage ditches mentioned earlier, in addition to the existing surface impoundments. The water table tends to be higher in the vicinity of both the drainage ditches and surface impoundments.

Within the sediments underlying the site, six main water-bearing zones have been identified, based on the interpretation of available geophysical logs and drill hole data. Four of these zones are within 200 feet (161 m) of the ground surface. All six zones appear to be continuous over the site and have higher permeabilities than the intervening silty-clay strata. The uppermost zone, 'A', consists of placed fill and the underlying Younger Bay Mud deposits. Potential usage of ground water within this zone is considered very limited due to the low permeability of the Younger Bay Mud deposits.

The five remaining zones exist at depths below this uppermost unit and consist primarily of sand-silt-gravel mixtures that are confined by clay strata. These units are discussed in order of increasing depth.

Zone 'C' consists of several large discontinuous sandy lenses within a silty-clay sequence. This zone extends from elevations -20 to -90 feet (-6 and -27 m) below sea level (BSL). The ground water in zone 'C' is moderately brackish and based on drinking water standards and chemical analyses, it is not considered potable.

The third zone, 'B', is relatively continuous and pnderlies the site between elevations of -100 and -130 feet (-30.5 and -40 m) BSL. The water within this zone is fresh and considered potable. The estuarine clay acquiclude layer bounding these zones is relatively impermeable and expected to act as a barrier to downward migration of contaminants.

The fourth zone, 'D', is also relatively continuous and occurs between elevations of -140 and -200 feet (-43 and -61 m) BSL. Like zone 'B' the water contained within this unit is considered potable and the zone is expected to be protected from downward migration of contaminants by the confining clay acquiclude.

The remaining two water bearing zones, 'D' and 'E', were not investigated during the hydrogeologic studies conducted on site, due to the depths at which they exist.

WASTE DISPOSAL HISTORY

As previously described, the entire evaporation pond area, which includes the wastewater treatment pond system and the fertilizer plant, lies within a former tidal marsh. Prior to the evaporation pond system development, the area was traversed by numerous natural sloughs and man-made ditches. Examination of an 1898 topographic map of the area indicates that the northern and eastern portions of the area were once pasture and farm land. In addition, a trash dump was located in the northwest corner of the site and extended into the area that is presently occupied by Pond 3A (see Figure 1). There appears to have been no other man-made modifications on site prior to the present-day facility's construction.

The fertilizer plant and evaporation pond system were constructed during the late 1950's and early 1960's. Pre-construction preparation of the plant area involved the removal of several feet of soft marsh deposits, followed by placement of compacted fill onto the underlying Younger Bay Mud. The plant foundation was then constructed in the placed fill. There are several parts of the facility in the western portion of the site that are supported by piles due to the thicker marsh deposits in this area. The ground surface throughout the plant area is presently at an elevation of +10 to +11 feet (3 to 3.4 m) above mean sea level.

300.68(e)(3) (iii) extent of adequacy of current containment barriers

The facility's pond boundaries are formed by dikes that were initially constructed with soils excavated from adjacent marsh areas. The initial elevation of these structures was between +8 and +10 feet (2 and 3 m) and they were probably less than 10 feet (3 m) wide at the base. Subsequent to their original construction, the dikes have been gradually enlarged, using borrow fill materials of varying composition. In September 1980, all perimeter dike embankments had been widened to at least 20 feet (6 m) at the base at an elevation equal to the planned maximum pond level which is +11 feet (3.4 m) for the majority of ponds. In addition, the pond side of all exterior dikes have 2.5 feet (.8 m) additional height to provide a minimum of two feet of freeboard against overflow by wind generated waves. In conjunction with construction activities to increase the height and thickness of the dikes to permit higher pond levels, steps were also taken to improve their stability and leakage resistance. These modifications are further discussed in a later section.

The facility's present disposal/evaporation pond system occupies 100 acres (40 ha) of land and has a total capacity of 150 million gallons (5.7×10^7 l). There are a total of 14 ponds in the system which are divided into six areas according to the waste-type contained in each. The six areas are listed and described below.

300.68(e)(2) (i)(B) amount and form of substances present

- Area 1: Fungicide ponds
  Includes evaporation ponds 1E, 1W, 2, 3A, and BA (bioaeration); total of 45 acres (18 ha) and used for treatment and disposal of carbamate fungicide wastewater consisting of primarily sodium salts and fungicide intermediates (THPA, THPI) with trace amounts of carbamate fungicide and solvents

- Area 2: Pesticide ponds
  Includes the "Pesticide pond" and ponds B and 3E; total of 11 acres (4.4 ha) and used for disposal of pesticide aqueous process waste containing salts, some heavy metals, and pesticides

- Area 3: Fertilizer ponds
  Recycle, evaporation, and borrow ponds cover 21 acres (8.4 ha); wastewater contains ammonium salts (primarily chlorides), sulfates, and nitrates

- Area 4: Storm water
  West Pond covers about 11 acres (4.4 ha) and receives rainwater runoff from the agricultural chemical manufacturing areas. Ponds 1W, 2, and 3A may also be used to contain storm runoff, as required. Constituents of stormwater runoff are a combination of materials contained in process waste streams from the various manufacturing areas in low concentrations

- Area 5: Spill pond
  The emergency spill pond covers about 1 acre (.4 ha) and is available for spill containment

- Area 6: Solid wastes
  Approximately 13,000 cubic yards of solid waste material from the bottom of an old evaporation pond that no longer exists were disposed along Pond 3E's southern boundary and along pond 3A's eastern perimeter.

DESCRIPTION OF CONTAMINATION

The possibility of surface and ground water contamination from the evaporation pond system is controlled by the following factors:

300.66(C)(2) (iii) assess most of the contamination migration potential

- Thickness and permeability characteristics of the natural sediments and/or man-made dikes and liners that confine and underlie ponds
- Hydraulics of the pond system, i.e., pond levels
- Local area weather conditions, i.e., wind velocity, precipitation
- Hydraulics of the near-surface ground water zone.

Although the evaporation pond system at the site had performed relatively well over the years, there were incidents which suggested that leakage and/or seepage had occurred in the past. There were two dike areas in particular that were cause for concern. One area was located along the west dike of West Pond and the other adjacent to the east and west dike of the Fertilization Pond. In the first case wastewater seepage was pumped from the adjacent drainage ditch, collected and returned to the pond. In the case of the Fertilization Pond, ammonia contaminated wastewater was detected in the sloughs that run along the south and west dike boundaries of the pond and within the storm drain that runs along the outside of the east dike of the pond (see Figure 1). Ammonia contamination was estimated to be limited to the pipe bedding material along most of the storm drain's length starting from the southern headwall, which is approximately 1,500 feet (457 m).

The potential hazard of lateral wastewater seepage was not considered high because the ground water flow gradient was away from populated areas and the low permeability of the underlying Bay Muds inhibited waste migration. However, it was not until February 1980, that the overall integrity of the site became a critical concern to the public and the facility's management. During the period February 20-22, 1980, 3.5 million gallons (1.3 x 10^7 l) of ammonia-containing liquid waste was discharged from the plant's fertilizer waste evaporation ponds in order to prevent overtopping of the ponds as a result of an intense rainfall.

WQCB staff quickly decided that the ammonia-containing fertilizer water should be discharged to the bay rather than releasing the pesticide contaminated pond water. Alternatives were limited. Either a controlled release was maintained or the dikes would have been topped and completely breached. If the latter was allowed to occur, the spill could have been as much as 40 to 50 million gallons (1.5-1.4 x 10^8 l). Biological studies were conducted to determine the effect of the spill on marine life in the bay by the State Regional Water Quality Control Board and the Department of Fish and Game. Results revealed no evidence of widespread fish kill due to the release. Rapid dilution minimized any potential damage. The WQCB's response to the spill incident was an enforcement action ordering that the waste evaporation ponds be upgraded to preclude any recurrence of the discharge. At the time the WQCB order was given, Anon A had already retained a consultant to conduct a site study. The objectives of the study were to: 300.68(f) investigation

- Define the ground water regime and water quality across the site and possible presence of contamination in subsurface soils
- Evaluate the integrity (permeability and stability) of the perimeter dikes surrounding the ponds
- Evaluate the permeability of the pond bottoms.

The study was completed in October, 1980 and a report was submitted to WQCB.

Using the results of this study, necessary actions were planned for improving the overall integrity of the evaporation pond system. Investigative findings directly relating to the release and seepage and leakage problems are discussed in the remainder of this section. 300.68(g) development of alternatives

The hydrogeologic study identified two usable sand-gravel aquifers beneath the site area. These units were referred to as zones 'B' and 'D' in the previous section on the area's hydrogeology. The two water bearing units are horizontally continuous and occur at approximate depths of 130 and 175 feet (40 and 53 m) respectively. Direction of flow of these water bearing zones is from southeast to northwest. The important feature concerning these two zones is that they are confined by low 300.68(f) investigation permeability (10^{-7} cm/sec) silty-clay material that acts as a barrier inhibiting downward migration of contaminants.

Contamination is absent within these two zones with the exception of manganese. The presence of manganese cannot be explained with existing information. The most shallow two water bearing zones, zone C and the ground water table zone, zone A, both contain non-potable water. The water is brackish and exceeds federal drinking water standards for salinity. The following constituents were detected in high concentrations in these zones:

- Total Dissolved Solids (TDS)
- Sulfate
- Chloride
- Arsenic
- Heavy Metals (Lead, Cadmium, and Selenium)
- Lindane (one occurrence in zone A).

Concentrations of ammonia, carbamate fungicide, tetrahydrophthalic acid (THPA) and tetrahydrophthalimide (THPI) were also detected, although not in quantities which exceed EPA limits. The areal distribution of arsenic, pesticides, and ammonia concentrations in the ground water samples are shown in Figure 2. Generally, higher concentrations were found around the treatment and evaporation ponds when compared to samples taken east of Street X, particularly in the northwest corner of the site. In summary, the uppermost two water bearing zones contain poor quality water which was initially non-potable due to its high salt content. The lower two aquifers have high artesian heads indicating that the silty-clay layers confining them are relatively impermeable (10^{-7} -10^{-8} cm/sec), thus inhibiting vertical leachate movement.

The hydrogeologic investigation indicated that downward movement of contaminants would be greatly retarded by the impermeable muds underlying the site, as well as the upward artesian pressure from the deeper aquifers, lateral movement in the upper water table zone could occur towards the bay, away from populated areas. The area of highest parameter concentrations appeared to be in the near-surface zone at the northwest corner of the site, where landfilled materials influence soil permeability. This area northwest of Pond 3A, as previously stated, was historically a trash dump. Two former sloughs had originally passed beneath the dikes in the northwest area of the sites. The permeable fill material in the

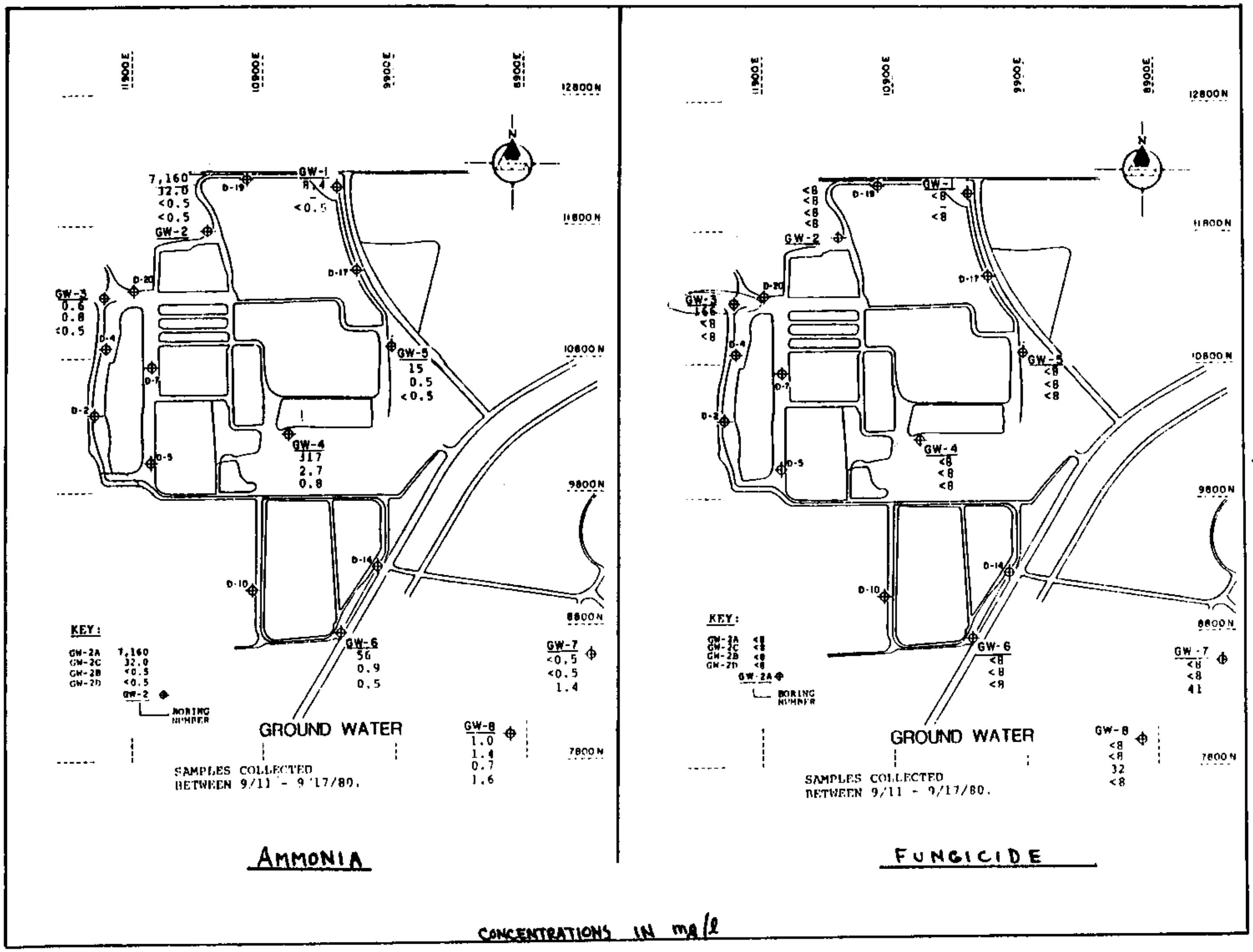

Figure 2. Groundwater Test Results (Source: Anon A consultant's report)

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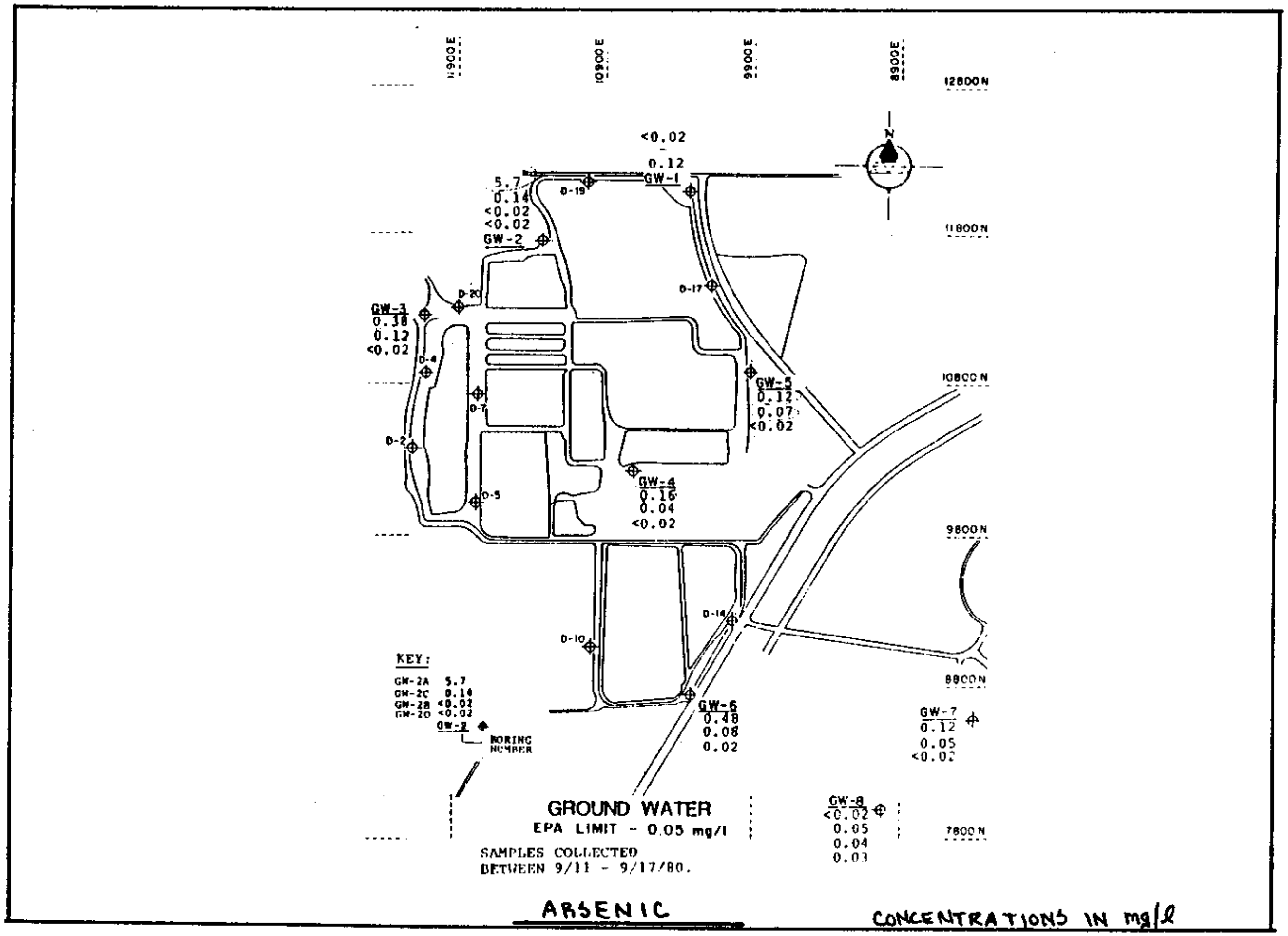

Figure 2. (continued)

sloughs could allow rapid movement of fluids through this corner area.

Laboratory soil chemical tests were conducted on soil samples collected at 18 locations in the site area. The soil samples were composites which incorporated the upper 10 feet (3 m) of each boring, typically in two depth increments of 0-5 feet (0-1.5 m) and 5-10 feet (1.5-3 m).

Analytical results indicated that only manganese concentrations exceeded EPA EP toxicity limits for solid waste. The samples tested were extracted from a boring hole located along the eastern boundary of Pond 2.

Ammonia was present in nearly all samples tested, with the higher concentration (115 mg/l) occurring in the area of a farmer depository for fertilizer materials. The areal distribution of ammonia concentrations in soil samples collected on site are shown on Figure 3.

Carbamate fungicide was detected in soils around West Pond, Pond 3B, the borrow pond, and along the northern boundary of the site as shown in Figure 3. The highest level found was 0.135 ppm which occurred in the area of the borrow pond. Small quantities of THPI were detected in most sample locations, along with concentrations of THPA. The highest THPA level was 0.123 ppm.

Arsenic was detected at most sampling locations, although no samples exceeded EP toxicity limits. The highest concentrations were found in the borrow pond area.

On the basis of the analytical results, the upper 10 feet (3 m) of soils in the evaporation pond area contain some significant concentrations of certain organic compounds, ammonia, and arsenic. However, within the group of parameters that have EP toxicity limits, only the limit for manganese was exceeded at one location and, as was previously noted, there is, to date, no valid explanation for its presence.

Two of the five most important factors affecting the potential for contamination in the evaporation pond area can be controlled by proper design and system operation specifications. These two factors are (1) the thickness and permeability characteristics of the man-made dikes and liners that confine and underlie the ponds and (2) the hydraulics of the pond system. With well designed and constructed perimeter dikes and liners and well planned operating procedures, the remaining three factors over which there is minimal control, i.e., (1) thickness and permeability of natural sediments, (2) local area weather

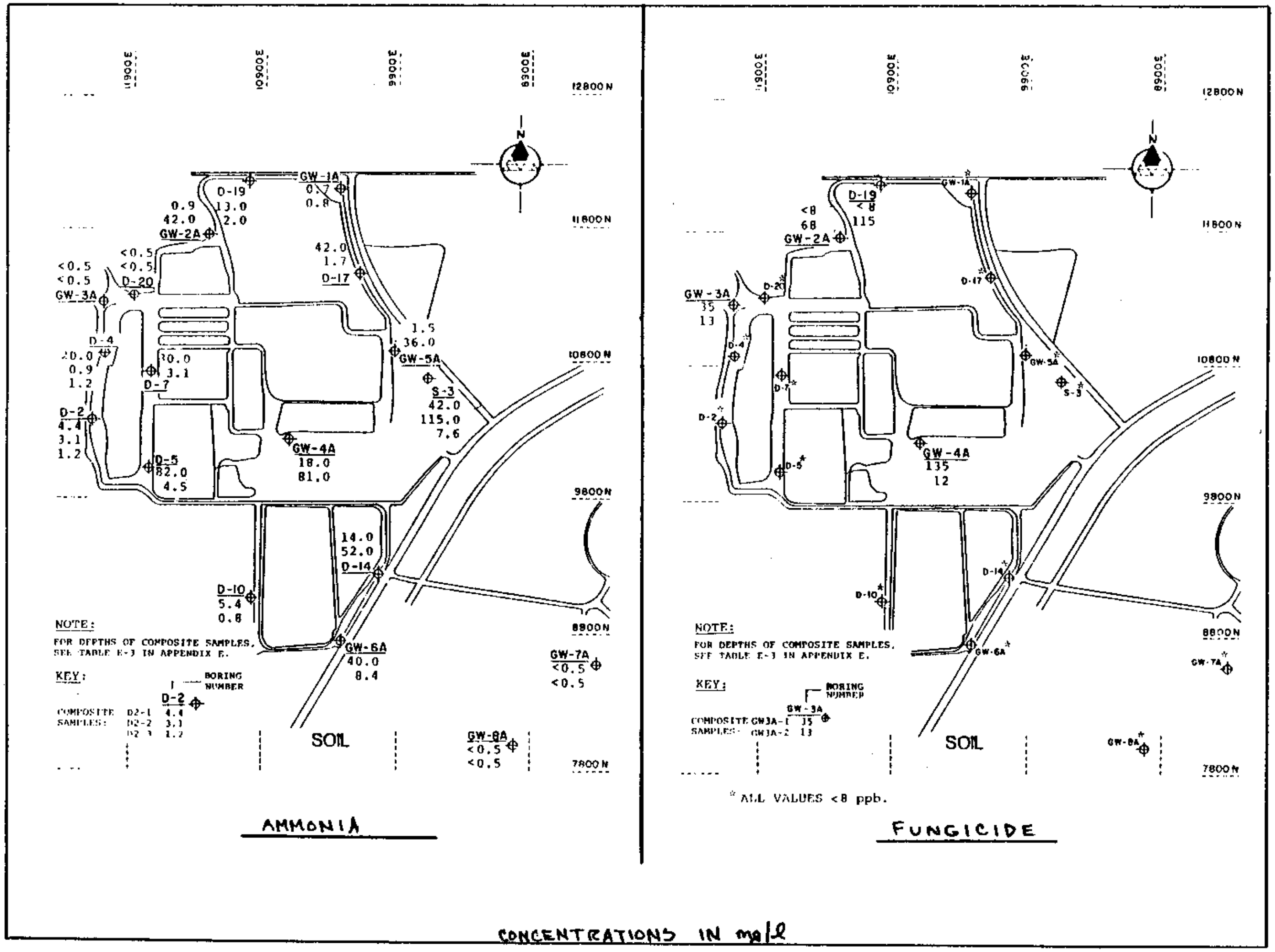

Figure 3. Soil Test Results (Source: Anon A consultant's report)

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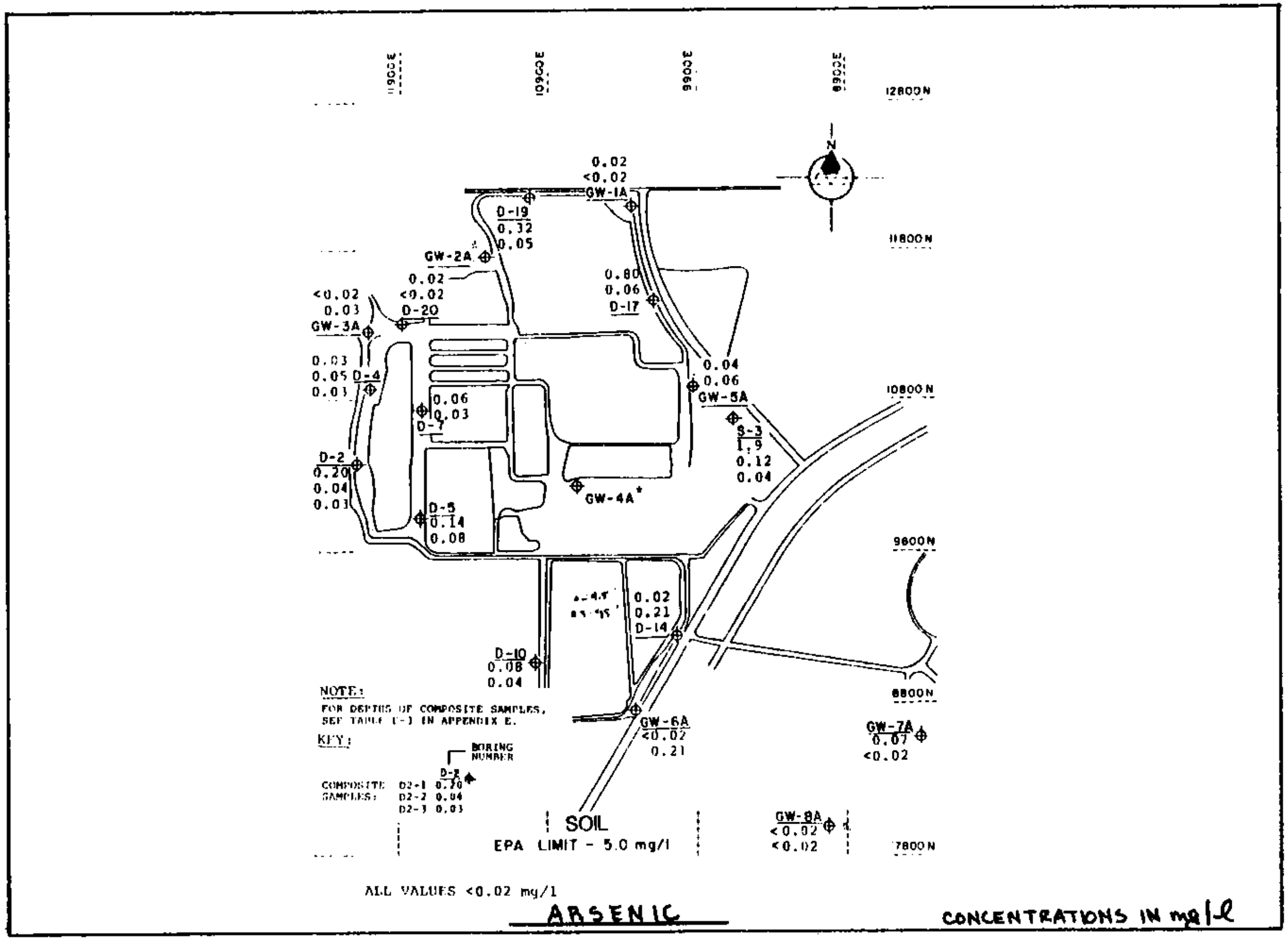

Figure 3. (continued)

conditions and (3) the hydraulics of the near-surface ground water zone; can be counteracted and a balance can be achieved, so that leachate migration is minimized.

There are several reasons for potential dike integrity problems at the site. Many of the perimeter dikes bounding the ponds were originally built using highly organic and peaty materials from marsh areas immediately adjacent to the dikes. These soils are typically quite permeable due to the open framework produced by the existing roots and decaying organic constituents. In addition, compaction of the dike material was probably the result of shrinkage from drying and later to traffic using the dikes as roadways. Sun and heat dried the mud, producing shrinkage cracks within the dikes that could become conduits for leakage. Since original construction of the evaporation pond system, perimeter dikes adjacent to the drainage ditch were blanketed with a clay layer that was intended to improve stability and reduce leakage into surrounding site areas (see Figure 4). Clay blanketing could have caused dike failures because of the need to trench down into the Bay Muds to create an acceptable seal. The resulting instability would then cause the dikes to fail in the direction of the trenches. To avoid this situation, only very short sections of dikes were trenched and blanketed at a time, minimizing the time a trench section remained open. This procedure helped minimize dike failure but created many more interfaces in the clay thereby increasing the potential of a poor seal within the clay lining. As a result, some sections of the clay liner have experienced seepage problems.

The next section will discuss the most recent and largest effort to improve the overall integrity of the pond system and to prevent the recurrence of the February 1980 chemical spill.

PLANNING THE SITE RESPONSE

Initiation of Site Response

Formulation of the final site response program began on April 2, 1980 when the WQCB sent a letter to Anon A directing it to submit a technical report by May 15, 1980 on upgrading the pond system to comply with Class I hazardous waste disposal facility standards. On May 15, 1980 Anon A submitted information on the scope of a study being undertaken by its consultants. On May 20, 1980 the WQCB adopted a Cease and Desist Order (CDO) that required Anon A to "achieve compliance with waste containment

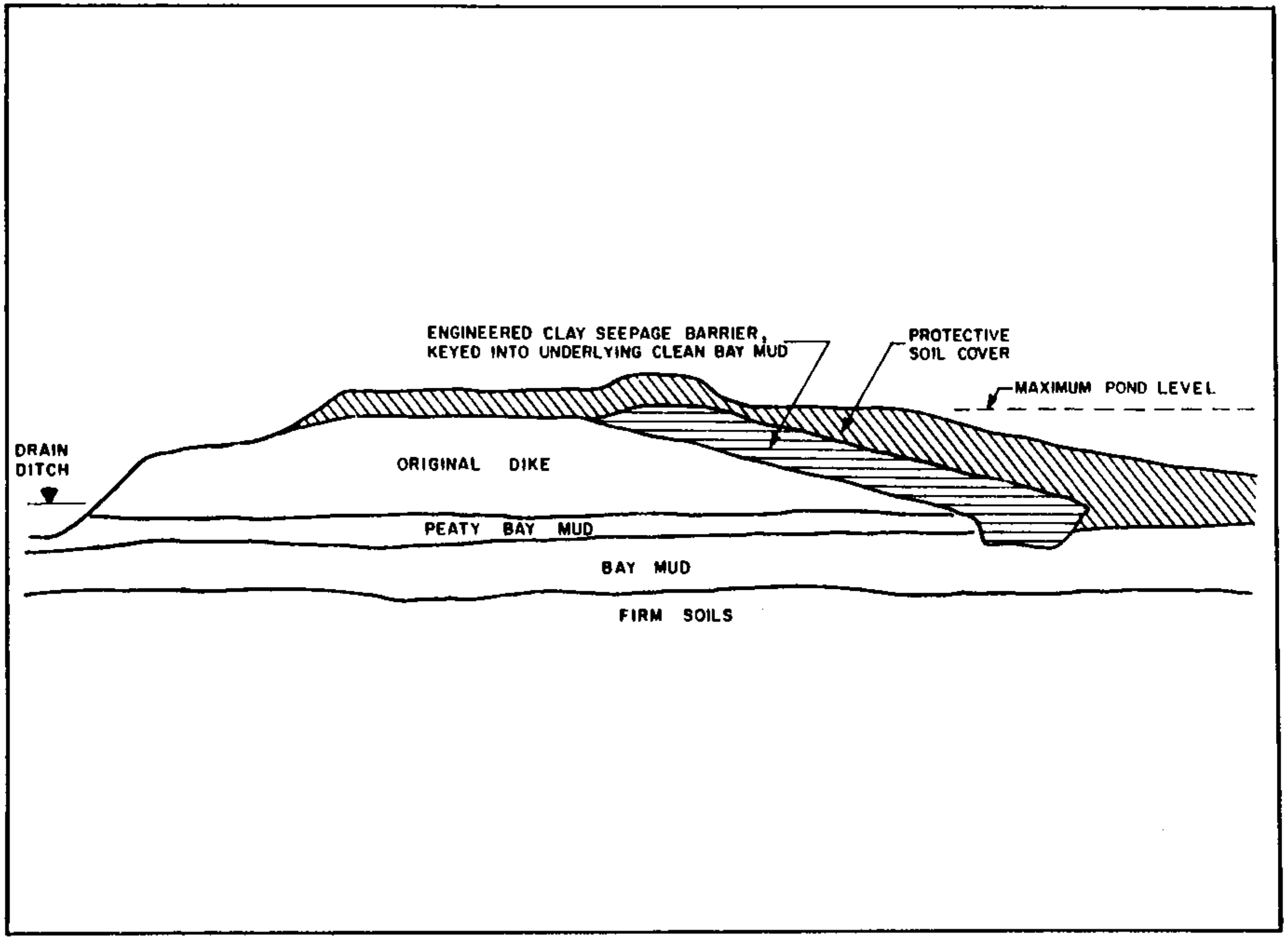

Figure 4. Schematic Cross Section Through Dike Showing Seepage Barrier
(Source: Anon A consultants report, 1980)

requirement by October 1, 1981", and study and report on the following items:

- The causes of the February 1980 discharge and overloading of the ponds
- An interim plan of action and commitment to implement the containment necessary to cover a 25-year rainfall during the upcoming winter rain season
- The scope and schedule for permanent improvements to the pond system, to comply with Class I standards.

This CDO provided the formal institutional framework for the interim response to prepare for the rain season of 1980-1981.

To comply with the Class I facility requirement of containing a 100-year rainfall, a WQCB engineer determined that the pond system would need an 87 million gallon (3.3×10^8 l) surge capacity. The particular methods and materials for attaining this surge capacity were worked out through discussions between the state, and Anon A and its consultants. Two general means were used for this interim site response. First, about 77 million gallons (2.9×10^8 l) of waste water were pumped out of the ponds anddisposed of at an immediate removal approved facility. Contingency for additional disposal was arranged with the facility by Anon A. Second, the perimeter dikes were upgraded by increasing their height and width, as well as installing an ASPEMIX cut-off wall on the outer sides of the West Pond. The installation of the ASPEMIX wall using the vibrating beam technique during the summer of 1980 allowed the WQCB and Anon A to assess its effectiveness so that they consider its use for the permanent improvements to be implemented in the future.

300.65(a) immediate removal

300.65(b)(6) immediate removal

300.68(e)(3) (iii) adequacy of barriers

The final site response, formalized in Waste Discharge Requirements on December 1, 1981, included two important directives that further shaped the final site response. The first general directive was that the disposal site should be upgraded to Class II-1 standards, not Class I standards as initially considered. This change was recommended by a WQCB engineer in an internal memo dated November 25, 1981 "because the wastes pose a low degree of hazard as concurred with by the Department of Health Services, Hazardous Materials Management Branch and since the site will be controlled regarding input and output, "i.e., no wastes generated outside the facility will be accepted and no discharge from the pond system to state waters will be permitted. Class II-1 designation will be sufficient for the containment of the wastes on-site in accordance with provisions set forth in the California Administrative Code, Section 2511 concerning Class II-1 disposal sites."

300.68(e)(2) (iii) State approach to similar situation

Second, the Order included a specific acceptance of the proposed use of the ASPEMIX cut-off wall for providing lateral waste containment. Permission for using the ASPEMIX cut-off wall was orginally requested in a March 30, 1981 letter to the WQCB. But, since tthe WQCB did not provide that acceptance by April 12, 1981 as requested by Anon A in order to construct during the dry season, the construction was not carried out in 1981. The CDO was amended to allow for a later completion date for installation. Officials of Anon A stated that they used the intervening year for testing to optimize the ASPEMIX material. The implementation of the formalized permanent site upgrading plan to bring the site into compliance with Class II-1 facility standards began in the summer of 1982 and is expected to be completed in the summer of 1983.

300.68(j) selection of alternative

Selection of Response Technologies

The WQCB worked with Anon A and its consultants to select the necessary response technologies that would bring the site into compliance with Class II-1 facility standards. The state waste discharge requirements for Class II-1 hazardous waste disposal facilities have two basic elements. First, the containment structures must have a permeability of less than or equal to 10^{-6} cm/sec. Second, no discharge to public waters is permitted. These were general goals used as criteria for selecting response technologies. The following section discusses the factors involved in the overall planning of the program and the selection of specific response technologies.

300.68(j) selection of alternative

The initial action taken in response to existing conditions at the Anon A site following heavy rainfall in 1980, was the disposal of approximately 74 million gallons (2.8×10^8 l) of wastewater to create pond system capacity. The operation was undertaken prior to the initiation of the site response program involving the installation of the ASPEMIX cut-off wall. Details of the disposal operation are discussed in the "Design and Execution" section.

The site response program involving the installation of an ASPEMIX wall was organized in response to a Cease and Desist Order issued to the facility by the WQCB, in

May 1980, following the February 1980 release. The Order consisted of items with which Anon A had to comply within a specified period of time. Items that were included in the Order were as follows:

- Provide adequate pond containment to prevent a recurrence of the February 1980 discharge.

- Permanently repair the west dike of West Pond

- Conduct a technical study of the site, and based on results, design and implement an improvement plan for the entire site, as needed.

The basic plan of action proposed by Anon A regarding the four points listed above entailed the following:

- Increase system's surge capacity to handle a 25-year rainy season

    - widen certain sections of dikes
    - increase pond evaporation rates
    - transport water off-site to extent necessary

- Contingency plan to handle rainfall up to a 1 in 100 year rainy season

    - take some pesticide ponds out of service and reserve them for excessive rainfall

    - transport water to offsite disposal sites during winter

- West Pond dike repair

    - use an asphalt seepage barrier wall

- Overall dike area improvements

    - would be based on consultant studies already underway.

The final actions taken to diminish the possibility of another chemical discharge as it occurred in February 1980, generally did not involve the upgrading of the dike areas and because the remainder of this report is focused upon the dike upgrading activities, the means by which the first two Order items were complied with, will not be discussed in any further detail.

As previously stated, the main area of concern at the time the Cease and Desist Order was issued, was the west dike of West Pond. The decision to use an asphalt seepage barrier wall resulted from careful examination of several alternatives. Table 1 describes each alternative considered, and the reasons for which it was either rejected or accepted in the Anon A site case.

300.68(h) initial screening of alternatives

An ASPEMIX wall was installed around West Pond to correct dike seepage problems. ASPEMIX was selected because it appeared to be both economically and technically superior to other alternatives.

In October, 1980, Anon A's consultants completed a report describing the on-site hydrogeologic investigation. This report contained evidence that there was a low-level ammonia contamination problem in the Fertilizer Pond slough and its tributaries. The source was identified as being the pipe bedding material along a 42-inch (107 cm) storm sewer drain that runs along the east side of the Fertilizer Pond. The extent of contamination was estimated to be along most of the pipe bedding length, amounting to about 1,500 feet (457 m) in total length. A dam-type structure was installed at the southeast corner of the pond to isolate the storm sewer and any seepage from the bedding material below it, from the main ditch (see Figure 5). Ammonia concentrations in the slough dropped significantly during the next 3-month period, November 1980 through February 1981. However, data collected over the period February 1981 to early May 1981 indicated that ammonia levels in the slough were again increasing. The rise and fall of ammonia concentrations continued over the course of the following year. In April of 1982, it was speculated that the most recent ammonia contamination in the slough was occurring due to the same encroachment problem that had existed along West Pond, i.e., the pond level was sufficiently high that wastewater was encroaching the protective clay cap that overlies the clay seepage barrier and directly seeping into the slough. In May 1982, action was taken to prevent further direct seepage into the slough from the pond. The action consisted of constructing a 150-foot (46 m) ditch along the west side of the Fertilizer Pond. The ditch acted as an interceptor trench and the seepage fluid collected was pumped back into the pond. This system, however, did not function properly, and during the summer of 1982, additional measures were taken and two dams were built at the southwest and northwest corners of the slough to prohibit further contaminant movement through the drainageway.

The ASPEMIX barrier wall technique was not officially approved by WQCB for the Cease and Desist Order until December, 1981. It was at this point that the facility

300.68(c) State evaluation of proposal

TABLE 1. ALTERNATIVE REMEDIAL TECHNIQUES FOR PERMANENTLY UPGRADING DIKE AREAS AT ANON A FACILITY

Remedial Alternative	Technique Description	Rationale for Rejection/Acceptance	NCP Reference
1. Bay Mud-Clay Dikes (Rejected)	Reconstruction of dike exclusively using Bay Mud	• Past record of clay-soil embankments on site not impressive; continual seepage/ leakage problems caused by clay shrinkage and cracking, and interfaces in the clay due to construction in short sections in order to minimize dike instability • Limited Bay Mud on site due to past recovery operations • Transport of clay from distant source would create lapses in placement or moisture content and could result in flaws in the seal • With decreases in moisture content, clay shrinks and develops cracks; when conditions are dry and pond levels dry, risk is great for cracking, especially along higher elevations of dike • Problem of dike stability during construction activities; dike failures inevitable • Length of time needed to complete would have been 2 years • Expense high due to length of time needed for completion	300.70(b)(1)(ii)(B)(1) surface water controls

(continued)

Source: JRB Associates

TABLE 1. (continued)

Remedial Alternative	Technique Description	Rationale for Rejection/Acceptance	NCP Reference
1. Bay Mud-Clay Dikes (Continued)		• Cost for the wall much less than a technique using clay . • Time required to install equal lengths of an asphemix wall and a clay based structure differ greatly; the ASPEMIX wall could be installed in half the time	
2. Wastewater Disposal (Accepted)	Disposal of 74 million gallons (2.8×10^8 l) of wastewater at appropriate facilities	• Most economically and technically feasible means of bringing pond system back into positive water balance and provide needed surge capacity	
3. Soil-Bentonite and Cement-Bentonite Slurry Trench Cut-off Walls (Rejected)	Construction of a seepage cut-off wall between dike and drainageway using the slurry trench technique; entails excavating a trench, using a slurry to keep the trench open and then backfilling with soil-bentonite or using the slurry, in the case of a cement-bentonite wall	• Bentonite mixtures incompatible with fluids in ponds • Possible site access problems, high water table and saturated ground conditions • Past experience manifested very little confidence in clay barriers of any type • High risk of dike collapse during trenching activities	300.70(b)(1)(iii)(A)(1) slurry walls (continued)

TABLE 1. (continued)

Remedial Alternative	Technique Description	Rationale for Rejection/Acceptance	NCP Reference
4. Interceptor Trenches (Rejected)	Construction of trenches between dike and drainageway in which any seepage would be collected and pumped back into pond system	• High water table produces potential dike stability problems • Site access problems due to saturated ground conditions • Higher potential for surface water contamination due to increase in volume of water surrounding ponds • Requires continuous maintenance	300.70(b)(1)(ii)(B)(2) surface water controls
5. Synthetic Liners (Rejected)	Placement of liners along inside of pond dike walls	• Pond system operations would have been required to stop while liners were emplaced • High potental for ruptures/punctures along liner seams • Great difficulty involved with installing liners in pre-existing facility structures	300.70(b)(1)(iii)(D)(3) liners

(continued)

TABLE 1. (continued)

Remedial Alternative	Technique Description	Rationale for Rejection/Acceptance	NCP Reference
6. ASPEMIX Wall (Accepted)	Installation of an ASPEMIX cut-off wall between dike and drainageway; the ASPEMIX is injected into the ground using the vibrated beam method; and consists of asphalt emulsion, sand, cement, and water.	• ASPEMIX is compatible with all pond fluids • Laboratory testing revealed permeabilities ranging between 10^{-13} cm/sec to 10^{-10} cm/sec. • The ASPEMIX wall is relatively plastic so as to resist cracking • Minimal maintenance required	300.70(b)(1)(iii)(A)(1) slurry walls

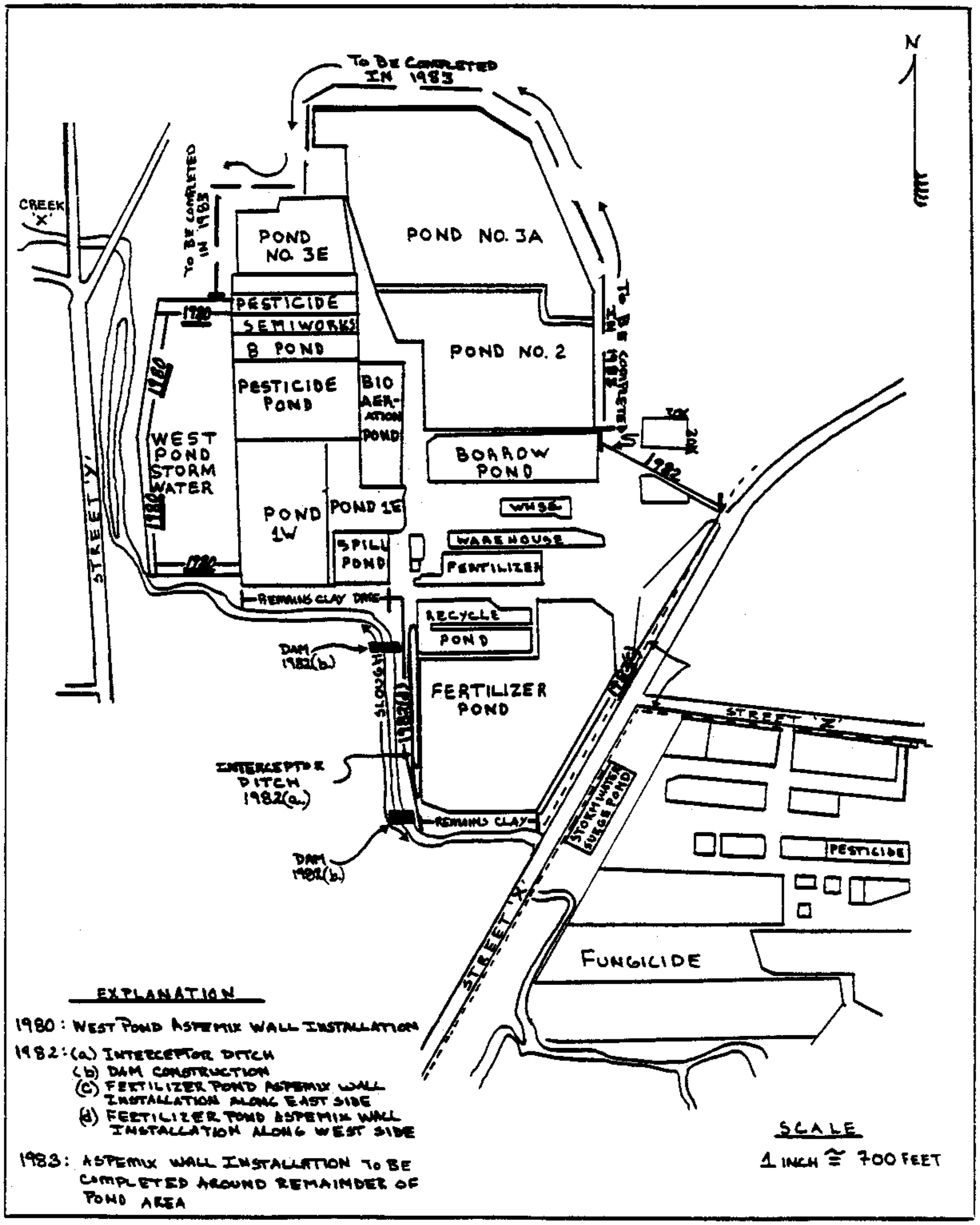

Figure 5. Sequence of Response Activities at Anon A Site

management finalized its plans to install an ASPEMIX wall around the remainder of the pond site with the exception of two relatively small areas. During the months of August and September, 1982, a wall was installed along the west and east sides of the Fertilizer Pond (see Figure 5). It was then projected that the remainder of the pond area would be secured with an ASPHEMX wall during the dry season of 1983.

Extent of Site Response

Although the site response program has not yet been completed as of January 1983, the extent of the site response was determined to constitute the work necessary to bring the site into compliance with the Waste Discharge Requirements for Class II-1 hazardous waste disposal facilities under the California Administrative Code, which were adopted for the site in December 1981. The two basic requirements for Class II-1 disposal facilities are that they allow no waste discharge to surface drainage courses or to usable ground water, and that they provide protection from discharge during a 100-year rainfall.

300.68(j) extent of remedy

300.68(c) administrative process

The waste discharge requirements for this site specifically stipulate that a containment structure must have a permeability of less than or equal to 10^{-6} cm/sec and the underlying Bay Mud into which the barrier wall is being keyed must have a permeability of 10^{-7} cm/sec. The California Class II-1 requirement to contain a 100-year rainfall, is based on the dike height and stability and the wastewater surge capacity with contingency plans for additional off-site disposal if necessary.

DESIGN AND EXECUTION OF SITE RESPONSE

The first response action undertaken at the Anon A site was the removal and disposal of 74 million gallons (2.8×10^8 l) of wastewater from the surface impoundment system. Because of the heavy rainstorms during 1981, a wastewater disposal operation was undertaken by Anon A to provide the needed surge capacity, and to bring the pond system back into a positive water balance. Wastewater was pumped into 5,400-gallon (20,439 l) tank trucks and shipped to approved disposal facilites. The disposal operation occured during the summer and fall of 1980 at a rate of over 100 truck loads per day, and was completed on October 16, 1980. The different wastewater types (e.g., fertilizer and pesticide wastewater) were disposed of at different facilities based on their hazard category and related statutory disposal category (see Table 2). Since the disposal operation was largely a straight forward

TABLE 2. WASTEWATER DISPOSAL OPERATION SUMMARY

Waste Type	Amount	Disposal Location
Carbamate fungicide wastewater	44.6 million gallons (1.7×10^8 l)	Collinsville, CA Class II-1
Pesticide wastewater	9.3 million gallons (3.5×10^7 l)	Martinez, CA Class I
Fertilizer wastewater	20.5 million gallons (7.7×10^7 l)	Unknown soil reclamation

pumping, hauling and disposal operation, the primary focus of this section is on the ASPEMIX cut-off wall.

The final compositional design of the ASPEMIX wall at the Anon A site resulted from the interplay of several factors. However, past experience with embankments consisting of clay materials had a major influence on the selection of a wall composed of a material other than clay. In the case of the Anon A pond system, the wall material selected is an asphalt mixture. The "ASPEMIX", as it is termed, is a combination of asphalt emulsion, sand, cement, and water. The exact proportion of each constituent that was used in the mixture(s) was determined through laboratory compatibility testing of various asphalt mixtures and existing pond fluids. Testing was performed over a period of 2 to 3 months. The asphalt mixture used around the different ponds is essentially the same, with slight variations depending upon the fluid contained within the pond.

The parameters involved in the structural design of the ASPEMIX barrier wall are: wall width, depth, length, and linear configuration. The depth to which the wall extends below the surface, the length and its linear configuration in the case of the Anon A facility were all dependent upon the pre-existing dikes, the geologic conditions, man-made structures (both surficial and subsurficial e.g., power lines, pipe systems) and the locations of the areas in need of repair. The width or thickness of the ASPEMIX wall was not dependent upon site conditions but rather was pre-determined by the width of the beam used for wall installation.

Construction of an ASPEMIX barrier wall requires the use of one crane suspended I-beam which is connected to a vibrator. The beam is locked in a guide frame for positioning purposes and stabilized by a hydraulic foot that provides guidance and aids in keeping the inserted beam vertical. The ASPEMIX material is mixed and contained within a small mixing plant at the rear of the beam rig and is injected through a set of nozzles located at the base of the vibrated beam (see Figure 6). At the completion of each panel, the rig is moved along the direction of the wall. Every injected panel is overlapped by the following insertion in order to ensure continuity of the completed wall. This process is repeated until the wall is complete. All wall installations required the use of one beam rig.

The first ASPEMIX wall at the Anon A facility was installed during the summer of 1980, along the north, west, and south boundaries of West Pond. The total time taken for installation was 6 weeks. Operations began in the northeast corner of the pond and progressed southward and around to the southeast corner where the wall terminates. The wall is approximately 2,000 feet (510 m) in length, 10 inches (25 cm) in width and extends to an average depth of 17 feet (5 m), passing vertically through the center of the dike along the outside of the clay seepage barrier (see Figure 7).

Pre-construction site preparation activities were often necessary. These activities most frequently involved widening the dike structures to enable the ASPEMIX rig to move along the top of the dike. Dike reinforcement involved extending the dike width to a minimum of 25 feet (8 m). This widening process was often selective due to the fact that some dike areas already had a minimum width of 25 feet (8 m). When the installation process was complete and the rig equipment removed, the dikes were then built-up to meet dike height requirements. Consolidation of the earthen material due to the weight of the equipment caused the lowering of the top elevation of the dike.

The actual wall installation process involved a great deal of testing and visual monitoring to ensure an effective barrier. The two most important and critical features of the completed ASPEMIX wall are; (1) the verticality and alignment of the beam-injected panels and (2) the uniform composition of the ASPEMIX across the wall. Verticality and precise alignment of the ASPEMIX panels is of great concern during and after installation, because without precise alignment the chances that gaps or windows remain within the wall are greatly increased. During installation along West Pond a general type of level device used to measure the angular displacement of the beam as it was driven into the ground.

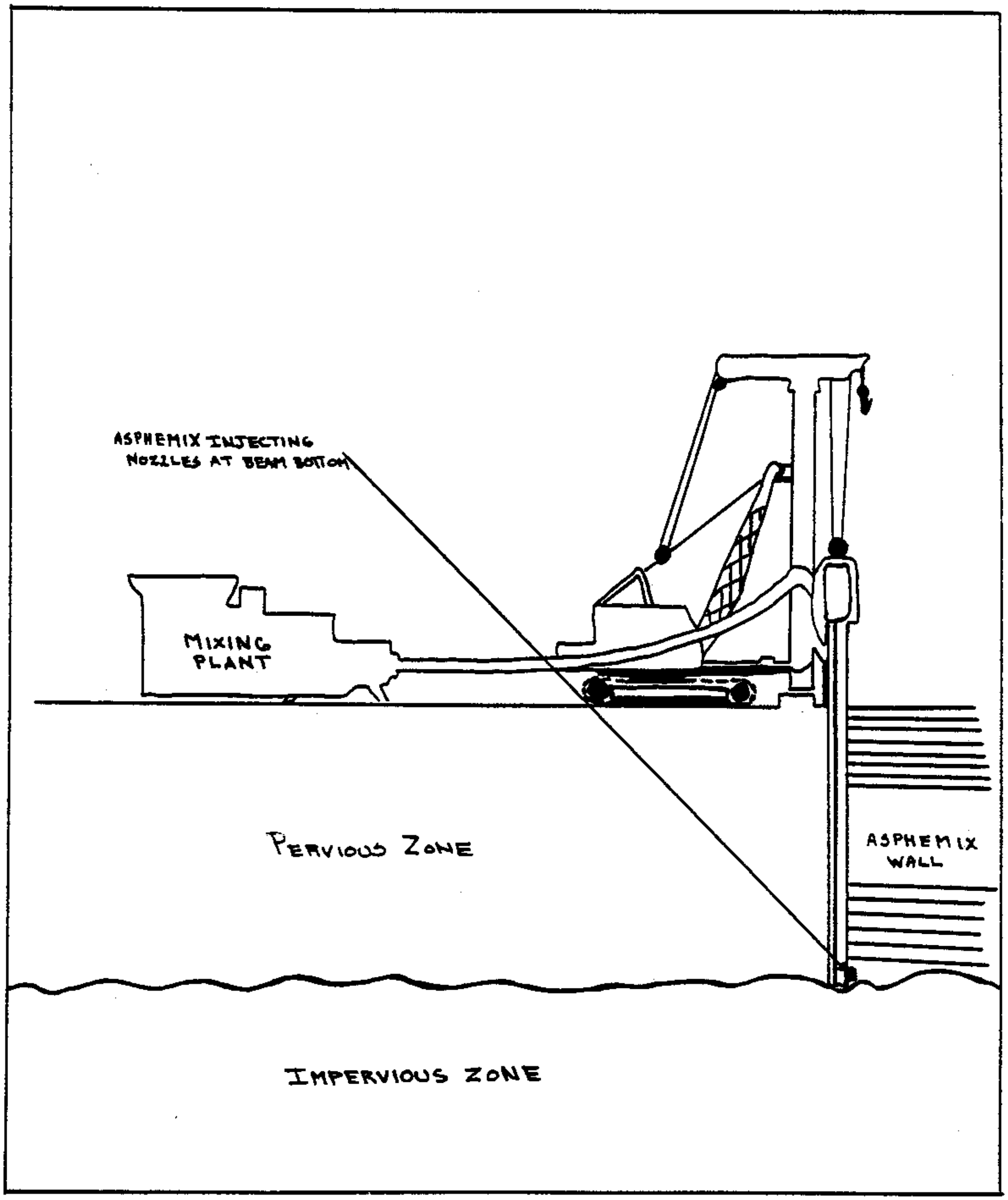

Figure 6. Schematic Diagram of the Asphemix Injection Beam Rig
(Source: Asphemix wall contractor product literature)

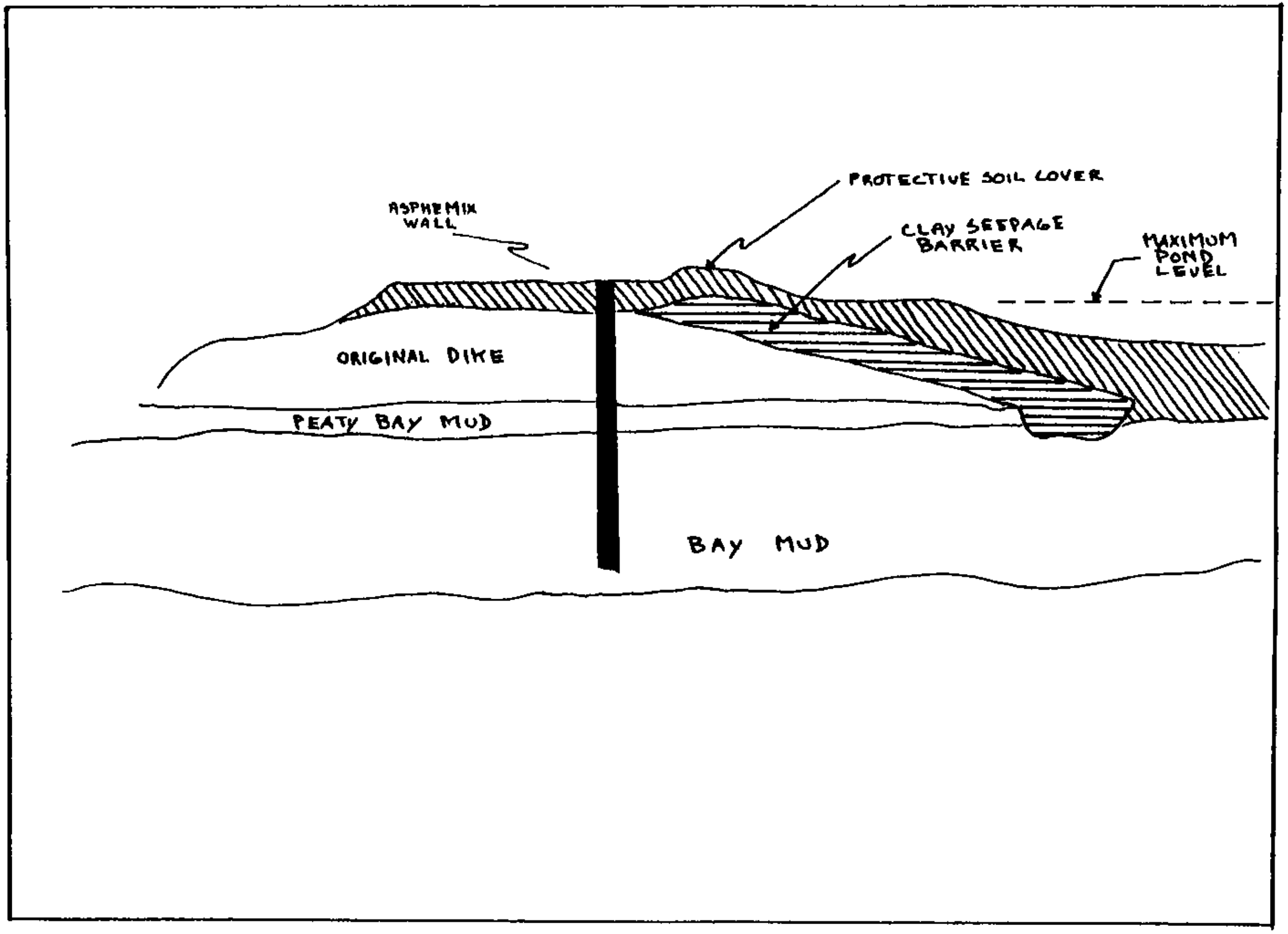

Figure 7. Schematic Cross Section Through Dike Showing Asphemix Wall and Seepage Barrier

In addition to beam verticality, there were several other parameters relating to the character of the ASPEMIX that required close monitoring during installation. There were five tests performed on the asphalt mixture to ensure that its consistency did not vary and they were as follows:

- Mix consistency
- Fluid content (asphalt and total moisture)
- Asphalt content
- Aggregate particle size
- Stockpile moisture content.

The first two tests (mix consistency and stockpile moisture content) were conducted as required; at times when, for example, material was brought in from a new source or the appearance of the mix was slightly different than what it should have been. The remaining three tests (fluid content, asphalt content and aggregate particle size) were each conducted twice daily. At the outset of installation activities, it was necessary to monitor these ASPEMIX characteristics as often as twice daily, however it was the overall belief that, with time, the variability initially observed in the ASPEMIX, over the course of a day, would lessen, and such stringent testing would be deemed unnecessary. This predicted decrease in variability, however, did not occur and consequently the original testing schedules were maintained.

As previously stated, the barrier wall installed around the exterior portions of West Pond terminates at the pond's southeast corner. The wall does not continue along the southern sides of Pond 1W and the spill pond (see Figure 5). These dike areas contain clay liners and there has been no evidence of seepage problems in these areas and therefore they were viewed as not requiring additional improvements.

The construction season or dry season of 1981 passed without any additional work being performed at the pond site. Prior to any further installation, it was necessary that the ASPEMIX wall technique be approved by the WQCB. The time lapse between wall installations was primarily due to the fact that WQCB didn't receive the site response plans from Anon A for review until March 30, 1981. The WQCB wasn't able to complete its review by April 12, as requested by Anon A in order to meet the 1981 dry season schedule. The technique was approved in December 1981.

At this point, final plans were made to continue the wall along the east side of the Fertilizer Pond (see Figure 5).

Installation of the ASPEMIX wall along the east side of the Fertilizer Pond began on July 15, 1982 and was completed on September 25, 1982. The total time taken for completion was approximately 6 weeks, the same time taken for West Pond. Although the same amount of the time was necessary for the two installations, there were differences between the two installation operations, and differences between the walls themselves. The Fertilizer Pond's east side wall is 2929 feet (893 m) in length, 17 feet (5 m) in depth, and about 10 inches (25 cm) in width. The wall extends from the southeast corner of the Fertilizer Pond, along the railroad track for approximately 2,200 feet (670 m), and then shifts west toward the southeast corner of the Borrow Pond where it ends. The approach taken during the design stages of the second wall were slightly different than those taken during the design of the West Pond wall. In the second case the facility management took command of the structural design and played a major role in the design of its composition. The facility management in agreement with their contractor, arranged for additional compatibility testing on various asphalt mixtures. During the design of the West Pond wall, the ASPEMIX testing was performed exclusively by the contractor. This degree of involvement on the part of facility management did not result from any particular problems. They believed that the additional testing would enhance the quality of the final product and its effectiveness.

Operations along the east side of the Fertilizer Pond were somewhat more complicated than those for the first installation due to the presence of powerlines, storage facilities, pipeways, and railways. Detailed wall design and construction planning prior to the actual installation were both critical in anticipating and avoiding problems and delays that could have been caused by these structures. Several facilities were relocated and underground pipeways and railways were moved. In addition, twice the entire fertilizer plant's power was shut off so that power lines could be relocated. Despite the extra construction activities necessary during the second installation and the additional 1,000 linear feet (305 m) of area to cover, the second installation was completed in the same amount of time as the first. The difference in completion time between the two operations was primarily due to the fact that during the Fertilizer Pond installation, both contractor and facility management were working with the experience gained from the West Pond operation and overall organization was greatly improved.

During the second operation two angular displacement measurement devices were initially used simultaneously. One device was a digital "tiltmeter" and the second instrument consisted of a laser guidance device. At a certain point during operations the use of the digital tiltmeter was discontinued due to the time-consuming process of using it which required that the beam be stopped for each reading. The improved laser device permitted the continuous operation of the vibrated beam, resulting in a faster rate of wall installation. The ASPEMIX testing procedures for both operations, were the same.

It was 6 days after the completion of the Fertilizer Pond's east side that installation activities began along the pond's west side. Installation on the west side began on September 1, 1982 and was completed on September 16, 1982. The west side wall is 1,173 feet (358 m) in length, 17 feet (5 m) in depth and approximately 10 inches (25 cm) in width. It extends from the northwest corner of the spill pond to the southwest corner of the Fertilizer Pond. An ASPEMIX wall was not installed along the south side of the Fertilizer Pond due to the fact that seepage problems were never observed along the south dike and that studies showed the clay liner to be intact.

All testing and monitoring procedures were similar to those undertaken during installation along the east side. There was one considerable difference between these two operations. During the west side installation, approximately two-thirds of the distance down to the southwest corner of the Fertilizer Pond where the wall was to end, the vibrated beam rig was relocated at the southwest corner and proceeded along the dike in a northerly direction. This change in direction was instituted due to the presence of an aerial powerline that ran perpendicular to the line of installation. Subsequent to the change in direction to avoid the powerline, the rig then moved northward to meet and connect with the earlier installed segment. Other than the single powerline, there were no further complications. The completion of the east wall ended the construction activities undertaken in 1982.

The remaining exterior dikes through which an ASPEMIX wall will be installed, include all the areas not yet discussed. The final wall to be installed will extend from the southeast corner of the Borrow Pond and will follow the dike areas north and then east to the northwest corner of West Pond. Construction activities for this wall's installation are presently scheduled to commence on July 1, 1983. The wall will be approximately 4,000 feet (1219 m) long, 17 feet (5 m) deep and 10 inches (25 cm) wide. The entire process is estimated to take about 6 weeks.

Initially the remaining unfinished areas were to be completed in 1982 following the wall installation along the east side of the Fertilizer Pond. There were problems with this proposal, however, due to high pond levels and saturated ground conditions along these dike areas. The greatest area of concern was the north side of the site. Directly north of this boundary lies a residential area.

There was concern that heavy equipment positioned on the saturated earthen embankments would cause a dike failure and possible pond release. The facility management felt that the risk of dike failure and its potential hazards from a dike failure was much too great to proceed as originally planned. For this reason the decision was made to complete the installation along the east side of the site and continue the remaining areas in 1983.

COST AND FUNDING

Source of Funding

The company paid for all projects costs which amounted to a total of $10,314,276.

Selection of Contractors

The environmental/engineering consulting firm was chosen for overall design and constructing management because of their previous 12 years of work related to the site. The general construction contractor was chosen for the cut-off wall installation because they were the only company with demonstrable experience with this type of cut-off wall. They also provided specialized equipment and expertise. A local construction company was subcontracted to perform the installation based on their capability and competitive price.

Project Costs

Cost information on the installation of the ASPEMIX cut-off wall during 1981 and 1982 and transportation and disposal of the wastewater during the 1980 is given below. The cost information was obtained verbally from the company and its contractors, no invoices were available.

ASPEMIX Wall

The total cost for the 103,734 square feet (9,637 m^2) of ASPEMIX wall and related construction during 1980 and 1982 was approximately $1.8 million. About $1.2 million, or 68% of this total was for the cut-off wall

300.70(b) (iii)(A) impermeable ground water barrier itself. The grading of a 25 foot (8 m) staging path on top of the dikes to facilitate the ASPEMIX wall construction, cost about $350,000. Utility alterations, including sewer and water line reconstruction, cost about $200,000.

The unit construction cost of the 17 foot (5 m) deep cut-off wall, excluding site preparation and material testing varied from about $7/square foot ($75/m^2) during the 1980 installation of about 2,000 linear feet (610 m) or 34,000 feet^2 (3,159 m^2), to about $14/square foot ($150/m^2) during the 1982 installation of about 4,100 linear feet (1,250 m) or 69,700 feet^2 (6,457 m^2). For most flat, unobstructed sites, costs for an ASPEMIX wall estimated by the contractor at about $5/square foot ($54/m^2). Two factors that resulted in increased costs for the Anon A site were:

- Labor costs in the area are relatively high. For example, according to the contractor, a crane operator on this job earned $38.28/hour compared to $10/hour in the Houston, Texas area. The average hourly labor cost was $28.50/hour compared to $5/hour in Houston.

- Equipment operation on top of the dikes was problematic and time consuming. Descending and remounting the dike was necessary for several utility obstructions. This cost would be insignificant with a flat staging area.

The low cost of $7/square foot ($75/m^2) for the 1980 installation was maintained at some loss to the contractor in order "to get a foothold in the area" market, and also because the 1980 section was relatively easier to install than the 1982 section. The unit cost for the final section in 1983 is expected to be about $8-9/square foot ($86-97/m^2), because of fewer obstructions and greater experience with installations through dikes. This unit cost will, however, depend on material costs at the time.

The component costs of the ASPEMIX wall installation were about equally divided between three categories: labor, equipment and materials. The daily equipment costs were about $2,000 (other component costs were inconsistently available or were claimed to be properietary). The major equipment costs were: 80-ton (73 Mt) crane - $600/day, vibratory pile drive assembly - $600/day, ASPEMIX mixing equipment - $500/day, and miscellaneous support equipment - $300/day. Mobilization cost was about $40,000.

The direct equipment costs for measuring the verticality and alignment of the beam during installation proved to be less important than the indirect cost resulting from their use. The laser unit cost more to rent than the Digitilt Tiltmeter, but was less time consuming to use. The laser alignment system rental cost was about $1,500-2,200/month. The monthly rental cost for the complete Digitilt Tiltmeter system, including a bore hole sensor and readout display with connecting cable and pulley assembly, was about $480-655/month. Despite its lower cost, the Digitilt Tiltmeter was discontinued because it was more time consuming to use than the laser system.

300.68(i) alternatives analysis cost

The quality control operation costs were greatly streamlined as Anon A gained confidence in the contractor. During the initiation of the construction, there were more inspectors on-site than laborers, but later the number of inspectors was reduced significantly as QC became a routine part of crew work. The QC testing for the composition of the ASPEMIX material was performed once a week by a local engineering firm for a total of about $20,000.

Future costs of the ASPEMIX wall at the Anon A site include construction of the final 4,000 feet (1219 m) around the northeast corner of the ponds (see Figure 2) and future monitoring. The monitoring system and its costs have not yet been established as of January 1983, but will be part of compliance with the site's waste discharge requirements as a Class II-1 disposal site. Assuming a unit cost of about $8-9/square foot ($86-97/m^2), the 17 foot (5 m) deep x 4,000 foot (1219 m) long cut-off wall or 68,000 square feet (6,317 m^2), will cost between $544,000 and $612,000. This would bring the total project construction cost to about $2.3-2.4 million.

Wastewater Disposal

The total cost for disposing of about 74 million gallons (2.8×10^8 l) of various types of wastewater during 1980 to provide extra surge capacity, was about $8.5 million. The wastewater disposal contingency plan for controlling surges during heavy rains was also used to a lesser extent during 1981 and 1982. But, since this subsequent wastewater disposal could not be quantified, the partial list of project costs was not summed in Table 3 to avoid the impression of a total project costs.

Because of its differing chemical characteristics, and correspondingly different disposal costs, the wastewater was separated into the following three categories: carbamate fungicide waste, pesticide waste and fertilizer waste. Disposal of this waste was on a per-gallon basis, which included both transportation and disposal. Costs are detailed in Table 3. The costs for pumping equipment and labor, and support logistics are not included because these activities were in-house costs for Anon A and could not quantified.

Pesticide waste was considered a State of California Class I hazardous waste and was disposed of at a properly licensed facility in Martinez, CA, about 15 miles (24 km) from the site. The total cost for disposal and transportation of 9.3 million gallons (3.5×10^7 l) of pesticide wastewater was about \$1.4 million. The unit cost for pesticide waste transportation and disposal was about \$0.15/gallon (\$0.04/l) or \$0.01/gallon/mile (\$.0024/l/km). The trucks held 5,400 gallons (20,439 l), hence the transportation and disposal cost was about \$810/truckload.

Carbamate fungicide wastewater was considered a Class II-1 waste, and was disposed of at a licensed facility in Collinsville, CA, about 50 miles (80 km) from the site. The total cost for the disposal of 44.6 million gallons (1.7×10^8 l) of carbamate wastewater was about \$5.2 million. The unit cost for carbamate wastewater transportation and disposal was about \$0.12/gallon (\$.03/l) or \$.0024/gallon/mile (\$.0004/l/km). The disposal and transportation for each of the 5,400 gallon (20,439 l) trucks was about \$648,000.

Removal of the excess fertilizer wastewater involved only transportation costs, because the water was trucked to a U.S. EPA subsidized land reclamation project at Veale Tract Farms in the Sacramento River delta area. At a unit cost of \$0.02-0.03/gallon (\$0.005/l), the transportation of 20.5 million gallons (7.7×10^7 l) of fertilizer wastewater cost about \$408,000-612,000.

The future costs for wastewater disposal include the removal costs for future surge capacity, as needed. This removal is part of the contingency plan for handling future rain storms beyond the pond system capacity, and was already used in 1981 and 1982 during heavy rainstorms.

PERFORMANCE EVALUATION

The effectiveness of the ASPEMIX walls currently installed at the Anon A pond site, to date, has been assessed only by means of visual inspection. No monitoring well data are currently available because the monitoring well system has recently been installed. The exterior portions of the dikes bounding the West Pond and

TABLE 3. SUMMARY OF COST INFORMATION-ANONYMOUS SITE "A", NORTHERN SAN FRANCISCO BAY AREA, CA.

Task	Quantity	Actual Expenditure	Unit Cost	Estimated Future Cost	Funding Source	Period of Performance
A. Total Waste Water (W.W.) Transportation and Disposal	Total: 74.3 million gallons (19.6 million l)	Total (c) $8.53 million	--	Unknown (a)	Anon A.	July-Oct. 1980
1. Pesticide W.W.	9.3 million gallons 15 miles (24 Km.)	($1.395 million)	15¢/gallon (4¢/l) 1¢/gallon/mile (0.2¢/l/km)	Unknown	Anon A.	July-Oct. 1980
2. Carbamate fungicide W.W	14.6 million gallons (168.8 million l) 50 miles (80 km)	($5.23 million)	12¢/gallon (3.2¢l) 0.24¢/gallon/mile (0.04¢/l/km)	Unknown	Anon A.	July-Oct. 1980
3. Fertilizer W.W. (b)	20.5 million gallons (77.2 million l) distance unknown	($408,000-612,000)	2-3¢/gallon (0.5¢/l)		Anon A.	July-Oct. 1980
. ASPEMIX Wall and Related Work	Total: 103,734 feet^2 (9,637 m^2)	Subtotal: $1,784,276	--	--	Anon A.	--
1. Dike grading	25 foot (8m) wide staging area as intermittently needed	($350,000)	--	--	Anon A.	Intermittent 1980 - 1982
2. Utility alterations	water, sewer and electrical work	($200, 000)	--	--	Anon A.	Intermittent 1980 - 1982
3. ASPEMIX Wall (d) Installation i) 1980 ii) 1982	34,000 feet^2 (3159m^2) 69,734 feet^2 (6478m^2)	($238,000) ($976,276)	\$7/foot^2 (\$75/m^2) \$14/foot^2 (\$150/m^2)	$544,000-612,000	Anon A. Anon A.	June-Aug. 1980 July-Sept.1982
TOTAL		$10.3 million				

(a) Future disposal is a part of the heavy rainfall contingency plan, and was used during winer 1981

(b) Transportation cost only, disposal was free at a U.S. EPA subsidized land reclamation project

(c) Excluding in-house pumping and logistical costs

(d) 17 feet (5m) deep

the Fertilizer Pond are, however, inspected regularly for any signs of seepage. The results of these inspections have been positive according to representatives from both the facility management and WQCB. Some of the most convincing evidence that the wall is performing as it should, is the absence of seepage fluids along the boundaries of West Pond, for it had been along these boundaries that the past seepage problem had been most prominent and visible.

In addition to the regular inspections conducted to ensure that there is no further seepage occurring along the drainageway, there is a test section of the ASPEMIX wall which can be inspected directly. The test section, approximately 30 ft x 30 ft x 6 ft (9 m x 9 m x 2 m) is separate from the seepage barrier and has been excavated such that a portion of the ASPEMIX wall is visible. This open section of wall will be used in the future for purposes of testing the ASPEMIX material to detect any degradation that might be occurring. In general, the asphalt-based mixture is resistant to most chemicals, and inorganic chemicals in particular pose no hazard to an ASPEMIX wall's integrity and containment capability. The overall consensus among those involved with the site's upgrading appears to be that the seepage problem has been arrested. Both the state and the facility management feel, however, that monitoring well data is necessary to make a complete assessment of the present conditions. A monitoring well system has recently been installed and includes a number of wells along the three existing walls. Only when monitoring data becomes available, will a complete and thorough assessment of the wall's effectiveness be possible.

The remedial work at the Anon A site is not yet complete due to the combination of the site's large size and the seasonal weather conditions in the area. The projected completion date for the remaining wall installation activities is estimated to be mid-August 1983. Meeting this deadline, however, will depend upon pond levels and ground conditions at the time when activities are to begin in July 1983.

The vibrated beam ASPEMIX method for constructing a barrier wall is a relatively novel technique and because it has not been extensively utilized for hazardous waste management, there are many questions relating to its ultimate effectiveness. Two of the greatest concerns with ASPEMIX wall installations are: (1) the vertical alignment of the beam-injected ASPEMIX panels and (2) the ability to key the panels into an impervious layer below (unless the waste to be contained is floating). As previously mentioned, it is extremely important to ensure that the individual panels are identically aligned and overlap one another. If, in fact, alignment is not identical and panels do not overlap, gaps or windows will remain within the wall. These windows can then act as conduits for seepage. To minimize the potential for such openings, the process of lowering the beam into the ground during installation must be scrutinously monitored and checked. This aspect of the installation process is of utmost importance and must be ensured. To provide assurance against potential openings in the wall, the ASPEMIX walls at the Anon A site were installed under strict specifications and monitoring requirements. To complement the contractor's specifications and provide extra confidence in the final product, Anon A designed and implemented additional process monitoring requirements.

The second concern involves the ability to key or tie the wall into an impervious layer below. A barrier wall that is not continuous with depth is of little use in a situation where contaminants are able to migrate downward. The key-in of a wall is not a concern if the waste is less dense than water and floats on the water surface. This aspect of a wall installation , the key-in, in the case of the Anon A site, however, was not a major concern due to the presence and extent of the Bay Muds below the site. The subsurface conditions at the Anon A site are, in fact, probably the most desirable for an ASPEMIX wall installation because clays are relatively impermeable and easily penetrated, allowing the undisturbed passage of the beam into the ground and easy injection of the ASPEMIX.

There are numerous site scenarios in which the ASPEMIX barrier wall may not be applicable and prior to any decision, a variety of factors must be considered. The waste type(s) to be contained is a major consideration in deciding whether or not to install an ASPEMIX wall. Asphalt is resistant to most chemicals, e.g., inorganic chemicals, dilute acids, lower alcohols, glycols, and aldehydes. However, it is not compatible with concentrated mineral acids, polar, and non-polar solvents, and chlorinated, aliphatic and aromatic hydrocarbons. Ketones will also affect asphalt, and phenols may induce slow degradation. These are only general guidelines and any remedial action selection process should entail an extensive compatibility testing program prior to a final decision.

Another factor which can ultimately limit the applicability of an ASPEMIX wall at a particular site is the site's geologic environment. Subsurface conditions are critical for several reasons. In order to lower the vibrated beam into the ground the subsurface materials must be granular in nature. It is virtually impossible to penetrate hard materials with a vibrated beam. Boulder sized rocks are also cause for problems during installation. The other point to be made concerning geologic conditions involves the issue of the wall key-in with an impervious layer. The optimal conditions for this requirement are those found at the Anon A site i.e., the existence of penetrable and impermeable clays. In most scenarios, the wall must be keyed into a relatively impermeable layer, however, an impervious layer that is impenetrable may produce problems in ensuring that the wall is, in actuality, keyed-in. There is no method available with which to monitor whether or not the ASPEMIX wall forms a seal at depth. Grouting any open areas between the wall bottom and the impervious layer is not as easy a solution in the case of an ASPEMIX wall as it is, for example, in the case of a bentonite slurry wall because it is not possible to grout through an ASPEMIX wall. It is possible, however, to inject grout along the sides of the wall.

The effectiveness of an ASPEMIX wall in a particular situation, as with any other remedial measure, reflects the extent to which the site conditions and remedial options have been investigated and thoroughness with which these are understood. Depending upon the site scenario, an ASPEMIX wall can either be highly effective or it can be entirely wrong approach to the problem. In the case of the Anon A site, to enclose most of the pond area with an ASPEMIX barrier appears to have been, from a technical standpoint, the most appropriate choice, and appears to be performing as anticipated with no reason to believe it will perform any differently in the future.

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ANONYMOUS SITE B

NORTHERN CALIFORNIA

INTRODUCTION

NCP Reference

A large chemical company operates a manufacturing and packaging plant in northern California. In the fall of 1979, Company officials learned of complaints from neighboring firms of bad-tasting well water. Additionally, Company officials noted an unexpected dry-season water discharge into a nearby bay from a storm drain at the plant. The discharge was analyzed and found to contain herbicides. Subsequently, the Company tested ground and well water and discovered that, while contamination of neighboring wells was not detected, ground water below part of the plant's wastewater treatment system was contaminated with solvents and several herbicides. The Company reported the problem to the appropriate state officials.

Background

The Company has operated at the site for over 80 years, manufacturing and packaging industrial chemicals, and pesticides. The site is directly adjacent to a bay, in a heavily industrial urban area. In 1971, the Company constructed a system to collect and treat rainfall run-off and rinsewater from the plant's chemical handling areas. The system included a series of tanks, ponds, carbon columns, and a 300-foot-long (91 m) underground chemical drain connecting a tank to a pond. For part of its length the chemical drain closely paralleled a storm drain and a sanitary sewer beneath Avenue "X". (See Figure 1) After conducting a number of test borings along and between Avenues X and Z in autumn, 1979 and finding toluene and various herbicides in shallow ground water, Company geologists concluded that the sources of contamination were: seepage from the chemical drain; a buried "skimmer tank"; a number of small chemical spills; and possibly an unlined evaporation pond.

In January 1980, the Company presented their findings to the State. Over the next six months, Company and State officials further investigated the nature and extent of contamination and reached an agreement on response measures that the Company was to take.

Synopsis of Site Response

Between August and November of 1980, the company took three measures to reduce contamination at the site, including: installing a subsurface interceptor drain, taking out of service and decontaminating the skimmer tank, and replacing the 300-foot (91.4 m) chemical drain. The interceptor drain, or "French drain", was the major element of the response. The drain is 261 feet (80 m) long, and 12 to 17 feet (3.6-5.2 m) deep. It is filled with gravel and contains a perforated pipe at the bottom which drains into a sump. Intercepted contaminated water is pumped from the sump through the chemical drain to the same carbon treatment columns that treat the plant's wastewater. The Company decommissioned the skimmer tank by removing sludge, rinsing the tank, perforating it to allow ground water to fill it, filling it with gravel, and capping it with soil.

SITE DESCRIPTION

Site B, located in northern California, is situated along the tidal flats of a bay in an industrial center. It is approximately 82 acres (32.8 ha) in size and is within 1500 to 2000 feet (457-610 m) of private residences. Figure 1 shows a schematic diagram of Site B.

Surface Characteristics

The region in which Site B is located maintains an average annual temperature of 59°F (15°C). The frost-free season is 260 to 300 days and the average annual precipitation is 14 to 22 inches (36-56 cm). 300.68(e)(2)(i)(E) climate

The site itself is relatively flat with elevations at or near sea level in some places and between 10 and 20 feet (3.0-6.0 m) in most. The southern and eastern portions of the site lie along marshland, while the southernmost boundary is adjacent to a mudflat located in the bay.

The soils at the site are predominantly classified as Urban Land, while those in the southeastern corner are classified as Reyes Silty Clay. These are small areas where 20 to 40 inches (51-102 cm) of silty clay loam or loams have been deposited. Generally, the entire site is of the Clear Lake-Cropley Association. These soils are nearly level to gently sloping, very poorly drained, and

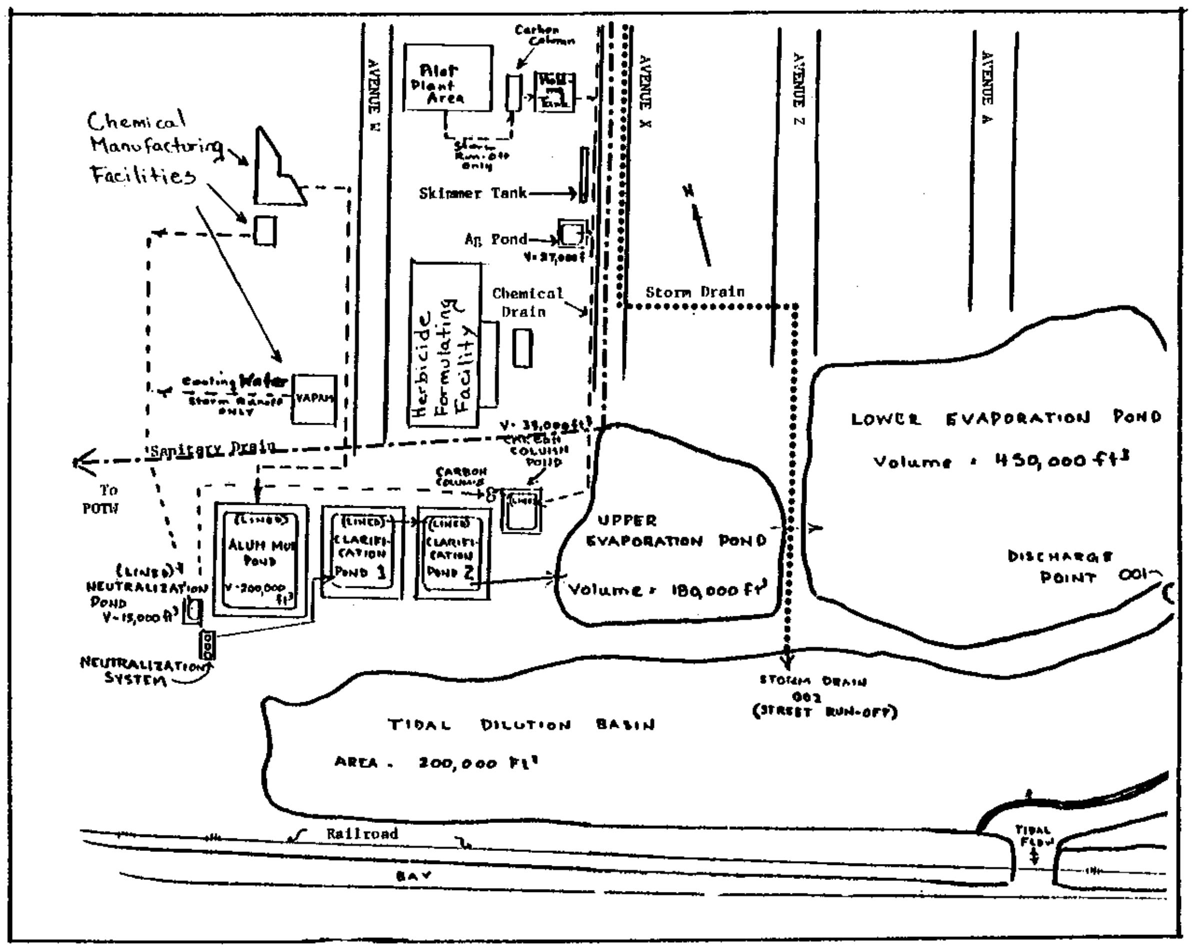

Figure 1. Anonymous Site B Schematic Diagram
(Source: California Regional Water Quality Control Board, 1982.)

moderately well-drained clays on valley fill and in coastal valley basins. Hence, permeability is slow and available water capacity is 0.5 to 3.0 inches (1.3-7.6 cm). Runoff is very slow, therefore there is no hazard of erosion. Some areas are, however, subject to inundation during high tides. Thus, the soils are moist and the water table is high to very high. Vegetation in this area includes pickleweed, saltgrass, and some sedges.

Hydrogeology

300.68(e)(2)(i) (D) hydrogeological factors

A hydrogeologic investigation of the site included soil auger borings and installation of ground water monitoring wells in the areas shown in Figures 2 and 3. These studies revealed that surficial fill materials, as thick as 2 feet (0.6 m) in some instances, overlie a 3 to 4-foot (0.9-1.2 m) thick plastic to very firm and dark gray clay layer. This clay layer eventually grades through a 2-foot (0.6 m) interval into a light gray silty clay. This light gray silty clay contains some pebbles and streaks of white, crumbly sand. It is underlain by a yellow-brown, clayey fine sand that is very clayey and firm at the top and gradually becomes less clayey (as the sand and/or pebble content increases) with depth. The upper clayey interval is usually moist but not saturated. The thickness of this layer of clayey sand and gravel is variable, ranging from a few feet to approximately 20 feet (6.0 m). The next layer which underlies the clayey sand and gravel layer is a very firm, unsaturated silty clay layer. The water bearing zone is therefore, only a few feet thick and confined at both the top and the bottom by unsaturated clayey beds.

Cross sections of some hand auger borings taken on Avenue X are shown in Figure 4. As these cross sections show, the subsurface materials are predominantly fine-grained with some coarser material. The horizontal distribution of the coarser material varies at the site. Very little coarse material is found north of Avenue Y (see Figure 2). A gravel and coarse sand zone however, does exist in a southeast-northwest trend from the skimmer tank area. This area is characterized as a fine clayey sand with gravel lenses separated from other gravel lenses by the fine clayey sand.

Ground water level elevations were determined for Site B from October 1979 through December 1980. The ground water levels for representative Wells 2 and 10 are shown in Table 1. It is important to note that the levels shown from August 1980 and beyond represent the ground water levels that were present once the remedial action of ground water pumping at Site B had begun. As Table 1

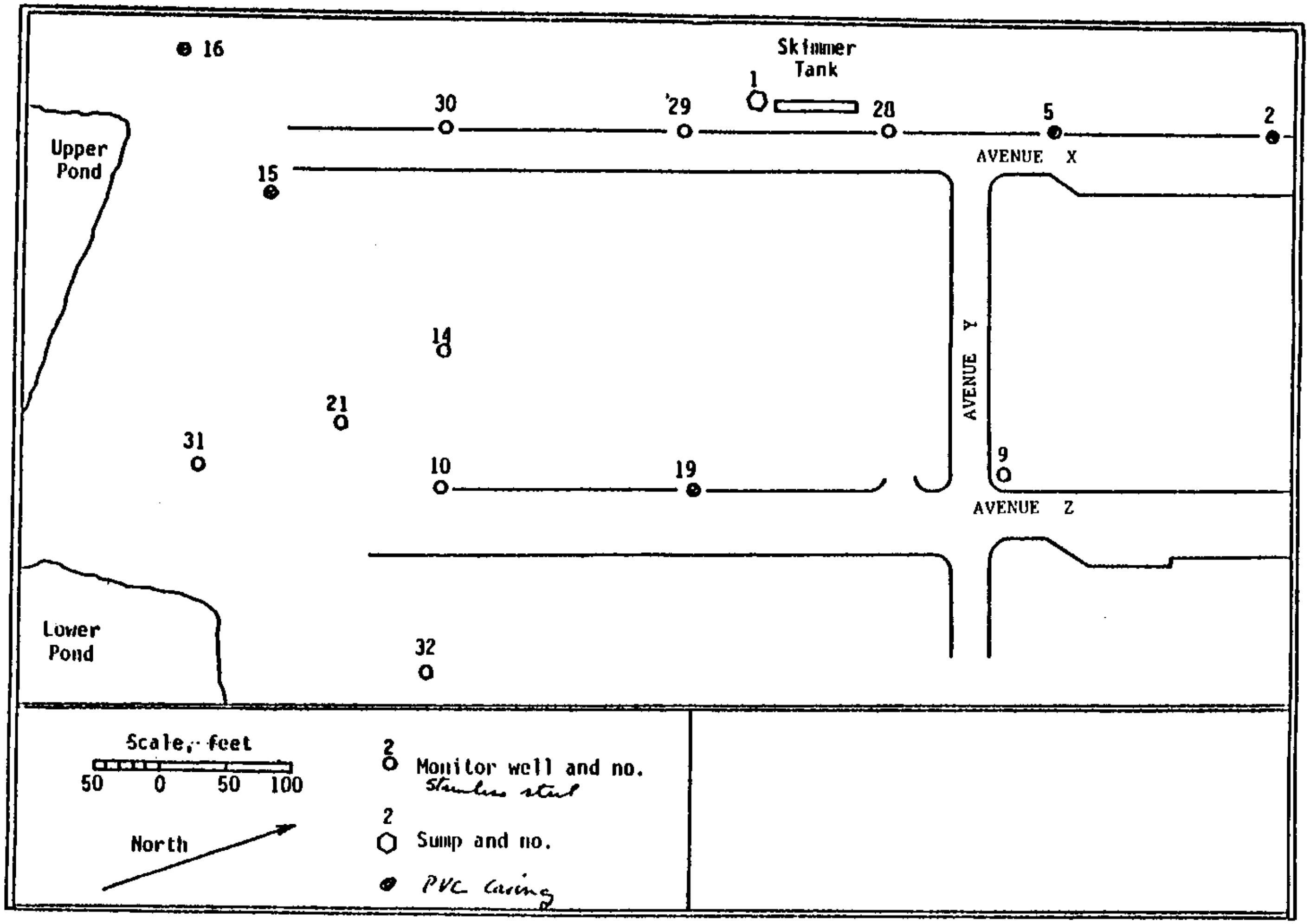

Figure 2. Anonymous Site B Ground Water Monitoring Well Locations
(Source: Anonymous Site B Company Geology Department, 1980.)

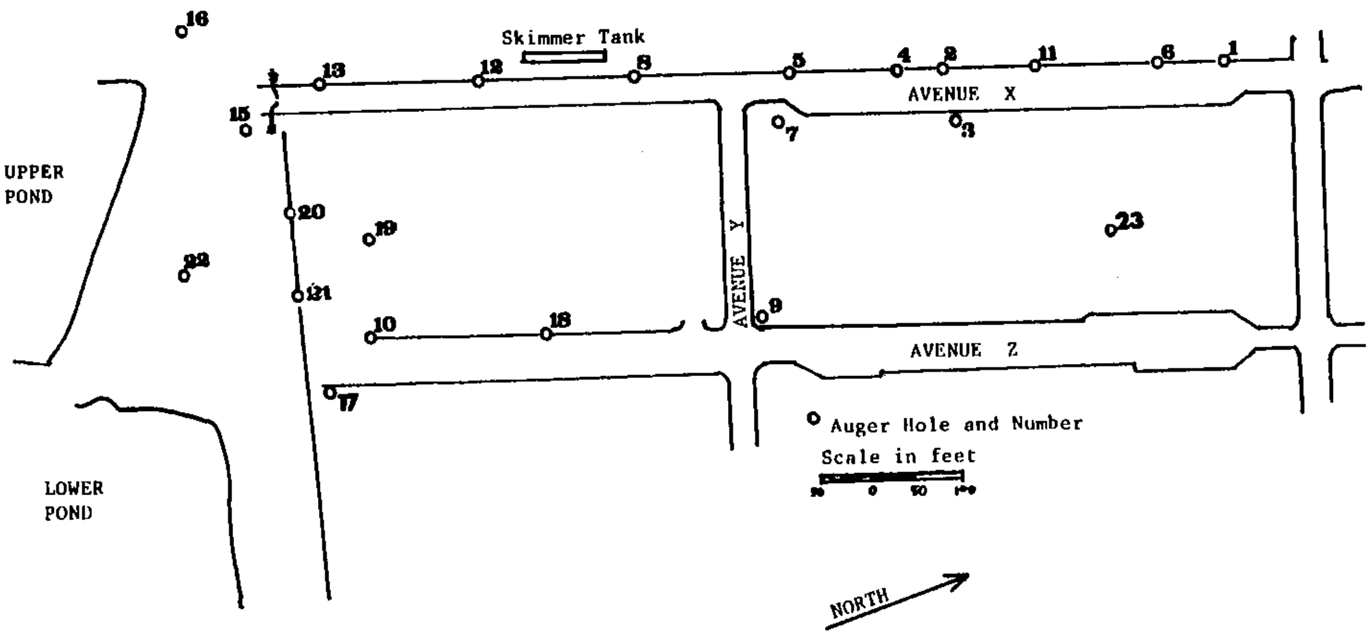

Figure 3. Anonymous Site B Auger Boring Locations
(Source: Anonymous Site B Company Geology Department, 1980.)

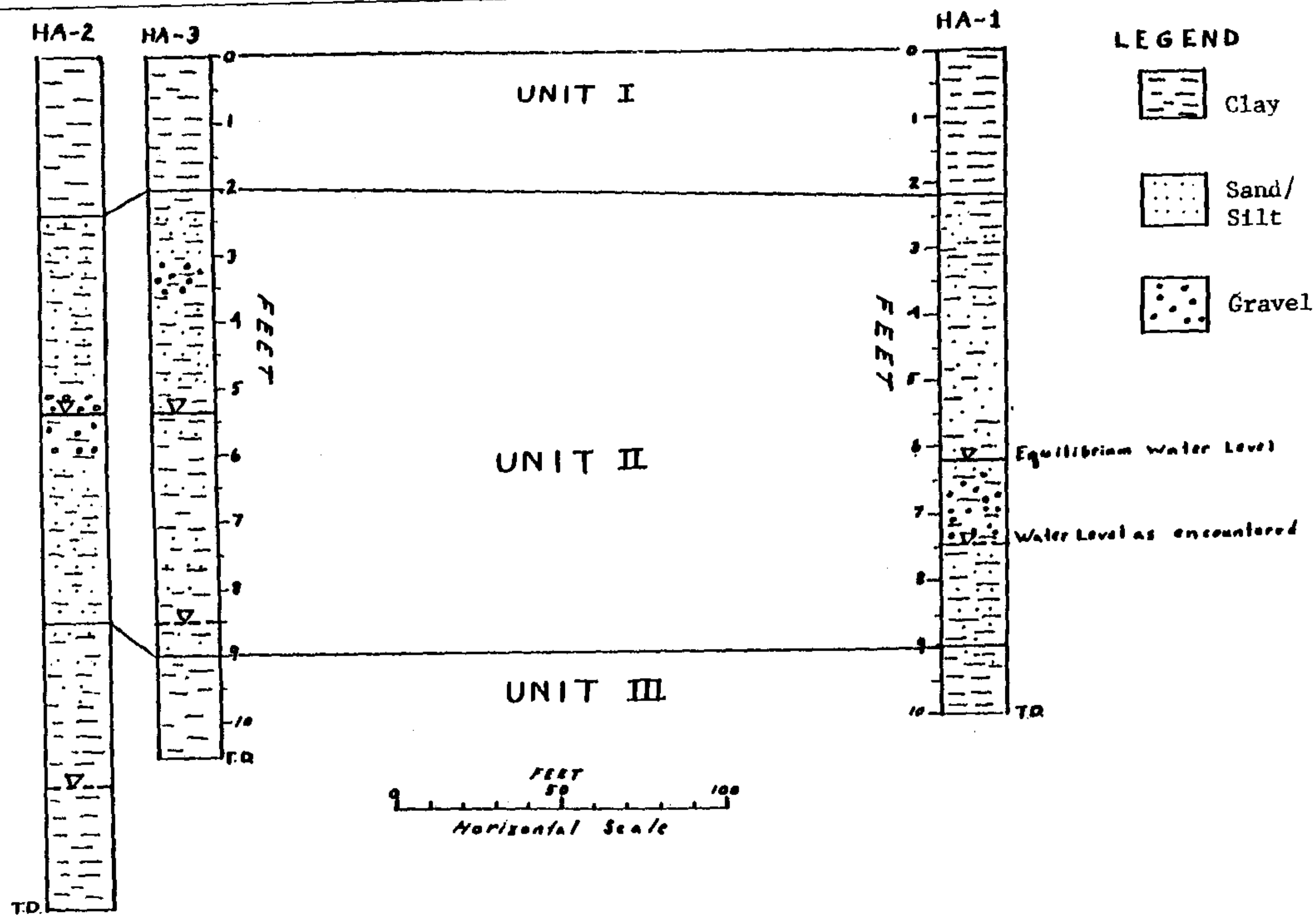

Figure 4. Cross Sections of Selected Hand Auger Borings Along Avenue X
(Source: Anonymous Site B Company Geology Department, 1980.)

TABLE 1. WATER LEVEL ELEVATIONS IN WELLS 2 AND 10
AT ANONYMOUS SITE B

DATE	ELEVATION OF WATER ABOVE SEA LEVEL (ASL)	
	WELL #2 (FT. ASL)	WELL #10 (FT. ASL)
10/5/79	10.0	--
10/25/79	10.125	--
11/5/79	10.25	--
11/20/79	10.50	--
12/15/79	10.75	--
12/25/79	11.0	--
1/5/80	11.2	--
1/25/80	11.5	--
2/5/80	11.4	8.5
2/25/80	11.75	8.6
3/10/80	11.6	8.61
3/25/80	11.5	8.7
4/5/80	11.25	8.7
4/25/80	10.9	8.25
5/5/80	10.8	8.0
5/25/80	10.7	7.9
6/5/80	10.7	7.9
6/25/80	10.6	7.9
7/5/80	10.6	7.8
7/25/80	10.5	7.7
	START OF TRENCH PUMPAGE	
8/5/80	10.4	7.6
8/25/80	10.0	7.0
9/5/80	9.7	6.4
9/25/80	8.8	2.7
10/5/80	--	1.25
10/9/80	--	1.10

(Source: Modified from data from Anon B Co. Geology Dept.)

shows, there was less than 2 feet (0.6 m) of water rise during the rainy season and by the end of July 1980, the water level in Well 2 was only slightly above the level of the previous October. This, along with the fact that the water levels in Wells 1 through 5 rose only from 1.4 to 2.6 feet (0.43-0.79 m) during the rainy season, indicate that this aquifer system is not very dynamic or responsive to rainfall. This assumption is probably valid considering the overlying clay-confining bed and the amount of fine-grained sediments that comprise the aquifer.

Figure 5 shows the ground water elevations of Site B from July 1980 well readings. The ground water flows generally southward under a slight artesian head. The gradient flattens out to the south of Avenue Y which is most likely because of the greater amount of gravel present. This increases the permeability and thickness of the water bearing zone.

WASTE DISPOSAL HISTORY

Site B is both a chemical manufacturing and a research facility that has been in operation for over 80 years. The manufacturing facility formulates agricultural chemicals. The research program involves the manufacturing and testing of pesticides and herbicides. A schematic diagram of the facility is shown in Figure 1.

The only on-site disposal of waste at Site B was that of iron pyrite residues which resulted from a sulfuric acid manufacturing process that was discontinued at the site in 1960. According to a State official, iron oxide residues were deposited along the Bay well above sea level prior to 1960 and there was probably no cinder deposition there prior to 1950.

The old cinder bed lies underneath the area where clarification ponds 1 and 2 now lie, and extends about 100 feet (30 m) to the north of these ponds (see Figure 1). In 1971, following a State request, Company officials encapsulated the cinder bed area. A 2-foot (0.6 m) layer of clay was placed atop the cinder bed area. A 1-foot (0.3 m) layer of topsoil was placed on top of the clay cap and the entire area was seeded with grasses. State officials have determined that the old cinder bed area is stabilized and does not pose a threat to human health and the environment.

300.68(e)(3)
(iii)
extent and adequacy of current containment barriers

As Figure 1 shows, a chemical drain feeds into a carbon treatment and neutralization system just above the Tidal Dilution Basin. This system was constructed in 1971

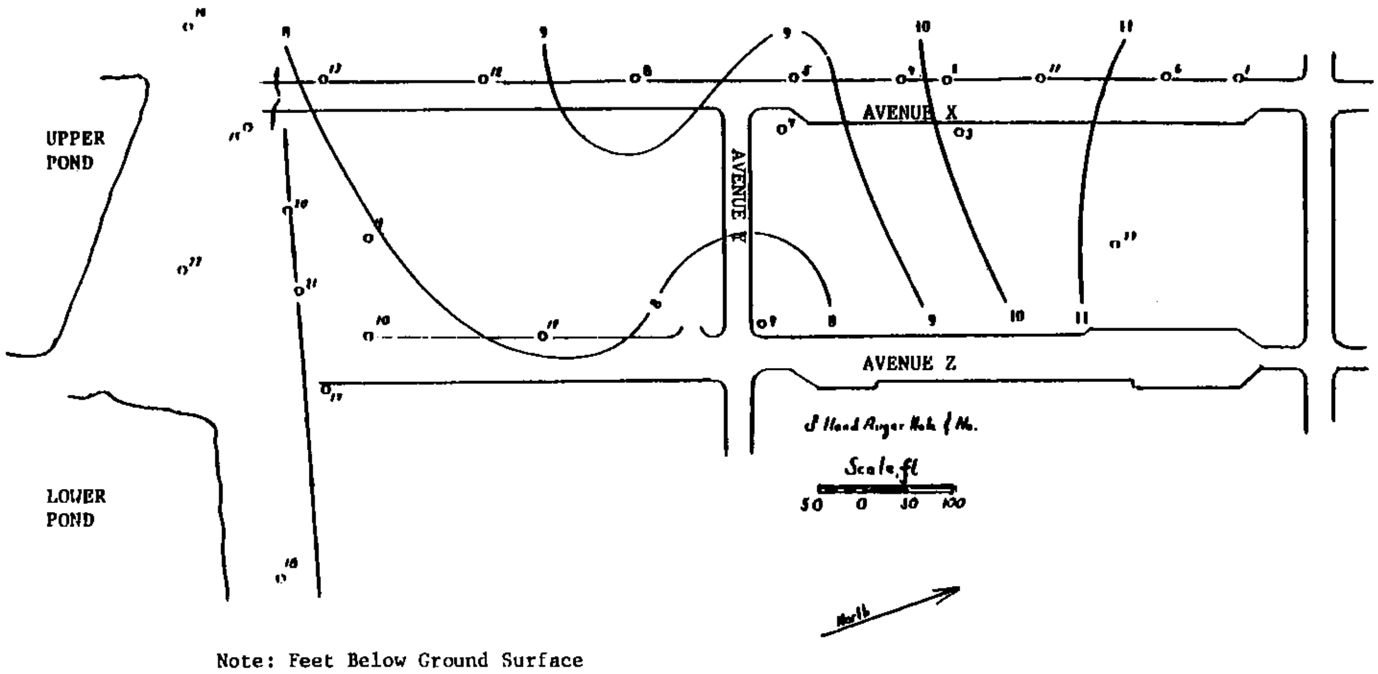

Figure 5. Ground Water Elevations Prior to Trench Construction, July 29, 1980
(Source: Anonymous Site B Company Geology Department, 1980.)

at the same time that the clay cap was placed on top of the iron cinder beds. The clarification ponds were dug into the cinder beds at a depth which varies from 8.5 feet to 9.5 feet (2.6-2.9 m). This is approved by the State because the ponds are lined with Hypalon and do not have direct contact with the cinder beds. The activated carbon system consists of two carbon columns, each containing 12,000 pounds (5,400 kg) of activated carbon. Treated wastewater passes from the carbon column system through 3-inch (7.6 cm) fiberglass lines into the neutralization system. As Figure 1 shows, this neutralization system serves to treat the wastewater from both the pilot plant and the manufacturing facility. A lined neutralization pond feeds into the neutralization tank which is equipped with a pH adjustment system. Caustic is added to neutralize the acid and this then feeds or overflows by gravity to clarification pond 1 and then into clarification pond 2. The wastewater then flows by gravity into the upper evaporation pond and next into the lower evaporation pond. The treated wastewater is released into the Tidal Basin at discharge point 001. Discharge into the evaporation ponds is allowed year round. However strict limitations to prevent overflow are applied.

After this carbon column treatment and neutralization system was installed in 1971, a smaller carbon column treatment system was installed at the pilot plant area (see Figure 1) to treat contaminated storm water runoff and rinse water from the equipment cleaning procedures. Since there had been spills in this area throughout the history of the plant from both pilot plant operations and unloading of tank trucks, the ground surface contains many contaminants. Hence, storm water runoff from this area can by highly contaminated. The Company installed a series of trenches around the area which feed contaminated storm water runoff into a 50,000-gallon (189,000 l) underground tank. This tank stores the stormwater runoff as well as rinse water which has been contaminated from cleaning the pilot plant machinery. The water from this tank is fed through a small carbon column bed and then into a 30,000-gallon (4,000 l) above-ground steel holding tank. This water is then laboratory tested on-site for contaminant concentration. If it is highly contaminated it is shipped off-site. If it is fairly clean it is sent to the lower carbon treatment and neutralization system via the chemical drain. The only direct discharge of untreated rinse water or storm water runoff into the chemical drain is overflow from the underground tank during extremely heavy rains.

Prior to 1971, wastewater from the pilot plant area flowed through the chemical drain and was treated through a neutralization system and unlined settling ponds. Any acid drips from manufacturing on the west side of the plant were intercepted in the plant sewer system and carried to a neutralization system. The skimmer tank was also used as part of this process for treating wastes from the pilot plant process area. The tank (shown in Figure 1), which measured approximately 5 feet by 56 feet by 8 feet (1.5 x 16.8 x 2.4 m) and had a capacity of approximately 15,000 gallons (56,800 l), had an inlet and an outlet pipe leading from the chemical drain which was located 8 feet (2.4 m) away. Organics present in the process wastewater would either float to the top or settle to the bottom of the skimmer tank depending upon their density. The skimmed wastewater would then be directed back into the chemical drain for treatment in the carbon column and neutralization treatment system. The skimmer tank was taken out of operation in October 1980 because the Company found that chemicals were seeping from it. The chemical drain line was disconnected from the skimmer tank and it now only feeds pre-treated rinse water from equipment cleaning processes, storm water runoff, and direct overflow (during heavy rains) from the underground storage tank in the pilot plant area, into the lower carbon column treatment system. At the present time, no process rinse water is run directly through the chemical drain. Any process wastes are shipped off-site to a State approved land disposal site. The pilot plant, formulation, and handling areas are enclosed by berms to contain spills. Any spills which occur are swept up and removed or recovered.

DESCRIPTION OF CONTAMINATION

Between April and September of 1979, personnel at Site B noticed a dry weather discharge into Bay Channels near the storm drain outlet 002 (see Figure 1). This seemed unusual as there is not normally a discharge from the storm drain during the dry season. Additionally, Company officials learned of complaints about a disagreeable taste in the water from neighboring companies' wells. This led the Company to drill and sample from several test wells in the area.

300.68(e)(1) (iii) contaminated drinking water

The sampling points were chosen based on assumptions about where the contamination might be originating. The most obvious source of contamination appeared to be one or more of the three drainage lines which run parallel to one another along Avenue X. As Figure 1 shows, these lines are a chemical drain, a sanitary drain, and a storm drain. Therefore, the Company analyzed samples from the first water-bearing stratum at several points alongside the

300.64 preliminary assessment

sand-bedded pipeway containing the three parallel drainage lines. Additional samples were taken and analyzed from wells used by neighboring companies on Avenue Z about 250 feet (76 m) east of the chemical drainage line.

The analytical results showed the presence of the solvent toluene and several herbicides (referred to here as Herbicides I, II, and III) in concentrations greater than 0.01 ppm (parts per million) along Avenue X. Herbicide I which had been test manufactured at the pilot area but is no longer produced at the site, was present in the shallow ground water at a maximum concentration of 7.4 ppm near the skimmer tank and at a concentration of 1.2 ppm north of the upper evaporation pond. Toluene was present at a maximum concentration of 46 ppm and Herbicide II (which is presently manufactured at the pilot area) was present at 0.87 ppm, both near the pilot plant. None of the suspected chemicals were detected in the wells of the neighboring companies, however the use of these wells for drinking water has been discontinued.

300.68(e)(3)(ii) extent of present or expected migration

In January of 1980, having completed their analyses and determined that contamination at the site was present, Company officials notified State authorities that they suspected ground water pollution along the eastern edge of their facility. A series of meetings were then held between Company officials and State authorities to determine the proper site response. This resulted in further investigations as to the source and concentration of the contaminants.

300.63(a)(3) notification of release by Federal or state permit holder

These investigations determined that herbicide contamination was found in the storm drain. Additional levels of contaminants were detected in the pilot plant area. Further research revealed that 12 years previously there was a significant spill of Herbicide I which had been test manufactured at the pilot plant. This spill was believed to be routed to the upper evaporation pond for containment. The data from the hand auger (HA) samples at locations shown in Figure 3, revealed high concentrations of herbicides near the Herbicide II manufacturing facility at HA-2, near the skimmer tank at HA-8, and downgradient of HA-8 at HA-12.

300.68(e)(3)(ii) extent of present or expected migration

A television monitoring inspection was conducted during August and September of 1980 along the 1800-foot (549 m) length of the storm drain to determine if the contamination was coming from one or more leaks in the storm drain. The inspection determined that two joints of the storm drain line showed some leakage, but not enough to indicate that the drain was a significant pathway for contaminant transport.

Company and State officials discussed the results of the television monitoring inspection in light of the other sampling and site inspection results. The Company geologist found that the path of migration of contaminants in the ground water was southeast from the skimmer tank. This is downgradient or in the direction of ground water flow which correlates with the fact that the migration occurred through an area of coarser, more permeable sediments. An example of this southeasterly flow of contaminants in the ground water is shown in Figure 6 which shows the concentration of Herbicide III in the ground water at Site B.

State and Company officials concurred that the contamination was the combined result of spills in the pilot plant area and seepage from the skimmer tank. Various spills had occurred at the site, including the spill of Herbicide I 12 years previously. Contaminants from these spills had slowly moved downgradient and into the area along Avenue X by surface runoff. The major cause for the contamination however, appeared to be seepage from the skimmer tank which was part of the process wastewater treatment system described previously.

300.64(a)(2) identification of the source and nature of the release

During the dry season in 1979, the contaminants found in the storm drain along the tidal basin were the result of skimmer tank seepage which was manifested in the storm drain. The storm drain apparently had carried the contaminants along Avenue X and eventually to the monitoring well at the NPDES permitted discharge point (storm drain 002 in Figure 1) where they were discovered.

PLANNING THE SITE RESPONSE

Initiation of Response

Company and State officials agreed that the contamination did not pose an immediate threat to human health. The direction of ground waste flow in the contaminated area was southeast, toward the bay and away from any wells or buildings. Soils in the area were predominantly clays with relatively low permeability. Finally, no contamination was detected in neighboring wells, the closest of which were about 250 feet (76 m) northeast of the contaminated area. The Company and the State agreed however, that measures should be taken to prevent further migration of contamination that might threaten aquatic life in the bay.

300.68(e)(2)(iv) environmental effects and welfare concerns

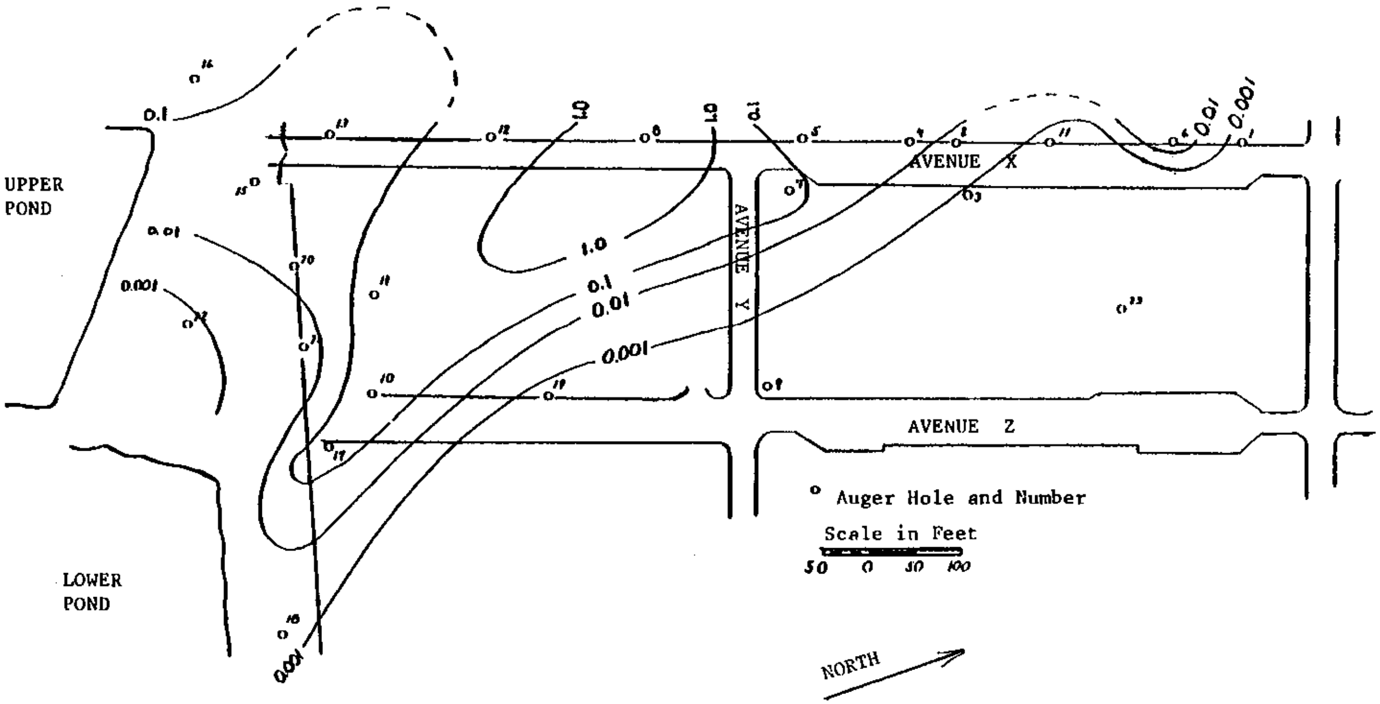

Figure 6. Concentrations of Herbicide III in Ground Water(mg/1) May 6, 1980
(Source: Anonymous Site B Company Geology Department, 1980.)

Selection of Response Technologies

Company officials worked closely with State officials to determine an effective plan for site response. Although State officials aided the Company in determining what options were available, the final plan for corrective action was designed by the Company and approved by the State.

300.68(g) development of alternatives

Company officials considered the following three options:

300.68(h) initial screening of alternatives

- Wellpoints and pumping for ground water removal
- Slurry wall containment
- Interceptor drain with carbon treatment; disconnect skimmer tank.

The Company examined wellpoint pumping as a possible solution to the contaminated ground water problem at Site B because this could act to lower the water table by creating a cone of depression. Company officials determined that this was cost prohibitive.

300.70(b)(1)(iii)(C) ground water pumping

Another consideration was that of installing a barrier such as a slurry wall to isolate the area. This did not seem feasible because of the original deposition or iron pyrite cinders at the site. There was concern that during construction these would be disturbed and possibly carried into the Bay, particularly if the tide seeped in and removed any cinder material. Company officials realized that this did not meet with their primary objective which was to not only contain the plume, but also to pump out the contaminated water. A cut-off wall would neither remove contaminated ground water, nor the threat that contaminants might still leach into the Bay. Further, a slurry wall was rejected because there were indications that sand lenses were present in the aquifer. A cut-off wall may have erroneously been keyed into sand lenses instead of impermeable mud and would not form a complete hydrologic barrier. Additionally, during construction, a sand lense itself could become contaminated, again posing the risk of release of contamination into the Bay.

300.70 (b)(1)(iii)(A) impermeable barriers

The alternative selected was installation of an interceptor drain to collect the contaminated ground water and pump it into the carbon treatment system already in operation at the site. This seemed to be the most feasible alternative because it would meet the objective of not

300.70(b)(1)(iii)(C);(D)(1) ground water pumping; subsurface drains only containing the plume, but also of removing and treating the contaminated ground water using a treatment system that was already in place. Hence, the cost for dewatering in this way was much lower than the cost of installing a wellpoint system. Company officials also determined that the best solution to the seepage problem from the skimmer tank would be to disconnect the skimmer tank from the chemical drainage line, pump out the materials in the tank, rinse the tank, and finally encapsulate it.

300.70(b)(2)(ii) (B)(3); (C)(2) neutralization; carbon adsorption

In June of 1980 Company officials submitted detailed plans to the State outlining the response technologies which they had chosen.

300.68(c) state or federal evaluation of clean-up proposals

Extent of Response

The State concurred with the Company's choice of response measures because the actions appeared adequate to remedy the spread of contamination. The contamination was confined to a relatively small area near the skimmer tank and the chemical drain, and posed no immediate threat. Decommissioning the tank and replacing the chemical drain provided reasonable certainty that additional chemicals would not seep into the soil, and the interceptor drain seemed likely to prevent further migration of contaminants. The State was willing to wait until these measures were executed and their effectiveness evaluated before deciding whether additional work would be required. Since completion of the work, the State has concluded that the Company's response actions were, in fact, adequate to control the contamination.

300.68(j) extent of remedy

DESIGN AND EXECUTION OF SITE RESPONSE

Company officials submitted to the State specifications for installing the interceptor trench and decommissioning the skimmer tank. The trench was designed to intercept contaminated ground water and direct it to a sump with a submersible pump that would pump it into the on-site carbon column treatment system. Once ground water flowed into the trench, the resulting cone of depression would induce additional flow of contaminated ground water into the trench. This in addition to closing out the skimmer tank, would then confine the migration of the contaminated ground water.

300.70(b)(1) (iii)(C); (D)(1) ground water pumping; subsurface drains 300.70(b)(2)(ii) (B)(3); (C)(2) neutralization; carbon adsorption

The most critical design consideration was the determination of where the interceptor trench should be installed. Trench placement (see Figure 7) was based on the geologic investigation conducted by the Company

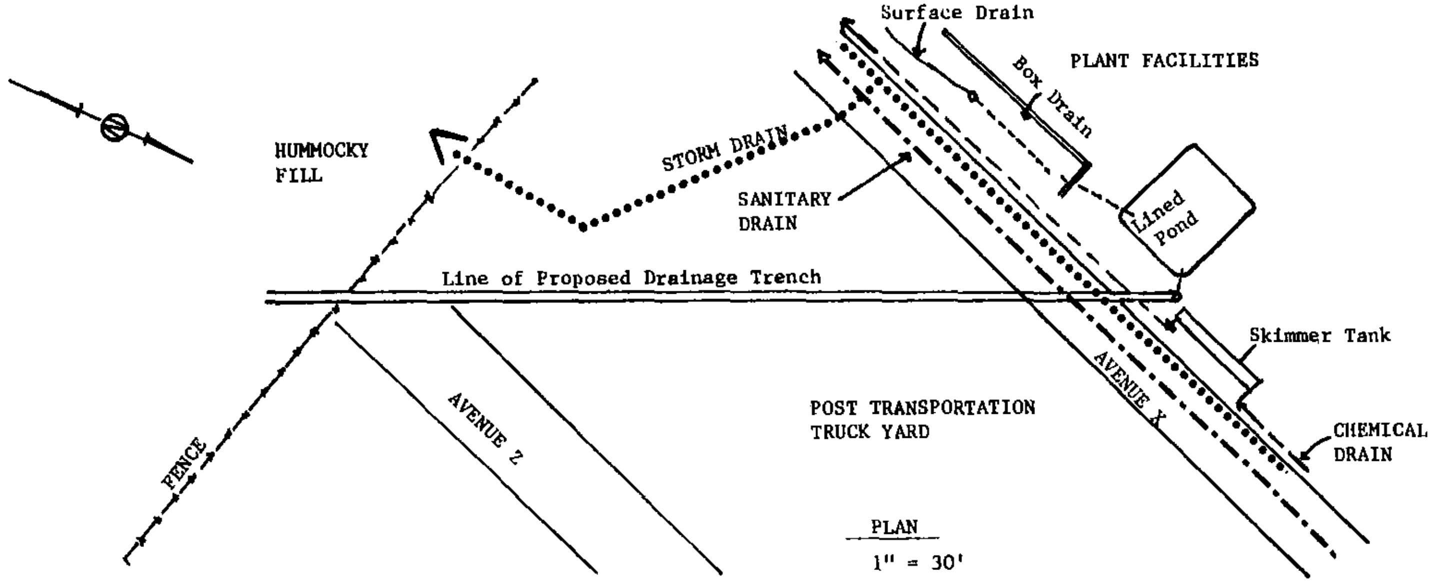

Figure 7. Line of Proposed Drainage Trench
(Source: California Regional Water Quality Control Board, 1982.)

geologist. The auger samples as described previously showed predominantly fine-grained with some scattered coarser sand and gravel deposits. The horizontal distribution of the coarser material is variable with little coarse material present north of Avenue Y. The gravel deposits appear to follow a southeast-northwest trend from the skimmer tank area. This zone contains much clay and silt and is best described as a fine clayey sand with gravel lenses. The Company geologist determined that although the gravel lenses are clayey and discontinuous, their relatively higher permeability controls ground water flow and contaminant transport. The greatest extent of migration was found towards the southeast (see Figure 6) which is roughly perpendicular to the water level contours (see Figure 5). Therefore, by installing the trench on a southeast-northwest trend from the skimmer tank towards Avenue Z, the most permeable zone would be dewatered along its length. Once trench placement had been determined, the final design plans were made.

The site response was designed to take place in two phases: trench installation followed by skimmer tank decommissioning. The following discussion will describe the trench design and installation first and then the design and implementation for decommissioning the skimmer tank. The Company had a full-time industrial hygienist on-site during the installation of the trench and closing of the skimmer tank to make sure that the operation was carried out safely and that personnel were wearing the proper safety equipment.

300.71 worker health and safety

The lowest end of the trench was the sump end. It was installed near the skimmer tank so that the highest level of contamination would be intercepted before it would have a chance to migrate downgradient. This location would also have the practical advantage of being near the carbon column treatment system, minimizing the amount of piping needed.

A diagram of the trench design is shown in Figure 8. The original design required that the trench be 500 feet (150 m) in length. This determination had been based on a series of shallow wells which showed the high point of the water table to be present at a depth between 3 and 4 feet (0.9-1.2 m) at a distance of approximately 500 feet (150 m) along the area where the trench was to be placed. However, Company geologists conducted ground water analyses at the same time which showed that the contaminants in the ground water decreased significantly at distances less than 500 feet (150 m) from the skimmer tank, hence a trench of 500-foot (150 m) length was not needed. Additionally, if the trench was as long as originally

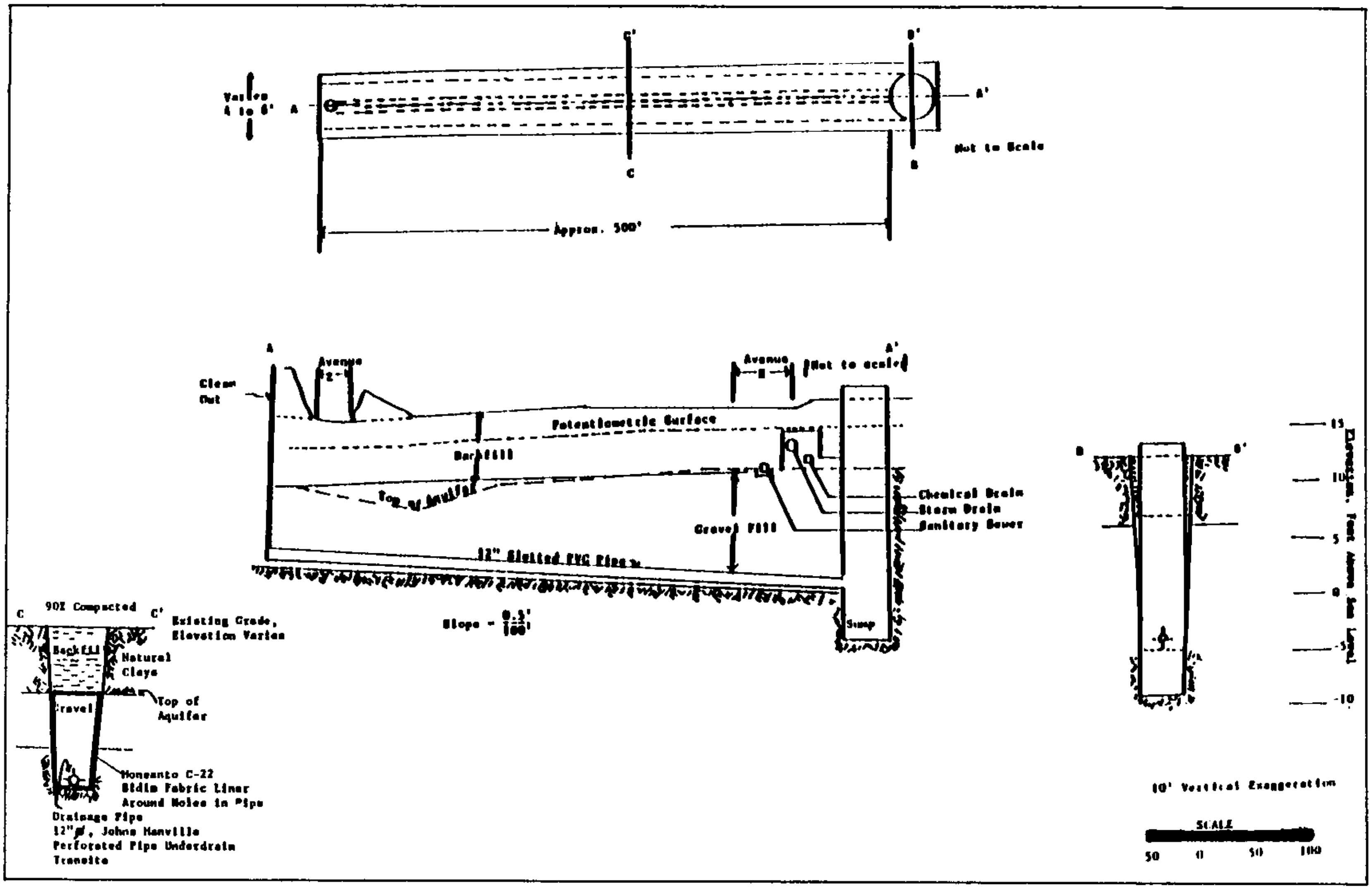

Figure 8. Design of Interceptor Trench

(Source: California Regional Water Quality Control Board, 1982 and Company Engineer, 1982) designed, it would have been almost to, or actually at, the lower evaporating pond. The natural clay barriers of the pond could have been damaged, inadvertently promoting on-site contamination from the release of pond water. The final length of the trench was 261 feet (79.6 m). Company officials had determined that this would be sufficient for the maximum amount of dewatering as long as the sump system was constructed properly.

The trench was designed as Figure 8 shows, with the drainage pipe sloping to the northwest where it empties into a 4-foot (1.2 m) diameter sump of approximately 350 gallon (1,330 l) capacity. The sump was designed to be float controlled and automatically pump the water up into the lined pond which is normally used to collect and store storm water. The nominal capacity of the pump was designed to equal the expected initial drainage rate of 20 gallons per minute (76 lpm). The pumped water was to pass through a totalizing flow meter in the line. Company engineers calculated that the lined pond with a 30,000 gallon (114,000 l) capacity would initially fill up in 25 hours. Company engineers also planned to have laboratory personnel sample the collected water before the pond filled up to ensure that the pond did not contain sufficient organics to deplete the carbon beds of the treatment system. If the level of organics was substantial, then the management could have opted to have the pumped water hauled to a licensed disposal site. After testing, the pond pump was to be manually started to transfer the collected water into the chemical sewer system at 200 gallons per minute (760 lpm). The lined pond level instrumentation was designed to be connected to the sump pump so that the sump would automatically stop if the pond filled up before testing was completed. Company engineers had designed the system so that as the ground water level stabilized, the sump pumping rate could be decreased to as low as 200 gallons per day (760 lpd) if desired. Three months after start-up, the Company was to connect the sump pump up directly to the chemical sewer system and bypass the lined pond. This would leave the pond free to carry out its normal function of storm water collection.

Construction of the trench commenced in August of 1980. The original design had been for the contractor to supply the materials, however the Company purchased the materials itself believing that this was more economical. The contractor did provide the construction equipment and the steel sheeting which was used for shoring up the interceptor trench.

The trench was designed to cut through the thickness of the water bearing zone which would allow for the maximum amount of dewatering. The sump end of the trench was excavated to a depth of 17 feet (5.2 m). The sump itself, 4 feet (1.2 m) in diameter, was extended to a depth of 20 feet (6 m) so that the water collected in the pipe would flow along the pipe and into the sump as shown in Figure 9. The depth of the sump was determined based on the geologist's findings that contamination did not exceed 15 feet (4.6 m) below the surface. This extra 5 feet (1.5 m) in depth would ensure that the contaminated ground water was being intercepted. The far end of the trench was excavated to a depth of 12 feet (3.7 m) in order to provide the necessary slope for drainage along the trench to the sump end. A layer of filter fabric, known as Bidim, was laid on the trench bottom and a 6-inch (15 cm) layer of gravel was placed on the fabric. Next, a perforated 12-inch (31 cm) concrete asbestos drain pipe was installed. An additional layer of Bidim supported by screening was wrapped around the drain pipe to prevent plugging of the perforations by fine-grained sediments. The trench was then backfilled with gravel to a depth of 4 to 5 feet (1.2 - 1.5 m) below the surface. The remainder of the trench was then backfilled with compacted clay material.

During trench construction normal plant operations continued. However, it became necessary to make a significant modification to the trench itself. When excavating for the installation of the sump west of Avenue X, a 4-foot (1.2 m) thick concrete slab made it impossible to drive the needed piling. The construction crew attempted to offset the trench around the slab but this meant improperly placing the piling which resulted in the trench sides caving in. This produced an ever-widening trench which extended almost to the edge of Avenue X (see Figure 1). This resulted in the damage of approximately 30 feet (9.1 m) of the chemical drain. At that time the Company decided to repair the 30 feet (9.1 m) of damaged pipe. However, upon closer examination, they determined that perhaps it would be advisable to replace the remaining 300 feet (91 m) of the chemical drain. Hence, the chemical drain was repaired from its position parallel to the skimmer tank and south for 300 feet (91 m) (see Figure 1). The replacement pipe, repaired by the same contractor that installed the interceptor trench, was 8-inch (20 cm) ceramic tile sewer pipe.

300.70(b)(1)(iv)(B)
pipe relining and sleeving

To repair the caved in trench, the Company decided to excavate caved in material and to fill the trench with coarse gravel, thereby allowing ground water to enter the sump from which it could be pumped into the treatment system. This did not reduce the functional efficiency of the interceptor trench. The trench design was modified so that a second sump was constructed on the east side of Avenue X. Installation of the trench was completed in October 1980.

The skimmer tank was taken out of operation in October 1980 and was closed out by November 1980. Company engineers determined that the first step for closing out the skimmer tank would be to install a pipe along the chemical drain which would bypass the line that leads into and out of the skimmer from the chemical drain. Once the bypass sewer line was installed, the skimmer tank connections were blinded off at both the skimmer tank and the sewer manholes. The intervening pipes were disconnected so that if later the empty skimmer tank had tended to float due to buoyant action of ground water, there would no longer have been any pipe connections to disturb the integrity of the sewer line.

The accumulated sludge in the tank was analyzed so that its constituents were known for proper treatment. The Company contracted with a permitted waste hauler to pump out the contents of the skimmer tank and haul it to their treatment facility approximately 15 miles (9 km) from the site. The permitted waste hauler also rinsed out the tank to remove any residuals and also transported this rinse water to their treatment facility. The skimmer tank was rinsed a second time and the rinse water was pumped into the chemical sewer for treatment in the activated carbon system. As soon as the skimmer tank was empty, six 1-inch (2.54 cm) holes were drilled in the bottom of the skimmer tank to collect any perched ground water. The perched water that was present was immediately pumped into the chemical sewer for treatment in the activated carbon system. The skimmer tank was then filled with sand by the same contractor that had built the interceptor trench. The skimmer tank was then covered with local soils. Vegetation soon established itself in the area.

300.70(b)(1)(ii) (A); (D) surface seals; revegetation

At the present time the dewatering of the trench is continuing and both sump pumps are operating at a combined rate of 18 to 20 gallons per minute (68-76 lpm). This rate, equivalent to approximately 28,000 gallons per day (106,000 lpd) is maintained steadily throughout the year except for times when one or both of the pumps malfunction(s). The pumps each have their own discharge line into the carbon treatment unit so that if one is not operating the other can. Repair is usually completed within two weeks. The only other times the pumps do not operate are during heavy winter rains because the plant treatment system can not handle the water from the intercept trench in addition to the storm water runoff.

Ten permanent ground water monitoring wells have been left in place at Site B. These are checked monthly by Company officials and reported to the State to ensure that the dewatering system is operating properly.

COST AND FUNDING

Source of Funding

The Company paid for all investigation and response actions at the site.

300.68(c) responsible party

Selection of Contractors

The Company used its own geology and engineering departments to investigate the site and design the interceptor drain, therefore contracting was not necessary for these elements of the response. For construction of the trench, the Company initially requested fixed-price bids from a number of contractors. However, all bids submitted were far in excess of the $65,000 that the Company had estimated the work would cost, ranging from $90,000 to over $100,000. Consequently, the Company elected to act as its own contractor, directly purchasing most of the materials required for the drain and hiring an excavation contractor on a time and materials contract. The Company selected the excavation contractor on the basis of past favorable experience with the firm.

Project Costs

The total cost of the investigation and remedial actions was $268,217. The bulk of the cost, almost 80 percent, was for constructing the interceptor drain. The remainder was for investigation, engineering, replacing the chemical drain, and decommissioning the skimmer tank. A summary of the costs appears in Table 2.

Site Investigation

The site investigation cost $23,974. Most of the expenditure was for in-house work by the Company geology department, which totalled 80 man days at $274 per day, or $21,920. Most of the investigation took place between the fall of 1979 and June 1980, but the geology department also performed some data analysis during the drain construction between August and November 1980. The work included: drilling 32 soil borings, 19 with a hand auger and 13 with a power auger; analyzing the borings; mapping water levels and the zone of contamination; and working with the Company engineering department on design of the

300.68(f) investigation

TABLE 2. SUMMARY OF COST INFORMATION - ANONYMOUS SITE B

Task	Estimated Expenditure	Actual Expenditure	Variance	Estimated Future Cost	Funding Source	Period of Performance
Site investigation	N/A	$23,794	N/A	N/A	Company	9/79-6/80
Engineering	N/A	$21,177	N/A	N/A	Company	4/80-11/80
Intercept drain Installation	$65,000	$207,046	+218%	$150/year	Company	8/80-10/80
Chemical drain replacement	N/A	$ 9,000	N/A	N/A	Company	10/80
Closing skimmer tank	N/A	$ 7,200	N/A	N/A	Company	10/80
TOTAL		$268,217				9/79-11/80

(Source: Company Engineer, 1983)

drain. In August 1980, the Company spent $1,874 for an outside contractor to conduct a television inspection of 1,800 feet (549 m) of the storm drain.

Engineering

Engineering for the remedial actions cost $21,177, all of which was in-house work by the Company engineering department. This work included reviewing remedial alternatives; designing the interceptor drain; preparing bid specifications; reviewing bids; and overseeing installation of the drain. This work took place between April and November 1980.

Execution of Remedial Actions

The total cost of installing the interceptor drain, replacing the chemical drain; and decommissioning the skimmer tank was $223,246. This includes $206,523 for the construction contractor, $9,662 for materials purchased by the Company, $6,250 for off-site disposal of waste from the skimmer tank, and $811 for 66.5 hours of in-house labor.

Since all three tasks were performed at the same time by the same contractor, the available data do not permit an exact breakdown of the cost of each task. However, it is possible to make the following reasonably accurate estimates.

300.70(b)(1)(iii)(D)(1) ground water controls: subsurface drains

<u>Drain Installation</u> - The bulk of the cost, about $207,000, was for installation of the 261 foot long (80 m), 12 to 17 foot deep (3.6-5.2 m) interceptor drain and 20 foot (6 m) deep sump. This figure includes about $197,500 for the contractor, $9,000 for materials, and $500 for in-house labor. The contractor cost includes labor, equipment rental, and gravel fill. Of the materials cost, the largest element was $2,921 for 550 feet (168 m) of 12-inch (30 cm) pipe purchased before the planned trench length was reduced from 500 feet (150 m) to 261 feet (80 m). Other material costs were: $1,189 for 147 feet (45 m) of 2-inch (5 cm) carbon steel pipe and fittings, used for carrying intercepted water from the two sumps to the treatment system; $799 for submersible pumps and accessories; $537 for 2,700 square feet (251 m^2) of vinyl-coated wire screen for wrapping the pipe; $213 for 338 square yards (283 m^2) of Monsanto C-22 permeable pipe wrap; and other miscellaneous items.

The Company's initial estimate for installing the interceptor drain was $65,000. While it is difficult to determine why the actual cost was 218 percent more than that figure, there were some factors that clearly added to the cost. First, two sumps, rather than only one, had to be built, both with pumps and plumbing, when the first sump excavated west of Avenue X was found to be obstructed. Second, some steel sheet piling rented for the trench excavation could not be removed after the trench was completed, and had to be purchased and left in place.

Chemical Drain Replacement - The Company paid the construction contractor about $9,000 to replace 300 feet (91 m) of the chemical drain with 8-inch (20 cm) ceramic tile pipe, buried 4 feet (1.3 m) below grade along the east side of Avenue X. This figure includes all materials.

Decommissioning Skimmer Tank - The Company spent approximately $7,200 to disconnect, clean out, backfill, and close the 15,000 gallon (57,000 l) skimmer tank. Most of this cost was the $6,250 spent on transportation and disposal of sludge and rinse water at a licensed hazardous waste landfill. There were no available data on the quantity of waste removed. The rest of the cost was for in-house labor and plumbing and backfilling by the construction contractor.

Operation and Maintenance

Operation and maintenance costs for the interceptor trench are very low. There are no costs for treatment of contaminated water because the water is treated in the plant's existing treatment system, which has ample capacity. The cost of electricity for the two 0.5 horsepower sump pumps is negligable. The pumps are replaced about once per year, at a cost of about $150 each. Company personnel monitor water levels in observation wells monthly, which takes about 30 minutes per month.

PERFORMANCE EVALUATION

The response actions taken at Site B appear to have been timely and effective for controlling and removing the contaminated ground water discovered. The selection of the interceptor trench as opposed to a wellpoint system or a barrier wall was the most economically and technically feasible choice in view of the past history at the site. Additionally, the choice to decommission the skimmer tank by removing its contents, rinsing, and then filling it in appeared to be the best way to eliminate the source of the contaminant problem. However, because the skimmer tank was the primary source of the contamination, it might have been advisable to have emptied its contents prior to or in conjunction with, the installation of the interceptor trench as opposed to after, so that the possibility of any further contaminants entering the ground water would have been eliminated.

The interceptor trench and ground water pumping have apparently met the objective of creating a cone of depression intercepting and containing the contaminated water. However data is not available to indicate whether or not the concentration of contaminants in the ground water has been reduced.

Hydrographs were prepared by the Company geologist. As Table 1 shows, there was only a slight decline in water levels from April to July 1980. Thus, the ground water level at the end of July prior to trench construction appeared stable. The changes in water level noted once trench construction had begun were the result of trench dewatering. A sharp decline in ground water levels can be seen during the period from August to October in both Wells 2 and 10. This indicates that the dewatering process was indeed effective. The difference in the change between Wells 2 and 10 is because Well 2 is 430 feet (131 m) from the trench while Well 10 is much closer to the trench at a distance of 24 feet (7.3 m). Additionally, Figures 5, 9, and 10 show water levels prior to construction of the trench, water levels during trench construction, and water levels after one and one-half months of continuous pumpage during trench construction. By the end of September 1980 a pronounced cone of depression had been produced by the trench dewatering. Water levels continued to decrease through December 1980. Apparently the interceptor trench has succeeded in intercepting and containing the contaminated water. In order to determine whether or not the contaminant concentrations have decreased it would be necessary to compare monitoring data before, during, and after trench construction. Because this data is not available, a complete evaluation of the system cannot be made.

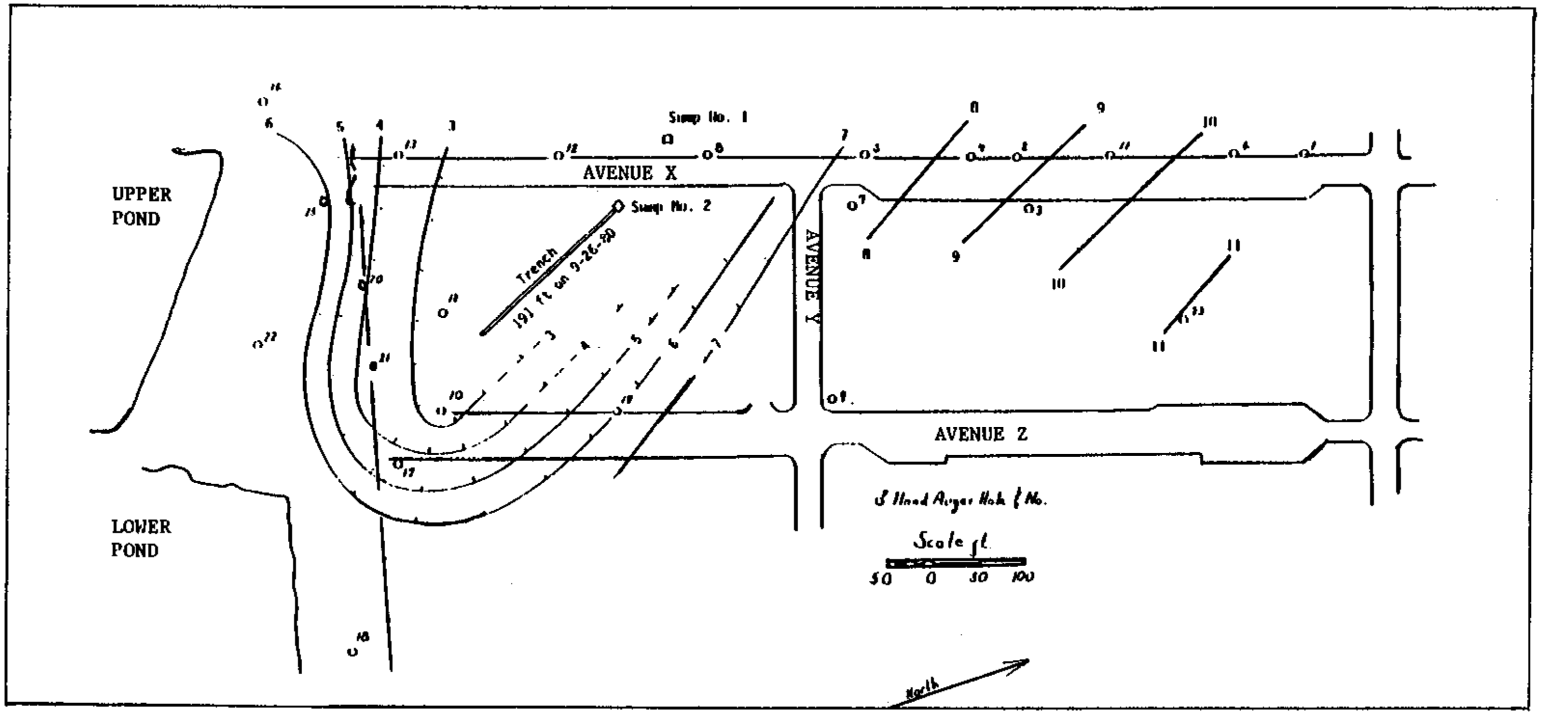

Figure 9. Ground Water Elevations During Trench Construction, September 26, 1980 (Source: Anonymous Site B Company Geology Department, 1980.)

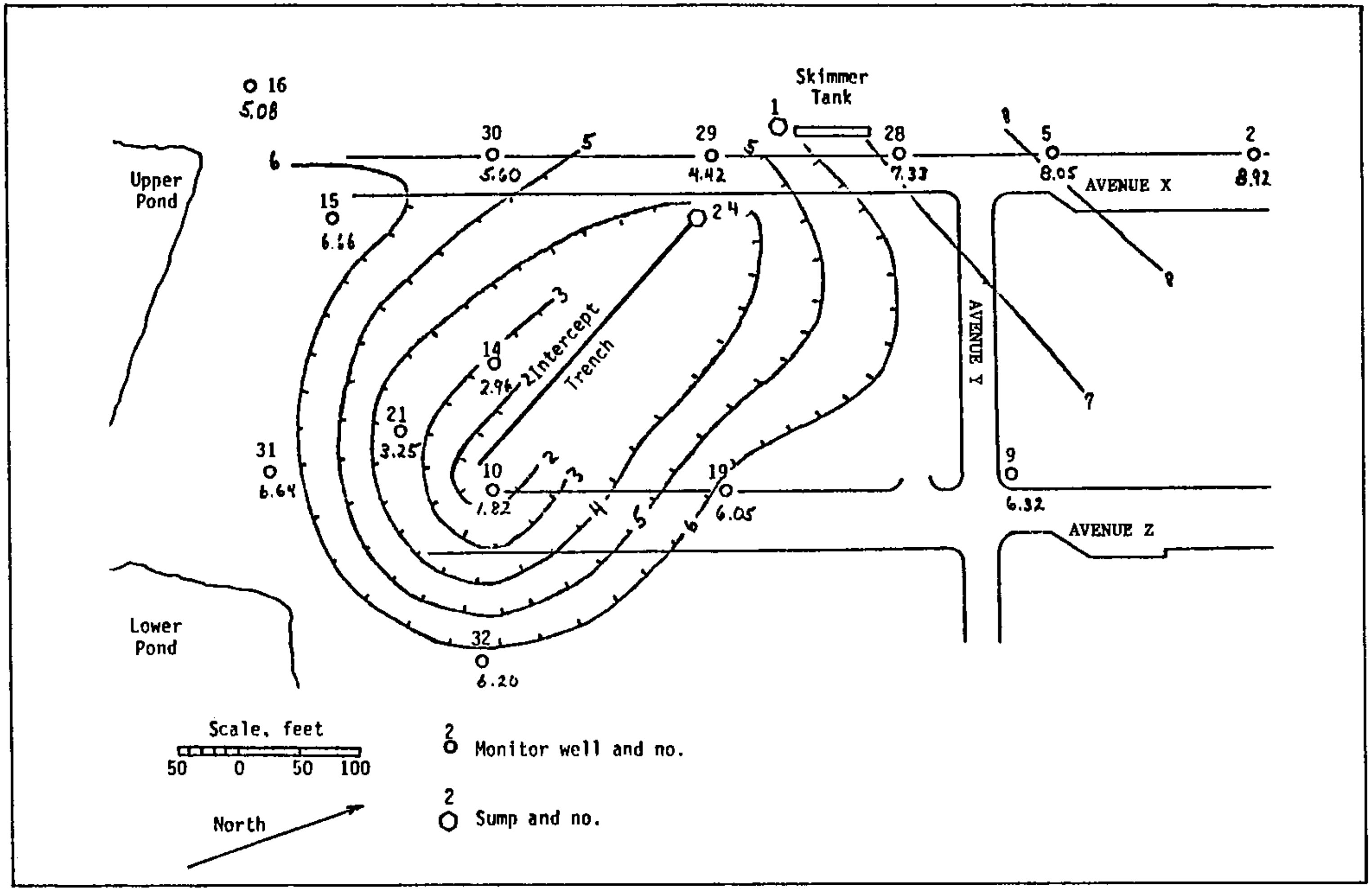

Figure 10. Ground Water Elevations After Trench Installation, December 8, 1980
(Source: Anonymous Site B Company Geology Department, 1980.)

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ANONYMOUS SITE C

DEPERE, WISCONSIN

INTRODUCTION

NCP Reference

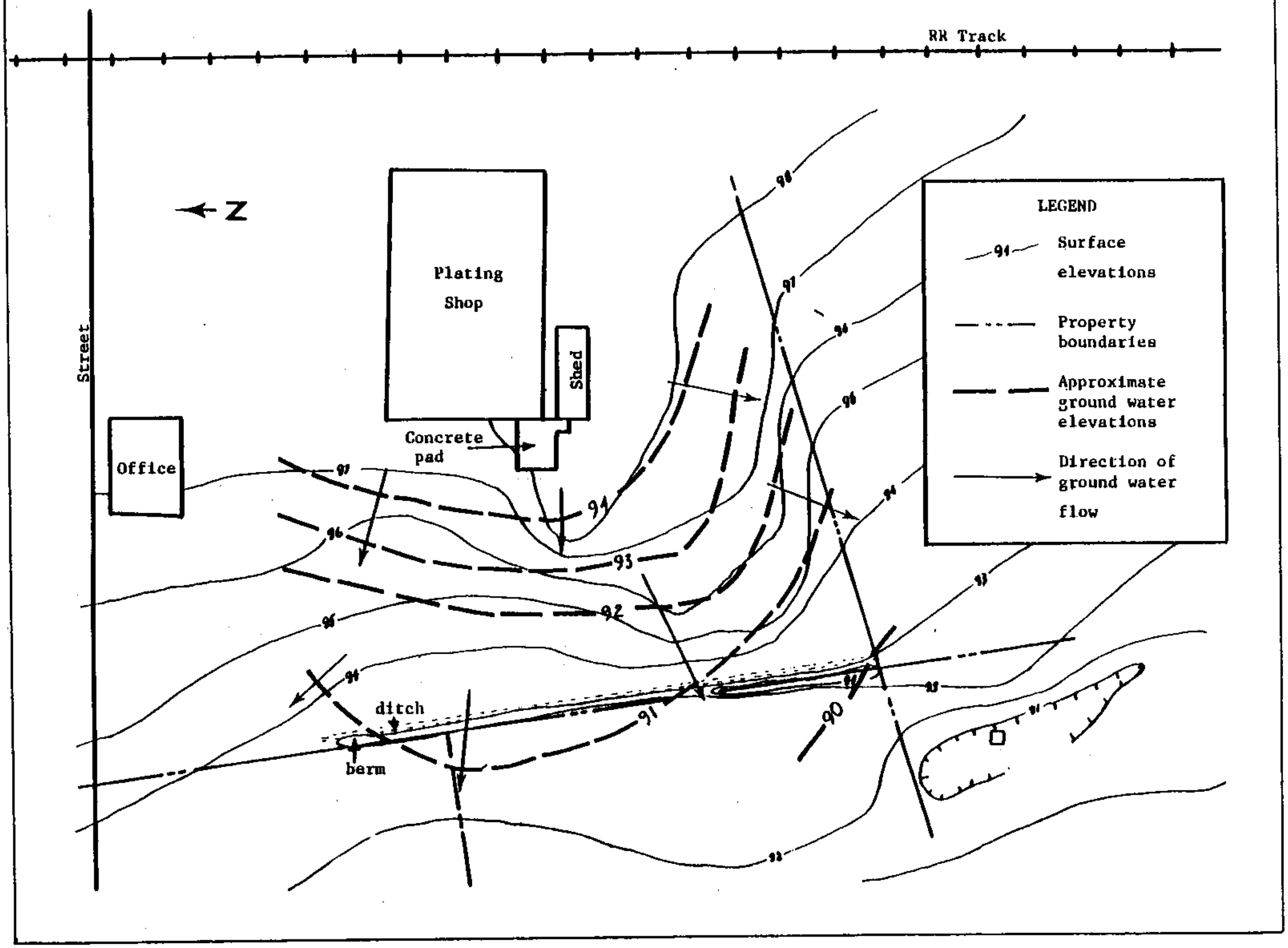
Anonymous Site C is a small chrome plating shop located in a residential neighborhood in DePere, Wisconsin, near Green Bay. In late 1978 and early 1979, the Wisconsin Department of Natural Resources (WDNR) responded to neighbor's complaints of spillage of liquid chromium waste from the Anonymous Site C facility. Investigation by the WDNR and by an engineering contractor hired by Anonymous Site C showed that soil and shallow ground water at the site were heavily contaminated with hexavalent chromium, and that some contamination had migrated into a garden adjacent to the site.

Background

Anonymous Site C has occupied the DePere site since 1971, performing custom chrome plating on industrial machinery. From late 1978 through June 1979, the WDNR investigated a series of complaints from neighbors adjacent to the site reporting that Anonymous Site C personnel were dumping yellow liquid on the ground on the west side of the building (Figure 1). The analysis of ground water samples from the site in June 1979 indicated hexavalent chromium contamination levels up to 1,200 mg/l. The WDNR ordered Anonymous Site C to conduct an investigation of the extent of soil and ground water contamination at the site. A preliminary investigation in June 1979 and a detailed investigation during July to December 1979 revealed that soil was contaminated with as much as 1,406 mg/kg of total chromium and ground water contained up to 1,440 mg/l of hexavalent chromium. The WDNR ordered Anonymous Site C to submit a plan detailing the measures that the company would take to remedy the contamination. At the time of the order, all parties assumed that it would probably be necessary to excavate and remove as much as 600 cubic yards (460 cu. m) of soil, in addition to controlling the flow of surface and ground water.

300.68(e)(2) (i(B)) amount and form of substances

Figure 1. Surface Characteristics and Ground Water Flow Patterns at Anonymous Site C



In April 1980, Anonymous Site C engineering consultant, Soil Testing Services of Wisconsin (STS) submitted a plan to the state proposing construction of a 12 foot deep (4 m) interceptor drain around the two downgradient sides of the contaminated area, in lieu of removing contaminated soil. The plan also proposed a dike and an impoundment to control surface water.

300.70(b)(1) (iii)(D)(1) ground water controls: subsurface drains

The WDNR accepted the concept of the plan, but required further sampling to ensure that the proposed trench would extend below all contamination. Subsequent well sampling indicated ground water contamination at 25 feet (7.6 m) beneath the ground surface. Consequently, in August 1980 the WDNR ordered Anonymous Site C to construct the trench to a depth of 25 feet (7.6 m) which would have cost three to four times as much as the originally proposed 12 foot (4 m) depth. Anonymous Site C rejected WDNR's order, responding that the deeper contamination detected was a result of seepage through the monitoring well casing.

During the fall of 1980, the state initiated an enforcement action against Anonymous Site C, to bring the company into compliance with WDNR's remedial action requirements. The enforcement action was prompted by the company's protest against excavating a 25-foot (4.6 m) deep trench. The owner of Anonymous Site C, basing his opinion on earlier test result data, claimed that contamination did not extend beyond 12 feet (4 m) and a 25-foot trench was unwarranted. In defense of this position the company conducted additional soil borings and groundwater sampling at the site and confirmed the fact that contamination didn't extend beyond 12 feet (4 m). Consequently in December 1980, WDNR approved Site C's original plan, allowing the drain to be installed at a depth of 12 feet (4 m).

Synposis of Site Response

The remedial actions at Anonymous Site C consisted of two major components: ground water control and surface water control. The ground water control was constructed in January 1981 and consists of a 240 foot long (73 m), 12 foot deep (4 m), L-shaped subsurface drain running along the southern and western boundaries of the Anonymous Site C property, sloping toward a sump at the northern end. The drain is a perforated pipe at the bottom of a gravel-filled, clay-capped trench.

The surface water control was built in May 1981, and consists of a 2 foot high (0.6 m) earthen dike paralleling the trench, which diverts runoff to a 25 foot (7.6 m) square surface impoundment. The collected surface and ground water is pumped through a sanitary sewer to the DePere sewage treatment plant.

In addition, in July 1981, a contractor for Anonymous Site C excavated the top 3 feet (1 m) of soil from a garden immediately west of the trench on neighboring residential property, and replaced it with clean topsoil. Some of the excavated soil was added to the dike, and the remainder was spread on the Anonymous Site C property southwest of the plating shop.

Currently, Anonymous Site C submits quarterly surface and ground water monitoring reports to the WDNR.

SITE DESCRIPTION

The surface characteristics and hydrology of the Anonymous Site C site are discussed separately below.

Surface Characteristics

The company occupies approximately three acres in a residential community. The northern and eastern boundaries of the site are defined by a city street leading to the plant entrance and a railroad track, respectively (See Figure 1). A shallow ditch runs parallel to a 2 foot (0.6m) berm along the western site boundary with four residential properties abutting the site to the south and west. Most of the land on the site is relatively flat except for a downward 4 to 5 percent slope from the plating shop toward the south and southwest corner of the property.

300.68(e)(2) (i)(A) population at risk

Hydrogeology

The first 25 to 30 feet (7.6 to 9.1 m) of soil underlying the site consists of glacial till composed primarily of a reddish brown silty clay laced with lenses of clayey sand, fine sand, and fine gravel. In the site area specifically, there also exists fill material consisting of clay chunks, and trace roots, extending to a depth of about 5 feet. This uncontrolled fill was backfilled into the area south southwest of the plating shop during an unspecified period of time. The deeper zone of contamination may be attributed to this fill material because it provides a more permeable path for contaminant migration.

300.68(e)(2) (i)(D) hydrogeological factors

Beneath this layer is a layer of Galena-Plattville dolomite, approximately 200 feet (61 m) thick and characterized by small horizontal fractures which prevent significant downward migration of water. This formation is also a low yielding (generally less than 10 gallons [38 l] per minute) drinking water aquifer which is tapped by several private wells in the area. A major aquifer, heavily used for all purposes in the area, lies beneath the dolomite layer and is composed of Saint Peters sandstone.

Water movement in the upper 25 feet (7.6 m) of soil at the site generally follows the surface elevation contours (See Figure 1) and, because of the uneven distribution of clays, sand, and gravel, the rate of ground water flow would be expected to be quite variable; probably ranging from slow to very slow to no movement at all within short vertical sampling intervals.

WASTE DISPOSAL HISTORY

In January 1979 WDNR documented one spill of concentrated chromic acid plating bath from the western door of the Anonymous Site C facility. Prior to and immediately following that spill, local residents reported numerous incidents of intentional dumping of chrome plating waste in the same area. Some of these complaints included reports of damage to the vegetation on two neighboring properties. It is uncertain whether any intentional dumping actually occurred at the site, however, there was no question that large amounts of chromium had escaped from the plating shop and seeped into the surrounding soil.

HISTORY OF CONTAMINATION

The Wisconsin Department of Natural Resources (WDNR) was called to the site several times during 1978 by local residents who claimed that the facility was engaged in illegal dumping and that this dumping was damaging neighboring lawns and gardens. During these visits, WDNR officials were not able to document any evidence that the dumping had actually occurred. Finally, in January 1979, a large spill of chromic acid plating solution escaped through the west door of the plating shop and covered much of the southwestern corner of the site. A lot of this spillage, described in WDNR reports as several pools of yellow liquid mixed with snow, apparently seeped into the ground despite efforts by Anonymous Site C employees (in response to a WDNR request) to shovel chromium contaminated ice and snow back inside the plating shop where it could melt and enter the floor drain leading to the sanitary sewer. To minimize the migration of the

300.63(a)(4)
discovery

300.68(c)
administrative
process

unrecoverable chromium, WDNR officials directed Anon. Site C to cover the entire affected area with a synthetic liner. The WDNR also required Anon. Site C to hire a consultant to do some preliminary soil and ground water sampling at the site. The sampling effort, conducted in June of 1979, included the construction of 16 shallow soil borings (using hand augers) at between 0 and 2.5 feet (0 to 0.8 m) deep and 8 wells (also using hand augers) between 2.5 and 3.6 feet (0.8 to 1.2 m) deep. Figure 2 shows the location of these sampling areas which were backfilled after the sampling was complete. It should be noted that the synthetic liner was only temporarily removed during these investigations and that the liner remained in place until all of the remedial actions were completed at the site.

300.64
preliminary
assessment

Hexavalent chromium in well #16 was measured at 1200 mg/l and only two (#19 and #21) of the eight sampling wells showed no apparent chromium contamination. The 22 soil samples taken from the soil borings could not be reliably quantified because they were not digested with acid prior to analysis; rather, 10 grams of each sample was leached for 24 hours with 200 ml of water. However, the results of these soil leaching tests strongly indicated chromium contamination because of the large ranges of values obtained from samples taken within such a small area of land. Also indicative of contamination was the high concentrations of hexavalent chromium which is not normally present in the natural environment.

On the basis of these preliminary findings, WDNR required Anonymous Site C to retain a consultant to: 1) conduct a full scale soil and groundwater study of the site, 2) determine the areal extent of the contamination, and 3) propose possible remedial measures.

300.68(f)
investigation

The sampling for the second investigation at the site was conducted from July to December 1979 and involved the drilling of 10 wells between 5 and 27.3 feet (1.5 to 8.3m) deep and exploratory borings between 11.5 and 15.6 feet (3.5 to 4.7 m) deep (Figure 3). Both the soil borings and well holes were drilled with a solid stem auger attached to a CME-55 rig mounted on a Bombardier all-terrain vehicle. Occasionally there were problems with hole collapse necessitating a change from the solid stem auger to a roller bit attachment. In these situations, a 3 3/8 inch (8.6 cm) casing was driven to the depth of the auger hole and the roller bit was activated using water as the drilling fluid. After completion of each well boring a 1 1/4 inch (3.1 cm) diameter slotted PVC observation well was installed with a 4 inch (10 cm) diameter, carbon steel protector pipe and lock. The annulus of each well was

Figure 2. Locations of Shallow Borings and Wells Sampled During Preliminary Investigation at Anonymous Site C

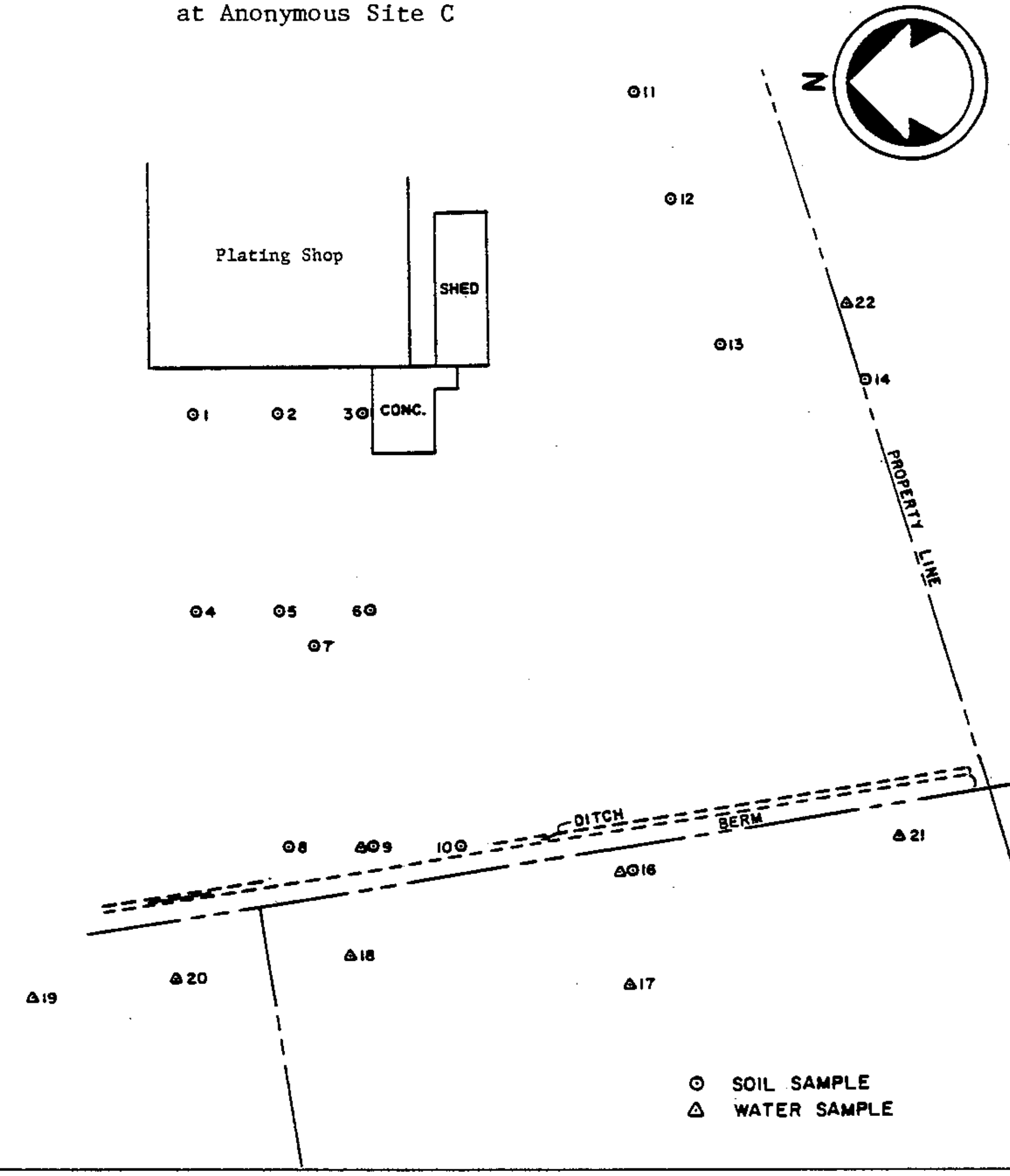
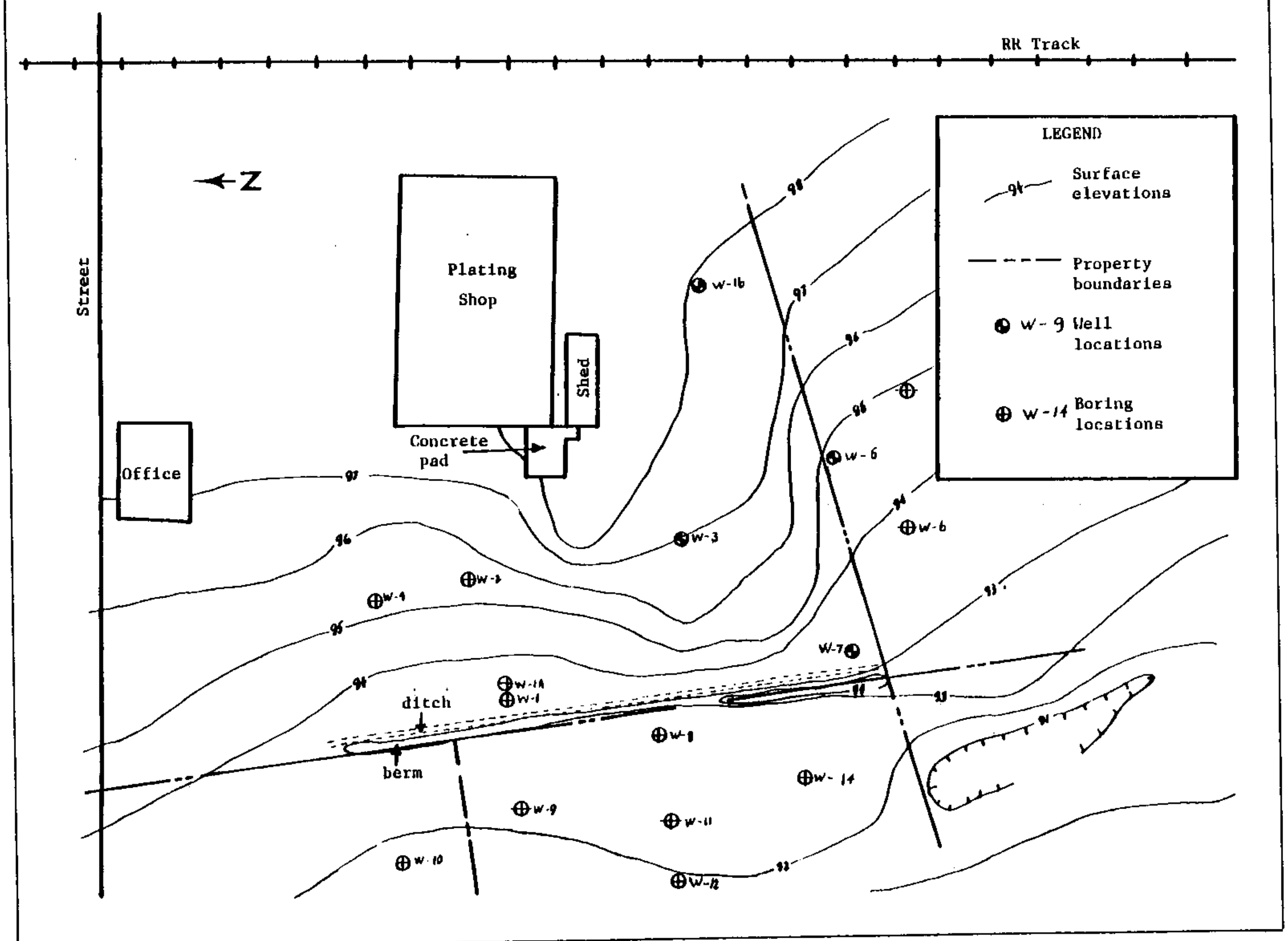


Figure 3. Location of Soil Borings and Wells Constructed During the Second Round of Sampling at Anonymous Site C



filled first with pea gravel, then with a bentonite slurry followed by a sand and gravel layer, another bentonite layer, and a concrete plug at ground level. All soil borings were backfilled with bentonite-sand mixtures. Soil samples were taken in most of the well and bore holes at 2.5 foot (0.8m) intervals with a split spoon sampler.

The results of this second round of soil sampling revealed an average total chromium level in the soil of about 190 mg/kg (dry basis). This level was determined using agressive hydrofluoric digestions of the soil samples to completely solubilize all the chromium bound by the soil. The use of this method on uncontaminated soils from the same general site area established a background total chromium level of 60 mg/kg (dry basis). The highest level of chromium found in the contaminated soil area was 1400 mg/kg (dry basis). Figure 4 outlines the approximate surface area beneath which the chromium-contaminated soils were found. The depth of the contaminated soils in this area ranged from zero to 12 feet (3.6m) with the highest concentrations generally occurring between 3 to 5 feet (1 to 1.5m).

Ground water samples taken during the second round of sampling were found to contain up to 1,511 mg/l total chromium and 1,440 mg/l hexavalent chromium. Background total and hexavalent chromium levels in the ground water were measured at < 0.1 and < 0.05 mg/l, respectively. The areal extent of ground water contamination was not determined conclusively, however the general flow of groundwater in the area was demonstrated to be very slow due to relatively impermeable soils. It should be noted that seams of silty clayey sand found in the area could have transported contaminated ground water beyond the boundaries of contaminated soils shown in Figure 4. However, it is just as possible that these seams, which were encountered in all but the dry wells, may not be continuous.

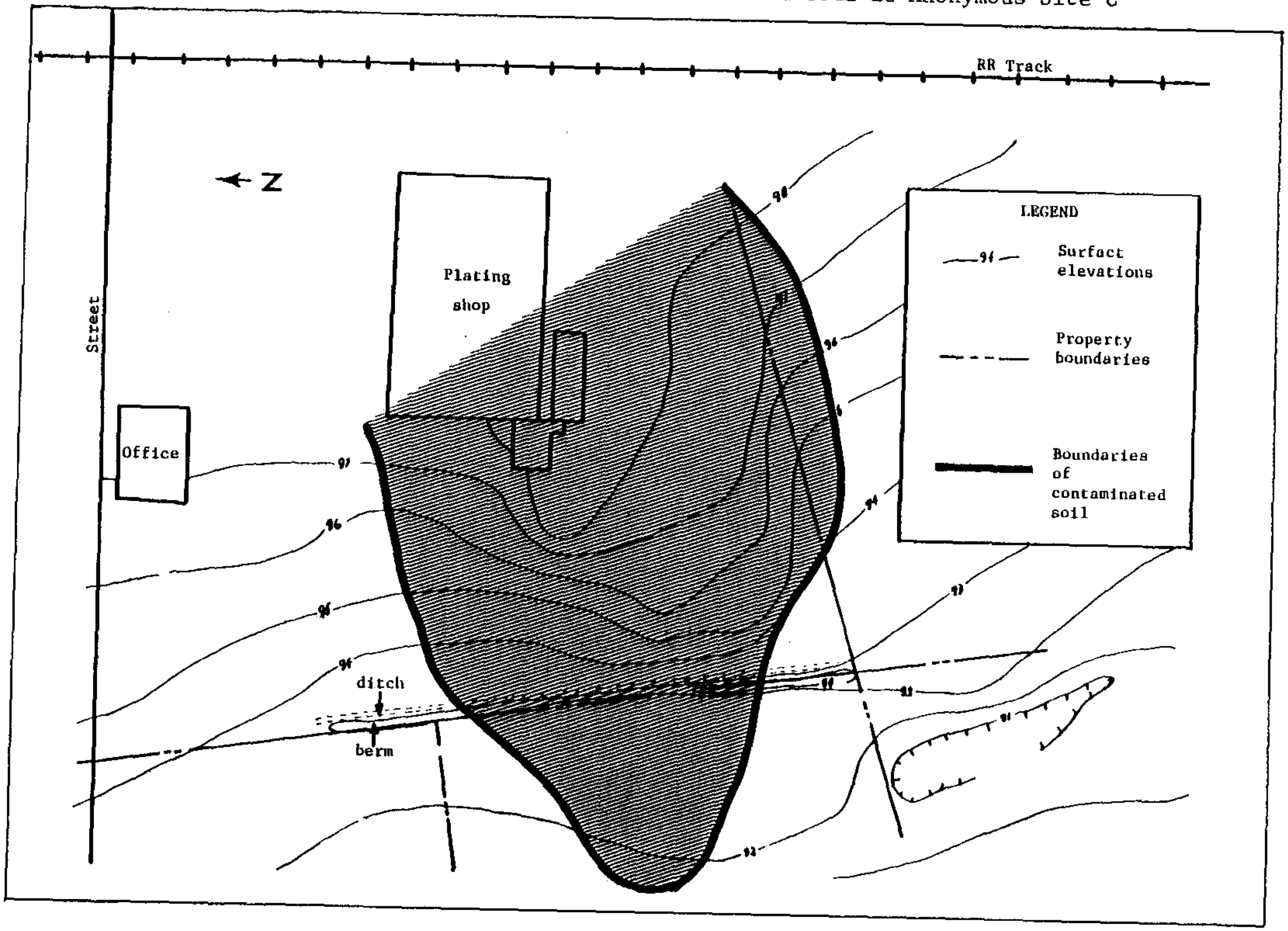
PLANNING THE SITE RESPONSE

Initiation of Response

The WDNR order to implement a remedial response at the Anonymous Site C site was based on a potential, rather than immediate threat to human health and the environment posed by uncontrolled hexavalent chromium contamination. The contaminated surface water or ground water could have entered a storm sewer, a pathway likely to carry the contamination a great distance from the site. The contaminated surface water ponded on the site also

300.68(e)(2) (i)(A) population at risk

Figure 4. Approximate Boundaries of the Contaminated Soil at Anonymous Site C



posed some potential for exposure to humans or animals by direct contact.

Further, contaminated surface or ground water may have posed some threat to vegetation near the site. A neighbor adjacent to the Anonymous Site C property alleged that trees and grass in her yard were killed by chromium migrating from the site. Another neighbor, whose garden abutted the Anonymous Site C property, feared that her produce would be rendered inedible by the chromium.

300.68(e) (2)(iv) environmental effects

The contaminated ground water posed no immediate threat to drinking water supplies, since the contamination was limited to a small area in soils of relatively low permeability and all homes in the area were supplied by the city water system.

300.68(e)(2) (i)(D) hydrogeological factors

Selection of Response Technologies

The WDNR and the Anonymous Site C were in regular communication as the extent of contamination at the site was being determined. During this period, it was generally believed by both parties that all of the chromium-contaminated soil needed to be excavated and removed from the site. In December of 1979, the consultant to the Anonymous Site C determined that approximately 300 to 600 cubic yards (229 to 459 M^3) of soil would have to be excavated and removed if this initially-proposed option was selected. However, the final report, submitted by the consultant in April of 1980, recommended a different remedial design option which included the following components:

300.68(h) initial screening of alternatives

- A ground water interceptor trench to collect contaminated ground water for pumpage to the city sewage treatment plant.
- A surface impoundment to collect surface runoff from the contaminated areas.
- Excavation of contaminated soils from a neighboring garden.

These recommendations were followed by lengthy negotiations between officials from the state, the city, and the Anonymous Site C.

The major issues raised during these talks centered on:

- The relative cost and benefits of excavation and removal vs trenching and collection

- The appropriate depth of the interceptor trench

- The potential for added costs to the city resulting from their acceptance of chromium-contaminated water from the interceptor trench.

The excavation issue was resolved in favor of the trenching and collection option because the chromium adsorbed to the soils was primarily in the trivalent state which is virtually nontoxic and immobile; therefore the relative risks posed by the site would not have been significantly reduced by the more costly option of soil removal. It should be noted that this reasoning did not apply to the chromium contaminated soils in a neighboring garden. Here, there was additional concern over chromium uptake by vegetables grown in the garden.

The issue of trench depth resulted from review of ground water sampling data after the recommended remedial response was proposed. Samples from one of these wells indicated that the depth of contamination was about 10 feet (3m) lower than originally believed. To resolve this issue, 3 additional soil borings were made in the area of the suspect well. The results of these borings revealed that seepage must have occurred from the upper soil layers through the annular space of the well.

The issue of contaminated interceptor trench water was resolved through a formal agreement between officials of the city sewerage system, the Mayor, and Anonymous Site C officials as described in the following section.

<u>Extent of Response</u>

300.68(j)
extent of remedy

The WNDR faced three issues in deciding what the extent of the remedial action should be: the question of whether the soil should be excavated; the appropriate depth of the subsurface drain; and the effluent criterion that would determine when operation of the surface and ground water collection systems could cease. During the site investigation in late 1979 the WDNR assumed that, in addition to installing some kind of ground water control, it would probably be necessary for Anonymous Site C to excavate as much as 600 cubic yards (459 cu. m) of contaminated soil and dispose of it in a licensed hazardous waste landfill 120 miles (193 km) from the site. This requirement would have increased the cost of the remedial actions 500 to 1,000 percent over the cost of the remedial actions that were finally implemented. Anonymous Site C, a small business, probably would not have had the resources to finance such a project.

Upon further study, however, the WDNR concluded that, because of the chemical properties of chromium, soil removal would not be necessary provided a ground water control was installed. Hexavalent chromium, the valence state of the chromium spilled from the Anonymous Site C shop, is highly toxic and mobile in water and soils. However, as hexavalent chromium moves through soil, it tends to react with organic matter or other electron donors and is reduced to trivalent chromium, which is readily adsorbed to the soil particles and is relatively non-toxic. Consequently, the WDNR concluded that it was permissible to leave the soil in place. Much of the hexavalent chromium in the soil and ground water could be expected to be reduced to trivalent chromium, and the remaining hexavalent chromium could be expected to eventually be removed by the subsurface drain.

300.68(e)(2) (i)(C) hazardous properties

The second issue concerning the extent of the remedial action was the appropriate depth of the drain. The WDNR and the company's engineering consultant agreed that the drain should be placed below the contaminated zone. After the consultant submitted the remedial action plan, there was some dispute between Anonymous Site C and the WDNR about the actual depth of contamination. When the WDNR concluded in December 1980 that the contamination only extended to approximately 12 feet (4 m), Anonymous Site C was permitted to construct the drain as originally proposed.

Finally, the WDNR established criteria defining the duration of operation of the surface and ground water collection systems. Anonymous Site C is required to continue pumping water from the sump and the surface impoundment into the sanitary sewer until discharge monitoring shows, in a consistent trend, that total chromium is below 0.5 mg/l, and that hexavalent chromium is below 0.05 mg/l. The WDNR based its criteria on chromium discharge limits established in the Wisconsin Pollution Discharge Elimination System (WPDES).

300.68(e)(2) (iii) state approach to similar situations

The remedial action plan submitted by the company's consultant in April 1980 qualified that at a minimum, a 2-year pumping period would be required before ground water levels would fall below the discharge limits. Additional time extensions would be available if groundwater flow rates were slower than anticipated. Recent sampling indicates that groundwater still remains highly contaminated, suggesting that it will be necessary to continue the operation of the system.

The DePere sewage treatment authority agreed to accept the effluent from the system without pretreatment because the chromium concentrations were low enough that the contaminated water posed no danger of impairing the operation of the treatment plant. Anonymous Site C signed a contract with the city that contained a number of conditions regarding the city's acceptance of the effluent, requiring Anonymous Site C to:

300.70(b)(2)(ii) direct waste treatment methods

- Record the quantities of water pumped into the sanitary sewer,
- Sample the water regularly,
- Pay a fee for regular city inspections of the collection system,
- Indemnify the city for any additional costs of disposal of sludge that might result from Anonymous Site C effluent causing the sludge to be classified as hazardous.

DESIGN AND EXECUTION OF SITE RESPONSE

The remedial response at the Anonymous Site C site consisted of three major components. These were:

- A groundwater interceptor trench

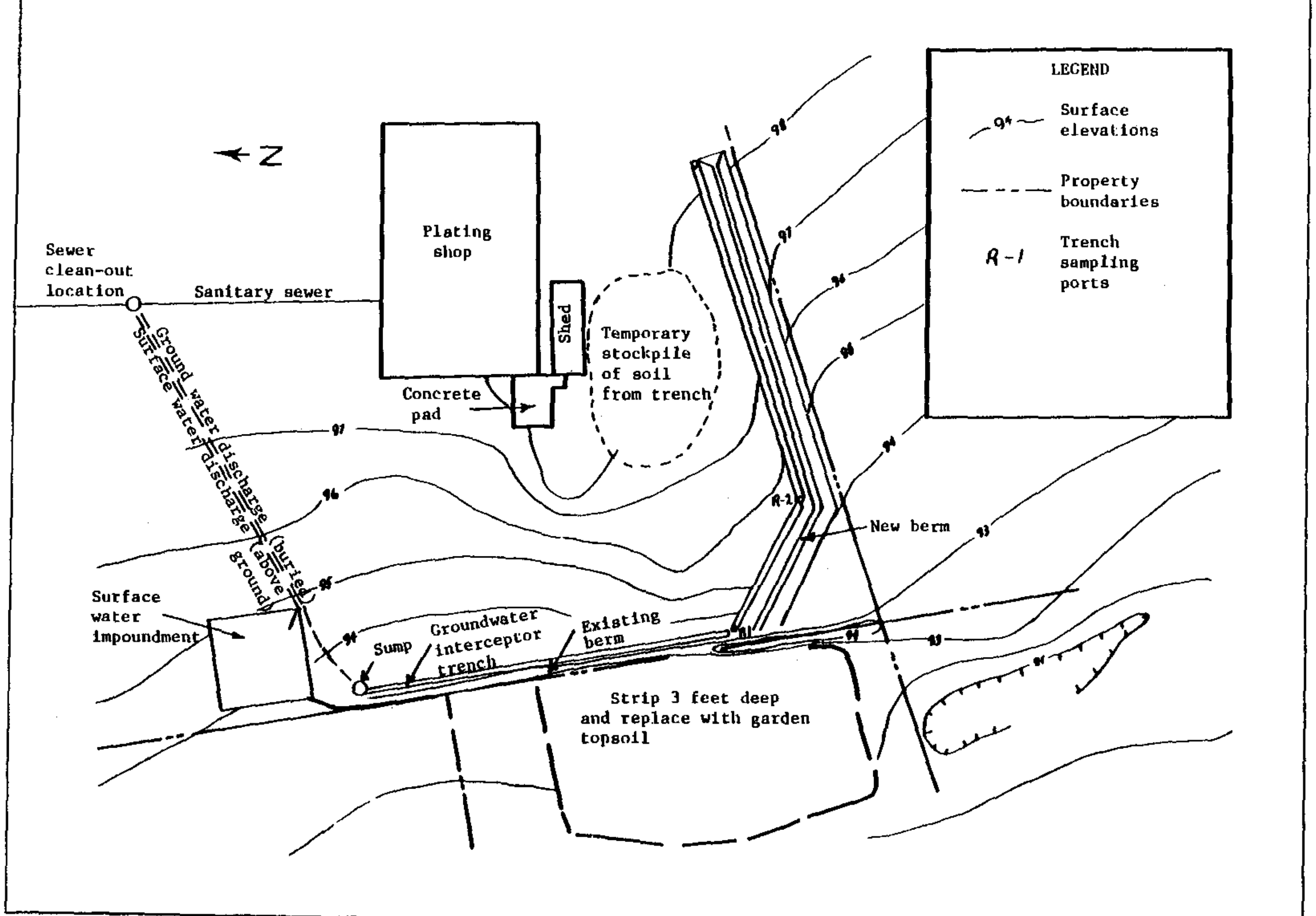
300.70(b)(1)(iii)(D)(1) subsurface drains

- A surface impoundment
- Soil removal at a neighboring garden.

300.70(C)(2)(i) excavation

In January 1981, the ground water interceptor trench was constructed with a small backhoe to an average depth of 12 feet (3.6 m) around the perimeter of the contaminated area (Figure 5). This depth was estimated to be between 2 or 3 feet (0.6 or 0.9m) below the extent of the contaminated soil. After excavation, the bottom of the trench was lined with a 4 foot (1.2m) wide sheet of polyethylene and 240 feet (73 m) of 6-inch (15.2cm) diameter, slotted PVC pipe was installed. This drain pipe was intersected vertically at 3 locations with 4-inch (10cm) diameter PVC sampling pipes (R-1, R-2, and R-3 in Figure 5). Each of the sampling pipes extend about 1 foot (0.3 m) below the drain pipe to ensure collection of adequate sample volumes. The drainage pipe has an average slope of

Figure 5. Remedial Design Installed at Anonymous Site C



0.7 percent toward the 4 foot (1.2 m) diameter fiberglass sump. The sump was placed such that the drain invert intersects it about 3 feet (0.9 m) from its base. This sump is periodically pumped to the nearest sewer clean-out location through an underground connector pipe (See Figure 5).

After the drainage pipe was placed into the trench, it was backfilled with 1 1/2 inch (3.8 cm) diameter washed stone to the ground surface and the stone was capped with clay material.

The excavated material from the trench was temporarily stockpiled at the southwest corner of the plating shop prior to being used to construct a 2 foot (0.6 m) high berm between the trench and the adjoining properties along the southern border of the site. This berm was connected to an existing berm running along the western border of the site so that all surface water would flow toward the surface impoundment.

300.70(b)(1) (ii)(B) surface water diversion and collection systems

The surface impoundment was completed in May 1981 using a Ford 7500 front-end loader/backhoe and was designed to contain the runoff from a 2.5 inch (6.3 cm) rainstorm at the site. The impoundment is approximately 25 feet long on each side and 4 feet deep and has a 3-inch (7.5 cm) deep coarse gravel liner to prevent erosion. The impoundment is situated about 100 feet (30 m) from the northwest corner of the plating shop along the western boundary of the property. The contents of the impoundment are periodically pumped into the nearest sanitary sewer clean-out location through an above-ground connection (See Figure 5).

The excavation of contaminated soil from a neighboring garden (see Figure 5) was done with a Ford 7500 front-end loader backhoe and a pick-up truck. Approximately 300 cubic yards (230 m^3) of soil were stripped from the garden area to an average depth of 3 feet (0.9 m). The excavated soil throughout was spread on the Anonymous Site C property. The excavated area was then filled with topsoil.

COST AND FUNDING

Source of Funding

Anonymous Site C paid for all remedial work and virtually all of the site investigation. The Wisconsin Department of Justice paid for some soil sampling in November 1980 in order to determine the appropriate depth of the drain.

300.68(c) responsible party

Selection of Contractors

Anonymous Site C did not engage in a competitive contractor selection process; instead they chose local contractors who were qualified to do the work. The first contractor selected was Foth & Van Dyke and Associates, Inc., a consulting engineering firm in Green Bay, Wisconsin. Foth and Van Dyke performed the initial site investigation in July 1979, and continues to perform quarterly sample analyses.

In the fall of 1979, Foth and Van Dyke referred Anonymous Site C to Soil Testing Services of Wisconsin, Inc. (STS), another consulting engineering firm in Green Bay, when it became apparent that the site investigation and remedial design would require STS's more extensive geotechnical expertise. STS performed further site investigation, designed the remedial actions, and gave Anonymous Site C technical assistance in meetings and legal proceedings with the WDNR.

Anonymous Site C chose DeGroote Construction Company, an excavation and construction contractor in Green Bay, to implement STS's remedial action plan in January, May, and July of 1981. Anonymous Site C used DeGroote, rather than STS, to implement the plan because Anonymous Site C believed that DeGroote could perform the work for a lower cost.

Project Cost

The total cost of the investigation and remedial work at Anonymous Site C from September 1979 to July 1981 was approximately $23,000. In assembling the data for this case study, it was not possible to determine the exact cost of the work because Anonymous Site C records were not available for review. Consequently, only a general breakdown of expenditures, based on estimates provided verbally by persons involved in the clean-up, is possible (see Table 1).

Site Investigation and Remedial Design

Anonymous Site C incurred approximately $15,000 in expenses from STS between the fall of 1979 and the fall of 1980. Of this amount, about $8,000 was for the site investigation, including soil borings, well installation, sampling, and interpretation of data. Design of the surface and ground water collection system cost about $2,000. Anonymous Site C incurred a cost of about $5,000 for the time STS spent after the remedial action plan was submitted, helping Anonymous Site C negotiate with the WDNR over the depth of the drain.

300.68(f)
investigation

TABLE 1. SUMMARY OF COST INFORMATION-ANONYMOUS SITE C, DEPERE, WISCONSIN

Task	Expenditure	Estimated Future Cost	Funding Source	Period of Performance
Site investigation	$8,000	N/A	Anon C	7/79-12/79
Remedial design	$2,000	N/A	Anon C	12/79-3/80
Technical assistance in negotiations w/ WDNR	$5,000	N/A	Anon C	4/80-12/80
Installation of drain, surface controls	$8,000	N/A	Anon C	1/81-7/81
Operation and maintenence	N/A	$600/ year (a)	Anon C	
TOTAL	**$23,000**			9/79-7/81

(a) Duration of operation undetermined. Figure does not include sampling.

Foth and Van Dyke also performed some initial investigation, but an estimated of the cost of that work was not available.

Construction of Intercept Drain and Surface Water Diversion System

DeGroote Construction's execution of the remedial actions cost about $8,000. This included: all labor and materials involved excavating the 240 foot long, 12 foot deep trench; installing the drain, sump and pump; building the dike; constructing the 25 foot square, 4 foot deep surface impoundment; and replacing 300 cubic yards (230 cu. m) of topsoil in the neighboring garden.

300.70(b)(F)(iii)(D)(1) ground water controls: subsurface drains

Operation and Maintenance

The cost of operating and maintaining the surface and ground water collection systems is probably less than $600 annually, excluding sample analysis. The major cost is regular inspections by the DePere sewage treatment authority, which are performed two or three times per month, and cost $15 per inspection. DePere does not charge Anonymous Site C for treatment of the effluent because the city's sewage treatment charges are based on water consumption, rather than on discharge.

The cost of electricity for pumping the collected subsurface and ground water approximately 100 feet (30 m) to the sanitary sewer is negligible. During 1981, the sump pumps, operating intermittently for a total of 60 hours, pumped about 72,000 gallons (275,520 l) of water to the sewer, at a rate of 20 gallons (76 l) per minute.

No cost information was available for sample analysis. Every three months, Anonymous Site C personnel collect samples from eight locations in the collection systems and monitoring wells, and deliver them to Foth and Van Dyke, where they are analyzed for total chromium and hexavalent chromium.

PERFORMANCE EVALUATION

WDNR now requires the Anonymous Site C to submit quarterly monitoring reports on water samples taken from the R-1 and R-2 sampling points, the surface impoundment, the trench sump, and from wells 1-A, 2, 3, 5, and 16. These monitoring data are eventually expected to show a decline of total and hexavalent chromium at these sampling locations.

To date however, there is no indication of a reduction in chromium levels at any of these sampling locations. In fact, the four sets of monitoring data compiled in 1982 show that hexavalent chromium levels in 3 wells have exceeded the previously detected maximum of 1,511 mg/l; reaching a new maximum chromium concentration of 4,300 mg/l. Seven of the 12 samples taken from these three wells in 1982 had hexavalent chromium levels above 2,500 mg/l and six of these seven were at or above 4,000 mg/l hexavalent chromium. Samples taken at R-1, R-2, and the sump have chromium levels in the same general range as the well samples. The surface impoundment is generally low in chromium, usually ranging from < 0.1 mg/l to a maximum of 0.2 mg/l. However, on occasion, levels have been as high as 60 ppm. Although all the samples were analyzed for both total and hexavalent chromium, virtually all the chromium present was found to be in the hexavalent form.

The high chromium levels found in all sampling locations except the surface impoundment, indicate that a very long time period will be needed to flush all the chromium from the site. This does not necessarily mean, however, that the chosen remedial response was inadequate or was poorly installed. Rather, the long time period needed to restore the site probably reflects the slow and uneven drainage in the area. It is not possible to draw a final conclusion on whether the remedial response was sufficient to arrest the further escape of chromium from the area because several more soil borings would be needed to determine whether the sand and gravel seams in the area are continuous; and, if so, whether they extend below the interceptor trench. In any event, it can be stated with confidence that: 1) surface water runoff from the contaminated area has been adequately controlled and 2) if any continuous sand or gravel seams do exist in the area, they would not be likely to contaminate any drinking wells or cause any other adverse exposure situation. The first of these statements is supported by the past performance of the runoff control system which consists of the berms and the surface impoundment. It is felt by some that supporting evidence for the second statement is found in the local geology which includes of a 200-foot (61 m) layer of dolomite beneath the contaminated area. Although this is not condoned by all parties involved it is generally felt that despite the dolomite layer being used as a source of drinking water in the area, its alkaline chemistry would precipitate out any chromium moving down with the water from the upper contaminated zone. As previously mentioned, the homes in the immediate area of the Anonymous Site C site are supplied by the city water system.

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BIOCRAFT LABORATORIES

WALDWICK, NJ

INTRODUCTION

NCP Reference

Biocraft is a small synthetic penicillin manufacturing plant located on a 4.3-acre (1.72 ha) site in an industrial park of the town of Waldwick, NJ (population 10,800) (see Figure 1). Sometime between 1972, when the plant opened, and 1975, when the pollution problem was discovered, two pipes leading from the plant to underground waste solvent storage tanks leaked into the ground, contaminating an area 360 feet (110 m) x 90 feet (27 m) about 10 feet (3 m) thick. The waste solvents seeped into a storm sewer, which flowed into a nearby creek (see Figure 1) and also contaminated the shallow aquifer. The pollution was suspected by local health officials as having been responsible for a fish kill in 1973. A town drinking water well less than a 1/4 mile away draws from a deep aquifer. The town of Waldwick was concerned that the high level of contamination would eventually contaminate the well, but the state believed that contamination of wells was unlikely because of hydrogeology. On July 1, 1981 before the ongoing ground water decontamination operation began, a test well was installed on-site, upgradient from the pollution source and an artificial ground water mound. Chemical analysis revealed 85,000 ug/l acetone, 55,000 ug/l methylene chloride and 648 mg/l COD (chemical oxygen demand) in samples taken from this well.

300.68(e)(2)(iv) environmental effects

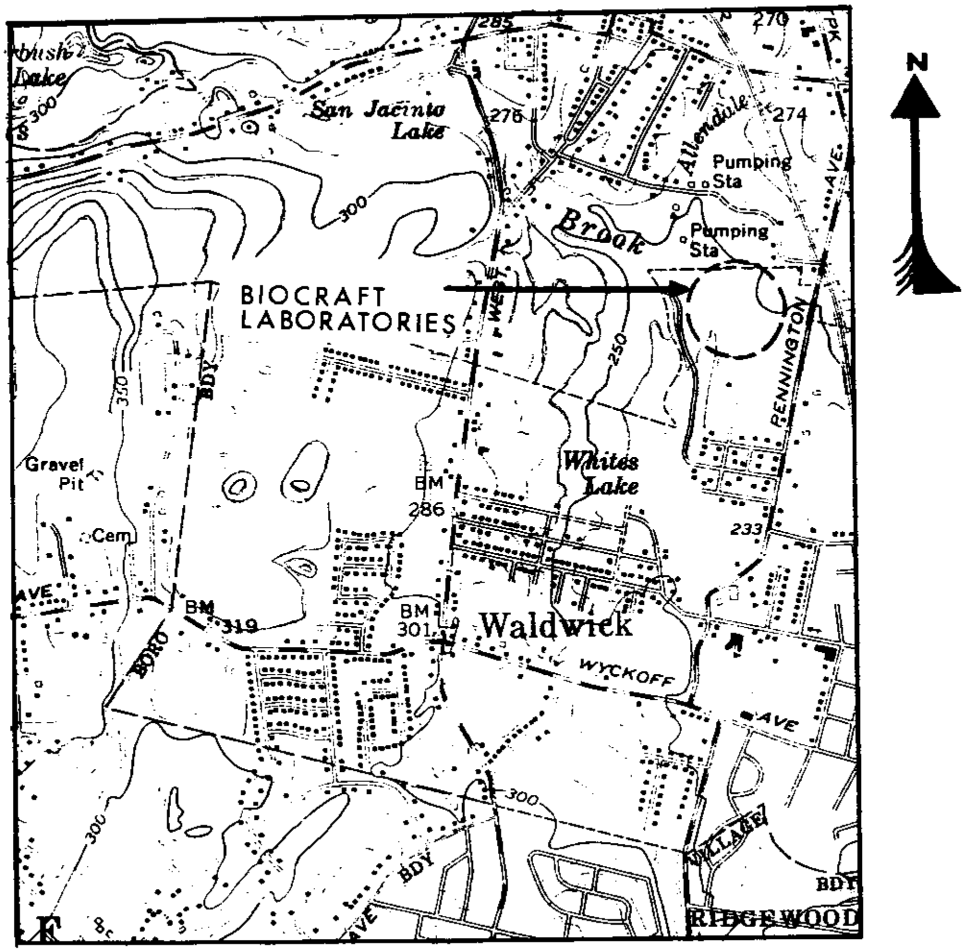
300.65(a)(2) drinking water threat

300.68(e)(2)(i)(D) hydrogeological factors

Background

Between 1972, when the plant opened, and 1975, when the pollution problem was discovered, two pipes connecting underground waste solvent storage tanks leaked an undetermined amount of butanol, acetone and methylene chloride into the ground. The amount of leaked waste solvents is unclear, but it could have been as much as 33,000 gallons (125,000 l), assuming that the gauging system would not have detected less than 50 gallons per transfer of lost solvent and about 660 transfers, were made prior to problem discovery. The waste solvent traveled through a

300.68(e)(2)(i)(B) amount and form of substances present



1 INCH ≅ 2000 FT

Figure 1. Location of Biocraft Laboratories, Waldwick, N.J.

storm sewer that ran through and in front of the site, and led into a tributary of Allendale Brook (New Jersey State stream designation FW-2 non-trout).

300.70(b)(1) (iv)(B) contamination of sewer line

In the spring of 1975 the director of the Northwest Bergen Regional Health Commission (NWBRHC) called the New Jersey Department of Environmental Protection (DEP) to report an "obviously...degraded ecological condition" in the Allendale Brook and its tributary, Hohokus Brook. Wastes from Biocraft were suspected to be responsible for a 1973 fish kill in a pond into which Hohokus Brook empties. The mayor of Waldwick was concerned about the lack of a report from the Fish and Game Commission about the fish kill, and about the health of the children who played in the brook.

300.64 preliminary assessment

300.68(e)(2) (i)(A) population at risk

On June 2, 1975, a representative of the Passaic-Hackensack Basin Element of the DEP and two NWBRHC officials performed a preliminary investigation of the Biocraft site for possible discharges into the tributary leading to the Allendale Brook. A storm sewer was reported to be discharging contaminants into the tributary, based on observations of "a strong pungent odor...in the brook and in the sewer pipe", and a "grayish-black algal growth covering the entire bed of the tributary down to its junction with Allendale brook" and in the storm sewer. The odor and the discharge flow were traced back to the storm sewer junction leading from the Biocraft plant site, where a water sample was taken. An inspection of the storm sewer grates showed no discernible flow coming from above the pipe leading from Biocraft. A dye test of the sanitary-industrial waste sewer did not reveal any leaks into the storm sewer, that would have suggested the presence of an underground leak or unknown connection. A study subsequently performed by Biocraft's consultant revealed that a leak in the lines to underground waste solvent storage tanks was responsible for the discharge.

300.63(a)(4) discovery

Synopsis of Site Response

The underground feed lines to the storage tanks were sealed in the winter of 1975 and above ground feed lines were installed to prevent future ground water contamination. On February 13, 1976, Biocraft, with its consultant Princeton Aqua Science (PAS), began selectively pumping five wells and disposing of the contaminated water off-site at an industrial wastewater plant in Tonawanda, NY. An incinerator at Tricil, Inc. in Canada was later used to dispose of the contaminants, and a pretreatment facility in New Jersey also served briefly as the disposal site. Because of the expense and problems with disposal

300.65(b)(4) controlling source of release

300.65(b)(6) off-site removal

300.70(b)(1) (iii)(d)(1) subsurface drain site availability, Biocraft sought other alternatives such as biodegradation, using in-house expertise from its antibiotic manufacturing staff. 300.60(b)(2)(iii)(E)(3) microbiological degradation

Biocraft initiated the currently (as of January 1983) ongoing remedial action on June 30, 1981, using a new new ground water collection system, on-site treatment and reinjection into the ground. The contaminated ground water is collected from a recovery well (#P13) in an interceptor trench located on the west side of the Biocraft building and from two shallow wells (#'s P30 and P32A) on the west property line (see Figure 2). This contaminated water is piped to settling and activation tanks where aeration and nutrient addition accelerate the activity of microorganisms that degrade contaminants in the water. The treated water with elevated levels of aerobic bacteria is injected into two trenches on the southwest side of the property, upgradient from the source of the contamination. Nine underground aeration wells were installed along the path between the injection and withdrawal trenches to enhance the aerobic biodegradation in the ground water. In September 1982 air injection through two monitoring wells was added. 300.70(b)(iii)(c) groundwater pumping 300.70(b)(2)(ii)(A)(3) 300.70(b)(2)(ii)(A)(3) biological reactors

SITE DESCRIPTION

Surface Characteristics

The Biocraft site is located in a small industrial park in the Borough of Waldwick, Bergen County, New Jersey.

Climate is typical of the northern New Jersey area. Winter months are moderately cold with average temperatures of 35°F (0.56°C). The average daily minimum temperature is 27°F (-2.8°C). Lowest recorded winter temperature for this area was -7°F (-22°C) recorded in Newark in 1949. Average summer temperature for the area is 73°F (23°C) with an average daily maximum of 82°F (28°C). The highest recorded temperature was 105°F (37.8°C) in 1953 and 1966. 300.68(e)(2)(i)(E) climate

Precipitation averages 42 inches (107 cm) annually with a range of 30 to 56 inches (76-142 cm) annually. Thunderstorms occur about 26 days a year predominantly in summer. The average seasonal snowfall is 28 inches (71 cm). Storms producing more than 4 inches (10 cm) of snow occur on the average of twice per winter.

Relative humidity averages 54 percent in mid-afternoon, with higher values at night, averaging about

73 percent near dawn. Prevailing winds are from the Southwest, with an average speed of 10 miles (16 km) per hour.

The Biocraft property is about 4.3 acres (1.7 ha) in size. It lies in a relatively flat area with slopes from 0 to 3 percent. The original topography of the surrounding area has been somewhat modified by regrading for buildings, parking lots, and streets. About 30 percent of the area of the property is paved or covered with buildings. The area around the main building, roughly 10 percent of the property, is grassed. The remaining 60 percent is lightly forested with water tolerant hardwoods and undergrowths of ferns, grasses, and sedges. The properties to the east of the Biocraft site are predominantly covered by asphalt paving and office buildings.

Three basic soil types were found to occur in the vicinity in a 1925 soil summary, i.e. Merrimac gravelly loam, Papakating silt loam, and muck. Drainage for these soil types ranges from very well drained to poorly drained. Ponded areas were observed near the southern property boundary indicating shallow groundwater.

300.68(3)(2)(i) (A) population at risk

The western property boundary is located about 350 feet east of a small creek, which flows toward the southwest. The creek receives stormwater runoff from the Biocraft site and from other plant sites in the industrial park. The creek empties into Allendale Brook which drains into Hohokus Creek. Allendale Brook and Hohokus Creek are designated by the State of New Jersey as "FW-2 Non-trout; suitable for potable, industrial, and agricultural water supply; primary contact recreation; and maintenance, migration, and propagation of natural and established biota."

A municipal ground water well is located about 1,000 feet southeast of the contaminated area. Biocraft also operates a deep well that is directly under the contaminant plume. Figure 2 shows surface features of the Biocraft site.

Hydrogeology

300.68(e)(2) (i)(D) hydrogeological factors

The Biocraft site is located in an area of unstratified and stratified drift deposited by the "Wisconsin" Glacier and its melt waters during the Pleistocene Epoch of the Quaternary Period. A geologic column showing the underlying substrata at the site is shown in Figure 3. Thin layers of silt and gravel can be found at the surface up to 3 feet (1 m) thick in the area, presumably due to

Figure 2. Configuration of Biocraft Site, Waldwick, N.J.

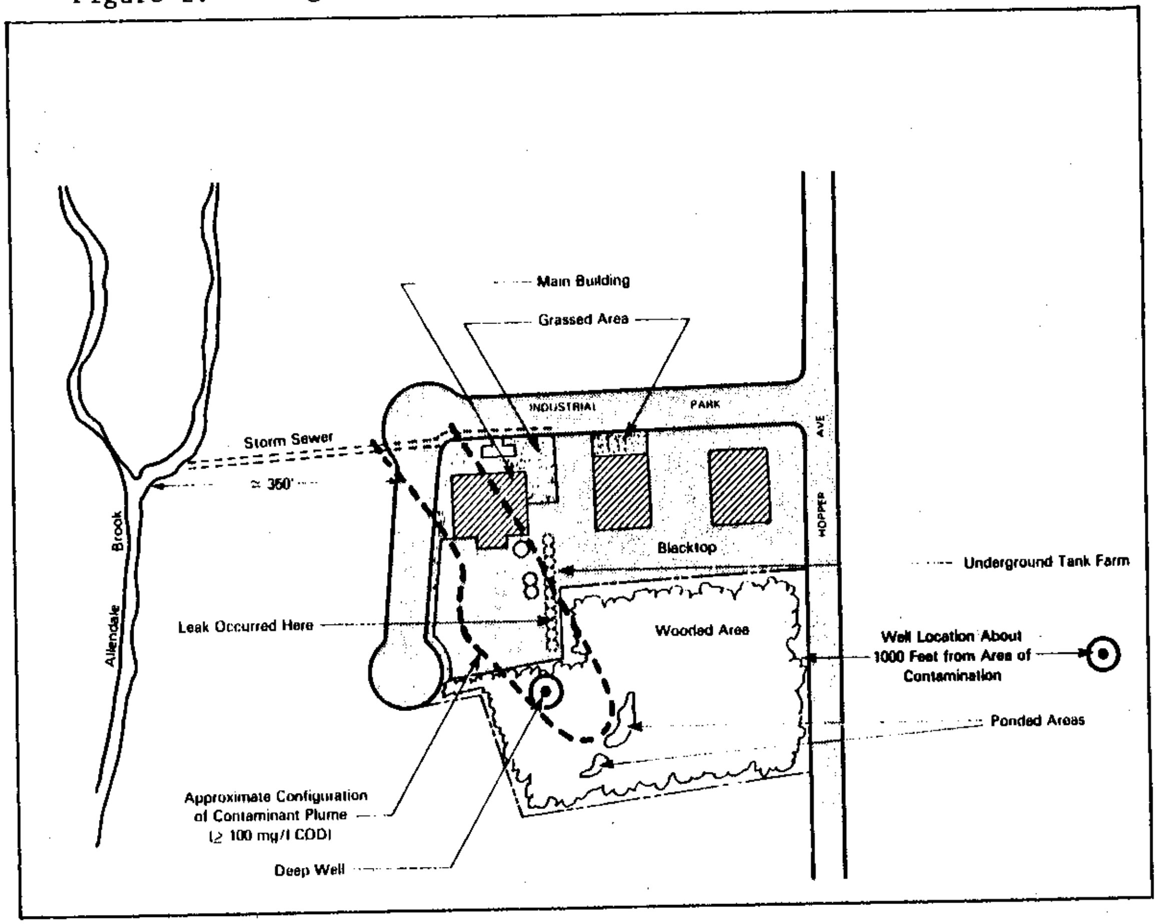
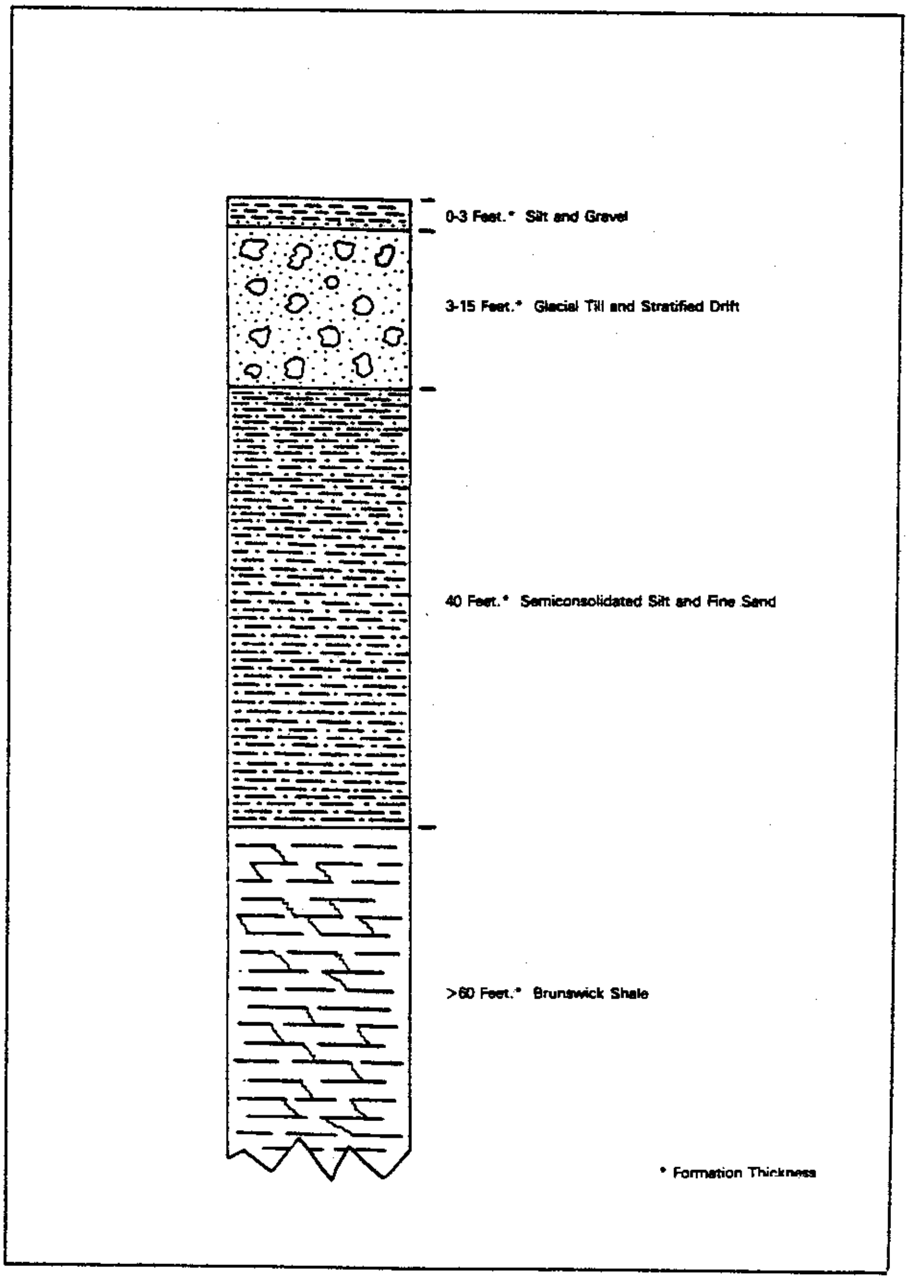


Figure 3. Geologic Column for the Biocraft Site.



earlier stream deposition. In addition, regraded soils can be found near the surface due to construction activities.

Glacial till (unstratified drift) underlies the surface at a thickness of about 8 to 15 feet thick. It is a poorly sorted mixture of boulder, cobbles, pebbles, sand, silt, and clay. Some stratification occurs within the till layer due to glacial meltwater deposition which is believed to have resulted in large permeability differences around the site. Permeabilities (hydraulic conductivities) have been calculated for five monitoring wells from slug tests and have been found to range from 0.02 to 36 gallons per day per square foot ($9.4 \times 10^{9} - 1.7 \times 10^{5}$ m/s).

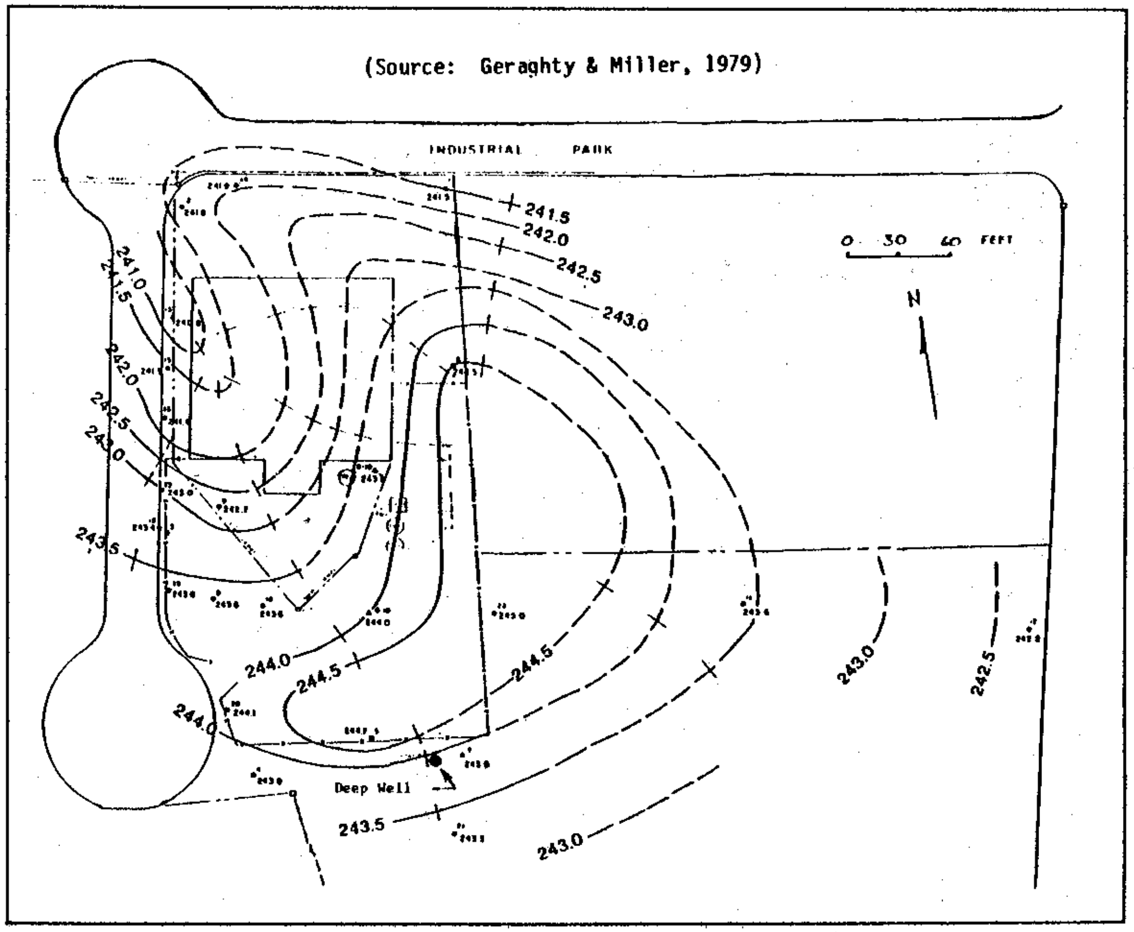
Approximately 40 feet of semiconsolidated silt and fine sand underlies the till layer. Visual inspection of the material in this deposit suggested very low permeability, but no actual testing was conducted on this strata. This formation was considered to be an aquiclude.

Brunswick Shale of the Triassic Newark Group underlies the site at a depth of 50 to 60 feet (17 - 20 m), and a thickness of several hundred feet. The Brunswick formation is the primary water supply aquifer for the area, yielding an average of 125 gallons (473 l) per minute for 29 wells in the area with an average well depth of 320 feet. Primary ground water flow occurs in the interconnecting fractures, vertical joints, and faults in the shale, while little or no yield is obtained in the rock. Most of the wells of substantial yield have been drilled to great depths in order to contact a sufficient amount of water bearing fractures.

A municipal deep well is located in the Brunswick formation approximately 1,000 feet southeast of the underground discharge area. Biocraft Laboratories have also installed a deep well (in the Brunswick Shale) on-site to supply water to their chemical manufacturing operation.

Ground water elevations, flow rates, and directions were calculated by Geraghty & Miller, Inc., Consulting Ground Water Geologists and Hydrologists, Port Washington, N.Y. in March, 1979. Twenty-two wells with continuous level recorders were used to define the ground water regime. Figure 4 presents ground water monitoring well locations, and typical elevations, isopleths, and flow directions at the Biocraft site. As can be seen from Figure 4, ground water flow is somewhat irregular in this area, being affected by heterogeneous geology, surface

Figure 4. Water Table Configuration at Biocraft site



(Source: Geraghty & Miller, 1979)

cover, and possibly other factors. The configuration is not constant but can change substantially with the season and the amount of precipitation.

A noticeable ground water mound is present, corresponding to the south and east ends of the blacktopped area (see Figure 2). This has been explained by the consulting geologists to be an area of ground water recharge due to higher relative permeabilities in the area of well number 22 and surface characteristics conducive to recharge (wooded rather than blacktopped).

Ground water flow from the mound is omni directional with the major flow regimes moving towards the northwest, northeast, and south. In November, 1980 the predominant flow direction was to the south, confirming the variable flow regime.

A distinct ground water flow regime trough occurs in the northwest corner of the property, corresponding to an area of surface coverage and higher permeability. As shown by the flow direction lines in Figure 4, a contaminant plume emanating from the leak area would tend to flow northwest toward the trough area. It is also possible that the plume could travel toward the northeast and south given the changing nature of the ground water configuration and the fact that the area of subsurface leakage is inside the highest isopleth in this particular plot.

Available monitoring well data indicates that the average ground water depth ranges from zero to about 9 feet, depending on seasonal fluctuations. Average ground water temperature ranges from 50°F to 54°F (10-12°C). Ground water velocities were calculated by Biocraft's consultants based on the range of permeabilities [0.02 to 36 gallons per day per square foot (9.4×10^{-9} - 1.7×10^{-5} m/s)] and hydraulic gradients [0.002 to 0.03 feet per linear foot (0.0006 - 0.01 m/m)] found at the site. Flow velocities were calculated to range from a maximum of 1.5 feet (0.5 m) per day to a minimum of 0.0002 feet (7×10^{-5} m) per day. Average flow velocities on the more permeable zones were calculated to average about 0.4 feet (0.1 m) per day. This value indicates that the time required for ground water to travel from the leak area to the eastern property boundary (collection point) would be about 1 1/2 years.

WASTE DISPOSAL HISTORY

300.68(c)(2) (i)(B) amount and form of substances present

The Biocraft site is a bulk manufacturing plant that produces a wide variety of semi-synthetic penicillin products including 6 aminopenicillanic acid, ampillicin trihydrate, amoxicillin trihydrate, sodium oxacillin monohydrate, sodium cloxacillin monohydrate, D(-)alpha-phenylglycine methylacetoacetate potassium salt, and D(-)-p-hydroxyphenyl glycine methylacetoacetate potassium salts. A number of organic and inorganic raw materials are used in the process. Organic feedstocks include potassium penicillin G, methylene chloride, N-butyl alcohol, acetone, methyldichloro silane, dimethyl aniline, ethylene glycol, and ethyl chloroformate. Inorganic chemicals used on-site include phosphorus pentachloride, liquid nitrogen, ammonium hydroxide, and hydrochloric acid.

Ten 10,000-gallon (37,800 l) underground storage tanks are located at the southeast corner of the building. Seven tanks store virgin and recovered N-butyl alcohol, acetone, and methylene chloride. The eighth tank holds process wastewater which is periodically shipped to Earthline Services, Newark, NJ for pretreatment. The ninth tank holds spent solvents and centrifuge cake washings from penicillin cleavage and includes the following identified substances:

- Acetone
- Methylene chloride
- Dimethylaniline
- N-butyl alcohol
- Phosphorus acid
- Ethyl alcohol
- Methanol
- Ammonium chloride.

The tenth and last tank stored spent solvents from ampicillin processing, including acetone and methylene chloride. Stored liquids from the last two storage tanks were trucked about twice per week to Chemical Pollution Systems, Old Bridge, NJ for solvent recovery services.

The underground discharge causing the contamination problem was traced to a leaking transfer pipe which fed storage tank number nine, which held spent solvents and centrifuge cake washing liquors. It is not known when the underground line started leaking, however an estimate has been made on the amount of material discharged from the time the plant opened in June, 1972 to November 24, 1975, the date when the lines were replaced. The estimate is based on: (1) the actual number of transfers to the storage tank during the above period (660); (2) a tank gauge accuracy of 50 gallons (190 1), i.e. discrepancies under 50 gallons (190 1) could not be detected; and (3) the average composition of the mixture. Biocraft estimated quantities discharged into ground water for the major components of the mixture, as shown in Table 1.

Trace substances included phosphorus acid, ethyl alcohol, methanol, and ammonium chloride. Other trace substances, later detected in the ground water which were not clearly associated with Biocraft's processes were heptane, octane, dissobutylene, chloroform, trichloroethylene, tetrachloroethylene, benzene, toluene, m-p-xylene, and dichloroethane.

DESCRIPTION OF CONTAMINATION

Contamination at the Biocraft site was caused by the leaking underground lines feeding spent process solvents to an underground storage tank. Although it is not known from the plant's investigations, contamination could have occurred for as long as 3 years, from when the plant opened to when the source of contamination was found and repaired. It has been estimated by the plant itself that over 285,000 pounds (130 Mt) of solvents and other organic substances may leaked into the subsurface during this time period. Quantity estimates of individual compounds have been previously given in Table 1.

The contaminant plume flowed predominantly north and northeast toward the eastern edge of the property and a storm sewer, and also south toward the southern property boundary. The storm sewer discharged into a small creek which emptied into Allendale Brook. A contamination problem was first suspected in 1973, when a fish kill occurred in a pond receiving flow from Allendale Brook. Subsequent inspections in 1975 revealed that the tributary to Allendale Brook was in a degraded condition, characterized by grayish-black algal growth. The storm sewer was suspected of being the source of pollution, since the same algal growth appeared in portions of the line and an organic odor was detected at the discharge point. Data from sampling of the flow in the sewer indicated that concentrations of methylene chloride, n-butyl alcohol, and dimethyl aniline were as high as 114, 343, and 32 mg/1, respectively. Chemical oxygen demands (COD) were found to be as high as 7,539 mg/1. Contaminated flow from the sewer was finally attributed to joint infiltration of grossly polluted ground water emanating from the Biocraft site. The leaking underground transfer line was discovered as a result of an underground tank and pipe

TABLE 1. ESTIMATED QUANTITIES OF ORGANICS DISCHARGED AT THE BIOCRAFT SITE (Biocraft Laboratories, 1983)

Substance	Percent	Estimated Quantity	
		Pounds	Metric tons
Methylene chloride	50	181,500	82.33
N-Butyl alcohol	30	66,825	30.31
Dimethyl aniline	10	26,300	11.93
Acetone	5	10,890	4.94
Water and trace substances	5	10,890	4.94

testing program initiated by Biocraft after they were issued a New Jersey Department of Environmental Protection Cease (NJDEP) Administrative Order.

Six ground water monitoring wells were installed on-site in January, 1976 under the supervision of Princeton Aqua Science, New Brunswick, N.J. These were 2 inch (5 cm) well points with depths ranging from 10 to 15 feet (3.3 - 5 m). The maximum depth corresponds to refusal resulting from contact with the semi-consolidated silt/fine sand layer (see section on hydrogeology). Monitoring data from February, 1976 to June 1976 for the six wells showed ranges of concentrations of general pollutant parameters as shown in Table 2.

TABLE 2. RANGES OF INITIAL MONITORING WELL DATA AT THE BIOCRAFT SITE

FEBRUARY, 1976 TO JUNE 1976

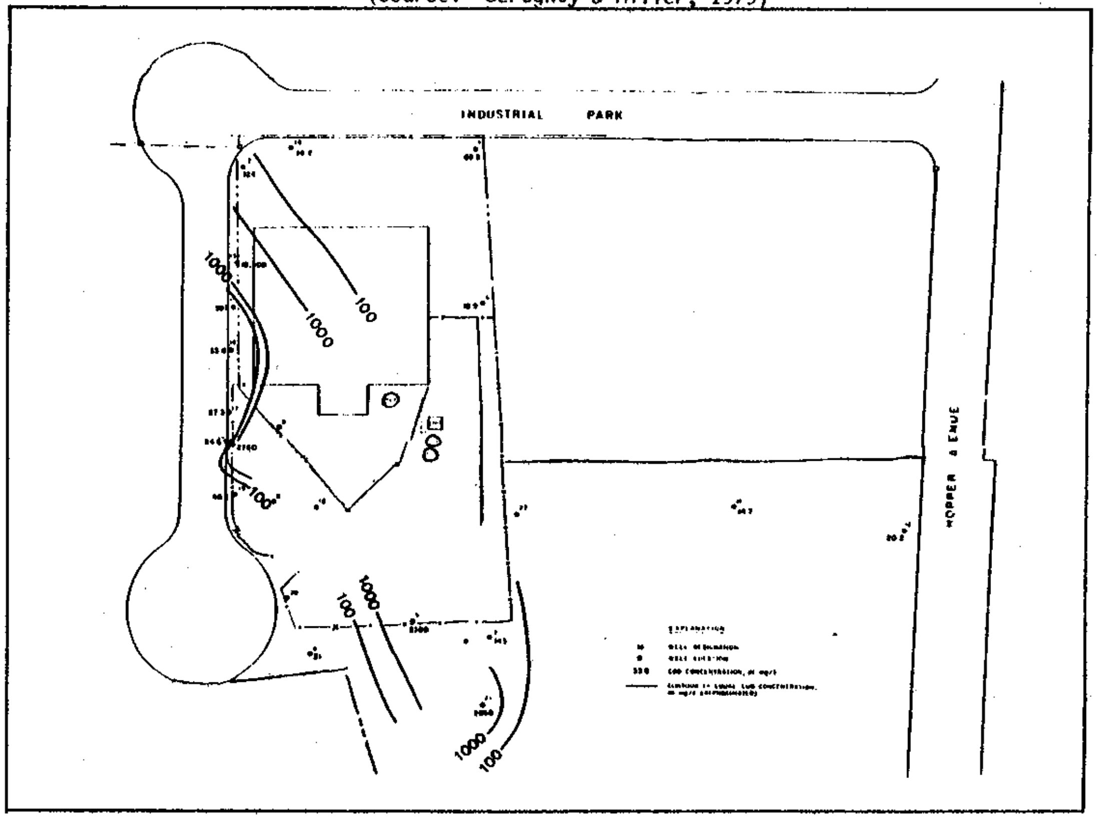
Parameter	Range
pH	5.2 - 7.5
BOD	2 - 21,000 mg/1
COD	8 - 31,000 mg/1
TOC	2 - 9,625 mg/1
Chloride	5 - 6,246 mg/1

In the period from June, 1976 to early in 1979, 16 additional wells (making a total of 22) were installed for monitoring and selective pumping of contaminated ground water. Geraghty and Miller used these 22 wells for their investigation of hydrology and contamination at the site. Eight of the 22 wells were drilled specifically for the Geraghty and Miller investigation early in 1979. No wells were drilled into the semi-consolidated silt/fine sand layer, since this was not required by the NJDEP.

Monitoring data from 1977 through 1978 indicated that Chemical Oxygen Demand (COD) was the best indicator parameter for showing levels of pollution in the ground water. Geraghty and Miller plotted COD isopleths for the 1,000 mg/1 and 100 mg/1 level based on levels found in the wells on March 5, 1979. Figure 5 shows the COD isopleths along with COD levels in the various wells. The north-south flow components of the contaminant plume are easily distinguishable from this plot. Also, some wells outside the main plume boundary have elevated concentrations of COD. Geraghty & Miller stated that these areas were

Figure 5: Groundwater COD Isoplethe at the Biocraft Site

(Source: Geraghty & Miller, 1979)



contaminated during periods when the water table had a different flow configuration.

Wells 2, 3, 8, 10 or 13 were selectively pumped at different time intervals from January 1977 through 1978 after monitoring data showed an increase in COD. At the time of the Geraghty and Miller study, COD levels had dropped significantly (2% of initial value, in some cases) due to this selective pumping procedure. As mentioned earlier, no monitoring wells were drilled into the Brunswick shale aquifer. However, Biocraft's deep well taps this aquifer directly under one of the most contaminated portions of the southern component of the plume.

Data from this well in 1979 indicated a COD of 1 mg/l, suggesting that no contamination had entered the deep aquifer at the well location or within the radius of influence of the well.

PLANNING THE SITE RESPONSE

Initiation of Site Response

In a letter dated November 20, 1975, the DEP directed Biocraft to cease discharges and to begin studying the contaminated storm sewer discharge problem. The letter responsible party stated that the wastes were entering the Allendale Brook through the storm sewer serving Industrial Way and the DEP had determined the discharges were of "a continuing nature" and thus were in violation of State law. The DEP letter was in response to discovery of surface water pollution due to the Biocraft site and the need to determine its cause and potential impact on ground water. Biocraft performed a hydrogeological study in 1976 in response to the DEP request.

Ground water pumping and disposal was initiated on February 13, 1977, and was undertaken pursuant to an Administrative Consent Order (ACO) dated January 12, 1977. This ACO was agreed upon by DEP and Biocraft based on a recommendation by the company's consultant, Princeton Aqua Science (PAS). The January 12, 1977 ACO provided that if the DEP was not satisfied that sufficient progress was being made to decontaminate the affected ground water, it could pursue other statutory remedies. Additional ground water was extracted through the use of bucket wells installed along the storm sewer line along the northern and western property lines. This pumping was undertaken because DEP was not satisfied with progress of the original pumping system. In an Administrative Order dated December 6, 1978, NJDEP ordered Biocraft to add these

300.65(b)(6)
off-site removal

bucket wells and to otherwise comply with the January 12, 1977 ACO and to develop an improved decontamination program for NJDEP approval.

A biostimulation process for decontaminating ground water was instituted in July 1981 pursuant to plans that were codified in a September 25, 1980 ACO. This process was developed pursuant to the December 1978 Administrative Order by Biocraft in conjunction with its consultants, Geraghty and Miller, PAS, and Sun Tech, Inc. This new system was installed to improve the containment and accelerate the decontamination of the ground water.

300.70(b)(2)(ii)
(A)(3)
biological
reactors

Selection of Response Technology

A number of alternative response technologies were considered before the collection/biostimulation/injection process was undertaken. These included the following:

- Collecting and treating all discharge from the storm sewer (interim measure to alleviate surface water problem)
- Resleeving sewer pipe, grouting joints, or replacing pipe with non-infiltrating sewer pipe
- Excavating entire contaminated soil column under Biocraft site
- Surrounding area with a grout or slurry cutoff wall.

In December, 1975, NJDEP proposed collecting and treating all of the discharge from the storm sewer as a temporary measure to prevent further discharge to the stream. Biocraft rejected this alternative on the grounds that this would require collection of runoff from other properties in the Industrial Park as well, and enormous flows from precipitation would have to be treated or disposed. Biocraft felt that this alternative was inequitable and impractical. In June, 1976, Biocraft proposed that the town of Waldwick replace or repair the sewer pipe to prevent infiltration of contaminated ground water in the sewer. Technically, this alternative would not adequately deal with the ground water problem since contamination could spread in the other subsurface flow directions.

300.70(b)(1)(iv)
contaminated
water and sewer
lines

From January, 1977 through 1978 Biocraft selectively pumped five wells to control the plume, including some bucket wells installed in compliance with a December 1978, NJDEP Administrative Order. Collected ground water had been transported to three different disposal facilities, including NEWCO, a landfill in Tonawanda, New York; Tricil an incinerator facility in Canada; and Earthline, a pretreatment facility in Newark, N.J. This additional Administrative Order also stipulated that clean-up was proceeding too slowly and an improved decontamination program should be developed.

300.70(b)(1) (iii)(C) ground water pumping

The Town of Waldwick indicated concern for an accelerated clean-up program, because of degraded water quality in Allendale Brook and the possibility of future contamination of their municipal production well, located about 1,000 feet from the contaminated area (see Figure 3). They proposed that the contaminated soil be excavated from under the Biocraft site. Biocraft rejected this alternative because it would require shutting down the entire Biocraft facility, which it considered impractical.

300.68(h) initial screening of alternatives

300.70(c)(2)(i) excavation

As another possible alternative, NJDEP proposed that a slurry wall or grout curtain be constructed around the site, and contaminated ground water pumped from within the cut-off wall and treated or disposed. Biocraft found this alternative to be infeasible because of the dual costs of constructing the cut off wall and either treating or disposing of wastes. Also, pumping did not insure that contamination would be removed from the underlying soil, which could preferentially absorb the wastes.

300.70(b)(1) (iii)(A) impermeable barriers

Biocraft and their consultants, Princeton Aqua Science, Geraghty and Miller, and Suntech, Inc. developed the selected alternative in May, 1979, which included:

(1) Collecting the contaminant plume in a down gradient subsurface drain

300.70(b)(1) (iii)(D)(1) subsurface drain

(2) Treating collected ground waters to remove contaminants in an aerobic biological treatment system

300.70(b)(2)(ii) (A)(3) biological reactors

(3) Injecting treated water upgradient in two trenches to flush soil and ground water of contaminants

(4) Enhancing in-situ biodegradation of contaminants in soils and ground waters by installing a series of continuous aeration wells.

The selection of this process was believed to provide both contaminant plume containment and removal of the source in a cost effective manner, since collected ground waters were treated on-site biologically and the treated effluent could be reinjected into the ground water, eliminating the added cost of disposal or sewerage. Carbon treatment was considered but was found to be cost prohibitive. Ozone treatment was also considered but bench scale testing indicated it was relatively ineffective. Initial studies of microbial population in the contaminated ground water suggested that an adapted population was presently feeding on the methylene chloride and other organics present. Later bench scale work to optimize the process proved successful.

300.70(b)(2)(ii)
(B)
chemical methods

Extent of Site Response

Reduction in the level of ground water contamination is the primary criterion by which clean-up progress is measured at the Biocraft site. Sealing of the storage tank lines and the storm sewer were important in eliminating the source of the contamination, but did not directly mitigate threats to the public health and the environment. Treatment and reinjection of ground water is directed at mitigating these threats. Contaminated soil that was excavated during the construction of the injection and collection trenches is being aerated to background (as of December, 1982). These actions were directed by Administrative Orders and Administrative Consent Orders, and were completed in accordance with these orders.

300.68(j)
extent of remedy

300.68(c)
administrative
process

The ground water quality clean-up goals for the decontamination program were set forth in the ACO dated September 25, 1980. This ACO required Biocraft to operate the decontamination system until the DEP determined that the ground water has an acceptable quality, or until the system is found to be incapable of achieving acceptable levels of clean-up. To this extent the goals set forth in the ACO are tentative. Acceptable water quality is defined in the ACO by the following parameters:

BOD_5	6.0 mg/l
COD	23.0 mg/l
TOC	18.0 mg/l
chlorides	153 mg/l
pH	4.0 - 7.5
Acetone	100 mg/l
methylene chloride	8.0 mg/l
butanol	100 mg/l

No time limit was set for meeting these standards, but the DEP may order other measures at any time if it deems them necessary. Biocraft has stated that at least 18 months (from the July 1981 start-up) would be necessary for the decontamination program to show results.

DESIGN AND EXECUTION OF SITE RESPONSE

Installation of the ground water collection/treatment/injection system was completed in June, 1981. The research and development stage for this operation included a hydrogeologic study (discussed earlier), bench and pilot scale studies for the biological treatment system, and design and construction of system components (collection and injection trenches, aeration wells, mixing tanks, etc.). Research and development of the biostimulation process spanned a period of 2 1/2 years. This process was subsequently patented by Biocraft and subsidiary, Ground Water Decontamination Systems (GDS), which was formed to sell the biostimulation process to other parties having similar ground water problems. A description of the design and construction of the essential system components is given below.

Bench and Pilot Studies

300.70(b(2)(ii) direct waste treatment methods

A number of studies were conducted during the research and development stage to determine if the contaminated ground water was amenable to biodegradation. Past research indicated that acetone, n-butyl alcohol (BuOH) and dimethyl aniline (DMA) ranged from fair to good with respect to biodegradability. The biodegradability of methylene chloride (MeCl), the major contaminant, was uncertain based on past research and Biocraft was concerned that methylene chloride's toxicity would inhibit biodegradation. Biocraft conducted an initial survey in August 1978 to determine the presence of microorganisms in the ground water. The survey showed that a mixed microbial population existed in all the ground water monitoring wells at a concentration of 10,000 to 100,000 cells/ml. This suggested that the microbes were using the contaminants as a carbon source since two to three orders of magnitude fewer cells are found in uncontaminated ground water. Biocraft conducted shaker flask studies to determine optimum growth conditions. Addition of nitrogen and phosphorus were found to increase cell growth as much as four times the control. Results of the shaker study are shown in Table 3. The first pilot study was initiated in December, 1978. A small paint type compressor was used to supply air to monitoring well #3 via a flexible air diffuser. Nutrients were added directly to the well in

TABLE 3. NUTRIENT STUDY
(Biocraft Laboratories, 1983)

CHEMICAL	CONCENTRATION (mg/l)	FLASK # 1	2	3	4	5	6	7	8	Control
$(NH_4)_2SO_4$ Ammonium Sulfate	100	x		x	x	x	x	x	x	
NH_4NO_3 Ammonium Nitrate	100		x							
$Na_2HPO_4 \cdot 7H_2O$ Sodium Phosphate dibasic	40	x	x	x	x	x		x	x	
$NaH_2PO_4 \cdot H_2O$ Sodium Phosphate monobasic	40			x	x	x	x	x	x	
KH_2PO_4 Potassium Phosphate monobasic	100	x	x							
$MgSO_4 \cdot 7H_2O$ Magnesium Sulfate	20	x	x	x	x	x	x	x		
Na_2CO_3 Sodium Carbonate	100	x	x	x	x	x	x			
$CaCl_2$ Calcium Chloride	1	x	x	x	x	x				
$MNSO_4$ Manganese Sulfate	2	x	x	x	x					
$FeSO_4 \cdot 7H_2O$ Ferrous Sulfate	0.5	x	x	x						
Concentration of cells (mg/l, dry weight)		24.1	25.7	21.6	23.3	22.4	20.0	19.2	19.6	7.7
Total Count (cfu/ml)		1.3×10^7	1.6×10^7	4.5×10^7	3.0×10^7	2.4×10^7	1.9×10^7	2.3×10^6	10^7	2.2×10^5
		Incubation temperature 18-20°C								

aqueous solution. After 7 days, the total count increased from 10,000 to 1 million cells/ml. Batch and continuous process bench scale studies were carried out using water from well #13 in 3.7 gallon (14 l) glass fermentors. Batch studies were run at 68°F (20°C) with the nutrient mix used in Flask #2 (see Table 3). A large decrease in COD was observed on the eighth day. A large increase in cell count was observed on day nine. A residual COD of 300 to 400 mg/l was observed after the 12th day, and was attributed to biomass. Studies conducted at 86°F (30°C) showed a slight increase in biodegradation rate at the higher temperature. When 10 liters per minute of air was added, the rate of biodegradation increased dramatically. Results are shown in Table 4, in which levels of specific organics were steady for the first 2 days and then dropped. This suggests that volatilization of organics was not a significant factor in reduction of contaminant levels. Acetone levels increased in day 3. This was explained by the presence of isopropyl alcohol, (IPA) which is transformed to acetone under aerobic conditions. The IPA was formed from acetone in anaerobic conditions in the ground water and was reconverted upon aeration. The IPA was masked in the GC/MS analysis by the methylene chloride peak.

Continuous process experiments were also done with two 3.7 gallon (14 l) glass fermentors set up in series. The first was used as the aeration tank while the second vessel was used as a settling tank. A retention time of 17 hours was maintained in the aeration tank. Other process parameters such as temperature and nutrients were similar to that of the batch studies. Results of two runs are shown in Tables 5 and 6. After 4 days, $MeCl_2$ was reduced about 98% and BuOH was reduced 99%. Levels of acetone rose as predicted and dropped to 60 percent of the initial value on the fourth day. In another run, $MeCl_2$ decreased more than 90% in 3 days while DMA was reduced 90%.

A pilot scale study was carried out to give basic information for design of the full scale treatment unit. Two 55 gallon (208 l) drums arranged vertically were used as aeration and settling tanks. An air sparge system, immersion heater, circulation line, and refrigeration line were installed in the aeration drum. Four additional 55 gallon (208 l) drums were used to store and feed contaminated water to the pilot plant. A schematic of the pilot plant is shown in Figure 6. Continuous biodegradation studies were performed for 17 days. Retention time in the aeration tank was 17 hours. A nutrient solution was pumped at 1 percent of the feed volume and the aeration

TABLE 4. BATCH EXPERIMENT
(Biocraft Laboratories, 1983)

Day	COD*	Acetone*	$MECl_2$*	BuOH*
0	4326	-	-	-
1	3970	84	3290	29
2	1499	69	3190	27
3	2715	230	826	ND
4	1346	134	311	ND
5	912	92	28	ND
6	678	21	ND	ND
7	513	11	ND	ND
8	307	ND	ND	ND
9	255	ND	ND	ND
10	241	ND	ND	ND

ND: Not detected. (Limit 1 mg/l)

*All values in mg/l

TABLE 5. CONTINUOUS PROCESS STUDIES RUN #47
(Biocraft Laboratories, 1983)

	INFLUENT CONCENTRATIONS*				CONTINUOUS AERATION TANK			
Day	$MeCl_2$†	Acetone†	BuOH†	COD†	$MeCl_2$†	Acetone†	BuOH†	COD†
1	9975	29	1091	11939	9045	64	893	11497
2	4571	20	491	6320	3285	73	303	5287
3	4847	21	518	6360	1943	143	81	1908
4	4690	43	508	6460	719	43	ND	1113
5	5040	48	584	6460	707	20	3	518
6	4725	78	501	6115	818	32	30	1127
7	4583	79	476	5933	891	34	ND	759
8	4448	147	431	6437	227	57	6	440

ND: Not detectable. Detection limit 1 mg/l.
†All values in mg/l
*Extracted daily from Well #13

TABLE 6. CONTINUOUS PROCESS STUDIES-BATCH #50
(Biocraft Laboratories, 1983)

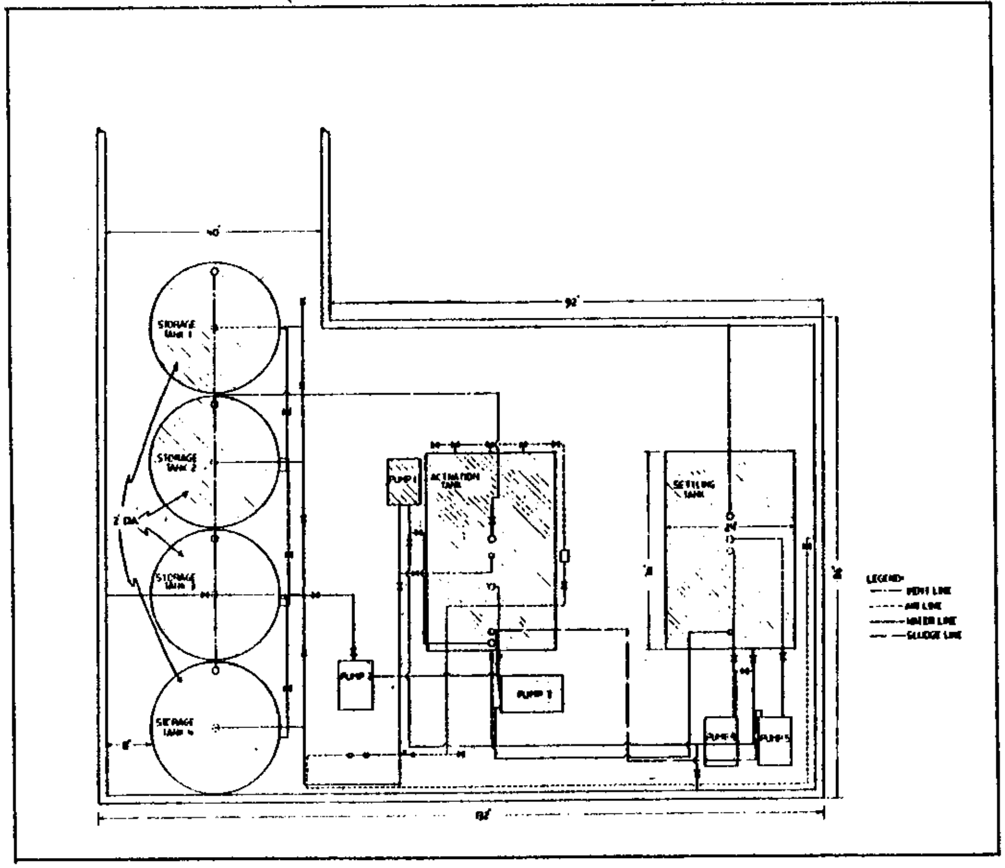
	WELL #13			ACTIVATION TANK		
Day	$MECl_2$*	DMA*	COD*	$MECl_2$*	DMA*	COD*
1	29	64	342	10	18	190
2	7	63	271	4	23	182
3	13	69	397	ND	28	184
4	15	61	305	ND	16	164
5	14	61	311	ND	22	168
6	6	67	405	5	20	170
7	3	57	174	ND	24	178
8	16	66	344	ND	15	141
9	9	65	337	ND	7	118
10	ND	72	334	ND	1	117
11	7	64	342	ND	1	130
12	5	45	266	ND	1	122
13	10	59	297	ND	1	120
14	5	34	149	ND	ND	86
15	ND	6	187	ND	ND	118

ND: Not detectable. Detection limit 1 mg/l

*All values in mg/l.

Figure 6: Pilot Plant Design

(Source: Biocraft.Laboratories, 1983)



rate was 0.1 gallons (0.5 l) per minute. Results are shown in Table 7.

Methylene chloride levels indicate an average reduction of more than 99%. Butanol levels were reduced an average of more than 96%. The DMA average removal efficiency of 59% was substantially lower than that of bench scale studies. Average removal efficiency of acetone for the 17 day period was only 8 percent, because of the formation of acetone by aerobic transformation of isopropyl alcohol. Average removal efficiencies of acetone, calculated for the period after day 4, indicate an average removal of more than 81 percent, which is more representative of steady state removal efficiencies. The COD removal efficiency averaged about 58 percent. This relatively low efficiency may result from the contribution of residual biomass to COD.

Full Scale System

The full scale system consists of a ground water collection trench (Trench A), a four tank dual biological treatment system, two effluent injection trenches (trenches B and C), and a series of nine in-situ aeration wells placed along the path of contaminant flow. A site map showing the locations of the treatment system components is shown in Figure 7. Essential elements of the system are described below.

--Ground Water Collection System

300.70(b)(1) (iii)(D)(1) subsurface drains

The primary ground water collection system consists of a subsurface drain (Trench A) about 80 feet (24 m) long, 4 feet (1.2 m) wide, and about 10 feet (3 m) deep. A backhoe was used to excavate the trench. Wooden shoring was used to support the sides from caving in until the gravel and piping could be installed. The configuration of the ground water collection trench is shown in Figure 8. A central collection well was used in the system design. This well (#13) is a 12 inch (30 cm) diameter steel casing with a 2.5 foot (0.76 m) slotted screen and a 10 gallon (38 l) per minute stainless steel submersible pump. It was originally installed as a bucket well (large gravel filled well) to control the contaminant plume. Two 16- inch (15 cm) galvanized steel collection pipes were hand slotted and welded to the 12 inch (30 cm) casing. Slot size is 1/4 inch by 3 inches (0.6 x 7.6 cm) and the position of the slots are at 3 and 9 o'clock around the pipe wall. The collection pipes are sloped at 1 percent toward the collection well. The trench has two 2-inch diameter PVC monitoring wells installed on each side of the central collection well. The envelope consists of a

TABLE 7. PILOT PLANT STUDIES
(Biocraft Laboratories, 1983)

INFLUENT CONCENTRATION (WELL #13)						AERATION TANK*					
Days	$MeCl_2$	Acetone	BuOH	DMA	COD	Solids	$MECl_2$	Acetone	BuOH	DMA	COD
1	980	93	54	240	1843	512	10	98	ND	102	647
2	865	105	53	235	1664	741	5	53	ND	90†	574
3	145	27	54	412	2608	NA	50	80	ND	173	1002
4	1200	20	52	430	2683	NA	5	50	1	169	968
5	1145	9	53	417	2593	NA	5	1	2	162	947
6	1180	9	57	445	2713	NA	5	1	2	184	1043
7	1060	23	57	425	2638	1047	5	23†	1	167	934
8	1020	12	57	419	2488	740	4	1	ND	150	1167
9	1140	20	59	420	2765	951	5	5	3	152	1147
10	1085	10	51	335	2178	596	90†	7	7	150	1385
11	967	10	50	320	2269	853	1	1	ND	113	1160
12	900	5	46	305	1842	NA	5	NA	ND	128	942
13	830	8	45	300	1912	NA	525†	8†	36	256†	1719
14	865	5	46	290	2158	836	5	ND	ND	96†	922
15	1170	10	71	357	2996	936	5	ND	ND	132	913
16	1080	15	76	365	3112	746	5	ND	ND	120	1007
17	1187	29	71	357	3276	NA	5	5	ND	45†	1219
Avg.	989	24	56	354	2455	796	8	<22	<4	146	1041

ND: Not detected. Detection limit 1 mg/l.

NA: Data not analyzed

*All values in mg/l.

†Analytical results questionable.

Figure 7: Elements of the Groundwater Decontamination System.

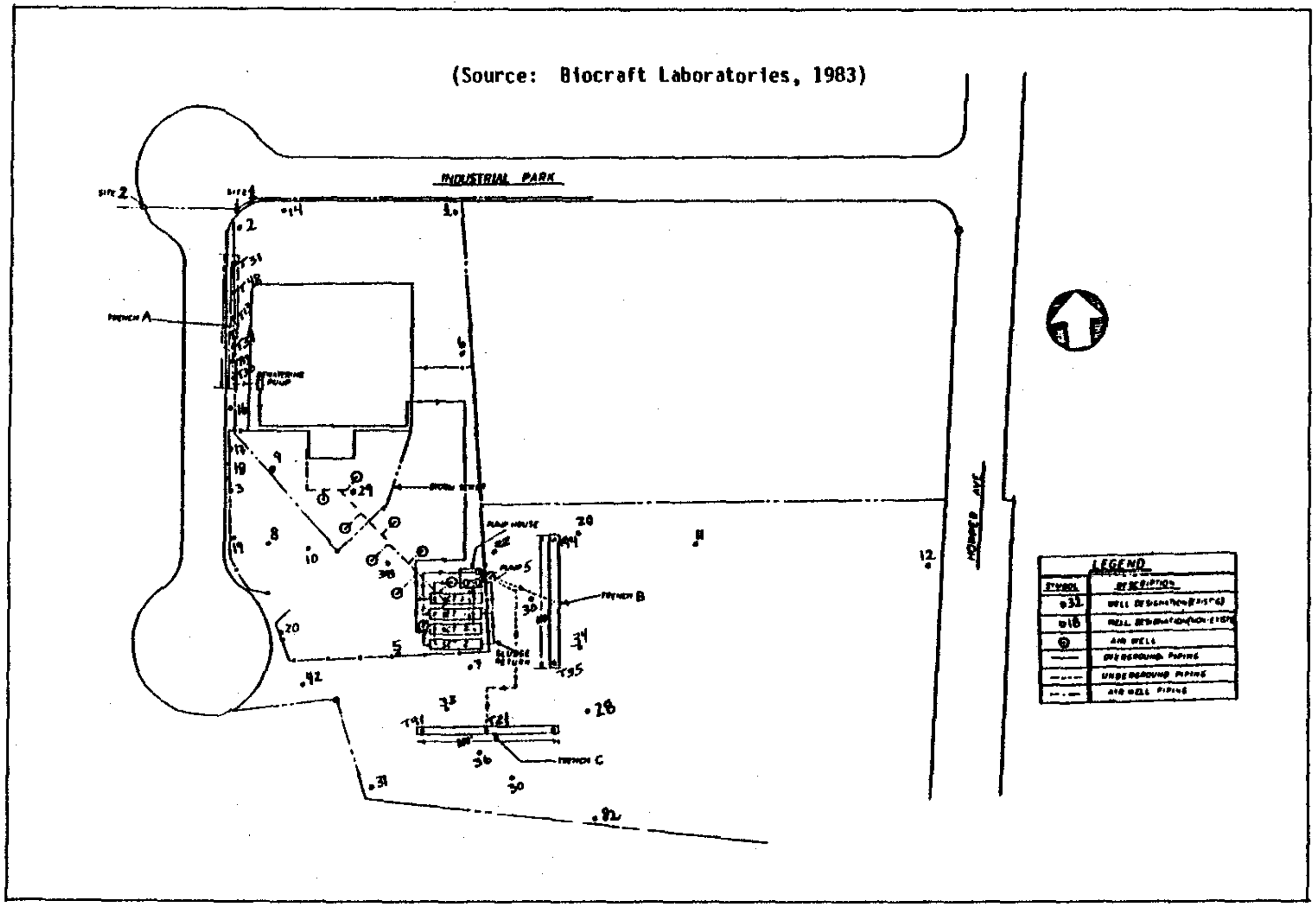
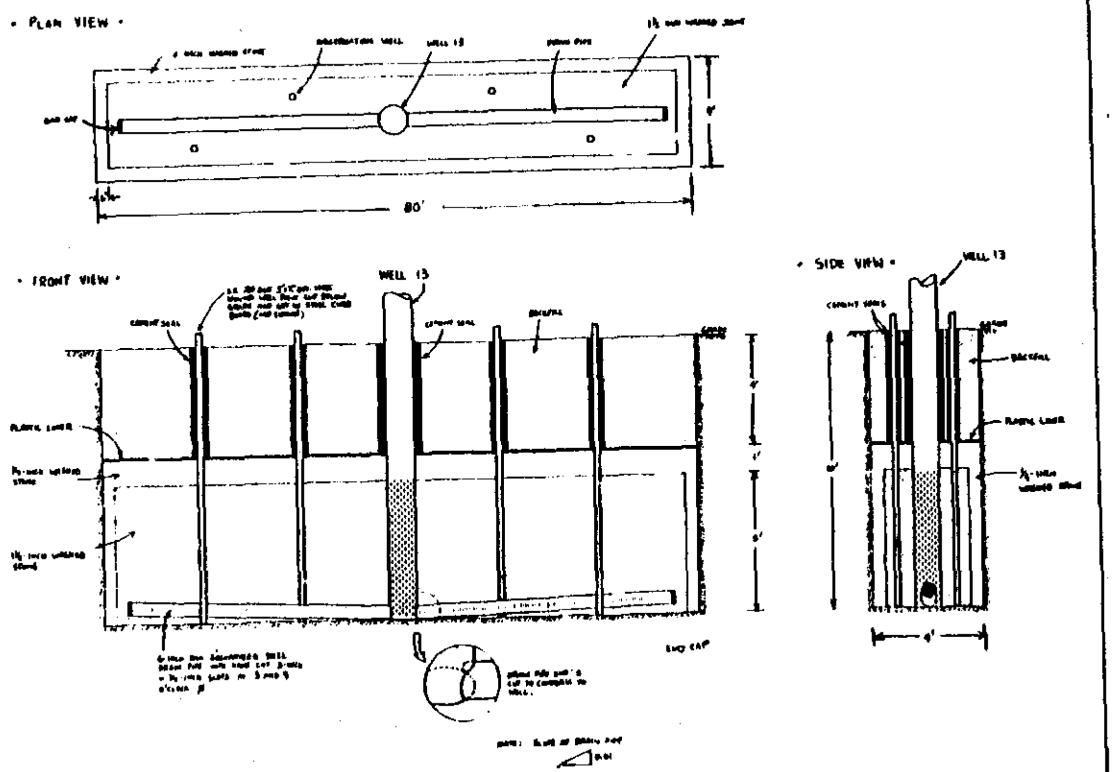


Figure 8: Configuration of Collection Trenches

(Source: Biocraft Laboratories, 1983)



dual media gravel pack with a 6 inch bottom and side layer of 1/4 inch (0.6 cm) washed stone, about 4.5 feet (1.4 m) of 1 1/2 inch (3.8 cm) washed stone, and a 1 foot (0.3 m) top layer of 1/4 inch (0.6 cm) washed stone. Additional shoring was required to install the side layers of fine aggregate. The envelope was covered with plastic sheet and backfilled with earth to grade.

Ground water pumping is also being carried out in two bucket wells (#30 and #32A) on the southern edge of the property to collect the southern component of the contaminant plume. They consist of backhoe dug trenches about 10 feet (3 m) deep by 4 feet (1 m) wide by 16 feet (5 m) long. Well #30 has an 8-inch PVC fully slotted casing and well #32A has a 12-inch PVC fully slotted casing installed in the trench. The trench has been backfilled with 5 feet (1.5 m) of 1 1/2 (3.8 cm) washed stone and about 5 feet of earth finished to grade.

Initial pumping rate to the biological system was about 5,760 gallons (21,800 l) per day which was steadily increased during a 1 year period. Presently, an average of 13,680 gallons (51,780 l) per day is pumped from the collection trench and the bucket wells to the biological treatment system.

--Above-ground Biological Treatment System

The above-ground biological treatment system was completed in June, 1981. It consists of a dual system of two aeration tanks and two sludge settling tanks, each tank having a capacity of about 5,400 gallons (20,000 l).

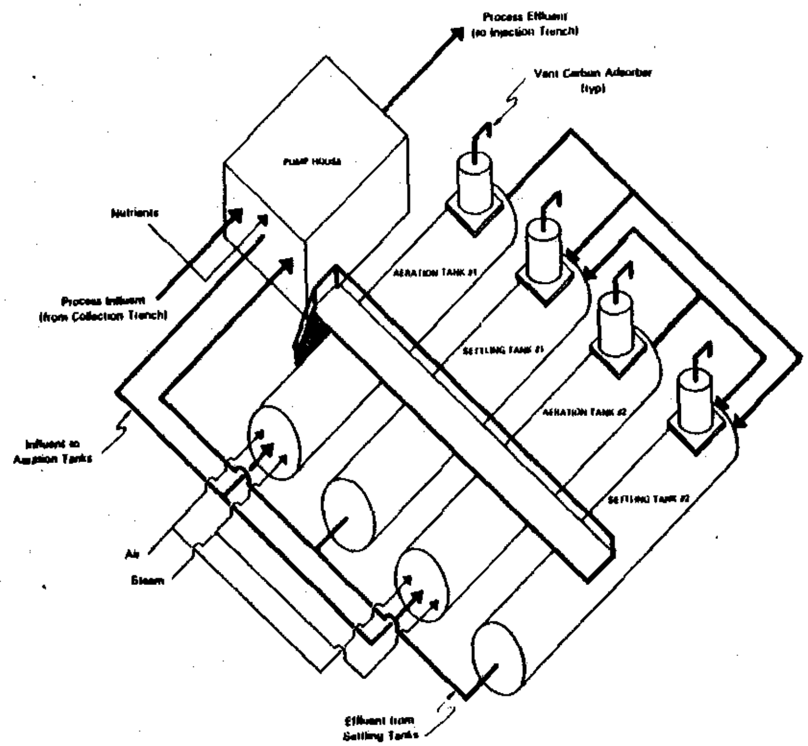
300.70(b(2)(ii)
(A)(3)
biological
reactors

A drawing of the process layout is shown in Figure 9. The stainless steel tanks were originally used on milk trucks and after the trucks became unserviceable, the tanks were modified by Biocraft for process use.

Influent water from the collection trench and two interceptor wells is pumped first to the aeration tanks, where most of the biodegradation occurs. Air is added to each tank through a series of porous ceramic tube diffusers at a rate of 20 standard cubic feet (0.8 m^3) per minute. Temperature is kept constant at 68°F (20°C) using a single pass steam coil unstalled in the tanks. The tanks have 2 inches (5 cm) of insulation which helps buffer ambient temperature effects. A nutrient solution is metered in from mixing tanks in the pump house to obtain the following concentrations in the aeration tanks.

Figure 9: Above-Ground Biological Treatment System Design

(Biocraft Laboratories, 1983)



Nutrient Salt	Concentration (mg/1)
NH_3Cl_2	500
KH_2PO_4	270
K_2HPO_4	410
$MgSO_4$	14
Na_2SO_4	9
$CaCl_2$	0.9
$MnSO_4$	1.8
$FeSO_4$	0.45

The system is presently operating at an average flow rate of 9.5 gallons (36 l) per minute with a retention time in the aeration tank of 17.5 hours. The system has the capability to handle a flow of up to 14 gallons (53 l) per minute or 20,000 gallons (76,000 l) per day with a retention time of 12 hours, but the pumping wells are presently at capacity flow.

Effluent air from the aeration tanks is passed through replaceable activated carbon adsorbers to remove any volatilized organics. The amount of volatilization is not believed to be substantial, based on indications from pilot plant studies and the fact that the carbon adsorbers have not yet required replacement in over 1 1/2 years of operation.

The effluent stream from the aeration tanks is combined and pumped to two sludge settling tanks in which some biomass solids are settled out and recycled to the aeration tanks. The supernatant from the settling tanks is pumped to the reinjection trenches. Much of the biomass is allowed to pass with the supernatant into the recharge trenches in order to continually inoculate the trench and subsurface with microorganisms. Waste sludge production is minimal, at approximately 11 gallons (42 l) per month because of (1) sludge recycling to the aeration tanks and reinjection trenches, and (2) low cell reproduction rates associated with the biodegradation of relatively refractory organics.

Process influent and effluent concentrations are given for 1 1/2 years of operation in Table 8. The

TABLE 8. BIOLOGICAL TREATMENT
ORGANIC INFLUENT & ORGANIC EFFLUENT
(mg. per liter unless noted)

	INFLUENT					EFFLUENT				
Date	IPA	$MeCl_2$	Acetone	BuOH	DMA	IPA	$MeCl_2$	Acetone	BuOH	DMA
1981										
8/18- 8/31	NA	101	77	49	115	NA	10	29	7	77
9/1 - 9/15	NA	63	58	38	68	NA	3	3	3	41
9/16- 9/30	NA	99	79	60	60	NA	6	7	1	19
10/1 -10/15	NA	132	113	96	68	NA	11	10	5	26
10/16-10/31	NA	103	109	91	52	NA	10	21	3	10
11/1 -11/15	NA	93	83	78	37	NA	22	31	5	18
11/16-11/30	NA	116	97	100	41	NA	1	3	ND	9
12/1 -12/15	NA	39	35	26	20	NA	1	1	ND	4
12/15-12/31	NA	30	12	8	6	NA	ND	ND	ND	1
1982										
1/ 1- 1/15	110	71	32	20	14	ND	ND	ND	ND	1
1/16- 1/31	15	91	28	22	17	ND	1	ND	ND	3
2/ 1- 2/15	6	91	17	8	5	ND	ND	ND	ND	1
2/15- 2/28	9	83	35	27	11	1	ND	2	ND	2
3/ 1- 3/15	7	68	23	18	10	ND	1	ND	ND	2
3/16- 3/31	9	61	26	129	10	1	2	2	1	2
4/ 1- 4/15	8	33	16	13	4	ND	2	1	ND	2
4/16- 4/30	9	41	17	15	3	ND	ND	1	ND	1
5/ 1- 5/15	12	50	22	15	5	ND	1	2	ND	1
5/16- 5/31	2	41	21	10	8	ND	ND	ND		
6/ 1- 6/15	8	42	18	11	6	1	1	1	ND	1
6/16- 6/30	12	53	20	14	6	ND	ND	ND	ND	ND
7/ 1- 7/15	15	73	29	25	9	ND	ND	ND	ND	2
7/16- 7/31	74	149	54	44	13	ND	ND	2	ND	2
8/ 1- 8/15	120	185	53	45	21	ND	2	12	10*	4
8/16- 8/31	ND	200	59	52	21	ND	6	4	11*	2
9/ 1- 9/15	ND	203	51	45	17	ND	3	10	ND*	1

(continued)

TABLE 8. (continued)

	INFLUENT					EFFLUENT				
Date	IPA	$MeCl_2$	Acetone	BuOH	DMA	IPA	$MeCl_2$	Acetone	BuOH	DMA
9/16- 9/30	ND	151	51	42	6	ND	4	7	ND*	ND
10/ 1- 10/15	ND	170	63	71	13	ND	5	5	ND*	3
10/16- 10/31	ND	165	67	55	10	ND	6	5	ND*	5
11/ 1- 11/15	ND	142	57	43	9	ND	7	2	ND*	4
Average	52	98	47	43	23	<1	<2.2	<5.6	<1.4	<8.3

*mcg per liter

ND - Not Detected. Detection limit 1 mg. per liter

ND* - Not Detected. Detection limit 10 mcg. per liter

NA - Not analyzed

average removal efficiency for contaminants in Biocraft's ground water is given below.

Substance	Removal Efficiency (%)
Isopropyl Alcohol (IPA)	>98
Methylene Chloride ($MeCl_2$)	>98
Acetone	>88
Butyl Alcohol (BuOH)	>97
Dimethyl aniline (DMA)	64

--Reinjection Trenches

Effluent from the biological treatment plant is reinjected in two recharge trenches located at the ground water mound to flush the soil and subsurface with treated water, in order to remove residual contaminants.

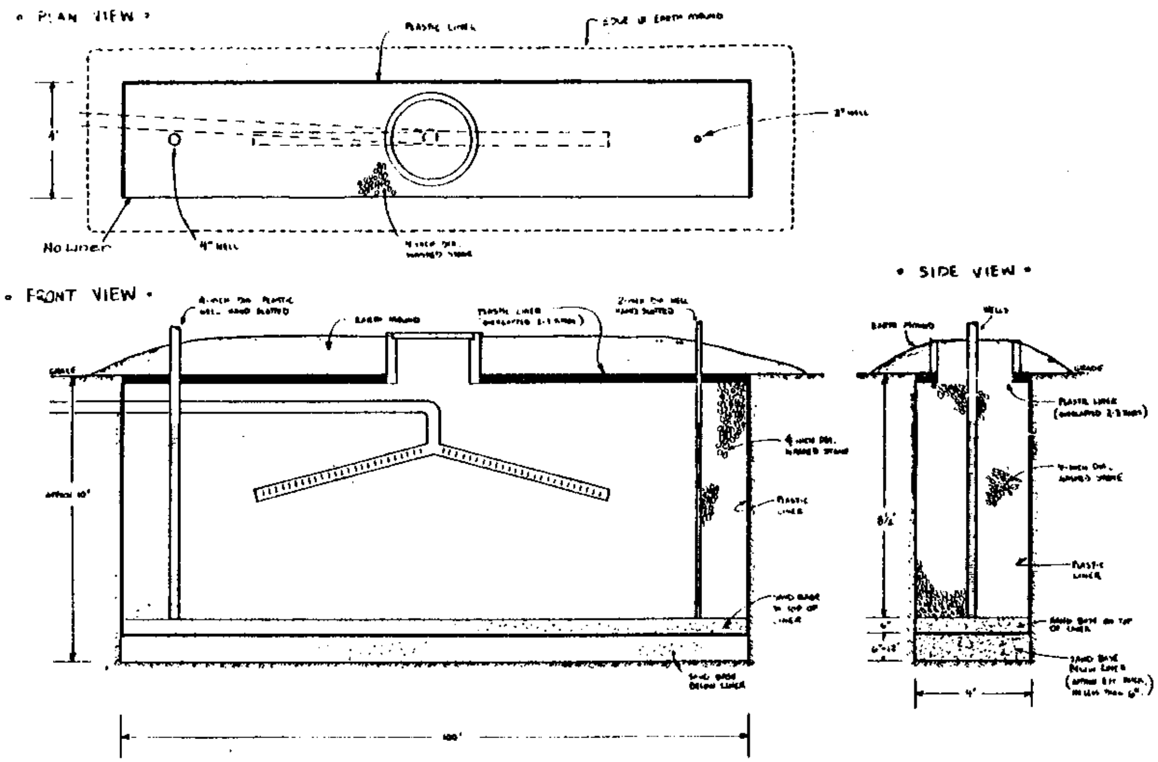
The two injection trenches (B and C in Figure 7) were excavated with a backhoe. Wooden shoring was used to support the trench walls until gravel and backfill were in place. The dimensions of each trench are approximately 100 feet (30 m) long, 4 feet (1 m) wide, and 10 feet (3 m) deep. The trenches are lined on the bottom, ends, back, and top with a 15 mil (0.025 mm) plastic liner, so that injected water is allowed to exit from only the front side of the trench. The bottom section of the liner was covered with a 3 inch (7.6 cm) sand layer and then hand filled with 2 inch (5 cm) washed stone to a thickness of 5 feet (1.5 m). Piping consists of a 2 inch (5 cm) vertical inlet pipe ending in a "Y" connection. Two 20 foot (6 m) sections of 2-inch (5 cm) slotted pipe were mounted to the "Y". The trench was then backfilled with 2 inch (5 cm) washed stone to the surface. A four foot (1.2 m) high manhole was installed over the recharge pipe for access. A four foot (1.2 m) high soil mound was then placed over the top liner to insulate the trench from freezing. Each trench has two monitoring wells, one on each end of the trench. These wells can also be used for flushing the system of sludge accumulation if required. Trench design is shown in Figure 10. Average flow if effluent to the two trenches is about 13,680 gallons (51,780 d) per day.

Air is injected into the recharge line, as effluent flows from the treatment plant to the trench, using a jet eductor or compressed air when flow rate is low.

Aeration of the reinjected effluent has the effect of creating a biological trickling filter in the trench to

Figure 10: Configuration of Reinjection Trenches

(Biocraft Laboratories, 1983)



Note: Treated water exits only from one side of the trench.

further increase biodegradation of organics. The water level in the trench is kept at surface elevation in order to flush contaminants in the shallow soil layers.

Excavated soil from the trenches was placed on plastic sheeting in a 2 to 3 foot (0.6-1 m) layer about 100 feet long and 16 feet wide. The soil layer is exposed to the atmosphere to induce natural aeration and biodegradation of contaminants in the soil.

--In-situ Aeration Wells

A series of nine continuous aeration wells were installed in the subsurface along the major path of contaminant plume movement as shown in Figure 11. The configuration of the wells is shown in Figure 12. Air is injected into each well at a pressure of 4 to 9 pounds per square inch (PSI). The addition of air to these wells creates a zone of subsurface aeration where contaminated groundwater passing near the wells is aerobically biodegraded. The nine wells are spaced about 30 feet (9 m) away from each other and are arranged in a rectangular matrix about 30 feet (9 m) wide and 100 feet (30 m) long. The arrangement of the wells was designed assuming a 15 foot radius of influence. Residence time through the intended aerated zone was calculated using an average ground water velocity of 0.4 feet (0.1 m) per day. Residence time ranges from 65 to 300 days, depending on the direction of ground water flow through the aerated zone. Ground water temperature is 54°F (12°C) which provides adequate temperature conditions for biodegradation.

In addition, two of the monitoring wells, numbers 4a and 9, are presently being aerated.

COST AND FUNDING

Source of Funding

All project costs were paid by Biocraft Laboratories, Inc.

300.68(c) responsible party funding

Selection of Contractors

Generally, contractors were selected based on qualifications. A high level of expertise was needed for all project work because the process was new and required innovation. Formal competitive bidding was not used, but Biocraft found that its contractors were within a competitive price range. Geraghty and Miller, Inc. (G&M) of Syosset, NY was chosen as the hydrogeological consultant

Figure 11: Location of In-Situ Aeration Wells

(Geraghty and Miller, 1979)

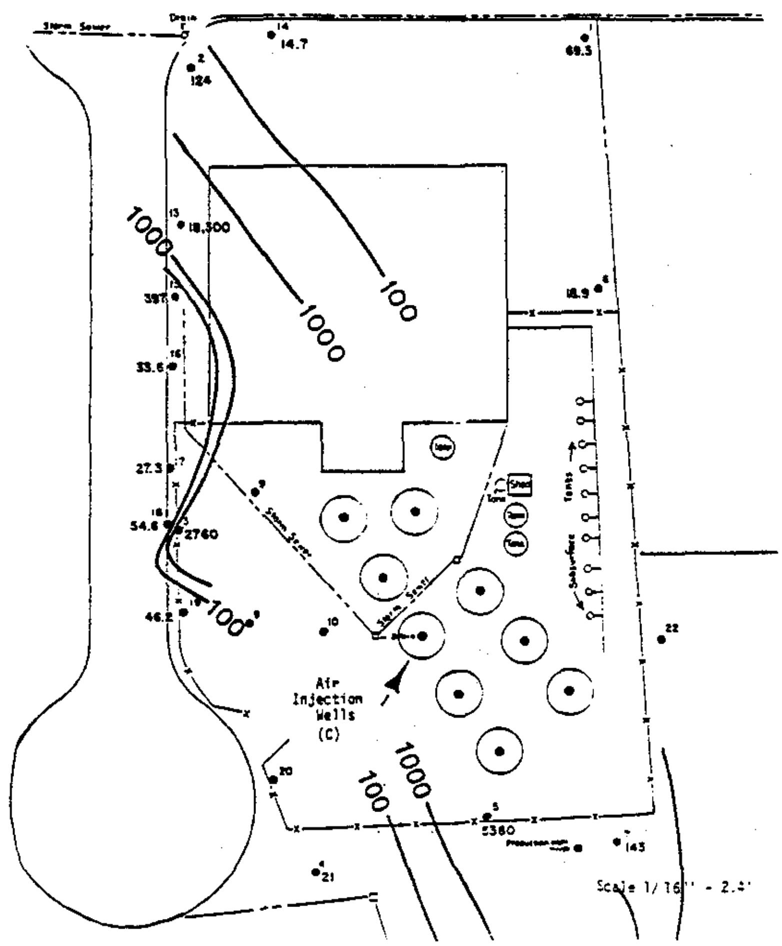
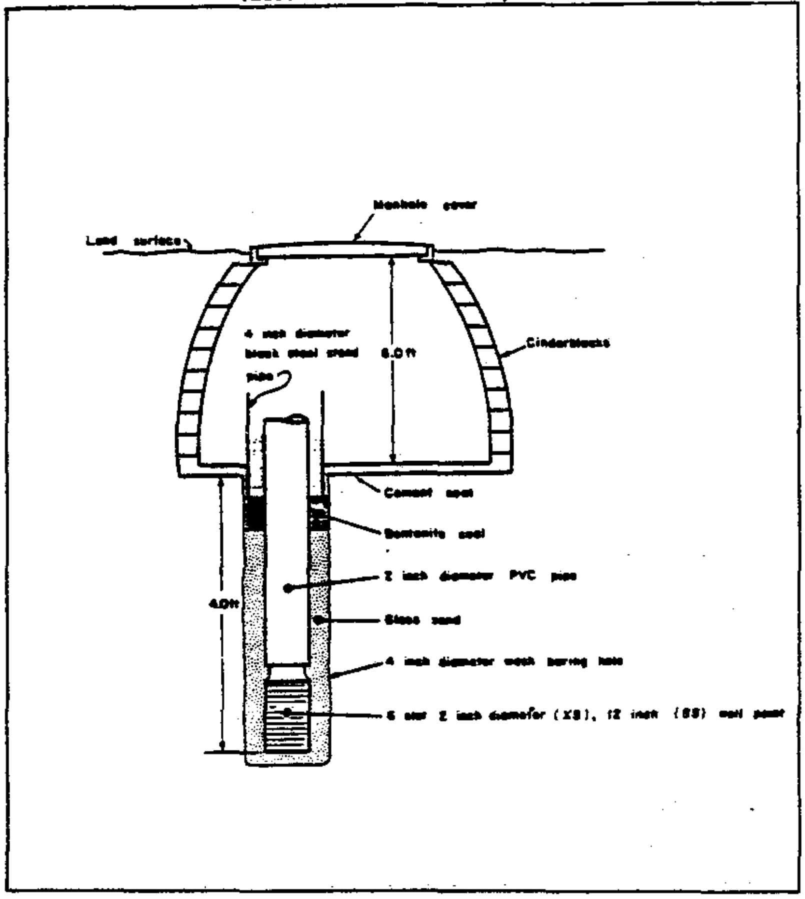


Figure 12: Air Well Construction

(Biocraft Laboratories, 1983)



based on three factors G&M was recommended by Biocraft's initial consultant, Princeton Aqua Science; G&M was among those referred to Biocraft by NJDEP, and G&M had written a frequently used hydrogeology textbook. The C&R Construction Company of Westwood, NJ has done construction work for Biocraft since about 1970. Biocraft chose C&R because it believed that C&R's ability to follow plans, its good business dealings, and its especially high level of competence with concrete construction would be useful for this work. The L&L Chemical Construction and Engineering Company, Inc. of East Rutherford, NJ was also chosen by Biocraft based on past satisfactory work. In 1971, when the original Biocraft plant was built in Waldwick, L&L helped refine the plans, and thus showed its trouble-shooting ability, which Biocraft considered useful for the biostimulation work.

Project Costs

Biostimulation Project Cost Overview

The total cost of research and development (R&D) and capital design and construction of the biostimulation operation at Biocraft was about $926,000. About half of this cost ($446,280) was for in-house process development, including a pilot plant. Virtually all of this process development cost was a one-time only expense. The general cost categories for R&D, and capital design and construction, which are discussed below and tallied in Table 9 are as follows:

- Hydrogeological Study - Problem Definition
- In-house Process Development
- Ground Water Collection/Reinjection System
- Biostimulation Plant

These costs include expenditures contributing to the biostimulation project from 1975 through March 13, 1982. In-house research, planning, management and overhead are included as estimates by Biocraft officials to within about 10% of expected actual cost range.

Cost for legal services and repair of the leaking underground waste storage tansk are not included. All information is based on actual goods and services costs between 1975-1982 drawn from invoices and from estimates by the plant manager, the plant engineer, and the fermentation director, and not on current market value.

TABLE 9. SUMMARY OF PROJECT COSTS- BIOCRAFT LABORATORIES, WALDWICK, N.J.

Task	Actual Expenditure	Unit Cost	Period of Performance
A. Hydrogeological Study-problem definition	$73,948	--	1976-1978
B. In-house Process Development (R&D)	$446,280	--	1978-1981
C. Ground Water collection/injection system total	$184,243	--	
1) Design	($61,490)		
2) Installation	($122,753)		1980-1981
D. Biostimulation plant Design and Construction total	$221,207	--	1981
1) Engineering Design	($58,400)	--	1981
2) Masonary Construction	($73,975)	--	1981
3) Equipment and Miscellaneous Installation	($88,832)	--	1981
CAPITAL AND R&D TOTAL	$926,158	--	
E. Operation & Maintenance (O&M)			
1) Utilities	$47.40 /day		
i) Electricity 26.4 kw(24 hours/day)	($46.82/day)	7.39¢/kwh	1983 rates
ii) Steam 72 pounds (33kg)/day @ 90PSI	(58¢/day)	0.8¢/pound	1981
2) Maintenance see text	$159.93/day		
3) Nutrient Salts see Table 15	$19.20/day	see Table 15	1983
Total Water treated - 13,680 gallons (51,779 l)/day	O. & M total:$226.53/day	$0.0165/gallon ($0.0044/l)	

Hydrogeological Study - Problem Definition

The total cost for the initial ground water assessment study was about $74,000, as shown in Tables 9 and 10. 300.66(c)(2) assessment

TABLE 10. INITIAL GROUND WATER ASSESSMENT STUDY COST BIOCRAFT LABORATORIES, INC., N.J.

Monitoring wells and test borings	$ 6,874
Laboratory testing	$27,704
Environmental and hydrogeological consulting	$39,370
Total	$73,948

Independent and in-house testing cost $27,704 (in-house: 400 hours @ $50/hour). The sum of $39,370 for environmental and hydrogeological consulting work included 200 hours of Biocraft employees' time spent working with consultants. 300.68(f) survey and monitoring

In-house Process Development Cost

The total cost for research and development of the biostimulation process and construction of the pilot plantwas about $446,280. This cost includes in-house labor, equipment, and quality control laboratory overhead as shown Tables 9 and 11.

TABLE 11. IN-HOUSE PROCESS DEVELOPMENT - BIOCRAFT LABORATORIES INC., WALDWICK, N.J.

Labor	$296,280
Equipment	$100,000
Quality control lab	$ 50,000
Total	$446,280

The cost for building construction, installation, piping and pumps for the pilot plant was about $40,000. Laboratory work occurred from December 1978 to March 1980, followed by operation of the 2.7 gallon (10.2 l)/hour pilot scale testing from March 1980 until June 1981, when full scale plant operation began.

Ground Water Collection/Reinjection System

The total cost for the design and construction of the ground water collection/reinjection system, including the air injection system, was about $184,00 as shown in Tables 9 and 12. The in-house labor costs of $26,400 includes the plant manager and director of fermentation (each 200 hours @ $50/hour) and the plant engineer (160 hours @ $40/hour).

300.70(b)(iii)
(c)
ground water
pumping

The system was installed primarily during November 1980 and was substantially completed by March 1981. Most of the installation work for the ground water collection/ injection system was done by C&R Construction Company, Inc., and cost about $122,753, including construction of trenches A, B, and C; air well construction and project supervision. Two major cost elements of the construction of trenches A, B and C were: (1) $7,490 for extra labor and equipment (including a backhoe/frontloader) and 162 tons (147 Mt) of 3 to 4 inch (7 to 10 cm) stone; and (2) $12,278 for the 3/4 inch (2 cm) plywood sheeting and labor necessary to shore up the trenches during construction. The digging of bucket well #30 (10 feet x 4 feet 16 feet (3 m x 1 m x 5 m)) and filling it witht stone cost $2,586. The construction cost for the nine air injection wells included $5,850 for nine, 6 foot (2 m) deep cinderblock and cement manholes; and $5,400 for digging the 320 linear foot (98 m) trench across the asphalt parking lot for the air line. The added expense for the access manholes was later determined to be unnecessary by the plant manager, because surface injection would have been adequate. The $4,500 for clearing of trees and land for construction was one of several secondary costs involved in the installation work.

Biostimulation Plant Design and Construction

The total cost for the design and construction of the *biostimulation process* plant was about $221,000 (see Tables 9 and 13).

300.70(b)(2)(ii)
(A)(3)
biological
reactors

The sum of $58,400 for engineering design of the final system included in-house costs of 160 hours for the plant manager and 200 hours for the director of fermentation, both at $50/hour. About 960 hours of engineering time was used, at $40/hour. Most of the design work occurred during 1980 and construction occurred during early 1981. The system went on-line in June 1981. Most of the contracted engineering and construction work on the

TABLE 12. GROUND WATER COLLECTION/REINJECTION SYSTEM

A. Design		
1. Laboratory testing		$10,418
2. Labor		
a. Hydrogeology consultants		$24,673
b. Biocraft (in-house)		$26,400
	Subtotal	$61,490
B. Installation		
Air and monitoring well points		$12,740
Trench, air well construction and miscellaneous site work		$80,500
Hydrogeologist supervisor		$21,513
Engineering		80,000
	Subtotal	$122,753
Total		$184,243

TABLE 13. BIOSTIMULATION PLANT DESIGN AND CONSTRUCTION
BIOCRAFT LABORATORIES, INC. WALDWICK, N.J.

A. Engineering Design		
Biocraft, in-house		$ 18,000
Engineer		$ 38,400
Draftsman/Blueprints		$ 2,000
	Subtotal	$ 58,400
B. Masonry and Construction		
Masons		$ 14,500
Piping		$ 27,800
Electricians		$ 16,675
In-house maintenance and engineering		$ 12,000
	Subtotal	$ 73,975
C. Equipment & Miscellaneous Installations		
Tank trailers with modifications		$ 28,560
Duct (includes installation)		$ 8,000
Rotameters, rollers, pipe, tanks		$ 9,000
Ceramic diffusers (air spargers)		$ 6,000
Threading diffuser		$ 3,000
Pipe, valves, etc.		$ 15,000
Temperature Recorders		$ 1,500
Compressor		$ 4,954
Pumps		$ 2,500
PCV liner		$ 1,500
Gauges (0-5 PSI)		$ 1,000
Metering Pumps		$ 3,000
Charcoal		$ 1,318
Miscellaneous		$ 2,000
	Subtotal	$ 88,832
Total Process Plant Design and Construction		$221,207

Biostimulation plant was performed by L&L Chemical Construction and Engineering, Inc. Some ancillary work for the process plant was done by C&R such as the construction of the catwalk and stairs, and railroad tie support piles for the activation and settling tanks, which totalled $2,874.

The masonry and construction work listed in Table 13 generally includes above-ground work such as pump house construction, tank installation and plumbing, and trench connections. The construction of the new pump house shell by C&R cost $4850. Biocraft provided 200 hours of both maintenance and engineering labor at $35 and $40 per hour respectively.

The largest single cost among the equipment and miscellaneous installations listed in Table 13 is $28,560 for the four 5,400 gallon (20,000 l) used milk tank trailers used for the activation and settling tanks. This cost includes delivery, set-up, and modifications such as a vent on the manhole, installation of a rear outlet 3 inch (8 cm) butterfly valve, a 2 inch (5 cm) valve in the belly, and several 2 inch (5 cm) nipples for various sampling, feed, filter and effluent lines, and 1 1/2 inch (4 cm) steam nipples.

The used milk tank trailers have 2 inches (5 cm) of insulation, which helps buffer ambient temperature effects on the maintenance of the 20°C process. The cost per modified tank trailer was about $6,250. The plant engineer and manager have subsequently determined that lined standard carbon steel tankers would have been much less expensive, even with the additional estimated $4,000 cost for lining, which would have been necessary to make them suitable for this use.

The cost for secondary elements, such as the ceramic air spargers and vent carbon adsorbers was affected by innovative specifications. The cost of threading the ceramic diffusers was necessary because the diffusers could only be purchased in 2 foot (0.6 m) lengths, and needed to be connected to form tank-long air spargers in the activation tanks. A specially designed roller-support apparatus was constructed to allow the air-spargers to be rolled out for maintenance to eliminate clogs. This system was intended to obviate the cost and risk of sending a maintenance technician into the tanks to remove the biomass buildup on the air-spargers. This maintenance cleaning has not yet been needed. The four carbon adsorbers mounted on the tanks to prevent volatilized solvent emissions, were constructed from used, retrofitted drums and $750 worth of charcoal. The $1,318 charcoal cost in Table 13 also provided enough charcoal for one annual replacement. Wooden pallets were used to construct an inexpensive saddle for mounting the drums. This innovation obviated the need for purchasing for commercial vent carbon adsorbers for $1,960.

Operation and Maintenance Costs

The operation and maintenance (O&M) costs are listed in Table 14, and are separated into utility, and maintenance labor and overhead. The largest utility cost of the system is $46.82/day for 26.4 kwh of electricity (55 Amps @ 480 Volts) at 7.39¢/kwh, based on the latest 1983 "Large Power and Lighting Service" industrial rate schedule. The 58¢/day for steam is based on a 0.8¢lb cost for 3 lb/hr @ 90 pound/square inch (PSI). The 0.8¢lb cost is based on the boiler manufacturer's estimated O&M cost for Bicoraft's Cleaver Brooks Model 4-watertube boiler generating 150 PSI and 4.5 million BTU (MBTU)/hour using either #2 oil ($1.0845/gallons, 29¢/1) or natural gas ($5.50/M BTU).

The maintenance costs include both labor and overhead expenses for in-house laboratory services. The $24.40/day for the quality control lab services includes the cost of 10 hours/week of "technician A" time at $14.00/hour, for labor and overhead. The $20.26/day for in-house maintenance includes labor and overhead for 7 hours/week at $20.26/hour. This cost is expected to decrease from the initial expense since the duties of monitoring and repairing pumps and valves will decrease after initial debugging. The supervision expense of $17.14/day includes about 4 hours/week of oversight time at $30/hour.

The daily nutrient salt cost is listed in Table 15. The sum cost of $19.20/day for the necessary USP or food grade nutrient salts to treat 13,680 gallons (51,779 1) of contaminated water results in a unit cost of about $0.0014/gallon ($0.005/1).

At a daily treatment rate of about 13,680 gallons (51,799 1), and total O&M cost of about $226.53/day, the unit cost for the biostimulation project is about $0.0165 gallon ($0.0044/1). Since the length of the project and the total volume of water treated is still unknown, no life cycle cost can be estimated in order to include capital costs.

TABLE 14. OPERATION & MAINTENANCE COST
BIOCRAFT LABORATORIES, WALDWICK, N.J.

I.	Utilities		
	A.	Electricity 26.4 kw x 7.39 ¢/kwh x 24 hrs/day	$46.82/day
	B.	Process steam 72 lbs/day @ 90 PSI x 0.8 ¢/lb	58 ¢/day
II.	A	Nutrient Salts	$19.20/day
III.	Maintenance Labor and Overhead		
	A.	Quality control lab & technician A	$24.40/day
	B.	Fermentation lab and technicians	$97.10/day
	C.	Maintenance	$20.26/day
	D.	Supervision	$17.14/day
		Total O&M	$226.53

$226.53-13,680 gallons (51,779 l/day treated = $0.0165/gallon ($0.0044)

TABLE 15. NUTRIENT SALT COST - BIOCRAFT LABORATORIES, WALDWICK, NJ

Nutrient*	Amount Used (Pounds/day)	Daily Cost
Ammonium chloride	34.6 (15.7 kg)	$5.63
Potassium phosphate (monobasic)	19.0 (8.6 kg)	$5.25
Potassium phosphate (dibasic)	28.4 (12.9 kg)	$7.50
Magnesium sulfate	2.0 (0.9 kg)	$0.36
Sodium carbonate (soda ash)	0.6 (0.29 kg)	$0.05
Calcium chloride	0.06 (0.029 kg)	$0.40
Manganese sulfate	0.13 (0.06 kg)	$0.01
Ferrous sulfate	0.03 (0.014 kg)	$0.0005
	Total daily cost	$19.20
*USP or food grade		

PERFORMANCE EVALUATION

Groundwater Decontamination

The biostimulation process implemented at the Biocraft site is generally reducing pollutant concentrations in the groundwater beneath the property. Data from different monitoring wells show that the removal efficiency has been somewhat variable. Figure 13 shows the location of presently existing on-site monitoring wells. Tables 16 through 20 give chemical analysis of groundwater for selected pumping and monitoring wells from July, 1981 to December 1982. Pumping well #13 in the main collection trench has shown a dramatic decrease in pollutants during the 18 month period of operation, with concentrations of methylene chloride in the parts per billion (ppb) range. Pumping well #30 which intercepts the southern component of contaminant flow, is showing a significant decrease in COD, dimethyl aniline, and isopropyl alcohol and reduced but varying levels of methylene chloride, acetone, and butanol. It is believed that pockets of gross contamination are still being collected by this well. Contaminant levels are expected to stabilize and reduce as pumping continues. Wells 4A and 31 in the southwestern corner of the property show dramatically reduced levels of contamination presently in the ppb range. Wells 1 and 2 along the northern property boundary, and wells 11 and 12 in the extreme eastern side of the property show relatively low concentrations of COD.

Some of this amount may be attributable to humic substances. However, residual contaminants are also suspected to be present and contributing to the COD level. Because of the hydrogeology of the area, low level contaminated ground water in property line wells is not believed to be in the area of influence of the collection trench and pumping wells and is expected to migrate offsite. These levels are relatively low and residual contamination will be gradually diluted with time. Contamination of the municipal deep well by these contaminants is a remote possibility, since any downward migrating substances would probably be adsorbed by clay and silt particles at these levels.

Groundwater Collection System

The design of the groundwater collection trench and pumping wells is generally adequate. The advantage to using collection wells is that if a pocket of contamination was discovered a pumping well can be installed quickly and economically. Monitoring wells can also be pumped if required, but the collection of ground water is

Figure 13: Well Location Map

(Source: Biocraft Laboratories, 1983)

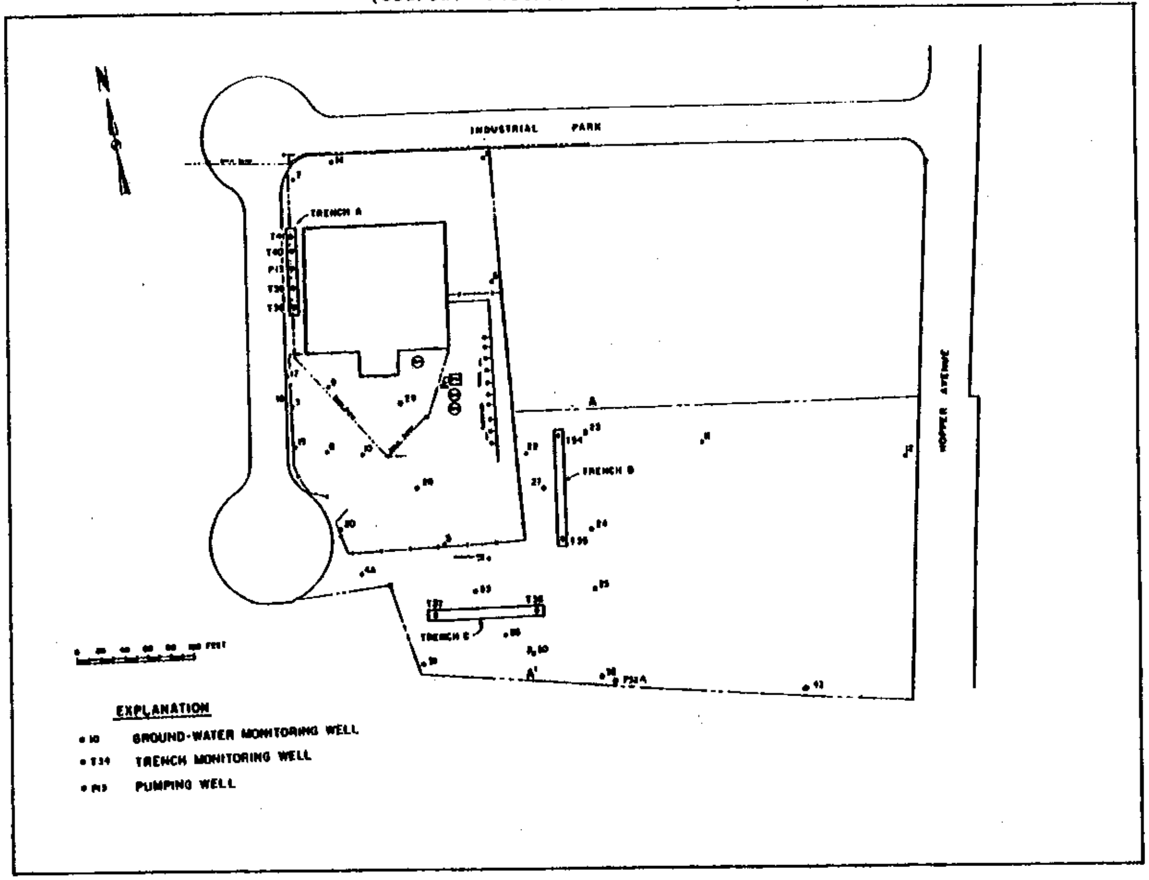


TABLE 16. LEVEL OF ORGANIC CONTAMINANTS PUMPING WELL #13
(Biocraft Laboratories, 1983)
July 1981 - Dec. 1982

Date	$MeCl_2$	Acetone
1981		
July 1-15	175	64
July 16-31	88	62
Aug. 1-15	-	-
Aug. 16-31	38	34
Sept. 1-15	-	-
Sept. 16-30	-	-
Oct. 1-15	64	57
Oct. 16-31	-	-
Nov. 1-15	5	3
Nov. 16-30	3	2
Dec. 1-15	1	1
Dec. 16-31	1	1
1982		
Jan. 1-15	23	14
Jan. 16-31	ND	11
Feb. 1-14	ND	17
Feb. 15-28	ND	8
Mar. 1-15	ND	4
Mar. 16-30	ND	3
Apr. 1-15	ND	3
Apr. 16-30	ND	2
May 1-15	ND	2
May 16-31	ND	3
June 1-15	ND	ND
June 16-30	ND	ND
July 1-15	ND	ND
July 16-31	ND	1
Aug. 1-15	7*	NA
Aug. 16-30	11*	NA
Sept. 1-15	53*	NA
Sept. 16-30	8*	NA
Oct. 1-15	33*	NA
Oct. 16-31	115*	NA
Nov. 1-15	32*	NA
Nov. 16-30	9*	NA
Dec. 1-15	8*	NA

ND: Not detected. Detection limit 1 mg. per liter

*mcg. per liter. Detection limit 8 mcg. per liter

All other values mg/1

NA: Not analyzed

TABLE 17. LEVEL OF ORGANIC CONTAMINANTS AND COD PUMPING WELL #30 (Biocraft Laboratories, 1983)
July 1981 - Dec. 1982*

Date	$MeCl_2$	Acetone	BuOH	DMA	IPA	COD	TSS
1981							
July 24-31	98	86	27	145	NA	1418	330
Aug. 1-15	77	67	28	137	NA	1300	626
Aug. 16-31	86	77	50	87	NA	1250	481
Sept. 1-15	68	67	43	73	NA	1009	615
Sept. 16-30	67	51	33	36	NA	1109	526
Oct. 1-15	123	108	82	48	NA	1505	558
Oct. 16-31	106	96	73	38	NA	1432	487
Nov. 1-15	64	55	52	21	NA	870	427
Nov. 16-30	72	42	36	21	NA	958	415
Dec. 1-15	37	21	17	10	NA	640	586
Dec. 16-31	62	23	16	10	NA	582	278
1982							
Jan. 1-15	115	39	24	11	15	650	266
Jan. 16-31	162	44	33	16	21	815	342
Feb. 1-15	68	18	14	8	7	436	170
Feb. 16-28	144	58	46	14	13	838	173
Mar. 1-15	107	34	28	11	10	602	217
Mar. 16-31	85	36	31	10	12	596	210
Apr. 1-15	49	24	19	4	11	543	129
Apr. 16-30	46	19	15	2	10	461	206
May 1-15	62	26	21	6	18	580	241
May 16-31	26	7	4	4	5	518	161
June 1-15	38	16	10	5	10	330	159
June 16-30	37	18	8	4	18	433	176
July 1-15	27	12	4	2	8	361	139
July 16-31	41	17	8	2	9	461	177
Aug. 1-15	76	23	16	4	20	569	243
Aug. 16-30	99	29	20	6	ND	648	257
Sept. 1-15	120	35	25	10	ND	713	293
Sept. 16-30	104	32	25	2	ND	729	219
Oct. 1-15	132	44	43	8	ND	572	246
Oct. 16-30	105	55	42	6	ND	743	262
Nov. 1-15	118	54	46	7	ND	761	228
Nov. 16-30	34	19	12	1	ND	290	152
Dec. 1-15	41	24	13	ND	ND	420	166

NA: Data not available. Starting Jan. 1982 IPA was determined. Previous levels were recorded with methylene chloride.

ND: Not detected. Detection limit 1 mg/liter.

* All values mg/1.

TABLE 18. LEVEL OF ORGANIC CONTAMINANTS, WELL 4A
(Biocraft Laboratories, 1983)

JULY 1981 - OCT. 1982

Date	$MeCl_2$	Acetone	BuOH	DMA
1981				
July 1-15	67	67	ND	23
July 16-31				
Aug. 1-15	45	80	ND	74
Aug. 16-31	35	78	ND	65
Sept. 1-15	8	26	ND	26
Sept. 16-30	ND	ND	ND	2
Oct. 1-15	ND	ND	ND	ND
Oct. 16-31	ND	ND	ND	ND
Nov. 1-15	ND	ND	ND	ND
Nov. 16-30	ND	ND	ND	ND
Dec. 1-15	ND	1	1	ND
Dec. 16-31	ND	ND	ND	ND
1982				
Jan. 1-15	ND	ND	ND	ND
Jan. 16-31	ND	ND	ND	ND
Feb. 1-14	1	ND	1	1
Feb. 15-28	10	ND	ND	ND
Mar. 1-15	ND	ND	ND	ND
Mar. 16-30	ND	ND	ND	ND
Apr. 1-15	ND	ND	ND	ND
Apr. 16-30	ND	ND	ND	ND
May 1-15	ND	ND	ND	ND
May 16-31	ND	ND	ND	ND
June 1-15	0	1	ND	ND
June 16-30	ND	ND	ND	ND
July 1-15				
July 16-31	ND	ND	ND	ND
Aug. 1-15	20*	ND	ND	ND
Aug. 16-31	11*	NA	NA	NA
Sept. 1-15	8*	NA	NA	NA
Sept. 16-30	8*	NA	NA	NA
Oct. 1-15	8*	132*	110*	NA
Oct. 16-31	ND*	NA	NA	NA
Nov. 1-15	20*	NA	NA	NA

NA: Not analyzed
ND: Not detected. Detection limit 1 mg per liter
*mcg/liter, all other values mg/l
ND* Not detected. Detection limit 8 mcg per liter

TABLE 19. LEVEL OF ORGANIC CONTAMINANTS, WELL 31
(Biocraft Laboratories, 1983)
JULY 1981 - DEC. 1982

Date	$MeCl_2$	Acetone	BuOH	DMA
1981				
July 1-15	2	6	ND	ND
July 16-31	ND	6	ND	ND
Aug. 1-15	ND	ND	ND	ND
Aug. 16-31	ND	1	ND	1
Sept. 1-15	4	14	ND	1
Sept. 16-30	34	25	ND	3
Oct. 1-15	74	57	ND	16
Oct. 16-31	78	81	ND	10
Nov. 1-15	53	68	ND	4
Nov. 16-30	45	59	ND	1
Dec. 1-15	28	34	ND	1
Dec. 16-31	23	24	ND	1
1982				
Jan. 1-15	ND	44	ND	1
Jan. 16-31	ND	26	ND	13
Feb. 1-14	50	63	19	2
Feb. 15-28	ND	44	ND	1
Mar. 1-15	ND	39	ND	2
Mar. 16-31	ND	63	ND	1
Apr. 1-15	ND	57	ND	1
Apr. 16-30	ND	28	ND	ND
May 1-15	ND	21	ND	ND
May 16-31	ND	23	10	ND
June 1-15	ND	4	ND	ND
June 16-30	ND	12	ND	ND
July 1-15	ND	12	ND	ND
July 16-31	ND	ND	ND	ND
Aug. 1-15	ND	ND	ND	ND
Aug. 16-31	ND*			
Sept. 1-15	ND*			
Sept. 16-30	ND*	NA	NA	NA
Oct. 1-15	ND*	NA	NA	NA
Oct. 16-31	ND*	NA	NA	NA
Nov. 1-15	ND*	NA	NA	NA
Nov. 16-30	ND*	NA	NA	NA
Dec. 1-15	ND*	NA	NA	NA

ND: Not detected. Detection limit 1 mg per liter
ND*: Not detected. Detection limit 8 mcg per liter
*All values mg/l unless noted

TABLE 20. CHEMICAL OXYGEN DEMAND OF MONITORING WELLS JULY 1981-DEC. 1982
(Biocraft Laboratories, 1983)

Date	WELL #1	WELL #2	WELL #11	WELL #12
1981				
July 1-15	NA	NA	62	73
July 16-31	NA	NA	NA	NA
Aug. 1-15	NA	NA	81	77
Aug. 16-31	NA	NA	35	NA
Sept. 1-15	35	NA	47	107
Sept. 16-30	6	302	17	57
Oct. 1-15	NA	88	70	NA
Oct. 16-31	NA	NA	69	76
Nov. 1-15	NA	NA	37	33
Nov. 16-30	NA	NA	NA	NA
Dec. 1-15	NA	NA	NA	NA
Dec. 16-31	NA	NA	57	NA
1982				
Jan. 1-15	8	50	NA	NA
Jan. 15-31	8	18	NA	NA
Feb. 1-15	21	22	65	34
Feb. 16-28	0	2	34	20
Mar. 1-15	NA	NA	25	NA
Mar. 16-30	50	25	NA	NA
Apr. 1-15	12	9	17	21
Apr. 16-30	NA	NA	NA	NA
May 1-15	10	30	20	NA
May 16-31	40	30	70	33
June 1-15	35	40	40	40
June 16-30	NA	NA	NA	NA
July 1-15	125	9	NA	NA
July 16-31	ND	ND	9	29
Aug. 1-15	NA	NA	20	48
Aug. 16-30	NA	NA	7	6
Sept. 1-15	NA	NA	13	12
Sept. 16-30	NA	NA	13	16
Oct. 1-15	NA	NA	17	24
Oct. 16-31	NA	NA	5	44
Nov. 1-15	10	NA	13	32
Nov. 16-30	45	10	22	24
Dec. 1-15	NA	0	NA	NA

NA - Not analyzed
* All values in mg/l

primarily a matter of well location. Since the biological treatment system is capable of economically handling up to 20,000 gallons (76,000 l) per day, any additional flow would not be a treatment capacity problem.

The design of the collection trench envelope is unconventional for dual media designs. Usually there is a much greater thickness of fine aggregate and just a thin layer of coarse aggregate around the collection pipe. Biocraft's design is opposite. This design may eventually result in sediment buildup in the collection line which could require flushing.

Biological Treatment Plant

The biological treatment plant had extremely high removal efficiencies (greater than 98 percent) for all but one substance. The sludge generation rate is extremely low for a biological process. Volatization of organics does not seem to be a significant factor in contaminant removal, however, Biocraft has recently implemented a testing program to investigate this.

Injection Trenches

There is some degree of hydraulic backflow behind the injection trenches, even with the plastic liner. Pumping wells 30 and 32 are probably pumping some of this backflow. In lieu of the liner, a partial cutoff wall could have been installed which may have offered improved containment of the backflow. The additional expense of installing such a wall, which would probably be over 300 feet (90 m) long, would be substantial. Grouting or sheet piling would probably be unfeasible because of the glacial till geology. A slurry wall or other excavated and installed barrier would be more appropriate. If a steeper hydraulic gradient were present at the site, very little backflow would be expected from the liner system. It is also recommended that geotextile fabric be used to protect the liner from puncturing during gravel fill operations and rock projections in the trench wall.

In terms of construction, Biocraft has experienced minor difficulties with the present design of the system. The aeration well manholes were allowing ground water to seep into the installation and had to be grouted. Biocraft now recommends that an access manhole is unnecessary and troublesome, and will eliminate it in future designs.

In-Situ Aeration Wells

The aeration wells are an interesting innovation but because of lack of testing, their actual effectiveness remains unclear. The placement of wells on 30 foot (9 m) centers was based on an assumed aeration radius of 15 feet. No testing has been performed to investigate the radius of aerations, and so it is as yet difficult to determine if the zone of aeration is continuous. If the zone of aeration is not continuous, the residence time of 65 to 300 days through the well bank does not apply. In a non-continuous aeration zone situation, it is more useful to assess biodegradability in terms of dissolved oxygen. If it is assumed that groundwater coming into contact with an aeration well will become saturated with dissolved oxygen, the average removal of organics by biodegradation will range from 3 to 4 mg/l. This suggests that if the well matrix produces a non-continuous aeration zone, it will be relatively ineffective with high groundwater contaminant levels, but may be very effective with residual organic concentrations of less than 5 mg/l.

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CHEMICAL METALS INDUSTRIES

BALTIMORE, MARYLAND

INTRODUCTION

NCP References

Hazardous substances were stored in drums, containers and tanks at this now bankrupt precious metal reclamation and chemical manufacturing facility in Baltimore, Maryland. Off-site migration of these substances threatened to contaminate the nearby Gwynns Falls, a tributary of the Patapsco River, and the presence of strong acids, basics and cyanide presented a risk of explosion and release of toxic vapors that could threaten the health and safety of residents in the surrounding residential area.

Background

Chemical Metals Industries (CMI), owned by L & M Associates, Inc., filed for bankruptcy in August 1981. It was dissolved by court order on August 28, 1981 and the property placed in the hands of a court-appointed receiver. For 7 years, CMI had operated as a precious metal reclamation facility and a manufacturer of copper sulfate. The site had been in commercial use since the 1950's, with one previous owner operating a gas station on part of the premises.

The site was investigated in September 1981 by the Maryland Office of Environmental Programs (OEP) and by the Technical Assistance Team (TAT) for the Region III office of the U.S. Environmental Protection Agency (EPA). The CMI facility had consisted of two sites separated by a block containing 20 occupied residences. Site 1, as it was called in the On Scene Coordinator's report, was the location of the old gas station. It was enclosed by an 8 foot (2.4 m) cinder block wall, within which approximately 1,500 drums were found. The drums were filled in different degrees with a variety of chemicals, including caustics, organic solvents and cyanide. They were deteriorated and damaged and piled haphazardly about the site. Apparently this site was used primarily for storage.

Site 2 was enclosed by a dilapidated fence and contained the metal reclamation plant with its adjoining yard. About 50 drums and containers marked as acids and oxidizers were found in the plant building. The laboratory and laboratory storage area of the building contained small quantities of reagents along with various labelled and unlabelled rare and heavy metal formulators. In the yard were 15 above ground storage tanks containing varying amounts of liquids and crystallized materials. The yard also contained approximately one hundred 55-gallon drums that were believed to contain wastes from the metal reclamation operation. Many of these deteriorated drums were leaking their contents onto the ground. Some were located near an open storm drain that led to the public sewer system. A storage vault containing various solid materials, including zirconium powder, was also found on Site 2.

Materials stored on CMI property primarily were wastes that had accumulated from two manufacturing processes. One process involved production of copper sulfate and copper hydroxide. The other process involved dissolution of trace amounts of precious metals from waste chemical solutions and printed circuit boards. For example, gold from circuit boards was dissolved in aqua regia, a mixture of nitric and hydrochloric acids that is highly corrosive. The aqua regia was then neutralized, causing the metals to crystalize out of the solution. It appeared that Site 2 had been used mainly for these manufacturing processes.

In October 1981, EPA concluded that the site posed an emergency and authorized immediate removal of the waste using CERCLA funds.

<u>Synopsis of Site Response</u>

The emergency response at CMI took about 7 weeks from October to December, 1981. Workers first removed a large amount of trash and debris from the two sites. A 35 ton (31.7 Mt) crane was used to move the haphazardly piled drums about so they could be sampled and analyzed. The 2,000 drums found at the two sites were classified as empty, partially full or full. Empty drums were subclassified as salvageable or unsalvageable. Salvageable drums were removed by a chemical company and unsalvageable drums were crushed and removed by a scrap metal dealer if uncontaminated or disposed of at a licensed facility if contaminated. Partially full and full drums were overpacked if necessary and subclassified according to their contents: acidic, basic, solvent, and cyanide. Cyanide drums were taken to a licensed disposal facility. Solvents went to a cement kiln for use as a low grade fuel. Acids and basics were taken to a nearby chemical treatment and disposal facility.

At Site 1, three underground tanks, one of which contained waste oil with 0.42 ppb PCB's, were pumped out and their contents disposed of. The tanks were then cut open, filled with cement grout, covered and the area capped with clay. A garage located on the site was removed. Four monitor wells were installed. Then the site was graded, capped with clay, and covered with topsoil and seed.

Site 2 had 15 above ground liquid storage tanks. Their contents were sampled and analyzed. Bulk liquid acids and basics were removed by a vacuum truck. Seven of the tanks were stainless steel and were removed by a company in exchange for the tanks. The remaining tanks were dismantled and removed. A building and several walls were left standing at Site 2. Their exteriors were sandblasted and the interior of the building was cleaned with detergents and disinfectants. Zirconium powder found in a vault in the building was removed and burned under controlled conditions. Four monitor wells were installed, then the site was graded and paved with asphalt.

SITE DESCRIPTION

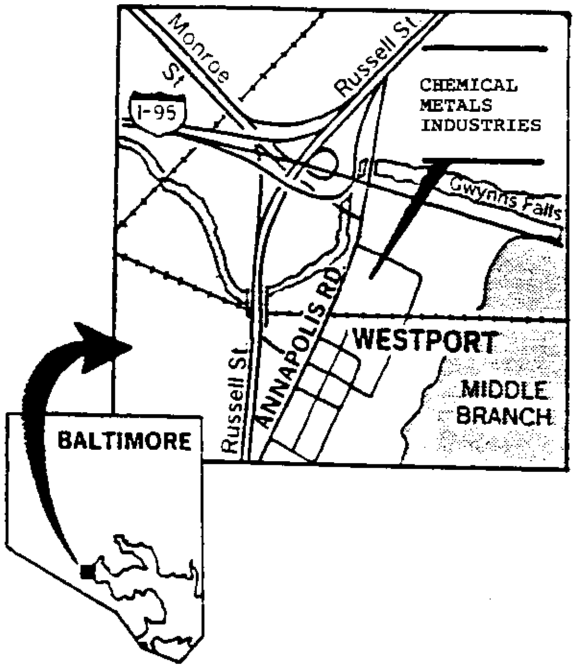
Surface Characteristics

CMI consists of two parcels of land separated by a block of about 20 residences in southern Baltimore, Maryland, near the Baltimore - Washington Expressway (see Figure 1). Site 1 is at 2001 Annapolis Road and Site 2 at 2103 Annapolis Road. Railroad tracks run next to the northern and southern boundary lines of Site 2 (see Figure 2). Soil at the two sites is in the Lenoir - Bettsville association and is sandy loam to clay loam over clay. The soil is moderately well drained, with a subsoil of predominantly silty clay loam and silt loam, underlain by thick stratified sediment.

The area has a changeable but equable climate because it is located between the colder northern and milder southern climates, and between the Appalachian

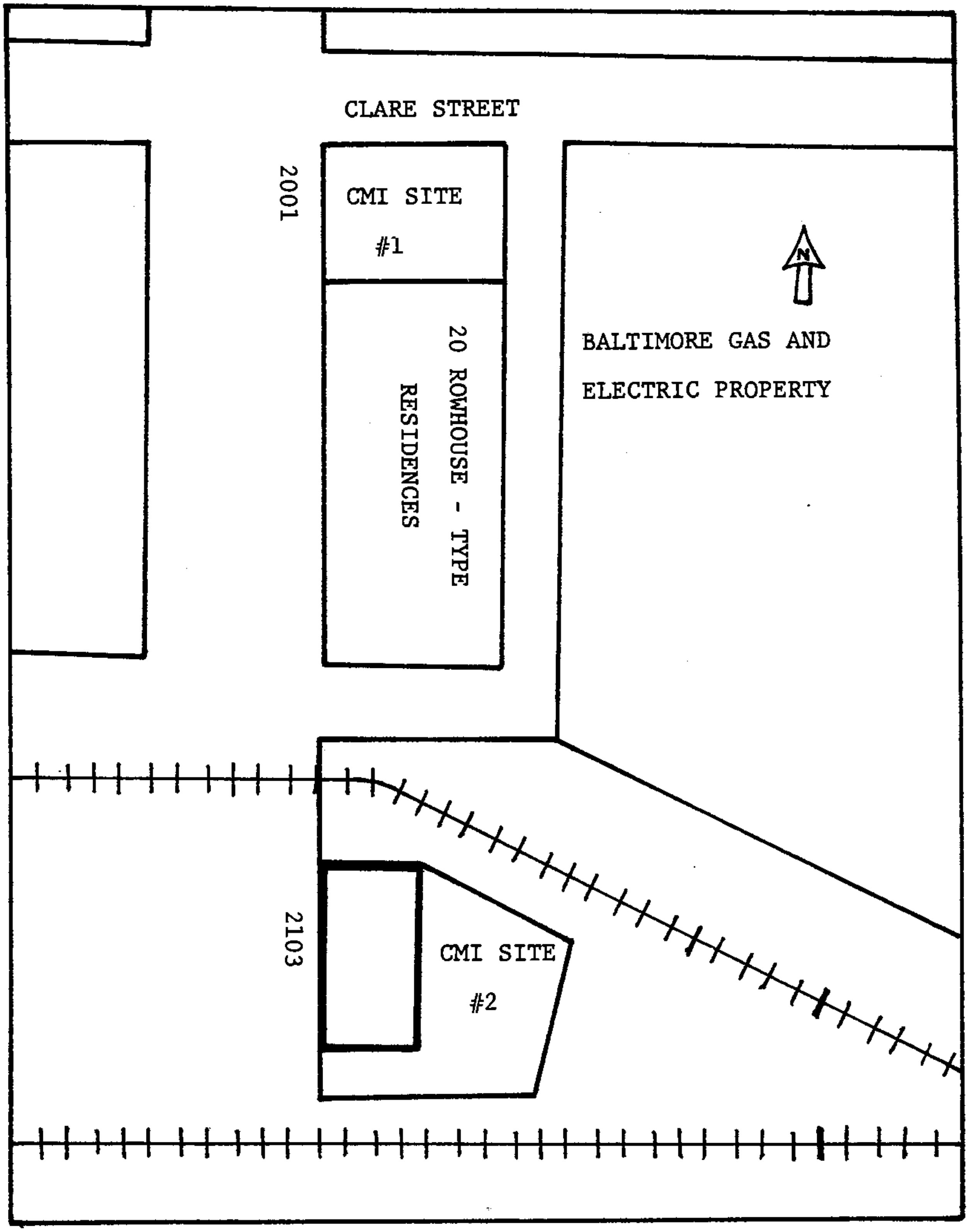
300.68(e)(2)
(i)(E)
climate

Figure 1. Location Map of Chemical Metals Industries Site, Baltimore, MD



Source: The Sun, Baltimore, MD, 10/23/81

Figure 2. Locations of CMI Sites #1 and #2



Atlantic Ocean to the east. This area is located near the average path of the low pressure systems that move across the country, which cause frequent changes in wind direction. Precipitation occurs fairly uniformly throughout the year, averaging about 40.46 inches (102.8 cm) annually. Temperatures range from an average minimum daily temperature of 33.4 degrees F. (0.8 C.) in January to an average maximum of 76.6 degrees F. (24.8 C.) in July.

Hydrogeology

Although monitor wells were installed at the two CMI sites, apparently no study of the area's hydrogeology was made. Ground water was found at least within 8 feet (2.4 m) of the surface at Site 1, and at an unknown depth at Site 2.

300.68(e)(2)(D) hydrogeological factors

WASTE DISPOSAL HISTORY

Wastes disposed of at the two CMI sites resulted from two on-site manufacturing processes. The first process involved the manufacture of copper sulfate or copper hydroxide by reacting a waste liquid, copper ammonium sulfate, with either sulfuric acid or sodium hydroxide. The second process involved placing printed electronic circuit boards in aqua regia, which is a mixture of nitric and hydrochloric acids that is highly corrosive. The aqua regia dissolved gold out of the circuit boards, leaving the plastic intact. Then the aqua regia was neutralized to make the gold crystalize out of the solution.

These manufacturing processes resulted in large amounts of incompatible wastes such as acidics, basics and cyanide, which were stored close together in above ground tanks and haphazard piles of drums, some of which were badly deteriorated. Numerous other substances, such as zirconium powder, reagents and heavy metals formulators, were also found in a vault in the building located on Site 2. The three underground tanks at Site 1 contained relatively small amounts of water and gasoline mixtures in two tanks and a waste oil with 0.42 ppb PCB's in the third. These had been used by the previous owner of Site 1, a service station operator. It was not clear whether or how the CMI operators had used these tanks.

DESCRIPTION OF CONTAMINATION

Preliminary investigation of CMI was performed by the OEP and a more detailed investigation was conducted by the TAT. Environmental contamination at the CMI sites was rather slight; the principal reason for the

300.65(a)(3) risk of fire or explosion

emergency response action was the threat of explosion and fire presented by the improper storage of incompatible materials in areas next to occupied residences. Most of the contamination was confined to drums, tanks, debris and surface soils. An estimated 100 tons (90.7 Mt) of contaminated debris and surface soil was removed from Sites 1 and 2, but no breakdown of this figure was available. It appeared from the initial investigations that the surface contamination resulted mainly from the contents of deteriorated drums and tanks spilling onto the ground. Acid fumes were detected in the soil at Site 1 and EP toxicity tests of soil at Site 1 also indicated cadmium levels in excess of standards.

300.68(e)(1)(ii) absence of effective drainage control system

The extent of ground water and surface water contamination that resulted from the two CMI sites is not clear. Investigators observed some bluish-green run-off from the site, and early in the emergency response they placed a sorbent sausage boom at two locations to contain run-off. Leaking drums stacked near an open storm drain at Site 2 posed a threat of contaminated run-off into the drain system. Surface run-off from the CMI sites eventually goes into Glynns Falls, a tributary of the Middle Branch of the Patapsco River.

300.65(b)(5) sampling

Eight monitor wells were installed, 4 at each site. On Site 2 a bluish-green water was observed in some wells; it was subsequently found to contain a high concentration of copper sulfate, with the highest concentration being in the center of the site. On Site 1, gasoline was found in one well at a depth of 8 feet (2.4 m).

Contamination of the air was a major concern at CMI because cyanide was found close to strong acids, the mixture of which could produce extemely toxic hydrogen cyanide gas. This concern was underscored by reports from neighbors of noxious odors at the sites. Several fuming drums were observed during early site investigations. The initial analysis of air samples by the TAT using a MSA cyanide detector showed cyanide concentrations in excess of 30 ppm. This led to a cessation of all site activity while TAT investigators attempted to confirm these results with a Draeger detector. When the Draeger detector failed to confirm the initial results, the investigators consulted with the manufacturer of the MSA detector and learned that the high concentrations of nitrogen dioxide gas, resulting from the degradation of nitric acid at the site, may have caused an erroneous cyanide reading. On another occasion, the Draeger instrument had a cyanide reading of over 30 ppm, but when the area was sampled with the MSA detector this was

300.65(b)(5) sampling

not confirmed. Discussions with Draeger Company representatives determined that ammonia vapors at the site could have caused a false positive reading. Nitric acid or hydrochloric acid vapors also could have discolored the Draeger tubes and given a false positive reading. Investigators eventually determined that fumes emanating from some of the drums probably resulted from the mixture of moisture with acids in leaky drums.

PLANNING THE SITE RESPONSE

Initiation of Site Response

CMI was discovered when an inspector from the Maryland Office of Environmental Programs (OEP) noticed it while driving to a licensed chemical treatment plant in South Baltimore. A review of state files revealed that, while CMI had operated for 7 years, OEP had no record of its existence. Nor did the state Department of Health have records about it.

300.63(a)(4) random observation by government

The OEP entered the site on September 2, 1981 to conduct an initial investigation. Officials determined that the situation posed a significant threat of contamination and explosion, requiring an immediate response. Since neither the OEP nor L & M Associates, the owner of CMI, had sufficient funds for this clean-up action, the state requested federal assistance under section 104 of CERCLA. EPA Region III sent its Technical Assistance Team (TAT), which was Ecology and Environment, Inc., to inspect the site on September 15.

300.64(a) preliminary assessment

300.67(b) state request for federal assistance

The TAT inspected conditions at CMI, conducted ambient air monitoring, and took drum samples to the EPA Region III Central Laboratory for analysis. A visual inspection of CMI found that several attempts had been made to start fires. Local residents interviewed by TAT personnel reported that noxious vapors had emanated occasionally from CMI over the past few years, and that a green liquid and noxious odors had entered the basement of an adjoining residence.

300.64(a) preliminary assessment

Markings on drums at the site revealed the presence of inorganic acid and acid solutions, alkali salts and alkali solutions, cyanide-bearing compounds, mixes and solutions, and ammonia compounds and ammonia solutions. This combination of chemicals presented a serious threat to public health; as the TAT report stated, "acids, when brought into contact with cyanides evolve actively toxic hydrogen cyanide vapors which are fatal in concentrations of 300 ppm." The TAT conducted ambient air monitoring, which showed low concentrations of hydrogen cyanide vapors and organic vapors at the

300.65(a)(1) toxic exposure

site.

The TAT report agreed with the conclusion of the state that conditions at CMI justified emergency response action. The TAT outlined three major threats: (1) formation and release of hydrogen cyanide vapors from leaking drums; (2) off-site migration of contaminated surface water from leaking drums, affecting walkways, streets and the Patapsco River; and (3) the danger of fire, which treatened nearby residences and the environment with the release of toxic vapors and water run-off from fire fighting efforts. To stabilize the site and reduce these threats, TAT proposed that EPA secure the drums, assess the integrity of the above ground storage tanks, and inventory, sample, analyze, categorize and dispose of all wastes.

300.65(a) immediate removal risk to human health or environment

On October 19, EPA authorized an emergency response action at CMI, to be funded under CERCLA, making CMI the first Superfund site in Maryland. Response action began that day. Before authorizing the response, however, EPA had to resolve a conflict it had with the U.S. Coast Guard. Between the time of the DEP request for assistance on September 2 and EPA's authorization on October 19, the state performed some containment action at CMI. Upon Maryland's request, the Coast Guard agreed to reimburse certain state costs under the section 311 fund of the Federal Water Pollution Control Act, which the Coast Guard administered. The state fenced both sites to prevent unauthorized entry and removed trash to prevent fires. The Coast Guard supplied sorbent barriers to be placed at two locations to prevent run-off of contaminated material into the storm drain.

300.65(b)(3) security fencing

300.65(b)(7) physical barriers

Due to the Coast Guard's prior involvement with CMI, some debate arose between it and EPA regarding allocation of supervisory authority and funding for the clean-up. This debate may have contributed to delay between the state's request and EPA's Superfund authorization. In early October, the agencies signed a Memorandum of Understanding allocating jurisdiction over the site. EPA's On Scene Coordinator (OSC) was given final authority over all actions taken at CMI. The OSC requested $58,000 from EPA headquarters to pay for staging and intitial response action costs. This amount was authorized by headquarters on October 19. Then the OSC made an oral demand upon the receiver for CMI for clean-up funding, which was followed by a written demand. The receiver responded that no such funds were available. On the same day as the receiver's response, EPA hired J & L Haulers of Baltimore, Md. to serve as primary contractor for the clean-up.

300.64(a)(93) determination of party's willingness to clean up

Selection of Response Technologies

The technologies employed at CMI were drum, tank and bulk liquid removal, and grading and capping. Drum, tank and bulk liquid removal were chosen in order to eliminate the threat of explosion or fire. Drums and liquids were divided into classes and subclasses to facilitate safe handling and expedite disposal or treatment. Both CMI sites were graded and capped. Site 1 was capped with clay and sod for use as a small park and Site 2 was capped with asphalt for use as a parking lot surrounding the building that had been prepared for use as administrative offices. The underground tanks at Site 1 were filled with cement grout, covered and capped because they were not contaminated enough to warrant the high cost of excavation and removal. Four monitoring wells were installed at each site to determine whether the removal action prevented further ground water contamination. Ground water extraction was not performed because there were no drinking water supply wells located nearby. Officials took a "wait and see" approach to this issue, preferring to observe monitor well results to determine whether further work was needed.

Extent of Response

300.65(c) completion of immediate removal

300.68(j) extent of response

Response action at CMI ceased when all materials of concern were removed from the two sites and the surface areas capped, thereby ending the immediate threat of explosion or fire. Little information is available concerning how deep the contractors excavated surface soil at the sites to remove contamination; it appears that they simply scraped the sites to where the soil appeared clean and then graded the area in preparation for capping. Nor is it clear how it was determined that the building at Site 2 was safe for re-use. Given the nature and extent of contamination there, the cleaning and sandblasting measures apparently were sufficient.

DESIGN AND EXECUTION OF SITE RESPONSE

On the night of October 19, 1981, when Superfund money was authorized for CMI, EPA, the TAT, the Maryland OEP and J & L, the primary contractor, met to outline a plan for set-up at the site and to allocate responsibilities. A primary concern of all parties was the safety of the nearby population. The TAT was to perform continuous site boundary air monitoring and was to develop an evacuation plan in the event of explosion or fire. The Baltimore City Police and Department of Traffic and Transit were to close off the area where CMI was located to prevent unauthorized entry during the emergency response period. This meeting also established a community relations plan, whereby a small team from EPA would explain to local residents what remedial actions would be taken at the site.

Participants at the preliminary meeting were also concerned for worker safety at the site. The TAT was given responsibility for drafting a site safety plan for EPA approval that outlined operating procedures and precautions. The plan required medical physical examinations for all on-site personnel, daily safety meetings, prior training for all tasks to be performed, continuous site monitoring, and availability of a respiratory system. In addition, J & L was given responsibility for establishing a safety protocol for its personnel and those of its subcontractors. J & L's plan provided a respiratory protection program, decontamination facilities, and trained medical personnel on-site. J & L also supplied initial site security during non-working hours, with Baltimore police providing security later.

300.71
worker health
and safety

Site monitoring featured prominently in the TAT plan with the setting of a base line for NCN, NH3 and explosive vapors, as measured by Draeger tubes and a MSA explosimeter, and with sample results recorded in a log. Criteria for on-site vapor concentration were established; if on-site vapors exceeded 10 ppm, site periphery monitoring would be conducted, and if cyanide concentration at the periphery exceeded 2 ppm, the Maryland Health Department would be notified immediately and appropriate action would be taken. In addition, the TAT plan identified different categories for air sampling during drum handling, according to the degree of hazard.

The TAT plan also designated three zones of contamination at CMI. Zone 1 was the "clean zone", where no uncontained waste or contaminated equipment and personnel were permitted. Zone 2 was located mainly around Site 2 and required appropriate safety equipment for each task. Zone 3 was at Site 1 and required, at a minimum, that each person use a respirator, safety suit, PVC boots and gloves. No one was permitted to work alone in this area.

Work at the site began October 20, the day after the meeting. It consisted mainly of drum and bulk liquid removal; approximately 2,000 empty, partially full or full drums were removed and bulk liquids were taken from 15 above ground and 3 underground storage tanks.

300.65(b)(6)
moving
hazardous
substances
off-site

Drums were classified as empty, partially full or full, with the empty category being broken down further into salvageable and unsalvageable. The partially full and full categories were subcategorized by content: acidic, basic, solvent and cyanide. Empty salvageable drums were removed by a local chemical company at no charge, while empty unsalvageable drums were crushed and either given to a scrap metal dealer if uncontaminated or disposed of at the Browning Ferris Industries (BFI) Solley Road facility if contaminated.

300.65(b)(11) salvage operations
300.70(c) off-site transport for treatment, storage or secure disposition

Partially full or full drums were handled according to their contents. Drums containing cyanide went to a permitted disposal site in Camden, New Jersey. Many of these were deteriorated and had to be overpacked. Drums holding solvents were taken to the Delaware Container Company in Coatesville, Pennsylvania for use in a low grade fuel for a cement kiln. Drums of acidic and basic waste were sent to Chem-Clear Inc. in Baltimore, Maryland for chemical treatment and disposal. Bulk liquids pumped from storage tanks at CMI also were handled according to this classification system.

Removal action at CMI's Site 1 took place in the following manner. Workers first removed debris from the site (approximately 100 tons (90 Mt) of debris and contaminated soil were removed from Site 1). Then they began sampling, analysis and categorization of the drums. Deteriorated drums were overpacked and disposed of at the appropriate places. A vacuum truck withdrew compatible bulk liquids from drums, such as acids and neutrals or basics and neutrals, and transported the liquids to a chemical treatment and disposal facility. Since many drums had deteriorated, a 35-ton (31.7 Mt) crane supplied by the Baltimore Health Department was used to manuever drums for sampling and removal. The crane began at the top of the pile of drums and worked down.

Three underground storage tanks were found at Site 1, two containing gas and water mixtures and one containing waste oil with 0.42 ppb PCBs. These liquids were pumped out and disposed of. Then a backhoe removed surface soil down to the tops of the tanks, which were about 4 feet (1.2 m) below surface. Part of the top of each tank was removed and cement grout was pumped in until it flowed out of the tank vents. The tops were then replaced and the area backfilled. A 6 inch (15.2 cm) clay cap was placed over the area, which in turn was covered by top soil.

A garage located on Site 1 was removed. It had a common wall with the residence on the adjoining property, so extra care was taken to avoid damage to the latter structure. After removing the garage, workers sandblasted the common wall to remove possible contamination and prepared it for painting.

After the drums were removed and underground tanks filled, 4 monitoring wells were installed at Site 1. Finally, the site was graded, capped with clay, and covered with a layer of sod. It is now being used as a playground by neighborhood children.

300.70(b)(1)(ii)
(A);(C);(D)
surface sealing;
grading;
revegetation

Site 2 was similar to Site 1 in terms of procedures for removing drums and bulk liquids. However, several distinguishing removal actions took place here. First, Site 2 had 15 above ground storage tanks (see Figure 3). Their contents were sampled. Bulk liquid acids and basics were removed by a vacuum truck. Then the tanks were flushed with water and the water was removed for treatment.

One tank contained copper sulfate, a hard crystalline material that required that the tank be cut apart with a welding torch and removed by hand. Seven other tanks were made of stainless steel; a company removed than at no charge in exchange for the tanks. The remaining tanks, 5 of steel and 2 of fiberglass, were dismantled and removed.

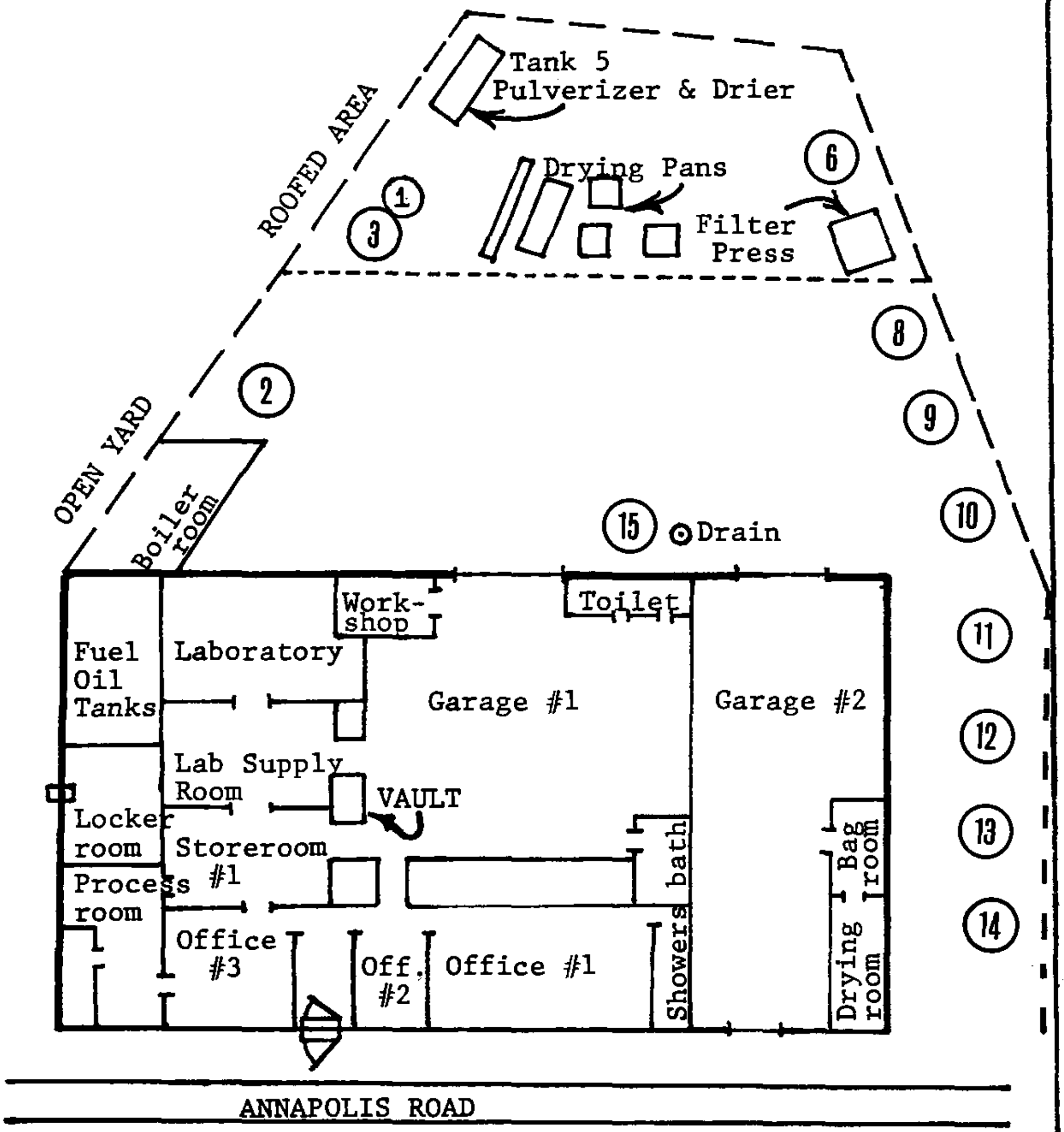
A second difference between the CMI sites was that Site 2 contained a building and several walls which were decontaminated and left standing (with the exception of one unstable wall that was removed). Exteriors were sandblasted while the interior of the building was cleaned with detergents and disinfectants so that it could be used later. A third difference between the two sites was that highly explosive zirconium powder was found in a vault in the building at Site 2. This was carefully removed and burned by the Baltimore Bomb Squad.

300.70(c)(1)
off-site
transport
for destruction

Finally, while Site 1 was capped and sodded for use as a playground, Site 2 was paved for use as a parking lot around the building, which was to be used for offices and storage. Dye studies that had been made to investigate possible run-off of contaminated water during the removal operation were used to plan the grading of the site to insure proper drainage. Four monitoring wells were installed at Site 2. After the area was graded, it was paved with a 2.5 inch (6.3 cm) layer of asphalt.

300.70(b)(1)(ii)
(A); (C)
surface seal;
grading

Figure 3. Chemical Metals Industries Site #2



Source: On-Scene Coordinators Report

COST AND FUNDING

Source of Funding

Before EPA authorized the use of Superfund money for the CMI clean-up, the Coast Guard promised a relatively small reimbursement of the state's costs under section 311 of the FWPCA. This money was for the costs of fencing both CMI sites and removal of trash to prevent fires. In addition, the Coast Guard supplied sorbent barriers as a temporary measure to prevent possible run-off of contaminated material into the storm drain. As of July 1982, this reimbursement had not been made.

EPA paid for most of the response action at CMI, using the CERCLA immediate removal funds. The intitial authorization was for $58,000, but unforseen difficulties in the removal process as well as unexpected contamination problems necessitated several funding increases, bringing total EPA funding to $205,000. For example, the first funding increase occurred on October 24, five days into the clean-up. A sum of $30,000 was authorized mainly because zirconium powder was discovered in a locked vault in the building at Site 2.

300.61(c) CERCLA - financed response action

Selection of Contractors

Ecology and Environment served as the on-site Technical Assistance Team (TAT) under its 3-year contract with EPA Region III. It was responsible for coordinating special projects, sampling, documentation, and planning. J & L Industries of Baltimore, Md. was hired as the clean-up general contractor. It was selected by EPA because of its experience and proximity to CMI, and a direct procurement time and materials contract was used. J & L oversaw the removal and disposal of all drums, tanks, bulk liquids, and contaminated soil and debris. J & L subcontracted with the Delaware Container Company for disposal of solvents. J & L hired the firm due to past work experience and the company's proximity to CMI. J & L hired Clean America of Baltimore to pump out bulk liquids at CMI and transport them to appropriate disposal facilities. Clean America was hired primarily because it had vacuum trucks that were capable of doing the job.

EPA hired several companies directly to treat and dispose of various substances. It hired Chem-Clear, a chemical waste treatment and disposal facility in Baltimore, to dispose of the acids and basics from CMI. A time and materials contract was used with Chem-Clear, which was selected because of its expertise in the field, the technical capabilities of its facility, and its proximity to CMI. EPA hired CAMAX Corporation to remove and dispose of all non-zirconium materials from the vault and laboratory area at Site 2. EPA also hired Martel Laboratory Services, Inc. of Baltimore (through TAT Special Projects) for analysis of samples from CMI for RCRA disposal capability and precious metal content, as well as monitoring well samples for ground water contamination. Martel was selected because it was located nearby and had the capacity to perform prompt analyses, while state and federal labs in the region had too much backlog.

T & A Excavating, Inc. was hired to do the final site clean-up, including removing the building from Site 1, grading and sodding that area, grouting the underground tanks at Site 1, clay capping the tank area, and grading and paving Site 2. T & A originally subcontracted with J & L but later worked directly for EPA under a sole source fixed price contract.

Two Browning Ferris Industries (BFI) facilities were used by J & L, Chem-Clear and Delaware Container for disposal. All non-liquid hazardous substances from CMI, including sludges from Chem-Clear and Delaware Container, were disposed of at BFI's Solley Road facility. Non-hazardous solid wastes such as debris and some empty decontaminated drums were disposed of at BFI's sanitary disposal facility. BFI had an open disposal contract with Chem-Clear and Delaware Container for their sludges. J & L had a contract with BFI to dispose of contaminated soil and debris, and EPA had a separate contract with BFI for disposal of the non-hazardous materials. BFI's proximity and capability to receive these wastes were major reasons for its selection.

EPA had several local firms perform designated removal work under formal or informal agreements in exchange for the materials removed. Abbey Drum Company in Baltimore removed about 600 empty uncontaminated drums from sites 1 and 2 at no charge and was allowed to keep them. Included in this number were 51 drums loaned to CMI by Robinson Chemical Company, which Abbey returned to Robinson as a favor to its client. Spectron, Inc. removed stainless steel tanks from Site 2 in exchange for the tanks. Finally, Klaff Metals of Baltimore, a scrap metal dealer, agreed to remove over 400 empty uncontaminated unsalvageable drums and uncontaminated debris, which totalled over 31,000 pounds (14,061.4 kg). These firms appear to have been selected because they were willing and able to remove these materials quickly and at no charge to EPA or the state.

Project Costs

The emergency response action at CMI cost \$340,343.42 (see Table 1). Most of the CMI project was funded directly under authority of CERCLA, although the State of Maryland and City of Baltimore contributed substantial funds and services also. According to the On Scene Coordinator's (OSC's) report, a total of \$199,143.42 in direct costs was funded under CERCLA, with most of that amount going to J & L Industries, the general contractor (\$152,289.17), followed by Chem-Clear (\$25,435.25), T & A Excavating (\$15,000) Clean America (\$4,989) and Williams Mobile offices (\$1,430).

The State of Maryland had spent an estimated \$103,500 as of February 1, 1982 for personnel and equipment. Personnel who spend time on the projcet included a representative to the Regional Response Team, chemical and civil engineers, a biologist, a geologist, well drillers, investigative staff and Assistant Attorneys General. Maryland also provided such support equipment as a well drilling rig, a van and a 4-wheel drive vehicle, respirators, an MSA self-contained breathing apparatus, and monitoring equipment. The state also paid for some costs incurred by T & A in capping the sites, but these weren't specified in the OSC report.

300.62(a) state role in response

Baltimore provided 24-hour site security for part of the project's duration, a 35-ton (31.7 Mt) crane for moving drums, a Civil Defense van, fire equipment (ladder truck and pumper), a recharging self-contained breathing apparatus, plus the time of personnel from the Fire Department, Bomb Squad, Health Department and Mayor's representative to the Regional Response Team. These goods and services were estimated to total \$7,700 as of February 1, 1982.

The OSC estimated that the cost of the Technical Assistance Team's special projects relating to CMI came to \$30,000, although this figure was not broken down into costs for specific tasks.

The U.S. Coast Guard agreed to expend some money under section 311 of the FWPCA to reimburse some state costs incurred during the initial response to the CMI site before response authority was switched to EPA and funding to CERCLA. The Coast Guard agreed to reimburse the state for the cost of fencing the sites and placing sorbent barriers to prevent run-off. No reimbursement had been made as of July 1982. The costs of these actions were not included in the OSC's report.

TABLE 1. SUMMARY OF COST INFORMATION-CHEMICAL METALS INDUSTRIES, BALTIMORE, MD.

Task	Quantity	Expenditure	Unit Cost	Funding Source	Period of Performance
General contractor (oversight of all removal and disposal work -- 1400 drums, 15 tanks, 100 tons (90.7 Mt) contaminated soil and debris		$147,789.17	NA	CERCLA	10/19/81-12/18/81
Disposal of contaminated soil and debris	100 tons(a) (90.7 Mt)	$4,500	$45/ton(a) ($40.82/Mt)	CERCLA	10/19/81-12/18/81
Treatment and disposal of bulk liquids acids and basics	19,500 gal. (73,815 1)	$25,435.25	$1.30/gal ($0.34/1)	CERCLA	10/24/81-12/18/81
Pumpout and transport of bulk liquids	19,500 gal. (73,815 1)	$4,989	$0.25/gal ($0.07/1)	CERCLA	10/24/81-12/18/81
Grading, sodding and capping Sites 1 & 2	NA	$15,000	NA	CERCLA	11/27/81-12/18/81
Mobile office rental	1	$1,430	NA	CERCLA	10/20/81-12/18/81
Workplan, safety protocol, chemical analysis	NA	$30,000	NA	CERCLA	10/19/81-12/18/81
State of Maryland equipment and personnel	NA	$103,500	NA	Maryland	9/2/81-12/18/81
City of Baltimore equipment and personnel	NA	$7,700	NA	Baltimore	10/19/81-12/18/81
TOTAL	NA	$340,343.42			9/2/81-12/18/81

NA = Not available (a) From OSC report

PERFORMANCE EVALUATION

The emergency response at the CMI sites was completed in approximately 7 weeks and appears to have accomplished its objective, namely, to eliminate the threat to public health and the environment posed by possible fire or explosion. Several causes of delay in the response action can be identified. First, the dispute between the U.S. Coast Guard and EPA concerning authority over the clean-up action apparently contributed to the delay of over one month between the Maryland Office of Environmental Programs' (OEP's) request for funds under section 104 of CERCLA on September 2, 1981 (EPA's TAT agreed on September 15 that an emergency response was warranted) and EPA's authorization on October 19. Since this was the first Superfund action in Maryland, this type of delay might not occur again.

A second delay in the response action resulted from the circumstances at CMI. The unstable piles of leaking drums found at the sites necessitated the use of a 35-ton (31.7Mt) overhead crane to remove the drums one at a time, working from the top down. This procedure was very slow but necessary for safety reasons, since the contents of many drums were unknown but some drums were identified as containing incompatible chemicals. Adding to the delay in removing drums was the fact that the sites had little room for a staging area where drums could be sampled, overpacked and categorized for removal and disposal. The lack of staging area led to the temporary storage of some drums at the Chem-Clear facility, pending analysis of their contents for precious metals, giving rise to a concern that the response action might be abating a hazard at one location by creating a new hazard elewhere. This concern was alleviated fairly promptly, however, because once initial analytical results indicated no commercially recoverable precious metals, the drum contents were treated and disposed of.

One important issue in this response action concerns the asphalt cap placed over Site 2. This site was cleared and graded in December 1981 in preparation for paving. T & A Excavating, the paving contractor, advised the OSC that the cold weather at that time could cause the asphalt to crack later because it might not set properly. T & A also stated that the 2.5 inch (6.3 cm) asphalt would not support heavy vehicles. T & A advised that the paving be postponed until warmer weather, but the OSC and the Maryland Office of Environmental Programs (OEP) wanted to finish the response action because the delay would impose additional costs and require re-grading the area when paving was to be done. The OSC chose to pave the site in December. According to reports from T & A and the OEP, the asphalt had begun to crack by August 1982 and may require patching by the state. The OSC had to choose between finishing the response action with the risk that the pavement would not set properly, in which case more money would be required from some source, most likely the state, or delaying completion of the project, in which case the total paving cost to the Superfund might be lower but the site would be exposed to the elements in the meantime. Although the OSC's decision may result in additional paving costs to the state, it did have the beneficial effect of capping Site 2 in the short term, even if this may not be entirely effective in the long term.

The role of ground water monitoring in the CMI response action is somewhat unclear. Most of the clean-up work at these two sites was in the nature of an emergency removal action: first, hazardous substances and contaminated soil and debris were removed and disposed of, then monitoring wells were installed. Hence, the results from these wells did not guide the response action that was performed but could indicate the need for future remedial action. It was apparent from the first series of samples that there was ground water contamination at both locations: copper sulfate at Site 2 and gasoline at Site 1. The OSC decided not to perform ground water extraction and treatment because there were not drinking water wells nearby. If this is so, there would be no need for future ground water treatment and, thus, no practical need for continued operation of the wells. However, Maryland state law apparently requires continued monitoring for a period after site closure.

One of the highlights of this response action was the OSC's adroit use of ways to have materials removed from the sites at no charge. Local companies removed salvageable drums and tanks as well as crushed drums and scrap metal in exchange for these materials. Hazardous substances such as solvents, acids and basics were recycled whenever commercially possible. This work was time consuming and would have greatly increased the response costs if EPA had hired contractors to do it.

Another important feature of the CMI response was the close cooperation between EPA, the State of Maryland, the City of Baltimore, and the various contractors. The work was generally well planned and carried out, with agencies and departments contributing much of needed personnel, equipment and services.

Government respresentatives, together with the TAT, developed a good safety protocol and workplan for conducting the site response. These parties also took steps to inform local residents of the situation and developed an evacuation contingency plan. The only notable instances of noncooperation were the Department of Defense, which would not to permit the burning of the zirconium at a defense installation, and state and federal labs in the area, which because of backlogs were simply unable to do the chemical analysis quickly.

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CHEMICAL RECOVERY SYSTEMS, INC.

ROMULUS, MICHIGAN

INTRODUCTION NCP Reference

Chemical Recovery Systems, Inc. (CRSI) has operated a solvent recycling facility on a 15.75 acre (6.38 ha) tract in Romulus, Michigan since 1972. Previous owners of the site, Cam Chemical Company and Product Sol, also used the property for solvent recovery, but their disposal methods resulted in severe contamination of ground water below the property with organic and inorganic chemicals, solvents and heavy metals. This in turn contaminated an adjoining drainage ditch that leads to the Ecourse River.

Background

The Cam Chemical Company purchased this site from the Sinclair Oil Company in 1960 and used it to recover waste solvents for resale as lacquer thinners, resins, driers and paint additives. "Still bottoms" from the recovery process were stored in 55-gallon drums onsite. After about 45,000 drums had accumulated, the company excavated 4 unlined trenches to store still bottoms; these overflowed in the later 1960's to form one large pond. Cam Chemical purchased an incinerator to dispose of its chemical wastes and thereby expand its recycling capacity, and soon accumulated 60-70 thousand more drums. The incinerator proved inadequate and the company ran into financial difficulty. It sold the property to Product Sol Corporation in early 1971. Product Sol constructed 4 large clay-lined lagoons during the summer of 1971 to store chemical wastes. It sold the property at the end of 1971 to CRSI, the present owner.

Synopsis of Response

Since 1972, CRSI has removed approximately 100,000 drums containing still bottoms from the site and disposed of them. The 4 clay-lined ponds were removed, with three being excavated between May and October 1974 and the fourth in 1980. CRSI installed an underdrain system in 1976 to collect contaminated ground water. Subsequent tests showed that it was ineffective, and in 1980 another one was installed. The Trouton Drain, which adjoins the site and was contaminated, was dredged twice, once in 1977 and again in 1980. In 1980, CRSI installed an asphaltic slurry wall to complement the underdrain system and prevent movement of ground water from the site to Trouton Drain. In early 1983, wastes were removed from the large pond (vinyl pond shown in Figure 1).

SITE DESCRIPTION

The Chemical Recovery Systems, Inc., site is located in Wayne County, Michigan, about 25 miles (40 km) from downtown Detroit (Figure 1A). The surface characteristics and hydrogelogy of this site are discussed separately below.

Surface Characteristics

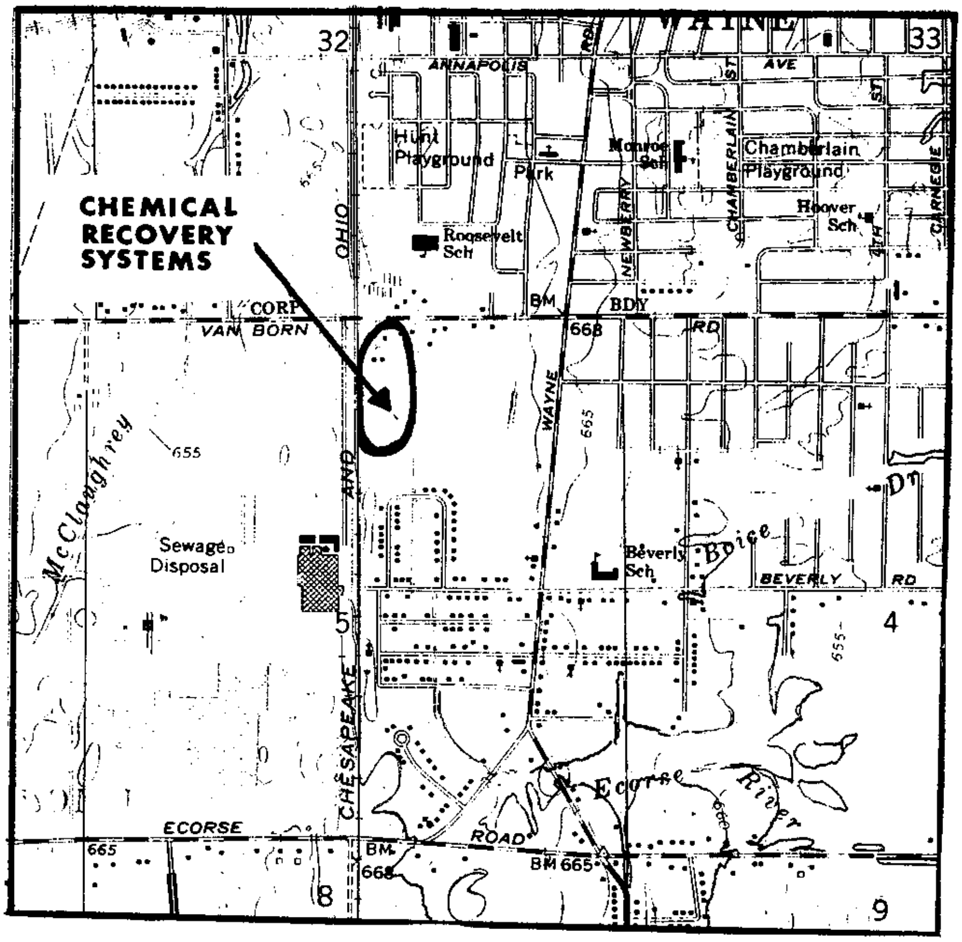
The site is approximately 1,300 feet (396 m) long and 900 feet (274 m) wide enclosing a total of 15.75 acres (6.38 ha) (Figure 1B). The northern boundary of the site parallels Van Born Road and includes its only entrance. The western portion of the site is bounded by a C&O railroad track and the eastern portion by Trouton Drain. Classified by USGS as an intermittent stream, this drain forms part of the headwaters to the Ecourse River--a medium-sized tributary of the Detroit River. Less than 1/4-mile (0.4 km) south of the site is residential community of about 100 single-family homes with Trouton Drain running through the center. The areas in the immediate vicinity of the site along Van Born Road are occupied primarily by small businesses with a few single-family residences, a large industrial plant, and a school.

Vegetation on the site consists of tall weeds, trees, and shrubs along the southern boundary and southwest corner thinning to a few shrubs, grass, and bare ground in the remaining portions of the site. At least 1/3 of the property is devoid of vegetation because of the presence of dirt roads, the parking lot, buildings, drum storage areas, and a large pit of wastes known as the vinyl pond.

Hydrogeology

300.68(e)(2)
(i)(D)
hydrogeological
factors

Topography of the site is very level with less than an 0.5 percent decline in slope from the northwest to the southeast boundaries. Several test borings taken over the past 10 years show an upper layer of topsoil, 8 inches (20 cm) thick, overlying a sand aquifer with thicknesses ranging between 7 and 10 feet (2 to 3 m). Beneath the



1 INCH ≈ 2000 FT

Figure 1A. Chemical Recovery Systems, Inc. Site

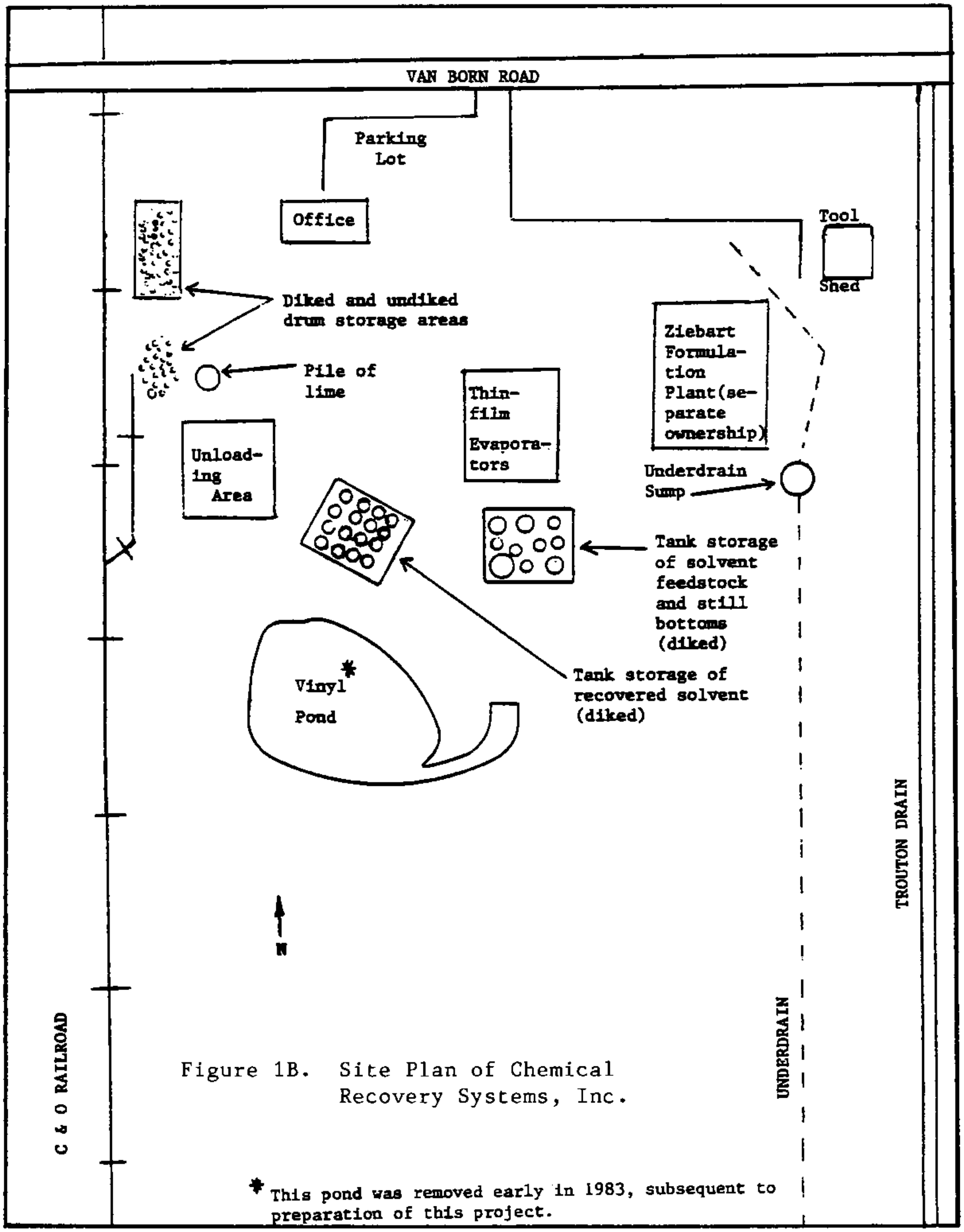


Figure 1B. Site Plan of Chemical Recovery Systems, Inc.

sand is a layer of very stiff clay. The thickness of this clay layer was not determined: however, the existing data show that it extends to at least 10 feet (3 m) in depth beneath the deepest portion of the sand layer. Data was not available on the geology below the clay layer.

The sand layer was determined to have an average hydraulic conductivity of 30 gallons per day per square foot (1,222 $l/day/m^3$) and an average downward gradient of 0.006 running east to southeast. Using these estimates, the average velocity of groundwater moving through the site toward Trouton Drain was calculated at 0.12 feet (3.6 cm) per day.

WASTE DISPOSAL HISTORY

Prior to 1960, the site was owned by the Sinclair Oil Company. It was then purchased by the Cam Chemical Company who used the site to recover waste solvents for resale as lacquer thinners, resins, driers, and paint additives. At first, the still bottoms from this operation were pumped into 55-gallon (208 l) drums and stored on site. A few years later, after about 45,000 drums had accumulated on site, Cam Chemical excavated three unlined trenches, each with a capacity of 450,000 gallons (1.7×10^6 l), and began using them to store still bottoms and other unrecoverable wastes. These trenches overflowed in the late 1960s to form one large pond which is shown in Figure 1 as the vinyl pond. In 1969, Cam Chemical purchased a Franklin incinerator in an attempt to reduce the volume of still bottoms on site and to bring in more business from the surrounding industries. The incinerator proved incapable of burning the still bottoms at a fast enough rate and, as a result, between 60 and 70 thousand more drums of waste were brought on site for which Cam chemical did not have an economical means of disposal. Now in financial difficulty, Cam Chemical sold the site in early 1971 to Product Sol Corporation which provided the capital to construct four lagoons lined with 2 feet (0.6 m) of "blue clay" and ranging in capacity from 500,000 to 2,000,000 gallons ($1,89 \times 10^6$ to 7.57×10^6 l). These lagoons, completed in the summer of 1971, were all constructed along the eastern boundary of the property less than 50 feet (15 m) from Trouton Drain. One of the lagoons was filled with an off-specification grease compound from a local chemical company, two others were filled with still bottoms, and the fourth contained waste oils. At the end of 1971, the site was sold to its present owners, Chemical Recovery Systems, Inc. Since that time, CRSI has removed over 100,000 of the drums left by the previous owners, drained and filled in the four clay-lined lagoons, installed and replaced an underdrainage system, and constructed a slurry wall around the downgradient side of the site. There are currently about 6,000 drums on the site. Wastes were removed from from a large vinyl pond which contained approximately 15,300 cubic yards (11,670 m^3) of hazardous wastes, early in 1983. However, this remedial action was undertaken after the research for this case study was completed and will therefore not be discussed further.

DESCRIPTION OF CONTAMINATION

The earliest documentation of contamination at the CRSI site occurred in August of 1970. The Michigan Department of Natural Resources took numerous ground water and surface water samples around the site in response to odor complaints lodged by nearby residents. The results of the sampling showed high levels of phenol, chlorides, and chloroform in both the ground water and water and sediment samples taken from Trouton Drain. In some areas, levels of chloroform, phenol, and chlorides in the ground water exceeded 200, 18, and 1500 mg/l, respectively.

300.64(a) preliminary assessment

300.68(e)(3)(i) water pollution

By the summer of 1978, a special task force made up of various State officials identified the presence of eight chemical contaminants in Trouton Drain and in an interceptor trench which was installed during the summer of 1976. These chemicals included benzene, toluene, xylene, dichloroethane, dichloromethane, trichloroethane, trichloroethylene, and phenol. The vinyl pond was also sampled and was found to contain dichloromethane, dichloroethane, trichloroethane, toluene, and perchloroethane. Table 1 provides characterizations of the chemicals found in and around the Chemical Recovery Systems, Inc., site.

Additional chemical pollutants were not discovered at the site until a June, 1982, lab report revealed pockets of high PCB concentrations within the vinyl pond. The pond sampling was done by setting up a grid system of 24 sampling points across the pond and taking core samples at from 0 to 4 feet (0 to 1.2 m) and from 4 to 8 feet (1.2 to 2.4 m) at each point. Although most of the 48 samples taken within the pond showed PCB levels below regulated concentrations, 11 of the samples had concentrations of PCB's between 51 and 175 mg/kg.

TABLE 1: CHARACTERIZATIONS OF THE CHEMICALS FOUND IN AND AROUND THE CRSI SITE (from data compiled by the Michigan Office of Toxic Materials Control).

Chemical Name	Solubility in Water (mg/l @ 20°C)	Relative Acute Oral Toxicity to Mammals
1,2 Dichloroethane	8,700	moderate
1,1 Dichloroethane	5,000	slight
Dichloromethane	20,000	slight
Vinyl Chloride*	1.1 (25°C)	slight to moderate
Trichloroethylene**	1,070	slight
Perchloroethylene**	150 (25°C)	slight
1,1,1 Trichloroethane	4,400	slight
Benzene***	800	slight
Toluene	515	slight
Xylene	175	slight
Phenol	82,000 (15°C)	moderate

* Proven human carcinogen

** Proven carcinogen to laboratory mice

*** Suspected human carcinogen

PLANNING THE SITE RESPONSE

Initiation of Response

Early response efforts by CRSI were prompted by complaints from nearby residents. As early as 1970, the Michigan Department of Natural Resources (DNR) responded to resident's complaints about odors from Trouton Drain by taking samples of ground water and surface water around the site. Ground water samples from below the site and sediment samples from Trouton Drain showed high levels of phenol, chlorides and chloroform. The rupture of 2 waste-filled lagoons in the winter of 1972 further contaminated Trouton Drain, triggering more complaints by residents and more sampling by the state. Pursuant to an agreement between the state and CRSI in 1973, the company began removing the 4 clay-lined lagoons. The parties also agreed that CRSI would begin removing drums. To control seepage of contaminated ground water into Trouton Drain, CRSI hired Keck Consultants to design an underdrainage system. This was installed in 1976. In 1977, the state dredged part of Trouton Drain to remove contaminated and odorous sediments.

300.63(a)(4) observation by public

300.64(a) preliminary assessment

300.68(e)(1)(iv) hazardous substances above surface and in drums

300.68(e)(2)(i)(D) hydrogeological factors

Public pressure to clean up the site increased during 1977-1979, leading to a public meeting between local residents, CRSI personnel and DNR officials and the appointment of a special task force of state officials to investigate the site and make recommendations. During 1978 and 1979, the state continued to install ground water monitoring wells and take soil samples from the site, adjacent property, and Trouton Drain. CRSI continued to remove drums.

In August 1979, the state filed a civil action against CRSI, alleging violation of the state Water Resources Commission Act. CRSI filed a countersuit alleging that it had already taken extensive and responsible clean-up efforts on property that was contaminated when purchased. While these suits were pending, CRSI and the state studied alternative remedial actions and continued their sampling to determine the nature and extent of contamination. In February 1980, the state and CRSI settled their lawsuits by a Consent Agreement that stated the specific remedial actions that CRSI would undertake, at its own cost.

300.68(c) judicial process

300.68(g) development of alternatives

300.68(c) private funding

Primary remedial technology specified in the agreement included construction of a slurry wall to contain all wastes migrating off the site and installation of a second underdrain system to collect contaminated ground water on-site. Secondary or complementary remedial actions

300.68(e)(2) source control

required under the Consent Agreement included removal of 6,000 remaining drums of on-site waste; removal and proper disposal of approximately 33,000 cubic yards (25,230 m^3) of contaminated soils and sludges from the remaining two waste ponds; removal of hot spots of top soil located on the property; backfilling of excavated areas with clean fill; and restoration of the proper grade and reseeding of the surface to control run-off. When CRSI completed construction of the slurry wall and underdrain, the state agreed to dredge Trouton Drain again and CRSI would reimburse $10,000 of the state's costs.

300.68(e)(1)(iv) hazardous substances in drums
300.68(e)(1)(v) highly contaminated soils at or near surface

Selection of Response Technologies

Numerous remedial actions have been selected and used to control pollution at the Chemical Recovery Systems, Inc. site. These actions have included:

- Removal of four clay-lined lagoons in 1974 and
- Dredging of Trouton Drain in 1977 and again in 1980
- Installation of two underdrains to interrupt contaminated ground water--one in 1976 and the other in 1980 after the first one failed
- Removal of over 100,000 drums since 1972 hazardous
- Installation of a vibrating beam type slurry wall in 1980.

The selections of these methods have occurred without the benefit of any thorough feasibility analyses and have been initiated by both the State and CRSI. The removal of the four lagoons was the result of an agreement in May of 1973 between CRSI and the State. This decision was made because the ponds had previously ruptured and continued to pose a threat to Trouton drain. The exact manner in which they were removed was negotiated between CRSI and the state.

The dredging of Trouton Drain in 1977 and in 1980 was recommended by State Officials. These recommendations were made in response to accumulations of odoriferous materials in the slow-moving drain.

The first underdrain was installed under a recommendation by an engineering consulting firm. This underdrain system was removed and replaced after a series of tests showed that it had failed and was no longer intercepting the contaminated ground water from the site.

The decision to remove drums from the site was reached mutually by the State and CRSI. The deteriorated condition of the drums and the resulting leakage and fumes were undesirable to both parties.

The slurry wall resulted from independent efforts by CRSI to find the most effective method of preventing contaminated ground water from entering Trouton Drain. CRSI management had already made some of the initial contacts with the contractors that installed the slurry wall prior to suggesting this method to the State. After reviewing the specifications for the slurry wall, the State incorporated them into the Consent Agreement which was signed between the two parties in May of 1980.

Extent of Response

Since the Consent Agreement between CRSI and the state established specific remedial actions for CRSI to perform, some of the company's response efforts have ceased with the completion of the required actions, e.g., construction of the slurry wall and new underdrain system. Not all of the required actions had been completed by the time research for this case study was concluded; for example, the vinyl pond has not been removed as of October 1982, and about 6,000 drums remain on-site. However, it can be expected that response actions at this site, with the exception of ongoing monitoring and maintenance of the underdrain system, will cease when the actions specified in the Consent Agreement are completed.

300.68(j) extent of remedy

DESIGN AND EXECUTION OF SITE RESPONSE

Each of the actions performed at the CRSI site required different equipment and techniques. Therefore, each different type of action is discussed under a separate subheading below.

Removal of Four Clay-Lined Lagoons

This action was begun in May of 1974 and all but one lagoon were removed within 5 months. The remaining lagoon was not removed until 1980. The reason for the long time period needed to complete this action was mainly related to CRSI's inability to pay the associated disposal costs.

300.68(e)(1)(v) highly contaminated soils at or near the surface

In carrying out this action, all liquids were pumped out of the ponds into tank trucks and sent off-site for incineration. The solids in the bottoms of the ponds were

300.70(c)(2)(1) excavation

excavated and mixed on the ground with lime using a backhoe; then transported in dump trucks for disposal at a nearby landfill. The purpose of the lime mixture was to solidify the semi-solid portions of the dredged materials and to create heat for volatilizing some of the organics in the wastes. Although the pond dredgings were slightly acidic, they were not considered to be a RCRA corrosive waste, thus neutralization was not a primary objective of the lime additions. The lime mixing process was continued until the pond dredgings were of adequate consistency to be loaded into a dump truck.

300.70(c)(1) off-site transport for destruction

Trouton Drain Dredging

Trouton Drain was dredged first in 1977 and again in the fall of 1980. The first dredging was done by a private contractor under contract with the Wayne County Department of Public Works. Records were not available from either party on the equipment and methods used to accomplish this first dredging.

300.70(c)(2) removal of contaminated soils and sediments

The second dredging was done by Inland Waters Pollution Control, Inc. under contract to the Michigan Department of Natural Resources. Using a "Gradall-600" and a dump truck, 1 foot (0.3 m) of sediment was scraped from the bottom and from the sides of the drain along a 1700-foot (518 m), continuous segment between Van Born Road and Joan Street. The drain sediments that were removed were replaced with a mixture of fresh sand and gravel. A total of 400 cubic yards (306 m^3) of drain sediments were replaced and the dredgings were piled along the drain to decant the excess moisture. They were then loaded on the dump truck and landfilled. The entire operation took about one month to complete.

Underdrain Installation

The first underdrain system consisted of a 4-inch (10 cm) diameter, corrugated plastic tube running approximately 1,000 feet (305 m) in a north/south direction. The trench for this drain was excavated with a backhoe approximately 60 feet (18 m) away from the Trouton Drain, and was backfilled--first with 6 inches (15 cm) of pea gravel surrounding the drain pipe and then with native materials. The underdrain was placed just above the clay layer, however, it did not penetrate the underlying clay over its entire length. Thus, a portion of the ground water continued to flow in the sand layer beneath the underdrain and into Trouton Drain. Another problem with the first underdrain was the specified minimum thickness of 6 inches (15 cm) for the pea gravel. This thickness was not

300.70(b)(1)(iii)(D)(1) subsurface drains sufficient in preventing siltation and rapid blockage of the drain slots in the pipe.

The installation of the new underdrain system took approximately two months to complete (February to March of 1981). Although it has almost identical specifications to the first underdrain (Figure 2), a 6-inch (15 cm) diameter pipe was used instead of the previous 4-inch (10 cm) pipe and more care was used in the placement of the new drain such that it would be set into the clay layer at 0.5 to 0.3 percent downward slope toward the new 96-inch (244 cm) diameter concrete sump. The thickness of pea gravel around the drain pipe was increased to a minimum of 3 feet (0.9 cm) to prevent the clogging problems experienced with the earlier drain. The new sump was constructed of steel reinforced concrete with a 6 foot (1.8 m) drop from the invert drains to the sump floor. The contaminated ground water entering this sump is pumped with a portable submersible pump to the Detroit sewer system at a rate of between 700 and 4,000 gallons (2,650 to 15,142 l) per day depending on the amount of rainfall. The city takes monthly grab and composite samples of these discharges and analyzes them for phenolics and for several standard wastewater parameters including pH, BOD, COD, metals, oil and grease, and suspended solids. The results of these analyses are similar to the results of previous ground-water samples taken at the site.

Drum Removal

300.68(e)(1)(iv) hazardous substances in soil

The types of wastes contained in the drums are still bottoms from past solvent recovery operations. These still bottoms are composed of particulate matter and mixed with varying proportions of halogenated and non-halogenated solvents. Because these wastes are generally consistent between different drums only occasional analyses are performed on them and significant deviations have not been observed.

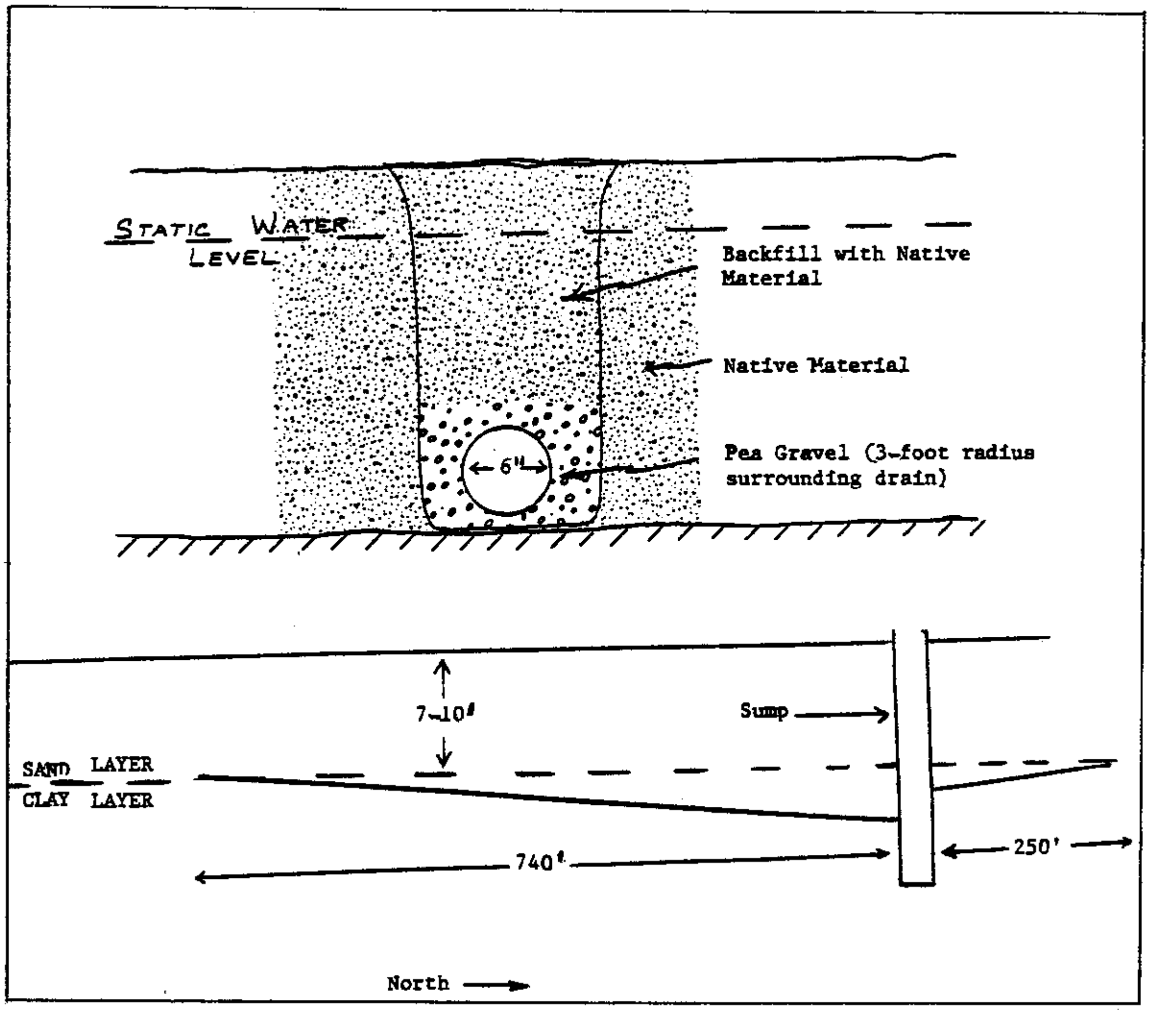
300.70(c) off-site transport for disposition

Prior to 1978 drum disposal was accomplished by loading the drums on a trailer and hauling them to the nearest acceptable landfill. By 1978 this method became prohibitively expensive and was replaced by the following procedures:

- Remove the head of the drum

- Pump any liquids from drums into tankers for transport to nearby cement kilns and steel mills for use as secondary fuels

Figure 2. Cross-Section and Site-view of the New Underdrain System at Chemical Recovery Systems, Inc.



- Punch four equally spaced holes down the side of the drum to allow any free liquids to drain out

- Remove solids for treatment with lime and landfilling at Belleville

- Crush the empty drum and treat with lime prior to landfilling at Belleville.

The free liquids draining from the holes punched in the drums are mixed with lime in a 8 by 50 by 3 foot (2.4 by 15 by 0.9 m) ramped concrete pit using a bulldozer. The mixed wastes are disposed at the Belleville landfill. The reasons for lime treating the contaminated liquids and solids are to solidify the wastes and to volatilize the organics with the heat generated from the reaction between the slightly acidic wastes and the lime. Lime addition and mixing are terminated when a dirt-like consistency is attained.

Slurry Wall

300.70(b)(1)(iii)(A) impermeable barrier

The initial contact with the Slurry Systems Division of Thatcher Engineering Corporation, was made by the CRSI officials. Slurry Systems then requested CRSI to send them samples from the two remaining on-site ponds. Slurry Systems tested the samples against different slurry mixtures including bentonite-cement, bentonite-flyash, and kaolin in various proportions. The tests consisted of falling head permeabilities using a 12 by 16-inch (30.5 by 40.6 cm) lucite cylinder in which 1.5 inches (3.8 cm) of slurry mixture were placed beneath 1 foot (0.3 m) of the polluted pond liquor. None of the slurry mixtures maintained structural integrity for more than a few days of exposure to the CRSI sample. Finally, a relatively new, asphaltic slurry called "ASPEMIX" was tested. This formulation consists of an asphalt emulation, fine sand, cement, and water. After seven days of testing, the average permeability of the slurry was 3.22×10^{-8} cm/sec. This average permeability was determined in accordance with U.S. Corps of Engineers engineering manual 1110-2-1906; page VII-3. The results of this testing prompted Slurry Systems to recommend "ASPEMIX" for use in the construction of the slurry wall at CRSI.

The State DNR accepted the proposal for an "ASPEMIX" slurry wall to be used in conjunction with the underdrain system to contain ground water seepage into the Trouton Drain. The bottom of the wall was keyed into the clay layer underlying the sand at an average depth of 10 feet (3 m). The top of the wall, which can be seen at the ground surface, extends 65 feet (20 m) from east to west at the northern end of the property, then turns south for approximately 1,000 feet (305 m) before turning west for 400 feet (122 m) (Figure 3). The installation was done by the vibrating beam method in which a large I-beam is literally vibrated with sufficient intensity that it works its way into the soil. After the required depth is reached, the beam is withdrawn at a rate of about 3 meters per minute as slurry is pumped at 75 to 125 psi into the hole through nozzles at the base of the beam (Figure 4). At the Romulus site, a 40-ton (36 MT) crane was used to suspend a 7 ton (6.3 MT) beam and vibrator unit over the work area. The vibrator was a single, 275 horsepower motor of French design. Each injection is overlapped with the previous one by a margin equal to 10 percent of the total beam depth. The length of each injection is a total of 47 inches (119 cm) including the 14-inch (36 cm) beam fin (Figure 5). The vertical straightness of each beam injection is controlled by guide leads which maintain a vertical plane within a tolerance of 1 percent. The thickness of the wall varies between 4 and 6 inches (10 to 15 cm) depending on the size of the interstices between the soil surrounding the hole.

The total time needed to construct the wall at CRSI was about 1 month and the construction was complete in June of 1980. The wall would have been completed earlier but a pump used to blend the asphalt slurry broke, taking two weeks for replacement.

COST AND FUNDING

Source of Funding

Most of the remedial work was funded by CRSI pursuant to an agreement negotiated between the company and the state in 1973, as well as a Consent Agreement signed by the parties in 1980 that settled their lawsuits over the clean-up. In addition, the City of Romulus paid for the first dredging of Trouton Drain in 1977. The second dredging was paid for solely by the Michigan DNR.

300.68(c)
private funding

Selection of Contractors

Keck Consultants

Keck Consultants, of Lansing, Michigan, was originally hired by CRSI to design the first underdrain system. This firm was hired based on reputation and a lump sum contract was used. CRSI did the construction work. When the system failed, CRSI hired Keck again to design a more extensive system because that firm was

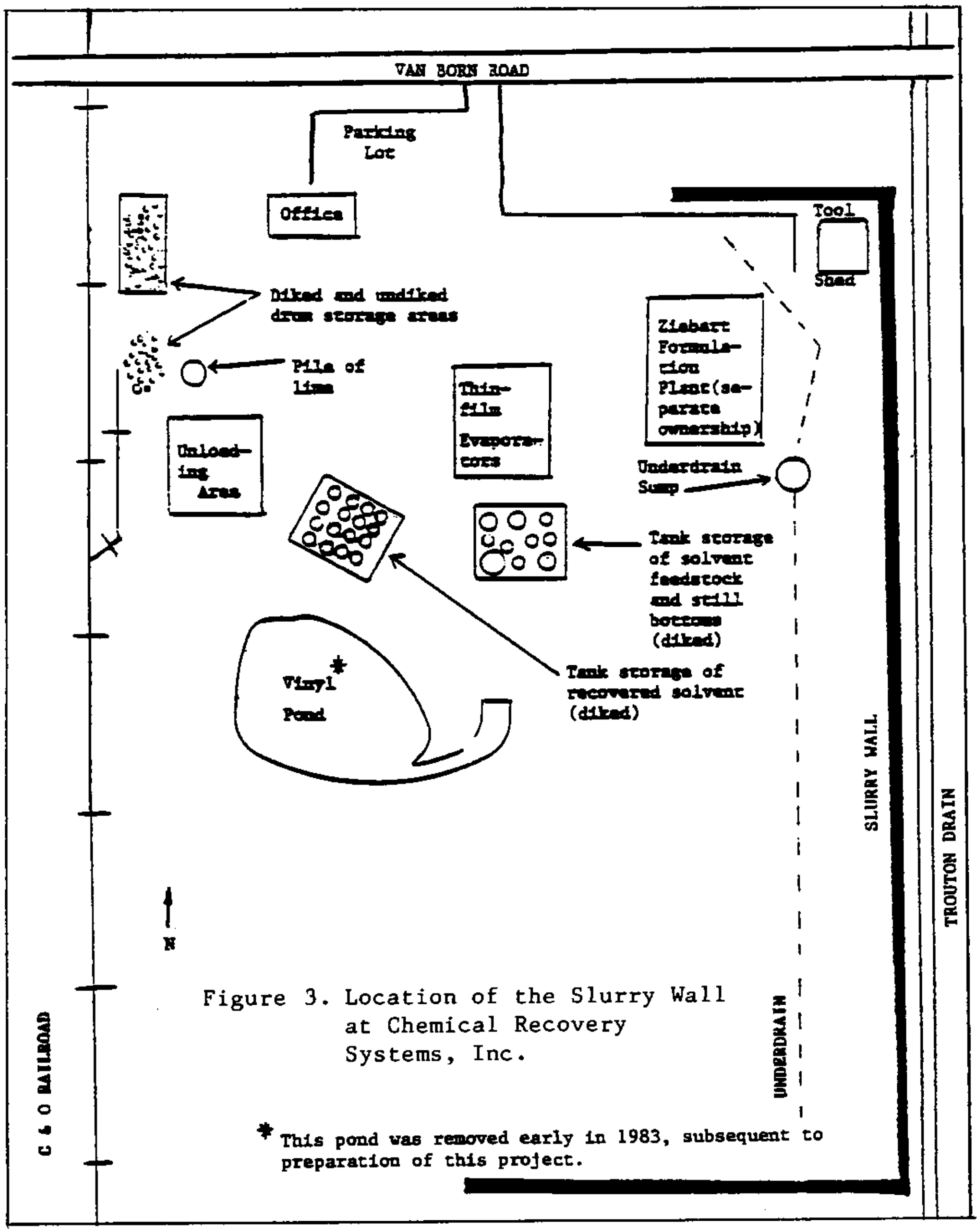


Figure 3. Location of the Slurry Wall at Chemical Recovery Systems, Inc.

* This pond was removed early in 1983, subsequent to preparation of this project.

Figure 4. Placement of a Slurry Wall Using the Vibrating Beam Method.

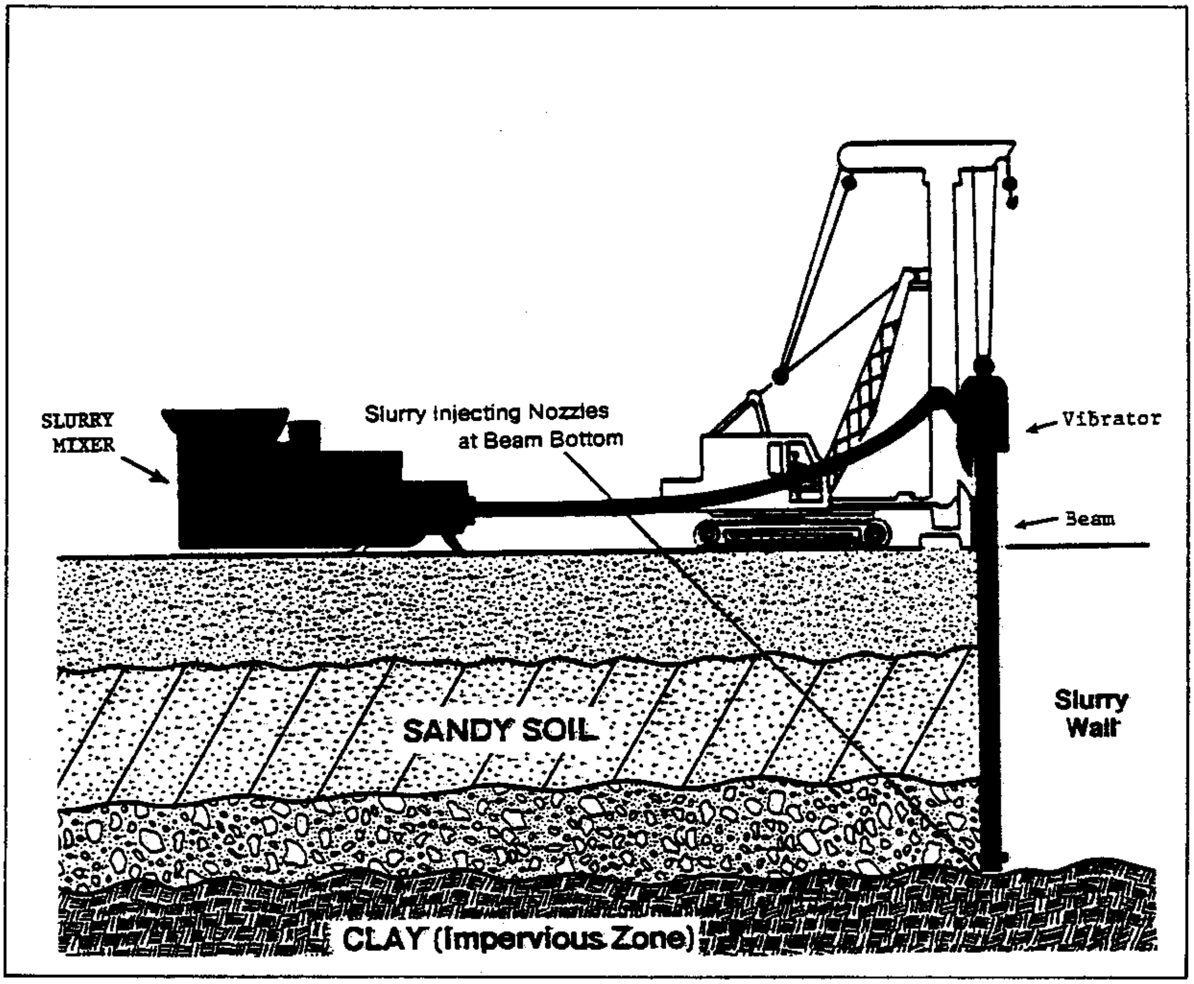
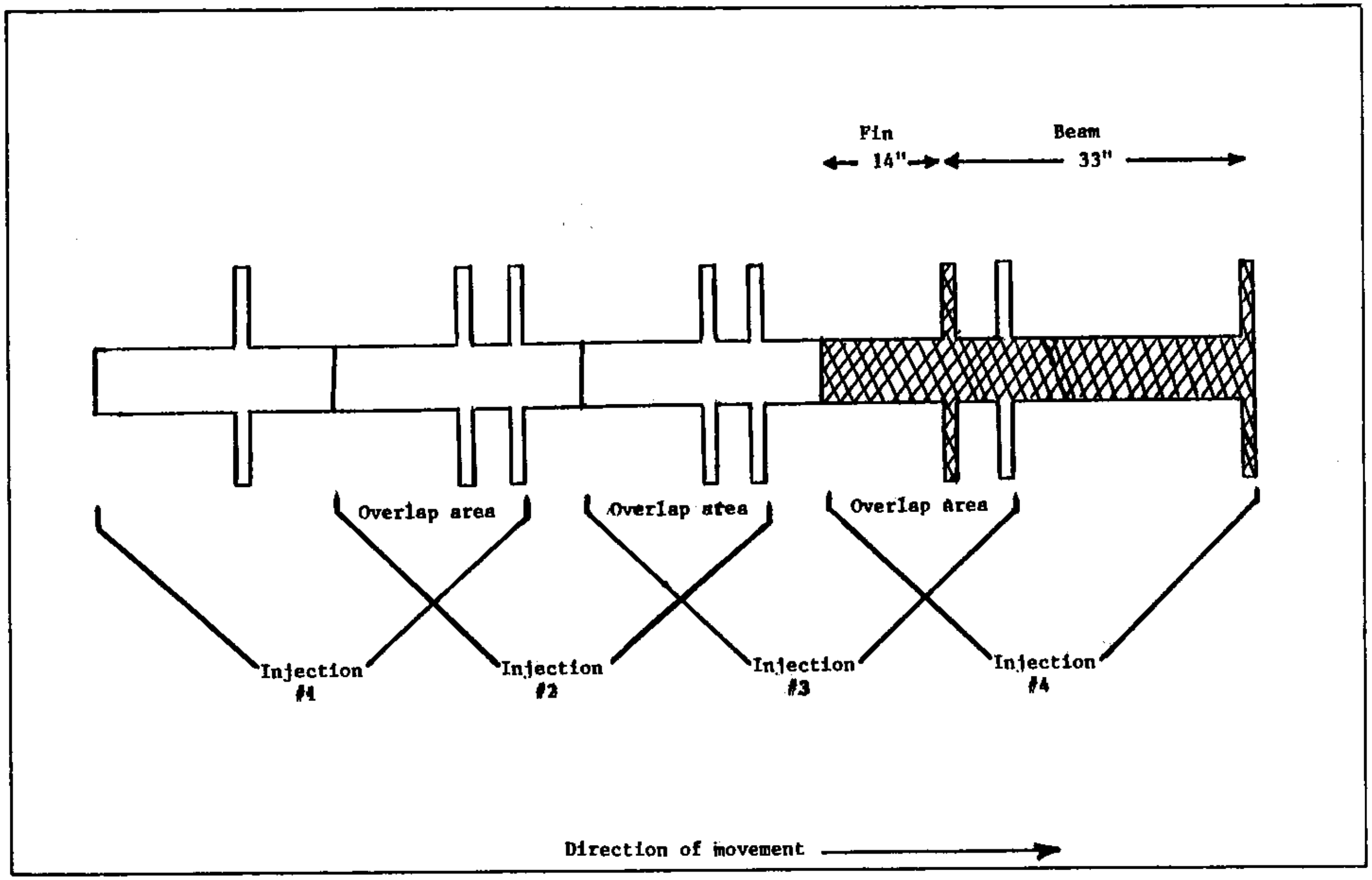


Figure 5. Schematic Diagram of the Ground Surface After Four Overlapping Injections Using the Vibrating Beam (Cross-Hatched Area Denotes Outline Made by Injection #4)



familiar with the site. CRSI did the construction work on this systems also.

Slurry Systems

Slurry Systems, of Gary, Indiana, was hired on a lump sum contract to design and install the slurry wall. Slurry Systems was hired primarily because of its asphaltic slurry. In addition, this company offered a two-year guarantee on the wall.

Project Costs

The total cost of remedial action related to the Chemical Recovery site has been approximately $1.4 million, funded by state, municipal and private sources. Of this amount Chemical Recovery has incurred most of the cost. The Michigan DNR has spent approximately $14,000 plus an unaccounted for dollar amount of man hours. The City of Romulus has spent approximately $50,000. The cost data are summarized in Table 2. The costs of particular remedial actions are discussed below.

Removal of Four Clay-Lined Lagoons

The cost of removing four of the five waste ponds located on the site was approximately $450,000. Chemical Recovery financed the entire amount, including disposing of over 100,000 gallons (378,500 l) of liquid waste. Disposal costs ranged from 3 to 4 times the costs of labor and equipment.

Trouton Drain Dredging

The Michigan DNR dredged the Trouton Drain in 1980 at a total cost of $23,870. The originally estimated cost of dredging the drain was $10,000; however, this figure was based on what proved to be an underestimated amount of contaminated sediment. DNR assumed the cost of the $13,870 overrun and Chemical Recovery funded the remaining $10,000. The City of Romulus had previously dredged the drain in 1977 along and south of the site at a cost of approximately $50,000. CRSI paid for approximately $6,000 of the first dredging but refused further payment because they felt that the job was not being performed properly. The total cost of dredging the Trouton Drain, then, was $73,870.

300.62(a) state role

Underdrain Installation

The original underdrainage system has designed and installed in 1976 for a total cost of $6,000. This system failed and, in 1980, a new intercepter drain was installed for a total cost of $65,540. The Consent Agreement

TABLE 2. SUMMARY OF COST INFORMATION CHEMICAL RECOVERY SYSTEMS, INC.

Task	Quantity	Estimated Expenditure	Actual Expenditure	Variance	Unit Cost	Estimated Future Cost	Funding Source	Period of Performance
1. Lagoon removal			$450,000			$1,000,000	CRSI	6 yrs and ongoing
2. Trouton Drain dredging								
a. 1977			$50,000				Romulus	3 mos.
b. 1980		$10,000	$23,870	$13,870			CRSI ($10,000) and DNR ($13,870)	1 mo.
3. Underdrain								
a. 1976		$6,000	$6,000	0			CRSI	6 wks.
b. 1980 desing		$30,000	$30,000	0			CRSI	2 mos.
c. 1980 installation		$35,540	$35,540	0			CRSI	1 mo.
4. Drum removal	10,000 drums		$750,000				CRSI	8 yrs. and ongoing
5. Slurry Wall		$83,000	$83,000				CRSI	2 mos.
TOTAL		$164,540	$1,428,410	$1,263,870		$1,000,000		

required that the drainage system be designed by an engineering firm. The actual construction of the drainage system was undertaken by Chemical Recovery personnel.

Chemical Recovery hired Keck Consultants to design the system through direct procurement on a lump sum contract in 1980. The cost of designing the drainage system was set at $30,000. Keck Consultants completed the design and it was approved by DNR without incurring any cost overruns. The construction of the drainage system was undertaken by Chemical Recovery during July of 1980, immediately subsequent to the construction of the slurry wall. The cost of construction was approximately $35,540, bringing the total cost of the drainage system to $65,540. It is not possible to break down the cost estimates into labor and materials.

Drum Removal

Removal and disposal of approximately 95,000 55-gallon drums of hazardous waste from 1972-1980 has cost approximately $750,000. Chemical Recovery financed all of the drum removal and disposal activities. In 1972, when the company first began to remove the drums, the cost of diposal per drum was approximately $4 at an incinerator in Ohio. By 1978 the cost per drum had increased to approximately $25-30. At that time, Chemical Recovery began to dispose of the drums by collecting the wastes in tanker trucks. The cost for bulk disposal was approximately 30-40 cents per gallon ($0.08 - $0.10/1) or $16 to $22 per drum, at a landfill in Belleville, Michigan. The empty drums were crushed on-site and also disposed of in that landfill.

Slurry Wall

The slurry wall was installed in 1980 for a total cost of $83,000. The cost per square foot was approximately $2.50 ($26.91/m^2). Slurry Systems of Gary, Indiana, a subsidiary firm of Thatcher Industries Inc., signed a lump sum contract with Chemical Recovery in 1980 and finished two weeks after the estimated date of completion. The two week overrun resulted from a failure in the pump used to mix the asphalt slurry mix. There was not cost overrun.

PERFORMANCE EVALUATION

The previous sections of this report have described five types of remedial actions used at the CRSI site. Of these five, the two underdrain systems and the slurry wall are the only remedial actions for which performance evaluation data have been collected. Therefore, evaluations are not provided for the pond removals, drum processing activities, and drain dredgings. It is assumed, however, that these activities were properly performed and the disposal of the wastes from these operations did not seriously contaminate any off-site areas. The evaluations of the two underdrains and the slurry wall are discussed separately below.

Underdrains

The failure of the first underdrain system was documented in a 1980 survey of ground water elevations at the CRSI site. This survey resulted in the construction of the ground water contour map shown in Figure 6. The reasons for failure of the first underdrain have been given as (1) clogging because of an insufficient amount of pea gravel surrounding the drain pipe and (2) bypassing of ground water beneath the drain because of inconsistent contact between the drain pipe and the underlying clay layer.

Figure 7 shows dramatic changes in ground water flow patterns at the site after installation of the new underdrain and the slurry wall. However, the validity of this map may be questioned because two of the ground water levels on which the map is based are assumed, rather than measured, values. Of these two values (i.e., 653.81 at MH and 645.66 at the underdrain sump) the sump elevation is the most questionable. This sump is not perforated and thus would not drain all of the surrounding soil.

Regardless of the potential errors in Figure 7, the new underdrain was designed such that is no longer undercut by the bottom portion of the sand aquifer. Further, five times more pea gravel has been added around the drain pipe to prevent clogging of the drain slots with fine silt. The extra pea gravel has not been entirely sucessful as evidenced by an incident of clogging in the new underdrain. This problem apparently was solved, however, by backwashing the underdrain with the same jetting equipment as is used to clear obstructed sewer lines. Since this incident has occurred, periodic backwashing of the drain has become a routine procedure. Perhaps a more thorough evaluation of alternative drain design (e.g., a geo texile envelop or a different size of gravel) may have prevented the need for periodic backwashing of the present drain.

Slurry Wall

The effectiveness of the slurry wall cannot be assessed accurately due to an insufficient amount of data

Figure 6. Groundwater Flow Patterns at Chemical Recovery Systems, Inc. Before Installation of the Slurry Wall and the Second Underdrain. (Elevation data and diagram were provided by Keck Consulting Services, Inc.)

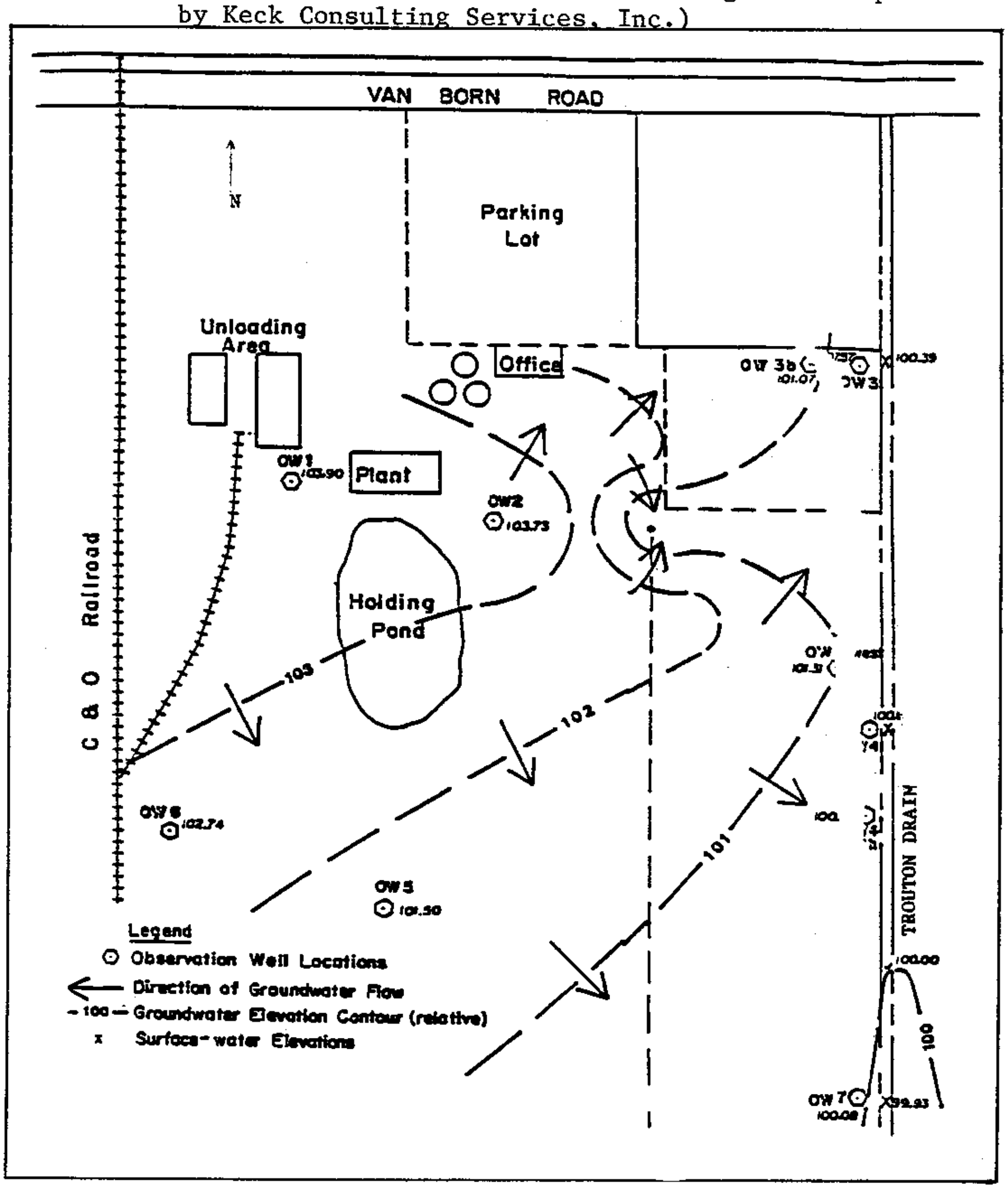
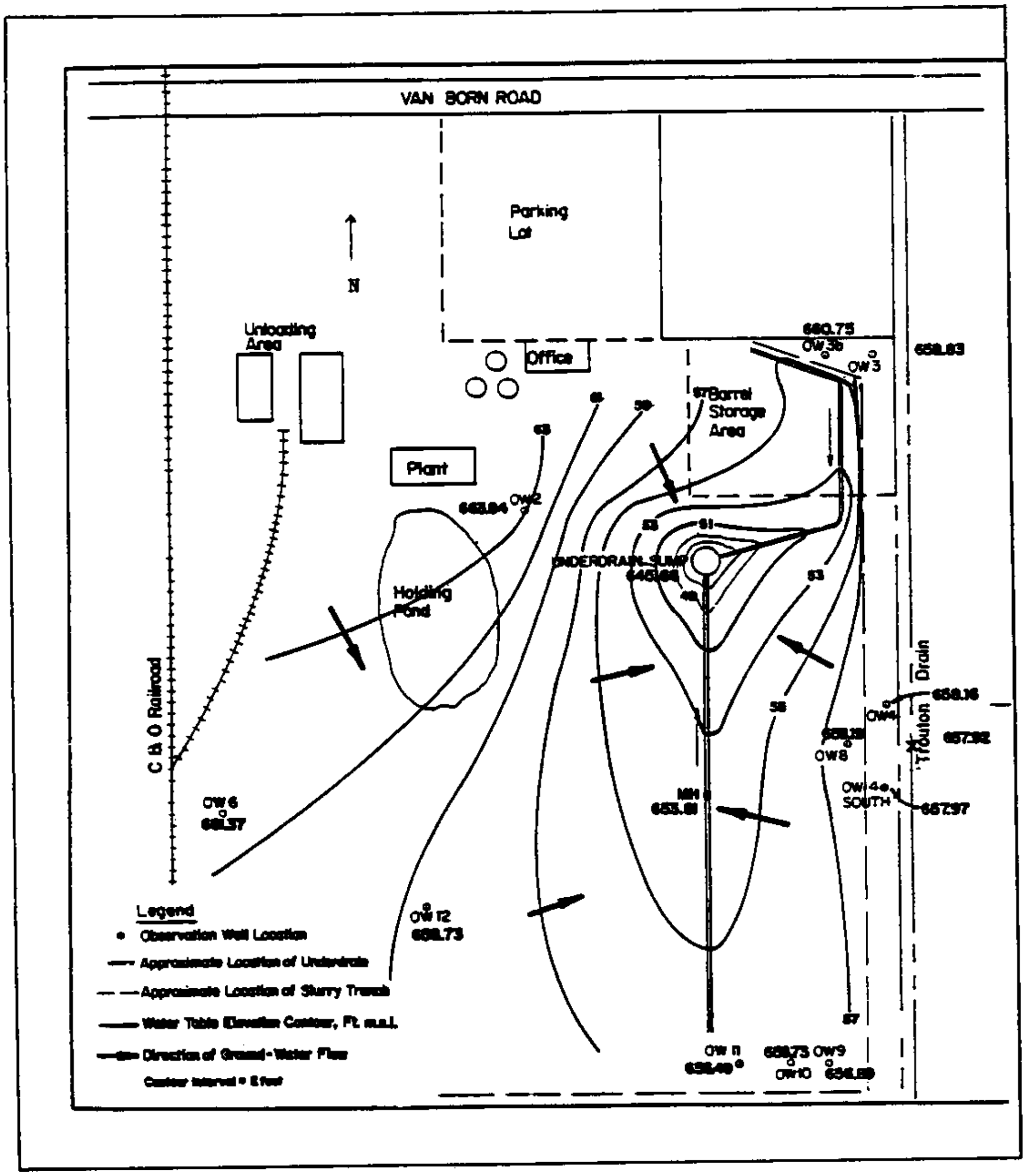


Figure 7: Groundwater Flow Patterns at Chemical Recovery Systems, Inc. After Installation of the Slurry Wall and the Second Underdrain. (Elevation Data and Diagram were Provided by Keck Consulting Services, Inc.)



(since the wall and underdrain were implaced, only four ground water elevation surveys have been conducted at the site, one of which was used to draw the contour map in Figure 7). However, in looking at the ground water elevations shown in Figure 7, there seems to be an unexpectedly high water level at well number OW-8; i.e., the ground water levels east of the underdrain would be expected to be somewhat lower than those at a comparable distance west of the drain. Because there are not enough readings on the present well and because there are not enough wells to draw a reliable ground water contour map, an explanation cannot be given for the high reading in well number OW-8.

Although it is not possible to accurately test the effectiveness of the slurry wall, it is likely that the wall is an effective barrier to contaminated ground water at the CRSI site. This assessment is made after considering the permeability tests performed on the slurry mixture (using the actual ground water from the CRSI site) and the carefully controlled methods of installing the slurry wall.

Conclusions

The preceding case history illustrates the same lack of organized planning that has been noted in other remedial actions across the country. Without a thorough feasibility analysis, it is impossible to determine whether the most efficient and cost-effective methods were used to control contamination at the CRSI site. Further, without a carefully planned testing method, it is impossible to determine the effectiveness of the chosen remedial action alternative after it was installed. It should be noted that the need for such planning is even more critical when a new technology or a new application of an old technology is being considered. For example, in the foregoing case study, a relatively new method, the vibrating beam, was used to install an asphaltic slurry wall. The beam method has been used in the United States for only 8 years and, at only a handful of remedial action sites. The asphaltic slurry used at CRSI has had an even shorter history of application at remedial action sites. For these reasons, more water-level wells should be installed and monitored to determine the effectiveness of these new technologies. Further, the time periods for falling-head permeability tests, which were used to select the asphalt slurry, should be lengthened to determine whether the slurry would continue to work after years of contract with contaminated ground water from the CRSI site. In any event, the Michigan DNR should be contacted by US EPA to obtain periodic updates on any testing to determine the effectiveness of the slurry wall at the site.

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COLLEGE POINT SITE

QUEENS, NEW YORK

NCP References

INTRODUCTION

The College Point Site was a lagoon contaminated with polychlorinated biphenyl (PCB) located on a 1/2 acre (0.2 ha) of land owned by the City of New York. As shown in Figures 1 and 2, the site lies in an industrial environment adjacent to Flushing Bay within a vacant city-owned lot near 31st Avenue and 123rd Street in College Point, Queens. At the time of the response action in 1980, the lagoon contained a 4 inch (10 cm) layer of PCB contaminated oil overlying approximately 318,000 gallons (1.2×10^6 l) of waste water. Prior to removal in 1980, the level of PCB contamination in the oil layer was measured at 240 milligrams per liter (mg/l).

Background

The history of the site was not a subject of investigation by those involved in the 1980 clean-up, and therefore little is known about when, how, and by whom the PCB contaminated oil was dumped into the lagoon. Official discovery of the PCB contaminated oil at the site occurred in May of 1978 when a United States Coast Guard helicopter pilot flying over the area noticed a discoloration on the water surface of Flushing Bay. A Coast Guard investigation followed to determine the source of the contamination and traced the spillage to oil in the lagoon. In order to prevent further discharge into Flushing Bay, the U.S Coast Guard had the City of New York flush out the storm drain through which the lagoon oil had travelled to the bay. The drain was then plugged to prevent future run-off, and the Coast Guard terminated its involvement based on its determination that the lagoon posed no further imminent or substantial threat to navigable waters.

300.63(a)(4) observation by government agency

300.65(b)(4) defensive action; source control

300.65(a)(3) threat of fire

Figure 1. Site Locator Map- College Point, Queens, New York

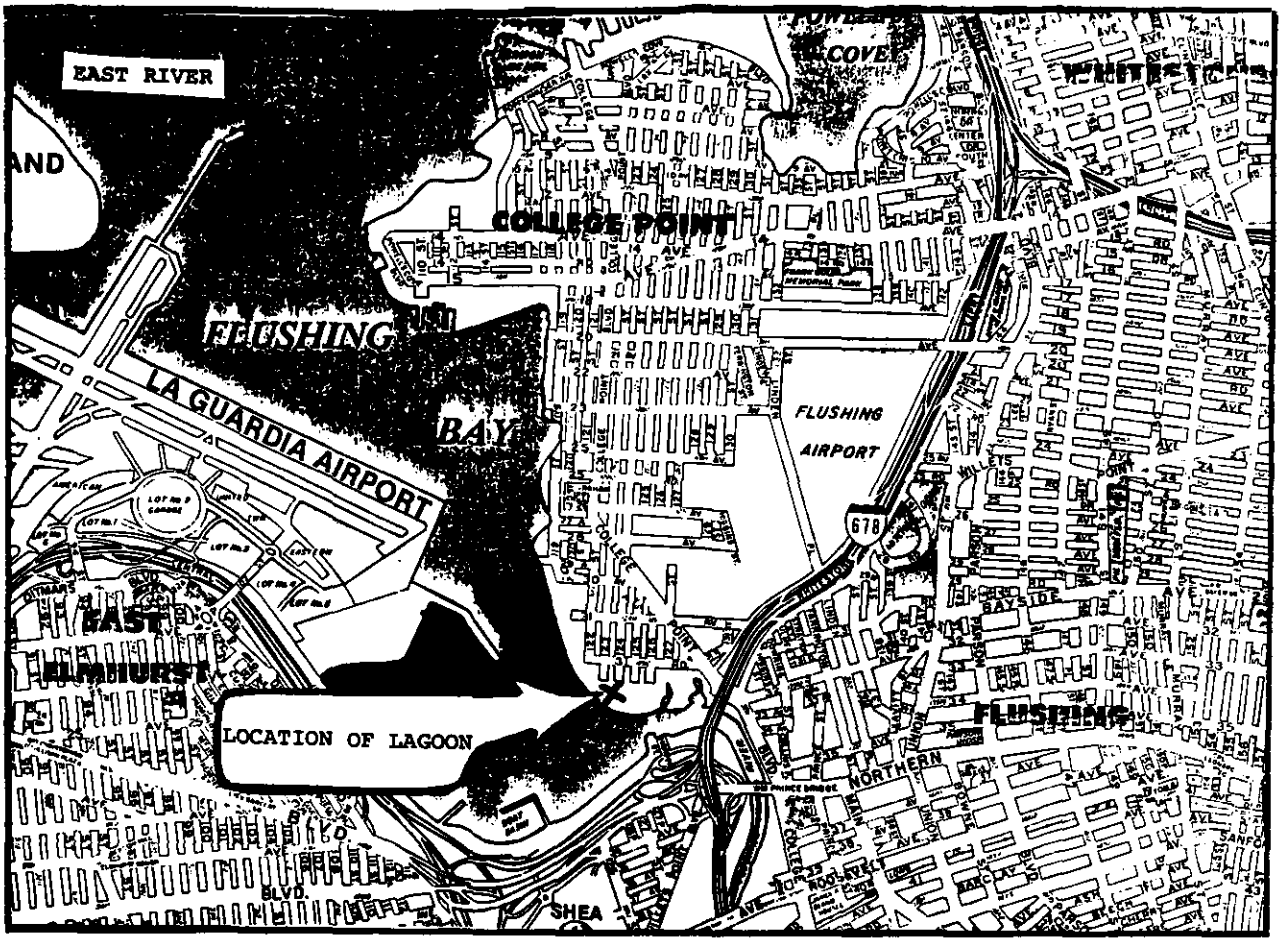
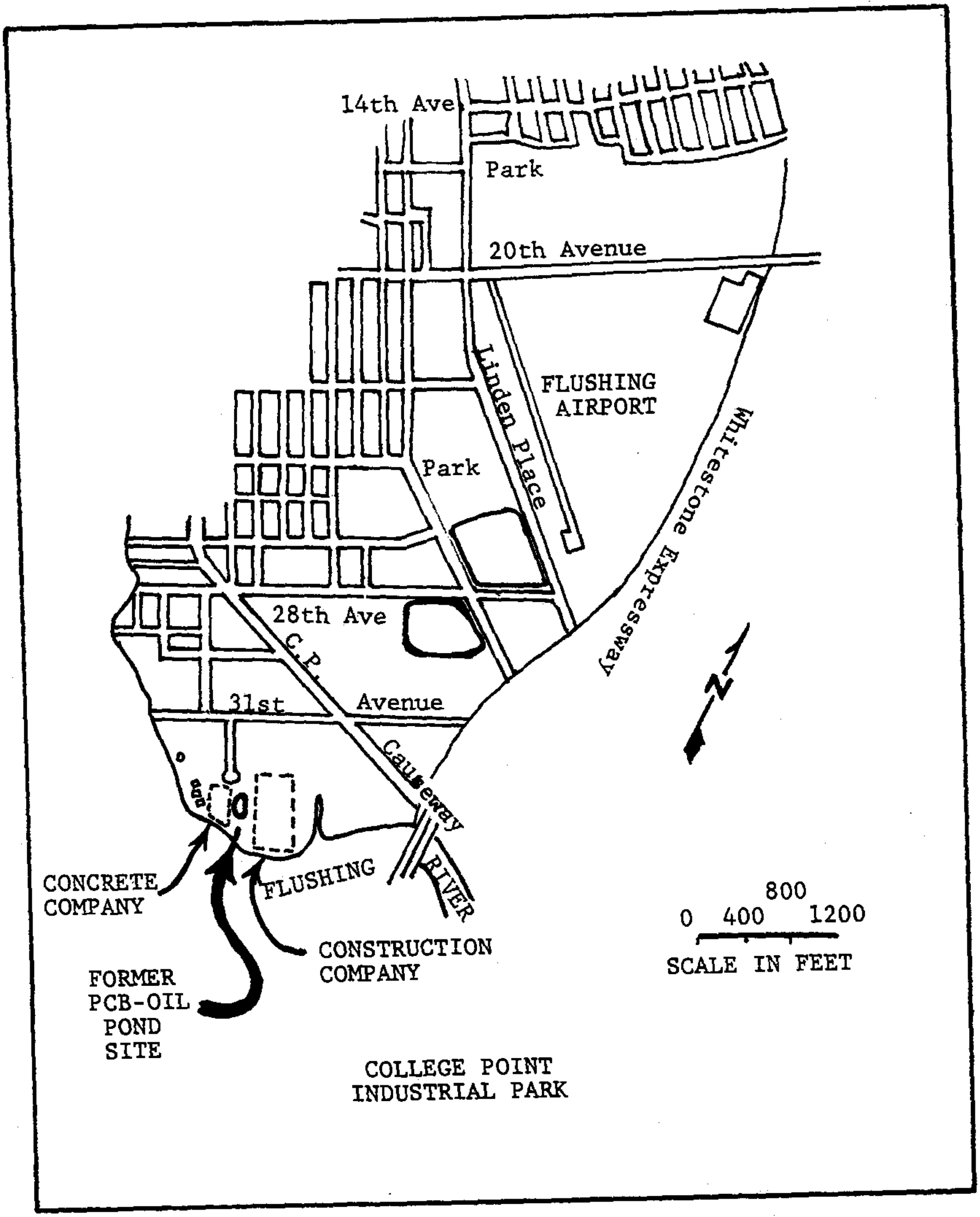


Figure 2. Location Map of College Point Site, Queens, New York



Further response action at the site was prompted by an April 1980 fire which drew the attention of local residents and politicians. The City of New York and the U.S. EPA investigated the site further and determined that the level of PCB contamination (240 mg/l) in the oil layer warranted a complete clean-up. Since the land was owned by the City of New York, responsibility for the clean-up fell within the purview of the city's Department of Environmental Protection (NYC DEP), which initiated response action in April 1980.

300.64(a) preliminary assessment

300.65(a) risk to human health or the environment

Synopsis of Site Response

On June 5, 1980 the NYC DEP contracted with Chemical and Environmental Conservation Systems International, Inc. (CECOS) of Niagara Falls, NY to remove and dispose of the PCB contaminated oil, waste water, and PCB contaminated soil and sludge at the College Point site. Between June 23 and November 7, 1980, CECOS solidified and disposed of the PCB oil and treated the water. The oil was skimmed and pumped from the surface and solidified with fly ash on-site before disposal at CECOS' landfill. A total of 231 truckloads (2,772 tons, 2514 Mt) of solid waste left the site from July 8, 1980 to November 3, 1980. The fly ash/PCB oil mixture comprised 2,124 tons (1,926 Mt) or 77% of the total solid waste taken from the site. The remaining portion of solid waste was composed of soil, sludge, rock, and debris.

A total of 318,000 gallons (1.2×10^6 l) was pumped and treated by filtration and settling on-site to lower its oil/grease concentration before disposal at a nearby New York City sewage treatment plant. The lagoon, when emptied, required approximately 1 foot (30.5 cm) of scraping to reveal clean soil beneath. It was then backfilled and graded.

SITE DESCRIPTION

Surface Characteristics

The College Point dump site is located in the Queens borough of New York City near 31st Avenue and 123rd Street adjacent to the Flushing Bay. The oil lagoon is situated within a vacant, 1/2 acre (0.2 ha) lot and is bordered by a concrete recycling company on the west side and Queens Structures, a construction company, on the east side. Just north of the lagoon is a dead end street that is used as a parking lot. Flushing Bay and the East River are both classified as "SD" in the New York State usage designation. Class SD waters are defined as; "All waters not primarily for recreational purposes, shellfish culture or the development of fish life and because of natural or man-made conditions cannot meet the requirements of these uses."

The average annual temperature is 54.3°F (12.4°C), and the average daily minimum and maximum temperatures are 47.4°F (8.5°C) and 61.1°F (16.2°C) respectively. Average January and July temperatures, which are the extremes of the monthly averages, are 32.1°F (0.05°C) and 76.7°F (24.8°C), respectively. The average annual precipitation is 41.61 inches (105.7 cm). Winds are usually out of the west northwest, at an average speed of 12.2 miles (19.6 km) per hour.

300.68(e)(2)
(i)(E)
climate

Hydrogeology

No extensive hydrogeological investigation has been performed a the College Point dump site. The information in this section was drawn from a general 1968 U.S. Geological Survey paper and maps for Queens County, from which a section is shown in Figures 3 and 4.

The site is located on recent artificial fill (AF) probably deposited from Flushing Bay in the early 1900's. It is underlain directly by primarily undifferentiated Pleistocene ground moraine (Qu) to a depth of about 50 feet (13 m), which holds a fluctuating Upper Glacial Aquifer with a salinity of over 40 mg/l. The fresh ground water underlying the site is separated from this Upper Glacial Aquifer by a 150 foot (40 m) thick clay member of the Raritan formation (Krc). This aquiclude from the Upper Cretaceous extends from 50 - 200 feet (13 - 53 m) deep and slopes eastward toward the Atlantic Ocean as a result of Pleistocene glacial erosion. Underlying this member at the site is the Lloyd sand member (Krl), which extends from about 200 - 300 feet (53 - 79 m) deep overtop of the Precambrian bedrock. This member is the only fresh water bearing formation below the site. The 40 mg/l line of the salt wedge was found in this aquifer about one mile (0.6 km) north of the site in 1968.

Upper Glacial Aquifer

Below a thin skin of artificial fill, a layer of ground moraine deposits extending to about 50 feet (13 m) deep contains the uppermost ground water. These Pliestocene deposits were laid down during the retreat of the Wisconsinian glaication about 9,000 years ago. It consists of some glacial outwash sand and gravel deposits, but mainly of ground moraine deposits at the site, which is north of the terminal moraine. This

Figure 3. Queens Surficial Deposit and Section Locator-College Point Site

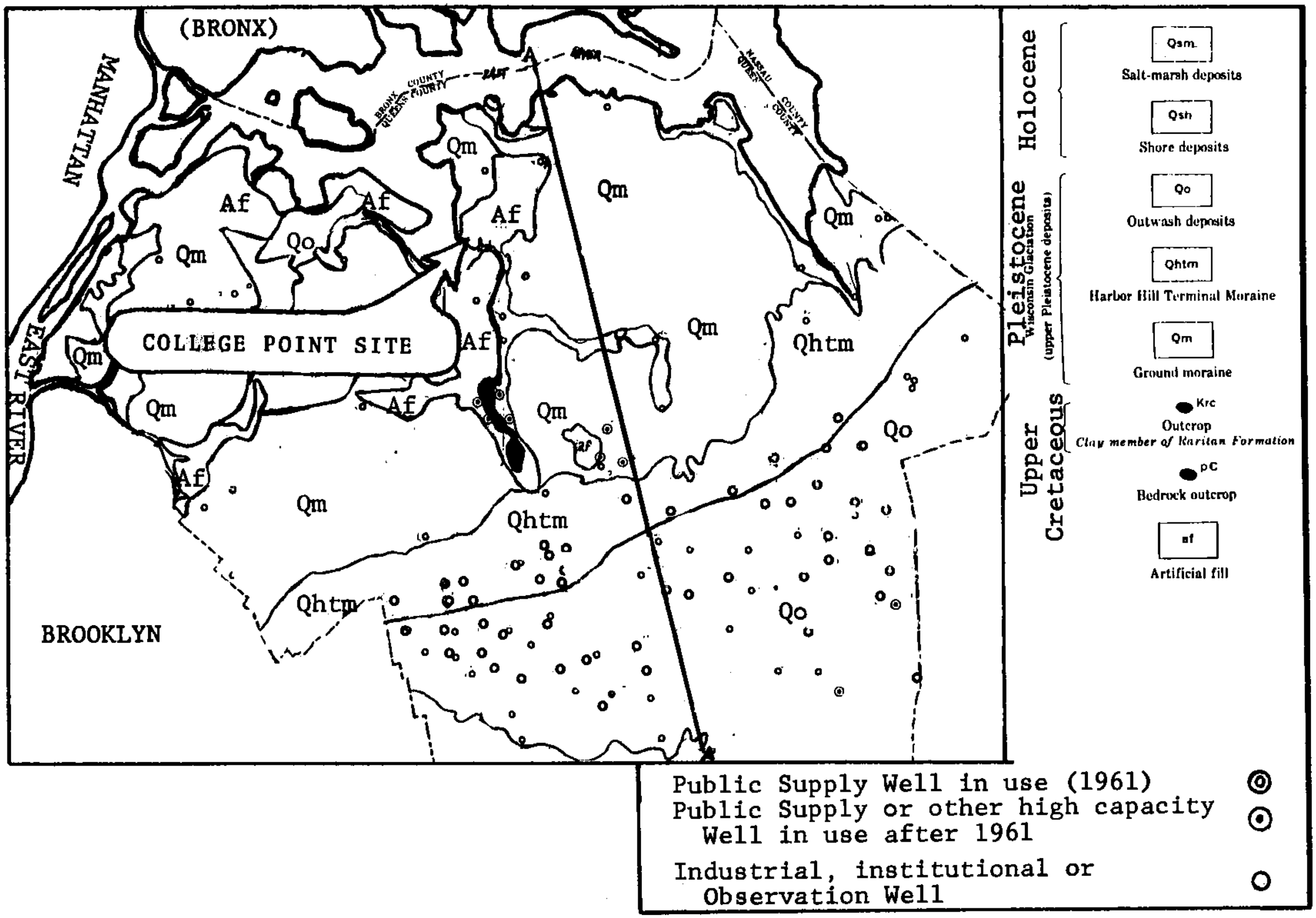
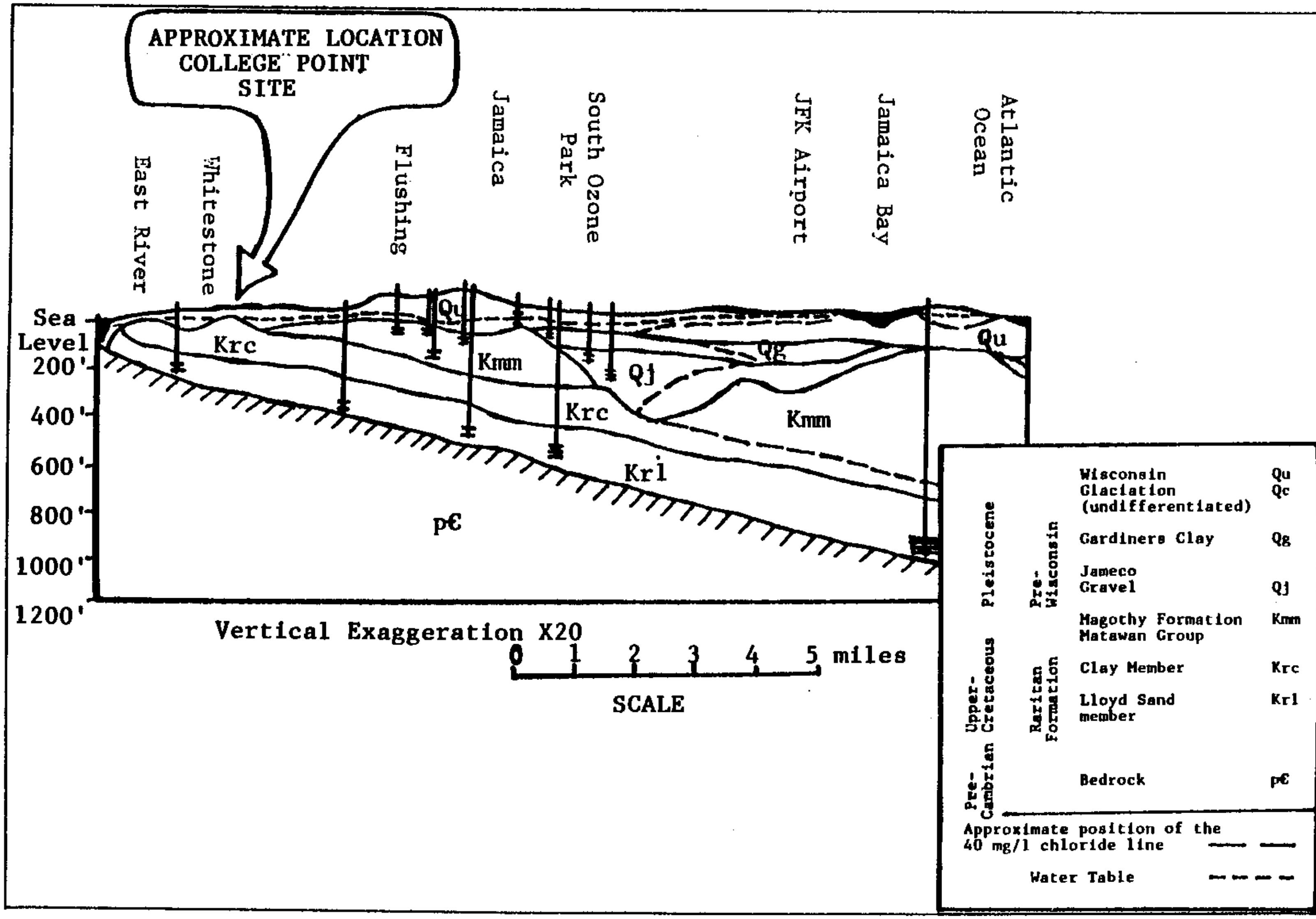


Figure 4. Geohydrologic Sections, Queens County, New York



aquifer has a porosity of about 40%, and a coefficient of permeability (rate of flow water, in gallons per day, through one square foot under a gradient of 100%) of about 1,000 gallons/day/square foot (40,743 l day/m^2).

Raritan Clay

This clay ember of the Raritan Formation was deposited during the Upper Crataceous. This member is composed of clayl, silty clay and clayey fine sand. It contains beds and lenses of lignite, payrite and sand with local occurrences of thin gravel beds. This clay forms a partial aquiclude which is poorly permeable but does not completely prevent downward vertical migration of water. It does confine the Lloyd aquifer below.

Lloyd Sand

This member of the Upper Cretaceous Raritan Formation is the lowest water bearing formation below the site and the lowest aquifer in Queens County. It is confined between the underlying bedrock and the overlying poorly permeable Raritan Clay member. The Lloyd aquifer consists of beds of sand and gravel intercollated with beds of clay and silt. The sand and gravel beds commonly contain varying amounts of interstitial clay and silt. The average permeability of the aquifer is about 500 gallons/day/square foot (20,371/ l day/m^2). It is composed of fine to coarse quartzose sand, and small to medium pebble gravel commonly containing much grayish white, light gray and yellowish interstitial clay and silt. Lignite and pyrete occur widely throughout. Development of this aquifer is regulated and limited because large with-drawals tend to induce salt-water intrusions. Below this aquifer is an unconformity with the Precambrian bedrock of schists and gneiss.

WASTE DISPOSAL HISTORY

The NYC DEP officials involved in the clean-up at College Point reported that they knew nothing about the history of the PCB disposal at the lagoon.

DESCRIPTION OF CONTAMINATION

Although soil borings were taken around the lagoon immediately before and after the removal action, lab reports were not available for this report. The first indication of the PCB contamination comes from a New York State Department of Environmental Conservation (NYS DEC) sample taken on June 13, 1978 following the investigation into spillage into Flushing Bay. This data indicated a PCB concentration of 160 mg/l in the

300.64(a) preliminary assessment

oil layer on top of the lagoon. The next sampling was performed by U.S. EPA Region II on April 10, 1980 and revealed a PCB level in the oil layer of 240 mg/l.

300.68(e)(2)(i)(B) amount and form of substance present

The oil layer was reported to be an average of 4 inches (10 cm) thick across the surface of the lagoon, covering a surface area of approximately 18,000 square feet (1672 m^2). Using the formula for volume, this yields approximately 44,886 gallons (169,894 l) of contaminated oil in the lagoon. The contractor found that the level of PCB contamination dropped as the pool was emptied, which was attributed to the chemical attraction between oil and PCB.

Information about concentration levels of PCB in the lagoon water and surrounding soils immediately prior to removal could not be obtained.

PLANNING THE SITE RESPONSE

Initiation of Response

The lagoon cought fire in April 1980. The NYC DEP initiated the removal action because it believed that the lagoon posed a threat of future fires as well as a threat of contaminated air emissions caused by the combustion of PCB contaminated oil.

300.65(a)(3) threat of fire

In addition, the EPA sampling of April 10, 1980 revealed a PCB contamination level of 240 mg/l which exceeded the limit of 50 ppm established by the Toxic Substances Control Act of 1976 (TSCA).

Selection of Response Technologies

The range of technological responses for remedying the threat posed by the contaminated lagoon was limited to the necessary pumping of the oil and water from the lagoon, treatment of each, and disposal. Only the treatment processes chosen for the oil and water might have allowed a variety of options. According to the CECOS contract, the detailed plans for the removal and treatment of the oil and waste water were not specified in advance but were to be determined by CECOS and submitted for approval to U.S. EPA, NYS DEC, and NYC DEP. The PCB contaminated oil was mixed with fly ash before disposal to comply with the "non-flowing consistency" requirements of TSCA for landfilling. While the oil could have been solidified off-site, generally, it is cheaper to arrange for a solidification process on-site. The EPA specified that a mixture of 5 parts fly ash to 1 part oil would be acceptable. Treatment of the lagoon water was necessary to lower its

300.68(h)(3) acceptable engineering practices oil/grease concentration level to 30 mg/l, as required by EPA. The method chosen to satisfy this requirement involved the installation of filters in line between the lagoon and the holding tanks. In general, on-site treatment for both the oil and water was chosen over commercial pre-treatment because of its relative cost effectiveness.

Extent of Response

The NYC DEP sought a complete removal of the PCB contaminated wastes from the College Point site. The criteria established by contract was for complete removal of all PCB contaminated wastes with concentration levels of 50 ppm or greater. This criteria was apparently chosen by NYC DEP in order to comply with the requirements established by the Toxic Substances Control Act of 1976 and was the primary factor that determined the extent to which the site was cleaned up. Correspondence between the NYC DEP and EPA indicates that sludge was removed down to a level of 2 ppm PCB contamination. Data from soil borings taken after the removal was not available. However, the soil was removed to a level of visual cleanliness according to the best professional judgement of the officials involved in the clean-up.

300.68(j) appropriate extent of remedy

The treatment criteria established by EPA for the contaminated water also determined the extent of response. Treatment of the lagoon water was required in order to lower its oil/grease concentration level to 30 mg/l before its disposal in a NYC sewage treatment plant. The 30 mg/l standard was set by U.S. EPA specifically for the site.

Funding problems were not a limiting constraint, as an adequate amount had been set aside by the NYC DEP, not to exceed $1,878,285. The NYC DEP officials described the clean-up as complete.

300.65(c) completion of immediate removal

DESIGN AND EXECUTION OF SITE RESPONSE

The response action conducted at the College Point site from July 23, 1980 to November 7, 1980 consisted of five activities: removal, treatment, transportation, disposal, and backfilling.

Removal

The surface oil was removed from the lagoon by sequestering the oil onto one side of the lagoon with an oil boom and pumping the oil into the mixing pit with a 2 inch (5 cm) trans-vac unit. Small pockets of oil that

300.70(c)(2)(i) removal of contaminated soils and sediments collected on the shore of the lagoon were removed with absorbent pads. In addition to the oil and lagoon water, some of the surrounding rock, soil, and debris were also removed in order to gain safe access to the lagoon. There was also a small island in the lagoon that required removal prior to use of the oil boom. The daily site reports indicate a total of 231 truckloads (2,772 tons/2514 Mt) left the site and went to the landfill. Assuming 12 tons (11 Mt) per truckload, the solid waste that left the site can be broken down roughly into 54 truckloads (648 tons/588 Mt) of contaminated soil, sludge, debris and rock and 177 truckloads (2124 tons/1926 Mt) of solidified soil and fly ash.

Water was pumped from the lagoon into portable treatment tanks erected adjacent to the lagoon, using transvac pumping system. Daily site reports indicate a total of 53 truckloads of lagoon water left the site for Tollman Island Sewage Treatment Plant. At 6,000 gallons (22,710 l) per truckload, the total amount of water removed from the lagoon totalled to 318,000 gallons (1.2×10^6 l).

Solidification

The treatment process for the PCB contaminated oil involved pumping the oil onto piles of fly ash in a mixing pit dug just south of the lagoon. The liquid was mixed using a backhoe. The mixture was tested periodically at the site by compaction to test for any free oil that might escape during transportation to the landfill. The minimum ratio established by EPA was 5 parts fly ash to 1 part oil, however batch samples taken from truckloads of stabilized waste mixed between July 28 and August 4, 1980 were analyzed by DEP's Industrial Waste Division and showed an average ratio of 99 parts fly ash to 1 part oil.

300.70(b)(2) (iii)(C) solidification

Water Treatment

The treatment process chosen to lower the oil/grease concentration level in the lagoon water to 30 mg/l involved the installation of two 55 gallon (208 l) drum/filters in line between the lagoon and the holding tanks. The waste water was allowed to settle for 24 hours to precipitate out contaminated solids. When the tanks were full, random samples were taken for oil/grease concentration levels. If under 30 mg/l, the water was then pumped into 6,000 gallon (22,710 l) tank trucks for disposal. If the oil/grease exceeded 30 mg/l, further treatment was to be carried out. It is unclear from available information what "further

300.70(b)(2) (ii) direct waste treatment methods treatment" involved. However, daily site reports indicate that on at least one occasion, the water was filtered a second time to further reduce its oil/grease concentration.

Transportation and Disposal

Trucks used to haul the solidified waste from the site were lined with plastic, secured with a canvas tarp, and washed before leaving the site. Tail gates were sealed with a thick asphaltic based sealant. The solid material was transported 400 miles (249 km) to the CECOS secure landfill in Niagara Falls, New York. These 231 truckloads left the site from July 28, 1980 to November 3, 1980.

300.70(c) off-site transport for treatment or secure disposition

From August 20, 1980 to October 28, 1980, 53 truckloads of lagoon water were taken to the Tollman Island Sewage Treatment Plant at 127th Street and East River in College Point, Queens. The Tollman Island Sewage Treatment Plant is part of the New York City sewer system.

Backfilling

The bottom of the lagoon was scraped using a smooth blade backhoe and clean dirt was discovered after 6 inches to 1 foot (15 - 30.5 cm) of scraping. The excavated area was then backfilled with soil and "landscaped", according to the daily site reports.

300.70(b)(ii) (C) grading

COST AND FUNDING

Source of Funding

The New York City Department of Environmental Protection paid for the entire 1980 clean-up of the College Point site because New York City, was the owner of the site. The Coast Guard had determined that the threat to navigable waters of Flushing Bay did not warrant funding for the clean-up under section 311 (k) of the Federal Water Pollution Act.

Selection of Contractors

The NYC DEP selected Chemical and Environmental Conservation Systems International, Inc. (CECOS) because it believed that CECOS was the only firm qualified to cleanup the PCB contamination at the time and because of its licensed landfill in Niagara Falls, New York. The contract signed June 5, 1980 was on a time and materials basis, and CECOS was the sole source contractor.

Project Cost

The total cost of the clean-up at College Point of $1,845,020 is based on invoices submitted by CECOS to the NYC DEP. As specified by contract, the costs for the clean-up were billed on a time-and-materials basis. Invoices state the daily rates for labor, daily travel costs, materials costs, and rental charges for equipment, but, with the exception of transportation and disposal, do not state the tasks for which these inputs were used. Transportation and disposal were separate categories, and thus these two components of the remedial action could be separated out by costs as shown in Table 1. Given these limitations, discussion of the various project costs is limited to the three categories shown in the table.

Transportation of the solidified PCB oil, sludge, rock, soil, and debris over 400 miles (644 km) to the CECOS landfill in Niagara Falls, New York cost a total of $202,410, which yields a cost per truckload of $876. This results in a unit cost of 18 /ton/mile (13 /Mt/km). The total cost of disposal at the CECOS landfill was $531,581 or $192/ton ($211/Mt). The combined cost of transportation and disposal was $733,991 or 40% of the total cost of the response action.

Transportation and disposal of the pre-treated lagoon water was not listed as a separate item in the invoices.

PERFORMANCE EVALUATION

The clean-up was described by the NYC DEP officials as complete. Although a payments dispute arose between the NYC DEP and CECOS, it did not appear to retard the progress of the site clean-up. The NYC DEP received EPA's approval of the completed removal action in November of 1980. The threat of future fires at the site and the public health and environmental threat posed by the high levels of PCB contamination were effectively mitigated by the removal action. However, in the absence of any monitoring data on soil contamination levels after the clean-up, it is not possible to evaluate precisely the level of clean-up achieved.

While the NYC DEP appeared to have removed most of the source of contamination at this site, three follow up actions are warranted. First, since the NYC DEP knew nothing of the site's disposal history, it should conduct site visits in the future to inspect for any

TABLE 1. SUMMARY OF PROJECT COST INFORMATION-COLLEGE POINT SITE, QUEENS, NEW YORK

Task	Quantity	Actual Expenditure	Unit Cost	Funding Source	Period of Performance
Excavation, solidification, and waste water treatment	• 2771 tons (2514 Mt) solid waste • 318,000 gal (1.2×10^6 l) lagoon water	$1,111,029	N/A	NYC Department of Environmental Protection	July 23, 1980 to Nov. 7, 1980
Transportation of solidified PCB waste (400 miles/644 km)	• 2771 tons (2513 Mt)	$ 202,410	18¢/ton/mile (13¢/Mt/km)	NYC Department of Environmental Protection	July 28, 1980 to Nov. 3, 1980
Disposal of solidified PCB waste	• 2771 tons (2514 Mt)	$531,581	$192/ton ($212/Mt)	NYC Department of Environmental Protection	July 28, 1980 to Nov. 3, 1980
TOTAL		$1,845,020		NYC Department of Environmental Protection	July 23, 1980 to Nov. 7, 1980

N/A: Not Applicable

continued dumping activities. Second, a hydrogeological study of the site area should be conducted to determine the extent, if any, of threat to ground water and surface water. Third, since some PCB/oil discharge into the Flushing Bay occurred, at least at the time of the Coast Guard involvement, any future study or clean-up of Flushing Bay contamination should specifically address this section of the Bay.

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FAIRCHILD REPUBLIC COMPANY

HAGERSTOWN, MARYLAND

NCP References

INTRODUCTION

The Fairchild Republic Company in Hagerstown, Maryland disposed of chromium sludge in a landfill area near its manufacturing site. Chromium levels averaging greater than 0.05 mg/l were found in the ground water underlying the landfill. Several domestic wells near the company's property also showed slightly elevated levels of chromium.

Background

Fairchild Republic used chemical solutions to clean sheet aluminum that is used in the manufacture of airplanes. Sludge and liquids containing heavy metals and a high concentration of chromium and miscellaneous organic solvents resulted from this operation, and were deposited in an open landfill on plant property between 1950 and 1967. As a result of rainfall and surface water percolating through the sludge, the surrounding soil and ground water became contaminated with chromium and organic chemicals.

In August 1978, the Maryland Department of Natural Resources, Water Resources Administration (WRA) conducted ground water monitoring prior to reissuing a permit for two sludge lagoons operated by Fairchild Republic. The permit had expired in 1978. WRA's ground water monitoring results revealed a "hot spot" of chromium contamination approximately 400 feet (121.9 m) away from the sludge lagoons. The nearby open landfill containing chromium sludge was found to be the source of the contamination.

300.63(a)(2) government investigation

Synopsis of Site Response

After initiating ground water monitoring in the fall of 1978, WRA issued a 90 day permit to Fairchild Republic, which provided that Fairchild Republic could continue using the lagoons for 90 days and thereafter would be required to put new sludge in a state approved landfill. In addition, the state required Fairchild Republic to remove the existing sludge to prevent the leaching of chromium from the lagoons. In the fall of 1979, after the sludge was removed from the lagoons, Fairchild Republic hired engineering consultants Metcalf and Eddy, Inc. to do an investigative study of the landfill area.

Upon completing the study, Metcalf and Eddy drew up a work plan that proposed alternatives for remedial action at the landfill area and suggested the best alternative. Fairchild submitted the entire work plan to the state, which accepted the recommended remedial action. That action included removing the sludge and contaminated soils, installing a clay cap, covering it with topsoil, and grading and seeding the site. To implement the plan, Fairchild hired Metcalf and Eddy to do ground water and soil sampling and analysis from late 1979 through early 1980. Fairchild hired Diggs Sanitation to do the soil excavation in the spring of 1981. When Mr. Digg's haulers license was revoked by the state in April 1981, Fairchild Republic hired Bohager Waste Systems in November 1981, which completed the removal work in December. Bohager backfilled the excavated area and installed a clay cap over part of the site in December 1981, and after the winter capped the rest of the site, covered it with topsoil and seeded it in April 1982.

SITE DESCRIPTION

Surface Characteristics

The Fairchild Republic property is located in a rural area about 2.5 miles (3.2 km) north of Hagerstown, Md. near the Pennsylvania border (see Figure 1). The landfill in which the contamination was detected was located north and northwest of the "Hot Fire Pit Area" located behind Plant No. 11 (see Figure 2. The landfill is designated the "Hot Fire Pit Dump Area"). The landfill had an irregular shape with a maximum length of about 350 feet (106.7 m) and a maximum width of about 160 feet (48.8 m). Test pits dug throughout the landfill area showed a depth of refusal of 2 - 5.5 feet (0.6 - 1.7 m), as shown in Figure 3.

Figure 1.

Location of Fairchild Republic Company
Hagerstown, Maryland

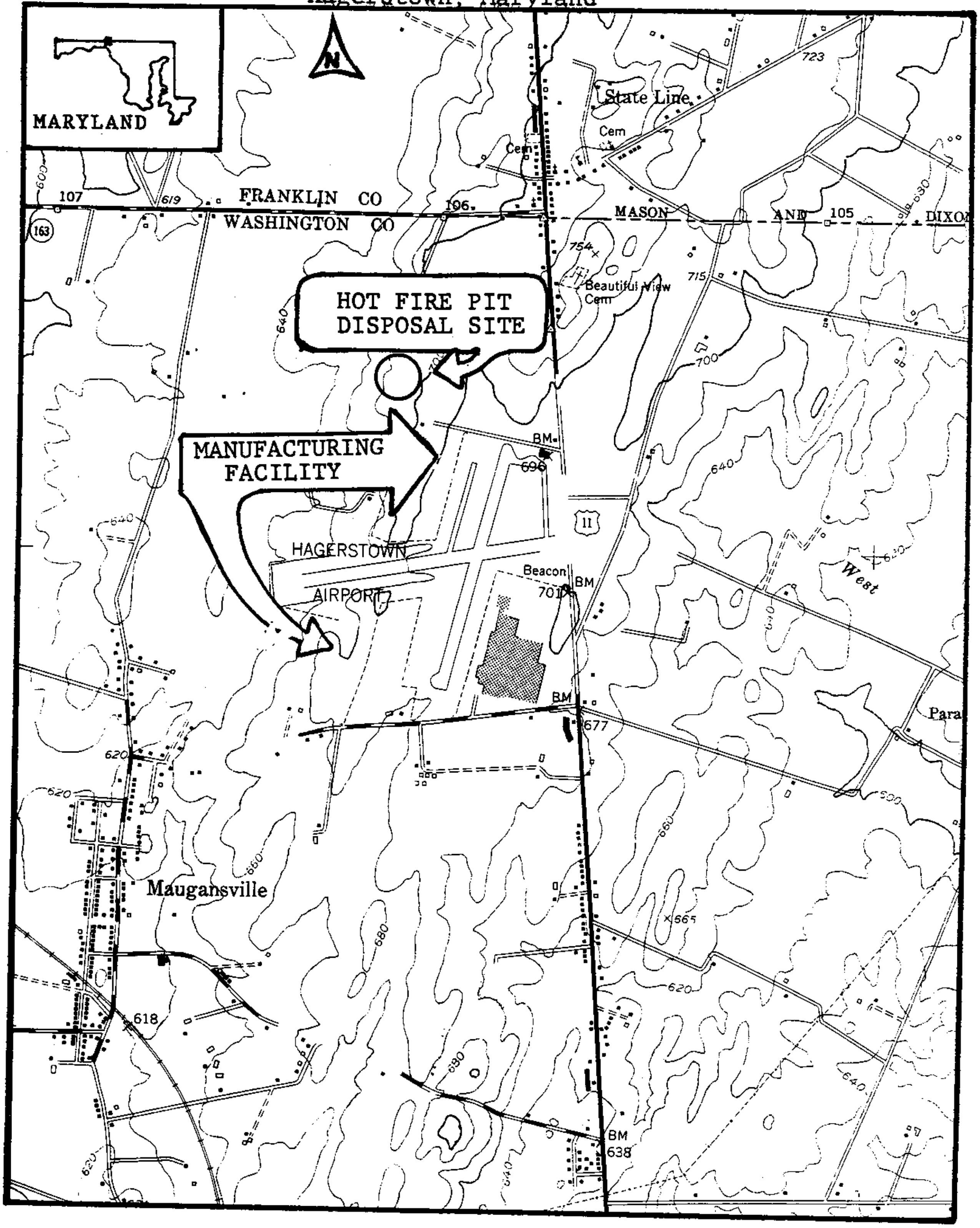


Figure 2.
Disposal Site Location

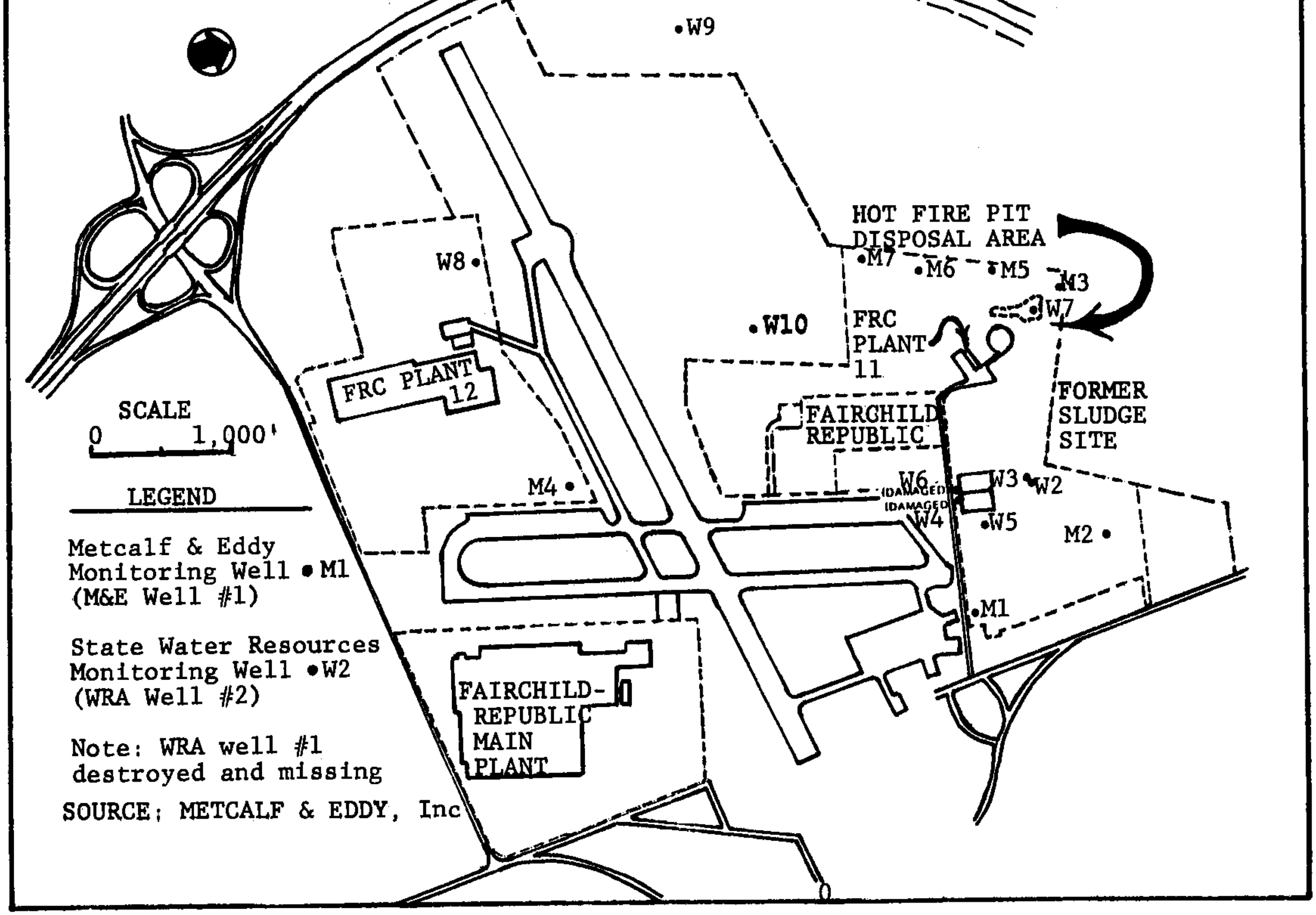
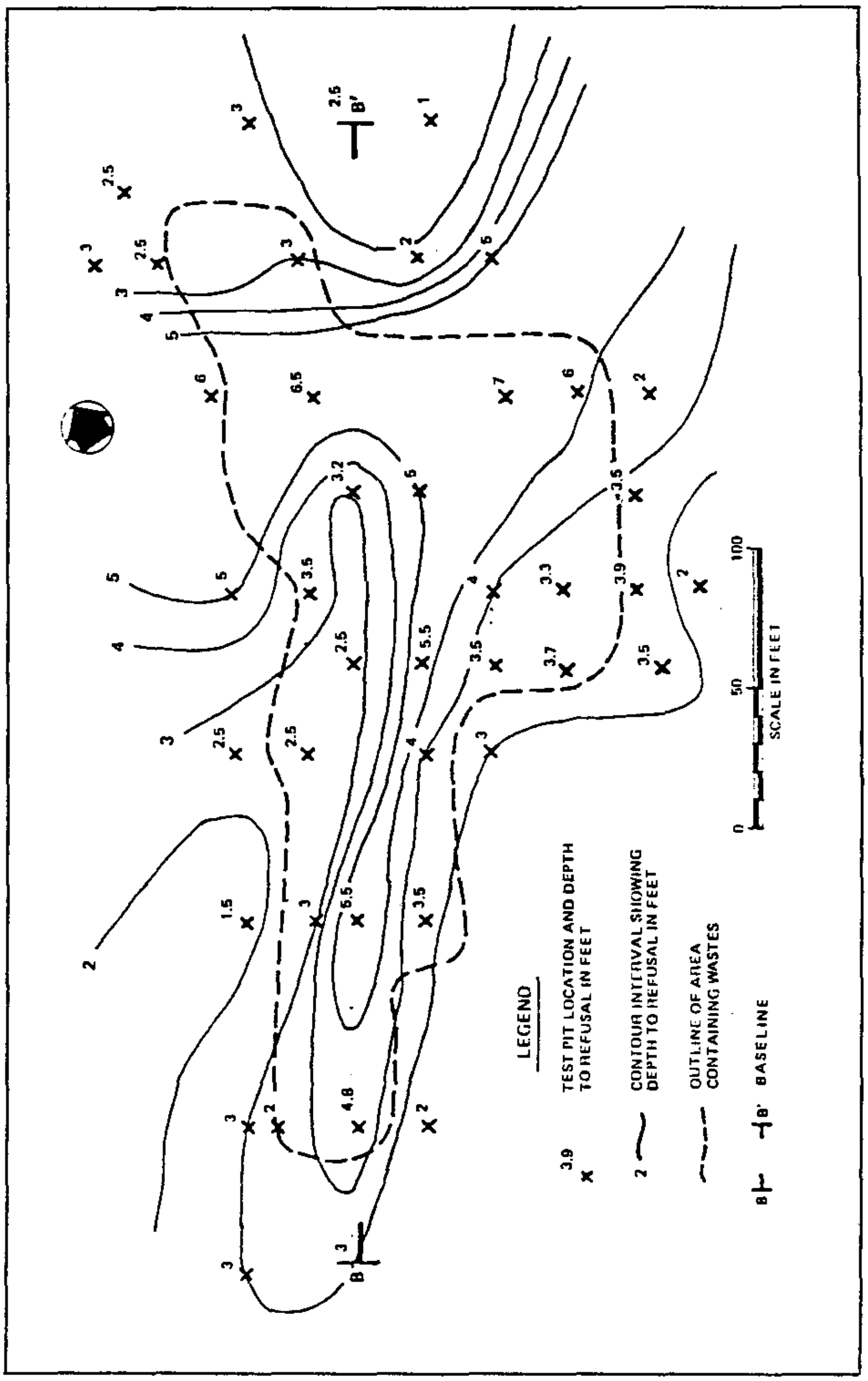


Figure 3. Contour Map of Depth of Refusal, Hot Fire Pit Disposal Area



Source: Metcalf & Eddy, July 1982

The soil at this site is a silty clay loam in the Hagerstown-Duffield-Frankstown association and is generally characterized as reddish, well drained, deep, and medium textured. Below the silty clay at the landfill area lies a limestone bedrock with numerous fractures and cavities. The stratigraphy of the bedrock is a series of parallel folds with the axial traces trending N 15 degrees E, somewhat resembling the fingers of a hand. The joint measurements trend in two directions: strike N 80 degrees E, dip 85 degrees NW; and strike N 50 degrees E, dip 60 degrees SE.

Climate in this area is continental with maximum afternoon temperature averaging 88 degrees F. (31 degrees C.) in late July and minimum early morning temperature averaging 21 degrees F. (-6 degrees C.) in late January - early February. Annual precipitation is rather even throughout the year, with the mean for the past 30 years at 37.08 inches (94.2 cm).

300.68(e)(2)
(i)(E)
climate

<u>Hydrogeology</u>

A carbonate aquifer lies below the Fairchild Republic facility, with the water table ranging from 34.1 feet (10.4 m) below surface in dry fall months to 11.9 feet (3.6 m) in wet winter months.

300.68(e)(2)
(i)(D)
hydrogeological
factors

WASTE DISPOSAL HISTORY

Between 1950 and 1967, Fairchild Republic disposed of solid and liquid manufacturing plant wastes in an open dump located near the Hot Fire Pit. Liquids consisted of both a metal cleaning solution used to clean aluminum sheet metal and waste sludge from Fairchild's waste treatment facility. The cleaning solution contained a number of spent organic solvents and the sludge contained primarily total chromium and hexavalent chromium, as well as other heavy metals. During the mid-1960's an improved waste treatment plant was constructed, which enhanced the removal of heavy metals through chemical addition. The resulting sludge, which was more concentrated, was dewatered through filter presses and placed in several sludge lagoons. Sludge was then hauled to the Browning Ferris Industries licensed disposal facility at Glen Burnie, Md. for a number of years. Recently, trivalent chromium was declassified as a hazardous substance; since then, Fairchild Republic has disposed of the trivalent chromium sludge at a local sanitary landfill.

DESCRIPTION OF CONTAMINATION

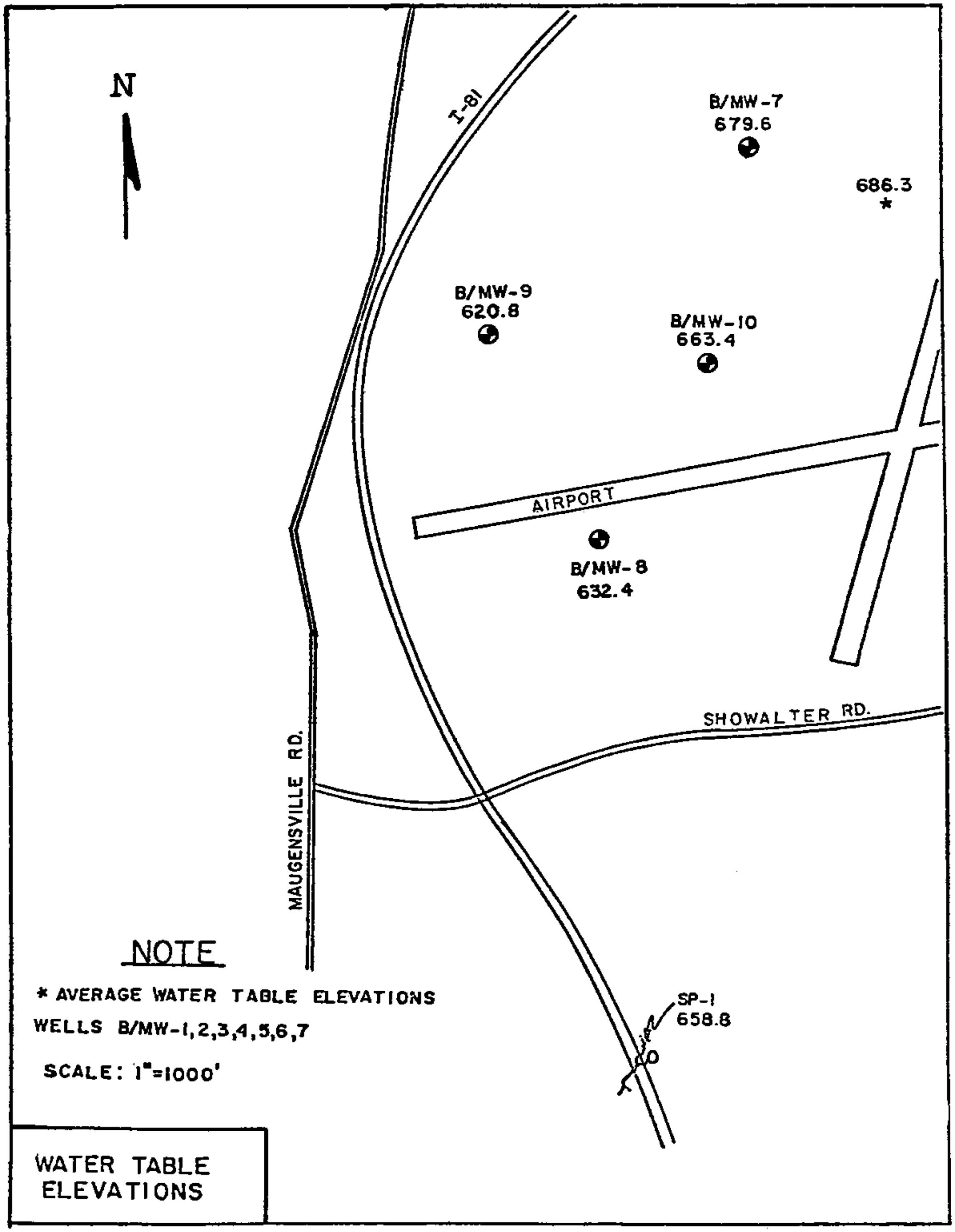
Metcalf and Eddy, Inc. was hired as the consulting engineering firm for the clean-up. It undertook soil and hydrogeological investigations at the site, using test pits, monitoring wells and laboratory analyses of soil, ground water and waste samples. The ground water and surface water systems were assessed in two phases. The first phase sought to determine local ground water quality. The contractor installed 5 monitoring wells near the sludge basins and analyzed samples from them and from 15 nearby domestic wells and 5 streams or springs. Four series of samples were analyzed and significant concentrations of chromium were detected in some samples. This led to the second phase, which tried to determine the path of migration of chromium from the disposal areas. Five additional monitoring wells were constructed. Three series of samples were analyzed from these wells and an additional surface water point. Figure 4 shows the average water table elevations in the area, and Figure 5 presents the chromium concentrations found. Migration from the disposal areas appeared to be westerly or southwesterly.

The major contaminants found at the site included heavy metals such as chromium, copper, zinc and aluminum, as well as organic materials, most notably 1, 1, 1-trichloroethane, 1, 1-dichloroethylene, ethylbenzene, methylchloride, toluene, trichloroethylene, and xylenes. There were two relatively easily distinguishable classes of wastes discovered at the site: a black, powdery material and a bluish-green sludge. The black, charcoal-like material consisted primarily of the spent organic solvents and some heavy metals. The bluish-green material had a high concentration of total chromium, in the order of 10,000 mg/kg or greater. Since chromium was found to be the dominant heavy metal contaminant in the area (the highest concentration of chromium found in the ground water was 0.32 mg/l of total chromium and 0.28 mg/l of hexavalent chromium), it was used as a surrogate indicator for all other metals. Metcalf and Eddy assumed that if chromium concentrations were found to be above the natural background levels, the other heavy metals would also be at higher than normal concentrations.

300.68(e)(2)(i)(B) amount and form of substances present

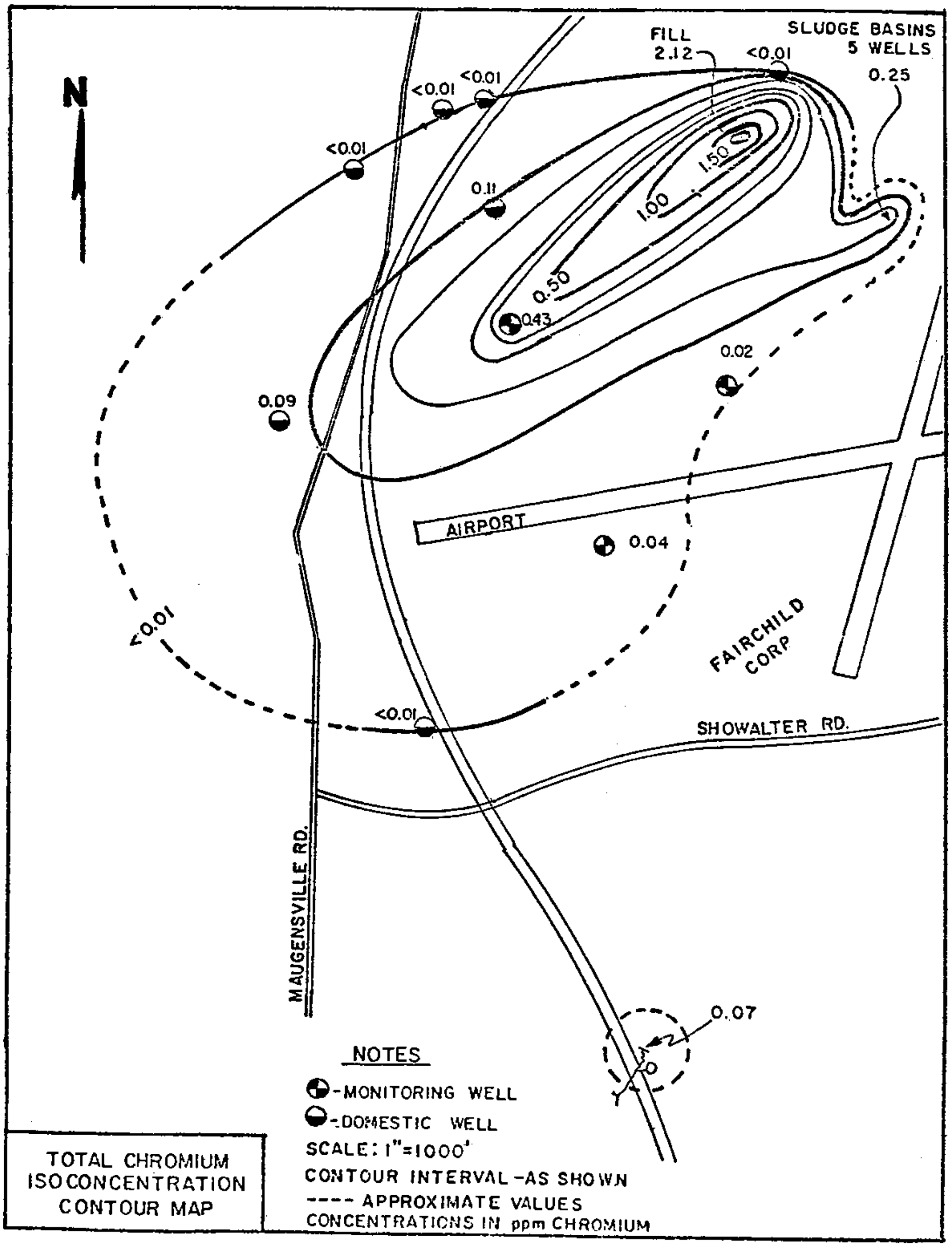
Test pits and surface sampling locations were established around a base line (B-B' shown in Figure 6) which ran through the middle of the contaminated area. Distribution of chromium contamination at the surface, as indicated by soil samples, is presented in Figure 6. The total chromium concentration of the samples

Figure 4. Water Table Elevations



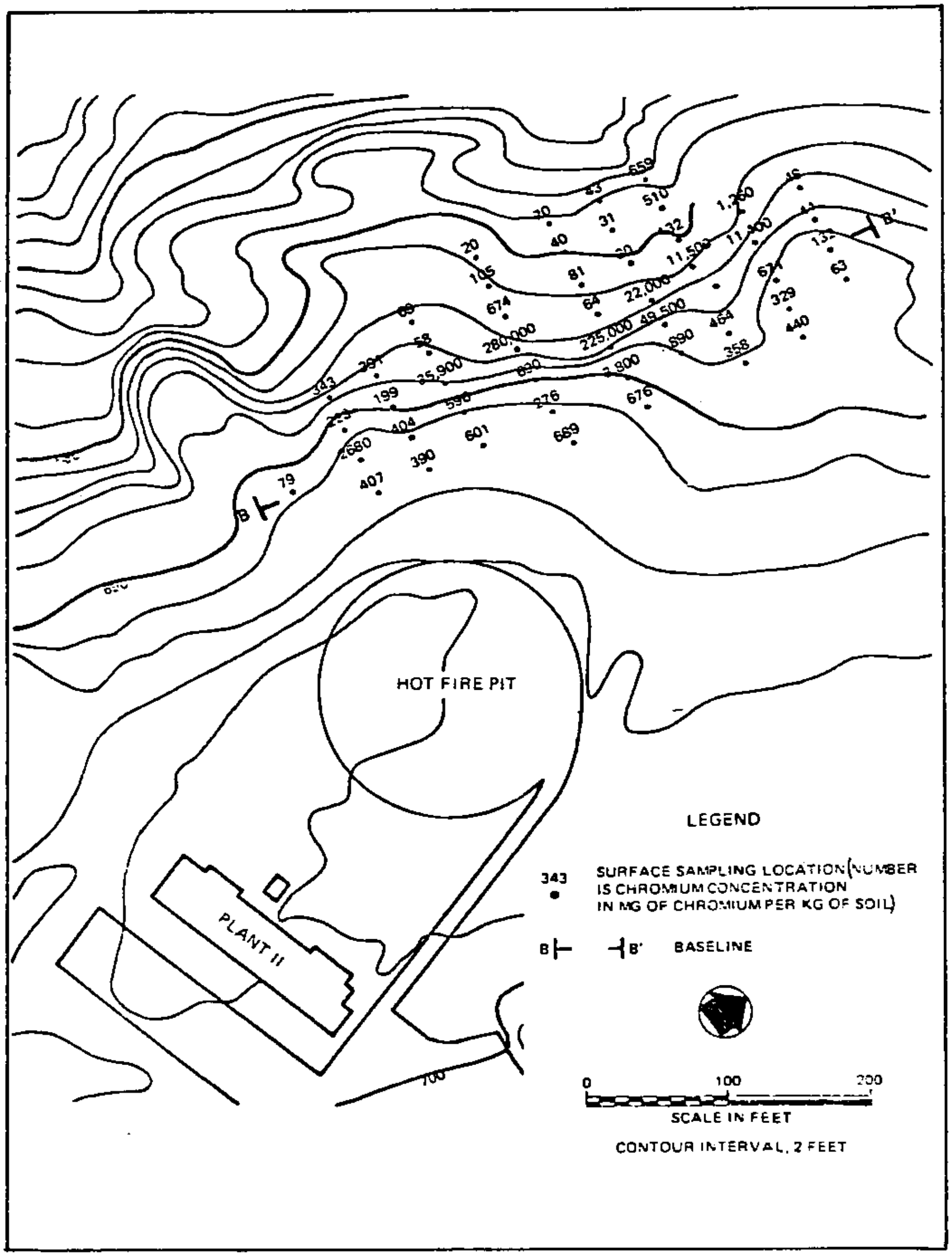
Source: Metcalf & Eddy, May 1980

Figure 5. Total Chromium Isoconcentration Contour Map



Source: Metcalf & Eddy, May 1980

Figure 6. Surface Sampling Locations and Total Chromium Concentrations



Source: Metcalf & Eddy, July 1982

ranged from 20 mg/kg to 280,000 mg/kg with the natural background level of total chromium in the range of 50 to 100 mg/kg. From these analyses, a visual correlation was made that the material having a bluish-green color contained chromium in excess of 10,000 mg/kg.

The estimated volume of material in the area containing the wastes was approximately 5,400 cubic yards (4,128.84 cu.m). About 50% of this material was determined to be contaminated soils. The remainder of the material was believed to be only partially contaminated, and lay either above or beneath the wastes. The total surface area which required excavation was about 1 acre (0.4 ha) and generally less than 5 feet (1.5 m) deep. Figure 3 shows the depth to probable bedrock. Figure 7 presents graphically the distribution of wastes in the abandoned open pit site, indicating areas where contamination was near or directly on the bedrock, areas where the soil was at least 2 feet (0.6 m) thick between the contamination and the bedrock, and areas where contamination appeared to be restricted to within 1 foot (0.3 cm) of the surface. This presentation format was valuable in helping Metcalf and Eddy estimate the total volume of wastes that should be exhumed. Cross-sectional views of the site are shown in Figures 8 and 9, and the locations of the cross-sections in Figure 10.

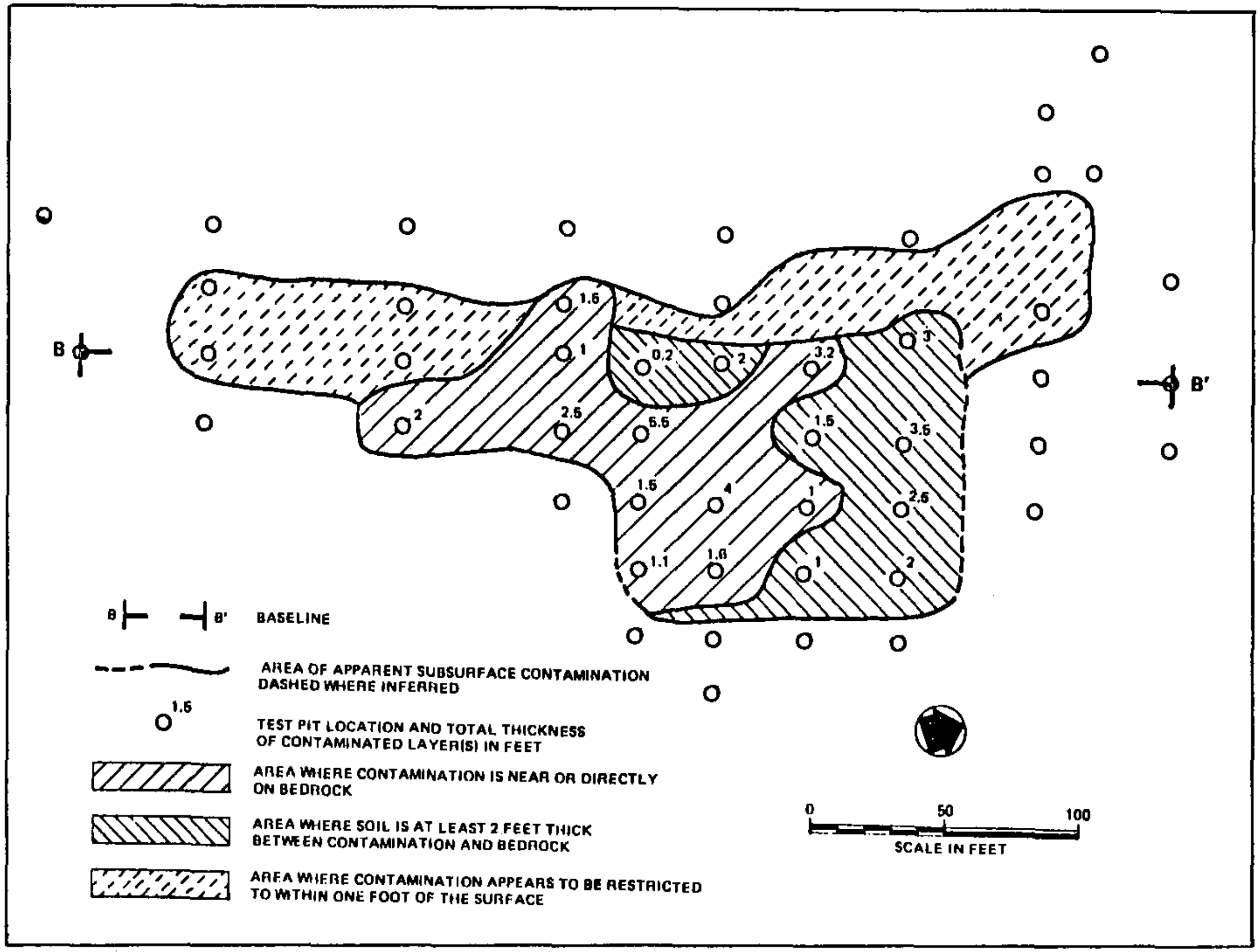
PLANNING THE SITE RESPONSE

Initiation of Response

Fairchild Republic had a state permit to operate two on-site sludge lagoons. When the permit expired in 1978, the state conducted routine ground water monitoring tests prior to reissuing the permit. The tests showed that a substantial amount of chromium sludge existed in an open landfill 400 feet (121.9 m) from the lagoons. The state concluded that it presented a threat to the aquifer. In the fall of 1978, the state WRA issued Fairchild a 90 day permit for continued use of the lagoons, after which time the company had to remove the sludge. Fairchild and the state began discussions regarding the clean-up of the landfill, and Fairchild volunteered to clean up the site and pay for all costs of remedial action and disposal. The state issued no clean-up order and imposed no penalties with respect to the landfill.

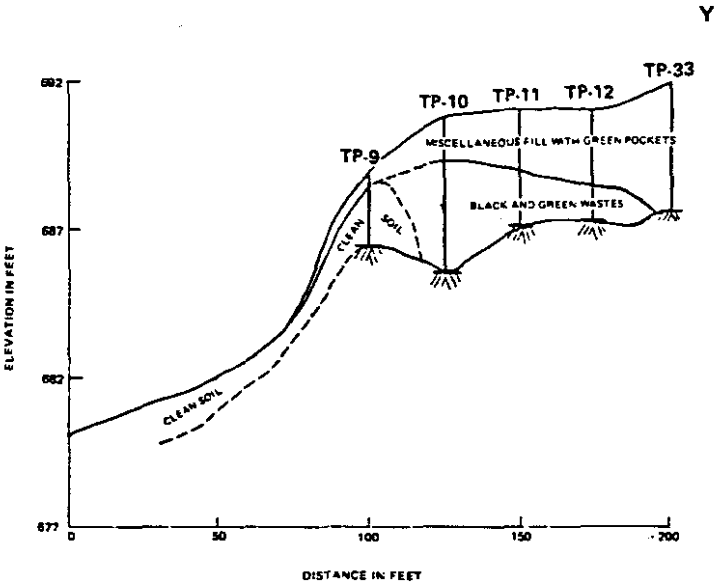
300.68(c)
private
clean-up

Figure 7. Distribution of Wastes



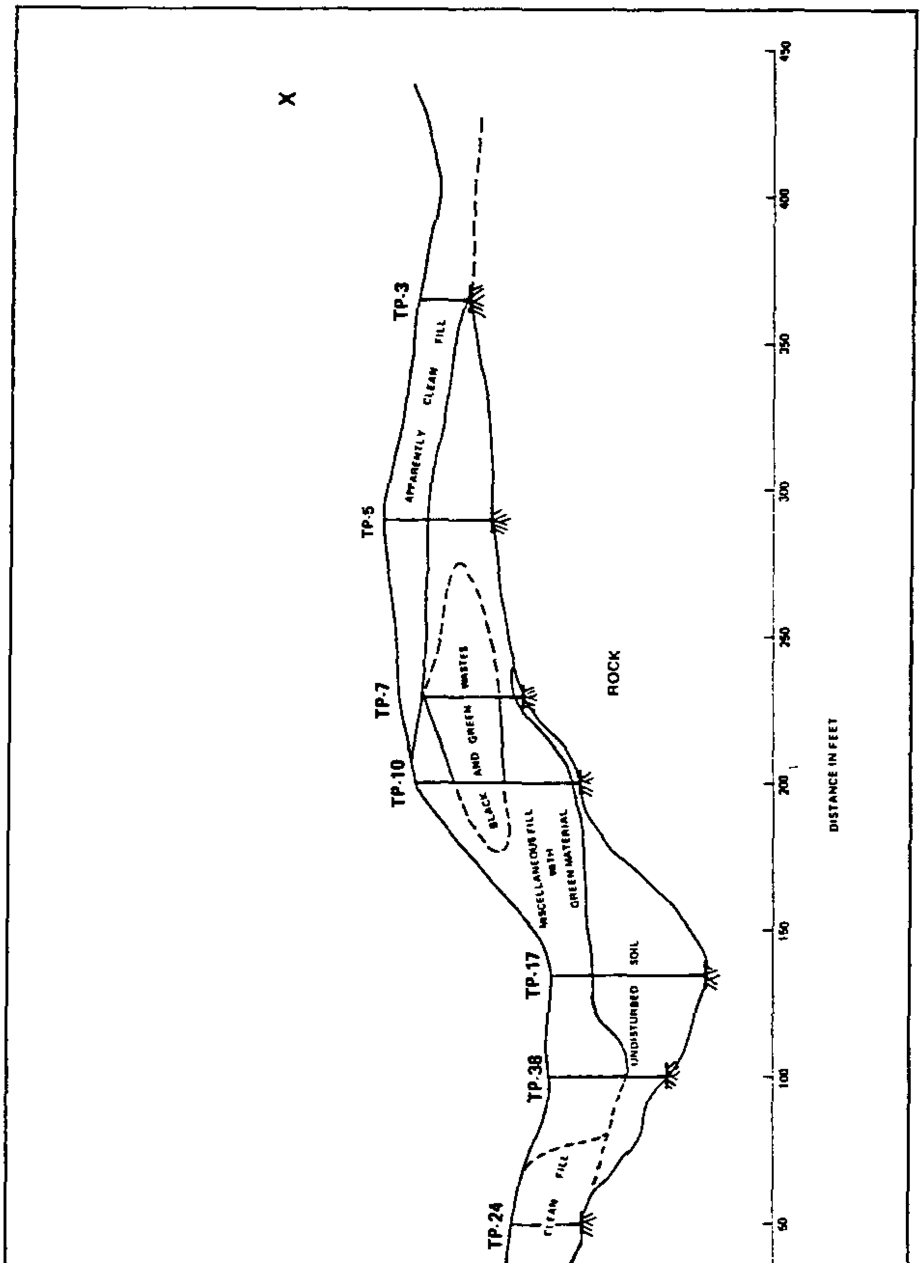
Source: Metcalf & Eddy, July 1982

Figure 8. Geologic Cross-Section Y-Y



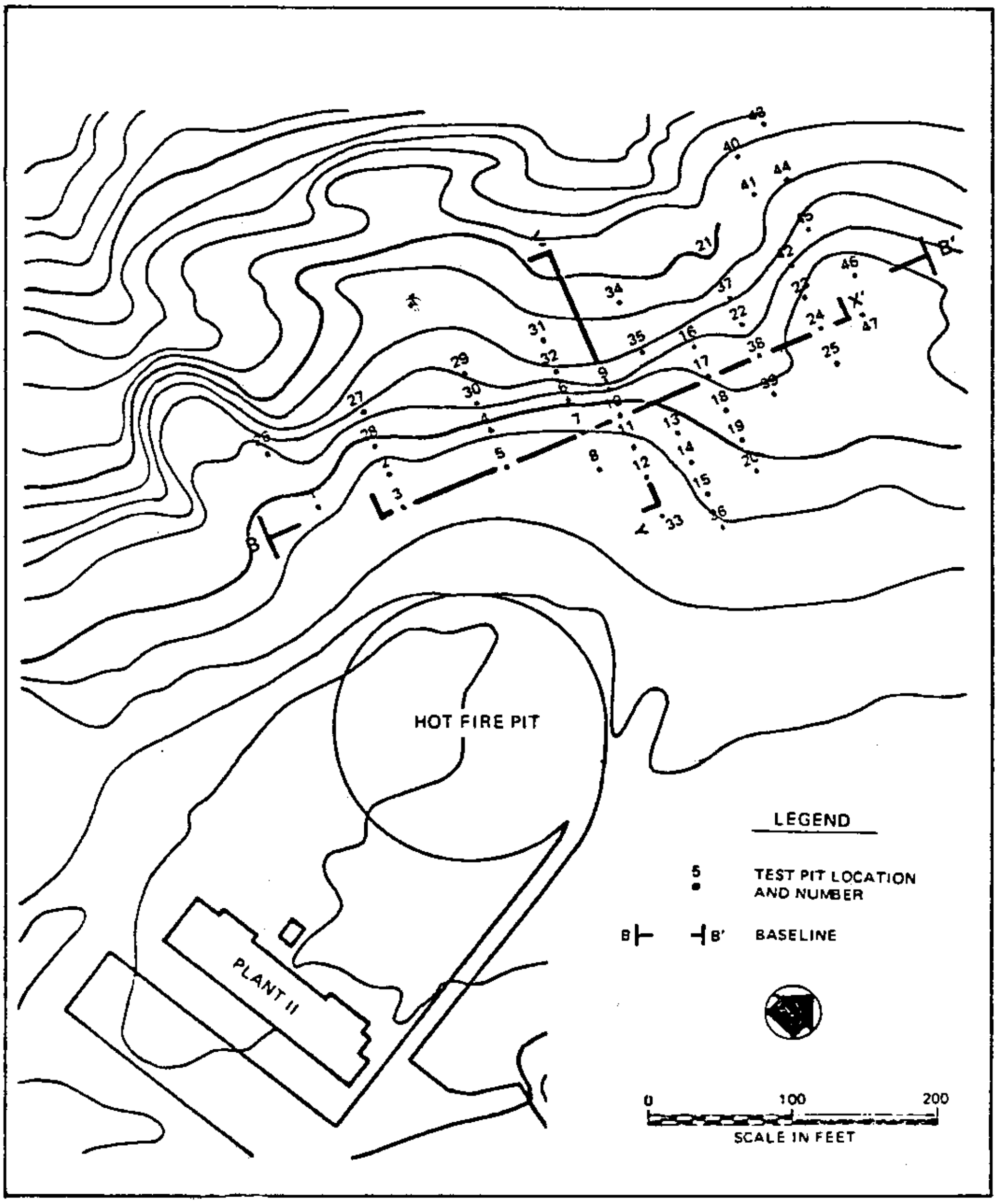
Source: Metcalf & Eddy, July 1982

Figure 9. Geologic Cross-Section X-X



Source: Metcalf & Eddy, July 1982

Figure 10. Locations of Cross-Sections Y-Y and X-X, Hot Fire Pit Disposal Area



Source: Metcalf & Eddy, July 1982

Selection of Response Technologies

Metcalf and Eddy was hired by Fairchild Republic to study the extent of site contamination and propose remedial action options. Metcalf and Eddy proposed four options to clean up the landfill: (1) chemical fixation of the waste and storage on-site; (2) chemical fixation of the waste and disposal off-site; (3) off-site disposal in an approved hazardous waste landfill; and (4) on-site disposal in an approved hazardous waste landfill. It used the following criteria in evaluating the options: (a) technical feasibility; (b) conformance with applicable federal, state and local regulations; and (c) estimated cost. The objective of the first two alternatives was to render the material non-hazardous so that it could be placed in a local landfill rather than to an approved hazardous waste disposal site. An advantage of these alternatives was that rendering these wastes non-hazardous would reduce transportation and disposal costs.

300.68(g) development of response alternatives

300.68(h) initial screening of alternatives

The possible use of the chemical fixation alternative was contingent upon its ability to stabilize the waste (i.e., to prevent leaching of heavy metals and organics). Chemical fixation had to be rejected as technically unfeasible because the end-product material did not pass leachate test requirements. Extractable total chromium was 1.31 mg/l and extractable hexavalent chromium was 0.20 mg/l. The volatile organics extracted were as follows: 1,1-dichloroethylene, 33ug/l; 1, 1, 1-trichloroethane, 340 ug/l; trichloroethylene, 2,000 ug/l; and tetrachloroethylene, 11 ug/l.

The third alternative, off-site disposal in an approved hazardous waste landfill, had the advantage of removing the wastes from above the contaminated aquifer. It also offered the opportunity to clear and rehabilitate the disposal area for possible future use by the plant. Disadvantages included the expense of transportation and the costs of hazardous waste disposal at an approved facility.

The benefits of alternative four, on-site disposal in an approved hazardous waste landfill, were that Fairchild could maintain control of the waste and eliminate transportation and disposal fees. However, there would be some project delay due to the necessity of designing and constructing the facility. In addition, the disposal site would require long-term maintenance, monitoring, and a lengthy permit application procedure. Further, the state was reluctant to allow disposal of wastes above the aquifer.

The proposed on-site facility would be a double-lined surface impoundment with a leachate collection system between the liners. The leachate collection system would remove any leachate migrating through the upper liner material. Two specific designs were considered. The first used a reinforced concrete pad as the lower liner and the second a 2 foot (0.6 m) thick clay liner. In both designs, a fabric material believed to be imperbeable would serve as the upper liner. The facility required approximately 1 acre (0.4 ha) of land and would be constructed with approximately 4 foot (1.2 m) high walls and a 3:1 ratio sidewall slope surrounding the pit. The landfill and material would be covered with a fabric liner followed by 18 inches (45 cm) of local soil, predominantly clay, and 8 inches (20 cm) of topsoil. It would be seeded with a grass legume mixture and graded to encourage runoff. The total costs for the concrete based and clay lined facilities were estimated to be $840,000 and $240,000, respectively.

Metcalf and Eddy recommended the third alternative, removal of the wastes and ground water monitoring for three years, as opposed to alternative four, even though the latter was felt to be the lowest cost alternative. The main reasons for this choice were the long term maintenance costs and responsibility associated with on-site disposal. Fairchild favored this alternative because it wanted to avoid prolonged involvement in waste management. The state, after reviewing these alternatives, approved this third alternative in the summer of 1980.

300.68(c) state evaluation of clean-up proposals

Extent of Response

The state did not impose specific environmental criteria or remedial technology requirements. Its objective was to lower the level of total chromium was the soil, domestic water wells and monitoring wells. (The U.S. EPA drinking water standard for total chromium is 0.05 ppm and the U.S. EPA standard under the Resource Conservation and Recovery Act for total chromium in hazardous wastes was 5 ppm at the time of the response.) The WRA did not indicate that meeting EPA standards was the objective of the remedial action, only that the total chromium had to be lowered from the amount measured prior to the remedial action. Although organic contaminants were also found in the soil and ground water, the state asked Fairchild Republic to conduct ground water monitoring of organics but did not require that any pre-determined organic standards be met. Two reasons for this appear to be that EPA did not have standards for organics in drinking water at that time and the contamination did not appear to be

300.68(j) extent of remedy

extensive.

Contractors completed the remedial action according to the Metcalf and Eddy workplan. Excavation of contaminated materials was stopped when it reached fissured bedrock, which state inspectors agreed was the practical limit. Subsequent composite soil samples from the excavated area indicated that total and hexavalent chromium concentrations were not EP toxic. The contractor then backfilled and capped the site and covered it with topsoil and grass seed. Work was stopped when the specifications of the workplan for excavation, removal, backfilling and capping had been met. After completion of the clean-up, ground water tests indicated that the chromium contamination level was lower, as the state required.

DESIGN AND EXECUTION OF SITE RESPONSE

Site Investigation

300.68(f) remedial investigation

The most important elements in determining the technology for removing the material were knowledge of the contaminants, definition of the amount of decontamination desired and location of the exact area of contamination. In order to obtain this information, soil and hydrogeological investigations were undertaken. These primarily involved making exploratory backhoe test pits, installation of monitoring wells, and laboratory analysis of soil, ground water, surface water, and waste samples. The results of these tests are discussed above in the section "Description of Contamination." After Metcalf and Eddy had determined the nature and location of contamination, it developed a workplan for the remedial action.

Removal of Contaminated Materials

300.70(c)(2) (i) removal of contaminated soils

Two contractors, Diggs Sanitation and Bohager Waste Systems, working at different periods of time, performed the excavation, transportation and disposal of contaminated materials. Personnel from Metcalf and Eddy, Fairchild Republic and the state periodically inspected the site to observe work and collect soil samples for chemical analysis.

Diggs Sanitation

Diggs worked from October 1980 to April 1981, when he was arrested for illegally disposing of the excavated contaminated materials. Metcalf and Eddy personnel delineated the site on October 14 and 15, and Diggs began excavation on the 15th using a front-end loader and two dump trucks. Before the end of the first work day, Fairchild Republic ordered him to stop because he lacked necessary permits. At that time, the excavated material was stockpiled on-site. Diggs resumed work on April 3 after securing the permits. The contaminated soil was intended for disposal at the Municipal Industrial Service Site Landfill in Clairton, Pa., about 125 miles (201 km) away.

Diggs began excavation at the northern end of the landfill area (see Figure 11, line P), using the front-end loader and this time 5 instead of 2 dump trucks. Contaminated soil and materials were excavated and stockpiled at the site on a daily basis, with the extent of excavation and the size of the pile limited to reduce possible exposure due to rainfall and run-off. Generally, the trucks were loaded in the morning from the stockpile remaining from the previous day's excavation. Sometimes trucks would return in the late afternoon or early evening for a second load, but apparently most made only one trip per day.

During the first week of work, Diggs constructed a shallow diversion ditch along the east side of the landfill area to prevent surface waters from running into the excavated area. Odor from contaminants was occassionally strong, especially when the front-end loader encountered large pockets of black colored wastes. When this occurred, the operator used an air-purifying respirator with combination filter/chemical cartridges.

300.70(b)(1)
(ii)(B)(2)
ditch,
diversion

Metcalf and Eddy personnel periodically inspected the site to advise Diggs about the extent to which soil should be removed. Visual observations backed by chemical analysis reports from previous inspections established that contaminated materials were readily distinguishable from clean clay: the former were usually black or blue-green and the latter was orangish. In areas of slight or not visually apparent contamination, Metcalf and Eddy's graphic distribution of contaminants was used to guide removal (see Figure 7). Where contaminated materials were found in the folds of the bedrock, they were removed using hand tools.

Officials from the Maryland Department of Health and Mental Hygiene (MDHMA) also made regular site inspections also. During the first week of work, Diggs did not have covers for his dump trucks during transport. State inspectors notified Diggs and Fairchild that these would be required. The state also required Diggs to take further measures to control potential site run-off. In response, Diggs constructed

300.70(b)(1)
(ii)(B)(1)
berm

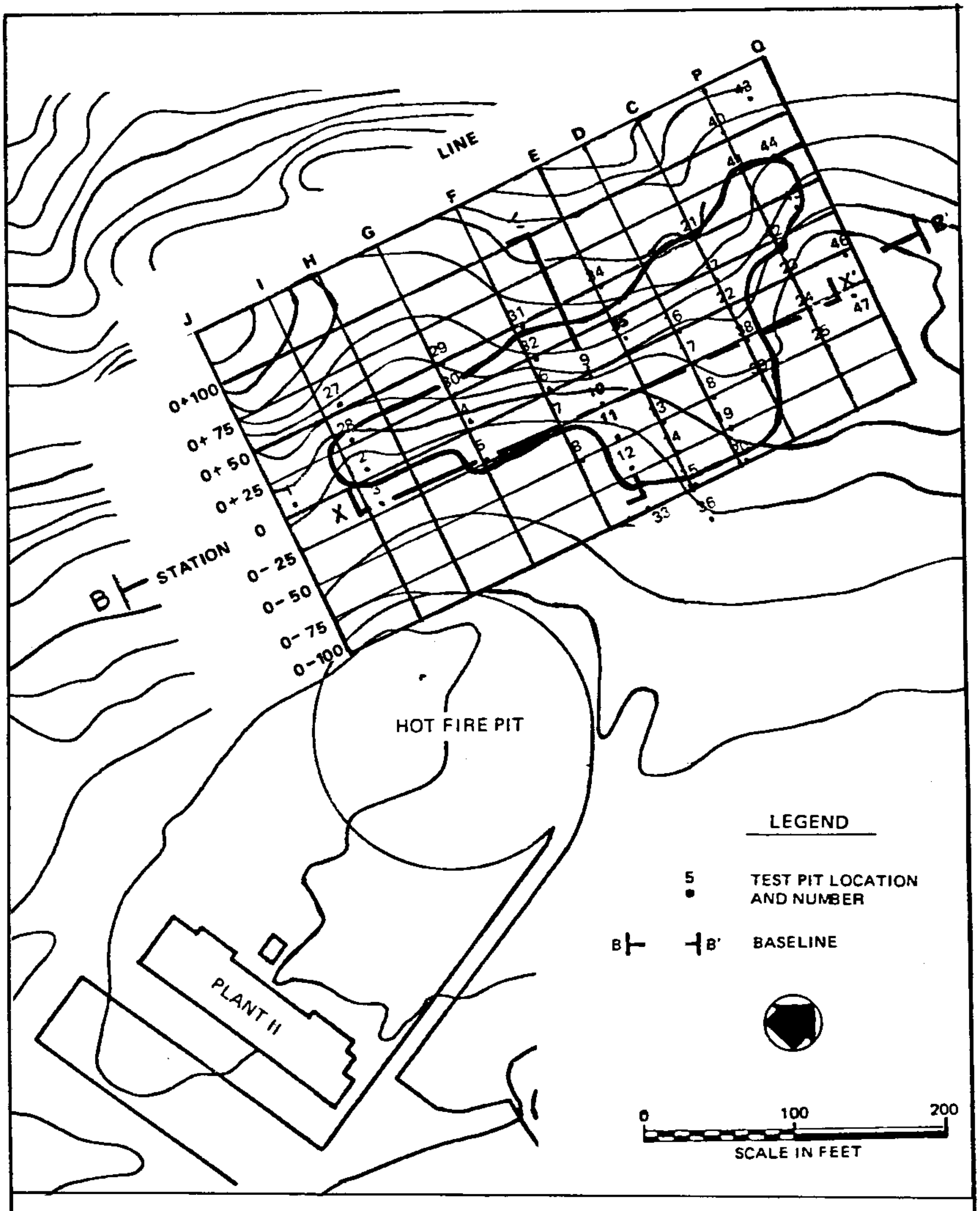


FIG. 11 EXCAVATION GRID, HOT FIRE PIT DISPOSAL AREA

a berm northwest of the excavation across a major swale that drained the area (see Figure 11-the berm was between lines D and E near Stations 0 + 50 to 0 + 75).

Work by Diggs ended on April 23 when his hauler's certificate was revoked by MDHMH. Fairchild Republic records indicated that he removed 2,428 cubic yards (1,856.4 cu m) of contaminated soil and materials. The excavation site was left open and no soil or materials were removed until November 1981, when a new contractor began work, a delay of about 6 months.

Bohager Waste Systems

After being selected by Fairchild and obtaining all necessary permits, Bohager Waste Systems began work on November 16, 1981. Bohager followed basically the same excavation workplan as Diggs, but transported the exhumed contaminated materials to the Solley Road Hazardous Waste Landfill in Glen Burnie, Md., a distance of approximately 70 miles (112 km). Inspections were resumed by Fairchild Republic, Metcalf and Eddy, and the state. Bohager began work in the previous excavation, using a front-end loader and 6 dump trucks. Contaminated soil and materials were excavated and stockpiled on a daily basis and trucks were loaded either directly from excavation or from the pile. Usually 6 trucks were loaded in the morning and 3 returned in the afternoon for a second load.

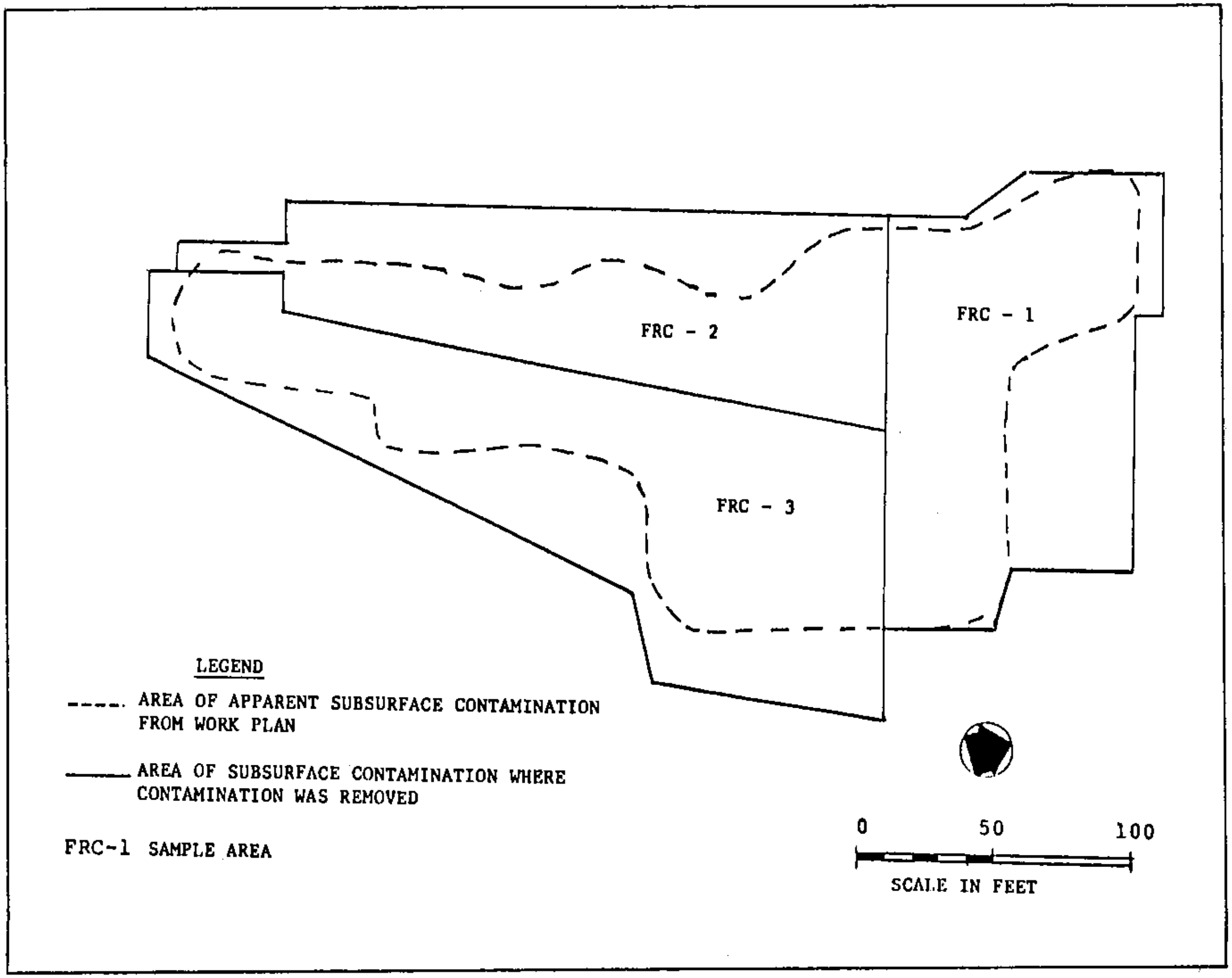
300.70(c) off-site transport for secure disposition

At first, Bohager excavated the area from Station 0 - 75 to 0 + 30 between lines F and E as shown in Figure 11 and removed a stockpile left by Diggs extending from Station 0 + 30 to 0 - 50 between lines E and C. During this early stage, Bohager's industrial hygienist took on-site air samples to determine dust levels, and from the low levels detected concluded that respirators were not necessary.

During the next two weeks, Bohager worked in the section southwest of line F in Figure 11 and cleaned and prepared the northern section for soil sampling. Composite samples, consisting of 12 evenly spaced subsamples taken from the upper 2 inches (5 cm) of soil at the bottom of the excavated area, were taken on November 30, 1981 in sample area FRC - 1 (see Figure 12).

Subsequently, Bohager was directed not to work in the FRC - 1 area and worked in the remaining southwest portion of the site for the next week and a half. According to Metcalf and Eddy, the contaminated materials had either been dumped onto or had seeped into

Figure 12. Composite Sample Area FRC-1, Hot Fire Pit Disposal Area



Source: Metcalf & Eddy, July 1982

the fractured bedrock in the southwestern section of the landfill. State inspectors agreed on December 10 that the practical limit of excavation had been reached in this area, and Bohager stopped work. Fairchild Republic records showed that Bohager removed 2,741 cubic yards (2,096 cu.m) of contaminated material. Total amount removed by Bohager and Diggs was 5,169 cubic yards (3,952.4 cu.m).

Composite soil samples were taken from sample areas FRC-2 and FRC-3 (see Figure 12). The composite samples were analyzed by Gascoyne Laboratories, Inc. of Baltimore, Md., using EPA's EP toxicity test, for extractable total and hexavalent chromium, the chosen indicator contaminant. According to Metcalf and Eddy, the results indicated that "all three composite samples did not excced (sic) the maximum concentration of contaminants for characteristics of EP Toxicity (i.e., 5.0 mg/1) for total hexavalent chromium." These results were then submitted to the state with a request for written agreement that a sufficient amount of contaminants had been removed and approval to install the clay cap.

The results are shown in Table 1 below:

TABLE 1. RESULTS OF EPA-EP TOXICITY TEST ON SOIL SAMPLES FROM EXCAVATION

	Sample Area		
Constituent	FRC-1	FRC-2	FRC-3
Total chromium	0.00	0.14	0.69
Hexavalent chromium (measurements in mg/1)	0.00	0.11	0.48

Source: Metcalf and Eddy, Inc. July 1982.

Backfilling and Capping

A clay layer approximately 2 feet (0.6 m) thick was placed directly on the exposed bedrock and compacted to retard penetration of rainfall and prevent further movement of contaminants into the ground water. The pit was then backfilled with clean soil and crushed rock and compacted. A clay cap was then installed according to Metcalf and Eddy's specifications for materials, density, permeability and compaction.

300.70(b)(1) (iii)(A) impermeable barrier

300.70(b)(1) (ii)(A) surface seal

The clay cap was installed in two stages by Bohager Waste Systems. Before beginning work, Fairchild Republic obtained verbal authorization from state inspectors. The first stage occurred on December 10, 1981, when the northern part of the landfill area was capped (see Figure 12- the area capped corresponds roughly to sample area FRC - 1). Equipment used included a roller, a front-end loader and three dump trucks.

The second stage of capping occurred during the week of April 12, 1982. Metcalf and Eddy reported that the almost 4 month delay was due to poor weather conditions during the winter and early spring months. Fairchild Republic received written approval from state officials prior to placing the remainder of the cap. The cap covered the southern part of the landfill area (see Figure 11-the area corresponds roughly to sample areas FRC-2 and FRC-3). Bohager used a roller, two-wheel vibrator, front-end loader and dump trucks.

Grading, Topsoil and Seeding

300.70(b)(1)
(ii)(C)
grading

(300.70(b)(1)
(ii)(D)
revegetation

The clay cap was graded to encourage run-off and thereby minimize surface ponding. In addition, it lessened the opportunity for vertical infiltration should percolating rainfall reach the clay barrier. A perimeter drain was installed around the facility to further minimize the movement of run-off water onto the decontaminated site. A topsoil cap of approximately 6-8 inches (15.24 - 20.3 cm) was placed over the clay and seeded with a grass-legume mixture. The purpose of the soil was to preserve and protect the integrity of the clay layer, while the grass helped eliminate erosion of the topsoil and reduce the amount of water reaching the clay cap by optimizing evapotranspiration. Monitoring wells previously installed by the state and Metcalf and Eddy were used to collect ground water samples and determine the overall long-term impact of the response action.

COST AND FUNDING

Source of funding

300.68(c)
private
clean-up

Fairchild Republic paid for the entire response action. The company also reimbursed the state for certain costs, such as the installation of monitor wells and the analysis of soil and water samples.

Selection of Contractors

Fairchild Republic hired Metcalf and Eddy, Inc., of Boston, Massachussetts as consulting engineers for the site investigation and response action. This firm was hired on a sole source, fixed price contact because of its reputation and its familiarity and prior work experience with Fairchild's Hagerstown facilities. Metcalf and Eddy conducted soil and hydrogeologic investigations of the Hot Fire Pit area, developed alternative remedial action plans for the clean-up, conducted routine inspections of contamination levels during the remedial action, and submitted a closure report to Fairchild Republic with recommendations for a post-closure monitoring program.

In August 1980, Fairchild Republic initiated a competitive bid process to select a contractor to perform the remedial action. Fairchild solicited bids from six contractors, three of which submitted proposals. One of these proposals was considered not responsive because it failed to identify a state and federally approved disposal site as required by the RFP specifications. These specifications also required the contractor to have a state license to transport hazardous waste, and to comply with federal and state hazardous waste laws. Bids were based on cost per cubic yard of contaminated soil to be excavated, plus the costs of backfill and capping materials. Fairchild Republic hired Diggs Sanitation of Cumberland, Md, as lowest bidder. Diggs began excavating contaminated soil and materials in April 1981 under the direction of Metcalf and Eddy. At about that time, the state discovered that Diggs Sanitation was illegally diposing of the contaminated soil and materials. The state arrested Mr. Diggs, the president of the company, and charged him with violations of Maryland's hazardous waste laws. This led to an order by Fairchild Republic for Diggs to stop work. Diggs' contract performance was suspended from April 1981 until August 1981, when the contract was terminated. Diggs' hauler's license was revoked through a state administrative action. Later, Diggs was convicted in the Allegheny County Circuit Court in December 1981 of civil and criminal charges related to the incident.

When Diggs was charged with illegal disposal of hazardous wastes, Fairchild hired Bohager Waste Systems in the summer of 1981 to complete the remedial action. Chosen through a competitive bid process, Bohager was not the lowest bidder, although its bid was in the competitive range. It was selected because it had a good reputation and planned on using Browning Ferris Industries (BFI) as the disposer. Fairchild preferred the BFI facility to other licensed landfill sites. To transport the excavated waste, Bohager subcontracted with three haulers at varying prices. Bohager accepted higher hauling costs in order to minimize the total site clean-up time. It hired reputable haulers who would continuously remove the wastes as they were exhumed. Information about the identify of these haulers and the prices they charged was not available.

Project Costs

According to an estimate by Metcalf and Eddy, the total expenditure for the Hot Fire Pit clean-up was $450,000. Of this figure, $107,000 went to Metcalf and Eddy for engineering services, leaving $343,000 for the excavation and removal work. That sum can be broken down further into charges of $90,000 and $253,000 by Diggs Sanitation and Bohager Waste Systems, respectively. The major elements of the total cost are presented in Table 2. Because the excavation, transportation and disposal work was conducted by two contractors with different sets of costs, the expenditure in terms of unit costs for this work is not available. However, it is possible to assume that Bohager Waste Systems conducted the entire operation and that its unit costs rather than Diggs' represent the true unit costs required for properly conducting the operation. This assumption seems plausible since Diggs' costs were low because of his illegally disposing of the contaminated matrials. If the quantity of materials removed by Diggs are multiplited by Bohager's unit cost this portion of the work would have cost $180,886, over twice the amount charged by Diggs.

While these assumptions are necessary to derive meaningful unit costs, it should be noted that this approach generalizes over the entire project, whereas, in fact, the actual cost components of the remedial action were adjusted by the contractors. Fairchild Republic officials reported that when one cost component ran higher than Bohager had proposed, the contractor would try to eliminate some of the expenditure in another component by modifying its implementation of the work plan. For example, since excavation expenditures were greater than projected, Bohager decided to use less topsoil than was originally specified in Metcalf and Eddy's work plan. These alterations, however, did not significantly deviate from the workplan.

Unit costs for backfilling, clay capping and seeding were taken from the contract between Bohager Waste Systems and Fairchild Republic. Costs for grading were included in the cubic yard unit prices for backfill, clay and topsoil.

TABLE 2. SUMMARY OF COST INFORMATION-FAIRCHILD REPUBLIC CORP., HAGERSTOWN, MD.

Task	Quantity (a)	Estimated Expenditure (b)	Actual Expenditure	Variance	Unit Cost (c)	Funding Source	Period of Performance
Excavation, transportation and disposal Diggs Sanitation (transportation distance NA)	2,428 yd^3 (1,856.4m^3)		$90,000		$37.07/$yd^3$ (48.48 m^3)	Fairchild Republic	10/80-4/81
Bohager Waste Systems (transportation distance: 70 mi. 112 km)	2,741 yd^3 (2,096 m^3)		$204,204.50		$74.50/$yd^3$ ($97.43/$m^3$ ($1.06/$yd^3$/mi) ($0.87/m^3/km	Fairchild Republic	11/81-4/82
Subtotal	5,169 yd^3 (3,952.4m^3)	$340,200	$294,204.50	$45,995.50	$56.92/$yd^3$ ($74.44/$m^3$)	Fairchild Republic	10/80-4/82
Backfilling	NA		NA		$7.50/$yd^3$ ($5.73/$m^3$)	Fairchild Republic	
Clay cap	NA		NA		$9.75/$yd^3$ (7.45/m^3	Fairchild Republic	
Topsoil	NA		NA		$10.25/$yd^3$ (7.84/m^3)	Fairchild Republic	
Seeding	NA	NA	NA		$0.40/$ft^2$ ($0.12/$m^2$)	Fairchild Republic	
Subtotal		$40,000	$48,796	$8,796		Fairchild Republic	12/81-4/82
Engineering, sampling and chemical analysis		$35,000	$107,000			Fairchild Republic	11/79-7/82
Total		$415,000(d)	$450,000	$35,000		Fairchild Republic	11/79-4/82

NA = Not available

(a) from Fairchild Republic records

(b) from Metcalf and Eddy workplan, May 1980 which assumed that 4,800 yd^3 (3,670 m^3) would be excavated, transported 75 miles (120 km), and disposed of at $50/$yd^3$ ($38.23 m^3)

(c) from contract between Bohager Waste Systems and Fairchild Republic (except unit cost for work by Diggs Sanitation)

(d) does not include contingency of $35,000 (20% contingency applied to all items except disposal cost)

Two important unquantifiable costs were encountered. The major unquantifiable cost was the 6-month delay due to the dismissal of Diggs Sanitation. The actual costs attributable to finding a new contractor, preparing for Diggs' trial, and the inflationary costs of construction over a longer project duration, are not available. Another unquantifiable factor was that the Washington County Health Department warned several residents whose non-drinking water supply wells were adjacent to the landfill area that total chromium contamination was just above the U.S. EPA drinking water standard of 0.05 ppm. But the public health officials could not recall if any wells were subsequently closed. Fairchild Republic did, however, install softeners and filter systems in several affected wells.

Future costs associated with the hot fire pit dump will consist of ground water sampling at several monitoring wells and at some nearby private wells. Precise costs are not available.

PERFORMANCE EVALUATION

The response action at the Fairchild Republic plant is a good example of private and public cooperation to mitigate the threat posed by an uncontrolled hazardous waste site. When the Hot Fire Pit dump was discovered, the company promptly hired Metcalf and Eddy to investigate the site and cooperated with the state to monitor soil and ground water and develop a remedial action plan.

State officials did not intervene in the remediation, but instead allowed Fairchild Republic to carry it out subject to state monitoring and approval. In return, Fairchild Republic generally executed the remedial steps in an efficient and cost-effective manner. The only set-back was the performance of Diggs Sanitation, the first contractor. Diggs later was found to be disposing of waste improperly. After a delay, Fairchild Republic selected Bohager Waste Systems to continue the operation. This time Fairchild officials did not select the lowest bid, preferring to assure themselves of both a reputable contractor and a reliable disposal site for the waste.

A potentially significant concern about this response action is that the change of contractors resulted in a 6 month delay in work, during which time the excavation area remained open and exposed.

Effectiveness of Clay Cap

Regarding the technical aspect of the response, removal of contaminated material and capping with a clay layer can be an effective long-term solution for a contaminated site such as this one. Several factors should be considered in assessing the effectiveness of this technique at this site: the extent of bedrock contamination, the solubility of the waste materials, and the existing level of ground water contamination. Each of these issues will be discussed in turn.

During the removal of contaminated surface material, Metcalf and Eddy determined that fractured bedrock zones were contaminated, to a certain degree, with precipitated heavy metals. The precipitation of the heavy metals is enhanced by limestone and dolomite bedrock because of the high pH associated with these formations. If heavy metals have precipitated they will remain as an insoluble fraction of the bedrock until dissolved or solubilized by the ground water. It would have been possible, although extremely difficult and expensive, to remove the bedrock material. In this case, substantial major construction involving blasting and heavy construction equipment would have been required. It is questionable whether sufficient benefit would have been derived from this approach. Further, it also may have been possible to pump the ground water and treat it for removal of the contamination. Although appropriate in certain circumstances, it seemed unnecessary in this case since the ground water is currently not being used locally as a drinking water supply. If the ground water is used as a drinking water supply source in the future, it may have to be treated, depending on the relevant potable water standards.

The volatile organics found on the site are typically highly soluble and very mobile in water. Because the limestone formation at Fairchild Republic did not significantly impair this solubility, the total amount of organics dissolved in the ground water should remain constant or decrease with time. There may exist pockets of concentrated organics in the ground water which, because of reduced ground water movement, would be measured in monitor well samples for several years. However, most of these should volatilize, degrade chemically or biologically, or be diluted in the ground water over time, although there is no accurate way of determining the amount of organics in the ground water or their expected behavior for this specific site.

Excavation of Volatile Organics

There are several important considerations with respect to the effectiveness of the construction activities of the remedial action. In any remedial action involving excavation, it is essential that the nature of the volatile organics be checked to assure that they are nontoxic to the working environment and will not cause atmospheric pollution. During the removal operations, large quantities of volatile organics were evolved through evaporation into the atmosphere. For this particular site, though, there was little concern over this evaporation since on-site air samples indicated that the vapors encountered were at non-toxic concentrations.

During construction it is also necessary to assure that there is sufficient control of contaminated soil. The movement of heavy construction equipment can cause dust to be carried in dry periods by winds to surrounding areas. This dust should be controlled by covering the trucks that will haul the material from the area and by periodic wetting of the construction site. Contaminated soil can also be lost during wet conditions, through the tracking of large equipment; some of the muds on the site can leave the facilities on the tires or treads of the heavy equipment working in the area. There was little apparent control of contaminated soil during this excavation, other than management of stockpile size and construction of a small berm and diversion ditch.

The effectiveness of this remedial action is also dependent on the potential increase in ground water contamination due to the direct exposure of the sludge or contaminated material to rainfall. If heavy rainfall occurs during the period of construction, it is possible for contaminated material to move vertically downward and increase the pollution of the ground water. Plastic sheets might have reduced the amount of leachate created by intercepting rainfall. Such temporary capping measures would have been especially useful during the six month delay during 1981, as well as other potential exposures to rainfall.

Since the movement of ground water is relatively slow, there is some probability that this wash out would not be observed in local monitoring wells for several weeks or months subsequent to the event. In this case, there was frequent rainfall during the excavation period, yet only one ground water monitoring well showed an increase in the level of contamination. The others decreased, possibly due to dilution.

Long-term Concerns

The long-term concerns regarding the effectiveness of this action are (1) the extent of contamination of the fractured limestone and dolomite beneath the site and (2) the influence of vertical ground water fluctuations on the leachability of the metals. While the percolation of rainfall through the contaminated zone has been eliminated, the variation in the elevation of ground water is not so easily controlled. The continuous natural rising and falling of the ground water elevation associated with both rainfall events and seasonal variations will periodically expose the contaminated fractures to lower pH conditions, thereby dissolving some of the metal precipitates. As a protective measure, a grout curtain could be installed, although it might not be effective in preventing the metal from precipitating because voids could still exist in the bedrock after installation of a curtain.

In addition, although it was not a principal part of the remedial action plan, since this study focuses on the landfill clean-up, the removal of contaminated material from the sludge lagoons should be considered in terms of the overall effectiveness of the site clean-up. No study or formal plan for decontamination of the lagoons was made. Based on the available information, the lagoons were unlined but probably underlain by the natural clay that predominates throughout the area. No known analytical testing was made of the site soil subsequent to material removal and prior to clay backfilling. Visual inspection was apparently used to assure complete material removal. The effectiveness of this approach was, in all likelihood, comparable to the landfill remedial action, although no analytical data other than monitoring well samples exist to support this conclusion.

Level of Chromium Contamination

Overall, the excavation technology appears to have been effective in reducing the chromium contamination. Following completion of the action, there was continual decrease in chromium levels observed in the samples from ground water monitor wells. The highest value reported prior to this writing was less than 0.05 mg/l hexavalent chromium. Although no precise objective was set, if monitoring data continues to reveal total chromium contamination at less than 0.05 mg/l, the clean-up probably will have been effective. Given the limited data on the organic chemical contamination, an accurate assessment of the organic chemical removal cannot be made at this time.

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GENERAL ELECTRIC

OAKLAND, CALIFORNIA

INTRODUCTION

NCP Reference

The General Electric site in Oakland, California, occupies about 24 acres (9.7 ha) in a mixed use industrial-residential-commercial area in the southwest section of the city about 1-1/2 miles (2.4 km) east of San Francisco Bay. An estimated 20,000 gallons (75,700 l) of polychlorinated biphenyls (PCBs) and petroleum based 10-c oil were spilled onto the property at various times during the production and repair of transformers from 1927 to the late 1970's. PCB-oil was found on-site in soils from shallow to intermediate depths and within subsurface sand and gravel lenses. Of the initial 12 on-site monitoring wells sampled, 2 were found to contain PCBs in the water at levels of 0.63 and 15.0 parts per billion (ppb). PCB contaminated ground water was not found off-site but the large volume of the PCBs on-site caused concern within State agencies about the off-site migration potential. In the storage and loading areas nearby, virtually all unpaved soil had PCB concentrations of greater than 5 parts per million (ppm) and hot spots of 11,000 ppm PCBs were found.

300.66(c)(2)-(iii) migration potential

Background

Spills, leaks and disposal of PCB contaminated material occurred throughout the 50 year period of Pyranol use at the Oakland GE site. Use of the insulating fluid called "Pyranol," consisting of equal portions of PCBs (Aroclor 1260) and trichlorobenzenes, began in the early 1930's and peaked in the mid 1950's. After 1968, when transformer production at the site ceased, only a minimal amount of Pyranol was used on site for the repair of warrantied transformers. The last year of PCB use at the facility was in 1975 when the last drum of Pyranol was delivered from Monsanto Industrial Chemicals Company. Sources of site contamination during this period included:

- Leaks in tanks that sometimes went undetected

- Trench burial of liquid PCBs and contaminated solids such as dialectric paper

- Pyranol spills from a mobile filtering unit that would occasionally "blow" from too much pressure

- Discharges from a lab sink that emptied out onto the ground, following the collapse of a septic tank.

The total amount of Pyranol beneath the site was estimated at about 20,000 gallons (75,700 l).

In response to a complaint from a GE employee about mishandling of PCBs that were spilled on a truck bed, a California Department of Health Services (DHS) inspector toured the site to view their PCB handling procedures on July 20, 1979. He found no improper handling of PCBs on-site, but was asked by the employee to reinspect. On July 30, 1979, he reinvestigated the site and took soil samples of two oily areas, which were found to have 63 and 170 ug/g PCB (analyzed for Aroclor 1254). Upon interviewing the plant manager, who had worked at the site since the late 1940's, he learned that no Pyranol was presently stored in bulk. However, two 1000-gallon (3785 l) tanks had been used to store Pyranol on the east side of Building 2 (see Figure 4) but they had been removed in 1976. These discoveries led to the site study by GE and their consultant and the immediate mitigation measures that followed.

300.63(a)(4) discovery

Synopsis of Site Response

In the fall of 1981 the immediate mitigation plan was implemented, consisting of a French drain collection system, treatment of contaminated ground water, surface sealing and runoff control. A three-armed French drain and sump were installed to create a cone of depression where the oil-contaminated ground water mound had formed under the tank farm. The surface sealing involved a soil-bentonite cover on the unpaved contaminated areas with a gravel cover to prevent its erosion. Runoff was controlled by installing curbs and gutters throughout the site to ensure that precipitation would not become contaminated before discharge into a storm sewer.

Constructing the French drain and treatment system was the primary activity in the immediate mitigation plan. Two of the French drain's three arms extend on either side of the tank farm site, and the third was placed from the central sump directly away from the tank farm. The trenches are about 25 feet deep (7.6 m) and are filled

300.70(b)(1) (iii)(D)(1) subsurface drain with gravel. Slotted PVC collection pipes are located at depths of 25 feet (7.6 m), 22 feet (6.7 m) and 19 feet (6.8 m) and run into the sump, which is 29.5 feet (8.85 m) deep. The oil floating on the water in the sump is pumped with a skimmer to a FRAM oil/water separator and pumped into a storage tank. The remaining oily water is then pumped through a water treatment system before being discharged into the East Bay Municipal Utility District (EBMUD) sewer system.

SITE DESCRIPTION

The General Electric site is located in Alameda County, California, approximately one mile east of San Francisco Bay at 5441 East 14th Street, Oakland (see Figures 1-A and 1-B). The latitude and longitude coordinates for the facility are 37°45'56" and 122°12'15", respectively.

Surface Characteristics

The local climate is characterized as being mild marine or Mediterranean with little fluctuation in temperature. The average winter temperature is 50°F. The temperatures during the summer months average around 63°F. The annual average temperature for the area is approximately 57°F. Temperatures during the month of January have been known to reach the low 20's. On the average, freezing temperatures occur 7 to 10 days each year over the county. During the summer months, temperatures have risen as high as 115°F. Maximum temperatures of 90° or higher occur about 4 days per year in the immediate San Francisco Bay area.

300.67(c)(6) weather conditions

300.68(e)(i)(E) climate

There is a wide variation in the seasonal precipitation in the site area. Most of the precipitation falls between the months of November and March; very little precipitation occurs during the remainder of the year. Localized showers are infrequent, most of the rain falls during winter storms that move through the area. These storms are usually of moderate duration and intensity but there are times when precipitation is heavy enough or persistent enough to cause flooding. Mean annual precipitation is approximately 19 inches (48.2 cm) occurring mostly during the 5-month period of November through March.

Relative humidity during the winter months averages between 85 and 90 percent at night and drops to 60 or 70 percent during the afternoon. The humidity is less during the spring and summer seasons but the driest time of the

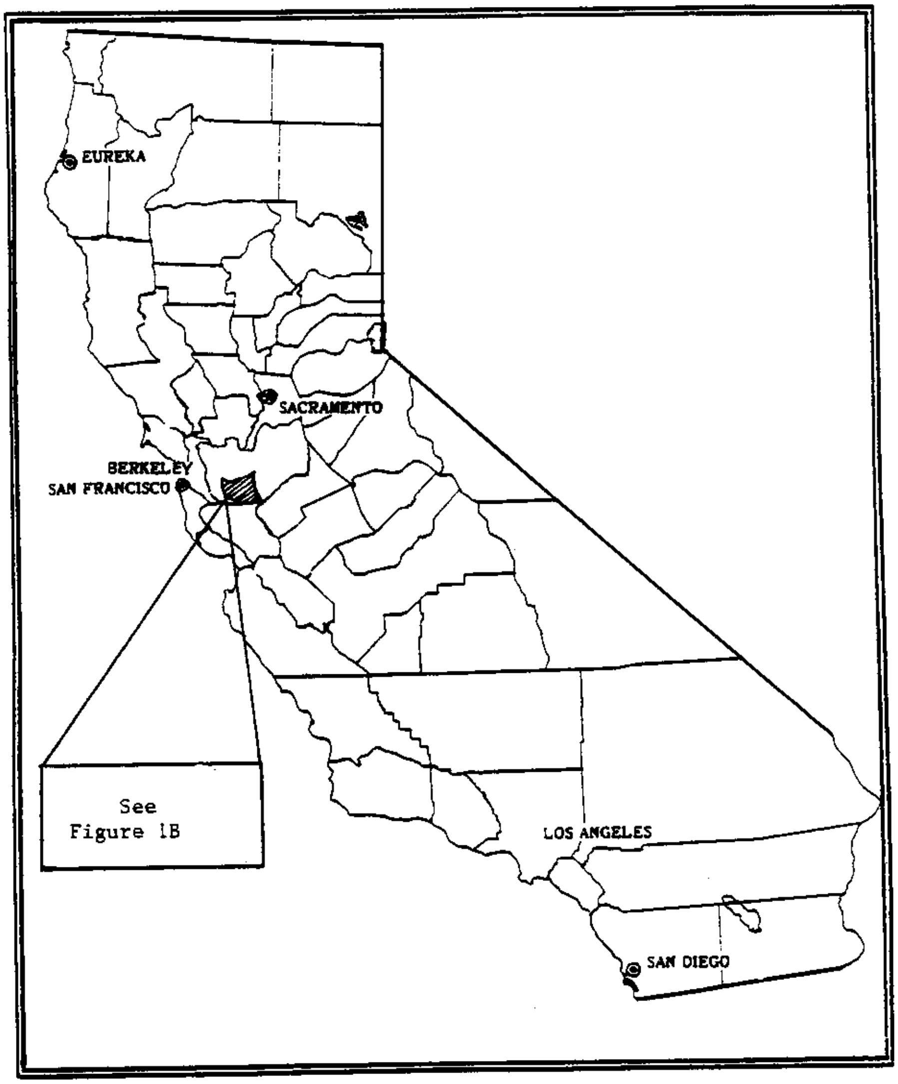

Figure 1-A. General Electric Facility Location

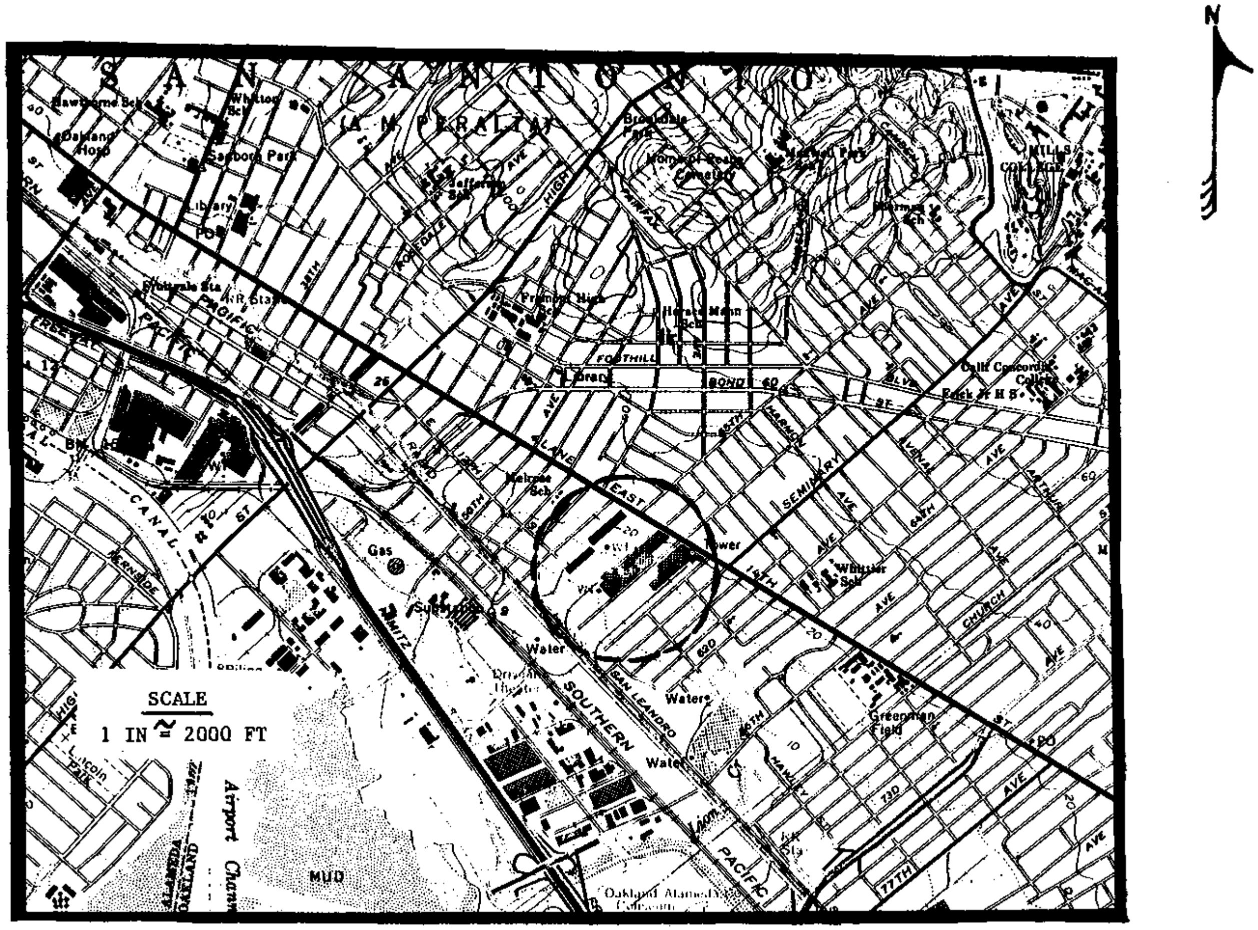

Figure 1-B. General Electric Facility Location

year is autumn, when humidity ranges from 50 percent during the daylight hours to 70 percent during the night.

Winds are predominantly westerly, from the ocean, across the bay and toward the San Joaquin Valley. Strong winds are unusual. Windspeeds are less than 6 miles (30.6 km) per hour for more than 50 percent of the time and exceed 12 miles (19 km) per hour for only 10 percent of the time. The annual average wind velocity is about 8 miles (13 km) per hour.

The site is located in a coastal region characterized by subdued topography. Elevations across the site range from 20 feet (6m) on the northeast boundary at East 14th Street, to approximately 8 feet (2m) along the southwest boundary along the Western Pacific Rapid Transit railroad line. In general, the drainage across the site area is southerly with surface runoff eventually emptying into San Francisco Bay. The entire facility is located within a 100-year floodplain. Flooding may be caused by runoff produced by high-intensity precipitation on the Berkeley Hills to the east.

The facility property is bounded on the southwest and southeast by industrial development. The northwest and northeast sides are bounded by residential and commercial properties, respectively.

The native soils on-site consist of dense alluvial deposits composed of various percentages of silt and clay materials. Overlying the native soil, across much of the site, is artificial fill composed of a mixture of sand, gravel, building debris and crushed rock. The fill material ranges in thickness from 0 to about 5 feet (0-1.5m).

Hydrogeology

300.68(e)(2)(i)-(D) hydrogeological factors

On-site stratigraphy is a complex sequence of tightly packed silty clay and discontinuous sand and gravel lenses. These deposits are members of the San Antonio formation and continue to unknown depths beneath the site. The depth to the nearest confined aquifer is approximately 230 feet (70 cm). A typical geologic cross-section of the site area to a depth of 60 feet (18 m) appears as shown in Figure 2.

Due to the discontinuous nature of the strata beneath the site, the ground water flow system in the area is defined here as a single homogeneous unit extending to a depth of 60 feet (18 m) for the purpose of calculating average vertical and horizontal permeabilities and ground water flow rates. The average vertical permeability for

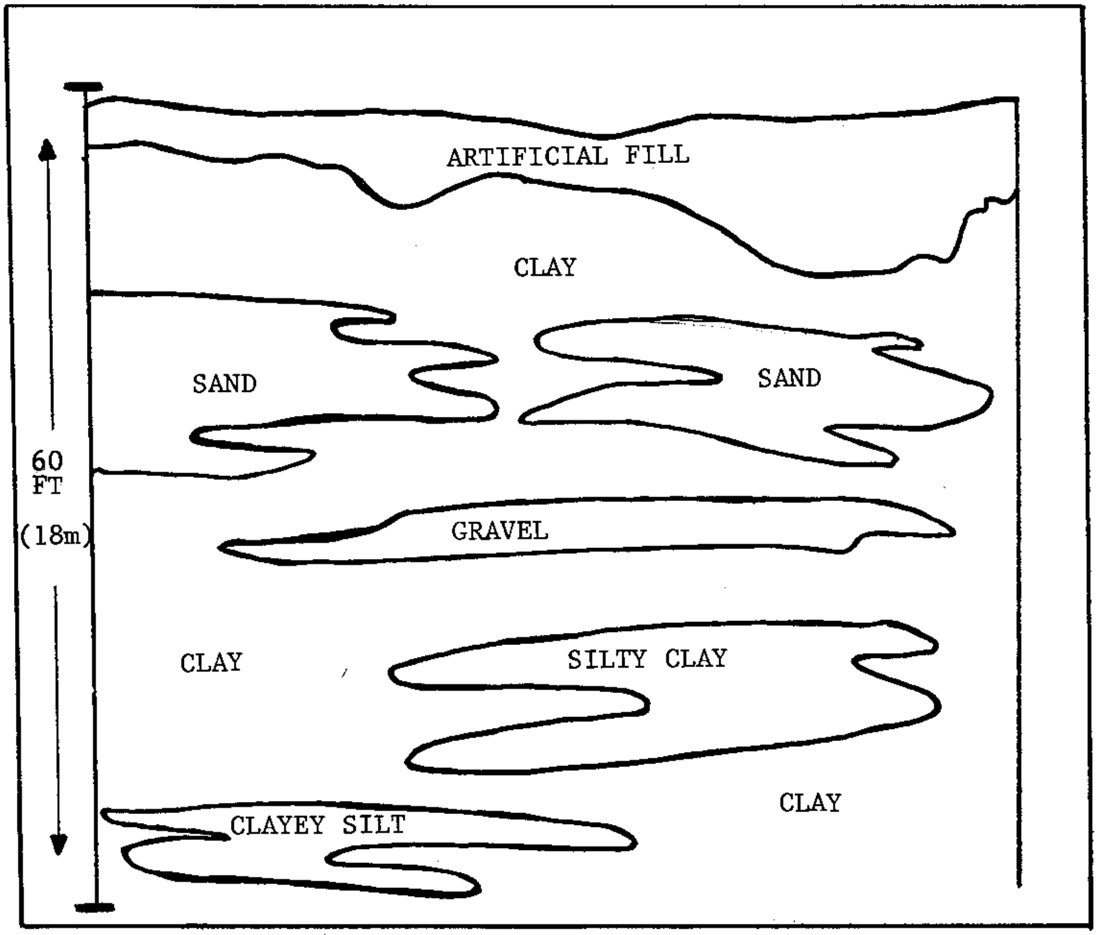

Figure 2. Typical Geologic Cross Section of the G.E. Site Area

on-site material from 0 to 60 feet (0-18 m) is 5×10^{-8} cm/sec. The average horizontal permeability is 3×10^{-4} cm/sec. The direction of ground water flow within the upper 60 feet (18 m) of on-site material tends to be away, in all directions, from a ground water mound identified at the northern most corner of the tank farm (see Figure 3). Large fluctuations have been noted in levels of the ground water mound between December (dry season) and April (rainy season). It seems likely that the mound is produced by rainfall collecting in the diked tank farm area and infiltrating slowly into the ground.

There is slight vertical downward ground water movement extending to the northeast of the site but with exception of this area, all flow appears to be occurring horizontally. The average flow velocity is in the range of 5×10^{-4} and 5×10^{-3} cm/sec.

Ground water levels in the site area vary between approximately 5 and 30 feet (1.5 and 9 m) below the ground surface. The shallowest ground water levels have been identified in the southwest area of the site. The site's northern section has much greater ground water level values. This difference in ground water levels across the site is the result of the extent to which the site's natural surface has been covered over by either buildings or asphalt pavement. Asphalted surfaces and existing buildings overlie deeper ground water levels because infiltration is not able to occur. Recharge areas, those in which precipitation can directly contact the natural ground surface and infiltrate downward, tend to have more shallow ground water levels. The amount of infiltration directly affects ground water levels across the site area.

It has been estimated that ground water across the site moves vertically downward at a rate of .002 ft/day (.061 cm/day) or 30 feet (9 m) over a 40 year period.

WASTE DISPOSAL HISTORY

The General Electric Oakland facility began operating in 1924 and has since undergone numerous expansions, additions and demolitions. One of the more critical expansions made at the facility involved the installation of an additional oil storage system to store Pyranol. The introduction of Pyranol as a transformer insulator/coolant required a greater facility oil storage capacity separate from the 10-c oil system installed in the 1920's. Ten-c oil (also called transil oil) is a mineral oil that was used as a dielectric fluid for transformers prior to the introduction of Pyranol. Thus during the early 1930's,

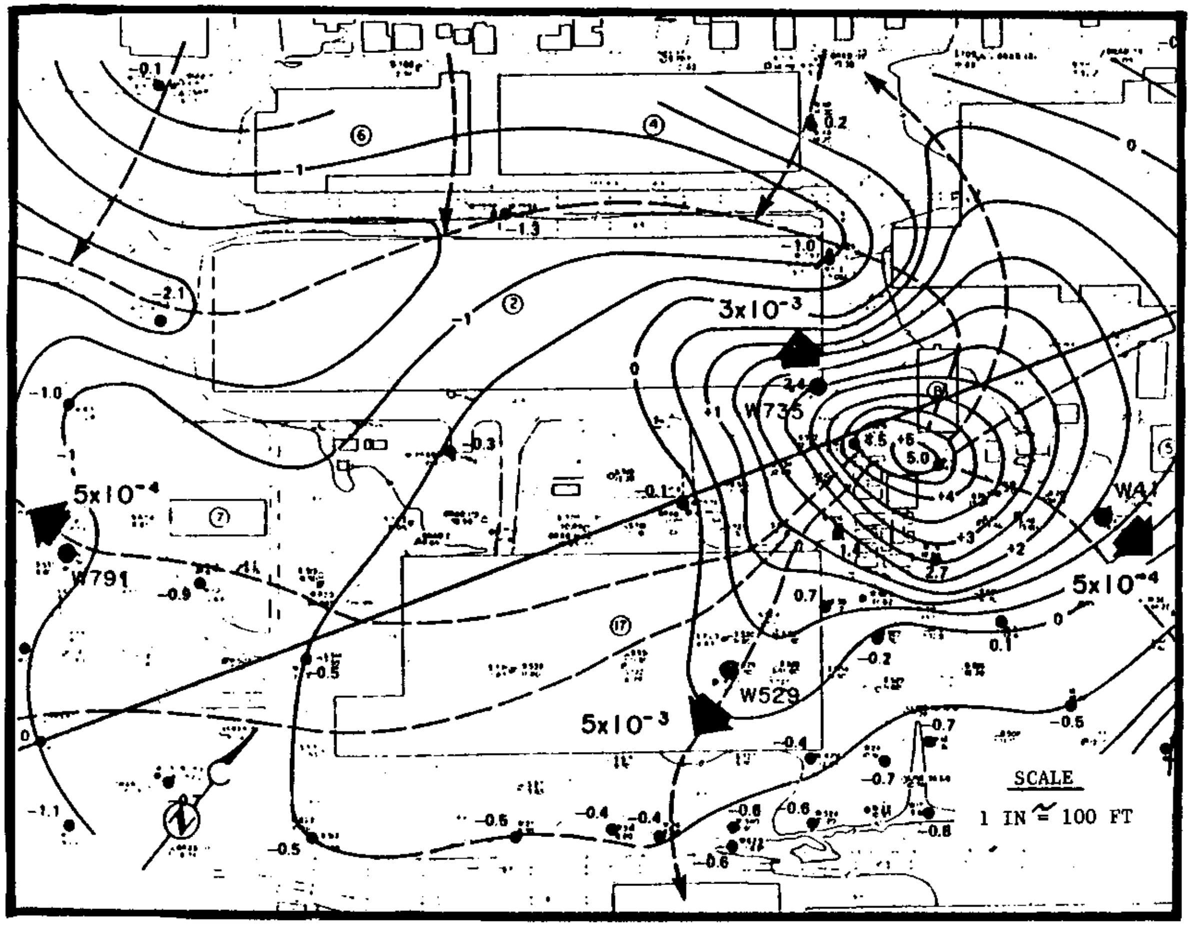

Figure 3. Groundwater Flow Direction
(Source: Final Phase II Report, G.E., Co., CA, June, 1981)

two 5,000-gallon (18,927 liter) oil tanks were installed aboveground at the northeast corner of the present Building 2 (see Figure 4). These tanks were used exclusively to store Pyranol.

The growth of the Pyranol-filled transformer market paralleled the growth of industrial and high-density construction in the region. However, as Oakland facility's total capacity increased over the years, the levels of Pyranol usage at the Oakland facility actually decreased, due to increased efficiency of the manufacturing process.

Monsanto Industrial Chemicals Company of St. Louis served as the facility's sole Pyranol supplier. Their shipments of Pyranol to the GE facility between 1954 and 1975 varied from a high of 9,245 gallons (35,038 l) per year in 1959 to a low of 55 gallons (208 l) per year in 1975.

The production of Pyranol-containing transformers was finally terminated at the Oakland facility in 1964, however the facility continued to service units under warranty until the transformer manufacturing plant was closed in 1975.

During the facility's operation, Pyranol was pumped from 5,000-gallon (18,950 l) tank cars into two 5,000-gallon (18,927 l) storage tanks to the rear of Building 1. From these tanks the Pyranol was transported through an underground system to the rear of Building 1. Since the plant closed in 1975 the Pryanol tanks have been cleaned and relocated to be used for waste oil storage.

The tank farm, located near the northern corner of Building 17, (see Figure 4), consisted of eleven tanks when the facility closed down in 1975. Three of the tanks were used for Varsol (petroleum-based thinner) and the remaining eight held 10-c oil.

300.68(c)(2)(i)(B) amount and form of substances present

Disposal of both solid and liquid wastes took place at the GE Oakland facility over their operational period. During the years prior to 1940 when the facility manufactured a number of products, a significant amount of solid waste resulted from the production of motors. The solid waste accumulated and was eventually buried in a trench that was excavated in the general vicinity of what is presently Building 17 (see Figure 5, Area 1), and a second trench in the southwest area of the site (Figure 5, Area 2). The burial of solid waste ceased in the mid-1960's.

Liquid waste at this facility consisted primarily of waste 10-c and Pyranol oils. There were two locations

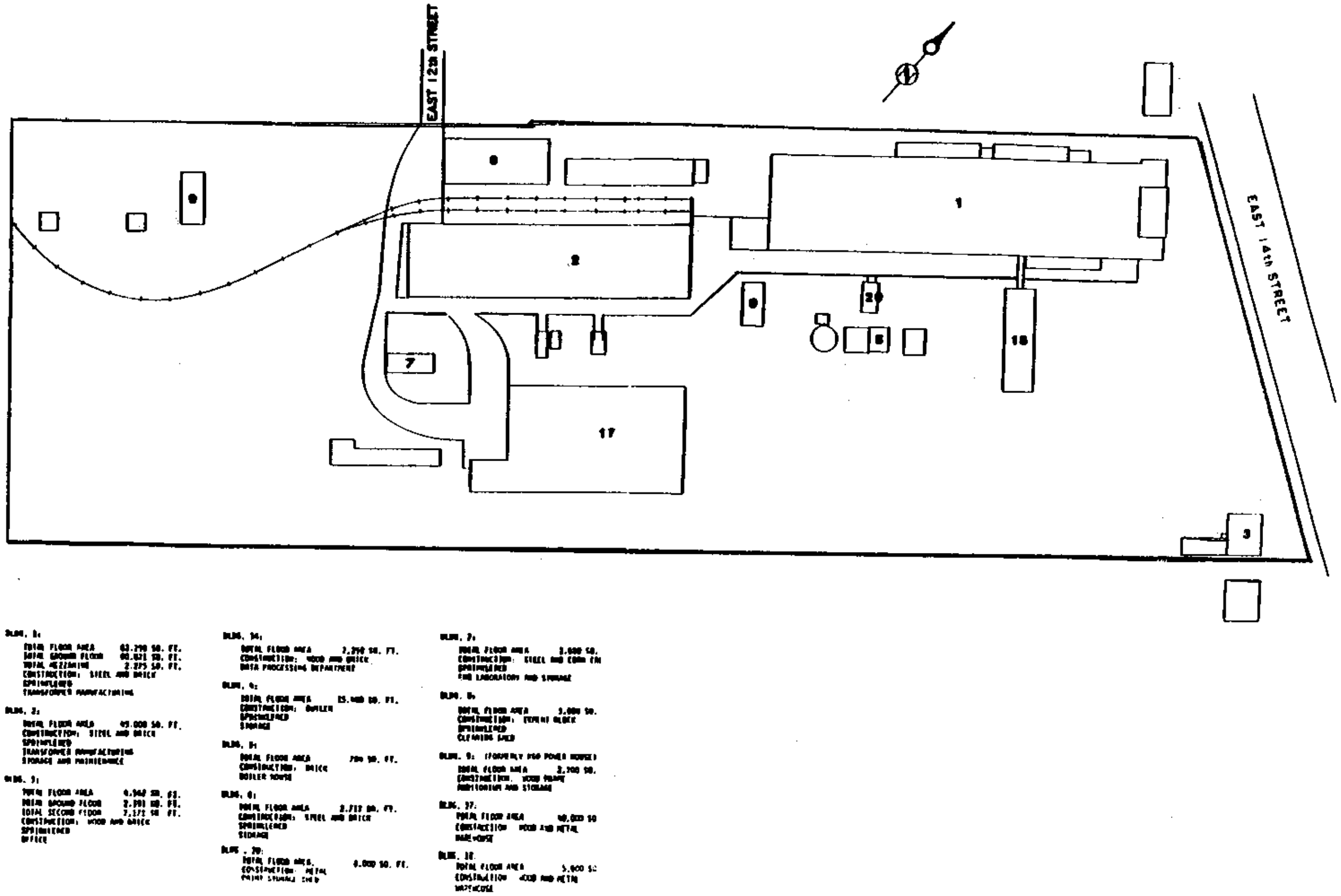

Figure 4. General Electric Site Layout

(Source: Final Phase II Report, G.E., Co., CA, June, 1981)

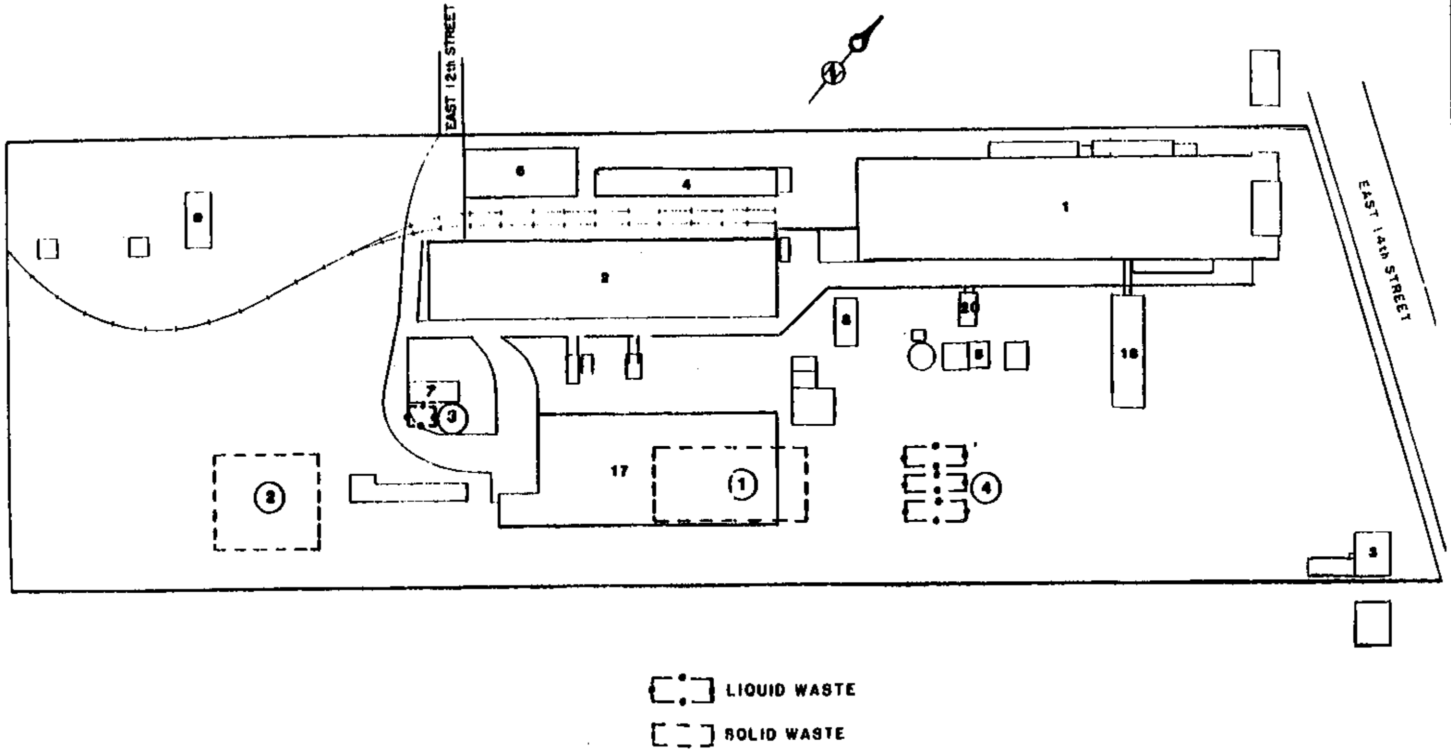

Figure 5. Liquid and Solid Waste Locations

(Source: Final Phase II Report, G.E., Co., CA, June 1981)

on-site where liquid waste was disposed. Area 3, adjacent to Building 7 in Figure 5, most likely received small quantities of both 10-c and Pyranol oils, as they were both brought to the quality control laboratory for testing. The laboratory sinks, into which oil samples were emptied, initially drained into a septic tank. However this septic tank eventually collapsed and the sink then drained directly to the ground surface and any waste oil from the laboratory either the infiltrated to subsurface or combined with rainfall runoff. This practice ceased in the early to mid-1960's when 55-gallon (208 l) drums were provided for test sample disposal.

300.66(c)(2) inspection

The main location where waste oils were disposed was a trench, designated as Area 4 in Figure 5. The trench was excavated in the late 1940's for the purpose of waste burial, after attempts to burn 10-c and other waste oil in plant boilers were unsuccessful. Waste oil burial practices ceased in the early 1950's when it became plant policy to store the oil in drums and tanks and sell it regularly to oil disposal contractors. Until the mid-1950's, there was no attempt made to separate the Pyranol from the waste 10-c oil. The two waste oils were accumulated together in tanks and drums located in the tank farm. Around 1955, the disposal contractors asked that the two oils be kept separate. The GE management agreed to carry out the request.

300.66(c)(2)(ii) assessing hazardous substances

Liquid waste spills most likely occurred where the waste oil was handled, i.e., pumped, filtered or transferred, in significant volumes. Three areas where these types of activities were undertaken are shown on Figure 6. Each area is described briefly below.

Area 1 - comprises the tank farm; a diked, unpaved enclosure which consisted of 11 tanks and associated pumping, mixing and filtering equipment; due to frequency of operation and the volume of oil handled, it was this area where majority of spills occurred.

Area 2 - includes the ground surface in vicinity of the two 5,000-gallon (18,950 l) Pyranol tanks and the forward end of the rail pit where oil cars were unloaded by pumping.

Area 3 - consists of the southwest end of what is presently Building 1; the least likely area to have had significant oil spills, however there is the chance that minor leakage occurred during oil-warming operations inside the building.

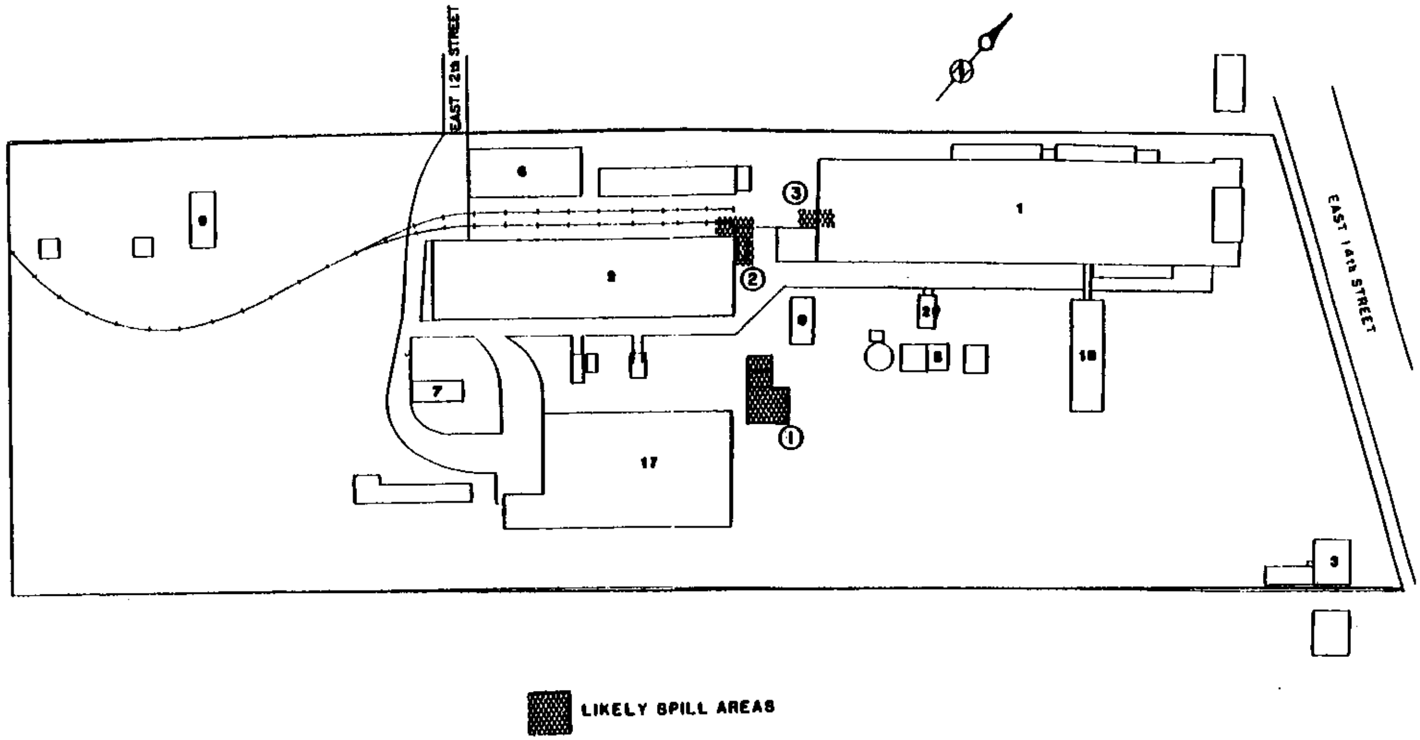

Figure 6. Spill Areas

(Source: Final Phase II Report, G.E., Co., CA, June 1981)

On July 20, 1979, a representative from the Hazardous Materials Management Section of the Department of Health Services (DHS), visited the GE facility in response to a complaint made by a GE employee concerning improper handling of PCBs at the site. At this time, the DHS representative found no reason to believe PCBs were being mishandled. The GE employee who initially contacted the DHS was not satisfied with this conclusion and requested that a second inspection be conducted. On July 30, 1979, the field inspector from DHS conducted a second inspection of the Oakland facility. Soil samples collected across the site indicated the presence of PCBs. Consequently, in a November 29, 1979, letter, the DHS directed GE to remove all PCB contaminated soil from the site for disposal at a Class I landfill.

300.66(c)(2) inspection

In January 1980, GE hired Brown and Caldwell Consulting Engineers to conduct the following four activities:

Activity 1: Preliminary Investigation

Develop operational history of facility; review existing geotechnical information; identify regulatory agencies involved

Activity 2: Field Investigation

Soil and ground water sampling to establish three dimensional distribution of PCBs on-site

Activity 3: Laboratory Analyses of Samples Collected in Activity 2

Activity 4: Data Assessment and Recommendation

Evaluation of contamination problems; evaluation of alternative correction programs.

Upon the completion of these activities and the review of the Phase I report by GE and the state, it became apparant to both parties that the contamination problem at the site was more extensive than had been initially believed and would require action other than soil removal. Subsequently, the state issued a Cleanup and Abatement Order to GE on December 5, 1980. The order consisted of the following requirements:

- Abatement of discharge of PCB oils and oily material and other waste constituents

- Submittal of a Phase II study by January 1981 providing additional data on the extent of contamination

- A study plan by January 1981 addressing control and removal of oil and containment of runoff

- By May 1981 a long-term mitigation plan for final site cleanup and corrective measures.

The following section discusses the data collected during the field investigative activities at the Oakland site, and the conclusions drawn from this information concerning the extent of contamination across the site.

There were two investigative phases that took place at the Oakland site. Phase I entailed predominantly surface sampling techniques such as shallow soil borings and seismic refraction. During the Phase I investigation, (December 1979-June 1980); the site was divided into three areas based on the type and extent of contamination. Surface sampling, however, did not adequately define the extent of contamination in all three areas. Areas II and III required additional investigative work. In January 1981, Phase II investigative activities were initiated. This second investigation involved deeper sampling and making use of multi-cased wells and borings. The Phase II investigation was completed in June 1981. Figure 7 shows the location of each of the three areas, in addition to soil boring and monitoring well locations for both investigative phases.

In Area I, surface PCB concentrations ranged between 0.1 and 220 ppm. PCB contamination in this area was limited to highly attenuated pockets of contaminated soils to a maximum depth of 5 feet (1.5 m). The higher PCB levels are restricted to near the surface and generally decrease to nondetectable levels by a depth of 5 feet (1.5 m).

By comparison to Area I, the contamination in Area II is much more extensive. PCB concentrations generally ranged from 0.33 to 1,900 ppm, however, hotspots with concentration levels up to 14,000 ppm were identified. All concentrations generally decreased with increasing depth. In addition to surface and subsurface soil contamination, Area II contained high concentrations of PCBs in the form of free oil located beneath the water table at the clay-sand interface in a number of isolated, discontinuous sand lenses. Oil contamination existed in soils from shallow to intermediate depths with a greatest observed depth of 32 feet (10 m) beneath the tank farm.

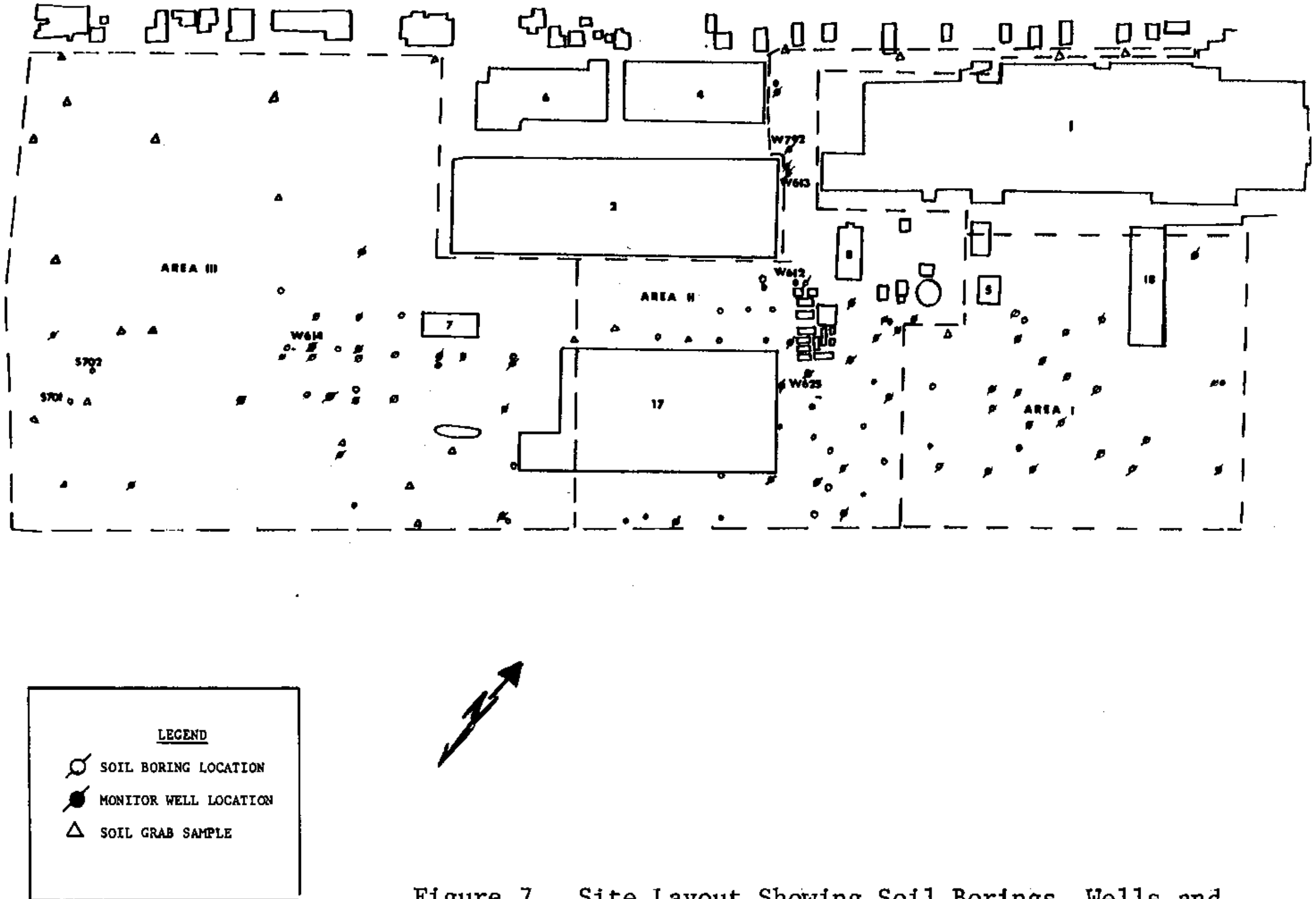

Figure 7. Site Layout Showing Soil Borings, Wells and Areas I, II and III

(From: Preliminary Phase I Addendum, G.E., Co., CA, September 1980)

The total quantity of oil in the contaminated area or plume of contaminated ground water was estimated to be 20,000 gallons (75,800 l) and the oil layer thickness measured in monitoring wells was a maximum of 8 inches (20 cm). The original areal extent of the oil plume is estimated as shown in Figure 8. Exploratory work in Area II was not complete at the end of the Phase I investigation due to the extent and severity of the problem. Additional data was then collected during a Phase II investigation.

Following the first field investigative phase at this facility, the extent of PCB contamination in Area III was roughly approximated. There were some PCBs identified but definition of the severity and extent of the contamination was incomplete. On the basis of the data made available following the initial Phase I investigation, the surface contamination appeared to be similar in severity and pattern to that observed in Area I. Subsurface PCB contamination within the saturated soil zone was, at this time, identified in only one portion of Area III, and free oil was not identified anywhere. In the southern portion of Area III, where PCBs were detected, contamination extended to about 2 feet (61 cm) except at well W503 (see Figure 7) where contamination occurred to depth of 15 feet (21m).

The state concurred with GE and its consultant and decided that additional data would be necessary in order to fully define the problems in both Areas II and III. The additional information needed on site conditions would be acquired during a Phase II field investigation which would be restricted to these two areas.

The Phase II field activities involved the installation of additional ground water monitoring wells and the collection of both additional ground water and soils samples.

PCB Distribution in Soils--Phase II Investigation Results

In the western part of the property, in Area III, detectable PCB concentrations extended to a maximum depth of 10 feet at soil borings S701 and S702 and monitor well W731 (see Figure 7). In the vicinity of Building 7, detectable PCB concentrations extended to a depth of 20 feet (6m). The highest PCB concentrations found in surface soils in Area III was 2,500 ppm at S702. These levels at S702, however, decreased to nondetectable levels (<1 ppb) at a depth of 15 feet (5 m).

Monitor well W791 is a deep multi-cased well, completed in a sand zone at a depth of approximately 35 to 40 feet (11 to 12 m). Soil analyses from W791 show a

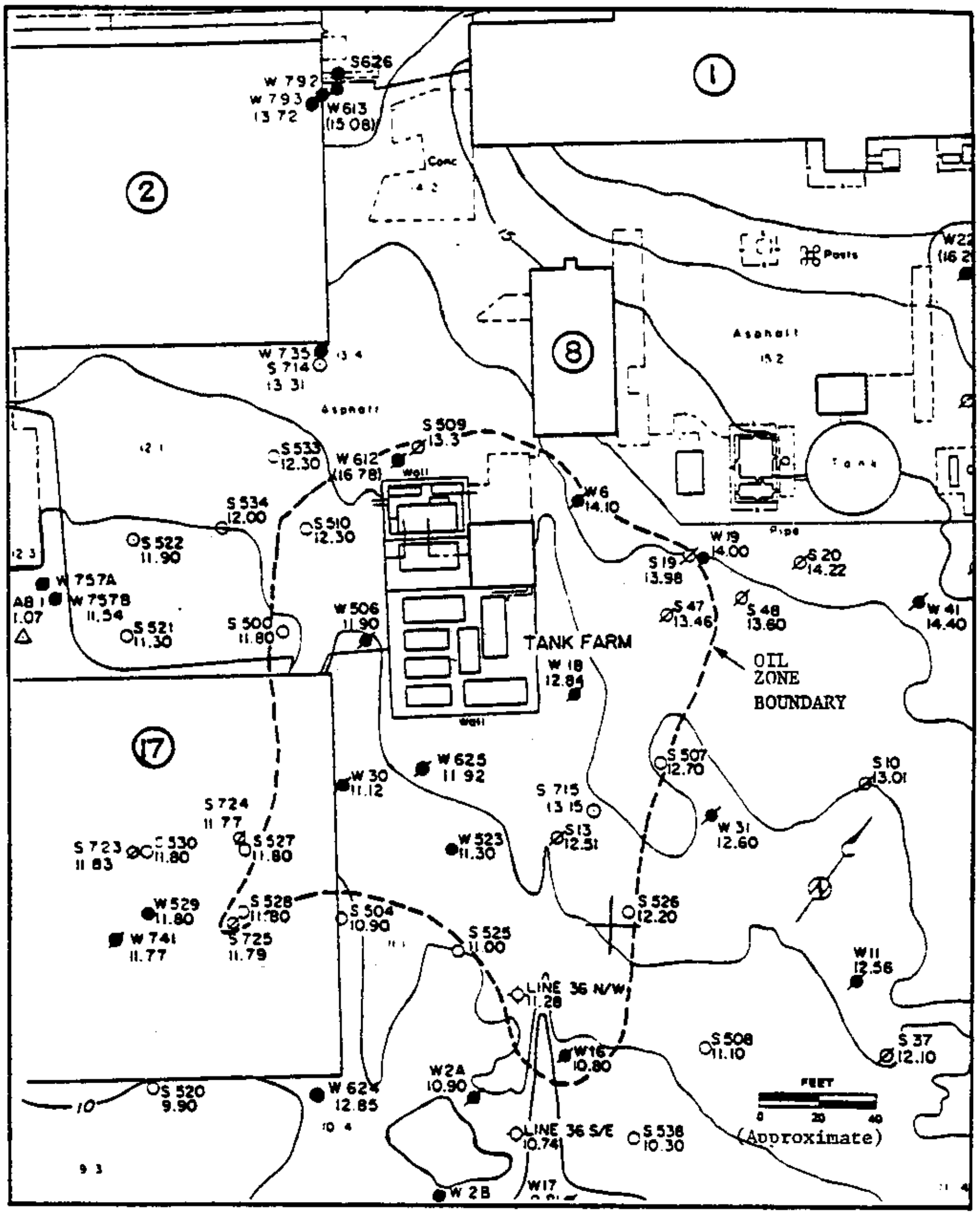

Figure 8. Oil Contamination Zone Boundary
(Source: Final Phase II Report, G.E., Co., CA, June 1981)

concentration of 83 ppm at the ground surface decreasing to less than 0.12 ppm below 10 feet. PCB concentrations in soils within the 35-40 feet (11-12 m) zone were nondetectable.

Along the northern boundary of the site, between Buildings 6, 4, and 2, the maximum PCB concentration level identified was 510 ppm at ground surface at soil boring W736. Detectable levels extended to a depth of 25 feet (8 m) at S710, S709, and W736; to a depth of 15 feet (5 m) at S711; and to a depth of 10 feet (3 m) at W758. Again, all concentrations levels decreased with increasing depth.

Between Buildings 17 and 2, detectable PCB concentrations extended to a depth of 35 feet (11 m), but levels were less than 1 ppm below 10 feet (3 m).

The highest PCB concentrations measured during the Phase II investigation were from soils at the monitoring well W792, located between Buildings 1 and 2. From the ground surface to a depth of 11.5 feet (4 m), values of 3,800 ppm to 5,500 ppm were measured. Between 15 and 25 feet (5 and 8 m) concentrations ranged from 900 to 1,400 ppm and below 33 feet (10 m) concentration values decreased to nondetectable levels.

In addition to defining the extent of surface and subsurface soil contamination, results from the Phase II activities confirmed the extent of the free oil plume presented in Figure 8.

Ground Water Analyses

Fluid samples were collected and analyzed from monitoring wells during both Phase I and II field investigations. The discussion that follows and the conclusions drawn result from the combination of data collected during both investigations.

Ground water samples were analyzed for PCB and oil and grease using the Freon extractable method. Using this analytical technique, if a sample was found to have detectable PCB levels (>0.3 ppb), it was filtered to remove suspended solids and reanalyzed. Because PCBs in oil tend to adsorb onto fine-grained soil particles, the removal of suspended solids ensures that the detected PCB concentrations are within the fluid itself and not a result of PCB adsorption onto suspended solids.

In addition, fluid samples collected were analyzed for all isomers of dichlorobenzene, trichlorobenzene and tetrachlorobenzene. Samples were collected from monitor wells W612, W613, W614 and W625. The resulting concentrations from the chlorobenzene analyses ranged from nondetectable (<0.001 ppm) to 11.7 ppm.

Final PCB analyses conducted on ground water samples collected from Areas II and III during the Phase I investigation, revealed nondetectable concentrations after filtering. PCB analyses conducted on samples collected during the Phase II study revealed unfiltered PCB concentrations ranging from 0.36 ppb to 1.8 ppb; filtered concentrations were all less than the detectable limit of 0.3 ppb. Oil and grease concentrations ranged from 6 ppb to 10 ppm.

The overall conclusions drawn from the field investigations concerning the extent of ground water contamination are the following:

- Detectable concentrations of PCBs were not found in on-site groundwater;
- Vertical migration of PCBs in shallow soils to deeper confined aquifers was insignificant.

PLANNING THE SITE RESPONSE

Initiation of Site Response

In a November 29, 1979 letter, the State Department of Health Services (DHS) directed GE "to remove all PCB contaminated soil...to a Class I disposal site for immediate burial"; and to sample the site area to determine the extent of contamination. This directive to excavate and remove the PCB contaminated soil was made because, under State law PCBs are defined as an extremely hazardous waste, and the law requires that "any hazardous material disposed of to the land, accidentally discharged to land or accidentally spilled on to the land be managed as a hazardous waste." After reaching an agreement with DHS on an engineering survey plan, GE retained Brown and Caldwell Consulting Engineers in January 1980 to prepare a detailed problem definition and correction plan. Their draft report dated June 1980 found a much larger volume of contaminated soil than was initially expected. For this reason the June 1980 report discussed a variety of site response options, aside from excavation, including the immediate correction plan eventually carried out: French drain and treatment system, and surface sealing with runoff control. The consideration of the other site response options will be discussed in the "Selection of Response Technologies" section.

300.65(b)(6) immediate removal

300.66(a) assessment

Aside from the legal mandate on hazardous waste disposal that compelled the state to issue the directive to GE, there were three general reasons that caused the state to seek action at the site:

1. The state was concerned about the migration potential of the PCB-oil under the tank farm where a ground water mound had formed. 300.66(c)(2) (iii) migration potential

2. Contaminated surface soil posed a potential hazard with direct contact by workers or others. 300.67(c)(4) surface soil hazard

3. Contaminated surface soils also posed a potential threat to surface waters and water resources in the San Francisco Bay area. A dry soil sample from an on-site drainage ditch with 100 ppm PCB caused a US Food and Drug Adminstration inspector, the DHS and the California Regional Water Quality Control Board (RWQCB) to be concerned about bioaccumulation in edible shellfiish in the Bay.

In a December 5, 1980 Cleanup and Abatement Order (CAO), the RWQCB found that there were "surface and subsurface soil and water contamination with PCBs...which create a serious threat of contamination to surface and ground waters of the State, to aquatic life and to public health. 300.66(c)(2) migration potential

The site response plan actually implemented in the fall of 1981 resulted primarily from cooperation and coordinated discussion between, GE, DHS and the RWQCB. The December 1980 CAO formalized the site study and correction plan that had been agreed upon. According to an internal memorandum from the RWQCB, the CAO was issued to assure "adequate control of a complex and severe pollution problem." In the CAO the RWQCB ordered GE to:

1. Submit a Phase II "Definition Study Implementation Plan" by January 1981 to refine the report submitted in June 1980.

2. Submit a detailed plan for "Immediate Mitigation Measures" by January 1981 and implement them as soon possible after approval. (The RWQCB stated in the CAO that they were "conceptually in agreement with the French drain extraction approach" as described in the Phase I Report.)

3. Submit a long term mitigation plan by May 1, 1981 "to remove and/or treat contaminated soil and ground water to acceptable levels..."

The final Phase II, "Problem Definition" report was submitted in June 1981 and approved in July 1981. A contract for the construction work was let in August 1981 and construction was completed in December 1981.

Selection of Response Technologies

The selection of response technologies for the GE site has been and will continue to be the result of the in-depth assessment of a number of alternatives. There are two site response program plans through which final mitigation of contamination at the site will be achieved. The first and immediate correction plan involves those response technologies that have already been implemented at the site and are presently in place. These technologies involve the following:

- Surface sealing
- Surface runoff controls
- A French drain extraction system
- Ground water treatment and storage
- Modification of existing tank farm.

These five response technologies are described in further detail in the remainder of this section.

The second response program plan, which has not yet been initiated, is the "Long Term Mitigation Plan." This plan is presently in the development stages. There are three areas presently being studied for future use and these are:

- In-situ microbial degradation of the waste materials; possibly in combination with methods such as solvent extraction or chemical pretreatment
- Soil treatment using liquid detergent to flush oil and soil pores into French drain
- Chemical destruction using a potassium hydroxide and polyethylene glycol combination.

GE projects that implementation of one of these techniques will take place in 1987.

The assessment of the immediate correction plan alternatives involved the identification, screening and evaluation of alternatives for each of the three existing areas. The selected response technology plans for the three specific areas of the site are based upon the recognition that there was significant variation in the type and range of problems encountered in each area. However, it was also realized that certain elements of the actions taken were similar in application wherever a specific problem existed on-site. For example surface soil contamination was treated similarily for all areas.

The PCB-contamination at the Oakland site occurred in three physical categories:

- PCB soil contamination confined to fill material at 0 to 5 feet (0 to 1.5 m) with no detectable levels in subsurface soils
- PCB soil contamination extending into the saturated soil zone
- An oil plume within the saturated soil zone, containing appreciable amounts of PCBs.

The following section discusses the selection of the response technologies utilized to immediately mitigate potential problems from off-site releases of PCB contaminants.

There were five overall objectives in the immediate corrective plan for the GE facility and these were as follows:

- Prevention of vertical movement of contaminants into deeper soils or ground water
- Prevention of contaminant movement off-site by surface runoff or other means
- Extraction or immobilization of free oil and associated PCBs
- Containment and extraction of oily ground water
- Meeting all appropriate regulatory requirements.

300.68(g) development of alternatives

The alternate means by which these objectives could have been met are described by specific area in Table 1. Table 1 describes the remedial alternatives considered for use at the GE site in both general terms and their applicability to each of the three site areas. Table 1 begins

TABLE 1. ALTERNATIVE IMMEDIATE CORRECTION RESPONSE TECHNOLOGIES

Area	Response Technology Alternative	Description	Rationale for Rejection/Acceptance	NCP Reference
I	(1) Excavation of Soil and Off-site Disposal (Rejected)	• Localized or area wide excavation of contaminated soils and off-site disposal of soils	• Excavation involves high risk of personal exposure to contamination • Due to fact that PCB contamination is localized, minimization of excavation and disposal quantities would have required additional soil sampling and testing • Only two alternative disposal facilities exist and the use of either would have involved long haul distances with consequent risks of spills	300.70 (b)(2)(c) (2)(i) contaminated soil removal
	(2) Containment by Surface Sealing (Accepted)	• Sealing to be used as an effective barrier to personal contact with soils and to provide limitation to movement of the contamination by runoff or hydraulic movement down to deeper soils or ground water; several sealing materials were assessed; (A) Soil/clay* (B) Grassed soil (C) Gravel (D) Asphalt* (E) Synthetic liner (F) Concrete*	• The three most feasible sealing techniques were soil/clay asphalt and concrete • Asphalt and concrete were rejected for majority of site area because they require leveling of ground to ensure <1% slope; possibility of deterioration cracks fissures, eliminates possible future site vegetation generally limits site's future utilization; asphalt used within manufacturing plant area only • A soil/clay seal selected due to easy construction; unnecessary to move contaminated materials off-site; reliable based upon proven performance	300.70 (b)(1)(ii)(A) surface seals
	(3) Runoff and Erosion Control (Accepted)	(A) Drain channels (B) Drain rock (C) Curbing and terracing	• Soil/clay overlaid with 6-9 inches of graded stone to prevent erosion and control runoff • Lined concrete drain channels with curbing allows runoff to be conveyed from sealed area and collected	300.70 (b)(1)(ii) (B); (i)(2)(5)(6) surface water diversions

*(Accepted)

(continued)

(Source: Adapted from Vol. 1 Preliminary Phase 1 Report GE Co., CA, June 1980)

TABLE 1. (continued)

Area	Response Technology Alternative	Description	Rationale for Rejection/Acceptance	NCP Reference
I (continued)	(4) Grading (Accepted)	• Where necessary the area was graded prior to placement of seal	• Area surface slope needed modifications in order for the newly designed drainage systems to operate properly	300.70 (b)(1)(ii)(c) grading
	(5) Surface Runoff Treatment (Rejected)	• Necessary if sealing or runoff control is inadequate	• Sealing and runoff control was adequate	
II	(1) Excavation of Soil and Offsite Disposal (Rejected)	• Physical removal of contaminated soils both saturated and unsaturated and transport of excavated material to approved disposal facility	• Necessary to excavate below water table into sands containing free oil resulting in a need for ground water control i.e., dewatering • Dewatering posed additional problems e.g., ground water treatment would be necessary; possible soil contamination by vertical ground water movement • High risk of contamination to personnel involved in excavation and disposal process • High risks of offsite discharge of hazardous substances through erosion and runoff • High cost	300.70 (b)(2)(c)(2)(i) contaminated soil removal
	(2) Excavation, On-Site Treatment and Recompaction (Rejected)	• Substitutes on-site decontamination of the soils for off-site disposal • May have been less expensive than alternative (1)	• If overall process retained all or most of the technical difficulties related to alternative (1), would have required a substantial amount of laboratory and pilot scale investigation to establish technical feasibility	300.70 (b)(2)(iii) in-situ treatment of contaminated soils and sediments
	(3) Containment and In-Place Solvent	• Involves injection of solvents to effect extraction of contaminants	• Full containment not technically feasible due to fact that there	300.70 (b)(2)(iii) in-situ treatment of

(continued)

TABLE 1. (continued)

Area	Response Technology Alternative	Description	Rationale for Rejection/Acceptance	NCP Reference
II (continued)	Extraction (Rejected)	from soil • Requires full containment, i.e. physical bbarriers on all sides of property (slurry trench cut off wall) beneath area (chemical grouting) and on ground surface (surface sealing); also requires complex treatment system for contaminant removal and solvent recovery from extracted fluids	would have been no way to ensure that contaminants would not move through the horizontal barrier which would have been constructed by chemical grouting • A long-term, high energy-consumption ground water monitoring and sampling program would be necessary following completion of extraction process; this would be very expensive	contaminated soils and sediments 300.70 (b)(1)(iii)(A) ground water controls impermeable barriers 300.70 (b)(1)(iii)(C) ground water controls-ground water pumping
	(4) Containment with Partial Extraction (Rejected)	• Includes same containment elements as alternative (3), but extraction elements would be reduced • Would not include solvent injection • Requires treatment of extracted fluids	• Full containment necessary for system to operate successfully, however full containment, for the above mentioned reasons, is not technically feasible	300.70 (b)(1)(iii)(A) ground water controls-impeermeable barriers 300.70(b)(1)(iii)(c) ground water controls-ground water pumping
	(5) Partial Containment with Partial Extraction (Rejected)	• Would include slurry trench cutoff wall and surface seal but not the grouting beneath the site • Vertical containment would be accomplished by continual lowering of water table within contaminated zone by use of extraction system • Phreatophytes would be planted to assist in maintaining hydraulic gradients, through ground water removal by evapotranspiration	• Decided that a barrier around perimeter of property unnecessary • Unnecessary costs involved	300.70 (b)(1)(iii)(A) ground water controls-impermeable barriers 300.70 (b)(1)(iii)(C) ground water controls-ground water pumping
	(6) Hydraulic Containment, Extraction and Treatment (Accepted)	• No physical barriers involved except a surface seal of bentonite and soil to prevent infiltration • Surface runoff controls • A French drain collection system and extraction sump which includes three levels of perforated pipe for each of three French drain arms • A ground water treatment and storage system for treated ground water, sediment and oil • Modification of the existing tank farm for approved temporary bulk storeage of PCB fluids and drummed storage of sediments	• No expense for perimeter slurry trench cut-off wall; moderate in construction cost • Possibility that flow rate would be reduced after removal of oil in order to lower treatment costs by using phreatophyte system • Use of a 3 level French drain system makes it possible to intersect any number of discontinuous oil-bearing sand zones • Contaminated zone very large • Low risks of personnel exposure to contamination during construction.	300.70 (b)(1)(ii)(A) surface seals 300.70 (b)(1)(iii)(c) (1) & (2) ground water controls-ground water pumping 300.70 (b)(2)(ii) direct waste treatment

(continued)

TABLE 1. (continued)

Area	Response Technology Alternative	Description	Rationale for Rejection/Acceptance	NCP Reference
II (continued)		• Disposal of PCB-contaminated oil and sludge sediments at a Class I landfill	• A successful French drain system is operating for similar problem at a GE site in Pittsfield, MA	
	(7) Ground water Monitoring (Accepted)	• Monitoring of ground water that has been recovered and treated	• State and Federal regulations require that fluids that are discharged into a surface water body must be monitored	
	(8) Containment without Extraction (Rejected)	• Employ physical barriers such as surface sealing, a bentonite slurry trench cutoff wall around the area and chemical grouting beneath the contaminated zone to immobilize the free oil by restriction of ground water movement through contaminated zones • There would be no extraction of fluid phase	• No way of ensuring the integrity of a chemical grout curtain, therefore there is high risk that contaminated oil and oily ground water would move downward through breaks in grout curtain	300.70 (b)(1)(iii)(A) ground water controls-impermeable barriers
	(9) Well pumping system for Extraction (Rejected)	• Installation of wells to recover oil	• Subsurface materials are heterogenous; oil zone configuration not precisely defined thus would not be efficient; French drain much more flexible • Large number of wells would have been necessary due to large plume size; even if geologic conditions were uniform the number of wells required would have greatly increased operational costs	300.70 (b)(1)(iii)(C) ground water controls-ground water pumping
III	(1) Surface Grading and Runoff Controls (Accepted)	• Grading and construction of berms where necessary; growth of vegetative cover	• Only grading (vs. grading and surface sealing) deemed necessary due to insignificant levels of PCBs present in area • Constructing runoff control structures such as berms was undertaken in response to request by state that GE control storm water drainage from this area	300,70 (b)(1)(ii)(c) grading 300.70 (b)(1)(ii)(B); (1),(2),(5),(6) surface water diversions

(continued)

TABLE 1. (continued)

Area	Response Technology Alternative	Description	Rationale for Rejection/Acceptance	NCP Reference
I, II & III	(1) Surface Runoff Monitoring and Discharge (Accepted)	• Three separate drainage systems all of which eventually discharge through one main outlet (1) Drainage from bentonite soil seal areas (2) Drainage from building roofs (3) Drainage from paved areas • Fluids passing through each drainage system monitored separately and then discharged	• Provides flexibility of system isolation if monitoring results ever indicate high contamination levels • Establishes effectiveness of selected response technologies	

with those corrective measures considered for Area 1. As previously described, the problem in Area I involved surface soil PCB contamination to a maximum depth of 5 feet. Consequently the alternative remedial techniques were confined to this zone of contamination.

300.68(h) initial screening of alternatives

The overall contamination in Area II was much more widespread than in Area I. The surface soil contamination levels were higher and contamination extended further below the ground surface. In addition, free oil containing high concentrations of PCBs occurred in sand lenses. Due to the more extensive contamination problem, the corrective measures considered for Area II involved a higher degree of complexity, than those considered for Area I. Table 1 continues with detailed descriptions of the remedial alternatives assessed for Area II.

The Phase II field investigation activities conducted in Area III revealed insignificant PCB concentration levels in both soil and ground water samples. On the basis of the low contamination levels it was decided that the necessary response in this area would involve the grading of the area, as opposed to grading and surface seeding for other areas. In addition, the state required that the facility management provide storm water control in this area.

Extent of Site Response

The ultimate extent of the site response has not yet been established, as of January 1983. The site response that has already been carried out, and is described above is the immediate correction plan; a long term remedy has not yet been initiated, but is required by the state, and is now being developed by GE. The goal and scope of the long term plan, as well as the extent of the immediate correction plan is considered below.

The "Long Term Mitigation Plan: as described in the 1980 CAO should "remove and/or treat contaminated soil and ground water to acceptable levels." The research for this plan, occurring at GE's Schenectady, New York research and development laboratories includes, as previously mentioned, three areas of study:

1. Microbial degradation of the waste in-situ or in combination with other methods such as solvent extraction or chemical pretreatment.

300.70(b)(iii)(E)(3) microbiological degradation

2. Treatment of the soil with a liquid detergent to "wash" the oil out of the soil pores and flush it into the French drain. — 300.70(b)(iii)(E)(1) solution mining

3. Chemical destruction with a potassium hydroxide and polyethylene glycol combination similar to the sodium polyethylene glycol (NaPEG) system developed by the Franklin Institute. — 300.70(b)(ii)(B) chemical methods

The implementation of a "Long Term Mitigation Measure" is anticipated in 1987 after completion of a research and pilot scale program.

The extent of the immediate site response was determined primarily by two decisions: — 300.68(j) extent of remedy

1. Selection of the French drain instead of another alternative such as excavation and removal, is discussed in detail above in the "Selection of Site Response" section, and only in general terms in this section.

2. The level of treatment for the collected wastewater had to be established for removal of PCB laden oil and grease. This decision on the level of treatment for the water was an implicit result of choosing the French drain. This system collects PCB oil and slightly contaminated water, which must be decontaminated to some allowable PCB concentration before discharging to the East Bay Municipal Utility District (EBMUD). EBMUD held a meeting with GE in April 1981, regarding the proposed discharge at which time GE indicated that discharge to the storm drainage system was not very viable, perhaps due to required level of treatment.

The selection of the French drain largely determined the extent of the site response for the immediate correction plan. In general, the French drain was accepted by the state based on their understanding with GE that a long term mitigation plan would be developed and implemented. In addition, the state believed that some immediate containment and runoff control was needed, but concurred with GE and its consultant that immediate excavation and removal would be excessively risky and costly. However, because the state law required that PCBs be safely disposed of, as discussed in the "Initiation of Site Response" section above, the long term mitigation plan is considered a necessary element of the site response.

The decision to limit the concentration of the effluent from the treatment system to an average PCB concentration of 50 ppb and a maximum of 150 ppb was based primarily on estimated quality of the effluent which could be produced from the FRAM unit. It was determined that these average and maximum concentrations would not disrupt the EBMUD's treatment process or violate NPDES permit compliance conditions. When the EBMUD was asked by GE to set a standard for PCBs in a revised discharge permit for waste going into the EBMUD system, they referred to their wastewater control ordinance, which has no specific PCB standard, but requires them to prohibit anything that will cause harm to District facilities. After determining that PCBs would not harm the system, the EDMUD considered the limits set forth in the NPDES permit, which also has no specific PCB standard, but only a limit on the amount of Total Identifiable Chlorinated Hydrocarbon (TICH). By calculating the PCB influent as an additional identifiable chlorinated hydrocarbon to be considered among the TICH effluent, the EBMUD set the PCB levels given above, assuming that PCBs are not removed at all and pass directly through the plant (Aroclor 1260 is generally considered to be very refractory). The EBMUD's TICH effluent was approximately doubled by the addition of the GE waste to about 0.2 ppb, which is still significantly below their NPDES permit level. This level was set by the RWQCB to meet federal regulations (40 CFR, Sections 129.105(4)) which states that "The ambient water quality criteria for PCBs in navigable water is 0.001 ppb. Since Aroclor 1260, has a solubility of 3 ppb in water, the saturated oil-free FRAM effluent has a PCB level at or below 3 ppb before dilution. Subsequently, a new discharge permit was issued to GE based on monitoring of the effluent from this facility at a point nearer to its discharge into the sanitary sewer after the FRAM oil removal unit wastewater has comingled with other plant wastes.

DESIGN AND INSTALLATION OF RESPONSE TECHNOLOGIES

The response actions finally selected for use at the site, were designed to provide containment and control of (1) the oil-contaminated zone and (2) surface runoff. The oil plume control system operates to remove oil from subsurface soils and controls the water table gradients in the oil plume area to preclude any movement of ground water or other fluids vertically downward into deeper formations and therefore provides containment of contaminants in the oil plume area. The established surface runoff controls prohibit the movement of PCB-contaminated soils into surface runoff and greatly reduces infiltration of

300.70(b)(1)
(iii)(c)
[(1) & (2)]
ground water
controls -
ground water
pumping

rainfall through the soils to the ground water. In reducing infiltration, the runoff controls also act to enhance the ability of the oil plume control system to control ground water gradients.

300.70(b)(1) (ii)(A,B,C & D) surface water controls

The plans and specifications for implementation of the response measures at the GE site were completed in June 1981. The successful bidder for the project was selected in August 1981. Construction began in August 1981 and was completed in December 1981. The response program included the following facilities:

- A surface sealing system of bentonite and soil overlaid with a permeable gravel layer; and asphalt paving
- Surface runoff controls including curb and gutters, catch basins, drainage piping, drainage channels and a monitoring station
- A three-trench French drain system with a central collection sump and mechanical extraction system
- Disposal of recovered PCB-oil and sediments at a Class I landfill
- A ground water treatment system and storage facilities for treated ground water, sediment and PCB-contaminated oil
- Modification of the existing tank farm for approved temporary bulk storage of PCB fluids and drummed storage of sediments.

Surface Sealing and Runoff Control System

The design for the surface sealing and runoff control system at the GE facility consists of two soil sealing techniques, various types of drainage controls and three separately, structured drainage systems. The two types of soil sealing techniques utilized are (1) a soil-bentonite mixture covered with a gravel blanket and (2) asphalt paving and base rock coated with a surface sealant. The soil-bentonite seal was used over those site areas where (1) there were high concentrations of PCBs, (2) where automotive traffic was, and currently is, prohibited and (3) those areas where no facility expansion plans existed.

A schematic representation of the soil-bentonite seal and a typical drainage channel is shown in Figure 9. Prior to applying bentonite to designated areas, grading was often necessary to provide uniform slopes for surface

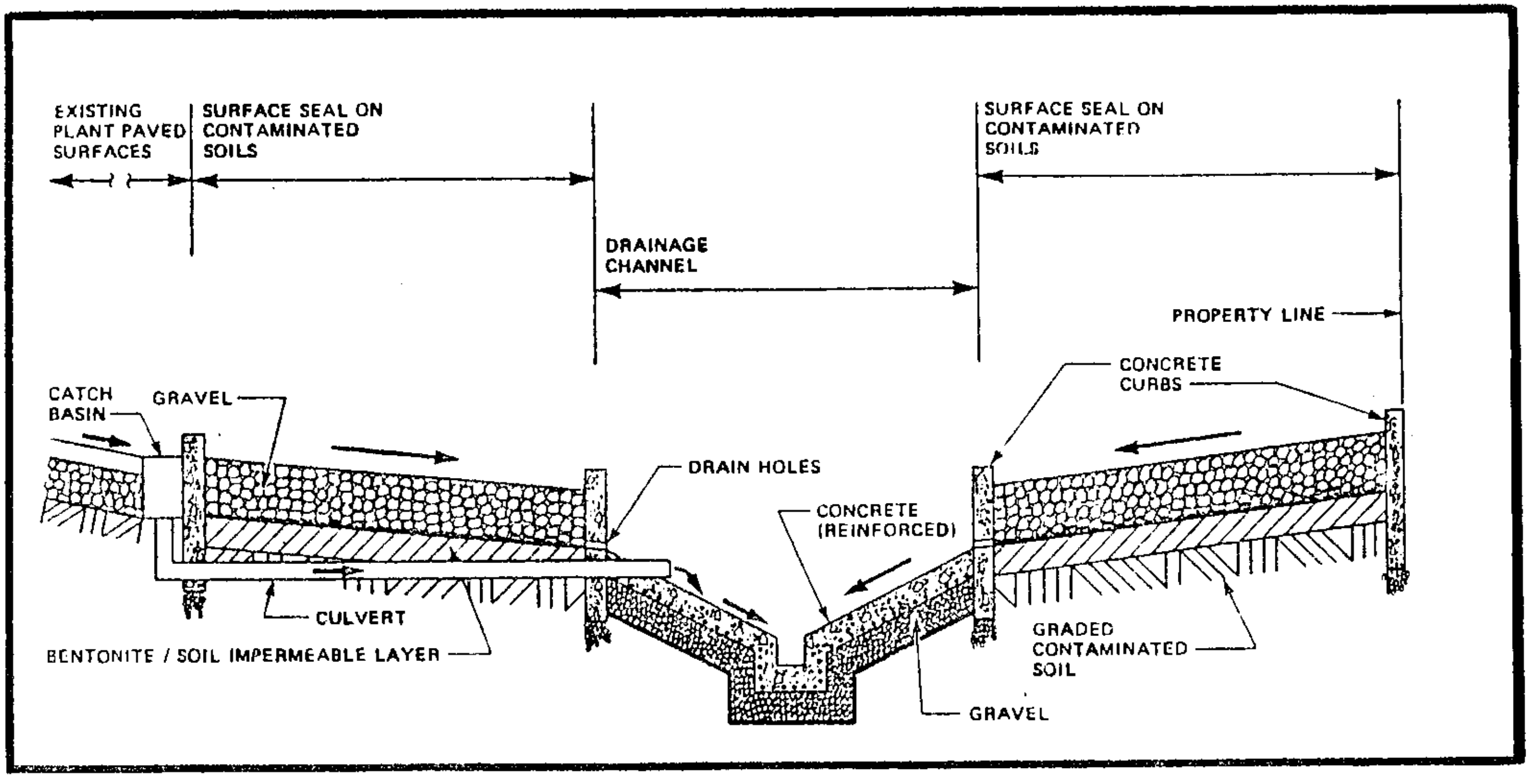

Figure 9 Typical Surface Seal and Drainage Channel

(From: Immediate Correction Plan Report, G.E., Co., CA, January 20, 1981) runoff control. Following the grading process, dry bentonite was applied over the contaminated area using a truck designed with a rear spreader through which the dry bentonite was applied. The bentonite supply was kept in a hopper located on top of the truck. The rate of bentonite application depended on the rate at which the truck was traveling. On the average, the truck would spread 150 tons, (136 Mt) of bentonite over 7 acres every 2 days. About 4 pounds (2 kg) of bentonite was used per square foot (.093 m^2). Following behind the truck was a plow-type vehicle which served to churn up the bentonite and soil, mixing the two together. The mixture was then compacted with a diesel driven roller. The permeability of the final seal, when compacted to 80 percent at optimum moisture content, is approximately 1×10^{-7} cm/sec. Following application of the soil-bentonite mixture to an area, a six inch blanket of gravel was constructed over the impermeable layer, and sufficient curbs and channels were provided to control runoff. Bentonite and gravel were applied over a total area of 156,000 ft^2 (14,492 m^2).

All drainage from the soil-bentonite areas is conveyed to concrete drainage channels which collect the runoff for discharge through a single outlet. The drainage system constructed for the soil-bentonite sealed areas is one of the three systems previously mentioned. The two other drainage systems that are being utilized control runoff from (1) building roofs and (2) the site's paved areas. The effluents from the three systems are passed through monitoring systems before being combined and discharged through a single outlet. This main outlet is located in the southwest corner of the site and empties into a channel which eventually empties into San Francisco Bay. Making use of three structurally separate systems provides flexibility of system isolation if monitoring results ever indicate high PCB concentration levels in the combined discharge. The construction of the three systems involved the reconstruction of the sewer system around the plant. These construction activities were ongoing throughout the site response program.

The asphalt paving technique was only utilized over the area inside the manufacturing plant where there is known heavy vehicular traffic. A total area of 135,000 ft^2 (12,542 m^2) was sealed with asphalt during the site response program. In preparation for setting the asphalt seal, the soil was compacted using the diesel driven roller and then a gravel layer was laid down. Once these preparations were complete an oil slurry seal was applied at a rate of 0.101 gallons per square yard (0.38 l per 0.84 m^2). This seal was applied over both existing and newly paved areas to seal any existing fissures.

Surface sealing was deemed unnecessary for Area III due to the low levels of PCBs present. The state, however, requested that GE provide some degree of storm water control in this area. The facility management consented to the request by grading the area, constructing berms where they were necessary to control runoff and establishing a vegetative cover over the area. A total area of 154,000 ft^2 (14,307 m^2) was revegetated. With the use of these techniques, runoff drainage from Area III is controlled and directed to the main discharge outlet in the southwest corner of the property.

300.70(b)(1)(ii)
(c)
grading
300.70(b)(1)(ii)
(D)
revegetation

The areas of the site which were already paved with asphalt required little or no modification. Where modifications were necessary, construction involved bounding the areas with runoff diversion features such as curbs and gutters. This construction was undertaken to prevent runoff movement onto unpaved areas and to direct it to appropriate catch basins.

Drainage from building roofs is collected and conveyed to either catch basins or buried drain lines, or permitted to drain across paved areas to installed catch basins.

300.70(b)(1)(ii)
(B)
surface water
diversion and
collection
systems

In general, drainage across the site is from east to west, and north to south. The parking lot along the east side of the site, and the curb and gutter structure along East 14th Street eliminate storm water runoff from entering the site from the north. Storm water is prevented from entering the site from the east by a drainage channel along the property's south perimeter that was constructed as part of the site response program. Along all other portions of the site perimeter, concrete curbs have been constructed.

300.70(b)(1)(ii)
(B)[(2) & (3)]
surface water
diversion and
collection
systems

Much of the construction that took place involved excavation of contaminated soil. This soil was never removed from the facility property and disposed of elsewhere. All excavated soils were used on site for the construction of the various runoff control structures.

<u>French Drain Extraction System and Ground Water Treatment</u>

The system selected to contain and gradually eliminate the PCB contamination problem in Area II consists of three French drains, a central collection sump and two pumps. An oil-water interface is created within the sump which enables one pump to remove the oil while the other pumps ground water to the surface. A plan view and cross section of this unit are given in Figure 10. As previously described in the "Selection of Response Technologies" section, the overall success of the site response systems at GE depends upon the oil and ground water extraction processes and their ability to control subsurface flow and eliminate the potential for offsite contaminant migration. A schematic diagram of the French drain and oil collection facility is shown in Figure 11.

300.70(b)(2)(iii)(C)[(1) & (2)] ground water controls -- ground water pumping

Extending from the extraction sump are three French drains each of which consists of three 6-inch (15 cm) diameter perforated pipes. The three pipes within each arm are vertically separated from one another by about 3 feet (1m). The three level design provides flexibility in the collection of oil and ground water. The bottom pipes in each arm are between 25 and 30 feet (8-9 m) below the surface; the top pipes are about 20 feet (6m) below the surface. The piping is surrounded by drain rock which extends within about 1 foot (.3m) of the ground surface. The drain rock is overlaid by compacted fill and then by a surface seal so as not to permit surface infiltration into the French drains. The lengths of the arms are 60, 70, and 80 feet (18, 21, and 24m). In the design of the system, the lengths of the arms were not considered critical to the success of the extraction process. The important design feature for the success of the system was the 3 level drain arm. With 3 levels the oil-water interface could be intersected at various points due to the existence of a cone of depression. The difference in arm lengths reflects decisions made during installation. There are two main differences between the as-built and the originally designed French drain system. One of these differences involves arm pipe placement. Where buildings were present in the vicinity of the installation site, drain arm lengths were modified. It was for this reason that the final arm lengths varied. The second deviation from the original design was the absence of valves along the insides of the pipes, which would have regulated the fluid flow. It was discovered during the installation of the system, that there was not enough flow to warrent the use of valves and therefore they were eliminated.

The location of the collection sump with respect to the oil plume is shown on Figure 12, along with the soil borings used to define the plume and the observation wells that are maintained to monitor any changes in the configuration and size of the oil plume.

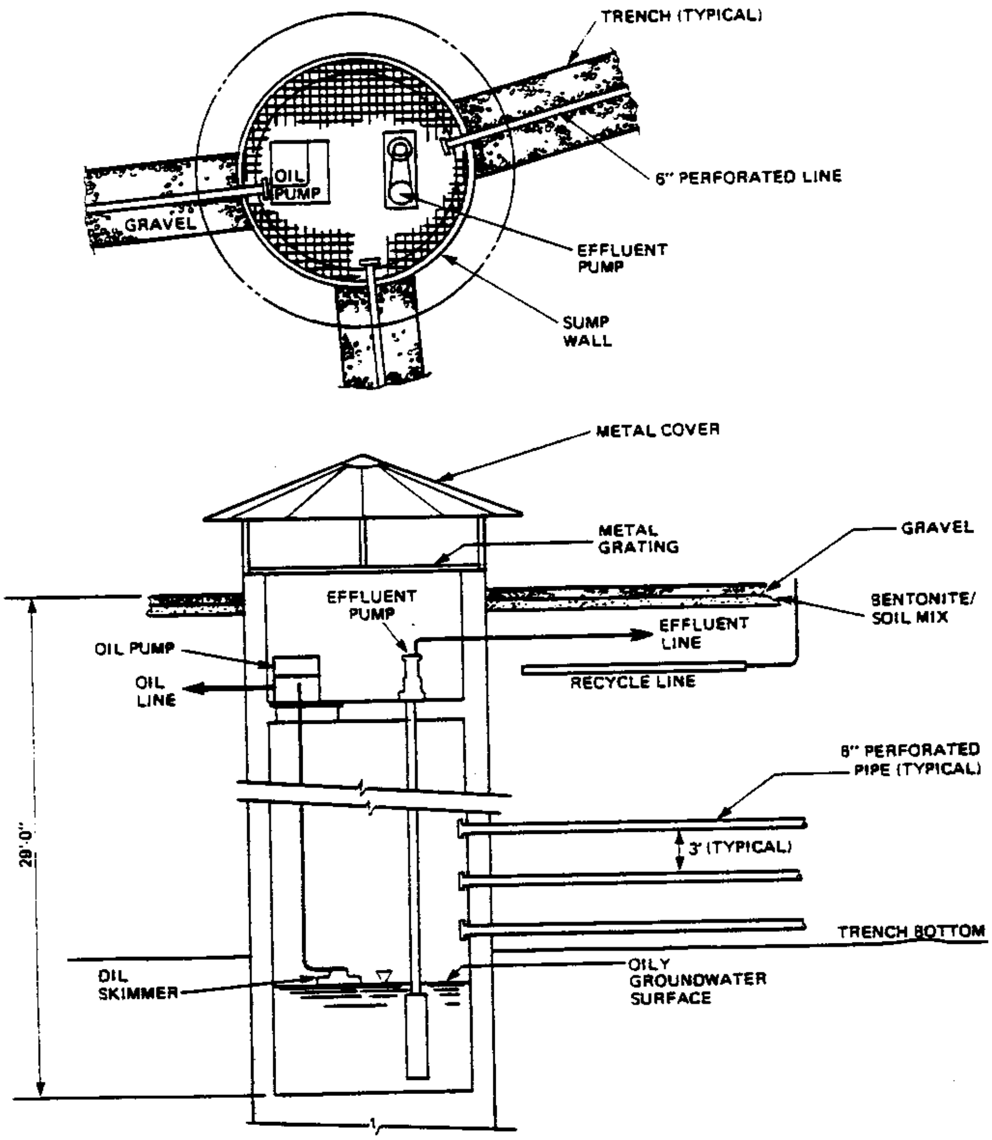

Figure 10. Plan View and Cross Section of French Drain and Extraction Sump

(Source: Paper by B.E. Bracken and H.M. Theisen, Brown and Caldwell, CA, 1982)

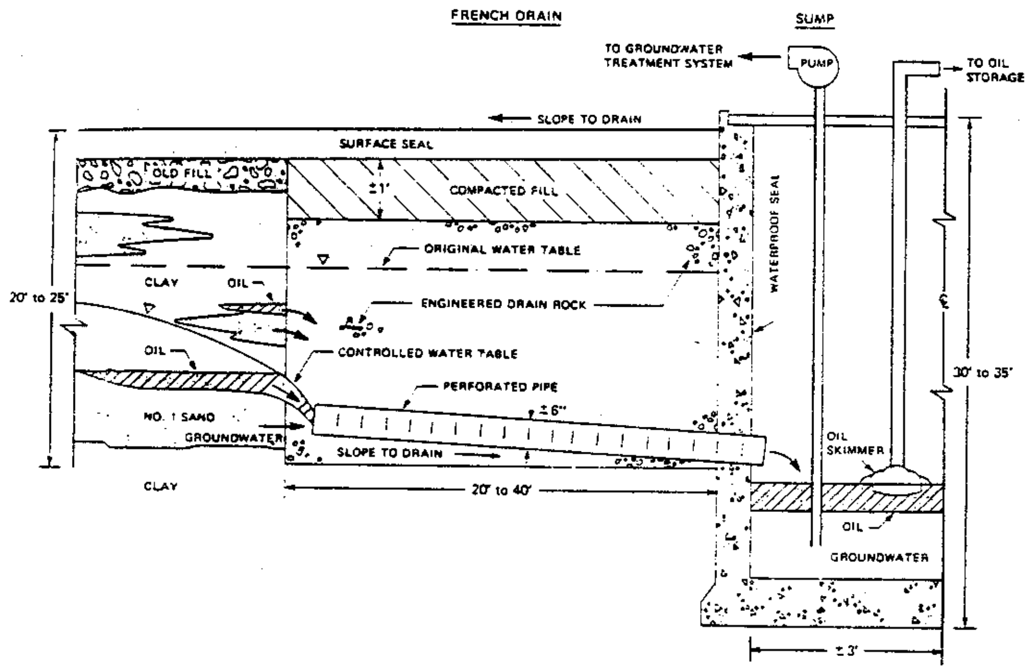

Figure 11. French Drain and Extraction System

(Source: Volume I, Preliminary Phase Report, G.E.,Co., 1-20-81)

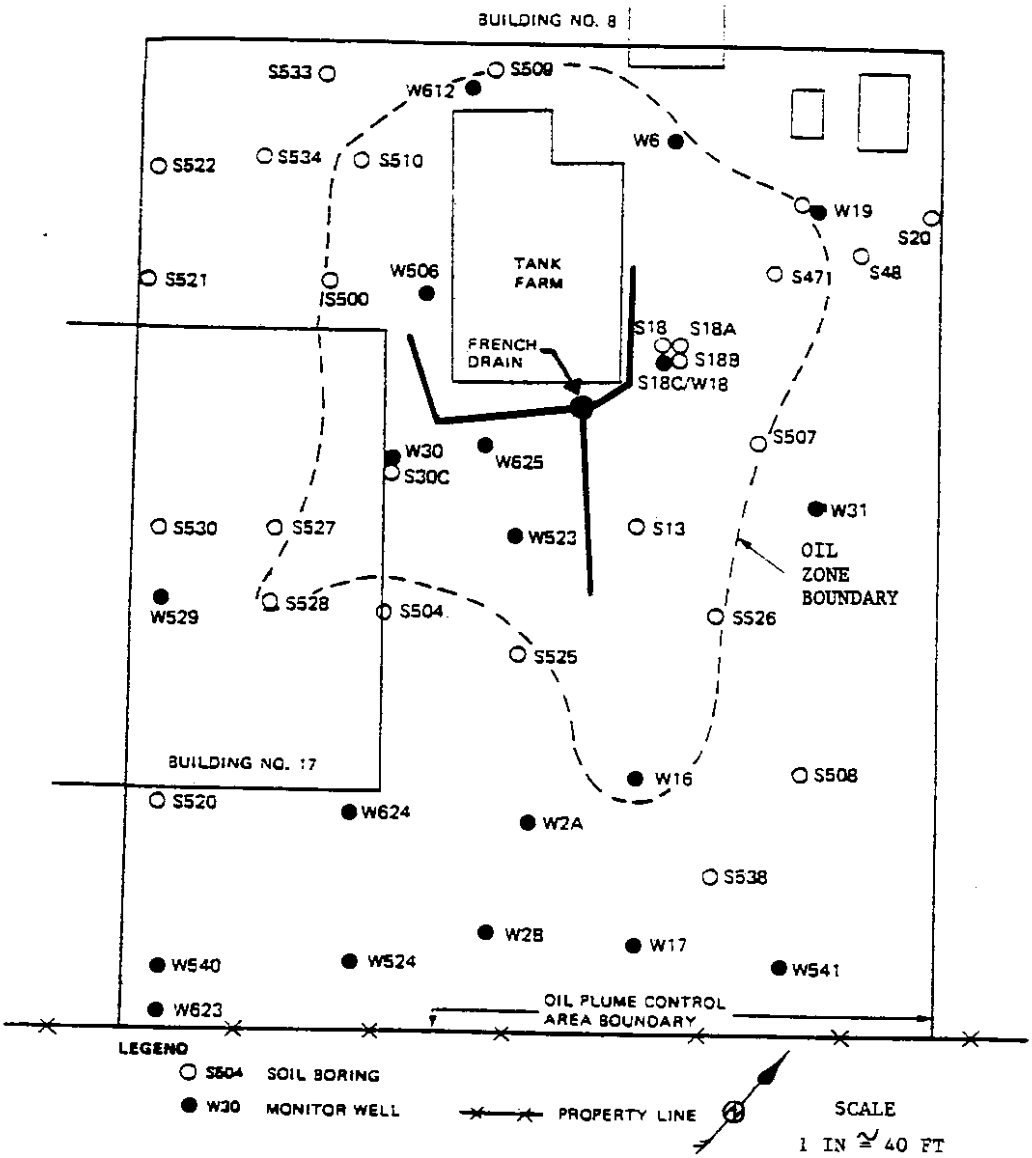

Figure 12. French Drain Location

(Source: Immediate Correction Plan Report, G.E.,Co., 1-20-81)

300.70(b)(2)(ii) direct waste treatment Class methods

Oil and sludge sediments recovered by the extraction system are stored on-site in 55-gallon (208 l) drums for a period of 90 days after which they are disposed of at a I landfill. The oily ground water treatment system which was supplied by FRAM Industrial Filter Corporation is shown schematically in Figure 13. Oil is collected through a surface skimmer directly to a storage tank. Oily ground water is extracted and pumped to the oil-water separator. The separator consists of a rectangular steel box made up of a series of vertical and horizontal coalescing, hydrophobic and oilophobic plates. The fabricated steel box is 20 feet (6m) long, 6 feet (2m) wide and 6 feet (2m) high. The plates within the separator box cause any fine oil droplets to coalesce into larger oil globules. The larger globules more readily float to the surface where they are easily collected via a static skimming pipe. Any solids present settle to the bottom of the separator and then drop into sludge hoppers for collection by periodic pumping. Treated effluent flows by gravity through a monitoring station and then into the East Bay Municipal Utility District's sanitary sewer collection system. Effluent that is in need of further testing is pumped to a storage tank prior to discharge, until additional tests for PCB-concentration levels are conducted.

As part of the design phase of the French drain system and the treatment system, detailed analyses of their expected efficiencies were made. The analysis of the efficiency of the French drain system involved simulation of the drawdown and inflow effects due to extraction. Simulated effects were calculated using standard ground water flow equations. The objectives of this simulation were to determine (1) the inflow rate to the drain, (2) the change in the inflow rate with time and (3) to predict the drawdown produced by the operation of the extraction system. With the results from the simulation, the size of the pump needed to produce optimum extraction of oil and water was calculated. The simulation results also provided conceptual verification that sufficient drawdown would occur to reverse the shallow ground water gradients.

The expected performance of the treatment system was evaluated by the pilot testing of a small scale version of a specialized package plant coalescer. The system was tested at the GE facility using small scale equipment rented from FRAM Industrial Filter Corporation and influents similar to those expected during initial operation of the extraction system. On-site pilot testing of the treatment system showed oil removal efficiencies in the range of 95.7 to 99.7 percent. The full scale system was expected to yield similar results.

It was during the preliminary stages of the French drain system installation that the tank farm was modified to provide temporary bulk storage of PCB fluids and drummed sediments. All stored sediments were eventually used for the construction of embankments as part of the overall site drainage system. At no time were contaminated sediments moved off-site.

Due to the fact that the tank farm was identified as a contributor to the subsurface oil plume as well as being the primary contributor to the ground water mound which had the potential to cause increased mobility of the oil plume, it was decided that the tank farm would be decommissioned and partially removed. This process entailed breaking down the boundary dike system surrounding the tank area, removing all but 4 tanks and constructing a building to shelter the modified storage area. A general layout of the drainage system and the surface sealing at the GE site is shown in Figure 14.

The construction activities undergone at the GE site were performed by several different construction crews. One crew was responsible for all excavation work; another crew oversaw the pile driving process; a third crew was responsible for all the piping and installation work; another group was soley responsible for reconstructing the sewer system and a fifth crew was in charge of constructing the buildings to shelter the modified storage tank area. Construction equipment utilized over the course of the program are listed in Table 2.

The site response program at the GE site was completed within a 5-month period. The response program began in August 1981 and was completed in December 1981. The firm Brown and Caldwell acted as the preparer of all contract documents and provided engineering services throughout the duration of the project. Probably the single most important feature of the construction program implemented at the GE site was the assignment of a full-time on-site project manager by General Electric. This individual had a thorough understanding of the site's history and was granted complete authority to execute contract change orders and make field decisions for G.E.

As with many construction projects, there were unanticipated delays. The most critical delays and their causes associated with the GE project are discussed in the following.

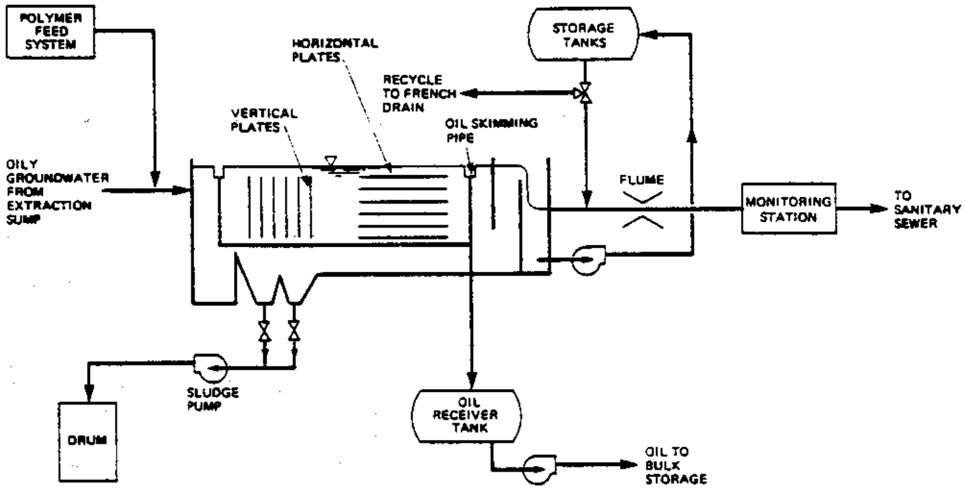

Figure 13. Groundwater Treatment System

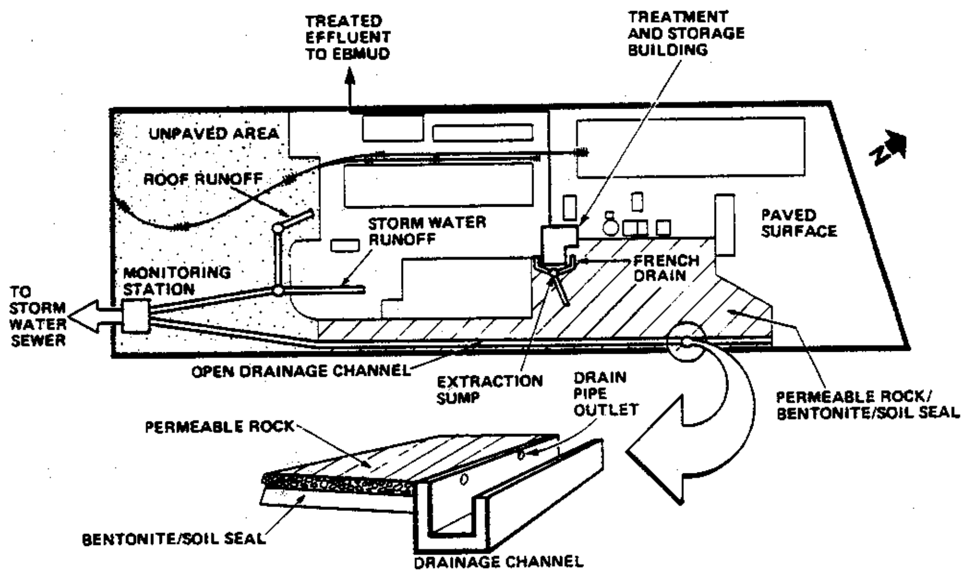

Figure 14. Surface Sealing and Drainage System

(Source: Paper by B.D. Bracken and H.M. Theisen, Brown & Caldwell, CA, 1982)

TABLE 2. EQUIPMENT TYPES AND USES

Type of Equipment	Quantity	Purpose
Deep Backhoe	1	Trenching for French drain installation
Pile Driver (A) pneumatic (B) diesel driven	2	Soil stabilization during trench excavations
Bulldozer	2	Grading; earth moving
Crane	1	Placement of pipes; moving oil/water separator
Grader	1	Grading
Diesel Driven Roller	1	Soil compaction
Bentonite Spreading Vehicle	1	Bentonite seal construction

In preparation for the excavation for the extraction sump and French drains, the contractor attempted to drive sheet piling through the site soils to prevent soil cave-in and ground water encroachment into the excavation. Initially, a pneumatic pile driver was used, however, time and time again the piles would shift and the ends would buckle due to the presence of a hard clay layer below. It was then decided to use a diesel driven pile driver but there were still technical difficulties. It is believed that the use of newer and thicker piles would have proven more successful. Eventually two different techniques were utilized to drive the piles using the diesel driver. For the excavation of the area for the extraction sump, a 24-inch diameter (0.61 m) auger was used to drill several deep holes in the sump, permitting the piles to be driven. The French drain trenches, which were approximately 25 feet deep were excavated in sections with the use of a backhoe with sheet piling added later rather than attempting to drive them into the ground during excavation. The reason the French drain trenches were excavated to a depth of 25 feet (8 m) as opposed to the depth to which oil contamination had been found i.e., 32 feet (10 m), is because a major oil-containing sand lense exists at 25 feet (8 m). It was decided that this lense would serve as the main extractable soil unit. Underlying this unit are primarily clays and discontinuous lenses.

Soil control was an important aspect of the excavation process. As soil was removed from the trench and sump excavations, it was piled according to contamination level. It was later replaced to its original excavation area and depth. Contamination levels were determined and logged during the field investigations. Excavation during this stage of the project required a much longer period of time than anticipated which resulted in higher costs and overall project delays.

Additional time delays occurred during the response activities at the GE site due to contract specifications requiring that all construction equipment leaving the site first be inspected and cleared. Inspection activities included what is known as a wipe test. The wipe test consisted of wiping one square foot of a piece of construction equipment with a swab doused in acetone and then analyzing the swab for PCBs. Wipe test analyses had to show less than 100 micrograms per square foot of PCBs before the piece of equipment could leave the site. When equipment did not pass inspection clearing the equipment to meet the specifications proved time consuming and expensive for the contractor.

The monitoring wells that are present on-site, of which there are 76, produced some problems during construction activities. Close to one third of the wells were damaged by impact with construction equipment. The wells did not extend far enough above the ground surface to be easily seen by equipment operators.

Another problem encountered involved underground piping and utility lines. As-built drawings of the facility were not available and it was therefore necessary to spend a good deal of time locating piping and utility lines prior to actual construction.

The original time schedule planned by GE for the completion of construction activities at the Oakland site comprised 120 calender days, with the contractor required to be finished by November 1, 1981. Neither of these deadlines were met. The project was not completed until December 1981, due to the problems described previously.

COST AND FUNDING

Source of Funding

General Electric Company paid for all project costs which amounted to a total of $1,583,300. The state did not assess any fines on GE to compensate for the monitoring costs.

Selection of Contractor

No information is available on the contractor selection process.

Project Cost

The total construction costs for surface sealing and drainage, and the oil recovery system was about $1.6 million (see Tables 3, 4 and 5). This cost does not include preliminary study and design work by Brown and Caldwell. No cost information is available for the cost of this work, which included monitoring well installation, sampling and analysis, and repair, as well as design and planning. The following cost information is based on verbal discussion with a General Electric engineer; no invoices were available.

Surface Sealing and Drainage

The sum cost of \$734,000 for surface sealing and drainage includes the expenditures listed in Table 3 and highlighted in Table 5. The \$42,000 cost of grading is split between asphalt and clay capping costs for the purpose of calculating unit costs. At a cost of \$155,000, the unit cost for the 135,000 square feet (12,542 m^2) of asphalt pavement was \$1.15/square foot (\$12.36/m^2). At a cost of \$177,000, the unit cost for the 156,000 square feet (14,493 m^2) of bentonite capping with a gravel cover was \$1.13/square foot (\$12.21/m^2). The unit cost for constructing 4,150 feet (1,265 m) of curbs and gutters was calculated by dividing the total cost of \$132,800 by 4,150 feet (1,265 m), which results in a unit cost of \$32/foot (\$105/m).

300.70 (1)(b)(ii)(A) surface sealing

Oil Recovery and Treatment System

The sum cost of \$337,000 for the installation of the French drain system is based on drain arm lengths of 60, 70 and 80 feet (18,21 and 24 m). The unit cost of constructing a total of 210 feet (63m) of 20-25 feet (6-8m) deep trenches was about \$1,605/linear foot (\$5,264/m). This cost excludes expenditures for the sump and other related costs given in Table 4.

300.70(1)(b) (iii)(d)(1) subsurface drains

The operation and maintenance (O. & M.) cost for treating between 1,000 and 1,500 gallons (3,785-5,678 l) per month excludes equipment amortization and about two hours/week of the plant manager's time to perform batch treatments. At a total O. & M. cost of about \$50,00/year, the unit cost for this initial rate of treatment is \$2.70-4.16/gallon (\$0.73-1.10/l).

300.70(b)(2)(ii) direct waste treatment methods

PERFORMANCE EVALUATION

The monitoring plan developed to evaluate the effectiveness of the French drain system and the surface cover at the GE site involves the measurement of static ground water levels and the analyses of monitor well and surface runoff samples. Through this type of measurements and analysis, the following four conditions are monitored: (1) ground water, (2) recovered and treated ground water, (3) recovered sediment and oil, and (4) stormwater runoff. The monitoring program at the GE facility has, thus, been four-fold. A new and revised monitoring plan has recently been designed, however, the details of this plan are not yet available. The parameter descriptions, the monitoring and sampling frequencies discussed below originate from the initial monitoring plan implemented at the site.

TABLE 3. SURFACE SEALING AND DRAINAGE COST-GE, OAKLAND, CALIFORNIA

<u>Surface Sealing and Drainage</u>	
• Equipment mobilization	$ 26,000
• Equipment demobilization (includes cleaning)	$ 3,600
• Paving	$134,000
• Perimeter fencing	$ 6,000 ($10/foot, $33/m)*
• Drainage system pipe	$150,000 ($18/foot, $59/m)
• Curb and gutter	$132,800 ($32/foot, $105/m)
• Manholes	$ 4,700 ($280 each)
• Monitoring equipment at end of manhole for surface sealing	$ 12,000
• Supervision (on-site contractor and consultant oversight)	$ 20,000
• Soil removal	$ 47,000 ($23/cubic yard, $30/m^3)
• Grading	$ 42,000
• Claying sealing; top rock	$156,000
subtotal	$734,100

*Unit costs are as-built

TABLE 4. OIL RECOVERY SYSTEM COST - GE, OAKLAND, CALIFORNIA

Oil Recovery System	
• Equipment mobilization	$ 41,000
• Demobilization	$ 14,000
• Sump, including sheet pilling	$ 85,000
• Treatment system	$ 49,200
• Plumbing modifications on existing tank farm to receive material before treatment to test for treatment need	$ 8,000
• Tank farm building	$ 50,000
• Sanitary sewer system modifications to discharge treated effluent to EBMUD	$ 33,000
• Electrical and instrumental oil recovery system	$117,000
• Monitoring equipment for EBMUD	$ 12,000
• Project management for EBMUD modifications	$ 20,000
• French drain system	$337,000
• Prepurchased equipment (oil/water separator, pumps, water handling)	$ 80,000
subtotal	$846,200
• Operation and maintenance (excluding about 2 hours/week plant manager's time)	$ 50,000/year

TABLE 5. SUMMARY OF PROJECT COSTS-GENERAL ELECTRIC, OAKLAND, CALIFORNIA

Task	Quantity	Actual Expenditure	Unit Cost	Period of Performance
A. Surface Sealing and Drainage (a)		Subtotal:$734,100	--	1981
1.Asphalt paving	135,000 sq.ft. (12542 m^2)	($155,000)(b)	$1.15/sq.ft. ($12.36/m^2)	1981
2.Betonite cap with gravel	156,000 sq.ft. (14,493 m^2)	($177,000)(b)	$1.13/sq.ft. (12.21/$m^2$)	1981
3.Curbs and gutters	4,125 feet (1,265 m)	($132,800)	$32/foot ($105/m)	1981
B. Oil Recovery System(c)		Subtotal:$846,200	--	1981
1. French Drain(d)	length:210ft.(63m) depth:22.5ft.(7m)	($337,000)	$1,605/foot ($5,264/m)	1981
2. Operation and Maintenance of treatment system	1,000-1,500 gallons (3,785-5,678 l)/ month	$50,000/year	$2.70-4.16/gallon ($0.73-1.10/l)	1982
TOTAL Project Cost	--	$1,580,300	--	1981

(a) Subtotal also includes other costs given in Table 4.

(b) Cost includes half of $42,000 cost for grading.

(c) Subtotal also includes other costs given in Table 5.

(d) Excluding sump cost.

Ground Water

Ground water monitoring is performed to identify PCBs in the ground water and to determine changes in the ground water surface elevation. The parameters analyzed are static water levels, filtered and unfiltered PCBs, and oil and grease. Water level measurements have been taken monthly from all 76 on-site monitoring wells. All wells are monitored within the same 24-hour period. Samples for laboratory analysis are collected from 19 selected on-site monitor wells on a semiannual schedule.

The water levels measured are compared to previous readings to confirm whether or not the operation of the French drain continues to result in a drawdown of the ground water mound level and in a reversal of the shallow ground water flow direction. The result of the reversal in shallow ground water flow in the vicinity of the ground water mound, has been that ground water flow is in the direction towards and into the French drain system. Figure 15A shows ground water levels prior to the construction of the French drain while Figure 15B shows the same area and its ground water levels 8 months after the start-up of the system. It can be seen by the difference in the configuration of the ground water contours and the ground water flow direction that the extraction system has produced a reversal in the shallow ground water flow regime.

Recovered, Treated Ground Water

The treated effluent from the oil-water separator process is monitored to evaluate the treatment process and to ensure that the discharge to the district sewer system meets EBMUD requirements. The parameters analyzed includeflow rate, PCBs, total identifiable chlorinated hydrocarbons (TICH), oil and grease and total suspended solids (TSS). Parameter measurement and analysis is currently performed monthly on grab samples. Average weekly values for these parameters during the first 8 months of system operation are given in Table 6.

Recovered Sediment and Oil

The sediment sludge and oil recovered by the treatment process is sampled and analyzed to determine PCB concentration levels of the wastes removed by the treatment process. Parameters analyzed are PCBs for the sludge and oil; and fluid level in the oil storage containers. Sediments are usually stored on-site in 55-gallon (208 l) drums and samples of the sludge material are collected

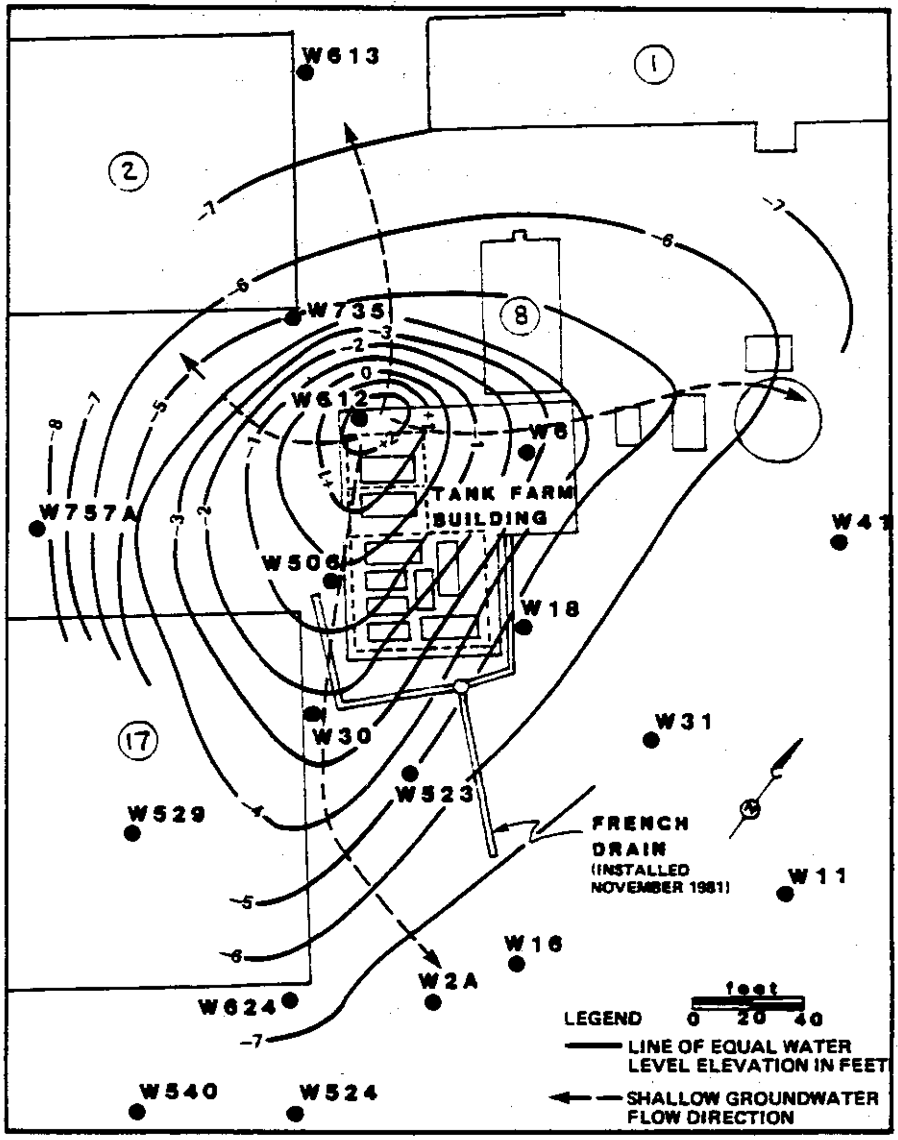

Figure 15-A. Groundwater Contour Map - September 1981

(Source: Paper by B.D. Bracken & Theisen, Brown & Caldwell, CA, 1982)

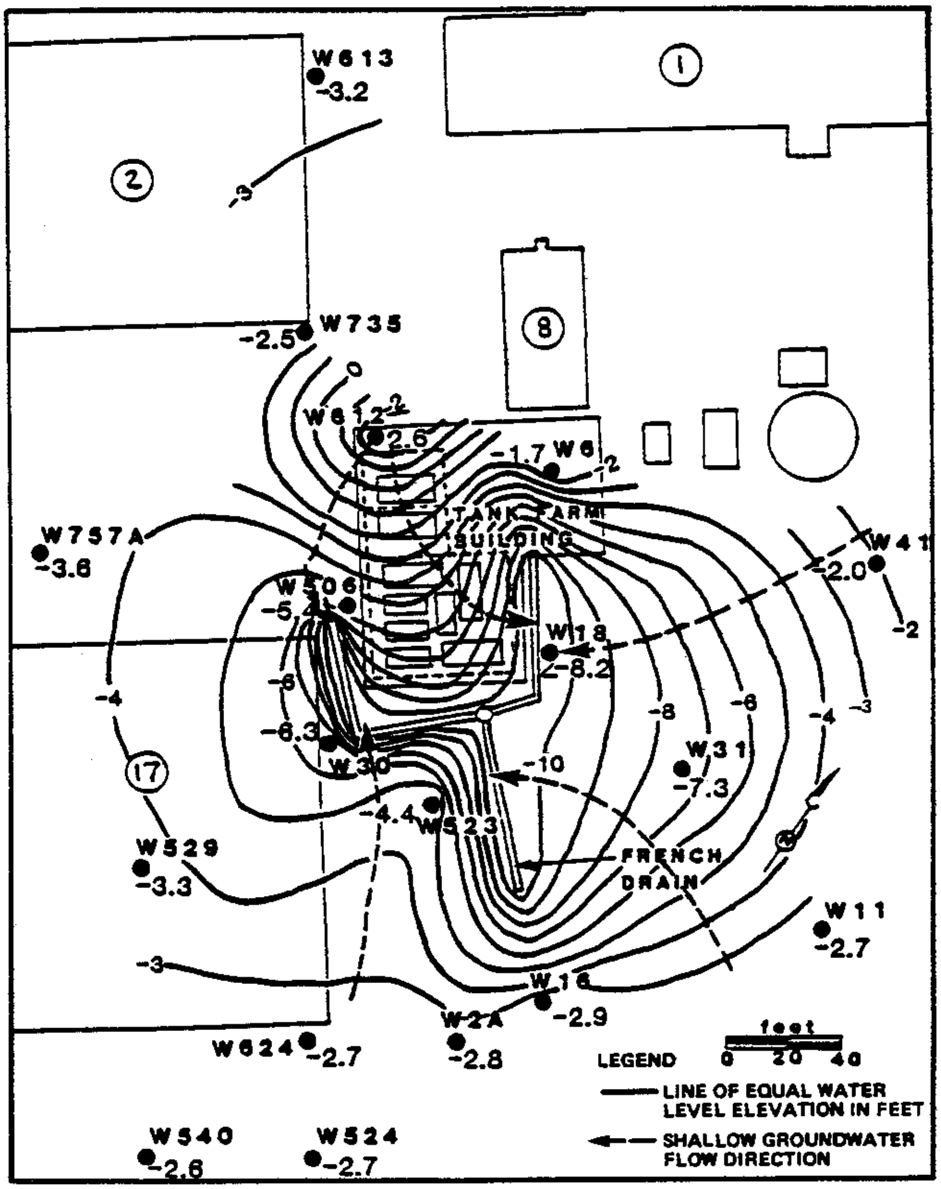

Figure 15-B. Groundwater Contour Map - August 1982
(Source: Paper by B.D. Bracken & H.M. Theisen, Brown & Caldwell, CA, 1982)

TABLE 6. RECOVERED, TREATED GROUND WATER MONITORING RESULTS FOR FIRST EIGHT MONTHS OF OPERATION

Parameter	Average value	
	Influent	Effluent
Flow, gpd	-	1,100
PCBs[a], ppb	6.5	0.1
Oil and grease, ppm	9.2	7.1
Total suspended solids, ppm	5.8	5.8

[a]Actually total identifiable chlorinated hydrocarbons.

Note: For first 8 months of operation.

(From: Paper by B.D. Bracken and H.M. Theisen, Brown and Caldwell, CA, 1981) from each drum prior to it being sealed. Oil samples are collected and analyzed on a monthly basis.

Stormwater Runoff

Stormwater runoff is monitored such that an evaluation can be made of the effectiveness of the bentonite and asphalt surface sealing systems across the site. Parameters analyzed are PCB and TSS content of surface runoff. Sample collection for surface runoff is automatic. The sample collection system in this case, was installed during the construction of the drainage system. It consists of a portable automatic vacuum compressor sampler, a sampler actuator and sample enclosure. The automatic sampler is set to collect approximately 4 liters over 24 hours of operation or 160 milliliters per hour. Samples are also removed from the sampler after every storm event or at least once every 48 hours for long-duration storms.

In addition to the seemingly complex monitoring system described above, during the first 6 months of the system's operation representatives from the Department of Health Services observed operating procedures and inspected site conditions bi-monthly. Currently, site inspections are infrequent and unplanned.

In general, the combined systems at the GE site are performing as anticipated. However, there are always differences between predicted and actual performance efficiencies. At this site, differences were noted between predicted and actual efficiencies the extraction system. As shown in Figures 15A and 15B, the operation of the French drain system has resulted in sufficient drawdown to control shallow ground water flow and reverse flow directions towards the French drain system. However, the quantity of oil and ground water removed is much lower than anticipated. The system was designed to recover 14,000-15,000 gallons of total fluids per month. Currently between 1,000 and 1,500 gallons of water per month are pumped and treated through the extraction-treatment system; and approximately 1 gallon (3.7 l) of oil is recovered per month. The overall consensus regarding these low recovery rates seems to be that the system is overdesigned for the existing hydrogeological conditions. As it turns out, ground water flow rates in the area are much lower than originally estimated. The system was designed for a ground water flow rate of 150 gpm. The flow rate on-site is only 15 gpm. In other words the design is more conservative than necessary for the existing hydrological conditions.

It was explained earlier in the discussion on the site's hydrogeological conditions, that the ground water flow system was defined as a single homogeneous unit for the purpose of calculating average permeabilities and ground water flow rates. As evidenced by comparison of the calculated values for flow rates and permeabilities, and actual recovery rates, it is apparent that it is very difficult to estimate average values for these parameters for strata that consist of discontinuous clay, sand and gravel units. The result of such an attempt, in this case, is a system designed for much higher ground water flow rates. It is for this reason that there is such a discrepancy between predicted and actual recovery rates.

The combined systems at the GE site have successfully controlled contaminant movement through the use of both surface and subsurface techniques. The surface seal and drainage systems together serve to (1) reduce infiltration of precipitation into the ground water system thus enhancing the ability of the oil control system to control ground water gradients and (2) to direct and control the movement of surface runoff such that all runoff is monitored and eventually discharged according to State regulations. The subsurface French drain system has worked to reverse shallow ground water flow directions and diminish ground water gradients, thus preventing any further movement of the oil plume. The treatment system performs adequately, discharging an effluent with constituents that are within the state and district's concentration level standards.

In general terms the response actions taken at the GE facility have proved successful. The extraction system does not recover materials at the rate which was originally estimated, but the effect produced has been that which was predicted. The primary concern during the design of the system was not oil removal, but rather the immediate reversal of ground water flow and the lowering of the shallow ground water table. The primary concern and goal was to prevent any further movement of the existing oil plume. The removal of oil was a secondary concern. In this light, the fact that the system recovers only 1 gallon of oil per month is not as critical an issue as it might be otherwise. The effect that the operation of the system has had upon the shallow ground water regime is that which was anticipated.

Surface sealing is applicable in any situation where there is a need to control surface infiltration. The need to diminish or eliminate infiltration will arise from problems associated with a particular area's ground water regime. Surface sealing is most frequently used in conjunction with some other contaminant control measure, such as ground water pumping or a French drain system as in the case of the GE site. A surface seal is most often used as an ancillary measure with another technique, serving as an aid for the successful operation of more primary contaminant controls. It is seldom a technique that can be utilized alone to remedy a ground water pollution problem.

Ground water treatment systems are utilized in situations where ground water will be pumped to the surface and ultimately discharged into some surface water system or back into the ground water system. The type of treatment system selected will depend upon the contaminants to be removed and pretreatment standards needed for the local Publicly Owned Treatment Works (POTW) to meet water quality regulations. This technique can either be used in conjunction with other measures, or soley on its own, depending on site specific conditions.

The French drain system is relatively new to the realm of site response actions and there are still many questions concerning its applicability. There are, however, some general guidelines that can be used during the response technique selection process.

The primary alternative to a French drain for extraction purposes is the use of a well pumping system. There are situations, however, in which a well pumping system is not the most efficient means to recover subsurface fluids. There are four types of conditions that influence the applicability of a French drain system in a particular situation and these are: (1) the movement of extractable fluid relative to ground water; (2) the permeability of the subsurface material; (3) the plume configuration and depth to plume and; (4) the viscosity and density of the plume fluid.

The initial consideration involved in the selection of a French drain system is whether or not the fluid to be extracted flows in the same direction as ground water in the area. In order for a French drain to operate properly the extrable fluid must be moving with the ground water so that it can be collected in a central sump.

The permeability of the subsurface materials affects the ease with which fluids can be extracted. In a situation where the materials have a very low permeability, if a well pumping system were to be employed, a large number of wells would probably be warranted due to the need for close spacing of the wells. The more wells and pumping time necessary, the more costly the operation. In a case such as this, if all other conditions permit, a French drain may very well be more cost effective. A French drain system relies on gravity for much of the fluid movement. The fluid is then collected in a central sump area from which only one or two pumps are necessary for final extraction. The French drain system is also applicable in situations where the subsurface material is heterogenous in nature, e.g. the GE site. Where geologic units are discontinuous, it may be difficult to precisely define the configuration of the contamination zone. In such a case, the French drain system provides greater flexibility in terms of the amount of area it is capable of extracting from. In a situation where the geologic conditions are discontinuous due to impermeable strata such as clay, the system would not be able to operate and therefore would not be considered applicable.

The configuration of the contamination zone and the depth to the zone and also important considerations. A French drain system is applicable where contamination exists over a large area, because the system is capable of creating a large zone of influence. In the case where a large contamination zone exists, such as a plume with a 100-foot radius, if a well pumping system was selected, the conditions would demand that a large number of wells be used and, as previously mentioned, this results in a very costly operation. In a case such as this, the French drain should be viewed as a viable alternative.

The depth to the plume surface can also play a large part in the decision-making process. The deeper the drain trenches will have to be excavated, the greater the cost of construction.

The last factors to be considered are the viscosity and density of the fluid to be extracted. The French drain system is most applicable in the case where the fluid floats on the water, i.e., its density is less than water; and where the fluid has a low viscosity. Where the contaminated fluid is naturally separated from the existing water, with the use of a French drain system, the two fluids can be extracted separately. This would not be possible with a well pumping system. The viscosity of the fluid is considered because a highly viscous material may cause clogging within the drains. The French drain system, therefore, is more suitable for recovery of low viscosity fluids.

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GALLUP SITE

PLAINFIELD, CONNECTICUT

INTRODUCTION

NCP References

During 1977-1978, approximately 1,400 barrels and an unknown quantity of free liquids were dumped into three gravel pits located on a parcel of land in Plainfield, Connecticut. Chemical wastes identified on the site included chlorinated and unchlorinated solvents, flammable sludges, organic chemicals, and acidic and caustic materials. The wastes contaminated ground water below the site that discharges into Mill Brook. Although contamination of Mill Brook had not occurred, the state intitiated remedial action on the site because of the threat of pollution of Mill Brook and nearby wells. Levels of contamination in the ground water under the site exceeded drinking water standards for copper, nickel, iron, zinc, cadmium, dissolved solids, chlorides, and various solvents.

Background

Hazardous waste dumping on a 29 acre (11.74 ha) site in Plainfield, Connecticut began in 1977 when Stanton Gallup, the property owner, agreed to receive shipments of hazardous waste from the Dick Trayner Trucking Company. Trayner made arrangements for Chemical Waste Removal, located in Bridgeport, Connecticut, to transport free liquids and barrels of hazardous waste to Gallup's property in Plainfield. While Chemical Waste Removal was licensed by the Connecticut Department of Environmental Protection to transport hazardous wastes to licensed disposers, neither Gallup nor Traynor had permits to dispose of these wastes.

The site was discovered in January 1978 when hunters on the property witnessed drums being thrown out of a box trailer into the gravel pit. The hunters photographed the incident and later gave the pictures to the Conncecticut State Police (CSP) and Connecticut

300.63(a)(4) incidental observation by public

Department of Environmental Protection (DEP), which immediately began investigating the site. Trayner and Chemical Waste Recovery were linked to the disposal operations by the photographs, which showed the license number of a trailer that was leased to Chemical Waste Recovery. Chemical Waste Recovery acted as a transporter for hazardous wastes between generators and disposers. During the course of police investigation, Chemical Waste Recovery was linked with illegal dumping operations in Coventry, Rhode Island. State officials believe that when this site caught fire in 1977, an arrangement was made with Gallup to provide needed disposal capacity.

300.64
preliminary
assessment

In February 1978, after approximately one month of police surveillance, simultaneous raids were made on Gallup's property in Plainfield and Canterbury, Connecticut and on Chemical Waste Recovery in Bridgeport, Connecticut. Gallup, Trayner, and the owner of Chemical Waste Recovery were arrested and charged with violation of Connecticut law prohibiting the discharge of substances or materials into the waters of the state without a state permit. Gallup pleaded nolo contendre to these charges and agreed to pay the state the sum of $15,000 for the costs of immediate protection and control of the site. Gallup also agreed to reimburse the state for its clean-up costs up to the sum of $750,000. Further, the state fined him $25,000.

Synopsis of Site Response

The Connecticut Department of Environmental Protection conducted a two phase site response. The first phase consisted of a hydrogeological assessment of the site and was conducted from June to August 1978 by Fuss and O'Neill Consultants under contract to DEP. The second phase, which ran from June through August 1978, consisted of excavation and removal operations. Chemtrol Pollution Services Inc, a subsidiary of SCA Disposal Services, conducted all phase 2 operations under contract to DEP. Remedial work included excavation of waste pits and lagoons and excavation and removal of approximately 1,400 barrels of waste. Chemtrol transported the excavated wastes and heavily contaminated soil to its Model City Landfill in New York, 580 miles (928 km) away. Slightly contaminated soil was transported 1.5 miles (2.4 km) to a nearby landfill in Canterbury, Connecticut. Clean-up operations took two months with crews working 12-14 hours a day, seven days a week.

Treatment of the ground water was not undertaken as part of the site response because the hydrogeological assessment suggested that the geology of the area would cause a natural attenuation of the plume and dilution of contaminants to the point where they would no longer be a threat. Thus, the state's clean-up goal was only to remove the source of contamination, not treat the ground water.

SITE DESCRIPTION

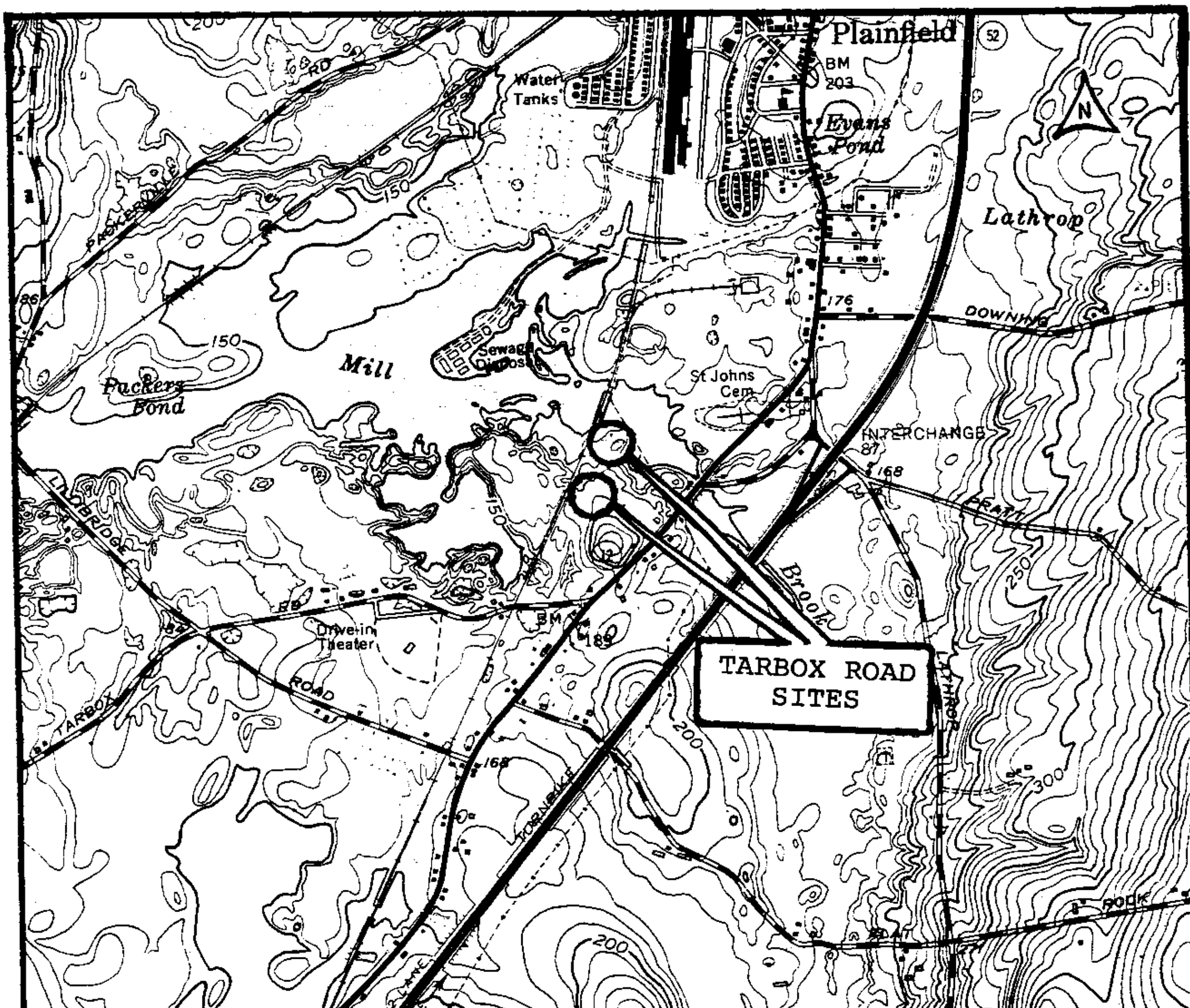
Surface Characteristics

The Gallup site is located on a 29 acre (11.7 ha) tract of land in Plainfield, Connecticut (see Figure 1). This vacant property is bounded on the west by railroad tracks for about 2,400 feet (731.5 m), on the north by a power transmission line crossing the property at an oblique angle, on the south by Tarbox Road, and on the east by Connecticut Route 12 and several rural residential tracts. Mill Brook meanders from east to west across the northern portion of the Gallup property and passes under the railroad tracks. A large wetland area is associated with the brook. Before the dumping incident, DEP designated Mill Brook as a "class A" stream, meaning that it was considered to be pristine and a potential future drinking water supply and that no treated industrial discharges were allowed into it. (As of January 1983, it has been redesignated "class B/A," which means that it has been polluted but that DEP's goal to bring it back to class A status). The Gallup parcel was once used for a gravel mining operation and its generally flat surface has many excavation pits and overgrown stockpiles, but no significant vegetation overall.

Continental glaciation during the Pleistocene period significantly affected the soils and topography of the site, as it did the entire New England region. Glacial ice advanced through the area, eroding soil and upper bedrock, then retreated, depositing a lodgement (or lower till) consisting of a wide range of materials having various textures, colors and thicknesses, and an ablation till (or upper till) made of a friable mixture of sediments that ranged from silt and clay to large cobbles and boulders.

From June 6 to October 30,1978, Fuss & O'Neill conducted a geologic assessment of the Gallup site using 22 borings and 18 test pits. The bedrock underlying the site was a metamorphic rock, gneiss, believed to be part of the Putnam gneiss. Its surface was not weathered, apparently because the weathered zone had been removed by glacial scour. This rock was extensively fractured, with a predominant fracture dip of 47 degrees that was

Figure 1. Location Map of Gallup Hazardous Waste Site, Plainfield, Connecticut



believed to dip in a northerly direction. Below the bedrock's surface were found numerous vertical weathered cavities or fractures that were similar to solution cavities in limestone. Larger cavities were filled with a gray silt that probably came from overlying soils. Fuss & O'Neill believed that these vertical cavities or fractures were associated with a vertical fault with relative horizontal motion that was located near some of the borings. A bedrock contour map in Figure 2 shows that the bedrock surface rises beneath a hill in the east-central part of the property and slopes northward beneath the disposal areas to form the southern flank of a buried rock valley that contains Mill Brook and its sediments.

An almost continuous layer of glacial till overlies the bedrock. A dense to friable gray silt and fine sand and soil mixture that contains clumps of medium to coarse sand, gravel, cobbles and boulders, this glacial till varies from 2-22 feet (0.6-6.7 m) thick. The till was thickest on the hill at the east-central part of the property and thinned to the north and northwest.

For most of this tract of land, a layer of interbedded sands and gravels, with isolated units of silt, overlies the glacial till. This layer is 3-40 feet (0.9-12.2 m) thick, and Fuss & O'Neill believed it to be deposition from glacial outwash along the Mill Brook valley. Above the sand and gravel layer lies a fine grained sediment unit originating from glacial Lake Quinebaug deposit. This unit was found to be 2-18.5 feet (0.6-5.6 m) thick.

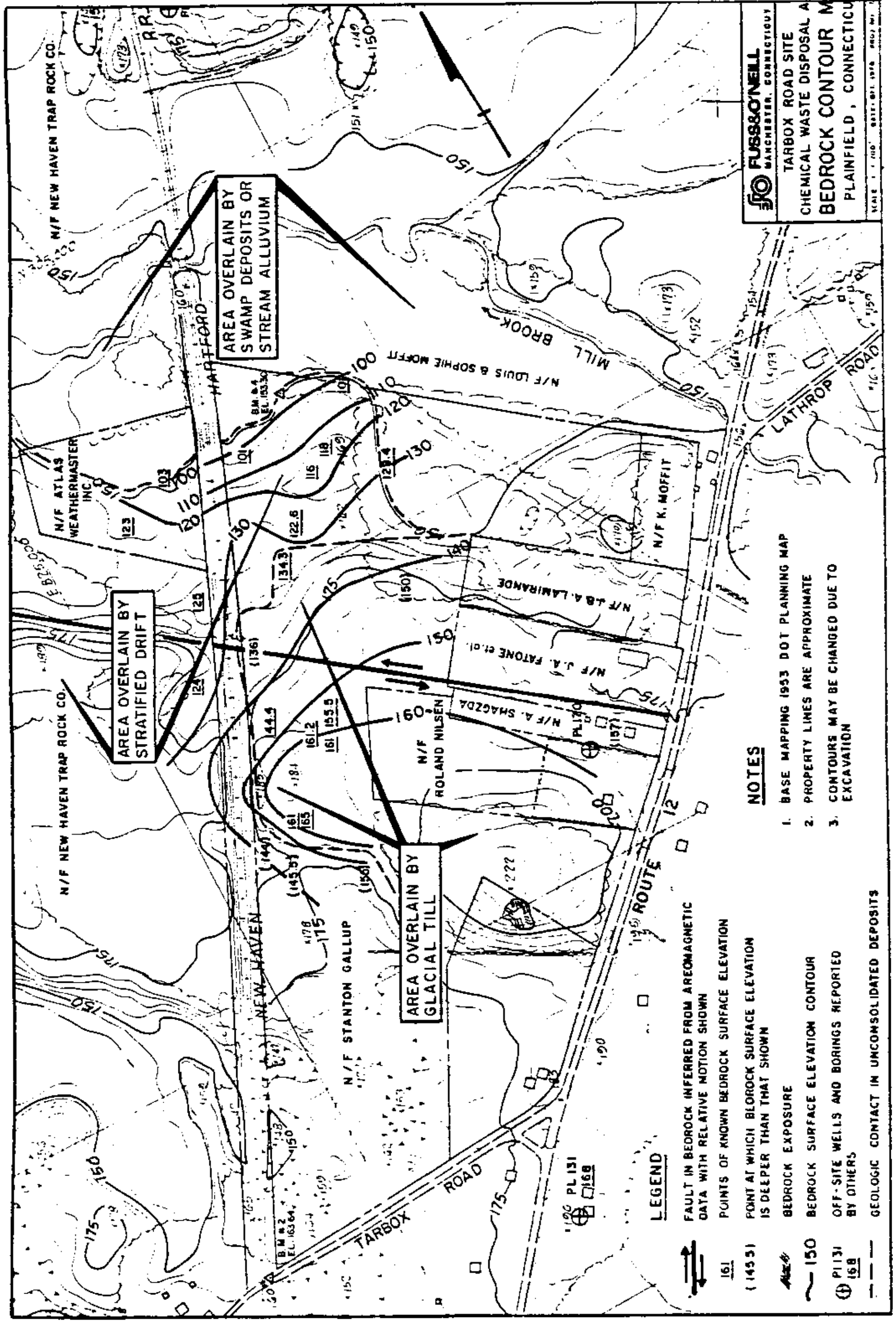
These upper layers of soils have various distortions in depth and area due, according to Fuss & O'Neill, to erosion and accumulation of stream alluvium and swamp deposition since glacial time.

<u>Hydrogeology</u>

300.68(e)(2) (i)(D) hydrogeological factors

Fuss & O'Neill used 22 monitoring wells placed in borings and 13 wells placed in test pits on-site plus 12 surface water reference points, which were believed to reflect the ground water system, to determine the hydrogeology of the Gallup site. Wells had polyvinyl chloride (PVC) screens that were placed at various zones below the water table and connected by solid PVC riser pipes to the ground surface. The wells were developed by pumping so that they could yield water for sampling and react freely to local changes in head. Some wells were sunk into the saturated bedrock by inserting the solid riser piper into core holes in the bedrock and

Figure 2. Bedrock Contour Map, Gallup Site



Source: Fuss & O'Neill, January 1979

sealing them to the rock with rubber gaskets and a bentonite seal.

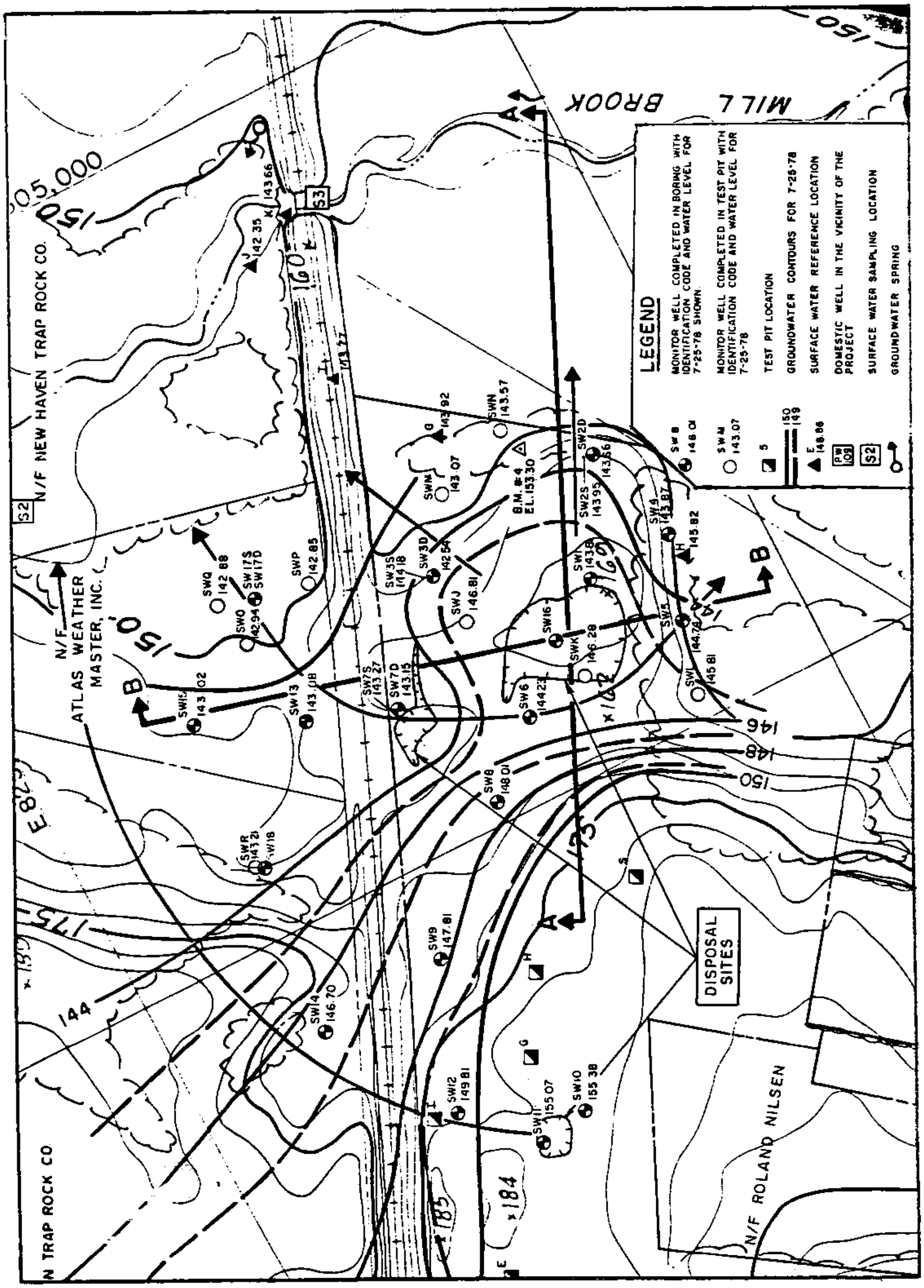
Fuss & O'Neill periodically monitored water levels in these wells to develop the water table contours and define horizontal ground water flow. To determine vertical flow, pairs of wells were installed at certain locations with differing depths. This enabled the engineers to compare the differences in ground water heads. The ground water contours shown in Figure 3 suggest that the shape and slope of the water table is "significantly influenced by the local geologic materials and demonstrates a continuous relationship between flow in the fractured bedrock and the saturated, unconsolidated materials," according to Fuss & O'Neill.

Generally speaking, ground water flows radially from the hill located at the east-central portion of Gallup's property. From the west side of the hill, ground water moves westerly to northerly and discharges into Mill Brook and its wetlands. From the north side of the hill, ground water moves northerly to Mill Brook and its wetland located east of the railroad. This flow has a significant downward vertical component of flow caused by a recharge mound found near wells SWI, 2D, 2S, 3D, 3S and 16, as shown in Figure 3.

Several local features of the ground water system west and northwest of the main hill were noted. Near wells SW 10 and 11, the water table is within the fractured bedrock and moves northwesterly with a gradient of 0.05 ft./ft. (1.5cm/30.48 cm). Around well SW 12, the flow is in the upper fractured bedrock and bottom 5 feet (1.5 m) of glacial till and moves in a northerly direction with a gradient of 0.02 ft./ft (0.6 cm/30.48 cm). Fuss & O'Neill state that the smaller gradient in this area "reflects the increasing system transmissivity in the downgradient direction." Along the flow path near wells SW 14, SW 18 and SWR, the flow is in the fine-grained stratified drift sediments that overlie the till and bedrock. The flow is northerly with a gradient of 0.01 ft./ft. (0.3 cm/30.48 cm). At wells SW 15 and SW 171, the water table gradient flattens further to 0.0025 ft./ft. (0.08 cm./30.48 cm), which is believed to reflect "the increased saturated thickness and material permeability in this direction."

Using its monitoring well data, along with some assumptions about relative quantities of recharge rates in the till compared to the stratified drift areas, and about the saturated thickness of the bedrock system, Fuss & O'Neill calculated order of magnitude values for

Figure 3. Hydrogeologic Map, Gallup Site



Source: Fuss & O'Neill, January 1979

material permeability, flow rates and flow volumes (see Table 1). The firm's report stated that "although there is an increase of more than two orders of magnitude in the system permeability, there is only a one-half order of magnitude increase in the flow volume and velocity. That is a direct result of increasing system transmissivity and material porosity."

Fuss & O'Neill stated that the ground water flow pattern, described above with respect to flows westerly and northwesterly from the main hill, was similar to that found northerly from that hill. The latter flow was presented graphically by two cross sections (see Figures 4 and 5; the locations of the cross sections are shown in Figure 3). These cross sections show soil and rock materials, ground water heads and flows paths.

Several local features of this northerly flow pattern were discovered. Ground water flow near wells SW 6 and SW 8 is within the glacial till and moves northerly. North of these wells, the flow is found mainly within the stratified drift sediments at wells SW 1- SW 5 and SW 16. These sediments were thought to be from the Mill Brook outwash, discussed above. Overlying this outwash are fine-grained Lake Quinebaug deposits that restrict the upper portion of ground water flow. These fine-grained materials, combined with locally high recharge rates caused by overlying coarse-grained sediments, have created a ground water mound 3 feet (0.9 m) high. This mound causes a downward ground water flow, as shown in Figure 4.

Apparently, the water table in this portion of the property fluctuates with the seasons. During dry summer months, the ground water discharges into Mill Brook and its wetlands through a deep flow path. During winter months, the water table is higher and a second path of discharge exists through the coarse materials that overlie the fine-grained Lake Quinebaug deposits (see Figure 4). According to Fuss & O'Neill, "a seasonal water table rise of 2 feet (0.6 m) or more would cause flow rates to increase by more than one order of magnitude along the upper portion of the water table due to the increased material permeability."

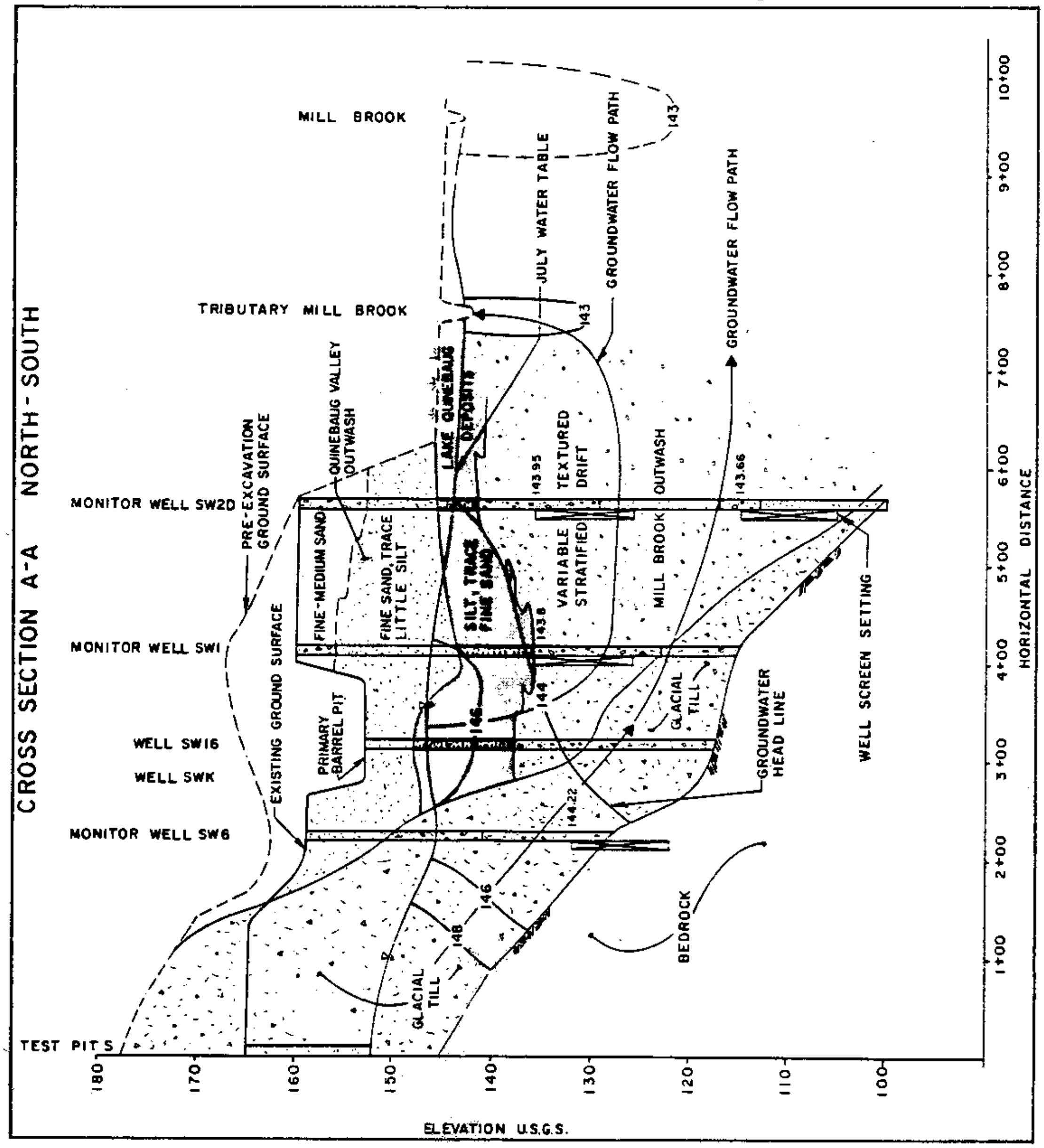
Beavers have modified ground water flows beneath the northern portion Gallup property recently. A beaver colony built a dam across Mill Brook where it passes under the railroad, creating a small impoundment across the stream channel and raising the elevation of the surrounding wetlands. This seems to have changed the radial flow system discussed above to a flow through system, whereby the pond recharges the ground water

TABLE 1. ESTIMATE OF HYDROGEOLOGIC PARAMETERS, GALLUP SITE

	Gradient (ft./ft.)	Estimated Average Annual Recharge Along Flow Path	Permeability (ft./day)	Porosity	Velocity (ft./day)	Saturated Thickness	Net Discharge (ft.^{3}/day)
Bedrock Flow	.05	1.0 ft.^{3}/day	0.2	.05	.2	Bedrock 100 ft.	1.0
Glacial Till Flow System	.02	0.2 ft.^{3}/day	8.0	.15	1.06	Till 5 ft.	1.2
Fine-Grained Stratified Drift Flow System	.01	1.26 ft.^{3}/day	15.5	.20	0.77	Lake Sediment 12 ft.	2.46
Coarse-Grained Stratified Drift Flow System	.0025	2.16 ft.^{3}/day	89.4	.25	0.90	Outwash 20 ft.	4.62

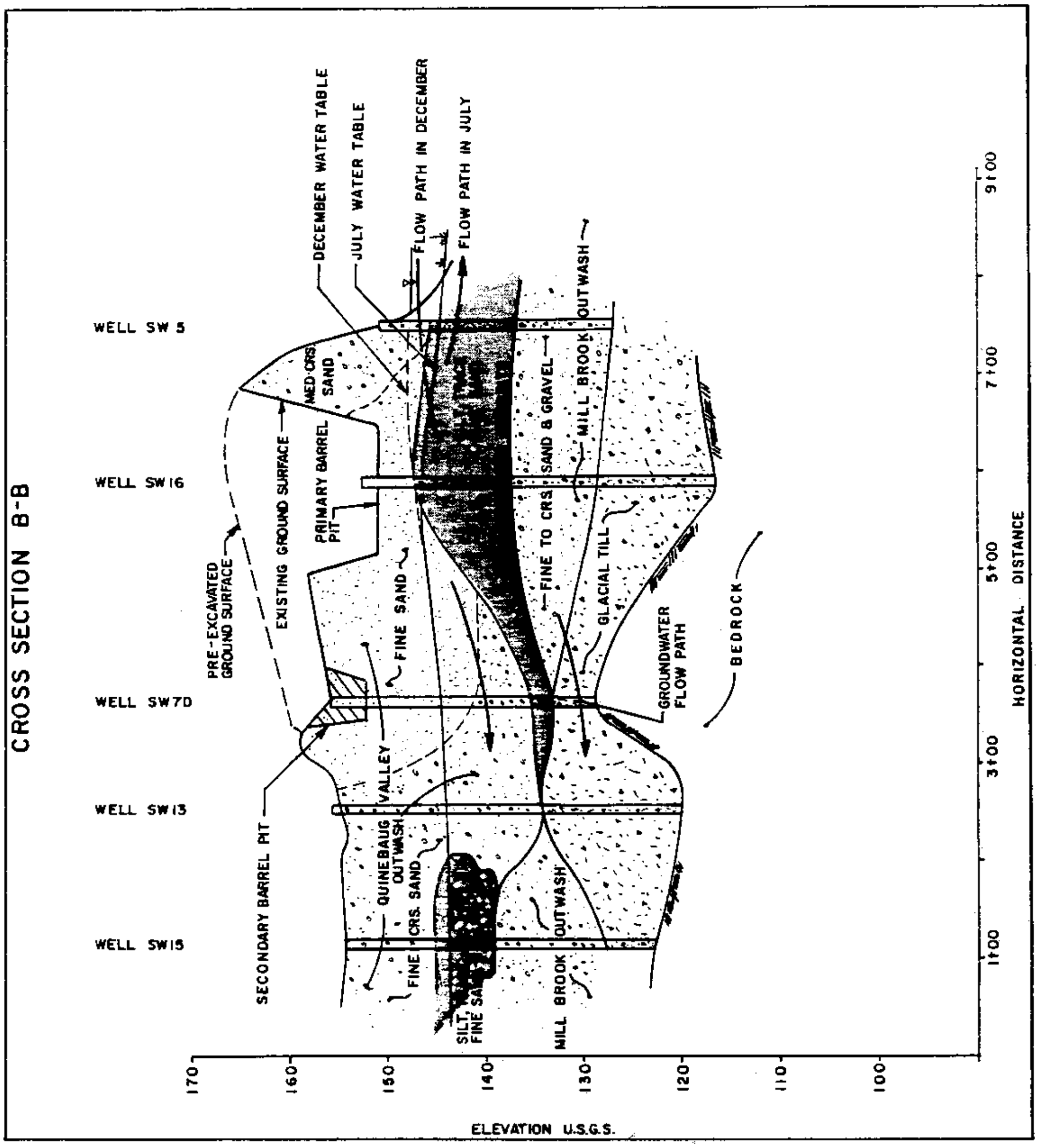
Source: Fuss & O'Neill, January 1979

Figure 4. Cross-Section A-A, North-South, Gallup Site



Source: Fuss & O'Neill, January 1979

Figure 5. Cross-Section B-B, East-West, Gallup Site



Source: Fuss & O'Neill, January 1979

system along the northern and eastern wetland-terrace border and the ground water flows westerly through the terrace to the railroad. However, ultimate discharge still is into Mill Brook. The changed flow patterns are shown in Figures 5 and 6 (in Figure 5, the beaver-altered flow pattern is referred to as "Flow Path in December").

WASTE DISPOSAL HISTORY

Disposal operations took place at three locations on the Gallup property: a seepage bed, a primary barrel pit and chemical lagoon, and a secondary barrel pit and liquid burial area (see Figure 7). The disposal took place sometime during 1977.

Seepage Bed

The seepage bed was an area approximately 50' x 40' (15.24 x 12.19 m) that had been excavated down to the glacial till and partially backfilled with crushed stone. Some of the layer of crushed stone was covered by an inverted dump truck body, which in turn was covered with soil. A metal pipe connected the dump body to the surface. Liquids were pumped through the pipe into the dump body and then seeped through the crushed stone into the surrounding soils. An unknown quantity of liquids were disposed of in this manner.

Primary Barrel Pit and Chemical Lagoon

This was a pit about 0.4 acres (0.16 ha) in area and about 10-15 feet (3-4.6 m) deep. Approximately 1,200 barrels of wastes were dumped into the southern portion of the pit, while the northern portion was used as a lagoon for an unknown quantity of free liquids.

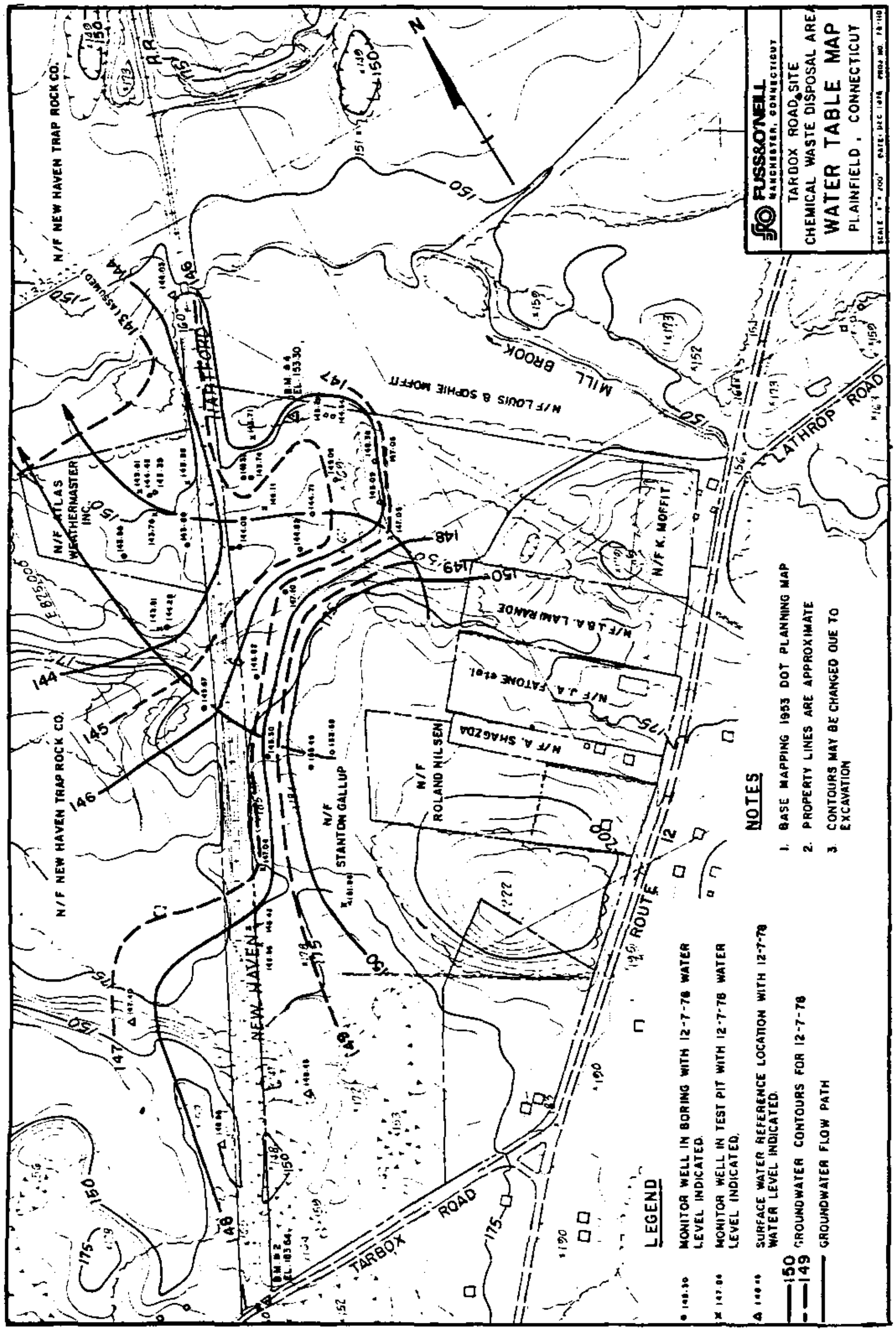
Secondary Barrel Pit and Liquid Burial Area

This area was located about 100 feet (30.48 m) west of the Primary Barrel Pit and near the railroad. It covered 0.67 acres (0.27 ha) and was about 7-10 feet (2-3 m) deep. The Secondary Barrel Pit contained about 200 drums of wastes and an unknown quantity of free liquids apparently had been dumped into it and covered. At least two layers consisting of crushed drums, liquids and soil were discovered here.

DESCRIPTION OF CONTAMINATION

Fuss & O'Neill conducted a field investigation at the site consisting of ground water, surface water and soil samples. Ground water samples were taken from

Figure 6. Water Table Map, Gallup Site



Source: Fuss & O'Neill, January 1979

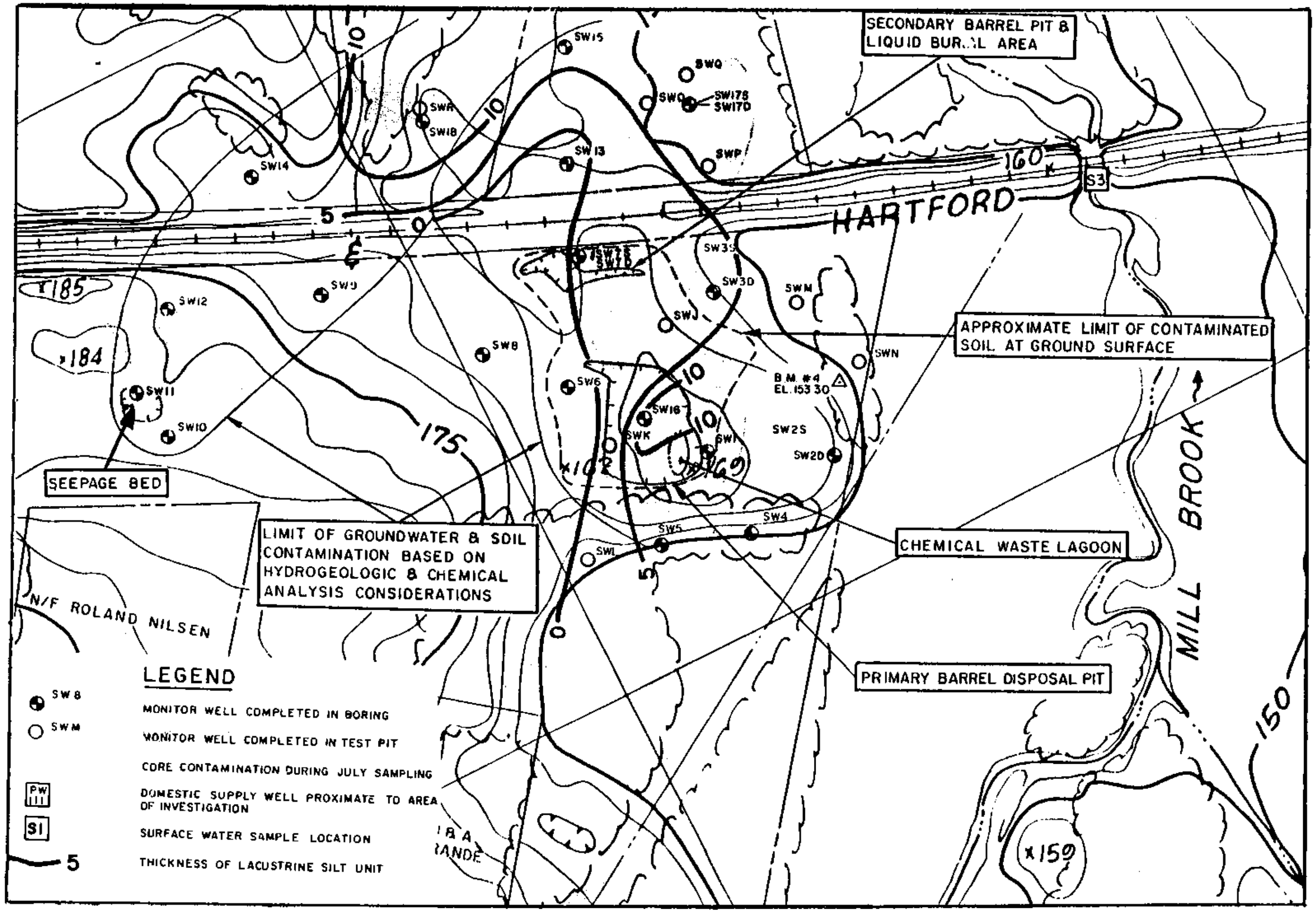


Figure 7. Impact Map Gallup Site

Source: Fuss & O'Neill, January 1979

monitoring wells that had been placed in area borings and test pits in and around the apparent disposal areas, as well as from nearby domestic water wells. Surface water samples were taken at points that had been selected based on their relation to the disposal areas and current knowledge of the geology and hydrogeology of the site. As the samples were analyzed, the new data were used to expand the network of monitoring wells.

Water extracted from the wells was initially analyzed for three field parameters: specific conductance, pH and in-situ temperature. In addition to these parameters, samples taken in July 1978 were analyzed by gas chromatography for the presence and relative concentration of metallic ions. When chemical species were identified, they were verified by more detailed gas chromotography and atomic absorption. Gas chromotographic methods used included flame ionization detection for aromatics, hydrocarbons, esters and ketones; electron capture for chloro compounds; and ultra violet for phenols. These methods had the following detection limits:

	Lower Detection Limit	Accuracy
Ultra Violet	1 ppm	± 0.05 ppm
Electron Capture	1 ppm	± 10 ppm
Flame Ionization	1 ppm	± 10%

Source: Fuss & O'Neill, January 29, 1979.

A second set of ground water samples was taken in October 1978 and analyzed for indicator parameters, hydrocarbon constituents and metallic ions, with the latter being evaluated directly by atomic absorption. A third set of samples was taken in December 1978 and similarly analyzed.

The results of the sampling and analysis program are discussed below with respect to each disposal area.

Seepage Bed

Prior to installing the monitor wells for this area, Fuss & O'Neill obtained some contamination information from the clean-up contractor. During excavation of the inverted dump truck body, the equipment operator and observing geologist encountered a vapor irritant that caused a burning sensation in their

300.68(e)(2)
(i)(B)
amount and form of substances present

eyes and mouths. They left the pit open for some time to allow the vapors to subside, then the clean-up contractor sampled and analyzed the soil moisture and ponded surface water that resulted from a rainfall. Results indicated a pH of less than 2 and a specific conductance of contact water exceeding 10,000 ohms, suggesting that a low pH liquid had been dumped here. The contractor then took soil samples from the test pit walls and performed an extraction analysis for metallic ions. Metals found included:

Iron as Fe	25 - 6100	mg/l
Manganese as Mn	2.7 - 98	mg/l
Copper as Cu	1.5 - 7.9	mg/l
Zinc as Zn	0.2 - 9.7	mg/l
Nickel as Ni	0.2 - 5.8	mg/l
Chromium as Cr	0.3 - 4.2	mg/l
Cadmium as Cd	0.1 - 4.0	mg/l
Cobalt as Co	0.24 - 0.33	mg/l
Free Acid as H_2SO_4	0 - 1.3%	
Equivalent Acid as H_2SO_4	1.5 - 3.0%	

Source: Fuss & O'Neill, January 29, 1979.

Fuss & O'Neill believed that these data were characteristic of an industrial pickling liquor.

Based on this information about soil contamination, Fuss & O'Neill installed monitoring wells SW 10, 11 and 12 within the fractured bedrock system and located in and around the Seepage Bed (see Figure 7). Significant levels of contamination were found in the July and October samples; indicator chemical analysis showed elevated total dissolved solids, total acidity, and very low pH. Various solvents were found in wells SW 11 and 12, including acetone, methyl ethyl ketone (MEK), and methanol. Analysis also detected a nonvolatile salt, possibly a high molecular weight nitrogenous compound believed to be an industrial dye. This substance had a concentration of about 100 ppm at well SW 11 (it also was found at wells SW 7S, 7D, 9, 10 and 12). The analysis for metallic ion concentration found significant quantitites of dissolved copper, nickel, iron, zinc, and aluminum, plus trace levels of titanium, chromium, silver, and cadmium.

Downgradient from the Seepage Bed, lesser contamination levels were observed in wells SW 9, 14, 18 and R, as shown in Figure 7, although each well showed elevated dissolved solids concentration and a low pH. Trace levels of hydrocarbon compounds were found in wells SW 9 and 14, but wells SW 18 and R had very high concentrations of ethanol, methanol, isopropanol, ethyl acetate, plus trace levels of trichloroethylene and trichloroethane, which suggested to Fuss & O'Neill that dumping activities other than what occurred at the Seepage Bed were responsible. Metallic ion concentrations in all downgradient wells showed significant levels of iron and nickel in wells SW 9, 14 and 18, and trace levels of copper, nickel, zinc, titanium and cadmium.

Primary Barrel Pit and Chemical Lagoon

Most of the dumping occurred at this area, including about 1,200 barrels and an unknown quantity of free liquids. Barrels were dumped in the southern part of the pit and liquids were found in a pond in the northern part, as shown in Figure 7. Wells SW 1, 6, 16, J and K were placed in and around this area, as shown in Figure 7. Underlying soils were found to determine significantly the direction and extent of contamination; the Primary Barrel Pit was located in free-draining soils under which lay or almost continuous silt unit, the Lake Quinebaug deposits.

Fuss & O'Neill observed that during the period between cessation of dumping activities in mid-winter of 1978 and the first series of samples in July 1978, contaminated ground water in the saturated section above the silt unit flowed radially west, north and east and discharged into the wetlands northeast and east of the pit. Although contamination also was found within and above the silt unit, wells SW 1, 4, 5, 25, 2D, 3S and 3D showed littled impact. However, the October samples from well SW 1 showed a significant increase in hydrocarbon constituents (indicator parameters showed a 12-fold increase in chemical oxygen demand value and a 6-fold increase in total organic carbon/total carbon values) below the silt unit, indicating that contamination had broken through the silt unit between July and October. Metallic ion concentrations for copper and nickel also increased during this period.

East of the Primary Barrel Pit, wells SW 4 and 5 remained unaffected by the dumping throughout the period of investigation. Fuss & O'Neill stated that although normally the radial ground water flow at the site would have carried contaminants to these wells, the changed flow patterns resulting from the beaver dam, which caused water to flow from the area of the wells toward the pit, prevented contamination of the wells.

South of the pit, wells SW 6 and 8 were relatively unaffected by disposal activities. The engineers reported that SW 6, located close to the pit and its nearby temporary barrel storage area, had trace levels of TCE and trichloethane, possible resulting from migration of these volatile chemicals laterally from the pit area through unsaturated soils.

Although breakthrough of contaminants did not occur in the wells to the east and south of the Primary Barrel Pit, breakthrough seemed to have occurred in wells SW K and 16, located near each other within the pit (see Figure 7). Well SW K was screened in the saturated material in and above the silt unit, while SW 16 was screened in the Mill Brook outwash sediments immediately below the silt unit. Significant contamination was found at each well with individual parameters more concentrated at SW K, above the silt unit, than at SW 16. Hydrocarbon solvent concentrations at both wells had similar compositions and were at the 20 ppm level. Low level metallic ion contamination was significantly higher at SW K than at SW 16, suggesting again that the silt unit retarded migration.

Secondary Barrel Pit and Liquid Burial Area

This disposal site was a linear trench adjacent and parallel to the railroad in the northeast corner of Gallup's property. About 200 barrels of wastes were buried here along with an unknown quantity of free liquids. Wells SW 7S and 7D were placed close together next to the Secondary Barrel Pit, wells SW 13, O, P, Q, 17S and 17D were located northwest and downgradient from the pit, and wells SW 15, 18 and R were situated more distant from the pit and to the west (see Figure 7).

Indicator parameters at wells SW 7S and 7D showed a sharp decline in contaminant levels from July to October but some increases from October to December, resulting in a relatively lesser decline as measured between July and December. At well SW 7S, chemical oxygen demand went from 8,050 mg/l in July down to 3,900 mg/l in October but back up to 4,900 mg/l in December. A similar pattern was observed for dissolved solids, while chlorides and organic carbon concentrations increased throughout the study period. Well SW 7S had some of the highest levels of contamination by metallic ions of any wells tested, with very high concentrations of copper, aluminum, nickel, iron, manganese, magnesium, zinc chromium, cadmium and boron. These levels decreased from July to October but returned to about the initial levels in December. Even at their lowest point in October, some levels were still extremely excessive: for example, copper went from 1,185 mg/l in July to 625 mg/l in October, but Connecticut's drinking water standard for copper is 0.5 mg/l, and most accepted standards for adverse impact to sensitive fresh water fish are below 1.0 mg/l. The results from wells SW 7D were similar to SW 7S - significant levels of copper, nickel, iron, zinc, chromium and cadmium.

Downgradient from the Secondary Barrel Pit, concentrations of indicator parameters increased significantly over the observation period, with hydrocarbon concentrations (solvents) following the down-and-up pattern exhibited by wells SW 7S and 7D. Fuss & O'Neill concluded that "the results suggest that we are observing a dynamic chemical wave migrating and changing over time and distance. Concentrations in the central core of the wave are decreasing due to dilution, dispersion and downgradient migration. Downgradient wells are exhibiting a concentration which has yet to pass those ground water observation points."

The samples indicated that the ground water had numerous contaminants, the diversity and concentration of which decreased over time. For example, Well SW 7S in July had a total solvent concentration of 100-200 ppm with at least 10 distinct chemical species identified. In October, concentration was about 60 ppm with distinctly fewer chemical species. But in December, total solvent concentration was in the 85-130 ppm range with 6 major species constituting most of the contamination. Generally speaking, the long term trend seems to be decreasing concentration and diversity.

Consistent with the chemical wave hypothesis, downgradient well SW 13 showed a slight increase in total solvent concentration between July and October, with major chemical species shifting from xylene and toluene in the first samples to acetone, isopropanol, methanol, and various aromatics (including xylene and toluene) in the second. Then from October to December, the diversity and concentration of solvent contaminants decreased by about 50 percent, with acetone and MEK as the main constituents. On the whole, at well SW 13 all indicator parameters in December were significantly more concentrated than in July, but chemical oxygen demand, dissolved solids and chloride parameters were more concentrated in October than in December. Significant and increasing levels of metallic ions were detected at SW 13, including copper, nickel, iron, zinc, chromium and cadmium.

Wells SW 17S, 17D, O, P and Q were located further downgradient than well SW 13 and their samples fluctuated unpredictably over the investigation period. Some anomalies also occurred. For example, well SW 15, which was west of the Secondary Barrel Pit and out of the predicted ground water flow from the pit area, changed from parts per billion levels in July to parts per million levels of hydrocarbon concentration in October and December, plus had increases in the indicated parameters. Well SW 15 also had increased concentrations of copper, zinc, nickel, iron and cadmium over the period of investigation. Another anomoly was that wells SW R and 18, thought to be out of the ground water plume, had very high solvent concentrations and high indicator parameters such as dissolved solids and chemical oxygen demand.

Fuss & O'Neill offered several hypotheses for the aberrant data: hydrocarbons might migrate in ways significantly different from ground water flow; there may have been distict disposal stages, with hydrocarbons being deposited first and hence migrating at the leading edge of the contaminant plume; or the existence of undetected disposal areas around the Gallup property. None of these hypotheses were tested during the period of investigation, although Fuss & O'Neill noted some evidence that tended to weigh against the hypotheses about unique hydrocarbon migration and additional disposal areas at this site.

Fuss & O'Neill drew several conclusions from the sample data regarding the contaminant plume emanating from the Secondary Barrel Pit:

(1) ground water contamination had existed at the pit area for 1.5 years and had just begun to be removed from the system by discharge into Mill Brook;

(2) the core of contamination had migrated less than 140 feet (42.7 m) during that period, and it would take at least 2 more years before the core began discharging into Mill Brook;

(3) contaminant concentrations at the core of the plume had not abated significantly over the one-half year investigation period;

(4) assuming that the decline in concentration at the point of discharge would occur at the same rate as the observed concentration increase, a minimum of 8 years of contamination would be predicted;

(5) high levels of residual soil contamination would add to the time required for concentrations to decrease, with the extra time computed to be as high as one order of magnitude (4-44 years).

These conclusions were also believed to apply reasonably well to the Primary Barrel Pit and the Seepage Bed.

Off-site Water Supply Wells

Fuss & O'Neill sampled domestic supply wells on neighboring properties and detected no hydrocarbon contamination. Analysis for metallic ions revealed only low levels that were believed to reflect the general background quality of the area's ground water and not be attributable to disposal activities at the Gallup Site. A 525 gpm (1,987 l/m) public water supply well, owned by the Gallup Water Company and located about 4,000 feet (1,219 m) north of the disposal areas, apparently was not tested for contamination. However, Fuss & O'Neill concluded after an analysis of the well's location and specifications (525 gpm, 1,987 lpm; 756,000 gpd, 2,861,771 lpd) that any interaction between contaminated ground water at the disposal areas and the area of well influence would be unlikely.

Mill Brook

Surface water samples were taken along Mill Brook and its tributaries in September, October and November 1978. Samples were taken at the following locations (see Figure 7):

Sample Point	Location
S1	Mill Brook at Route 12
S2	Wetland impoundment 350 feet northwest of SW 15
S3	Mill Brook at railroad bridge

S4	Mill Brook above confluence with Fry Brook
S5	Fry Brook above confluence with Mill Brook
S6	Plainfield Sewage Treatment Plant overflow to Fry Brook
S7	Mill Brook below Packer Pond

Source: Fuss & O'Neill, January 29, 1979.

September samples were taken when Mill Brook was at 1.4 times the annual low flow, i.e., at 75 percent flow duration. Water quality in Mill Brook was fairly uniform. The Fry Brook sample had noticeably more copper, nickel, zinc and lead, which were attributed to discharges from the sewage treatment plant upstream from the sample point. All samples from Mill brook and Fry Brook had trace levels of trichloroethylene and trichloroethane. The Mill Brook sample from point S3, at the railroad bridge, contained a C-7 or C-8 hydrocarbon in the low ppm range; however, since no such chemical was found in the ground water at the Gallup site, Fuss & O'Neill did not attribute it to the disposal activities.

A second series of samples taken later in September again showed fairly uniform content for indicator parameters and metallic ions in Mill Brook, but sample points S3 and S4 (at Mill Brook above the confluence with Fry Brook) showed increased hydrocarbon diversity and concentrations. These levels were in the ppb range, but Fuss & O'Neill thought they might reflect some contamination from the Gallup site. November samples, taken when Mill Brook was approaching annual low flow, further supported this hypothesis because hydrocarbon content at S4 increased dramatically. Trichloroethylene, methylene, chloride and trichloroethane levels were detected at 20-70 ppb. Moreover, these constituents were also present in the ground water downgradient from the disposal areas. Since the ground water samples had levels of these chemicals that weren't concentrated enough to account for the surface water levels, Fuss & O'Neill postulated that higher concentrations might have passed the monitor well areas prior to ground water sampling, or that the beaver impoundment might have modified ground water flow in ways that increased these concentrations.

300.68(e)(2) (ii) extent of substance migration

To supplement its surface water sampling program, Fuss & O'Neill attempted to estimate the total impact of contaminated ground water on Mill Brook. It predicted that outflow from the three major disposal sites into Mill brook was 10,300 gallons/day (38,989.7 l/d). The flow of Mill Brook was estimated to be 867,000 gallons/-day (3,281,932 l/d) at the 90 percent flow duration. To compute the contaminant impact, the engineers took the concentrations observed in the October 1978 samples from individual wells and weighted them based on estimated transmissivity at each well over total transmissivity at all wells. They then converted the results into pounds per day loading and a maximum concentration increase at the stream (see Table 2).

Fuss & O'Neill concluded that copper and iron had the greatest potential for concentration, followed by methanol, nickel and zinc. Copper was considered to pose the greatest ecological threat to the stream. Eventually, such toxic and possibly carcinogenic substances as trichloroethylene, toluene, xylene and chloroform are expected to enter the stream from the site.

300.68(e)(2) (iv) environmental effects and welfare concerns

The engineering firm pointed out in its final report that metallic ions seemed to be migrating toward Mill Brook at slower rates than the hydrocarbon constituents or indicator parameters such as the chloride ion. If so, this might lower the concentrations of metallic ions predicted in Table 2, but it also would lengthen the critical period of impact to Mill Brook.

PLANNING THE SITE RESPONSE

Initiation of Response

The Connecticut Department of Environmental Protection (DEP) learned of the site's existence in January 1978, seized it in February, and began investigating the nature and extent of contamination. The DEP hired Fuss & O'Neill to conduct a hydrogeological assessment of the site, which it performed from June to December 1978. Fuss & O'Neill found that the ground water was contaminated by a wide range of metallic ions and hydrocarbon solvents and that it was moving north and northwesterly from the Gallup property toward ultimate discharge into Mill Brook, which was then a "Class A" recreational stream but not a drinking water source. The DEP concluded that an immediate response action was necessary because, although Mill Brook appeared fairly uncontaminated and nearby private drinking water wells were not contaminated, the continued loading of contaminants from the disposal areas into this ground water system eventually could result in

300.68(f) remedial investigation

TABLE 2. ESTIMATED IMPACT ON MILL BROOK

Parameters	Pounds/Day	Milligrams/Liter
Methanol	0.291	.04
Acetone	0.1	.01
Higher Acetates	0.117	.016
Chlorinated Propane	0.01	.001
Isopropanol	0.162	.022
MEK	0.069	.009
MIBK	0.217	.029
Propyl Acetate	0.155	.021
Toluene	0.004	ppb
Xylene	0.003	ppb
Aromatics	0.031	.004
Ethylene	0.013	.001
Copper	1.877	.26
Nickel	0.231	.031
Iron	1.49	.203
Zinc	0.336	.046
Titanium	0.006	ppb
Chromium	0.008	.001
Silver	----	ppb
Cadmium	0.011	.001

a significant plume of pollutants threatening the stream and possibly the wells.

Selection of Response Technologies

DEP officials stated that the choice of clean-up measures was based on the nature of the contamination and the hydrogeology at the site, not on cost considerations. DEP chose to remove contaminated soil, drums and free liquids from the site in order to prevent further ground water contamination. Pumping and treatment of the ground water was rejected because DEP believed that the hydrogeological system would dilute the plume of contaminated ground water to levels considered acceptable for discharge into Mill Brook.

300.68(e)(2) source control remedial action

300.68(h) initial screening of alternatives

Extent of Response

The DEP's clean-up goal was to eliminate the source of contamination by removing all contaminated soil, drums and free liquids from the disposal areas. This goal was apparently accomplished at two of the disposal areas, the Primary and Secondary Barrel Pits, where excavation was done down to soil containing only a residual amount of contamination. Composite soil analyses were performed and soil was divided into highly contaminated, lightly contaminated, and residually contaminated classes. The goal did not appear to be met with respect to the Seepage Bed, however. During excavation at this area, which tests had shown to contain solvents, both the equipment operator and an observing geologist encountered irritating vapors. The excavation pit as left open for some time until the vapors subsided. When excavation resumed, it became clear that there was extensive soil contamination that would require removing a very large volume, which was considered economically prohibitive. Since the soil was highly acidic, the state's computations indicated that a neutralizing dose of lime would bring the pH into an acceptable range. State officials decided to apply a massive dose of lime (approximately 30 tons, 27.2 Mt) to neutralize the contaminants in situ, then cover the pit with local soil. Thus, economic considerations seemed to play a critical role in determining the extent of response at the Seepage Bed, but not at the Primary and Secondary Barrel Pits.

300.68(j) cost effectiveness

Officials from DEP stated that settlement of the department's law suit against Gallup, whereby Gallup agreed to pay for clean-up costs up to $750,000, did not affect the extent to which the state sought to remedy the problem. The $750,000 figure represented DEP's estimate of the total clean-up cost for the site. The officials acknowledged some contraints from this settlement figure: since state funds would have to be used for all costs above $750,000, the state tried to monitor clean-up costs closely to insure that the operation came in under this amount which, in effect, was a self-imposed budget. DEP officals stated that if unforeseen problems had arisen, the state was prepared to pay any necessary additional costs. Regarding the clean-up of the Seepage Bed, it appears that the extent of response was determined by a decision that excavation of contaminated soil was unnecessary or too costly.

DESIGN AND EXECUTION OF SITE RESPONSE

Upon learning of the probable nature and extent of contamination, DEP decided to remove the contaminated soil, drums and free liquids from the three main disposal areas. Chem-Trol, Inc., a subsidiary of SCA, Inc., was the clean-up contractor and performed the excavation, transportation and disposal work. The techniques used varied according to the characteristics of each disposal area.

Seepage Bed

This area had significant amounts of metallic ions and hyrocarbon solvents. First Chem-Trol removed the soil surrounding the inverted dump truck bed. The soil had very little contamination. Then the dump truck bed was removed. When the field crew attempted to remove the highly contaminated trap rock below the truck bed, the equipment operator and an observing geologist encountered irritating vapors that forced them to cease work and leave the pit open until the vapors subsided. Removal of rock and soil resumed, but it became clear that contamination was extensive and would entail removal of a large soil volume. State officials decided that removal was too expensive, and sought to neutralize the contaminants in situ with about 30 tons (27.2 Mt) of lime. The pit was then filled and covered with fresh local soil. No subsequent field testing was performed to determine the effect of this treatment, other than continued sampling of the surrounding monitoring wells.

300.70(b)(2)
(iii)(E)(2)
in situ
treatment;
neutralization

Primary Barrel Pit and Chemical Lagoon

Response action in this area had two phases. First, the free liquids in the lagoon, which were primarily solvents, were pumped out. Mud at the bottom of the lagoon was removed with excavation equipment and stockpiled on-site in depression zones to minimize run-off. It subsequently was mixed with drier heavily contaminated soil to lower the average moisture content and facilitate handling and disposal. The second phase

300.70(c)(2)
contaminated
soil removal

involved removing drums and contaminated soil. A clear area adjacent to the disposal site was excavated to a depth of between 15 and 18 feet (4.6 - 5.5 m) and constructed with an access ramp. From there lateral excavation of the contaminated materials took place. The technique employed for exposing the drums was to slightly undercut the lower soils, allowing the overlying layered soil to slough by gravity and expose the drums. As the drums were exposed they were selectively and carefully removed without damage using barrel hooks. Drums and contaminated soil were removed down to recognizably clean soil.

Secondary Barrel Pit and Liquid Burial Area

300.70(c)(2) contaminated soil removal

Excavation of this area was similar to the Primary Barrel Pit. An area next to the pit was cleared and excavated to a depth of 12-15 feet (3.6 - 4.6 m), then work proceeded laterally into the burial area. Layers of drums and contaminated soil were removed using the techniques employed in the Primary Barrel Pit. Excavation continued down to recognizably clean soil.

On-Site Storage of Contaminated Materials

Heavily and lightly contaminated soils were separated upon excavation and placed into different piles located in depression areas on-site. This was done to minimize surface run-off. Separation of soils was done by visual examination and smell: heavily contaminated soil was noticeably colored and had a very strong odor, while lightly contaminated soil was less stained and had less odor. Free liquids pumped from the Primary Barrel Pit were placed in a recently constructed 100 x 40 foot (30.5 x 12.2 m) bermed containment area having a hypalon liner.

Drums were also stored on-site prior to transport to a disposal landfill. The contents of each drum were analyzed, using a mobile laboratory equipped with a gas chromatograph and recorder, flash point tester, pH and conductivity meters, and various other laboratory supplies and sampling equipment. An inventory and description of the composites of the drum contents was made and included the following classes:

- Aqueous Subclass of Acids
  Number of drums, pH range, percent free acid as sulfuric acid, percent equivalent acid, total inorganic carbon, and total organic carbon.

- Aqueous Subclass of Alkaline Wastes
  Number of drums, pH range, percent free

alkalinity as sodium hydroxide, percent equivalent alkalinity as sodium hydroxide, percent equivalent alkalinity, total inorganic carbon, and total organic carbon.

- Aqueous Class of High Total Organic Carbon
  Number of drums, pH range, total inorganic carbon and total organic carbon.

- Solvent Class of Nonchlorinated Solvents
  Number of drums, BTU's per pound, BTU's per gallon, and percent chlorine.

- Chlorinated Solvents
  Analyzed only for specific gravity. The limited testing on the chlorinated solvents was based on the fact that attempts to make a composite sample for analysis caused polymerization and precluded further analysis.

Classification of Substances for Disposal

The contaminated materials stored on-site were classified into 4 groups for disposal: (1) an aqueous class subcategorized into acids, bases and high total organic carbons; (2) a solvent class subcategorized into chlorinated and nonchlorinated solvents; (3) a contaminated soils class subcategorized into highly contaminated and slightly contaminated soils; and (4) flammable sludges.

Transportation and Disposal

300.70(c) off-site transport for secure disposition

Chem-Trol handled the transportation and disposal work. Drums and heavily contaminated soil were transported in 20 ton (18 Mt) sealed dump trucks to the licensed SCA facility in Model City, N.Y., a distance of 580 miles (928 km). Free liquids were transported to the Model City facility in one tanker that had a 4,000 - 5,000 gallon (15,141.6 - 18,927 l) capacity. Lightly contaminated soil was taken in 20 ton (18 Mt) sealed dump trucks a distance of 1.5 miles (2.4 km) to the Yaworski, Landfill in Canterbury, Conn.

COST AND FUNDING

Source of Funding

All costs of response at the site were paid by the state which, in turn, was reimbursed in full by Mr. Gallup. Following its discovery of the disposal activities in January 1979 and seizure of the property in February, DEP filed a civil suit against Gallup on

May 17, 1978, charging him with violation of Connecticut law prohibiting the discharge of substances or materials into state waters without a permit. While this suit was pending, Gallup asked DEP to estimate the total costs of cleaning up the site so that he could attempt to settle the suit. During July, DEP worked with Fuss & O'Neill to determine the extent of the problem and the required response actions, and concluded it would cost about $750,000. On September 13, 1978, Gallup pleaded nolo contendre to the charges against him, was assessed a $25,000 fine by the court, and agreed to reimburse the state $15,000 for the costs of immediate protection and control of the site, plus up to $750,000 for response costs, payable in $100,000 installments.

300.68(c) judicial process

Selection of Contractors

DEP hired Fuss & O'Neill Consulting Engineers, of Manchester, Conn., to perform the hydrogeological assessment of the site. Fuss & O'Neill was selected by direct procurement based on past experience, and a lump sum contract with a ceiling of $90,000 was used. Work was completed on time, although a no-cost 3 month extension was required for the firm to complete its final report, and for almost $30,000 below the ceiling. DEP hired Chem-Trol Pollution Services, Inc., a subsidiary of SCA Chemical Services, Inc., of Model City, N.Y., to perform all excavation, transportation and disposal work. Chem-Trol was hired under a time and materials contract with a $640,000 ceiling and with payment to be made monthly on the basis of itemized vouchers. The firm was selected based on past experience. Chem-Trol subcontracted the disposal of the lightly contaminated soil to Yaworski, Inc., of Cantebury, Conn. because of its proximity to the site; the remaining materials were disposed of at SCA's licensed facility in Model City.

Project Costs

Response costs totalled $610,445.35, well under the settlement figure of $750,000, and are summarized in Table 3. Approximately 7,020 tons (6,368 Mt) of soil and drums were excavated, transported and disposed of, consisting of 4,020 tons (3,647 Mt) of drums and heavily contaminated soil and 3,000 tons (2,721 Mt) of lightly contaminated soil. This amounted to 201 dump truck loads of drums and heavily contaminated soil and 150 loads of lightly contaminated soil, with an average load of 20 tons (18 Mt). The quantity of material excavated was assumed to be the sum of the quantitites of soil and drums transported and disposed of. Approximately 5,114

TABLE 3. SUMMARY OF COST INFORMATION-GALLUP SITE, PLAINFIELD, CONN.

Task	Quantity (a)	Expenditure	Unit Cost	Funding Source	Period of Performance
Excavation	7,020 tons (6,368 Mt)	$89,285.47	$12.72/ton ($14.02/Mt)	Gallup	11/78-12/78
Transportation A. drums & heavily contaminated soil	201 loads (4,020 tons; 3,647 Mt)	$269,742.00	$1,342/load(b) ($67.10/ton; (73.96/Mt)	Gallup	11/78-12/78
B. lightly contaminated soil	150 loads (3,000 tons; 2,721 Mt)	$2,534.60(c)	$16.90/load(b) ($0.84/ton; $0.93/Mt)	Gallup	11/78-12/78
C. bulk liquids	1 load 5,114 gal. (19,359 l)	$1,342.00	$1,342.00/load(b)	Gallup	11/78-12/78
Subtotal-transportation		$273,618.60			
Disposal A. drums & heavily contaminated soil	201 loads (4,020 tons; 3,647 Mt)	$160,800.00	$800/load(b) ($40/ton; 44.09/Mt)	Gallup	11/78-12/78
B. lightly contaiminated soil	150 loads (3,047.4 tons; 2,764.5 Mt)	$21,331.80(c)	$142.21/load (b) ($7 ton; $7.72/Mt)	Gallup	11/78-12/78
C. bulk liquids	1 load 5,114 gal (19,359 l)	$1,789.90	$1,789/load (b)	Gallup	11/78-12/78
Subtotal-disposal		$183,921.70			
Engineering & hydrogeologic studies		$60,324.78		Gallup	6/78-10/78
State Health Lab-analysis fees		$1,009.46		Gallup	
Equipment & Consumables		$2,285.33		Gallup	
TOTAL		$610,445.34		Gallup	6/78-12/78

(a) 1 load of soil = 20 tons, 18.14 Mt.
1 load of bulk liquids= 4-5,000 gal.
(15,142-18,927 l)

(b) from contract between Chem-Trol (SCA) and DEP

(c) based on invoices

gallons (19,359 l) of free (bulk) liquids were transported in one tanker with a 4,000 - 5,000 gallon (15,141.6 - 18,927 l) capacity.

Fuss & O'Neill was paid a sum of $60,324.78 for the hydrogeological study. The State Health Lab charged $1,009.46 for some chemical analyses performed on water samples. Equipment and consumables relating to the response action were also charged as costs.

PERFORMANCE EVALUATION

DEP's decision to remove the source of contamination but not to pump and treat the ground water was based on the available data regarding probable dilution of the plume of contaminated ground water and the fact that no sources of drinking water were threatened. The data upon which DEP made its decision seem sound, but the decision is open to criticism on the ground that it reflects only short term health concerns and doesn't sufficiently consider longer term public health and environmental concerns. The Fuss & O'Neill study showed clearly that numerous species of metallic ions and hydrocarbon solvents would continue to discharge into Mill Brook for at least 8 and possibly as long as 44 years. Although these contaminants can be expected to be diluted by the ground water system and by the waters of Mill Brook itself, the extent of dilution and the total amount of contaminant discharge are unknown. Given the hazardous substances present at the site, this decision could commmit the stream to a substantial degree of pollution. The planning process lacked the necessary consideration of contaminant sources, fate and transport, sensitive receptors or a clear planning horizon to mitigate this pollution cost effectively or to understand it.

Justification of the state's goal of only removing the source of contamination is undermined by the fact that one of the three sources of contamination, the Seepage Bed, was not excavated to recognizably clean soil. Further, no test of the effectiveness of the in situ lime treatment was made, other than continuing the normal sampling program. While the lime might neutralize some of the acids in the soil, it is not likely to immobilize other contaminants such as volatile organic compounds (VOCs) and metallic ions. Metallic ions may be substantially immobilized, but not completely and not permanently, which is important since they may be elemental and hence will not biodegrade into begin metabolitis. The effectiveness of lime or VOC's is evnr less substantial, but many VOCs will eventually biodegrade, even in a capped anaerobic environment. Although the large amount of contamination at this area might have been very expensive in the short run to remove, the extent of contamination would seem to argue strongly for a response that more effectively mitigates and minimizes the long term threat to public health and welfare and the environment.

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GOOSE FARM

PLUMSTED, N.J.

INTRODUCTION | NCP Reference

The Goose Farm abandoned hazardous waste dump is located in a rural area in Plumsted Township, Ocean County, New Jersey (see Figure 1). Originally, the site was a pit in which drums and bulk liquid chemical wastes, including solvents, chlorinated solvents, and polychlorinated biphenyls (PCB's), were dumped. At the time the site was discovered, ground water near the pit was contaminated and seepage containing organic chemicals was discharging into a stream on the site that drains into the Delaware River.

Background

From 1945 to 1969, a manufacturer of rocket propellants, ammunition, and specialty chemicals dumped and buried various hazardous wastes in a pit 300 feet by 100 feet by 15 feet deep (91 by 30 by 4.6 m) on a piece of property called Goose Farm, under contract with the owner of the land. Wastes disposed on the site included solids and liquids in bulk, 55-gallon (208 liter) drums, 5-gallon (19 l) pails, and lab packs. The site is located approximately 20 miles (32 km) southeast of Trenton, N.J., in a 2-acre (0.8 ha) clearing surrounded by woods, farms, cranberry bogs, and scattered homes. The closest residence is about 400 feet (122 m) from the site, and about 30 other homes are within one-quarter to one-half mile (0.4-0.8 km) of the site. Site location is shown in Figure 1.

In the course of a New Jersey Department of Environmental Protection (DEP) investigation of possible pesticide contamination of local drinking water wells in January 1980, the Plumsted Township Sheriff's office informed DEP of the existence of the Goose Farm site and several other sites in the area. Over the next 6 months, DEP resistivity studies and ground water monitoring indicated that a plume of contaminated ground water extended from the pit. In addition, tests of a small stream running past the site indicated surface water contamination. — 300.68 (f) investigation

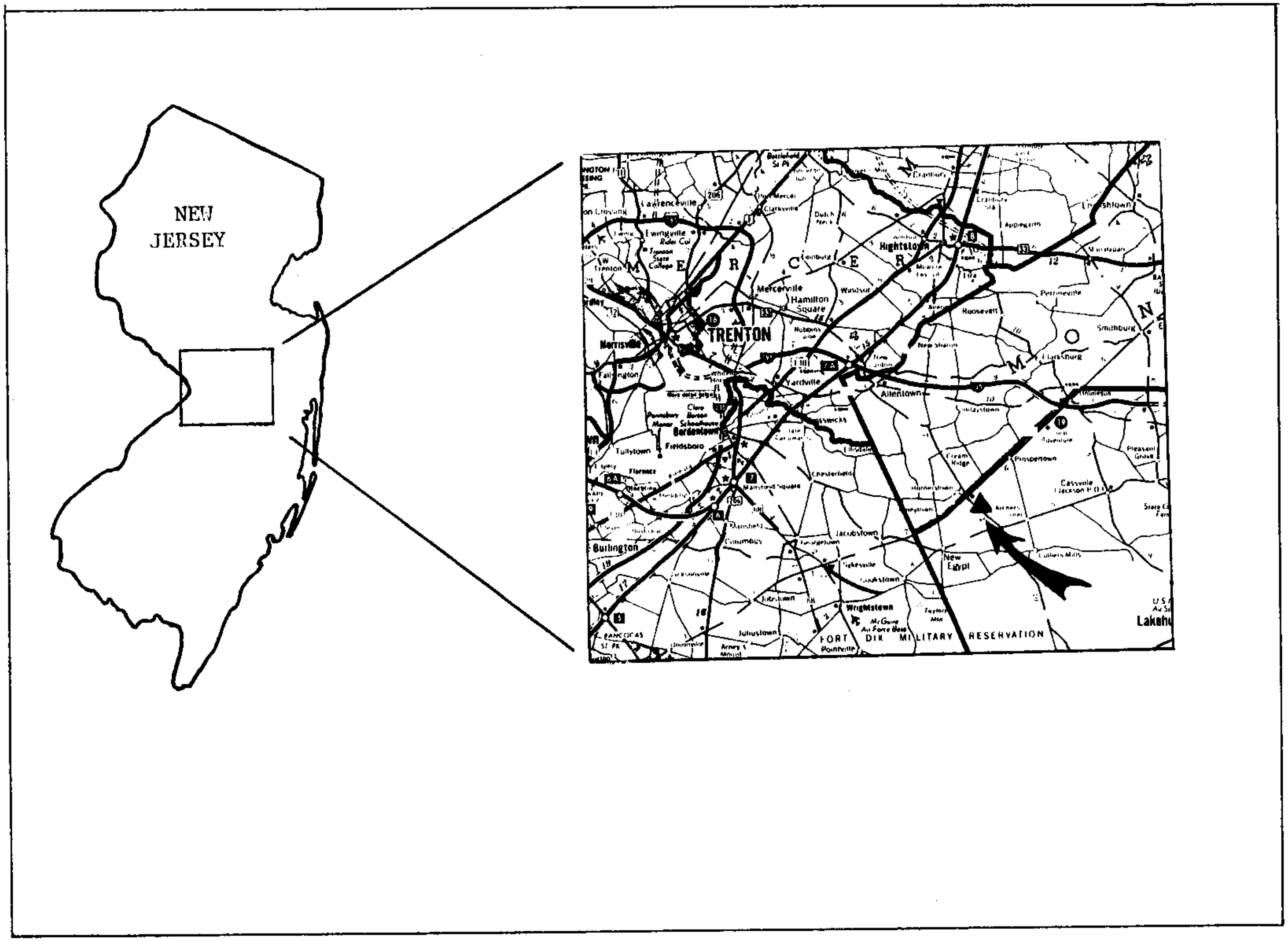

Figure 1. Index Map for Location of the Goose Farm Site

Metal detectors indicated a large quantity of buried metal on the property.

Synopsis of Site Response

In July 1980, DEP decided that the site posed an immediate threat to human health and in August 1980, hired O.H. Materials, Inc. (OHM) to conduct preliminary environmental testing to determine the extent of contamination. In September 1980, OHM began an emergency clean-up of the site using money from the New Jersey Spill Fund. From September 1980 to March 1981, OHM installed and operated a ground water recovery and treatment system to contain the plume, prevent contaminants from entering the stream, and flush contaminants from the soil. In addition, OHM excavated contaminated soil and over 4,800 drums and pails from the pit during the autumn of 1980. Over 9,000 gallons (34,000 l) of liquid were bulked and transported off-site for disposal, although soil, drummed solids and treatment system wastes remained. In March 1981, the ground water recovery system was dismantled and all operations at the site except security ceased. From October 1980 through March 1981 the clean-up was funded almost entirely by the Revolving Fund under section 311(k) of the Clean Water Act, and by the Superfund Emergency Response Fund. The remaining necessary funds were provided by the state.

There was a seven-month period between March 1981 and autumn 1981, when clean-up operations came to a halt. This interlude occurred due to a lack of available State and Federal funds.

In autumn of 1981, additional funds were provided and operations resumed when DEP hired OHM and CECOS International to bulk and transport the remaining wastes and heavily contaminated soil to a CECOS landfill in Niagra Falls, N.Y. The site was graded and additional ground water monitoring wells were installed. In September 1982, the U.S. Environmental Protection Agency (EPA) authorized Superfund funding for an investigation to determine the extent of contamination remaining at the site.

SITE DESCRIPTION

Surface Characteristics

The Goose Farm site is located in a unique ecological area known as the Pinelands. The New Jersey Pinelands is characterized by acidic sandy soils and low lying forests predominantly of pine with a lesser population of oak.

The local climate is continental, experiencing significant seasonal, daily, and day-to-day temperature fluctuations. The average winter temperature is 33° F (0.6° C) with the average daily minimum temperature reaching 24° F (-4.4° C). The lowest recorded winter temperature in this area was -14° F (-26° F) recorded in Toms River in February, 1961. Average summer temperature is 72° F (22° C) with an average daily maximum of 83° F (28° C). The highest temperature recorded in the county was 103° F (40° C) on July 4, 1966.

300.68(e)(2) (i)(E) climate

Precipitation averages between 42 to 46 inches (107 - 117 cm) per year with a range of 25 to 67 inches (64 - 170 cm) per year. The period of highest rainfall has been found to be between July and August while January, February, and October tend to be the driest months. Precipitation is distributed relatively evenly throughout the year; however, droughts and heavy rains have occurred (highest 1-day rainfall was 4.9 inches - 12.4 cm). Thunderstorms occur about 25 days per year predominantly in summer. The average seasonal snowfall is 17 inches (43 cm) with the highest recorded snow depth for any 1 time being 13 inches (33 cm).

Relative humidity averages about 56 percent in mid-afternoon with higher values at night, averaging 81 percent at dawn. The percentage of average daily sunshine is 45 in winter and 60 in summer.

Winds are predominately southerly from April through October, changing to northwest during winter months. The highest average windspeed is 12 miles (19 km) per hour in March.

The site is located in a gently sloping well-drained area adjacent to a small stream to the north. Slopes are typically from 0 to 5 percent. The surrounding soil has been classified as the Evesboro sand, a sandy soil of high permeability, low water capacity, and low organic content and fertility. Unless limed, the soil is acidic. Evesboro sand possesses severe wind erosion characteristics.

Goose Farm is located in a relatively sparsely populated area about 2 miles (3.8 km) northeast of New Egypt, a small town with a population of 1,769. The site is about 1 mile (1.6 km) southeast of the lesser town of Hornerstown. There are a number of residences in the area with private wells.

The site is located about 400 to 600 feet (122 - 152 m) south of a small stream flowing northward. The stream is a tributary of Lahaway Creek, which drains

300.68(e)(2) (i)(A) populatiton at risk

into the Delaware River. Lahaway Creek is designated by the State of New Jersey as "FW-1 Non-trout; suitable for potable water supply". A number of cranberry bogs are located from 1/2 mile (0.8 km) to 1 mile (1.6 km) east to southeast of the site.

Hydrogeology

The Goose Farm site is situated in the Coastal Plain (consisting of tertiary and cretaceous sedimentary formations of sands, clay silts, shell beds, and glauconite.

300.68(e)(2) (i)(D) hydrogeological factors

Strata which are exposed within a mile of the site include the Red Bank, Hornerstown, Vincetown, Kirkwood, and Cohansey formations. Figure 2 is a geologic map of the Goose Farm area. Although the regional survey shows the site is located within the outcrop of the Vincetown formation, local test well drilling has indicated that a thin veneer of the Kirkwood formation underlies the site. Figure 3 shows a geologic cross section of the regional formations relative to the Goose Farm site. A brief description of each formation is presented below:

Cohansey Formation (Tch)--
The Cohansey is a light gray to yellow-brown to red, medium to coarse quartz sand with visible amounts of ilmenite present. It may contain clay lenses varying from an inch to more than 2 feet (0.6 m). The Cohansey is the single most important aquifer in the State and is the water table aquifer for much of South Jersey. However, as can be seen from Figures 2 and 3, the recharge zone for the Cohansey is well outside the perimeter of the site and outcrops at a higher elevation than the Goose Farm area.

Kirkwood Formation (Tkw)--
The Kirkwood is the uppermost formation underlying the Goose Farm site, and ranges from 0 to 15 feet (0-4.6 m) thick in this area. It consists of two distinct units, an upper unit of fine to very fine slightly clayey quartzy sand and a lower unit of dark brown fine to very fine, peaty or lignitic quartz sand and silt. The Kirkwood serves as a recharge zone in the Goose Farm area for both the Kirkwood and the lower Vincetown Aquifer.

Manasquan Formation (Kmg)--
The Manasquan is an aquitard composed of two substrata. The upper member is a greenish gray to tan clayey silt. The lower unit is a dark greenish gray clayey quartz-glauconite sand. The Manasquan ranges from a depth 15 to 23 feet (4.6-7.0 m) thick with the upper regions pinching out into Kirkwood.

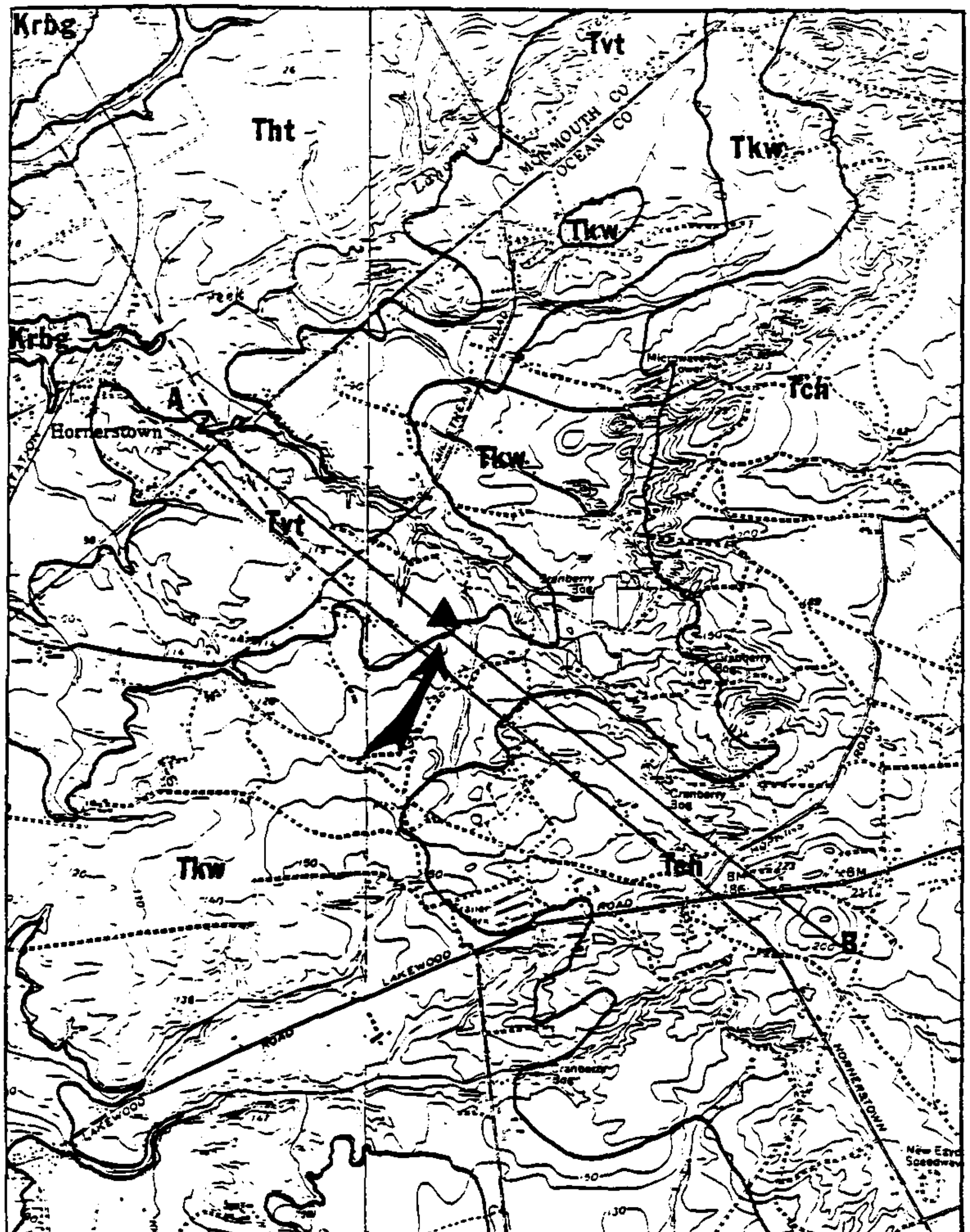

Figure 2. Geologic Map of the Goose Farm Site Area
(O.H. Material Co., 1981)

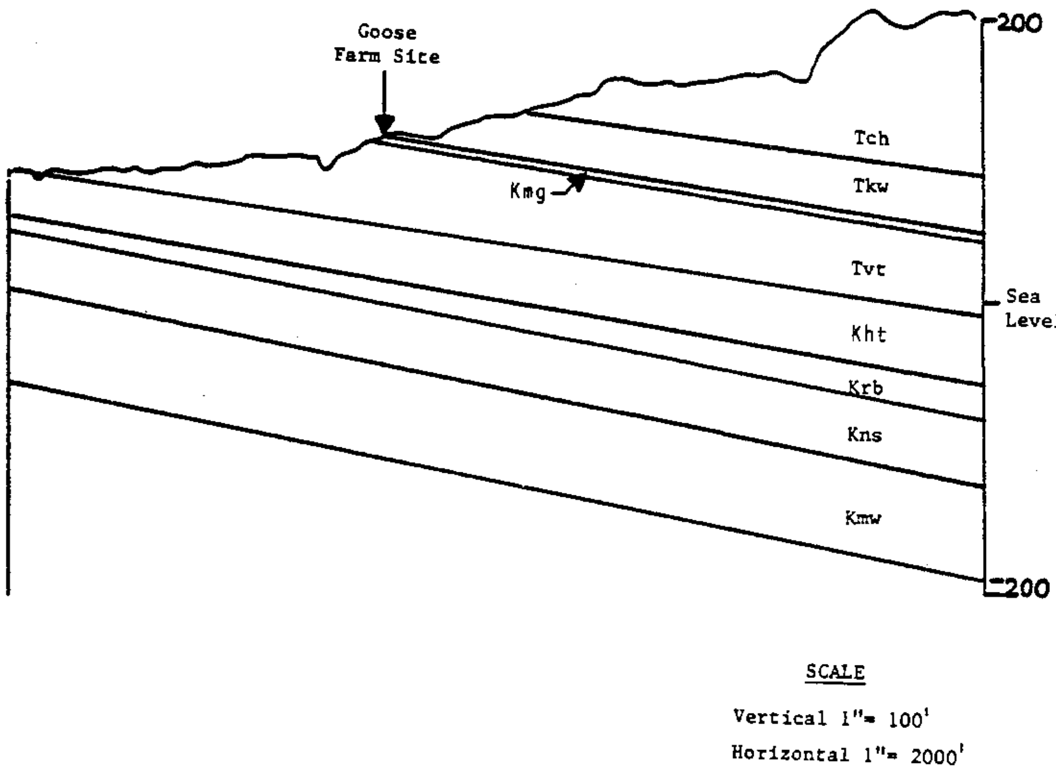

Figure 3. Subsurface Cross Section of the Goose Farm Area

Vincetown Formation (Tvt)--
The Vincetown is an aquifer composed of two units. The upper member ranges from a greenish gray clayey, micaceous, glauconitic, calcareous fine-to-medium grained sand to a sandy, clayey coquina. The clays are calcitic originating from decomposed shell fragments. Occasional indurated sandstone or limestone beds occur. The Vincetown is 30 to 50 feet (9.1-15 m) thick beneath Goose Farm and is the drinking water source for 6 of the 96 local wells.

Hornerstown, Red Bank and Navesink Formations (Kht; Krb; Kns)--
The Hornerstown, Red Bank, and Navesink formations are aquicludes separating the Vincetown from the underlying Mt. Laurel-Wenonah aquifer. The uppermost of these aquicludes is the Hornerstown, composed of 99 percent glauconite clayey sand with a thickness ranging from 30 to 35 feet (9.1-11 m). The Red Bank consists of a dark clayey, very micaceous glauconite sand in the Goose Farm area at a minimum thickness of 10 feet (3.0 m). Most of the Navesink consists of a massive dark green to grayish black, medium to coarse grained glauconite sand with varying amounts of sand and clay at a thickness of 35 feet (11 m). Shell layers are present in the lower regions with a massive shell bed separating the Navesink from the Mt. Laurel-Wenonah formation.

Mt. Laurel-Wenonah Formation (Kmw)--
This formation is a major aquifer in Ocean County with about 1 million gallons (3.8×10^6 l) of water pumped daily. It is used by other counties as well. The Mt. Laurel-Wenonah is the source aquifer for 76 percent or 73 of the 96 local wells. The Mt. Laurel begins with a massive shell bed in the upper layer but is primarily composed of a glauconitic clayey to fine to very coarse pebbly sand. The lower Wenonah formation consists of a silt to medium grained yellow uniform micaceous sand. The Mt. Laurel-Wenonah is about 90 feet (27 m) thick and occurs at a depth of about 150 feet (46 m) in the Goose Farm area.

The uppermost water table (Kirkwood) follows the general topography, i.e. ground water flow direction is 5° to 10° east of north toward the stream. The rate of flow had been calculated to be about 0.5 feet (0.15 m) per day horizontally and about 0.6 feet (0.2 m) per day vertically. Estimated permeability of the underlying Manasquan formation is about 2×10^{-3} feet (6×10^{-4} m) per day, which suggests it is a leaky aquitard. A second flow regime exists in the underlying Vincetown formation, which dips to the Southeast. Gross permeability of the Vincetown foundation has been measured by pumping tests to be 1 to 3 feet (0.3-0.9 m) per day. The two nearest drinking water wells tapping the Vincetown aquifer are located more than one mile (1.6 km) south of the site. Most wells on the area are located in the isolated Mt. Laurel-Wenonah foundations.

WASTE DISPOSAL HISTORY

The Goose Farm site was used as a hazardous waste disposal site between 1945 and 1965 by a manufacturer of solid rocket propellants, ammunition, miscellaneous plastics, synthetic rubber and organic fibers. The wastes were dumped at the Goose Farm site under contract with the then owner of the property. Data suggest that dumping may have continued until sometime in the mid-1970's.

300.68(e)(2)
(i)(B) amount
and form of sub-
stances present

The dump site was a pit dug into the fine sand, approximately 100 feet (30 m) by 300 feet (91 m) and from 10 to 15 feet (3.0-4.6 m) deep. Fifty-five gallon (208 l) drums containing liquids and solids, 5 gallon (19 l) lab packs, and bulk liquids were dumped into the pit. Clean-up efforts indicated that over 4,800 drums and containers of miscellaneous chemicals were disposed at the site. Over 9000 gallons (34,000 l) of bulk chemicals have been removed from the site. Since many drums and containers had deteriorated and the dumping of bulk chemicals was also involved, the estimation of exact quantities disposed at the site is not possible.

Samples from the upper ground water and surface seepage indicate that a large variety of organic and inorganic chemicals may have been dumped at the site, including chlorinated compounds, solvents, and pesticides. During drum excavation, numerous drums containing PCBs were found. Specific chemical substances identified at the site are listed below:

Toluene	Mercury
Ethylbenzene	Zinc
Xylenes	Adipic acid
Styrene	Phenols
Pentachlorophenol	Naphthalene
Endrin	Pyrene
BHC (lindane)	Methylene chloride
Antimony	Vinylidene chloride (1,1-dichloroethane)
Arsenic	Ethylene dichloride (1,2-dichloroethane)
Beryllium	Trichloroethane

Chloroform	1,1,2-trichloroethane
Trichloroethylene	1,1,1-trichloroethane
Benzene	Chromium

DESCRIPTION OF CONTAMINATION

In January 1980, the Plumsted township sheriff's office informed the NJ Department of Environmental Protection (DEP) of the existence of the Goose Farm site. This information was provided as input to a DEP investigation of possible pesticides in drinking wells in the Plumsted area. During the next six months, DEP conducted hydrogeological assessment activities including sampling the nearby stream, installing and logging 17 ground water wells, conducting a metal detector and resistivity survey, and reviewing regional geology and well drillers logs from existing local wells.

300.63(a)(2) investigation

The results from the metal detector survey identified the location of two separate drum disposal pits. Also the data from the test well cores were used to construct the following lithology beneath the site.

300.64(a) preliminary assessment

A surface resistivity survey was performed to approximate the extent of ground water contamination from the site. By varying the spacing of electrodes, different depths in the subsurface can be tested. The resistance of the subsurface media is measured at various depths to provide an indication of changes in strata or evidence of ground water contamination. Profiles of a certain depth across a horizontal distance can also be obtained to indicate strata variations or contamination. The resistivity profiles conducted by DEP indicated a contaminant plume 200 feet (61 m) wide originating from the drum pit and moving to the stream north of the site. The resistivity soundings suggested potential contamination of up to 60 feet (18 m) in depth beneath the site, with the majority of contamination occurring within a depth of 40 feet (12 m).

Stream sampling data has also indicated that polluted ground water was leaching into the stream causing contamination of surface water. Resistivity sounding data on the other side of the stream indicated that contaminant migration was halted by the hydrologic barrier created by the

TABLE 1

GENERALIZED GEOLOGIC SECTION OF SITE

Depth Below Site (feet)	meters	Formation
0-13	0-4	Kirkwood (upper)
13-15	4-4.6	Kirkwood (lower)
15-23	4.6-7	Lower Kirkwood and Manasquan
23-60	7-18	Vincetown
60-62	18-19	Hornerstown

stream. DEP also concluded that the contamination extended into the Vincetown aquifer and possibly down to the Vincetown-Hornerstown interface, but did not affect any local wells. However, a potential for future contamination of wells in the Vincetown aquifer did exist if the problem was not corrected.

In August 1980, O.H. Materials Company (OHM), Findlay, Ohio, initiated additional ground water monitoring and prepared to implement site clean-up through an existing state contract. O.H. Materials Company installed 34 additional wells to further define the contaminant plume, took soil samples and developed data to support the design of a ground water recovery system. The OHM data from monitoring wells indicated that the plume was less than 140 feet (43 m) wide. O.H. Materials Company also concluded that the plume had not reached below a depth of 36 feet (11 m), which corresponds to a cemented sand seam encountered in the Vincetown formation. A review of monitoring data indicates that contamination data at depths greater than 36 feet (11 m) were available from only three of the monitoring wells, one of which was outside the boundaries of the shallow plume. The hydrologic data developed from the resistivity survey and well sampling was adequate for assessing the shallow ground water and surface water contamination. However, resistivity data is qualitative below 40 feet (12 m) at this site due to the complex geology. Therefore, because only three wells were used to define the lower limit of plume depth, complete definition of the plume at depths below 40 feet (12 m) was not developed.

Initial levels of contaminants in ground water were highest for methylene chloride, benzene, and toluene at 134, 106, and 88 parts per million (mg/l), respectively. Total organic carbon in shallow ground water depths ranged from 1600 to 17,000 ppm (mg/l). Metals values were in the parts per billion (ug/l) range and not considered a problem. Soil samples were also taken which also gave very high TOC readings.

PLANNING THE SITE RESPONSE

Initiation of Response

Based on data from DEP tests of surface and ground water that indicated the presence of a number of contaminants, including benzene, toluene, and methylene chloride, DEP concluded in July 1980 that the Goose Farm site posed a threat to human health. Ground water testing indicated contamination of a shallow aquifer below the pit. Tests of a deeper aquifer, which provides drinking water to nearby residents, were inconclusive. However, local geological characteristics, the downward vector of ground water movement, and the long period of time that wastes had been at the site suggested that the lower aquifer might soon become contaminated. In addition, an uncontrolled discharge to surface water, which justified funding under 311(k) of the Clean Water Act, prompted DEP's response. Although tests of nearby drinking water wells during the summer of 1980 showed no contamination above background levels, DEP believed that the threat to drinking water was additional incentive to justify immediate action. Another factor prompting DEP's response was the fact that the site was causing an apparent uncontrolled discharge into the adjacent stream system and thus was potentially eligible for section 311(k) funding.

300.68(e)(2) (i)(C) hazardous properties

300.68(e)(2) (i)(D) hydrogeological factors

300.65(a)(2) threat to drinking water

Selection of Response Technologies

The selection of response activities and technologies at the Goose Farm site occurred before definite protocol was available from the presently emerging (CERCLA) Superfund program such as the procedures outlined in the National Contingency Plan. Also, selection of specific technologies and the decision to clean-up the site seems to have been carried out under a climate of urgency prompted by the executive management of DEP and the potential availability of 311(k) funds. As mentioned earlier, the N.J. Department of Environmental Protection (DEP) conducted the preliminary site investigation during January through June, 1980. They then utilized OHM in August 1980 through an existing time and materials contract basis to accomplish the following objectives:

- Accumulate data that indicated there was an uncontrolled release of hazardous substances into the tributaries of Crosswick Creek and determine if this release was originating from Goose Farm site

- Obtain sampling data to show the extent of the ground water contamination to a degree sufficient to enable assessment with respect to the elimination of the discharge to the Creek

- Contain the discharge by a three-phased approach which included:

    - a peripheral ground water treatment system (referenced as System A in the literature),
    - excavation of the drums and the most grossly contaminated soil on site,
    - possible further ground water control at the heavily contaminated area, if needed.

- Improve or protect ground water quality at and adjacent to the site sufficient to assure that further significant surface water discharges would not occur.

The DEP directed OHM to proceed with clean-up efforts using ground water pumping and treatment to remove the contaminants from the ground water. In addition, OHM proposed (with DEP approval) to use their patented system to collect contaminated ground water directly under the drum burial site, treat the collected water, and spray irrigate and pressure inject treated water over the site to flush contaminants from the underlying soil with time. O.H. Materials Company also proposed to use biological degradation with mutant microorganisms to complete the soil clean-up process.

Several alternative remediation techniques were considered by DEP, including:

- Installing an open or gravel filled trench between the site and the stream to intercept contaminated ground water with treatment prior to discharge

300.68(g) development of alternatives

- Pumping and treatment to contain the plume rather than to collect it

- Installing a slurry wall with ground water pumping or a french drain upgradient of the wall

- Capping the site

The first two measures were temporary containment measures that could have been implemented to stop the immediate ground water discharge to the stream. The major benefit of utilizing the trench or pumping methods would have been to provide DEP with temporary stabilization of conditions at the site while a more detailed assessment could be conducted to determine optimal long term remediation. These measures would have involved lower quantities of collected ground water requiring treatment. Thus, lower treatment costs would have resulted over the short term. 300.68(e)(1) initial measures

The installation of a slurry wall to a 60-foot (18 m) depth (beginning of Hornerstown aquiclude) with pumping of the upper aquifers may have been a technically and economically viable long-term alternative, given a more detailed hydrogeological and engineering assessment. The slurry wall may have prevented migration of the contaminated ground water into the stream, and further into the aquifer. The Hornerstown, Red Bank, and Navesink formations consist of 75 to 80 feet (23-24 m) of relatively impermeable strata. The thought behind considering a slurry wall is that it would have cut off a portion of the aquifer (or the entire aquifer depending on design) so that a minimum of clean ground water would be pumped during pumping of the contaminant plume. This would have substantially reduced pumping and treatment costs, especially given the high permeability of the subsurface at the Goose Farm site. The slurry wall alternative at this time, however, wasn't considered by state and Federal decision-makers to be a reliable technology and there were doubts concerning this technology's effectiveness in the situation at hand.

Extent of Response

The DEP's goals in the Goose Farm clean-up were to eliminate the discharge of contaminants to surface water and to mitigate the threat to ground water. The DEP issued itself a permit which established an effluent criterion for the treatment system, requiring that water discharged from the system contain less than 100 mg/l total organic carbon (TOC). By December 1980, NJDEP had established a ground water clean-up goal of 100 mg/l TOC. The pumping and treatment response was terminated in March 1981 when NSDEP had determined ground water contamination to be below 100 mg/l. 300.68(j) extent of remedy

Another factor that determined the extent to which the site was cleaned up was the amount of available funds. While DEP had intended, after the ground water treatment system was dismantled, to attempt a relatively complete decontamination of the soil and ground water using biological treatment, no state funds were then available, and the section 311(k) and Superfund funds were only available for emergency responses. By March 1981, the situation at Goose Farm was not considered an emergency. The DEP removed the excavated wastes in November 1981, when additional state funds became available.

DESIGN AND EXECUTION OF SITE RESPONSE

The following sections describe the design, construction, and operation conducted at the Goose Farm site from August 1980 to January 1982.

Remedial actions conducted at Goose Farm consisted of the following activities:

- The installation of a wellpoint collection/spray irrigation system to contain and thereby prevent contaminated ground water from entering the creek (System A)
- The installation of a wellpoint collection and recharge system to flush contaminants from the soil and collect contaminated ground water directly beneath the drum disposal area (System B)
- Treatment of contaminated ground water
- Drum removal, segregation and treatment
- Temporary storage of drums and bulked wastes
- Final disposal of drums and bulked wastes.

The above remedial actions are discussed in the following sections:

Wellpoint/Spray Irrigation (System A)

Wellpoint system A was installed in September 1980 between the drum pit on the Goose Farm Site and the nearby stream to prevent further contamination of the surface water by contaminated ground water seepage. The The wellpoint system composite cone of depression acted as hydrologic barrier to the migration of the contaminant plume to the stream. The wellpoint system

300.70(b)(1)-(iii)(c)(2) ground water pumping; plume containment consisted of about 400 feet (122 m) of 6-inch (15 cm) exposed aluminum header pipe with 52 wellpoints spaced about every 7.5 feet (2.3 m). The wellpoints were comprised of 3-foot long (0.9 m) long jettable recovery points screened with 200 mesh dutch weaved stainless steel screens. The wellpoints were joined with 1 1/2 inch (3.8 cm) diameter metal pipe, and installed by water jetting to a depth of approximately 22 feet (6.7 m), which corresponds to the beginning of the Manasquan aquitard. (The configuration of wellpoint system A is shown in Figure 4.) The wellpoint system was pumped at a rate of about 50,000 to 75,000 gallons (189, 271 - 283, 906) per day to contain the migration of contaminants. Following treatment to remove contaminants (which will be discussed later in this section) the collected ground water was spray irrigated via 6-inch (15 cm) aluminum headers. Two spray irrigation systems were initially installed to handle the flow from the system A wellpoints. The primary spray irrigation system was located behind the main battery of wellpoints, so that the mound created by infiltrating water would form a second positive hydraulic barrier in addition to the negative hydraulic barrier created by the wellpoints' composite cone of depression. A secondary spray irrigation system was located northwest of the collection area to handle the remaining flow. The primary spray system was dismantled after a time and used as a recharge system for wellpoint system B in the drum pit area.

A vacuum receiver (himulator) was used to effect ground water recovery in the wellpoint system. A second vacuum system had to be added to achieve the required flow rate for creating an adequate cone of depression.

Certain operational requirements were addressed during site clean-up with respect to wellpoint system A. Winterization of the wellpoint system had to be carried out to protect system elements from freezing temperatures. This was accomplished by constructing wooden housings (snake barns) around the piping. Wooden housings were also constructed around vacuum system elements. Adjustments to the wellpoint system were made throughout pumping. Initially the system was adjusted to give uniform flow. Later adjustments to the system involved turning off wellpoints in which relatively clean water was being pumped. This action allowed greater pumping of wellpoints located in pockets of higher contamination.

During the course of pumping, OHM decided to extend a section of wellpoints 60 feet (18 m) to the southeast, to offer greater containment of the contaminant plume.

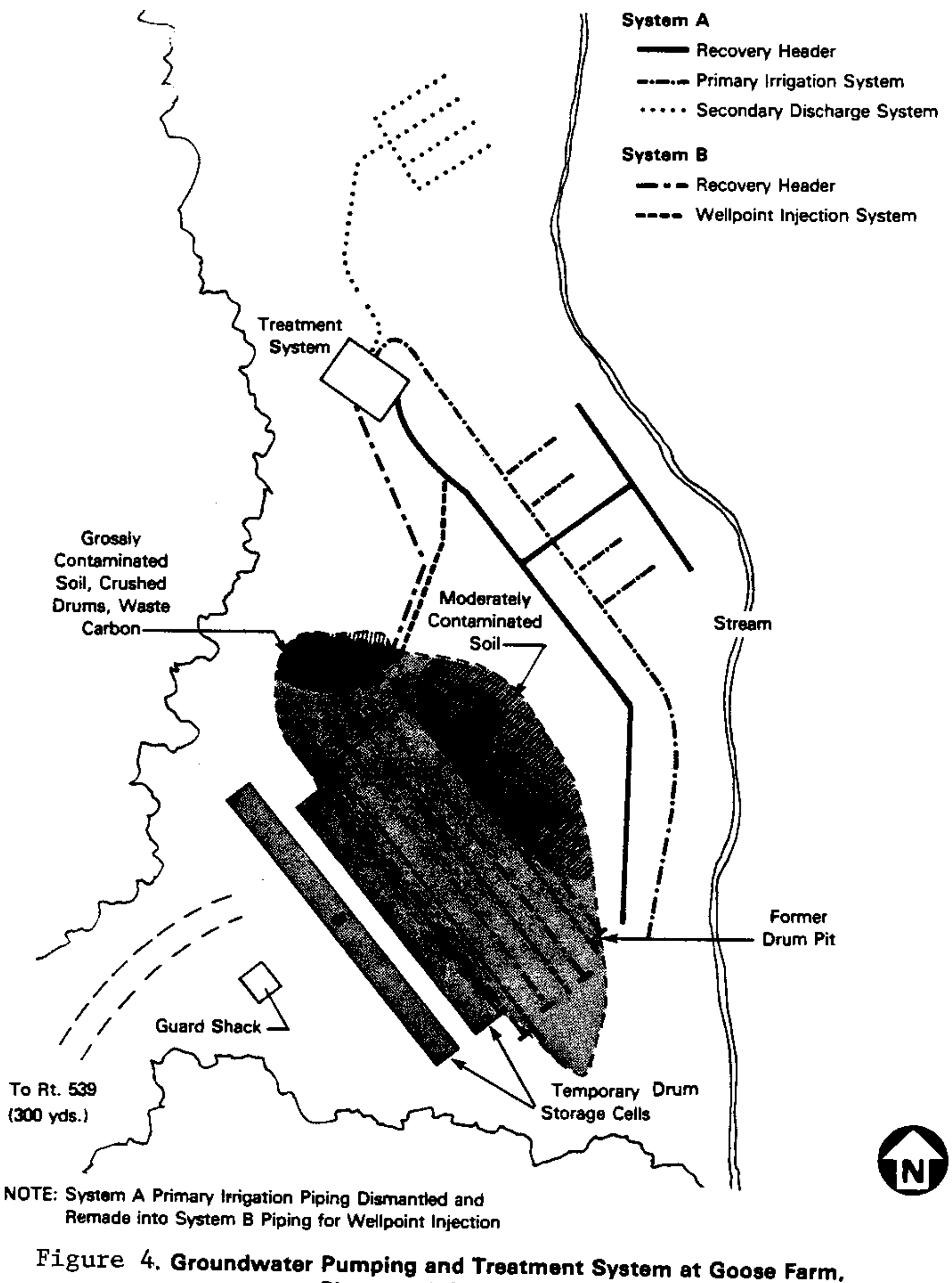

Figure 4. **Groundwater Pumping and Treatment System at Goose Farm, Plumstead, New Jersey**

During the winter operation of the spray irrigation system it was noticed that spray nozzles were freezing and clogging. The spray nozzles were removed and the system continued to be operated without any significant performance impact. At one point during the pumping/treatment/irrigation operation, runoff from the secondary spray irrigation system was severely eroding a channel to the stream. The eroded area was filled with gravel to control future erosion problems.

System A was operated from September 1980 to February 1981, when it was determined that the drawdown from system B was enough to contain the plume.

Wellpoint Collection/Spray Irrigation/Pressure Injection (System B)

Wellpoint collection/injection system B (also shown in Figure 4) was installed during December 1980 in the drum burial area to remove contaminants in the unsaturated zone and the ground water directly beneath the site. The first phase of operation consisted of installing wellpoints to a shallow depth, i.e. in the unsaturated zone above the water table, which occurred at depths of around 7 to 13 feet (2-4 m), under the site. Ground water collection and injection at this depth would flush contaminants from the unsaturated zone. Later, the wellpoints were lowered into the water table to collect the contaminated ground water plume. Collected water underwent treatment, as did the water from System A. Initially, treated water was spray irrigated onto the drum disposal area to flush contamination from soils in the unsaturated zone. Eventually treated water was pressure injected via a separate wellpoint system directly into substrata in the drum disposal area in order to accelerate flow movement along surfaces of less permeable layers. As with system A, wellpoints were constructed of 3-foot (0.9 m) Dutch weave stainless steel screens joined with 1.5 inch (3.8 cm) metal pipe on centers of 7.5 feet. Approximately 100 wellpoints were connected to about 900 feet of 6-inch (15 cm) aluminum header pipe. Again, a vacuum system was used to recover the ground water.

300.70(b)(2)-(iii)(E)(1) in situ treatment: solution mining

Prior to soil flushing, observations in test pits (dug by a backhoe) indicated that contamination was present as a black ooze above a clay layer, which was 3 to 4 feet (0.9-1.2 m) deep. Analysis of the clays indicated that a high level of organics (30 mg/g TOC) was seeping slowly through the clay layer. To facilitate flushing of the contaminants from the low permeability clay layer, the pressure injection system was operated with varying pressures by using on/off relays in order to create a pressure pulse.

Initially, bench scale leaching tests indicated that 10 complete soil rinses, or a total of 11,000,000 gallons (4.2×10^7 l) of water would be required for complete soil flushing to acceptable levels. When OHM was asked to terminate operations, the total amount of water processed was approximately 7.8 million gallons (2.9×10^7 l) for systems A and B. Soil TOC values in the drum pit area at the termination of soil flushing operations averaged about 3,300 mg/l. The above criteria suggest that decontamination of soils may have been incomplete. System B operations were terminated in March 1981.

As with system A, snake barns were constructed around piping to protect against freezing during winter operation.

Contaminated Ground Water Treatment

The 250,000 gallon (950,000 l) per day capacity treatment systems at the Goose Farm site received contaminated ground water collected by wellpoint system A and B. It consisted of an activated carbon fume scrubbers to remove volatilized organics, a clarifier, a four-cascade aqueous carbon treatment system, aeration to strip organics not treated by the aqueous carbon treatment system, and an effluent storage tank. The configuration of the treatment system is shown in Figure 5.

300.70(2)(ii) direct waste treatment methods

Contaminated ground water flowed through each of the two wellpoint systems to two vacuum receivers, one for each system, which developed the necessary suction for the collection systems. The vacuum in these units enhanced volatilization of organics from the aqueous to the vapor phase. Organic loading in the influent stream averaged about 157 mg/l Total Organic Carbon (TOC). Volatilization occurring at the vacuum receiver removed about 13 percent of the TOC present in the aqueous stream. Vapor phase carbon treatment systems (fume scrubbers) were then used to remove organic contaminants from the resultant vapor stream. The carbon fume scrubbers reduced organics in the vapor phase from about 800 ppm to below 100 ppm.

The carbon adsorption units off the vacuum receiver were vessels with a bed surface area of approximately 38.5 square feet (3.57 m^2). Air flow (generated by the vacuum receiver) could reach up to 300 cubic feet (8,500 l) per minute. Each vessel was charged with up to 4,500 pounds (2,041 kg) of carbon for treating the organic vapors.

300.70(b)(2)(ii)-(C)(2) carbon adsorption

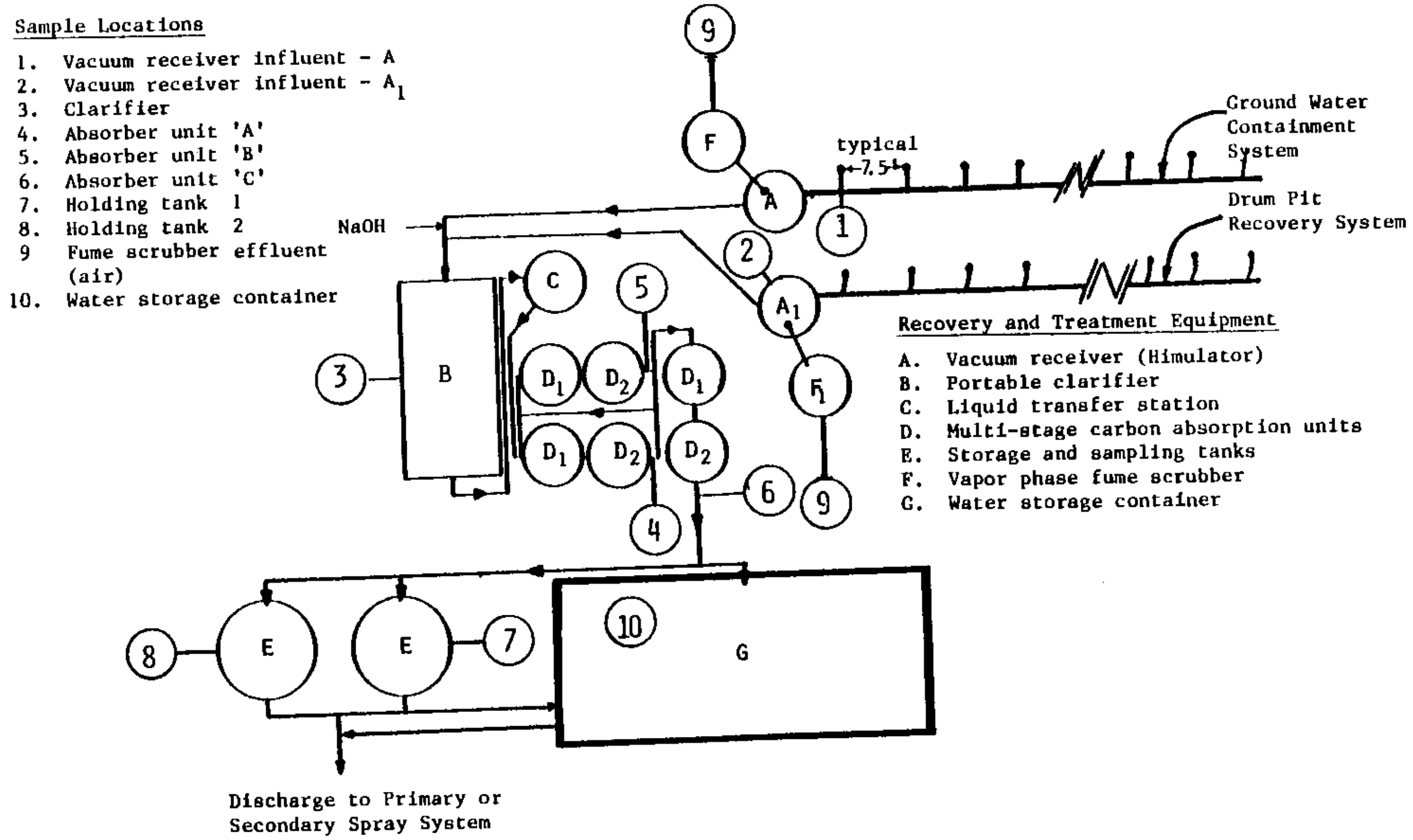

Figure 5. Schematic View of Treatment System at the Goose Farm Site (O.H. Materials Co., 1981)

The aqueous effluent from the two vacuum receivers flowed into a clarifier to reduce suspended solids and heavy metals prior to treatment with carbon. The pH of the stream was adjusted with sodium hydroxide to about 6.0 to enhance clarification. Polymer flocculants were tried but found to be only marginally effective. The clarifier was a portable unit of 12,000 gallon (45,000 l) capacity with a mixing chamber, a sludge collector and decant system, and a skimming apparatus. Detention time in the clarifier was about 200 minutes. Organic loading in the clarifier influent stream averaged about 136 mg/l. About 9 percent of TOC in the influent stream was removed by the clarifier. Effluent from clarifier flowed to a transfer station, where flow equalization occurred. Multi-stage pumps provided a flow rate range of from 25 to 150 gallons (95 -568 l) per minute to the carbon adsorption system.

Carbon adsorption of the aqueous stream consisted of three 2-cell adsorbers, in which any two would be connected in series during operation, while the remaining unit was being recharged with fresh carbon. Influent to the carbon adsorption system averaged 125 mg/l. The carbon adsorption system removed about 62 percent of the remaining TOC. Final effluent TOC after carbon adsorption was about 54 mg/l, which demonstrates an overall removal efficiency of 66 percent. Spent carbon was stored on-site for six months prior to off-site disposal.

A 100,000 gallon (3.8×10^5 l) storage tank was installed as a modification to the existing system to collect effluent overnight prior to discharge. This eliminated the additional cost of night-time sampling and also provided a safeguard against releasing water that was above the effluent discharge limit of 100 mg/l TOC.

TOC was the main parameter used to monitor treatment plant operation. Analyses for additional chemical compounds were conducted only during the 21-day treatment plant study period in February 1981. It was during this time that methylene chloride was observed to be breaking through the carbon system, i.e. it was not being adequately removed and causing abnormally high effluent concentrations.

The methylene chloride problem was solved by installing an aeration system within the 100,000 gallon (380,000 l) storage tank. The aeration system consisted of a series of 3-inch (7.6 cm) PVC headers installed about 3 feet (1 m) over the liquid surface. Stored water was recycled through the spray aeration system until the water met the discharge limits.

300.70(b)(2)
(ii)-(C)(1)
air stripping

During winter operation the spray irrigation system was observed to be sagging due to the weight of the ice on the headers; however, no corrective action was required. The treatment system was operational from September 1980 to March 1981, during which a total of 7,800,000 million gallons (2.9 X 10^{7} 1) of contaminated ground water was treated and discharged.

Waste Removal

300.70(c)(2)(i)
excavation

Waste removal operations at the Goose Farm site were carried out from September to October of 1980. During a 45-day period, over 4,880 drums and containers were excavated, analyzed, secured, and segregated. Table 2 gives an inventory of drums and containers recovered from the burial area.

TABLE 2

Inventory of Recovered Drums and Containers

Drummed Solids	1,201
Drummed Liquids	402
Overpacked Solids	23
Overpacked Liquids	278
Lab Packs	92
5 gallon (19 1) drums (full)	2,037
5 gallon (19 1) drums (empty)	512
55 gallon (208 1) drums (empty)	288
55 gallon (208 1) drums (crushed or fragmented)	54
TOTAL containers	4,887

Excavation operations proceeded as follows: The boundaries and the depth of drum burial were defined. A bench was then excavated near one end of the burial pit to the drum pit floor level. This allowed "above-ground" access to the buried waste materials. Excavation of drums, containers and contaminated soil proceeded from one end of the pit to the other.

A backhoe/front end loader and two OHM-designed drum grapplers were used to complete removal operations. The backhoe was used to excavate to the surface of the drums. The drum grapplers were used to grasp the drums and transfer them from the excavation area to the front end loader. The loader was used to transport drums to the operations area and to the staging area. Drums that could be overpacked were overpacked. Other drums containing solids were secured on site while badly degraded drums containing liquids were tested for compatibility and emptied into separate concrete tanks according to whether they were acid, base, or neutral materials. Bulked liquids totalling 9,077 gallons (34,000 l) were disposed of via Chem Clear, an aqueous waste pretreatment facility in Chester, PA.

About 3,500 tons (3,200 Mt) of highly contaminated soil and about 20,000 tons (18,000 Mt) of moderately contaminated soil were excavated from the drum burial area and segregated into two separate piles on site. The severely contaminated soil was analyzed and found to contain less than 50 mg/kg PCB.

Temporary Storage of Drums and Bulked Wastes

By December 1980, drums and bulked wastes were staged on-site in anticipation of final disposal. Provisions for temporary storage were made. Contaminated soils and PCB contaminated carbon were stockpiled on-site. A 6-ml black plastic liner was placed as a foundation for the waste piles while a plastic liner was also used to cover the piles. Wood from dismantling the snake barns was used to weigh down the plastic top liner. Stored drums were underlain and covered with a clear plastic liner.

The wastes remained on site for several months awaiting funding for final disposal. In July 1981, a site visit revealed general deterioration of provisions for temporary storage. Wind conditions had partially torn plastic top liners from the drum storage area and waste piles. Drums were observed bursting from the excessive heat caused by a "greenhouse" effect resulting from using clear plastic to cover the drums. The clear plastic lining was degrading due to contact with the organic vapors and citizens in the area were complaining about health problems they felt were caused by noxious fumes from the site. Heavy rains had eroded some of the waste from the storage piles. Several of the drums were in danger of falling into the drum pit, because of erosion.

Final Disposal

In November 1981 final disposal of the stored materials was initiated. O.H. Materials Company used a dozer and a front end loader to empty and crush the drums, and loaded the bulked wastes for transport. About 4,320 tons (3,930 Mt) of wastes, including the 3,500 tons (3,200 Mt) of highly contaminated soil, were transported in 205 truck loads to the CECOS International disposal site in Niagara Falls, New York. In addition, 12 drums of PCB waste were transported to Rollins Environmental Services, Bridgeport, NJ for disposal.

300.70(c) off-site transport for storage, treatment, destruction, or secure disposition

COST AND FUNDING

Source of Funding

Before initiating a response, state officials attempted to enlist the cooperation of the party responsible for dumping the wastes. The state was not able to negotiate an acceptable settlement with the dumper. The DEP began work on the site on August 25, 1980 using money from the New Jersey Spill Compensation Fund. By October 19, 1980, costs for the clean-up averaged $25,000 per day, and the state had spent $1.1 million.

300.68(c) responsible party

As the state neared the limit of available Spill Fund monies, DEP made a request through U.S. EPA to the U.S. Coast Guard for funds under the Clean Water Act section (311k) Revolving Fund. Since the site was contaminating surface water that flowed into the Delaware River, a navigable water of the U.S., the clean-up was eligible for emergency funds under section 311(k). The request was approved as state funds ran out.

Accordingly the Coast Guard approved section 311(k) funding for the site and set an initial spending ceiling of $500,000. An on-scene coordinator for the site was appointed from the Emergency Response and Hazardous Materials Inspection Branch in the Region II office of EPA. Federal funding for the clean-up began on October 20, 1980. The DEP's Division of Hazard Management continued as the managing authority at the site, while EPA reviewed invoices and forwarded them to the Coast Guard, which then reimbursed the state. The DEP stayed in charge throughout the clean-up, choosing the contractors, technologies, and the clean-up criteria in coordination and with concurrence of the Federal government.

300.68(b) state RA

There was no formal cooperative agreement between New Jersey and either EPA or the Coast Guard concerning the specific uses of the federal funds. The state had a memorandum of understanding from the Coast Guard stating that the Coast Guard would reimburse the state only for expenditures approved by the EPA on-scene coordinator. The Coast Guard placed an important restriction on spending at the outset of EPA involvement, namely that section 311(k) funds could not be used for waste disposal. The Coast Guard believed that New Jersey Spill Fund money should be used to pay for disposal.

As work on the site progressed, EPA made requests to the Coast Guard every 2 to 4 weeks to raise the spending ceiling at the site, usually in increments of $500,000 or $1 million. In December 1980 the Coast Guard began authorizing smaller increases, ranging from $30,000 to $200,000 because the 311K money was nearly depleted. In February 1981 part of the ground water recovery system was dismantled and most of the clean-up personnel and equipment were removed from the site. These actions were intended to reduce clean-up costs at the site to $5,000 per day.

The Emergency Response Division (ERD) of the EPA Office of Emergency and Remedial Response assumed authority over section 311(k) funding for Goose Farm in March 1981. ERD reviewed the status of Goose Farm and concluded that the site did not present an emergency and should be given a low priority in view of the limited funds available to ERD and the more immediate problems at other sites. Accordingly, the ERD terminated federal funding for the Goose Farm clean-up in March 1981, with a final total authorization of $2.75 million. According to both EPA and DEP, the site no longer posed an immediate threat to human health when operations ceased.

300.68(k) balancing

In November 1981, additional state funds became available for Goose Farm. The DEP spent approximately $600,000 from the Spill Fund to remove and dispose of the wastes that had been excavated the previous year.

Selection of Contractors

In August 1980, DEP chose O.H. Materials, Inc. (OHM) of Findlay, Ohio to install and operate a ground water recovery and treatment system and to excavate wastes. The state signed a sole-source contract with OHM on a time-and-materials basis, using the New Jersey "X-83" contracting system. The X-83 system was a mechanism wherein the state accepted price sheets for time and materials from a number of contractors, then chose contractors as the need arose, basing the selection primarily on qualifications and availability of the firm and secondarily on prices.

At the time of the site response DEP believed that OHM was the only contractor offering the ground water treatment technology that was selected. O.H. Materials billed the state weekly for labor and equipment used in the clean-up. No limit was set on total expenditures for the job. The DEP kept an official on the site throughout the clean-up to oversee the work and review invoices submitted to the state.

The second major contractor chosen for the clean-up was CECOS International of Niagara Falls, New York, which was also prequalified and had received an X-83 contract. The DEP chose CECOS in November 1981 to transport and dispose of 4,320 tons (3,930 Mg) of waste excavated from the site. CECOS was chosen through an informal competitive bidding arrangement because the firm offered the lowest price for transportation and disposal.

Project Costs

The cost of the Goose Farm clean-up operations from August 1980 to January 1982 was $5.1 million. Of this amount, $2.35 million came from the New Jersey Spill Fund and $2.75 million from federal sources. Because the project was ongoing when CERCLA was enacted in December 1980, the federal funds came from both the section 311(k) Revolving Fund ($1.75 million) under the Clean Water Act and the Superfund Emergency Response Fund ($1 million). Table 3 provides a summary of cost information.

300.61(c) CERCLA-financed response

Precise cost breakdown of each of the clean-up elements is not possible for two major reasons. First, the New Jersey DEP did not provide detailed information on costs, as well as on other aspects of the clean-up, because release of such information might have been detrimental to the state's litigation against the responsible party. A cost summary was made available, but did not give a detailed breakdown of expenditures. Second, the more detailed cost information that EPA provided on the section 311(k)-funded portion of the clean-up did not differentiate between the various tasks that OHM performed concurrently at the site because bills were submitted to DEP on a time-and-materials basis. While invoices specified hourly rates for labor and daily rental charges for equipment, they did not state the tasks for which the labor and equipment were used. Given these limitations, only a general analysis of expenditures is possible.

TABLE 3. SUMMARY OF COST INFORMATION - GOOSE FARM, PLUMSTED TOWNSHIP, N.J.

Task	Quantity	Estimated Expenditure	Actual Expenditure	Variance	Unit Cost	Funding Source	Period of Performance
Mobilization, excavation and demobilization			$3,104,845			N.J. Spill Fund 311(k)/Superfund	8/80-4/81
Groundwater recovery and treatment operation cost only	7,817,480 gal (29.5 million l)		$1,120,000		14¢/gal. (3.7¢/l) (25-40¢/gal. including set-up)	N.J. Spill Fund 311(k)/Superfund	9/80-3/81
Bulking and loading wastes for disposal	4320 tons (3900 Mg)	$380,000(a)	$193,834	-$186,166 (-51%)	$45/ton ($50/Mg)	N.J. Spill Fund	11/81-12/81
Disposal of soil and drums at CECOS	4320 tons (3900 Mg)	$1,258,000(a) Transportation and disposal	$171,272	-$840,728 (-67%)	$40/ton ($44/Mg)	N.J. Spill Fund	11/81-1/82
Transportation of wastes to Niagra Falls, N.Y 440 mi (708 km)	4320 tons (3900 Mg) (205 loads)		$246,000		$1200/load or $57/ton or 12.9¢/ton/mi. (8.8¢/Mg/km)	N .J. Spill Fund	11/81-1/82
Off-site sample analysis			$150,000			N.J. Spill Fund 311(k)/Superfund	7/81-1/82
PCB transportation and disposal at Rollins, Bridgeport, N.J.	12 drums	$15,000(a)	$4,100	-10,900 (-72%)	$341/drum	N.J. Spill Fund	1/82
Drilling monitoring wells			$24,127			N.J. Spill Fund 311(k)/Superfund	7/80-12-81
Site security guards			$58,371			N.J. Spill Fund 311(k)/Superfund	4/81-1/82
Electric power			$19,260			N.J. Spill Fund 311(k)/Superfund	4/81-1/82
Miscellaneous			$12,123			N.J. Spill Fund	7/80-1/82
Total		$5,000,000 (b)	$5,103,932	+103,932 (+2%)			

(a) NJDEP estimate - May, 1981 (not a binding contractual estimate)

(b) NJDEP estimate - October, 1980 (not a binding contractual estimate)

Ground Water Recovery and Treatment--

Installation, operation and dismantling of the ground water recovery and treatment system cost between $2 million and $3 million, paid for from both state and federal funds. Of the $2 to 3 million, DEP estimated that the cost of operating the system, including chemical analyses, was $1.12 million. Counting operation costs alone, the treatment cost for 7,817,480 gallons (2.96×10^7 l) of recovered ground water was $0.14 per gallon (3.8¢ per liter) based on the DEP estimated operating cost. However, if installation and dismantling costs are included, the cost probably ranged between $0.26 and $0.40 per gallon (6.8 - 10.1¢ per liter). Unit cost of operation varied, depending on the quantity of water processed. For example, during the last week of November 1980, when only the A system was operating and no other work was ongoing at the site, the unit cost for recovery and treatment was $0.27 per gallon (7.1¢ per liter). The unit cost of treatment can also be expressed as a function of TOC removal. During a 21-day efficiency study of the treatment system in February 1981, when both the A and B systems were operating, the system removed an average of 31 pounds (14 kg) of TOC per day. Unit removal cost ranged from $343 to $1,300 per pound ($156 - $591 per kg) of TOC removed.

Waste Removal and Disposal--

The cost of excavating and staging 4,887 drums and 30,000 cubic yards (22,800 m^3) of contaminated soil was between $1 million and $2 million, all federally funded. Again, an exact figure is unavailable because of the lack of a cost breakdown.

Final removal and disposal of 4,320 tons (3,900 Mt) of drums and soil and 12 drums of PCBs cost the state $615,000. Of that amount, $194,000 was paid to O.H. Materials for emptying and crushing drums and loading the waste on to trucks, and $417,000 to CECOS International for transporting and disposing of the waste in its Niagara Falls landfill. Transportation cost $246,000 for 205 truckloads or $1,200 per load. The distance transported was approximately 440 miles (708 km). Disposal costs were $171,000, or $40 per ton ($44/Mt). Based on these figures, the unit costs of the removal action were $45 per ton ($50/Mt) for bulking and loading; $57 per ton ($63/Mt) for transportation or 17.8 ¢ per ton per mile (10.1 ¢/Mt/km), and $40 per ton ($44/Mt) for disposal. Total per-ton cost for removal and disposal was $142 per ton ($156/Mt). Transportation and disposal of 12 drums of PCBs by Rollins Environmental Services in Bridgeport, N.J. cost $4,100, or $341 per drum.

Sampling and Analysis--

Chemical analysis of samples performed off-site cost $150,000. The cost of drilling 51 monitoring wells was $24,127. No costs are available for resistivity testing.

Other Expenses--

The DEP hired security guards from the Plumsted Township Police Department to guard the site full-time from April 1981 through January 1982. Security cost about $1,500 per week, totalling $58,371.

The electric power cost for both the initial clean-up activities from August 1980 to April 1981, and the waste removal activities from November 1981 to January 1982, totalled $19,260. Miscellaneous expenses totalled $12,123.

PERFORMANCE EVALUATION

It is evident from the preceding case history that thorough planning is essential to the successful technical and financial conduct of response actions at hazardous waste sites. Protocol for planning site response has been made available through the development of the National Contingency Plan. At the time of the Goose Farm clean-up, no such protocol existed and guidance from past experience was minimal. These facts must be considered in a just evaluation of the response at the Goose Farm site.

The initial intent of the clean-up, as mentioned in the section on Selection of Site Response, was to eliminate the discharge of contaminated ground water to the stream and also to provide additional treatment of ground water as required. No monitoring data was available to ascertain whether the discharge to the stream has been eliminated. The other major objective of the site clean-up was to achieve some level of ground water quality at and adjacent to the site. The established criterion required that the average ground water TOC level be less than 100 mg/l. Again, no monitoring data were available to determine whether this criterion had been met.

Additionally, it appears that there may have been some degree of uncertainty concerning the extent of ground water contamination at the site, due to the limited monitoring well data. There also seemed to be a climate of urgency related to the site clean-up resulting from public concern in the area, and due to these emergency response requirements and availability of funds, design of the wellpoint system was based on the limited data available at the time.

It should also be pointed out that available ground water remediation technology at the time of the Goose Farm clean-up was not broadly used or developed, thus adding to the difficulty of site clean-up efforts.

As mentioned earlier, preliminary data from resistivity studies suggested that the contaminant plume may have reached a depth of 60 feet (18 m). From limited monitoring well data, OHM concluded that ground water contamination was limited to 36 feet (11 m). They designed their wellpoints (System A) for plume containment with a screen depth of approximately 17 to 22 feet (5.2 - 6.7 m) to key into an aquitard. There is some suggestion in the OHM literature that the wellpoints were supposed to be lowered at a later date to take care of deeper contamination, presumably to 36 feet (11 m). However, the System A wellpoint network was shut down in February 1981 during the operation of System B. The System A wellpoints were never lowered to a greater depth to collect deeper ground water contamination (the reason for not lowering System A wellpoints is not known). In any case, it is evident from the documentation that ground water treatment objectives were initially not well defined and were being modified as the clean-up proceeded.

Another occurrence at the Goose Farm site was that ground water pumping, treatment, and recharge operations were carried out during the winter. Winter operations required that piping systems be insulated by wooden snake barns and that process buildings be constructed around treatment plant unit operations. The construction of shelters for these components resulted in significant time delays and additional costs. Also, winter operation caused operational problems that were described in the previous section. The expense of winter operation should be considered in the future in the design and planning of responses for uncontrolled hazardous waste sites.

Proper planning relative to the timely removal of waste materials staged on-site is also an important aspect of site response. At the Goose Farm site, a delay in transporting staged wastes off-site caused a degradation of temporary containment provisions, and may have resulted in recontamination of previously cleaned soils.

At present, the documentation suggests that contamination of the lower ground water regions has not been thoroughly removed and may still pose a significant threat to drinking water wells. Remediation relative to this problem may be necessary. A report has been prepared by Weston Consultants (Weston), West Chester, Pennsylvania detailing additional sampling and analytical requirements for adequately defining the lower aquifer contamination at the Goose Farm site. These include the installation of multi-level cluster wells, a piezometric survey, monitoring wells for EPA priority pollutants, pumping tests on a minimum of two wells on-site, contaminated soil analysis and detailed mapping of the extent of contamination. Also, in the report, a number of alternatives for cleaning up the remaining ground water contamination are assessed in terms of technical feasibility and costs, including the installation of a slurry trench, french drains, radial wells, deep well ground water pumping, and alternate aqueous treatment scenarios. Weston concluded that the best clean-up option would be one similar to the OHM system, but would be designed using more detailed data on contamination.

Temporary measures to control site discharges can be implemented at uncontrolled hazardous waste sites to allow time for proper program planning prior to initiation of extensive site clean-up activities. Thus, more efficient and effective remediation techniques can be identified and implemented. An alternative response which may have given greater flexibility at the Goose Farm site would have been to install one of the temporary containment actions described in the section of this case study entitled Selection of Site Response. Thus, a cut-off drain or pumping just to contain the plume could have been used on a temporary basis, while a detailed engineering report could be prepared which would provide an adequate assessment of existing data, further monitoring requirements, and a detailed analysis of long-term remedial action alternatives.

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H & M DRUM COMPANY

DARTMOUTH, MASSACHUSETTS

INTRODUCTION — NCP Reference

Hazardous wastes were stored and disposed at a former gravel mining site in North Dartmouth, Massachusetts between late 1978 and early 1979. Contamination of ground water and surface waters resulted from corroding drums buried in a backfilled disposal pit that had been excavated below the water table during previous mining operations. A municipal well located approximately 1,400 feet (427 m) downgradient from the drum disposal pit was closed under state order due to the likelihood that contaminated ground water from the disposal pit would migrate towards the well. 1,1,1 trichloroethane trichloroethylene and other volatile, chlorinated organics were detected in an observation well located 700 feet (213 m) from the municipal well. The concentration of 1,1,1 trichloroethane exceeded 1 mg/l.

Background

The H & M Drum site is situated on a 150-acre (61 ha) tract of land immediately south of Route 6 in Dartmouth, Massachusetts. The property had been previously used for gravel mining operations before being leased to Harold Mathews, president and owner of H & M Drum Company, for use as a refuse yard. In 1978, Mathews began storing drums of hazardous waste in a warehouse located on the property. Discovery of this site resulted from a local police investigation into hazardous waste disposal by H & M Drum in the nearby town of Freetown, Massachusetts in April 1979. Investigation of the Freetown incident led the Massachusetts Department of Environmental Quality Engineering (DEQE) to investigate the Dartmouth site shortly thereafter. — 300.63(a)(4) discovery

At the time of discovery by DEQE, the Dartmouth property contained a warehouse with approximately 1,000 drums of waste, a trailer with 100 drums, and four earthen-covered disposal pits used for disposal of drums. The primary disposal pit contained approximately 300 corroding and leaking drums of waste mixed with metal debris and — 300.64(a)(2) preliminary assessment tires. Direct discharge of contaminants into the groundwater occurred because rusting and leaking drums of waste burined in the pit lay partially submerged in the groundwater. The other three pits contained fewer than 20 drums in total. Figure 1 presents a layout of the site.

Synopsis of Site Response

Following site discovery, DEQE sampled a small number of drums from the warehouse and found them to contain a wide range of organics. Based on their preliminary assessment of the site conditions and the contents of the drums, DEQE directed the town of Dartmouth to close the downgradient municipal well because of the potential threat to public health. The town has had to purchase additional water from New Bedford in order to meet their needs. A limited hydrogeologic investigation was subsequently initiated. The results indicated that there were high levels of volatile organics in the shallow ground water in the area of the main disposal pit and that the contaminants were migrating towards the Route 6 well.

300.65(a)(2) contamination of drinking water supply

300.65(b)(2) alternative water supplies

Response action to clean up the site was carried out in two phases due to a time lapse in funding from the state legislature. The first appropriation of $223,000 for the Dartmouth site paid for the majority of the cleanup, undertaken from November 11, 1979 to February 19, 1980. This initial clean-up effort included excavation and removal of 320 tons (290 Mt) of heavily contaminated soil mixed with crushed drums, use of sorbents to remove non-miscible organics from ground water, construction of an interceptor trench, and aeration of slightly contaminated soils. Because of the funding constraints, DEQE focused on preventing further contamination of the ground water by removing the source of pollution and did not seek to decontaminate the ground water.

300.65(b) immediate removal

Phase II of the cleanup began upon receipt of additional funding from the legislature a year and a half later and occurred from September 23 through October 9, 1981. A private firm under contract to DEQE removed the remaining 738 segregated drums and 50 tons (45 Mt) of contaminated soil. Stockpiled tires and metal scraps excavated from the disposal pit were not removed, and the ground water remains contaminated.

In the Spring of 1982, the town of Dartmouth funded a detailed hydrogeologic study to determine the extent of contamination and potential remedial measures for

300.68(f) sampling and monitoring

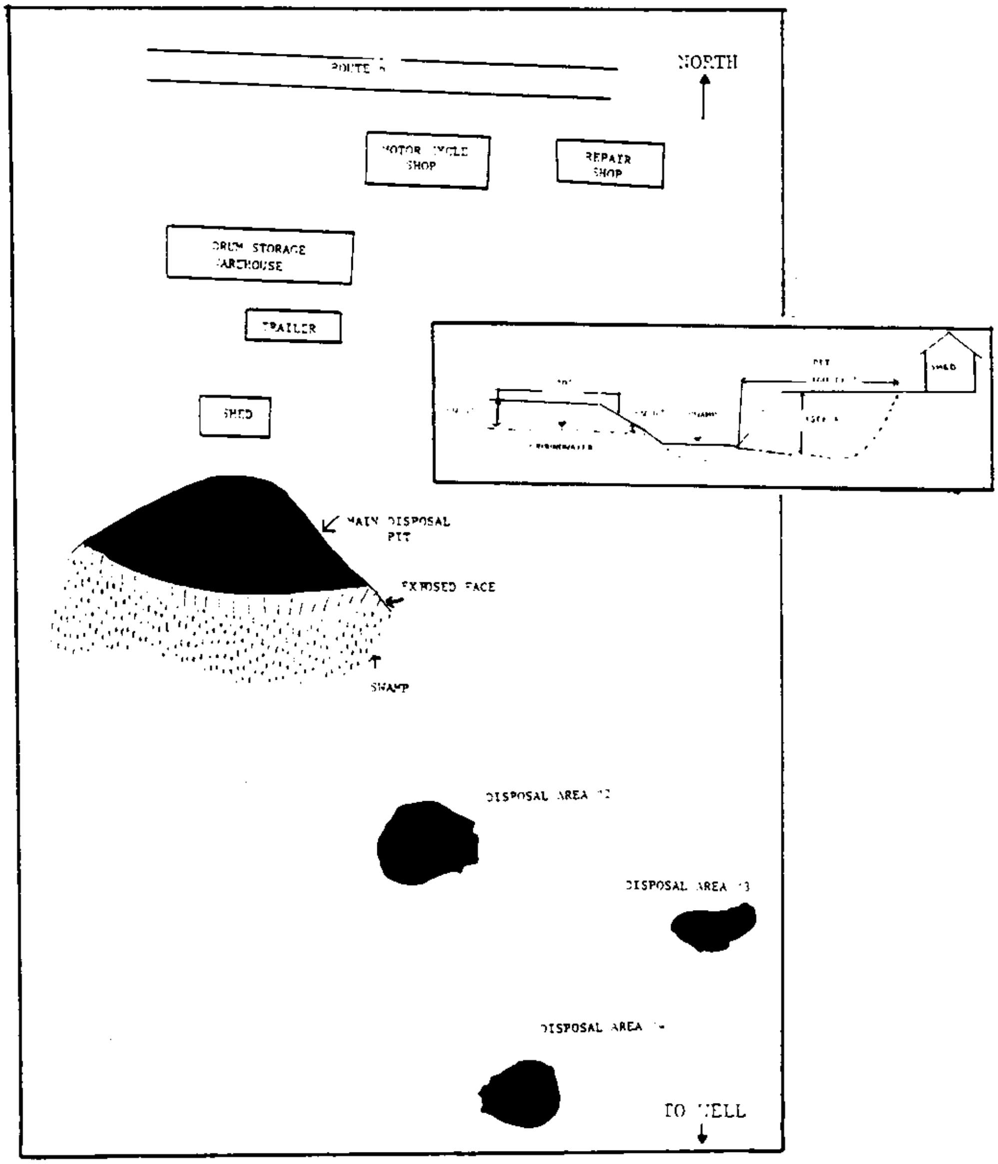


Figure 1. Layout of the H&M Drum Site, Dartmouth, Massachusetts.
(not to scale)

restoring the well or identifying alternative water supplies. As of November 1982, this study had not yet started.

300.68(d)(1)
scope of
emedial actions

SITE DESCRIPTION

Surface Characteristics

The H & M Drum Disposal site, is located in Dartmouth, Massachusetts in the southern part of Bristol County. The site is situated just south of Route 6, approximately 1500 feet (500 m) east of the intersection of Route 6 and Reed Road. This is an area of mixed commercial, light industrial and residential use but the area immediately surrounding the site is sparsely populated. The major concern with regards to the location of the H & M Drum site is the presence of the Route 6 municipal well approximately 1400 feet (427 m) south of the site. This well has a capacity of 0.5 MGD, sufficient to serve about 65 percent of Dartmouth's population. Figure 2 shows the location of the H & M Drum site.

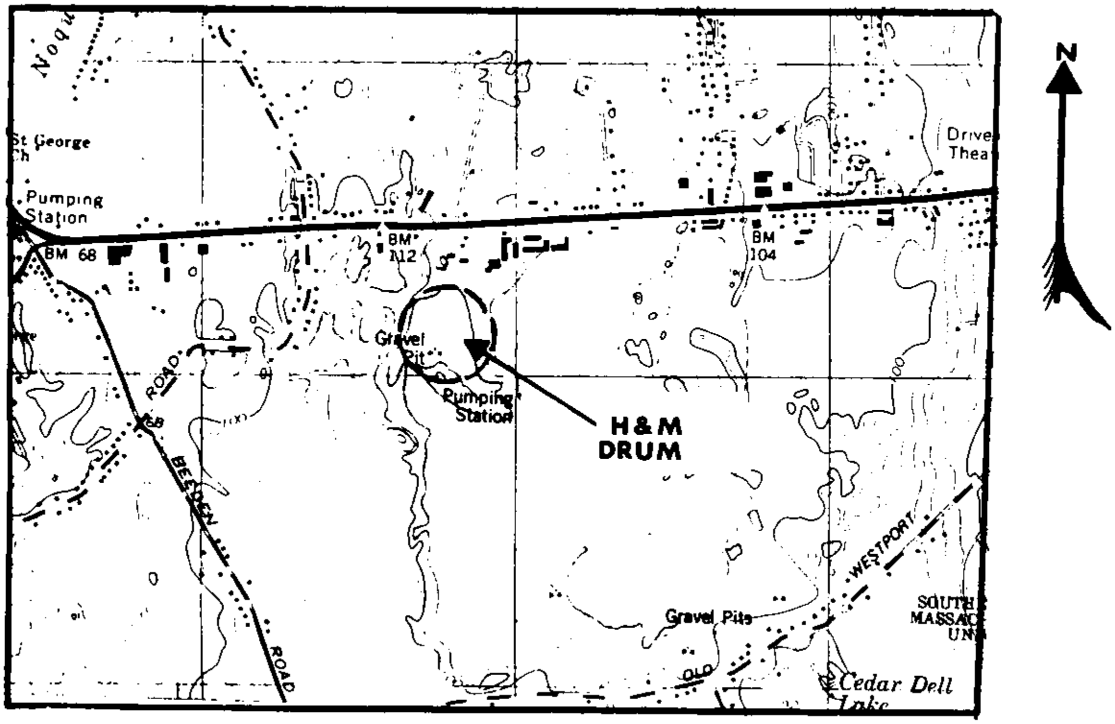
300.68(e)(2)(i)
(A)
population at
risk

The local climate of Bristol County is continental, experiencing significant seasonal, daily and day-to-day fluctuations. The average winter temperature is 31°F (-0.6°C) and the average daily minimum temperature is 23°F (-5°C). In summer, the average temperature is 70°F (21°C) and the average daily maximum temperature is 80°F (27°C). Total annual precipitation in the area is 42 inches (107 cm). Of this, 21 inches (53 cm) or 50 percent usually falls in April through September. In 2 years out of 10, the rainfall during this period is only 16 inches (41 cm). Average seasonal snowfall is 36 inches (91 cm). The prevailing wind is from the southwest. Average windspeed is highest, 12 miles per hour (19 km/hr) in March.

300.68(e)(2)(i)-
(E)
climate

The natural topography in the vicinity of the disposal site was formed when sand and gravel from glacial outwash were deposited along the edges of a retreating ice mass. These delta kames, as they are called, were left behind as flat topped hills which are often exploited as sand and gravel pits. Such was the case in the immediate area of the H & M Drum site. Depth of excavation varied but the water table is at or near the surface in most of the area immediately surrounding the site. There are also outcrops of bedrock in the immediate area, as a result of the excavation of gravel pits. Infiltration in the area is high and runoff is low. Lack of soil material makes the area unsuitable for most uses.

300.68(e)(2)(i)-
(D)
hydrogeological
factors



1 INCH ≅ 2100 FT

Figure 2. Location of the H&M Drum Site, Dartmouth, Massachusetts

The Route 6 well lies on the west bank of a swamp adjacent to the abandoned sand and gravel pits. The area is level, and consists of deep, very poorly drained soil. The soil is classified as Swansea muck and was formed in highly decomposed organic material underlain by sand and gravel. The soil has a high water table at or near the surface most of the year. Permeability is moderate or moderately rapid in the organic material and very rapid in the substratum. The area is mainly woodland and the high water makes it poorly suited for most other uses.

Hydrogeology

No detailed studies have been published on the subsurface geology in the area of the H & M Disposal site and the Route 6 well. However, limited geological mapping was performed during installation of the Route 6 well in 1962. Figure 3 shows the geological cross section in the area of the well. Medium to coarse sand with some coarse gravel was encountered at depths of about 17 to 35 feet (5-11 m) below the surface. Such sand and gravel deposits of the outwash plains are typically an excellent source of large supplies of water. Pumping tests have shown that the Route 6 well can sustain a safe yield of about 350 gallons (1325 l) per minute or 0.5×10^6 gallons (1.9×10^6 L) per day. At a depth of 35 feet (10.7 m) a strata of uniform fine sand was encountered and refusal was encountered at 37 feet (11.3 m).

300.68(e)(2)(i)-(D) hydrogeological factors

The natural ground water flow in the area follows the general topography, flowing in a north to northwest direction. However, the Route 6 well, during its operation from 1976 through April 1979, created a drawdown which caused ground water beneath the site to flow south towards the well. This has been verified by sampling of observation wells located 700 and 250 feet (213 and 76 m) from the well which showed movement of the contaminant plume from the H & M Drum site towards the well. The ground water sampling will be discussed further below.

WASTE DISPOSAL HISTORY

On April 8, 1979, the Freetown, Massachusetts police, acting on a complaint, encountered two individuals at an old sand and gravel pit in Freetown. The individuals admitted to emptying the contents of the drums taken from a truck marked H & M Drum Company Incorporated. The truck registration was subsequently traced to Harold Mathews, the owner and operator of H & M Drum Company. The EPA

300.63(a) discovery of release

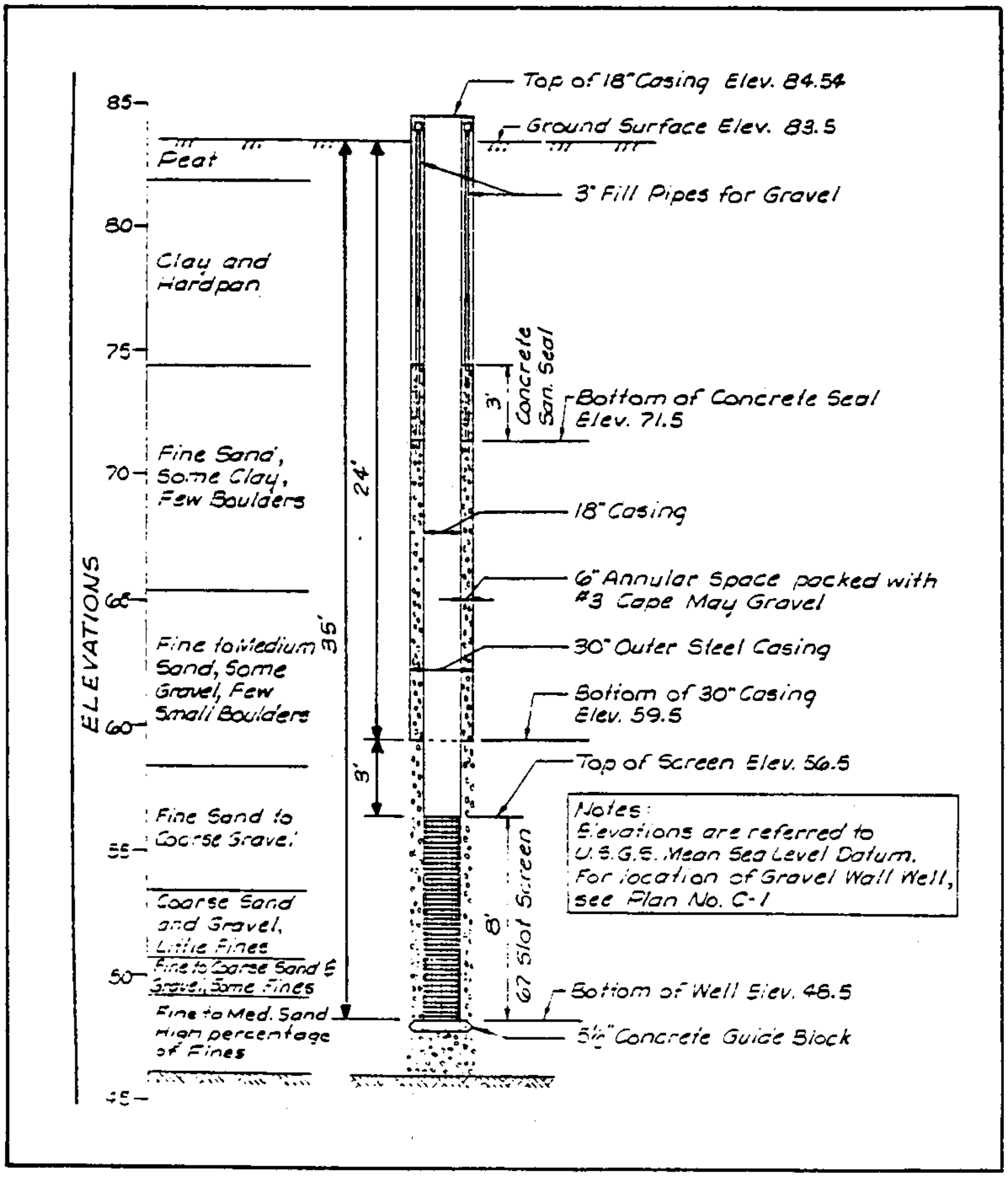


Figure 3. Geological Cross-Section and Details of the Route 6 Well
(Source: Fay, Spofford and Thorndike, 1962)

Regional Office in Lexington (Regional) and the DEQE were informed of the incident. Mr. Mathews was subsequently questioned regarding his disposal practices. He agreed to accompany DEQE to his leased warehouse off Route 6 in Dartmouth. Approximately 1000 drums were estimated to be stored at the site.

300.64(a)(1) preliminary assessment

300.68(c)(2)(i)-(B) amount and form of substance present

It was learned from limited drum sampling which followed, and from an investigation of Mathew's disposal practices, that many of the drums contained still bottoms, paint sludges and other organic residues. Specific compounds which were identified from drums included toluene, ethyl benzene, trichloroethylene, methyl ethyl ketone and xylene. In addition to drums in the warehouse, drums were found in a trailer, in an abandoned gravel pit and in three smaller disposal areas in the rear of the warehouse. Disposal in the abandoned gravel pit raised the greatest concern because the pit had been excavated down to the level of ground water during previous gravel mining activities and the drums were backfilled haphazardly along with metal debris and tires, causing the drums to rust and rupture.

It was these investigations and inquiries that led to the State ordered closure of the Route 6 well on April 20 and the eventual cleanup of the North Dartmouth site. However, storage of drums at the Route 6 warehouse was known to EPA prior to April 1979 but apparently was not considered hazardous. An investigation of the warehouse by the Region I EPA, Hazardous Waste Section in July, 1978, revealed the presence of 300 to 400 drums. New England Testing Laboratory conducted air sampling for volatile organics in the warehouse in early October. Sample analyses were made using a gas chromatograph with a thermal conductivity detector and a gas chromatograph with a flame ionization detector. None of the 4 samples taken revealed concentrations in excess of 50 ppm. An odor was reported by the testing laboratory but was attributed to the former use of the facility as a cheese warehouse. Apparently no further action was taken at the site until the April 1979 investigation.

Ledge Incorporated was the owner of the property off Route 6, which was rented to H & M Drum Company or Harold Mathews. Neither Ledge, Incorporated, nor Cecil Smith, president of Ledge had applied for or received a license to operate a hazardous waste storage or disposal site. Mr. Mathews and H & M Drum Company were licensed in 1978 to transport hazardous waste but they had never been licensed to store or dispose of hazardous wastes in the State. Independent of its knowledge of H & M's illegal disposal operations, the DEQE had revoked Harold Mathews license in March 1979, for noncompliance with administrative regulations regarding State hazardous waste transportation reporting requirements.

The State currently has a lawsuit against the property owner to recover the costs of cleaning up the site. The Massachusetts Attorney General's Office is handling this case, which has not been tried as of September 1982. In April 1979, the state sued Harold Mathews, the disposer, for violations of Massachusetts criminal statutes pertaining to hazardous waste. After a trial in September 1979, Mathews was convicted of four counts of illegal transportation and storage of hazardous waste. He received an 18 month sentence, served 12 months and was released, and declared bankruptcy. No fines were imposed and no money recovered to reimburse the state for its clean-up costs.

DESCRIPTION OF CONTAMINATION

On April 19, 1979, approximately one week after site discovery, DEQE procured samples from three drums stored in the warehouse. These samples were analyzed for volatile organics by EPA's Regional Laboratory in Lexington, Massachusetts. Identified chemicals included 2-ethyl hexanal, toluene, ethyl benzene, methyl isobutyl ketone, trichloroethylene, xylene and methylene chloride. The following day DEQE inspected the primary disposal pit area and collected waste samples. Based on visual observations of contamination, DEQE gave a verbal directive to the Dartmouth Department of Public Works to close down the Route 6 municipal well.

300.65(a)(2) contamination of drinking water

On April 25, 1979, DEQE and Coastal Service, from East Boston, MA, the sole source contractor hired by the State to respond to waste emergencies, conducted a limited hydrogeologic investigation. Shallow test pits, which ranged in depth from less than 1 foot to 7 feet (0.3-2.1m), were excavated using a backhoe and hand shovels. A Century Organic Vapor Analyzer was used to determine the levels of volatile organics at various depths in the pits. Figure 4 shows the locations of the test pits and the levels of volatile organics. The concentration of volatile organics were generally found to be 500-1000 ppm at a depth of 5 feet (1.5 m) in the major disposal pit.

300.65(b)(5) measuring and sampling

In August 1980, nearly 16 months after closure of the well, and 6 months after the Phase I cleanup effort had been completed, DEQE collected and analyzed groundwater samples from observation wells located 700 feet (213 m) and 250 feet (76 m) from the Route 6 municipal well.

300.68(f) sampling and monitoring

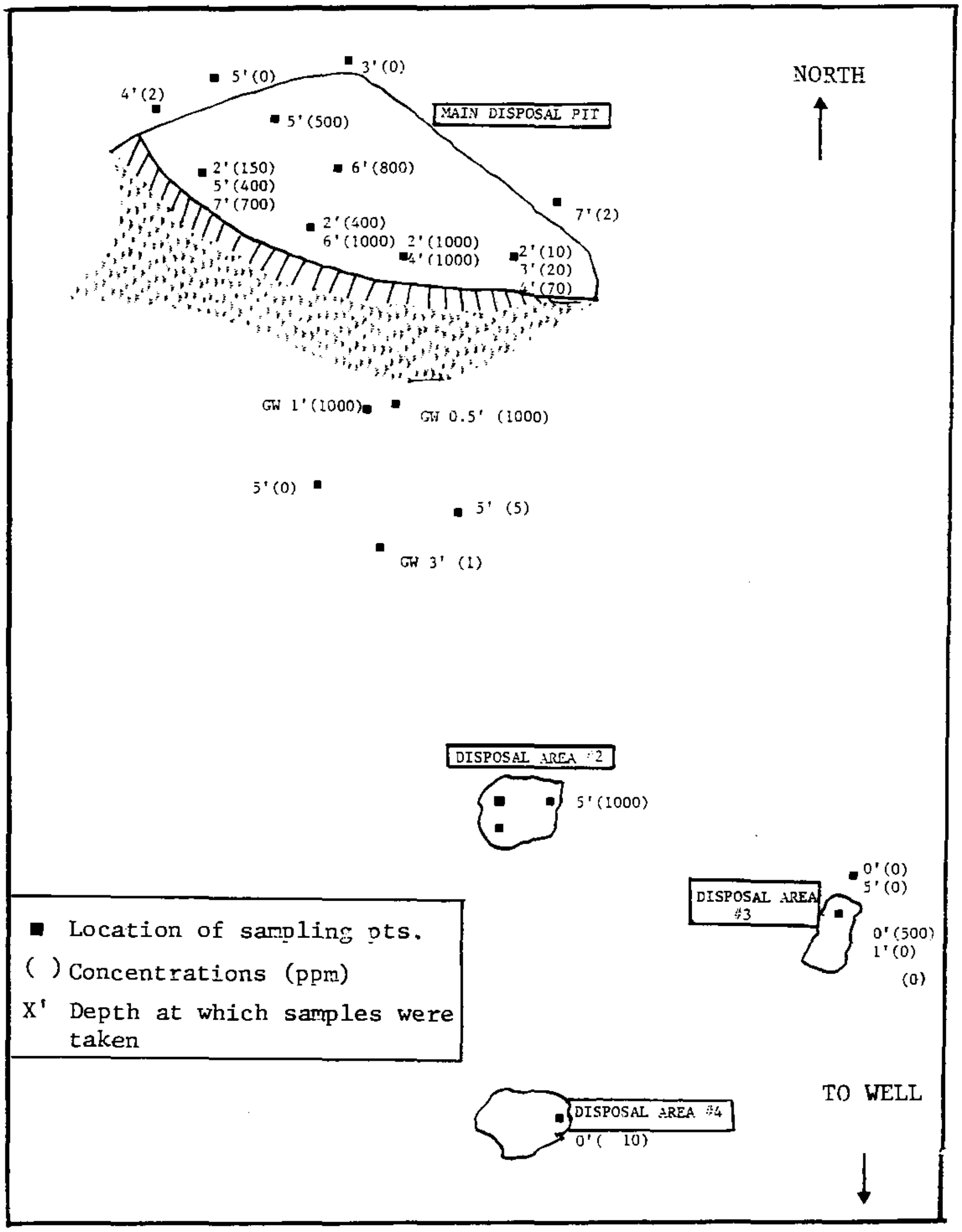


Figure 4. Results of April 25,1979 Sampling of Shallow Test Pits (Not to Scale)

Samples were analyzed for a number of volatile organics. The results are summarized in Table 1. As the results indicate, dichloroethane, tetrachloroethylene and trichloroethylene were present in the ppb range in the observation well located 700 feet (210 m) from the municipal well and the concentration of 1,1,1 trichloroethane exceeded 1 ppm. These results confirmed the suspicion that the contaminants had migrated towards the well. Further migration towards the well was likely to occur if pumping was re-established and the City of Dartmouth ordered that the well remain closed.

300.68(e)(2)(ii) extent of migration of substances

Dartmouth Departments of Public Health and Public Works have decided to keep the well closed until further study of the extent of ground water contamination can be made. In the spring of 1982, the Board of Selectmen designated $40,000 of the town's annual budget to fund a detailed hydrologic study of the site to be performed by Fay, Spofford and Thorndike engineers from Boston, Mass. As of November 1982, the study had not yet started due to difficulty in obtaining easement. The study will include installation of monitoring wells to determine extent of contamination, aquifer characteristics (such as storage coefficients and flow velocities), extent of contaminant migration, the effect of the Route 6 well pumping on contaminant transport, and an evaluation of potential treatment and remedial alternatives. The town has stated that it will reopen the well only if the results of the study show that no public health threat would be created by putting the well on line again.

300.68(f) sampling and monitoring

SITE RESPONSE

Initiation of Response

The site response at H & M Drum was triggered by the April 1979 discovery of contaminated ground water and soil within 1400 feet (427 m) of the Route 6 municipal well. Due to the nature of the threat to the municipal well, immediate cleanup was needed. However, funding was not available until September 13, 1979, when the State made a supplemental appropriation to DEQE to pay for the cleanup.

300.65(a)(2) contamination of drinking water

Selection of Response Technologies

Following site discovery in the spring of 1979, DEQE planned clean-up measures for the site based on the preliminary site investigation conducted by DEQE and Coastal

300.65 immediate removal

TABLE 1. TEST RESULTS FOR ORGANIC CHEMICAL SOLVENTS

Intermediate Monitoring Wells
Route #6 Well - Dartmouth, Massachusetts
Conducted July 28, 1980

Chemical Compound	Test Results in Parts Per Billion	
	250'*	700'*
Methylene Chloride	N.D.	N.D.
Dichloroethane	N.D.	66.5
Trichloroethylene	N.D.	0.9
Chloroform	N.D.	N.D.
Trichloroethane	3.5	1250
Carbon Tetrachloride	N.D.	N.D.
Trichloroethylene	2.1	540
Dibromoethane	N.D.	N.D.
Bromoform	N.D.	N.D.
Tetrachloroethylene	1.7	140
Total Organic Carbon	500	700

*Distance of Test Well from Town Well

N.D. = Not Detectable

Services. DEQE's proposed site clean-up had originally consisted of the following measures:

300.66 evaluation and determination of appropriate response

1. Site preparation for removal and offsite disposal of contaminated soil;

2. Excavation, aeration, and treatment of slightly contaminated soils;

3. Transport and disposal of contaminated wastes and soils at an approved disposal facility;

4. Analysis, segregation, bulking, crushing, and disposal of drums.

5. Pumping of contaminated ground water; sampling; and installation of monitoring wells; and

6. Activated carbon treatment of contaminated ground water.

The estimated cost of these measures, approximately $1.246 million, combined with the estimated cost of cleaning up the Freetown site, was DEQE's basis for requesting $2.5 million from the State legislature. However, as stated earlier, DEQE received only $500,000 for both sites, and approximately $223,000 for the Dartmouth site alone. Thus, due to this funding constraint from the legislature, DEQE was forced to reconsider clean-up options. With about $223,000 to address the contamination problem, DEQE abandoned its original plan, which included groundwater decontamination (activities 5 and 6) and targeted the majority of the funds to reducing the source of contamination and the likelihood of further ground water contamination. Accordingly, the remedial measures selected for the site were primarily drum removal and soil excavation and removal (activities 1-4, above).

Extent of Response

300.65(c) completion of immediate removal

Given the constraint of limited funding, DEQE sought primarily to remove the source of contamination and not to decontaminate the ground water. This goal appears to have been achieved. All drums have been removed from the site. Approximately 370 tons (336 Mt) of heavily contaminated soil were removed, and slightly contaminated soil was aerated to lower the level of contamination to 1-5 ppm. Treatment of contaminated ground water was limited to application of sorbents to remove non miscible contaminants. The extent of remaining ground water contamination cannot be precisely described in the absence of hydrogeological data on the site. The shutdown of the municipal well in April of 1979 caused the town to lose a major portion of its water supply. Replacement water has since been purchased from the nearby town of New Bedford, but the town of Dartmouth would like to resume use of the municipal well and has authorized a $40,000 hydrogeological assessment of the site in order to determine the feasibility of future remedial work to decontaminate the ground water. DEQE does not plan further work on the site because of the competition for limited state funding posed by more immediate public health threats caused by other sites in the State.

300.65(b)(2) providing alternate water supplies

300.68(k) balancing

DESIGN AND EXECUTION OF SITE RESPONSE

The response actions at the H & M Drum site were conducted in two phases. Phase I consisted mainly of construction of an interceptor trench along the toe of the main disposal pit, use of sorbents to remove non-miscible organics in ground water, excavation and segregation of debris, wastes and contaminated soils, aeration of slightly contaminated soils and segregation of drums in the warehouse with removal of most of the liquid wastes. At that time funds ran out and the rest of the drums had to be stored in the warehouse for about a year and a half until additional funds became available. Phase II consisted of the removal of the remaining drums and contaminated soils.

Phase I

Excavation of Disposal Areas

The excavation operation was primarily focused on the main disposal pit where about 300 drums, metal debris and tires had been backfilled. The surface area of the disposal pit measured approximately 160 feet by 90 feet (49 m by 27 m) and was about 15 feet (5 m) deep (See Figure 1). In order to minimize the impact of the cleanup operation on the ground water quality, an interceptor trench was dug along the toe of the disposal pit. The trench measured approximately 60 to 80 feet (18-24 m) long and about 4 feet (1.2 m) deep. It extended between 0.5 to 2.5 feet (0.2-0.8 m) into the ground water. Several times throughout the cleanup operation, sorbent pillows were used to remove a non-miscible organic layer. The objective was to prevent this non-miscible layer from moving downgradient and towards the well.

300.65(b)(4) controlling the source of release

Excavation of the disposal area was a slow and selective process. The drums had been haphazardly disposed of along with metal debris and tires and the soils had been

300.65(b)(6) removing hazardous substances compacted. Because of these disposal practices, many of the drums were badly damaged or void of contents. Equipment used in the excavation included a backhoe, a front end loader and a bobcat. Slings and other attachments were used with the backhoe for lifting drums. Some drums ruptured during the excavation operation and pumps were used to clean up the spilled material. The front end loader was also used as a temporary receptacle for leaking drum contents. Approximately 300 drums along with debris and contaminated soils were segregated over a 23 day period. The slow rate of progress was attributed to the haphazard disposal, the poor condition of the drums and the cold weather.

Because of the large quantities of contaminated soils and the limited funds available for disposal, a decision was made to segregate heavily contaminated and slightly contaminated soils. Heavily contaminated soils were those with an organic vapor concentration in excess of 500 ppm, the concentration at which the soils were considered saturated. These soils, along with empty, crushed drums, were stockpiled in an 18 inch (46 cm) high bermed area with a polyethylene liner and diamtomaceous earth used to absorb seepage. Approximately 320 tons (290 Mt) of the heavily contaminated soils were stockpiled and later transported to CECOS's secure landfill in Niagara Falls, New York towards the end of Phase I.

Slightly contaminated soils, defined as having an organic vapor concentration of 1-500 ppm, were landspread and treated on site by aeration. The contaminated soils were spread across the sandy, native soils in 6 inch (15 cm) lifts and aerated using a rototiller. The soils were aerated several times over a two week period until monitoring detected an organic vapor concentration of only 1-5 ppm. Continued passes across the soil allowed semi-liquid organics and solids to be pulled up to the surface. This material was then raked up and stockpiled with heavily contaminated soils for removal to CECOS.

Air pollution from the landspreading operation was not a major concern. There were no residences in the immediate area and exposure of field personnel was minimal since the operation was performed in December and January when cold temperatures kept the vapor pressures low.

The piles of metal debris and tires which were excavated from the disposal pit were not considered hazardous by DEQE and the town of Dartmouth was directed to remove them. However, the Department of Public Works felt that these materials would contaminate the local municipal sanitary landfill. Furthermore, the town did not want to spend public money to remove the solid wastes from the private property and the town instructed the property owner to remove the wastes. To date no action has been taken.

Drum Segregation

Under Phase I, drums in the warehouse and the trailer were identified and segregated, leaky drums were repacked and most of the liquid wastes were pumped into vacuum trucks and hauled off site for incineration.

300.65(b)(6) removing hazardous substances

Many of the drums were badly rusted and the source of the wastes could not be identified. It was determined, however, that most of the wastes were solvent recovery still bottoms, paint sludges and other organic residues.

Testing criteria were developed which could segregate the wastes for final disposal. Based on test procedures which included viscosity, water solubility, specific gravity and pH, the drums were segregated into the following categories:

17	Acids
302	Water Insoluble Flammables
120	Water Soluble Flammables
121	Flammables with Resins/Sludges
358	Sludges, Organic Paint
82	Chlorinated Fuels
54	Oils - Soluble and Insoluble
36	Miscellaneous
1090	TOTAL

Approximately 19,250 gallons (72,860 l) of highly flammable liquids were pumped from drums and transported to Recycling Industries, Inc., of Braintree, Mass., for incineration. The miscellaneous drummed wastes including 16 drums containing acids, 15 containing gels and 5 containing ammonia were also transported to Recycling Industries. 1250 gallons (4730 l) of chlorinated oils were pumped and transported to Rollins Environmental Services in New Jersey because Recycling's incinerator did not have the capability to incinerate chlorinated solvents.

Most of the remaining drums contained sludges of various consistencies. Sawdust was mixed into the drums until the consistency was considered suitable for acceptance by a landfill. When Phase I was terminated, 738 solidified drums remained in the warehouse.

Demobilization

Equipment used during Phase I was decontaminated on site using hot rinse water which was collected for disposal. The disposal areas were regraded to their original topographical contours. There was no follow up monitoring done at the site.

Phase II

In September 1981, approximately a year and a half after completion of Phase I, additional funds were appropriated to complete the cleanup of the Dartmouth site. The Phase II effort was completed over a 6-week period and consisted of removal of 738 drums and 50 tons (45 Mt) of contaminated soils and debris.

Most of the Phase II effort was devoted to further sampling and segregation of the drummed wastes to prepare them for acceptance in the SCA Chemical Services secure landfill in Model City, New York. During the interim between Phase I and Phase II, RCRA regulations had been promulgated requiring that additional sampling and recording be undertaken prior to transport and disposal. An initial random sampling of 5 percent of the drums was undertaken to establish waste disposal codes and categories. Based on the results of the random sampling, the following 5 categories were assigned by Model City to the project wastes.

Disposal Category	Type
Chlorinated Organic Residues	Drums
General Organic Residues	Drums
Low Flash Organic Residues	Drums
Empty Crushed Drums and Contaminated Soils	Bulk
Contaminated Sand, Soil and Sawdust	Bulk

Flash point (using the closed cup tester) and organic chlorine/sulfite testing were done on all samples. Composites from 25 drums were prepared and shipped off-site for PCB analysis. The Model City secure landfill could not accept drums of residue having a flashpoint of less than 70°F (21°C). The flashpoint was raised, when necessary, by adding reclaimed freon TMC, a flashpoint suppressant. Liquid comprised only 2-5% of the contents of most of the drums. It apparently rose to the top as the absorbent added during Phase I settled. Additional absorbent was added to solidify the drums.

Ten loads of drums were labelled and shipped in box trailers to Model City. Front end loaders were used to load dump trailers with contaminated soils, sawdust and crushed drums. Contaminated soils around the drum loading dock were excavated and removed along with the bulk loads.

Decontamination of the warehouse proceeded throughout the project. Consolidated floor sweepings were drummed and removed under the appropriate code. The warehouse floor and the equipment used for cleanup were rinsed at completion of the project.

COST AND FUNDING

Source of Funding

Upon determining that ground water and soil were contaminated, the DEQE requested funding from the State legislature for cleaning up both the Dartmouth and Freetown sites because the department lacked funds. Private funding was unavailable and the state planned to bring criminal actions against Harold Mathews. Due to the nature of the threat to the municipal well, immediate clean-up was needed. DEQE requested $2.5 million, which would have funded actions at both sites that included establishing a well point system, dewatering, ground water treatment, treatment of contaminated soils, drum removal, and soil excavation.

On September 13, 1979, the state legislature made a supplemental appropriation for DEQE to pay for cleaning up both the Dartmouth and Freetown sites. Although the DEQE had requested $2.5 million, the legislature appropriated only $500,000, to be divided between the Dartmouth and Freetown sites. Dartmouth's allocation was $223,000.

300.62(a) State funded response

The remedial action was conducted in two phases due to a time lapse in funding. The first phase of clean up began on November 11, 1979 and ended February 19, 1980. The majority of remedial work conducted on the site was undertaken during Phase I. However, the supplemental funding provided by the legislature ran out before work was completed, so DEQE had to go back to the legislature with a request for additional funding. It took over a year to obtain this second appropriation, which was made in September 1981. Over the course of the next year and a half, DEQE and the town of Dartmouth actively sought to persuade the State legislature to allocate funds to complete the site cleanup. On August 27, 1981, DEQE was notified that additional funding for completion of the Dartmouth site had been secured from the legislature. Phase II of the project cost $105,234.

Selection of Contractors

Four separate contractors conducted work on the H & M site. These contractors, in chronological order of work performed were: Coastal Services (initial site assessment), Black Gold Industries/Jetline (Phase I clean-up), A.D. Little Management Consulting (management of Phase II), and Recycling Industries (Phase II clean-up).

Coastal Services performed the initial site assessment in cooperation with DEQE from the date of site discovery on April 11, 1979 through June 30, 1979. Coastal Services was selected by DEQE to perform the initial site assessment because the firm was under contract with DEQE at the time. The contractual arrangement was made according to the State Water Pollution Revolving Fund, which requires DEQE to designate a private firm every two years as the sole source contractor to respond to waste emergencies.

When Coastal Service's contract expired on July 1, 1979, Black Gold Industries/Jetline from Stoughton, Massachusetts, was hired as the State emergency response contractor for the next two years. When funding for clean-up was appropriated by the legislature on September 13, 1979, Black Gold Industries/Jetline was in the position to respond immediately to the Dartmouth and Freetown sites. Subsequently, DEQE amended the Black Gold/Jetline contract to include clean-up responsibility for Dartmouth and Freetown. DEQE opted for an amendment to the existing State-wide emergency response contract with Black Gold/Jetline rather than requesting proposals in a competitive bidding process because of the urgency of the clean-up situation and the fact that securing State funding had already taken six months.

Black Gold subcontracted with Recycling Industries, a subsidiary of SCA, of Braintree, Massachusetts for assistance in the work performed on the site and for use of the latter's incinerator for liquid waste disposal. Black Gold/Jetline also entered into an agreement with Chemical and Environmental Conservation Systems (CECOS) of Niagara Falls, New York for use of its approved secure landfill for waste disposal and with Rollins Environmental Services in Logan Township, New Jersey for incineration of chlorinated oils.

Black Gold/Jetline began clean-up operations on November 11, 1979. Work continued through February 19, 1980, when funding was exhausted. Funding from the State legislature to complete the clean-up was not secured by DEQE until a year and a half later. During this time DEQE was in the process of hiring a management consulting firm to provide assistance in managing the clean-up of hazardous waste sites throughout the state. This involved a time consuming selection process based on competitive bidding. Ultimately, on June 5, 1981, A.D. Little, Inc. (ADL) Cambridge, MA, was awarded the management contract with DEQE. ADL's period of performance extended from June 6, 1981 through October 29, 1982, with a ceiling of $467,108. When DEQE secured additional legislative funding to complete the H & M clean-up, ADL managed the contractor selection process for Phase II of the clean-up.

On August 14, 1981, Recycling Industries, Inc., was selected to complete the H & M clean-up. Recycling Industries had been a subcontractor to Black Gold/Jetline under the first phase of clean-up. Selection of Recycling was based on a competitive bidding process. Four firms submitted bids for the H & M clean-up; however, only two firms, Recycling and another firm, were judged by ADL to have the technical capability to complete the work. Black Gold/Jetline, although still under contract with DEQE as emergency response contractor when bid proposals were taken for phase II, did not submit a bid because DEQE believed that awarding another contract to that firm would be considered favoritism. The choice of Recycling rather than the other firm was based on DEQE's evaluation that Recycling had superior technical capabilities and a better contingency plan. Estimated costs of work to be performed were not a major factor of selection because there was not a large variance between bids in terms of total costs. Recycling's contract with DEQE was based on time and materials with a ceiling of $162,000. Work on the site began on September 11, 1981, and was completed under budget three weeks later on October 9, 1981.

Project Costs

Although the remedial action conducted at the Dartmouth site was a rather straightforward excavation and removal operation, it was, in effect, two separate operations due to the funding problem.

The summary of cost information shown in Table 2 reflects the difference between the two phases as far as can be determined from available information. The Phase I expenditure was in one lump sum of $148,000, excluding

TABLE 2. SUMMARY OF COST INFORMATION FOR H&M Drum - DARTMOUTH, MASSACHUSETTS

Task	Quantity	Estimated Expenditure	Actual Expenditure	Unit Cost	Funding Source	Period of Performance
Phase I						
Start-up soil and drum excavation(a)	o 320 tons bulk (290 Mt) crushed drums and soil o 20,500 gal (77,600 l) liquid waste from 350 drums		$148,000	NA	State of Massachusetts	11/11/79-2/11/80
Disposal	Same as above		$27,000 25,000 $52,000	$84/ton (93/Mt) $1.22/gal ($4.26/l)	State of Massachusetts	11/11/79-2/19/80
Transportation 480 miles (772 km)	17 loads or (320 tons/290 Mt)		$23,000	$1,353/load or $72/ton $0.15/ton/mile ($79/Mt) ($0.10/Mt/Km)	State of Massachusetts	11/11/79-2/19/80
Phase I subtotal			$223,000			11/79-2/80
Phase II						
Start-up+labor, equipment, materials(b)			$50,852	NA	State of Massachusetts	9/23/81-10/9/81
Disposal	o 738 drums o 50 tons (45 Mt) soil & contaminated debris		$37,859	NA	State of Massachusetts	9/23/81-10/9/81
Transportation	o 738 drums o 50 tons (45 Mt)		$15,929	NA	State of Massachusetts	9/23/81-10/9/81
Phase II subtotal			$104,640			9/81-10/81
TOTAL		$1,246,000 (c)	$327,640			11/11/79-10/9/81

NA : Not Applicable

(a) Also includes drum segregation, aeration and landspreading of slightly contaminated soil. The time and material invoices made the separation of the costs of the components impossible.

(b) There still exist piles of metal debris and tires excavated from the primary disposal pit.

(c) Estimate includes costs of ground water decontamination.

transportation and disposal of liquid waste from the warehouse and contaminated soil from the disposal pit. The lump sum included: start-up costs, segregation and repacking of drums in the warehouse, pumping out the flammable liquids, soil and drum excavation from the disposal pit and land spreading of the slightly contaminated soil. Another $75,000 was spent on the disposal and transportation of the materials. Liquid wastes were incinerated at Recycling Industries and Rollins Environmental Services at an average cost of $1.22 per gallon ($4.62/l) and the bulk waste was transported to CECOS at $72/ton ($79/Mt). The Phase I operation was terminated for lack of funding after 320 tons (290 Mt) and 20,500 gal (77,600 l) of liquid wastes were removed. There remained 783 drums, mostly containing solid wastes, and 50 tons (45 Mt) of excavated contaminated soil.

From the standpoint of cost, Phase II was conducted more cautiously than Phase I. Phase II employed a written request for bids, an evaluation of bids and a system that tracked the progress of the remedial action. The Phase II effort was completed at a cost of $104,640 which was $57,360 lower than expected.

The costs incurred during Phase II included $15,929 for transportation and $37,859 for disposal of drums and contaminated soils at the SCA secure landfill in Model City, New York.

Another aspect of the cost of the response action is the alternative supply of water which the town of Dartmouth had to obtain when its municipal well was closed. Before its shutdown, the well supplied 15% of the town's water and had the potential for serving up to 65% of the population. To replace the lost water, the town had to increase its share of water purchased from the nearby town of New Bedford. Total cost of the water from 1979 to March 1982 was $98,262. Operation costs saved from the well shutdown were $27,812, producing a net cost of $70,450 to the town. Since the well probably will remain closed for some time, the net cost of alternative water supplies will increase at this rate.

PERFORMANCE EVALUATION

The effectiveness of the overall response activities at the H & M Drum site must be evaluated in terms of the constraints of limited funding. While originally the goal planned by DEQE was for both removal of the source of pollution and decontamination of ground water, lack of adequate funding forced DEQE to redefine its cleanup goals. DEQE eventually sought only to reduce the source of contamination to the extent possible with the limited funding. The emergency cleanup activities appear to have been successful insofar as the drums and the bulk of contaminated soils were removed from the site, an alternate source of water supply was made available to residents formerly supplied by the Route 6 well and the immediate public health threat was eliminated.

However, due to insufficient funds, there has been no follow-up monitoring to determine the effectiveness of the cleanup or the extent of ground water contamination. Efforts taken to date have not been effective in restoring the high yield municipal well. This has forced the town of Dartmouth to incur expenses in excess of $70,000 for buying replacement water since the well closed in April 1979.

The possibility of future remedial work on the ground water is speculative from both a cost and technical perspective. Dartmouth's position is that a detailed hydrogeological assessment is needed before they can assess the cost and feasibility of restoring the well. The town has funded this assessment which was expected to begin late in 1982.

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HOUSTON CHEMICAL COMPANY

HOUSTON, MISSOURI

INTRODUCTION

NCP Reference

The Houston Chemical Company plant is located in a rural area in southern Missouri. On June 14, 1979, a storage tank at the site collapsed and spilled 15,000 gallons (56,800 l) of diesel oil containing 5% pentachlorophenol (PCP) down a hillside and into a farm pond, killing aquatic life in the pond. The pond threatened to overflow into a tributary of the Big Piney River, a valuable wildlife and aquatic life habitat. When it became apparent that the plant owner was not taking action to remove the oil, the caretaker of the pond property informed the Missouri Department of Conservation about the spill. After inspecting the site and noting a total fish kill in the pond, the Department of Conservation informed the U.S. Environmental Protection Agency Region VII office (EPA) in Kansas City, Kansas of the spill.

300.63(a)(4) discovery

Background

The Houston Chemical Company plant (also known as Cairo Wood Treatment) is located in Texas County, Missouri, about three miles south of the small town of Houston, in a lightly populated area of farms and woods. At the time of the spill in June 1979, the plant was in the business of mixing 95% diesel oil and 5% PCP for use as a wood preservative. PCP is considered toxic to humans and animal life.

On June 14, 1979 a 21,000 gallon (79,500 l) steel storage tank at the plant buckled, sheared off a valve, and spilled approximately 15,000 gallons (56,800 l) of oil/PCP mixture. There was not a dike around the tank for spill containment. The oil/PCP mixture flowed approximately 300 yards (274 m) down a hillside, along a roadside drainage ditch, through culverts under two roads, and after pooling in a dry depression, flowed underground for 100 feet (30 m) into a 0.7 acre (2,835 m^2) farm pond. The oil/PCP covered the pond surface in a layer 1/4 inch to 1 inch (0.64 to 2.54 cm) thick (see Figure 1).

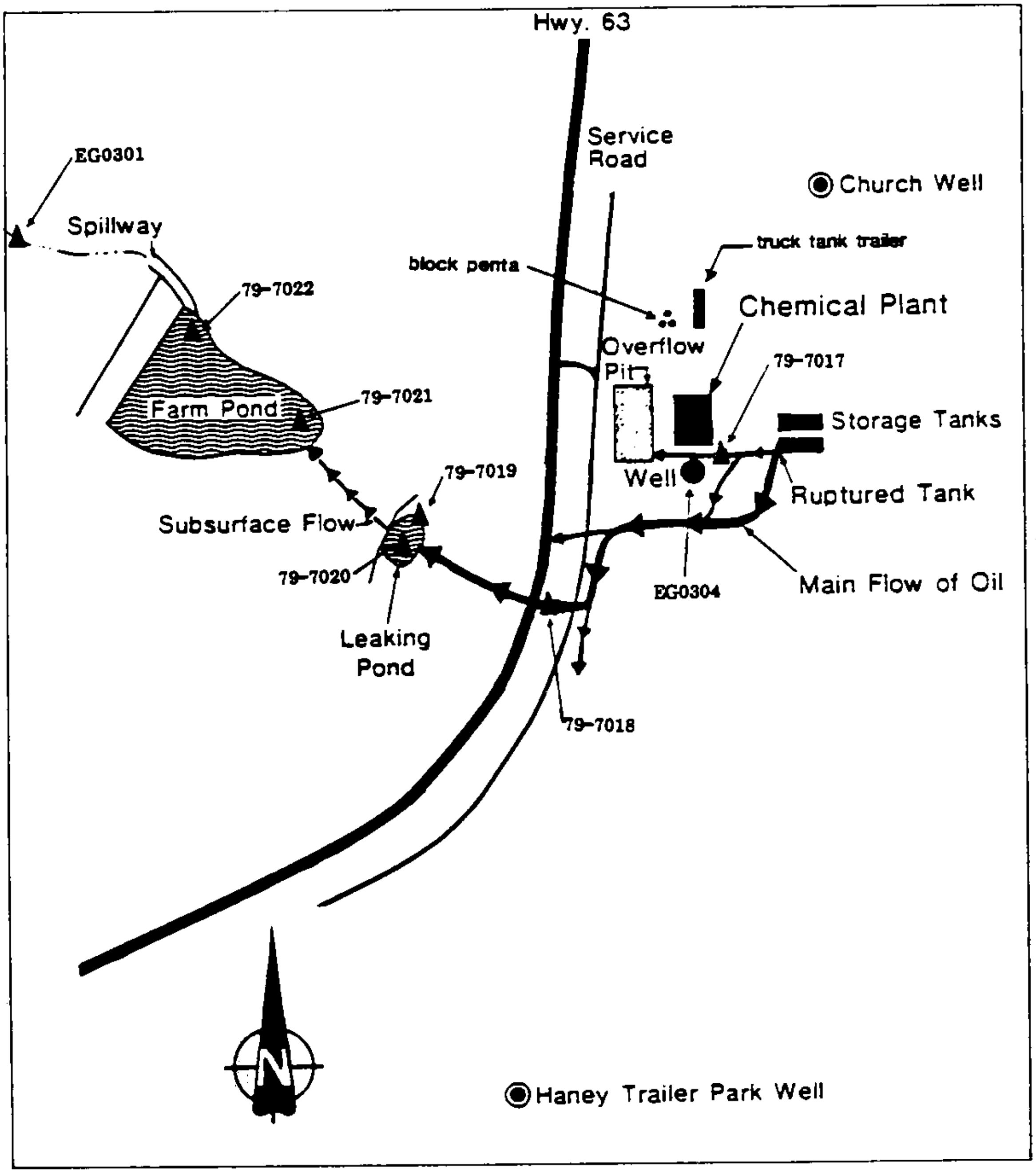

Figure 1. Houston Chemical Co. Spill Site and Sampling Locations

An intermittent stream linked the pond with Hog Creek, a tributary of the Big Piney River, which flows into the Gasconade River and then into the Missouri River. Hog Creek at the intermittent stream and the Big Piney at the mouth of Hog Creek are officially designated by Missouri for protection of livestock, wildlife, and aquatic life. In addition, the Big Piney is a navigable water of the United States. At the time of the spill, the pond surface was a few inches below its spillway, and the oil did not travel beyond the pond.

Synopsis of Site Response

On June 19, 1979 the EPA on-scene coordinator (OSC), acting under section 311(k) of the Clean Water Act, engaged O.H. Materials Co. (OHM), of Findlay, Ohio to undertake an emergency cleanup of the pond and pill path. Over the next six weeks, OHM removed approximately 10,000 gallons (37,900 l) of oil/PCP from the pond and spill path using skimmers and a vacuum pump; drained the pond and filtered the water with a mobile carbon filtration unit; flushed the spill path surface with water; and excavated contaminated soil from the spill path, pond banks, and pond bottom. O.H. Materials returned the recovered oil/PCP to a secure tank in the Houston Chemical Co. plant and transported 2,636 cubic yards (2,015 m^3) of contaminated soil to a licensed hazardous waste landfill in Wright City, Missouri.

During the final two weeks of the cleanup, OHM introduced nutrients and freeze-dried cultured bacteria into the refilled pond in an attempt to biologically degrade the remaining PCP. O.H. Materials ended work at the site on August 6, 1979, at which time sample analysis indicated that the PCP level in the pond was below the target level of 10 ug/l.

Over the next two months, PCP levels in the pond rose to 200 ug/l as small amounts of oil/PCP continued to seep from underground into the pond. In October 1979, the OSC purchased nutrients and freeze-dried cultured bacteria, introduced them into the pond, and aerated the pond. Final sampling of the pond in November 1979, after all cleanup activity ceased, indicated approximately 400 ug/l of PCP. In December 1979, eight barrels of absorbent pads were removed from the site and taken to a landfill. This was the last work done at the site. According to the Missouri Department of Conservation, in the three years since the spill the pond has returned to a healthy condition, based on visual inspection. Aquatic life has returned and effects of the spill are not apparent.

Litigation is ongoing against the owners of Houston Chemical Co. to recover federal funds spent in the cleanup.

SITE DESCRIPTION

The Houston PCP oil spill site is located near a saddle at S 1/2, NW 1/4, Section 30, Township 30 north, Range 9 west, south of the town of Houston, Missouri. Figure 2 shows the spill site's location on a portion of the Houston topographic quadrangle. Numerous dwellings exist near the site, the closest being a church approximately 250 ft. (76 m) north of the site, and a trailer park approximately 900 ft. (274 m) southwest of site.

300.68(e)(2)(i)
(A)
population at
risk

The plant site itself consists of a mixing plant building with attached block penta vat, two cylindrical storage tanks for the PCP/oil mixture, a holding pond to contain spills from the plant, a truck tank trailer, and an area for solid, block penta storage.

Surface Characteristics

The local climate of the area, as well as the State of Missouri, is classified as continental. Large seasonal and daily temperature fluctuations are not uncommon. The average annual temperature at the site is approximately 59°F (15°C). Daily maximum and minimum temperatures during July are 90°F (32°C) and 68°F (20°C), respectively; while during January the daily maximum and minimum temperatures are 45°F (7°C) and 24°F (-4°C), respectively. Temperature extremes recorded in the state are 115°F (46°C) and -22°F (-30°C).

300.68(e)(2)(i)
(E)
climate

Average annual precipitation for the spill site is 42 inches (107 cm), with approximately 42 percent of the precipitation occurring during the period of May to August, inclusive. The period of highest rainfall occurs from March to June and the period of lowest rainfall occurs from November to February. Mean annual snowfall for the area is approximately 14 inches (36 cm), with the average annual number of days with snow cover being about 35 days.

Annual prevailing winds are from the south at about 10 mph (16 km/hr). Prevailing wind direction and speed throughout the year does not vary significantly from the annual values. Wind speeds as high as 66 mph (106 km/hr) have been recorded nearby and these were associated with winds from the west.

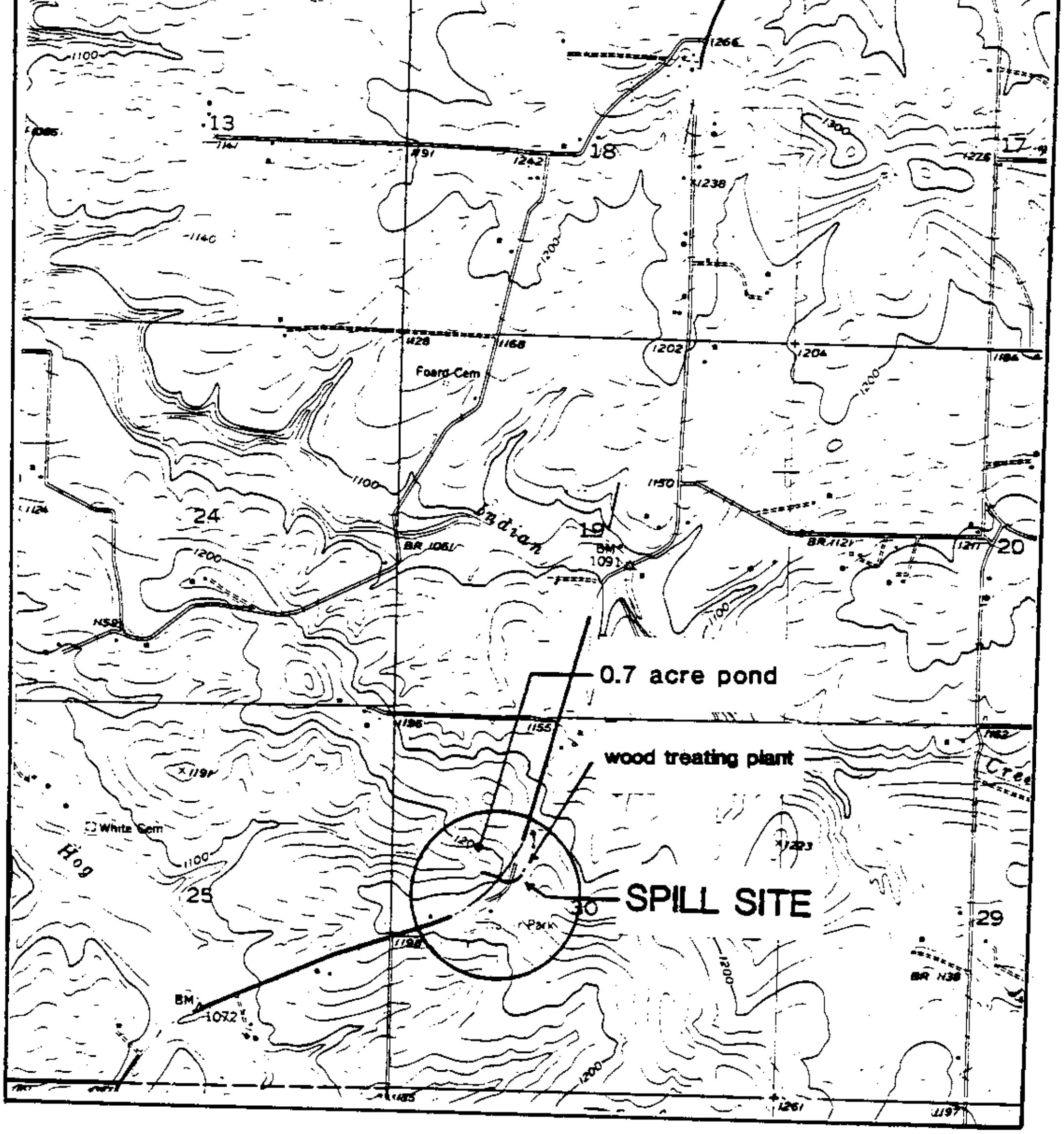

Figure 2. Location of Houston Chemical Co. Site

300.68(e)(2)(i) (D) hydrogeologic factors

Soils in the area surrounding the site are classified as Clarksville Gravelly Loams. These soils were formed from the weathering of cherty to moderately cherty limestones. In character, these soils vary from gravelly to moderately gravelly soils, gray to brown in color, and from friable red clay through gravelly and stoney clays to hardpan subsoils. The content of chert gravel varies form almost zero to seventy-five percent, and usually increases with depth. Permeabilites vary from high to low depending upon the stone content of the soil. These soils are naturally low in nitrogen and phosphorus. Vegetation supported by the soils locally are pasture land and forests.

Drainage from the plant site is westward towards a spring fed farm pond (Figure 1). Discharge from the 0.7-acre (2835 m^2) farm pond extension enters an unnamed intermittent tributary to Hog Creek. Hog Creek flows northwest to Big Piney River. Average annual runoff for the spill area is approximately 14 inches (36 cm).

The use of surface water in the area is varied. The farm pond is stocked with numerous species of game fish (e.g., bass). Local streams are known for their recreational use including fishing, boating, and swimming. Stream water is also utilized for watering livestock. Wildlife are also dependent on local streams as watering sources.

Hydrogeology

The Houston spill site is located in the Salem Plateau sub-province of the Ozarks physiography province. Physiographically, the Ozarks are an enlongated dome that extends across Missouri from the Mississippi River to northeastern Oklahoma and northern Arkansas. The surficial geology is largely Cambrian and Ordovician Rocks, although some later Paleozoic age rock remain. Drainage patterns are more or less radial. Streams have destroyed much of the Salem Plateau and developed valleys many hundreds of feet deep.

The geology of the spill site consists mainly of rocks from the Canadian Series of the Ordovician System. The major formations present are the Jefferson City Formation and the Roubidoux Formation. A thin layer of Pennsylvania Sandstone is also present as a cap rock at the site (i.e., as described by the State Geologist). A brief description of the major formations are presented below (Howe, 1961):

> Jefferson City formation. - The Jefferson City formation is composed

principally of light brown to brown, medium to finely crystalline dolomite and argillaceous dolomite. The thickness of the Jefferson City ranges from 125 to 350 feet (38 to 107 m); its average thickness is 200 feet (61 m).

Roubidoux formation. - The Roubidoux formation consists of sandstone, dolomitic sandstone, and cherty dolomite. The thickness of the Roubidoux ranges from 100 to 250 feet (20 to 76 m). The formation's greatest thickness is at the southwestern part of the Ozarks, and its least thickness is along the northeastern part of the area.

Gasconade formation. - The Gasconade is predominantly a light brownish-gray, cherty dolomite. The formation contains a persistent sandstone unit in its lowermost part that is designated the Gunter member. In the central Ozark region, the average thickness of the Gasconade is 300 feet (92 m). Data from wells in southeastern Missouri indicate a maximum thickness of 700 feet (214 m) for the Gasconade in that area.

The Ozark area of Missouri is the most extensively developed, fresh ground water supply source in the state. The ground water reservoir in this area consists of a section of more than 2,000 feet (610 m) of Cambrian and Ordovician dolomite and sandstone, overlain in the eastern sections by Mississippian limestone. Because of the widespread development of the Ozarks and the great depth of weathering that has occurred, pollutants can migrate to considerable depth. In order to safeguard water supplies from pollutants, wells are locally cased to a dense stratum below the surface and cemented. Considerable casing depth is sometimes required because the depth of weathering is great. For example, at West Plains, Howell County (next County, south of site), 1,000 feet (305 m) of casing is set, at Springfield 250 to 400 feet (76 - 122 m) is set, and Rolla about 400 feet (122 m) of casing is required.

The five principal fresh-water aquifers in the Ozarks that are likely to yield dependable ground water supplies are the Lamotte Sandstone, Potosi Dolomite, Gunter Member of the Gasonade Dolomite, Roubidoux Formation, and the St. Peter Sandstone. The aquifers present at the spill site area are the Jefferson City Formation, Roubidoux Formation, and the Gasconade Formation of greater depths. Specific capacities of wells in this area range from approximately 2 to 10 gallons per minute per foot at down-drawn (25 to 125 liter per minute per meter of drawdown).

Ground water usage in the area surrounding the spill site is high because of the remoteness of the location to public supplies. Approximately 30 wells are located in the vicinity of the spill site and these are either utilized for domestic supplies or livestock water. Of most concern were three wells located in the immediate vicinity of the spill site; one on the plant site, one northeast of the site at a church, and one southwest of the site used as a water supply source for a trailer park (refer to Figure 1 for locations). Most wells are drilled to depths of 200 to 250 feet (61 to 76 m). However, some of these wells are cased only in the upper 40 feet (12 m) which could make them susceptible to contaminants. The aquifer utilized by these wells is probably the Roubidoux Formation (based on State Geologist description).

Numerous springs occur in the area surrounding the spill site. Of most importance are the springs that fed the farm pond located west of the site (refer to Figure 1). These springs are located below the surface water level of the pond. Ground water discharged by springs in the area appears to originate at or slightly below the Jefferson City - Roubidoux Formation contact.

WASTE DISPOSAL HISTORY

The case study differs from other studies presented in this document in that the response actions performed were in response to an emergency spill situation, rather than a waste disposal problem. Therefore, a detailed waste disposal history at the site is not warranted.

The Houston Chemical Company mixes solid pentachlorophenol with oil for use as a wood preservative. Solid PCP is stored at the site in containers. Mixing operations occur in the plant and the 5% pentachlorophenol/oil mixture (PCP/oil) is normally stored in one of two storage tanks located behind the plant. These two cylindrical storage tanks can hold a total of 36,000 gallons (136,300 l) of PCP/oil; i.e., 15,000 and 21,000 gallons (56,800 - 79,500 l).

300.68(c)(2)(i)(B) amount and form of substance present

PCP has been used as a wood preservative since the 1940's when it was introduced as an alternative to the more commonly used creosote. Other applications of PCP are as fungicides, biocides and herbicides. During the production of PCP numerous toxic impurities can be introduced which are more toxic than the PCP itself. For example, the elevated temperatures required during the latter stages of chlorination favors the formation of polychlorinated dibenzo-p-dioxins (PCDD) and polychlorinated dibenzofurans (PCDF). A chemical analysis of different grades of pentachlorophenol is given in Table 1. Analyses performed on various brands and samples of PCP showed that the hexachlorodioxin and octachlorodioxin concentrations can vary greatly; i.e., hexachlorodioxin <2 ppm to 21 ppm, octachlorodioxin <1 ppm to 3600 ppm. These contaminants in PCP are considerably more toxic than the PCP itself. The toxicity of PCP to terrestrial mammals and aquatic biota is shown in Table 2. The effect of PCP on humans is not well documented, but the reported oral lowest lethal dose is 29 mg/kg, and the oral lowest toxic dose is 196 mg/kg (i.e., affected the central nervous system). Toxicologists point out that these results may not be fully attributable to the PCP but in part to its contaminants (i.e., dioxins).

300.65(a)(1) exposure to acutely toxic substances

DESCRIPTION OF CONTAMINATION

On the night of 14 June 1979, an above ground, 21,000 gallon (79,500 l), steel, horizontal storage tank collapsed, shearing-off the drain control valve and piping. This action allowed the contents of the tank to spill onto the ground. An estimated 15,000 gallons (56,800 l) and a 5% solution of PCP in diesel oil was released. The probable reasons for the tank failure as described by a Technical Assistance Team member on site are:

300.64(a)(2) source and nature of release

- Saddle support blocks were not sufficient to support the weight of the tank and its contents; both in spacing and number
- Tank was weakened by heavy corrosion and past abuse
- Saddle support blocks were not engineered to fit the curvature of the tank
- Drain pipe and valve should not have been installed at the underside of the tank where they are subject to damage in the event of a tank collapse.

TABLE 1. CHEMICAL ANALYSIS OF PENTACHLOROPHENOL
(Excerpted from Jones, 1981)

Compound	Concentration		
	Technical	Commercial[a]	Improved[b]
Pentachlorophenol	84.6%	88.4%	89.8%
Tetrachlorophenol	3%	4.4%	10.1%
Hexachlorodibenzo-p-dioxin	8 ppm	<0.1%	<0.1%
Heptachlororadibenzo-p-dioxin	520 ppm	<6.2%	-
Actachlorodibenzo-p-dioxin	1,380 ppm	2,500 ppm	15.0 ppm
Tetrachlorodibenzofuran	≤4 ppm	125 ppm	6.5 ppm
Pentachlorodibenzofuran	40 ppm	4 ppm	1.0 ppm
Hexachlorodibenzofuran	90 ppm	80 ppm	<1 ppm
Heptachlorodibenzofuran	400 ppm	80 ppm	1.8 ppm
Actachlorodibenzofuran	260 ppm	30 ppm	<1 ppm

[a] Dowicide 7

[b] Dowicide EC-7

TABLE 2. TOXICITY OF PENTACHLOROPHENOL REPORTED IN THE LITERATURE

	Reported Toxicity Range		
Species	LD_{50} (mg/kg-bw)	LD (mg/kg-bw)	LC_{50} (ppm)
Rat	27-330		
Mice	120-140		
Rabbit		40-350	
Guinea pig	100		
Dog	150-200		
Sheep	120		
Calf	140		
Bluegill			0.02- 0.05
Goldfish			0.05- 0.27
Catfish (fingerling)			0.12- 0.14
Fathead minnow			0.06- 8.00
Crayfish			9.00-53.00
Sheepshead minnow			0.22- 0.44
Rainbow trout			0.13
Shrimp			3.3

The spilled PCP/oil mixture was not adequately contained on the Houston Chemical Company property because suitable dikes had not been constructed around the storage tanks. Approximately 5% of PCP/oil mixture was contained on-site in an overflow pit adjacent to the plant (Figure 1). The remaining 95% of the PCP/oil mixture bypassed the overflow pit and flowed in a southwesterly direction for 75 yards (69 m) into a roadside ditch. The PCP/oil flowed in a southerly direction in this ditch for approximately 125 yards (114 m) to a road culvert under old U.S. Highway 63 (i.e., service road). The PCP/oil continued flowing in a westerly direction overland to a culvert located under new U.S. Highway 63. From this point the PCP/oil flowed into a manmade catch basin where it was temporarily detained. Eventually the mixture infiltrated through the basin's bottom and reappeared approximately 125 feet (58 m) below the basin. From there the PCP/oil flowed into a 0.7-acre (2835 m^2) farm pond. The farm pond acted as a retention structure to prevent further spreading of the PCP/oil.

300.64(a)(1) evaluation of magnitude of hazard

A spill report was not received by EPA until 18 June 1979, four days after the spill occurred. The initial report by plant personnel was that approximately 10,000 gallons (37,900 l) of PCP and P-9 oil mixture had spilled, and that it was contained in a dike and being removed by vacuum truck. Emergency spill response actions were not initiated at the time because EPA was assured that problems did not exist in the cleanup effort and that local waterways were not threatened by the PCP/oil.

A subsequent visit to the site on 18 June 1979 by a Conservation Officer with the Missouri Department of Conservation revealed that approximately 95% of the spilled material had escaped and now covered a 0.7-acre farm pond (1835 m^2); approximately 1.5 x 10^6 gallons (5.7 x 10^6 liters); with a 1-inch (2.5 cm) layer of PCP/oil. The Conservation Officer also reported that a total fish kill had occurred at the pond which included more than 82 game fish (e.g., bass, catfish).

300.65(a)(1) exposure to acutely toxic substances

Although the PCP/oil was temporarily detained in the farm pond, the situation was deemed serious because near overflow conditions existed in the pond. If rainfall occurred, PCP/oil would likely have been discharged over the spillway into a tributary to Hog Creek.

Samples of soil, water, and oil and water were taken to aid in characterizing the site. Figure 1 shows the location of these samples and Table 3 gives the results of the EPA laboratory analysis. The concentrations of PCP in the drainageways above the farm pond's spillway were

300.65(a)(5) measuring and sampling

TABLE 3. PENTACHLOROPHENOL SAMPLE ANALYSIS, 19 JUNE 1979

Sample Identification Number	Sample Type	Pentachlorophenol Concentration
EG 0301	Water	0.30 ug/l
EG 0304	Water	3.0 mg/l
79-7017	Oil	38,000 mg/l
79-7018	Oil	36,000 mg/l
79-7019	Soil	2,928 ppm[a]
79-7020	Oil	36,000 mg/l
79-7021	Oil & Water	43,000 mg/l
79-7022	Oil & Water	34,000 mg/l

[a]ppm in this case indicates mg/g of soil

extremely high and would be considered toxic to most organisms. PCP concentrations below the farm pond were low (0.30 ug/l) and probably would not be considered toxic. Concentrations of PCP in the well located at the plant site were elevated (3.0 mg/l) and would be considered toxic.

An analysis of one of the soil samples (79-7022) was also performed to determine the level of dioxin (2,3,7,8-tetrachlorodibenzodioxin) in the PCP. Analysis by multiple ion detection GC/MS indicated that if 2,3,7,8-TCDD was present, its concentration was less than 20 ug/l in the PCP/oil (22 ng/g on a weight basis). The choice of analyzing for 2,3,7,8,-TCDD was made because this was thought to provide the best indicator of dioxin contamination since this isomer of dioxin is usually present in highest concentrations.

PLANNING THE SITE RESPONSE

Initiation of Site Response

On June 19, 1979, the On-Scene Coordinator (OSC) decided that the oil/PCP spill constituted an immediate threat to navigable waters of the U.S. Further, the OSC decided that a cleanup should begin immediately. These decisions were based on the toxic nature of PCP, and on the likelihood of contaminaton spreading if was not contained and removed at once. While the spill had not yet travelled beyond the farm pond, a heavy rain would have been sufficient to cause the pond to overflow and carry oil/PCP into Hog Creek.

300.65(a)(1) exposure to acutely toxic substances

300.68(e)(1) (vii) weather

An additional concern of the OSC and of officials at the Missouri Division of Health was the possibility of contamination of drinking water wells in the area. There were 30 such wells within a 1 mile (1.6 km) radius of the site.

300.65(a)(2) contamination of a drinking water supply

Selection of Response Technologies

Because the PCP/oil spill posed an imminent threat of discharge of a hazardous substance and oil into United States waters, and the spiller was not able to mitigate the situation, a Regional Response Team (RRT) meeting was convened in Houston, Missouri, on June 19, 1979. Attendees of the RRT meeting included representatives from U.S. Environmental Protection Agency, U.S. Department of Transportation, U.S. Coast Guard, U.S. Food and Drug Administration, Occupational Safety and Health Administration, U.S. Corps of Engineers, Missouri Departments of Natural Resources, Health Conservation, and Highways, Ecology and Environment Inc., O.H. Materials Inc., U.S. Senator's Office, and Houston Chemical Company. The purpose of the meeting was to assess the problem at the spill site, clarify clean-up resources, and implement clean-up actions.

The initial clean-up actions determined necessary at the RRT meeting were to:

- Skim floating PCP/oil from the pond's surface and removed it with a vacuum truck

300.65(b)(6) moving hazardous substances off-site

- Remove PCP/oil from the catch basin above the farm pond with a vacuum truck
- Excavate and remove contaminated soils from around the plant and along the spill path to the pond
- Recirculate pond water through a carbon filtration system until PCP concentrations are below 10 ug/l and then release filtered water to receiving stream
- Construct diversions around the pond so that rainfall would not enter and overtop pond.

300.65(b)(7) physical barriers

O.H. Materials of Findlay, Ohio was contracted to perform all clean-up activities. The clean-up was done under contract to the U.S. Coast Guard and monitoring of activities were performed by an EPA Region VII OSC with the assistance of the U.S. Coast Guard Gulf Strike Team.

After initial clean-up operations were undertaken, it became evident that further activities were necessary to adequately clean up the spill site. These activities were:

- Excavating contaminated pond sediments

300.65(b)(6) moving hazardous substances off-site

- Sealing the well on the plant site to deter ground water contamination
- Flushing of drainageways to aid in removing and leaching of PCP/oil

- Inoculating the refilled pond with microorganisms to maintain PCP levels below 10 ug/l because of leaching contaminants.

The selection of the clean-up activities were performed on site based primarily on best engineering judgements to quickly and effectively eliminate the hazard posed at the spill site.

<u>Extent of Response</u>

On July 19, 1979 the Missouri Department of Conservation conducted bio-assays on bluegill for PCP, and reviewed U.S. Fish and Wildlife Service data on PCP effects on fish, in order to determine a clean-up target level. According to the studies, all test bluegill died in less than 30 minutes at a PCP concentration of 2.5 mg/l. In pond water containing 32 ug/l PCP, 50% of the test bluegill died within 96 hours. Water samples from the pond at Houston contained 59 mg/l PCP. The Department of Conservation concluded on July 19 that 10 ug/l PCP would be a safe level, and the Regional Response Team agreed to set that level as the cleanup target.

300.68(b)(5) measuring and sampling

When OHM completed introduction of bacteria on August 6 pond samples contained less than 10 ug/l PCP. However, the Coast Guard continued funding for a small amount of additional work on the site until the end of October. During that period, an aerator remained operating on the pond to facilitate bacterial action. Also, EPA periodically took water samples, and a local contractor occasionally replaced sorbent pads on seeps of oil/PCP at the site.

When EPA and the Coast Guard ended funding for work at the site on October 30, pond samples averaged 200 ug/l PCP, substantially higher than the target level of 10 ug/l. The aerator was removed because it did not appear to be controlling the contamination, since the PCP level in the pond had been rising since mid-August. By December 1979, while some oil/PCP seepage continued and pond samples contained 400 ug/l PCP, the Coast Guard concluded that there was nothing further that could be done at the site. Based on the Missouri Department of Conservation's report that the pond has since returned to normal and is supporting aquatic life, it appears that the final remedy occurred through natural dissipation of the remaining PCP.

300.65(c) completion of immediate removal actions

DESIGN AND EXECUTION OF SITE RESPONSE

The following section describes the different clean-up actions taken at the Houston oil spill site. Actual clean-up operations at the site started on 20 June 1979 and lasted through October 30, 1979. The main clean-up operations performed at the site were:

- Skimming and vacuuming floating PCP/oil from the catch basin and pond
- Excavating and removing contaminated soil from the PCP/oil spill path and from the farm pond bottom
- Recirculating and treating farm pond water with a carbon adsorption unit
- Constructing surface water diversions around the farm pond
- Sealing of the well at plant site
- Inoculating the refilled farm pond with microorganisms in order to degrade PCP/oil.

Location of equipment set-up at the site by O.H. Materials is shown in Figure 3.

Skimming and Vacuuming Operations

300.65(b)(6) moving hazardous substances off-site

Concentrated PCP/oil was removed from the catch basin (leaking pond) and farm pond using skimmers and a vacuum truck. The catch basin contained nearly pure PCP/oil, while the farm pond had an approximately 1-inch (2.54 cm) layer of floating PCP/oil. PCP/oil was vacuumed directly from the catch basin, and was skimmed and vacuumed from the pond surface. Approximately 10,000 gallons (37,900 l) of PCP/oil was recovered during the vacuum operations. Recovered PCP/oil was trucked to the wood treating plant and stored in an inside storage tank that was deemed safe. The skimming and vacuuming operations started on June 20, 1979 and continued until June 21, 1979.

Soil Excavation Operations

The soil excavation operations were carried out in two phases: spill path excavation and pond bottom excavation. Excavation of the spill path was initiated first using backhoes. Contaminated soils were excavated from around the plant site initially and then proceeded westerly along the spill path to Highway 63. Excavated

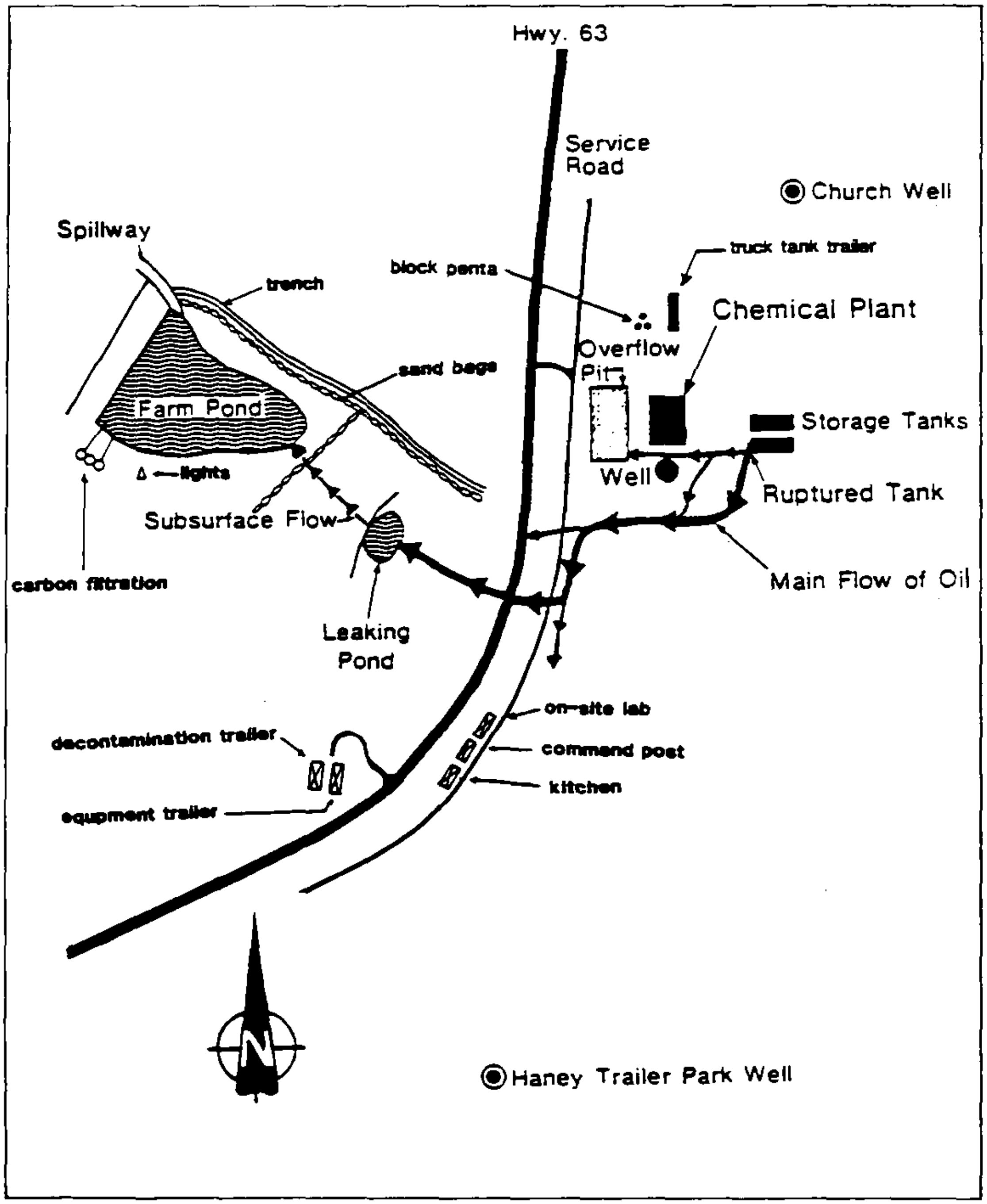

Figure 3. Houston Chemical Co. Response Actions

soils were loaded and trucked to Bob's Home Service, Inc., (closest approved hazardous waste landfill) located in Wright City, Missouri, approximately 170 (272 km) miles away Trucks used for hauling of the contaminated soil were lined with plastic to avoid leakage during transport. Approximately 942 cubic yards (720 m^3) of contaminated soils were removed along the spill path and transported to the landfill.

As soil excavation proceeded along the spill path, on-scene personnel determined that some PCP/oil still remained in the soil and was leaching out. To abate this problem, the drainageways were flushed with water. Three 8-inch (20 cm) plastic pipes were placed through Highway 63 to divert flushing water into a carbon filter box before it entered the pond. Flushing water was obtained from the well on-site or was carried from Hog Creek using a vacuum truck.

Excavation of the farm pond bottom started as soon as the pond's water level was lowered sufficiently to allow equipment access. Approximately 4 to 6 inches (10 - 15 cm) of the pond's bottom sediments were removed. Sawdust had to be mixed with the sediments to control it's consistency and satisfy the state's landfill regulations. Excavation operations eventually outpaced hauling operations, requiring brief storage of contaminated sediments on higher ground within the pond. Stockpiled sediments were placed on plastic to prevent the recontamination of underlying soils. Approximatley 1,694 cubic yards (1296 m^3) of the pond sediments (some mixed with sawdust) were hauled to the Wright City landfill.

During the pond excavation operations, numerous wet weather springs or seeps were noticed in the floor of the pond. These springs were found to be heavily contaminated with PCP/oil (3100 ug/l of PCP). In order to remedy this problem, sorbent pads were placed around the springs. When flow could not be contained by the sorbent pads, the contaminated water was vacuumed and pumped through a carbon filtration system.

After the excavation operations were completed, the drainage ways and pond area were regraded and restored (includes reseeding and landscaping). Contaminated vegetative material and sorbent pads were hauled to the landfill for disposal. A total of 2,635.9 cubic yards (2016 mq) of contaminated soil were excavated and disposed of from the spill site. Excavation operations started on June 20, 1979 near the plant area and ended on July 20, 1979 with the removal of the last loads of pond sediments.

Treatment of Pond Water

While the skimming and vacuuming operations were occurring at the farm pond to remove the floating PCP/oil, the contaminated pond water was being circulated through a carbon filtration system. The filtration system consisted of a mix-media prefilter (pea gravel/limestone) and a three-stage carbon filter. Total charge of carbon was 2400 pounds (10,896 kg). Two pumps were utilized with the unit, a 3-inch (7.6 cm) electric pump and a 4-inch (10.2 cm) diesel trash pump. The intake pipe was floated in the pond in a boomed-off area with the actual intake 2 to 4 feet (0.6 to 1.2 m) below the surface. This prevented highly concentrated PCP/oil from entering the system. The carbon filtration unit was operated 24-hours per day until the water in the pond was completely removed.

The initial plan was to recirculate the pond water back to the pond after filtration until the PCP level was less than 10 ug/l. This plan was changed to filtering the pond water and releasing it to Hog Creek when the PCP concentrations were reduced to below 10 ug/l. At the onset of filtering the pond water, it was recirculated back to the pond because OHM did not have their on-site laboratory operational and the contaminant level could not be checked. Carbon filtration and recycling started on June 20, 1979 and lasted until June 25, 1979 when on-site laboratory was made operational. After this date, filtered pond water was released to a tributary of Hog Creek. Complete filtration and removal of original pond water was completed on July 8, 1979. Approximately 700,000 gallons (2.6×10^6 l) of water had been released to drain the pond completely. The total amount of water filtered by the carbon filtration system was nearly 2×10^6 gallons (7.6×10^6 l) because the water had to be recycled for the first six days until an on-site lab was operational, allowing OHM to determine that treated water was below 10 ug/l. During the treating and draining of the farm pond, the carbon filtration unit was recharged once. Spent carbon was disposed of in the Wright City landfill.

The carbon filtration unit was reactivated on July 9, 1979 because a local rainfall partially refilled the pond, and operated intermittently for the next ten days. Filtering and releasing the water from the rainfall and wet weather springs in the pond was accomplished by July 18, 1979. The carbon filtration unit was deactivated on this date. Carbon filtration units were completely removed from site on August 2, 1979.

Diversion Construction

Because the level of water in the pond was near overflow, a trench and sandbag diversion was constructed at the site to divert surface runoff around the pond. Location of the trench and sandbags is shown in Figure 3. Construction of the runoff diversions began on June 20, 1979 and was completed on June 21, 1979. The diversion structures remained in place until July 18, 1979 when they were removed. During the time the structures were in place the pond did not overflow the spillway and release water.

300.65(b)(7) physical barriers to deter spread

300.70(b)(1)(ii)-(B)(1) dikes and berms

Sealing of Plant Well

An investigation was performed at the plant site to determine if the plant well was acting as a route for aquifer contamination. Initial investigations made by obtaining a water sample at an outside tap showed that an oily film was present in the water, probably PCP/oil. Sampling revealed that the concentration of PCP in the well was 3 mg/l. Further investigations showed that an old buried water line that was not sealed was the cause of the PCP/oil intrusion. To prevent contamination of the underlying aquifers, the plant well was purged until contamination was not observed. Samples taken at this time showed PCP levels to be less than 0.50 ug/l. The OSC determined at the time that the plant well should be sealed to prevent any further contamination of the local aquifers. This was deemed necessary because the plant well was improperly cased and the potential for contamination was great. On June 27, 1979 the components of the plant well were removed and the well sealed by pouring cement throughout its drilled length.

Bioreclamation of Refilled Pond

Because of the potentially long term leaching of PCP/oil into the pond from bottom seeps and the large amount of soil that would need to be excavated to eliminate the leaching, the OSC decided to allow the farm pond to refill and then introduce more organisms to degrade any newly leached PCP. The type of organisms chosen were pseudomonas bacteria (Bio-Pac Sybron culture DC 1007 pp) originally developed for degradation of phenols. PCP is more difficult to degrade than phenols but it was believed that 80% degradation could be accomplished. Microorganisms were shipped freeze-dried to the site where they were acclimated in a holding pool with controlled nutrient, temperature, and oxygen levels. Once acclimated, the organisms were added to the pond. Self-contained electric aerators were floated on the pond to help maintain oxygen levels above 2 mg/l.

300.70(b)(2)(ii)(A)(2)
aerated lagoon

The first batch of organisms were added to the pond on July 28, 1979 and successive batches were added until August 4, 1979. A total of approximately 100 pounds (220 kg) of organisms were added to the pond during this period. Microorganism concentrations in the pond for part of this time period are shown in Table 4. Bioreclamation operations were discontinued after October 30, 1979 when the aerator was removed and the spill clean-up terminated.

Two problems arose during the bioreclamation operations: excessive die-off of organisms and overtopping of the spillway caused by heavy rain. The excessive die-off of organism in the pond was apparently caused by the property caretaker turning off the aerators in the pond. Once this was discovered the problem ended.

During the bioreclamation operation heavy rains occurred twice causing the pond to discharge contaminated water through the spillway. Carbon filter dams (primary and secondary) had been built on the spillway to minimize contaminant releases. Despite the damage incurred to the dams during the second overflow, a fish kill or extensive damage did not occur in local receiving waters.

In early October, the OSC attempted to reintroduce a bacteria population in to the pond and ordered 100 pounds (45 kg) of freeze-dried bacteria from Sybron, Inc. The OSC was not optimistic that the attempt would succeed, but believed that the relatively small investment of $1,000 for the bacteria and nutrients was justified by the chance that they might work. Subsequent sampling of the pond indicated that the new batch of bacteria had no apparent effect. The aerator was turned off on October 30. In November, the last pond sample taken contained about 400 ppb PCP.

COST AND FUNDING

Source of Funding

On June 19, 1979 EPA and Coast Guard officials sought an agreement from representatives of Houston Chemical Co. to pay for the clean-up. When the effort failed, the only other available source of funds was the section 311(k) Revolving Fund. The OSC obtained an initial spending authorization of $50,000 from the 2nd Coast District

300.68(c)
responsible party

TABLE 4. MICRO-ORGANISM CONCENTRATIONS

Date (1979)	Micro-organism Count (organism/ml)			
	Incubation Batch	Pool Sample	Upper Pond	Lower Pond
30 July	1.3×10^6	1.1×10^7		4×10^3
31 July	1.2×10^7	4.8×10^6	5.2×10^5	8.4×10^4
1 August		6.0×10^6 1.1×10^6	8.0×10^4	1.9×10^5 1.7×10^5
2 August			4.0×10^4 1.5×10^4	1.5×10^5 1.4×10^5

office in St. Louis, Missouri. The Coast Guard periodically raised the spending authorization during the cleanup as the OSC requested more funds. The OSC initially estimated that the cleanup would take 30 days to complete and would cost about $500,000.

Selection of Contractors

On June 19, the OSC contacted O.H. Materials, Inc. of Findlay, Ohio, and engaged the firm to begin cleanup operations as soon as possible. The first OHM personnel arrived at the site that afternoon. According to the OSC, OHM was chosen to do the work because, at that time, they were one of only two firms in the U.S. qualified to respond quickly and effectively to chemical spills. O.H. Materials was chosen over the other firm because EPA Region VII recently had used the other firm in a different clean-up and believed it was equitable to use OHM for the spill at Houston. The OSC, acting as agent for the Coast Guard, contracted with OHM on a time-and-materials basis, using an OHM price list for labor and equipment that EPA already had on file. The contract did not specify the tasks that OHM was to perform, leaving the OSC broad discretion to define the nature and scope of work.

At the request of the OSC, on June 20 the EPA Region VII office contracted with a dispoal facility in Wright City, Missouri, approximatley 170 miles (274 km) from the site, and made arrangements for disposal of contaminated soil that was removed during the cleanup. The facility, a landfill called Bob's Home Service, Inc. was chosen because it was the closest facility available that was licensed to accept hazardous wastes. Initial plans had called for removal of both contaminated soil and recovered oil/PCP. However, the OSC decided that the oil could be transferred safely to a secure tank inside a building at the Houston Chemical Co. plant, saving the expense of transporting and disposing of the oil. Houston Chemical Co. officials consented to the OSC's decision. EPA's initial estimate of the quantity of soil to be disposed of was 800 cubic yards (612 m^3). The actual amount of soil taken to Bob's Home Service was 2,636 cubic yards (2015 m^3).

Project Costs

The total cost of the Houston Chemical Co. cleanup, from June 18, 1979 to December 29, 1979, was $709,427. All monies came from the section 311(k) Revolving Fund. Most of the expenditures occurred during the 49 days from June 19 to August 6 when the initial cleanup, soil disposal, and biological treatment took place. The total spent during this period was about $704,000. The remainder of the expenditures occurred from August 7 to December 29 for a small amount of follow-up work. A total of $3,370 was spent on grading and reseeding to restore the site, and for replacing the sorbent pads placed over oil seeps on a weekly basis for six weeks. Another $1,111 was spent on freeze-dried bacteria and nutrients in the attempt to reintroduce a bacteria culture in the pond during October 1979.

The EPA's original estimate of the cleanup cost, made two weeks after work at the site began, was approximately $500,000 for the whole job. The cleanup cost $209,000 more than anticipated for three reasons. First, EPA had not expected to have to excavate and remove contaminated soil from the pond bottom. When the pond bottom was found to be contaminated, the amount of soil that had to be removed and disposed of tripled the original estimate of 800 cubic yards (612 m^3). Second, heavy rains in early July delayed excavation work and necessitated reactivation of the carbon filtration system. Third, EPA initially had not intended to employ biological treatment, which added about $60,000 to the total clean-up cost. Table 5 summarizes the cost breakdown by operations.

Soil Excavation, Vacuuming, and Carbon Filtration

The bulk of expenditures, approximately $459,000, occurred during the initial 32 days of the cleanup, from June 19 to July 20. During this period, OHM built surface water diversion structures; excavated all contaminated soil from the spill path and pond; vacuumed 10,000 gallons (561,800 l) of oil/PCP; and began restoration of the carbon site. Because many of the tasks were performed concurrently, and because OHM billing for time-and-materials did not break down charges on a task-by-task basis, it is not possible to calculate accurate costs for each task performed. However, average daily costs for different phases of the cleanup give some indication of the relative costs of various tasks.

300.65(b)(6) moving hazardous substances off-site

Daily costs were highest for the first 11 days of work, averaging about $20,000. During this period, 17-20 workers were on site, setting up and beginning operation of the carbon filtration system, mobile and analytical lab, and vacuum truck, and excavating the spill path. Skimming and vacuuming were completed during this period. Daily costs from the 12th day to the 32nd day averaged $12,000. Costs during this period were lower because containment, set-up and vacuuming were already complete. Twelve to 15 workers were on site during this period,

TABLE 5. SUMMARY OF COST INFORMATION-HOUSTON CHEMICAL CO.. HOUSTON, MO.

Task	Estimated Quantity	Actual Quantity	Estimated Expenditure	Actual Expenditure	Variance	Unit Cost	Funding Source	Period of Performance
Vacuuming oil/ PCP		10,000 gal. (561,775 l)						
Carbon filtration of pond		2 million gal. water (7.6 million l)						
Soil excavation	800 cu.yds. (612 cu. m.)	2,635 cu.yds. (2015 cu. m.)		$458,954 (1)			311(k)	6/19/79-7/18/79
Soil Disposal-Landfill	800 cu.yds. (612 cu. m.)	2,635 cu.yds. (2015 cu. m.)	$33,600 (2)	$110,708	$77,108 (+229%)	$42/cu. yd. ($48/cu.m)	311(k)	6/23/79-7/21/79
Soil Transportation-170 mi (273 km)	800 cu.yds. (612 cu.m)	2,635 cy.yds. (2015 cu.m)	$16,000 (2)	$52,646	$36,646 (+229%)	$20/cu.yd. or 11.7¢/cu/yd./mi.	311(k)	6/23/79-7/21/79
Biological Treatment			$20,000	$61,181	+$40,181 (+205%)		311(k)	7/21/79-8/6/79
EPA personnel and travel		440 hours		$ 7,219			311(k)	6/18/79-11/2/79
Coast Guard Personnel and travel		860 hours		$10,826			311(k)	6/79-8/79
Restoration and follow-up work				$ 3,371			311(k)	8/6/79-12/29/79
Miscellaneous Expenditures				$ 4,523			311(k)	6/6/79-12/29/79
Total			$500,000 (3)	$709,428	+$209,427 (+41%)		311(k)	6/18/79-12/29/79

(1) Breakdown by individual task not possible.

(2) Extrapolation based on initial soil quantity estimate.

(3) EPA estimate.(not a binding contractual estimate)

completing soil excavation and removal, carbon filtration, site restoration, and equipment breakdown.

Biological Treatment

The second phase of the cleanup, introduction of bacteria and nutrients to the pond, lasted 13 days, from July 25 to August 6, and cost $61,181. Daily costs were biological about $4,700. Two to four OHM personnel were on site during this period. The original OHM cost estimate for the biological treatment was $20,000, or one-third of the actual cost.

Transportation and Disposal

A total of 2,636 cubic yards (2,015 m^3) of contaminated soil, vegetation, absorbent pads and spent filter carbon were disposed of at Bob's Home Service, Inc., a licensed hazardous waste landfill in Wright City, Missouri. The disposal cost for all materials was $42 per cubic yard ($48/m^3), or a total of $110,708. The material was transported in 130 truckloads at $355 per load. An OHM subcontractor carried 122 of the loads, which added 15% to the cost per load. Eight loads were contracted for directly by the Coast Guard. The total cost of transportation was $52,610, or $19.96 per cubic yard ($26 per cubic meter) of soil or 11.7 cents per cubic yard per mile (15.3 cents/m^3/km).

Administrative Costs

Costs to EPA for salaries, transportation, and per diems associated with the cleanup totalled $7,218. Seven different EPA personnel were on site at various times during the clean-up working a total of 440 hours. Wages, including overtime, totalled $5,305. Transportation and per diems totalled $1,913. These amounts do not include sample analysis and administrative work performed at the EPA Region VII offices.

Costs to the Coast Guard for salaries, per diems, and transportation totalled $10,825. Three Coast Guard personnel worked a total of 860 hours on clean-up related duties, at a cost of $4,524 in salaries. Per diems cost $5,759, and transportation cost $542.

Miscellaneous Expenditures

Miscellaneous expenditures totalled $4,523. Included in this figure are $1,211 for telephone service, $1,111 for additional bacteria, and a number of smaller expenditures on such items as chartered airplanes to send samples to Kansas City, film, and rental of a motel room for use as a command post.

PERFORMANCE EVALUATION

An assessment of the performance of the types of clean-up actions taken at the Houston Company spill site must consider the nature of response. This clean-up effort was performed at an emergency spill response, not as a planned remedial action. The actions taken at the site were done to prevent the spread of PCP and cleanup the site as quickly as possible. The decisions made were often based on insufficient data and time constraints did not allow for the development of extensive studies to determine the "best" or the most cost effective clean-up action.

The intent of the clean-up effort was to eliminate the hazard posed by the PCP/oil spilled at the site. As part of this, a target level of less than 10 ug/l of PCP in the local surface waters was to be attained to prevent potential toxic effects to the ecosystems. The only standard to determine if the clean-up actions taken at the site were effective in eliminating the PCP hazard is the water quality monitoring data.

Ground water quality data available for the site is shown in Table 6. These data indicate that the local ground water had not been significantly affected as of June 26, 1979. The high concentration of PCP found in the plant well on June 19, 1979 was caused by contaminants that leaked into the water lines that carried water to the plant building. Sealing of the well was an appropriate action because the possibility for contamination was great. Extensive monitoring of wells in the area did not indicate that the PCP/oil had migrated into the deep underlying aquifers. Depending upon the permeability and velocity of these aquifers, the contaminants may have not traveled far enough to be detected by the end of operations in December.

Surface water quality data for the site is shown in Table 7. At the end of operations on October 30, 1979 the farm pond had a PCP concentration ranging from 250 ug/l to 400 ug/l, a concentration greater than ten times the target level. Based upon data, it is evident that the clean-up operations at the site did not completely accomplish their goals for reduction in surface water contamination. The main reason for this is that the bulk of the clean-up operations at site (i.e., soil excavation, carbon filtration, and skimming and vacuuming) were designed to

TABLE 6. GROUND WATER SAMPLES

Date (1979)	Sample No.	Description	Concentration
June 19	EG 0304	Well at plant	3.0 mg/l
June 24	EG 0322	Well at church	<0.1 ug/l
	EG 0323	Well at plant	1.2 ug/l
	EG 0324	Well at Haney trailer park	0.7 ug/l
	EG 0325	Well at Jaus farm	<0.1 ug/l
	EG 0326	Well at Fisher junkyard	<0.1 ug/l
June 26	EA 0405	Well at plant	0.20 ug/l
	EA 0406	Well at plant	<0.05 ug/l
	EA 0407	Well at trailer park	<0.05 ug/l
	EA 0408	Well at trailer park	<0.05 ug/l

TABLE 7. SURFACE WATER SAMPLES

Date	Sample No.	Description	Concentration
June 19	79-7017 79-7018 79-7020 79-7021 79-7022	Along spill path near plant - oil Along spill path east of Hwy 63 - oil Catch basin above farm pond - oil East end of farm pond - oil/water Near spillway of farm pond	38,000 mg/l 36,000 mg/l 36,000 mg/l 43,000 mg/l 34,000 mg/l
June 24	EG 0315 EG 0316 EG 0317 EG 0318	Tributary to Hog Creek below farm pond Tributary to Hog Creek above 400 yds before confluence Confluence at Hog Creek On Hog Creek about 25 yards above confluence	0.74 ug/l 0.40 ug/l 0.17 ug/l 0.27 ug/l
June 25	EA 0402 EA 0403 EA 0404	Tributary to Hog Creek below farm pond Tributary to Hog Creek above confluence Hog Creek below confluence	0.7 ug/l 0.2 ug/l 0.4 ug/l
June 26		Pond water	20,600 ug/l
June 29		Pond water	16,500 ug/l
July 8		Pond pumped dry	----------
July 9		Pond water (after rainfall)	1,167 ug/l
July 16		Springs into pond	3,100 ug/l
July 28		Bioreclamation started	----------
July 30		Pond spillway water (after heavy rain) Hog Creek	1,440 ug/l 3 ug/l
July 31		Pond water (composite)	20 ug/l
Aug 1		Pond spillway	<10 ug/l
Aug 2		Pond spillway Batch tank (p001)	<10 ug/l <10 ug/l
Aug 5		Pond water	<10 ug/l
Aug 6		Pond water	<10 ug/l

(continued)

TABLE 7. (continued)

Date	Sample No.	Description	Concentration
Aug 14		Pond water	<10 ug/l
Aug 20		Pond water	153 ug/l
Aug 29		Pond water	60 ug/l
Sept 7		Pond water	80-90 ug/l
Oct 5		Pond water	>100 ug/l
Oct 30		All operation stopped	----------
Nov 2		Pond water (4 samples) low mean high	 250 ug/l >300 ug/l 400 ug/l
Nov 6		Pond water	200 ug/l
Dec 11		Pond water	400 ug/l

eliminate known "visible" contamination (e.g., floating PCP/oil, contaminated soils, contaminated pond water) not PCP/oil which seeped into the shallow aquifers.

An unknown amount of PCP/oil had infiltrated below the depth of soil excavation and possibly into the shallow ground water table. This is evidenced by the high concentration of PCP in the springs found in the pond's bottom (3100 ug/l) after complete water removal. The method chosen to control the PCP seeps was bioreclamation of the pond water after the pond refilled. Early indications were that the bioreclamation was performing as expected because the PCP concentrations were reduced below 10 ug/l between August 1, 1979 and August 14, 1979. However, after this date the PCP concentrations approached 400 ug/l, after clean-up operation termination.

A factor that may have contributed to the failure of the bioreclamation efforts at the site was that the property caretaker was turning off the aeration pumps. However, other uncontrollable factors such as weather conditions, water chemistry, and natural nutrient loading could have also had an effect on the bioreclamation effort. Based on information provided by the bioreclamation manufacturer, the oxygen concentrations in the pond needed to be maintained above 2 mg/l to ensure viability of the organisms. Oxygen levels less than this would cause excess die-off of organisms. However, hard data is not available to conclusively show what caused the failure of the bioreclamation operations at the site.

In retrospect, it appears that the clean-up operations at the site were performed in an appropriate manner to minimize the hazard posed. The reason for not obtaining the goal of less than 10 ug/l of PCP in the surface water was the inadequacy of the plan to deal with the heavily contaminated springs in the pond bottom. Whether or not the bioreclamation procedures would have been completely successful in eliminating this problem is unknown because sufficient data were not available.

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HOWE, INC.

BROOKLYN CENTER, MINNESOTA

INTRODUCTION

NCP Reference

Howe, Inc., formulates and stores agricultural chemicals at a small facility in Brooklyn Center, Minnesota, a residential suburb of Minneapolis. In January 1979, a warehouse at the site, containing a variety of pesticides, fertilizers, and explosives, was consumed by fire. Water used to extinguish the fire carried pesticides into a nearby stream bed and infiltrated into the soil. Sampling by state officials revealed hazardous levels of pesticides on the ground surface, in soil, and in ground water.

Background

Howe, Inc. occupied five buildings on a 5.3 acre (2.1 ha) parcel in Brooklyn Center, immediately west of the Minneapolis city limits (see Figure 1). The site is located in a small area of industrial buildings in an otherwise residential neighborhood of detached single-family homes. At the time of the fire, Howe's north building contained about 100 different pesticides, totalling 80 tons (73 Mt) of active ingredients. The predominant active ingredients were two organic herbicides: atrazine, known commercially as Aatrex 4L, and alachlor, known commercially as Lasso.

300.68(e)(2)
(i)(B)
amount and form of substances

Fire broke out in the north building on January 6, 1979 (see Figure 2). In the course of the six-hour effort to extinguish the fire, the Brooklyn Center Fire Department sprayed more than a half-million gallons (1.9×10^6 l) of water on the building. Some of the water collected in shallow ponds on the Howe property, but most of the water flowed through a culvert and emptied into the dry bed of a small intermittent stream named Ryan Creek, which runs immediately south and east of the site and drains into the Mississippi River, about two miles (3.2 km) to the east. The pesticide-laden water flooded an area of the stream bed about 900 feet long by 15 feet wide (275 x 5 m). The flooded area lay within the City of Minneapolis on property owned by the Soo Line Railroad.

Figure 1. Howe, Inc. Location
(Barr Engineering, 1980)

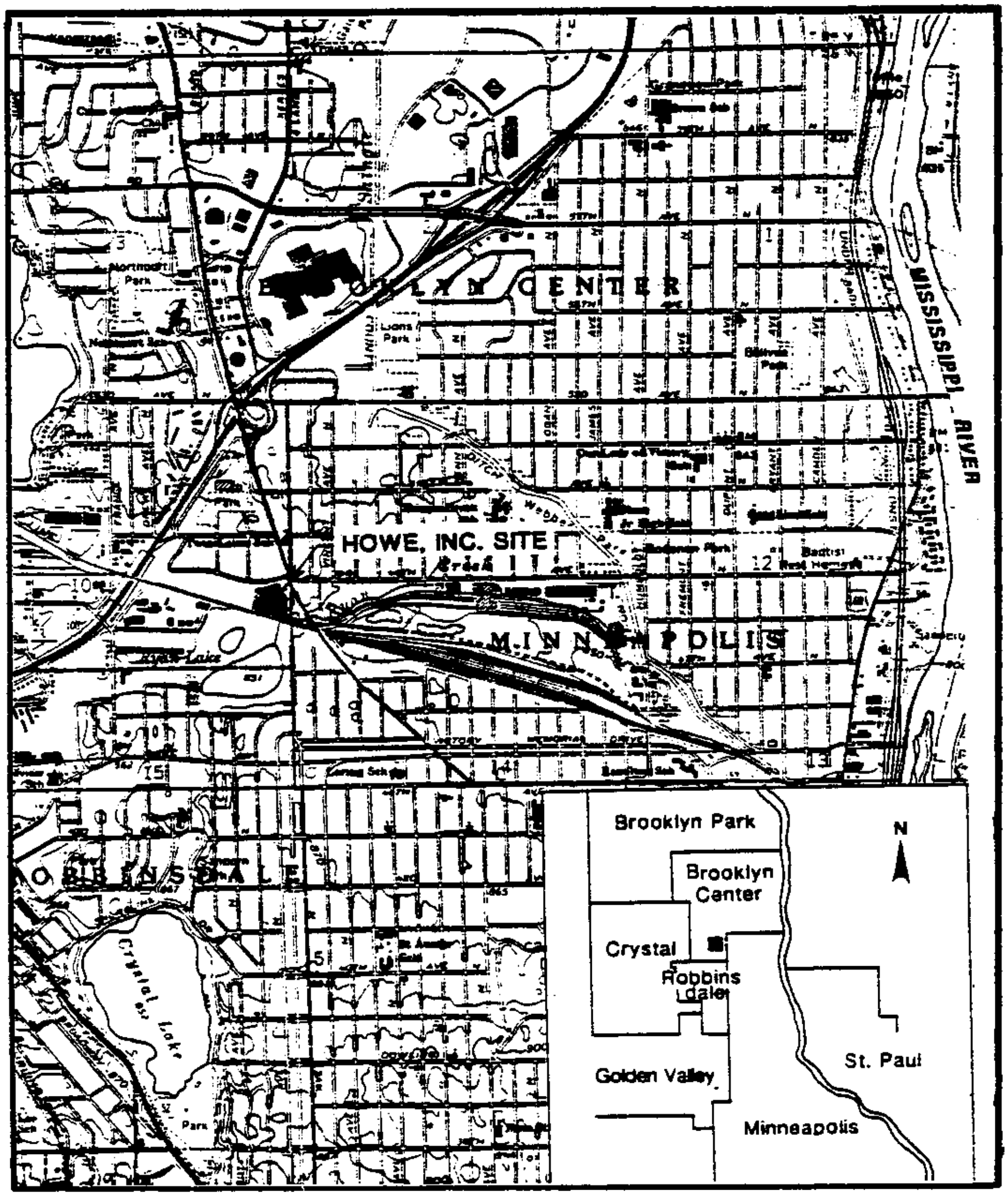
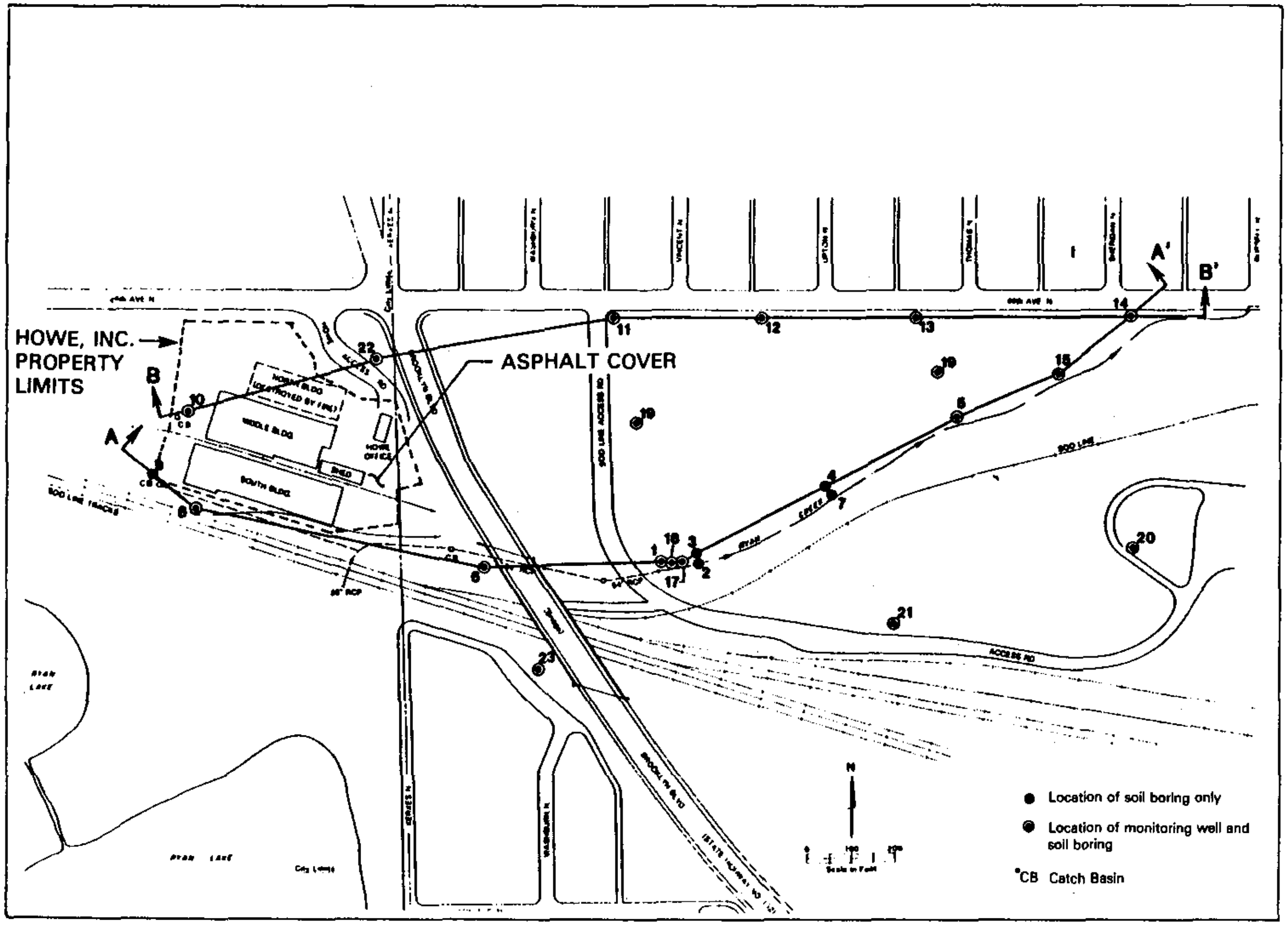


Figure 2. Howe, Inc. Site Map (Barr Engineering, 1980)



Synopsis of Site Response

This case study describes the actions carried out in response to contamination left in the aftermath of the fire, and does not include the actual firefighting efforts. A number of government agencies participated in the Howe clean-up, including the Minnesota Pollution Control Agency (MPCA), the Minnesota Department of Agriculture (MDA), the Minnesota Department of Health (MDH), and the cities of Minneapolis and Brooklyn Center. The major elements of the clean-up were: emergency response actions; provision of alternative water supplies, removal of contaminated ice, snow, and soil; removal of building and other fire debris; a hydrogeological investigation; and ground water recovery. Most of the clean-up occurred from January 1979 to November 1979.

The response began on January 6, 1978, the day of the fire, when the City of Minneapolis built two temporary sand dams on Ryan Creek, east of the Soo Line Access Road, to contain the contaminated water. During the following seven days, after most of the water had been absorbed into the stream bed and the water remaining on the surface had frozen, a contractor hired by MPCA constructed a diked, plastic-lined containment area on the Soo Line property and placed the contaminated ice and snow from the stream bed and the Howe property in the initial containment area. The City of Minneapolis erected a fence around the containment area.

300.65(b)(7) physical barriers to deter spread of release

300.70(b)(1)(ii)(B)(1) dikes and berms

300.65(b)(3) security

Meanwhile, state and Minneapolis officials were concerned that air emissions from the fire might have contaminated snow down-wind of the site. Although sampling did not detect significant snow contamination, Minneapolis officials closed a nearby area to sledding and posted signs around the industrial area east of the site which read "Hazardous Materials, Keep Out."

Ten days after the fire, the MDH ordered 11 nearby residents to discontinue use of their drinking water wells. The City of Brooklyn Center subsequently connected these houses to the municipal water system. On the same date, the MDH contracted with Barr Engineering Co., an engineering consulting firm, to investigate the level and extent of soil and ground water contamination and to evaluate remedial alternatives.

300.70(d)(2) provision of alternative water supply

300.68(f) remedial investigation

State officials spent one month seeking a means of disposing of the contaminated ice and soil, encountering strong citizen opposition as each proposed disposal alternative was made public. In early March 1979, a contractor hired by MPCA excavated 1,000 cubic yards

300.68(e)(2) source control: removal

(765 cu. m) of contaminated soil from Ryan Creek and lined the stream bed with sand and plastic to prevent spring runoff from carrying the remaining contaminants downstream or deeper into the soil. The excavated soil and 1,600 cubic yards (1,220 cu. m) of ice and snow were trucked to a farm in Martin County, Minnesota, 140 miles (225 km) from Brooklyn Center. The ice and snow were placed in a plastic-lined pit and the soil was piled nearby. Two months later, the melted ice and snow was sprayed over 74 acres (30 ha) and planted with corn. In September 1979, the contaminated soil was spread over 2.5 acres (1 ha) and mixed with manure to enhance microbial breakdown of the pesticides.

300.70(b)(1)
(ii)(A)
surface seals

During the spring of 1979, Howe, Inc. and owners of some of the stored pesticides removed the remaining chemicals and fire debris.

In June 1979, Barr Engineering installed four 35 foot deep (10.6 m) ground water recovery wells along a 1,200-foot (366 m) section of Ryan Creek. Over the next five months, almost 90 million gallons (340×10^6 l) of water were pumped from the wells into the Minneapolis sanitary sewer system. The ground water recovery system was shut down for the winter in November 1979. In August 1980, after reviewing ground water sampling data, the MDH concluded that it was not necessary to resume pumping.

300.70(b)(1)
(iii)(C)
ground water
pumping

Currently, the State of Minnesota is suing Howe, Inc., to recover clean-up costs.

SITE DESCRIPTION

The Howe, Inc. site occupies 5.3 acres (2.1 ha) in the southern portion of Brooklyn Center, Minnesota, immediately west and north of the city limits of Minneapolis and Robbinsdale, respectively. Figure 1 shows the site's location and prominent surface features in the site vicinity. The following discussions of regional and site surface characteristics and hydrogeology are based upon information presented in a report by Barr Engineering (1980).

Surface Characteristics

The most prominent natural feature within a one-half mile (0.8 km) radius of the site is Ryan Lake to the south; Crystal Lake to the south, Twin Lakes to the west and the Mississippi River to the east are within two miles (3.2 km) of the site. Other nearby water bodies include Ryan Creek to the east which flows into County Ditch No.

13 and thence to the Mississippi River. In general, with the exception of the Howe site itself and adjacent Soo Line Railroad properties, the dominant land use in the area is residential, including both single and multiple family dwellings. The most prominent man-made features of this area, though, are Brooklyn Boulevard, a four-lane state highway, the Soo Line Railroad tracks south of the site, and the Soo Line Railroad's Humboldt Yard east of Brooklyn Boulevard. The area of greatest potential contamination immediately surrounding the fire site consisted of about 60 acres (24 ha) encompassing all of the Howe property as well as some Soo Line Railroad property, and crossed by the Soo Line tracks, Brooklyn Boulevard and Ryan Creek (see Figure 2). Brooklyn Boulevard conveniently divides this area into eastern and western sections for purposes of further discussion.

As Figure 2 shows, the western portion of the area of most concern includes the Howe property, containing two large fertilizer manufacturing buildings, the pesticide storage building and an office building. The pesticide storage building (north building), a one-story wood-framed structure, was the building destroyed by the fire. The ground near these buildings slopes gradually from north to south with a maximum relief of about four to six feet (1.2 to 1.8m). The lowest spots on this western section are three storm water catch basins eventually draining nearly all runoff north of the railroad tracks, south of 49th Avenue North and west of Brooklyn Boulevard (see Figure 2). The southeast and southwest catch basins, in turn, are hydraulically connected with an underground concrete culvert installed to divert overflow from Ryan Lake under the Soo Line tracks, Brooklyn Boulevard, and Soo Line access road to Ryan Creek. The western catch basin does not seem to have an outlet. As Figure 2 indicates, asphalt covers a limited area around the Howe buildings; the asphalt extends only to the western catch basin.

The eastern section of the area of most concern is dominated by Ryan Creek, a stream flowing infrequently and only during heavy rainfall or runoff. Ryan Creek flows northeastward from the underground culvert outlet on the east side of the Soo Line access road to 49th Avenue North and Russell Avenue. At this intersection, the stream flows back into another culvert paralleling 49th Avenue North and reemerges at Oliver Avenue and flows eventually into County Ditch No. 13. Otherwise the eastern portion of the area in the immediate vicinity of the site is generally featureless, being flat, undeveloped, and covered with grasses and small brush.

Hydrogeology

Surficial Geology

The surficial geology of the Twin Cities area is characterized mainly by glacial deposits of Pleistocene age, in particular by those resulting from the Superior and Des Moines ice lobes which covered the area during the late Wisconsin phase of glaciation. Both ice lobes advanced from the northwest, the Superior first depositing a sandy non-calcareous till and the Des Moines later covering and modifying the Superior with a silty and clayey calcareous drift. Sand-laden meltwater from the retreating Des Moines later formed a series of coalescing outwash plains called the Anoka Sand Plain. After retreat of the Des Moines lobe, the Mississippi River cut through the drift deposits, forming the present river valley and leaving the Mississippi Valley Outwash deposits. As a result of these events, the metropolitan area is covered by a surficial sand and gravel aquifer, and soils are generally sandy and well drained. The underlying unconsolidated glacial deposits are an average 40 to 70 feet (12 to 21 m) thick.

Information from soil borings taken during site clean-up confirm the site is covered by a surficial sand and gravel aquifer resulting from the Mississippi River Outwash and possibly the Anoka Sand Plain. Below the surface of the western portion of the area, the sand and gravel outwash generally overlies a number of discontinuous fine organic swamp and lacustrine deposits of varying or unknown, but generally significant, thicknesses. The uppermost layers are topsoil and miscellaneous fill, including primarily silty sand, as well as silty loam, debris, and trace organics and gravel. East of Brooklyn Boulevard, the surficial geology is dominated by deposits consisting of clean, well-sorted medium to coarse sand, and some gravel. One isolated deposit of clayey silt was discovered midway along 49th Avenue North.

Bedrock Geology

The bedrock geology of the Twin Cities area is dominated by a sequence of Ordovician-age sandstone and dolomite formations. The St. Peter Sandstone, directly underlying the drift deposits, averages 150 feet (45.7 m) but varies greatly in thickness due to erosion by interglacial and post-glacial streams. Some of these ancient streams cut valleys up to 150 feet (45.7 m) deep through the St. Peter Sandstone and into the Prairie-du-Chien dolomites and sandstones below. In general, the thicknesses and elevations of all of the major surficial and bedrock units in the area vary greatly. Logs of two wells within two and three miles (3.2 to 4.8 km) and northeast and east of the Howe site, respectively, show thickness variations of 20, 85, and 135 feet (6.1, 25.9 and 4.1. m) for the glacial sediments, St. Peter Sandstone and Prairie-du-Chien Group, respectively.

Borings taken in the immediate vicinity of the Howe site unfortunately were not sufficiently deep to confirm the presence of these bedrock units.

Ground Water Hydrology

The regional ground water table in the surficial aquifer moves on a gradient of 0.38% in an easterly direction, originating at Twin Lakes and discharging into the Mississippi River. Wells near the Howe site confirm the easterly direction of flow, but on a gradient of less than 0.25%. The depth of the ground water table ranges from 12 to 18 feet (3.7 to 5.5 m) west of Brooklyn Boulevard and from 5 to 14 feet (1.5 to 4.3 m) east of Brooklyn Boulevard near the site.

Generally shallow (less than 25 feet, or 7.6 m, deep) soil borings prevented confirmation of the presence of till underneath the Howe site. Literature reports of borings taken near the site are also inconclusive; therefore, the degree to which the till limits vertical ground water flow cannot be ascertained. In addition, none of the clay seams discovered in wells near Ryan Creek have been found to be continuous and thus are not effective barriers to vertical ground water movement. If till were present, its 70 foot (21 m) thickness and hydraulic conductivity of 3×10^{-7} cm/sec would make it a relatively effective barrier. Even if the till were absent and the surficial aquifer was hydrologically connected to the St. Peter Sandstone, the majority of ground water would probably flow horizontally through the more permeable outwash deposits.

WASTE DISPOSAL HISTORY

No hazardous waste disposal, as such, occurred at the Howe, Inc. site. Rather, fire debris and the water used to put the fire out became contaminated by the chemicals stored in the building and, in turn, became potential sources of surface water, ground water, and soil contamination.

The fire started at the east end of Howe's north building on the morning of January 6, 1979, following a small explosion due to a faulty acetylene torch being used in the building's machine shop. An inventory of the building's contents taken four days prior to the fire indicated storage of approximately 100 different pesticide products and six different fertilizer products containing 80 tons (72.5 Mt) of active ingredients (see Table 1). One-half of the active ingredients consisted of a commercial product called Aatrex 4L, containing the organic herbicide atrazine; another 22 percent could be accounted for by another commercial pesticide, Lasso, containing the organic herbicide alachlor. Other pesticide products stored in the north building included Furadan, Thimet, Lorsban, and Dyfonate. These substances are toxic to humans and to certain plants and animals in varying degrees, but all are potentially damaging to humans as well as plants and animals.

While area fire departments were able to confine the fire to the north building and extinguish it within a few hours, an estimated minimum 500,000 gallons (1.9×10^6 l) of water was applied to the blaze at a rate of 2,000 gallons (7,500 l) per minute. This fire water mixed with the various pesticide chemicals stored inside the building, and flowed over the asphalt and frozen soils around the building toward the three catch basins at the site's periphery (see Figure 2). From the southeast and southwest catch basins, the contaminated fire water flowed via the underground concrete culvert to Ryan Creek, which was dry at the time. The fire water ponded at the western catch basin. To prevent additional runoff from flowing any further along the creek, officials constructed an earthen dike across Ryan Creek about 80-100 feet (24 - 30 m) downstream of the culvert outlet. To prevent flooding of the Soo Line access road behind this dike, a second dike was built further downstream and the first dike was intentionally breached. At day's end, the ponded fire water was up to two feet (0.6 m) deep along the creek bed, although it never actually reached the second dike, and up to three feet (1 m) deep near the southeast and southwest catch basins. On the next day, January 7, officials observed that 90 percent of the water previously ponded in the creek and near the three catch basins had infiltrated through the soil, leaving 10 percent frozen on the surface.

DESCRIPTION OF CONTAMINATION

As a result of the fire and the manner in which it was extinguished, a great variety of sources and avenues of contamination by hazardous substances was created. These are discussed in the following in order of most to least imminent threat posed to human health and the environment.

TABLE 1. HOWE CHEMICAL CO. FIRE PARTIAL INVENTORY
(Barr Engineering, 1980)

Company	Product	Type	Active Ingredient	Amount of Product	Total lbs. of Active Ingredient	Formulation	Active Ingredient Acute Oral LD50 (rats)
CIBA-GEIGY	Aatrex 4L	herbicide	atrazine	20,000	80,000	liquid (EC)	3,080
Monsanto	Lasso	herbicide	alachlor	8,610 gal.	34,440	liquid (EC)	1,800
Dow	Dow DMA-4	herbicide	2,4D	2,600 gal.	10,000	liquid (Amine Salt)	370
FMC	Furadan 10G	insecticide	carbofuran	80,400 lbs.	8,040	granular	11
Dow	Lorsban 15G	insecticide	chlorpyrifos	24,350 lbs.	3,652	granular	163
FMC	Thiodan EM-2	insecticide	endosulfan	1,764 gal.	3,528	liquid (EC)	100
CIBA-GEIGY	Diazinon	insecticide	diazinon	800 lbs. 227 gal. 1,500 lbs.	1,770	granular, WP, liquid	300
CIBA-GEIGY	Dual	herbicide	metolachlor	315 gal.	1,890	liquid (EC)	2,780
PPG	Chloro IPC	herbicide	chloropropham	400 gal.	1,600	liquid (EC)	3,800
Dow	Bexton	herbicide	propachlor	2,000 gal. 240 gal.	1,360	granular liquid (EC)	710
U. Carbide	Sevin 80W	insecticide	carbaryl	1,640 lbs.	1,312	WP	500
Shell	Bladex	herbicide	cyanazine	30 lbs. 330 lbs. 210 gal.	1,104	WP, liquid (EC) granular	334
American Cyanamid	Thimet 15G	insecticide	phorate	7,000 lb.	1,050	granular	3
Stauffer	Dyfonate 4E 20G	insecticide	fonofos	1,250 lb. 180 gal.	970	granular liquid (EC)	10
Elanco	Treflan EC	herbicide	Trifluralin	197 gal.	788	liquid (EC)	10,000
Dow	Dow Pon M	herbicide	dalapon	1,930 lbs.	772	liquid (Salt)	970
Stauffer	Eradicane 6.7E	herbicide	EPTC	115 gal.	770	EC	2,000

(Source: Barr Engineering Co. draft report, August 1980)

Air Pollution/Direct Exposure

The fire itself involved the combustion of pesticide vehicle compounds, many of which were organic solvents, producing a dense smoke containing volatilized pesticides. Pigeons flying through the smoke plume were observed to fall dead immediately, and a great number of pigeons were discovered dead on the Howe site the day after the fire. In addition, bystanders reported intense respiratory irritation, and 11 fire fighters became ill and a news reporter was hospitalized due to smoke inhalation. Fortunately, the smoke plume moved over a predominantly industrial area at a relatively high altitude. However, some concern was voiced over the possibility that fallout from the smoke plume had contaminated snow covering the off-site areas in the plume's path, and that children sledding in these areas would thus be directly exposed to the pesticide contaminants. Analysis of snow samples taken from these areas, however, did not indicate dangerous levels of pesticides.

Also of concern were the odoriferous and irritating vapors that could be detected emanating from the building debris, pesticide residues and ice removal operations from blocks away for several days after the fire. Clean-up workers were not experiencing symptoms at that time, however, and only the pesticides Endosulfan I and II could be detected in the air samples analyzed.

At a later point during the ice removal operations, however, several clean-up crew members complained of a burning sensation on their hands, faces and upper respiratory tracts. These symptoms were treated successfully with skin cream and respirators, respectively. In addition, the ice removal crew foreman collapsed on the job and was hospitalized for one day. The reason for his collapse could not be ascertained.

Contaminated Building Debris

The building and other fire debris on the Howe site was categorized into three classes: (1) high level wastes consisting of ruptured pesticide containers or pieces of burnt or frozen pesticides material; (2) heavy iron such as burned trucks; and (3) low level wastes such as building rubble. Only the "high level" waste category above was considered a high priority disposal issue by the state. Table 2 contains a post-fire inventory of chemicals recovered and removed from the site.

As a result of the contamination and runoff of fire water, the state had to remove a total of 1,600 cubic

TABLE 2

HOWE, INC. FIRE
CHEMICALS RECOVERED AND REMOVED FROM SITE

Company	Product	Amount of Product Recovered	Comments
Stauffer	Dyfonate 10G & 20G	12,225 lbs.	
Stauffer	Eptam, Sutan, Eradicane	105 gals.	amounts of each not discernable
Stauffer	Thimet 10G	750 lbs.	
CIBA-GIEGY	Aatrex 4L	3,425 gals.	
CIBA-GIEGY	Dual 6E	540 gals.	
CIBA-GIEGY	Diazinon 50W	900 lbs.	approximate
Dow	Telone II Telone C-17	4,150 gals. 700 gals.	
Monsanto	Lasso	2,520 gals.	

(Source: Department of Agronomy Services memorandum, Feburary 23, 1979) yards (1,223 cu. m) of ice and snow containing 270 pounds (123 kg) of atrazine and 280 pounds (127 kg) of alachlor, and 1,000 cubic yards (765 cu. m) of surface soil containing 300 pounds (136 kg) of atrazine and 700 pounds (318 kg) of alachlor.

Ground Water and Subsurface Soil Contamination

Barr Engineering conducted a study of ground water and soil contamination at the Howe site from January through April, 1979. Ten soil borings were completed in January and February, 1979, along Ryan Creek and on the Howe property in areas where ponding and/or infiltration of contaminated runoff was known or suspected to have occurred (see Figure 2). Eighteen ground water monitoring wells and one pumping well were installed in the same areas in two separate phases (see Figure 2). In order to assess the relative significance of each pesticide in a sample and to compare the relative degree of contamination from one sample to another, an artificial parameter called a "control ratio" was created. For a given sample and pesticide, the control ratio was the ratio of the concentration measured in the sample to the standard set for that parameter by the Minnesota Department of Health (MDH). A control ratio of less than one, then, indicates that the parameter does not exceed the MDH standard.

300.65(b)(5) sampling

Barr Engineering (1980) made the following observations with respect to the soil test values:

- "Soil samples from the borings along Ryan Creek (B-1, 2, 3, 4, 5, 7) show significantly higher concentrations of nearly all pesticides under analysis than from the borings near the Howe, Inc. property (B-6, 7, 8, 9 and 10).

- "With few exceptions, Thimet and Bladex concentrations govern the control ratio in Ryan Creek borings, although levels of Atrazine, Lasso, Ramrod, Endo I, Endo II and Diazanon exceed MDH standards in many samples.

- "Bladex tends to govern the control ratio in borings near Howe, Inc. property with levels of Atrazine, Thimet and Diazanon exceeding MDH standards in a few samples.

- "The highest levels of contamination, as measured by control ratio, are from borings B-4 and B-5 which are located along Ryan Creek and downstream from the culvert outlet. Thimet and Bladex governs the control ratio and results in the control ratio increasing with depth.

- "In borings along Ryan Creek where Bladex tends to govern control ratios (B-1, 2, 7) the control ratio shows the tendency to decrease with depth.

- "Control ratios in borings near Howe, Inc. property generally appear to decrease with depth. Below a depth of 2 to 4 feet (0.6 to 1.2 m) in borings B-8 and B-9, and 10 to 12 feet (3.0 to 3.7 m) to borings B-6 and B-10, control ratios are less than unity.

- "No obvious correlations appeared to exist between soil texture and levels of concentration of any of the pesticides under analysis. There is some tendency, however, for the finer grained soils encountered near ground surface on the Howe, Inc. property to contain higher pesticide concentrations than the coarser subsoils."

Barr Engineering made these additional observations with respect to ground water test values through April, 1979:

- "Monitoring wells on the Howe, Inc. site (P-6, 8, 10 and 23) shows significantly lower concentrations of nearly all parameters analyzed in comparison to wells along the banks of Ryan Creek (P-1, 5, 15, 16 and 17). The only exception to this condition was for Atrazine, which exceeds MDH standards in wells P-8 and 10, but in no other monitoring wells within the study area.

- "Monitoring wells nearest the culvert outlet to Ryan Creek (P-1, 16, 17, and W-1) show the highest control ratios encountered in the study area. Bladex, Lasso, Ramrod and Thimet concentrations exceeded MDH standards in most of these wells, with Bladex generally governing the control ratio. The concentration of Bladex, Ramrod and Lasso decreases by more than an order of magnitude within the first 20 feet (6.1 m) of water table.

- "Further downstream of the culvert outlet, at well P-5, Bladex, Ramrod and Thimet concentrations exceed MDH standards. However, the control ratio in P-5 was about one-half of the control ratio for P-1 or P-16. At P-15, which is down gradient of P-5, only Bladex concentrations exceeded MDH standards.

- "The monitoring wells south of Ryan Creek (P-20 and 21) were generally clean except for the Bladex concentrations in P-21 which slightly exceeded MDH standards.

- "The monitoring wells along 49th Avenue North (P-11 through 14) and north of Ryan Creek (P-18 and 19) were also generally clean except for the Thimet concentrations in P-12 which exceeded MDH standards.

- "The rate and direction of the movement of contaminants or changes in concentrations with time could not be strictly established with the data available through April , 1979."

PLANNING THE SITE RESPONSE

Initiation of Response

Alternative Water Supply

On January 15, 1979, the MDH ordered that use of all drinking water wells within a three-block radius of the site be discontinued. All houses in Minneapolis east of the site were already connected to municipal water, as were most houses in Brooklyn Center, north of the site. Consequently, it was only necessary to connect 11 houses in Brooklyn Center to municipal water to ensure that residents were not exposed to contaminated drinking water. As ground water monitoring had not yet begun, the MDH's order was based on very limited data on the extent of contamination. The only sampling data available at the time of the order was for ice, which was found to contain as much as 5,200 mg/l of atrazine. The MDH concluded that in light of the larger volume of contaminated water that had been absorbed into the highly permeable soil, it was prudent to err on the side of caution and close nearby wells. Later, monitoring revealed that ground water contamination was limited to the area along Ryan Creek, and that the closed wells were hydrogeologically upgradient from the contamination.

300.65(b)(2) alternative water supplies

300.65(a)(2) contamination of drinking water supply

Ice, Snow, and Soil Removal

The MPCA believed it was necessary to remove contaminated ice and soil from the site as soon as possible to prevent contamination from spreading. If temperatures had risen, the ice would have melted and possibly leaked from its temporary containment structure. Runoff into Ryan Creek would have carried pesticides from the most highly contaminated layer of soil near the surface downstream or deeper into the ground water. Further, officials of the

300.68(e)(2) source control: removal

City of Minneapolis and of the Soo Line Railroad insisted that the State move quickly to remove the materials from the Soo Line property.

Ground Water Recovery

In late March, 1979, the MDH decided to install a ground water recovery system along Ryan Creek in order to reduce the potential for exposure of nearby residents to hazardous levels of pesticides. Although exposure through drinking water was not a concern since all homes near the site were by this time connected to municipal water, there was a possibility that spring runoff would flood basements along 49th Avenue North and carry pesticides into homes. The MDH had no means of assessing the health risk to residents if such an event were to occur and, thus, might have been forced to evacuate any homes that flooded. The MDH viewed ground water pumping as a means of avoiding this problem.

300.70(b)(1) (iii)(C) ground water pumping

A secondary reason for pumping ground water was that some nearby residents used wells for irrigating lawns, which posed a potential for direct contact exposure to pesticides. Finally, there was a slim possibility that contaminants could have migrated to municipal drinking water wells miles away from the site.

Selection of Response Technologies

The following subsections describe the identification and evaluation of alternative response technologies for the Howe site. These descriptions are based upon information presented in a comprehensive review of events at the site, particularly of decisions made by the state, contained in an MPCA file document (undated).

300.68(g) development of alternatives

Fire Debris Removal and Disposal

As described earlier, there were three categories of building and miscellaneous debris resulting from the Howe fire. No alternatives to the disposal methods outlined below were seriously considered by the state. The "high level waste" containing ruptured pesticide containers and frozen or burnt pieces of pesticide material was separated into identifiable and unidentifiable pesticide products. Several pesticide manufacturers sent representatives to the site to identify their products so that they could be transported out of state for recovery or disposal. The unidentifiable, usually mixed pesticide residues, were trucked to a hazardous waste disposal facility in Illinois, because no such facilities existed in Minnesota and the RCRA regulations prohibited its disposal in a sanitary landfill. The heavy iron portion of the fire debris was magnetically separated on-site from the rest and then trucked to a nearby foundry where it was cut up and reclaimed as scrap iron. The remaining "low level waste", mainly wood timbers and paper sacks, was determined nonhazardous and therefore was disposed of in a nearby sanitary landfill.

Ice, Snow and Surface Soil Disposal

A great number of alternatives were proposed and evaluated for removal and disposal of the contaminated ice, snow and surface soils. These are described below in approximate order of their consideration.

1. Land Spreading - Elk River Farm Site. This option involved trucking the contaminated ice, snow and soil to a farm site near Elk River, Minnesota where it could be applied safely to agricultural land like any other agricultural chemicals. The site was selected above others due to its higher soil organic content, greater distance from surface water bodies, and lower slope. A number of technical problems were raised - and some resolved - with this proposal. In any event, a Commissioner of Anoka County, the county in which the Elk River site was located, threatened to seek an injunction if the waste was brought to the county, thereby effectively killing the entire plan.

2. Special Area in a Sanitary Landfill. This option involved placement of the contaminated materials in a specially designated area of a sanitary landfill with a sealed bottom. This plan was rejected because: (1) the $60,000 cost of preparing the special area was not deemed affordable; and (2) the MPCA was unwilling to approve the idea given that hazardous waste regulations they were about to promulgate specifically prohibit such a practice.

3. Sugarbeet Plant. A sugarbeet plant offered to mix the contaminated ice and soil with their plant waste which was degraded in a series of ponds and then sprayed on grass or alfalfa fields. Calculations indicated the dilution of the ice and soil in the system would be so large that no environmental or health impact would result. Local opposition, however, killed the plan.

4. Gasohol. A farmer in Webster, Minnesota offered to apply the ice and soil to 280 acres (111 ha) of corn fields used solely for the production of

alcohol. While the approval of the Rice County Commissioners was carefully sought and obtained prior to public knowledge of the plan, the farmer's neighbors heard of it and strongly objected. The farmer withdrew his offer.

5. Incineration at 3M Company. 3M Company offered to incincerate the contaminated ice and soil at their Twin Cities area facility which is used to burn organic wastes. Although the incinerator had an operating temperature greater than the 1,800°F (982°C) needed to break down pesticides, the system's 0.1 second retention time was determined insufficient for complete waste decomposition.

6. Incineration at the King Plant. Northern States Power Company (NSP) offered to incinerate the waste at their Allen S. King plant on the St. Croix River. The plant boiler's operating temperature of 2,800°F (1,538°C) and two seconds of retention time were more than adequate to break down the pesticides. A scheme was devised involving mixing of contaminated ice and snow with coal in a 1:99 ratio such that 10 days would be required to burn all of the waste. In addition, certain potential plant worker health problems related to ventilation were able to be resolved in advance. However, before waste already transported to the plant could be incinerated, the citizens of the local community, Oak Park Heights, learned of the plan through the news media and forced a special meeting of the City Council. The Council passed a resolution forcing NSP to withdraw its offer to incincerate the waste.

7. Out-of-State Disposal. Failing all of the above disposal alternatives, state officials devised a plan to truck the wastes to a permitted hazardous waste disposal facility in Illinois. The plan would have involved two trips by a convoy of 40 end dump trucks. An emergency disposal permit application for the waste to be trucked was submitted to the Illinois EPA. Before the application could be reviewed, however, Illinois EPA officials decided not to grant the emergency permit, preferring instead to hold public hearings as in the course of a normal permit application process in Illinois. The minimum advance public notice of 21 days for such hearings, however, was felt by Minnesota officials to pose

too great a risk of melting and leakage from the stockpiles of contaminated ice and soil.

8. Land Spreading - Robertson Farm Site. As a last resort, the state's new Commissioner of Agriculture convinced a neighhoring farmer to allow the waste to be applied to his land in the spring after the ice melted. The Commissioner was also able to win the approval of local citizens.

Ground Water and Subsurface Soil Decontamination

To address its several concerns over potential ground water contamination, the state hired Barr Engineering to conduct hydrogeologic studies of the Howe fire site, to evaluate alternative methods to mitigate contamination, and to recommend and implement the most promising such plan. Barr assumed that contaminants in the subsurface soils would eventually degrade or be washed down to the water table where they could be controlled or removed. As a result, further evaluation of mitigative measures focused on the ground water problem. Of the many mitigative methods evaluated, barrier wells, impervious barriers, chemical treatment by injection, and a single, large-diameter, deep well proved to be too costly, ineffective or too slow. Three methods were selected as being potentially most effective, including: (1) open pumping from ditches or sumps; (2) a shallow, low-capacity well point system; and (3) a deep, high capacity, gravel-packed well system.

Barr Engineering (1980) provided the following description of the basic design, operation, advantages, disadvantages and conclusions regarding the three selected mitigative methods:

1) "Open ditches and sumps -- continuous rock or gravel-lined excavations parallel to Ryan Creek with 2 to 1 (horizontal to vertical) side slopes and cut approximately 10 feet into the water table. This scheme was found to be relatively impractical for several reasons:

   - Limited depth of intercepting ground water
   - High excavation costs
   - Possibility of accidents from open excavation
   - Exposure of contaminated waters to environment
   - Extensive areas scarred by excavation

- Increased pumping during periods of rainfall and runoff.

2) "Shallow well points -- multiple (5 to 10), small diameter (or 5.1 to 10.1 cm) (2 to 4 inches), well points placed several feet into the water table and located parallel and perpendicular to Ryan Creek. This scheme was found to be less expensive and more pratical than open-pumping, but still had several problems. These were:

   - Would not intercept ground water at depths below about 10 to 15 feet (3.0 to 4.6 m)

   - Difficult to control and monitor individual well performances if not using individual well pumps

   - Time required to cleanse area of contaminants could be long if wells are of low capacity

   - Discharge piping becomes expensive

   - High maintenance costs.

3) "Deep wells -- 3 to 5 screened and gravel-packed wells, 6 or 8 inches (15 or 20 cm) in diameter, individually controlled and installed to some depth below the water table (20 to 30 feet [or 6.1 to 9.1 m]) along Ryan Creek. This scheme was found to be the most practical. Major advantages were:

   - Less expensive than ditches or sumps -- easy installation

   - Safer than ditches or sumps

   - Greater control over system operation, cost and duration of pumping

   - More flexibility in varying vertical and lateral extent of interception, discharge rates, local gradient, and drawdown

   - The ability to use the wells for field tests to determine aquifer characteristics

   - More easily and cheaply protected than numerous well points."

As a result of these evaluations, Barr Engineering recommended the deep-well pump-out system for the recovery of contaminated ground water near Ryan Creek.

Extent of Response

Soil Removal

The MPCA's contractor excavated 1000 cubic yards (765 cu.m) of contaminated soil at a depth of one to two feet (30-60 cm) from a 900 foot by 15 foot (275 x 5m) area of Ryan Creek extending east from Brooklyn Boulevard. The MPCA based the extent of excavation on sampling data available at the time indicating that the stream bed was the most contaminated area, and that soil contamination was concentrated in the top one to two feet (30-60 cm) of soil, tapering off rapidly with increasing depth. Soil borings showed that the Howe property, which was mostly paved, was not heavily contaminated. The MPCA believed that spring recharge would wash the remaining deeper soil contamination down to the water table where it would be removed by ground water pumping expected to begin later that spring.

300.68(j)
extent of remedy

Ground Water Recovery

Barr Engineering used a hydrogeological computer model to determine the most efficient size and design of the ground water recovery system. Barr analyzed the soil permeability and ground water gradient to predict the number and spacing of wells and the pumping rate that would create sufficient water table drawdown to encompass the zone of significant ground water contamination.

The MDH determined the goal of ground water pumping by establishing "levels of concern" for each of the pesticides found in the ground water, intending to continue pumping until monitoring indicated that the contamination was below the levels of concern. The acceptable levels of pesticides in ground water were set based on information from three primary sources: (1) "suggested no adverse-effect levels in drinking water" developed by the National Academy of Sciences; (2) "allowable daily intakes" set by the World Health Organization; and (3) extrapolation from crop tolerance levels established by the Environmental Protection Agency. The National Academy of Sciences no-adverse-effect level in drinking water for a particular contaminant is derived by combining the maximum no-observed-adverse-effect level from animal studies with an uncertainty factor to calculate an acceptable daily intake (ADI) for humans. The ADI is then adjusted by a factor to account for a portion of exposure anticipated from drinking water. For atrazine and alachlor, the predominant contaminants, the uncertainty factor is 1,000. The relatively high uncertainty factor for these two chemicals reflects the paucity of toxicological data on which to base the ADI.

Because there were no established acceptable levels of pesticides in soil, it was necessary to calculate soil levels based on acceptable ground water levels. In order to make this calculation, several assumptions were made. First, it was assumed that the moisture content of the soil in question was approximately 15 percent. Second, it was assumed that the pesticides in the soil would be completely and rapidly leached into the ground water with the spring infiltration. Finally, it was assumed that the pesticides in the water component of the soil cannot be above the acceptable levels in ground water. Then by multiplying the moisture content by the acceptable ground water level for each pesticide, an acceptable soil level was obtained. It should be noted that these levels are given in micrograms per liter of soil and should be corrected for the difference in the density of soil and water if comparisons are made with measured values (see Table 3).

Ground water pumping began on June 7, 1979. The MDH had hoped to complete pumping by the end of that month; however, contaminant levels had not been reduced significantly by that time, so pumping continued until November 14, 1979. When pumping stopped in November, the levels of most contaminants in most of the wells were lower, but were not all below the MDH levels of concern. The MDH stopped pumping because of the difficulties of operating the system during winter, intending to sample ground water the following spring and evaluate the need to resume pumping.

The final ground water samples were taken in June 1980. Contaminant levels had dropped further in some wells, but had risen in some of the easternmost wells, which were hydrogeologically down-gradient. This suggested that the contamination was migrating with the flow of ground water, and that some contaminants had probably passed beyond the effective zone of influence of the ground water recovery system. In August 1980, the MDH decided not to resume pumping, concluding that, since the ground water in the Ryan Creek area was not used for drinking water, the levels of contamination present did not pose a health threat. Further, there was some doubt about whether the reductions in contamination that had been recorded were even primarily attributable to the ground water recovery system, or were instead a result of dilution caused by spring recharge of the contaminated aquifer.

TABLE 3. MINNESOTA DEPARTMENT OF HEALTH LEVELS OF CONCERN FOR PESTICIDES AT HOWE, INC.

Common and or Trade Name	Chemical Name	Acceptable Ground Water Levels, ug/l	Acceptable Soil Levels, ug/l of Soil
Ethoprop or Mocap	0-ethyl S,S-dipropyl phosphorodithioate	1.0	0.15
Phorate or Thimet	0,0-diethyl S-((ethylthio)methyl) phosphorodithioate	0.7	0.11
Diazinon	0,0-diethyl 0-(2-isopropyl-6-methyly-4-pyrimidinyly) phosphorothioate	14.0	2.1
Malathion	diethyl mercaptosuccinate S-ester with 0,0-dimethyl phosphorodithioate	160.0	24.0
Alachlor or Lasso	2-chloro-2", 6'-diethyl-N-(methoxymethyl) acetanilide	700.0	105.0
Endosulfan I and II or Thiodan I and II	6, 7, 8, 9, 10, 10-hexachloro-1, 5, 5a 6, 9, 9a-hexahydro-6,9-methane-2, 4, 3-benzodiox-thiepin 3-oxide	50.0	7.5
Cyanazine or Bladex	2-((4-chloro-6-(ethylamino)-s-triazin-2-yl)amino)-2-methylpropionitrile	2.0	0.3
Propachlor or Ramrod	2-chloro-N-isopropylacetanilide	700.0	105.0
Chloropyrifos or Lorsban	0,0-diethyl 0-(3, 5, 6-trichloro-2-pyridyl) phosophorothioate	11.0	1.7
Terbufos or Counter	S-(tert-butylthio)methyl) 0,0-diethyl phosphorodithioate	2.0	0.3
Atrazine or Aatrex 4L	2-chloro-4-ethylamino-6-isopropylamino-s-triazine	150.0	22.5

(Source: Minnesota Department of Health, 1979)

DESIGN AND EXECUTION OF SITE RESPONSE

The two major elements of the Howe site response are covered in this section; they are: (1) the removal and disposal by land spreading of the contaminated ice, snow and surface soils; and (2) the decontamination of ground water by a ground water pump-out system.

Land Spreading of Contaminated Ice, Snow and Surface Soils

The following description of the design and execution of land spreading the Howe site's contaminated ice, snow and surface soils is based primarily on a January 1981 MDA summary of these activities.

A number of potential technical problems were identified and some resolved prior to land spreading the contaminated materials. First, a special and unpredictably adverse runoff situation might occur if the contaminated materials were applied over a field covered by two feet (0.6 m) of snow. Second, the inhomogeneity of the contaminated ice and snow could produce a situation in which pesticide concentrations exceed acceptable levels in small localized areas even though, on average, calculations showed a safe application rate. Third, the inhomogeneity of the contaminated ice and show applied would also make it impossible to accurately measure the crops harvested for their suitability for human consumption. All three of these potential problems were resolved simply by storing the contaminated materials in a holding pit until both the snow covering the fields and the contaminated ice and snow in the pit melted. After the contaminated ice and snow melted, the resulting contaminated water could be mixed to achieve homogeneity. One problem that was not addressed was that the contaminated materials contained up to 60 compounds in an unknown mixture, and that the persistence of mixtures of pesticides in the enviornment is known to be far greater than that of individual pesticide compounds.

On the Jim Robertson farm, therefore, a contractor for MPCA constructed a 200 foot long, 20 foot wide and 5 foot (61.0 x 6.1 x 1.5 m) deep holding pit with bermed sides and a bottom lined with two layers of PVC. In late March, the contaminated ice and snow from the fire site was transported and placed in the pit along with several tanker loads of contaminated liquid collected at the fire site. The contaminated soil was also transported to the farm and piled in the holding area along the side of the pit.

In April of 1979, the impounded ice and snow had begun to melt, and samples were taken and analyzed to determine pesticide concentrations. After analysis, the contaminated liquid was applied to a field on the farm which had been planted with corn. The contaminated water was spread on the fields on seven separate days within a 30-day period during May and June, 1979. A liquid manure spreader with a 2,200 gallon (8,330 l) capacity and 20 foot (6.1 m) wide spread pattern was used to apply the liquid. This equipment was necessary since the pesticide mixture was so dilute as to require the application of a relatively large volume - approximately 2,500 gallons per acre (23,900 l/ha) in order to reach pesticide label application rates. In all, 73.5 loads or 161,700 gallons (612,000 l) of liquid containing an estimated 162 pounds (73.5 kg) of alachlor and 16 pounds (7.3 kg) of atrazine were applied over 74 acres (29.3 ha). This resulted in a pesticide application rate of 0.22 pounds (0.1 kg) of atrazine and 2.2 pounds (1.0 kg) of alachlor per acre. Soil samples from this acreage were taken and analyzed before and after application of the contaminated liquid.

The soil stockpiled in the holding area was also sampled and analyzed for pesticide contaminants. In September, 1979, after analysis, the soil and lime (from the fire site containment berms) were spread out and mixed over the entire 2.5 acres (1.0 ha) of the holding area, and large rocks and other debris were removed by hand. To promote biodegradation of the pesticide compounds, this soil was frequently cultivated and liquid hog manure was applied as a source of organic matter. Additional soil samples were taken and analyzed to monitor the breakdown of the pesticide compounds.

During crop growth, corn plants were visually monitored for symptoms of chemical injury. No symptoms were observed; the seedlings grew and developed at a normal rate. Good weed control and higher yields were observed in the treated areas. Leaf and ear tissue analyses for pesticides were negative.

At this writing, the 74 acre (29.3 ha) liquid spreading area is being cultivated and produces normal, marketable corn. The 2.5 acre (1.0 ha) soil spreading area, however, is still being cultivated with manure and is not used for crop production.

Ground Water Recovery System

The deep-well pump-out system's purpose was to remove contaminated ground water in the vicinity of Ryan Creek. Thus, the planned zone of capture included 49th Avenue

North between Xerxes and Russell Avenues, and extended to the Soo Line Railroad Yard south of the creek. The assumed maximum depth of contamination to include in the capture zone was 25 to 30 feet (7.6 to 9.1 m). Optimal well locations and discharge rates for the planned zone of capture were determined by computer modeling. Several different well configurations and discharge rates were evaluated, and conservative drawdowns were predicted along 49th Avenue North and the Soo Line Railroad Yard. Of the various well network designs analyzed, the one that proved most effective consisted of four wells placed along the north bank of Ryan Creek about 300 feet (91.4 m) apart and pumping 100 gpm (378 l/min) if the permeability of the screened strata is 0.025 cm/sec or 200 gpm (757 l/min) if permeability is 0.050 cm/sec (see Figure 3). State and Minneapolis officials agreed contamination levels of the pumped ground water would allow direct discharge to the sanitary sewer system, thereby avoiding the cost of on-site treatment.

Barr Engineering obtained a temporary permit from the MDNR to dewater the area for the purpose of removing contaminants. The permit extended from May 7 through June 30, 1979, and was later extented to June 30, 1980. The MDH obtained approval from the Metropolitan Waste Control Commission (MWCC) to discharge contaminated water to the Minneapolis sanitary sewer system, which outlets at the MWCC Metro Plant in Pig's Eye, Minnesota, for treatment. The maximum permitted pumping rate was 800 gallons per minute (3,000 l/min) for all four wells or 1.15×10^6 gallons per day (4.35×10^6 l/day).

The pumped ground water was collected via a six-inch (15.2 cm) PVC pipe and discharged via a eight-inch (20.3 cm) PVC pipe to a catch basin at the intersection of 49th Avenue North and Upton Avenue North, accessing the combined storm and sanitary sewer underlying 49th Avenue North (see Figure 3).

The four wells were installed in May, 1979. Each well was placed with a bottom screen 25 feet (7.6 m) below the water table. Pumping began in June, 1979, and extended five months to November 1979. The combined discharge rate of the four wells, as calculated from well flow meter readings, averaged 390 gpm (1,480 l/min), and for the five months of operation totalled nearly 990×10^6 gallons (3.75×10^9 l). Occasionally the wells were shut down for repairs due to overheating or sediment build-up inside casings, pumps and meters.

Ground water was sampled at two- to four-week intervals from the four pump-out wells as well as the smaller

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Ground Water Recovery System

The deep-well pump-out system's purpose was to remove contaminated ground water in the vicinity of Ryan Creek. Thus, the planned zone of capture included 49th Avenue

North between Xerxes and Russell Avenues, and extended to the Soo Line Railroad Yard south of the creek. The assumed maximum depth of contamination to include in the capture zone was 25 to 30 feet (7.6 to 9.1 m). Optimal well locations and discharge rates for the planned zone of capture were determined by computer modeling. Several different well configurations and discharge rates were evaluated, and conservative drawdowns were predicted along 49th Avenue North and the Soo Line Railroad Yard. Of the various well network designs analyzed, the one that proved most effective consisted of four wells placed along the north bank of Ryan Creek about 300 feet (91.4 m) apart and pumping 100 gpm (378 l/min) if the permeability of the screened strata is 0.025 cm/sec or 200 gpm (757 l/min) if permeability is 0.050 cm/sec (see Figure 3). State and Minneapolis officials agreed contamination levels of the pumped ground water would allow direct discharge to the sanitary sewer system, thereby avoiding the cost of on-site treatment.

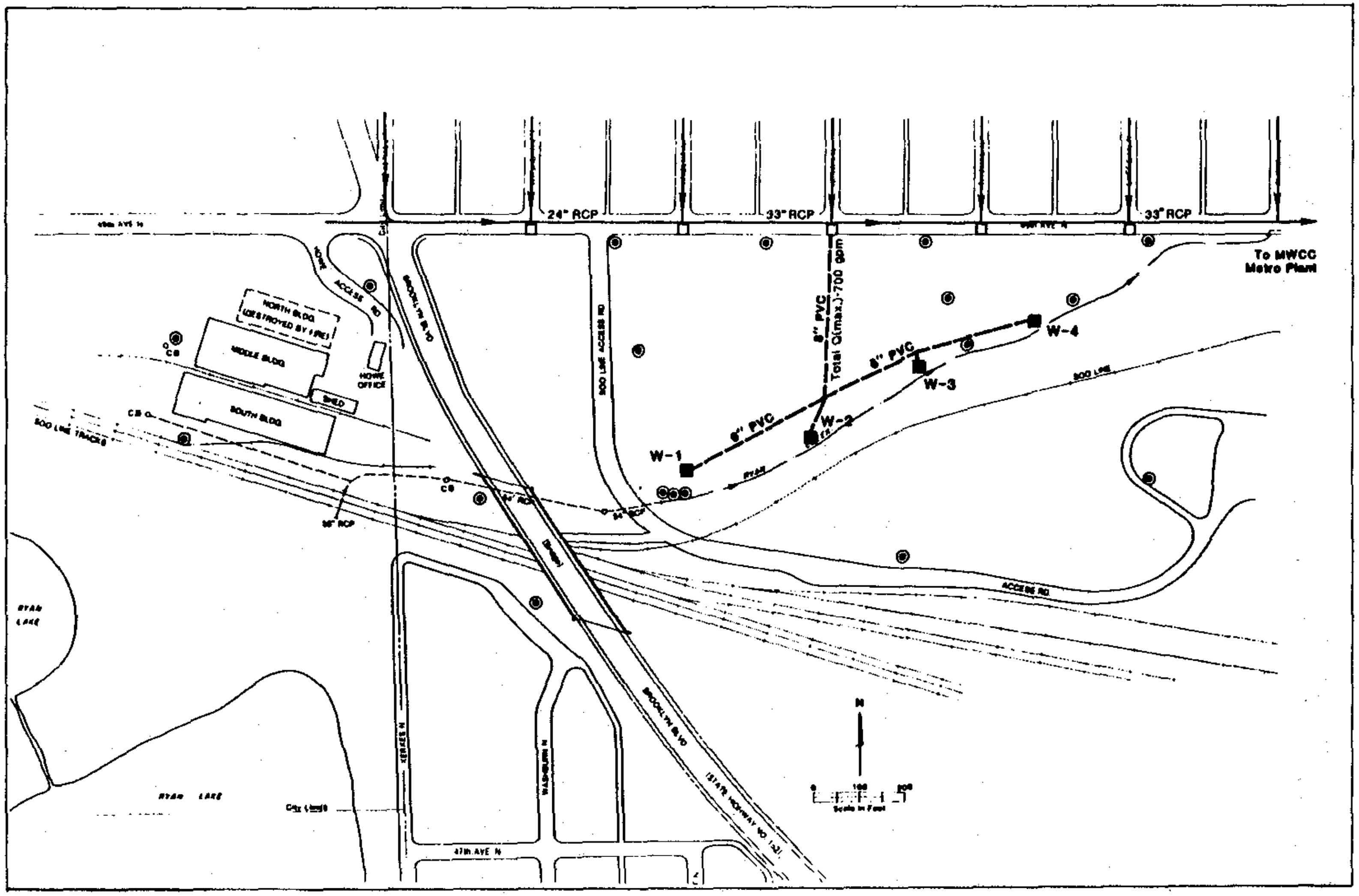
Barr Engineering obtained a temporary permit from the MDNR to dewater the area for the purpose of removing contaminants. The permit extended from May 7 through June 30, 1979, and was later extented to June 30, 1980. The MDH obtained approval from the Metropolitan Waste Control Commission (MWCC) to discharge contaminated water to the Minneapolis sanitary sewer system, which outlets at the MWCC Metro Plant in Pig's Eye, Minnesota, for treatment. The maximum permitted pumping rate was 800 gallons per minute (3,000 l/min) for all four wells or 1.15×10^6 gallons per day (4.35×10^6 l/day).

The pumped ground water was collected via a six-inch (15.2 cm) PVC pipe and discharged via a eight-inch (20.3 cm) PVC pipe to a catch basin at the intersection of 49th Avenue North and Upton Avenue North, accessing the combined storm and sanitary sewer underlying 49th Avenue North (see Figure 3).

The four wells were installed in May, 1979. Each well was placed with a bottom screen 25 feet (7.6 m) below the water table. Pumping began in June, 1979, and extended five months to November 1979. The combined discharge rate of the four wells, as calculated from well flow meter readings, averaged 390 gpm (1,480 l/min), and for the five months of operation totalled nearly 990×10^6 gallons (3.75×10^9 l). Occasionally the wells were shut down for repairs due to overheating or sediment build-up inside casings, pumps and meters.

Ground water was sampled at two- to four-week intervals from the four pump-out wells as well as the smaller

Figure 3. Pumping Well, Discharge Line and Sanitary/Storm Sewer Locations (Barr Engineering, 1980)



diameter monitoring wells. Water levels inside the well casings and selected well points in the area were also monitored periodically to ensure that drawdowns were not excessive.

Pumping was discontinued in November until spring as freezing weather approached and contamination levels began to decline. Low contamination in further samples taken in April and June of 1980 led the MDH to suspend pumping indefinitely.

COST AND FUNDING

Source of Funding

Funding for the Howe, Inc. clean-up came from a number of sources, including:

State of Minnesota	(contracting)	$335,564
	(internal)	$ 59,294
City of Minneapolis		$ 53,576
City of Brooklyn Center		$ 12,000
Howe, Inc.		$ 10,000
	Total	$470,434

Of the state funds, the largest part was a $152,321 emergency appropriation from the Governor's Executive Council, made twelve days after the fire, after initial containment measures were complete. The balance of state expenditures came from the operating budgets of the MPCA, the MDH and the MDA. A summary of the cost and funding for activities conducted at the Howe Site is given in Table 4.

300.62(a)
state role

Of the City of Minneapolis expenditures, most were sewer charges for accepting recovered ground water into the municipal sanitary sewer treatment system. There were miscellaneous additional expenditures totalling $2,121. The City of Brooklyn Center expenditure represents the cost of connecting eleven houses to the municipal water system.

The Howe, Inc. expenditure is a partial reimbursement to the MPCA for initial containment work at the site. Howe did not contribute further to remedial work outside the firm's property, although the company did spend $215,802 to remove fire debris from the company premises. This work is not included in the figure for the total remedial expenditures.

TABLE 4 . SUMMARY OF COST INFORMATION-HOWE, INC., BROOKLYN CENTER, MINNESOTA

Task	Quantity	Expenditure	Unit Cost	Funding Source	Period of Performance
Initial response	N/A	$25,290	N/A	State of Minnesota Minneapolis, Howe	1/6/79-1/13/79
Alternative water supply	11 houses	$12,000	$1,091/house	Brooklyn Center	1/79
Soil excavation	1,000 cu.yd (765 cu.m)	$13,881	$8/cu.yd. ($10/cu.m)	State of Minnesota	3/8-3/16/79
Transportation of ice & soil (140 mi) (225 km)	2,600 cu.yd (1,988 cu.m)	$74,273	$28.56/cu.yd 20¢/cu.yd/mi. ($37.36/cu.m) (16.6¢/cu.m/km)	State of Minnesota	3/8-3/16/79
Disposal of ice and soil	2,600 cu.yd. (1,988 cu.m)	$49,273	$7.41-18.95/ cu.yd. ($9.69-24.78/ cu.m)	State of Minnesota	2/79-9/79
Surface water removal	2.1 million gallons (7.9 million l)	$29,479	.014¢/gal (.0037¢/l)	State of Minnesota, Minneapolis	2/27-4/20/79
Ground water investigation	N/A	$50,000	N/A	State of Minnesota	1/79-5/79
MDH sample analysis	N/A	$12,536	N/A	State of Minnesota	1/79-6/80
Ground water recovery	90 million gal. (340 million l)	$62,329	.00069¢/gal. (.00015¢/l)	State of Minnesota	7/7-11/14/79
Ground water treatment (POTW)	90 million gal. (340 million l)	$50,169	.00056¢/gal. (.00015¢/l)	Minneapolis	6/7-11/14/79
Ground water recovery system data analysis	N/A	$24,719	N/A	State of Minnesota	12/2/79-8/30/80
Administration	4,225 hours	$46,758	$11.06/hr	State of Minnesota	1/79-5/81
Miscellaneous	N/A	$19,727	N/A	State of Minnesota	1/79-4/79
TOTAL		$470,434			1/79-5/81

Selection of Contractors

The first contractor hired for the response at Howe, Inc. was Fuel Recovery Company at St. Paul, Minnesota, a firm experienced in emergency oil and chemical spill clean-ups. Fuel Recovery was first contacted by the U.S. Environmental Protection Agency, and began work on containing ice and snow the day after the fire, before it was clear who would pay for the work. The MPCA, which had a standing emergency response contract with Fuel Recovery, agreed on the same day to pay for the work, and elicited an agreement from Howe, Inc. to pay for $10,000 of the expenditures.

All firms that the state subsequently hired for the Howe clean-up were contracted on an emergency basis, bypassing normal state procurement requirements, under authority granted to the involved agencies by the Executive Council. All contracts were for time and materials.

On January 15, 1979, the MDH retained Barr Engineering Company of Minneapolis to begin an investigation of soil and ground water contamination at the site. The investigation was estimated to cost $50,000, and it was understood that further expenditures might be required if the study found that remedial work was necessary.

C.S. McCrossan, Inc. of Osseo, Minnesota, was an excavation contractor originally subcontracted by Fuel Recovery to excavate ice and build the containment structure during the initial site response. Five weeks later, the MPCA contracted directly with McCrossan to excavate contaminated soil from the bed of Ryan Creek, line the stream bed with sand and plastic, and load the ice and soil for transport. The contract was limited to $15,000.

In late January 1979, the MPCA hired Scrap Haulers, of Riverdale, Illinois, to secure an Illinois disposal permit and to haul the ice and soil to an Illinois hazardous waste landfill. This disposal option was rejected a few weeks later in favor of landspreading, but the state paid Scrap Haulers for some administrative and testing expenditures.

In February 1978, the MPCA contracted with James F. Robertson, the owner of a hog farm in Martin County near Huntley, Minnesota, for the use of approximately 77 acres (31 ha) for landspreading contaminated ice and composting contaminated soil. The state agreed to pay Robertson $100 per acre ($247/ha) for landspreading, and $300 for the area occupied by a containment basin and contaminated soil. The state further promised that the materials would not pose a health hazard, that the pesticides in the melted ice would be spread at normal agricultural rates, that the state would pruchase Robertson's corn if it was found to be contaminated, and that the crop of the following year would not be adversely affected. Robertson agreed to spread the water when it melted, and to cultivate the contaminated soil with liquid manure from his hog farming operation.

The MPCA contracted with Robertson after exploring a number of other disposal options, each of which was rejected because of high cost or local citizen opposition. The MPCA located Robertson through his neighbor, who was the Minnesota Commissioner of Agriculture, and who helped to allay local concerns about the waste materials.

The MPCA hired G&T Trucking Co. of Elko, Minnesota to transport the ice and soil from the Howe site to the Robertson farm, a distance of 140 miles (225 km). G&T was hired on the basis of the competitive rates they charged, and because the firm was a licensed hazardous materials transporter.

In late February 1979, the MPCA hired W. Hodgman and Sons, Inc., an excavation contractor in Fairmont, Minnesota, to construct a containment basin for ice and snow at the farm. Hodgman was selected because the firm was located near the farm, reducing the cost of transporting equipment and personnel. The MPCA hired H.R. Loveall Construction, Inc., of Winnebago, Minnesota, to backfill the the containment basin after it was emptied and to spread the contaminated soil for composting. Again, Loveall was selected because the firm was located near the farm, reducing transportation costs.

Project Costs

The total cost of the Howe, Inc. clean-up was $470,434. Of this amount, the two largest components were: removal and disposal of contaminated materials, accounting for 35% of expenditures, and ground water investigation and recovery, accounting for 42%.

Initial Response

The initial response work at the site lasted eight days, from January 6 to January 13, 1979, and cost $25,290. Most of this amount, $23,159, was for work by Fuel Recovery, the MPCA's emergency response contractor. This work included constructing a plastic-lined containment area and excavating and moving 1,600 cubic yards

(1,223 cu. m) of contaminated ice and snow. Fuel Recovery's labor charge for 312 hours was $8,679, averaging $27.81 per hour. Excavation contractors cost $7,786; lime and sand for lining the containment area cost $5,612, delivered; miscellaneous costs totalled $1,089.

The City of Minneapolis spent $2,121 in the initial response, including $1,291 for a fence around the containment area, $401 for a police bomb squad to remove dynamite from the burned building, $279 of warning signs, and $150 for surveying Ryan Creek.

Alternative Water Supply

The City of Brooklyn Center spent $12,000 to connect eleven houses to the city water system, or $1,091 per house.

Removal and Disposal of Contaminated Materials

The total cost of excavating, transporting, and disposing of the contaminated ice, soil, and run-off water was $166,905. This amount is broken down by contractor expenditures as follows:

City of Minneapolis	$ 1,286
C.S. McCrossan	$ 13,881
James F. Roberston	$ 8,235
W. Hodgman & Sons	$ 31,602
Brock-White	$ 6,376
G&T Trucking	$102,465
Loveall Construction	$ 2,644
Town of Center Creek	$ 416
Total	$166,905

<u>Excavation</u>--C.S. McCrossan excavated 1,00 cubic yards (765 cu. m) of soil from a 900 foot by 15 foot (275 x 5 m) area of Ryan Creek, stripping off the top one to two feet (30 - 60 cm) of soil. McCrossan loaded the soil and the stockpiled ice into trucks for transport off-site. After excavating, McCrossan covered the stream bed with a layer of sand, placed a 20,000 square foot (1,858 sq. m), 10 mil polyethylene liner over the sand, and covered the liner with another layer of sand. Of the $13,881 paid to McCrossan, $6,688 was for equipment rental, $3,539 was for labor, $2,595 was for 865 cubic yards (661 cu. m) of sand, $790 was for the polyethylene liner, and $290 was for protective clothing.

300.70(c)(2)(i)
offsite
transport:
excavation

The available data are insufficient to enable calculation of an exact unit cost for soil excavation and loading, since McCrossan performed a few tasks simultaneously. However, a resaonable estimate is that soil excavation and loading cost about $8 per cubic yard ($10.97 cu. m).

Transportation--The state paid G&T Trucking $102,465 for transporting contaminated materials. From March 8 to March 16, 1979, G&T transported 1,600 cubic yards (1,223 cu. m) of ice and snow and 1,000 cubic yards (765 cu m) of soil 140 miles (225 km) to the Robertson farm in 232 loads, averaging 11.2 cubic yards (8.6 cu. m) per load. G&T charged $296 per load, plus a $410 premium for ten loads transported on a Sunday, totalling $69,082. G&T charged an additional $559 for lining trucks with plastic, and $4,632 for demurrage when the contaminated materials froze in the truck beds and delayed operations. The total cost of transporting the ice and soil was $74,273, or $28,56 per cubic yard, or 20 cents per cubic yard per mile ($37.36/cu. m or 16.6 ¢/cu. m/km).

300.70(c)
offsite transport

The state paid G&T $28,193 for removing melt-water runoff from the Howe site. From February 27 to April 20, 1979, G&T removed about 2.1 million gallons (340×10^6 l) of surface water from the site, pumping most of it directly into the Minneapolis sanitary sewers, and transporting some of it in tank trucks to the St. Paul sanitary sewer system. The City of Minneapolis incurred $1,286 in treatment costs for the water. The total unit cost of removing and treating surface water was about 0.014 cents per gallon (0.0037 ¢/l)

Disposal--The total cost of disposal of the contaminated ice and soil by landspreading was $49,273. The largest component of the cost, $31,602, was paid to W. Hodgman and Sons for constructing a containment basin at the farm and for unloading trucks. This work took 21 days, from February 27 to March 19, 1979. The state paid James Robertson, the owner of the farm, $8,235 for rental of approximately 77 acres (31 ha) of land, spreading the melted ice, and applying manure to the contaminated soil. H.R. Loveall Construction received $2,644 for restoring the basin site after it was emptied and for spreading the contaminated soil over 2.5 acres (1 ha). The state paid Brock-White Company $6,376 for a 20 mil 45 foot by 280 foot (14 x 85 m) PVC liner, including $5,040 for the liner itself and $1,336 for shipping and installation assistance. The state reimbursed the Town of Center Creek $416 for regraveling a road leading to the farm.

300.70(b)(2)
(iii)(3)
microbiological
degradation

Based on all costs incurred in the landspreading operation, the unit cost of disposal of 2,600 cubic yards (1,988 cu. m) of contaminated ice and soil was $18.95 per cubic yard ($24.78/cu. m). However, this figure is not an accurate representation of the cost of landspreading itself, since the bulk of expenditures, about 60%, was for constructing, lining, and later removing the containment basin. If the operation had not taken placed during winter, the contaminated materials could have been spread immediately, eliminating the need for a storage structure. The cost of the basin can only be approximated, given the available data, but was probably about $30,000. If this cost is not included in the disposal cost calculation, the unit cost of disposal would be about $7.41 per cubic yard ($9.69/cu. m), most of which was for unloading the ice and soil, rental of the land, spreading water, and treating the soil with applied compost.

Ground Water Investigation and Site Dewatering

The ground water investigation took place from January to May 1979. Barr Engineering installed the dewatering system in late May and early June 1979, and operated it from June 7 to November 14, 1979, a total of 160 days, recovering almost 90 million gallons (340×10^6 l) from the Ryan Creek area. Over the following nine months, Barr did some addtional sampling, analyzed data, and produced a final report.

The total cost of the ground water investigation, removal, and treatment was $199,753. The state paid Barr Engineering $137,048, including $50,000 for the ground water investigation and initial design of the dewatering system, $62,329 for final design, installation and operation of the system, and $24,719 for analyzing data after dewatering ceased. The unit cost of installing and operating the system, not including investigation, was 0.69 thousandths of a cent per gallon (0.00018 ¢/l). In interpreting the unit cost, it is important to note that over 90% of the installation and operation cost was for final design work and installation, and of the remaining operation cost, the majority was for data analysis. Consequently, the unit cost of ground water recovery was primarily a function of the total quantity of water removed, rather than the cost of operating the system.

The City of Minneapolis paid $50,169 for treatment of 90 million gallons (340×10^6 l) of water discharged to the municipal treatment works. The unit cost of treatment was 0.56 thousandths of a cent per gallons (0.00015¢/l). The MDH spent $12,536 analyzing soil and ground water samples taken during the site investigation, the dewatering operations, and after dewatering ceased.

Administrative Costs

The state's administrative costs for overseeing the response at Howe, Inc. totalled $46,758. This figure does not include sample analysis, or the costs of cost-recovery litigation, which is ongoing. The MDH incurred costs of $27,953 for 2,625 hours of labor, averaging $10.65 per hour. The MPCA incurred costs of $13,709 for 1,200 hours averaging $11.42 per hour. The MDH incurred costs of $5,096 for 400 hours, averaging $12.74 per hour.

Miscellaneous Expenses

Miscellaneous expenses totalled $19,727. The state paid Scrap Haulers $8,702 for the administrative costs of obtaining an Illinois disposal permit, a disposal option that was ultimately rejected.

In late January 1979, the state paid G&T Trucking $2,015 for loading and transporting four loads of ice 40 miles (64 km) to the Northern States plant in Stillwater, Minnesota, for an incineration test, and then for taking the loads back to the Howe site after public opposition prevented the test from taking place.

In late April 1979, the state paid G&T $6,528 in loading and trucking costs and $2,482 in disposal fees to remove the emptied ice containment structure at the Howe site. G&T loaded and transported 73 truck loads, or about 900 cubic yards (688 cu. m) of sand and lime to a sanitary landfill about 30 miles (48 km) from the site. The unit cost of loading and transportation was $7.25 per cubic yard ($9.48/cu. m); the unit cost of disposal was $2.75 per cubic yard ($3.60/cu. m).

PERFORMANCE EVALUATION

Delays in Ultimate Disposal of Contaminated Ice, Snow and Surface Soils

For the most part, state officials responded to the Howe emergency clean-up efficiently and effectively. The various agencies involved quickly organized a task force, which was on the scene to make critical decisions at all the right times, and continued to coordinate smoothly among themselves throughout the clean-up period. However, two related factors, neither fully within the state's control, caused substantial delays in identifying a means and place for ultimate disposal of the contaminated ice, snow and surface soils removed from the Howe site.

First, Minnesota had no commercial facility for disposing of hazardous wastes. Pronounced public opposition had blocked proposals for siting new hazardous waste management facilities as far back as 1974. An inadequate plan for involving the public prior to the location decision has been cited by many as one of the chief causes for the failed proposal. Second, of the first seven disposal alternatives considered and rejected by the state, only one failed for technical reasons. The other six plans, including one to dispose of the wastes in a permitted landfill in Illinois, were killed by public oppositition. In at least some of these cases, it would be fair to say that the degree of public concern over the nearby disposal of hazardous wastes from an uncontrolled site clean-up was underestimated by the state. While decisions had to be made in an atmosphere of some urgency, it is clear that more planning to involve the public, especially to inform and educate them in advance of any disposal decisions, would have assisted in expediting safe ultimate disposal of the clean-up wastes.

Effectiveness of the Ground Water Recovery System

Minnesota officials deserve recognition for having established acceptable levels of pesticide contaminants for both ground water and soil in advance of ground water decontamination operations. However, a number of questions arise relating directly or indirectly to these standards:

1. To what extent were ground water contaminant levels reduced further downstream in the direction of flow?

2. To what extent were contaminant levels in the soil reduced?

3. To what extent were the standards actually used in deciding when to stop pumping?

4. To what extent was the recovery system responsible for the observed reductions in ground water contaminant levels?

These questions are discussed in turn below.

First, at the conclusion of their work, Barr Engineering (1980) pointed out that increases at the time in the levels of some parameters in the site's eastern most wells correlated with the predicted direction and rate of ground water flow at the site. In the 18 months since the fire, the leachate plume very likely could have migrated from the area of highest initial ground water contamination, i.e., where the fire water ponded at the culvert outlet on the western end of the Soo Line property, to these easternmost wells. Barr, therefore, recommended that additional monitoring wells be installed to the east of those wells most easterly at the time (W-4, P-15), and that these be monitored until no further threat to public health existed. This recommendation was never implemented, and therefore, it is difficult to determine whether ground water contamination eventually migrated downstream away from the site and toward nearby residential areas.

Second, Barr Engineering (1980) recommended that additional soil borings be taken in areas where MDH soil contamination standards were exceeded initially. The original assumption that pesticides in the soil would degrade or be washed down to the water table was never tested by taking more borings during the course of Barr's study. Since this recommendation was also not followed, it is difficult to determine to what degree ground water quality at the site continues to be threatened by significant concentrations of contaminants in the soil column.

Third, as discussed earlier, increases in some contaminants were observed in the easternmost wells when samples were taken in June 1980. In addition, many wells still showed contaminant levels above MDH standards. Nevertheless, the MDH decided not to resume pumping, concluding that the contamination levels present posed no threat to public health, since ground water in the Ryan Creek area was not used for drinking water. This decision raises the question of how seriously the MDH's levels of concern were taken as decision-making criteria.

Finally, since there was some evidence of leachate plume migration at the site, it is difficult to determine to what extent the ground water recovery system was responsible for the observed reductionos in contaminant levels in many wells. In addition to migration of the leachate plume, dilution due to the spring recharge of the contaminated aquifer could have accounted for some of the reduction.

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MARTY's GMC,

KINGSTON, MASSACHUSETTS

INTRODUCTION

NCP References

About 470 drums and buckets of paint sludges, still bottoms, polychlorinated biphenyls (PCBs) and various other organics and contaminated soil were illegally dumped on and buried in a hillside behind an auto dealership named Marty's GMC. The site is located near Kingston, Massachusetts, a small rural town of approximately 7,400 people about 40 miles (25 km) southeast of Boston on Plymouth Bay (see Figure 1). The neighboring auto dealer who was concerned about his on-site drinking water well, reported the dumping, prompting much concern from the town, which was constructing a new drinking water well field near the site. Analysis of the liquid wastes showed that some of them were highly flammable. Slightly less than 1 mg/l dichloromethane (methylene chloride) was detected in the ground water in July 1981.

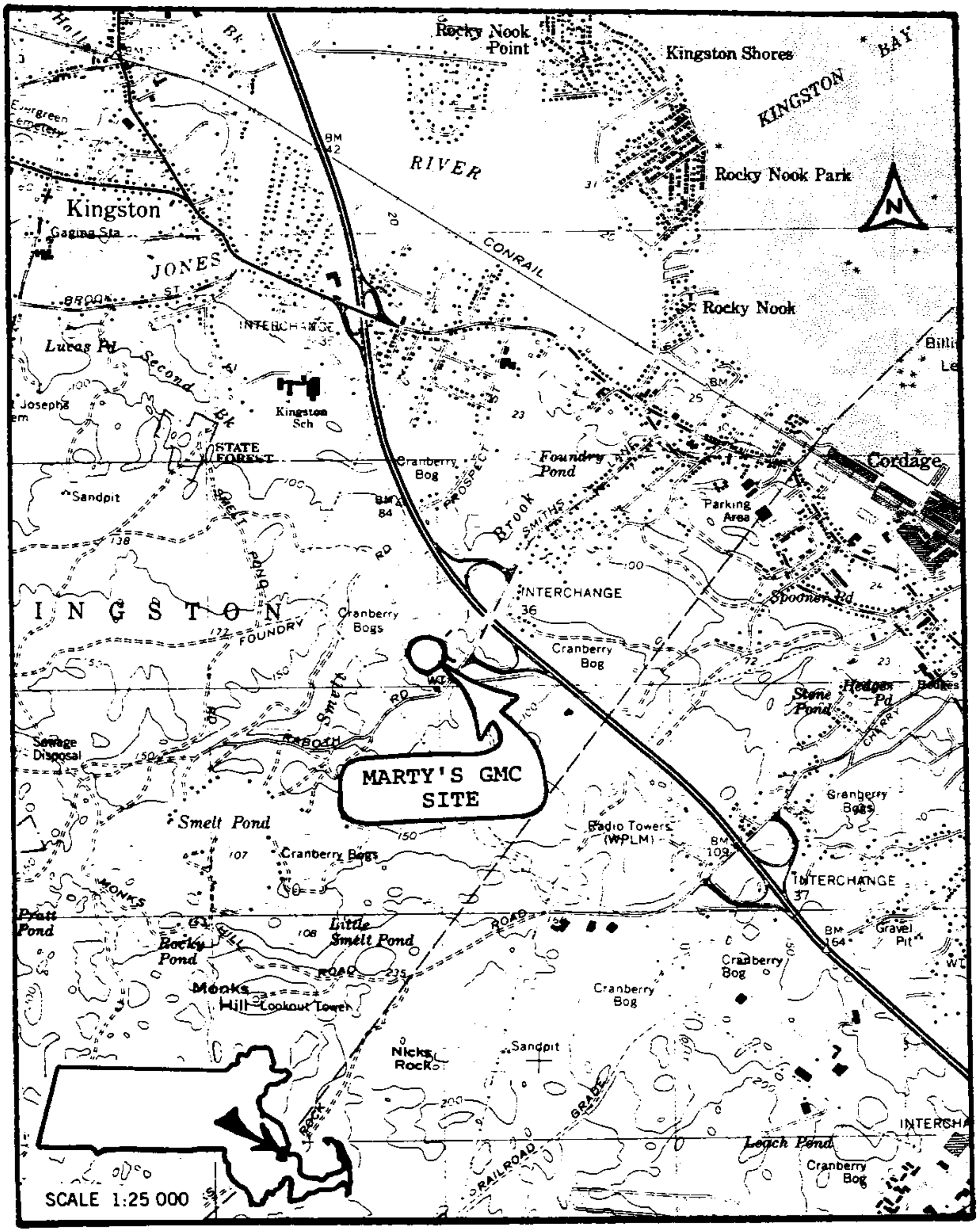
Background

From January to April 1980, about 470 drums and buckets of hazardous waste and contaminated soil were dumped on the hill behind Marty's GMC (see Figure 2). The wastes included paint sludges, filter paper residue, still bottoms, waste oil and solvents, and were among demolition debris and other material dumped there. The site was discovered when the neighboring auto dealer reported midnight dumping to police who reported it to the Massachusetts Attorney General's (AG) office, who reported it to the Massachusetts Department of Environmental Quality Engineering (DEQE) in April 1980. On April 5, 1980 State Police assigned to the AG, AG staff, additional State Police, DEQE personnel and technicians from Black Gold Services, Inc. "raided" the site as the state termed it, to inspect and sample the chemicals present. At this time, gas chromatograph/mass spectrometry (GC/MS) testing revealed a variety of chemicals in the drums and soil, including chlorinated

300.63(a)(4) discovery

300.65(b)(1) evidentiary sampling

Figure 1. Location Map of Marty's GMC Hazardous Waste Site, Kingston, Massachusetts



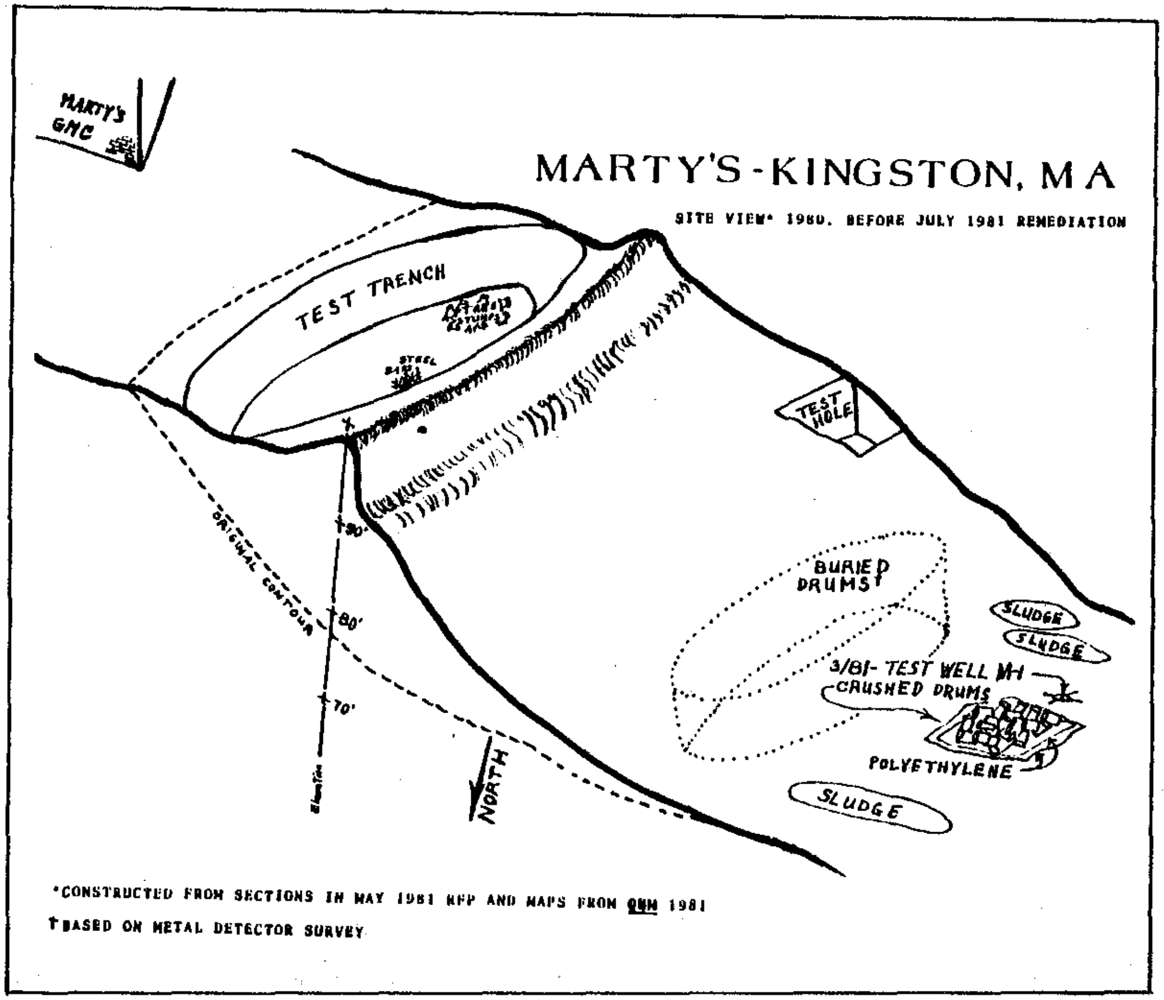


Figure 2. Site View

and flammable organic solvents. Some drums contained solids covered by very alkaline water, while others contained flammable liquids.

300.64(a)(2) preliminary assessment

Both Mr. Hamilton, who had a private drinking water well downgradient on the adjacent property, and the town of Kingston, which was planning to construct a well field about 1/2 mile (0.8 km) upgradient, were very concerned about the possible effect of the hazardous waste on the ground water. In addition, the Kingston water tower is located about 1000 feet (300 m) from Marty's. Although the water for this storage tank is drawn from another source several miles away, its proximity to the site prompted some of the town's concern. At the time Mr. Hamilton's well had only very low concentrations of chloroform, which were thought to be an equipment artifact, but it was directly in the apparent path of ground water flow, downgradient from Marty's GMC. In July 1981 DEQE found that methylene chloride was the major contaminant in the ground water (735, 432 and 134 ug/l at 48, 78 and 93 feet (14.63, 23.67 and 28.35 m), respectively.

Synopsis of Site Response

From April 1980 to May 1981, the state's standby spill response contractor, Black Gold Services, crushed, secured or wrapped about 150 empty drums in plastic, and removed another 99 drums for examination and disposal, during the spring and summer of 1980. Through the winter and up to the remedial action in July 1981, Black Gold personnel returned to the site several times to recover the drums with polyethylene.

300.65(b)(4) immediate removal source control

In April 1981, the state's hydrogeological consultant, Goldberg Zoino Associates (GZA), began to study the nature and extent of the groundwater contamination. It maintained and sampled the wells through July 1981, when the remedial action occurred.

300.66(c)(2)(iii) assessing migration potential

In July 1981 Oil and Hazardous Materials, Inc. (OHM) of Findlay, Ohio excavated and removed approximately 470 drums and buckets, and 475 tons (427.5 Mt) of contaminated soil. Soil with low levels of contamination (less than 10 ug/g PCBs) was capped and reseeded on-site after being aerated by spreading. The remediated site now lies open, with the only restriction on it being a prohibition against growing crops.

SITE DESCRIPTION

Surface Characteristics

Eastern Massachusetts, where Marty's is located, is situated near the edge of the general geomorphological region known as the New England province. This area of the province is relatively flat, and is covered with temperate deciduous second growth forest and marshes. The site is about 1 mile (1.6 km) from the center of the Town of Kingston (population 7,400).

The surface water lying closest to the site (1,000 feet 1300 ml northwest) is Smelt Brook, which drains Smelt Pond (3,200 feet (960 m) southwest), and ultimately flows out to Kingston Bay (7,000 feet 2,100 m northeast) through the Jones River (see Figure 1). At its closest approach, Smelt Brook has been altered to support an area of cranberry bogs. The Massachusetts state stream use classification for Smelt Brook is Class B. According to the State Water Laws "Waters assigned to this class are designated for the uses of protection and propagation of fish, other aquatic life and wildlife; and for primary and secondary contact recreation." The influence of Smelt Brook on the ground water was found to be localized. The dominant influence on the ground water flow below the site is the ocean.

Precipitation in the area averages 41.7 inches (106 cm) per year, distributed evenly throughout the year. Average summer and winter temperatures are 74° and 22°F (23°-6°C), respectively. Winds are predominantly southerly from April to October, changing to northwesterly during the winter months.

Hydrogeology

The Marty's GMC site is located in an area of loose sandy glacial till (see Figures 3 & 4) of the Monk's Hill moraine, which was deposited by a pause in the retreat of a glacier about 8,000 years ago, consisting of a relatively thick 90-150 foot (27-45 m) sequence of stratified sands, gravels and silts overlying a thin discontinuous glacial till of course gravel and unconsolidated sediment. No bedrock outcroppings are present within about 1/2 mile (0.8 km) of the site. The glacial till is underlain by Dedham Grandiorite, which is a crystalline rock underlying much of southeastern Massachusetts. This bedrock was encountered at varying depths in the area. At the site itself, the bedrock was approximately 105 feet (31.5 m) deep.

Figure 3. Location of Test Wells and Borings

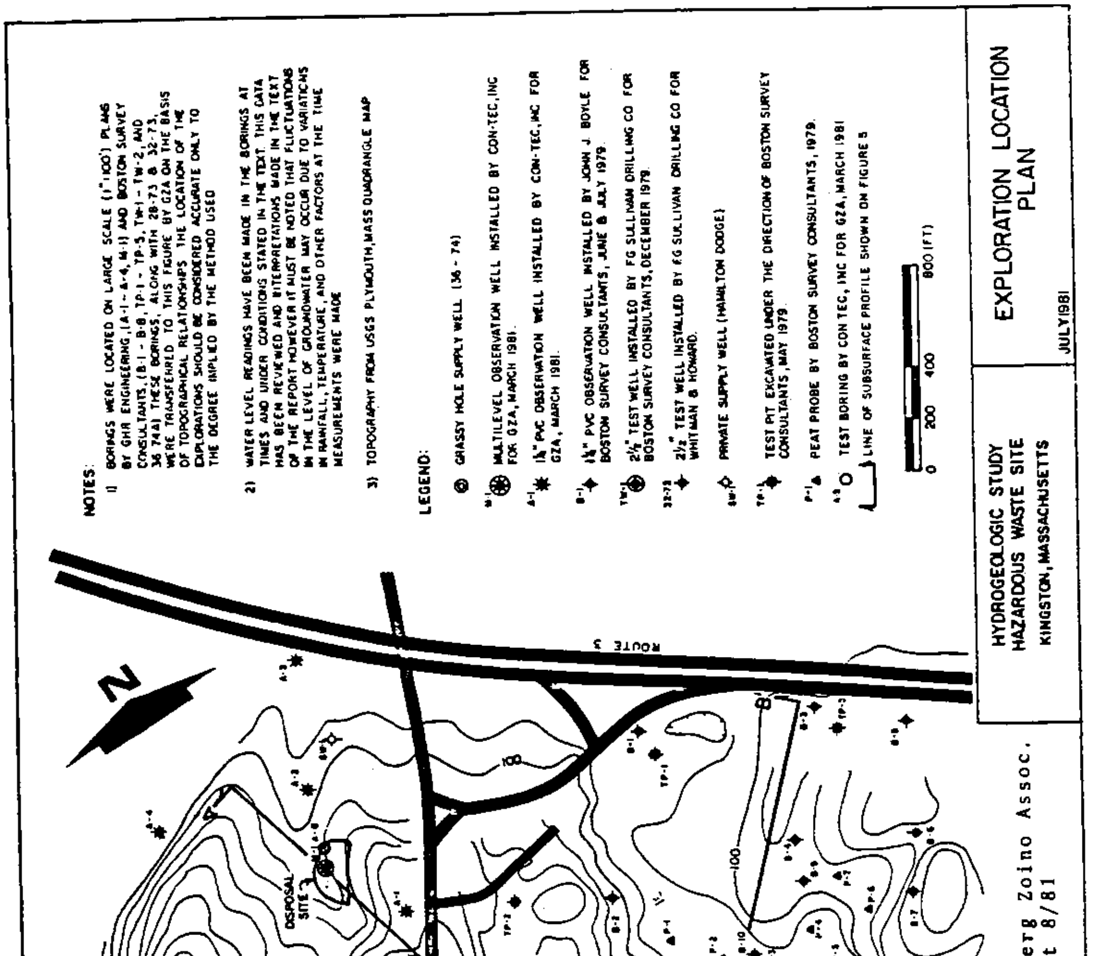
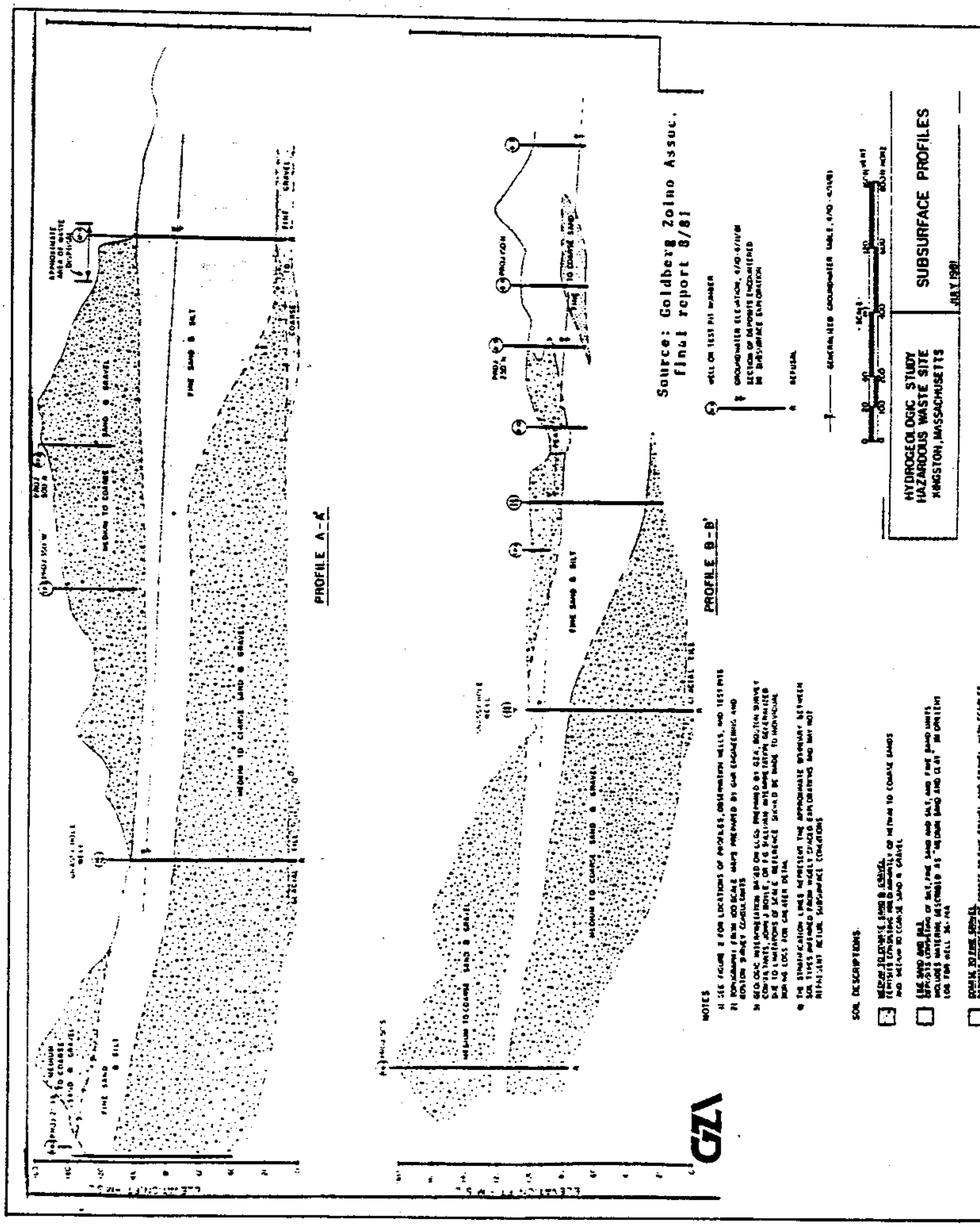


Figure 4. Subsurface Profiles



The ground water table (Figure 4) is located about 10-15 feet (3-4.5 m) deep at the site. This ground water is considered to be in an upper aquifer composed of sand and gravel extending from the surface to the fine sand and silt layer below, which acts as an aquitard allowing only minimal ground water flow. The lower aquifer is composed of medium to course sand and gravel below the fine sand and silt layer. This lower aquifer is 7 feet (2.1 m) thick at the M-1 well on-site, and is pinched-out by the thickening sand and silt aquitard to the northeast. The general ground water flow at the site is about 20° to the northeast.

WASTE DISPOSAL HISTORY

About 470 drums and buckets of hazardous wastes, and approximately 500 tons (454 Mt) of contaminated soil was dumped on a hill behind Marty's GMC (see Figure 2), from about January to April 1980. The actual amount dumped is unclear since the case was still in litigation as of October 1982. State officials believe that the dumpers initially mixed the wastes with soil at a lot down the street and then scooped up the soil/waste mixture to dump behind Marty's. This dumping was part of the operation known as the "Plymouth Ring," which dumped hazardous wastes at several sites in the area. The site owner, Marty Alexandis, had a wetlands fill permit, which allowed him to add clean fill to the back of his lot on the hill. Mr. Alexandis claimed that he thought that the drums were empty.

DESCRIPTION OF CONTAMINATION

300.65 (b)(1) evidentiary sampling

On April 5, 1980 state officials performed the first inspection and sampling of the site, to gather evidence for litigation and to assess the contamination. Gas chromatograph and mass spectrometry (GC/MS) analysis of the drum contents and soil revealed a variety of wastes including chlorinated organics and flammable solvents. Some of the drums contained solids covered with very alkaline water or low flash point supernatants. Among the wastes found at the time using GC/MS were: dichloromethane (methylene chloride), chlorobenzene, toluene, xylene, n-propanol, benzene, ethyl toluene, trimethyl benzene, 2-methyl propanol, methyl isopropylbenzene, ethyl xylene, naphthalene, tetramethyl benzene, propanol. Only a few drums were initially visible; more were discovered as test pits were dug. Solid waste such as reinforcing rods and bed springs were also found in the fill material.

Between the April 1980 raid and May 1981, the source of contamination was estimated by test trenches and sampling by Black Gold and DEQE, and during the hydrogeological study by GZA. Based on data from two test trenches and metal detector surveys by Black Gold, DEQE estimated that there were between 400-800 drums buried on-site, and about 300-400 cubic yards (228-304 m^3) of contaminated soil. Volatile organics were the most predominant contaminant in the soil, but during the remedial work, PCBs were also found in soil at about 50 ug/g. The highest level of PCB contamination was 62 ug/g, found in otherwise slightly contaminated soil during the remedial work. The depth of the soil contamination at the toe of the slope where liquid waste had pooled was found to be about one foot (0.3 m), based on an 8 foot (2.5 m) deep soil bore (A-5) next to the multilevel well (M-1).

Hydrogeological Study - Goldberg Zoino Associates

A hydrogeological study was performed by Goldberg Zoino Associates (GZA) of Newton Upper Falls, Massachussets from April-July 1981. To assess the present and future impact of the hazardous waste at Marty's GMC, GZA studied lithologic and water quality data from previous well logs in the area (Figure 3) as well as data from 5 new observation wells constructed near Marty's GMC. In addition, GZA advised DEQE on the predicted impact of the contamination on the nearby public and private wells. Subcontractors were used by GZA for the laboratory analysis of volatile organics and fecal coliforms, and to prepare site maps.

After studying the data from the well logs of the previous 14 borings in the area, GZA constructed 5 new observation wells near Marty's GMC. The location and depth of these wells (M-L, A-1, A-2, A-3, A-4) is shown in Figure 3 and Table 1, respectively. Note that the multilevel well, M-1, was constructed at the toe of the dump slope. This most often sampled well had an observation well sampler at 36 feet (10.8 m), and had 3 BarCad gas drive samplers at 47.5, 76.9 and 93.0 feet (14.25, 23.07 and 27.9 m) below land surface. These 5 newly installed wells, as well as the 14 previously existing wells, were monitored to establish ground water flow directions and determine water quality.

The water quality data in the final August 1981 report by GZA was based on a total of 21 ground water samples collected and analyzed by GZA on April 21 and 29 and June 12 and 26, 1981, from new and previously existing wells. Using gas chromatograph analysis (GC), methylene chloride was found to be the most significant contaminant in these samples. This contaminant was found only in the multilevel well located on site. Other contaminants were found at less than 50 ug/1 in

TABLE 1. WELL INVENTORY

Well #	Installed By	Depth Below Land Surface (feet)
A-1	Con-Tec for GZA [1]	77
A-2	"	35
A-3	"	33
A-4	"	25
M-1	"	36*
B-1	John J. Boyle for BSC[2]	16
B-2	"	16
B-3	"	32
B-4	"	33
B-5	"	30
B-6	"	57.5
B-7	"	62
B-9	"	42
B-12	"	26
B-14	"	16
B-16	"	26.5
B-18	"	72.5
32-73	F.G. Sullivan for W&H[3]	80
36-74A	"	95
TW-1	F.G. Sullivan for BSC[3]	95
TW-2	"	91

Note: * Multilevel sampling installation. Depth of observation well sampler given.

1. Wells constructed for MA DEQE near Marty's GMC

2. Wells constructed for planned shopping mall

3. Wells constructed for Kingston town drinking water well

Source: Goldberg Zoino Associates final report 8/81 this well, which was considered the reliable detection limit. Volatile organics were analyzed because they were believed to be the most mobile of the potential contaminants. The last ground water sample from the area was taken from the multi-level well on July 15, 1981 by GZA, and analyzed by OHM Findlay, Ohio labs using GC and mass spectrometry (MS). This final sampling corroborated the earlier finding of methylene chloride contamination only in the on-site multilevel well. Methylene chloride levels were found to be slightly higher in the OHM samples - 735, 432 and 134 ug/l at 48, 78 and 93 feet (14.4, 23.4 and 27.9 m) respectively. Test well 36-74A (Figure 3), located next to the new Kingston water supply well, was sampled and found to have no detectable volatile organics.

The boring cores from the test wells were also analyzed. This data primarily helped to clarify the underlying hydrogeology, but also suggested that soil contamination was only present at the M-1 well on-site. This finding of volatile organic contamination on-site in surface samples from M-1 prompted a shallow (8 feet (2.4 m) deep) test boring (A-5) on-site near M-1 with "continuous soil sampling... to assess the vertical extent of organic contamination at the location of the most highly degraded surficial soils" (GZA, 1981). An organic vapor analyzer (OVA) measurement of the soil from A-5 showed that the soil contamination there was the result of localized ponding of contaminated runoff water and was not expected to to present a significant source of ground water contamination. As in the ground water, methylene chloride was the most significant contaminant but vinyl chloride, which was found in water samples at M-1, was not found in the soil samples.

PLANNING THE SITE RESPONSE

Clean-up work at this site consisted of an emergency response action and a remedial action. These actions are discussed separately below.

Emergency Response

Initiation of Response

The Massachusetts Department of Environmental Quality Engineering (DEQE) first became involved in Marty's GMC when the Attorney General's Office (AG) asked it for technical support in the raid on the site on April 5, 1980 to stop the dumping and to gather evidence. Most of the information produced from the raid was intended for use by the AG in its case. The following information was useful to DEQE in assessing

300.65(b)(1) evidentiary sampling

the physical threat posed by the site:

1. A significant, but undetermined amount of contaminated soil and drummed wastes was buried in the hillside;

2. A significant amount of waste lay exposed in 55 gallon drums and contaminated soil; and

3. Gas chromatograph/mass spectrometry (GC/MS) testing and drum labels indicated that some of the wastes were very flammable and toxic.

Based on this information, DEQE had Black Gold return to the site a few weeks later to secure the surface drums because of the threat of fire from the drums of flammable wastes, and to dig test trenches to assess the need for future work.

300.65(9)(3)
risk of fire

Selection of Response Technologies

The general emergency response alternatives available to DEQE at Marty's were:

1. Clean-up work;
2. Site assessment; or
3. No action.

The DEQE's decision to combine the action alternatives 1 and 2 was based on the need to mitigate the fire hazard and to assess the potential ground water threat. The DEQE knew that the available Spill Fund money, $100,000 was not enough to fully remediate the site; hence some combination of clean-up work and site assessment to estimate future work was needed. The specific mix of surface drum clean-up and site assessment was largely based on limitations of funding and availability of information.

The clean-up work was limited to surface drums because that was all that the available funding would allow and still leave money for the needed site assessment. The surface drum work reduced the threat of fire but not the threat of ground water contamination. The state official in charge of the Emergency Response Branch stated that this level of clean-up was based more on the amount of money that was available, rather than a need to mitigate a specific hazard to a specific degree.

300.65(b)(4)
immediate
removal
source control

The site assessment primarily involved digging test trenches to estimate the extent of the dumping, because that was needed to estimate adequately the extent of the final remedial work needed, and also allow for the

300.68(k)
fund
balancing

maximum amount of immediate clean-up work. The use of the $100,000 exclusively for site assessment work would have meant that no action would be taken regarding the immediate mitigation of the threat of fire and, therefore, was excluded. A limited amount of metal detector investigation was undertaken to locate the buried drums on-site. Test trenches were specifically chosen because they were relatively cheap and adequate to estimate the extent of soil work needed. This also reserved resources for the clean-up. In addition, any of the other possible site assessment alternatives,such as ground-penetrating radar, resistivity studies, extensive test well construction and monitoring,were excluded as being unwarranted, given the information available from the AG's investigation, which indicated that only a short period of recent dumping during the middle of winter had occurred on the site.

Extent of Response

The emergency response ended because the money ran out and the general response goal of surface clean-up and site assessment had been achieved. As a result, all of the exposed empty drums were not removed from the site. Most of these drums were placed on plastic sheets pending completion of the rest of the response work.

300.65(c) immediate removal completion

Remedial Action

Initiation of Response

Because of delays in getting funds, further work at Marty's did not occur until 7 months after completion of the emergency response, when Goldberg Zoino Associates (GZA) was hired in February 1981 to construct and monitor 3 test wells. As with the initiation of all of the remedial action contracts (hydrogeological study, management consultant, clean-up contractor), the timing of the decision was based on balancing the desire of DEQE and local interests to have the site cleaned up as soon as possible, and the state legislature's desire to carefully control the expenditure of state funds. Local citizen concern had grown condsiderably from the time of the raid in April 1980 until the site clean-up was completed in July 1981. However, the delay through 1980 due to deliberations about the procedure for using the Capital Outlays Acts limited DEQE's ability to take any remedial action, because of lack of alternative funding.

When approval to use $5 million from the Massachusetts Capital Outlay Act was granted in January 1981, DEQE decided to hire a hydrogeological consultant, Goldberg Zoino Associates (GZA), to assess the impact, if any, of the hazardous waste at Marty's on the ground water. This possibility of contamination was of particular concern because the town of Kingston had already sunk one drinking water well 1,500 feet (450 m) from the site, and was planning to construct more wells. Although this well field was known to be upgradient from the site, the hydrogeologist verified this fact and then determined the potential threat to private wells downgradient. Local concern may have also been heightened by the proximity of the town water tank 1,000 feet (300 m) from the site. The hydrogeologist provided information that served to allay these concerns.

300.68(f) remedial investigation

DEQE was not prepared at that time to hire a clean-up contractor because they had agreed with the state legislature to contract a management consultant first to assist and train DEQE personnel in overseeing the clean-up of Marty's and other sites around the state, all of which were to be cleaned up with funding from the Capital Outlay Act. This agreement was reached between the state Senate and House Ways and Means Committees and DEQE during the scheduling of funds from the Capital Outlay Act. The contracts for the management consultant and the subsequent clean-up contractor were expected to be larger and more complicated than the hydrogeological consultant's and therefore could not be executed as quickly.

A request for proposals for a management consultant was issued in February 1981, and Arthur D. Little, Inc. (ADL) was selected in March 1981. The management consultant was hired for Marty's to improve on the efficiency of the clean-up supervised by the DEQE at Silresim, in Lowell, where a site cleanup went over budget and past schedule. On May 1, 1981, DEQE issued a request for proposals for the clean-up of Marty's GMC, which had been developed in conjunction with ADL. This action directly initiated the final remedial work that had been deemed necessary in the spring of 1980 to eliminate the ground water contamination source, but which had been delayed due to the lack of funding. In July 1981, O.H. Materials Inc. (OHM) was hired.

Selection of Response Technologies

The DEQE directed its contractor, OHM to combine excavation and disposal with aeration and capping in order to minimize disposal costs. Only material that could not be treated (aerated or biodegraded) was to be disposed of at an approved site. DEQE decided to excavate because the aquifer under Kingston is a sole source aquifer for the town. It is the largest aquifer of drinking water quality in the state and has the highest flow rate in the state. Exclusive use of other technologies - ground water withdrawal and treatment, in situ treatment, encapsulation, and complete excavation and disposal, was rejected because the technologies were considered unwarranted or unfeasible, or they were not believed to offer the same level of cost-effective ground water protection that the excavation-aeration option provided. The specific mix of disposal, treatment and capping resulted from decisions made on-site based on what was found during excavation and testing. In practical terms, the amount to be disposed was minimized by separating the excavated material into a high contaminated soil pile (HCP) and a low contaminated soil pile (LCP). This soil pile separation will be discussed below, along with the decision to dispose of the particular section of PCB contaminated soil, and the bulking method that was used.

300.68(h)(1) screening; cost

<u>Defining the LCP vs. HCP</u>--The DEQE decided to aerate part of the "low contamination soil pile" (LCP) and leave it on-site because officials believed that it was not a significant threat, and sought to minimize disposal costs. The separation of the LCP from the high contamination soil pile (HCP) began during the emergency test trench excavation, when Black Gold created the 2 distinct piles based on visual evidence of contamination (containing solid or wet hazardous wastes). This initial separation was part of DEQE's overall plan to minimize the amount of material requiring disposal.

During the remedial phase, the basis for separating the LCP from the HCP, which was disposed of at an approved landfill, was the organic vapor level emitted from the soil. O.H. Materials used a photoionization detector (PID) calibrated for organic contamination with uncalibrated response for all volatile hydrocarbons. If a PID reading of 20 ug/g or greater was found at ground level when soil was excavated, then that soil would go to the HCP for subsequent disposal. The resulting piles were assessed later for total organic carbon (TOC). The TOC level of the HCP was about 8,200 ug/g; the LCP was between 1,900-6,400 ug/g (most soil on the hillside was from 2,400-4,400 ug/g). By comparison, the TOC control of clean, dry sand at the site was about 500-520 ug/g.

The DEQE's decision to leave the LCP on-site, which was later amended because of the PCB discovery, was made without a specific regulatory framework because of the "emergency" nature of the work. Although the RCRA tests of ignitability, reactivity and (EP) toxicity were performed and considered in the decision, according to the DEQE's General Counsel and the on scene coordinator, the decision was based on "professional judgement" under the state law governing emergency operations, which gives DEQE authority to clean up hazardous waste sites using any environmentally safe means. The site was cleaned up by the Emergency Response Branch because it was the only unit of DEQE that had sufficient contracting expertise. The Site Management Branch, which now deals with long term clean-ups, was not effectively operational at the time. The use of the term "remedial response" is used in this report for the July 1981 work to distinguish it from the 1980 emergency work.

The cost basis for the decision on whether to dispose of the LCP off-site was very clear. In a Budget Variance Report for the period from July 10 - 16, 1981 OHM informed DEQE that disposal of the entire 750 cubic yards (573 m^3; 950 tons; 864.5 Mt) of LCP would cost $220,000 (transportation + disposal + 15%), and would put the project over budget. In addition, O.H. Materials proposed the alternative of biodegrading the contaminants out of the LCP at a cost of $96,000. Neither plan was used. As will be discussed below, PCB contamination of the LCP ultimately determined the extent of disposal of the LCP. The DEQE decided to aerate the LCP, which was only part of the proposed biodegradation plan, because it believed this would be adequate to reduce the volatile organics to the desired extent. The DEQE obtained "background" levels of volatile organics in the LCP.

300.70(b)(2) (iii)(E) in situ soil treatment

PCBs in the LCP--A relatively more complicated process was involved in the decision to leave on-site the part of the LCP that contained 7 ug/g or less of PCBs. Black Gold's testing during the emergency work did not detect any PCBs on the site. However, on July 15, during the first week of operation, OHM performed PCB screens along with pH testing (for compatibility) of all of the excavated material, and found low levels of PCBs in the LCP but none in the HCP. This prompted the DEQE to request a test to be run on the material at OHM's Findlay-based lab of a composite of 6 samples from the LCP. This test confirmed the presence of PCBs at 19 ug/g. The possibility of hot spots of PCBs prompted DEQE to have OHM split the LCP into 8 sections, and take 8 samples (4 sections on either side of a long, split oval) from each section. These samples were split and tested by OHM and ADL. Both labs found PCBs at about 50 ug/g in 3 of the 8 sections (OHM/ADL: 61/51, 62/24/42 ug/g) DEQE had these 3 sections, which were in one area, removed for disposal and ordered that an extensive sampling program be carried out throughout the site to make sure that no other PCB hot spots had been missed. Samples were taken from 26 locations throughout the site on July 29th after the 3 moderately contaminated sections had been removed from the site. While the results from these 26 samples were awaited from the Findlay labs, the soil was aerated by spreading it over the hillside for 4 days using a front loader. The last sample results were called in to DEQE on Sunday, August 2, when it was reported that no PCPs over 7 ug/g had been found. On Monday the LCP, which had been spread thinly on a 60 x 50 foot (18 x 15 m) area, was capped with 2-3 feet (0.6-0.9 m) of soil, followed by a 6 inch (0.15 m) cap that was applied to the whole site.

300.70(b)(2)(iii)(E) in situ soil treatment

Mixing liquids into the HCP--When the drums containing liquid hazardous wastes were excavated out of the hillside, they were emptied onto and mixed with the HCP, as OHM had recommended. DEQE agreed to the recommended action because it was feasible from the standpoint of liquids compatibility, and it was cheaper than bulking the liquids and transporting them separately in DOT-specified containers. The HCP was already slated for disposal in a Class I landfill, so it was considered economical to combine the 18 drums of liquid with the soil and avoid additional disposal expenses. In a weekly report from OHM to DEQE, dated July 23, 1981, the site manager for OHM noted that the 18 drums of liquids would not provide for significant economies of scale to warrant using a bulk tanker. He concluded "since there were not enough liquids to bulk together, that it would be more cost effective to mix the liquids into the highly contaminated soil pile for disposal."

After the contents of the drums were poured out, the drums were crushed with the front loader and disposed of in separate trucks. The full 5 gallon buckets were not emptied and separated. Instead they were simply dumped onto the HCP and mixed in, because unlike the 55-gallon drums they would not interfere with the mixing and loading for the disposal process.

Extent of Response

The DEQE ended the remedial operations because the planned excavation and partial disposal had been accomplished and, based on the best professional judgement of its officials, the site no longer presented a threat to public health or the environment. The specific decisions regarding the extent of disposal and the amount of material left on-site and capped are discussed above in the "Selection of Site Response" section. Generally, the plan to excavate the hillside and dispose of the drums, and all of the contaminated soil that could not be decontaminated adequately on-

300.68(j) extent of remedy

site, was carried out to completion.

The level of volatile organic contamination in the LCP left on site was reduced to the "background level." The LCP was aerated for four days by spreading and respreading it using a front-loader, while awaiting the results from the extensive PCB sampling. The only major surprise, which altered the planned completion date, was the discovery of PCBs. As discussed above, by disposing of the soil having about 50 ug/g PCB, only soil with a PCB concentration of 7ug/g or less was left on-site. This PCB problem extended the completion of the clean-up about a week, but did not significantly alter the planned clean-up.

DESIGN AND EXECUTION OF SITE RESPONSE

The following technologies were employed at the Marty's GMC clean-up.

1. Emergency Response (site stabilization and assessment)

2. Excavation

3. Bulking (drum opening and mixing contents with contaminated soil)

4. Soil Aeration

5. Laboratory Analytical Work

6. Capping

7. Safety Procedures

These technologies will be discussed in turn below.

As noted in the section above, the clean-up work at Marty's was separated into two distinct operations: emergency response, which occurred in April 1980, and remedial action, which occurred from July-August 1981. These opertions will be discussed separately in this section. The emergency response will be considered briefly because of the relatively small scale of the operation and because of the lack of documentation available. The remedial response will be discussed in sections according to the technology applied.

Emergency Response

The state's spill contractor, Black Gold Services, Inc. of Stoughton, Massachusetts, performed emergency mitigation work and assessed the site in preparation for future work. It became involved in the Marty's GMC cleanup when DEQE asked it for backhoes and technicians to assist in the April 5, 1980 raid. On that day Black Gold personnel sampled and removed an undetermined number of drums to provide the Attorney General's Office (AG) with direct evidence of hazardous waste dumping on-site. A backhoe was used to prove that there was buried hazardous waste on-site. The drums that were removed by Black Gold were placed in storage at Recycling Industries of Braintree, Massachusetts as evidence in litigation. Ten of the exposed drums were removed immediately because of the threat of fire posed by their flammable contents, while 89 other full or partly full drums were removed shortly thereafter. This initial 9 work-days of emergency work ended on June 3, when the exposed drums had either been removed from the site for evidence or, because of high flammability, had been covered with polyethylene (Figure 2).

300.65(b)(1) evidentiary sampling

On July 22, Black Gold returned to the site to dig test holes and secure the excavated soil and drums that came from these holes. Using 22.6 tons (20.16 Mt) of clay, a staging area was created away from the toe of the slope by spreading the clay and building a 2 1/2 foot (0.15 m) berm around the downgrade side. This clay platform and dike was then covered with polyethylene. A month and a half later, on September 4-5, 18 drums were removed from the site and stored prior to disposal. A total of 150 empty, but waste-contaminated drums were stored in this area until the remedial action began in July 1981, when they were removed and disposed of at a landfill. Black Gold returned to the site on 6 more days between September 30, 1980 and May 19, 1981 to maintain the secured soil and drum pile by replacing the polythylene plastic when it deteriorated or blew off.

300.65(b)(7) physical barriers

The site preparation and assessment work occurred in the spring and summer of 1981. Black Gold cleared a work area for the planned remedial action by cutting down all small trees in the future operating area and consolidating all of the uncontaminated tree stumps and demolition debris in a pile at the west side of the toe of the slope.

An organic vapor analyzer, borrowed from U.S. EPA Region I, was used to determine the level of contamination of soil as it was excavated. Black Gold used its metal detector to determine the location and extent of buried drums for estimating future work. Through these estimates, the depth of the contaminated fill and the location of the buried drums were determined, as shown in Figure 2. From Black Gold's work, the DEQE estimated that 400-800 drums, about half of which were empty, and 300-400 cubic yards (228-304 m^3) of contaminated soil were on-site.

300.66(c)(2) (ii) assessing hazardous substances

Excavation

Preliminary excavation work for the remedial phase began on Tuesday, July 14, 1981, one week after the OHM contract was signed and the same day that the site owner signed an authorization for the removal. A Case 580 backhoe was used to move to clean fill above the dumped material to prevent contamination of the soil. This fill was stockpiled in a clean area for future use as cover. A Caterpillar (Cat) 955 front-end loader was used to consolidate the contaminated soil and crushed drums in one area away from the toe of the slope where excavation would occur. This Cat 955 was also used to crush the empty drums and load them and the highly contaminated soil separately for disposal.

300.70(c)(2) (i) excavation

The three-day excavation operation into the hillside began on the next day, July 15, 1981, when the Cat 955 front loader, the Case 580 C backhoe and the Cat 215 backhoe, with a grappler attachment, were used to dig out the northeast half the staging area (See Figure 2). The excavation of soil of the slope nearest the drums was completed on Friday, July 17, 1980. A total of 1,058 cubic yards (809 m^3) of contaminated soil was excavated. Air monitoring that was performed throughout the excavation is discussed in the "Chemical Analysis" section below.

As discussed in the "Extent of Site Response" section above, material was excavated until it showed no visual evidence of contamination or PID readings of greater than 10 ug/g. Excavated soil was separated into 2 piles (high and low contamination) based on PID readings of above or below 20 ug/g. The piles of contaminated soil were placed on polyethylene sheets depending on whether PID readings of less than or greater than 20 ug/g were measured at ground level above the source of the excavated material.

The drums were removed from the hillside excavation using the grappler attachment to a Cat 215 backhoe, which is a large, long armed, caterpillar-treaded vehicle. The grappler attachment to the arm was a claw-like device that rotated 180 degress and was especially designed for manipulating 55 gallon drums. The drums were staged on polyethylene liners for compatibility testing prior to bulking and disposal.

Bulking

Of the 151 drums excavated from the hillside (excluding the 144 full buckets), 59 drums were "full", 41 of which contained solids such as filter paper residue, and 18 of which contained liquids. Of the 92 remaining drums, some were stored off-site as evidence, and some were empty and were crushed and disposed of with the other wastes. As the drums were excavated from the hillside, they were sampled for compatibility tests using a non-sparking brass punch on the Case 580-C backhoe to open the drums. On Friday and Saturday, July 17, and 18, the following three tests were performed on the contents to determine their compatibility for bulking:

1. pH testing was performed on the contents from the 18 liquid-filled drums to ensure that no violent exothermic reactions would occur from mixing them together;

2. PCB testing was performed to ensure that non-PCB contaminated material was not mixed with PCB-contaminated material, which requires special regulatory considerations for disposal; and

3. Cyanide testing was performed to prevent cyanide cross contamination. Cyanide is acutely toxic and may produce hydrogen cyanide gas when mixed with acid.

All wastes were found to be compatible and could therefore be bulked. Testing procedures and results are discussed in the "Chemical Analysis" section below.

Since the 18 drums of liquid were not believed to constitute a large enough volume to be cost-effectively bulked as a liquid, they were poured onto and mixed into the high contamination soil pile (HCP). A 10,000 gallon (38,000 l) mobile compatibility chamber was brought to the site but not used. Instead, the grappler equipped Cat 215 was used to pour the contents of the full drums onto the HCP.

The Case 580C backhoe was used to mix the liquids and solids from the 59 full drums and the 144 five-gallon buckets into the HCP for disposal.

Chemical Analysis

The chemical analysis program that was carried out by OHM involved an on-site laboratory trailer and base (Findlay, Ohio) laboratory work. This sampling and analysis program occurred from the first day of site response to the last day of demobilization.

At the clean-up site, testing was performed by hand held equipment and in the on-site mobile trailer laboratory. Upon arriving at the site and before beginning the excavation operation, an air scan was performed with 4 personal air sampling pumps with Tenax and Ambersorb XE-347 adsorbant material. These samples were taken around the site and sent to the Findlay lab for analysis. Three mobile infrared gas analyzers (MIRANS) were used during the excavation and bulking. These MIRANS were calibrated for chlorobenzene and toluene, based on the personal air sampler results. This MIRANS monitoring showed that chlorobenzene and toluene were present in the air only during bulking at maximums of 0.2 and 0.5 ppm, respectively. They were not detected during the excavation. A photoionization detector (PID) was used throughout the excavation and bulking to identify contaminated soil. This PID was calibrated for aromatic hydrocarbons, with an uncalibrated response for volatile hydrocarbons. A Drager portable air sampler was used on site with specific sampling tubes for phenol, benzene, cyanide, toluene and methylene chloride. Only benzene was detectable.

The mobile analytical trailer was used on site for storing and maintaining this field equipment, as well as performing additional analytical work. A gas chromatograph (GC) was used to screen the soil for PCBs, until a breakdown forced the PCB testing to be done in the Findlay lab during the last week. Total organic carbon (TOC) was also analyzed in the mobile lab to corroborate the findings of the PID identification. The low contamination soil pile (LCP) was also tested for the reactivity and ignitability for RCRA characterization (the EP toxicity testing was done in the Findlay lab). Ignitability testing was performed with a Pensky-Marten close-up analyzer to identify the flashpoint.

The Findlay lab provided additional testing facilities for air, water and soil samples. A total of 6 air samples (including 2 controls) were analyzed for volatile organics using gas chromatograph and mass spectrometry (GC/MS). The water samples from all 4 levels of the M-1 well on-site were analyzed using GC/MS. The results of this testing showed 735, 432 and 134 ug/l methylene chloride present at 48, 78 and 93 feet (14.4, 23.4 and 27.9 m) deep, respectively.

The Findlay lab tested both the extract and volatiles present in the LCP soil. A standard EP toxicity extract was tested using atomic absorbtion spectrophotometry for arsenic, selenium and mercury. This extract was also tested for chlorinated pesticides and chlorinated phenoxy acid herbicides using GC with an electron capture detector followed by GC/MS. The soil was also tested for volatile organics by heating it and running the air through GC/MS. In addition, a GC screen was done on the LCP soil to screen the soil for PCB's. This GC gas elutrient was then split to a flame ionization detector and an electron capture detector.

Soil Aeration

After the highly contaminated soil and drums were removed for disposal, the remaining low contamination soil pile (LCP) was spread at the toe of the slope to enhance the evaporation of the volatile organic contaminants. As discussed in the "Extent of Site Response" section above, the finding of low levels of PCBs in the LCP caused a hiatus of several days in the project while additional samples were taken and analyzed. While awaiting the results of the analysis and a decision on the LCP disposal, the Cat 955 front loader was used to turn and spread each of the 8 sections. This aeration process occurred for 4 days during this waiting period, in an effort to minimize the standby time of the front loader and operator, who remained onsite. As indicated by PID readings, volatile organics were at background levels at the end of the aeration.

300.70 (b)(2) (iii)(E) in situ treatment

Transportation and Disposal

A total of 28 truckloads of contaminated soil and drums were hauled 520 miles (825 km) to the Class I landfill at CECOS in Niagra Falls, New York. Crushed drums (3 truckloads) and contaminated soil (21 truckloads) were transported and disposed of separately from the PCB-contaminated soil (4 truckloads) which was disposed of in a double secure cell at CECOS.

300.70(c) off-site disposal

The average net weight of the loads was about 17 tons (15.3 Mt) instead of the 22 (19.8 Mt) ton rated truck capacity because the contaminated soil was too bulky to put 22 tons in one truckload. A 22 ton load would have occupied about 16.9 cubic yards (12.94 m^3), which would have overfilled the 13 cubic yard (9.94 m^3) capacity trucks. A conversion of 1.3 tons/cubic yard (1.54 Mt/m^3) was used by OHM, according to a company official. A full 13 cubic yard load of contaminated soil (9.94 m^3) weighed about 16.9 tons (18.6 Mt) (470 tons/28 truckloads). Crushed drums were transported separately in two truckloads on July 18, 1981.

Safety Procedures

Upon arrival at the site, the contaminated area was separated from the neighboring auto dealer's property by a rope fence, with colored ribbon surveyor's tape and "dangerous" placards. Support trailers and equipment were located in the designated clean area on this neighboring property. The entire area of visually apparent dumping was roped off from the rest of Marty's property a few days later. A portable decontamination building was located along the northern "contamination zone boundary" (see Figure 5.)

300.71
worker health
and safety

All personnel entering the site donned self-contained breathing apparatus and "moon suits" before entering until portable sampler and P.I.D. readings showed no detectable air contamination. All personnel entering the contaminated zone were required to have prior authorization from the DEQE and sign a site visit authorization and release form. Suits, tanks and other personnel equipment were decontaminated daily by OHM technicians. O.H. Materials also provided night security.

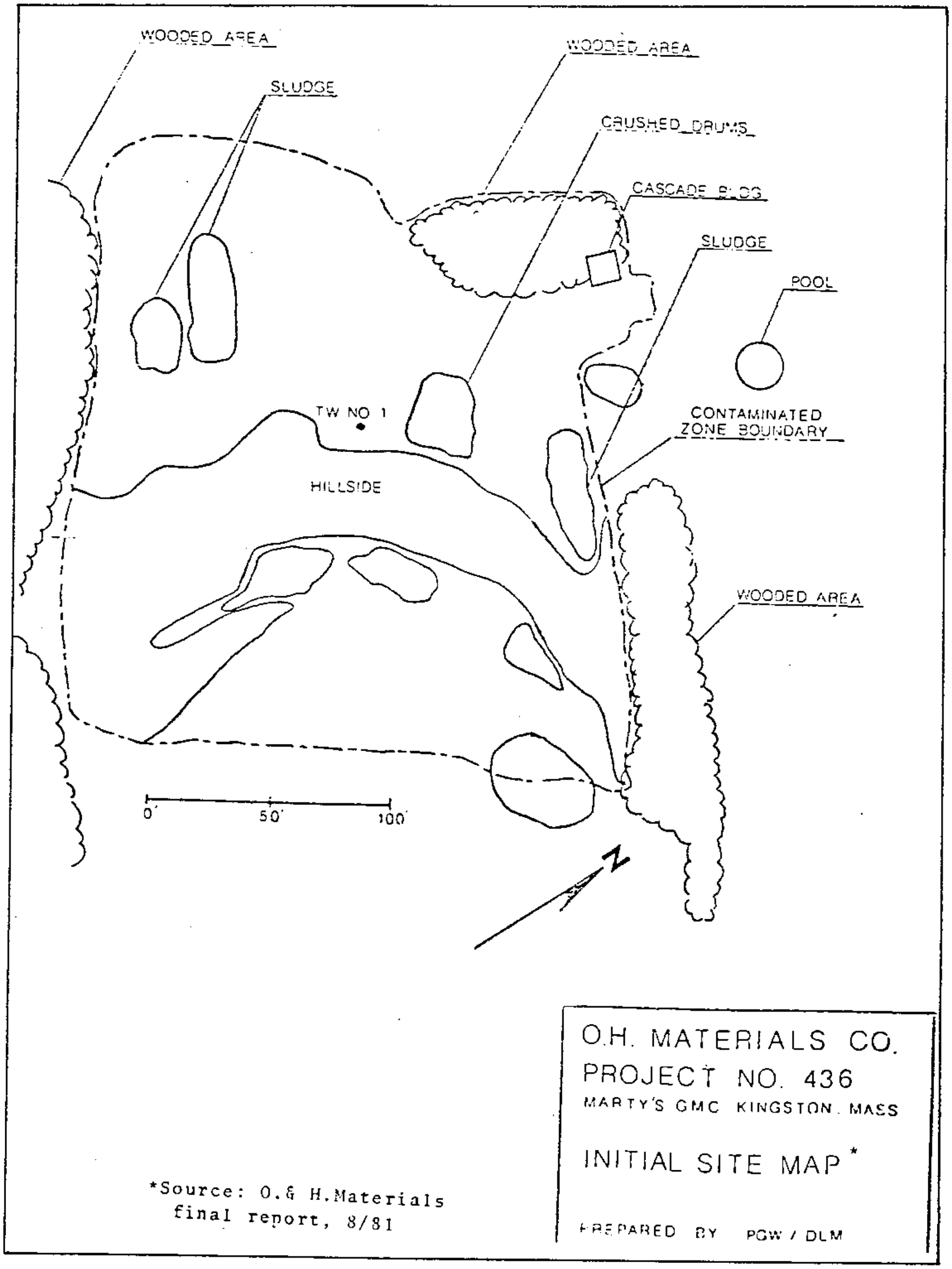
Cleaning and sealing of trucks coming from the site was done to avoid contamination of public areas enroute from the dump site to the secure landfill. All trucks, backhoes and equipment leaving the site were decontaminated using a high pressure water laser. Heavier contamination on the buckets, drum punch and grappler was removed using a sand blasting attachment to the water laser. Trucks containing contaminated material were sealed using a chemical sealing unit, including lining and covering of the load with polyethylene.

Capping

After the low contamination soil (LCP) pile was aerated and the three sections containing moderate levels of PCB contamination were removed, the remaining soil with low levels (less than 7 ug/g) of PCBs was spread and capped before an additional cap was placed on the entire site. The LCP was spread on the hillside onto on a 60 x 50 foot (18.29 x 15.24 m) area and covered with 2-3 feet (0.61 x 0.91 m) of soil. The entire site was then capped with 6 inches (21.24 cm) of native sandy loam soil throughout the area that had experienced contaminated fill dumping. Grass seed and fertilizer were then spread on the entire site, followed by straw to prevent intervening erosion.

300.70(b)(1)
(ii)(A)
surface
seals

Figure 5. Contaminated Zone Schematic



COST AND FUNDING

Source of Funding

Funding for the emergency response came from the Massachusetts Spill Fund because it was the only funding immediately available. (The Spill Fund was a $300,000 revolving fund that was originally designed for quick responses to oil spills). The other sources of funding that could have been considered (CERCLA had not yet been passed), and the reasons that they were excluded are as follows:

300.62(a) state-funded response

1. Governor's Emergency Account - This fund is only used when all other options have been pursued. The director of DEQE's Emergency Response Unit said that if the Spill Fund turned out to be inadequate for the desired level of emergency response, this fund might have been used. The Spill Fund was adequate, so it was not used.

2. Special appropriation from the state legislature - This funding method had been used previously for cleaning up hazardous waste sites by obtaining a site-specific appropriation. This source was not considered viable for Marty's because of political problems between DEQE and the state legislators.

The amount of $100,000 for emergency action at Marty's provided by the Spill Fund was established as a compromise between taking some emergency action at that site and the imminent need for taking emergency action at 2-3 other sites around the state. DEQE expected that 1/3 of the $300,000 fund would acheive a reasonable level of surface clean-up and site assessment. It is unclear if there was a conscious attempt to evenly distribute the Spill Fund among 3 sites.

300.68(k) fund balancing

The Capital Outlay Act (Acts of 1979, Chapter 798, Section 2, Item 2240-8801) was used to fund the remedial action at Marty's GMC because it was easier than using the only other potentially viable alternative-a special appropriation from the state legislature. Although funds from the Capital Outlay Act were not availbale until January 1981, the Act was designed specifically for the type of clean-up needed at Marty's. CERCLA had not yet become a viable alternative and the dumpers were virtually bankrupt. Lawsuits for cost recovery would have taken too much time regardless of their potential for success. The Capital Outlay Act was passed by the state legislature in November 1979 in an attempt to overcome some of the problems attendent with depending on special appropriations and other funding sources. It created a $5 million Fund for hazardous waste site clean-ups that was allocated according to a schedule worked out by the state House and Senate Way and Means Committees.

Selection of Contractors

DEQE chose Black Gold Services, Inc. to perform the emergency response work because the firm was DEQE's emergency spill contractor on stand-by at the time. Black Gold had been placed on retainer for a standard two year period beginning on July 1, 1979. DEQE hired Black Gold on a sole source basis for approximately $100,000 worth of time and materials. Black Gold was asked to provide a backhoe and technicans for the April 5 raid to sample drums and to prove that drums were buried. In addition, it subsequently removed or secured the surface drums to mitigate the fire threat, and dug test trenches to assess the extent of the buried drums.

The DEQE hired 3 firms in the course of the remedial work at Marty's:

1. Goldberg Zoino Associates (GZA) was hired on a sole source basis in February 1981 to install and sample 5 observation wells as part of the hydrogeological study of the area, and model the impact of possible ground water contamination. GZA's work began in March 1981 and its first draft report was submitted in June 1981. GZA was chosen on the basis of the professional judgement of DEQE water pollution specialists, who believed that GZA was the best hydrogeological firm in the area.

2. Arthur D. Little (ADL) was hired by DEQE to help them manage hazardous waste site clean-up projects covered by the Capital Outlay Act scheduling. The management consultant contract was let through an RFP process in February - March 1981. Proposals were reviewed by a standing committee and ADL was selected in March. In June 1981, a contract was executed with ADL that included plans for evaluating the clean-up contractors' proposals, monitoring the clean-up progress and costs, and training DEQE personnel to take over these tasks in the future. In October 1982, ADL's role had shifted largely to training DEQE personnel.

3. O.H. Materials (OHM) was hired in July 1981 as the primary clean-up contractor "to remove, transport, treat, and dispose of hazardous wastes" at Marty's GMC, according to the RFP, which was released in May 1981. From a field of four proposers, OHM was chosen on the basis of a multi-criteria bid evaluation procedure developed by ADL. The DEQE heeded the recommendation of ADL, who considered such factors as qualifications, technical approach, project management and cost as well as "other subjective factors such as reputation for quality work and DEQE's desire to use different contractors in order to broaden their base of experience," according to a draft Report of Bid Evaluation and Contractor Selection by ADL in June 1981.

The OHM contract was let on a time and materials basis because DEQE believed that a fixed price would lead to over-bidding by contractors trying to cover contingencies for unknown costs. Since the extent of the clean-up work needed was only roughly known, state officials believed that a fixed price would lock them into a bid that covered the higher end of the possible cost range. Based on the test trench estimates from Black Gold's work in Spring 1980, the RFP estimated that there were from 400-800 drums on-site, about half of which were empty, and 300-400 cubic yards (228-304 m^3) of contaminated soil.

The proposal submitted by OHM estimated the total clean-up costs based on an actual amount of work at the mean of DEQE's estimate and a detailed cost breakdown chart. The daily invoices from OHM were audited by ADL.

Project Costs

The Massachusetts Department of Environmental Quality Engineering (DEQE) was charged a total of $562,031 (see Table 2.) on the Marty's GMC clean-up and directly related activities from April 5, 1980 to August 10,1981. The amount DEQE actually paid was $551,049 because of a $10,982 discount for rapid payment of invoices for the remedial work. This total cost excludes administrative costs within the agency, which were estimated at about $400,000, but were not documented. Massachusetts paid for the work through its Emergency Spill Fund and the Capital Outlay Act of 1979, as itemized in Table 2. About three-quarters of the expense ($409,000) was incurred during the month of July 1981 for the excavation and disposal of 470 tons (426.5 Mt) of contaminated soil and 453 crushed drums and

TABLE 2. SUMMARY OF COST INFORMATION-MARTY'S GMC, KINGSTON, MA

Task	Estimated Quantity	Actual Quantity	Estimated Expenditure	Actual Expenditure	Variance	Unit Cost	Estimated Future Cost	Funding Source	Period of Performance
EMERGENCY RESPONSE									
Labor	NA	NA	NA	$13,418	NA	$19/man hr.	NA	State Spill Fund	4/5/80-5/19/81
Equipment	NA	NA	NA	$12,625	NA	see cost text	NA	State Spill Fund	4/5/80-5/19/81
Storage	NA	NA	NA	$ 3,378	NA	entry-$20/drum $1.00/drum/week	$50,000	State Spill	4/5/80-5/19/81
Disposal	NA	NA	NA	$ 8,360	NA	$70/drum			4/5/80-5/19/81
Subtotal				$37,781					
Hydrogeological Study	NA	NA	NA	$25,000	NA	NA	NA	State Capital Outlays Act (COA)	1981
Management Consultant	NA	NA	NA	$80,000	NA	NA	NA	COA	1981
REMEDIAL RESPONSE Excavation	300-400 cy.yds. ($228-400\ m^3$) 400-800 drums	1058 cu.yds. ($804\ m^3$) 151 drums	NA	$49,850	NA	$47/cu.yd. ($61/m^3$)	ø	State COA	7/14-8/6/81
Mobilization, Bulkin, Loading On-Site Analysis, Aeration, grading, Capping, seeding, Demobilization	NA	NA	NA	$241,718	NA	NA	ø	State COA	7/8-8/6/81
Off-site testing	NA	NA	$26,500	$12,367	-$14,133 (-53%)	NA	ø	State COA	7/11-8/5/81
Transportation (520 miles, 825 km)	47 truck-loads (16.9 ton (15.3 Mt) capacity)	28 truck-loads	$97,854	$60,000 (a, b)	-$37,854 (-39%)	$2300 truck-load (b) 26¢/cuyd/mile 18¢/m^3/km	ø	State COA	7/18-7/24/81
DISPOSAL Class I	1040 tons (943 Mt)	401 tons	$119,600	$55,315(a)	-$64,285 (-54%)	$92/ton(b) ($101/Mt		State COA	7/18-7/24/81
PCB	ø	69 tons (63 Mt)				$207/ton(b) ($228/Mt)	see emergency response text	State COA	7/30-7/31/81
Subtotal			$515,000	$419,250(c)	$95,750(d) (-19%)			State COA	7/8-8/5/81
TOTAL				$562,031(d)					

(a) ADL report for period 7/31 - 8/4/81

(b) Includes 15% added cost for sub-contractor handling

(c) Actual subtotal paid after discount was $408,268. Variance=$106,732 (-21%)

(d) Actual total paid after discount was $551,049.

buckets. The budgeted ceiling of $515,000 for the remedial response was not reached primarily because the amount of contaminated material found on site was lower than expected. The discovery of PCBs, however, raised the costs. The emergency work cost $44,468; the hydrogeological study cost $25,000; and the management consultant cost $80,000.

Labor

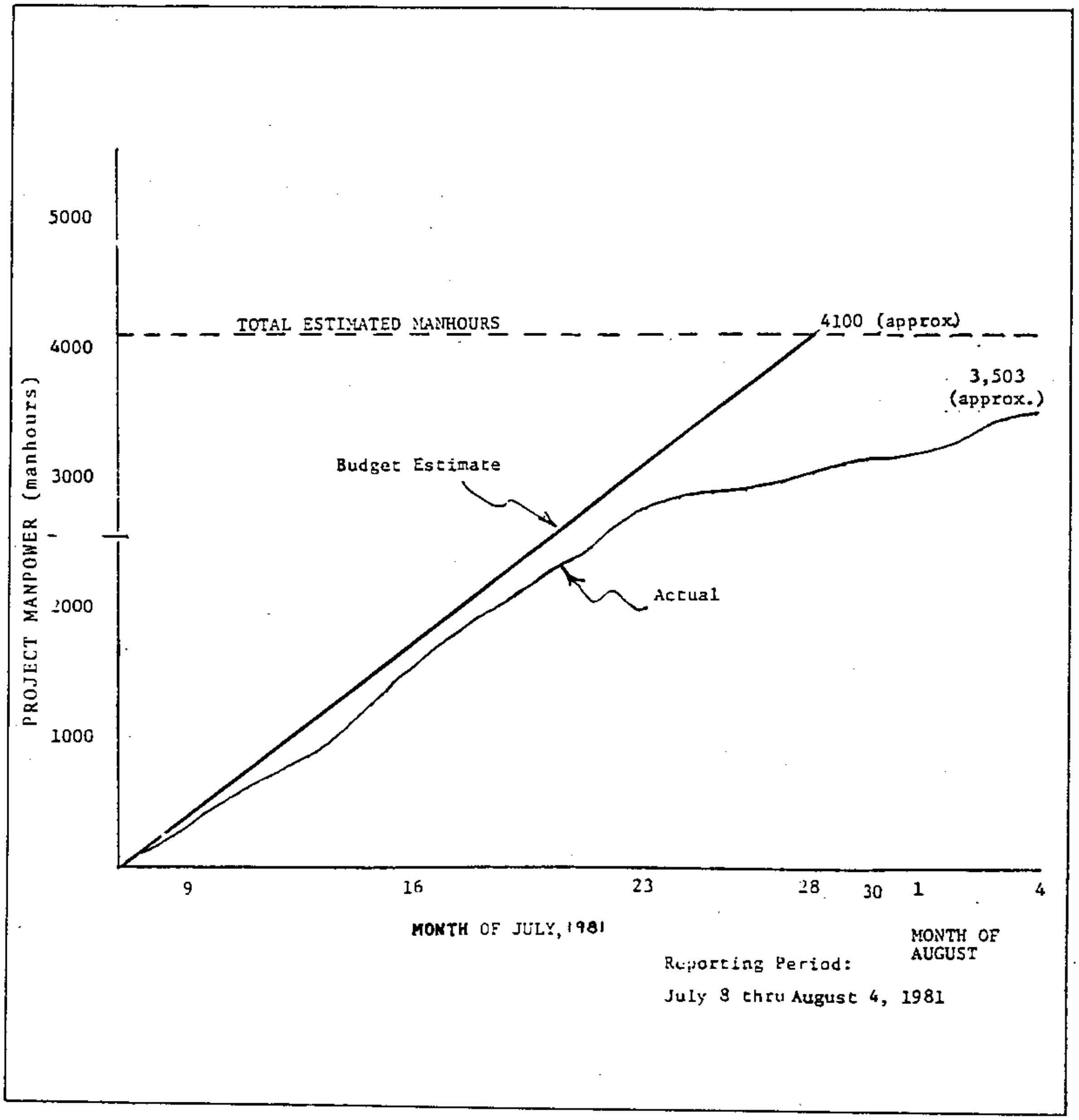
For both the emergency and the remedial response work, for which separate costs are available, labor costs accounted for about 1/3 and 1/4, respectively, of the total project phase costs (See Table 2). The difference in the proportion of the costs devoted to labor reflects the greater transportation and disposal costs during the remedial response. The labor costs given in Table 2 include only primary contractor personnel, i.e., Black Gold Services, and O.H. Materials. Since these labor costs do not include subcontractors or administrative personnel, the unit costs discussed below in the text may be more valuable. The comparison of actual and projected labor usage was tracked by charts such as Figure 6. Approximately 3,503 hours of labor was used during the remedial work by OHM. This was less than the expected 4,100 hours because of the lower amount of material found. The labor cost was $94,941, which was $36,771 (29%) less than the $128,712 expected.

Excavation - Remedial Phase

The total costs of excavation activities, which occurred on July 14-17, 1981, were not invoiced separately, but can be estimated only by correlating the time of the operation with the billings for the same period. On this basis, the total cost of the 4-day excavation activity, excluding subsequent transportation and disposal costs, was about $49,850 (3/7 x $86,912 - July 10-16 weekly invoice total), + $12,602 (July 17 daily invoice total), including all costs for the period (labor, equipment, per diem, analytical work and miscellaneous costs). The cost for mobilization, demobilization and mixing liquids with the HCP is not included in this amount. The cost of simultaneous sampling and support is included.

The volume of drums and contaminated soil excavated can be approximated by adding the 750 cubic yards (573 m^3) estimated to be in the LCP, to the 308 cubic yards (235 m^3) of non-PCB material (non-LCP) disposed of from the HCP. Hence, the unit cost for excavating contaminated soil and drums was about $47/cubic yard ($61/m^3).

Figure 6. Estimated and Actual Labor Hours in Remedial Phase



Source: Arthur D. Little weekly project report to MA DEQE 8/4/81

Transportation - Remedial Phase

The DEQE spent a total of \$60,000 for transportation during the remedial work. This cost was \$37,854 (39%) below what was expected because the lower than expected amount of contaminated soil on site required fewer truckloads. The disposal hauling of about 520 miles (825 km) was done by Tonawanda Trucking and Relco Systems. A 15% service charge was added to the subcontractor rate by O.H. Materials resulting in a rate of \$2,300 per 13 cubic yard (9.94 m^3) truckload, which held about 16.9 tons (15.3 Mt), according to an OHM official. The unit cost charged to DEQE was 26 /cubic yard/mile (18 /Mt/km).

Disposal - Emergency and Remedial Phases

The DEQE spent a total of \$63,675 on disposal during the emergency and the remedial responses. All disposal was carried out at the Chemical and Environmental Conservation Systems, Inc. (CECOS) facility in Niagra Falls, New York. Of the 101 full and partially full drums removed from the site during the emergency response, 89 remained in storage as of October 1982 at Recycling Industries, in Braintree, phase. Massachussetts, pending completion of the criminal litigation, for which they serve as evidence. The estimated future cost of \$50,000 for storing and disposing of these 89 drums is based on a verbal estimate by a DEQE official that the total emergency operation will ultimately total \$100,000, minus the costs accounted for in the invoices. The disposal costs charged by O.H. Materials includes a 15% service charge added to the unit costs.

Hydrogeological Study

The DEQE spent \$25,000 for the hydrogeological study by Goldberg Zoino Associates (GZA). Results of this study are discussed above in the "Description of Contamination" section." Three subcontractors were used by GZA: Con-Tec, Inc. (Concord, New Hampshire), for drilling the 5 test wells; Energy Resources, Inc. (Cambridge, Massachusetts) for laboratory analysis of the voltile organics in the soil and water samples and GHR Engineering (New Bedford, Massachusetts) for fecal coliform analysis of the ground water.

Management Consultant

Arthur D. Little, Inc., of Cambridge, Massachusetts (ADL) provided management consulting services to DEQE for the remedial phase of the Marty's GMC project as part of a contract with a ceiling of \$467,108 that extended from June 6, 1981 to October 29, 1982. The \$80,000 share of this work that related to the Marty's GMC clean-up, given in Table 2, is based on an estimate given by a DEQE official. This estimate was noted to include significant one-time start-up costs. For comparison, if the $467,108 were spread out evenly over the 16-month contract period at $29,194.25/month, the 2 1/4-month work related to Marty's GMC, the billing would have been $65,687 ($467,108 x 2.25).

Two subcontractors were retained by ADL, with DEQE's approval. Coopers and Lybrand of Boston, Massachusetts performed invoice auditing. Haley and Aldrich of Cambridge, Massachusetts provided independent hydrogeological advice, such as assisting in the ground water sensitivity survey of the area with DEQE and a Kingston town official.

The issue of the assistance versus the training function of ADL became important during the Marty's GMC phase of ADL's DEQE contract. The plan for using a management consultant involved having ADL train DEQE personnel to manage hazardous waste site clean-ups on their own. By September 1982, ADL was almost completely phased out because DEQE staff were able to perform the same work themselves. A DEQE official was concerned, however, that his newly trained engineers and managers would move to jobs in the private sector.

Officials in DEQE believed that the use of the management consultant was cost-effective for two reasons. First, the auditing of on-site work and invoices allowed DEQE to take full advantage of the potential economies of the time-and-materials clean-up contract. Since the exact amount of contaminated material at Marty's GMC was found to be lower than expected, the careful scrutiny by the on-scene coordinator ensured that a commensurately lower charge was billed. A DEQE official said that experienced engineers were needed to perform this on-site scrutiny. In addition, cost tracking was enhanced by comparing expected and actual costs against 8 specific milestones for the operation.

Second, the cost for the primary contractor was also reduced by payment within the discount period. Previous state contracts did not include a provision for a discount, since payment was usually delayed. A discount of 5% was offered if the bill was paid within 15 days, and 2% if paid within 20 days. The invoices were paid on a weekly basis. The discount rate was extrapolated for the day paid between 15-20 days after billing. Discounts were achieved for all invoices on an average of 2.62% and a total savings of $10,983. A DEQE official believed that the agency would not have obtained the discount without the greater accounting resources provided through the ADL contract.

An official with the contractor for the clean-up work, O.H. Materials, believed that additional savings were realized from the use of the management consultant because he believed that they were able to cut through the red tape at DEQE and communicate more effectively with the agency since the ADL had the credibility of an independent consultant.

Equipment - Remedial Phase

During the remedial phase, the DEQE spent a total of \$138,442 on contractor equipment rental, excluding subcontractor equipment. During the week of July 17 - 23, 1981, for which detailed invoices are available, subcontractor equipment accounted for about 1/10 (\$3925/\$40,023) the amount charged for equipment by OHM, including mobile analytical equipment and facilities, which accounted for about 20% of its equipment charges.

The unit costs charged by the different contractors for similar pieces of equipment were roughly similar. One contractor sometimes charged more for one piece, but less for another. For example, OHM charged \$56/hour for a 955 CAT front-loader; whereas Black Gold, Inc. charged \$65/hour for a 955 CAT. However, an OHM subcontractor, CMC, Inc. charged \$25/hour for a Case 580 C backhoe, whereas Black Gold charged \$15/hour for a Case 680 C backhoe. The hourly charge for OHM's 30-foot CAT 215 backhoe reflects the substantially larger size of the CAT 215 over the Case 580 C backhoe. This large, treaded backhoe, and the drum grappler attachment (\$225/day) were primary pieces of equipment used for the clean-up that were not readily available elsewhere at the time. The cost for the compatibility chamber (\$500/day), which was brought to the site but not used, as mentioned above in "Technology: Bulking," was not charged. The cost for the mobile analytical laboratory (\$550/day) did not include the costs of hand held or large lab equipment, or field measurement equipment (PID, TOC, GC).

Safety Procedure Costs

Of the 2 elements of the cost of safety procedures used during the emergency and remedial actions - labor and equipment - only the equipment cost during the remedial action can be distinguished from the other costs. During the emergency response, no specific safety procedure information is availble for site surveillance, which was not provided by the contractor. From April 1980 - May 1981, the deputy fire chief who served as the acting hazardous waste coordinator for Kingston, and the police chief of Kingston regularly drove by the site to ensure that the polyethylene cover had not been removed. Although no schedule or billings were prepared for this site security provided by the town, a DEQE official estimated that this service would have cost the state an extra \$1,000 per month, if the state had paid for it.

During the week of July 17-23, 1981, for which detailed invoices are available, and during which the final excavation, bulking and loading occurred, the safety procedures were the most extensive of the entire remedial operation. For this week, the total cost of equipment devoted to safety procedures was an average of 33% (range 16-49%; standard deviation (SD) 11.2) of the overall equipment costs for the week; it was an average of 42% (range 20-63%; SD-0.15.) of the non-analytical equipment costs for the week. Since the total equipment costs were about 41% of the weekly invoice total (excluding the discount $40,023/$97,245), the cost of safety procedures accounted for about 14% of the weekly invoice total (33% x 41% or $13,428/97,245). Among the standard safety equipment included in these total safety equipment costs are the following: decontamination and equipment trailer ($350/day); high pressure water laser ($400/day); chemical sealing unit ($130/day); self-contained breathing apparatus ($150/day); regulated manifold air supply system ($105/day); protective clothing set ($100/day); portable pool ($75/day); emergency escape pack ($43/day).

PERFORMANCE EVALUATION

Through the project, the DEQE sought to acheive a cost-effective site response at Marty's GMC. The Massachusetts DEQE's technical and financial expertise with hazardous waste were important in thier apparent success at meeting this goal. The department's experience with earlier clean-ups had also suggested the need for greater cost control assistance, such as that provided by ADL at Marty's. The segregation of work into immediate and planned response phases provided a contructive means of allocating the state's limited resources between competing sites and balancing those needs with the remaining funds.

Another cost effectiveness control was achieved through the use of the time and materials type of contract. However, since the exact volume of material was the only major unknown in the RFP, a unit price contract might have been cheaper. Savings could have also been acheived by eliminating charges during analysis delays. But the contract change orders due to the discovery of PCBs might have eliminated these savings.

The work performed during the emergency phase effectively mitigated the threat of fire, which was the immediate concern. The site assessment during the emergency period was efficient and practical since it provided adequate information for future work and used available on-site equipment. Monitoring and maintenance of the temporarily secured drums ensured that the threat of fire did not arise again.

The work performed during the remedial phase was apparently effective in removing the source of contamination. The bulking of liquids and highly contaminated soil was a practical means of increasing the efficiency of this operation. An assessment of the environmental consequences of leaving the PCB contaminated soil (under 7 ug/g) must await future analysis and review. Planning for follow-up monitoring of the site was pending as of November 1982.

Future work at the site should primarily involve monitoring the capped area of PCB contaminated soil and ensuring that any contaminated ground water does not threaten public health or the environment. Generally, the PCB contaminated soil should be monitored to ensure the ability of the cap to prevent erosion and its effect on plants growing on the area. Since PCB is highly insoluble (Arochlor 1260 - 3 ug/l in water), the threat of downward migration into the aquifer is probably insignificant. The ground water which flows toward Kingston and Plymouth Bays should be monitored to determine the extent and route of contamination, if any. Construction of new water supply wells downgradient should be done very cautiously, if at all, to prevent public health problems. Although the commercial cranberry bogs are not hydrologically downgradient from the site, the proximity of these bogs and the potential for bioaccumulation suggests that they should be monitored in the future.

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N.W. MAUTHE, INC.

APPLETON, WISCONSIN

INTRODUCTION

NCP References

N.W. Mauthe, Inc. is a former chrome plating shop located in Appleton, Wisconsin. In March, 1982, the Wisconsin Department of Natural Resources (WDNR) discovered puddles of yellow chromium contaminated water along railroad tracks immediately south of the plating shop. Subsequent investigation revealed hexavalent chromium contamination of soil, surface water, and shallow ground water beneath and south of the shop. Contaminated water was seeping into a nearby residential basement, and threatened to enter the Fox River via storm sewers.

Background

From 1966 to 1976, Norbert W. Mauthe operated a chrome plating facility at 725 South Outagamie Street in Appleton, Wisconsin under the name of the Wisconsin Chromium Corporation. In 1976, Mauthe sold the name and chrome plating customer list to another company but continued to do cadmium and zinc plating at the Outagamie Street facility for some time thereafter. At the time of site discovery in March 1982, Mauthe remained the sole owner of the property at Outagamie Street.

An anonymous phone call to the WDNR led to site discovery. Yellow puddles were reported along the railroad tracks behind the chrome plating plant and in an adjacent ditch leading to a storm sewer which discharged to the Fox River. Investigation by WDNR revealed that chromium contaminated water was being pumped from a sump pump at a residence 150 feet (46 m) from the plant. WDNR responded with a quick sampling effort to determine the extent of contamination and discovered a high level of chromium contamination and low levels of cyanide, zinc, copper, cadmium and othe metals. Figure 1 presents a layout of the site and the primary areas of contamination.

300.63(a)94)
discovery

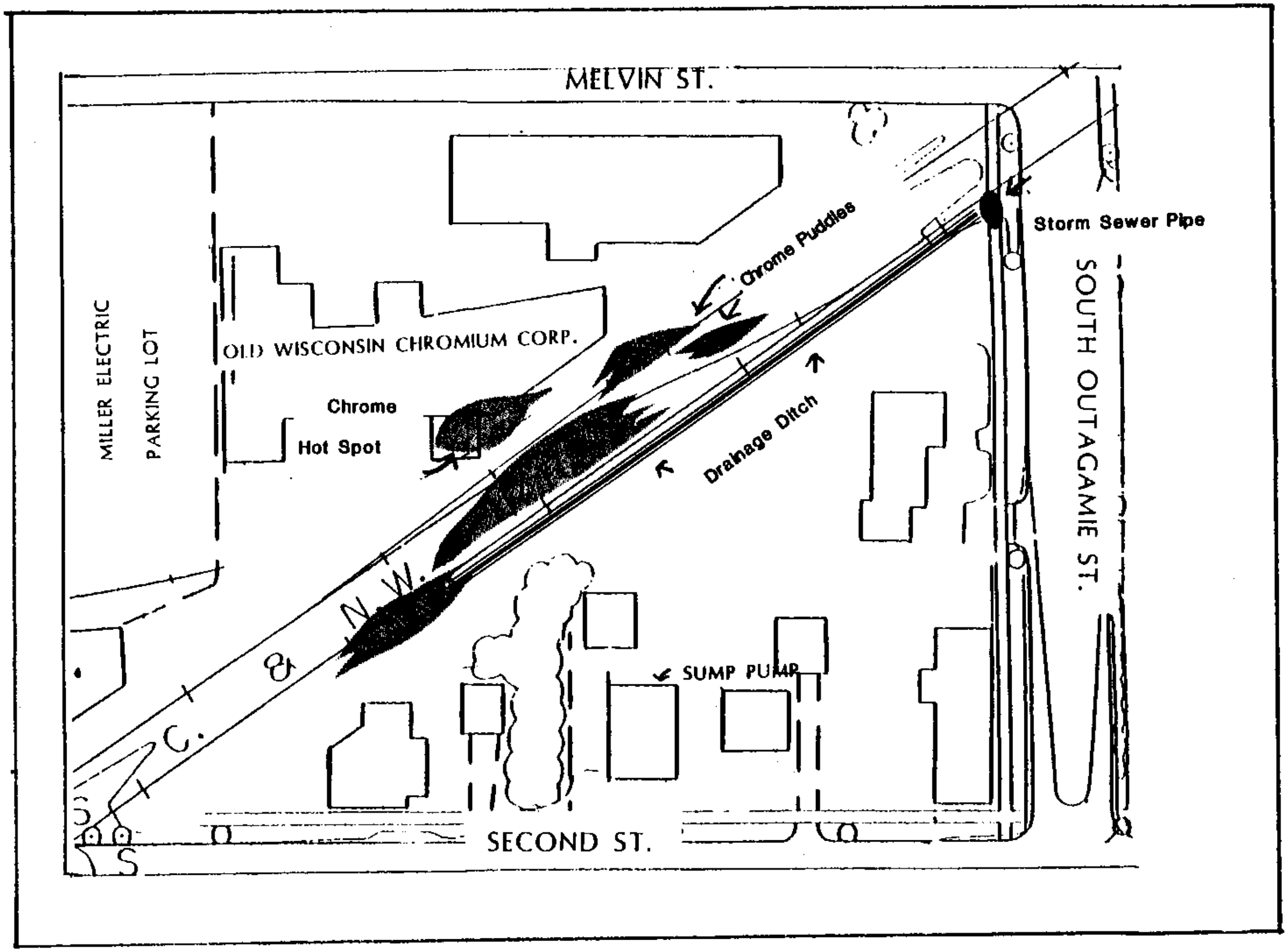


Figure 1. Location and Extent of Surface Chrome Contamination at the Mauthe Site

Synopsis of Site Response

The WDNR determined that snowmelt and rainwater were leaching chrome out of the soil near the plating building and transporting it laterally along the permeable railroad beds and to the nearby resident's sump pump. The immediate concern was to contain the contaminated surface water and remove it from the area to reduce possible exposure of nearby residents and to prevent the contaminated water from migrating into the Fox River via the storm sewers. The WDNR made an arrangement with a local contractor, Rocket Sewer Handling, to pump and dispose of the contaminated surface water from the puddles surrounding the site, from the drainage ditch adjacent to the railroad tracks, and from the nearby storm sewer. Beginning in April 1982, Rocket Sewer Hauling pumped and transported the contaminated liquid to the nearby City of DePere Sewage Treatment Plant. This effort was combined with the construction of a small dam across the drainage ditch to reduce the flow of contaminated water into the storm sewer, and application of loads of sand to contain the spill. Over the following six weeks, Rocket Sewer Hauling periodically returned to the site to remove puddles of contaminated water from melting snow and rainfall.

300.65(b)(6) moving hazardous substances off-site

300.65(b)(7) physical barriers to deter spread of release

Between May 18-20, 1982, Commercial Pumping and Incineration (CPI), under contract with WDNR, installed a more permanent collection system. The system included shallow subsurface drains which collected the contaminated surface water and shallow ground water and routed it to collection sumps where they were pumped into a holding tank. Contaminated soils were removed from the north side of the tracks in the process of installing the collection sump there. CPI also installed a drain pipe to collect clean rainfall runoff and divert it away from the subsurface drains so as to minimize the quantity of water which is collected, pumped and hauled off site.

300.70(b)(1)(iii) ground water controls

300.70(b)(1)(ii)(b) surface water diversion and collection

Rocket Sewer Hauling continues to haul the collected contaminated liquids to DePere Sewage Treatment Pland and as of December 1982, 273,000 gallons (1.03×10^6 l) of contaminated liquid have been pumped.

300.70(c)(2)(i) excavation of contaminated soils

In October 1982, Mauthe drilled through the concrete floor of the plating building, excavated a trench and installed a sump pump to pump contaminated liquid into the holding tank.

SITE DESCRIPTION

The Mauthe site is located in Appleton, in east central Wisconsin. The site is bounded by South Outagamie Street, 2nd Street and Melvin Street. The source of the contamination was the Wisconsin Chromium Corporation, formerly located at 725 Outagamie Street adjacent to the Chicago and Northwest Railroad tracks. This area is mixed industrial and residential. Private residences are located within 150 feet (46 m) of the source of contamination. There are 6 primary and secondary schools within one mile (1.6 Km) of the site, one of which is located just 1 1/2 blocks from the site. Figure 2 shows the location of the Mauthe site.

300.68(e)(2)(i)(A) population at risk

Surface Characteristics

The climate of Outagamie County is mild with long cold and snowy winters and warm summers. There is a considerable temperature range from season to season and from year to year. The maximum average daily temperature in Appleton ranges from a low of 26.1°F (-3.3°C) in January to 82.6°F (28.1°C) in July. The average daily minimum temperature ranges from a low of 9.8°F (-12.3°C) in January to a high of 61.9°F (16.6°C) in July.

300.68(e)(2)(i)(E) climate

The average yearly precipitation in Appleton is 25.5 inches (64.8 cm) and 55 percent of the precipitation falls between May and September. Snowfall and sleet average about 43.4 inches (110.3 cm), but vary greatly from year to year. The last freezing temperature occurs later than April 30th in 6 out of 10 years. Prevailing winds are from the northwest in winter and from the southwest in summer.

The city of Appleton and most of Outagamie County lie in the Fox River drainage basin. The river, which is about 0.5 miles (0.8 Km) south of the Mauthe site, flows in a southwesterly direction through Appleton and discharges into Lake Winnebago.

300.68(e)(2)(i)(D) hydrogeological factors

The topographic relief of Outagamie County was formed by recent glaciation. The soil are well drained, nearly level to gently sloping, and were formed in clayey glacial till. The upper soils are principally brown and red clays and silty clays. The permeability of these soils is slow to moderately slow. In the immediate area of the Mauthe site, much of the native soils have been covered with fill consisting of cinders, sand and gravel. This fill layer is discontinuous but is 1 to 2 feet (0.3-0.6 m) thick in some areas. A perched water table is present in the fill material.

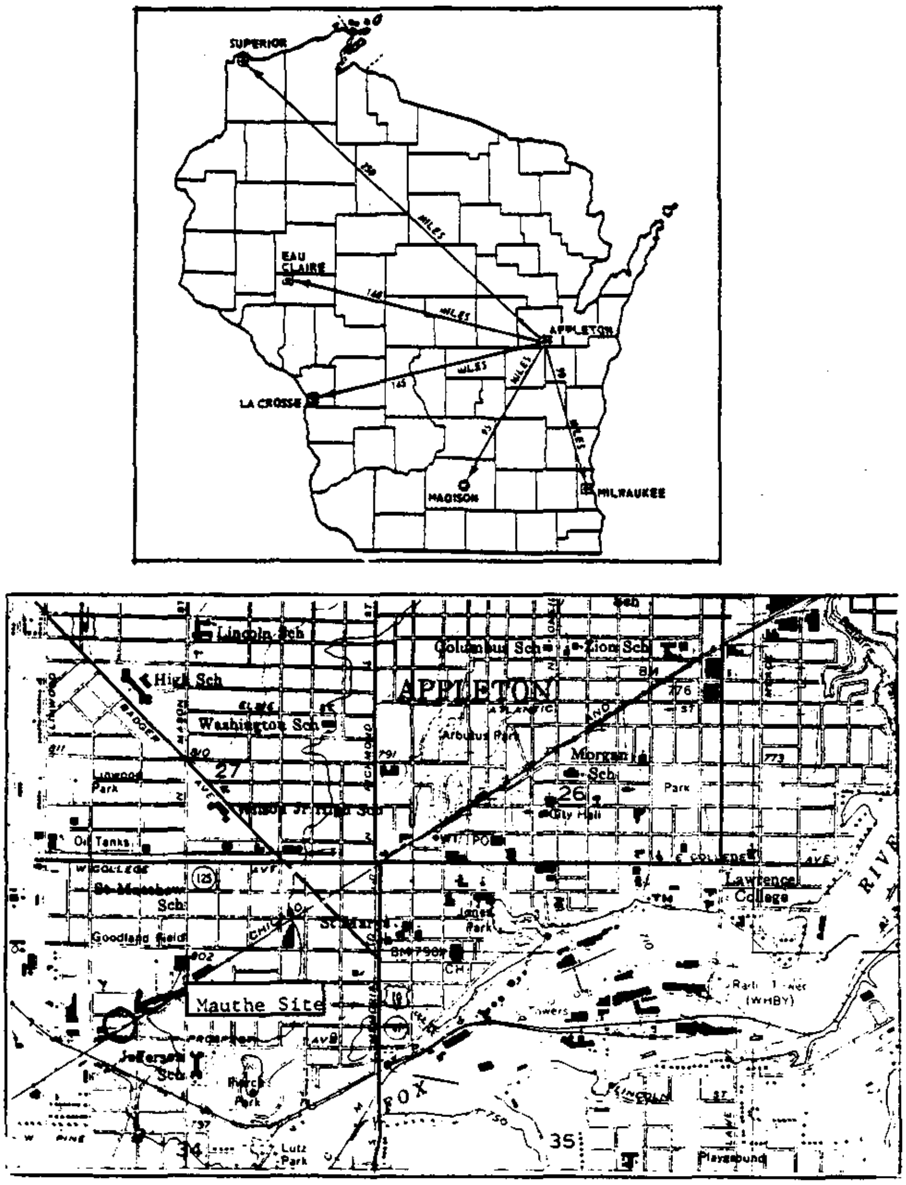


Figure 2. Location of the Mauthe Site - Appleton, Wisconsin

Hydrogeology

The surface geology of Outagamie County is characterized by a thick layer of glacial drift deposited during the Wisconsin stage of glaciation. These deposits are underlain by sandstone and dolomite of the Cambrian and Ordovician age. The geology in the area of the Mauthe site is outlined more specifically in the geologic cross-section shown in Figure 3 and in Table 1 which summarizes driller's well logs for two wells located within 0.5 miles (0.8 km) of the site.

The glacial drift which is mainly till containing sand, clay, silt and gravel varies widely in thickness in the area of Appleton and is reported to be about 60 feet (18 m) thick beneath the Mauthe site.

The upper 10 to 20 feet (3 - 6 m) of the glacial till has been characterized by borings which were taken during the site investigation efforts at the Mauthe site in May 1982. The drift was chiefly brown and red clays and silty clays with discontinuous sand and gravel seams. Thin sand and gravel seams of 1-2 inches (2.5-5 cm) were found in most borings and thicker sand seams of 1 to 5 feet (0.3 - 1.5 m) occured in several borings at depths below 5 feet (1.5 m). Water flowed freely where these highly permeable sand or gravel strata were encountered. The surrounding clay soils were generally saturated.

As indicated in Figure 3 and in the drillers logs (Table 1), the glacial till is underlain by a dolomite unit, ranging in thickness from about 20 to 80 feet (6 - 24 m). Vertical fracturing and numerous sandy and silty zones are characteristic of this formation. In some areas there is 15 to 20 feet (4.5-6 m) of fine to medium sandstone near the base of this unit.

As Figure 3 illustrates, the dolomite formation is underlain by a sandstone unit (St. Peter sandstone) which is characterized by fine to coarse grained sandstone containing some chert. This unit is discontinuous but is shown to be 70 feet (21 m) thick in the area of well No. 280.

The fractured dolomite or the sandstone, where found, is in turn underlain by an older, denser dolomite formation. This dolomite contains numerous shaly and sandy zones and layers of chert. It is over 100 feet (30 M) thick beneath the site.

Finally this dense dolomite formation is underlain by about 150 feet (50 m) of sandstone of the late Cambrian

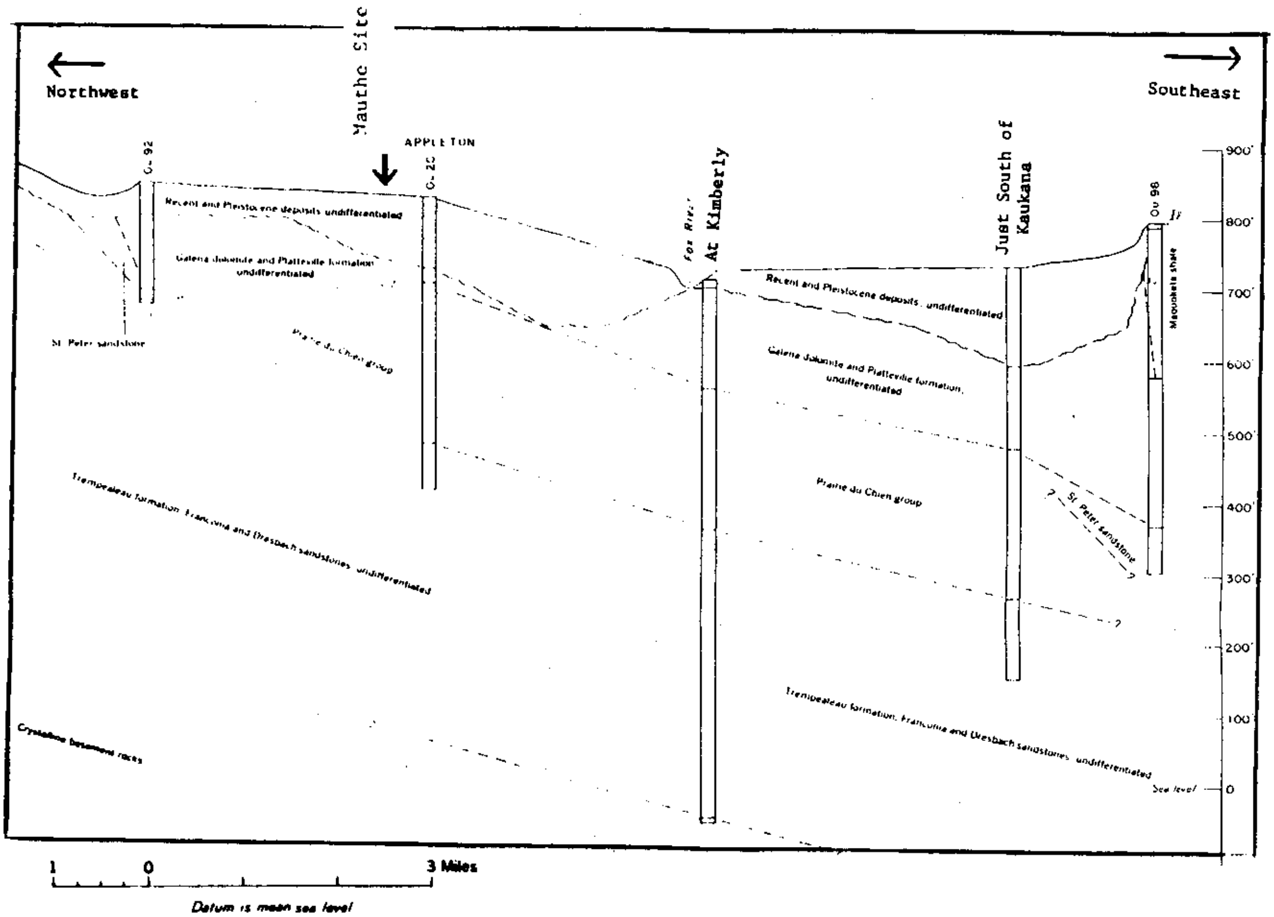


Figure 3. Geological Cross Section of Area Around the Mauthe Site

Source: LeRoux, 1957

TABLE 1. WELL LOGS FROM TWO WELLS WITHIN 0.5 MILES OF THE MAUTHE SITE

Well Ou 38. NW¼NW¼ sec. 34, T. 21 N., R. 17 E.	Thickness (ft.)	Depth (ft.)
Glacial drift:		
Sand, fine, gray-pink, weathered	5	5
Till, pink, dolomitic	80	85
Gravel, fine, stony	5	90
Till, light yellow-gray	5	95
Galena dolomite and Platteville formation:		
Dolomite, light-gray; some light blue-gray	10	105
Sandstone, medium-to fine-grained, light-gray, dolomitic	10	115
St. Peter sandstone:		
Sandstone, fine-to medium-grained, very light gray	20	135
Chert, gray, pink-gray	5	140
Shale, red; chert, green-gray, pink	5	145
Chert, gray, yellow-gray, pink-gray; quartzite, fine-grained, light-gray	40	185
Prairie du Chien group:		
Dolomite, very light gray	30	215
Dolomite, light-gray to very light gray	20	235
Dolomite, light-gray	40	275
Dolomite, light-gray, pink, some sand	5	280
Dolomite, very light gray, light-gray	30	310
Dolomite, very light gray, sandy; chert, gray, oolitic	3	313
Upper Cambrian series:		
Sandstone, very fine-grained, very light gray, dolomitic	10	323
Sandstone, very fine grained to silty, orange-pink, dolomitic	5	328
Siltstone, red-brown, red, red-orange, green-gray, glauconitic, dolomitic; shale, gray-green	25	353
Sandstone, fine-grained, pale-red, dolomitic, glauconitic	5	358
Sandstone, fine-grained, light pink-gray, dolomitic, glauconitic	12	370
Sandstone, fine- to medium-grained, light-gray, dolomitic, some glauconite	65	435
Sandstone, fine-grained, light-gray, some glauconite	15	450
Siltstone, light medium-grained, gray, dolomitic, hard	5	455
Sandstone, fine- to coarse-grained, light-gray, dolomitic	10	465

Well Ou 18. NE¼NW¼ sec. 18, T. 21 N., R. 17 E.	Thickness (ft.)	Depth (ft.)
Glacial drift:		
No samples	24	24
Galena dolomite and Platteville formation:		
Dolomite, blue-gray and gray	16	40
Dolomite, light-gray; chert, white	10	50
Dolomite, light-gray	30	80
Sandstone, fine- to medium-grained, light-gray, dolomitic; dolomite, very light gray	20	100
Prairie du Chien group:		
Dolomite, light-gray, sandy	10	110
Dolomite, light-gray	30	140
Dolomite, light-gray; sandstone, medium-to fine-grained, light-gray	5	145
Dolomite, light-gray	15	160
Dolomite, light-gray; chert, white	55	215
Dolomite, light-gray	60	275
Sandstone, fine- to medium-grained, light-gray, pink, dolomitic; chert	15	290
Upper Cambrian series:		
Sandstone, fine-grained, pink, dolomitic	10	300
Dolomite, sandy, red, gray, glauconitic	15	315
Sandstone, fine-grained, gray, red, dolomitic, glauconitic	10	325
Sandstone, medium- to fine-grained, light-gray, dolomitic; shale, red	45	370
Sandstone, medium- to fine-grained, light-gray, dolomitic	20	390
Sandstone, very fine to medium-grained, light-gray, dolomitic	15	405
Sandstone, coarse- to fine-grained, light-gray, dolomitic	15	420
Sandstone, fine- to medium-coarse-grained, light-gray	30	450

Source: LeRoux, 1957

Age. It is a fine to coarse grained sandstone which is shaly and dolomitic in some places.

Ground water occurs under both water table and artesian conditions in the Appleton area. Water table conditions prevail locally in bodies of clean sand and gravel and in the dolomite where water moves freely through cracks and solution channels. Artesian water occurs locally, confined by layers of silt and clay in the glacial drift. It also occurs throughout the bedrock formations wherever it is confined by relatively impermeable dolomite and shale.

The sandstones of the upper Cambrian series and the St. Peter's sandstone, where it is sufficiently thick, are the most important aquifers in Outagamie County. The dolomite formations also supply some water to domestic and industrial wells in the county but yields from these wells are generally low. Yields from wells drilled in the glacial till are good where the permeable layers are sufficiently thick. Piezometric maps indicate that the ground water flow is in a southeastern direction. This is a result of natural discharge into the Fox River, recharge from areas west of Appleton, industrial pumping along the Fox River and the eastward dip of the bedrock.

The city of Appleton is served by a municipal water supply and WDNR has indicated that there is only one domestic well in the "immediate" area. This well is not supplied by the glacial drift and is not contaminated. There are several industrial wells in Appleton and the sandstone and, to a lesser extent, the dolomite formations supply these wells.

300.68(e)(2)(i)(A) population at risk

WASTE DISPOSAL HISTORY

Norbert Mauthe purchased the property at 725 Outagamie Street in 1966. He operated the Wisconsin Chromium Corporation, a facility involved in chrome plating and other types of electroplating, until March 26, 1976, when he sold the name and the chrome plating customer list to Southern Plating located in another part of the State. Mr. Mauthe retained the Outagamie Street facility where he has continued to do cadmium and zinc plating.

As the name implies, Wisconsin Chromium Corporation was chiefly involved in chromplating. The process involved immersion of the metal into an acidic solution of chromic acid or chromium salts so that some of the base metal was converted to one of the components of

300.68(e)(2)(i)(B) amount and form of substance present the film by reaction with the aqueous solution. Chromium plating solutions contain chromic acid at concentrations of 400 g/l and small amounts of sulfuric acid or a mixture of sulfuric and fluoro-silicate or fluoride ions. Chromate conversions can be produced on a number of metals including zinc, cadmium, copper and aluminum and low concentrations of these dissolved metals can be found in the chromating bath.

During operation of the Wisconsin Chromium Corporation at South Outagamie Street, there were two possible sources of contamination. One was a blower vent located along the southern face of the facility which discharged chromium laden mist to the outside. The second source apparently resulted from leakage of chromium plating wastewater through cracks in the concrete floor. The chromating tanks were located along the south wall of the facility. A trough had run adjacent to tanks in order to catch the drippings and to conduct them to the sanitary sewer. Cracks in the trough and in the concrete flooring resulted in seepage of chromium bearing waste water into the underlying soil.

On March 31, 1982, the WDNR, responding to an anonymous complaint, discovered puddles of yellow water in the vicinity of the Outagamie Street plating facility and in a ditch which ran adjacent to the railroad tracks, as illustrated in Figure 1. Apparently the upward movement of the water table resulting from snowmelt and rain had caused the surface expression of the contamination. WDNR's subsequent investigation and sampling at the site verified the presence of high concentrations of hexavalent chromium and low concentrations of other metals and cyanide. Because of these findings, WDNR initiated both an emergency response and a planned remedial response.

DESCRIPTION OF CONTAMINATION

In the course of developing both an emergency response and a planned remedial response, WDNR has conducted several sampling and monitoring efforts to determine the extent and severity of the contamination problem.

300.68(f)
remedial
investigation

On April 1 and again on April 21, after emergency efforts had been undertaken to pump contaminated water from puddles and from the drainage ditches WDNR took a number of samples from shallow 18 to 36 inch (46-91cm) hand-dug, auger holes, from surface puddles, and from the sump pump of a residence located less than 150 feet (50 m) from the site. The samples were analysed for hexavalent chromium, cyanide and for a number of other

300.65(b)(1)
collecting and
analyzing
samples

metals. The location of the sampling points and the results of those sampling efforts are summarized in Figure 4 and Tables 2 and 3. The results clearly indicate the following:

- Hexavalent chromium was the major contaminant although cyanide, zinc and other metals were also detected.

300.68)(e)(2)(i)(B) amount and form of substance present

- The highest chromium concentrations were found at or near the surface in the area west of a concrete slab (see Figure 4, samples 3 and E), along the southern wall of the facility and adjacent to the blower discharge vent which was used for exhausting chromium laden mist.

300.68(e)(1)(v) highly contaminated soil at or near the surface

- The contaminated water had entered a drainage ditch which ran adjacent to the south side of the railroad tracks and discharged into the Fox River via a storm sewer.
- The permeable railway bed and the topography were causing the contaminated groundwater to move in a northeastern direction.
- The contaminated water was also moving in a southeasterly direction, as was evident from the high concentrations of chromium in samples taken from a nearby basement sump pump (Sample 9, Figure 4).
- Contaminant migrated to a lesser extent north and west of the site was minimal.

On May 6 and 7, 1982, two weeks prior to the installation of a surface water collection and diversion system, Soil Testing Services of Green Bay, Wisconsin conducted a subsurface exploration.

300.68(f) sampling and monitoring

Nine borings were drilled at the locations shown on Figure 5 using a trailer mounted hollow flight, split spoon sampler in accordance with ASTM specification D1586-67. Six, 20-foot (6 m) and three, 10-foot (3 m) borings were made and samples were taken at 2.5 foot (0.8 m) intervals. The boring logs which resulted from this effort were described under "hydrogeology." Table 4 summarizes the levels of total chromium found in the borings at various depths. Levels of 30 mg/kg or less are considered to be background levels. The results indicated that chromium had migrated vertically to a maximum of 13 feet (4 m) and further confirmed that the direction of migration was in a northeast and southeast direction. The

300.68(e)(2)(ii) extent of migration of substance

TABLE 2. RESULTS OF APRIL 1, 1982 SAMPLING AT MAUTHE SITE

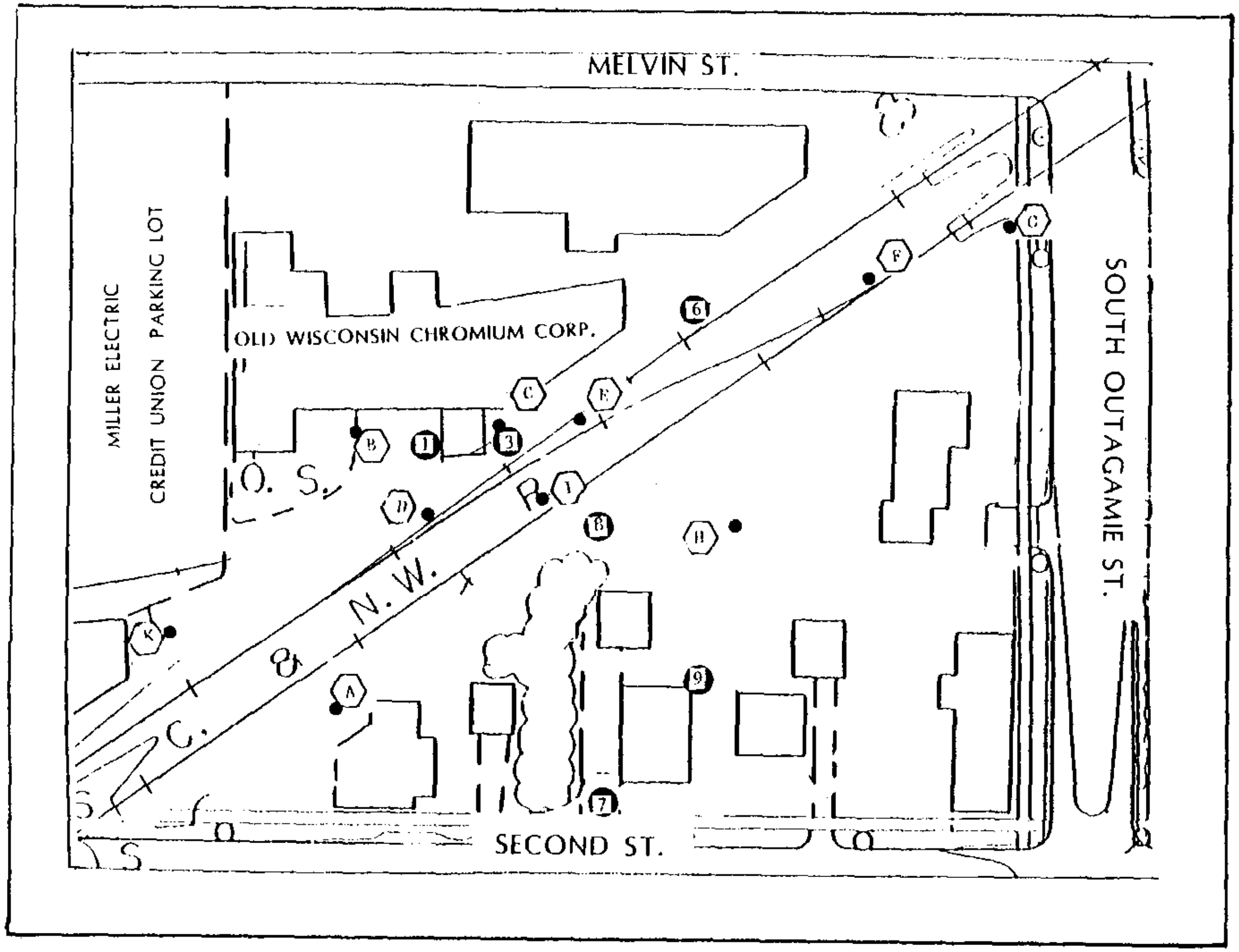
Sample Number	As mg/l	Ba mg/l	Cd mg/l	Cu mg/l	Fe mg/l	Pb mg/l	Se mg/l	Ag mg/l	Zn mg/l	Cr+6 mg/l	Cr-Tot. mg/l	CN mg/l
SA-1	<1	<0.4	<0.02	<0.05	1.4	<0.1	<1	<0.05	0.150	1.3	1.3	<.01
SA-3	<1	<0.4	<0.02	<0.05	0.8	<0.1	<1	<0.05	0.080	340	400	.02
SA-6	<1	<0.4	0.04	0.08	1.0	0.1	<1	<0.05	0.580	8.5	13	.21
SA-7	<1	5	<0.02	<0.05	5.1	<0.1	<1	<0.05	0.100	0.520	<0.1	---
SA-8	<1	<0.4	<0.02	<0.05	2.4	<0.1	<1	<0.05	0.280	22	21	---
SA-9	<1	<0.4	<0.02	<0.1	8.5	<0.1	<1	<0.05	0.170	96	110	<.01

All samples except SA-7 were properly filtered and preserved. All samples were from shallow (18-36 inches) augerholes except SA-9 which is a sump pump sample.

TABLE 3. RESULTS OF APRIL 21, 1982 SAMPLING AT MAUTHE SITE

Sample	As mg/l	Ba mg/l	Cd mg/l	Cr-Tot. mg/l	Cr-hex mg/l	Cu mg/l	Pb mg/l	Ag mg/l	Zn mg/l
A				15	15				
B				8.1	8.1				
C	<1	<0.4	<0.02	44	41	<0.05	<0.1	<0.05	<0.02
D	<1	<0.4	<0.02	110	100	<0.05	<0.1	<0.05	<0.02
E	<1	<0.4	<0.02	840	790	<0.05	<0.1	<0.05	<0.02
F				130	130				
G				43	41				
H				57	57				
I				290	280				
K				<0.003					

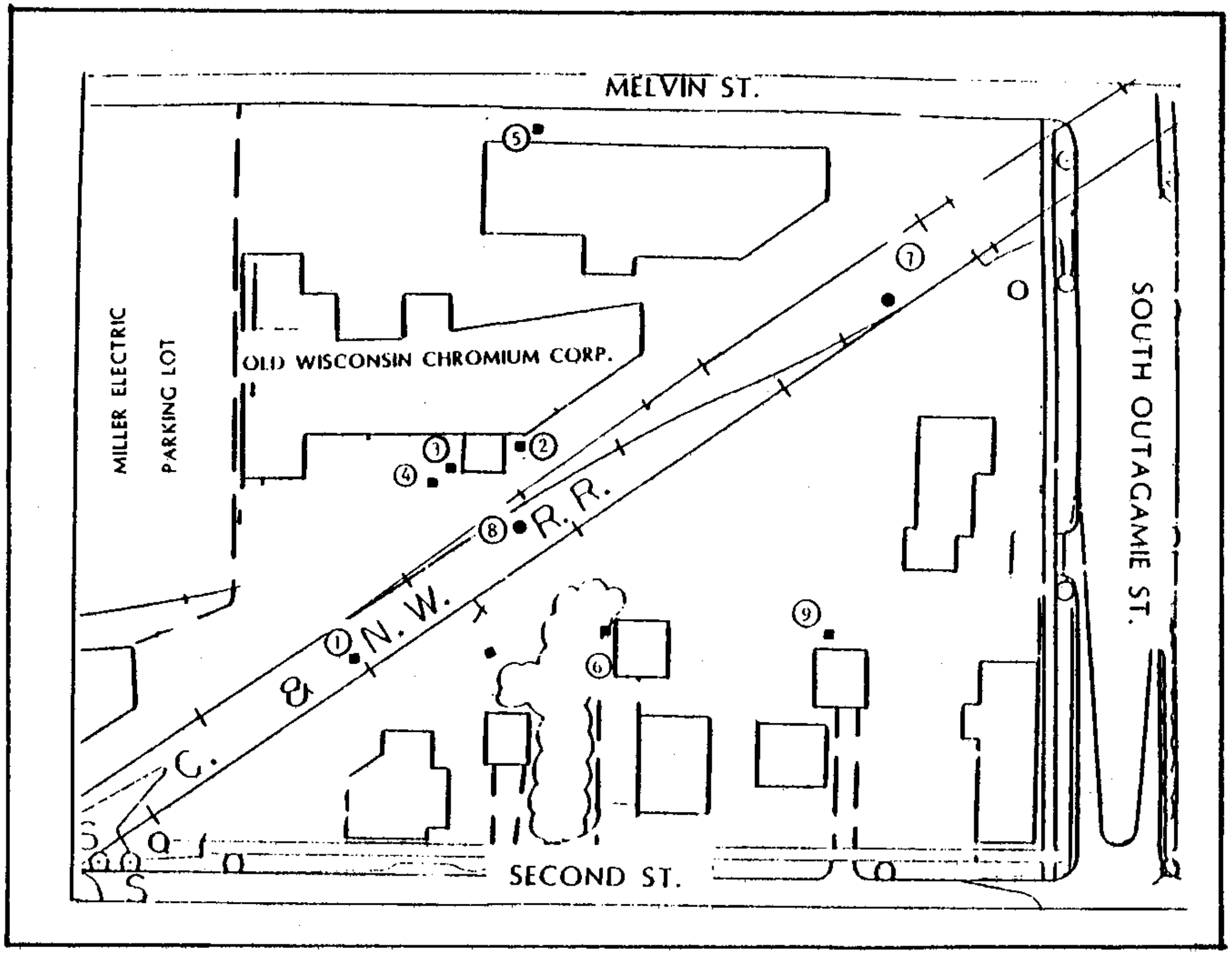
Samples A, B, C, F, H, I and K are water samples taken from 18-30 inch deep boreholes. Sample D is water from a one foot deep borehole, sample E is water from a surface puddle and sample G is water from the drainage ditch just upstream of sandbags. Blanks indicate that no analysis was made.



● April 1 Sampling Points

⬡ April 21 Sampling Points

Figure 4. Location of April 1 and April 21, 1982 Sampling Points



■ Borings

● Wells

Figure 5. Location of Borings and Wells Drilled and Installed on May 6 & 7,1982

TABLE 4. RESULTS OF MAY 1982 SOIL BORINGS - TOTAL CHROMIUM (mg/kg) (NITRIC ACID EXTRACTION) OF SOIL SAMPLES ON AND ADJACENT TO THE N.W. MAUTHE COMPANY.[1]

Depth[2] (ft)	Boring 1	2	3	4	5	6	7	8	9
1	80	4300	390	200	150	79	750	910	32
3	61	1300	770	390	110	310	280	120	34
6	30	420	160	62	82	51	55	120	29
8	27	720	220	110	210	44	41	110	23
11	30	810	140	120	150	16	23	25	24
13		1500			20	72	20	25	22
16	30	30					21	28	21
18	21	20					20		16
21	20	30					26		19

Soil sample immediately under plating buildings slab: 33,000 mg/kg total Cr

[1] Blanks indicate that sample was not taken

[2] All depths are ± foot.

high chromium levels detected in boring #5 were thought to be attributable to a small spill from the chrome plating facility. A grab sample of soil from underneath the building slab was also taken and had an extremely high chromium concentration of 33,000 mg/kg. This high chromium concentrations led WDNR to suspect that the blower vent was not the only source. WDNR subsequently investigated the building and found evidence of leaky collection troughs and cracks in the concrete flooring thorugh which the chromium had seeped.

In two of the 20 foot (6 m) borings, PVC observation wells were also installed. Figure 5 shows the locations of these wells. The wells were protected with steel protector pipes and locks. One well, B-7, was screened from 15 to 20 feet (4.5 - 6 m) and the other, B-8, was screened from 10 to 15 feet (3-4.5 m).

A second round of borings and monitoring wells were completed by Twin City Testing of Appleton in December 1982. Five borings made inside the plating building to a depth of 15 to 20 feet (4.5-6 m). Seven borings were made to a depth of 15 to 20 feet (4.5-6 m) at various locations in the area of south Outagamie and Second Street and twelve, 2-inch diameter schedule 160 PVC piezometers were installed. Drilling and sampling procedures were similar to those used during the May 6 and 7 hydrogeologic investigation. Boring and well locations, boring logs and sampling results were not available as of January 1, 1983.

PLANNING THE SITE RESPONSE

Initiation of Response

On March 31, 1982, the WDNR was alerted to the chromium spill at 725 Sout Outagamie Street by an anonymous phone call reporting yellow and green water pumping out of the ground around the site of Norbert Mauthe's chrome plating plant. The WDNR responded with an initial investigation to determine the type of contamination and immediately hired Rocket Sewer Hauling to begin pumping the contaminated liquid from puddles and from the drainage ditch next to the railroad tracks. The WDNR's initial sampling determined the contamination to be primarily hexavalent chromium in the soil and ground water. The immediate threat involved three factors: (1) the danger posed by human or animal exposure by direct contact to puddles of hexavalent chromium contaminated water, (2) the threat of human exposure by direct contact through seepage of contaminated water into local

300.64(a)(2) identification of the source and nature of the release

300.65(a)(1) exposure to toxic substances resident's basements, and (3) the possibility of contaminated water migrating to the Fox River about 0.5 miles (.8 km) south of the site.

Selection of Site Response

The emergency activities at the Mauthe site, which included periodic pumping of chromium contaminated water from the drainage ditch and from puddles, were viewed by WDNR to be interim control measures to provide them with the time they needed to determine the extent of contamination and to develop a planned response. Based on early sampling results and WDNR's inspection of the site, they proposed a response plan which included the following elements:

- Control and dispose of surface water in order to reduce potential health effects and to prevent contamination from entering the Fox River via the storm sewers (Phase I) — 300.70(b)(1)(ii) and (iii) surface water and ground water controls

- Identify the horizontal and vertical extent of contamination and the transport mechanisms (Phase II — 300.68(f) sampling and monitoring

- Design and implement a contamination containment or removal plan (Phase III + IV). — 300.70(b)(iii) ground water controls

Although WDNR could have continued to pump water from the puddles and drainage ditch, this approach was expensive and inefficient as a long-term solution. A lot of contamination was escaping these collection efforts and the WDNR was incurring a large expense because of the need to pump the puddles and ditch after every rain storm. In addition, unnecessary expenses were incurred from pumping large amounts of clean rainwater running on to the site. Therefore WDNR considered alternatives for controlling the surface water.

They decided that a drainage system should be installed to reduce the high costs and staff time involved with pumping from the ditch and the puddles. WDNR briefly considered alternatives to a drainage system but dismissed them. Dewatering wells would not have been effective because the soils were too clayey and the permeability too low.

300.68(g) and (h) development and screening of alternatives

The District WDNR staff decided that, due to a shortage of manpower and lack of staff engineering experience, the design and installation of the collection system should be performed by an outside contractor. WDNR contacted several potential contractors and on April 14 they received four proposals which included the remedial actions proposed in Table 5.

Table 5. PROPOSED REMEDIAL RESPONSE FOR PHASE I

Proposed Remedial Response	WDNR's Rationale for Selection or Rejection
Collection lines with meter sprinkler system to leach chromium from the soil	Rejected: high cost and soils too impermeable for leaching
Trench system with pretreatment prior to discharge to sanitary sewer	Rejected: high cost of pretreatment
Groundwater depression pump with collection and treatment	Rejected: soils too clayey to pump
Trench system with collection and off-site treatment of contaminated water; removal of highly contaminated soils; diversion of clean surface water	Selected: on basis of cost and effectiveness

WDNR accepted the proposal submitted by CPI. Due to a delay in funding, the work was not begun until May 18th. However most of the construction was completed by May 20th.

Phase III or the design of the remedial response activities is still ongoing at this time. As of January 1983, WDNR had just received the first round of monitoring data from the wells which were completed in December 1982, but the results will not be available until WDNR has reviewed and analyzed the data.

Extent of Response

During Phase I the WDNR sought primarily to contain the immediate threat of the chromium contamination by minimizing migration of the contaminated ground and surface water from the site. Consequently the selection of the length and depth of the drainage system and the amount of soil excavated was based upon WDNR's evaluation of what was necessary to remove the immediate threat. The response activity thus far can be termed an emergency

300.65(c) immediate removal is complete
300.68(j) extent of remedy

response and an interim control measure. The WDNR is in the process of analyzing the most recent hydrogeological data and planning a more extensive response to the site in order to prevent further horizontal and vertical migration of the contaminated water.

300.66(a) assessment for further action

DESIGN AND EXECUTION OF THE SITE RESPONSE

As indicated previously, the remedial response activities at the Mauthe site have involved an emergency response, the planned, Phase I interim response for more efficient control and collection of surface water and the planned Phase IV response for containing or removing remaining contaminated ground water.

Emergency Response

Within hours after WDNR was notified by the chromium contamination problem, they reviewed their list of qualified contractors and Rocket Sewer Hauling Company from Appleton was contacted and requested to begin pumping operations. Over a 5 day period from March 31 to April 4, Rocket Sewer Hauling, collected 6000-7000 gallons (11,400-26,5001) of contaminated liquid from the drainage ditch running adjacent to the railroad tracks, from pools on the ground surface and from a nearby storm sewer. The snowmelt and heavy rains which occurred over the first several days of the emergency response were causing the drainage ditch running parallel to the railroad tracks to fill up rapidly and were also resulting in the surface expression of chromium contaminated water in puddles throughout the area. The drainage ditch emptied into the storm sewer system via a corrugated drain pipe at south Outagamie Street and the storm water was eventually discharged into the Fox River. Therefore, WDNR was very concerned with minimizing discharge from the ditch into the storm sewer.

300.65(b)(6) moving hazardous substances off-site

On April 2, with the threat of heavy rains, WDNR constructed a small coffer dam across the drainage ditch to minimize discharge of contaminated water into the storm sewer. They also used sandbags to isolate the highly contaminated area and to prevent the chromium contaminated water from gravitating back into the residents yards. However, these efforts were not very successful. The rain was very heavy and the water flooded over the drainage ditch and into the backyards of the residents threatening to flood their basements. It was necessary to break the dam and release some of the water into the storm sewer.

300.65(a)(7) use of barrier to deter spread of releases

The Department of Public Works then brought in two loads of sand which were used to isolate the most heavily contaminated area in an area of about 50 feet by 50 feet (15m by 15m) and to divert the uncontaminated runoff from the Miller Electric Co. parking lot just west of the site. After the water which had flooded over the ditch water had receded, sand bags were again placed in the ditch near the storm sewer pipe. These measures, together with periodic pumping from puddles and the drainage ditch, were effective in minimizing the quantity of contaminated water discharged into the storm sewer.

In addition to pumping and diking, WDNR and the city of Appleton took a number of other measures to reduce public health hazard. The Department of Public Works put up several hundred feet of snow fence to isolated the heavily contaminated area from the adjacent residence. The sump pump hose from a nearby house which was discharging into Second Street was rerouted into the area of heavy contamination.

300.65(b)(3) security fencing

Phase I: Collection and Control of Surface Water

With the immediate emergency abated, WDNR began further investigation of the site to determine the extent of contamination and to plan for a more effective and efficient surface water control system.

On April 15, WDNR selected CPI to install a surface water and shallow ground water collection system, divert clean water away from the site and to haul away highly contaminated soils. However, due to problems in funding, installation of the system was not begun until May 18, 1982. By this time Soil Testing Service had completed the first series of borings and monitoring wells (drilled on May 6 and 7, 1982). Although this information indicated that chromium had migrated to a depth of 13 feet (3.9 m) in the area of highest contamination, the results were not available in time to be used in designing the collection system and this information is being considered for Phase II.

Through April and early May, prior to the construction of the collection system, Rocket Sewer Hauling continued to pump the chrome contaminated liquid and to haul it to the DePere Sewage Treatment Plant. By April 14 about 10,000 gallons (38,000 l) had been hauled and, by May 4, the volume had reached about 20,000 gallons (75,700 l) DePere had only agreed to accept 15,000 gallons (56,800 l) and it was necessary for WDNR to negotiate a long term contract with DePere. The city of DePere Sewage

Treatment Plant was the logical choice for treating the contaminated water for the following reasons:

- The plant ran very efficiently whereas the Appleton STP, the only other reasonably close plant, had operational problems and occassionally had to bypass due to overload

- Treatment thus far had not caused any operational problems at the DePere STP

- Sludge was incinerated and the ash disposed of in a licensed landfill, whereas Appleton's sludge was landspread.

The major elements of the collection system are shown in Figure 6. The system includes 3 parallel subsurface drains which are about 3 feet (1 m) deep and have the following lengths:

300.70(b)(1)(ii)(B)
surface water diversion and collection

- Drain to the north of main track - 325 feet (99 m)

- Drain to the south of main track - 275 feet (84 m)

- Drain to the south of switching track - 150 feet (46 m)

The drains were installed by excavating a trench about 2 feet (0.6 m) wide and 3 feet (1 m) deep using a track type backhoe. The trenches were sloped at one percent grade to two collection points as shown in Figure 6. Four inch (10cm), perforated schedule 40 PVC pipe was laid in the trench and surrounded with about 2 inches (5cm) of gravel. The trenches were then backfilled with native soils. Sumps were installed at each of the two collection points. The sumps were connected to each other by about 25 feet (7.6 m) of PVC pipe so that water collected in the sump south of the tracks could be pumped into a larger sump north of tracks. The sump on the south side of the tracks is a 4 foot diameter (1.2 m by 1.2 m) perforated concrete cylinder which was installed about 4 feet (1.2 m) below the grade of the railroad tracks. The sump on the north side of the tracks, located in the area of highest chromium contamination consists of two of these concrete cylinders, one on top of the other, and was installed 6 feet (1.8 m) below railroad track grade. This sump is equipped with a pump which empties the contents into a 10,000 gallon (38,000 l) steel tank.

During installation of the sump on north side of the tracks, CPI encountered layers and streaks of yellow and green (chromium) stained soil. The contaminated area contain or remove contaminated ground water. The extent of the Phase IV activities will be largely determined by the results of a detailed hydrogeologic investigation controls which is currently underway. This investigation includes soil sampling and ground water monitoring from borings and wells which were completed by Twin City Testing in December 1982. As of January 19, 1983, WDNR had received the first set of ground water monitoring data from the newly installed wells, but the data had not been analyzed.

Potential remedial measures which WDNR is considering include the installation of deeper subsurface drains to collect contaminated groud water, removal of additional contaminated soils with the possibility of razing the old chromeplating building to remove any contaminated soils beneath it.

COST AND FUNDING

Source of Funding

The WDNR was able to procure funding for the site clean-up through the state's Emergency Spill Fund, authorized by the Wisconsin Hazardous Waste Management Act of 1978. However, the State of Wisconsin has brought suit against Norbert W. Mauthe in Circuit Court for reimbursement of the expenses incurred in the site clean-up for which he is charged with statutory responsibility. A complaint was filed in Circuit Court by the Wisconsin Department of Justice on October 4, 1982, and a trial is expected. If these expenses are collected from Mauthe, the money will be returned to the Emergency Spill Fund.

300.68(c) responsible party

Selection of Contractors

The WDNR staff performed some of the initial site investigation and then contracted with Soil Testing Services in Green Bay, Wisconsin to perform a hydrogeologic investigation which was conducted on May 6 and 7, 1982. Rocket Sewer Hauling in Appleton was contracted for regular pumping and transportation of the accumulated chromium water to DePere Sewage Treatment Plant. These two contractors were selected by the WDNR on an informal basis during the emergency phase. After the initial emergency, WDNR formally sought bids from waste haulers to haul the chromium contaminated water to DePere. Rocket Sewer Hauling was again selected because they had the lowest bid. The DePere Sewage Treatment Plant was the logical choice because the Appleton Sewage Treatment Plant was not equipped to accept the chromium contaminated water. SST and Twin City Testing of Appleton responded to WDNR's August 31, 1982 quotation request for additional soil borings and of these two firms, Twin City Testing was selected to provide the additional subsurface exploration.

After deciding to install a more permanent collection system, the WDNR invited nine contractors to submit proposals for its design and installation by April 14, 1982. The WDNR provided prospective contractors with the opportunity to visit the site and four of the potential contractors subsequently submitted proposals. Two of these four proposals were rejected on the bases of cost. A third proposal was rejected because it proposed ground water pumping which WDNR felt would be ineffective in the low permeability soils. WDNR judged the proposal submitted by CPI to be the most cost effective and they were awarded the contract.

Project Costs

A breakdown of the project costs by category of activities is shown in Table 6. This cost information was derived from purchase orders from the WDNR as of mid-December 1982 and therefore may reflect in some cases planned purchases rather than actual services received. The total amount spent on the emergency response and surface water collection system as of mid-December 1982 is $72,229. Since the Appleton site has only been temporarily contained and more complete actions are planned, this is not a total cost. The WDNR is in the planning stages of Phase IV of the site clean-up and reimbursement is being sought for the costs of the emergency response and Phase I from Norbert Mauthe, the owner of the chrome plating facility. Rocket Sewer Hauling continues to transport contaminated water to the DePere Sewage Treatment Plant, and thus the total expenditure continues to increase with time. Transporting this contaminated water has been the largest portion of the clean-up expense, comprising over 51% of the total.

Site Investigation--

The total of $7,643 shown for soil testing is the sum of two figures: $1,643 paid to Soil Testing Services for the initial drilling, sampling and monitoring, and $6,000 to Twin City Testing of Appleton, WI for additional drilling, monitoring and sampling. WDNR had just received the first round of monitoring data from Twin City Testing at the time of this writing (January 1983) and the data were in the process of being analyzed by the WDNR as part of the planning and design (Phase III) for the Phase IV remedial action.

Pumping and Transportation--

As of mid-December 1982, \$41,000 was authorized for the Emergency Spill Fund to Rocket Sewer Hauling for pumping and transportation of contaminated water. As of mid-December 1982, \$38,180 had actually been paid to Rocker Sewer. This sum includes some initial start-up costs for pumping puddles of water which were charged to WDNR on an hourly basis. Therefore, unit costs are not obtained by dividing \$38,180 by the number of gallons transported. Rather, the unit cost figures shown in Table 7 were taken from Rocker Sewers standard charge of \$210 per \$3,000 gallon (11,400 l) load. The pumping and transportation costs for the contaminated water at \$210 per 3,000 gallon (11,400 l) load, transported a distance of 50 miles (81 km) to DePere Sewage Treatment Plant resulted in a unit cost of 0.14 cents/gallon/mile (0.02 cents/l/km).

Collection System and Soil Removal--

CPI was paid a total of \$13,975 for the construction and installation of the subsurface drains, the sump pumps, and the clean water collection and diversion system. CPI also received a total of \$7,564 for soil excavation and removal. Transportation and disposal costs for the contaminated soil were \$6,100 or \$61/cubic yard (\$80/m^3). Excavation and loading costs for the soil were \$1,464 or \$14.60/cubic yard (\$19/m^3).

Water Treatment and Disposal--

A total of \$2,275 had been paid to DePere STP as of mid-December 1982 for the treatment and disposal of contaminated water. The unit cost is \$25 per 3,000 gallon (11,400 l) load or less than 0.08 cents per gallon (0.22 cents/l). The total volume of water treated and disposed of was 273,000 gallons (1.03×10^6 l) as of mid-December.

TABLE 6. SUMMARY OF COST INFORMATION-N.W. MAUTHE,INC., APPLETON, WISCONSIN

Task	Quantity	Expenditure	Unit Cost	Funding Source	Period of Performance
Soil Testing, Sampling Monitoring	N/A	$7,643	N/A	Wisconsin Emergency Spill Fund	April 1982-Jan. 1983
Pumping and Transportation of contaminated water	273,000 gallon (1.03×10^6 l)	$38,180	.14¢/gallon/mile (.02¢/l/km)	Wisconsin Emergency Spill Fund	Continuous since April 1982
Treatment and disposal of contaminated water	273,000 gallon (1.03×10^6 l)	$2,275	.8¢/gallon (.2¢/l)	Wisconsin Emergency Spill Fund	Continuous since April 1982
Construction of sump pumps, drainpipe, collection system	N/A	$13,975	N/A	Wisconsin Emergency Spill Fund	May 1982
Transportation & disposal of soil	100 cu.yds ($76.5m^3$)	$6,100	$61/cubic yd. ($80 per m^3)	Wisconsin Emergency Spill Fund	October 1982
Excavation & loading of soil	100 cu.yds. ($76.5m^3$)	$1,464	$14.60/cu.yd ($19/m3)	Wisconsin Emergency Spill Fund	October 1982
Miscellaneous (incl. steel tank at sewage treatment plant)	N/A	$2,592	N/A	Wisconsin Emergency Spill Fund	
TOTAL		$72,229		Wisconsin Emergency Spill Fund	April 1982 - January 1983

N/A: Not Applicable

PERFORMANCE EVALUATION

There is only limited data available from which to evaluate the performance of the collection system at the Mauthe site. Delivery logs recording the volume of contaminated liquid hauled to the DePere Sewage Treatment Plant indicate that 273,000 gallons (1.03×10^6 l) were collected and treated from April through December 1982. As Table 7 indicates, the concentration of hexavalent chromium in the collection tank has ranged from 230 to 430 mg/l. Assuming an average concentration of 300 mg/l, an estimated 683 pounds (310 kg) of hexavalent chromium was collected during this 8-month period. The surface water collection system has apparently been effective in minimizing off-site migration of chromium. However, the limited monitoring data summarized in Table 7 does not permit any more quantitative evaluation of performance.

In evaluating performance of the collection system installed at the Mauthe Site, it is important to keep in mind that the system was intended to collect surface water and shallow ground water and was not intended to remove or contain the contaminated groundwater which had migrated outside the influence of the collection system. As mentioned previously, a more complete response is planned in Phase IV.

TABLE 7. SUMMARY OF MONITORING RESULTS AT MAUTHE SITES[1]

	April 1		May 24		June 2		July 7		August 19	
Sample Location	Cr^{+6}	Cr Total	Cr^{+6}	Cr Total	Cr^{+6}	Cr Total	Cr^{+6}	Cr Total	Cr^{+6}	Cr Total
	(mg/l)		(mg/l)		(mg/)		(mg/l)		(mg/l)	
Well #7	--	--	--	--	--	--	0.020	0.024	0.020	0.024
Well #8	--	--	--	--	--	--	73	73	120	110
Small Crock	--	--	--	--	--	--	67	71	76	78
Collection Tank	--	--	230	--	250	--	260	--	430	440
Residence Sump Pump	96	110	--	--	--	--	70	74	100	100

[1]--Indicates that no analysis was done

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OCCIDENTIAL CHEMICAL COMPANY

LATHROP, CALIFORNIA

INTRODUCTION

NCP References

The Occidential Chemical Agricultural Products Company's Lathrop, California facility is located in the San Joaquin River Valley in a rural agricultural area about 60 miles (95 km) east of San Francisco, 55 miles (90 km) south of Sacramento and 1.0 mile (1.6 km) east of the San Joaquin River. Storage and evaporation of rinse water from the fertilizer and pesticide operation in unlined surface impoundments, and burial of waste pesticides, caused groundwater contamination near the plant. The primary ground water contaminants were dibromochloropropane (DBCP) (1-1200 ug/l) and sulfate (500-7,000 mg/l). Other ground water contaminants included EDB, sulfolane lindane, alpha-BHC, delta-BHC, Dimethoate, and Disyston.

Background

At various times during the operation of the Lathrop plant since it opened in 1953, Occidential Chemical Company (OCC) and/or its predecessor, Best Fertilizer, disposed of process wastes into several unlined surface impoundments, and buried solid pesticide wastes in an area known as the "boneyard." These wastes resulted from the production of fertilizers and related chemicals, and the synthesis and formulation (blending of concentrates with inert ingredients) of about 150-200 different pesticides for retail and wholesale trade. Pesticide formulation began at the Lathrop plant in 1957. Among the wastes disposed of on-site were DBCP, gypsum (calcium sulfate), lindane and other isomers of BHC; ethylene dibromide (EDB); heptachlor; ammonia and waste heavy metal catalysts. Because of its persistence, lipophilicity, mutagenicity, carcinogenicity and volume of use, DBCP was the main contaminant of concern in the ground water throughout the remedial work.

The problems at the site were initially suggested in a December 1978 meeting between Occidental and the California Regional Water Quality Control Board (WQCB), where OCC informed the WQCB that documents would be released

300.63(a)(3) notification by federal or state permit holder soon in ongoing litigation showing that organic and inorganic chemical concentrations had increased in the ground water near the plant. No specifics were provided. On January 2, 1979 the WQCB received a letter from the US EPA Region IX office noting that the above-mentioned documents, disclosed in an Ohio court case, specifically alleged that pesticide disposal on-site has caused ground water contamination around the Lathrop facility. Following an immediate discussion with the plant operators on Monday, January 5, 1979, an inspector from the WQCB took samples from the gypsum ponds on January 6 indicating that surface sulfate levels had risen from 26 mg/l in 1962 to 1700 mg/l in 1979. Pesticide wastes were also found on site, resulting in another site inspection and testing of local drinking and irrigation water wells. On February 8, 1979 the Libby-Owens-Ford (LOF) well on the property adjacent to the Occidential site was sampled, by the WQCB along with the well of a nearby dairy farmer. Both of these wells were found to be contaminated with DBCP at about 13 ug/l, and the owners were immediately advised to stop using them. A consultant for Occidental later found 58 ug/l of DBCP in the neighboring dairy farmers well in February 1979. (David Keith Todd Inc. Oct. 1979). The state's advice to the neighbors was based on the assumption that any level of DBCP was harmful, which in turn was based on the facts that the state has had an action level of 1 ug/l for DBCP and laboratory animal tests showed that it caused stomach cancer at 3 mg/l as well as the fact that the U.S. FDA action level was 1.5 mg/l in milk fat (55 ug/l in whole milk) (3/19/79 letter from Vaughn, Stockton sanitary engineer to Robertson, Executive Director of the WQCB).

300.64 preliminary assessment

300.64(a)(1) evaluation of the magnitude of the hazard

300.65(b)(2) providing alternate water supplies

300.64(b) collection or review of literature

Synopsis of Site Response

The remedial action was carried out under the general provisions set forth in a Consent Decree lodged on February 6, 1981, and were worked out in detail through the US EPA's National Enforcement Investigations Center (NEIC) and the state WQCB and DoHS. The "boneyard" of pesticide wastes, as well as the contaminated sediments in the gypsum ponds were excavated by the end of February 1981. A ground water extraction/treatment/reinjection system was approved in January 1982 by the US EPA and State of California, and went on-line in July 1982. The system extracts contaminated ground water from five wells, treats it in a reverse pulse granular activated carbon systems, and then reinjects it into an unusable briny aquifer through an injection well about 500 feet (90 m) deep. The carbon system is intended to reduce the DBCP concentration, which was agreed upon as the surrogate criterion for all other contaminants, from about 2000 ppb

300.68(c) responsible party clean-up

300.68(e)(2) source control

300.70(c)(2)(i) excavation

300.70(b)(2)(ii)(C)(2) carbon absorption to an effluent concentration of 1 ug/l. As of December 1982 the effluent DBCP concentrations being injected into the deep unusable aquifer were initially between 4-6 ug/l. The use of an additional carbon contractor column was expected to enable the system to achieve the agreed upon level of decontamination.

SITE DESCRIPTION

The surface characteristics and hydrogeology of the Occidental Chemical Company site are discussed separately below.

Surface Characteristics

The OCC site occupies approximately 130 acres on the northern edge of the San Joquin Valley (Figure 1). The site is bounded on the north by Louise Avenue and by residential areas and schools on the outskirts of Lathrop. To the east, west and south of the site are large areas of farmland that are typical of the San Joquin Valley. Southern-Pacific, Inc. railroad tracks and Howland Road bisect the eastern portion of the site and a Libby-Owens Ford, Inc. glass factory occupies an area immediately west of the northern portion of the OCC site. Besides the Libby-Owens Ford company, other entities in the area include an Army depot and an Air Products, Inc. plant.

300.68(e)(2)(i) (A)population at risk

All of the land in the area slopes gently north toward the San Francisco delta (about 2 feet per mile or 0.38 m/km) and lies about 10 feet (3 m) above mean sea level. This flat area is about 35 miles (56.3 km) wide, bounded on the east by the Sierra-Nevada range and on the west by the Diablo range. Rainfall in this area of the valley averages about 11.45 inches (29 cm) per year with 80 percent of this falling between November and March. The annual evaporation rate is five times greater than the annual rainfall necessitating a considerable need for agricultural irrigation water.

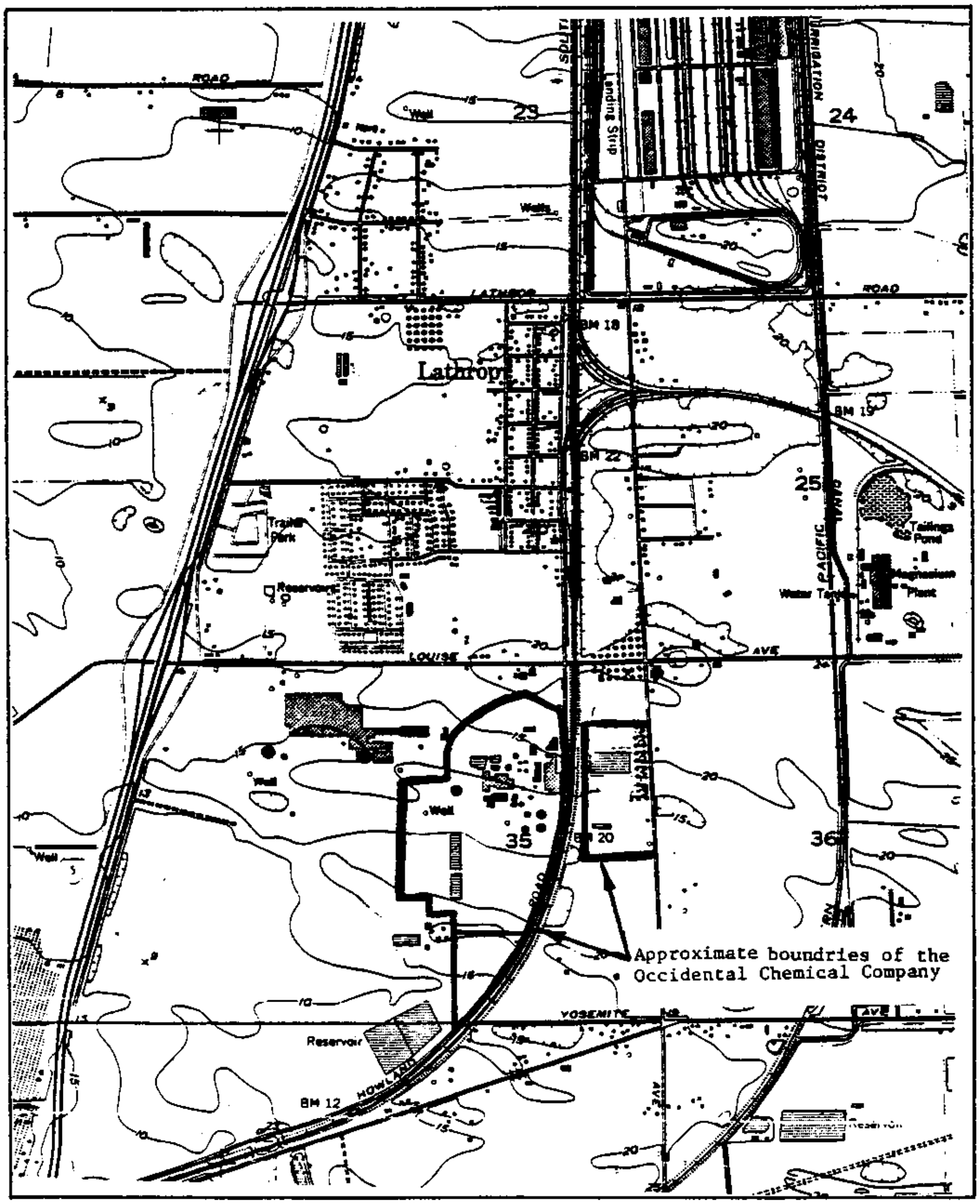
300.68(e)(2)(i) (E) climate

Hydrogeology

The first 230-foot (70 m) depth of alluvial plain, on which the OCC site is situated, is composed of great thicknesses of interbedded sands, silts, clays, and gravels. Several water-bearing units, located in the semi-continuous layers of sand and gravel in this layer, combine to form the large aquifer system which lies within 13 to 26 feet (3.9 to 7.8 m) of the surface and supplies the primary source of domestic, agricultural, and

300.68(e)(2)(i) (D) hydrogeologic factors

Figure 1. Location of Occidental Chemical Company Site



industrial water for the area. The horizontal permeabilities in this aquifer system vary between 10^{-4} cm/sec and 10^{-2} cm/sec. Vertical permeabilities are lower, ranging between 10^{-5} and 10^{-6} cm/sec. The overall aquifer has a transmissivity of 21,000 gallons per day per foot and a storage coefficient of 7×10^{-5}.

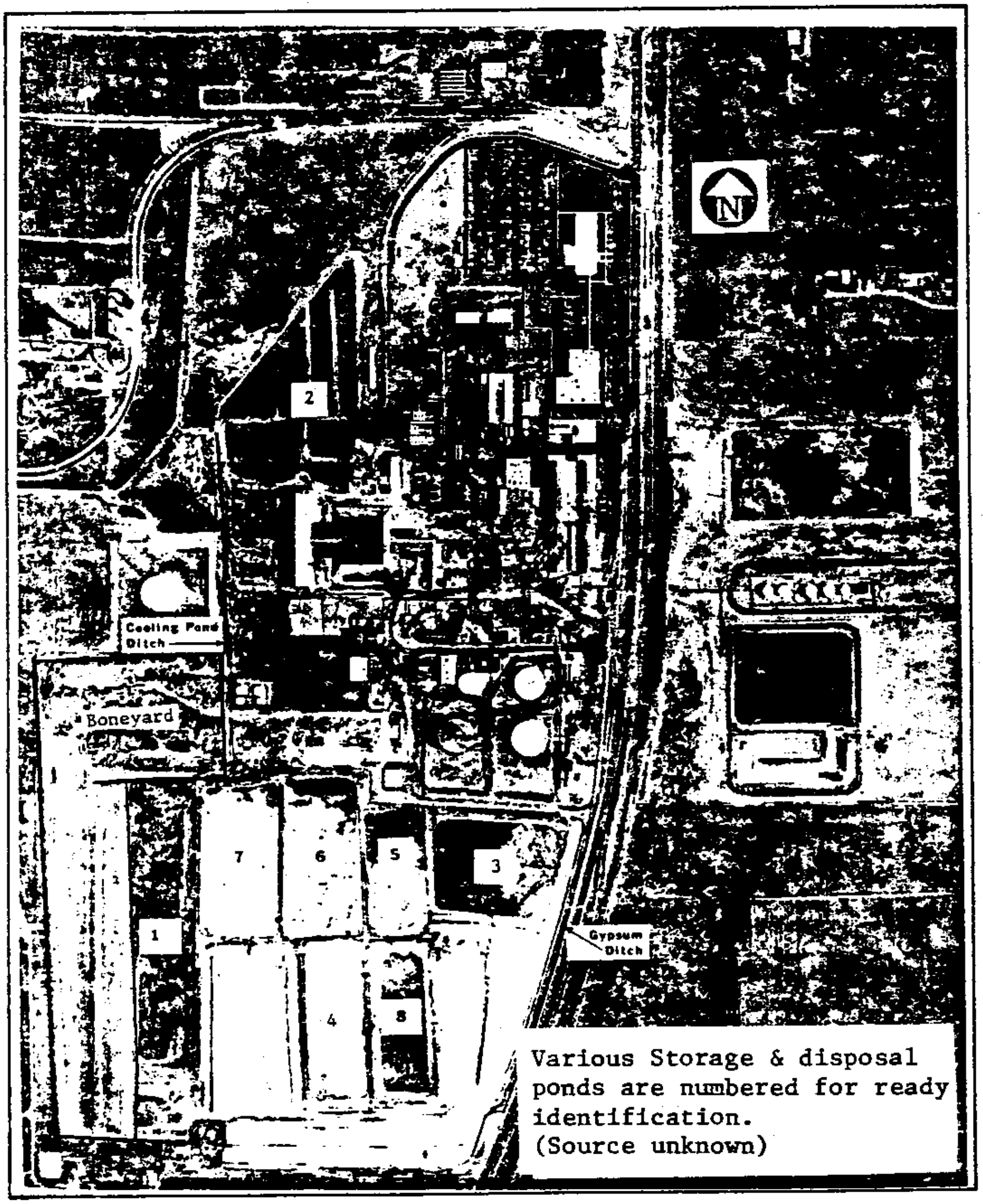
Lying beneath the aquifer is an approximate 90-foot (27.5 m) thickness of blue and yellow clay which extends horizontally for several miles in all directions. This layer is believed to be part of the massive Corcoran clay deposit which formed when the entire area was flooded by a large body of water. Several bore holes and test wells have confirmed the continuity of this clay layer and have uncovered permeable zones beneath this layer which extend downward from about 310 feet (94.5 m) below the surface. The waters in these lower zones are high in dissolved solids and chloride indicating a possible connection with the San Francisco Bay Delta.

The nearest permanent surface water in the site area is the San Joquin River which is about 1 mile (1.6 km) to the west. Due to the arid climate, flat topography, and permeable soils, there are no well-defined natural drainage channels connecting the OCC site area and the river.

WASTE DISPOSAL HISTORY

The present site was first developed in 1953 by the Best Fertilizer Company which constructed several lagoons to receive fertilizer wastes. In 1964, Occidental Chemical Company purchased the site and began manufacturing several fertilizers such as phosphoric acid, aqua ammonia, and ammonium sulfate. In addition to these product lines, the OCC plant began formulating between 150 and 200 different pesticides. Until 1976, all liquid wastes from the pesticide operations (about 5 tons per year) were placed into a 5-acre pond, labelled 1 in Figure 2. (There are also undocumented reports of pesticide dumping in a well which is located south of the pesticide-formulation area and has since been capped.) In addition to the liquid pesticide wastes, this pond received contaminated cooling water from the 4.5-acre phosphoric acid concentrator pond (Pond 2 in Figure 2). This cooling water travelled in a 700-foot long ditch connecting the two ponds. Since 1976, all liquid pesticide wastes have been collected in tanks prior to transport to an off-site hazardous waste landfill.

Figure 2. Aerial Photograph of the Occidental Chemical Company, Lathrop, California



Various Storage & disposal ponds are numbered for ready identification.
(Source unknown)

Between 1964 and 1970 solid wastes from the plant were buried in the unpermitted "boneyard". These wastes included:

- Off-specification pesticides
- Pesticide containers
- Burned solid wastes
- Spent catalysts (Va, Ni, Cu, and Zn)
- Off-specification fertilizer
- Spent activated carbon
- Construction debris.

After 1970, burial of wastes in the "boneyard" was discontinued and, by 1979, the solid pesticide wastes and the spent catalysts were being sent to a California Class I landfill. The other wastes are presumably sent to other types of landfills.

Gypsum slurry produced during the manufacture of phosphoric acid, has been deposited in a number of unlined settling ponds around the site since 1953 (the most recent of these are identified as ponds 3 through 8 in Figure 2). The OCC facility has since converted to a dry phosphoric acid production process thereby eliminating the need for these ponds.

The only other documented disposal of hazardous waste at the OCC site involved a pond which received cooling water from the phosphoric acid concentrator. This pond was filled in and used as a building site in 1968.

DESCRIPTION OF CONTAMINATION

The possibility of ground water contamination at the OCC site was brought to the attention of the Regional Water Quality Control Board in 1978. The Board did some preliminary testing of the lagoons and the ground water at the site and confirmed a suspected violation of OCC's previously set discharge standards which expressly prohibited any ground water or surface water contamination at the OCC site.

300.63(a)(3) notification by a federal or state permit holder

In March and July 1979, further testing of the lagoons, burial ditches, and ground water revealed the following contaminants:

300.64 preliminary assessment

Lagoons and burial ditches

DBCP	Disulfoton
Malathion	Dursban
Methoxychlor	DEF
Dibrom	Ethion
Chlordane	EDB
Endosulfan	DDT
Ethyl Parathion	

Ground water

EDB

alpha-BHC

delta-BHC

DBCP

ETDB

Benzene Hexachloride (BHC)

Ethyl Parathion

DNBP

Lindane (gamma BHC).

The concentrations of these substances reached 90 ug/l in some of the test wells and 2,000 ug/l in portions of the ditches and lagoons. Some pesticides, primarily DBCP, were also detected in some private well water supplies in the vicinity. In addition, high radiation levels (up to 113 p Cu/l) were detected in nearby public wells. The source of these high levels were thought to come from the unlined gypsum ponds since the gypsum there was high in uranium; but naturally high background levels have not been rulled out.

300.68(f) remedial investigation

As a result of the above investigations, the State of California and the U.S. EPA filed a lawsuit against the Occidental Petroleum Company (the parent company to OCC) requiring OCC to initiate a multi-phased remedial strategy beginning with a comprehensive study of the site (Phase I). OCC then contracted with an outside firm to conduct the Phase I study. The Phase I study was completed in December of 1980 and included:

- A complete hydrogeological assessment of the entire area

- A thorough sampling and analysis plan to include all quality control/quality assurance measures

- A complete assessment of the type, concentrations and extent of chemicals buried around the site

- The establishment of a permanent ground water monitoring system including new wells constructed on the site as well as existing on-site and off-site wells.

This study included the development of 42 monitoring wells at 14 locations (3 wells per location) at the site. These three wells at each location were designed to penetrate three zones with respect to the plume of contaminated ground water: 1) the zone of greatest contamination; 2) the zone in the middle of the plume; and 3) the zone just below the plume. Sulfate was chosen as the contaminant for indicating the desired drilling depths because a large amount of sulfate had seeped from the OCC site into the ground water, sulfate was as mobile as any other constituent in the contaminated plume, and it could be monitored rapidly and inexpensively. To locate the three zones at each location, three representatives bore holes were drilled using a dual tube reverse air rotary rig. This drilling method allowed an almost instantaneous and continuous review of the cuttings by an expert geologist and ground water sampling at 10-foot (3 m) intervals for inorganic constituents (SO_4, NO_3, pH, NH_3). Once the desired depth for each well was achieved, permanent wells were constructed by drilling 12-inch (30 cm) diameter bore holes with a conventional rotary rig and installing 6-inch (15 cm) steel casing with 5-foot (1.5 m) diameter stainless steel screens.

Samples from the monitoring wells were analysed for 29 organic pesticides, several inorganics, and radiological assays. The nematocide DBCP was found in the majority of these wells and six other chemicals (EDB, lindane, delta-BHC, alpha-BHC, Demethoate, and Disyston) were found in over 10 percent of the wells. Most of the other 22 organic chemicals that were found were at or near their detection limits. Sulfate was the major inorganic pollutant found in the wells--exceeding 500 mg/l at all but one test well site. All of the contaminants in the test wells exhibited decreasing concentrations with depth. The downward gradient that caused the deeper contamination (despite relatively low vertical permabilities) was created by several deep-pumping irrigation wells around the site. The total area of ground water contamination was estimated to occupy 1 square mile and reach a depth of 200 (61 m) feet below the surface. Figures 3 through 8

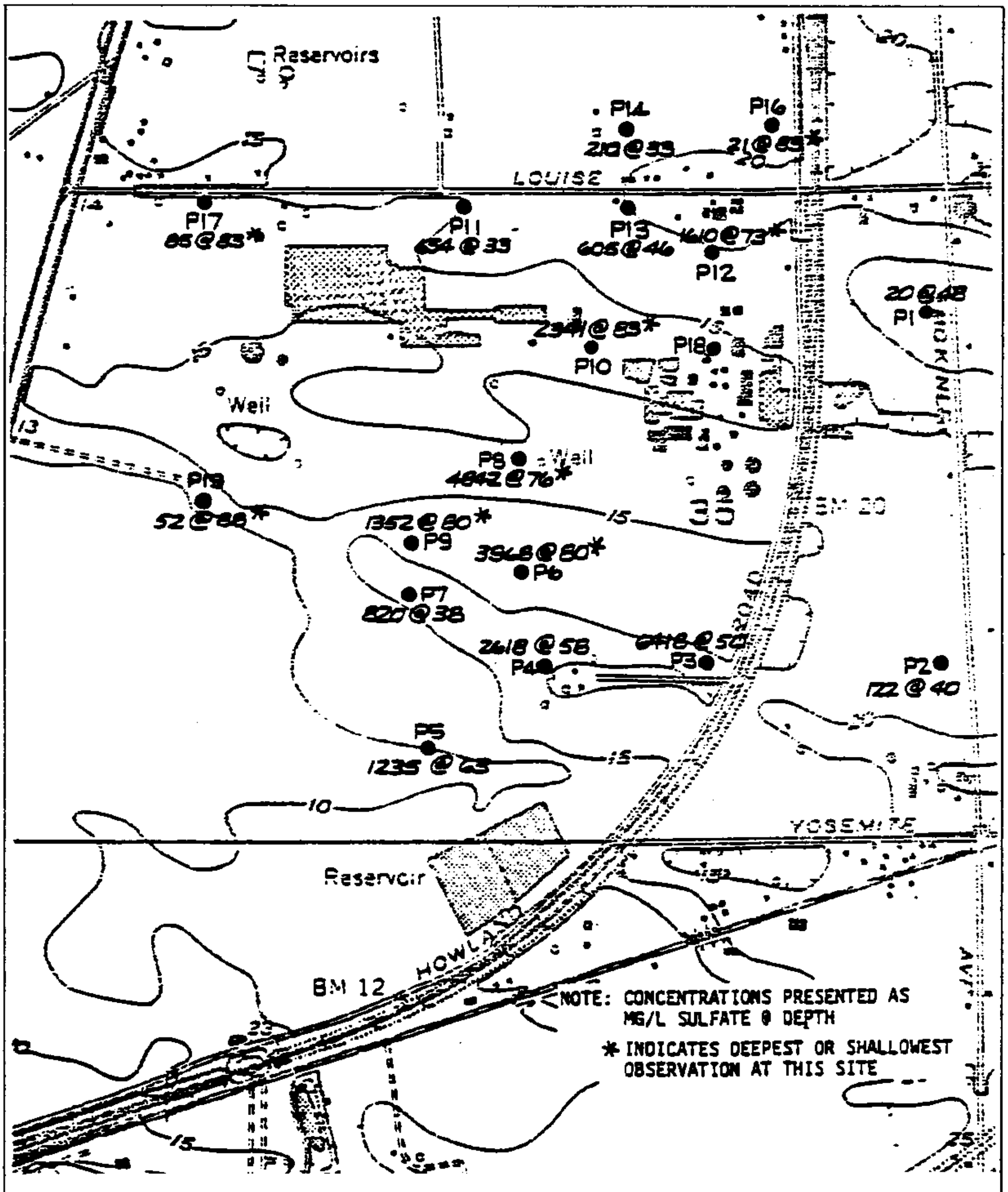


Figure 3. Averaged Observed Sulfate Concentrations in Shallow Monitoring Wells
(Source: Camp, Dresser, and McKee July, 1981)

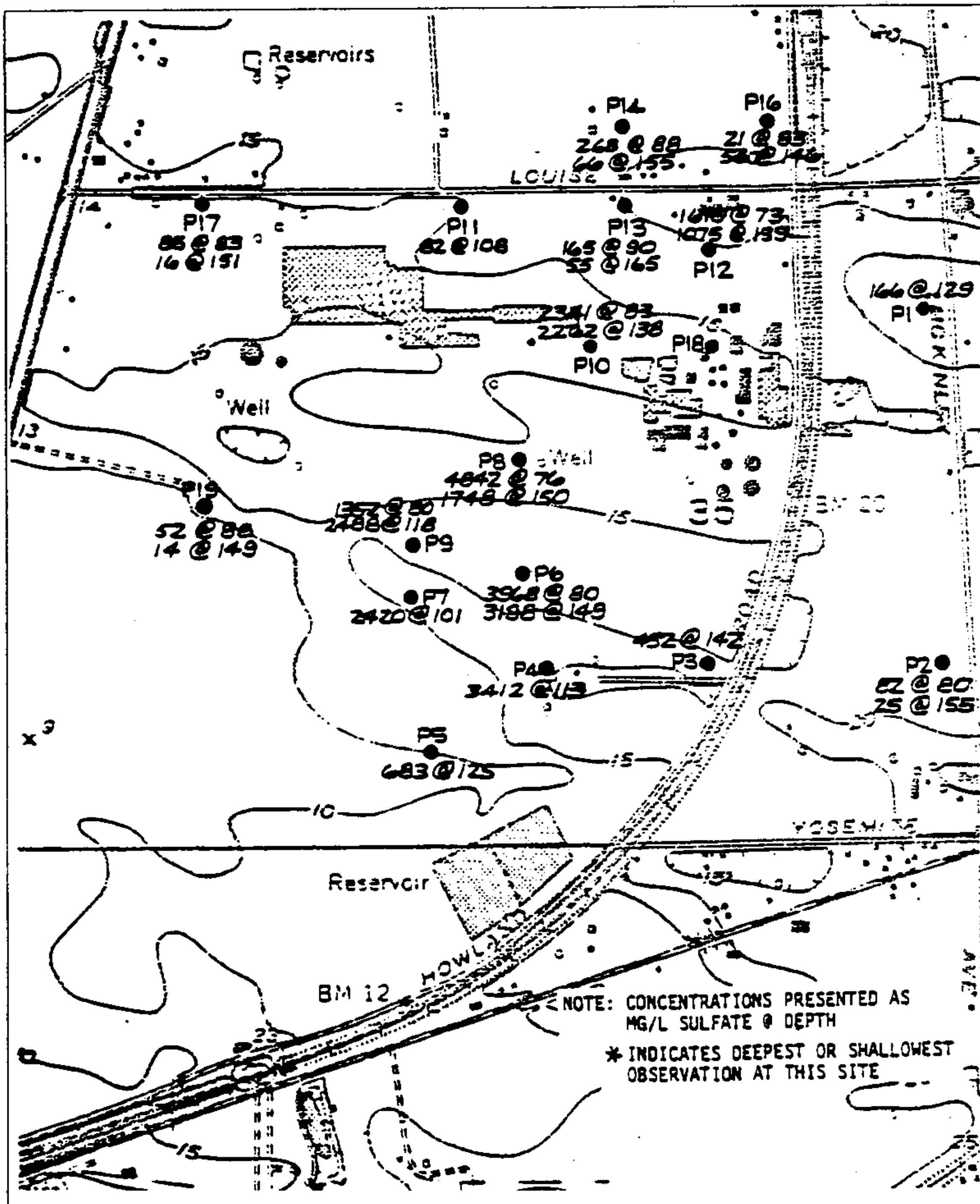


Figure 4. Average Observed Sulfate Concentrations in Intermediate Depth Monitoring Wells
(Source: Camp, Dresser, and McKee, July, 1981)

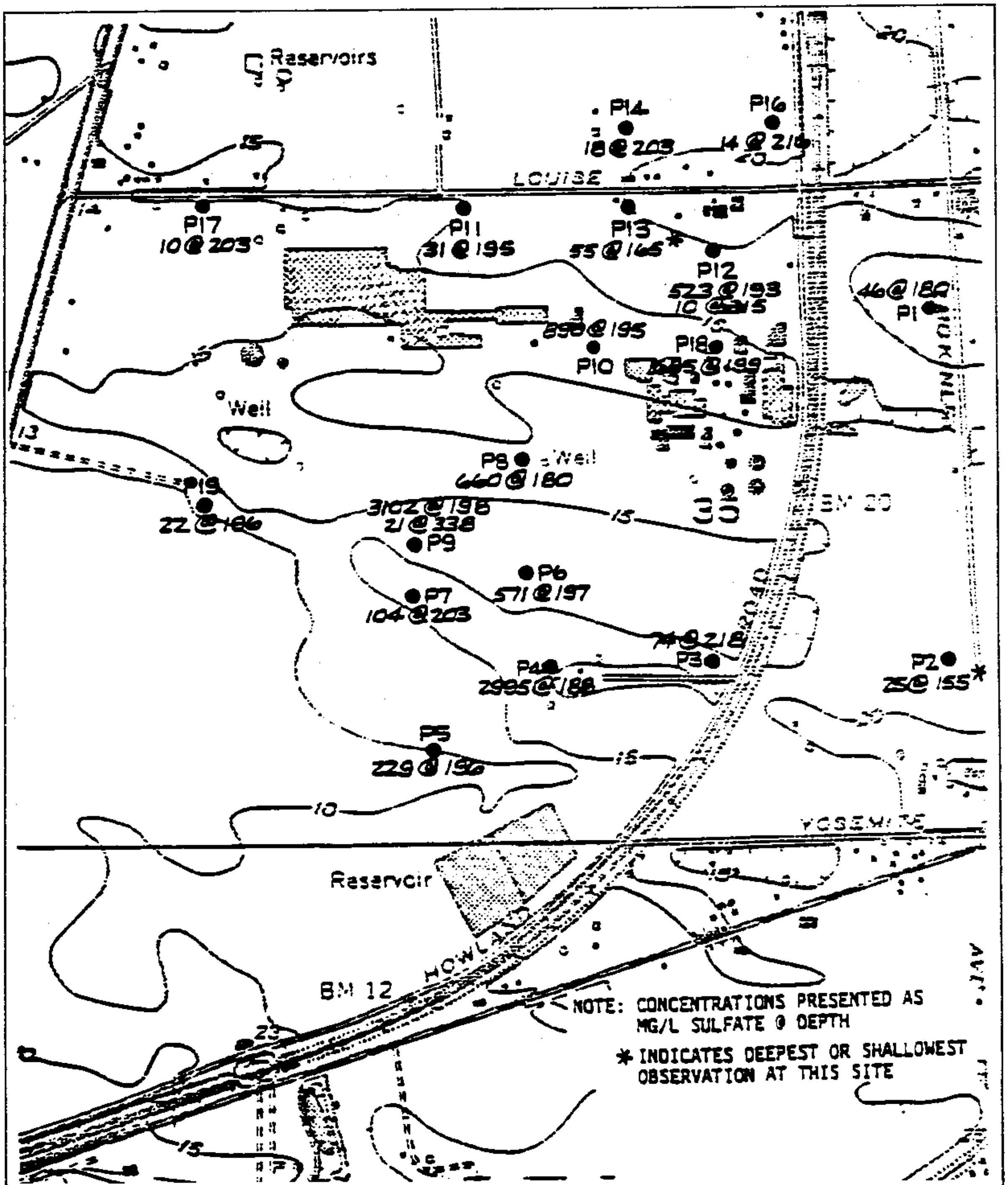


Figure 5. Average Observed Sulfate Concentrations in Deep Monitoring Wells
(Source: Camp, Dresser, and McKee, July, 1981).

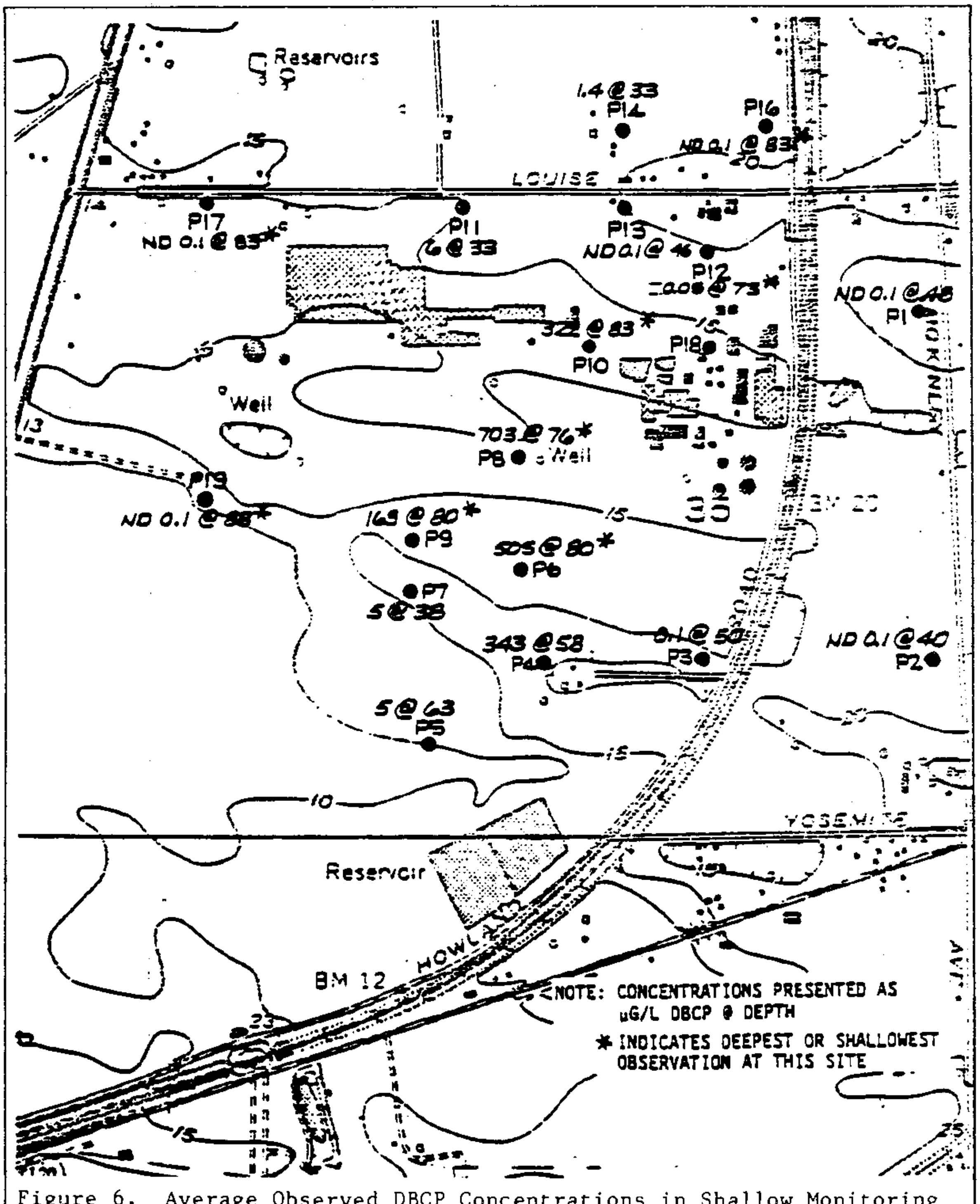


Figure 6. Average Observed DBCP Concentrations in Shallow Monitoring Wells

(Source: Camp, Dresser, and McKee, July 1981)

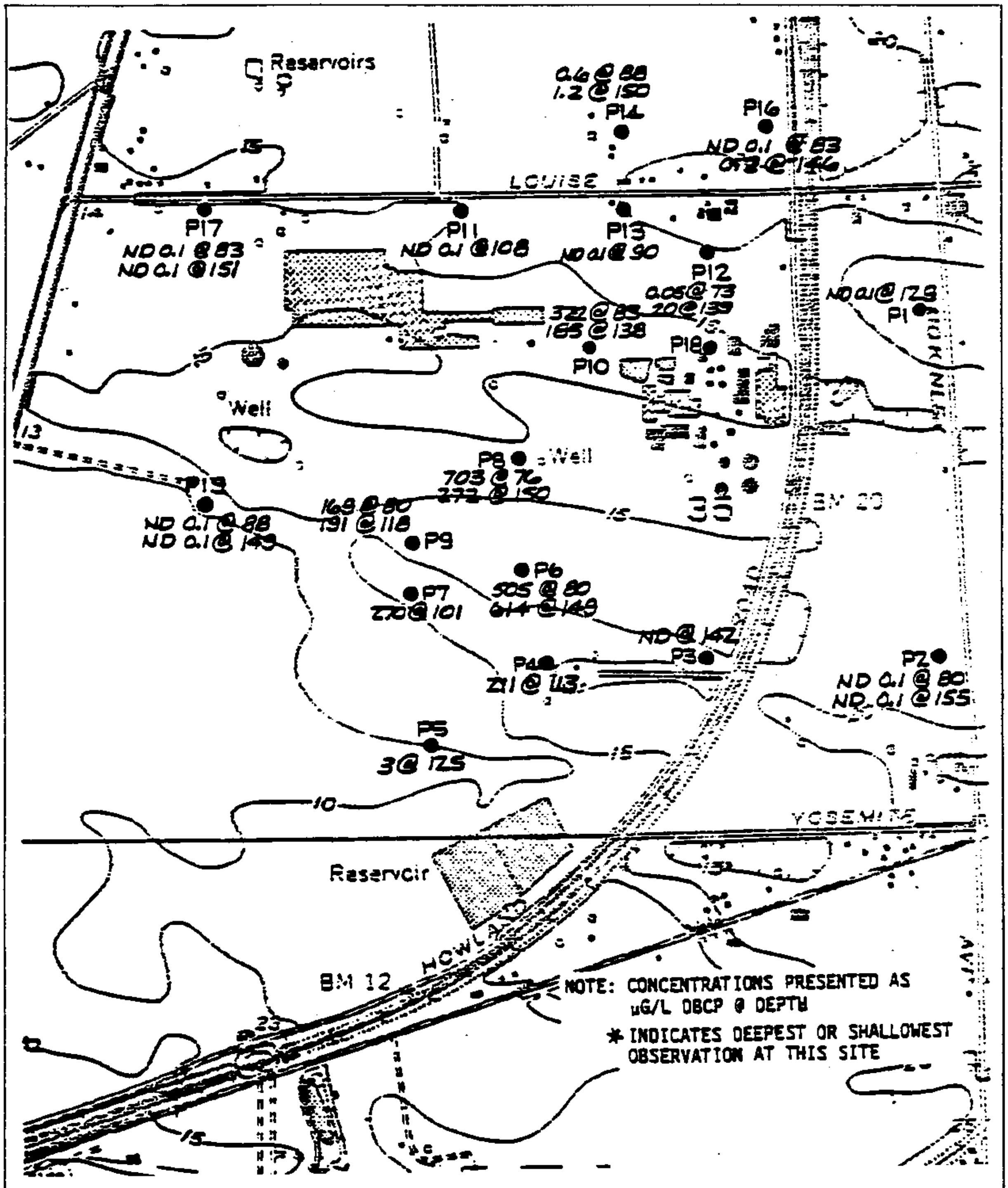


Figure 7. Average Observed DBCP Concentrations in Intermediate Depth Monitoring Wells
(Source: Camp, Dresser, and McKee, July, 1981)

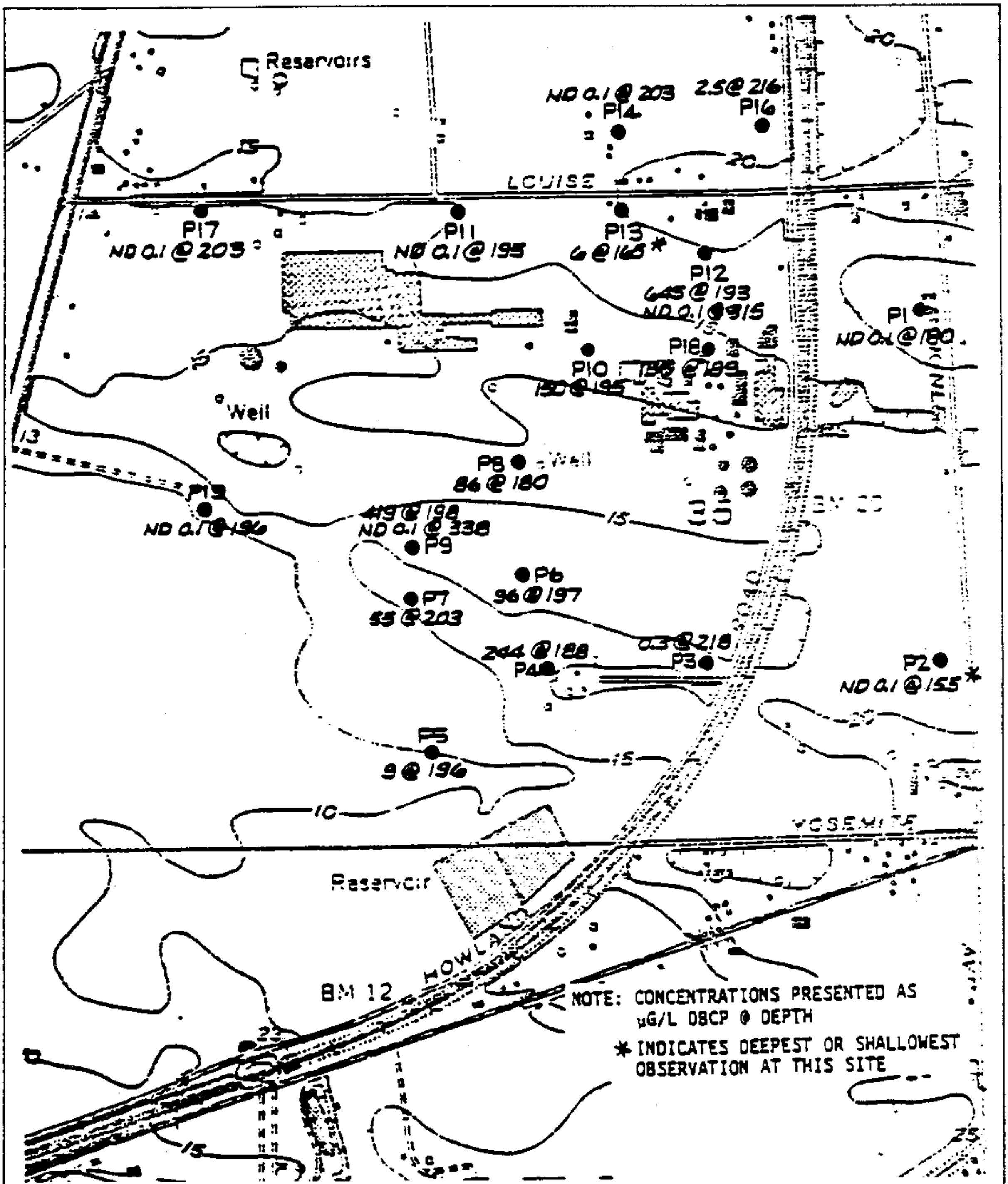


Figure 8. Average Observed DBCP Concentrations in Deep Monitoring Wells (Source: Camp, Dresser, and McKee, July, 1981)

provide concentrations of DBCP and sulfate at various depths and locations throughout and OCC site.

The Phase I study also included the excavation of 16 exploratory trenches and the drilling of 17 soil borings. Several shallow test pits were also excavated. These activities revealed the presence of 4 hazardous waste disposal trenches and pits within the "boneyard" area containing thousands of small (1/2 to 1 pint or 0.25 to 0.5 l) glass pesticide bottles located above and below the water table (see Figure 2). These bottles contained 29 types of pesticides formulated at to OCC plant. In addition, a large area of pesticide-contaminated soil was found in the southern portion of Pond 1 (see Figure 2).

PLANNING THE SITE RESPONSE

Initiation of Site Response

On March 23, 1979, the WQCB issued a cease and desist order directing an immediate end to the discharges on the site and compliance with a site assessment and clean-up schedule because of the public health threat from DBCP contaminated ground water. On November 19, 1980, a "Stipulation and Judgement Approving settlement" was filed to settle a December 18, 1979 complaint against Occidental, and was lodged on February 6, 1981. This consent decree provided the framework for the remedial action eventually carried out at the site. The formalization of the remedial action was delayed from early 1979 to late 1980 for several reasons, including the following:

300.68(c) judicial process

1. Occidental asked the state to review the cease and desist order because they contended that the compliance schedule would require shutting down the plant. A revised cease and desist order was issued on April 27, 1979 that provided for an extended compliance schedule.

2. Negotiations on a consent decree failed in December 1979, resulting in the filling of the above-mentioned complaint.

During the period between the filling of the compaint in December 1979, and the settling of the consent decree in February 1981, the state, US EPA and Occidental worked together to study the site and develop remedial action alternatives. When the suit was settled on February 6, 1981, the company and the US EPA state had already established a rather detailed remedial plan and the excavation of contaminated material had already begun.

The excavation and removal work was completed within a couple of weeks, by February 25, 1981, in compliance with the March 1 deadline imposed by the settlement.

Following the immediate removal of the source of contamination, the long term remedial plan was developed during 1981 and placed on-line in July 1982. Details of the ground water extraction/treatment/injection plan were worked out between the U.S. EPA NEIC, the state WQCB and DoHS, and Occidential. The last significant approval was given by NEIC on January 28, 1982, when it indicated satisfaction that studies performed for Occidental has established (1) that the briny unusable aquifer into which the treated effluent would be injected was isolated from any other usable aquifer; and (2) that the extraction system was adequate to contain, collect and treat the contaminated groundwater. When this last approval was given, Occidental began implementing the long term remedial plan.

300.68(c) state or federal evaluation of clean-up proposals

Selection of Response Technologies

The preliminary selection of remedial actions for the OCC site was made in the recommendations section of the final Phase I report and involved several proposed alternatives. The criteria used to select among the various mitigation alternatives were:

- The chemical constituents present
- The hydrogeologic conditions
- The regulatory requirements
- Assessment of long-term risks
- The size of each mitigative area
- Economics
- Availability of the technology.

The U.S. EPA and the State reviewed and approved of the alternatives that were proposed in the Phase I study. However, there were numerous negotiations on and revisions to the original remediation plans prior to final approval of all parties involved.

The recommended remedial measures for the contaminated soils at the OCC site were proposed after consideration of the following alternatives:

300.68(h) initial screening of alternatives

- No action
- Excavation and disposal of contaminated soils offsite at a licensed facility

- In situ containment using:

  -- Containment barriers
  -- Fixation
  -- Groundwater gradient modification

- On-site treatment.

Of these, the excavation and off-site disposal of contaminated soils became the method of choice because it was shown to provide the most certainty that further ground water contamination would be prevented. After this selection was made, further selections were necessary to determine the proper method of closing the excavated areas and to prevent seepage of any remaining chemical residues. Several types of capping material were considered including:

- Mixing on-site soils with cement

- Hauling in clay from off-site

- Asphalt

- Cement

- Several types of synthetic liner including Hypalon, PVC and rubber.

The option of hauling in clay from off-site was chosen because it was the most cost-effective measure.

The suggested approach to ground water remediation was counterpumping coupled with treatment and disposal of the extracted water. Counterpumping was selected as a result of a comprehensive ground water modeling effort under Phase II of the overall plan. The modeling effort used parameters and constants developed during the extensive ground water testing efforts of Phase I and data from additional test wells which were drilled during Phase II of the project.

The modeling effort revealed that counterpumping was the only feasible method to arrest the northwesterly flow of contaminants. The model was then used to determine the number of extraction wells, their placement, depth, pumping rates, and the seasonal effects of other pumping wells in the immediate area.

Several treatment and disposal options for the extracted ground water were evaluated as part of the Interim Phase II study. Treatment options included:

- Air stripping
- Carbon adsorption
- Ultraviolet oxidation
- Peroxide oxidation.

Of these, carbon adsorption and ultraviolet oxidation were selected for bench scale and pilot plant testing. These tests resulted in the selection of carbon adsorption as the method of choice. Ultraviolet oxidation was rejected due to lower performance, scaling problems, and the formation of manganese oxide precipitants.

Disposal options considered for the treated effluent included:

- Reuse in the OCC process
- Spray irrigation
- Reuse in cooling towers
- Solar stills
- Deep well injections.

The reuse of treated water as process water in the OCC plant was rejected due to high dissolved solids which would ruin plant equipment. A further negative aspect of this option was that the supply of treated water at the proposed pumping rates would far exceed the plant's normal requirements.

The discharge of treated water to cooling towers, spray irrigation equipment, and/or evaporation ponds was rejected because the levels of dissolved solids in the treated water would exceed state standards, thereby necessitating unreasonable expenditures for lining the ponds that would be needed for each of these alternatives.

Solar stills were eliminated from further consideration because of possible vaporization of organics to the air coupled with the need to treat still bottoms having high dissolved solids.

Deep well injection into a confined, unusable aquifer, located over 300 feet beneath the ground surface, was chosen as the best disposal method for the treated effluent after extensive testing showed that this method was both feasible and environmentally acceptable.

Extent of Site Response

The February 6, 1981 settlement did not specify any numerical clean-up standards, but required that the excavation and remedial plan be carried out "in a manner consistent with the goals and standards stated in paragraph IV E of (the) Stipulation," which were general public health goals. As with other aspects of the remedial action, the extent of the excavation and ground water treatment were agreed upon by the U.S. EPA NEIC, the state WQCB and DoHS, and Occidental. Generally, both the excavation and the ground water treatment levels were based on a combination of available standards, contaminant and site characteristics, and best professional judgement.

During the excavation operation in February 1981, the decisions concerning whether particular material would be disposed in a Class I facility, a Class II-1 facility, or into the same trench were largely made on-site. The pesticide bottles and the visually obvious contamination, referred to by a WQCB official as type "C" material, were automatically disposed of at a Class I landfill with a minimum of testing to confirm the contamination. Similarly, the backfilled soil that had been placed over the wastes, referred to as type "A" material, was temporarily placed nearby to be tested before reusing as backfill after it had been found to be clean.

As noted in the "Design and Execution of Site Response" section, some of the contaminated soil was excavated using the "mud wave" technique. During this process, when the bulldozer was consolidating the contaminated material by driving through the saturated layer. The strip of soil behind the dozer blaze was visually monotired by the on-site coordinator. This strip of soil had to be inspected quickly before the water being pushed by the bulldozer could flow around the bulldozer blade and cover the soil again. The excavation was stopped when the on-site coordinator determined that the strip of soil behind the bulldozer blade was not contaminated. Thousands of gallons of contaminated water were pumped from the excavations and bulked with the company's other process waste water for landfilling off-site. After a backhoe had removed the accumulated solid material and placed it on polyethylene sheets, composite samples of 5 or 6 samples per pile were flown back to the Raltech labs via Federal Express for analysis. The analytical results were returned within 2-4 weeks, and provided the WQCB on-scene coordinator (OSC) with the necessary information for making the disposal decision. Using this analytical data, the state and federal officials on-site considered the following factors in deciding the fate of the material: mobility, based on solubility and soil adhesion characteristics of the contaminants; water quality standards, if any, for the particular contaminant; persistence; and the soil type.

The use of this procedure may be illustrated by considering two primary decisions made based on chemical and physical characteristics. First, the chemical characteristics were the overriding factor in deciding how to manage the DBCP contaminated material. Whether DBCP was within the range of confidence of the analysis technique (50 ug/l), dictated whether the material would go to a Class I landfill. This was the primary contaminant found in the type B material. Physical characteristics were used to decide on the disposal of pellets of catalyst waste. Any waste having the unique pellet texture, was put into overpack drums and diposed of at a Class I facility.

The performance standard of the treatment system was decided upon through a somewhat more institutionalized process. Although the treated effluent from the carbon filter system was to be injected into an unusable aquifer, the State of California and the US EPA required that a decontamination standard be met just in case the unusable deep aquifer was found to communciate with the upper usable aquifer, and also in case the injection well leaked into the surrounding upper aquifer through which it was injected. The decontaminated effluent level was set at 1 ug/l DBCP because it was concluded that DBCP served as an adequate surrogate criterion and 1 ug/l was the existing "action level" set by the state and supported by the federal government. This use of DBCP as a surrogate criteria for other contaminants was estalished through results from the pilot scale testing of the system. These results indicated that when DBCP was removed, all other organic contaminants were removed to below detectable levels except sulfolane. The state concurred with an OCC study that determined sulfolane presented an insignificant risk at the residual levels resulting from the DBCP removal to 1 ug/l and considering the aquifer where the treated water was injected. The 1 ug/l action level (the level at which some remedial action such as provision of alternative water sources and source clean-up would be undertaken) had recently been established by the state to manage a variety of DBCP contamination problems that had recently been discovered in the San Joaquin Valley. The action figure was set at this level because, even through the toxicologists and epidemiologist with the DoHS believed that 0.5 ug/l might have been safer, they were not confident enough about the existance of an additional risk reduction to recommend this level which would have required closing the number of wells that would be required, rather than the 1.0 ug/l standard, which would require closing only 10% of the wells.

DESIGN AND EXECUTION OF SITE RESPONSE

The remedial actions carried out at the OCC site were designed to:

- Prevent further leaching of contaminants from past disposal areas to ground water

- Extract and decontaminate ground water beneath the site to preclude offsite migration.

The fulfillment of the first goal was accomplished by excavation of contaminated soils within the site boundaries and capping the site. The second goal was achieved by installing a ground water extraction, treatment and reinjection system. The equipment and procedures used to implement these actions are discussed separately below.

Excavation and Capping

The initial activity began in the spring of 1980 and continued through the summer of 1980 during the Phase I investigations. The Phase I contractor excavated 16 exploratory trenches, drilled 17 test borings and dug several test pits. This work was keyed to the area of the site which contains pond number 1 and the "boneyard" because this is where OCC records indicated the majority of liquid and solid pesticides were deposited (see Figure 1). The exploratory excavation work led to the identification of several localized areas of contamination (Figure 9).

The trench excavations required a variety of equipment and procedures depending on whether the waste was above or below the water table. The following procedures were used:

Above water table:

- Removal of clean overburden

- Excavation of waste materials

- Placement of excavated materials on 20-foot (6.1m) wide strips of 4 to 8-mil thick polyethylene for

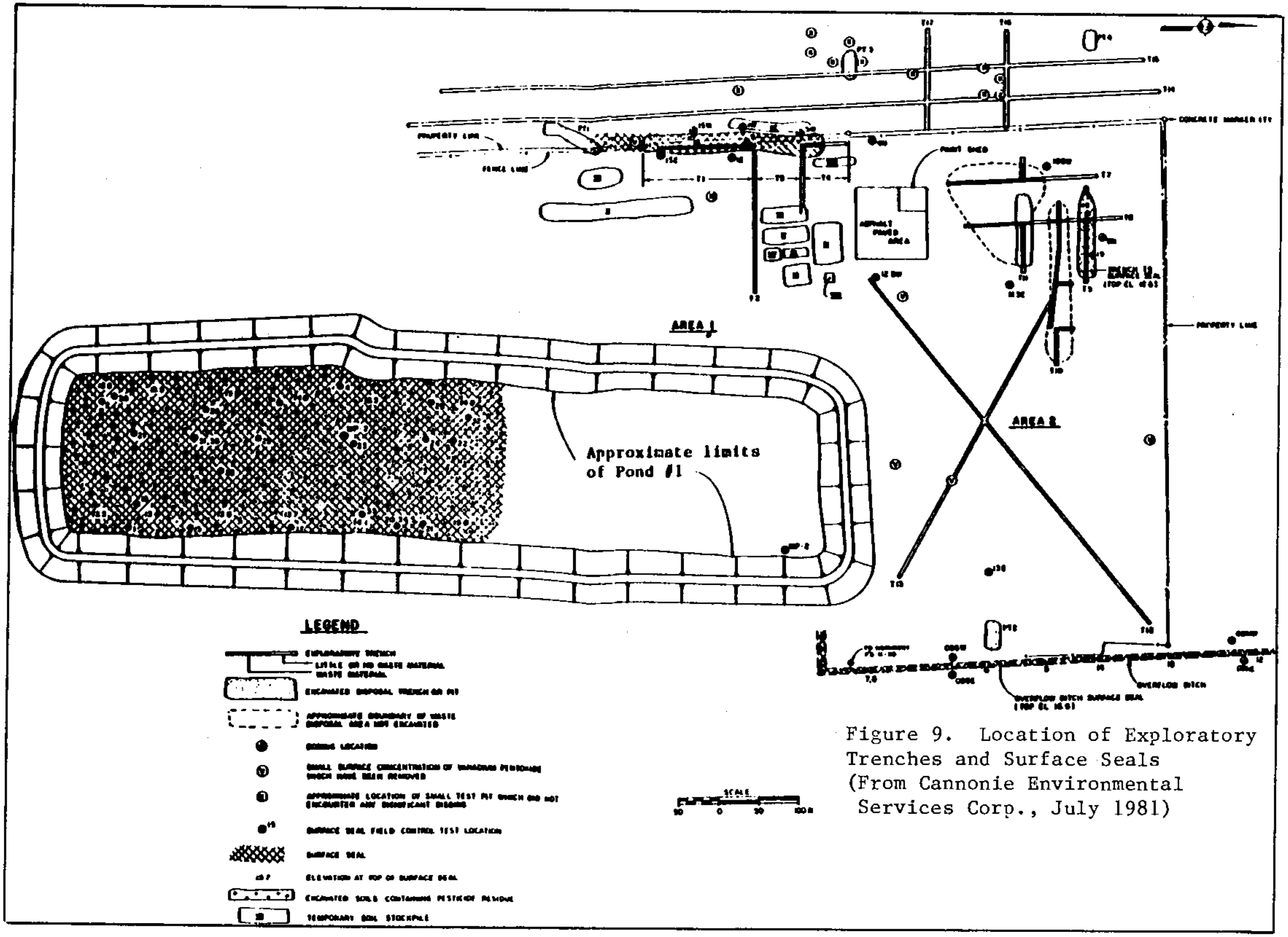


Figure 9. Location of Exploratory Trenches and Surface Seals (From Cannonie Environmental Services Corp., July 1981)

temporary storage. Other strips of polyethylene were placed over the wastes during non-working hours

- Selective removal of waste chemical-containing containers from the excavated material for placement into overpacks then into Class I dumpsters (specially sealed) prior to off-site transport and disposal

- Selective removal of empty containers from the excavated materials and placement into Class II sealed dumpsters prior to off-site transport and disposal.

Below water table:

- Backhoe was used to dig a trench into groundwater, creating a mud slurry from ground water and existing soil.

- Bulldozer was then used to push a wedge of dry soil down a ramp at one end of the trench to create a wave of mud slurry primed with contaminated ground water which was continuously removed by the backhoe and a portable pump

- The trench was gradually filled in as the process continued and eventually all the mud slurry and contaminated ground water were removed

- The excavated material was handled in the same manner as that used on the material from trenches above the water table and the contaminated ground water was stored in tanks prior to transport to a licensed disposal site.

After all of the exploratory trenching under Phase I was completed, a decision was made that, under Phase II, some additional contaminated soils would be removed and that all excavations would be sealed to prevent any possible future contamination. Figure 9 shows all areas within pond number 1 and the "boneyard" which were excavated and capped and Table 1 shows the type and amount of wastes removed from these areas, their method of disposal, and the phase of the study in which they were excavated. Table 1 and Figure 9 show that although twice as much material was excavated under Phase II, not all of the contaminated soils were removed and/or capped, because all soils were not contaminated with hazardous wastes. Therefore, some of the darkened exploratory trenches shown in Figure 7 contained only non-hazardous wastes.

TABLE 1. SUMMARY OF MATERIALS EXCAVATED AND REMOVED FROM THE OCC SITE

Location	Material Quantity	Type of Disposal	Type of Material
		PHASE I	
Trench 1, 5, 4	1,230 cu. yds.	Class I	Bottles, crushed drums, Soil
PT 3	30 cu. yds.	Class I	Drums, Debris, Bottles, Soil
Trench 9, 10, 11	100 cu. yds.	Class II-1	Vanadium pellets and crushed drums
Trench 1	160 cu. yds.	Class II-1	Sand & Vanadium pellets
PT 2 and Adjacent Area	100 cu. yds.	Class II-1	Sand & Vanadium pellets
PT 3 and PT 4	120 cu. yds.	Class II-1	Vanadium soil mix
		PHASE II	
Trench 9	80 cu, yds.	Class II-1	Vanadium soil mix
Overflow Ditch	210 cu. yds.	Class I	Top 2' of soil
Overflow Ditch	1,265 cu. yds.	Class II-1	Soil from 2' to 8'
Wastewater Pond	992 cu. yds.	Class II-1	Soil
Material from Piles II and X Excavated from B layer Trench 1 & 5	368 cu. yds.	Class II-1	Soil

(From Cannonie Environmental Services Corp., 1981)

The excavations under Phase II were conducted in a similar manner to those conducted under Phase I, therefore these methods will not be repeated. The capping of the contaminated areas shown in Figure 9 was accomplished by:

- Filling in the excavations (or stripping areas not previously excavated) to within 3 feet (0.9 m) of grade.

- Spreading clay from off-site borrow areas evenly in the 3-foot (0.9 m) depressions and compacting to a minimum thickness of 1 foot and a permeability of 10^{-6} cm/sec or less.

- Spreading a 2-foot (0.6 m) layer of clean fill over the clay to protect it from drying and cracking.

The spreading of soils and clay was done using bulldozers and the compaction of the clay was accomplished with four to eight passes of a tamping foot compactor. A nuclear density gauge was used to monitor the density of the compaction and the water content of the compacted clay was monitored using a Speedy Moisture instrument. The total sealed area was about 129,000 ft^2 (11,984 m^2), using approximately 5,200 cubic yards (4,000 m^3) of fill material.

300.70(b)(1)(ii)
(C)
grading

After the caps and cap overfill materials were in place, the entire area was graded to prevent surface ponding of rain water.

Ground Water Extraction, Treatment and Reinjection

Ground water remediation at the OCC site consists of five extraction wells coupled to an activated carbon treatment plant and 2 injection wells (Figure 10). These components are described separately below.

The five extraction wells were drilled and screened according to the specifications in Figure 11. All extraction wells were initially constructed with a 6-inch (15 cm) I.D. test well. The first 50 feet (15 m) of each finished well is a 30-inch (7.6 cm) diameter reamed bore hole with a 22-inch (56 cm) I.D. by 114 inch (290 cm) thick single plate conductor casing. The remaining portion of each well consists of a 20 inch (51 cm) diameter reamed bore hole cased with 12 inch (30.5 cm) I.D. by 3/16 inch (0.5 cm) thick copper/steel louvered casing in the upper portion and with 8 inch (20 cm) I.D. by 3/16 inch (0.5 cm) thick copper/steel plain casing in the lower 5 feet (1.5 m). Extraction wells numbers 1 and

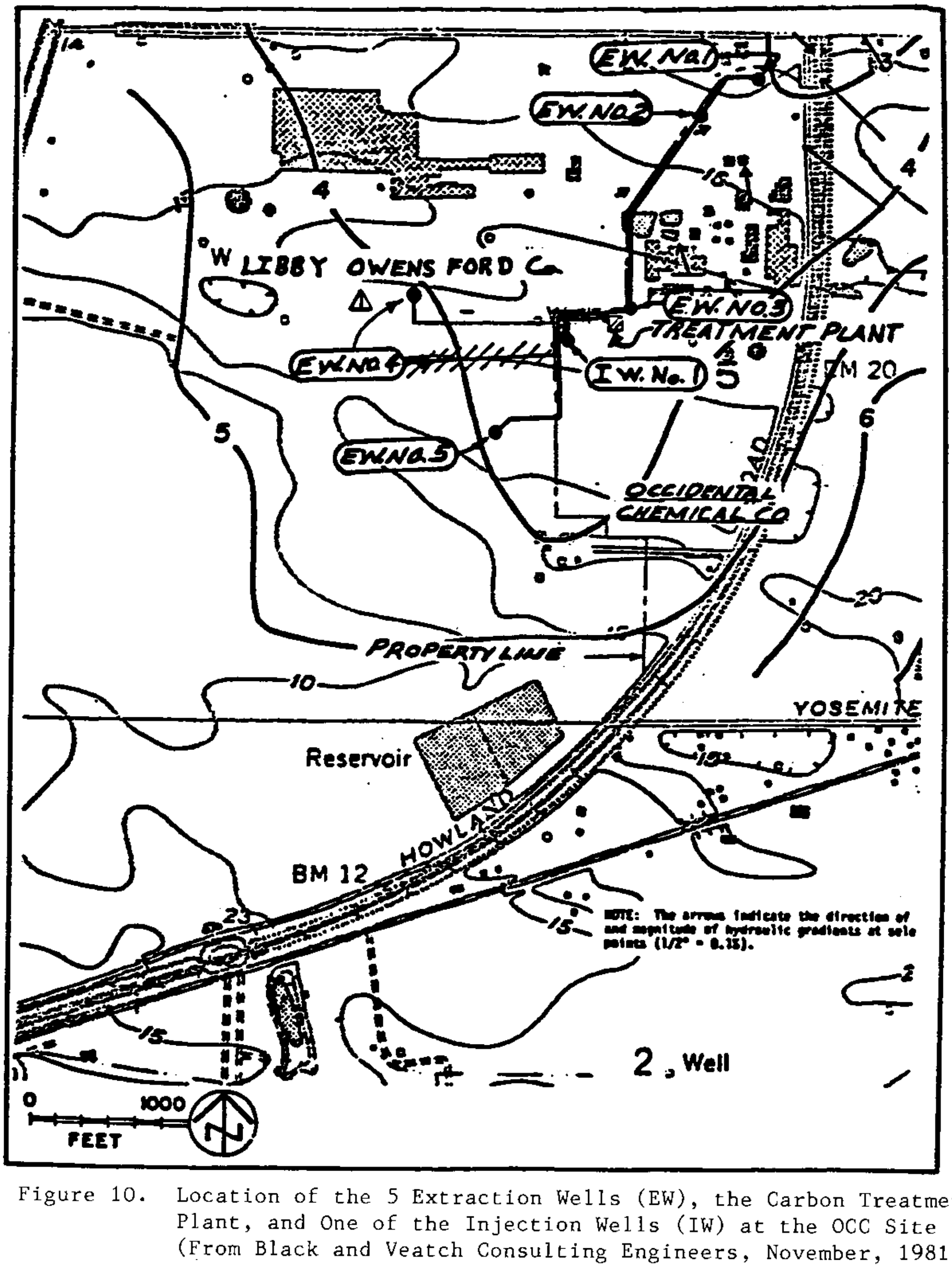


Figure 10. Location of the 5 Extraction Wells (EW), the Carbon Treatment Plant, and One of the Injection Wells (IW) at the OCC Site (From Black and Veatch Consulting Engineers, November, 1981)

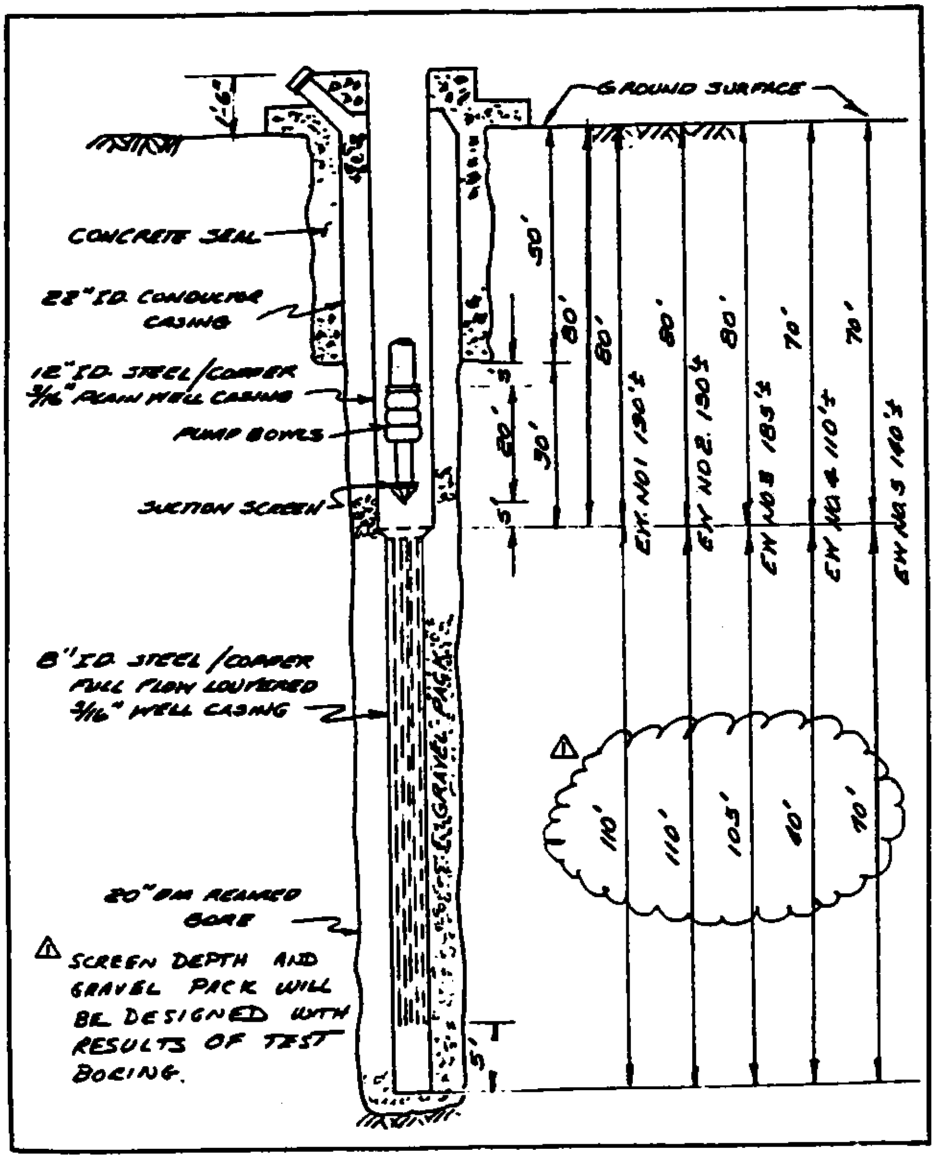


Figure 11. Design Specifications of the 5 Extraction Wells at the OCC Site (From Black and Veatch Consulting Engineers, November, 1981).

2 were fitted with 3-stage vertical turbine pumps capable of pumping at a rate of 300 gallons (1,136 l) per minute. The prescribed pumping rates of these wells are 150 gallons (568 l) per minute each in the summer and 100 gallons (379 l) per minute each in the winter. Extraction well number 3 has a 2-stage vertical turbine pump capable of 400 gallons (1,514 l) per minute although its pumping rate is only 200 gallons (757 l) per minute in summer and 150 gallons (568 l) per minute in winter. Extraction wells number 4 and 5 are fitted with 2-stage vertical turbine pumps capable of 150 gallons (568 l) per minute each. The present rate of pumpage from these wells is 75 gallons (284 l) per minute each in the winter and zero in the summer. The higher rates of pumpage in the northern wells during the summer were established to offset heavy pumpage from nearby irrigation wells located northwest of the site.

The carbon absorption treatment plant is joined to the extraction wells by 4, 6, and 8-inch (10, 15, and 20 cm) diameter, PVC pipes rated at 125 psi and with a combined capacity equal to the sum of all five extraction well capacities. The treatment unit consists of 2 upflow pulsed bed contactors, 2 blow cases, and a storage tank for spent carbon (Figure 12). The plant is arranged in a total redundant design such that only one carbon contactor is operational at a time with the other contactor on standby in case of failure. Each contactor has 20-foot (6 m) vertical sidewalls and a 10-foot (3 m) inside diameter capable of holding 40,000 dry pounds (18,144 kg) of carbon. The contactors are constructed of carbon steel with an interior coating of coal tar epoxy. The spent carbon tank is also carbon steel with a coal tar epoxy liner. It has 10-foot (3 m) vertical sidewalls and a 10-foot (3 m) inside diameter and holds 20,000 pounds (9,072 kg) of dry carbon. The carbon blow cases are 6 feet (1.8 m) high and 4 feet (1.2 m) wide and are constructed of unlined carbon steel. Carbon is used at a rate of about 5,400 to 11,000 pounds (2,449 to 4,989 kg) per month.

The 2 injection wells are connected to the treatment plant by 12 inch (31 cm) diameter, PVC pipe rated at 200 psi. Only one of these wells has been in operation since the remedial action began in the summer of 1982. The other well is on standby in case the primary well becomes clogged or more injection capacity is needed. Both wells were completed to depths of about 500 feet (152 m) using reverse rotary drilling techniques. In the first 290 feet (88 m) of each well, there is a 24 inch (61 cm) diameter bore hole cased with a 16 inch (41 cm) inside diameter by 1/4 inch (0.6 cm) thick high carbon steel pipe. The

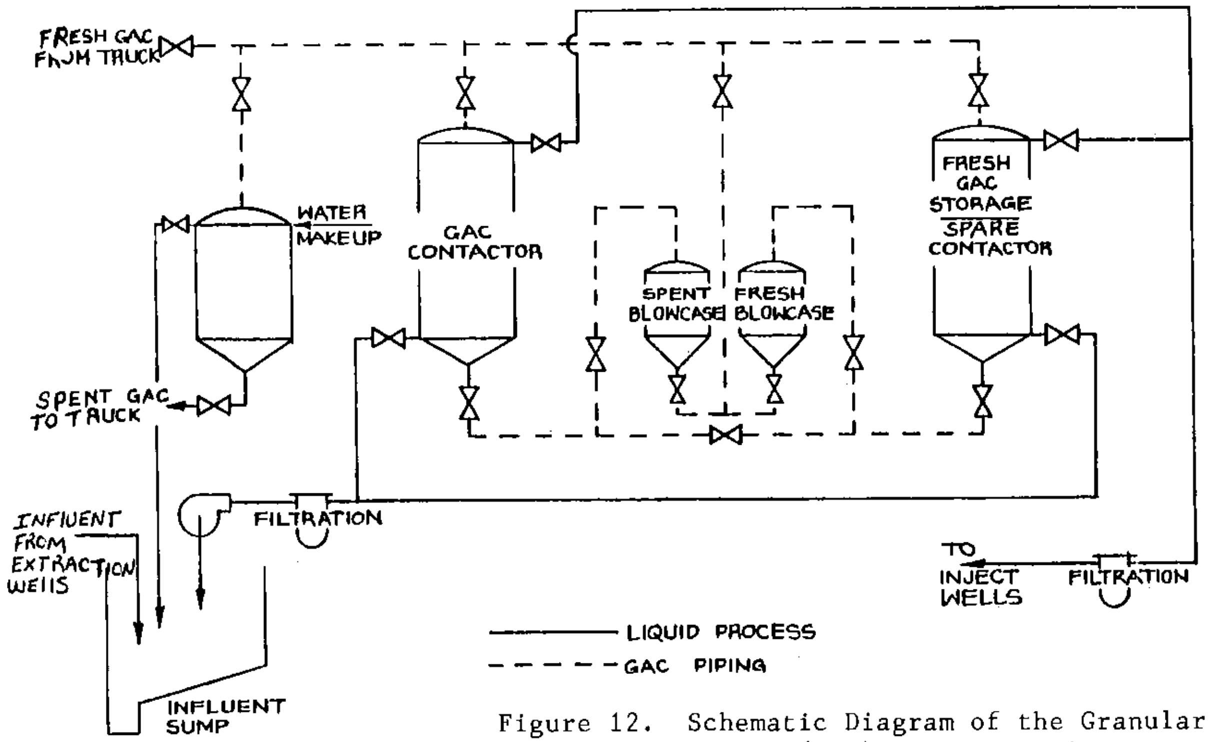


Figure 12. Schematic Diagram of the Granular Activated Carbon (GAC) Treatment Plant at the OCC Site (From Black and Veatch consulting Engineers, November, 1981).

remaining 210 feet (64 m) of these wells consists of a 15-inch (38 cm) bore hole cased with 8-5/8 inch (22 cm) OD by 3/16 inch (0.5 cm) thick stainless steel with louvered screens at the following intervals:

- 320' to 328' (97.5 to 100 m)
- 354' to 380' (108 m to 116 m)
- 404' to 414' (123 m to 126 m)
- 428' to 436' (130.5 m to 133 m)
- 482' to 492' (147 m to 150 m).

Figure 13 provides detailed specifications of the injection wells and the well head assemblies.

COST AND FUNDING

Source of Funding

The entire remedial action was funded by the Occidental Chemical Company (OCC), including alternative water supply hookups to 28 Lathrop area residents whose ground water wells were either contaminated or threatened with contamination. Occidental is making regular payments to the Department of Health Services and the Regional Water Quality Control Boards for their costs for sampling and testing as specified in the consent decree. Occidental also reimbursed the State and the Environmental Protection Agency for the costs of investigation prior to the settlement. Also, Occidental makes regular contributions to California universities for environmental research.

300.70(d)(2) provision of alternative water supply

Under the provisions of the February 1981 Consent Decree, OCC will maintain the ground water treatment system until the year 2001. As part of the divestiture following its recent acquisition of Cities Services, Inc., OCC sold the Lathrop facility to the Simplot Company. However, the remedial obligations of the Consent Decree including the cost of the ground water treatment system will continue to be met by Occidental. Occidental will retain ownership of the system, related equipment and the analytical laboratory located on-site. The individuals operating the system and laboratory will be retained by Occidental. The sales agreement provides permanent access for OCC to Simplot's property, to allow for system maintenance.

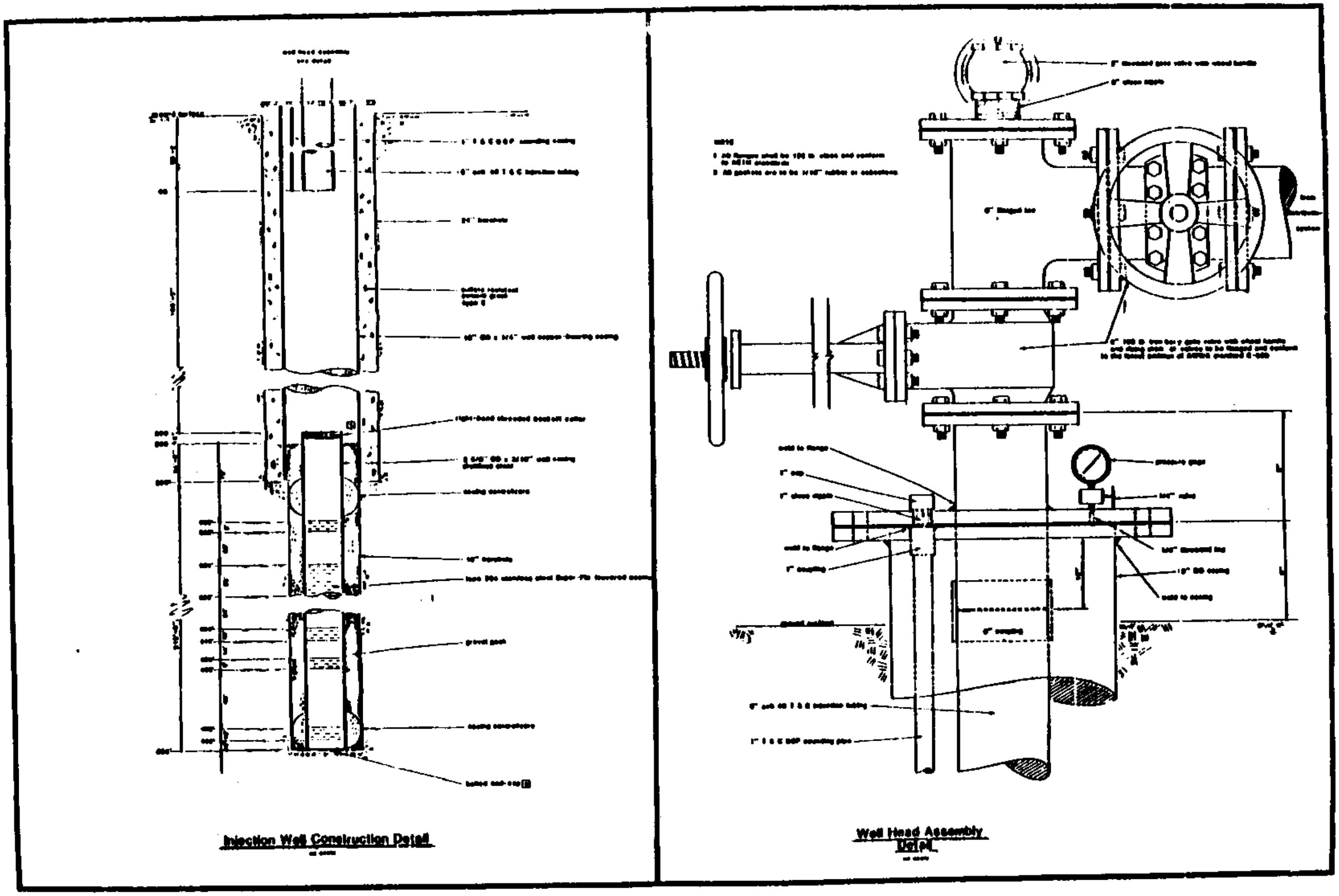


Figure 13. Detailed Design Specificatoins for the Injection Wells at the OCC Site (From Lundorff and Scalmanini, December, 1981).

Selection of Contractors

Contractors were generally chosen on both sole source and competitive bidding bases, but specific information on all major contracts was not available. The drilling contractor was chosen because his familarity with the local geology through direct experience was considered the most important factor. The contract for constructing the carbon system was let on an informal competitive bidding process between two bidders. This contract was let separately from the design and construction of the pilot carbon system. Contracts for each phase of the study and remedial work were also let separately, because the Occidental manager in charge of the project believed that no single contractor could offer the variety of services needed, but each had a useful specialty.

Project Costs

The cost information in this section (See Table 2) is based on verbal communications with involved parties, not on invoices.

Testing, Planning and Design Costs

The cost of the ground water modelling by Camp, Dresser and McKee (CDM) used to plan the ground water extraction well placement and prepare for the ground water restoration project, was about \$175,000. The cost of the soil and ground water sampling and analyses was about \$1.25 million. Most of the work was done by Raltech, Inc. Over half of the expense involved analysis costs. The analyses are now performed on-site by the OCC lab, which includes three specially-calibrated gas chromatographs. Part of the total ground water treatment system costs was devoted to design, development and construction of the system with bench scale and pilot scale systems.

Excavation

300.70(c)(2)(i) Excavation

The cost of excavation of the 4655 cubic yards (6088 m^3) of contaminated material described in "Design and Execution of Site Response" above and listed in Table 2, was about \$678,000. The primary equipment used for the excavation was a Case 450 bulldozer, a Caterpillar 977, and an Case 780 backhoe with a three foot bucket.

Transportation and Disposal

The costs of transportation and disposal were charged together on a per-cubic-yard rate based on the type of material and the location. Since the site was located directly along a highway I-5, these tipping rates were relatively low because of the low amount of wear and tear expected on the trucks, compared to what would be expected

TABLE 2. SUMMARY OF COST INFORMATION-OCCIDENTAL CHEMICAL CO., LATHROP, CA.

Task	Quantity	Actual Expenditure	Unit Cost	Funding Source	Period of Performance
Site Investigation	--	$1.25 million	--	OCC(a)	1979-81
A. Excavation	4655 cu.yds.(3,559m^3)	$678,000	$146/cu.yd. ($191/m^3)	OCC(a)	July 1980-Feb. 1981
B. Contamination Transportation and disposal	Total: 4655 cu.yds.(3,559m^3)	$247,450			
1. Class I 1) Extremely Hazardous	140 miles (225 km) 735 cu.yds.(562 m^3)	($80,850)	$110/cu.yd. $144/m^3)	OCC	July 1980-Feb. 1981
2. Class II-1	15 miles (24 km) 3185 cu.yds (2435 m3)	($114,475)	$35/cu.yd ($46.m^3)	OCC	July 1980-Feb. 1981
Total Removal Cost		$925,450			
C. Groundwater Restoration					
1. Modelling,planning	--	$175,000	--	OCC	1980-19[illegible]
2. Treatment system(b)	--	$1.56 million	--	OCC	1980-1981
Total Capital Cost		$3.91 million		OCC	1979-1981
D. Operation and Maintenance					
i) Carbon	5,400-11,000 lbs (11,880-24,200 kg/month	$58,320-125,400/year	90-95¢/lb (1.98-2.09/kg	OCC	1980-1981
ii) Electricity	1749-2000 kwh	$35,000-40,000/year	4.9 ¢/kwh	OCC	1980
iii) Maintenance	--	$40,000/year	--	OCC	1980
Total water treated	1.5-2.6 x 10^8gallons (6.8-9.8 x 10^8 1) year	O&M:$133,320-370-800/year	0.05-0.11¢ gallon (0.013-0.029¢1)	OCC	1980

(a) Occidental Chemical Company (b) Design, Development and construction if the site required driving along poorer quality roads. The thirty cubic ($23\ m^3$) yard capacity trucks were filled to between 15-20 yards ($11-15\ m^3$) because of weight limitations set by California state law. About 274 truck-loads of material were hauled off-site for disposal. The transportation distance to the Class I landfill in Coalinga, California was 140 miles (255 km). The Forward Class II-1 landfill in Stockton, California was 15 miles (24 km) from the site. The separation of material into Class I and II-1 disposal categories was based on DoHS criteria and best professional judgement of the regulatory personnel and OCC. Generally, technical grade pesticides were Class I and contaminated soil was Class II-1. Containers of pure pesticides, including concentrated vanadium pentoxide, were further segregated for disposal as Class I "extremely hazardous."

The total cost for transportation and disposal of the 4655 cubic yards ($6088\ m^3$) of excavated waste pesticide and contaminated soil was $247,450. This estimate is based on the following unit costs given verbally by OCC, and an even distribution of class I materials, noted by a DoHS engineer (See Tables 1, 2). At $110 per cubic yard ($\$144/m^3$), the 735 cubic yards ($562\ m^3$) of Class I "extremely hazardous" material transportation and disposal cost was $80,850. At $75 per cubic yard ($\$98/m^3$), the 735 cubic yards ($562\ m^3$) of Class I "hazardous" material transportation and disposal cost was $55,125. At $35 dollars per cubic yard ($\$46/m^3$), the 3185 cubic yards ($2435\ m^3$) of Class II-1 material transportation and disposal cost was $114,475.

Ground Water Treatment

The cost for designing, developing and constructing the ground water treatment system was about $1.56 million. The $175,000 cost for CDM's ground water planning study should be included in the restoration project costs. The annual operation and maintenance (O.&M.) costs are still unclear, but some estimates were offered, and some can be constructed from engineering data. Based on a carbon usage rate of between 5,400 and 11,000 pounds (11,880-24,300 kg) per month and a carbon cost of 90-95¢ per pound ($1.98 - $2.09/kg) the annual cost for carbon replacement will be about $58,320 - $125,400 per year. This is based on the use of a single contactor which will be changed to two contactors, and shipping the carbon to New York for replacement and regeneration. The minimum electricity costs for operating three 7.5 horsepower pumps in the extraction wells, which draw at least 49,090 kwh/year to maintain a cone of depression, is about $2,454. The estimate of present electricity cost is about $35,000 - $40,000/year for the entire system. The annual

300.70(b)(2)(ii)
(C)(2)
direct waste
treatment
methods-carbon
absorption

maintenance cost has been estimated at about $40,000. Hence, the total operation and maintenance for treating $1.65 - 2.6 \times 10^8$ gallons ($6.8 - 9.8 \times 10^8$ l) of water a year (300-500 gallons (1135 - 1893 l) per minute) is about $133,320 - $165,400 per year. This is a unit cost of 0.05¢ to 0.11¢/gallon (0.013 - 0.029 ¢/l).

This O.&M. cost estimate is very tentative since the system was still being modified at the time of this writing (January 1983). The cost for carbon regeneration could increase in the short term when the second contactor comes on line. However, in the long run this cost should decrease as the concentration of the contaminants in the ground water decreases. The replacement of the carbon system with a biodegradation process, which is now in a pilot scale stage of development, may also decrease the treatment cost although the effectiveness of such a process at reducing DBCP concentrations to below 1 ug/l was uncertain as of January 1983. Finally, analytical costs for maintaining and calibrating the system should decrease as the procedure becomes more streamlined through experience.

300.68(i)(2)(B)
Distribution of
costs over time

Alternative Water Supply Cost

The entire cost as well as the contracting responsibility for the alternative water supply system near the site is being borne by OCC. Aside from the construction costs, OCC is paying for legal fees, right of way acquisition, engineering, state and local permit fees, and the district connection fee for each resident who desires a connection. After completion and inspection, OCC will turn over ownership to the Lathrop County Water District. The District will assume future maintenance responsibility.

300.70(d)(2)
provision of
alternative
water supply

The construction costs are expected to total between $200,000 and $300,000 when completed in February 1983. This cost includes water main lines, services, fire hydrants, and appurtenences for two streets. An eight inch (20 cm) water main will be installed along Louise Avenue from 7th Street west, and north on Harlan Road. A twelve inch (30 cm) water main will be installed on Louise Avenue from 7th Street east to McKinely, and an eight inch (20 cm) main along McKinely Street south of Louise Avenue. A total of 28 residences will be connected.

PERFORMANCE EVALUATION

There were two types of remedial actions at the OCC site: (1) excavation and capping of contaminated soils, and (2) ground water extraction, treatment, and reinjection. The performances of these remedial measures are discussed separately below.

Soil Excavation and Capping

The excavation and capping of contaminated soils at the OCC site was done according to specifications which were preapproved by U.S. EPA and the State of California. Since the time this work was completed, frequent visual inspections have shown no ponding, cracking, or other evidences of failure in the capped areas.

Groundwater Extraction, Treatment, and Reinjection

The effectiveness of the ground water remediation at the OCC site is evaluated continuously through daily monitoring of all organic constituents shown in Table 3 in the influent and effluent to the carbon absorption treatment plant. DBCP concentration was selected as the key performance indicator after bench scale and pilot plant testing showed it to be the most difficult pesticide to remove. A maximum level of 1 ug/l DBCP was set as the performance standard for the treatment system since the California Department of Health services had previously established this concentration as an "action limit" for area drinking water. This performance standard was difficult to maintain when the ground water treatment began in July, 1982.

When the system first began operating, the average concentration of DBCP in the treated effluent was about 7 ug/l with about a 5 ug/l fluctuation about the mean. This was greater than a 99 percent reduction over the influent concentrations which usually lies in range between 1000 and 4000 ug/l. However, recently with the debrigging go the system completed, US EPA has indicated compliance with the consent-degree mandated 1 ug/l DBCP limit. Further, the OCC facility operator is now examining the possibility of connecting the two carbon contactors to double the carbon contact time and thereby expects to reduce the effluent DBCP concentration below the 1 ug/l performance level.

The performance of the injection wells is evaluated continuously by monitoring the piezometric response of the injection zone. This monitoring is done through 3 wells that were drilled into the injection zone.

In addition to evaluating the performance of the carbon treatment system and the injection wells, OCC is required to monitor the ground water at over 60 monitoring

TABLE 3. MONITORING PARAMETERS FOR WELL SAMPLES COLLECTED AT THE OCC SITE.

Major Organic Constituents*	
Alpha BHC	DBCP
Beta BHC	EDB
Delta BHC	Sulfolane
Gamma BHC	
Minor Organic Constituents**	
Aldrin	Heptachlor
Chlorodane	Methyl Parathion
DDE	Ethyl Parathion
DDT	Sevin
DEF	Toxaphene
Delnav	Disyston
Dieldrin	2,4-D
Dimetholate	2,4,5-T
Major Inogranic Constituents*	
Chloride	pH
Conductivity	Sulfate
Nitrate	Uranium
Minor Inogranic Constituents**	
Gross Alpha	Radium 226
Gross Beta	

*Found in significant quantities and/or in a significant number of wells
**Found in detectible concentrations in one or more monitoring wells

wells around the plant. Table 2 presents a list of parameters prescribed by the monitoring program. The major organics and inorganics shown in this table are monitored 3 time per year and the minor constituents are monitored only once a year. The purpose of the monitoring plan is to confirm the outputs of the ground water model on which the remedial extraction efforts are based. The model has been used to predict the effects of different extraction well pumpage rates and locations on the movement of contaminated ground water plume. By continuing to monitor the wells, the OCC facility operator and the regulatory authorities can determine whether the contaminated ground water is being contained and removed according to the chosen configuration and pumpage rates of the extraction wells (Figures 14 through 16). If descrepancies are found between the predicted and observed concentrations of ground water contaminants, either the model, the remedial design, or both will have to be adjusted depending on the nature of the descrepancy. Thus far, there is no indication of a problem with the present ground water extraction program.

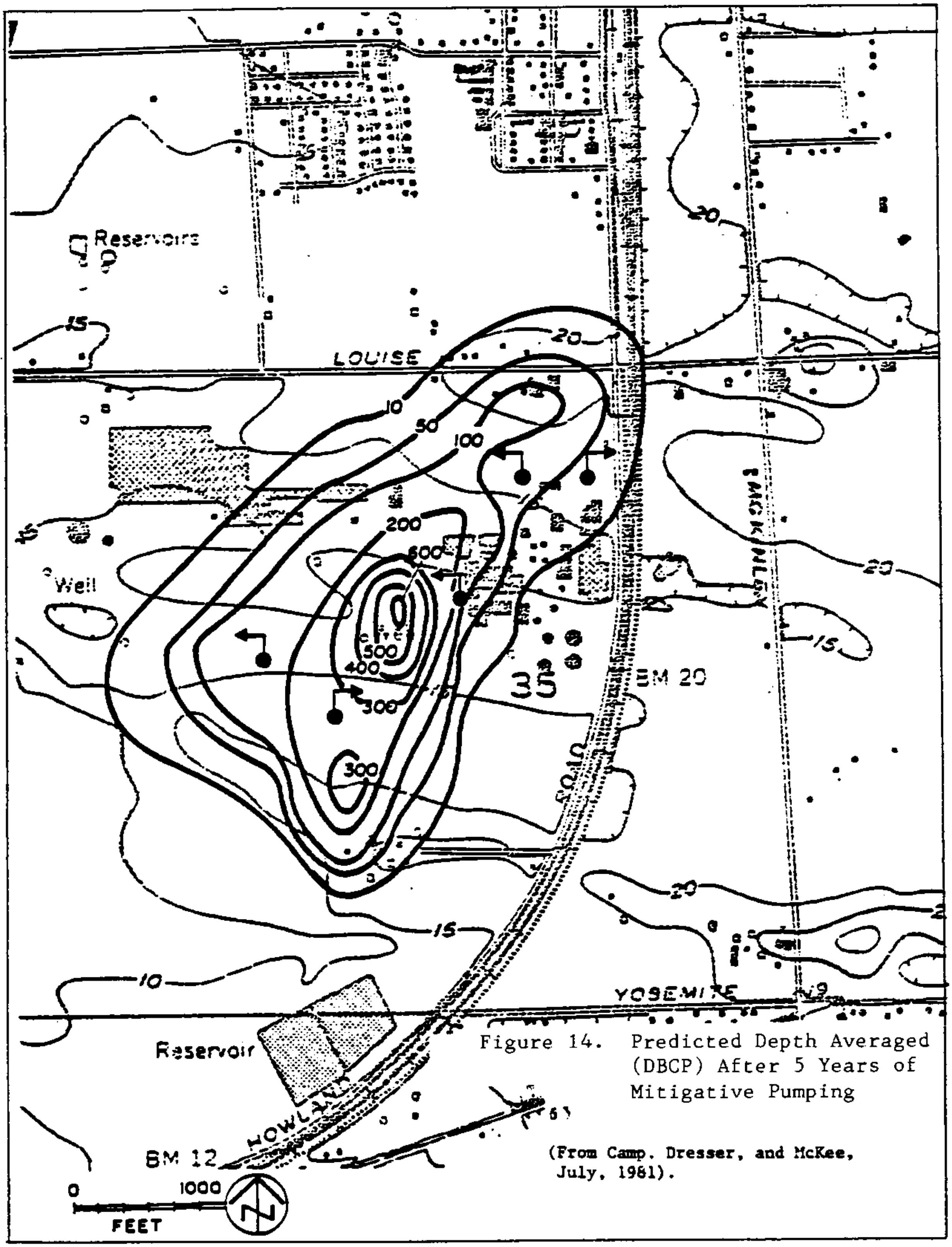


Figure 14. Predicted Depth Averaged (DBCP) After 5 Years of Mitigative Pumping

(From Camp. Dresser, and McKee, July, 1981).

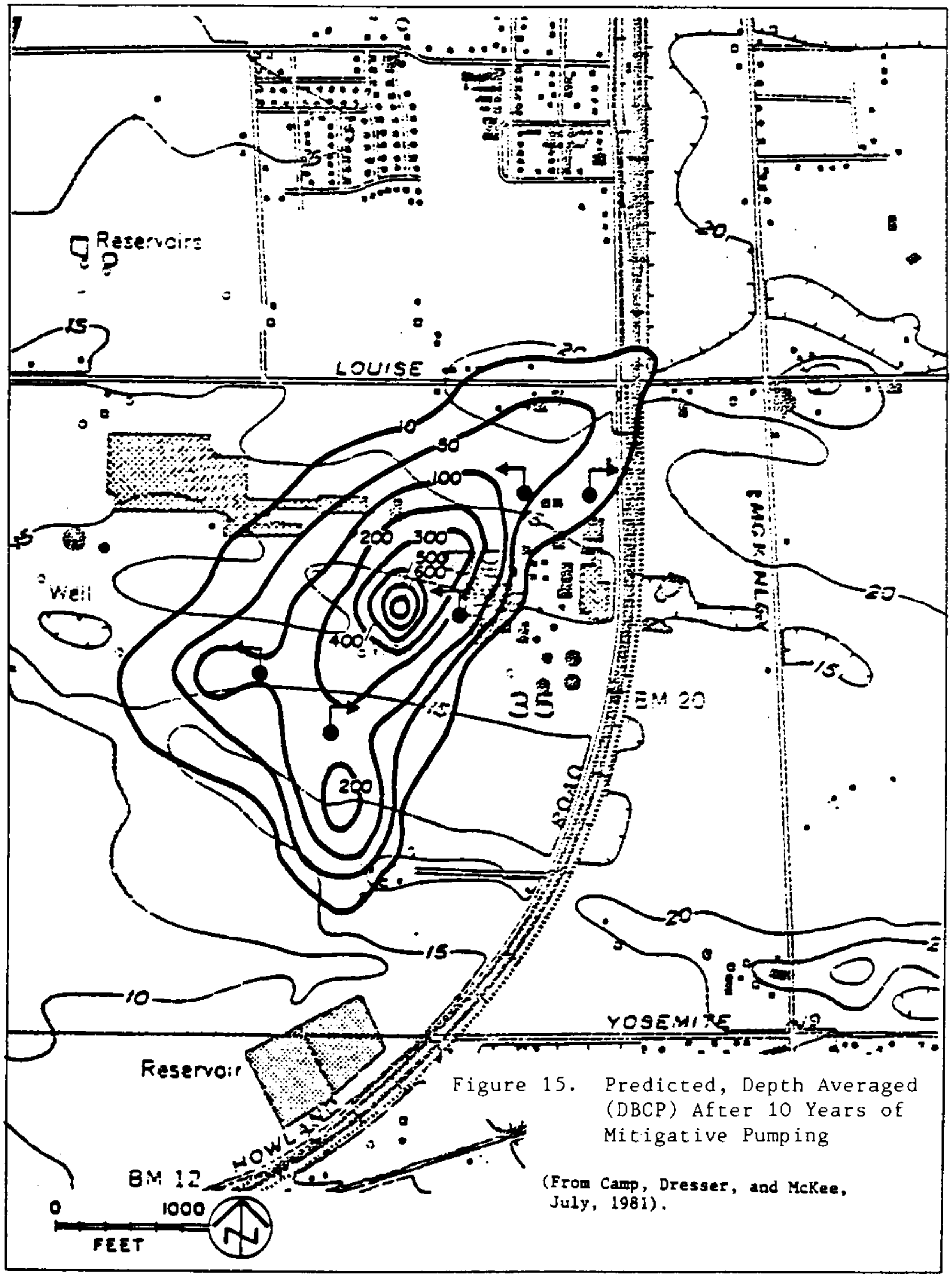


Figure 15. Predicted, Depth Averaged (DBCP) After 10 Years of Mitigative Pumping

(From Camp, Dresser, and McKee, July, 1981).

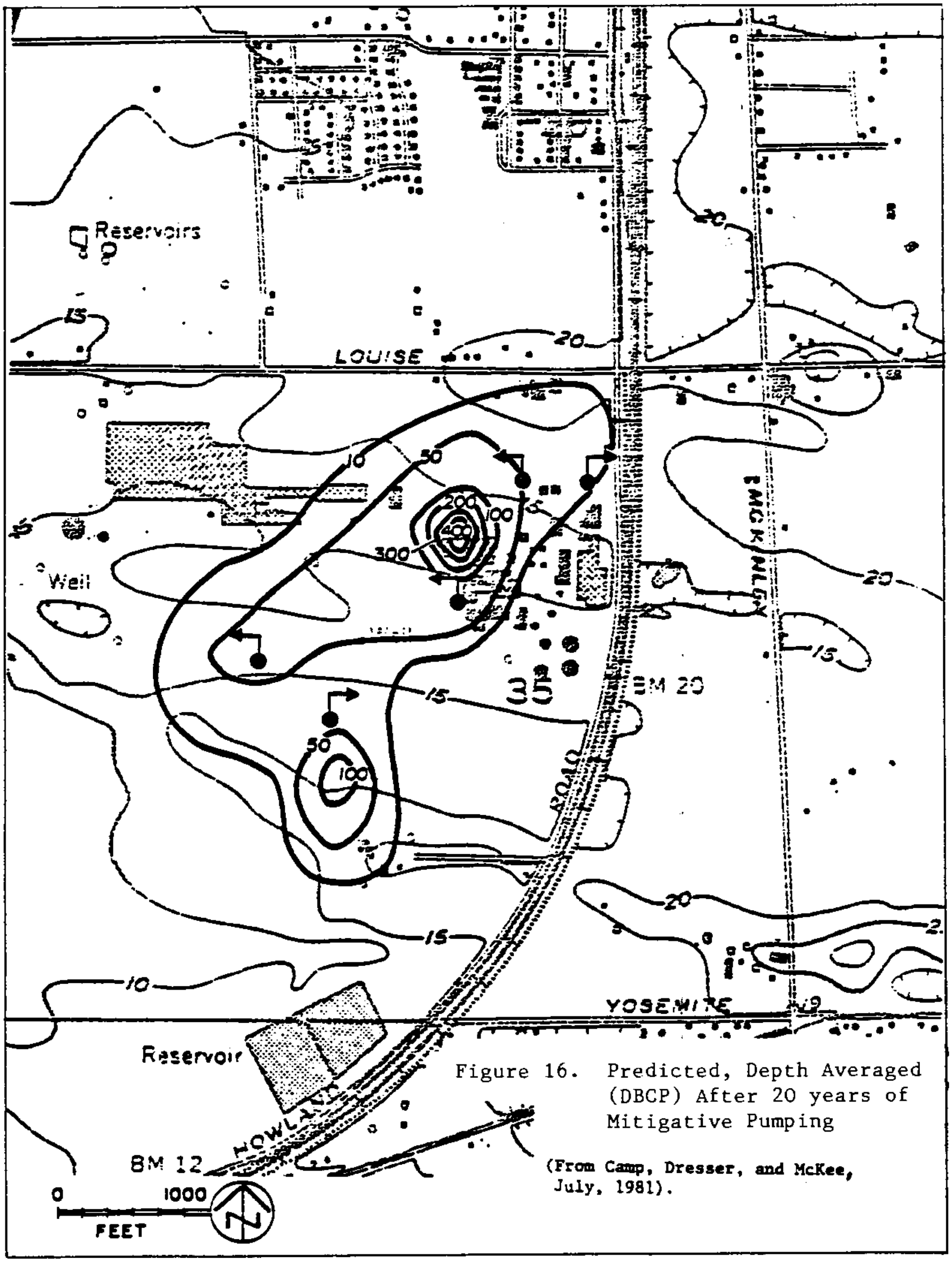


Figure 16. Predicted, Depth Averaged (DBCP) After 20 years of Mitigative Pumping

(From Camp, Dresser, and McKee, July, 1981).

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STRODSBURG

PENNSYLVANIA

A. INTRODUCTION

NCP Reference

The Stroudsburg site is located in the Borough of Stroudsburg, Monroe County, Pennsylvania at the site of a historical coal gasification plant (Figure 1-A). Over a 60-year period EPA officials estimated that approximately 1-2 million gallons of coal tar residuals from a coal gasification plant were injected into nine well adjacent to a small trout stream known as Brodhead Creek. Over time, the coal tar seeped from the wells into the underlying gravel stratum of the streambed. Erosion of the streambed eventually resulted in the migration of the coal tar into the surface waters of the creek.

In addition to Brodhead Creek being widely used for trout fishing, it is also a tributary of the Delaware River which serves as the main water supply to Eastern, Pennsylvania and as a recreational area. Due to the broad usage of both the Delaware River and Brodhead Creek, migration of coal tar into the creek posed a serious potential health hazard and environmental threat.

Background

From 1880 to 1940, Stroudsburg Gas Co. operated a coal gasification plant near the shores of Brodhead Creek. Coal tar residuals from the gasification process were injected into a well on the property down into a porous gravel stratum that occurs approximately 20 feet below the land surface. In the early 1900's the plant also supplied electricity to area residents via electrical generators located on the plant property.

In 1917, Pennsylvania Power and Light Company (PP&L) purchased the electrical section of the Stroudsburg Gas plant, and acquired four or five additional parcels of land over the next 30-year period. Most of this land was situated along the streambed of Brodhead Creek.

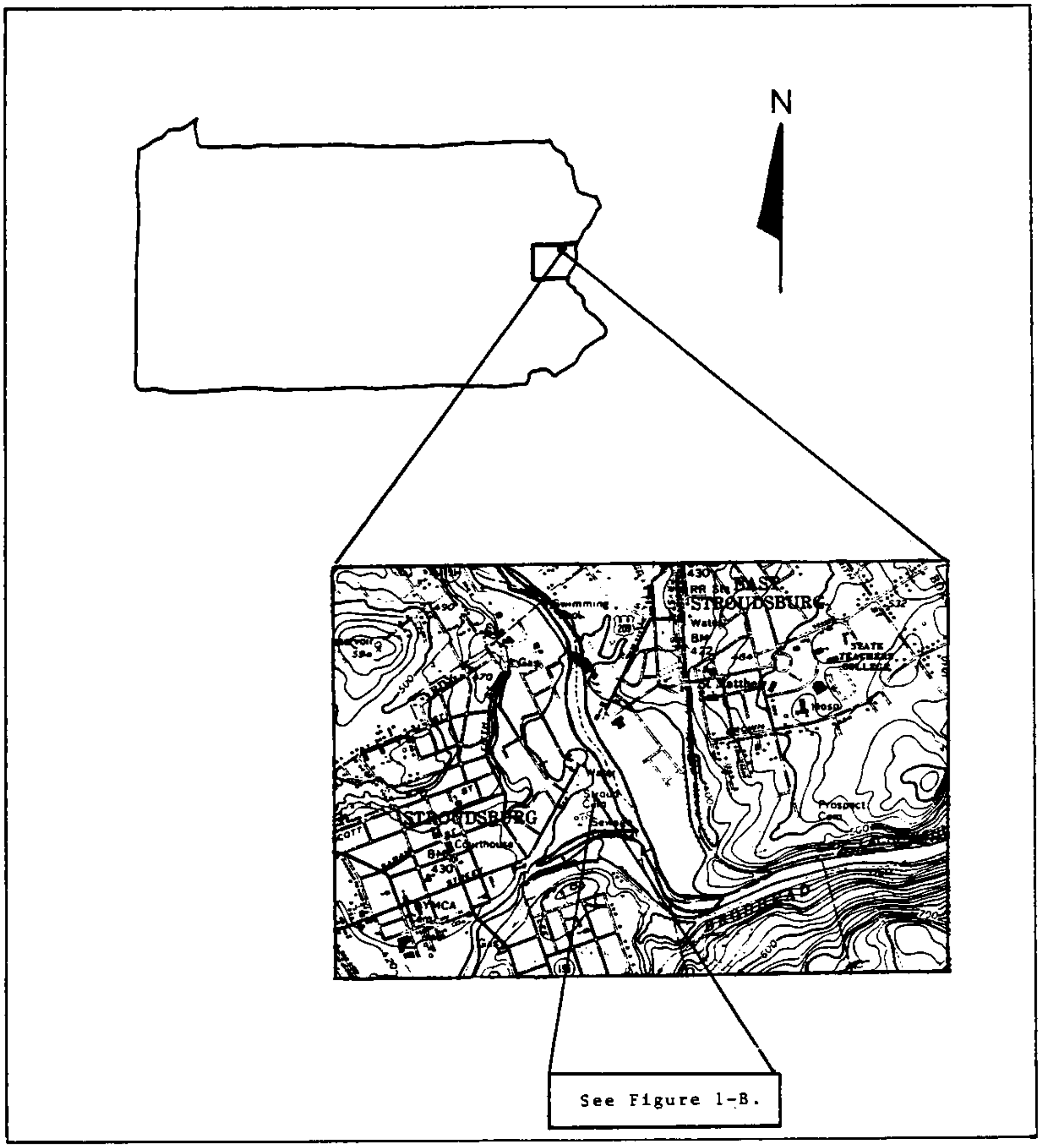

Figure 1-A. Stroudsburg Site Area and Location Map

In 1955, Hurricane Diane caused major flooding along the shores of Brodhead Creek, including land owned by PP&L. In 1960 the Corps of Engineers instituted a flood control program which involved straightening of the creek channel and construction of dikes approximately 50 feet high along either side of the creek.

During routine maintenance of the dike in the Spring of 1980, the State discovered that the streambed has eroded 6 feet. This was attributed to a change in stream flow as a result of earlier dike construction. To remedy this problem, the State began erosion control work along the streambed, placing the existing riprap deeper than it had been for the original dike construction. During low water conditions in October of 1980, black tarry globules (later identified as coal tar) were observed emanating from the base of the dike at an elevation of about 375 feet. The observed seepage was in the approximate location of the old coal-gas plant. The flow of the coal tar into the stream was nonuniform, noncontinuous, and nonhomogeneous, issuing from the stratum at several points along the side of the stream, similar to springs (Figure 1-B).

300.63(a)(4) discovery

Synopsis of Site Response

In response to the discovery of the coal tar seepage, the State began investigations to determine the extent of contamination and the level of response required to alleviate the problem. Six months later, in April of 1981, the State and EPA Region II responded to the problem under the authority of Section 311 of the Clean Water Act. This action concentrated on oil removal technologies including installation of filter fences and the construction of inverted dams.

300.68(f) field investigation

300.65(b)(7) physical barriers to deter spread of release

In September 1981 the State presented its findings on the problem in a report entitled the "Extent of Contamination at Brodhead Creek." The report recommended the construction of a slurry trench cut-off wall to effectively contain the coal tar and prevent further migration into the streambed. EPA began construction of the slurry wall upon the State's recommendation. The slurry wall was completed in January 1982.

Concurrent with actions taken by the State and EPA, PP&L conducted extensive on-site geological and water quality studies in April of 1981. The purpose of the studies was to answer questions concerning the extent of contamination and the type of technology necessary for removal, not just containment, of the coal tar. The

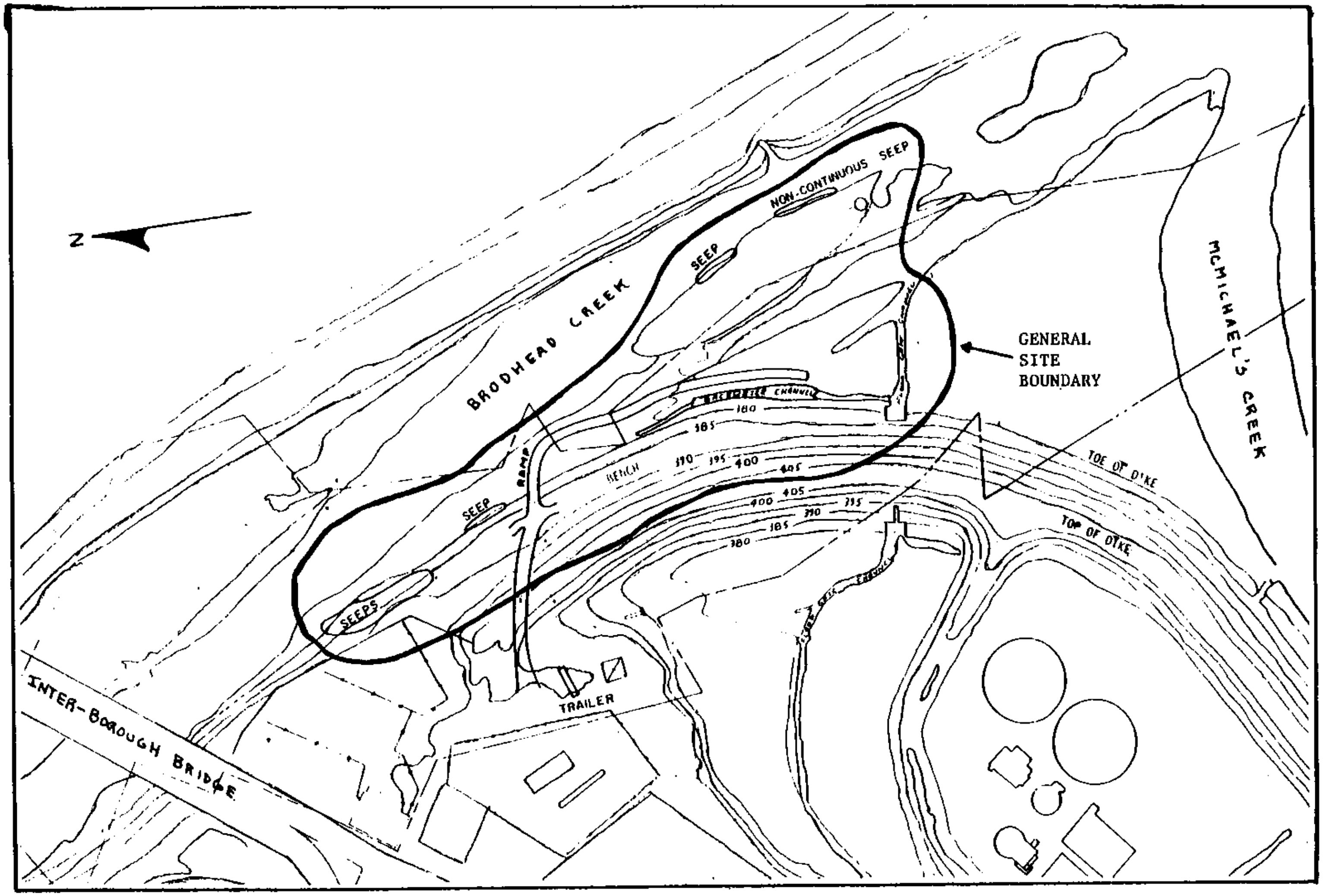

Figure 1-B. General Stroudsburg Site Area

studies identified a large accumulation of recoverable coal tar in an underground stratigraphic depression located near the flood control dike. Based on this information, PP&L decided that the most effective means of removing the coal tar was to reclaim it as a resource. PP&L determined that the optimum technology for accomplishing this task would be a recovery well system. In the fall of 1981 PP&L began and completed installation of the system.

SITE DESCRIPTION

The Stroudsburg site plant is located at latitude 40°58'50" and longitude 75°11'10", near the urban area of Stroudsburg, Pennsylvania, between the bridges of Route 209 and Route I-80.

Surface Characteristics

The Stroudsburg site and surrounding Monroe County are located in the Pocono Mountains of eastern Pennsylvania. The terrain consists of predominantly forested, rolling mountains dotted with numerous lakes, swamps, and streams.

The Stroudsburg site is located along one of the lower-most reaches of Brodhead Creek, in a relatively wide valley. Approximately 200 feet (61 m) from the coal tar site, Brodhead joins McMichael's Creek which flows in a southeasterly and then in an easterly direction for approximately 4 miles, (6.4 km) eventually emptying into the Delaware River.

The drainage area of Brodhead Creek is approximately 142 square miles (368 km^2) above the mouth of McMichael's Creek. The topography of the watershed is characterized by moderate to considerable relief.

The average flow of Brodhead Creek, based upon flow records for the past 28 years, is 2.2 cubic feet (.06 m^3) per second per square mile at a point near the Interborough bridge, upstream of the site area, the flow of Brodhead Creek was measured and was found to be 294 cubic feet (8.2 m^3) per second. The creek is characterized by frequent, yet brief, flooding events during the 7-month period, November through May. The highest degree of flooding, however, has been caused by hurricane-force storms that have occurred during the late summer months. A maximum peak of 266 cubic feet (7.5 m^3) per second per square mile was recorded on August 19, 1955. Normal minimum flows occur in August, September and

October and are generally between 5 percent and 10 percent of the average flow. The minimum flow recorded was 0.11 cubic feet (.003 m^3) per second per square mile and occurred on September 27, 1964.

The soils in the site area are members of the Holly 300.68(e)(2)(i)(D) series and are characterized by a fine loamy texture. The hydrogeology Holly soils are typically deep (60 inches (.02 m) in factors depth) and poorly drained. These soils were formed in alluvium that was derived from acid sandstone and shale, and occur on flood plains along major streams. Slopes range from 0 to 3 percent. Due to its fine-silty texture, poor drainage and the fact that they are usually located in flood prone areas, construction activities may be restricted in areas consisting of Holly soils. Excavations can be problematic due to the high moisture content of the soils and the area's high flood hazard potential. The construction of embankments, dikes, and levees with these soils requires addressing the problems that can be caused by piping (subsurface erosion). The erosion potential of these soils is low.

300.68(e)(2)(E) climate

The local climate is characterized as being humid continental. The average annual daily maximum and minimum temperatures are approximately 57°F (13.9°C) and 36°F (2.22°C), respectively (3). The average daily minimum temperatures during the months of November, December, and January are 29.3°F (-1.67°C), 18.0°F (-7.78°C) and 14.5°F (-10.0°C) respectively (4). During the winter months, prevailing winds blow from a west-northwest direction. During the summer months, the winds shift to a more west-southwesterly origination. Wind speeds average 8 mph (13 kmph).

Annual precipitation ranges between 40 and 60 inches (>.51 and 1.5 m), with an average of 45 inches (1.1 m) per year. Average snowfall is approximately 40 inches (.51 m) per year. During the month of November, there is an average of 3 days that have snow cover. December has, on the average, 13 days with snow on the ground and both January and February average 18 days each.

The Stroudsburg site is situated between the Borough of Stroudsburg to the west and the Borough of East Stroudsburg to the east. Combining these two areas, there is a total population of approximately 15,000 within a 1.5 (2.5 km) mile radius of the site, which increases substantially during the tourist season.

Hydrogeology

The Stroudsburg area is situated at the foothills of the Appalachians, in the Pocono Mountains and is characterized by gently rolling terrain, underlain by unconsolidated valley-fill glacial deposits. The geology of the area consists of at least 60 feet (1.5 m) of unconsolidated sediment overlying undifferentiated Devonian or Silurian calcareous bedrock. The unconsolidated material is generally composed of four different lithologies. A typical geologic cross section consists of the following units listed from the top to the base of the stratigraphic column; (1) swamp deposits and artificial fill, (2) coarse gravel alluvium, (3) fine sands and clayey silt, (4) ground moraine or till, and (5) calcareous bedrock (See Figure 2). This section is locally quite variable and has altered extensively during the flood control project.

300.68(e)(2) (i)(D) hydrogeological factors

The material present nearest the surface is a highly variable fill, consisting of swamp deposits, controlled fill from construction of the dike and assorted "dumped" materials. These components occur noncontinuously over the site area and, in some locations, are completely absent. Where fill material is absent, the surface layer consists of the alluvium material.

The coarse alluvium underlying the artificial fill consists of several sand and gravel beds of varying ages. For the purposes of this report, however, the alluvium beds will be treated as one unit. The thickness of the gravel bed is relatively consistent throughout most of the site area. There is one apparent pinch-out or thinning of the bed occurring in a southerly direction.

Underlying the coarse alluvium are sediments that range from medium grained sands to fine clayey silt. It is suspected that this material is a lake deposit. Test borings have revealed gravel lenses within this unit. The lens matrix, however, is fine grained.

The material directly underlying the coarse alluvium and overlying the calcareous bedrock in the site area, is a dense gray ground moraine or till. It occurs as a compact conglomeration of boulders, gravel, sand, silt, and clay.

The ground water regime in the area is controlled by both the configuration of glacial deposits and surface topography. Most of the ground water that flows through the glacial material is moving to the southeast, which is the same general direction as surface runoff. The median groundwater level is typically 10 ft (3 m) below the

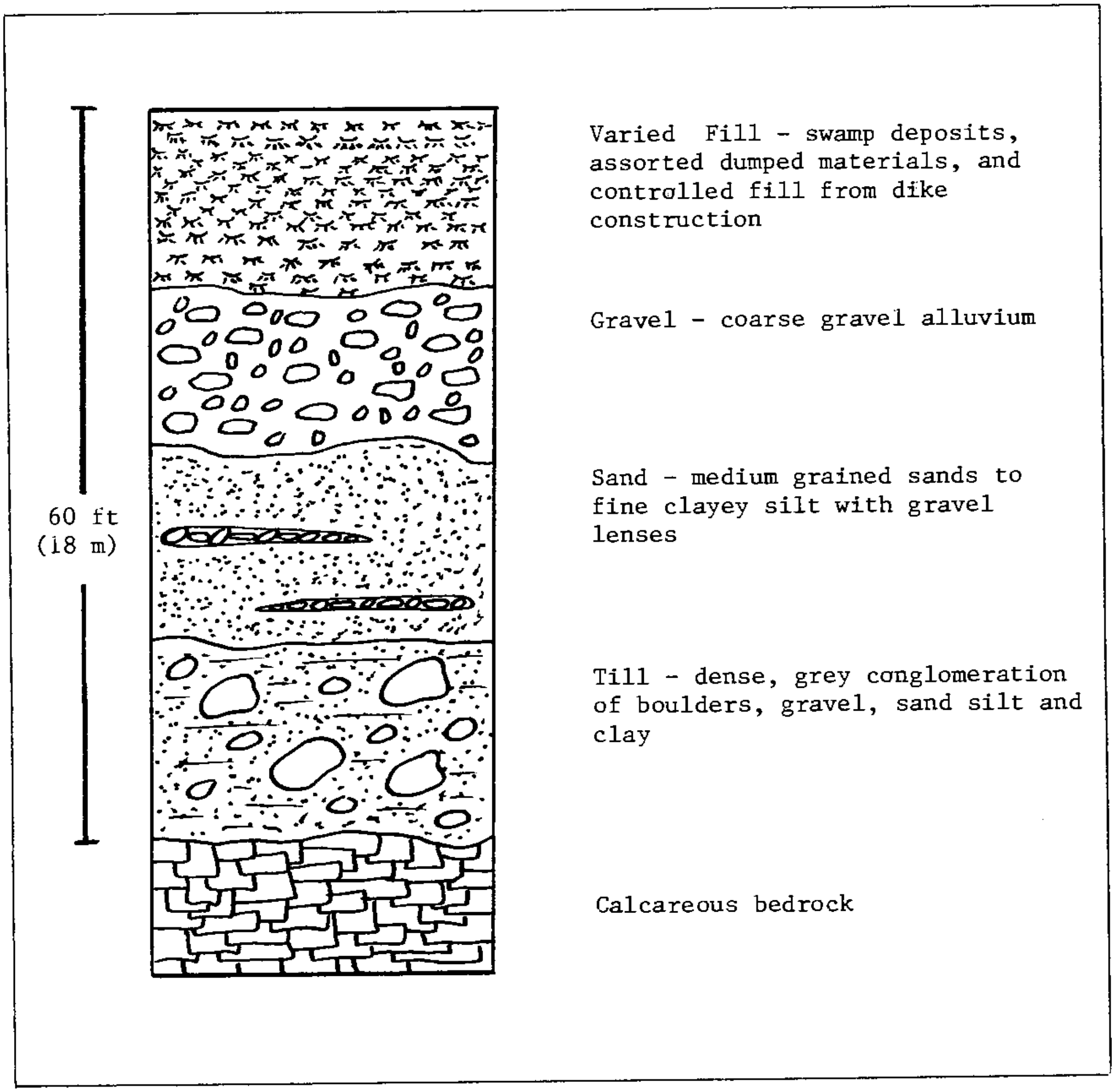

Figure 2. Typical Geologic Cross Section of the Stroudsburg Site Area

natural land surface and the median saturated thickness is approximately 65 ft (20 m) in the region. With this information and the fact that the overburden in the site area is approximately 60 ft (18 m) in depth, one can expect that most of the unconsolidated material overlying the bedrock at the Stroudsburg site is water saturated. It should be noted, however, that the term 'aquifer,' as used in this report, is meant to describe only the gravel alluvium. Water table contours for ground water levels at the site indicate that ground water migration is in a southeast direction toward Brodhead Creek, with an average hydraulic gradient of 0.015. Ground water contours are based on ground water level observations that were recorded in June, 1981. The ground water flow rate from the site to the creek has been calculated using Darcy's equation and is estimated to be 28 gpm. The overall velocity of ground water movement is approximately 2 ft (.61 m) per day.

WASTE DISPOSAL HISTORY

The Stroudsburg coal gasification plant was constructed near the shores of Brodhead Creek in the middle 1800's. The plant furnished coal gas as fuel for heat, power and light to residents of Stroudsburg and East Stroudsburg. Stroudsburg Gas Co. acquired the plant in the early 1880's and continued the operation until it was terminated in approximately 1940.

The coal gasification process at this site involved the destructive distillation of coal which left coal tar as a by-product.

Several disposal methods were utilized in the time span of plant operation. During the plant's early operation, coal tar, removed from the reaction vessels, was placed in a trench along the eastern edge of the property, adjacent to Brodhead Creek. The waste products that accumulated in the holding tanks were occasionally "blown down" to the ground.

During the late 1800's and early 1900's, technology developed to the extent that it became possible to remove commercially valuable material from the coal tar waste. The residue from the recovery operation was disposed of through an injection well, located in the northwestern quadrant of the plant property where the facility's boiler house previously stood. The well was constructed such that residuals were injected into the gravel alluvium stratum that underlies the plant area and is delineated approximately 20 ft (6.1 m) below the land surface. This disposal method represented a state-of-the-art technology and was an accepted practice during that time period. Waste injection was practiced at the Stroudsburg plant until its closing soon after World War II.

The total quantity of coal tar residue in the contaminated groundwater plume present at the Stroudsburg site, is currently estimated at 1.8 million gallons (6.8×10^6 l) and is generally confined to the gravel stratum. An underlying fine sand layer provides an effective barrier to further downward migration. Investigative studies have shown the contamination to be spread over an area approximately 8 acres. The largest concentration of coal tar has been located on the inside of the west bank levee, in a stratigraphic depression formed by the confining layer of fine silty sand.

300.68(e)(2) (i)(B) amount and form of substances present

The coal tar residue at Stroudsburg consists of a light fraction that floats on water and a heavy fraction that sinks. However, when slightly agitated in the presence of water, the tar breaks up into three phases; the light and heavy phases and a third phase of near neutral buoyancy, that remains dispersed in the water column. When strongly agitated, all the tar constituents dissolve to a degree to form an emulsion which is very slow to separate.

The chemical constituents of coal tar residue will vary depending upon the coal from which it is produced and the production process utilized. Coal tar is a mixture of many chemical compounds, of which, polynuclear aromatic hydrocarbons (PAHs), cyanides and ammonia, often exist in significant concentrations. These compounds have both acute and chronic health effects, some of them known and suspected carcinogens. Table 1 describes the partial analysis of a coal tar residue sample taken from the Stroudsburg site.

DESCRIPTION OF CONTAMINATION

As a result of the severe flood damage caused by Hurricane Diane in 1955, a flood control program was initiated by the State in 1958. The program was instituted by the U.S. Army Corps of Engineers under the State's supervision and consisted of rechanneling Brodhead and McMichael's Creek slightly to the west of their original course and placing the channel within a floodway lined with stabilized levees. The levees which stand approximately 50 feet (15 m) in height were constructed along the east and west banks of Brodhead Creek and along the north and south banks of McMichael's Creek. The con-

TABLE 1. PARTIAL ANALYSIS OF THE STROUDSBURG COAL TAR

PARAMETER		VALUE	UNITS
Naphthalene		3.60	%
Fluoranthene		3.20	%
Phenanthrene		2.30	%
Anthracene		2.30	%
Dimethyl Naphthalenes		2.15	%
Trimethyl Naphthalenes		1.78	%
Methyl Phenanthrenes		1.50	%
Trimethyl Benzene		1.30	%
Fluorene		0.98	%
Acenaphthylene		0.74	%
Acenaphthene		0.72	%
Pyrene		0.56	%
Benzo(a)anthracene		0.31	%
Chrysene		0.31	%
Benze(a)pyrene		0.10	%
Other		7.84	%
	TOTAL	29.69	%
Acidity		0.62	mg KOH
pH		4.6	standard
Free Carbon (Carbon I)		<0.01	%
Ash		0.00	%
Total Carbon		90.77	%
Total Hydrogen		8.12	%
Total Nitrogen		0.17	%
Sulfur		0.65	%
Chloride		50.	ppm
Ammonia		0.26	ppm
Cyanide		0.18	ppm
Iron		50.3	ppm
Copper		2.48	ppm
Manganese		2.11	ppm
Zinc		0.13	ppm
Nickel		0.19	ppm
Cadmium		0.01	ppm
Lead		0.5	ppm
Arsenic		12.7	ppm
Aluminum		22.4	ppm
Vanadium		1.6	ppm
Barium		0.5	ppm

Source: Villaune, J.F., Lowe, P.C. and Unites, D.F., Recovery of Coal Gasification Wastes: An Innovative Approach, Presented at: The Third National Symposium and Exposition on Aquifer Restoration and Ground Water Monitoring, May 25-27, 1983, Columbus, Ohio struction was completed in 1960. The levee construction along the shores of Brodhead Creek had a major effect upon the stream's morphological processes and that was to constrict its lateral migration and prohibit the development of meanders. This resulted in rapid downcutting of the stream channel, lowering the channel 6 ft (18 m) over the next 20 years and endangering the integrity of the levee by undercutting the rip-rap placed along the toe of the levee. By 1980 the creek had downcut below the level of the rip-rap, and action was taken by the Pennsylvania Department of General Services (DGS) in cooperation with the municipalities and the Corps of Engineers, to extend the rip-rap downward an additional 10 feet (3 m). Construction began in October 1980 and involved the excavation of a trench along the toe of the levee on the western shore of Brodhead Creek. During a low water condition, a black substance, later identified as coal tar residue, was observed emanating from the base of the dike at an elevation of 375 feet (114 m). The flow of the coal tar into the creek was nonuniform, noncontinuous, and nonhomogenous and entered the water from several points along the stream channel (Figure 3).

DGS completed the restoration and reported the incident to the State Department of Environmental Resources (DER), Bureau of Water Quality and the Fish Commission.

In response to the coal tar discovery, the State began investigations to determine the extent of contamination and the level of response necessary to alleviate the problem. An initial preliminary assessment of the situation was made in March of 1981. At this time, it was estimated that 3 to 8 million gallons (11 to 30 x 10^6 l) of coal tar was underlying an area of 11 acres (4.5 x 10^4 m^2) along Brodhead Creek and within a year there would be significant leaching into the creek. Based on these conclusions, it was recommended that a more detailed hydrogeologic investigation be conducted to ascertain the extent of pollution. 300.68(f) investigation

In March-April, 1981, DER requested the assistance of the U.S. Environmental Protection Agency (EPA), in the further investigation of the problem. It was also at this time that PP&L and other affected property owners were informed of the situation and ordered by EPA to undertake an investigation of the extent of contamination. Only PP&L complied.

The investigative field studies that followed involved three major areas; (1) the hydrogeology of the site area, (2) the impact of the coal tar on stream

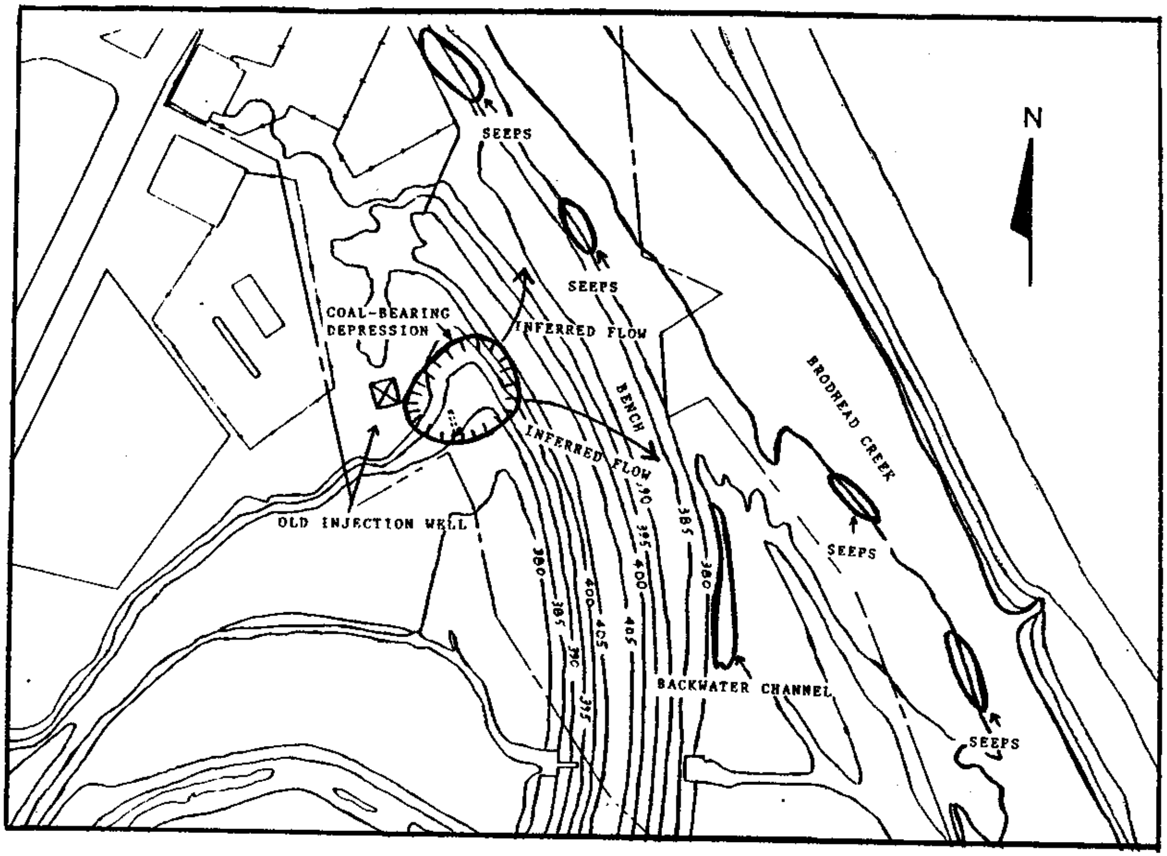

Figure 3. Extent of Contamination at the Stroudsburg Site

quality and its biological community and (3) the erosional behavior of the stream.

The hydrogeologic field work conducted at the Stroudsburg site involved several phases; (1) test pit excavation, (2) a contamination survey including test borings and additional test pits and (3) a groundwater monitoring program.

A total of 23 test pits were excavated during the second and third week of April, under State supervision with assistance from the EPA Technical Assistance Team (TAT). The excavations were made using a tractor mounted backhoe and a tractor mounted shovel. Coal tar was discovered in nine of those pits. The tar appeared to be confined to the gravel and cobble layer and was particularly concentrated on top of the fine sand bed that underlies the gravel stratum.

As a result of the test pit findings, an extensive contamination survey was undertaken by the State and EPA in May, 1981, to determine the extent of contamination present and the geological conditions affecting the movement of the contaminants and their entry into Brodhead Creek. This survey was conducted by PP&L and their geologic consultant TRC. The subsurface investigation that followed involved additional test pits, test borings, and an electrical resistivity survey. Results indicated that the contamination extended over an 8-acre (3.3×10^4 m^2) area. The largest concentration of coal tar, an estimated 50,000-100,000 gallons (1.2×10^5 - 3.8×10^5 l) was found on the inside of the west bank levee in a stratigraphic depression underlain by a confining layer of fine sand (see Figure 3).

The depression is located near the old injection well. Movement of the contaminants through the porous gravel appears to be primarily controlled by the hydrostatic gradient and the configuration of the sand bed. Movement is generally in the same direction as groundwater flow which is to the southeast, however, groundwater flow is not the predominant force behind the coal tar's migration pattern. If this were the case, a much larger tar concentration would be found downstream and to the southeast. Thus the specific gravity of the coal tar seems to have had a greater effect on its movement than did the groundwater flow direction.

A total of 17 test borings were drilled to determine the extent of contamination. At critical depths, continuous spoon samples were taken. In general, the holes extended at least 10 ft (3 m) beyond the last noticeable phenolic odor in the sand. There were several borings that required an extra 20 ft (6 m) of drilling beyond the sand-gravel interface. Eight additional test pits were also excavated.

With the data collected from the test pits and test borings, the extent of contamination was estimated. One of the most noticeable differences between the preliminary assessment and the estimates made following the completion of the field investigation was the much smaller size of the depression behind the west bank levee, which consequently lowered estimates of the coal tar volume.

The calculated volume of coal tar in the main subsurface reservoir of coal tar using the most recent boring data, is between 26,000 and 103,000 gallons (9.8×10^4 and 3.8×10^5 l) as opposed to the earler estimate of 100,000 to 150,000 gallons (3.8×10^5 and 5.7^5 l). The coal tar existing outside this reservoir is not concentrated in large depressions. The coal tar found outside the main reservoir either migrated over the depression lip or it was disposed of over the entire site area and found its way into subsurface strata. No conclusive evidence has been found to support either one of these possibilities.

The contaminated areas and volumes of coal tar present have been estimated and are given in Table 2.

The groundwater sampling and analysis program instituted at the site revealed that polynuclear aromatics, benzene, toluene and ethylbenzene were present in the shallow groundwater at either the part-per-billion level or within the range of known solubilities of the individual chemical species. The principal inorganic contaminants, ie, iron, aluminum, manganese and cyanide were detected at levels as high as 460, 218, 25.5 and 0.30 mg/l. These contaminants are responsible for the high conductivity readings taken from the water samples collected at the site.

The conclusion drawn from the sampling program is that there is a contaminated groundwater ring surrounding the coal tar deposits. The studies conducted to date, indicate that the extent of this contamination is not much beyond the main primary contamination plume due to the absence of drinking water wells in the site area, it was felt that the only potential impact of contaminated groundwater would be on the stream, and because groundwater flow in the area is only about 1/5,000th of the stream flow, the potential hazard of the contamination appears negligible.

300.68(e)(2) (iv) environmental effects and welfare concerns

TABLE 2. A REAL AND VOLUMETRIC ESTIMATES OF CONTAMINATION AT THE STROUDSBURG SITE

Subareas	Known Contaminated Area, in Sq. Ft. (m^2)	Estimated Contamination: Thickness in Ft. (m)	Estimated Contamination: Volume in Cu. Ft. (m^3)
Area inside the dike (includes area under the dike)	210,000 (19,900)	2 to 15 (0.61 to 4.6)	1,642,000 (47,000)
Area outside the dike	90,000 (8,400)	1 (.31)	90,000 (2,600)
Island Area	35,000 (32,000)	1 (.31)	35,000 (10,000)
TOTAL	335,000 (or 7.7 acres) (3ha)		1,767,000 (or 130,889 tons assuming 1 ton = 1/2 yd^3) (30,400)

Source: "Extent of Contamination of Brodhead Creek" report (9/81)

Concurrent with the extent of contamination surveys, an additional series of studies was conducted to assess the environmental impact of the coal tar on the aquatic community and water quality of Brodhead Creek. The performance of the studies was undertaken by the Pennsylvania Fish Commission (PFC), PP&L, and PA DER. During the period from April-August, 1981, these groups, individually and in conjunction with one another, conducted various sampling and analyses efforts to determine the effects, if any, of the contaminant plume on stream quality.

From the results of the various studies and surveys conducted on Brodhead Creek it was concluded that the stream's water quality and biological community had not been adversely affected. However the presence of the coal tar on-site, a highly toxic substance, was a potential hazard to the stream's integrity in the future. The potential for detrimental long term effects from coal tar seepage remained and the possibility of a catastrophic release of tar directly into the stream's waters was a primary concern.

300.68(e)(3)(i) water pollution problem

The third study conducted at the Stroudsburg site investigated the morphological processes of Brodhead

Creek, with particular interest in determining the reasons for the rapid downcutting that has occurred over the last 20 years. Knowledge of the mechanisms involved and the resulting changes in the stream's morphology was of major importance because the one greatest potential hazard posed by the coal tar is its sudden release in large volumes, caused by down-cutting of the stream bed. To evaluate the situation, PP&L contracted its consultants to report on the present day processes that are determining Brodhead Creek's evolution.

The investigation concluded that most of the channel down-cutting has occurred as a result of the rechannelization project. Brodhead Creek has a wide channel and a relatively shallow cross-section with alternate bars occurring throughout its natural and man-made reaches. These bars are what produce the low amplitude, long wavelength meanders characteristic of Brodhead Creek. Straightening of the stream channel produced an increase in stream gradient which has been documented to cause significant channel downcutting. The rip-rap that was placed along the levees, then perpetuated the channel downcutting process by prohibiting the channel to move laterally and form meanders.

It is the opinion of those involved in the investigation that the channel morphology is close to reaching equilibrium, although the channel gradient may still be too great. It is, however, difficult to determine present-day rates of downcutting because of the lack of historical and current data on stream bed configuration. Two recommendations for monitoring and limiting channel instability that were made are listed below:

- The channel should not be re-aligned, for this would result in renewed downcutting

- Channel cross-sections should be measured and monitored to determine if downcutting is continuing at high rates.

PLANNING THE SITE RESPONSE

Initiation of Response

Once preliminary assessment revealed that 3 to 8 million gallons of coal tar were underlying Brodhead Creek and the threat of continued coal tar seepage into the creek existed, DER requested funding from EPA and the Coast Guard under Section 311 of the Clean Water Act, to intercept the discharge. Funds were granted because navigable water was threatened by the release. The immediate measures consisted of filter fences and sorbent booms to intercept the coal tar moving from the back channel area into the stream. Additional studies, confirmed by the Pennsylvania Fish Commission, DER and PP&L, determined that the coal tar plume is toxic and potentially hazardous to the ecological integrity of the stream. Consequently, all parties agreed on the need to develop a long-term remedial response program. The result of the program was the construction of a slurry trench cut-off wall and the installation of a recovery well system.

Selection of Response Technologies

300.68(g) development of alternatives

The selection of remedial techniques at the Stroudsburg site proceeded under the influence of complex interagency decision-making, monetary and political limitations and the incertitude of the problem at hand. Results from the numerous surveys and studies conducted at the site were not easily compared due to varying degrees of control and the use of differing study methods. Thus, the difficulty in forming a single opinion as to the nature and extent of the problem, was complicated by the fact that there were data discrepancies between the studies upon which decisions were to be based. The remedial actions taken reflect a technically complex situation in which there was a continually rising sense of urgency due to (1) the possibility of a sudden release of coal tar into the stream and (2) the time and financial constraints involved in selecting response technologies. The following section describes the rationale that lay behind the selection of remedial techniques at Stroudsburg, Pa.

Remedial actions at the Stroudsburg site consisted of the following:

(1) Placement of filter fences and sorbent booms to intercept backchannel discharge into stream

(2) Inverted dams installed in sequence with filter fences

(3) Excavation of numerous recovery trenches and installation of recovery wells

(4) Storage and disposal of drummed contaminated materials

(5) Installation of a slurry trench cut-off wall along the bench of the west bank levee

(6) Installation of a recovery well system in the area of the coal tar reservoir.

The first action taken in an attempt to control the contamination problem at Stroudsburg was by EPA in April, 1981, under Section 311 of the Clean Water Act (Public Law 92-500). The emergency action taken was initiated as a Federal removal activity and involved the installation of filter fences, sorbent booms, and an inverted dam in the backwater channel to intercept the discharge of coal tar and contaminated water into Brodhead Creek. The filter fence measure proved inadequate when light rains caused the sheen to flow around the fence. At this point it was decided to include an additional measure and install an inverted dam. Thus the backwater channel was further excavated and a filter fence and inverted dam were installed in such a way as to allow only water to be released, preventing the flow into the stream of the oil sheen on the surface and the insoluble coal tar on the bottom (Figure 4-A). When one of these inverted dam/ filter fence combinations proved only partially effective, three additional filter fences were placed downstream in the backwater channel and another inverted dam and two filter fences were installed within the flood gate channel (Figure 4-B). The pipes within each dam, through which clear water flowed, were emplaced such that the submerged ends were downstream. This containment technique was a success until heavy rains caused the complete flushing of the backwater channel, destroying the dams and filter fences alike.

300.68(e)(1) initial remedial measure

300.70(b)(1)(ii) surface water control

It became apparent from the occurrences just described, that more permanent measures would have to be taken to prevent contaminant release. With results from the hydrogeological studies, it also became apparent that the contamination at Stroudsburg could not be cleaned-up in a relatively short period of time, as, for example, an oil spill could be. The coal tar problem at Stroudsburg warranted years of containment and capture. Funds for remedial actions at Stroudsburg were passed from Section 311 to CERCLA (Superfund). Beginning on November 9, 1981, funds were appropriated under Superfund, establishing Stroudsburg as the first site to recieve Emergency Superfund monies.

Concurrent with activities involving the inverted dam/filter fence installations and as part of the "extent of contamination" studies, a recovery trench was constructed on the west bank of Brodhead Creek to intercept coal tar that was thought to be migrating into the stream. During construction of this trench no significant

300.70(b)(ii)(D)(2) drainage ditches

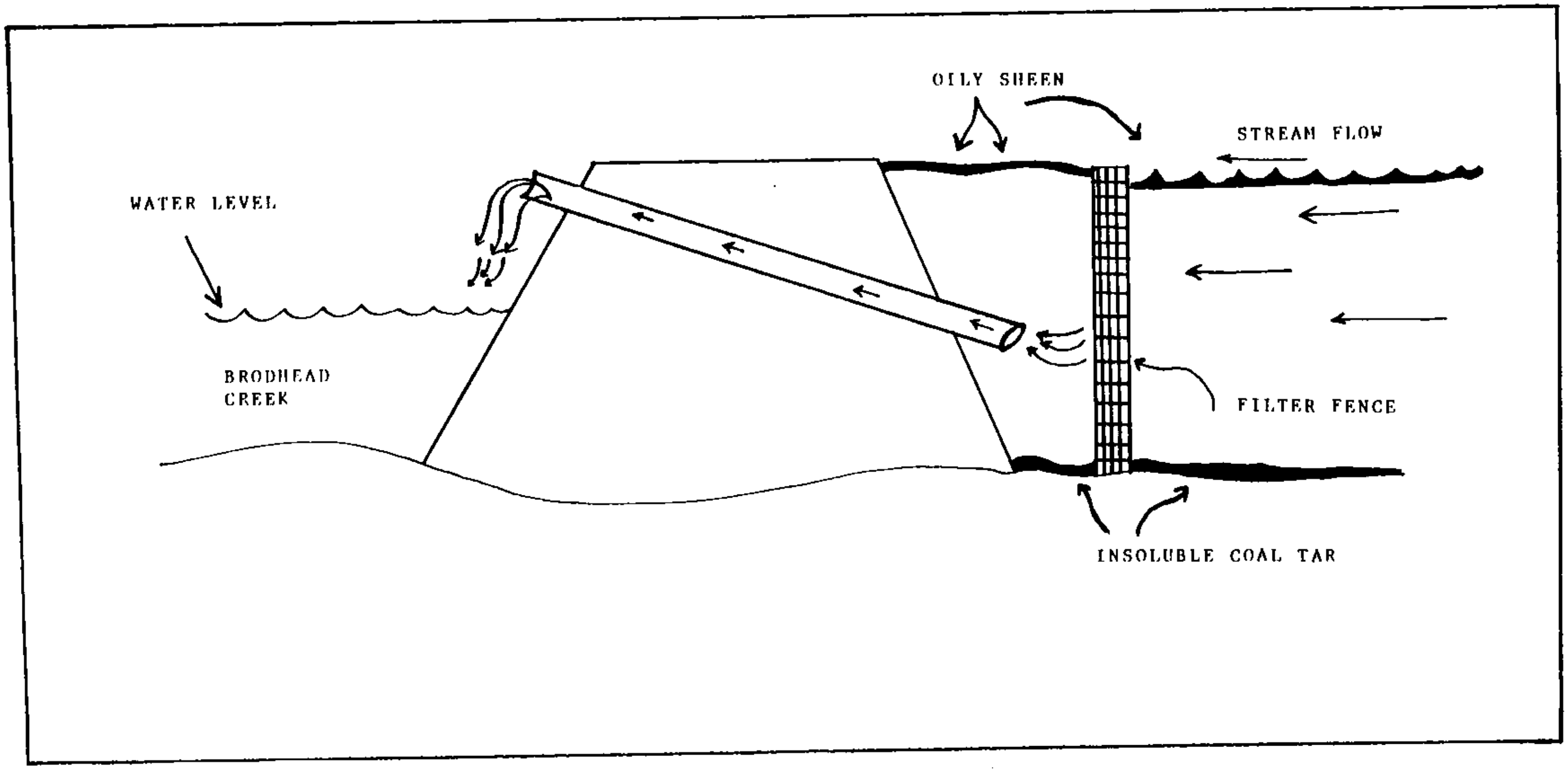

Figure 4-A. Schematic Diagram of the Filter Fence/Inverted Dam Combination Used at the Stroudsburg Site

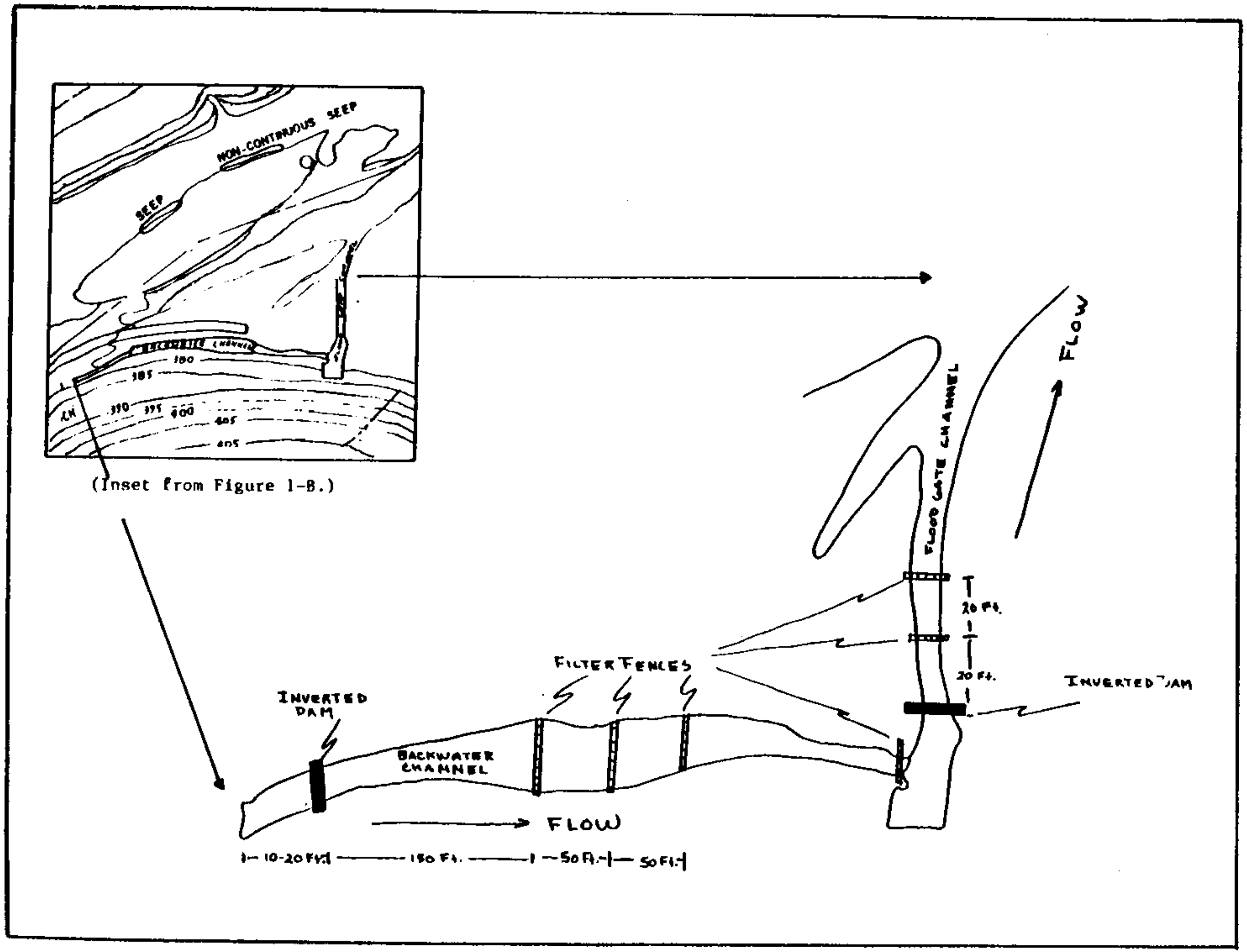

Figure 4-B. Schematic Diagram of Filter Fence/Inverted Dam Installations at the Stroudsburg Site

accumulations of coal tar were discovered, though the ground water did have a phenolic odor. A 4-hour pump test of the recovery trench was conducted during which pumping rates varied between 53 gallons (200 l) per minute (gpm) and 157 gpm. The water level was drawn down near the trench bottom. No significant accumulations of coal tar were observed flowing into the trench. Throughout this phase approximately 20 test pits were excavated in various locations along Brodhead Creek to intercept coal tar migration into the stream.

In conjunction with the excavation of test pits, recovery wells (RW's) were installed to determine where recoverable quantities of the coal tar were located. PP&L's geotechnical consultants, TRC, explored the area south of the recovery trench on the bench just above the backwater channel. Since coal tar was emanating into the backwater channel, it was thought that a recovery well might prove successful in intercepting any contaminant that was reaching the channel. Small amounts of coal tar were observed during drilling and installation of the well, however, recoverable quantities of coal tar were not encountered.

300.70(b)(1)
(iii)(c)
ground water
pumping

A second well was then drilled on the west side (interior) of the west bank dike in the area where the stratigraphic depression was thought to exist. During the drilling process, increasing quantities of coal tar were encountered until the surface of the sand layer was intersected. Below the sand layer, coal tar was not encountered. Data from the second recovery well (RW2) confirmed that a subsurface depression exists at this location and contains a relatively large coal tar reservoir. The reservoir thickness at RW2 was estimated to be 10 feet (3 m).

Different methods of pumping from RW2 were tested and evaluated to determine the feasibility of recovering large quantities of coal tar from the reservoir at a sustained rate. It was determined that it was possible to recover relatively pure coal tar (<1% H_2O), however, the physical characteristics of the coal tar and the fact that it is in contact with groundwater limited the usefulness of many of the pump configurations tested. The heavy fraction of the coal tar is slightly denser than water and although it separates from water and will settle at the well bottom, a minimal disturbance will cause a mixing of the coal tar and the water, which produces an emulsion that is highly viscous and resembles a brown-orange paste. Several of the pump configurations tested are described below.

- Diaphragm suction pump - satisfied minimum disturbance conditions and low shear at pump intake but maximum operating heads were only 20 feet (6 m).

- Peristaltic pump - effective in satisfying low-shear conditions and increased operating heads, however, attainable pump rate <.25 gpm was considered insufficient for recovery purposes.

- Gas-powered suction pump - use of high speed impeller caused disturbance at intake and perpetuated mixing and homogenization through pump. Also flow rates of this type of pump difficult to regulate.

- Submersible pump - feasible for recovery if provided with automatic shutoff to keep tar/water interface above intake.

The recovery well "system" installed at the Stroudsburg site was initially powered by a submersible pump as described above, however, due to problems that will be discussed in the next section, it was replaced by a nonsubmersible centrifugal electric pump.

The debris and contaminated materials generated during the Section 311 activities at the Stroudsburg site, were contained in drums and stored on site through the month of November, 1981, pending final disposal. The greatest number of drums stored at one time was approximately 200. These included steel drums that contained liquid coal tar and fiber and steel drums that held solid waste materials. Initially the drums were stored on the ground, in the open, with no labels or other identifying markings. Eventually they were placed on pallets, covered with plastic sheeting and stored in a fenced-in area.

300.70(c)(1)
off-site
transport

The materials generated during the Section 311 activities were disposed of at SCA, Model City, NY, beginning in November, 1981. Contaminated soils produced during slurry wall installation were sent to the SCA landfill in Niagara Falls, NY, and material generated during the excavation of the backwater channel during slurry wall construction was disposed of at GROWS, in Morrisville, PA.

On November 9, 1981, remediation funds were appropriated to the Stroudsburg site under Superfund. The coal tar could no longer be considered oil for clean-up purposes. Remediation of the situation required more time and money than what was available under Section 311. The following day, on November 10, 1981, EPA awarded a contract to the construction firm, ICOS, to install a slurry trench cut-off wall at the site. The filter fences however, continued to be maintained by the contractors, Environmental Cleaning Specialists, and Section 311 continued to fund disposal activities.

The decision on the type of containment system to be used resulted from a thorough investigation of numerous alternatives. Table 3 describes the most prominent of these alternatives, in addition to the final measures taken to stabilize the situation.

Extent of Response

The cleanup response at Stroudsburg consisted of two steps. First, coal tar seepage into the creek was intercepted to protect "navigable water" from contamination. The filter fence, sorbent boom, and inverted dam set in the stream adequately achieved this goal.

300.68(e)(1) initial remedial measures

Second, the response officials' long-term primary goal was to contain the coal tar plume such that further seepage into the stream was prevented. The purpose of constructing the slurry wall was to achieve this goal by creating a barrier between the coal tar reservoir and the stream. The barrier wall essentially cut across the gravel stratum which serves as the pathway for the contaminants. Other than the minor excavation of contaminated soil in the back channel, once the barrier wall was complete, the goal of the response action was achieved. Continued migration of coal tar into the stream has been arrested. The effectiveness of the barrier wall is discussed in the Performance Evaluation Section. Through the operation of the recovery well system, it is anticipated that 50% (approximately 37,000 gallons) of the coal tar present within the subsurface reservoir will be recovered. To this date about 7,500 gallons have been recovered. As such, the recovery operation will continue.

DESIGN AND EXECUTION OF SITE RESPONSE

Slurry Trench Cut-off Wall

The completed slurry trench cut-off wall is 648 ft in length, 1 ft wide and 17 ft (5 m) deep (Figure 5). The

300.70(b)(1)(iii)(A)(1)

TABLE 3. ALTERNATIVE RESPONSE TECHNOLOGIES FOR THE COAL TAR PROBLEM AT STROUDSBURG, PENNSYLVANIA

Response Technology Alternative	Description	Rationale for Rejection/Acceptance	NCP Reference
Filter Fence/Recovery Well System (Rejected)	Consisted of filter fences placed at seepage points along stream; recovery well system installed in coal tar reservoir area to ultimately remove all coal tar; at time of proposal, filter fences already on site and several recovery wells already installed; in terms of cost, this system would have required comparatively little additional funding.	• Required that PP&L resume responsibility and maintenance of filter fences; PP&L opposed proposal based on filter fence failure to adequately and consistently contain contaminants; • Complete removal of coal tar could not be accomplished within 6 months specified by Superfund policy.	300.70(b)(1)(ii) surface water control and 300.70(b)(1)(iii)(c) ground water pumping
Treatment Plant System (Rejected)	Locate treatment plant on site at one end of backwater-drained recovery trench; coal tar and contaminated water would be pumped and fed to treatment system	• Remediations performed under Superfund must be complete within 6 months and within a 1 million dollar budget treatment of contaminant could not be completed within 6 months; • Proposed location for treatment plant is a bank that is covered with water 6 months out of year • Very costly.	300.70(b)(2)(ii) direct treatment methods
Sheet Piling Barrier (Rejected)	• Interlocking steel sheet piling to be installed along eastern and southern boundaries of site and on west side of dike to min. of 15 ft. below surface gradient • Piles driven to min of 15 ft. below surface gradient or 5 ft below sand/gravel interface • Linked to concrete sluiceway on downstream side and retaining wall on upstream side • Area between sheet piling and rip rap toe reinforced within concrete cap • Minimum of 4 monitoring operations to be located between sheet piling wall and dike • Time required for implementation is 2 months; well within specified program restrictions	• Not compatible with site geology; glacial till consists of very coarse gravel type material; problems inevitably would arise due to presence of boulder-size material • Pounding involved in installation was cause for concern; could change structure of aggregation in flood control levees and disruption could result	300.70(b)(1)(iii)(c)(2) plume containment

(Source: JRB Associates)

(continued)

TABLE 3. (continued)

Response Technology Alternative	Description	Rationale for Rejection/Acceptance	NCP Reference
Steel Piling Barrier (continued)	• Total cost for job less than $1,000,000; within program specifications • Recommended that a contaminant removal program be instituted in conjunction with barrier		
Building Up and Capping Stream Banks (Rejected)	• Build stream banks up and out into stream bed • Ensure impermeability by then capping the banks with clay material	• Temporary in nature; length of time that situation would be stabilized not predictable • Very costly	300.70(b) (1)(ii)(A) surface seals
Slurry Trench Cut-off (Accepted)	• Cement-bentonite slurry wall (S.W.) installed by EPA • Installation along bench on outer face of west bank levee • Downstream end keyed horizontally into pressure grouted curtain and upstream end keyed into existing sheet piling wall below concrete flood wall • Slurry wall is 648 feet long, 1 foot wide and 12 feet deep; it is keyed 2 feet into sand stratum underlying the coal tar bearing gravel at elevation of 365 feet • Top elevation of wall is 380 feet along entire length except at one location where the top elevation of the gravel layer is higher	• Completion of installation possible within Superfund policy restrictions (6 months and one million dollars) • Time was crucial since Superfund money was being used, a decision had to be made and construction begun • Cement-bentonite used based on (1) compatibility test results; (2) insufficient room onsite for mixing soil and bentonite and (3) unavailability of fines on site for a soil-bentonite mixture	300.70(b)(1) (iii)(A)(1) slurry walls

(continued)

TABLE 3. (continued)

Response Technology Alternative	Description	Rationale for Rejection/Acceptance	NCP Reference
Cement-Bentonite Grout Curtain (Accepted)	• Forms the final downstream segment of the slurry wall; serves as a continuation of the wall to the dike • Keyed into clay core of the dike at one end and the slurry wall at the other • Approximately 50 ft in length • Constructed using cement-bentonite grout and the method of pressure grouting through a series of vertical holes in the ground and through the dike	• Excavation of a trench in close proximity to the dike could have impaired dike integrity; decision therefore made to continue wall to dike by another means besides a slurry trench wall; grouting was the most technically and economically feasible alternative	300.70(b) (iii)(A)(2) grout curtains
Recovery Well System (Accepted)	• Recovery project a separate action from S.W. installation • Four well clusters each containing one control well and three surrounding wells • Located behind west bank levee to remove coal tar from stratigraphic depression • Wells contain comparative probes to some tar-water interface, sending signal to controller which turns pump on or off	• PP&L wanted to clean up the site, not stabilize it; (EPA was charged by law to stabilize the situation, not clean it up) • Realized that any containment barrier would be complemented by a removal system	300.70(b) (1)(iii)(c) groundwater pumping
Excavation of Backwater Channel (Accepted)	• Complete excavation of backwater channel • Excavated area 350 feet long, 10 feet wide; 7 feet deep • Contaminated materials drummed and disposed of G.R.O.W.S. Landfill, Morrisville, Pa. • Channel then developed and fitted with uncontaminated clay soil and a stone rip-rap	• Backwater channel was one of the most highly toxic areas at the site	300.70(c) (2)(i) excavation (continued)

TABLE 3. (continued)

Response Technology Alternative	Description	Rationale for Rejection/Acceptance	NCP Reference
Disposal of Contaminated Materials (Accepted)	• Initially, contaminated materials (solid and liquid) drummed and stored on site • Fiber and steel drums utilized • Drums stored on pallet and covered with plastic sheets • Three landfills used for final disposal (1) SCA Model City, NY (2) SCA, Niagra Falls, NY (3) G.R.O.W.S., Morrisville, PA	• Three different disposal facilities used because of difficulty in locating sites that (a) would accept the wastes and (b) would pass Pa. DER standards and (c) were within activity financial limits	300.70(c)(1) off-site transport for secure disposition
Polyethylene Liner (Rejected)	• To be placed in slurry wall trench during construction for added wall strength	• Unable to properly place in trench due to its great length and weight	300.70(b)(1) (iii)(D)(3) liners
Monitoring Wells (Accepted)	• Eight monitoring wells; four located on either side of wall • For purpose of monitoring S.W. performance and groundwater sampling	• Necessary to determine effectiveness of wall	

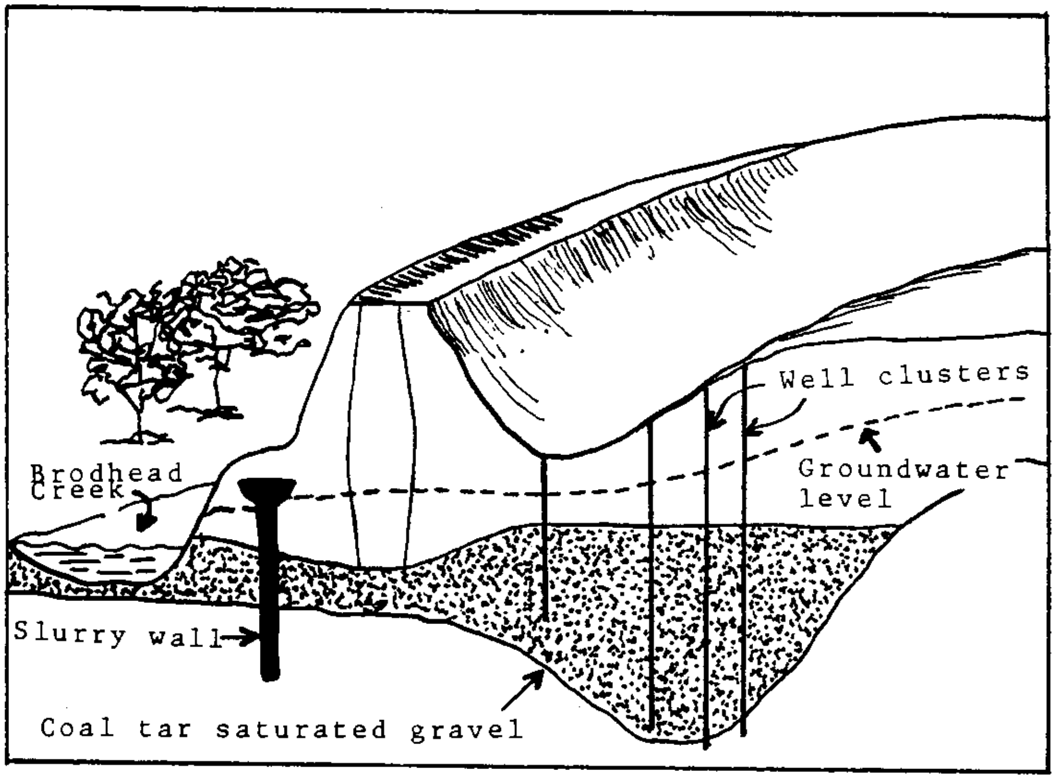

Figure 5. Cross-Section -- Brodhead Creek

Source: ELI report (1982)

slurry wall extends down through the gravel stratum that bears the coal tar and is keyed 2 ft (-6 m) into the underlying sand layer. It was not necessary to key the wall into an impervious aquiclude, due to the floating nature of the coal tar contaminants on the sand layer. The overall surface elevation of the wall is approximately 380 ft (132 m) above sea level. The upstream end of the wall is keyed into a sheet piling gate that is part of the existing flood dike. The downstream end of the slurry wall is horizontally keyed into an impermeable cement-bontonite grout curtain. The curtain was constructed to form the final downstream segment of the barrier wall because it was believed that trench excavation in close proximity to the dike would have impaired the dike's integrity. The grout curtain was installed by pressure grouting through a series of vertical holes in the ground. The curtain is approximately 50 feet long.

slurry walls

300.70(b)
(iii)(A)(2)
grout curtains

Pre-excavation for the slurry wall installation began on November 16, 1981 and actual wall construction commenced 9 days later. A ramp was constructed as an access road for heavy equipment used during project operations. During trench excavation earth was removed with a backhoe and the contaminated material was separated, and hauled by a track-mounted bucket loader to a small storage basin on-site. The stored material was periodically loaded onto a sealed truck and transported to SCA Disposal Services in Niagara Falls, NY.

In excavating the slurry trench, a calculated risk was taken regarding containment of the coal tar plume. The plume configuration was such that there were several areas extending out under the stream bed. Initially, EPA suggested excavation of the areas, but the PA Fish Commission opposed, claiming that excavation would be more detrimental than taking no action. It was decided that instead of excavating, the 'lost' plume areas were capped and rip-rapped. (See Figure 6).

300.68(i)(2)(E)
adverse effects

Under EPA supervision, compatibility testing was conducted to determine the most appropriate slurry wall composition. The decision to use a cement-bentonite mixture was based upon three factors; (1) the compatibility test results, (2) the lack of area for on-site mixing of a soil-bentonite backfill and (3) the unavailability of local clays for use in a soil-bentonite backfill. The cement-bentonite slurry mixture, used both as the slurry to keep the trench open during excavation and as the cut-off wall materials itself, was prepared using four standard sized bags of bentonite and 11 bags of cement per 3 cubic yards. The selected mixture has a design permeability of 1×10^{-6} cm/ sec and is considered sufficient to

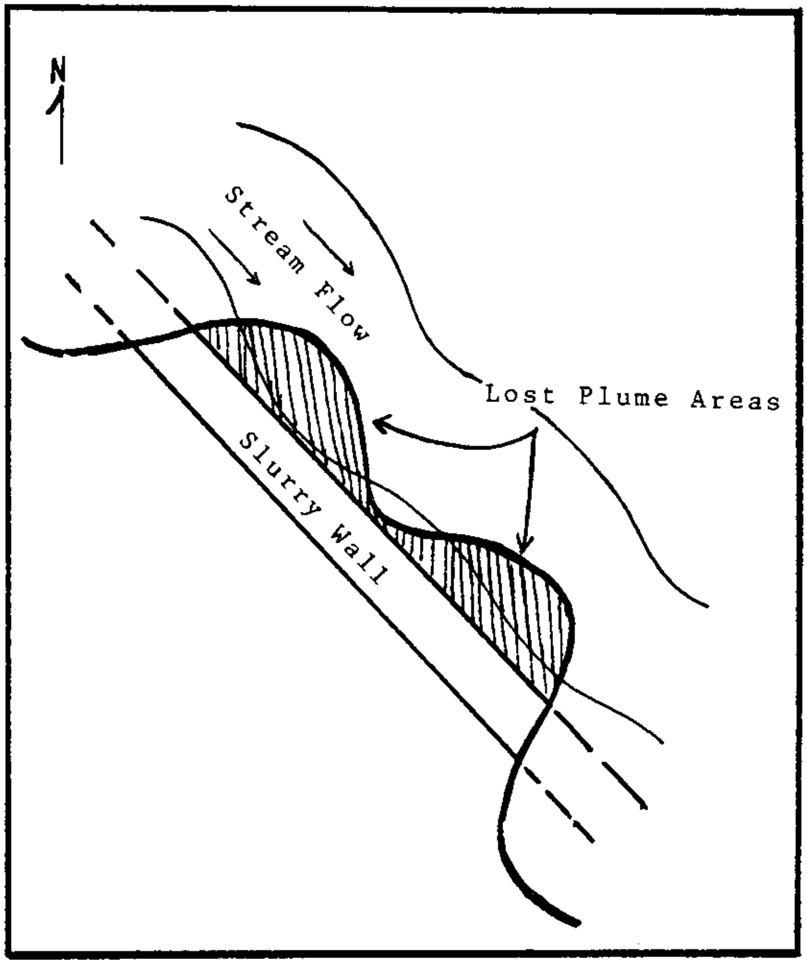

Figure 6. Lost Plume Areas After Slurry Wall Installation at the Stroudsburg Site

contain the coal tar. This judgement, is based on the assumption that the contaminant moves slowly through the gravel stratum, and the gravel material has a much higher permeability than the cement-bentonite. The original wall design included the use of a polyethylene liner along the wall's interior for added impermeability. The length and weight of the material, however, caused problems during attempted installations and as a result the material was never utilized.

The cement-bentonite slurry trench cut-off wall was installed in sections. Construction initially began downstream (see Figure 7) near the drainage way, however, problems arose due to the narrow bench from which the trench was being excavated and the cohesionless nature of the random fill that had been used to cover the levee core. Instability on the upslope side of the trench caused several sections to collapse repeatedly. The decision was made to continue upstream as far as the ramp and when the ramp was reached, construction activity then began at the downstream end once again, but this time the bench was widened and relocated farther from the control levee to minimize the possibility of collapse. Following wall completion at this end, construction began at the upstream end near the retaining wall and moved downstream towards the ramp. The section containing a gas line was excavated by hand. The final section to be completed was that which contained the access ramp.

Over the course of construction, cold weather conditions including rain and ice storms, periodically hampered operations but never entirely halted construction activities.

The slurry wall was completed on December 15, 1981, at which time drilling for the grout curtain, installation at the downstream end of the wall had been completed and grout injection had begun. The cement-bentonite grout curtain was completed within 7 days.

The wall design that was finally chosen for construction at the Stroudsburg site had a surface elevation of 380 feet (116 m). This design dimension caused some disagreement. The viewpoint held by the State at the time, was that the wall surface elevation should have been lower (approximately 378 ft) (115 m) to allow groundwater to flow over the wall. The rationale was that by not allowing flow over the wall and impounding the ground water behind the barrier, there was the possibility that the coal tar would build up and eventually discharge in the swamp area behind the levee, forming a small lake which could then drain through the floodgate tributary and

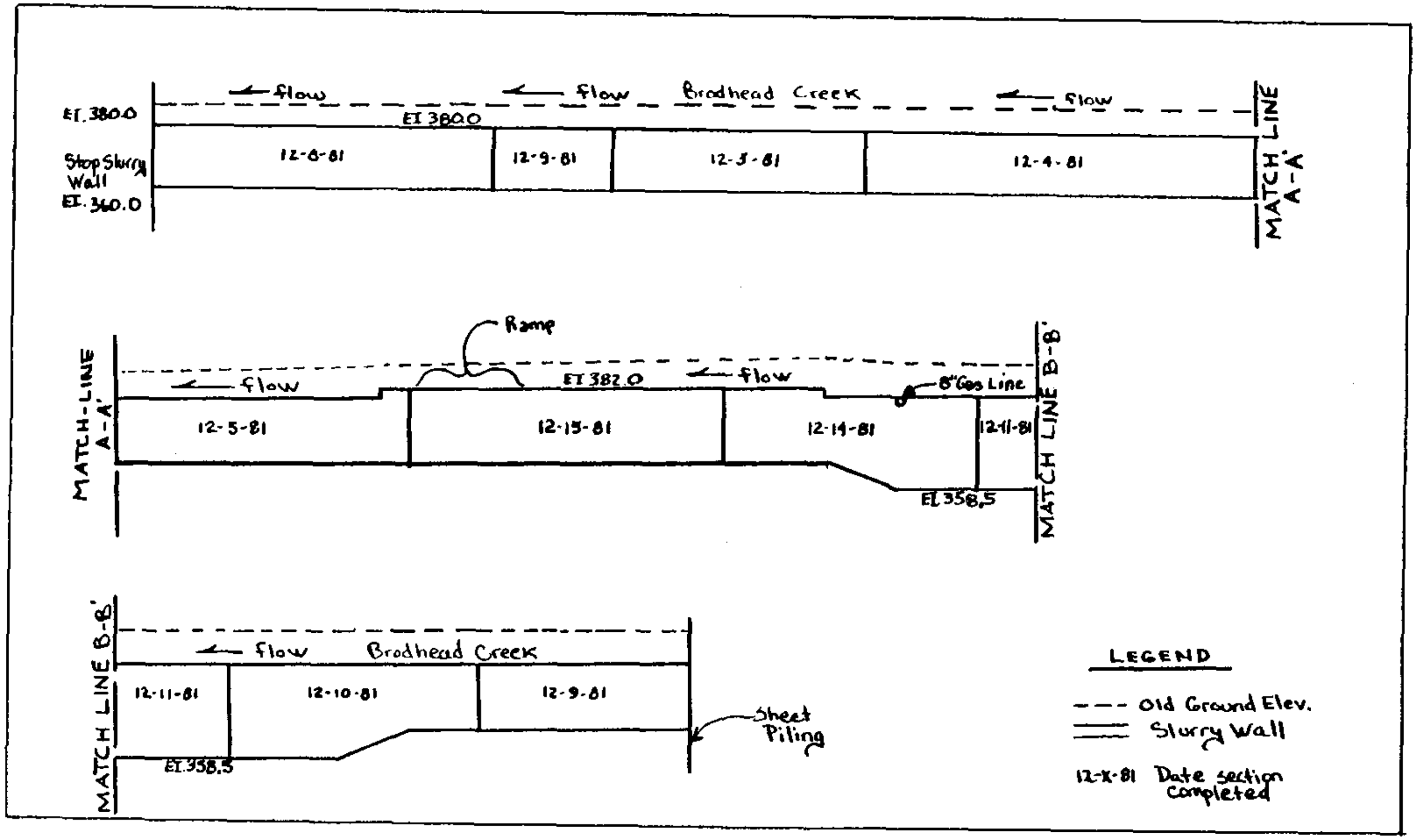

Figure 7. Slurry Wall "As-Built" Profile at the Stroudsburg Site
(Source: "Extent of Contamination Report" 1982)

into Brodhead Creek. In support of the lower elevation design, there was no evidence provided by the stream quality studies that there had been stream degradation caused by contaminated groundwater. It was therefore felt that ground water flow over the wall and into the stream was not a potential hazard to stream integrity. The State's primary concern was to contain the coal tar which existed at the lower portion of the groundwater column.

EPA representatives, on the other hand, were concerned about the contaminated groundwater issue and recommended a wall with a surface elevation of 380 ft (116 m), to prevent groundwater flow over the wall. This design was eventually implemented.

The surface elevation is 380 ft (116 m) over the wall's length except for a 100 ft (30 m) section in the northern area of the site (see Figure 7). The gravel stratum elevation along this segment is higher than anywhere else and therefore the wall surface was constructed at 382 ft (116 m). The wall bottom elevation is 365 ft (111 m) everywhere except along a section that is approximately 170 ft (52 m) long, where the gravel stratum is extended to a greater depth. This wall section is adjacent to the stratigraphic depression behind the levee to the west.

The following task involved restoration of the levee bench in order to permit the installation of monitoring wells. Once this was completed, eight monitoring wells were installed in support of a state supervised groundwater sampling program to determine groundwater quality in the vicinity of the wall. Four wells are located on the stream side of the wall, three wells are situated on the inland side of the wall, between the wall and the levee, and one well is located behind the levee and behind PP&L's retaining wall.

Excavation

The next phase in the Stroudsburg operation was the excavation of contaminated materials from the backwater channel. The excavated area was 350 feet (107 m) long, 10 feet (3 m) wide and 7 feet (2 m) deep. Approximately 280 cubic yards of contaminated material were removed, drummed and disposed of at a secure landfill in Morrisville, PA. The excavated channel was then dewatered and backfilled with approximately 600 cubic yards of uncontaminated clay capping soil. In addition, about 300 cubic yards of access ramp material were then placed over the clay capping which, in turn, was overlain by stone rip-rap. In concurrence with the channel excavation/backfilling

300.70(c)(2)(i)
excavation

process, several other restoration activities were underway and these included the following:

- Restoration of the flood control dike

- Hydroseeding of dike and other areas disturbed by site activities

- Asphalting the private road (Union Gas property) used by site activities.

By the end of January, 1982, demobilization and general clean up had been completed at the Stroudsburg site.

Recovery Well System

The recovery well installation project at the Stroudsburg site was initiated and completed privately by PP&L. This part of the response program did not fall under Superfund funding due to restrictions inherent within the Immediate Removal Program. Actions under this program are implemented to stabilize or control problems but not necessarily solve them. Stabilization of a problem must be accomplished with less than $1,000,000 and within a 6-month period, and operation and maintenance may not be provided after the end of the 6 months. The coal tar recovery system clearly did not fall within these specifications. PP&L felt however, that any amount of contaminant that was feasibly recoverable should be removed and thus installed a recovery well system. It should be noted here that neither the slurry wall nor the recovery well system could have properly solved the problem alone. The wall stabilized the situation but was not installed with the intention that it would eliminate the source of the problem. The recovery wells, on the other hand, were installed to remove coal tar from only one location, leaving other contaminated areas without remediation. These points and others will be further discussed in the next section, "Performance Evaluation".

300.70(b)(2) (iii)(c) groundwater pumping

The recovery well system consists of four well clusters located throughout the stratigraphic depression that contains the reservoir of coal tar (Figure 8). Each well cluster has been installed in a 30-inch (91-cm) hole and consists of four 6-inch (15 cm) gravel packed, slotted PVC pipes for recovery, centered around one 4-inch slotted PVC pipe used for monitoring (Figure 9). The pump configuration originally selected to power the recovery well system was a submersible pump with an automatic shutoff. This choice, however, did not prove to be suitable because the coal tar rapidly destroyed the pump and several

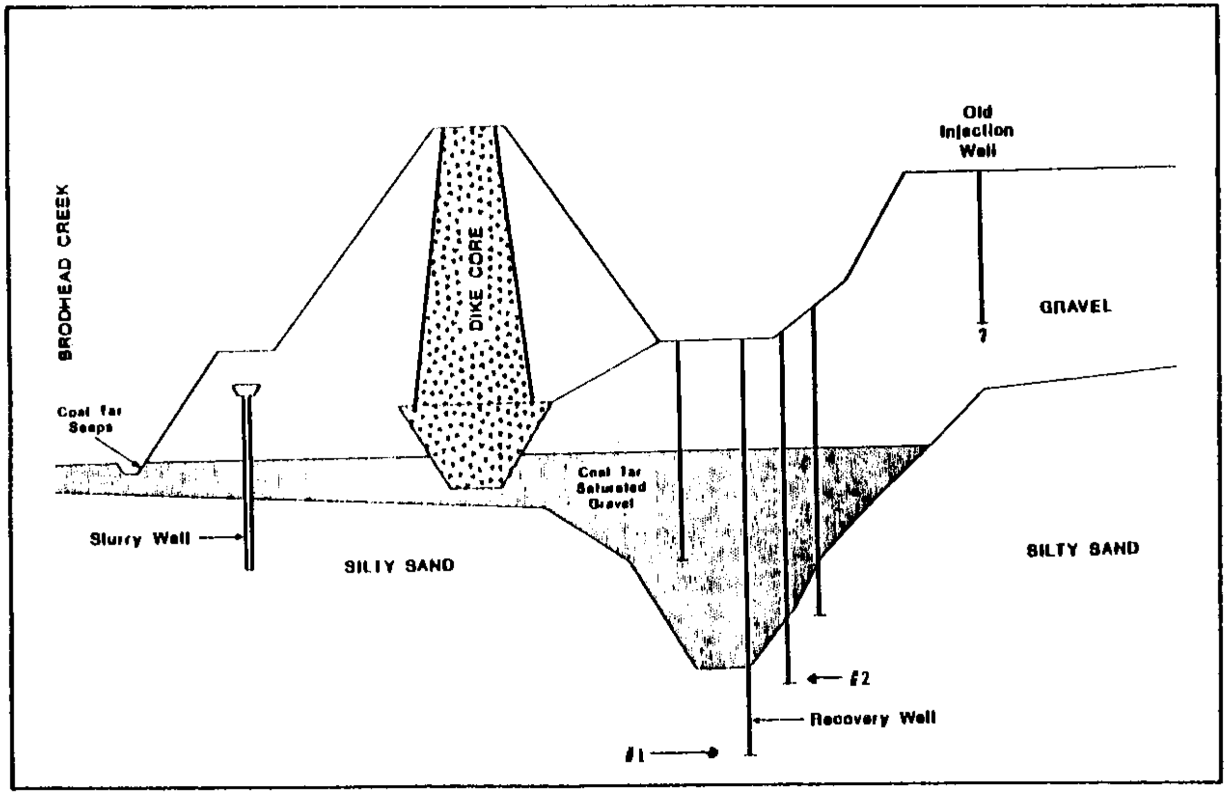

Figure 8. General Cross Section Through the Stroudsburg Coal Tar Site (Source: Paper by J.F. Villaume 1982)

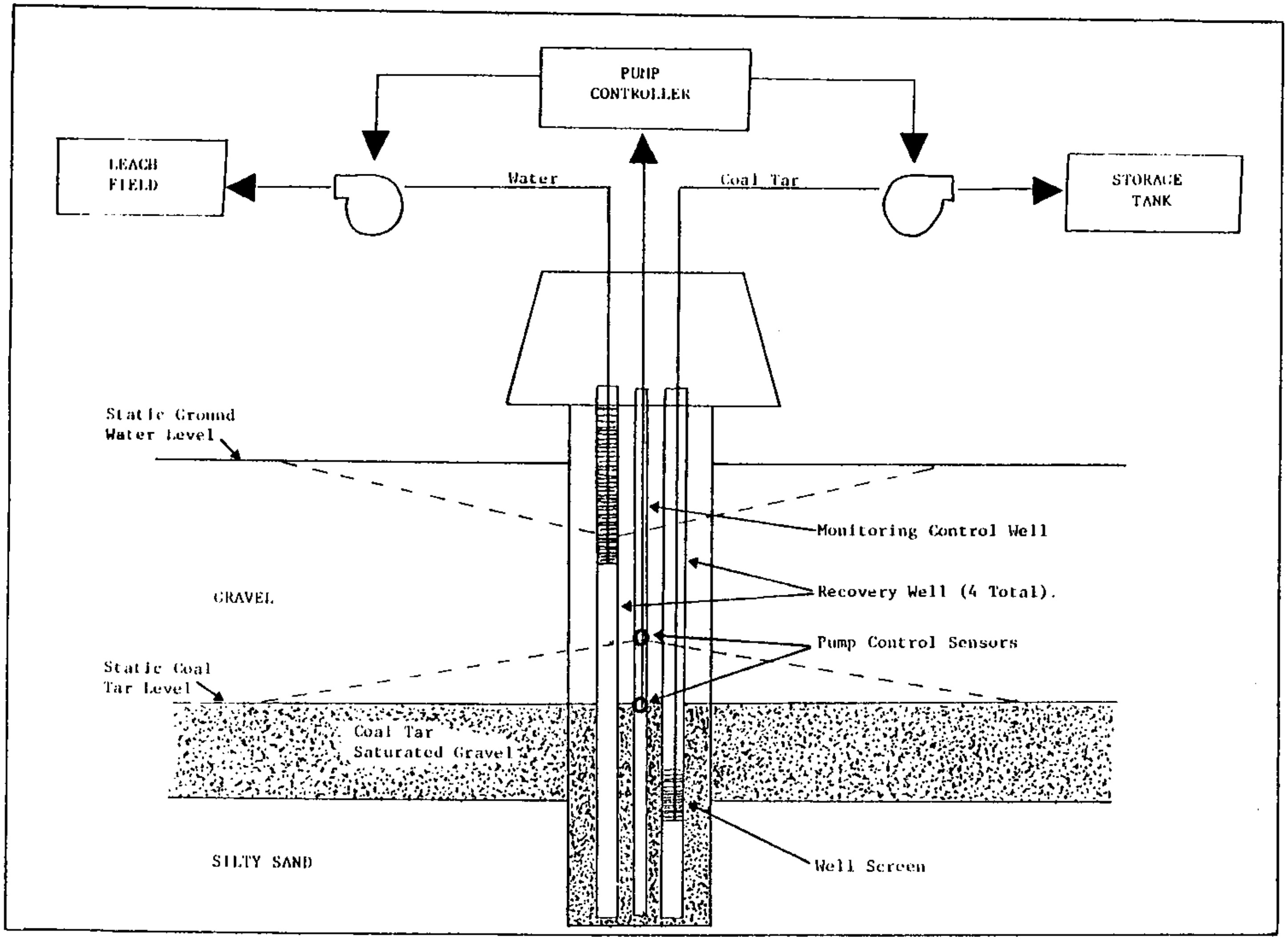

Figure 9. Generalized Cross-Section Through A Typical Coal Tar Recovery Well Cluster (Source: Papers by James F. Villaume (PP&L) 1982 & 1983)

replacement pumps. It was then decided that a nonsubmersible centrifugal pump be used. The pump is provided with automatic level control features. Two pump control sensors are located in the central monitoring well to sense the tar-water interface. A signal is sent from the sensors to the control device on the pump. The pump turns on when the interface reaches the upper sensor and it turns off when the interface drops to the lower one. In this way, the tar-water interface can be maintained above the well intake point and virtually pure coal tar (<11% H_2O) can be recovered. The recovered coal tar is then stored on-site in a 10,000 gallon (37,000 l) holding tank. PP&L had originally planned to use the coal tar as fuel in their own facility, but due to public opposition they sought other alternatives. Allied Chemical of Detroit, Michigan signed an agreement with PP&L to purchase the coal tar for use in their plants. Allied presently pays for the transport of the coal tar plus 40 cents per gallon.

There are differences between the original design and the "as-built" recovery system. Charges were made to increase the efficiency of the system. As mentioned earlier, the type of pump used to power the system was changed due to the corrosive nature of the coal tar. Originally it was anticipated that all four clusters would be operating. Presently, however, only RW1 is recovering coal tar. When the system's operation began, the movement of the coal tar water interface was not induced to enhance recovery rates. The interface level was allowed to recover at its own rate. About 6 months after the recovery operation began, PP&L decided that perhaps pumping ground water in the vicinity of the recovery well would increase the rate of coal tar recovery and initiated a ground water pumping test program using RW2, to determine the effect of ground water pumping on the coal tar recovery rate. Pumping tests did, in fact, show that recovery rates could be enhanced. Due to the density difference between the water and the coal tar, as water is removed from a designated area, the coal tar surface actually rises in that area. This produces stress on the system and causes the coal tar to flow toward the pumping point or well at an increased rate. Testing continued over the next 3-month period until the system was shut down for the winter in November 1982.

In the spring of 1983 the system resumed operation and ground water is being pumped through one of the four wells in RW1, as coal tar is recovered through another one of the four wells in RW1 as shown in Figure 9. Two pumps are being used, one for coal tar recovery and the other for ground water pumping. The water pump is a nonsubmersible centrifugal pump and is operated continuously. Groundwater is being removed at a rate of about 5 gpm. This has resulted in a 10-15 times improvement in the coal tar recovery rate. The coal tar pump being used is the same nonsubmersible centrifugal described earlier. The ground water is discharged to a leach field located about 65 feet upgradient of RW1, near the old coal tar injection pit. The field is an excavated pit, approximately 6 ft x 12 ft x 6 ft (1.8 m x 3.6 m x 1.8 m) backfilled with gravel.

COST AND FUNDING

Source of Funding

To date, the total cost of the site response actions taken by all parties at the Stroudsburg site comes to approximately $594,500. EPA and the owner of the site, Pennsylvania Power and Light, have spent the bulk of this amount (see Table 4).

The removal of coal tar which had seeped into Brodhead Creek was funded by EPA and the Coast Guard under Section 311 of the Clean Water Act. The slurry wall and grout curtain, a more permanent response, were funded by the Superfund Immediate Removal Program. PP&L installed the recovery wells on its own initiative. The entire coal tar recovery operation is expected to cost $190,000.

The available cost information allows discussion of the costs of only the slurry trench cut-off wall and the recovery well system. Costs of other activities are shown in Table 4.

Selection of Contractors

The selection of contractors in an emergency response situation such as the Stroudsburg case, is made by the on scene coordinator (OSC), who consults the EPA list of available contractors and makes a choice based on "best judgement." In this case the OSC talked with several firms and solicited bids. ECS was selected for the emergency removal operation and for the construction of the slurry wall. The inherent uncertainty and the emergency nature of this type of operation were cited by the OSC as the reasons the final cost of the slurry wall increased to $326,000 which exceeded planned costs by $88,000. The project was completed in 45 days, well within the specified period of performance of 60 days. PP&L contracted with TRC, Inc. in compliance with EPA's

TABLE 4. SUMMARY OF COST INFORMATION-STROUDSBURG, PENNSYLVANIA

Task	Actual Quantity	Estimated Expenditure	Actual Expenditure	Variance	Unit Cost	Funding Source	Period Performance
Slurry Wall	648 x 17 x ft: 11,016 ft^3 (198 x 5 x 0.3m: 308 m^3)	$ 238,000	$326,000(a)	$88,000 (+37%)	$29.59/$ft^3$	Superfund Removal	11/81-1/82
Recovery Well System	7,500 gal. 28,291 l.	--	field study: $130,800 installment: $110,000 additional: $40,000	--	--	PP&L (b)	11/81-ongoing
Filter Fences Sorbent Booms Inverted Dams	--	--	$43,500	--	--	FWPCA Section 311	4/81-7/81
Back Channel Excavation, Transportation and Disposal	280 cu.yd. (215 m^3)	--	$60,000	--	$214/cu.yd. (219/$m^3$)	Superfund Removal	1/82-3/82
Restoration (c)	--	--	$15,000	--	--	Superfund Removal	4/82-5/82
Total			$725,300				

(a) includes excavating the trench, transporting and disposing contaminated soil

(b) Pennsylvania Power and Light

(c) clean fill, grading and seeding

request, to perform the investigative studies on the site in April of 1981. A direct procurement contract was signed between the two parties. The original estimated cost for the studies was $125,000, which was exceeded by $5,000, bringing the total cost of the studies to $130,000.

Project Cost

Slurry Wall

The total cost of the slurry wall was $326,000. This corresponds to a unit cost of $29.60 per installed cubic foot. The allocation of the total expenditures for the slurry wall operation is uncertain. The material cost of the wall was between $5.00 and $8.30 per cubic foot. The remaining costs were associated with the excavation, transportation and disposal of the trenching waste, with the latter two estimated at $105.00 per cubic yard ($136.50 per cu m). Included in the total cost is the $20,000 spent on grouting at the downstream end of the trench. The entire slurry wall operation was funded by the Superfund Immediate Removal Program. It seems the excavation of the trench incurred a large portion of the total cost due to the difficulties of trenching in wet contaminated soil.

Recovery Well

Total expenditures to date by PP&L for the recovery well system including investigative studies and well installation, are $240,000. It is estimated that an additional $40,000 will be spent before the system is fully operational. Of the $240,000, $130,000 was spent on investigative studies and, $110,000 on well installation.

In the fall of 1981, PP&L signed a direct procurement contract with EMTEK out of Amherst, New Hampshire to install the well system. A procurement contract was used as opposed to open-bidding because PP&L had procured EMTEK's services in the past with effective results. Original estimates for total cost of the system were $150,000.

The estimated cost for the development of a demonstration well and its operation was $7,500. However, due to unanticipated problems an additional $10,000 expense occurred. Thus the total cost for phase one was $17,500. The second phase which involved the installation of the final four wells and an enhancement program to insure maximum coal tar recovery, has cost $92,500 to date. Installation has been completed but the system is not yet fully operational. Inclement weather over the past 3 months has prevented the continuation of work on the wells. PP&L plans to develop and institute an enhancement program. The estimated expenditure for the final part of the second phase is $40,000.

The installation of the recovery well system was undertaken in two phases. In the first phase, a single test well was installed in order to determine its effectiveness. Several problems arose due to three of the four pipes becoming clogged with silt and preventing the well from operating. Once this problem was corrected the second phase began which entailed the installation of the four wells proposed in the system design.

PERFORMANCE EVALUATION

The slurry trench cut-off wall at Stroudsburg was installed to stabilize a situation in which coal tar was entering a biologically active and healthy surface water body. Data collected from the eight wells used to monitor ground water conditions on either side of the slurry wall, indicate that the wall has been successful in preventing further horizontal contaminant migration into Brodhead Creek. The values for ground water levels on the outside of the wall (i.e., the stream-side) have been consistently lower than those for ground water on the inside of the wall (see Table 5). This suggests that the wall is indeed acting as a barrier to horizontal ground water movement and, consequently, coal tar movement towards the stream.

Visual inspections have been routinely made along the stream bed to ensure that the coal tar seepage has been successfully eliminated. Surface water sampling analyses also show positive results regarding stream water quality. Thus, it appears from followup investigations that the slurry wall has been effective in preventing coal tar contaminants from entering the creek. There is, however, some apprehension on the part of both the State and EPA, regarding the seemingly complete stoppage of contaminant migration. (Note: the term 'contaminants' is used here with reference to coal tar constituents within the ground water as well as the coal tar itself.) It seems reasonable to assume that the coal tar, itself, has been contained behind the wall for there are no further signs of seepage along the stream bed and it was demonstrated during the 'extent of contamination' studies that the tar does not penetrate the underlying sand to any significant degree. The issue that has sparked concern is possible vertical migration of contaminated groundwater. There has been regular groundwater level monitoring in the vicinity of the wall and regular surface water sampling, but there

TABLE 5.
MONITORING WELL GROUND WATER ELEVATIONS ON EITHER SIDE OF WALL

WELL No.	DATE / Well Top (top of steel cap) Elevation in (m) & Ft.	1-28-82	2-4-82	2-17-82	3-10-82	4-20-82	5-27-82	6-2-82
		Ground Water Elevations in Feet (m)						
1 -	(119.01) 390.01	-	(115.85) 380.15	(115.69) 379.55	-	(115.84) 380.05	(115.69) 379.55	(115.84) 380.05
2 o	(118.46) 387.70	(115.12) 377.70	(115.55) 379.10	(115.24) 378.10	(115.15) 377.80	(115.31) 378.30	(115.12) 377.70	(115.44) 378.75
3 I	(118.46) 388.68	(115.56) 379.16	(115.86) 380.12	(115.68) 379.53	(115.35) 378.45	(115,76) 379.78	(115.61) 379.29	(115.63) 379.38
4 I	(117.82) 388.50	(115.58) 379.20	(115.87) 380.16	(115.70) 379.60	(115.67) 379.50	(115.84) 380.05	(115.65) 379.42	(115.64) 379.40
5 o	(117.86) 386.56	(115.08) 377.56	(115.52) 379.01	(115.19) 377.91	(115.11) 377.66	(115.28) 378.21	(115.10) 377.62	(115.39) 378.56
6 o	(117.92) 386.89	(114.92) 377.04	(115.42) 378.69	(115.06) 377.49	(114.92) 377.04	(115.12) 377.69	(114.90) 376.96	(115.23) 378.05
7 I	(118.06) 387.34	(115.41) 378.64	(115.74) 379.74	(115.59) 379.24	(115.58) 379.19	(115.73) 379.69	(115,55) 379.09	(115.81) 379.94
8 o	(117.85) 386.85	(114.60) 376.26	(115.21) 378.00	(114.87) 376.86	(114.81) 376.66	(114.90) 376.96	(114.70) 376.32	(114.81) 376.66

o - Stream-side or outside of Slurry wall; - - Located behind PP&L's retaining wall
I - Inside or in land of slurry wall

Source: Department of Environmental Services
Wilkes-Barre, Pennsylvania

has never been a follow-up groundwater sampling and analysis program implemented, which is a major concern to the leading agencies involved. The question has become whether the only discharge point for the ground water in the site area is Brodhead Creek or whether there is vertical movement down through the underlying sand strata. If there is vertical ground water movement, soluble constituents of the coal tar, such as polyaromatic hydrocarbons, benzene, cyanide, and naphthalene (PAHs), will not be confined to the sand layer and the possibility of deeper aquifer contamination exists. If this were the case, an area such as East Stroudsburg might be affected. The water for this area is drawn from an aquifer that is 700 feet below the ground surface.

In response to their own concerns, EPA has decided to conduct an additional hydrogeologic investigation to supplement the information that is already available. The primary objective of the study will be to sample the groundwater that exists within the sand strata. In autumn of 1982, four to six additional monitoring wells were installed and used to sample the ground water present within the sand unit. When data collection is complete EPA will be able to make a complete and final assessment of the current situation at the Stroudsburg site.

The coal tar recovery rate originally anticipated for the recovery well system at Stroudsburg, was approximately 100 gallons (378 l) per day. This rate, however, has not been maintained due to the fact that only one of the four wells in one of the four clusters, (cluster #1) (Figure 8), has been in operation, recovering coal tar at a rate of 20-25 gallons (76-95 l) per day. The reason the other wells are not operational is because the level of pumpable coal tar does not extend to them as originally thought based on split-spoon samples. The coal tar in the vicinity of the other wells is associated with a considerable amount of free water, preventing the recovery of a nearly pure product. Initially during the operation of the wells, problems arose due to silt clogging several of the pipes and preventing their operation. However, even following the correction of this problem, coal tar recovery was only possible using one of the clusters. It was soon realized by PP&L, that the amount of "pure" coal tar available for recovery was much less than had been originally calculated, and this was the reason only one well could be utilized. The remaining three well clusters could only recover a tar-water mixture, due to the fact that there wasn't recoverable coal tar in these locations. Despite the use of only one well in one cluster, the original 67 feet (20 m) of "pure" coal tar in the reservoir has been greatly diminished to a thickness of 4 feet (1 m), after approximately 8 months of well operation. A total of 7,500 gallons (2.8×10^4 l) of coal tar has been recovered to date.

Although the decision-making processes were not always well-coordinated between the agencies and individuals involved with the Stroudsburg case, the final remedial actions taken have complemented each other in a very advantageous manner. The slurry cut-off wall was emplaced to block further coal tar migration into Brodhead Creek and accomplished just that. The intention behind the wall installation was to stabilize a potentially hazardous situation. The predominant fear at the outset of the site investigations was that a severe storm might cause the rapid downcutting of the stream bed, releasing a large quantity of coal tar directly into the stream. The slurry wall was installed to prevent further seepage of the coal tar to areas close to the stream bed where the potential for release was greatest. This remedial technique, however, did not eliminate the subsurface reservoir of coal tar and this was the issue that PP&L sought to address. PP&L felt that to solve the problem permanently, some action had to be taken to remove the coal tar from the underlying reservoir. They, then, designed and installed the recovery well system and although the system has not operated at the level that was initially anticipated, it has operated sufficiently and coal tar has been recovered at a steady rate.

One technique, the slurry wall, was utilized to alleviate the immediate problem, that of coal tar seepage into the stream, while the other remedial technique, the recovery well system, was installed to ensure that no future problems would arise due to coal tar movement. The two actions, taken under different authorities, have created what would seem to be the ideal conditions at a remediated site; amendment of the present and immediate problem coupled with continued elimination of the source of the problem.

The applicability of any remedial technique at a site depends upon the summation of surface, subsurface, and waste type conditions and for this reason it is difficult to make any type of judgement concerning general applicability. There are, however, some guidelines that can be offered which are briefly discussed below.

A recovery well system is most applicable in situations where a large enough quantity of material exists such that it is mechanically feasible to recover. The recovered materials must often be marketable in order that the system be economically feasible. Recovery of material from beneath the surface is a costly process and it must usually continue over a period of several years.

The cement-bentonite slurry wall has a much more diverse applicability than the recovery well system and for this reason it is being used more often at other sites. A slurry wall can be placed downgradient of the contaminant source as it was in the Stroudsburg case. It can be placed upgradient of the contaminant source to divert flow of groundwater away from or around the contaminant source or a wall can be installed around the contaminant source, for complete containment. In most cases, there must be an impervious layer or aquiclude into which the wall is keyed. This is an important criteria unless the wastes to be barred are floating or their vertical migration is prohibited, as they were by the sand strata at the Stroudsburg site. A cement-bentonite wall is used in situations where either (1) the wastes/leachates present are not compatible with a soil-bentonite backfill or (2) there is insufficient room on site to perform the mixing of soil-bentonite backfill.

The nature of the wastes and leachates and whether or not they will be in direct contact with the wall are major factors in (1) the decision to apply the wall technique and (2) the decision between use of a soil-bentonite or cement-bentonite mixture for the final wall composition. Site-specific compatibility testing must be conducted prior to making any decision to install a slurry wall.

These are simply general guidelines concerning the use of recovery well systems and slurry trench cut-off walls, and prior to making any decision concerning their applicability at another site, thorough investigations must be conducted to determine the surface, subsurface, and waste type conditions at the particular location.

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QUANTA RESOURCES

QUEENS, NEW YORK

NCP Refererences

INTRODUCTION

The Quanta waste oil processing facility occupies about 1.8 acres (0.74 ha) in an old inudstrial area in Queens about 450 feet (137 m) from the Newtown Creek, which leads into the East River (see Figure 1). About 500,000 gallons (1.89×10^6 l) of wastes were stored on site in tanks (see Figure 2) awaiting re-refining when the company abandoned the site in late 1981. The wastes on-site included PCB contaminated waste oil, cyanides, heavy metals and low flash point (82^oF, 28^oC) chlorinated organic solvents such as methylene chloride and trichloroethylene. The City and State of New York believed that there was a great potential for a major release of hazardous air pollutants such as dioxin from a fire.

Background

The waste oil recovery facility at 37-80 Review Avenue in an old industrial area of Long Island City in Queens, New York City (NYC) was originally built in the early 1900's. It was owned and operated by a variety of companies and individuals who processed and sold waste oil. No clear records were kept on the types of wastes processed and stored on-site, but a site survey in June 1982 revealed about 500,000 gallons (1.89×10^6 l) of wastes including PCB contaminated oil, cyanides, heavy metals and chlorinated solvents. The potential threat to public health from fire and toxic fumes became imminent when the owner, Quanta Resources Corporation, which had bought the site in July 1980, filed for bankruptcy on October 6, 1981, and abandoned the site on November 21, 1981. At this time, the immediate issue of site security to prevent arson or vandalism, which could cause toxic air and water emissions from fire or leakage, became very important. While hazardous wastes remained on-site, the city and state believed that the extent of the threat was indirectly related to the level of site security.

300.65(a) (3) Fire and/or explosion

300.65(b) (3) Security

Figure 1. Quanta Resources, Queens, New York, NY

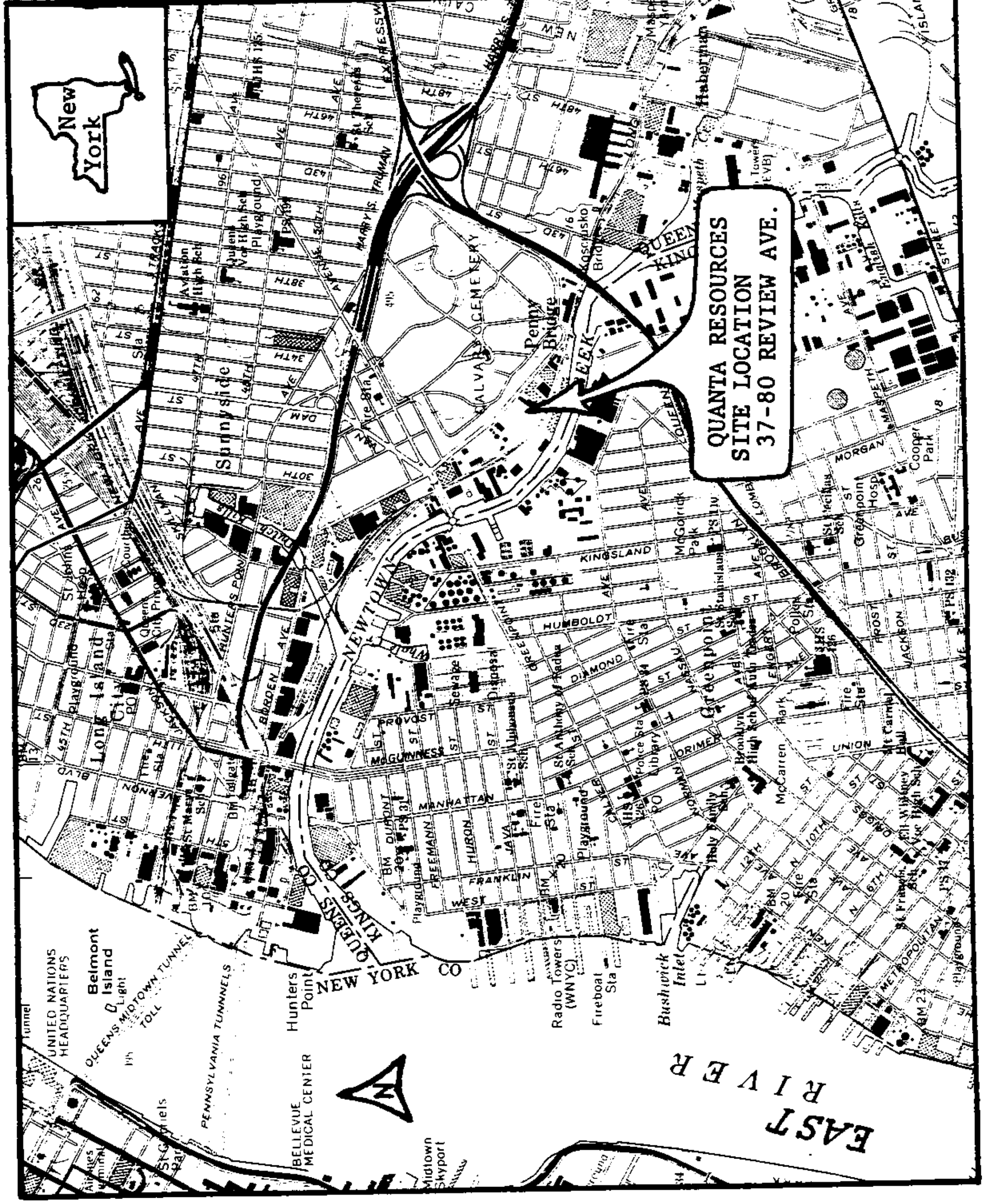
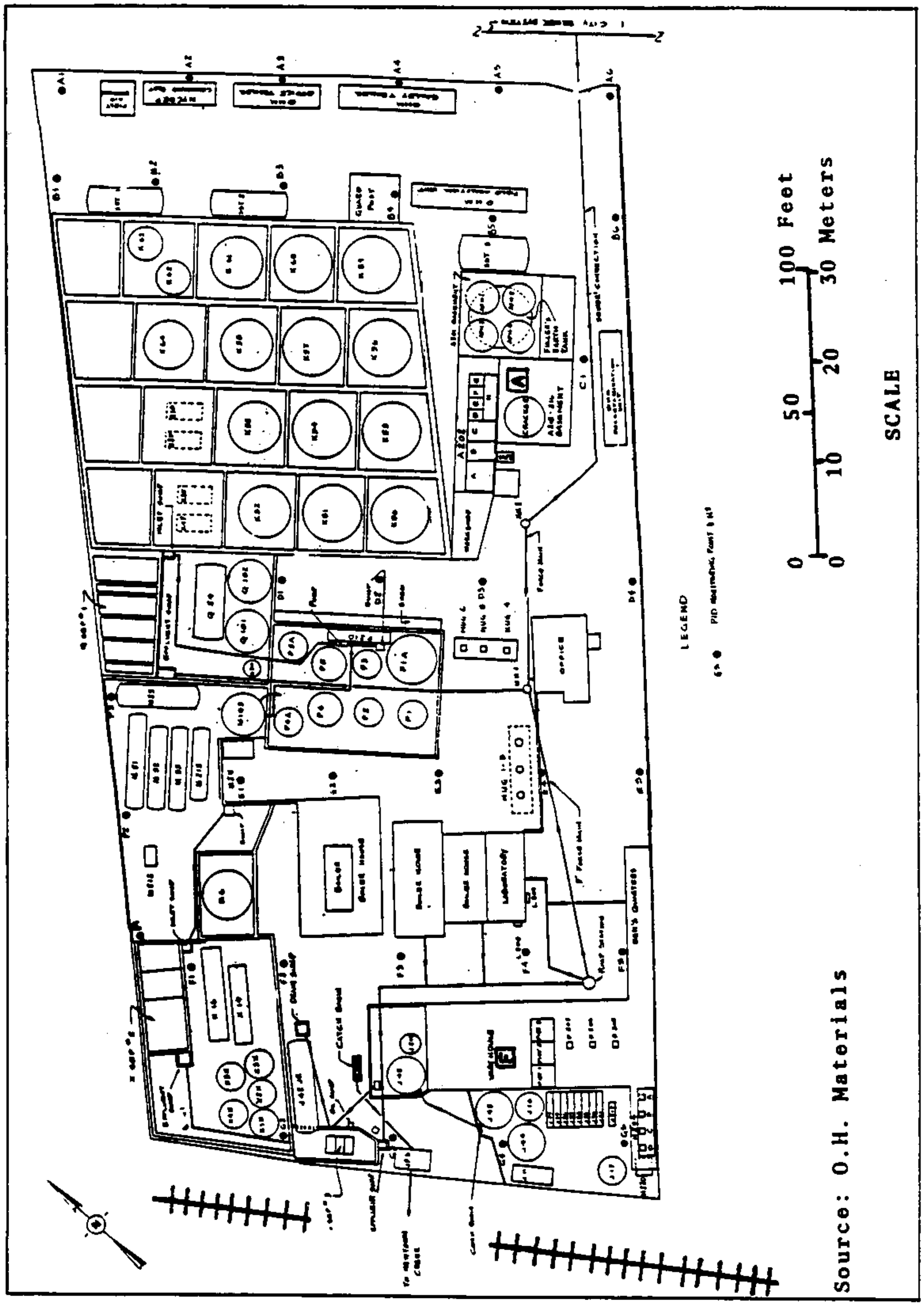


Figure 2. Quanta Resources Site Plan



The site discovery process underwent several steps involving different state and city agencies with different levels of information. On April 25, 1980, investigators from the New York State Department of Health (NYSDOH) and the NYSDEC inspected the site and reported health complaints from workers in adjacent facilities, and noted that they suspected on-site disposal of hazardous wastes. They also noted leakage from a tank of what they were told was lubricating oil. On July 30, 1981, NYSDEC sampled 19 tanks and found PCB contaminated oil, estimated at 65,639 gallons (248,443 l). The U.S. EPA subsequently tested another tank and labeled it after finding that its contents were PCB contaminated. The state and the site owner settled on a consent decree with a compliance schedule for repairing leaks and for general permitting requirements. In 1981, the U.S. Attorney in the Southern District Court of New York indicted the Quanta plant manager for conspiring to illegally dispose of hazardous wastes, including cyanides and contaminated oil, into local sanitary landfills. With this knowledge of the site hazards, NYSDEC and the NYCDEP were very concerned about the potential for fire and pollution when they were informed on Friday May 7, 1982 that the trustee for the bankrupt corporation planned to remove site security from the property. Because of city and state objections, the trustee maintained a guard on-site until June 8, 1982, when the U.S. Bankruptcy Court of New Jersey granted the trustee's motion to remove all security from the site due to lack of funds. Security was provided by NYSDEC guards and NYC police patrols until the city contracted with a guard service following a declaration of a site emergency by the NYCDEP Commissioner on June 16, 1982. The discovery of the exact problem on-site was further made during a survey by the NYCDEP and NYSDEC in June 1982. This survey identified and quantified low flash point (82°F, 28°C) liquids and PCB contaminated oil in leaking tanks, which provided the impetus for the subsequent clean-up work.

300.63 Discovery

300.65(b)(3) security

300.64(a) preliminary assessment

Synopsis of Site Response

The site response had three main phases - two site surveys and a surface waste removal operation. With assistance from NYSDEC, the NYCDEP took 142 samples from 92 tanks between June 15-25, 1982. A NYCDEP contractor, O. H. Materials (OHM), took 378 samples from 106 tanks between August 13-20, 1982. These surveys found approximately 150,000 gallons (567,750 l) of PCB contaminated oil and sludge, 266,000 gallons (1.007×10^6 l) of contaminated water and 121,000 gallons (458,000 l) of uncontaminated oil.

300.65(b)(5) sampling

The wastes were removed from the site by OHM under contract with NYCDEP between September and December 1982. Liquids were pumped into tank trucks and trains, and sludges were solidified with lime and transported by truck for disposal. All wastes were disposed of at licensed hazardous waste facilities. Following the removal, the tanks were cleaned with water followed by a diesel fuel rinse and aeration. A subsurface investigation is pending as of January 1983.

300.65(b)(6) removal

SITE DESCRIPTION

Surface Characteristics

The Quanta Resources waste oil processing facility (see Figure 2) consisted of four buildings and about 100 storage tanks, which contained about 640,000 gallons (2.4×10^6 l) of waste oil, sludge, chlorinated solvents and cyanide. One of the buildings encloses a cracking tower for re-refining waste oil in a 4 story corrugated steel section, located near the main gate at the northeast corner of the property. A one story warehouse containing pits and tanks is located at the southeast corner of the property. Two small boiler houses that were between these buildings were removed during the 1982 clean-up. Most of the 100 storage tanks were large above ground steel structures between 10 -45 feet (3-14 m) tall, with capacities between 5,000 - 51,000 gallons (18,925-193,035 l). Some of the tanks were converted railroad tank cars. The largest tanks, labeled "K" in Figure 2, are surrounded by a matrix of 4 foot (1.5 m) concrete dikes. There were also two buried tanks and three recessed effluent sumps. The ground is paved asphalt near the front and compacted oily dirt near the rear.

The 1.84 acre (0.74 ha) facility slopes down slightly from its 204 foot (62 m) long fenced frontage on Review Avenue. The Calvary Cemetary is located directly across Review Avenue. On the east side, the site is separated from the Guiness Harp beer distribution warehouse by a 392 foot (119 m) steel fence. The original 4 foot (1.5 m) fence on this side was replaced by a 10 foot fence in 1982 by NYCDEP. A Long Island Railroad (LIRR) line runs along the fence near of the site, which is about 450 feet from the Newtown Creek. The Nanco (construction) Equipment Company is located on the west side of the property, separated by a 10 foot barbed-wire fence. The closest residences are located about 500 yards south, across the Newtown Creek in Brooklyn, and about 800 yards west along 45th St.

300.65(e)(2) (i)(A) population at risk

The Quanta site is located in an old industrial area of Long Island City section of Queens in the approximate center of New York City at 73° 56' 15" longitude and 40° 45' 6" latitude. The gently sloping surface was formed by a combination of the retreat of the Wisconsonian Glacier about 10,000 years ago, and the relatively recent use of artificial fill, during the 19th century. (see Figure 3) The average annual temperature is 54.3 °F (12.4°C), and the average daily minimum and maximum temperatures are 47.4°F. (8.5°C.) and 61.1°F. (16.2°C.), respectively. Average January and July temperatures, which are the extremes of the monthly averages, are 32.1°F (0.05°5) and 76.7°F (24.8°C), respectively. The average annual precipitation is 41.61 inches (105.7 cm). Winds are usually out of the west northwest, at an average speed of 12.2 miles (19.6 km) per hour.

300.68(e)(2)
(i)(E)
climate

Newtown Creek, which lies 450 feet (137 m) south of the site, and the East River, into which it flows, are both classified as "SD" in the New York State usage designation. Class SD waters are defined as: "All waters not primarily for recreational purposes, shellfish culture or the development of fish life and because of natural or man-made conditions cannot meet the requirements of these uses."

Hydrogeology

The information in this section was drawn primarily from a paper published in 1971 by the U.S. Geological Survey (USGS). No hydrogeological study had been completed on the site as of January 1983; the NYCDEP is preparing to let a contract for a study. Relevant information is summarized and extrapolated from this paper and geological maps of Queens County.

300.68(e)(2)
(i)(D)
hydrogeological
factors

In the area of Queens where the site is located there are three aquifers consisting of sand and gravel from the Later Cretaceous and Pleistocene, overlying Precambrian bedrock (see Figure 4). The uppermost, Pleistocene aquifer is presently water-bearing and an additional aquifer lies nearby. The two Cretaceous aquifers have receded from the site area. The site rests on shallow artificial fill over Pleistocene glacial drift from the Wisconsinian glaciation. Within this Upper Glacial Aquifer, water table conditions (unconfined aquifer) exist at about 20 feet (6 m) deep. This layer of primarily undifferentiated Pleistocene deposits extends to about 50 feet (15 m) deep. A section of the Jameco Aquifer lies nearby the site directly beneath the Upper Glacial Aquifer. This lower Pleistocene Unit occurs occasionally throughout

Figure 3. Queens Surficial Deposit and Section Locator - Quanta Site

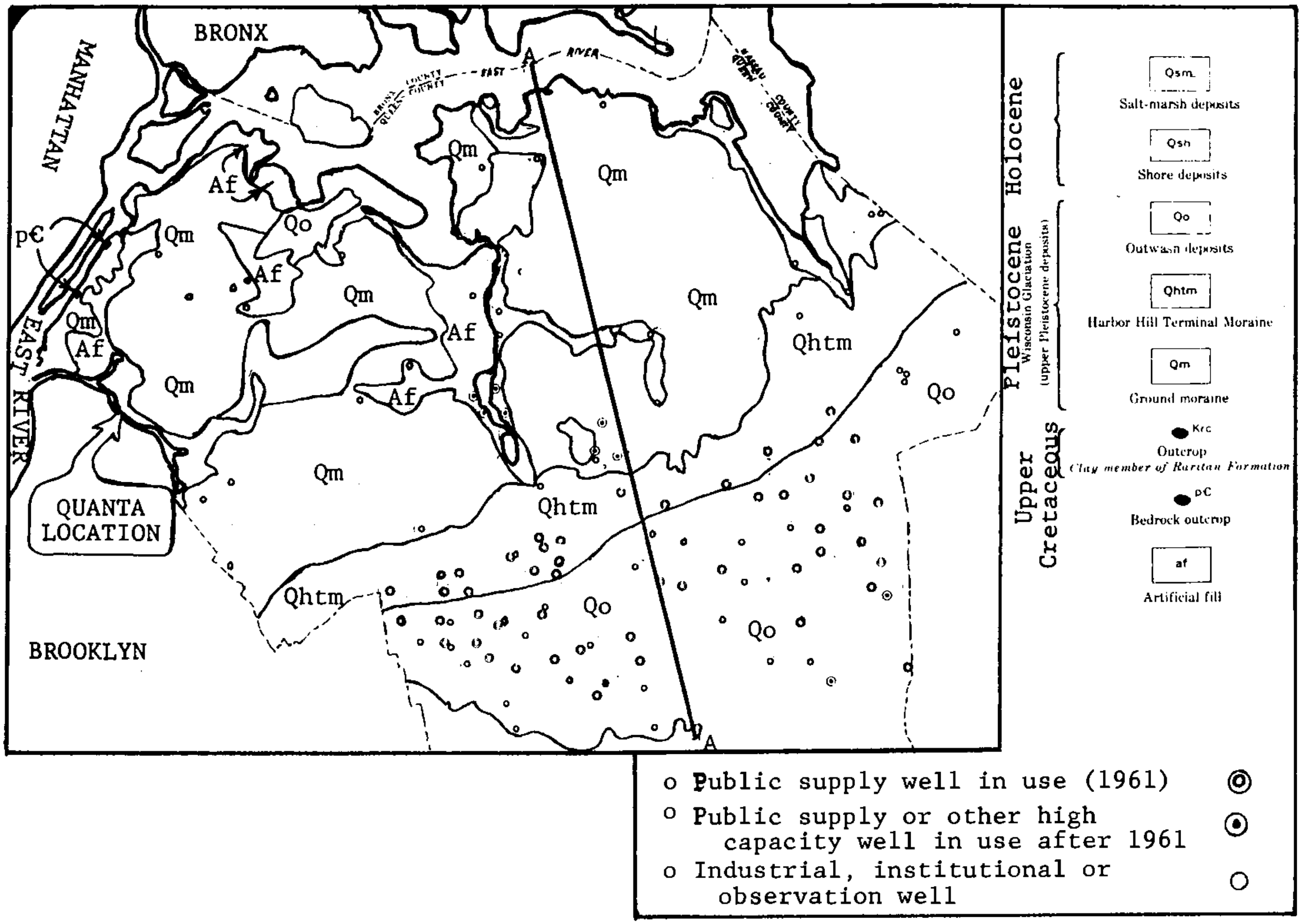
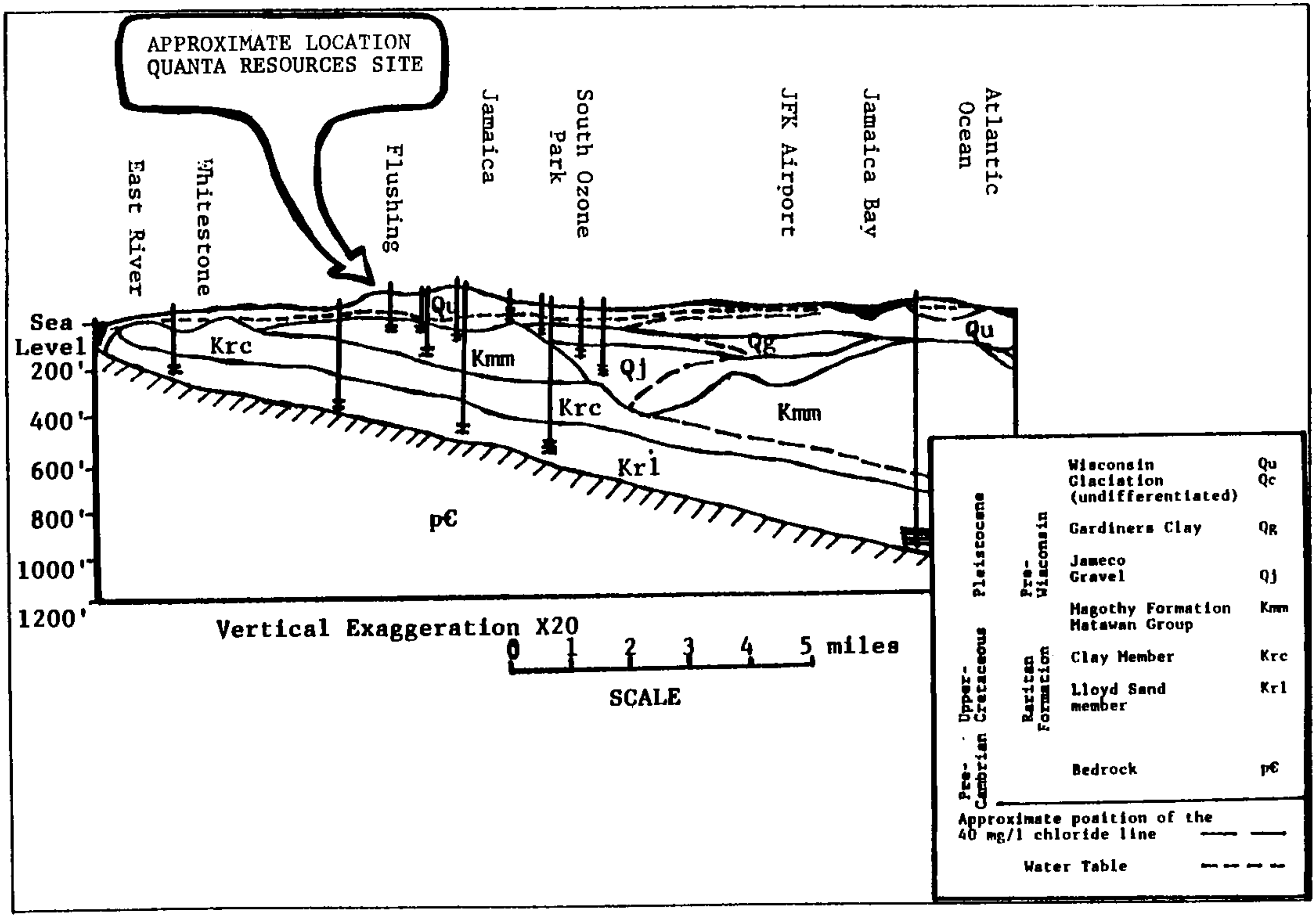


Figure 4. Geohydrologic Sections, Queens County, New York



the county in buried valleys. The Magothy is the second aquifer underlying the site. It occurs directly beneath the glacial drift layer in the Magothy Formation - Matawan group. This layer was deposited during the upper Cretaceous, and extends to about 175 feet (53 m). The hydrologic communication between the uppermost aquifers is very good. The first of two members of the Raritan group is a clay member extending from about 175 feet (53 m) to 350 feet (106 m). The second member is the Lloyd sand member, which extends from about 350 feet to 450 feet (106-137 m). Precambrian bedrock underlies the site at a depth of about 450 feet (137 m).

Upper Glacial Aquifer

This aquifer is presently the only actual water bearing unit under the site. It consists of some glacial outwash sand and gravel deposits, but mainly of ground moraine deposits at the site, which is north of the terminal moraine. This aquifer has a porosity of about 40%, and a coefficient of permeability (rate of flow water, in gallons per day, through one square foot under a gradient of 100 %) of about 1,000 gallons/-day/square foot (40,743 $l/day/m^2$).

Jameco Aquifer

The Jameco Aquifer is a lower Pleistocene buried valley consisting of coarse sand and gravel with small amounts of silt and clay. It extends primarily north-south, but a section of it underlies an area near the site. Since this is a relatively shallow water-bearing unit, its proximity may be relevant to the ground water quality. In addition, this aquifer has the highest permeability in the county, with coefficients as 2,000 gallons/day/ per square foot (81,485 $l/day/m^2$).

Magothy Aquifer

The closest extent of the Magothy aquifer in 1968 was about 1 1/2 miles (2.4 km) to the southeast of the site. Subsequent to the last USGS study, the aquifer has receded further to some extent. This Magothy formation is in the Matawan Group and consists mainly of intercollated beds and lenses of clay, clayey and silty sand, fine to course sand, and gravelly sand. There is a basal unit of sand in the aquifer, about 50 - 100 feet (15-30 m) thick. This variety reflects the fact that it was deeply eroded prior to the deposition of the Pleistocene units. The porosity and permeability of the formation vary widely, and are as yet unclear at the site location. The unit's coefficient of permeability varies from aboout 500 - 1,450 gallons/day/ square foot

(20,371-59,077 l/day/ m^2) and a porosity of about 30%.

Lloyd Aquifer

The closest extent of the Lloyd aquifer in 1968 was about $1^1/2$ miles (2.4 km) to the southeast of the site. Reduced infiltration and increased pumping have decreased the extent since the 1968 USGS study. This aquifer consists of the Upper Cretaceous Lloyd Sand Member of the Raritan Formation, and is the lowermost major aquifer unit in Queens County. It is confined between the underlying bedrock and the overlying poorly permeable Raritan Clay member. The Lloyd aquifer consists of beds of sand and gravel intercollated with beds of clay and silt. The sand and gravel beds commonly contain varying amounts of interstitial clay and silt. The average permeability of the aquifer is about 500 gallons/ day/square foot (20,371 l/day/ m^2).

WASTE DISPOSAL HISTORY

The date of the first processing of hazardous wastes at the Quanta site is unclear, but the age of the facility suggests that it paralleled the use of petroleum products through the 20th century. The NYCDEP estimates that the Quanta facility was built in the early 1900's. The Newtown Creek area is the oldest oil refining center in the country. Whale oil was previously refined by early plants in the area during the 18th and 19th centuries. The last wastes were brought on-site before November 1981, when Quanta Resources abandoned the property.

300.64(b)
data review

DESCRIPTION OF CONTAMINATION

Of the three sampling programs carried out at Quanta, the Phase I site survey program carried out by O. H. Materials (OHM) in August 1982 was the most extensive. Air, solids and liquid wastes were sampled, but liquid waste analysis was the primary task. This survey included 378 samples taken from 107 tanks, separators, basins and drums and was largely verified by a quality assurance program conducted by CH_2M Hill, as well as frequent spill samples analyzed by NYCDEP. The results of the sampling program are summarized in Table 1, and the methodology is described in "Design and Execution of the Site Response." The waste stream categories listed reflect the minimum regulatory disposal requirements of the wastes. Most tanks contained only one waste stream each. But uncontaminated material that could not be segregated from an adjacent layer is included in the total for the contaminated waste stream category. The survey determined the location, contents and condition of each tank on site.

300.65(b)(5)
sampling

TABLE 1. TYPES AND AMOUNTS OF WASTES AT QUANTA (August 1982)

Non-Contaminated oil	121,150 gallons (458,553 1)
Oil contaminated with chlorinated solvents	75,267 gallons (284,886 1)
Oil contaminated with PCB* (less than 500 mg/1)	97,742 gallons (397,953 1)
PCB oil (greater than 500 ug/1)	22,502 gallons (85,107 1)
Non-contaminated water	3,072 gallons (11,628 1)
Water contaminated with heavy metals	200 gallons (757 1)
Water contaminated with volatile organics	211,412 gallons (800,194 1)
Water contaminated with PCB	24,570 gallons (92,997 1)
Caustic	29,881 gallons (113,100 1)
Non-contaminated sludge	32,391 gallons (122,600 1) 162 cubic yards (124 m^3)
Sludge-- flammable	9,722 gallons (36,798 1) 49 cubic yards (37 m^3)
PCB contaminated sludge	31,283 gallons (118,406 1) 161 cubic yards (123 m^3)
Solids--non-contaminated	18 cubic yards (14 m^3)
Solids--toxic	5 cubic yards (4 m^3)

* Includes some (9%) non-contaminated oil and sludge that could not be separated cost-effectively from the contaminated layer during transfer.

Source: Compiled from reports by NYCDEP, OHM and CH_2M Hill.

Each category included an aggregation of more specifically analyzed components. The non-contaminated oil and sludge were found to be RCRA non-hazardous according to their constituents and properties. The oil and water contaminated with chlorinated organic solvents primarily contained methylene chloride, trichloroethylene, (TCE), benzene, xylene, 1,1,1-trichloroethane and tetrachloroethylene (PCE). The vapors from these contaminants caused the low flash points, which were as low as 82^{o}F (28^{o}C). Oil contaminated with PCB was defined as having PCB concentrations between 50 - 500 mg/l, while PCB oil had concentrations over 500 mg/l. Non-contaminated water met pretreatment standards for the city sewage system but was later pretreated with other aqueous waste before disposal. The primary heavy metals were zinc, mercury, chromium, lead and barium. A radiological survey, performed by a NYCDEP contractor, Radiac, found no measurable radioactivity onsite.

During the OHM survey, spillage occurred from two above ground tanks and a sump tank. Tank JSEP 3, a final oil separator basin at the lower southwest end of the site, was brimming with oil water. Stains around JSEP 3 suggested that it had overflowed previously onto the LIRR tracks. Tanks J10 and J44 were found to be slowly leaking oil from pipe fittings onto the ground below them. Also, 15 full drums were found near building A. A six inch (15 cm) barge loading pipe leading from the site to the Newtown Creek had one leak. Another 6 inch (15 cm) sewer line led under the LIRR tracks to the Creek. No detectable off-site organic air emissions were measured, using mobile infrared analyzers (MIRANS) and photoionization detections (PID). Detection limits were set for TCE and PCE at 4 mg/m^3. No air contamination was measured in the established "clean area", except inside and near the laboratory because of reagents. Explosimeter measurement showed combustible gases only at the lid of chlorinated solvent/oil tanks.

PLANNING THE SITE RESPONSE

Initiation of Response

Generally, responses were initiated at Quanta to prevent fire, which would have produced toxic air pollutants. The NYCDEP and NYSDEC agreed that the threat of fire required mitigation. But, the response was not initiated until after the NYCDEP took responsibility for the site clean-up.

There were two primary decision periods for the initiation of work at Quanta to prevent fire and toxic air and water emissions. The first response actions were taken by the city following the declaration of emergency on June 16, 1982 when the Department of General Services (DGS) contracted for site security and the NYCDEP began a site survey and sampling program. The second response was initiated in later July when the NYCDEP released a request for proposals (RFP) and contracted with OHM to perform another more extensive site survey and sampling program, which subsequently led to the clean-up actions in September- December 1982. Throughout the decision making process, there was extensive media coverage of the site by all major New York newspapers, magazines, radio and television stations, which created added pressure on government decision makers to begin a clean-up.

The NYC Department of General Services contracted with a security service for site security on June 16, 1982 to prevent arson or vandalism that would result in toxic air emissions from a fire or off-site surface water releases. The city, rather than the state, initiated this action because the NYSDEC believed that it did not have the necessary resources to provide continuing guard services. The NYSDEC had provided guards following the bankruptcy court's granting of the trustee's motion to remove its guards due to lack of funds.

300.65(b)(3)
security

The NYCDEP initiated a site survey and sampling program on June 15, 1982 to provide a more accurate assessment of the site hazards than that provided by the July 1981 NYSDEC survey. The NYCDEP was attempting to obtain federal or state assistence for a site clean-up, and intended to use the results of a site survey to make its request for assistance more specific. The NYCDEP initiated the site survey instead of the NYSDEC or the U.S. EPA because the other agencies believed that they did not have the necessary resources to perform the survey.

300.65(b)(5)
sampling

This site survey clarified the physical threat posed by the site, which provided the impetus for a clean-up. The NYCDEP identified the primary threat as the potential for fire from wastes with flash points as low a 82°F (28 °C). The combination of these low flashpoint wastes, with the presence of large volumes of PCB contaminated wastes in leaking tanks, created a potential for hazardous air emissions. This threat of fire was further heightened by the use of oxy-acetylene welding torches by an adjoining equipment company about 20 feet (6.1 m) from the Quanta tanks. Two of the buildings on-site were old and were highly flammable with the waste oil stored inside. The city and state believed that low temperature combustion of PCBs produces dioxin emissions and were very concerned about this public health threat.

The NYCDEP continued to try to compel the U.S. EPA or the NYSDEC to provide assistance for the site survey and clean-up. The NYCDEP was continuing to request funding or assistance from the U.S. EPA and the NYSDEC through administrative channels when, on July 16, 1982, a representative of the Mayor of New York City directed the NYCDEP to initiate a clean-up of the site. This directive followed a request by the New York State Select Committee on Crime dated July 14, 1982, for the mayor "to convene a task force to address immediately the Review Avenue situation." On July 20, 1982, the NYCDEP held a meeting to draw up a request for proposals (RFP), which was released on July 22, 1982. The commissioner of the NYCDEP made the last requests for federal or state assistance, prior to initiating city clean-up actions, to the Regional Administrator for the U.S. EPA and the NYSDEC Commissioner on July 30 and 26, 1982, respectively. The U.S. EPA did not provide any CERCLA funding for the site.

Selection of Response Technologies

300.65(b)(6) removal

The NYCDEP removed above ground wastes because this was the level of response necessary to eliminate the threat of fire and toxic air emissions. The only other alternative considered was the use of a new PCB oil decontamination system using sodium and catalysts to precipitate and filter out the PCB from the oil. This alternative was not chosen because the NYCDEP on-scene coordinator (OSC) was not confident of its proven practicality for decontaminating oil in a thorough and legal manner. A subsurface clean-up was not included in the site response because it was beyond the necessary action to mitigate the immediate threat of fire. Also, a subsurface clean-up would have required a hydrogeological study and design, which would have increased the time of the potential for fire.

300.70(b)(2) (ii)(B) chemical treatment methods

In addition, NYCDEP made three decisions regarding more specific response technologies. First, the NYCDEP decided to use lime dust to solidifiy the waste sludge because it was more cost effective and more dependably available than the alternatives of cement kiln dust or fly ash. The exact ratio was based on on-site testing performed by OHM chemists.

The NYCDEP's selection of on-site waste water pretreatment was the second specific technology choice. The alternative of off-site commercial pretreatment was not selected because the on-site system was adequate for most wastes and was less expensive. Cyanide wastes were commercially treated because NYCDEP and OHM believed the on-site system was inadequate to treat them.

Third, NYCDEP decided, as an overall site policy, to dispose of all wastes, hazardous and non-hazardous, at permitted hazardous waste disposal facilities because it was concerned about public reaction to disposal of any waste from this well publicized hazardous waste site. The alternative of sanitary landfilling of solidified non-hazardous sludge at no charge at city owned landfills was not chosen because of the potential public reaction in the wake of recently publicized cases of illegal hazardous waste dumping in city sanitary landfills. Similarly, the NYCDEP was concerned about reaction to standard boiler incineration of non-hazardous oil because of recent publicity about toxic emissions from the use of contaminated oil in city apartment buildings.

300.65(b)(6)
removal

Extent of Response

Generally, there were two decision areas for determining the extent of the response: extent of material removed and waste water treatment levels. The focus of the removal was on the liquid wastes and not on the potentially heavily contaminated soil because the hazard that initiated the response was the threat of fire and toxic emissions, not ground water contamination or soil erosion (e.g, runoff or contaminated dust). The clean-up action entailed removal of all wastes stored on-site, in addition to the low flashpoint wastes, because of the significant economies of undertaking the full removal at the same time since all wastes had been characterized. The tanks were emptied and decontaminated until they were "squeegee clean", and inspected for Gas-Free certification. The disposal of the uncontaminated sludge was at a standard above regulatory requirements because city officials were concerned about public anxiety over disposal of waste from a site known to contain contaminated materials.

300.65(c)
completion
of immediate
removal

300.67(a)(1)
substantial
cost savings

The levels of contaminants permitted in the wastewater before disposal into the sewage system are shown in Table 2. These levels for pretreatment were

300.70(b)(2)
(ii)(A)(1)
conventional
wastewater
treatment

TABLE 2. NYC INDUSTRIAL DISCHARGE CRITERIA

Parameter	Discharge Criteria
PCB	less than 10 ug/l
Cadmium	less than 5 mg/l
Chromium (hexavalent)	less than 5 mg/l
Copper	less than 5 mg/l
Cyanide	less than 2 mg/l
Nickel	less than 3 mg/l
Zinc	less than 5 mg/l
Bromine, Iodine, Chlorine	less than 100 mg/l

Source: NYCDEP, 1982.

set by the NYC Sewer Authority for two reasons. First, they have been determined to have no detrimental effect on the system's biological sewage treatment process. Second, these levels ensure that, with dilution, the system's final discharge will comply with its NPDES permit standards.

DESIGN AND EXECUTION OF SITE RESPONSE

The NYCDEP managed three general site responses at Quanta: initial site survey and protection, OHM site survey, and removal.

Initial NYCDEP Site Survey and Protection

300.64(a) preliminary assessment

On June 15, 1982 following verbal notification of the NYCDEP Commisioner's Declaration of Emergency, the NYCDEP Bureau of Science and Technology's (BST) Field Investigation unit had the NYC Fire Department cut the lock on the front gate. The three BST employees immediately began sampling and recording the size and condition of the tanks. On June 22, 1982, two NYSDEC employees assisted the BST workers on-site with the sampling. They also assisted on June 24 and 25, when the sampling was completed. A total of 142 samples were taken from 61 tanks and analyzed by the NYCDEP lab.

The NYSDEC and NYS Department of Health labs analyzed 23 duplicate samples. On July 16, 1982, a NYCDEP contractor, CECOS International, collected samples from tanks that were inaccessible because of shaky catwalks or bolted lids. A leak in non-hazardous tank 10 was plugged by the NYC Fire Department's Chemical Response Unit. The NYCDEP and the NYC Fire Department also spread sorbent material around leaky tanks.

300.65(b)(7) physical barriers

When the site emergency was declared on June 15, 1982, the NYCDEP also requested that the NYC Department of General Services contract for security guards and fence repair. Two 24 hour, armed commercial security guards were hired on June 16, 1982. Additional security was provided by regular NYC Police patrols. A 10 foot (3 m) galvanized steel fence with razor barbed wire was erected around the entire site. Existing lengths of 10 foot (3 m) fence on the north and south sides were repaired and barbed.

300.65(b)(3) security

On July 12, 1982, the NYCDEP sampled air on-site with an organic vapor analyzer (OVA) and a H-NU meter. Levels above background were found only inside the laboratory building.

Phase I - OHM Site Survey

Following the signing of a Letter of Intent with NYCDEP on August 11, 1982, OHM moved a mobile analytical laboratory, decontamination unit, backhoe, office trailer, crew/galley trailer and a vacuum skid unit to Quanta, and set up on August 12, 1982. Local hospitals were contacted to identify the nearest burn and poison treatment centers. Adjacent facilities and the local fire department were briefed about the project. Laboratory instruments were warmed and calibrated. To soak up recent run-off from tank JSEP3 and prevent runoff flows, OHM immediately spread 30 bags of sorbent material around the separator and along the LIRR tracks, and pumped its contents into tank J17. The oil was found to be uncontaminated.

The primary task of OHM's survey was liquid waste sampling. But air samples were also taken daily to ensure safe ambient levels in the "clean" on-site areas and off-site, and several soil samples were analyzed. To optimize the use of mobilized equipment and personnel, OHM sampled 12 hours/day, seven days/week from August 12 - 25, 1982. A "hot (contaminated) zone" was delineated with luminescent engineering tape on August 13, and air and tank sampling began. All personnel passing into this area south of the lab trailer (see Figure 2) wore a minimum of a hardhat with face shield, respirator with R-563 filter cartrige, tyvek suits, Rabor boots, and rubber gloves. Personnel who were opening tanks for sampling wore self-contained

300.65(b)(5) sampling

300.71 worker safety

breathing apparatus (SCBA), and Saran coated tyvek suits with hoods. On August 14, electrical power (triple phase 440 volt, single phase 220 and 110 volt) was established on-site.

A mobile infrared air analyzer (MIRAN) and a photoionization detector (PID) were used to sample ambient air daily. The two PIDs used were calibrated for benzene, but were sensitive to most organic vapors. A PID monitoring grid was established on August 13, consisting of 13 spray painted spots in the clean zone and 21 in the hot zone, and are shown as solid dots with letter/number codes in Figure 2. Throughout the survey air sampling was performed on these spots at least once daily. Other areas that were regularly sampled as wind and work activity conditions changed were: the portajohn area near the south end of the decontamination trailer; the SCBA bottle filling area near the north side of the decontamination trailer, the area in the building A filter room, and the inside of the lab trailer. Sample crews sampled air inside each tank upon opening it. Since the MIRAN's were mounted on carts, only about half of the grid points were accessible for simultaneous sampling with the PID.

Two MIRAN's with chart recorders were used for qualitative ambient air scans and for specific vapor analysis. One was calibrated for trichloroethylene (TCE) and the other for tetrachloroethylene (PCE). Both were capable of a lowest detection limit of 4 mg/m^3. The maximum allowable exposure for TCE and PCE set by OSHA is 100 mg/m^3. Two explosimeters were used to measure combustible gases inside tanks.

Upon initiating the liquids sampling on August 13, OHM performed an inventory and inspection of the tanks. A magnetometor (metal detector) was used to locate buried tanks. Because of metal structures and appurtenances, excavation was necessary to check metal detector readings. This survey revealed tank H-220, which was found under the south end of building H.

A total of 378 samples were taken from 106 tanks and two diked areas at an average rate of 12 tanks/-day. Samples were split for NYCDEP and CH_2M Hill verification. Volumes were estimated by measuring tanks, and liquid layer depths were measured and sampled with a bacon bomb sampler. Brass tools were used when necessary for opening tanks without sparking. Sludge was sampled with an aluminum hatched scoop on extension poles. Sampling equipment was decontaminated between samples by scrubbing with reagent hexane and rinsing with acetone. Sampling of tanks without product layering was performed by lowering an open quart glass jar with a nylon string. Duplicate one quart (0.95 l) aqueous samples were obtained for PCB and RCRA metal extraction procedure (EP) testing, as well as split 40 ml/amber vial samples for volatiles analysis.

On-site sample analysis work began on August 15 following connection of electrical power to the OHM analytical laboratory trailer by NYCDEP. The analytical methods used by OHM at Quanta were generally the minimum testing necessary to accurately classify the three waste types--oil, aqueous and sludge--into regulated waste stream categories. This scheme provided the background for an efficient removal and disposal operation. For example, PCB oil and sludge required different removal methods. The waste stream categorization decision matrix is summarized by the following outline:

I. Oil
   A. PCB oil (over 500 mg/l)
   B. PCB contaminated oil (under 50-500 mg/l)
   C. Non-PCB contaminated oil (under 50 mg/l)
      1. Chlorinated solvent contaminated oil (over 1% chlorination)
      2. Non-contaminated oil (under 1% chlorination)
         a. high sulfur saleable fuel oil
         b. low sulfur saleable fuel oil

II. Water
   A. PCB contaminated (at or over 10 ug/l)
   B. Non-PCB contaminated (under 10 ug/l)
      1. Contaminated with volatile organics (at or over 1 mg/l)
      2. Non-contaminated with volatile organics (under 1 mg/l)
         a. contaminated with heavy metals (at or over 5 mg/l)
         b. uncontaminated water (under 5 mg/l)

III. Sludge
   A. PCB contaminated (at or over 50 mg/l)
   B. Non-PCB contaminated (under 50 mg/l)
      1. Flammable (flash point at or under $60^{o}C$)
      2. Non Flammable sludge (flash point over $60^{o}C$)
         a. Toxic (EP toxicity for RCRA metals-positive)
         b. Non-toxic (EP toxicity for RCRA metals-negative)

All analytical protocols followed appropriate U.S. EPA, American Society for the Testing of Materials or National Institute for Occupational Safety and Health procedures. A Tracor 560 gas chromatograph was used for PCB and volatile organics analysis. Flash points were determined with a Seta-flash flash point detector. Metals analysis was performed with an IL single beam atomic absorption spectrophotometer. Blanks or standards were used for all analyses. Instruments were calibrated at the change of each shift or analyst.

Split samples taken by NYCDEP were passed on to its consultant, CH_2M Hill (Hill), for the quantity assurance (QA) program. The Hill engineer chose samples randomly for analysis by Hill's Montgomery, Alabama laboratory, amounting to about 15% of the total. Four spiked samples were also submitted to OHM and Hill's labs by NYCDEP. No significant differences in analytical results were found between OHM and Hill's labs. Aqueous results varied slightly because of OHM's re-filtering of samples.

Phase II - Removal

The actual removal and clean-up operation (see Table 3: "Quanta Waste Removal Summary") began on September 2, 1982. Following the end of the survey on August 25, OHM compiled a survey report, and moved clean-up equipment to Quanta in preparation for the Phase II operation, for which it was negotiating a contract with NYCDEP. The four main activities of the removal operation were: (1) waste consolidation, (2) waste removal and transport, (3) on-site waste treatment and off-site disposal, and (4) tank, dike, separator, piping, and building decontamination and certification. Other tasks performed by OHM included recommendation of available disposal facilities, sampling and analysis of wastes and treated water, and manifest preparation.

300.65(b)(6)
removal

Consulting services were provided to NYCDEP by CH_2M Hill during Phase II. The Hill engineer maintained the site diary and verified the amount of wastes treated and removed, as well as OHM's time and materials charges. Every third discharge to the sewer was verified by Hill analysis. Disposal sites were inspected as necessary by Hill field offices to verify materials arrival or check site compliance prior to transport.

On-Site Waste Consolidation and Transfer

To facilitate efficient truck and train loading, as well as to allow for tank decontamination, wastes were consolidated according to waste stream category in the tanks and separators shown in Figure 5 and listed in Table 4. The equipment used for transferring each waste stream category is listed in Table 4. Since non-aqueous wastes filled about 25% of the 1.5 million gallon (5.7 million l) tank capacity, well over half of the tanks could be emptied and cleaned before off-site disposal began. The need for this capacity will be discussed briefly in "Transportation and Disposal".

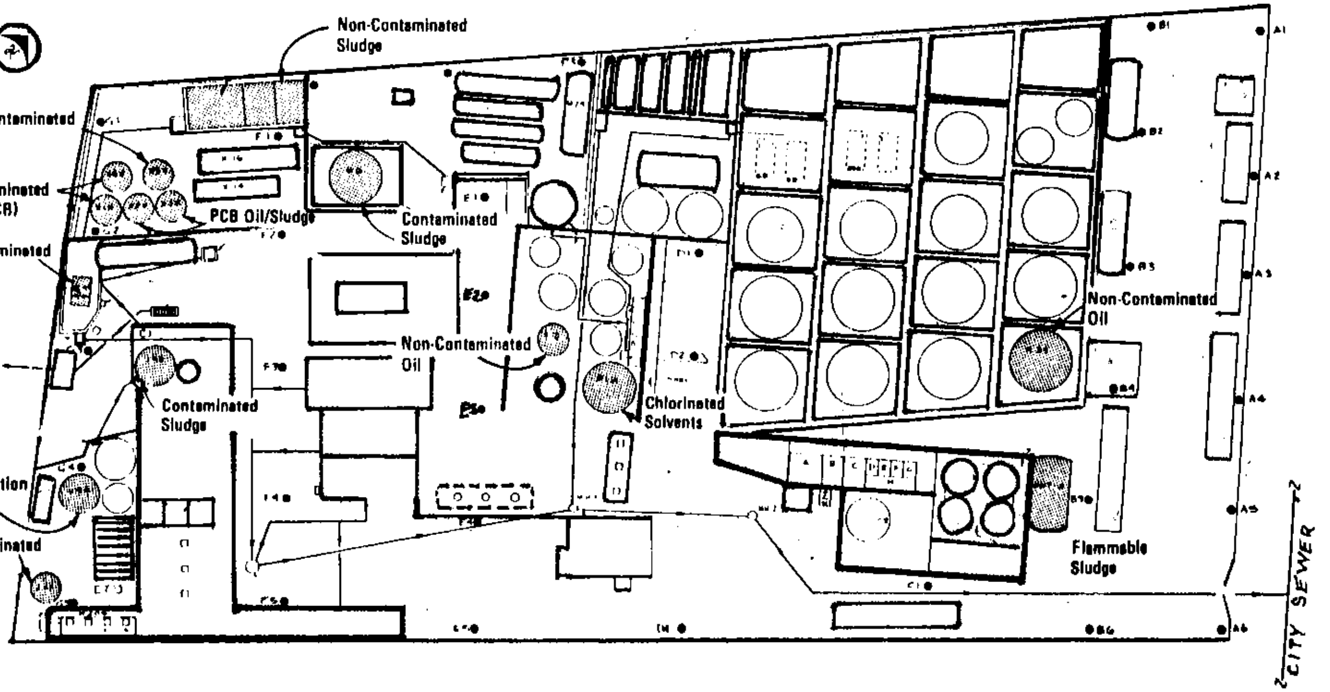
Since non-pumpable sludge was disposed of at a permitted hazardous waste landfill, RCRA regulations required solidification. Lime dust was chosen as the solidification material based on on-site tests by OHM chemists. A lime: sludge ratio of 1:1 by weight was based on OHM on-site testing to meet RCRA landfill requirements. Sludge was mixed with a total of 893 tons (810 Mt) of lime dust in the KF mixing area, (see Figure 5) and consolidated on and covered by polyethylene sheets.

Transportation and Disposal

Waste removal began on September 12 and ended on December 1, 1982. A total of 424,993 gallons of waste was transported off-site as listed by category, transport vehicle volume, date shipped and disposal facility in Table 3. Wastes were loaded using the same methods noted in Table 4 in "consolidation". Contamination of exterior vehicle surfaces was generally avoided, but spillage was wiped off before departure. After filling, all closed valves and hatches were sealed with evidence bands. Variations from the plan are discussed in "Project Costs" to the extent that they affected costs.

Decontamination and Certification

Following waste removal, all tanks were decontaminated using methods corresponding to whether or not they were PCB contaminated. Non-PCB tanks were cleaned according to American Petroleum Institute practices, using a Butterworth System. A Butterworth is a stainless steel unit that sprays water at high pressure in all directions by spinning on two perpendicular axes. The unit is lowered and raised in the tank until the walls are "squeegee" clean. The tanks were then vented with an electric blower; most tanks were further ventilated by cutting holes in the side about 10 square feet (10.9 m^2) in area.



LEGEND

Tank and Site Identification Number

Air Monitoring Stations

Figure 5. Major Waste Transfer/Storage Stations

SOURCE: O.H. Materials

TABLE 3. QUANTA WASTE REMOVAL SUMMARY

Material Category	Transport Vehicle	Volume Removed	Dates Shipped	Disposal Facility
Oil contaminated with PCB (a)	Rail	38,716 gal (146,540 l)	10/21/82	Rollins, TX
PCB Oil (b)	Truck	1,163 gal (4,402 l)	10/22/82	Rollins, TX
Waste Oil with Chlorinated over 10,000 ppm	Rail	78,920 gal (2987 l)	09/29/82-10/05/82	SCA, ILL
Non-contaminated Waste Oil	Rail	119,830 gal (453,557 l)	09/21/82-10/05/82	SCA, ILL
Flammable Sludge	Truck	5,000 gal (18925 l)	10/13/82	Rollins, TX
Pumpable Sludge Contaminated with PCB	Rail	57,000 gal (215,745 l)	10/15/82	ENSCO, AK
Non-pumpable Sludge Contaminated with PCB	Truck	430 tons (390 Mt)	11/09/82	SCA, NY
Cyanide Solution	Truck	9,425 gal (35674 l)	11/10/82	SCA, NJ
Non-pumpable PCB Sludge over 500 ppm	Truck	13 drums (1,705 gal) (6,453 l)	12/01/82	Rollins, TX
Contaminated Decontamination Liquid (Diesel Fuel)	Truck	1,100 gal (4,164 l)	12/01/82	Sea-Bright, KY
Nonhazardous Sludge	Truck	886 tons (804 Mt)	11/13/82-11/16/82	SCA, NY and BFI, MD

(a) PCB between 50-500 mg/l
(b) PCB over 500 mg/l

Source: CH2M Hill Report 1983.

TABLE 4. PUMPABLE AND MECHANICAL WASTE TRANSFER AND REMOVAL EQUIPMENT

TRANSFER/REMOVAL EQUIPMENT	WASTE TYPE			
	Aqueous	Oil	Pumpable Sludge	Non-pumbable Sludge
1500 gallon Vacuum Skid-Unit	X	X	X	X
Caterpillar 215 Backhoe				X
3000 gallon Vacuum Truck	X	X	X	
Caterpillar 955 Front End Loader				X
Diaphram Pumps	X	X	X	
Bobcat Front End Loader				X
Submersible Pumps	X	X		
Case 580 C Backhoe				X
Hydraulically Operated Centrifugal Pump	X	X		

Source: CH2 M Hill Report 1983.

Diesel fuel was used to decontaminate PCB-oil tanks X 2X and X3X, by triple rinsing. Using a 1,500 gallon (5,678 l) vacuum skid unit, about 1,000 gallons (3,785 l) were used to rinse these two tanks. Following the diesel fuel rinse, a fire hose was used to rinse the tanks with city water.

Piping and appurtenances were decontaminated with a high pressure water laser. Four crews wore hard hats, saranex suits with hoods, splash suits, full-face respirators, protective gloves and over boots, to clean contaminated piping after cutting it into workable lengths. The cracker tower building and the warehouse building were cleaned manually in a similar manner.

300.71
worker
safety

All tanks were certified "clean and gas free" by a licensed marine chemist from Marine Chemists Inc. of Hoboken, N.J. An explosimeter and visual inspection provided this certification on the first attempt for all tanks.

On-site Waste Treatment

The 166,469 gallons (630,085 l) of contaminated and non-contaminated water, which was in tanks, dikes, separators and building basements, was treated on-site before discharge into the NYC sewer system. This on-site pretreatment reduced costs by avoiding high priced disposal or off-site pretreatment. Some treated waste waters were used for tank rinsing in the decontamination operation and retreated. The water was treated according to NYC discharge guidelines, which are discussed in the "Extent of Site Response" section. All treated effluent as tested by the OHM lab for discharge approval by the NYCDEP OSC. Every third water sample was split with CH_2M Hill for verification. The results were not significantly different between the two labs.

300.70(b)(2)
(ii)(B)
chemical
treatment

The aqueous treatment sytem was a two step process: oil/water separation, and physical clarification and filtration. The system was set up on August 31 and September 1 before other removal activities began and consisted of five 10,000 gallons (37,850 l) pools, two chemical mixing tanks, a clarifier, a pressure sand filter, two carbon contact units, and several types of pumps (see Figure 6 for layout and location). The first 5,200 gallon (19,682 l) batch of water was treated on September 3, 1981 at a rate of about 20 gallons/minute (76 l/minute).

The following process flow description describes the system at Quanta. Oily water from tanks, separators, and containment dikes was pumped into pool I

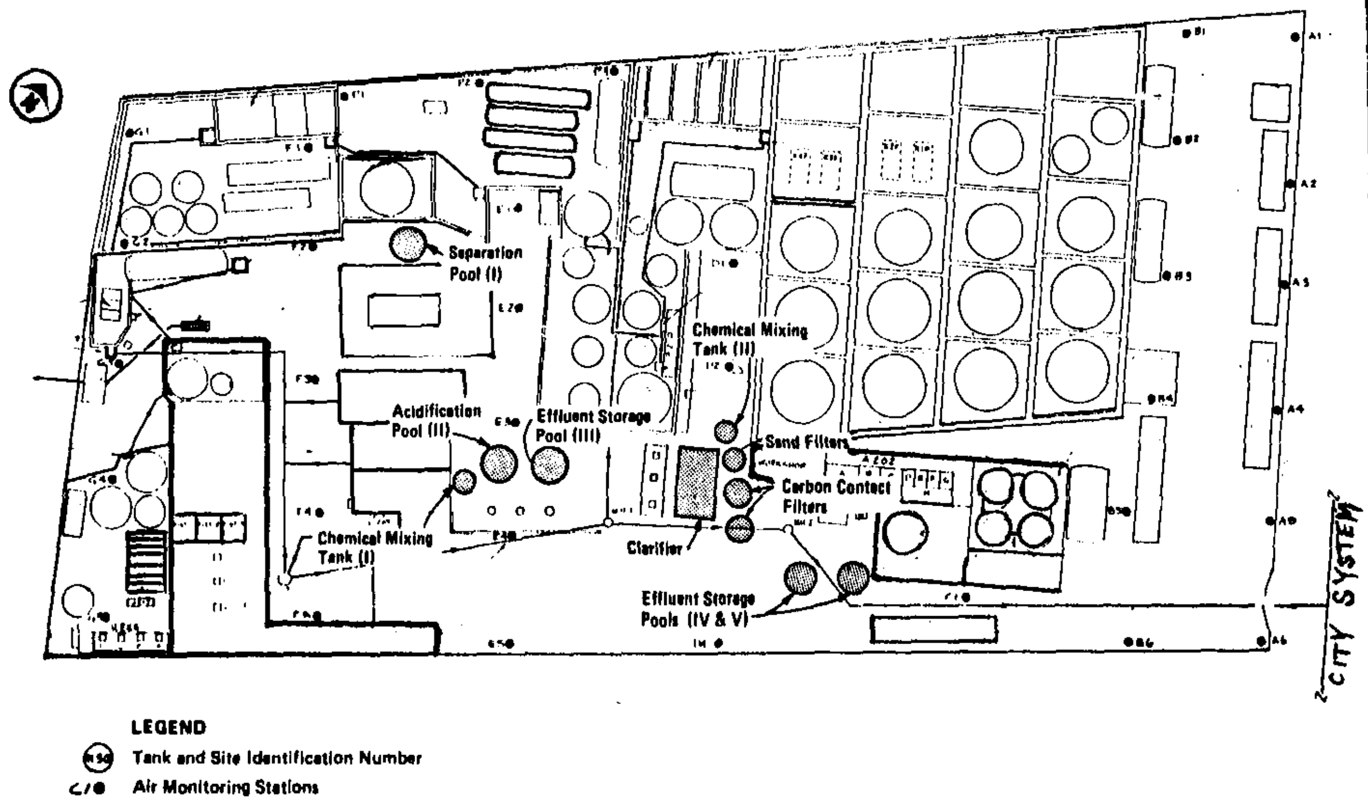


Figure 6. Onsite Waste Water Treatment Facility

SOURCE: O.H. Materials

to allow the free oil to separate from the waste water. The waste water from pool I was pumped to pool II where it was acidified to about pH 4 to break any oil emulsion and allow the oil to separate from the water. Waste water from either pool I or II was pumped to Chemical Mix Tank I (CMT I) and treated with caustic to raise the pH to 11-12. A polymer was also added to aid in the agglomeration of flocculant formed in alkaline solution. After pumping this alkaline waste water to Chemical Mix Tank II (CMT II) from CMT I, it is acidified to pH 6-9 to be compatible with the storage in pools III, IV and V and the sewer system. A clarifier tank was then used to allow the solids, heavy metals and PCB to precipitate and settle. Finally, a sand filter, filled with uniformly graded sand, was used to filter out any flocculant solids or other particulate matter that did not settle out in the clarifier. The carbon contact units were not used because adequate PCB and volatile organics removal was achieved in the preceding physical/chemical treatment.

COST AND FUNDING

Source of Funding

All project costs were borne by the NYCDEP, except site security, which was paid by the NYC Department of General Services Real Property Division. On December 29, 1982, the NYC Corporate Counsel petitioned the State Supreme Court to set aside the NYSDEC's denial of state Superfund money, and to direct the state to reimburse the city for expenditures of about $2.5 million for the Quanta response. The city has alleged, inter alia, that the state violated its mandated responsibilities under the state Environmental Conservation Law (ECL) and that the state's denial of the city's State Superfund request was "erroneous, arbitrary and capricious". The state contends that Quanta does not qualify as an inactive hazardous waste site under the state Superfund Law; and the NYSDEC lacked the resources to respond to Quanta under the ECL. The case is pending as of February 1983.

Selection of Contractors

Major contractors were selected by a competitive bidding process. Time and material contracts with price ceilings were used. This section only discusses the selection of the main survey and removal contractor.

On July 22, 1982, following the Mayor's July 16 directive, the NYCDEP released a request for proposals (RFP), "to furnish all labor, equipment and skills necessary to accomplish the removal and disposal of PCB contaminated oil, solvents, chemicals, water and other materials uncharacteristic of waste oil products which are a hazard to the public and the environment located at the Quanta... Long Island City." Six proposals were submitted by the July 29, 1982 deadline.

The proposals were evaluated by NYCDEP and its management consultant, CH2M Hill, of Reston Va. On July 29, 1982 the NYCDEP released a "Special Report" on proposed criteria for evaluating proposals. A description of each criterion was given, and the relative weight of each criterion was itemized (see Table 5). All six proposals were evaluated by NYCDEP BST, and on August 2 a report was sent to the Deputy Commissioner. The report considered 14 aspects of the OHM and the first runner-up proposal, including financial, management, and technical approach. Other proposals received decreasing scrunity proportional to their non-responsiveness. If the proposals were believed by NYCDEP to contain excessive "boiler plate" and inadequate specific site considerations, they were considered non-responsive. The OHM proposal was specifically believed by NYCDEP to show OHM to be "uniquely qualified" based on technical and operational abilities, program management, and transportation and disposal proposals. Recommendations on details like permits verification were also made in the NYCDEP proposal evaluation.

On August 9, 1982, CH_2M Hill submitted their proposal evaluation to NYCDEP. Two proposal evaluation teams independently reviewed proposals. Two of the 6 proposals were considered non-responsive and were given detailed scrutiny by only one team. Scores between 1-10 were given to each proposal for 43 different criteria. The general criteria categories and weighting were: general responsiveness to RFP (5%, 3 criteria), experience and qualifications (20%, 9 criteria), technical approach (50%, 23 criteria), financial considerations (25%, 8 criteria). These criteria were established through discussions with NYCDEP about its projects needs. Both evaluation teams picked OHM for recommendation, with no significant differences in the total scores.

Project Costs

The total cost of $2,398,959 for the Quanta Resources clean-up includes tasks listed in Table 6. This total exceeded the initial rough estimate of $1.5 million made in July 1982, partly because of delays and price increases during the transportation and disposal phase. This phase was the largest single cost item of the project.

TABLE 5. NYCDEP BST PROPOSAL EVALUATION CRITERIA FOR QUANTA - July 29, 1982

Criteria	100% Weight
Part One	
General Program and Plan	20%
a. Outline of project and objectives	
b. Problem areas	
Detailed Technical Approach	60%
a. Timetable 10%	
b. Public safety, monitoring and site security 10%	
c. Testing and quality assurance 10%	
d. Legal removal, transportation and disposal 20%	
e. Equipment and decontamination 10%	
Company experience and Qualifications	20%
a. Qualifications 12%	
b. Past performance 8%	
Part Two	
Financial Details	100%
a. Overall cost estimate 30%	
b. Time and Material costs 40%	
c. Company's resources (bonds, sureties, insurance) 30%	

Source: NYCDEP BST bid proposal evaluation special report

TABLE 6. SUMMARY OF PROJECT COSTS - QUANTA, QUEENS, NEW YORK

A.	Clean-up Contractor		
	1.	Site Survey	$ 217,395
	2.	Transportation and Disposal (Table 5)	$ 645,728
	3.	Tank Decontamination, Water Treatment, etc.	$1,236,877
		(Subtotal	$2,100,008)
B.	Management Consultant (Proposal Evaluation, On-Site Monitoring, Analysis, Quality Assurance)		$ 176,015
C.	Site Security		$ 73,920
D.	Electricity		$ 13,600
E.	Emergency Medical Service		$ 20,000
F.	Miscellaneous		$ 15,424
		Total	$2,256,377

Transportation and Disposal

The costs of transportation and disposal are summarized in Table 7. The total cost listed in Table 6 includes an additional $64,149 for miscellaneous transportation related costs, such as facility inspection and delivery monitoring. Also, the costs listed include a 15% subcontractor handling fee. Both trains and trucks were used for transportation. Train tankers held about 20,000 gallons (75,700 l). Tank trucks for liquids held 3,000 - 5,000 gallons while slide-off dumpsters for solidified sludge hauled 12 - 14 cubic yards each.

Four problems occurred during the transportation and disposal phase that increased costs. First, an additional transportation cost of $4,313 was incurred in September 1982 for double handling of non-hazardous oil. This extra handling cost occurred when on September 9, 1982 two tanker trucks, which had been loaded and inspected for shipment, were unloaded following a phone call from NYSDEC to NYCDEP. The NYSDEC halted the planned 100 mile (161 km) shipment to a rotary kiln in Marion, NY, south of Albany, becuase the facility's permit might have been revoked in the future. The transportation and disposal of the oil to the hazardous waste incinerator in Chicago (818 miles, 1316 km) also added some marginal cost compared to the Marion option. The second problem that occurred during transportation was leakage from two train tankers. While on route to the incinerator in Arkansas, a pressure valve on one tank car carrying PCB contaminated oil allowed the substance to splash on the sides of the tanker. On another car, substances splashed from an unplugged air vent valve and an ungasketed man-way. A third car arrived intact and sealed. The volume of spillage was unclear, because substances had expanded due to temperature changes. The NYCDEP's consultant, CH_2M Hill, travelled to the facility to inspect the cars, as well as renegotiate the incineration price, due to the unexpectedly high heavy metal content of the oil.

The third extra cost was incurred for extra handling of non-hazardous sludge when it could not be received by the Rollins facility in Bridgeport, NJ for technical reasons. On October 13, 1982, about 7,800 gallons (29,523 l) of non-hazardous sludge was pumped into two tank trucks, but upon arrival in Bridgeport they could not be pumped out by the facility's pumps. One tanker was emptied with difficulty but the other truck was returned and unloaded to pool 6 and tank J42 because Rollins believed that the sludge would clog the incinerator screens and appurtenances. This sludge was recategorized an non-pumpable.

TABLE 7. SUMMARY OF 1982 TRANSPORTATION AND DISPOSAL (a) COSTS
QUANTA RESOURCES, LONG ISLAND CITY, NEW YORK

Material	Quantity	Actual Expenditure Combined (Transportation/Disposal)	UNIT COST	
			Transportation (d)	Disposal (a)
PCB contaminated (b) oil	38,716 gallons(146,540 l) 1,740 miles (2,800 km)	$83,330 ($42,678/$40,652)	0.06¢/gallon/mile (0.01¢/l/km)R	$1.05/gallon ($0.26/l)I
PCB oil (over 500 mg/l)	1,163 gallons (4,402 l) 1,740 miles (2,800 km)	$7,607 ($6,386/$1,221)	0.32¢/gallon/mile (0.05¢/l/km)R	$1.05/gallon (0.26/l)I
Oil with over 10,000mg/l chlorinated organics	78,920 gallons(298,712 l) 818 miles (1316 km)	$36,466 ($29,837/$6,629)	0.046¢/gallon/mile (0.008¢/l/km)R	$0.084/gallon (I)
Non-contaminated oil	119,830 gallons(853,557 l) 818 miles (1316 km)	$45,254 ($39,262/$5,992)	0.04¢/gallon/mile (0.0035¢/l/k)R	$0.05/gallon ($0.01/l)I
Flammable Sludge	5,000 gallons (18,925 l) 100 miles (161 km)	$8,105 ($2,960/$5,145)	0.59 ¢/gallon/mile (0.097¢/l/km)T	$1.03/gallon ($0.27/l)I
Pumpable PCB contaminated sludge (b)	57,000 gallons(215,745 l) 1,420 miles (2,285 km)	$113,521 ($57,661/$55,860)	0.07¢/gallon/mile (0.01¢/l/km)R	$0.98/gallon ($0.26/l)I
Non-pumpable PCB Contaminated Sludge	430 cubic yards (329 m^3) 400 miles (644 km)	$86,410	$0.50/cu.yd./mile (c) ($0.41/m^3/km) T/L	
Cyanide Solution	9,425 gallons(35,674 l) 100 miles (161 km)	$15,495 ($2,771/$12,724)	0.29¢/gallon/mile (0.05¢/l/km)T	$1.35/gallon ($0.36/l)T
Non-pumpable PCB Sludge	1,705 gallons(6,453 l) 1740 miles (2,800 km)	$22,885	$0.0077/gal/mile (c) ($0.0005/l/km) T/L	
Contaminated diesel fuel (from decontamination)	1,100 gallons(4,164 l) 1340 miles (2160 km)	$4,416 (3)	$0.003/gal./mile(c) ($0.0005/l/km) T/I	
Non-hazardous Sludge	838 tons (760 Mt) 400 miles (250 km)	$149,730 ($91,070/$58,660)	$0.27/gallon/mile ($0.48/l/km)T	$70/ton ($77/Mt)L
	48 tons (44 Mt) 185 miles (295 km)	$8,280 ($5,640/$2,640)	$0.64/ton/mile ($0.43/Mt/km)T	$55/ton ($61/Mt)L
Miscellaneous	NA	$64,229	NA	
Total		$645,728		

(a) Incineration (I), Landfilling(L) or Treatment (T)

(b) Between 50-500 mg/l PCB

(c) Includes both transportation and disposal cost

(d) Rail (R) or Truck (T)

The fourth extra transportation cost was incurred during the transportation of non-hazardous sludge to landfills in Maryland (Browning Ferris Industries) and Niagra Falls, N.Y (SCA). Initially, NYCDEP had planned to dispose of solidified non-hazardous sludge in city-owned sanitary landfills. But because of long-term public concern about illegal hazardous material disposal in city-owned landfills, as well as illegal hazardous material incineration in apartment building boilers, NYCDEP decided that the Quanta disposal policy would be to dispose of all material, RCRA hazardous and non-hazardous, at permitted hazardous waste facilities. On November 3, 1983, 8 trucks transported solidified non-hazardous sludge to the BFI facility near Baltimore. After one truck was unloaded, the State of Maryland contended that the material was hazardous because of a low flash point, and halted unloading the other 7 trucks. The waste was recharacterized by OHM and CH_2M Hill, with the latter, an independent consultant, providing results showing it to be non-hazardous on November 9, 1982. Both used chromatograph mass spectrometry to identify the volatile organics. On the same date, the State of Maryland sent a letter to NYSDEC, noting that a gas chromatograph/mass spectrometry characterization would be needed. On November 16, 1982 the State of Maryland concurred with NYCDEP's analysis, and allowed disposal. In the intervening weeks, 838 tons (924 Mt) of non-hazardous sludge was sent 400 miles (295 km) to Niagra Falls to a permitted hazardous waste landfill at a cost of $1,000 transportation per truckload and $70/ton ($77/Mt) for disposal, compared with $700 transportation per truck load and $55/ton ($61/Mt) disposal for the 185 miles (298 km) to BFI. The NYCDEP's consultant, CH_2M Hill, concluded that, "After a thorough review of the circumstances related to the disposal problems at BFI, it is apparent that the rejection of Quanta non-hazardous sludge had less to do with the waste characterization data discrepancies as with inter-state regulatory political factors."

Management Consulting

The sum cost of $176,015 for management consulting by CH_2M Hill included assistance for proposal evaluation, contract negotiations, inventory assistance and on-site engineering. The $10,000 cost of the proposal evaluation work is the only cost that can be segregated from the other tasks.

Services performed by various city agencies cannot be precisely tallied, but some estimates on the level of effort were made. The Department of General Services paid for electricity, which was estimated at $8,100 for 90 days at $30/day, and $5,500 for the installation. The Department of Health and Hospitals paid for emergency medical services. This sum includes a specially equipped mobile first-aid station and supervisor, special transportation arrangements and the maintenance of medical profiles. About $20,000 was spent on equipment, and 2,140 hours of personnel time (54% overtime) and 246 hours of overhead were estimated. The NYC police provided about 2,000 hours of site surveillance.

Two 24 hour/day armed security guards, each with trained attack dogs, cost about $73,000. The site was guarded for about 22 weeks by a security service hired by the NYC Department of General Services from about June 16 - December 1, 1982. The unit cost for this level of security was $3,360/week or about $10/guard/hour. The services provided by NYCDEP BST can not be accurately accounted for, but level of effort by hours can be estimated. A total of about 4,000 hours was spent by the NYCDEP personnel on the preliminary assessment (1,100 hours) and survey/removal contract monitoring (3,000 hours). Over half (53%) of the contract monitoring was done on overtime. Miscellaneous NYCDEP expenditures totalled $15,424 including fence repair, flashpoint analysis equipment, preliminary tank sampling, safety coveralls, electrical supplies, waste drums and cans, rain coats, portable toilets, radiological survey and lab coats.

Future Cost

The future costs of work at Quanta are unquantified as of January 1983, but involve two primary tasks. The first is a hydrogeological study to determine the extent of subsurface contamination and remedial needs. The second potential cost is the implementation of a subsurface clean-up.

PERFORMANCE EVALUATION

The NYCDEP site response accomplished what it intended to accomplish—prevent a fire and toxic air emissions and remove hazardous wastes from the site. After its initiation in July 1982, the clean-up operation was performed effectively and rapidly with only a couple of relatively brief delays. Primarily, NYCDEP's meticulous and assertive oversight, and O. H. Materials' technical expertise and equipment, served to expedite this removal operation in a highly professional manner. The NYCDEP's management consultant, CH_2M Hill, helped resolve delays by providing an independent view of problems and solutions.

Three relatively minor technical changes could have improved the efficiency of the removal operation. First, the off-loading pumps at the disposal site to be used for non-hazardous sludge were less capable of pumping the sludge than the contractor's on-site sludge pumps. If the contractor had anticipated this problem, the cost of returning and off-loading the wastes could have been avoided. Second, the expansion of waste oil in the tank car traveling to Arkansas caused spillage through vents that could have affected sensitive populations en route. Extra head space to anticipate the spillage might have prevented this occurrence.

The third, and somewhat more general, technical improvement could have been made by undertaking a level of anlaysis that matched the selected disposal alternative. Since the policy decision was made, because of public concerns, to dispose of all wastes, hazardous and non-hazardous, at licensed hazardous waste facilities, the precise characterization at 13 distinct waste streams for disposal was unnecessary. A lower level of waste characterization, sufficient to analyze PCB, non-PCB and cyanide wastes, and segregate pumpable and flammable wastes would have been more cost-effective. The preliminary site survey, which cost NYCDEP about $2,000 and 1,000 hours of staff time, may have been adequate for this purpose with some supplemental testing. The OHM survey, which cost about $217,000 and created an extensive categorization of specific waste streams, was beyond the needs of general manifest requirements and PCB vs. non-PCB waste categorization. The specific analysis necessary for disposal cost determination could have been left for the disposal site operator to perform, with independently analyzed split samples.

The general problem of determining response authority and responsibility, which will be settled in court through the pending law suits, is largely beyond the scope of this technical evaluation, but it significantly affected the public health risk. During the several months when the various parties discussed their site response obligations, the public health threat at the site remained imminent. The need for parties to have clearly delineated authorities and responsibilities is as important in protecting public health as the technical innovation and expertise employed at the site.

In sum, however, the site response was successful in removing the imminent public health threat. Future work at the site will involve assessing and possibly mitigating surface, subsurface and ground water contamination. Also, the on-site structures will probably be removed for the site to be used in the future.

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RICHMOND SANITARY SERVICE

RICHMOND, CALIFORNIA

INTRODUCTION

NCP reference

Richmond Sanitary Service (RSS) is a commercially operated 350-acre (142 ha) landfill in Richmond, California. A 15-acre (6 ha) area of the site is used for disposal of Class I (hazardous) wastes, while the remainder of the landfill is used for Class II (non-hazardous) waste disposal. In 1975, the California Regional Water Quality Control Board (RWQCB) and the California Department of Health (DoH) found that the Class I area did not meet new state regulations regarding hazardous waste facility design and operation, and that the site posed a threat to surface waters, landfill employees, and air quality.

Background

300.68(e)(2)(iv) environmental effects

The RSS site is located on San Pablo Bay at the outlet of San Pablo Creek. The State-designated beneficial uses of the bay and the creek area are: recreation, aquatic, waterfowl, and migratory bird habitat, industrial water supply, and navigation. Richmond Sanitary Service began accepting municipal and industrial wastes in 1952. In 1973, the RWQCB ordered RSS to designate separate areas for Class I and Class II wastes. The designated Class I section, consisting of a six-acre (2.4 ha) drum burial area and a nine-acre (3.5 ha) liquid waste evaporation pond, was situated on top of an older layer of municipal solid waste.

Throughout the early to mid-1970's, state agencies cited RSS for numerous health, safety, and air pollution problems at the site. Drums of solid and liquid chemical waste often ruptured while being dumped from trucks, and were not segregated according to compatibility. Volatile liquids were dumped in the evaporation pond, causing nearby residents to complain of chemical odors. In 1975, the RWQCB ordered RSS to make a number of operational and design improvements in both the Class I and Class II areas. Richmond Sanitary Service responded with an engineering master plan for the site proposing a much expanded Class I area enclosed by a relatively impermeable bay mud subsurface barrier. In March 1976, the RWQCB rejected the Class I expansion plan but ordered RSS to construct a subsurface barrier, a two-foot high dike around the existing Class I area, and a basin to catch rainfall runoff and liquid waste overflow from the Class I area. Also in 1976, the DoH ordered RSS to improve waste handling and burial practices.

Synopsis of Site Response

On September 14, 1976, RSS began construction of the subsurface barrier, the dike, and the retention basin using RSS' own earth-moving equipment and operators. The work was inspected by the engineering firm that designed the improvements. The five-foot (1.5 m) wide barrier ranged from 5 to 30 feet (1.5 -9.1 m) deep, and was 2,765 feet (843 m) long. The new barrier was connected to 2,100 feet (640 m) of a pre-existing barrier to completely enclose a 25-acre (10.1 ha) area containing the Class I pond, drum burial area, and retention basin. The construction took 28 days over a seven-week period, including 16 days for the barrier and 12 days for the dike and retention basin. Six months later, ten monitoring wells were installed in the barrier.

300.70(b)(1)
(iii)(A)
impermeable
barriers

300.70(b)(1)(ii)
(B)(1)
dikes and berms

SITE DESCRIPTION

The Richmond Sanitary Service site is an active landfill which is permitted to accept solid municipal wastes (Class II) and hazardous wastes (Class I) from the San Francisco Bay Area. Class I wastes are currently limited to contaminated solids in the barrel storage area and acid and caustic rinse water in the holding pond.

Surface Characteristics

The site occupies approximately 350 acres (142 ha) of former marshland and tidelands adjacent to San Pablo Bay, in southwestern Contra Costa County. More specifically, it is situated at the foot of Parr Boulevard in the City of Richmond and is bounded on the west and southwest by the Bay and on the north by San Pablo Creek. The San Pablo Sewage Treatment Plant is located just west of the site. The area is highly industrialized. A large refinery is located less than 1.5 miles (2.4 Km) from the site boundaries.

300.68(e)(2)(i)
(A)
population at
risk

Figures 1 and 2 show the location of the site. Figure 2 also shows the relative location of the Class I and Class II areas. The Class I area comprises only about

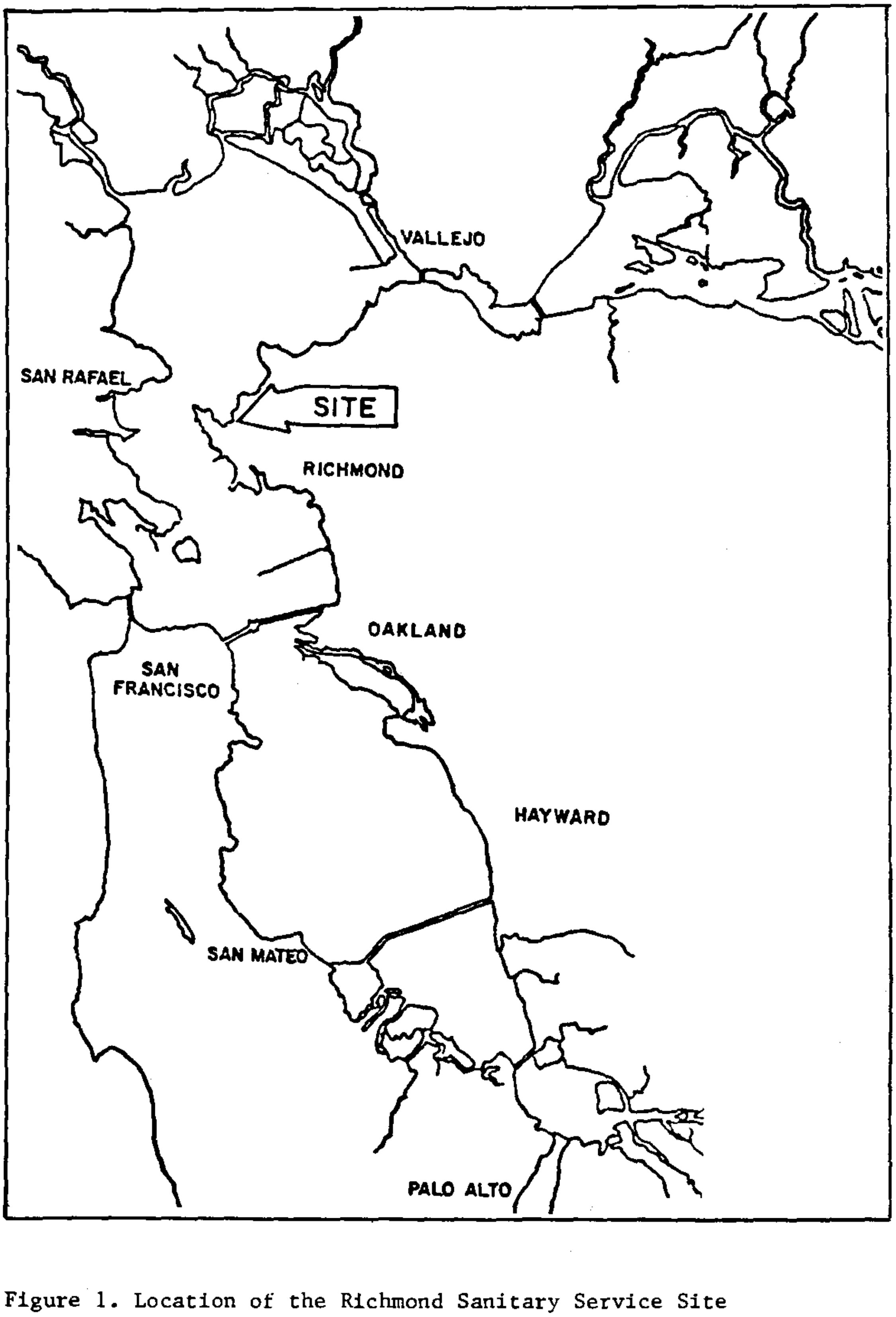

Figure 1. Location of the Richmond Sanitary Service Site
Richmond, California

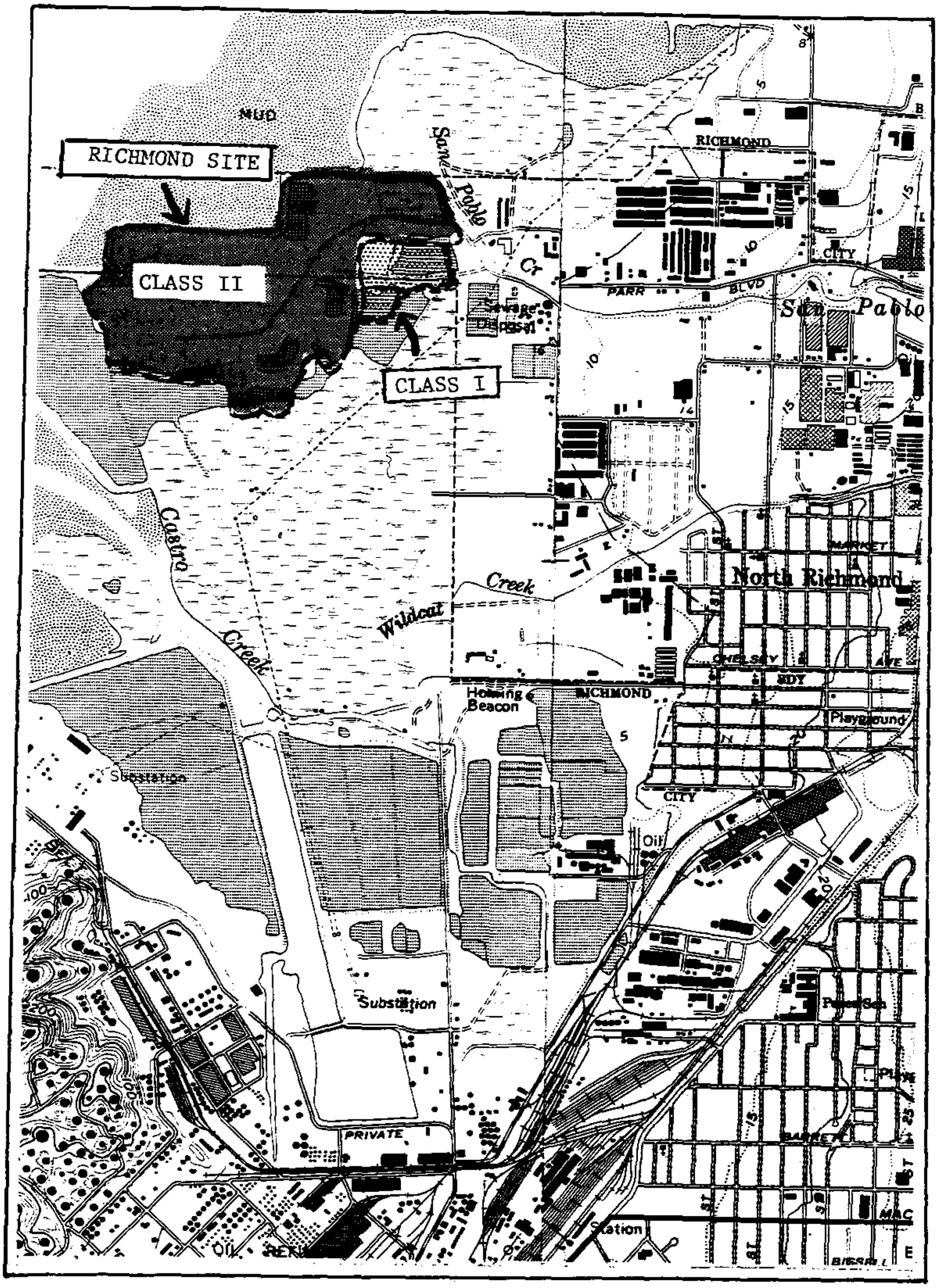

Figure 2. Location of the Richmond Sanitary Services Class I and Class II Disposal Areas in Richmond, California

25 acres (10.1 ha) or about 7 percent of the 350 acre (142 ha) landfill.

Because the site is situated in former tidelands and marshlands of San Pablo Bay, potential for flooding has been a concern. However, as Figure 2 illustrates, the Class I area is buffered from tidal action by the Class II area and by a perimeter dike. However, it should also be noted that lower San Pablo Creek closely parallels both the Class I and Class II areas along the northerly boundary of the site before emptying into San Pablo Bay. The magnitude of flood flow that reaches the Class I area is limited mainly by the channel capacity of San Pablo Creek and to a much lesser extent of Wildcat Creek.

300.68(e)(2)(i)
(D)
hydrogeologic factors

The San Pablo Bay area has cool, dry summers and mild, moist winters. The mean annual temperature is 58.2°F (14.6°C). The mean monthly temperature ranges from a low of 50.2°F (10.1°C) in January to 65°F (18.3°C) in September.

300.68(e)(2)(i)
(E)
climate

The average annual precipitation in Richmond is 22 inches (56 cm). The winters are moist and over 90 percent of the precipitation falls between November and May. Late in spring and summer coastal fog is common in the bay and usually clears by late morning. In winter, the relative humidity averages about 90 percent at night and 70 percent in the afternoon.

Hydrogeology

The RSS site lies in an alluvial valley which is covered with Reyes silty organic clay soils which are nearly level, very poorly drained, highly compressible, and nearly impermeable. These soils are commonly called Bay Muds. The water table is at or near the ground surface.

300.68(e)(2)(i)
(D)
hydrogeologic factors

Figure 3 shows the general geology in the area of San Pablo Bay. As shown, the alluvial valley in which the Richmond Site is located is separated from the bedrock formations to the northeast by the Hayward fault. The San Pedro - San Pablo fault separates the valley from the bedrock formation to the southwest.

The Hayward fault, located approximately 1.3 miles (2.1 Km) east of the site is seismically active and is one of the great earthquake faults in this part of California. The San Pedro - San Pablo fault is not considered to be seismically active. The San Andreas fault, although 16 miles (26 Km) southeast of the site, is considered to pose a greater threat than the Hayward Fault.

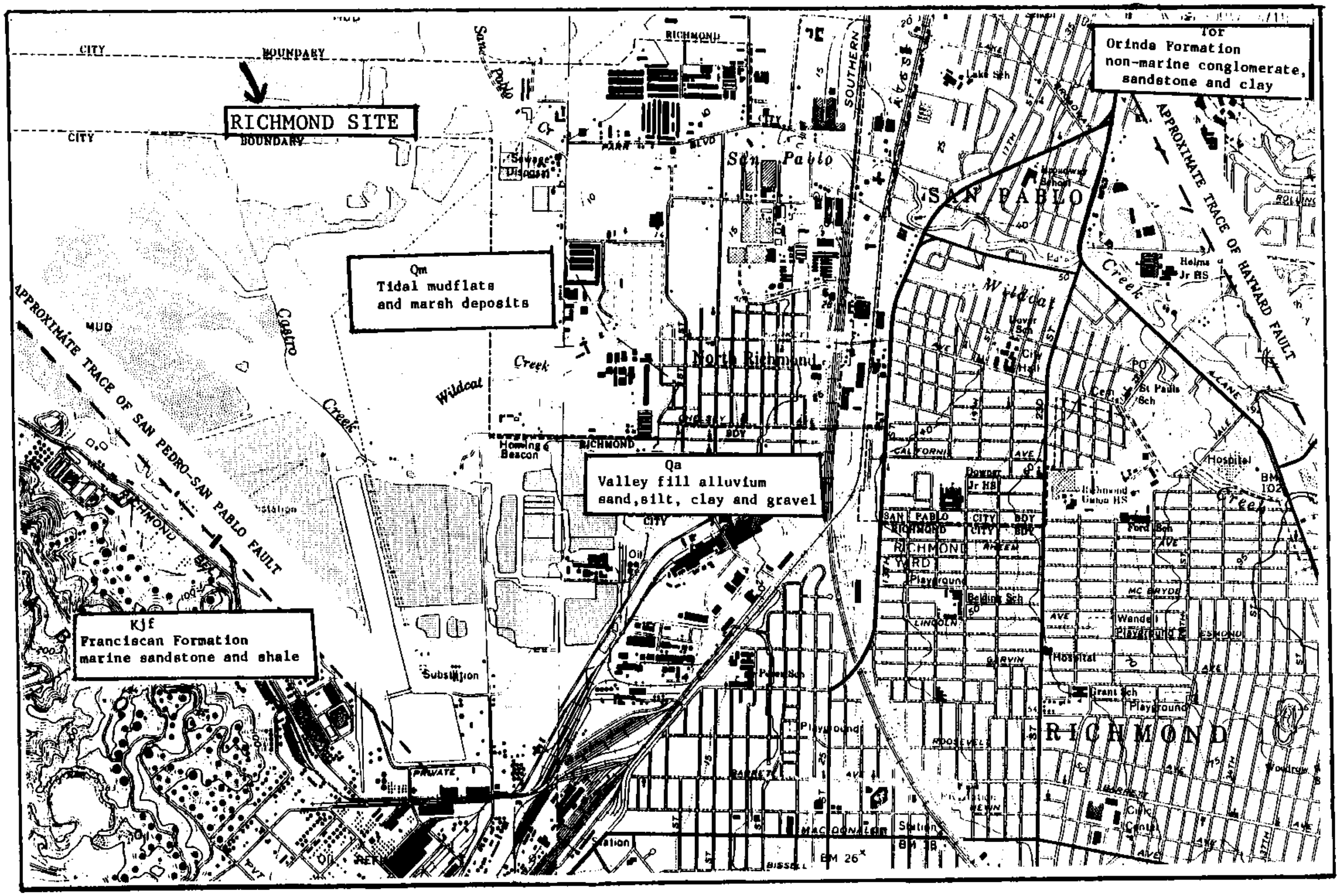

Figure 3. Surface Geology in the Area of the Richmond Sanitary Service Site

A combination of driller's water well logs, foundation borings, water level records, and etc. were used by Nevin and Ellis (1971) to construct a hydrogeologic cross-section of the area as shown in Figure 4. The alluvial valley is underlain by a considerable thickness of unconsolidated sediments consisting of silty clay with interbedded layers of sand, shells, and peat. These bay muds, as they are called, occur to a depth of at least 50 feet (15m) along the eastern boundary of the site and to at least 150 feet (46m) along the western boundary as shown in Figure 4. Lenses of sand found within the bay mud occur erratically and discontinuously. The bay mud is generally underlain by a sand unit deposited by stream channels which once traversed the area enroute to the Bay. These sand and gravel layers are sparse, highly variable in occurrence and generally only a few feet thick. These pervious layers are found mostly at depths below 100 feet (30m) where they constitute what is referred to in Figure 4 as the "deep aquifer zone". The zone constitutes the only productive aquifer in the area. It is encountered at depths of 80 to 100 feet (24 to 30m) several miles east of the study area but deepens to below 180 feet (55m) in the vicinty of the site.

This sand layer in turn overlies an older bay deposit which consists of stiff, silty clay. Bedrock is estimated to underlie the site at depths of about 300 feet (91m).

As shown in Figure 4 most of the aquifer material is overlain by thick, tight clay zones which serve as aquicludes to confine these aquifers under artesian pressure. The groundwater in the area is replenished mainly from percolation of streamflow in high areas considerably east of the project area where aquifers are not capped by impermeable clays and can receive surface water infiltration. The groundwater flows from these recharge areas towards the Bay. At the RSS site, groundwater flow is in a westerly direction towards the Bay but the hydraulic gradient is nearly flat and the rate of groundwater movement is very slow. Also, the highly impermeable bay mud and deeper clay deposits inhibit or greatly minimize lateral groundwater migration.

The capacity of the "deep aquifer zone" and the shallower sand lenses is rather limited since the zones are generally only a few feet thick and are discontinuous. Although well yields of 300 to 350 gallons (1136 - 1325 liters) per minute have been reported, the majority pump much less. Some wells which penetrate the most productive aquifer zone have a maximum yield of less than 50 gallons (189 liters) per minute.

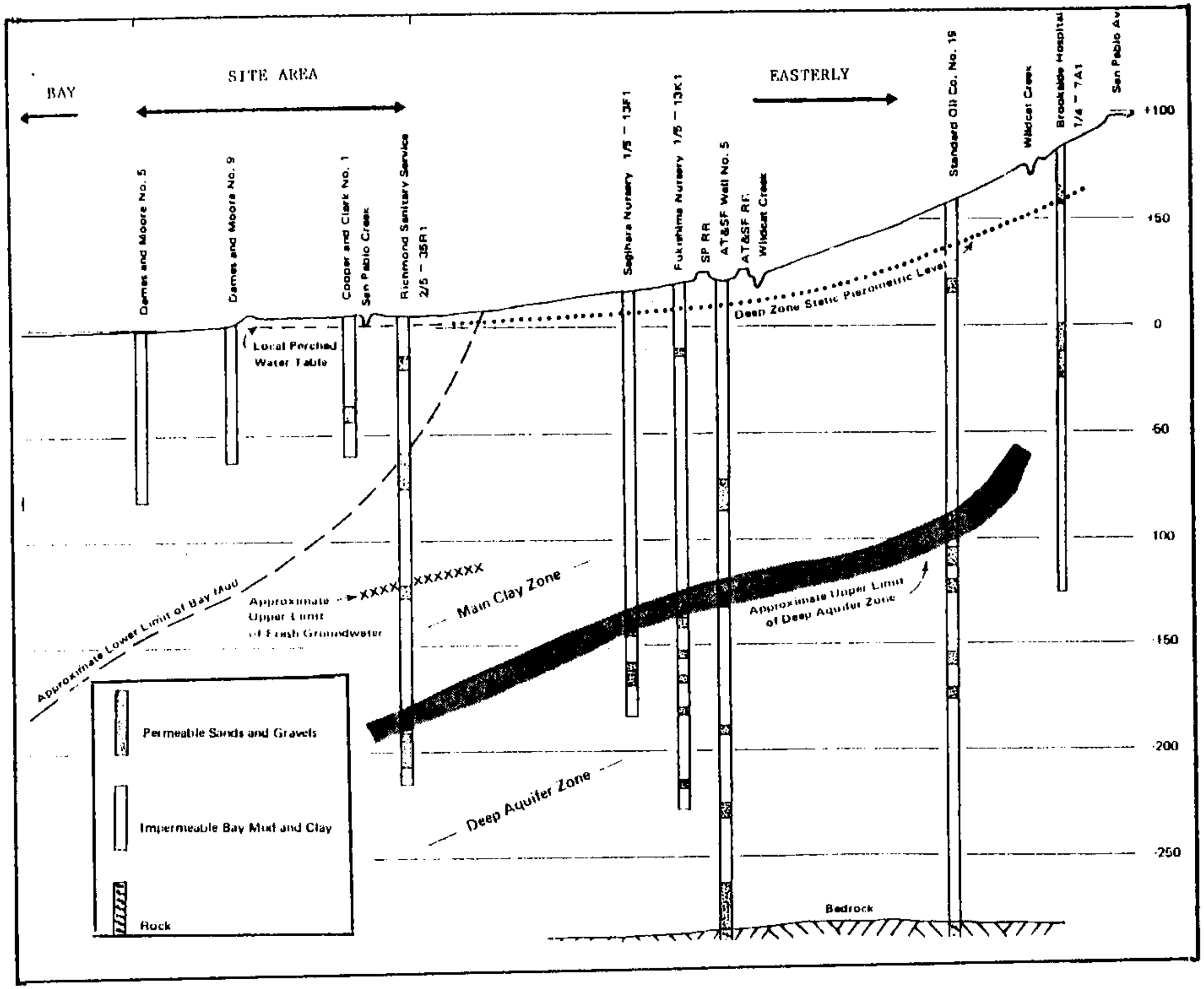

Figure 4. Geological Cross-Section of the Area around the Richmond Sanitary Services Site

Water levels in both shallow and deep wells are generally quite shallow where not influenced by pumping. However, pumping records show drastic drawdowns in many cases and specific capacities are commonly only 1 to 2 gpm of yield per foot (1.2 - 2.3 liter per minute of yield per meter) of drawdown.

Groundwater usage within the entire groundwater basin is very limited. There are no existing drinking water wells in the entire basin. In the locality of the site, aquifer zones located at depths of 50 to 100 feet (15 - 30m) are known to be brackish and unsuitable for most uses.

300.68(e)(2)(i)
(A)
population at risk

WASTE DISPOSAL HISTORY

The disposal practices at the Richmond site evolved over a 20 to 25 year period from haphazard, unregulated, dumping to carefully regulated and monitored disposal. This evolution paralleled the evolution of the State, and to a lesser extent, the Federal hazardous waste regulations.

Richmond Sanitary Service began acquiring the land currently used as a Class I and Class II disposal site in the early 1950's. In December of 1952, RSS was granted a land use permit by Contra Costa County for operation of a sanitary landfill. This permit, and a subsequent permit issued in 1960, placed minimal operational conditions for the handling of solid wastes, and handling of hazardous wastes was not addressed at all. As a result, throughout the 50's and most of the 60's RSS indiscriminately accepted hazardous wastes and took little or no precautions to protect public health, safety of the workers or the environment. Drums of wastes were often broken open, exposing workers and the public to flammable and toxic wastes. Incompatible wastes were not separated and volatile, toxic liquids were dumped indiscriminately. One of the few measures taken at the site during the 1950's was to construct a perimeter dike around much of the site.

300.68(e)(2)(i)
(c)
hazardous properties

In 1964, the Regional Water Pollution Control Board (predecessor of the present Regional Water Quality Control Board) issued a resolution requiring that disposal of solid municipal wastes and industrial wastes be done in a manner that is not detrimental to the state's waters. The Board established a self-monitoring program for RSS and ordered that they construct a dike to prevent wastes from leaching into the Bay. However, the resolution did not establish any operational requirement for handling hazardous materials.

300.70(B)(ii)(B)
(i)
dikes and berms

The 1970's marked the beginning of an increased awareness by the County and State of the problems at the Richmond Site. During 1970 about 1 x 10^6 gallons (3.8 x 10^6 l) of hazardous wastes and approximately 120,000 tons (109,000 MT) of non-hazardous wastes were discharged at the site. In 1971, the RWQCB was granted authority to establish specifications for solid waste disposal sites, including design and construction of any measures needed to protect state waters. The RWQCB ordered that the suitability of areas used for disposal of Class I wastes be determined based on soil engineering, hydrologic and hydrogeologic studies. Richmond Sanitary Service's consultants, Cooper-Clark and Associates, conducted these studies and made several recommendations for upgrading the site. In 1973, the RWQCB issued an order to RSS which incorporated Cooper-Clark's recommended site improvements and identified a Class I area for disposal of hazardous wastes and a Class II area for solid municipal wastes. Because RSS encountered unanticipated problems in meeting the requirements of various governmental agencies, the Class I facility was not upgraded at that time.

300.68(e)(2)(i)
(B)
amount and form of substances present

300.68(f)
remedial investigation
300.68 (g)
development of alternatives

The RWQCB was, however, investigating the site on a routine basis at this time. Several violations of the Board's order were documented. The most frequent violation was the deposition of hazardous wastes in the Class II area.

The state Department of Health (DoH) also investigated the site during the early 1970's and expressed concern over lack of precautions taken to ensure protection of workers and the public. Drums were still being disposed of haphazardly, incompatible wastes were not separated and volatile liquids were dumped indiscriminately. However until the passage of the California Industrial Waste Act of 1972, neither the RWQCB or the Department of Health had the authority to control operational aspects needed to protect public health and the environment. The Industrial Waste Act required the Department of Health to develop a hazardous waste control program by 1974.

300.68(e)(2)(i)
(C)
hazardous properties

In 1975, RSS submitted an engineering master plan for the site which proposed a much expanded Class I area enclosed by a bay mud subsurface barier. During 1975, the Department of Health, the RWQCB and the RSS site operators and their consultants, Cooper-Clark and Associates, met on several occasions to discuss needed improvements at the site. Although there was general agreement among the involved parties regarding the need for design and operational improvements, RWQCB rejected the expansion plan. They ordered RSS to construct the subsurface barrier, perimeter dike and retention basin. The Class I disposal area was upgraded between 1975 and 1978 to meet the requirements set forth by the RWQCB and the DoH.

300.68(c) state or federal evaluation of clean-up proposals

DESCRIPTION OF SITE INVESTIGATION

As part of the RWQCB's requirements that Richmond Sanitary Service institute a self-monitoring program to determine the acceptability of the site for handling Class I wastes, Cooper-Clark and Associates, under contract to RSS, conducted detailed soil engineering and hydrogeologic investigations of the site during 1971 and 1974. These investigations included the following activities:

300.68(f) remedial investigations

- Exploration of soil and ground water conditions in the existing and proposed Class I areas to depths that could potentially be affected by wastes
- Evaluation of physical characteristics of soil by laboratory testing
- Determination of potential reaction of wastes with bay mud.

Soil borings were drilled at 100 foot (30 m) centers to depths ranging from 3 to 60 feet (1 - 18m) using truck mounted, 5 inch (12.7 cm) diameter rotary-wash equipment. Undisturbed soil samples were taken using split-tube barrel samplers for visual inspections and laboratory testing.

Borings taken around the perimeter of the existing Class I pond encountered about 3 to 13 feet (0.9 - 4.0 m) of loose, permeable refuse. In one area 5.5 feet (1.7m) of chemical waste was encountered. The fills were directly underlain by bay mud containing varying amounts of sand lenses and peat. In contrast, very little refuse was encountered around what is now the barrel storage area, and the bay mud was relatively free of sand deposits at shallow depths. Groundwater was encountered within or above the fill in the existing filled area and near the ground surface in areas which remained unfilled.

Next, a series of soil engineering tests were performed on the bay mud and on the sand lenses. Testing included:

- Permeability of natural bay mud deposits and compacted bay mud materials. Natural bay mud was found to have a coefficient of permeability of

10^{-7} to 10^{-8} cm/sec. Bay mud compacted to 80 percent of maximum compaction at proper moisture content consistently had a permeability of 10^{-8} cm/sec.

- Determination of strength characteristics of bay mud using a portable Torvane Torsional Vane Shear test at natural moisture content. To aid in correlating the engineering properties of soil, moisture content and dry density tests were performed on all undisturbed samples.

- Grain size distribution tests on selected sandy soils.

Based on the results of field exploration and laboratory testing Cooper-Clark concluded that the bay mud was sufficiently impermeable to prevent leaching into the underlying ground water but that lateral seepage through the existing fill and sand lenses was a possiblity.

Although the permeability of the bay mud was extremely low, there was some concern over the potential for changes in permeability due to reactions with highly acidic or basic Class I wastes. The results of laboratory tests on bay mud samples saturated with a pH solution of 2 and 10 showed no changes in consolidation or permeability characteristics. No such laboratory tests were conducted to determine changes in consolidation or permeability characteristics as a result of exposure to organics. However, samples of bay mud from the existing Class I area which had been in contact with various waste types were tested, and showed no apparent change in permeability.

PLANNING THE SITE RESPONSE

Initiation of Response

In March 1976, the RWQCB ordered RSS to implement the site improvements in order to bring the facility into compliance with new hazardous waste disposal regulations. While no single incident triggered the order, the RWQCB concluded that the site posed a threat to state waters based on observations by state officials over the previous five years of numerous problems with the RSS facility design and operations. The order came after six months of negotiations between the RWQCB and RSS, during which RSS submitted proposals to greatly expand the Class I area pinto adjacent marshland and to construct a bay mud barrier enclosing the new Class I area.

The RWQCB rejected the expansion plans because RSS and the U.S. Army Corps of Engineers were then engaged in a dispute over the legitimacy of RSS' claim to title over the marshland. The RWQCB instead ordered RSS to construct the proposed barrier only around the existing 15-acre (6 ha) Class I area and an adjacent 5 acres (2 ha), which was to contain a retention basin for rainfall runoff from the Class I area and overflow from the Class I pond in the event of a dike failure. Figure 5 shows the layout of the Class I area. The order to build the barrier was part of a larger effort from 1975 to 1978 by the RWQCB and the DoH to improve the design and operation of both the Class I and Class II areas at the RSS site.

Selection of Response Technologies

Based on detailed hydrologic, hydrogeologic, and soil engineering studies performed by Cooper-Clark and Associates it became apparent that, although the low permeability of bay mud prevented vertical migration into underlying ground water, there was a potential for lateral migration into surface waters through existing refuse or sand lenses. These studies also indicated the potential for releases of hazardous chemicals in the event of flooding or seismic activity. Based on these studies and subsequent discussions with Cooper-Clark and Associates, the RWQCB ordered RSS to implement the following improvements:

- Construction of an underground, impermeable barrier which was to be keyed into the impermeable bay mud

- Construction of a perimeter dike surrounding the Class I area to prevent flooding

- Construction and maintenance of a retention basin with adequate capacity to contain maximum runoff plus maximum volume of liquid which would escape the Class I pond in event of a dike failure

- Installation of monitoring wells

- Raising the interior dike around the Class I pond to provide sufficient elevation and slope to ensure stability in the event of seismic activity.

Inspections made by the Air Pollution Control District and the DoH throughout the early and mid-1970's and complaints from area residents of odors indicated that severe potential hazards still existed at the site. These included disposal of extremely hazardous chemicals, mixing

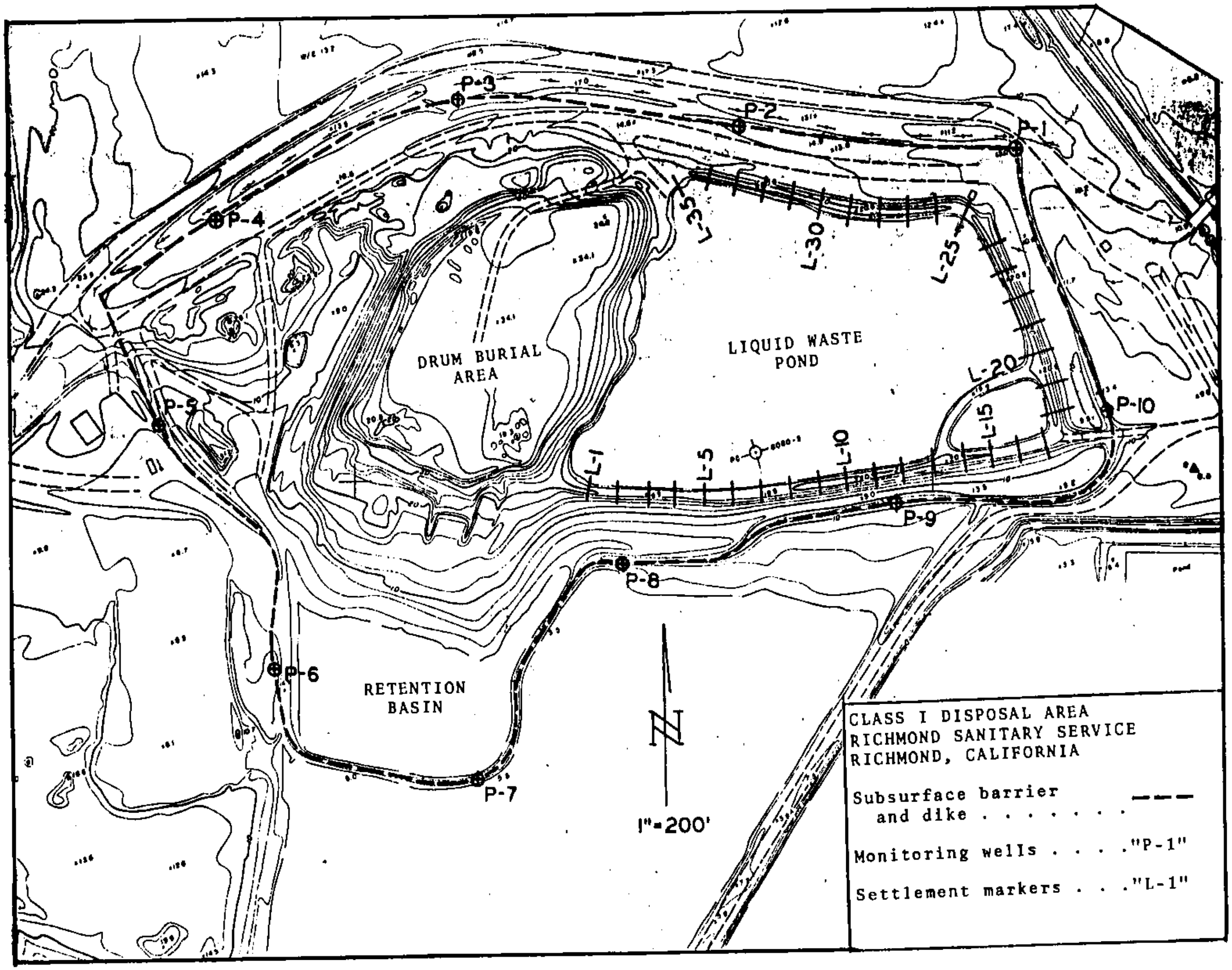

Figure 5. Layout of the Class I Disposal Area

of incompatible wastes, haphazard disposal of drums such that drums ruptured and leaked and lack of adequate safety precautions in handling wastes.

In November 1976, after the DoH's 1975 recommendation for operational improvements had not been implemented, the Department threatened issuance of a cease and desist order unless RSS made certain operational improvements. Richmond Sanitary Service initiated these improvements shortly thereafter, including separation of incompatible wastes in the barrel storage area and safer handling of drums and liquid wastes.

Extent of Response

The RWQCB specified in its order to RSS that the subsurface barrier be at least 5 feet (1.5 m) wide and have a permeability of not greater than 1×10^{-8} cm/sec. The depth of the trench excavated for the barrier was to extend at least two feet (0.6 m) into the underlying layer of bay mud. The order further required that the 2-foot (0.6 m) high dike surrounding the Class I area be compacted sufficiently to meet the 1×10^{-8} cm/sec permeability standard, that the retention basin be of a sufficient volume to contain any liquid waste release in the event of a failure in the Class I pond dike, and that ten monitoring wells be installed at equal intervals in the barrier. The RWQCB based the design criteria on facility standards set forth in State hazardous waste facility regulations. Since the site rested on a 50 to 150 foot (15 to 46 m) thick layer of bay mud with a permeability of 10^{-6} cm/sec., forming an effective aquiclude between the Class I wastes and the nearest useable ground water, State officials believed that the barrier would sufficiently mitigate the threat to State waters.

300.68(i)
extent of remedy

300.68(e)(2)(v)
state approach to similar situations

The order listed other operational improvements, requiring that two feet (0.6 m) of freeboard be maintained in the liquid waste pond, that each layer of buried drums be covered with at least 1 foot (.3 m) of compacted soil, that the height of the drum burial area not exceed 43 feet (13 m) feet above sea level, and that the retention basin not be used for waste disposal.

DESIGN AND EXECUTION OF SITE RESPONSE

The response activities designed to prevent surface water contamination and to minimize the risk to public health and worker safety were implemented between 1976 and 1978. The activities were conducted and funded by RSS under the supervision of the RWQCB and the Department of Health.

Construction of Impermeable Barrier, Perimeter Dike and Retention Basin

In order to protect adjacent surface waters from pollution caused by lateral or vertical seepage, an impermeable, underground barrier was constructed around the perimeter of the Class I area, and the area was enclosed with a dike to protect against flooding and ensure containment of runoff. Both the underground barrier and the perimeter dike were constructed using bay mud excavated from the site. The inherently low permeability and ready availability made the bay mud an excellent choice for the barrier material.

RSS began construction of the site improvements on September 14, 1976 and completed most of the work by October 30, 1976 in accordance with plans and specifications developed by the RWQCB and Cooper-Clark and Associates. The specifications required that the underground impervious key was to be a minimum of 5 feet (1.5 m) wide and extend a minimum of 2 feet (0.6 m) below the refuse material where it was keyed into the underlying bay mud. Where sand lenses were encountered within 5 feet (1.5 m) of the bottom of the fill, the trench was to be excavated through the sand and 2 to 3 feet (0.6 - 1 m) into the underlying mud. The newly constructed barrier was also to be keyed into those portions of the barrier which had been constructed during previous years. The "old" barrier had been constructed along the northeast and south boundaries of the Class I Pond and along the western perimeter of what was later to be the retention basin. The new barrier was 2,765 feet (843 m) long, and the old barrier was 2,100 feet (640 m) long.

(300.70(b)(1)
(iii)(A)
impermeable
barriers

The trench was excavated using a hopto, which is a large, track-mounted backhoe. Although the trench was required to be only 5 feet (1.5 m) wide, it sometimes reached 8 to 10 feet (2.4 - 3.0 m) wide in areas of heterogeneous refuse fill. During excavation, the backhoe encountered a considerable amount of refuse as well as demolition debris, chemical waste and drums. These materials were removed from the trench and disposed of in the Class II area. At one point during trench excavation, flammable liquids were encountered and the trench caught on fire. No safety equipment was worn by field personnel despite the fact that hazardous materials were encountered. Because of the considerable thickness of refuse and sand lenses encountered, it was necessary to excavate the trench to depths of 20 to 30 feet (6 - 9 m) in some

300.71
worker health
and safety

areas. The backhoe had a reach of only about 20 feet (6.1 m). Consequently, it was sometimes necessary to use a track-type dozer to excavate about 10 feet (3.0 m) below grade adjacent to the trench to serve as a temporary working area for the backhoe so it could excavate to the required depths.

Inflow of water into the trenches was another problem encountered during excavation. Inflow was particularly rapid in areas of more permeable refuse fill, and in the area of the Class I pond due to seepage of liquid wastes. However, the need for dewatering was eliminated by excavating and backfilling in about 30 linear foot (9 m) segments, avoiding long lengths of unsupported open trench.

A dragline was used to excavate the bay mud used for backfill from an area southeast of the retention basin. In some areas sand lenses were encountered and this material, unsuitable for backfilling, was discarded. The bay mud was dumped into trucks from the dragline and hauled to the work area where it was dumped into the trench. Dozers were also occasionally used to push the mud into the trench.

It was necessary to closely coordinate the rate of trench excavation and backfilling. If the excavation proceeded too far ahead of backfilling there was likely to be considerable inflow of water into the trench and dewatering would be needed. If, on the other hand, hauling of the bay mud for backfilling proceeded too far ahead of excavation, the material would be unsuitable for backfilling because it was required that it be dumped at its natural moisture content without letting it dry.

As requested by RWQCB, Cooper-Clark took undisturbed samples from the completed barrier at less than 500 foot (150 m) intervals for permeability testing. Both the "new" and existing barriers had permeabilities on the order of 10^{-8} cm/sec in compliance with the RWQCB's order.

Following completion of the key, RSS began construction of the above ground perimeter dike. The perimeter dike was constructed to a height of about 2 feet (0.6 m) above ground level which was considered adequate to prevent Class I area runoff from entering the Class II area. The completed dike area was 4,900 feet (1494 m) long.

300.70(b)(1)(B)
(B)(1)
dikes and berms

Again, bay mud was hauled in trucks from the area southeast of the retention basin. Large track-type bulldozers were used to roughly shape the slopes of the dikes. Smaller bulldozers, equipped with extra wide tracks, were used for polishing and finishing the slopes. The retention basin was also graded and finished using mainly the larger bulldozers for shaping and grading and a smaller bulldozer for final polishing. The dike was compacted to at least 80 percent of maximum density in order to attain the required permeability of 10^{-8} cm/sec. In order to ensure the adequacy of the dikes, laboratory permeability tests were performed on samples taken at less than 500 foot (150 m) intervals. Permeabilities on the order of 10^{-8} cm/sec were achieved consistently. Field density tests were performed at intervals of less than 500 feet (150 m) according to ASTM Test Procedure D1557-70 to ensure that the bay mud was compacted to the required 80 percent.

Installation of Monitoring Wells

In July 1977, Cooper-Clark installed ten monitoring wells at equal distances within the containment structure enclosing the Class I areas. The wells were drilled with a truck-mounted 7 inch (17.8cm) diameter, rotary wash drill rig approximately along the centerline of the containment structure. The wells extended through the existing bay mud key and at least 1 foot (0.3m) into the natural bay mud. The depth of the wells ranged from 10 to 13.5 feet (3.0 - 4.1m). It was essential for Cooper-Clark to install the wells within the barrier so that wastes which had been disposed of outside of the barrier limits during the 1960's and early 1970's would not be detected during monitoring.

After drilling each well, a 4 inch (10.2cm) diameter, perforated PVC pipe surrounded by at least 1 inch (2.5cm) of filter material consisting of 1 inch (2.5cm) maximum size pea gravel was installed. A cap was provided for each pipe, and the top 2 feet (0.6m) of backfill around the pipe consisted of impermeable bay mud to prevent surface water infiltration into the well. These wells are monitored quarterly by EMCON Associates and the data is submitted to the RWQCB.

Class I Pond

During late 1976 and early 1977, the 9 acre (3.6 hectare) Class I liquid pond came under critical examination by the RWQCB, the DoH and the Air Pollution Control District. The pond was filling up and the 2 foot (0.6 m) freeboard limit placed on it by the RWQCB was exceeded. On January 4, 1977, the RWQCB ordered RSS to stop placing waste in the pond.

The reason the pond exceeded it's freeboard limit was apparent. Prior to installation of the underground barrier, the pond acted as an infiltration basin, allowing the liquid wastes to seep into the old underlying refuse. Construction of the barrier in October 1976 severely restricted further infiltration. Also a persistent layer of 2 to 5 inches (5-13 cm) of oil on the pond prevented the liquid from evaporating.

In order to meet the requirements for a minimum of 2 feet (0.6m) of freeboard, it was necessary to raise the crest of the perimeter dike to an elevation of 21 feet (6.4m). The RWQCB granted permission to raise the elevation provided the following stipulations were met:

- o The permeability of the dike was not to exceed 10^{-8} cm/sec

- o The crest width was to be at least 5 feet (1.5 m)

- o Inboard and outboard slopes could not be steeper than 3:1 (horizontal to vertical) to assure slope stability in the event of seismic activity.

The crest of the dike surrounding the pond was elevated using procedures similar to those used for constructing the perimeter dike. The same types of large and small bulldozers were again used to shape, compact, and polish the dike.

Following completion of the dike, the RWQCB required that permanent settlement bench marks and liquid gauges be installed at equidistant intervals around the perimeter of the pond. The settlement bench marks consisted of nine capped steel pipes driven into the top of the dike at 200 foot (61 m) intervals. The liquid gauges consisted of four welded steel staff gauges which were installed at 400 foot (120 m) intervals. The top of the gauges were set at elevation 21 feet (6.0 m) to allow a direct reading of the pond freeboard relative to the top of the dike.

Loading Rate Determinations

Elevating the crest of the dikes to 21 feet (6.4 m) was not sufficient justification for reopening the Class I pond. The RWQCB required that RSS conduct an evaporation rate study in order to determine the liquid loading rate which could safely be accepted. They also required documentation that the retention basin located south of the barrel storage area had sufficient storage capacity to contain runoff and any conceivable discharge from the pond in the event of a failure of the perimeter dike.

Initially the engineering firm of Kister, Savio and Rei, Inc. submitted an evaporation study in which they estimated that 730,000 gallons (2.8×10^6 l) of liquid per month evaporated from the pond. However, the RWQCB considered this loading rate to be very optimistic. It assumed that the evaporation rate from the pond would be equivalent to pure water. This assumption was not true since, as the salt concentrations increased within the pond, surface tension increased and evaporation decreased. Also the industrial discharge to the pond typically contained substantial amounts of floatable oils which effectively prevented evaporation from the surface.

The RWQCB therefore recommended that the actual evaporation rates be monitored. Cal Recovery System Inc. made actual measurements of the evaporation rates between December 1977 and May 1978. Based on these studies they concluded that an acceptable loading rate was 500,000 gallons (1.9×10^6 l) per month, provided that the pond was cleaned periodically and that the rate be adjusted to reflect any unusual conditions such as very heavy rains or excessive oil and debris. This loading rate met with the approval of the RWQCB provided the 2 foot (0.6m) minimum freeboard was maintained.

The next task was to determine the adequacy of the retention basin tocontain Class I liquids in the even of a dike failure around the Class I pond. To answer this question, it was necessary to define a conceivable dike failure. Due to the configuration of the adjacent ground surface, Cooper-Clark determined that there was no possibility of failure to the north, west, and most of the east of the perimeter dike. However, in the event of the maximum credible earthquake along the San Andreas Fault, there was the possibility of lateral movement along the southern perimeter of the pond but not complete dike failure.

Cooper-Clark determined the stability of these slopes in the event of seismic activity using the "SHAKE 2" computer model made available through the University of California at Berkeley and was later confirmed using the results of the more complete "LUSH" program.

Assuming the most severe set of circumstances; that is a maximum lateral movement of the southern perimeter dike and maximum runoff resulting from a 100-year storm of 24 hour duration, Cooper-Clark determined that the retention basin would be filled only 61 percent of its capacity or 3.6×10^6 gallons (13.6×10^6 l). Therefore, the capacity of the retention basin was considered adequate.

Implementation of Waste Management Practices for the Class I Evaporation Pond and Retention Basin

Following completion of these remedial measures and studies for the Class I Pond, the pond was reopened. The RWQCB stipulated that RSS could accept up to 500,000 gallons (1.9×10^6 l) per month (provided a minimum 2 foot freeboard was maintained) of Class I liquid wastes with the exception of pesticides, paint sludges, solvents, tetraethyl lead sludge and oil, which cannot be accepted. The pH of the pond is now maintained near neutrality due to a balance of caustic and acid wastes.

In order to insure a minimum freeboard of two feet and to optimize evaporation, the pond is periodically skimmed to remove oils and animal fats which rise to the surface as a result of their disposal in the 1950's and 1960's. Skimming is only required infrequently when about 20% of the pond is covered with oil. The oil is pumped into a small adjacent pond and is later sold for fuel.

Finally the liquid level in the retention basin must be maintained such that sufficient capacity exists to store liquids from the Class I pond in the event of a dike failure. In order to ensure this capacity, rainwater is periodically pumped from the retention basin directly to the San Pablo Sewage Treatment Plant for treatment. Richmond Sanitary Service has an agreement with the treatment plant whereby the landfill accepts secondary sewerage sludge from the treatment plant in exchange for free treatment of the retention basin effluent. The effluent from the retention basin can be discharged directly into the bay if it meets minimum discharge requirements.

Implementation of Remedial Measures and Waste Management Practices for the Barrel Storage Area

In 1976, both the RWQCB and the DoH issued requirements for upgrading the barrel storage area. The RWQCB required that RSS submit a slope stability analysis for analysis for the slopes around the barrel storage area specifying the maximum slope and height of fill which could be developed without exceeding 80 percent of the shear strength of the underlying material. Slope stability was determined using the previously mentioned "SHAKE 2" and "LUSH" methods of analysis and assuming the maximum credible earthquake along adjacent portions of the San Andreas Fault. Based upon this analysis Cooper-Clark concluded that the maximum allowable slope should be 8:1 except for the easterly slope adjacent to the Class I pond, which should not be steeper than 4:1. The RWQCB also required that the barrel storage area not have an elevation greater than 43 feet (13m) above mean sea level to further assure slope stability.

During the later months of 1976 and early 1977, RSS instituted numerous operational improvements for the barrel storage area as required by the DoH. Bay mud and other clays were used to construct four separate barrel disposal cells for each of the following categories of waste:

- Acids
- Alkalies and cyanides
- Strong oxidizers
- Pesticides, solvents and organic chemicals.

The cells were separated with a minimum of 5 feet (1.6m) of clay or bay mud.

Special equipment was purchased so that drums could be unloaded and disposed of without damage. Equipment operators were required to wear respirators and safety shields were installed on the front of drum unloaders.

In February 1980, DOH ordered implementation of additional measures to upgrade the barrel storage area. These measures included:

- Bury the containers with a volume of soil sufficient to absorb the total volume of liquid in the drum.
- Completely cover the drums with earth at the end of the day
- provide a minimum of 1 foot (0.3m) of compacted soil prior to starting the next layer.

Rather than meet these requirements, RSS stopped accepting drums containing more than 10 percent liquids. They are currently accepting bulk or containerized contaminated soils or solids. A closure plan has been developed for the barrel storage area.

COST AND FUNDING

Source of Funding

Richmond Sanitary Service paid for construction of the site improvements out of its operating budget.

Selection of Contractors

Since RSS used its own equipment, operators, and materials to implement the site improvements, no contractor selection process occurred. Richmond Sanitary Service hired Cooper-Clark and Associates, a foundation engineering firm, to design the site improvements and oversee their construction. Richmond Sanitary Service based its selection on Cooper-Clark's longstanding business relationship with RSS and their familiarity with the site.

300.68(c) responsible party

Project Costs

While RSS made a number of site improvements from 1976 to 1978, this cost analysis focuses only on the major actions: the barrier, the perimeter dike, and the retention basin. Because RSS primarily used its own workers and equipment for the project, invoices were not available with which to calculate the precise cost of the work. Operators and earth-moving equipment were borrowed as needed from the daily landfill operations. Consequently, an estimate of the cost of implementing the site improvements was based on standard rates for contracting similar labor and equipment multiplied by the number of days and hours spent on the project. Since all of the bay mud used for the site improvements was taken from other areas of the landfill, the only material costs were for monitoring wells.

While the work occurred in 1976, 1983 rates were used to estimate the cost of the project, in order to make the costs more current. It is important to note that the estimated costs were based on limited data, and may vary from the actual cost by as much as 30%. The rates used were taken from Mean's Building Construction Cost Data 1983. Most of the costs were calculated from bare cost rates for daily equipment rental, hourly operating cost, and hourly labor, without including overhead and profit. However, since RSS hired trucks from outside to haul mud, the hauling estimate includes overhead and profit, and was calculated on a per-cubic-yard basis. A summary of the cost is provided in Table 1.

The total cost of constructing the 2,765-foot (843 m) long subsurface barrier, the 4,900-foot (1,494 m) long, two-foot (0.6 m) high compacted mud dike, and the 5-acre (2 ha) retention basin was about $111,000, in 1983 dollars. The bulk of the cost, about $77,000, was for excavation and earth moving. The remaining $34,000 was for Cooper-Clark's engineering services.

TABLE 1. SUMMARY OF COST INFORMATION-RICHMOND SANITARY SERVICE, RICHMOND, CALIFORNIA

Task	Quantity	Expenditure (1983 dollars)	Unit Cost	Period of Performance
Constructing subsurface barrier	7,313 cu.yds. (5,592m^3)	$56,118	$7.67/ cu. yd. ($10.03 m^3)	9/14/76-10/13/76
Constructing dike, basin		$20,718		10/18/76-11/9/76
Site investigation and design		$15,000		1976
Installing monitoring wells	10 wells	$15,000	$1,500/ well	6/28/77-7/7/77
Inspection Oversight of Construction	30 days	$4,200	$140/day	9/14/76-11/9/76
Total Cost		$111,036		

Subsurface Barrier

The total cost of building the 2,765-foot (843 m) long barrier, excluding engineering, was $56,118, or $20.29 per linear foot ($66.56/m). Since the depth of the trench varied from 5 to 30 feet (1.5-9.1 m), a more meaningful unit measurement of the cost is that 7,313 cubic yards (5,592 m^3) of trench fill were replaced with an equal amount of bay mud, at a cost of $7.67 per cubic yard ($10.03/ m^3) of replaced soil. Excavation of the trench cost $18,895 for rental and operation of a track-mounted, diesel, hydraulic backhoe and a large D-8 dozer. Excavation of bay mud from a borrow area elsewhere in the landfill cost $11,043 for operation of a dragline. Hauling bay mud in dump trucks to the trench, and hauling trench spoils to the Class II area cost $26,180. The cost of backfilling the trench is included in the hauling figure since most of the mud was dumped directly into the trench from trucks.

Dike and Retention Basin

The total cost of building the 4,900-foot (1,494 m) long, two-foot (0.6 m) high dike around the Class I area, and of building the 5-acre (2 ha) retention basin, was $20,718. Dragline excavation of bay mud cost $2,734, hauling cost $3,241, and basin excavation, grading, dike construction and compaction cost $14,743, using small dozers (D-6's and a JD-350) and a loader.

Engineering

The total cost of Cooper and Clark's engineering services was $34,000, including $15,000 for site investigation and design of the site improvements, $15,000 for installing ten monitoring wells in the barrier, and $4,200 for inspection and oversight during construciton.

Cost Components

The construction costs listed above are based on the following rates for rental and operation, and on the indicated amount of time each piece of equipment was used.

(1) Backhoe, diesel hydraulic, crawler mounted, 1.5 cubic yard (1.14 m^3) capacity; 17 days, 116 hours; <u>$10,883</u>. ($400/day rental, $15.80/hour operating cost, $19.40/hour labor.)

(2) D-6 Caterpillar dozer, 140 h.p.; 20 days, 160 hours: <u>$11,062</u>. ($295/day rental, $13.30/hour operating cost, $18.90/hour labor.)

(3) D-8 Caterpillar dozer, 300 h.p.; 9 days, 48 hours: <u>$8,012</u>. ($655/day rental, $25.20/hour operating cost, $18.90/hour labor.)

(4) Dragline, 1.5 cubic yard (1.14 m^3) capacity; 9,124 cubic yards (6,976 m^3): $13,777. ($1.51/cubic yard, $1.97/ m^3)

(5) Hauling, 12-cubic yard (9.17 m^3) dump trucks and 1-mile (1.6 km) round trips; 9,124 cubic yards (6,976 m^3) bay mud, 7,313 cubic yards (4,592 m^3) trench spoils: $29,421. ($1.79/cubic yard $2.34/$m^3$), including overhead and profit.)

(6) JD-350 dozer, 75 h.p.; 3 days, 234 hours: $994. ($128/day rental, $6.50/hour operating cost, $18.90/hour labor.)

(7) Loader, tractor, wheeled, 130 h.p.; 5 days, 40 hours; $2,697. ($255/day rental, $16.65/hr operating cost, $18.90/hour labor.)

PERFORMANCE EVALUATION

Based on all indications, the response activities undertaken at Richmond Sanitary Service have been effective in controlling migration of contaminants and in protecting public health and worker safety. By installing a system of dikes and an underground barrier composed of bay mud, RSS was able to take advantage of the low permeability of the natural silty clays found beneath the site to effectively control the source of contamination at a relatively low cost. The bay mud barrier and dikes were such logical choices for the response technology that no other technologies received serious consideration.

Available monitoring data verifies the performance of the barrier. As of August 1982, the results of groundwater monitoring have not detected any leakage of contaminants through the underground barrier. Another indication of the effectiveness of the barrier is the fact that the Class I liquid waste pond began to fill up rapidly after the barrier wall was completed. Prior to construction of the barrier, the Class I pond was acting as an infiltration basin allowing liquid wastes to seep into the underlying landfill. The barrier has restricted further infiltration.

Also, the dikes surrounding the Class I area have generally been effective in controlling runoff and flood waters. However, in February of 1980, there was a failure of the dike surrounding the retention basin during an intense rainstorm. This dike was redesigned and reconstructed and no further problems have been reported.

There is no information on the volume or type of contaminants which may have been dumped outside of the underground barrier prior to its construction and the extent to which these contaminants may be migrating into San Pablo Bay. However, the potential for migration into the Bay has been greatly minimized by construction of a second barrier around the entire perimeter of the 350 acre (142 ha) site. This barrier was required to have a maximum permeability of a 10^{-6} cm/sec. as compared to 10^{-8} cm/sec for the Class I barrier.

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TRAMMELL CROW COMPANY

DALLAS, TEXAS

INTRODUCTION

NCP reference

The Trammell Crow Company bought a 133 acre (53.2 ha) tract of land in western Dallas for development as an industrial park. The site had been used by the Texaco Oil Company as a petroleum refinery and tank farm from 1915 to 1945 but had been vacant since then. Oil sludge and coke cinders were stored on-site in five open ponds and totalled approximately 5,000,000 gallons (1.9×10^7 l) of sludge and 10,000 cubic yards (7,600 m^3) of cinders. Trammell Crow obtained an Urban Development Action Grant from the U.S. Department of Housing and Urban Development and a grant from the City of Dallas to finance part of the infrastructure of its industrial park, which included remedial action concerning the waste ponds. Waste kiln dust and fresh kiln dust were used to solidify the oil sludge and cinders and the resulting mixture was landfilled on-site. This innovative and economical technique was used in this instance for non-hazardous substances, but has possible applications on EPA defined hazardous wastes as well.

Background

The Texaco Oil Company operated a petroleum refinery on what is now the Trammell Crow site from 1915 to 1945. During that period, oil sludge from tank bottoms and coke cinders from the refinery's petroleum processing were put into five open ponds located on the premises. After closing the refinery in 1945, Texaco sold the property to Rogers and Wright, a Tulsa scrap metal firm that bought the property to salvage the tankage, piping and metal in the refinery. After reclaiming the metal, Rogers and Wright sold the land in 1959 to the Zale Corporation who held the land until 1980, when Trammell Crow purchased it.

Trammell Crow knew of the oil ponds when it bought the land. It planned to develop the site in two stages, with the second stage involving the acreage that contained the ponds. The Albert H. Halff Associates (Halff), a firm of consulting engineers and scientists, was hired to design roads, water mains, sewers and surface water drainage for the entire 133 acre (53.2 ha) site. Halff also was responsible for analyzing and supervising clean-up work. Halff took samples of the wastes and hired Southwestern Laboratories, a geotechnical testing firm, to drill soil borings and run standard soil tests. Results of the soil tests showed that the site was underlain by a layer of low permeability clay, a thick shale formation, and below that a deep aquifer. Thus, the oil sludge ponds posed a relatively minor threat to ground water. No measured surface water pollution occurred, because the ponds were banked and rainfall in that area was slight. Moreover, the waste materials had weathered for over 35 years, resulting in heavy sludges with thick crusts. Volatile substances had disappeared long ago. Extraction Procedure (EP) toxicity tests were negative.

Synopsis of Site Response

Halff surveys showed that the open ponds contained an estimated 5,000,000 gallons (1.9×10^7 l) of oil sludge and 10,000 cubic yards (7,600 m^3) of coke cinders, far more than Trammell Crow's prepurchase estimates. Halff selected what it considered to be the most effective and economical technology: solidification and disposal in an on-site landfill. They then planned and supervised the entire remedial action. Acting as owner's representative, Halff solicited bids for the work and selected H.B. Zachry, Inc. (Zachry) as low bidder. Trammell Crow then awarded the contract to Zachry.

Work began on April 21, 1981 with the excavation of the landfill adjacent to a cluster of three ponds. Oil sludge and coke cinders from four ponds were mixed with waste cement kiln dust in the landfill, pulverized, dried and compacted to specification. Oil sludge from the largest pond was mixed with fresh cement kiln dust in the pond, then transported several thousand feet to the landfill, where the steps for mixing, pulverizing, drying and compacting were repeated. After solidification of all five ponds, the landfill was capped, graded and seeded. Work was completed on September 1, 1981 and required approximately 75 working days. The rest of the site was then graded and a drainage system built in preparation for construction of a large warehouse distribution facility.

SITE DESCRIPTION

The Trammell Crow site is located in the western sector of the City of Dallas, Dallas County, Texas, approximately 1 mile (1.6 km) southwest of the junction where the West Fork and Elm Fork become the Trinity River. The site is situated on a 133 acre (53.2 ha) embankment area bordered by Interstate 30 to the south and the Texas and Pacific Railroad to the north. A stream which flows north into the Old West Fork Channel (the channel diverted from West Fork running parallel to the Trinity River) cuts through the site and along the waste ponds.

The site and area surrounding it are zoned for industrial use. To the north of the site is a Texaco gasoline storage facility while a General Portland Cement, Inc. plant is located to the south. East of the site are warehouse/distribution buildings and the Texas Industries, Inc. concrete pipe plant is to the west. A residential area is located approximately 2,000 feet (609.6 m) northeast of the sludge pit areas.

Surface Characteristics

300.68(e)(2)
(i)(E)
climate

Dallas County has a mild climate due to its location at the northern edge of a humid subtropical belt which extends into Texas from the Gulf of Mexico. There are no pronounced topographic features to influence the climate, so temperatures, precipitation, and snowfall are the results of the combined effects of warm moist air off the Pacific Ocean, the Gulf of Mexico and cold dry air from Canada.

Winter temperatures average 48°F (8.9°C), and the average daily minimum temperature is 38°F (3.3°C). The lowest recorded temperature in the City of Dallas was 7°F (-13.9°C) on February 1, 1971. Summer temperatures average 84°F (28.9°C), and the average daily maximum temperature is 94°F (34.4°C). The highest recorded temperature for Dallas County was 111°F (43.8°C) on July 25, 1954.

The prevailing winds are from the south producing generally clear skies. Frequently, from the fall through the spring, strong winds from the north rapidly sweep a cold air mass into the area, lowering temperatures by as much as 30°F (-1.1°C) in 2 or 3 hours. The strongest winds are during April, when the average wind speed is 13 miles (20.8 km) per hour.

Total annual precipitation in Dallas County is 36 inches (90 cm). The period of greatest precipitation is April through September when 20 inches (50 cm) or 57 percent of the total falls. On the average, thunderstorms occur 40 days per year, mostly in the spring. The heaviest recorded rainfall for one storm was 6.01 inches (15 cm) at Dallas on October 1, 1969. The average seasonal snowfall is 2 inches (5 cm), and the heaviest snowfall recorded accumulated 7 inches (17.5 cm).

Relative humidity averages about 55 percent in mid-afternoon. It is higher at night and at dawn it averages about 79 percent. Average daily sunshine is 75 percent in summer and 55 percent in winter.

The surface characteristics of the site are illustrated in the topographic map section in Figure 1. The site is located on a relatively flat area adjacent to a small stream that follows the waste ponds along their eastern and northern edges. The soil has been classified as the Trinity-Urban land complex, which is composed of deep, nearly level, poorly drained, dark clayey soils and areas of urban land or flood plains. Soil borings by Southwestern Laboratories were taken at the site in the locations shown in Figure 2. These borings confirmed that the surface soil is a Trinity Clay with a slope of less than 1 percent. Trinity Clay is a moderately alkaline soil of slow permeability (less than 0.06 inches [0.15 cm] per hour) and high water capacity. It is frequently flooded, has slow runoff capabilities, and a slight erosion hazard. The clay is fine-grained and over 97 percent will pass through a No. 200 sieve.

Hydrogeology

Southwestern Laboratories' geotechnical test results revealed that the Trinity Clay extends 20 to 45 feet (6.1-13.7 m) below the surface of the earth. Below this is Eagle Ford shale, a predominantly dark, blue-gray marine shale reaching a depth of approximately 400 feet (122 m) with an average thickness of 475 feet (145 m). The Eagle Ford formation contains minor beds of calcareous shale, shaley limestone, and numerous thin beds of bentonite. Below the shale formation lies the Woodbine Aquifer, one of the principal water-bearing beds in Dallas County. The transition between the Eagle Ford shale and Woodbine Aquifer is gradual; the sands of the Woodbine are overlaid first by sandy clays and then Eagle Ford clays. The Trinity Clay and Eagle Ford Shale formations form an impermeable barrier between the surface and the Woodbine Aquifer, so there is a negligible threat of ground water contamination at the Trammell Crow site.

300.68(e)(2)(i) (D) hydrogeological factors

300.68(e)(3)(ii) extent of present or expected migration

WASTE DISPOSAL HISTORY

The Trammell Crow site was originally owned and operated by Texaco Oil Company from 1915 to 1945 as a petroleum refinery and tank farm. When the refinery

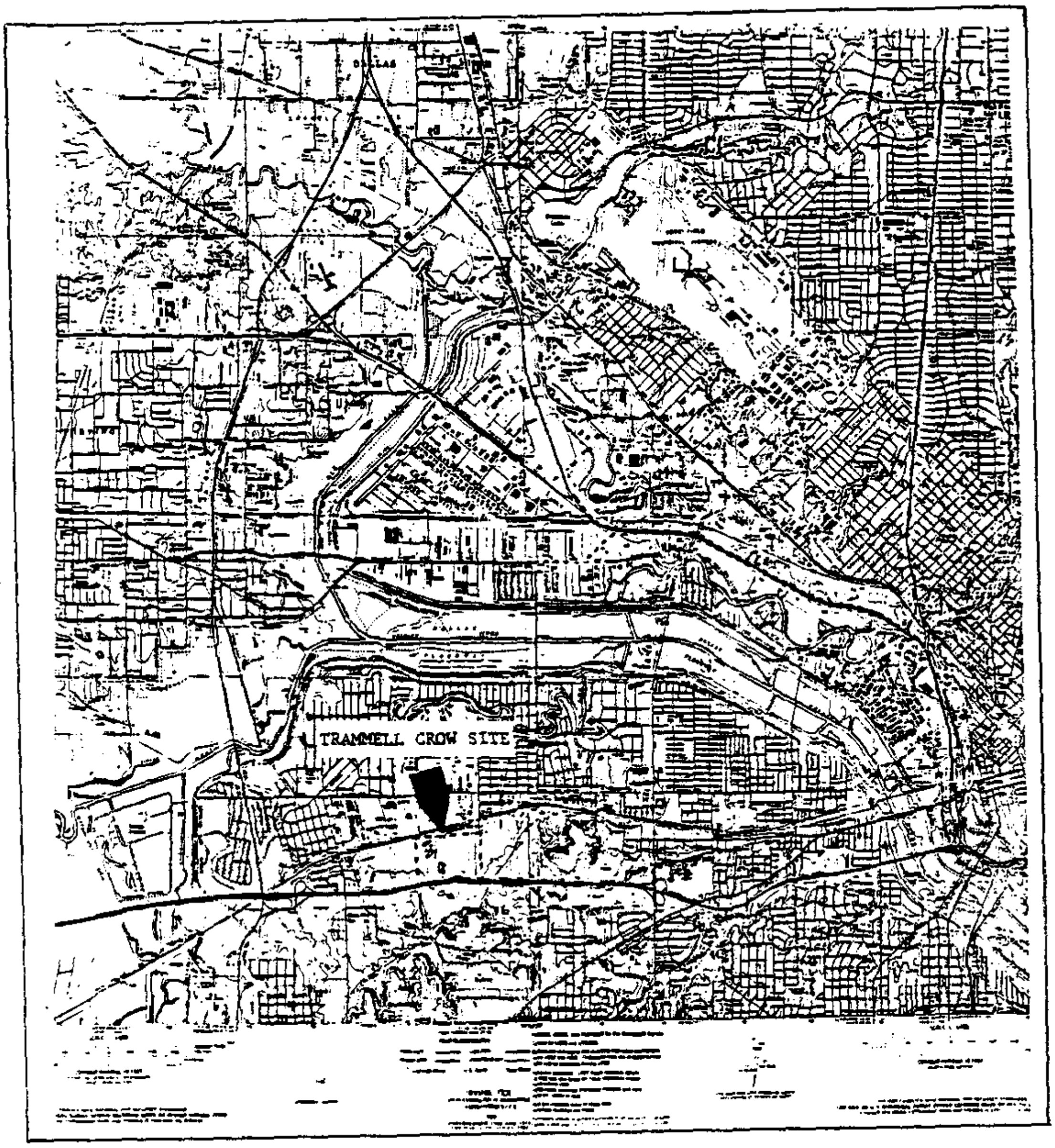

Figure 1. Topographic Map Section of Trammell Crow Site Location
(Source: USGS, 1973)

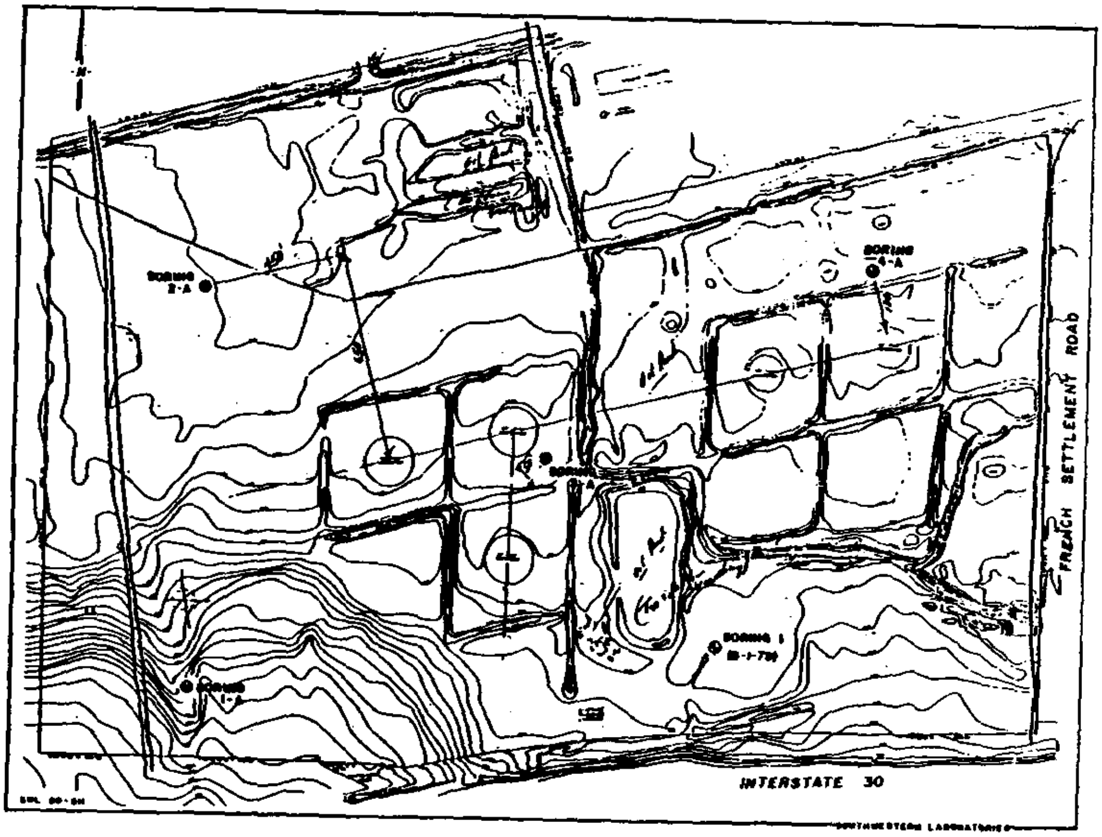

Figure 2. Location of Soil Borings at Trammell Grow Site
(Source: Albert H. Halff Associates, Inc., April 1981.)

ceased operations, the five major waste areas remained. From 1945 to 1959 the property was owned by a firm that had purchased the property for the purpose of reclaiming any valuable scrap metal from the site. In 1959 after the available metal was reclaimed, the site was sold to Zale Corporation. Trammell Crow Company purchased it in 1980. At that time, Trammell Crow Company hired Halff Associates to perform the initial site design which included designing a method of cleaning up the five waste ponds.

No records were available to detail what processes were used by Texaco at the refinery or what wastes were generated and buried in the ponds. Therefore, Halff Associates supervised a series of field surveys, soundings, and sampling and analysis procedures to determine the size, contents, and characteristics of the waste ponds. The five waste ponds, labeled A, B, C, D, and E, are shown in Figure 3.

300.68(f)
remedial
investigation;
sampling and
monitoring

DESCRIPTION OF CONTAMINATION

Pond A, as Figure 3 shows, was the largest of the five ponds, measuring 420 feet by 150 feet (128 x 46 m) with an average depth of 9 feet (2.7 m). The bottom and sides were clay, and the low permeability soil prevented much seepage into the subsurface Trinity Clay. The pond contained approximately 3,500,000 gallons (1.3×10^7 l) or 16,600 cubic yards (12,616 m^3) of waste.

300.68(e)(2)
(i)(B)
amount and form
of substances
present

The material contained in Pond A appeared to be tank bottoms, the residues that settle to the bottom of crude oil tanks. As the tanks at the Texaco refinery were cleaned, the residues were most likely placed in Pond A. The sludge in Pond A consisted of approximately 50 percent carbonaceous material, 35 percent water, and 15 percent ash. A 2-inch (5 cm) crust had developed over a semi-liquid oil/water emulsion which became thicker as it became deeper because the density of the oil was greater than that of the water. The carbonaceous portion of the sludge was made up of equal proportions of asphaltenes and paraffins. Complete chemical analyses of the oil sludge sediments and water content from Pond A are presented in Tables 1, 2, and 3. As Table 1 shows, the sludge was tested using the Extraction Procedure (EP) toxicity test to determine whether or not it was a hazardous waste by definition under RCRA. The results show that the sludge was below the maximum allowable concentrations as defined by RCRA.

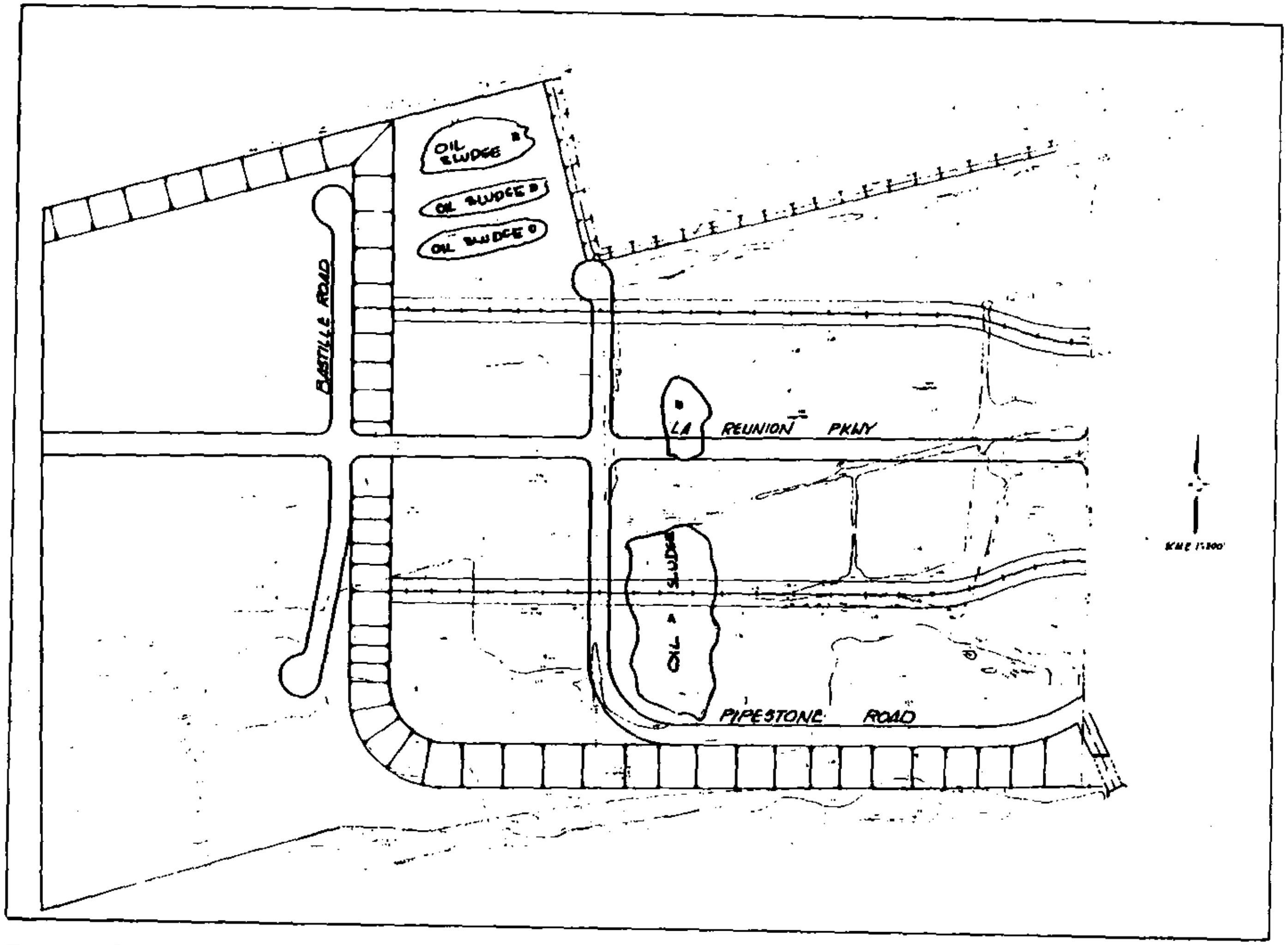

Figure 3. Location of Sludge Pits at Trammell Crow Site
(Source: Albert H. Halff Associates, Inc., 1981)

TABLE 1. CHEMICAL ANALYSIS OF OIL SLUDGE SEDIMENT FROM POND A

Test	Sediment sample (composite from three locations) As received	Dry basis
Moisture, %/wt.	34.3	--
Gross Heat of Combustion, BTU/lb	3,802	5,787
Flash Point, TOC, °F	301	301
Total Sulfur, %/wt.	0.63	.96
Vanadium, ppm	51	77
Ash, %/wt.	19.9	30.3

EP Toxicity Tests per 40 CFR 260.0 & 260.21

Contaminant	Test results mg/l of extractant	Maximum allowable concentrations mg/l of extractant
Arsenic	0.42	5.0
Cadmium	*0.01	1.0
Chromium	0.1	5.0
Lead	*0.05	5.0
Mercury	*0.002	0.2
Selenium	*0.01	1.0
Silver	*0.01	5.0
Barium	0.9	100.0

*less than

Source: Morgan, D.S. Albert H. Halff Associates, Inc., 1982.

TABLE 2. CHEMICAL ANALYSIS OF OIL SLUDGE FROM POND A

Test	Pond A North End	Pond A South End
Moisture content, %/wt.	30	37
Loss of heating, %/wt.	35	40
Ash content, %/wt.	10.5	8.3
Oil content, %/wt.	56.0	50.1
Gross heat of combustion, BTU/lb	8,316	7,057
Viscosity, SFS	*	*
Asphaltene	26.67%	24.62%

*There was insufficient sample to perform the analysis

Source: Morgan, D.S. Albert H. Halff Associates, 1982.

TABLE 3. WATER ANALYSIS FROM POND A

Identification: Water from south pond

pH 8.2
Conductivity 2200

	mg/l
Silica	77.3
Iron	3.05
Aluminum	1.16
Calcium	324
Magnesium	15
Sodium	340
Potassium	13.3
Carbonate	0
Bicarbonate	964
Sulfate	43
Chloride	205
Fluoride	0.6
Nitrate	1.9
Phosphate	1.2
Hydroxide	0
P-alkalinity (as $CaCO_3$)	0
Total alkalinity (as $CaCO_3$)	790
Total hardness (as $CaCO_3$)	870
Arsenic	0.15
Cadmium	* 0.01
Chromium	* 0.1
Lead	* 0.05
Zinc	0.07
Selenium	* 0.01
Silver	* 0.01
Mercury	* 0.002
Nickel	0.09
Boron	* 0.1

*less than

Source: Morgan, D.S. Albert H. Halff Associates, Inc., 1982.

Directly north of Pond A was Pond B. It measured 550 feet by 200 feet (152 x 61 m) with an average depth of 2.5 feet (0.76 m). Pond B contained approximately 10,000 cubic yards (7,600 m^3) of waste material.

The waste material in Pond B was a hard coke/slag material believed to be coke cinders from the refinery cracking process. This "clinker pit" was characterized by a soil boring and trenching of the surface. The findings showed that the coke material was approximately 4 feet (1.2m) deep in the northern portion of the pit and varied from a few inches along the edge to approximately 5 feet (1.5m) in the center.

Ponds C, D, and E were located next to one another along the northern edge of the Trammell Crow property. Although they were not all the same size, each pond was approximately 300 feet (91m) in length. Pond E was the largest with a width of 150 feet (46 m), while Ponds C and D were each approximately 50 feet (15 m) wide. They had been excavated almost 6 feet (1.8 m) below natural gradient. About 1,500,000 gallons (5.7×10^6 l) of sludge were found in Ponds C, D, and E combined.

The wastes in the three northern ponds (C, D, E) were believed to be sedimentation pond or oxidation pond residues. These oily sludges were approximately 4 feet (1.2 m) deep and were covered by a 6 to 7 inch (15 - 18 cm) layer of clean silt.

Although no significant contamination was evident at the Trammell Crow site, the sludge from these ponds had to be treated, removed, or both before construction at the site could begin in order to ensure maximum and safe development according to Texas state law.

PLANNING THE SITE RESPONSE

Initiation of Response

When the Trammell Crow Company bought this 133 acre (53.2 ha) tract in western Dallas, it believed that only a shallow pond of waste oil existed at the site and that it would be easy to remove. As discussed above, subsequent tests revealed that the shallow pond was really an oil sludge pit about 9 feet (2.7 m) deep that contained an estimated 3,500,000 gallons (1.3×10^7 l). Three smaller ponds on the property had layers of water and silt on their surface, but underneath were found to contain about 4 feet (1.2 m) of oil sludge, for an estimated 1,500,000 gallons (5.7×10^6 l). A fifth pond containing an estimated 10,000 cubic yards (7,600 m^3) of coke cinders was also discovered on the property.

Upon learning of the extent of wastes present on the site and the initial estimates of the development cost, Trammell Crow concluded that it would be economically unfeasible to develop the site at that time. It notified the City of Dallas of the situation and requested that the city obtain an Urban Development Action Grant (UDAG) from the Department of Housing and Urban Development (HUD). The Dallas City Council refused in 1980, but in 1981 it reconsidered Trammell Crow's request and decided to apply for the UDAG. The grant was made that year. Trammell Crow received $4,000,000 under the UDAG plus a $1,000,000 grant from the city to finance part of the construction of the infrastructure at the site, which included remedial action on the five ponds. The company financed the remaining construction costs itself.

Selection of Response Technologies

300.68(h) screening

300.68(g) development of alternatives

Halff Associates took several criteria into consider-consideration before selecting a remedial action. These included cost, feasibility, environmental factors, time, and legal implications. Before cement kiln dust solidification was chosen, 19 alternatives, including on-site and off-site disposal methods, were investigated (see Table 4). Each alternative was evaluated and given a preliminary cost estimate.

The first alternative to be investigated seriously was oil recovery. It seemed logical that some of the costs incurred for clean-up would be able to be recovered. To determine whether or not the sludge had recoverable oil, sludge samples were sent to various oil and wax refineries. Analyses showed that the oil, bound in a tight emulsion, would be difficult to recover using standard techniques. Unconventional recovery techniques, such as filtration through diatomaceous earth, produced a maximum of 5 to 10 percent oil by weight at a cost of $30 per barrel, a little above the current market price for a barrel. Halff Associates concluded that the expense of oil recovery was not worth the limited amount of oil that could be recovered.

Next, Halff Associates compared off-site and on-site disposal alternatives. The on-site solidification technique was found to be the most feasible, because the sludge was classified as a Class II industrial waste under Texas State law and therefore could not be placed in a municipal landfill. The closest industrial waste landfill was located on the Texas Gulf Coast, and the cost for

TABLE 4. DISPOSAL ALTERNATIVES FOR THE TRAMMELL CROW SITE

Off-site disposal methods	On-site disposal methods
Industrial waste landfill	Open pit burn
Municipal landfill	Incineration (mobile unit)
Fuel in asphalt plant	Storage facility
Mixture in asphalt	On-site land farm
Require Texaco to dispose of waste	Landfill on-site*
Use as road oil	Solidification*
Oil in grass-seed mix	Biological treatment plant
Sell oil to refinery	Incineration at permanent site
Off-site land farm	Recovery of oil and landfill on-site*
Transportation of waste to wax recovery plant	

*Alternatives that were further investigated

Source: Morgan, D.S. Albert H. Halff Associates, Inc., 1982.

transporting the waste would have been \$60 per cubic yard (\$45.60/m^3) or \$1,500,000. The on-site solidification technique was estimated to cost \$500,000 and thus was selected as the most cost-effective procedure for correcting the problem.

Extent of Response

Work began on May 21, 1981 and ended on September 1, 1981, for a total of about 75 working days. Clean-up work was stopped when all of the oil sludge and coke cinders had been solidified and landfilled and the site graded, capped, and seeded. All work was supervised by Halff and performed according to specifications once the landfill closure plan submitted by Halff Associates was approved by the Texas Department of Water Resources.

300.68(j) extent of remedy

DESIGN AND EXECUTION OF SITE RESPONSE

The design and implementation of the sludge solidification technique involved extensive laboratory tests to determine what materials in what quantities would produce the most stable compound when mixed with the sludge. Several factors had to be taken into account before the solidification materials and remedial design were chosen. These included mixing, solidification, and compaction characteristics; availability; cost, knowledge of percent moisture to avoid leaching; compatibility with Trinity Clay; and distance maintained from utility lines.

300.68(h)(3)(i) detailed analysis of alternatives

With these criteria in mind, Halff Associates began solidification testing using various local materials. These materials included on-site clay, sulfurs, cements, fly ash, fresh cement kiln dust, stale cement kiln dust, quick lime, waste quick lime, limestone screenings, sand, and various combinations of these materials. As Table 5 shows, the least expensive solidification additives were waste cement kiln dust at \$4.50 per ton (\$4.08/Mt.) and cement kiln dust at \$6.75 per ton (\$6.12/Mt.) (these costs include transportation). The waste cement kiln dust is known as stale dust because it has been stockpiled in cement manufacturers' quarries and exposed to the elements, so it has retained moisture. As Table 5 shows, the stale dust is in abundant supply because it was believed that the moisture content would hinder its effectiveness as a solidifying agent. Therefore, initial testing by Halff Associates did not include testing the stale kiln dust. Fresh kiln dust could only be obtained in limited supplies, because it had become a commonly used solidifying agent. Demand for this material had increased to such a great extent that rights to the fresh dust had been

TABLE 5. COST AND AVAILABILITY OF SOLIDIFICATION ADDITIVES

Product	Tons per cu. yd	Cost per ton*	Availability
On-site clay	1.28	$ 0**	Abundant
Sulfur	-	70.00 ($63.50/Mt.)	Delivery problems
Cement	1.27	69.00 ($62.60/Mt.)	Abundant
Fly ash	1.0	16.79 ($15.23/Mt.)	Abundant
Cement kiln dust	0.54	6.75 ($6.12/Mt.)	Limited supply
Waste cement kiln dust (38% moisture)	0.75	4.50 ($4.08/Mt.)	Abundant
Quick lime	0.34	65.00 ($58.97/Mt.)	Abundant
Waste quick lime (41% moisture)	0.55	12.50 ($11.34/Mt.)	Abundant
Limestone screenings	-	7.92 ($7.18/Mt.)	Abundant

*Delivered to site

**Exclusive of drying and grinding that would not have been cost-effective

Source: Morgan, D.S. Albert H. Halff Associates, Inc., 1982.

claimed prior to its production. Even though supplies of fresh dust were limited, initial tests included it as a viable solidifying agent.

Preliminary testing conducted by Halff Associates included a procedure to measure the compressive strength of various mixtures of sludge and solidifying agents. The compressive strength test was as follows:

1. Twenty-five grams of sludge were mixed with a predetermined amount of drying agent.

2. Combinations of drying compound and oil sludge by weight were tested in the following ratios: 0.5:1.0, 1.0:1.0, 1.5:1.0, 2.0:1.0, and 2.5:1.0.

3. The drying compound and oil sludge mixtures were each stirred until thoroughly mixed and lightly compacted to eliminate large voids.

4. The samples were each compacted 1 hour later by pressing the blunt end of a soil test pocket penetrometer into the mixture 10 times.

5. The soil test pocket penetrometer was then pressed into the mixture and the unconfined compressive strength was measured in tons per cubic foot.

6. The sample was loosened and the test was repeated 24 hours later and again 1 week later.

The results of these preliminary tests, presented in Table 6, show that several of the materials solidified the oil sludge effectively while others were less effective.

On-site clay, while most readily available, was not effective when wet. It was an effective solidifying agent when dried and pulverized. The strength tests on the dry clay after one hour were moderately strong. The wet soil, on the other hand, did not solidify to a satisfactory strength. Therefore, the moisture content of the soil appeared to be an important factor.

Neither crushed limestone nor sand proved to be good solidifying agents, as shown in Table 6. Both materials are very large grained and did not solidify because the grains became coated with oil.

Mixtures of cement with dry sand and wet sand were both tested as solidifying agents. The cement and dry sand showed poor compaction, dryness, and lack of

TABLE 6. SOLIDIFICATION TEST RESULTS PERFORMED BY ALBERT H. HALFF ASSOCIATES, INC.

Cost per ton ($)	Compound	Ratio CMPD;oil	Strength (tons/ft^3)			Description
			1 hr.	24 hr.	1 week	Conditions after approximately 1 week
8.50	Fly ash*	0.5:1	-	-	-	Too wet; never tested; thrown out
17.00	Fly ash	1.0:1	-	-	1.75	very black; moist; compacts well; stays tight
25.50	Fly ash	1.5:1	-	2.6	2.45	Black; moist; compacts; scrapes easily
34.00	Fly ash	2.0:1	-	2.85	2.50	dark brown; slightly moist; compacts; scrapes easily
42.50	Fly ash	2.5:1	-	2.00	2.50	Brown; very slightly moist; compacts; falls apart
3.53	Kiln dust	0.5:1	-	2.15	2.40	Black; moist; compacts well; very cohesive
6.75	Kiln dust	1.0:1	1.50	3.00*	-	brown; slightly moist; compacts; slightly cohesive
9.53	Kiln dust	1.5:1	1.40	2.25	2.70	Light brown; very slightly moist; compact; not cohesive

(continued)

*Not enough sample for accurate strength test.
**Soil was dried and pulverized before mixing with emulsion.

TABLE 6. (continued)

Cost per ton ($)	Compound	Ratio CMPD;oil	Strength (tons/ft^3) 1 hr.	24 hr.	1 week	Description Conditions after approximately 1 week
13.50	Kiln dust	2.0:1	2.20	2.10	1.5	Light brown; relatively dry; does not compact
19.00	Kiln dust	2.5:1	-	-	-	Too powdery
0.00	Soil*,**	0.5:1	-	-	-	Too wet; never tested; thrown out
0.00	Soil**	1.0:1	0.75	1.85	2.40	Black; moist; compacts well; cohesive
0.00	Soil**	1.5:1	2.20	3.20	3.40	Dark brown; not moist; compacts; slight cohesion
0.00	Soil**	2.0:1	2.65	3.35	3.35	Brown; not moist; compacts; crumbles easily
0.00	Soil**	2.5:1	3.30	3.60	3.4	Light brown; dry; compacts; crumbles very easily
3.96	Crushed limestone	0.5:1	-	-	-	Too wet; never tested; thrown out
7.92	Crushed limestone	1.0:1	-	-	-	Too wet; never tested; thrown out

(continued)

*Not enough sample for accurate strength test.
**Soil was dried and pulverized before mixing with emulsion.

TABLE 6. (continued)

Cost per ton ($)	Compound	Ratio CMPD;oil	Strength (tons/ft^3) 1 hr.	24 hr.	1 week	Description Conditions after approximately 1 week
11.88	Crushed limestone	1.5:1	-	-	-	Too wet; never tested; thrown out
15.84	Crushed limestone	2.0:1	-	-	3.25	Black; slight moist; compact; slightly; cohesion
19.80	Crushed limestone	2.5:1	-	1.30	3.35	Black; slight moist; compact slightly set but does crumble
5.75	Kiln dust, fly ash	0.5:1	-	-	1.75	Black; very moist; compacts well; very cohesive
11.50	Kiln dust,* fly ash	1.0:1	-	1.25	3.2	Black; moist; compacts well; cohesive
17.25	Kiln dust, fly ash	1.5:1	2.1	2.65	2.5	Brown; slight moist; will compact; slight cohesion
23.00	Kiln dust, fly ash	2.0:1	2.45	4.0	2.15	Light brown;dry; tough to compact; crumbles
28.75	Kiln dust, fly ash	2.5:1	3.20	3.75	2.25	Light brown; powdery; tough to compact; crumbles

(continued)

*Not enough sample for accurate strength test.

TABLE 6. (continued)

Cost per ton ($)	Compound	Ratio CMPD;oil	Strength (tons/ft^3) 1 hr.	24 hr.	1 week	Description Conditions after approximately 1 week
74.00	Dry sand,+ cement	5:0.5:1	1.20	1.25	1.25	5:0.5:1 Black; dry; does not compact well; crumbles
108.50	Dry sand,+ cement	5:1.0:1	1.85	1.75	1.70	5:1:1 Brown; dry; poor compaction; does not hold
177.50	Dry sand,+ cement	5:2.0:1	2.25	2.95	1.70	5:2:1 Light brown; dry; poor compaction; not cohesive
74.00	Wet sand,++ cement	5:0.5:1	1.5	4.50	4.5	5:0.5:1 Black; dry; set; crumbly
108.50	Wet sand,++ cement	5:1.0:1	1.75	4.50	4.5	5:1:1 Dark brown; dry; set; difficult to break
177.50	Wet sand,++ cement	5:2.0:1	2.6	4.50	4.5	5:2:1 Gray; dry; set; crumbles easily
53.10	Sand, sulfur	5:0.5:1	1.2	1.5	1.7	5:0.5:1 Black; moist; compacts; cohesive

(continued)

+Sand was dried before it was added to the mixture.
++Wet sand mixtures with cement set so the sample was not broken and re-compacted for the 24-hour and week tests.

TABLE 6. (continued)

Cost per ton ($)	Compound	Ratio CMPD;oil	Strength (tons/ft^3) 1 hr.	24 hr.	1 week	Description Conditions after approximately 1 week
311.50	Sand, sulfur	5:1.0:1	1.75	1.95	2.2	5:1:1 Black; slight moist; compacts; crumbles
583.50	Sand, sulfur	5:2.0:1	2.25	2.65	2.5	5:2.1 Brown; slight moist; compacts; slight cohesion
108.50	Sand, water, cement	5:0.5:1:1	-	4.5	4.5	Black; oily; solid; very strong; rigid
0.00	Wet soil	0.5:1	-	-	3.1	Black; moist; compacts; cohesive
0.00	Wet soil	1.0:1	-	-	3.25	Black; slightly moist; compacts; cohesive
0.00	Wet soil	1.5:1	-	0.5	3.55	Black; slightly moist; compact; slightly cohesive
0.00	Wet soil	2.0:1	-	0.5	3.0	Black; slightly moist; compact; crumble
0.00	Wet soil	2.5:1	-	1.55	4.0	Dark brown; dry; compact; crumble
3.45	Cement	0.05:1	-	-	-	Black; moist; not compacted well; paste-like
6.90	Cement	0.1:1	-	-	0.6	Black; moist; compact; very cohesive

(continued)

TABLE 6. (continued)

Cost per ton ($)	Compound	Ratio CMPD;oil	Strength (tons/ft^3)			Description
			1 hr.	24 hr.	1 week	Conditions after approximately 1 week
13.60	Cement	0.2:1	-	-	2.3	Black; slightly moist; compact; cohesive
13.60	Sulfur	0.05:1	-	-	-	Black; very thick fluid
27.20	Sulfur	0.10:1	-	-	-	Black; very thick fluid
54.40	Sulfur	0.20:1	-	-	-	Black; paste-like
16.60	Sulfur, kiln dust	0.05:0.5:1	-	1.0	2.4	Black; slightly moist; compact; slight cohesion
6.45	Cement, kiln dust	0.05:0.5:1	0.60	3.25	-	Black; slightly moist; compact; cohesive
6.68	Lime, kiln dust	0.05:0.5:1	1.65	3.10	-	Black; slightly moist; compacts; cohesive
3.00	Kiln dust	0.5:1	-	0.90	2.55	Black; slightly moist; compacts well; cohesive
3.68	Lime	0.05:1	-	-	0.70	Black; moist; compact; cohesive
7.36	Lime	0.10:1	-	-	1.60	Black; moist; compact; very cohesive
14.72	Lime	0.20:1	-	.70	-	Black; slight moist; compact; cohesive

(continued)

Source: Morgan, D.S. Albert H. Halff Associates, Inc., 1982.

cohesion. Mixed together, cement and wet sand formed a strong, concrete material that solidified quickly. One disadvantage of this mixture was that it could not to be broken up and re-compacted.

Other mixtures which were tested included lime, sulfur, and cement. These were combined in small ratios of each material to sludge ranging from 0.05, 0.1, and 0.2 parts of lime, sulfur, or cement to 1.0 part oil sludge. Although these compounds formed cohesive mixtures, they did not solidify well. They were paste-like, moist, and remained soft for 2 days.

Kiln dust and fly ash were the most effective solidifying agents, as they solidified at low mixing ratios and could be broken up and re-compacted. A 50:50 mixture of kiln dust and fly ash was also tested. This compound solidified the sludge well at lower ratios of kiln dust and fly ash to oil. At higher ratios of kiln dust and fly ash to oil, such as 2.0:1.0 and 2.5:1.0, the mixtures became powdery, easily crumbled, and were difficult to compact.

300.68(i)(2)(C)
constructibility

Halff Associates analyzed the results of these tests and determined that cement kiln dust and dried clay were the most feasible materials to use for the solidification process. Once this determination was made, these compounds had to be tested more extensively. Halff Associates directed Southwestern Laboratories to conduct further testing of various mixtures of clay, soil, kiln dust, and oil. At the same time, Halff Associates began a search for large supplies of cement kiln dust.

The results of Southwestern Laboratories' solidification tests are shown in Table 7. The compounds that were tested using clay as a solidifying agent demonstrated very high linear shrinkage. For an 8.0:1.0 ratio of clay to sludge, the linear shrinkage was 13 percent. Instability of solidified sludge in a large mass, such as at the Trammell Crow Site, would not be acceptable.

Cement kiln dust was mixed with the sludge at a 3.0:1.0 ratio. As Table 7 shows, Southwestern Laboratories tested this cement kiln dust/sludge mixture twice. The first mixture yielded a compressive strength of 2,210 psf and showed no linear shrinkage. The second test showed a compressive strength of 3,030 psf (3.01 x 10^9 Pa). Therefore, it can be assumed that cement kiln dust mixed with sludge at a 3.0:1.0 ratio will produce a strong, stable compound. As the results in Table 8 are examined more closely, it is apparent that the kiln dust showed little to no linear shrinkage and a low to zero

TABLE 7. PRELIMINARY SOLIDIFICATION TESTS BY SOUTHWESTERN LABORATORIES

Mixture description	Moisture content	Dry density (pcf)	Atterberg limits			Linear shrinkage %	Compressive strength (psf)
			LL	PL	PI		
Clay	20	93	55	23	32	14	4,650
Clay, sludge (8:1)	17	92	46	21	25	13	3,810
Kiln dust, sludge (3:1)	21	81	41	40	1	0	2,210
Clay, kiln dust, sludge (5:4:2)	22	93	43	41	2	0	4,980
Clay, kiln dust, sludge (6:2:3)	18	93	40	39	1	0	1,345
Clay, hydrated lime, sludge (13:1:3)	16	92	27	28	-	0	2,670
Kiln dust, sludge (3:1)	20	82	-	-	-	-	3,030
Clay, kiln dust, sludge (3:3:2)	23	86	48	47	1	1	3,220
Kiln dust, clinker (1:3)	11	65	51	48	3	2	3,930
Clay, quick lime, Kiln dust, sludge (10:1:33)	23	81	45	40	5	3	4,730
Clay, quick lime, sludge (13:1:3)	17	87	45	46	-	0	5,820
Clay, sludge (1 C.Y.:60 gal) (field test)	29	81	53	38	15	10	4,070
Clay, kiln dust, sludge (3:3:2)(Field test)	19	81	45	35	10	4	5,030

Source: Morgan, D.S. Albert H. Halff Associates, Inc., 1982

(continued)

TABLE 8. CHEMICAL COMPOSITION OF FRESH CEMENT KILN DUST

Compound	Percent by weight
CaO	53.8
SiO_2	17.2
Al_2O_3	5.5
Fe_2O_3	2.4
MgO	0.9
Na_2O	2.2
K_2O	3.1
SO_3	4.4
Miscellaneous	10.5

Source: Morgan, D.S. Albert H. Halff Associates, Inc., 1982.

plasticity index. The kiln dust combined readily with the sludge so that a mixture of fair strength could be tested within 1 hour. The kiln dust/sludge mixture increased in strength as the material cured, and did not crumble after being submerged in water for 24 hours. At ratios other than 3.0:1.0, linear shrinkage was observed and compressive strength decreased.

Quick lime (calcium oxide or CaO) and hydrated lime (calcium hydroxide or $Ca(OH)_2$), were tested by Southwestern Laboratories as solidifying agents with various combinations of clay, kiln dust, and sludge. The quick lime reacted with the water in the sludge to instantly combine with and dry the sludge. The most desirable ratio of quick lime to oil is 0.15 to 0.3 parts of quick lime to 1.0 part of oil. Quick lime, however, is expensive ($65.00 per ton or $58.97/Mt.) and would only be economical if used in smaller amounts to decrease the moisture content and linear shrinkage of a soil/sludge mixture.

Hydrated lime was mixed with clay, sludge, and kiln dust so that the ratio of clay to hydrated lime to sludge to kiln dust was 10:1:3:3. The compound formed had a compressive strength of 4,870 psf (4.84×10^9 Pa) and showed no linear shrinkage. This reduction in the linear shrinkage combined with a reduction in the plasticity index are factors that make hydrated lime a better solidifying agent than cement kiln dust. The hydrated lime however, was at least as expensive or more so than the quick lime, and would most likely be added to a cement kiln dust/sludge mixture in small amounts to improve the shrink-swell characteristics of the solidified mixture.

Once these preliminary tests were conducted, Halff Associates determined that the most cost-effective and technically feasible solidification agent was the cement kiln dust. Because of a large demand for fresh kiln dust, the supply was limited. Therefore, Halff Associates decided to have Southwestern Laboratories perform the same solidification tests using waste cement kiln dust and waste quick lime. These materials were both stockpiled in cement manufacturers' quarries and had been exposed to atmospheric conditions. Once water from the atmosphere came into contact with the waste kiln dust, the powdery waste cement kiln dust turned into a crumbly limestone (CaO or quick lime) and the CaO reacted with water to form $Ca(OH)_2$ or hydrated lime. Southwestern Laboratories had tested fresh hydrated lime and quick lime and found them to be worthwhile as solidifying agents, but restrictive in cost.

300.68(j) cost-effectiveness

Waste quick lime was tested to determine the percentage of available CaO, because the CaO reacts with water and produces steam and $Ca(OH)_2$. The chemical reaction is written as:

$$CaO + H_2O \longrightarrow Ca(OH)_2 + \text{heat}.$$

This chemical reaction quickly dried the oil sludge. Therefore, the previous tests by Southwestern Laboratories confirmed this using fresh cement kiln dust and quick lime. The fresh cement kiln dust contained approximately 50 percent CaO, while the quick lime contained approximately 85 percent CaO. Although these non-waste materials had produced excellent solidifying results, they were expensive. Therefore, Halff Associates decided to test the waste cement kiln dust and waste quick lime to determine how effective they would be.

The waste quick lime contained approximately 50 percent CaO. When mixed with the sludge, the waste quick lime had excellent adsorption characteristics, was water repellant, was easily compacted, and produced a stable fill. The waste quick lime was available for \$12.50 per ton (\$11.34/Mt.)

The waste cement kiln dust was also sampled and tested by Southwestern Laboratories. The sample which was used contained 41 percent moisture prior to mixing. When the sludge was mixed with the waste cement kiln dust sample, the resulting compound contained 55 percent moisture. The mixture after 24 hours was 45 percent moisture and maintained a compressive strength of 5,200 psf (5.16×10^9 Pa). The waste cement kiln dust showed excellent stabilization and solidification characteristics. The cost of the waste cement kiln dust at the time of testing was \$4.50 per ton (\$4.08/Mt.) and the local supply was abundant.

Southwestern Laboratories' tests confirmed that the best solidifying agents for the oil/sludge mixture at the Trammell Crow site were either cement kiln dust, quick lime, hydrated lime, waste cement kiln dust, waste quick lime, or a combination of some or all of these agents. The final determination of the solidifying agents best suited for this site was made based on cost and availability of materials.

The most inexpensive materials were the waste cement kiln dust (\$4.50 per ton or \$4.08/Mt.) and the fresh cement kiln dust (\$6.75 per ton or \$6.12/Mt). The fresh cement kiln dust produced the best results using small ratios of dust to oil at 1.0:1.0 or 1.5:1.0 parts dust to oil, while the waste cement kiln dust produced a suitable fill material when mixed with the oil at a 2.0:1.0 or 3.0:1.0 dust to oil ratio. Although the fresh cement kiln dust was difficult to obtain in large quantities, some was available locally. Gifford-Hill, Inc. owns a large cement manufacturing plant, in Midlothian, Texas approximately 30 miles (48 km) southwest of Dallas. The Gifford-Hill plant had some fresh cement kiln dust available and a large stockpile of stale kiln dust that they were willing to sell. Gifford-Hill could only supply 138 cubic yards (105 m^3) or 33 tons (30 Mt.) of fresh kiln dust per day (an average of three 25 ton (23 Mt.) cement transport trucks full). Because of the limited supply of fresh kiln dust and large supply of stale kiln dust available, Halff Associates decided to use a combination of fresh dust and stale dust.

300.68(j) cost effectiveness

Conservative estimates for the total quantity of dust needed were based on a ratio of 3 parts dust to 1 part oil, assuming that the majority of the bulking agents would be stale dust and that the best solidification once in the field would require a 3.0:1.0 ratio of dust to oil. By using this ratio of stale and fresh dust, enough dust would be available from Gifford-Hill on an as-needed basis.

The total amount of sludge to be solidified was estimated at 5,000,000 gallons (1.9×10^7 l) of oil, the equivalent of 25,000 cubic yards (19,000 m^3) of sludge at a density of approximately 1 ton per cubic yard. At the 3:1 dust to oil ratio, the estimated amount of kiln dust needed for solidification was 75,000 tons (68,039 Mt.). The projected cost for the kiln dust alone was $300,000. In addition, an on-site landfill for the solidification process and resulting solidified sludge was designed to be 5.5 acres (2.2 ha) on the surface and 12 feet (3.7 m) deep. Labor costs for the solidification and excavation were estimated at $200,000 or $500,000 for the entire job.

300.68(i)(2)(B) detailed cost estimation

Once Halff Associates had determined that the oil sludge solidification by cement kiln dust was a viable solution and the Trammell Crow Company accepted this alternative, a closure plan was filed with the Texas Department of Water Resources. The closure plan outlined the solidification process and the proposed on-site landfill for disposal of the solidified sludge. The 5.5 acre (2.2 ha) landfill was to be located in the area containing sludge ponds C, D, and E (see Figure 3) to avoid odor problems related to the moving and mixing of the sludge. No odor problems were discovered. There were standing orders left with Halff Associates by the City of Dallas to shut down the project if high winds were present

300.68(i)(2)(E) analysis and mitigation of adverse environmental impacts that might disperse the kiln dust. High winds did not occur, so the project did not have to be halted at any time.

After the closure plan was accepted by the State of Texas, Halff Associates acted as design engineer and construction supervisor on behalf of Trammell Crow Company for the implementation of the solidification and disposal process. With Trammell Crow Company's approval, Halff Associates combined the solidification and disposal process with the overall site grading and drainage that was necessary for the entire Trammell Crow development project. Halff Associates held a preconstruction meeting for prospective contractors to explain the sludge solidification process. The combined contract was awarded to the low bidder, H.B. Zachry Company of San Antonio, Texas.

The Zachry Company carried out the oil sludge solidification process on the smaller ponds before proceeding to Pond A. Figure 4 illustrates the sludge solidification and disposal method in engineering drawings prepared by Halff Associates. These drawings were used to describe the process to prospective contractors. The first step was to excavate the southern portion of the sludge disposal pit adjacent to Pond C to a depth of 12 feet (3.7 m). As the sludge was excavated from the pond in small portions, the pit was filled in with stale kiln dust and the mixture compacted. By testing a small portion at first, the field engineers could determine how the process was working under actual conditions and the equipment operators could get an idea of what quantities of sludge and dust their equipment was capable of handling most readily. Hence, the exact ratios of kiln dust to oil that had been determined in the laboratory were not necessarily valid in the field. As long as the solidification process and compaction yielded appropriate results the exact ratios were not necessary nor were they able to be determined as both fresh and stale dust were used together. Therefore, an overall ratio of 1.5 parts kiln dust to 1.0 parts oil was determined for the entire project. The solidification process, which began on May 21, 1981, is described in the following steps:

300.70(b)(2)-(iii)(C) solidification

1. The sludge disposal pit was excavated up to the edge of Pond C.

2. Stale cement kiln dust was delivered to the bottom of the excavated pit in 25 ton (23 Mt.) truckloads.

3. The kiln dust was leveled by a bulldozer into a 6 to 12 inch (15 - 30 cm) layer.

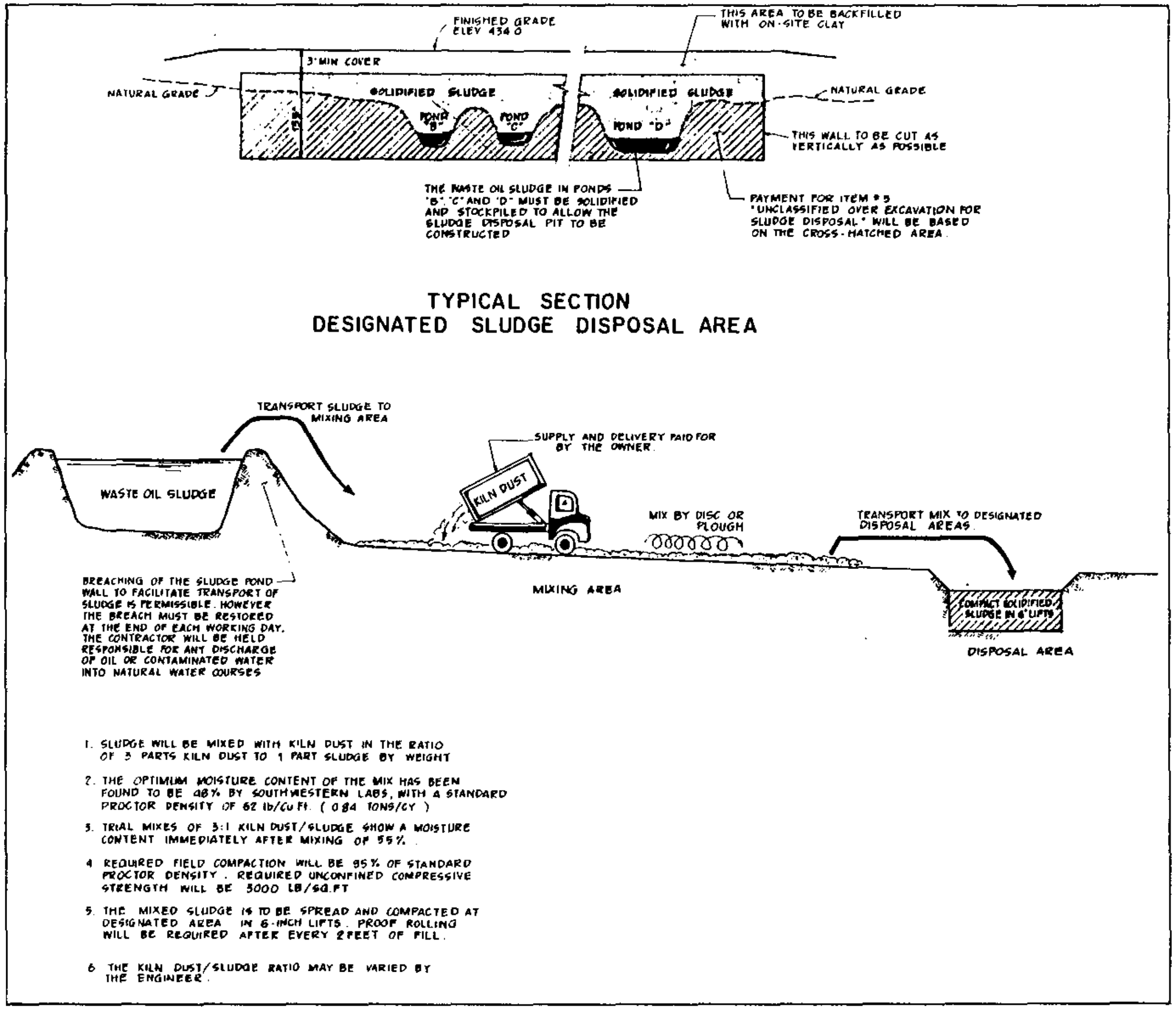

Figure 4. Proposed Sludge Disposal Method
Source: Albert H. Halff Associates, Inc., 1981.

4. The oil sludge was removed from the ponds by a backhoe and placed on top of the kiln dust in the disposal pit.

5. The kiln dust and sludge in the disposal pit was mixed by a bulldozer into 1 foot (0.30 m) layers.

6. A pulverizing mixer was then driven over each 1 foot (0.30 m) layer to completely homogenize the mixture.

7. Each layer of dust/sludge mixture air dried for approximately one day.

8. Each layer was compacted to a specified density and field tested to ensure proper compaction.

This procedure was followed until all of the oil sludge from the waste ponds C, D, and E had been emptied and solidified in the on-site landfill. The old ponds were engulfed by the landfill.

For the largest sludge pit, Pond A, the solidification process was modified, since the sludge was more liquefied and the pond itself was several thousand feet from the on-site landfill. Because of its more liquefied nature, the sludge was solidified using both fresh and stale kiln dust. The procedure for solidifying the sludge from Pond A incorporated the same layering process used for the three smaller ponds, however, the sludge was treated prior to placement in the on-site landfill. The procedure used for solidifying the sludge from Pond A was as follows:

1. Fresh cement kiln dust was blown into sludge Pond A.

2. The fresh dust was mixed into the sludge by a backhoe (this semi-solidified the sludge).

3. The semi-solidified sludge was loaded into a 40 cubic yard (3,040 m^3) belly dump truck and transported to the on-site landfill.

4. The semi-solidified sludge was dumped into the landfill and onto a bed of stale kiln dust.

5. The semi-solidified sludge was mixed in the same manner as outlined for the three smaller Ponds C, D, and E.

As each side of Pond A was excavated the pond was backfilled with clean soil until all of the sludge had been removed and solidified in the on-site landfill. The coke/slag material was removed from Pond B and mixed in with the sludge in the on-site landfill. Pond B was then backfilled with soil.

In order to ensure the quality of compaction, density tests were performed daily during the solidification process. The results of some of these tests are listed in Table 9. Proctor density tests were run in a laboratory and the results indicated that the 3.0:1.0 kiln dust to oil mixture would have a Proctor density of 73.9 pounds per cubic foot (1,182 kg/m^3) with an optimum moisture content of 33.8 percent. Based on the Proctor density tests, a compaction density of approximately 64 pounds per cubic foot (1,024 kg/m^3) was considered to be the minimum acceptable density. As Table 9 shows, the actual densities of the compacted layers were between 70 and 80 pounds per cubic foot (1,120-1,280 kg/m^3); well above the acceptable minimum of 64 pounds per cubic foot (1,024 kg/m^3).

The solidification process was completed by September 1, 1981 or within 75 working days. Five million gallons (1.9×10^7 l) of sludge were disposed of at an average of 66,700 gallons (252,487 l) per day using approximately 41,000 tons (37,195 Mt.) of cement kiln dust. This was much less than the 75,000 tons (68,039 Mt.) of kiln dust originally projected because the dust solidified with the sludge better in the field than in the laboratory. Therefore, the project cost only $377,527.10 as opposed to the estimated $500,000. This is much less than the off-site disposal alternative which would have cost $1,500,000.

Once the solidification process was completed a layer of soil from 3 to 5 feet (0.9 - 1.5 m) was placed over the on-site landfill to ensure adequate capping. The entire site was then completely graded and seeded with grass. Unfortunately, the grass seed was planted too late in the year and did not grow. However, the site was naturally seeded and is now covered with wildflowers and weeds. Presently, the site is adequate for building and is awaiting future development within the Trammell Crow industrial park.

300.70(b)(1)(ii)(A)
surface seal

300.70(b)(1)(ii)(C);(D)
grading;
revegetation

TABLE 9. SOLIDIFIED OIL SLUDGE KILN DUST FIELD DENSITY TESTS

Date	Field moisture (%)	Field density (lbs/cu.ft.)	Optimum moisture (%)	Proctor density (lbs/cu.ft.)	Percent density
5/22/81	36.5	79.0	33.8	73.9	106.9
5/22/81	37.5	78.2	33.8	73.9	105.8
5/22/81	35.2	81.6	33.8	73.9	110.4
5/22/81	35.4	81.2	33.8	73.9	109.9
6/11/81	35.2	75.2	33.8	73.9	102.2
6/11/81	40.4	71.2	33.8	73.9	96.2
6/11/81	41.4	74.7	33.8	73.9	101.1
6/23/81	30.7	77.9	33.8	73.9	105.4
6/23/81	28.7	74.3	33.8	73.9	100.5
6/23/81	34.4	74.9	33.8	73.9	101.4
7/10/81	36.0	72.3	33.8	73.9	97.8
7/10/81	35.8	73.3	33.8	73.9	99.2
7/10/81	34.2	73.4	33.8	73.9	99.3
8/21/81	33.3	74.9	33.8	73.9	101.4
8/21/81	37.2	74.1	33.8	73.9	100.3
8/21/81	36.2	74.4	33.8	73.9	100.7

Source: Morgan, D.S. Albert H. Halff Associates, Inc., 1982.

COST AND FUNDING

Source of Funding

The solidification and landfilling costs were paid in part by Trammell Crow and in part by the HUD and Dallas grants. However, the amounts that these sources contributed toward disposal costs cannot be given, because the grants subsidized the total infrastructure cost.

300.68(c) responsible party

Selection of Contractors

Albert H. Halff Associates

Trammell Crow hired Albert H. Halff Associates of Dallas, Texas to design roads, sewers and surface water drainage for the entire 133 acre (53.2 ha) site. Halff also was responsible for analyzing disposal alternatives, designing the remedial action plan, submitting government applications, monitoring the site, and supervising the clean-up work. Trammell Crow hired Halff based on prior work and reputation.

H.B. Zachry Company

To save time and reduce costs, Halff recommended to Trammell Crow that the oil sludge solidification and disposal work be included in the grading and drainage contract for the site. Trammell Crow agreed. Acting as owner's representative, Halff solicited bids for the work and held a preconstruction meeting to inform potential bidders about the solidification procedures. H.B. Zachry Company, of San Antonio, Texas was selected as low bidder. Although it had considerable experience with road and building construction, Zachry had never done this type of waste disposal. One reason contributing to Zachry's low bid was the fact that it had most of the required heavy equipment available nearby.

Project Costs

Engineering Feasibility Study-Solidification and Disposal

Halff's fee was based on a percentage of the construction costs. The total fee cannot be determined because construction is still in progress at the site and the percentage used was not disclosed. However, the firm estimated that the portion of its fee attributable to its engineering feasibility study regarding solidification and disposal was $50,000. The available construction cost information relates directly to solidification and disposal of the sludge (see Table 10). Included are the costs for loading the kiln dust, transporting it to the site, excavating, capping and grading the landfill, and manpower and equipment used to process the mixture of

TABLE 10. SUMMARY OF COST INFORMATION- TRAMMELL CROW COMPANY, DALLAS, TX.

Task	Estimated Quantity	Actual Quantity	Estimated Expenditure	Actual Expenditure	Variance	Unit Cost	Funding Source (a)	Period of Performance
Loading waste kiln dust		29,435 tons (26,703 Mt.)		$14,717.50		$0.50/ton ($0.55/ Mt.)	Trammell Crow	
Transporting waste kiln dust		29,407 tons (26,678 Mt.)		$104,394.85		$3.55/ton ($3.91/Mt.)	Trammell Crow	
Transporting fresh kiln dust		11,532 tons (10,461 Mt.)		$69,192.00		$6.00.ton ($6.61/Mt.)	Trammell Crow	
Excavation of disposal landfill, capping and grading		64,740 cu.yds (49,500 cu.m.)		$97,110.00		$1.50/cu.yd. ($1.96/cu.m)	Trammell Crow	
Labor and equipment to process sludge	75,000 tons (68,039 Mt.)	40,939 tons (37,139 Mt.)		$92,112.75		$2.25/ton ($2.48/Mt.)	Trammell Crow	
Subtotal			$500,000(c)	$377,527.10(d)	$122,472.90			
Engineering feasibility study solid-ification & disposal				$50,000(e)			Trammell Crow	
TOTAL				$427,527.10(d)			Trammell Crow	4/21/81-9/1/81

(a) portion of funds provided by UDAC and City of Dallas grant

(b) cost is for kiln dust as delivered to site, which includes cost of purchasing kiln dust.

(c) does not include engineering fee paid to Albert H. Halff Associates, Inc.

(d) does not include bonus of $34,061.00 paid to H.B. Zachry Co.

(e) estimate by Albert H. Halff Associates, Inc.

SOURCE: Morgan, D.S. Albert H. Halff Associates, Inc., 1982 sludge and dust. Halff Associates calculated both total and unit costs for each activity as part of its planning and supervisory work.

The key to controlling costs for this remedial action was the amount of kiln dust required. With the exception of excavation of the landfill, the cost of each remedial activity was directly affected by the tonnage of kiln dust involved. Consequently, the costs of these activities could be controlled by limiting the amount of kiln dust used. Halff took advantage of this situation by inserting an interesting provision in the contract with Zachry: the contractor was paid a bonus of $1 per ton ($0.907/Mt.) for each ton of dust not used in the solidification process. This reversed the economic incentives for Zachry, from using as much kiln dust as possible to maximize loading, transportation and processing charges to using as little as possible to cut its costs and earn the bonus. Regardless of the amount used, the solidification process had to conform to Halff's workplan and the results had to meet Halff's specifications for mixture and compaction.

Because the solidification technique worked better in the field than the laboratory, only 40,939 tons (37,139 Mt.) of kiln dust were used, only 55% of the original estimate of 75,000 tons (68,039 Mt). This is about a 1.5:1.0 ratio of dust to sludge, rather than the 3.0:1.0 ratio originally estimated. Reduced tonnage resulted in a total cost of $377,527.10, compared to an estimated cost of $500,000. Zachry received a bonus of $34,061, while Trammell Crow had the job done for $88,411.90 less than estimated. Even when the bonus is figured as part of the cost of solidification, this only totals $411,588.10, which is less than one-third of the cost of off-site disposal, which was estimated to be $1,500,000.

Capping, Grading and Seeding; General Drainage Work

The contract with Zachry included within the same category the tasks of excavating the disposal landfill, capping it and grading it, as well as general site preparation such as construction of the building pads and drainage channel. Zachry bid the entire category of work at $1.50 per cubic yard ($1.15/m^3). The cost of seeding was not included in Zachry's bid and no data on this item are available.

PERFORMANCE EVALUATION

The remedial action that was taken at the Trammell Crow site entailed detailed and innovative design and implementation. These observations are made after visiting the site, viewing a videotape of the actual solidification process, and discussing the remedial action with representatives of Halff Associates, Trammell Crow Company, and the Texas Department of Water Resources. Not only did Halff Associates devise a method to correct the problem of the sludge ponds on the property, but also they implemented a plan which recovered the land for further use in a cost-effective, timely, and novel manner.

Because this remedial action was a voluntary planned response with no strict time constraints, Halff Associates was able to thoroughly investigate all of the alternatives which were available for remediation. Halff Associates recommended the corrective action for this particular site only after carefully evaluating all of the options available, keeping in mind the interests of their client and government regulations. Once preliminary tests showed solidification to be a viable alternative, Halff Associates performed extensive tests to determine the best solidification materials based on technical stability, cost, and supply. Halff Associates then took this one step further when determinations found that the best solidification material, fresh cement kiln dust, was in short supply. They tested to see whether or not a material such as waste kiln dust, originally believed to be ineffective, would indeed be effective. The results show that this was indeed worthwhile.

The Trammell Crow Company and Halff Associates showed responsibility and cooperation in this remedial action. Care was taken to ensure that the appropriate Federal, state, and local officials were contacted and that the work performed at the site was acceptable at each level. Once it was determined that the waste oil was not EP toxic and did not fall within the limits of RCRA, Halff Associates maintained close communications with the Texas Department of Water Resources and the City of Dallas Health Department to ensure that the Class II wastes were handled correctly and that the solidification process posed no threat to human health or the environment. Prior to the solidification and removal of the waste oil from the sludge ponds, numerous carcasses of dead waterfowl were found along the banks of the sludge. With the removal of these ponds, this threat to local and migrating waterfowl is no longer present.

From a technical perspective, the site is stable and ready to be developed. The solidification technique worked better in the field than in the laboratory. It is impossible to tell by looking at the site that the solidified on-site disposal area contains oil sludge material and that the capped area, formerly Pond A, contained oil sludge.

One area of potential concern is the long-term stability of the solidified sludge. It is not possible to determine whether or not the kiln dust and sludge will indeed remain intact. Perhaps some type of monitoring or sampling could be conducted periodically to determine whether or not there is any actual leaching from the on-site landfill.

Another area of potential concern is the former Pond A, now a capped site. The site is graded over and the soil cover rises above ground level approximately 6 inches (15 cm). On top of the cap was quite a bit of water which had remained after a heavy rain. The water did not evaporate quickly, nor did it drain readily. Upon closer examination, it was concluded that there was no need to go to the expense of further drainage of this area because there is no apparent threat to percolation of contaminants reaching the Woodbine aquifer, as the clay layers are impermeable. Secondly, the site will have to be graded and drained prior to construction, at which time any puddles of water will be removed.

If these puddles do persist for long periods of time between rainfall, and construction is not imminent, then improvement of the site drainage would be prudent. Otherwise, the solidification and capping at the site are effective.

The Trammell Crow site is an example of a remedial action in which careful planning and investigation of numerous alternatives led to a successful clean-up. This action not only corrected a problem waste site, but turned it into one with potential for an economic return.

The scientists and engineers at Halff Associates are convinced that the technique used at the Trammell Crow site is applicable to many oil sludge sites where the waste is hazardous by definition under RCRA. Additionally, the concept that a substance not yet proven (stale kiln dust in this case) may be worth trying on a proven process is one that should be considered more often by industry. Therefore, it is important for decision makers to realize that the techniques now known for remedying hazardous waste sites are by no means the only techniques that will prove successful.

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UNIVERSITY OF IDAHO

MOSCOW, IDAHO

INTRODUCTION

NCP References

A chemical waste disposal site located on University of Idaho (UI) property in Moscow, Idaho (see Figure 1) was used from 1972 to 1979 for disposal of various chemical wastes from the university campus. Concern over the site was prompted by the City of Moscow's proposal to sink a new municipal well about 800 feet (244 m) away from the site. When the City applied to the state Department of Health and Welfare (DHW) for a permit to sink the well, DHW denied the permit because of the lack of information about the possible threat of ground water contamination from the hazardous chemicals. DHW further stated that the proximity of the hazardous waste dump to the university's existing wells located approximately 300 feet (91 m) from the site jeopardized the approval status of the university's water system. The disposal site (shown in Figures 1-3) consisted of 11 trenches located on a small hillside. At the time of site closure in 1979, the site contained approximately 10 to 15 tons (9-14 Mt) of pesticides, acids, mixed solvents, and miscellaneous laboratory wastes.

Background

In 1975, the Environmental Protection Agency approved a chemical waste dump constructed by the University of Idaho for disposal of miscellaneous wastes from campus laboratories and physical plant operations. About 10-15 tons (9-14 Mt) of wastes were dumped into 11 backhoe-dug trenches in an 80 by 40 foot (24 by 12 m) fenced in area (Figure 3). The disposal site was located on campus agricultural land adjacent to a nearby shopping center (Figure 2).

Figure 1. Former Disposal Site Location, University of Idaho, Moscow

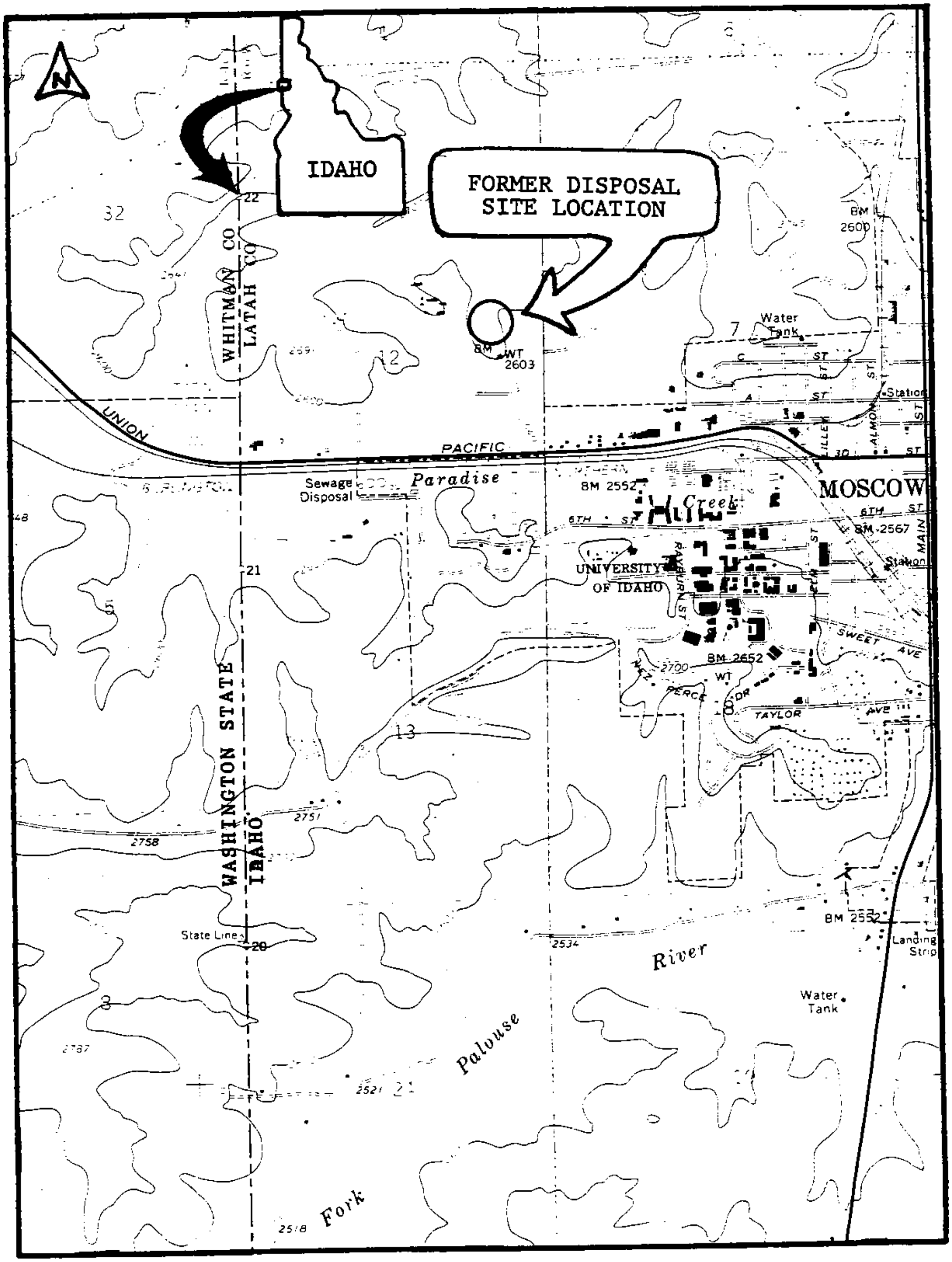


Figure 2. Former Disposal Site and Supply Well Locations

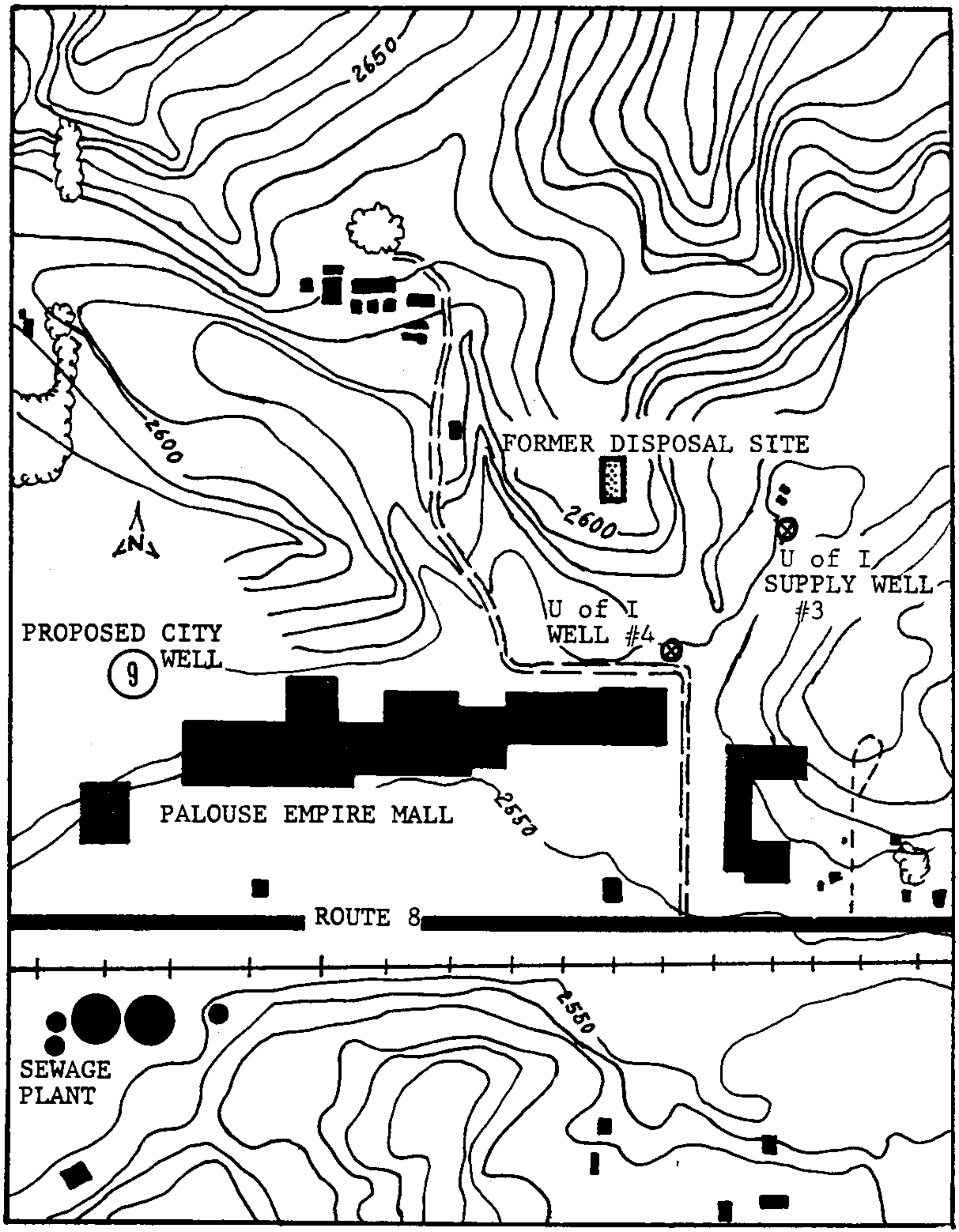
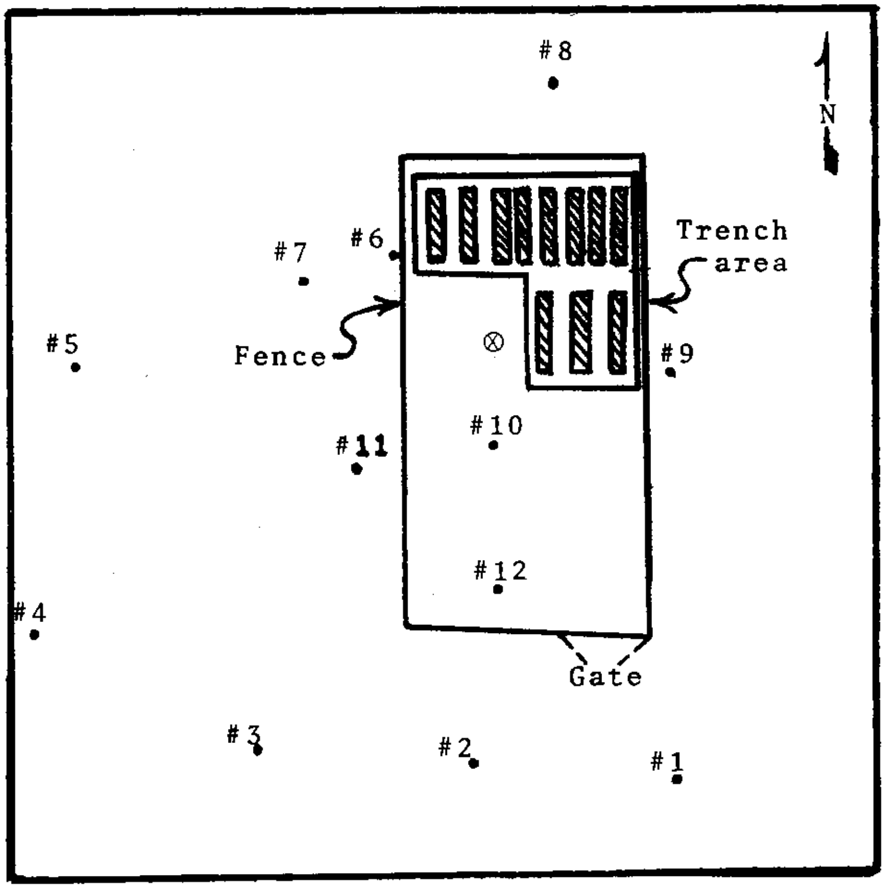


Figure 3. Monitoring Wells and Trench Location



The City of Moscow had planned to locate a new city water well some 800 feet (244 m) away from the site, but was denied approval by DHW based on the lack of information about possible ground water contamination from the dump site. Furthermore, because two university wells were also located approximately 300 feet (91 m) from the site, DHW determined that the approval status of the university's water system was in jeopardy. In order to clarify approval status of the university's well and to secure approval for the municipal well, DHW requested a study to address the geology and ground water conditions at the dump site and surrounding vicinity.

300.65(a)(4) discovery

300.68(f) remedial investigation

Synopsis of Site Response

A testing program was entered into jointly by the university and the city in response to DHW's request for a hydrogeological study. Environmental Emergency Services Inc. (EES) was hired to drill test wells and report the soil conditions, including the probability of migration beyond the site. EES reported a very limited and minor migration (discussed in "Description of Contamination" section), but recommended that the chemicals be removed before drilling a new well. The University of Idaho decided to proceed with excavation of the buried chemicals and contracted with EES for the excavation and removal of chemicals and contaminated soil. EES excavated a total of 817 cubic yards (625 m^3). The contaminated material was taken to an approved disposal facility at a site near Arlington, Oregon, owned by the State of Oregon and operated by Chem Security Systems, Inc. The land was back-filled with clean fill by the University of Idaho, and was cultivated with an alfalfa crop.

300.68(f) assessing the use of source control remedial action

Surface Characteristics

Moscow, Idaho (population 16,513) is situated west of the Bitteroot Mountains in northwestern Idaho bordering with Washington, 75 miles (120 km) southeast of Spokane, Washington. Moscow is at an elevation of 2,550 to 2,650 feet (777 to 808 m). The average temperature ranges from a high of 83.4 degrees F (28.5 C) in July to a low of 22.1 F (-5.5C) in January. On the average there are 11 days per year with temperatures reaching 90 F (32.2°C) or higher and only 3 days when the temperature falls to 0 F (-17.8 C) or below. Relative humidity is highest in the winter months ranging from 65 to 80%. The humidity is lowest in the summer months ranging from 25 to 75% with afternoon values 25 to 40%. Damaging winds are infrequent but do occasionally occur with thunderstorms during the winter months. Winds usually range 12 miles (19 km) per hour

300.68(e)(2)(i)(E) climate

or less. The greatest frequency of fog, low visibility and low clouds is during November through February. Average snowfall each season is 53.2 inches (135 cm) most of which occurs in the winter and spring. Average annual precipitation is 22.21 inches (56.4 cm). The disposal site itself is situated at a slight slope on a 50 foot (15 m) hilltop at an elevation of approximately 2600 feet.

Hydrogeology

The following description is drawn from a report made by a consulting geologist to the City of Moscow.

300.68(e)(2)(i)(D) hydrogeological factors

The area in the vicinity of the disposal site is underlain by a large thickness of mostly basalt overlying a granitic basement rock. The basalt and intercollated sediments form the primary aquifers for the cities of Moscow and Pullman. Wind blown silt or loess overlies the basalt, resulting in a low permeability of the soil, since loess has a uniformly low hydraulic conductivity. The driller's log from the university well describes the geologic material some 300 feet (91 m) from the disposal site. This data indicates that basalt was first intercepted 11 feet (3.4 m) below land surface. Given that the basalt level is fairly even in the immediate vicinity of the disposal site, the depth to basalt at the disposal site would thus be about 60 feet (18.3 m). The elevation at the top of the university well is about 2560 feet (780 m); at the top of the hill, 2610 feet (796 m). The University well is drilled to a depth of 747 feet, deriving water from depths greater than 600 feet (183 m) with a static depth to water greater than 200 feet (61 m). Thus the depth to water below the disposal site is 600 feet (183 m).

WASTE DISPOSAL HISTORY

The University of Idaho chemical waste dump was used for the disposal of chemicals from 1972 to 1979. Approximately 10 to 15 tons (9-14 Mt.) of chemical wastes were disposed of into 13 foot (4 m) deep trenches, which were dug with a backhoe. The disposal site consist of 11 trenches contained within a 80 by 40 foot fence (24 by 12 m). UI records indicated that large volumes of organic solvents, herbicides, insecticides, pesticides, and inorganic chemicals had been indiscriminately deposited within the cells. The trenches were unlined, and many of the containers in which chemicals were stored had ruptured and leaked contaminants in the trenches. In addition it is highly probable that the mixing of chemicals within the trenches altered the compounds to substances other than those recorded on the UI disposal sheets. A complete inventory of the waste was kept by the Safety Control Officer and turned over to the state of Idaho.

In 1979 the site was closed, and an alternate disposal method was arranged for at an off-site approved facility. The City of Moscow had been denied approval by DHW for a proposed well to be located some 800 feet (244 m) from the site. The DHW further determined that the proximity of the site to UI's water system jeopardized the university's approval status of and requested a complete hydrogeological study of the problem by the university.

DESCRIPTION OF CONTAMINATION

EES carried out a testing program from May 27 - 30, 1981 to determine the extent of migration of chemicals that were buried at the site. As shown in Figure 3, thirteen test wells were drilled at various locations in the area of the site, and soil samples were analyzed using a uniform testing system. The results of all tests performed were below detectable limits for each contaminant with the exception of copper and arsenic. The unusual elevation for these two elements was attributed to the lubricant used on the drill itself. The lubricant was shown to have been made of a copper material with an arsenic component.

300.68(f) sampling and monitoring

Table 1 shows the results of EES's soil test analysis for each of the four groups used to screen for persistent compounds. Thirteen multi-level monitoring wells were drilled with screen ranges of 6 feet (1.8 m) to 38 feet (11.6 m). The four groups of contaminants tested for were divided as follows.

Group 1. Organic phosphorous pesticides--This group includes Class A poisons; compounds which are extremely toxic but relatively short lived. Detectable level, less than 1 ug/g.

Group 2. Heavy metals--This group includes lead, copper, mercury, and arsenic. These materials do not degrade and can be expected to migrate through water. Detectable level, less than 1 ug/Kg.

Group 3. Chlorinated pesticides--In addition to pesticides, this group includes phenoxyherbicides and PCBs. Detectable limits, 1 ug/kg.

TABLE 1. RESULTS OF SOIL SAMPLES TAKEN PRIOR TO EXCAVATION

Sample #	Group 1	Group 2 (mg/kg)				Group 3	Group 4
		Hg	Cu	Pb	As		
1	bdl	bdl	9.7	bdl	.9	bdl	bdl
2	bdl	bdl	7.4	bdl	.9	bdl	bdl
3	bdl	bdl	6.6	bdl	.6	bdl	bdl
4	bdl	bdl	6.8	bdl	.9	bdl	bdl
5	bdl	bdl	7.7	bdl	.9	bdl	bdl
6	bdl	bdl	6.4	bdl	.8	bdl	bdl
7	bdl	bdl	5.6	bdl	.6	bdl	bdl
8	bdl	bdl	4.7	bdl	.7	bdl	bdl
9	bdl	bdl	6.0	bdl	.9	bdl	bdl
10	bdl	bdl	6.7	bdl	.9	bdl	bdl
11	bdl	bdl	8.6	bdl	1.0	bdl	bdl
12	bdl	bdl	5.4	bdl	.8	bdl	bdl
13	bdl	bdl	6.3	bdl	.5	bdl	bdl

Key: bdl- below detectable limits
Hg- Mercury
Cu- Copper
Pb- Lead
As- Arsenic

Source: Environmental Emergency Services, "Report on Site Investigation at the Old UI Chemical Waste Deposit Site," June 3, 1981.

Group 4. Solvents--This group contains carbon tetrachloride and benzene, in addition to other suspected solvents. Phenols were also added to this group at the request of the State of Idaho. Detectable limits, less than 1 ug/Kg.

With the exception of copper and arsenic contamination, which was determined to be an artifact of the lubricant used on the drill, all contaminants were shown to be below detectable limits. In addition, although data on contaminant levels was presented in terms of detectable limits and not drinking water standards, the EES report indicated that chemical concentrations were also below safe drinking standards, with the exception of copper and arsenic for the same reason as previously mentioned. In order to remove any possible future threat of migration of chemicals, EES recommended that the hazardous waste be excavated and removed from the site.

300.68(e)(2) source control remedial action

PLANNING THE SITE RESPONSE

Initiation of Response

Concern over the site was prompted when the City of Moscow was denied approval by DHW to sink a new city water well some 800 feet (244 m) from the site. In a letter of April 17, 1981, DHW requested the University of Idaho to arrange a study to "address the geology, soil characteristics, topography, and ground water flow at the dump site and surrounding vicinity." This information would then be used to determine the safety of both the university wells and the proposed city well. The University responded by soliciting proposals from EES and two other firms for soil testing and clean-up. Time considerations were given a high priority in order to minimize further delay in sinking the new municipal well.

Selection of Response Technologies

The response alternatives considered by UI were: (1) complete removal of contaminated soil, and (2) encapsulation of the site. Encapsulation of the site would involve installing an impervious cap over the site with layers of sand, PVC liners and crushed rock. This option would have been only a temporary measure which would only postpone ultimate removal of the soil. The University of Idaho determined that complete waste removal was in the best overall interests of all the parties concerned. Although DHW was prepared to accept some alternative plan for waste containment, UI made a

300.68(g) development of alternatives

decision for complete removal based on several factors: the possible threat of future migration of chemicals to the water supply, the detrimental future impact that the buried materials might have on the development of the property by the university, and the cost of continued monitoring that would be necessary without complete removal.

300.68(h) initial screening of alternatives

Given UI's goal of complete waste removal, the appropriate remedial technology was excavation, transportation, and disposal of chemicals and contaminated soils. On June 8, 1981, UI signed an "Hazardous Substance Excavation and Removal Agreement" with Environmental Emergency Services. The parties contracted to:

- remove the soil at the site to a depth of 13 feet from the original grade (estimated 600 to 900 cubic yards (459 to 688 m^3);
- to transport all excavated soil to Chem Security Systems in Arlington, Oregon for disposal; and
- to take soil samples from the bottom and sides of the excavation as are necessary to determine that the hazardous waste materials do not remain.

Extent of Response

From July 18 to 25, 1981, approximately 817 cubic yards of chemicals waste, contaminated soils, and debris were excavated from the UI site. The site was excavated to an undetermined depth, exceeding 13 ft (4 m), and 25 cubic yard (19 m^3) dump trucks were used to transport the contaminated material to an approved dump site in Arlington, Oregon operated by Chem Security Systems and owned by the state of Oregon. The resultant pit was divided into grids from which soil samples were taken. When the digging was stopped, the soil concentration of each hazardous substance was less than 10 ug/g, which was the interim drinking water standard for 2,4 - D at the time. The EES report to UI made on August 21, 1981 provided the following conclusion: "Although evidence of contamination still exists, the levels are relatively minor and represent no danger to nearby water sources. The concentrations of contaminants found represent an insignificant volume of material which will most likely remain bound in the soil until it ultimately degrades."

300.68(j) extent of remedy

Table 2 shows the results of soil samples taken following the excavation as reported by EES to UI on August 21, 1981. The City of Moscow built the water well, and the disposal site is now covered with an

TABLE 2. RESULTS OF SOIL TAKEN FOLLOWING EXCAVATION
(ug/g)

Ident.	Cu	As	Hg	Pb	Chlorinated Ionic	Pesticides Chlorinated Non-ionic	O-P (b)
#1	5.0	1.0	ND*	ND*	ND*	ND*	ND*
#2	5.5	1.1	ND	ND	ND	ND	ND
#3	5.1	1.0	ND	ND	ND	ND	ND
#4	6.0	1.6	ND	ND	2.0(2,4-D)	5.8 (DDT)	(trace) (a)
#5	5.4	1.7	ND	ND	ND	0.2 (dieldrin)	ND
#6	5.1	1.5	ND	ND	ND	0.8 (aldrin) 5.1 (dieldrin)	ND
#7	5.1	1.2	0.24	ND	ND	ND	ND
#8	9.6	1.3	0.62	ND	0.4(2,4-D)	0.8 (DDT)	ND
#9	5.7	1.4	0.26	ND	ND*	ND	ND
#10	6.7	1.5	1.2	0.5	ND	ND	ND
#11	9.8	1.9	1.5	0.4	0.1(2,4-D)	2.0 (dieldrin) 1.1 (DDT)	ND

Cu = Copper
As = Arsenic
Hg = Mercury
Pb = Lead

ND= None Detected

(a) Disyston found to be present but could not be quantitated.

(b) organophosphate pesticides

* Minimum detectable limit = 0.1 mg/kg except lead = 0.2 mg/kg

alfalfa crop which 3 harvests a year which are used for cattle feed. Although the Idaho Department of Health and Welfare had informed the university there is no need for futher monitoring of any of the test wells, the monitoring wells are still maintained and are available for field lab experience by hydrology classes on campus. Students can gain experience in testing in ground water contamination, and at the same time provide frequent inexpensive monitoring.

300.70(b)(1) (ii)(D) revegetation

DESIGN AND EXECUTION OF SITE RESPONSE

The basic components of the remedial action are listed and described in the following sections. The response action at this site was straight forward and without complication.

Sampling, Testing, and Analysis

The first part or Phase I of the remedial action involved drilling a series of 13 test holes and taking soil samples at various depths. The samples were analyzed by a certified laboratory using EPA approved procedures. Soil samples were taken from depths ranging from 6 feet to 38 feet (1.8 - 11.6 m) and at locations agreed upon by EES and UI. The drilling took place from May 27 to May 30, 1981. Samples were analyzed to determine the occurrence of any gross migration of chemicals or possibility of such migration which might affect the drilling of the proposed water well on UI property. The samples were analyzed specifically for the hazardous materials listed by the University of Idaho in the request for proposal. The tests were not designed to test for the presence of naturally occurring elemental materials inherent in the soils. The suspected chemicals were divided into four groups to screen for long lived toxic compounds associated with hydrophopic and hydrophilic leachate materials. Results of these tests are given in the "Description of Contamination" section. All four groups were shown to be below detectable limits with the exception of copper and arsenic in the heavy metals group. The elevated levels for copper and arsenic were determined to be erroneous due to contamination from the lubricant used on the drill itself. Gross migration of chemicals beyond the boundaries of the site was not found.

300.68(f) remedial investigation

Excavation, Transportation, Disposal

In accordance with the Excavation and Removal Agreement, EES excavated 817 cubic yards (625 m^3) of chemicals and contaminated soils from July 18 to 25, 1981. Soil removal was accomplished with a Caterpillar

300.70(c)(2) (i) removal of contaminated soils

30 ft (9 m) arm backhoe with a 2 cubic yard (1.5 m^3) bucket. The contaminated soil was placed in 25 cubic yard (19 m^3) dump trucks that had been lined and made water tight. The trucks were then covered and sealed after loading. The contaminated materials were then transported to Chem Security Systems in Arlington, Oregon for disposal. This is an approved facility owned by the State of Oregon. The contract provided that all work be done in accordance with federal and state regulations.

300.70(c) off-site transport for secure disposition

Post-Excavation Soil Analysis

Following the excavation, 11 soil samples were taken from predetermined locations within the resulting pit. The results of these tests are presented in the "Extent of Response" section, showing relatively minor levels of remaining contamination. This follow-up soil analysis was done in accordance with the contract signed between EES and UI.

The pit was backfilled by the university with clean fill taken from a construction site on campus. The site is now covered with an alfalfa crop.

COST AND FUNDING

Source of Funding

The total cost of Phase I of the remedial action--the initial sampling testing, and analysis--was shared equally by the University of Idaho and the City of Moscow, providing $9119 each for a total of $18,237. Phase II cost $156,660 and was paid for entirely by UI out of the facilities capital improvement fund.

300.62(a) state role in response

Selection of Contractors

On May 14, 1981, UI formally requested proposals from three companies for site clean-up and testing of soil in the vicinity of the site. The request for proposal specified that costs for excavation, loading, transport, and disposal shall be quoted on a cubic yard (m^3) basis, and costs for the initial report on soil conditions be quoted on a lump sum basis. Environmental Emergency Services of Portland, Oregon was chosen because it had both the lowest estimate and technical qualifications. EES estimated the excavation would involve removing 600 to 900 cubic yards (459 to 688 m^3) and quoted a price of $192 per cubic yard ($147/m^3). The Phase I estimate was originally $13,435 but was increased to $18,237 to accommodate UI requests to increase test hole depth, take additional soil samples, and perform additional contaminant testing. The contract for Phase I was signed on May 28, 1981. The contract for Phase II was signed on July 8, 1981.

Project Costs

The total cost of the Moscow clean-up was \$174,897. Precise cost breakdown of each of the clean-up elements is not possible because of the lump sum and cubic yard (m^3) basis on which costs were estimated and billed to the university. The \$192 per cubic yard (\$147/m^3) included the entire volume of activities in Phase II, totalling \$156,660. Table 3 summarizes the cost information for Phase I and II. One invoice was submitted for each phase simply providing totals for the work completed.

PERFORMANCE EVALUATION

The streamlining of this particular clean-up benefited from the cooperation between federal, state, and university officials. The full range of response to the site was accomplished in 3 1/2 months, from April 17, 1981 when DHW denied a permit to the City of Moscow for a new well to August 3, 1981 when DHW pronounced the area safe for future activity. The work done by Environmental Emergency Services was accomplished within the contractual time frames and was highly regarded. Delays in the response action were avoided due to the willingness of the University of Idaho to pay for the clean-up. The City of Moscow proceeded with construction of the new water well.

TABLE 3. SUMMARY OF COST INFORMATION FOR MOSCOW, IDAHO

Task	Quantity	Estimated Expenditure	Actual Expenditure	Variance	Unit Cost	Funding Source	Period of Performance
Testing, Drilling, and sampling of contaminated soil (Phase I)	--	$18,237	$18,237	0	--	City of Moscow: Univ. of Idaho:	May 27-June 3,1981
Excavation, Transportation, and disposal	817 cu. yards ($625 m^3$)	$192/cu.yd ($251/m^3)	$156,660	0	$192/cu.yd. ($251/m^3)	Univ. of Idaho	excavation, transportation disposal July 18-25, 1981 Final soil report submitted Aug. 21,1981
Total			$174,897				

-- : Not Applicable

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VERTAC CHEMICAL CORPORATION

JACKSONVILLE, ARKANSAS

NCP Reference

INTRODUCTION

The Vertac Chemical Corporation owns and operates an herbicide manufacturing plant in Jacksonville, Arkansas. On-site disposal of chemical wastes and discharges of process wastewater over a thirty year period resulted in contamination of soils, ground water and surface waters by several substances, most notably dioxin, in excess of Federal and state levels. Administrative and judicial orders have required the company to undertake five distinct remedial actions to date, and have required Vertac to submit studies of on-site and off-site contamination, which may necessitate further remedial action. Although remedial action at this site may not be complete, and some cost and engineering details are not available regarding this private clean-up, a large portion of the work has been done and sufficient information is available for this case study.

Background

The Reasor-Hill Company purchased the site in question from the U.S. Government in 1948. The Government had used it for a munitions factory in the 1930's. Reasor-Hill owned it from 1948-1961 and built a plant to formulate the insecticides DDT, aldrin, dieldrin and toxaphene. During the 1950's, it also began producing the herbicides 2,4-D; 2,4-5-T; and 2,4,5-TP ("Silvex"). The Hercules Chemical Corporation purchased the plant site in 1961 and continued manufacturing the same products. In 1967-1968, Hercules produced "Agent Orange," a 2,4,5- T/2,4-D mixture, for the Government. From 1971 to 1976, Hercules leased the plant to the Transvaal Corporation, a subsidiary of Vertac, Inc. Transvaal resumed production of 2,4-D and intermittently produced 2,4,5-T. Transvaal purchased the property from Hercules in 1976. In 1978, Vertac, Inc. underwent a Chapter XI bankruptcy reorganization and ownership of the site was transferred from Transvaal to the new company, Vertac Chemical Corporation, which is the present owner. Contamination of soil, surface water and ground water has resulted from the storage and disposal of process chemical wastes at this site between 1948 and 1979.

Synopsis of Site Response

Remedial actions have been completed at five major areas on the Vertac site to date. The Reasor-Hill landfill area was capped with clay, covered with soil, and seeded. Clay barrier walls were installed on three sides, leaving the downgradient side open. The Hercules-Transvaal landfill was also capped with clay, covered with soil and seeded, but had no barrier walls at the time of this study. The former above-ground storage area was capped, covered with soil and seeded; the old drums were repacked and placed along with new drums in a roofed storage warehouse. Two-thirds of the blow-out area, where spills from reactor vessels had occurred was paved with asphalt while the remaining portion was capped with clay, covered with soil and seeded. Extensive remedial work was performed on the equalization basin, which pre-treated the plant's process wastewater. Vertac dewatered the basin, solidified its sludge with lime, installed clay barrier walls around it, a French drain downgradient from it, and placed a clay cap, topsoil, and seed over it. The company then constructed an above-ground treatment system to replace it. Before and throughout the site response, extensive monitoring of soil, ground water and surface water has taken place, including 15 test pits, 42 test borings, 39 piezometers, and 19 ground water monitoring wells. In addition, numerous samples were taken from surface soil, surface water and sediments on and off the site. Further, Vertac was directed by a Consent Decree to have an independent consultant conduct studies of both on-site and off-site contamination and report on the effectiveness of the completed remedial actions.

SITE DESCRIPTION

The Vertac site is located in northwest Jacksonville, Arkansas, approximately 20 miles (32 km) northeast of Little Rock. The facility is about 93 acres (37 ha) in size. As Figures 1 and 2 show, the site is bounded to the east by Marshall Road and the Missouri-Pacific Railroad to the west. The northern boundary is an old artillery booster line. Adjacent to the site to the south is a housing development. Rocky Branch Creek flows along the western edge of the site and the East Branch is located to the east of the site. A cooling pond, formed by construction of an earthen dam across Rocky Branch, is located along the western edge of the site. Rocky Branch flows into Bayou Meto approximately 2 miles (3.2 km) south of

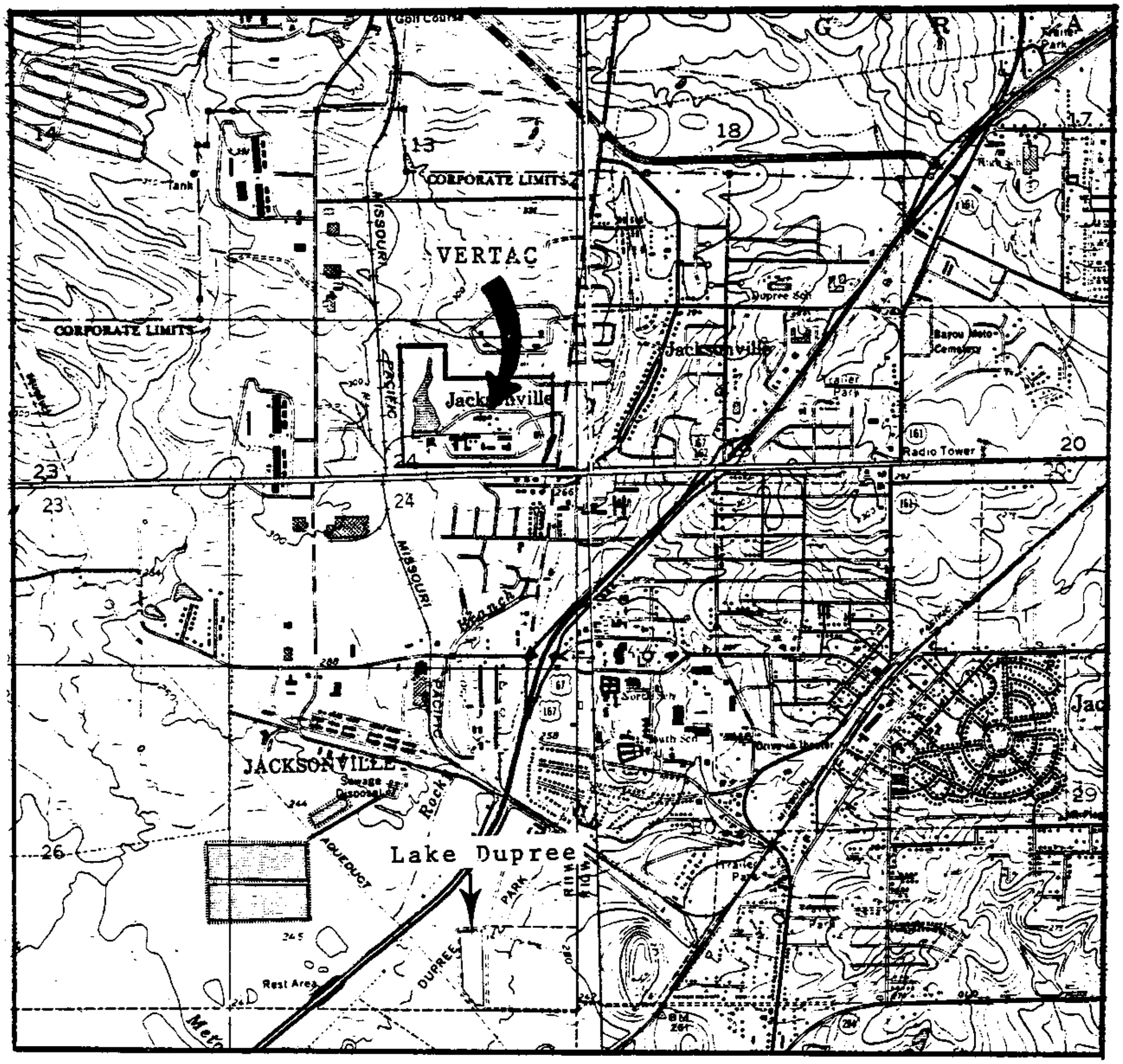


Figure 1. Topographic Section of Vertac Site Location
Source: USGS, 1975.

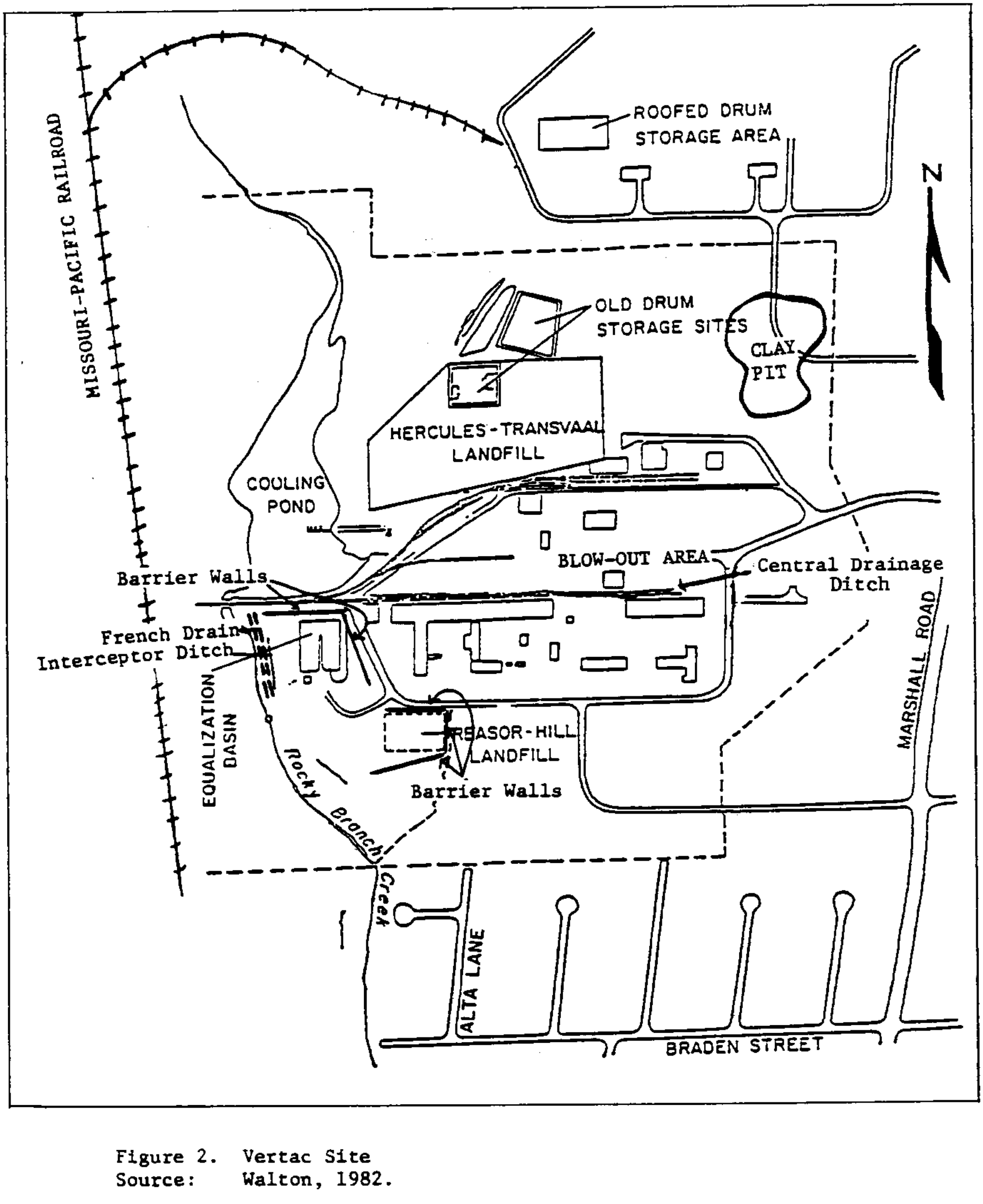


Figure 2. Vertac Site
Source: Walton, 1982.

the Vertac site. The entire site is fenced in with the main gate facing Marshall Road.

Surface Characteristics

The Vertac site is located in Pulaski County, Arkansas. The topography of Pulaski County (see Figure 1) does not have a major influence upon the climate. Climatic conditions are caused by exposure to all of the North American air mass types. Air which moves downslope from the higher elevations may be slightly warmer at lower elevations. Because of the lifting effect transmitted to moist air by local ridges and mountains, there is slightly more rainfall at higher elevations.

300.68(e)(2)
(i)(E)
climate

Winters are basically mild and relatively free of severe cold. The daily winter temperature averages at 41°F (5°C). January is the coldest month and a low of 10°F (-12°C) occurs frequently. The lowest temperature ever recorded in Pulaski County was -13°F (-25°C) in February 1899. Annual snowfall averages 5.7 inches (14.3 cm) per year, however almost half of this snowfall occurs during the month of January. The greatest monthly snowfall ever recorded was 12 inches (25 cm) in January 1966.

Summers in Pulaski County are hot with large periods of high humidity. The daily summer temperature averages at 82°F (28°C). The hottest months are July and August when a high temperature of over 100°F (38°C) occurs frequently. The highest temperature ever recorded in Pulaski County was 110°F (43°C) in August 1936.

Precipitation is fairly well distributed throughout the year, however May is normally the wettest month. The average annual precipitation is approximately 48 inches (120 cm). During March, April, and May approximately 15 inches (38 cm) or almost 31 percent of the annual total precipitation falls. The driest months are August, September, and October when approximately 3 inches (8 cm) of rain falls.

The soil has been classified as the Leadvale-Urban land complex with a 1 to 3 percent slope. The Leadvale series are composed of moderately well-drained, nearly level and gently sloping soils in valleys. They are formed mainly in loamy sediment washed from uplands consisting of weathered sandstone and shale and in some areas from material weathered from siltstone. The native vegetation is mixed hardwoods and pines. Leadvale soils show moderately slow permeability and maintain a medium level of available water capacity. The Leadvale-Urban land complex are areas of Leadvale soils that have been modified by urban development. The level of runoff from the Leadvale-Urban land complex is medium, while the erosion hazard is moderate if the soils are not protected by vegetation. Additionally, these soils maintain a seasonal perched water table, slow percolation rate, and moderate bearing capacity.

Hydrogeology

300.68(e)(2)
(i)(D)
hydrogeological
factors

Pulaski County is an area that is composed of two physiographic regions: the Interior Highlands and the Coastal Plain. The Interior Highlands are hilly and underlain by unconsolidated sediments which dip slightly in a southeasterly direction. The consolidated rock of the Interior Highlands underlies the unconsolidated sediments of the Coastal Plain. Above the lowest level of the water table, the consolidated rock of the Interior Highlands has been subject to weathering. This has formed soil and "rotten rock", which have a total maximum thickness of approximately 20 feet (6.1m). This weathered area is more permeable and porous than the original unweathered rock. Water is present in the intergranular voids of the "rotten rock" and soil while water is also present in secondary openings, such as joints and fractures in the unweathered rock.

The relationship of the Interior Highlands to the Coastal Plain is shown in Figure 3. The relationship of the rocks of the Coastal Plain to those of the Interior Highlands is shown in Figure 4. The Coastal Plain sediments, which make up Units 3 to 9, vary from high plasticity clays to sands and gravels. Additionally, permeabilities vary quite a bit between units. Units 3, 7, and 9 are major water sources in some areas throughout Pulaski County. Unit 3 is made up of beds of claystone, calcareous sandstone, sandy limestone, marl and conglomerate. Its thickness varies from 7 to 60 feet (2.1-18.3m). Unit 7 is composed of fine to medium sand with some interbedded clay lenses. Its total thickness is approximately 320 feet (98m). Unit 9 is composed of terrace deposits and alluvium. The terrace deposits are formed of sand while the alluvium, which is deposited by both the Arkansas and Mississippi Rivers, is made of a fine-grained top stratum which becomes coarser with depth. Unit 9 reaches a thickness of 120 feet (36.6m)near the Arkansas River and is much thinner at other locations. Units 4, 5, 6, and 8 are primarily fine-grained materials which, unlike 3, 7, and 9, do not yield much water.

The Vertac site is situated very near or possibly on the fall line of the Interior Highlands and Coastal Plain. Although geologic maps show that the Vertac site is

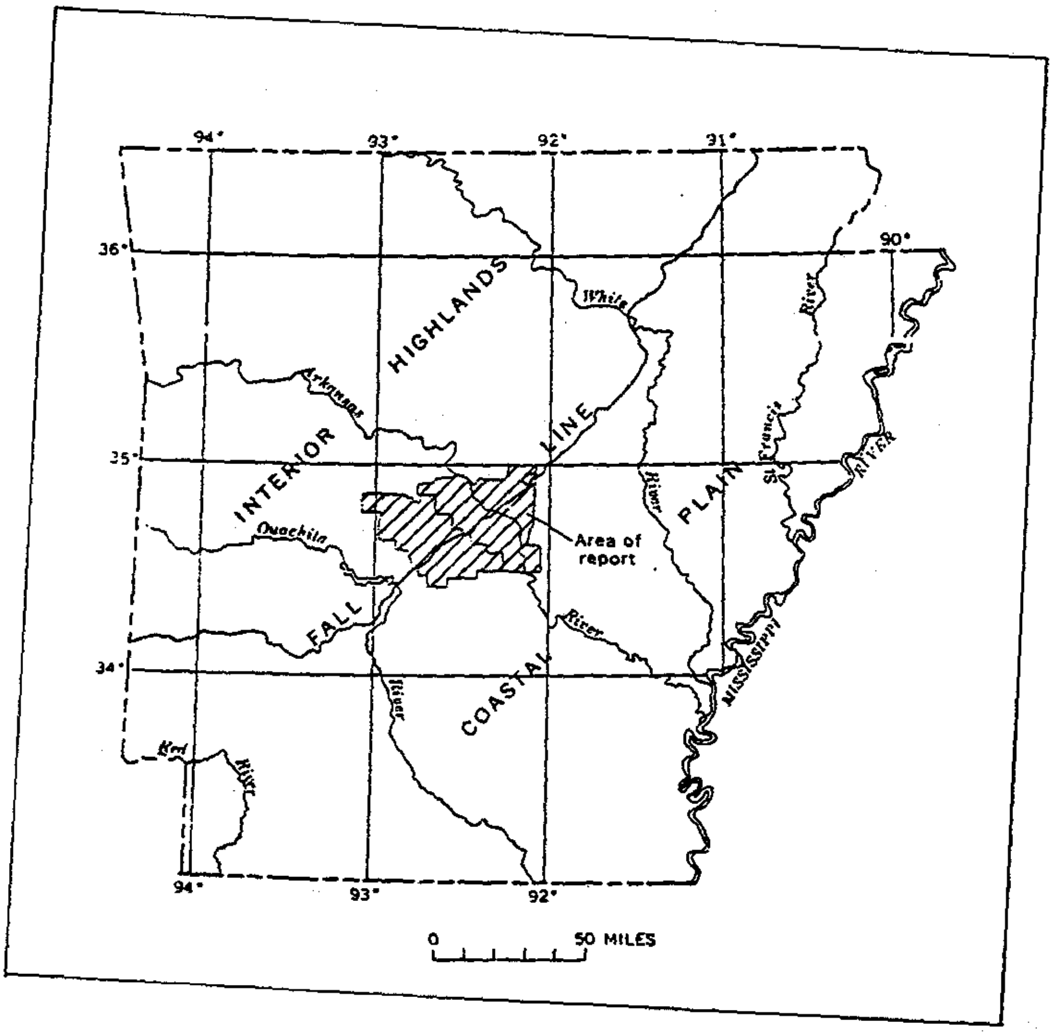


Figure 3. Relationship of Interior Highlands to Coastal Plain
Source: Walton, 1982.

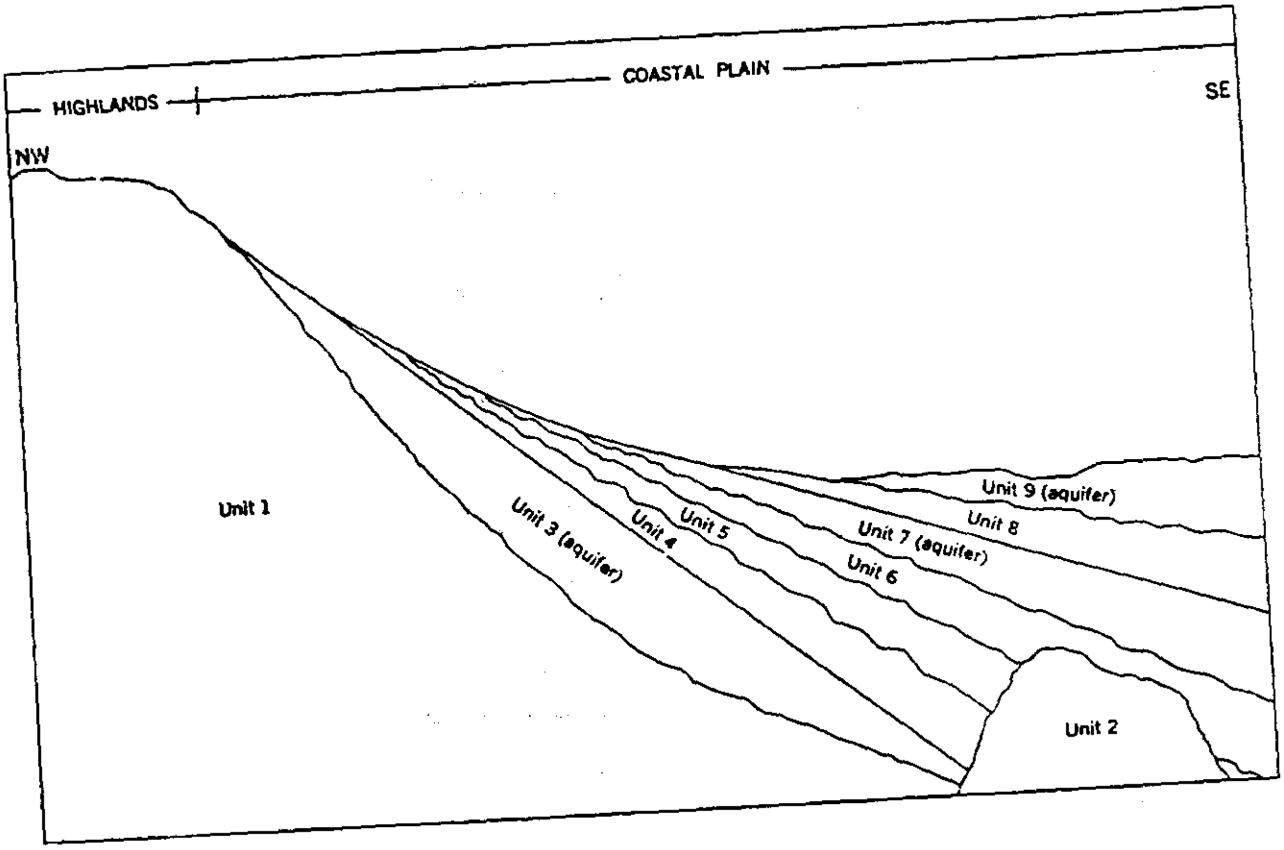


Figure 4. Relationship of Subsurface Characteristics of the Coastal Plain to the Subsurface Characteristics of the Interior Highlands

Source: Walton, 1982.

slightly to the west of the fall line, which would indicate that it is in the Interior Highlands, there is evidence which indicates that it is also in the Coastal Plain, or perhaps in a zone of transition between the two. The subsoils are part of the Atoka Formation which is found in the Interior Highlands, however clays of the Midway Group, which are present in the Coastal Plain, are known to exist in the northern part of the site. Additionally, a surficial geologic inspection made by Developers International Services Corporation (DISC), a consultant to Vertac, indicates that the surface soils near the eastern portion of the site are sedimentary, which further supports the theory that a portion of the site is in the Coastal Plain. Regardless, at relatively shallow depths, the Vertac site is underlain by the consolidated rock of the Atoka Formation which surfaces in the Interior Highlands and underlies the sediments of the Coastal Plain.

The Vertac plant is located on the south flank of a westward plunging syncline. The axis of the syncline is approximately 5 miles (8 km) north of the plant and has a strike between N 75°W and N 60°W. The bedrock is alternating gray to black shales and sandstones of the Atoka Formation which dips to the NE at a rate of almost 30°. Because the site is so close to the fall line, there are many discrepancies regarding the strike and dip of the rock strata at the Vertac site. Overlying the unweathered bedrock in ascending order is weathered bedrock approximately 5 feet (1.5m) thick, clays, and alluvium.

Drainage patterns at the Vertac site are predominately westerly and easterly as shown in Figure 5. The western 55 acres (22 ha) drain directly to Rocky Branch. Rocky Branch enters the Vertac site at the northwest boundary and flows into a man-made cooling pond. Approximately 700,000 gallons (2.7×10^6 l) per day of plant process wastewater enter the cooling pond. Flow from the cooling pond is by way of a concrete outlet structure at the southwest extremity of the pond. Additionally, a central ditch (see Figure 2) which acts as a surface drainage channel from the plant production area, flows into the cooling pond. The combined flow of surface runoff and process water enters Rocky Branch and flows south to Bayou Meto.

The eastern 38 acres (15.2 ha) of the Vertac site drain to the east into numerous small ditches. These are natural erosion channels with only a few man-made ditches along roads and driveways. Several catch basins located in the eastern portion of the site drain into a storm sewer which empties into an open ditch near the main plant

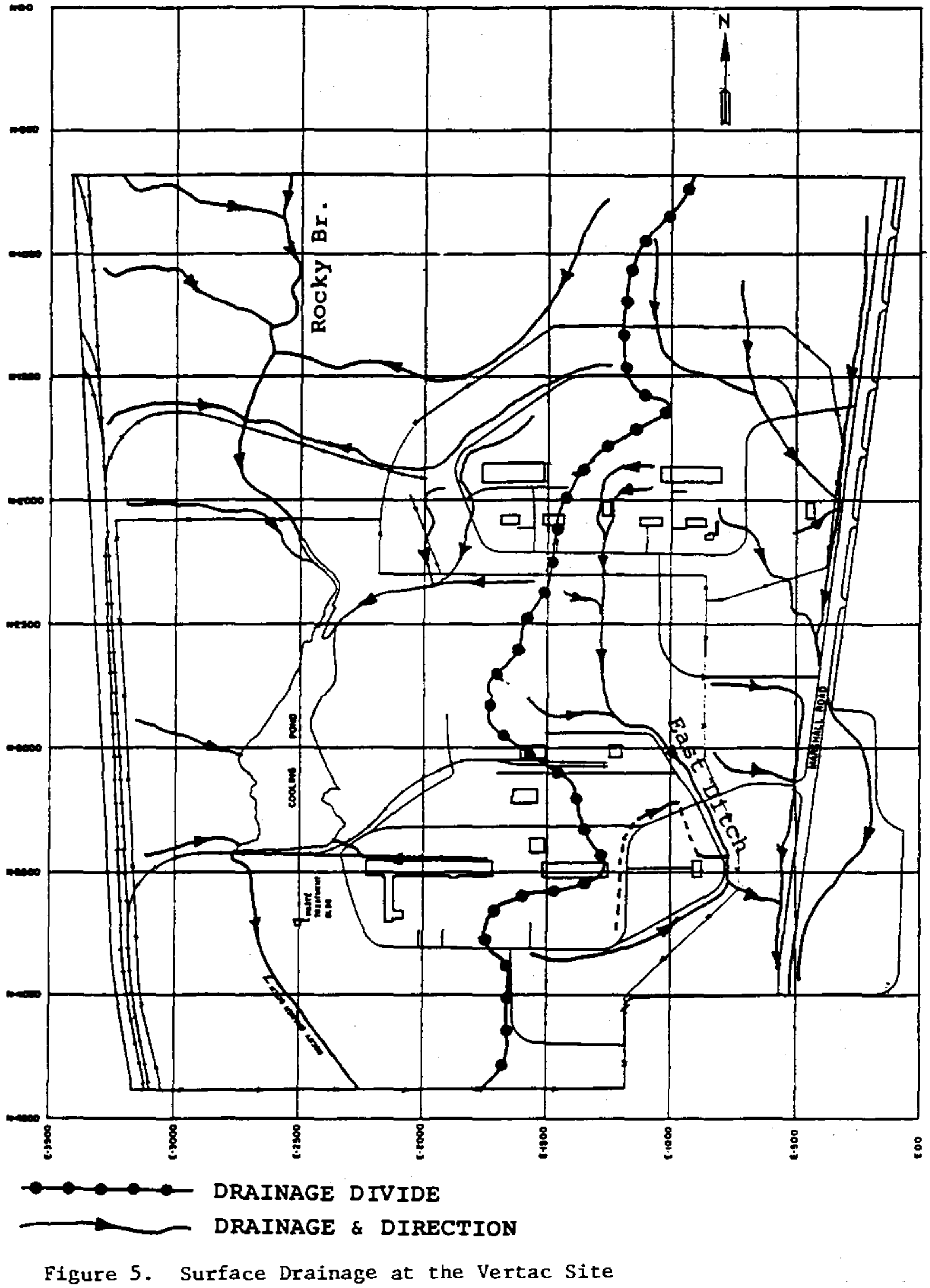


Figure 5. Surface Drainage at the Vertac Site
Source: Walton, 1982.

entrance. All surface runoff east of the drainage divide eventually flows into the East Branch of Rocky Branch. Most of this runoff is carried by the "East Ditch" (see Figure 5) to the East Branch. The East Branch eventually links with Rocky Branch south of the Vertac site.

Additionally, it is important to note that during heavy spring rains it is not uncommon for Rocky Branch to flood the area south of the Vertac site. This is significant because, as shown on Figure 1, there is a man-made body of water, Lake Dupree, located about 1.3 miles (2.1 km) south of the Vertac site. Lake Dupree is approximately 15 acres (6 ha) in size and has been used for recreational purposes. It is likely that flooding has contributed to contaminant transport from the Vertac site to Lake Dupree because contaminants discharged into Rocky Branch from the site subsequently may be removed and deposited in Lake Dupree during flooding.

300.68(e)(1) (vii) weather; substance migration

WASTE DISPOSAL HISTORY

The Vertac site was originally developed by the United States Government in the 1930's and was used as an ordnance plant during World War II. In 1948 it was purchased by the Reasor-Hill Company and converted into a chemical manufacturing facility.

The Reasor-Hill Company operated the facility from 1948 to 1961. At first, Reasor-Hill manufactured the insecticides DDT, aldrin, dieldrin and toxaphene. During the 1950's Reasor-Hill began production of the herbicides 2,4-dichlorophenoxyacetic acid; 2,4,5-trichlorophenoxyacetic acid; and 2,4,5-trichlorophenoxyproprionic acid (Silvex). Drums of organic waste were stacked in an open field immediately southwest of the production area and untreated wastewater was discharged from the west end of the plant and was channeled into Rocky Branch Creek.

300.68(e)(2)(i) amount and form of substances

Rocky Branch drains into Bayou Meto a few miles from the site. Bayou Meto is classified as a warm water fishery according to the September 1975 Arkansas Water Quality Standards. It is categorized as being suitable for desirable species of fish, wildlife, and other aquatic and semi-aquatic life, and as a raw water source for public water supplies.

Pollution problems associated with Bayou Meto and its tributaries, including Rocky Branch Creek, date back at least as far as 1955 when a fish kill occurred in the Bayou near Jacksonville. At that time the Water Pollution Control Commission and the Game and Fish Commission performed an investigation. They determined that the cause of the kill was oxygen depletion resulting from the effluent of the Jacksonville sewage treatment plant. However, other pollution sources were found further upstream along the creek, including the Reasor-Hill chemical plant and the Arkansas Highway Department shops. A strong chemical odor was noted at the Reasor-Hill plant's discharge into Rocky Branch. Other complaints of a "medicinal" taste and odor in fish caught in the Bayou were registered with and investigated by the Game and Fish Commission. They determined that the cause of the problem was the Reasor-Hill effluent. Complaints continued through June of 1958 at which time the Water Pollution Control Commission began a survey of the area. Chemical and bioassay tests on the Reasor-Hill effluent found it to be extremely toxic. The survey continued intermittently through the summer of 1959 when a taste test found no problem with fish from Bayou Meto. However, a biological report (quoted in a summary report found in U.S. EPA Region VI files) stated that "the bottom of the Bayou is devoid of life" and noted that "the stream will become barren unless the situation is corrected."

300.68(e)(3)(i)
contribution to
water pollution
problem

At this time, it became evident that the City of Jacksonville's sewage treatment plant was overloaded because of the increased growth of the city and the Little Rock Air Force Base. It was not until April of 1960 that a meeting was held with representatives of the Air Force and the Water Pollution Control Commission to discuss improvements for the sewage treatment plant. In 1961, following a study of the sewage treatment requirements for the area and a renegotiation of the city's contract with the Air Force, the city improved the sewage treatment plant. At this time, Reasor-Hill began discharging some of its wastewater into the city's sewage treatment plant.

The plant site was purchased by Hercules Chemical Corporation in 1961. Hercules continued to manufacture the same products as Reasor-Hill. The waste drums that were stacked near the plant were buried in the same area. This became known as the "Reasor-Hill landfill" (see Figure 2). Hercules continued to discharge some process wastewater into Rocky Branch Creek and some into the Jacksonville sewage treatment plant. A few months after Hercules gained ownership, the company informed the Water Pollution Control Commission that it intended to pretreat its wastewater to reduce the load on the Jacksonville sewage treatment plant.

Complaints about taste and odor in fish caught in Bayou Meto continued and on February 19, 1963, a massive fish kill occurred in the Bayou approximately 45 miles (72 km) downstream from Jacksonville, near Stuttgart. The Water Pollution Control Commission determined that this was caused by a slug of toxic chemicals from the Hercules plant. By May 20, 1963, Hercules was ordered to shut down operations at the plant and submit plans within 165 days for a pretreatment facility. Hercules complied and a neutralization and equalization pretreatment system was completed in August 1964. As of September 30, 1964, the plant's entire wastewater effluent was being discharged into the Jacksonville sewage treatment plant.

300.68(e)(3)(i) contribution to water pollution problem

Bayou Meto and Rocky Branch Creek were sampled in the summer of 1965 and again in January 1966. Continued improvements in stream ecology, fish, and bottom organisms were found. However, complaints of disagreeable fish taste and odor continued. Another fish kill occurred in Bayou Meto in December of 1965 between Jacksonville and Lonoke which was caused by oxygen depletion in the Jacksonville sewage treatment plant effluent. The Water Pollution Control Commission determined that the sewage treatment plant was overloaded and recommended that the city install a new sewage treatment plant. With joint participation from Hercules, the City of Jacksonville, and a grant from the Federal Government, the new sewage treatment plant was completed in 1969. It was specifically designed to handle Jacksonville municipal wastes and the chemical waste generated by the Hercules facility. Once the new sewage treatment plant went into operation, complaints of the taste and odor in fish decreased.

At approximately this same time, Hercules began to treat its wastewater via a solvent process. This new process separated out several by-products of the waste and produced toluene still bottoms. When hot, the still bottoms were liquid; however, they solidified when pumped into drums and allowed to cool. These drums of solid waste were then buried in an area north of the plant operations area, known as the Hercules-Transvaal landfill (see Figure 2).

From 1967 to 1968, Hercules was ordered to manufacture the herbicide Agent Orange, a 2,4,5-T/2,4-D mixture, for the United States Government. Agent Orange was used as a defoliant in the jungles of Vietnam. A finding of the possible teratogenic effects of Agent Orange by the National Cancer Institute caused a ban on Agent Orange use in the Vietnam War. Soon after the ban, other additional uses of 2,4,5-T were discontinued. Hercules then discontinued operations at the Jacksonville site.

From 1971 to 1976, Hercules leased the plant site to Transvaal, Inc., a predecessor company of Vertac. Transvaal resumed production of 2,4-D and intermittent production of 2,4,5-T. Toluene still bottom wastes from Transvaal's manufacturing processes were also buried in drums at the Hercules-Transvaal landfill area. In 1974 Transvaal ceased still bottom burial and began storing the drums above ground for ultimate recycling or off-site disposal.

In 1976, Transvaal purchased the Jacksonville plant from Hercules. That same year, an EPA inspection of the Jacksonville site did not indicate the presence of dioxin on the plant site. By 1978, Transvaal and three Vertac companies were involved in bankruptcy proceedings.

At that time, the rising concern over the health risks posed by Agent Orange and its dioxin by-product, caused Senator Mark Hatfield to institute a nationwide survey of potential dioxin sites. Vertac participated in this survey and in April 1978 Vertac officials reported to the U.S. EPA and the Arkansas Department of Pollution Control and Ecology that the toluene still bottoms located on the Jacksonville site contained 37 ppm of dioxin (2,3,7,8-tetrachlorodibenzodioxin also known as TCDD). Subsequently, U.S. EPA officials visited the site and took samples to verify Vertac's findings. The U.S. EPA samples did not show any evidence of dioxin in the still bottoms. Vertac scientists then requested verification of the EPA results to clarify the discrepancy between their findings and those of EPA. Meanwhile, in November of 1978, Transvaal and the other Vertac companies were brought out of bankruptcy by new owners to form Vertac Chemical Corporation.

300.63(a)(4)
discovery

In May 1979, using an improved analytical technique, EPA confirmed Vertac's orginal report that there was indeed 37 ppm of dioxin present in the toluene still bottoms at the Vertac site. Subsequently, EPA found trace quantities of dioxin, usually in the parts per trillion (ppt) level, at other locations at the Vertac site.

A final area of waste contamination at the Vertac site is referred to as the "blow-out area". This is an area onto which some of the materials from the trichlorophenol reactor (used by Hercules and Transvaal) were expelled during valve rupture blow-outs experienced by Hercules and Transvaal prior to 1976 (see Figure 2). In 1976, Vertac installed a catch basin into which the expelled contents of the reactor would be discharged during future blow-outs.

In summary, the waste disposal history of the Vertac site includes the following five major waste disposal areas of contamination:

- Reasor-Hill landfill area (drums of organic waste)
- Untreated wastewater discharge to Rocky Branch Creek and ultimately Bayou Meto
- Hercules-Transvaal landfill area (drums of toluene still bottoms)
- Above-ground storage area (drums of toluene still bottoms)
- Blow-out area.

DESCRIPTION OF CONTAMINATION

Historically, it is difficult to determine exactly when much of the contamination at the Vertac site occurred. It is evident that pollutants from herbicide manufacture were detected by 1955 when the previously mentioned fish kill occurred in Bayou Meto near Jacksonville; however, it may be possible that chemical contaminants might have been seeping into the ground, as well as into Rocky Branch Creek, from as far back as 1948 when Reasor-Hill first manufactured insecticides and stacked drums of waste in an open field. These drums consisted of various insecticide wastes and are believed to have contained such compounds as DDT, aldrin, and dieldrin. Still further, depending upon the waste disposal methods used at the time, some contaminants might have been building up in the soil, ground water, and/or Rocky Branch Creek from the 1930's when the Vertac site was originally operated as an ordnance plant by the U.S. Government. Dioxin could not have been present prior to the manufacture of 2,4,5-T in the 1950's. However, it was not known that dioxin contamination was present at the Vertac site until Vertac had discovered dioxin at 37 ppm concentration at the site in 1978, while responding to the previously mentioned nationwide survey of potential dioxin contaminated sites. Furthermore, it was not until May 1979 that EPA positively confirmed Vertac's findings. Therefore, the extent of the dioxin contamination was not even determined until after May 1979, at which time studies were sponsored and conducted by the Arkansas Department of Pollution Control and Ecology (ADPCE), EPA, and by contractors hired by Vertac.

Sampling and Monitoring History

300.68(f) remedial investigation

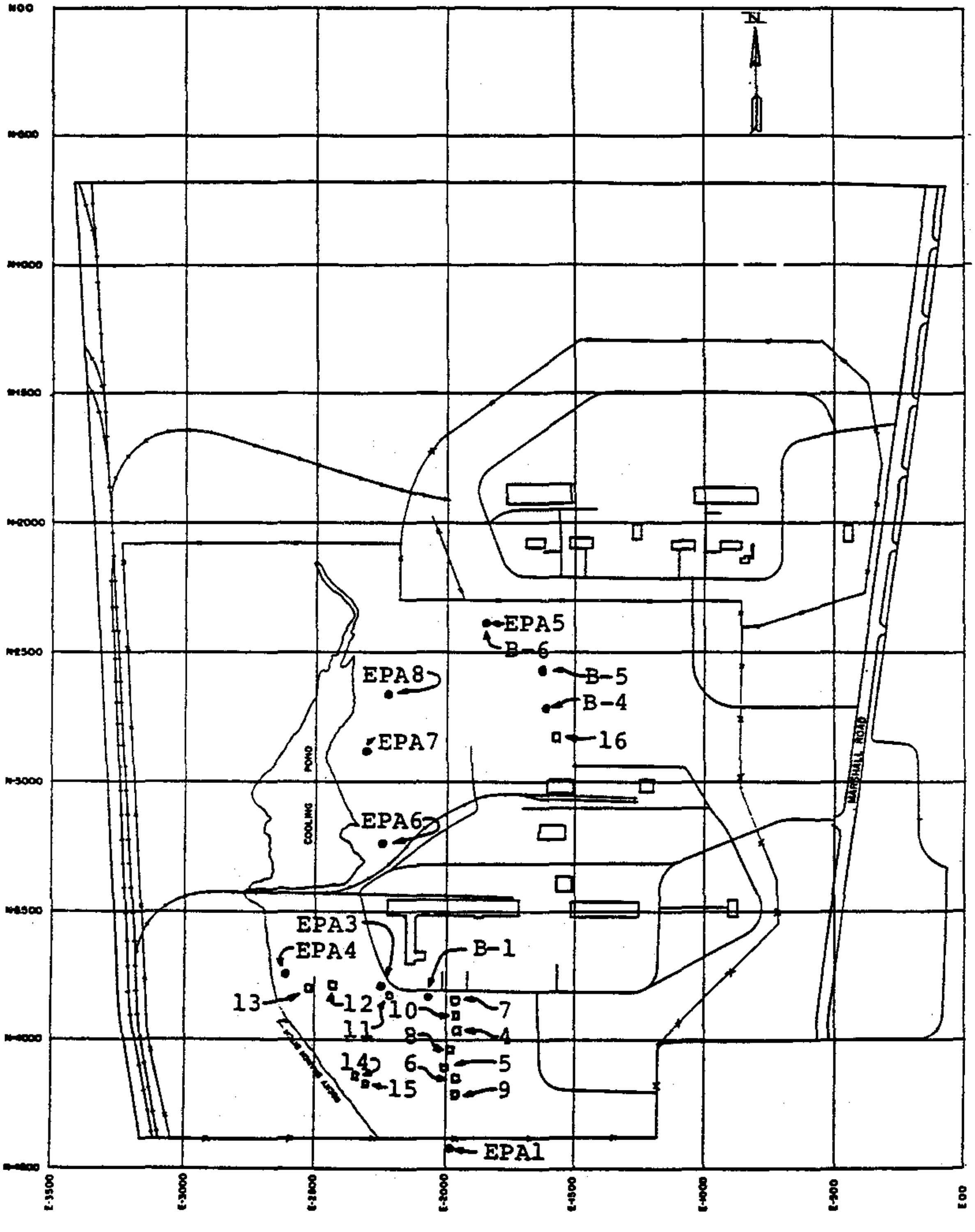
Once EPA had confirmed Vertac's findings that dioxin did exist at the Vertac site in concentrations of 37 ppm, a series of ground water monitoring wells were installed, samples were taken, and analyses were performed by several contractors as well as EPA and ADPCE personnel and laboratories.

During May and June of 1979, McClelland Engineers installed 15 test pits and made one log boring to determine subsurface conditions at the site. In October 1979, Southwestern Laboratories installed 8 more test borings at EPA's request. From May through October 1980 the ADPCE performed analyses of the monitoring well samples, while EPA performed analyses from May 1980 through March 1981. These test borings and test pits installed by McClelland Engineers and Southwestern Laboratories are shown in Figure 6. Additional samples were taken from the cooling pond and Rocky Branch Creek themselves.

In April 1982, Developers, International Services Corporation (DISC) made 41 auger borings at the Vertac site. DISC was hired by Vertac to help determine the extent of contamination, review remedial actions taken thus far, and make recommendations for further remedial work. The location of each of these 41 borings is shown on Figure 7. The data obtained from these borings was combined with the data obtained from the previously installed test pits and test borings to determine subsurface geologic conditions. DISC mapped these results in cross-sectional views of different segments of the site as Figure 8 shows. This example of a cross-section shows the subsurface geologic conditions determined by auger borings #119, #111, and #136.

Thirty-nine of the 41 auger borings made by DISC in April were subsequently used to install 39 piezometers to determine the characteristics of ground water flow. Hence, the location of each of the 39 piezometers is also shown in Figure 7; however, as noted, piezometers were not installed in borings #110 and #119.

By July 1982, DISC had begun a complete geotechnical investigation to describe the engineering properties of the soil and rock strata encountered. This was accomplished through conducting 11 test borings at the site. Once these 11 borings were completed, they were used as ground water monitoring wells. An additional 8 wells were installed, hence a total of 19 ground water monitoring wells were installed and sampled during July 1982. The 11 test borings which became ground water monitoring wells



- TEST BORINGS
- TEST PITS

Figure 6. Location of Test Borings and Test Pits Made in 1979
Source: Walton, 1982.

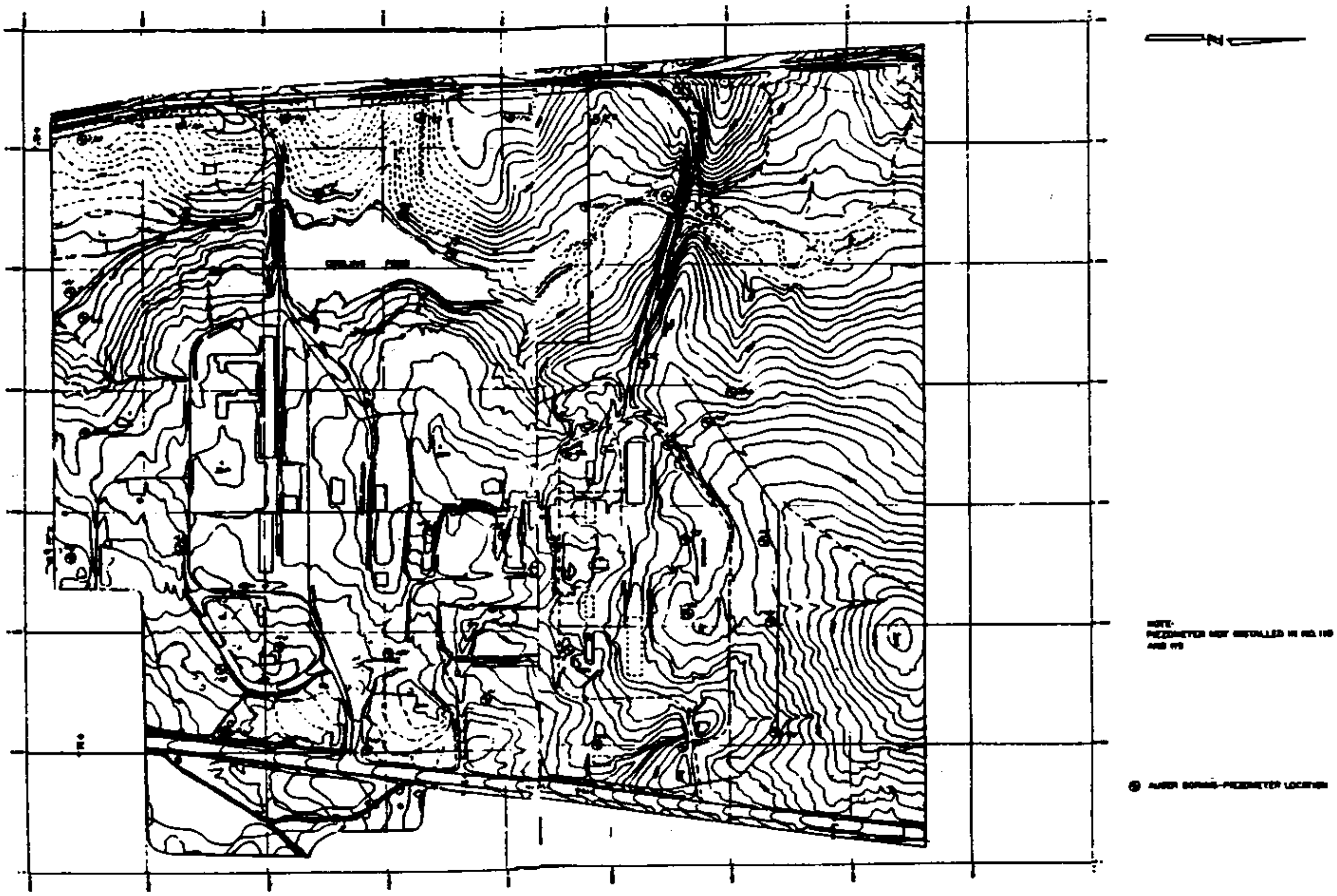
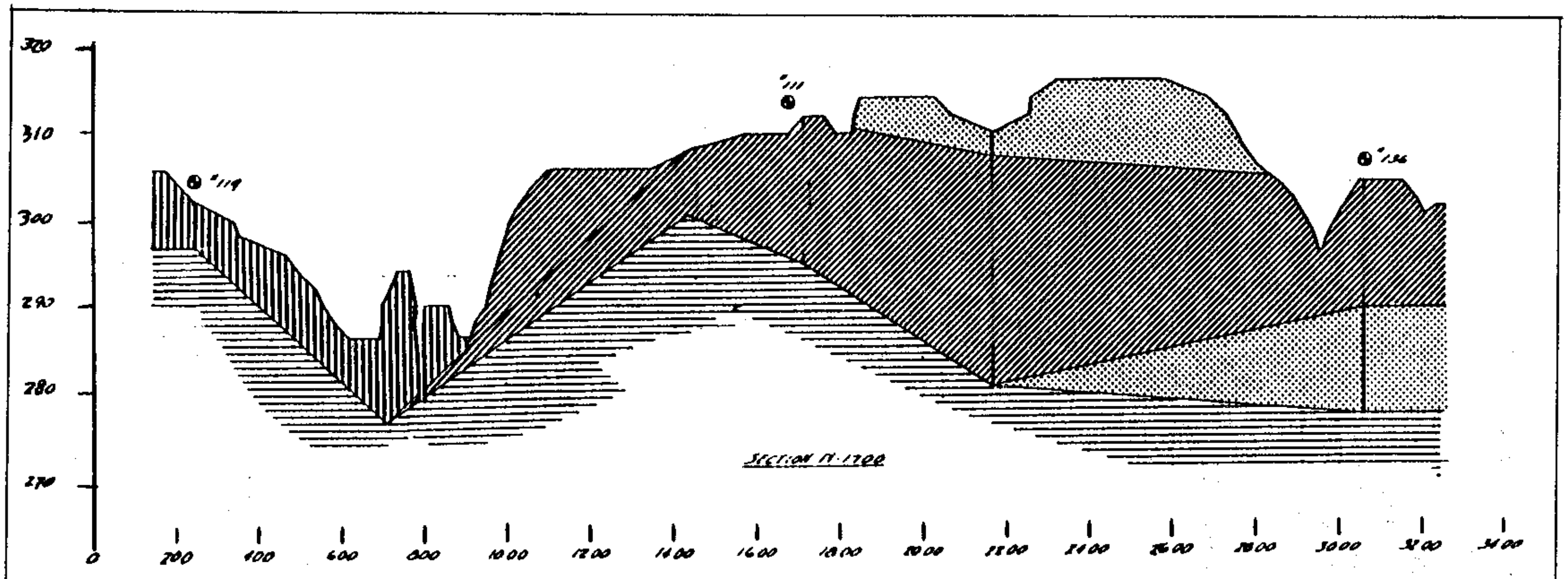


Figure 7. Location of Auger Borings and Piezometers
Source: Walton, 1982



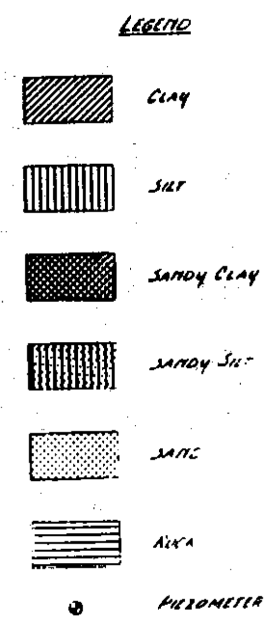


Figure 8. Cross Sectional View of Subsurface Strata From Auger Borings # 119, # 111, and # 136.

Source: Walton, 1982.

and the additional 8 ground water monitoring wells were located at the Vertac site as shown in Figure 9.

During July and August of 1982, DISC also performed sampling and analysis of surface soil, surface water, and sediments at the Vertac site. The surface soil at the Vertac site was analyzed for measurable concentrations of 2,3,7,8- TCDD at the areas shown in Figure 10.

Surface waters at the Vertac site were sampled by DISC at the locations depicted in Figure 11. These samples were measured for concentrations of chlorinated phenols, benzenes, anisoles, toluene, and phenoxy acids.

Finally, in August 1982, DISC sampled and analyzed sediments for concentrations of chlorinated phenols, chlorinated benzenes, toluene, and TCDD. These samples were drawn from the areas shown in Figure 12.

In total, the ADPCE, EPA, and Vertac investigations determined that the contamination of both the Vertac site and areas off-site, as well as the potential threat of contamination to other areas off-site, included the following (see Figures 1 and 2):

300.68(e)(2)(ii) extent of migration of substances

- Dioxin detected at the ppt level in certain sediment samples and species of aquatic life in Rocky Branch Creek and Bayou Meto. Contaminants were found as far as 45 miles (72 km) downstream in Stuttgart discovered by a massive fish kill that occurred in February 1963. These are probably from process waste discharges made by Reasor-Hill Company during herbicide production (1950's to 1961) and by Hercules Chemical Company from 1961 until May 20, 1963, when Hercules was shut down and ordered to build a pretreatment system

300.68(e)(2)(iv) environmental effects and welfare concerns

- Surface erosion, percolation, and seeps on top of, through, and attributed to the Reasor-Hill landfill and former above-ground drum storage areas. The estimated total volume of contaminated materials (which include chlorinated phenols, benzene, and toluene) lying within the Reasor-Hill landfill is 30,000 cubic yards (22,800 m^3). This may have also contributed to contaminant flow into Rocky Branch Creek

- The equalization basin that was installed as a process wastewater pretreatment system in 1964 contains contaminated still bottoms. Approximately 20,000 cubic yards (15,200 m^3) of material

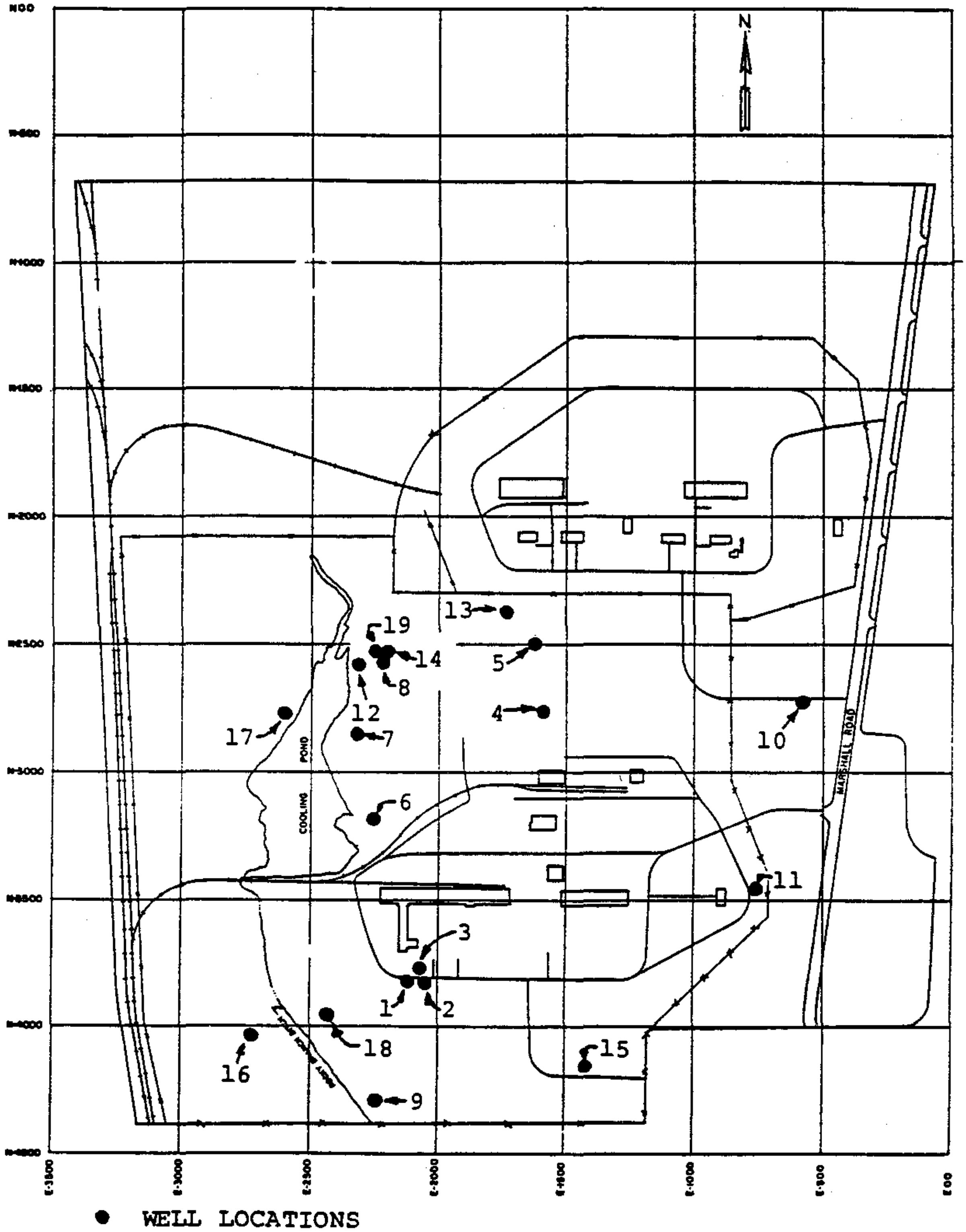


Figure 9. Location of 19 Ground Water Monitoring Wells
Source: Walton, 1982.

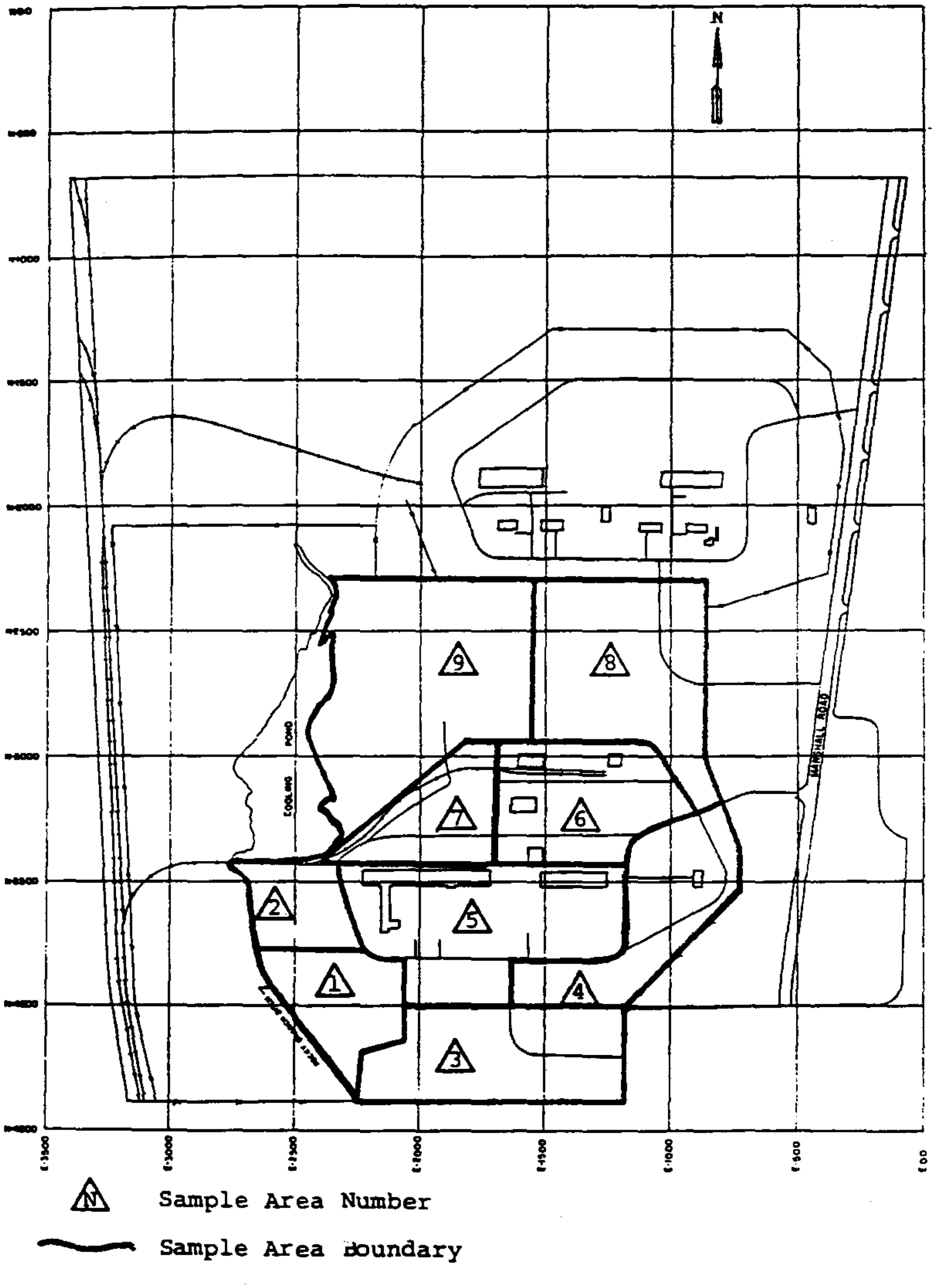


Figure 10. Location of Surface Soil Samples
Source: Walton, 1982.

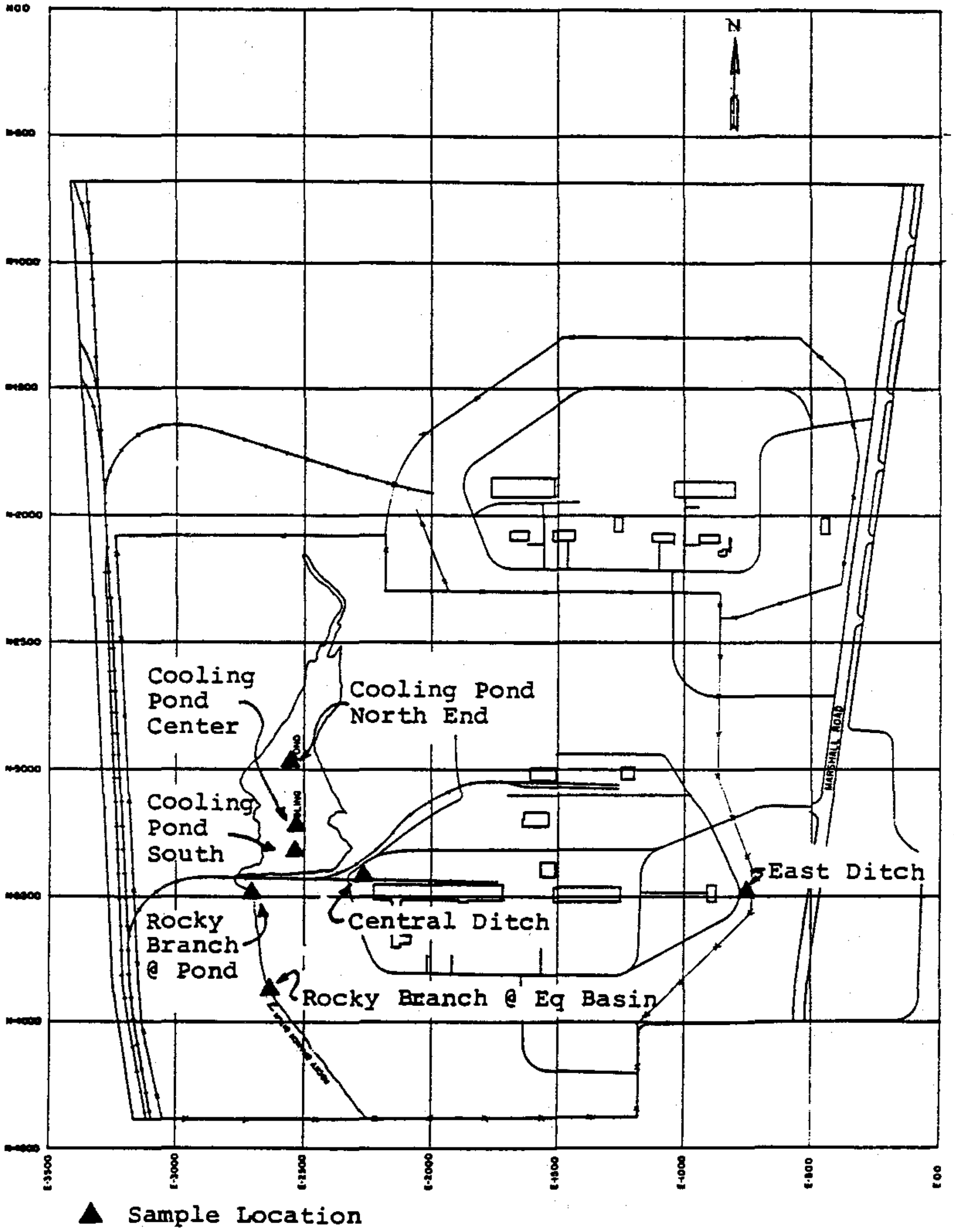


Figure 11. Location of Surface Water Samples
Source: Walton, 1982.

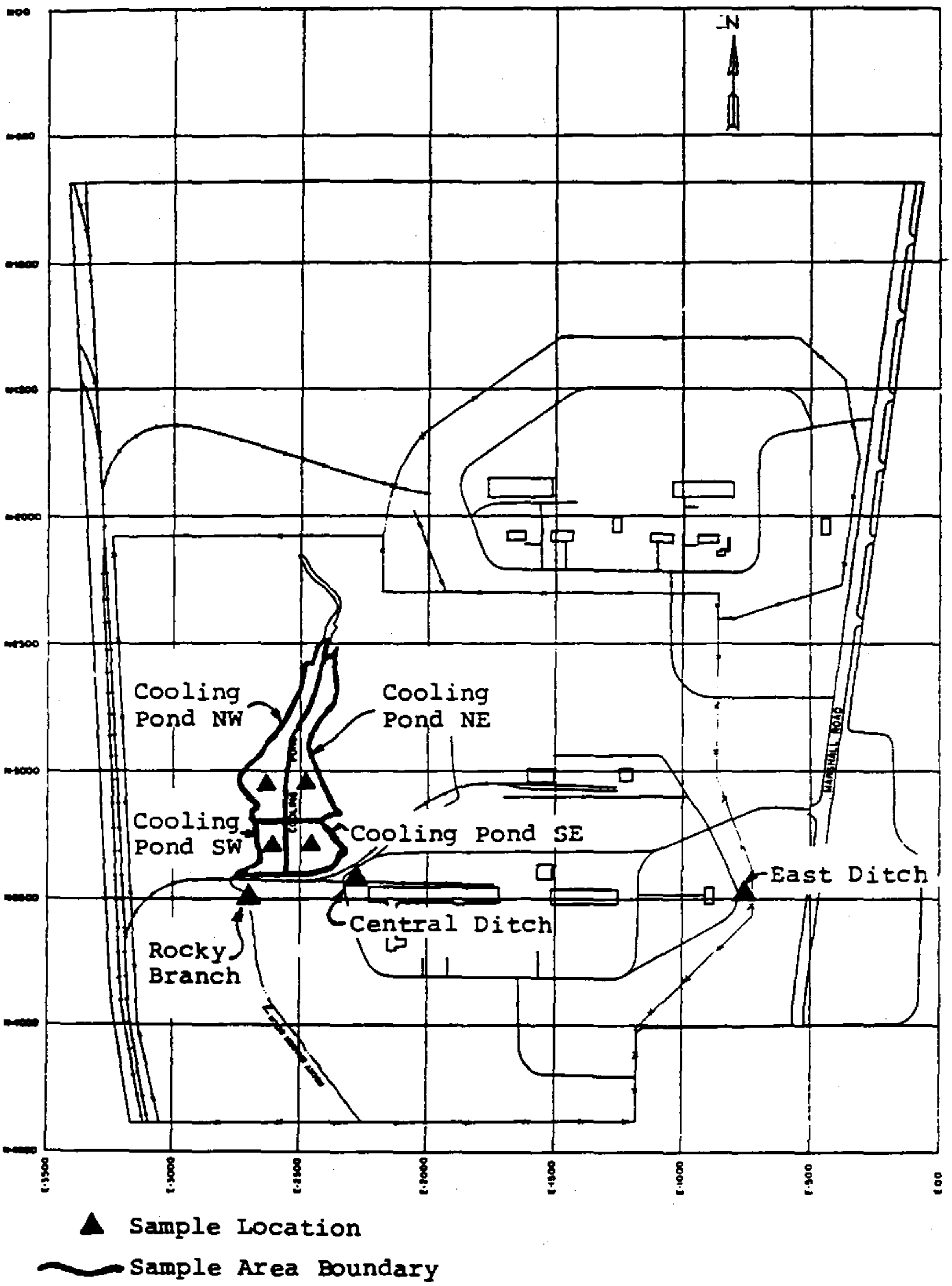


Figure 12. Location of Sediment Samples
Source: Walton, 1982.

is presently contained within the equalization basin. The basin was closed out in 1981 as part of Vertac's remedial response. This amount of material includes the clay cover which was placed on the basin at closure

- Leachate from the equalization basin was detected along the western portion of the property adjacent to the basin. This could have also contributed to the contaminant flow into adjacent Rocky Branch Creek

- 2,4-D, 2,45-T, and 2(2,4,5-T)P were detected in ground water monitoring wells down gradient from the Hercules-Transvaal landfill area. There is also a likelihood of co-solubilization of TCDD with the detected 2,4,5-T in the ground water adjacent to the Hercules-Transvaal landfill. The estimated total volume of materials lying within the Hercules-Transvaal landfill area is 100,000 cubic yards ($76,000m^3$)

- Contaminants from Hercules-Transvaal landfill migrated to the process cooling pond where dioxin was found

- Contaminants from the central drainage ditch and surface runoff at the Vertac site contributed to concentrations of dioxins in the cooling pond

- Cooling pond is in the Rocky Branch stream course; therefore, contaminants that leaked into the cooling pond and/or settled there probably flowed into Rocky Branch as well

- Blow-out area, which contained materials from valve ruptures of trichlorophenol reactor (used by Hercules and Transvaal), could be cause of dioxin percolation underground and/or surface runoff to the east. Drainage from this area is towards the east where contaminated sediments were discovered in East Branch

- Contaminants from spills that may have occurred during normal plant operations, exclusive of the blow-out area catch basin, may have entered East Branch following heavy rains

- At various points to the east of the site (other than East Branch), evidence of dioxin, which migrated from the blow-out area or perhaps from spills that occurred during normal plant operations, was found due to the downgradient movement of contaminated surface runoff as well as movement of subsurface contaminants. In particular, 1 ppb of dioxin contamination was detected along the creek bed adjacent to private residences located east of the Vertac site

- Dioxin contamination was found in fish and sediments of Lake Dupree, a 15 acre (6 ha) recreational lake approximately 1.25 miles (2 km) south of the Vertac site. The contamination is believed to have resulted from flooding of Rocky Branch during heavy spring rains which carried dioxin from Rocky Branch and into Lake Dupree

- Further contamination could have occurred during remedial action implementation, particularly at the equalization basin where movement of equipment noticeably disturbed the soil near a former interceptor ditch.

Another issue at the Vertac site is that of cross-contamination. In the Spring of 1979, Vertac halted 2,4,5-T production because EPA had banned most uses of 2,4,5-T at that time. In September of that year, Vertac switched to 2,4-D production. Since October of 1979, Vertac had been accumulating solid wastes from 2,4-D production. However, these wastes may have been cross-contaminated with dioxin by using the same equipment to produce 2,4-D as was used to produce 2,4,5-T. The extent of contamination at the Vertac site that may have resulted from this cross-contamination is not really known. Vertac, however, has been aware of the cross-contamination problem and has been setting aside the 2,4-D waste in drums since 1979. Since July 1982, Vertac has been recycling 2,4-D waste liquids and has eliminated the potential for cross-contamination through the use of new equipment.

It is important to note that at the present time, surface soils at the site show no measurable (detection limit of 50-100 ppt) concentrations of TCDD (dioxin) except in the area near the Reasor-Hill landfill. Additionally, no existing domestic or industrial water wells were located in the areas that are immediately downgradient from the site.

PLANNING THE SITE RESPONSE

Initiation of Response

The first major remedial actions at the Vertac site occurred in accordance with a June 15, 1979 Administrative Order issued by the Arkansas Department of Pollution Control and Ecology (ADPCE). Vertac had participated in a nationwide survey of potential dioxin sites in 1978, and in April 1978 had reported to U.S. EPA and the ADPCE that its toluene still bottoms contained 37 ppm of dioxin. Further testing and analysis was performed and EPA confirmed Vertac's findings in May 1979. This led to more ground water monitoring and subsurface testing at the site, performed by EPA, ADPCE, Vertac and its contractors. Negotiations among Vertac and the two agencies led to entry of the Administrative Order.

300.68(c) administrative process; private clean-up

The ADPCE Order referred generally to chemical wastes and by-products stored above ground or buried in the ground at the site, but specifically mentioned only dioxin. The basic thrust of this Order was to compel Vertac to undertake certain interim containment measures relating to the above ground storage of wastes and to the wastes buried in the ground. It specifically required Vertac to immediately install a clay cap over the Reasor-Hill and fill area. With respect to longer term containment measures, the Order directed Vertac to submit engineering reports regarding barrier dikes and interceptor ditches at the two on-site landfills and a detailed report on alternatives to the equalization basin. Subsurface sampling and development of a ground water monitoring plan also were required.

300.68(e)(1)(iv) above ground hazardous substances

While the Administrative Order directed Vertac to recontainerize any leaking drums stored above ground and place them in a newly built roofed storage area, it did not prohibit off-site disposal of drums. However, in early 1980, EPA issued a TSCA section 6 ruling directing Vertac to hold drums on-site containing 2,4-D and 2,4,5-T still bottoms and not dispose of them in landfills. This ruling was prompted by Vertac's finding of 0.7 ppb of dioxin in its 2,4-D still bottoms that were generated in late 1979 (the 2,4,5-T still bottoms were already known to contain dioxin). Apparently the 2,4-D wastes had become contaminated inadvertently through the manufacturing process. The EPA ruling provided that after May 12, 1980, Vertac could dispose of the still bottoms in an approved PCB landfill if their analysis showed only trace amounts of dioxin. A Vertac official reported, however, that by that time no PCB landfill would accept the drums because of the presence of dioxin. This situation led Vertac to

300.70(c) off-site transport for secure disposition develop a process for recycling the 2,4-D still bottoms, thus eliminating the dioxin as a waste. Vertac is also investigating, with EPA, the possibility of incineration.

The second major series of remedial actions at the Vertac site was also initiated by a legal order. While Vertac had completed or was implementing some of the tasks specified in the Administrative Order, it had not completed all of the work. On March 4, 1980, EPA and ADPCE sued Vertac and Hercules Chemical Corporation in Federal District Court under the "imminent threat" provisions of RCRA and Arkansas statutes. The agencies then obtained a Preliminary Injunction on May 12, 1980 that directed Vertac to undertake numerous specific actions. The Injunction required Vertac to repair the cap on the Reasor-Hill landfill (which was capped under the Administrative Order but had eroded) and install containment walls around it. Vertac also had to cap and cover several other areas at the site: the Hercules-Transvaal landfill, the old above-ground drum storage area, and the blow-out area. The Injunction stated that Vertac was to submit detailed engineering plans for an alternative to the equalization basin, as had been required by the Administrative Order but had not been done. Finally, the Injunction imposed on-site sampling requirements similar to those in the Administrative Order, but went further than the Order by directing Vertac to begin off-site sampling, i.e., sampling from the waters and sediments of Rocky Branch Creek. Thus, the May 12, 1980 Injunction was consistent with 1979 Administrative Order, continuing some work, requiring remedial work to be performed that previously had been studied, and directing new and complementary work.

300.68(c) judicial process; private clean-up

The next substantial remedial action was initiated on September 26, 1980, when the court ordered Vertac to proceed with its plans for replacing the equalization basin with an alternative system and remediating the basin area. Vertac submitted its plans to EPA and the ADPCE pursuant to the Injunction's requirements. The ADPCE approved them but EPA did not. Following a hearing, the court ordered Vertac to proceed with its plans, which the company did.

300.68(c) judicial process; private clean-up

During 1981, Vertac, Hercules, EPA and the ADPCE negotiated extensively, seeking to resolve their disputes. This led to the entry of a Consent Decree on January 9, 1982 in the suit that the agencies had filed in 1980. Like the Preliminary Injunction before it, the Consent Decree was consistent with the previously required work and added certain complementary tasks. Since most, if not all, of the required remedial actions had been completed,

300.68(c) judicial process; private clean-up the Consent Decree was concerned with assessing the effectiveness of those actions; the parties named an independent consultant, Developers, International Services Corporation (DISC), to do this study. The Decree also stated broad goals for protecting public health and the environment, and provided that Vertac would submit plans for additional on-site remedial work needed to meet those goals. In addition, Vertac was to submit plans for the study of certain areas of off-site contamination, such as Rocky Branch Creek, Bayou Meto and Lake Dupree. The Decree imposed various other tasks upon Vertac, including submission of a plan for managing accumulated stored wastes, exercise of best efforts to reduce the volume of wastes stored on-site, and submission of interim discharge limitations for Vertac's discharges into the Jacksonville STP. It appears that the Consent Decree generally seeks to ascertain the effectiveness of past remedial actions, study on-site and off-site conditions to determine the need for future actions, and manage and reduce the wastes stored on-site or discharged into the STP.

Selection of Response Technologies

The remedial actions that were chosen at the Vertac site were actions that did not come about through a simple examination of the problem, analysis of alternatives, and selection of the best remedial technologies available. Instead, the remedial actions which have been completed as well as those which are still on-going, were the result of the aforementioned administrative and court orders which took into account recommendations of EPA personnel, Arkansas Department of Pollution Control and Ecology personnel, Vertac officials, as well as those recommendations made by independent consultants that were used throughout the legal proceedings.

The remedial actions first implemented at the Vertac site were the direct result of the June 15, 1979, Administrative Order issued to Vertac by the ADPCE. Vertac had consented to the order once EPA had verified the presence of dioxin at the site in May 1979. As negotiations between Vertac, the ADPCE, and EPA took place prior to entry of the Administrative Order of June 15, 1979, Vertac had hired Shreeve Engineering of Little Rock, Arkansas, to conduct an objective study of the site and make recommendations for remedial actions. The recommendations made in the Shreeve Engineering Report, as well as recommendations made by EPA and ADPCE personnel, were the criteria on which the Administrative Order requirements were based.

The Administrative Order required Vertac to take the following actions (where not specified; compliance was required prior to October 1, 1979):

Above-ground Storage Area

- Inspect and inventory all wastes stored above ground in containers, and recontainerize any which were leaking

300.68(e)(1)(iv) above surface hazardous substances--direct threat

- Prepare secure on-site storage area(s) to be of adequate size to store all above-ground containerized wastes located at Vertac

- Conduct weekly visual inspections of each drum in storage

- Conduct daily visual inspection of tanks in which wastes are stored

- Containers must be located on sealed concrete or other sound, sealed, impermeable material

- Storage area(s) must be completely curbed to contain any spills or leaks from containers; must be capable of containing at least twice the volume of the largest container in storage; and all material including rainwater, contained within the curbed area must be analyzed for contamination. Any such contaminated material must be handled and stored as a waste material and disposed of as approved by the ADPCE

- Drum storage areas must be covered by August 15, 1979 by fixed roof structures of reinforced fiberglass or materials of greater strength to withstand forces such as wind and snow

- Storage areas must be well ventilated to prevent accumulation of toxic fumes and must be secure from unauthorized entry

300.70(b)(1)(i) air emissions control

- Drums in above-ground storage area must be recontainerized by July 9, 1979

- All other deteriorated drums must be recontainerized and relocated by October 1, 1979

- Maps must be drawn up immediately, delineating: outside boundaries of above-ground drum storage areas; portions of above-ground storage areas which overlie underground burial areas; all contaminated surface areas and recontainerization operations

• Locate and construct dikes to intercept and direct all surface drainage away from the above-ground container storage site	300.70(b)(1)(ii)(B) surface water diversion
• No excavation will be permitted in areas mapped for above-ground storage or that are delineated as contaminated areas	
• Install impermeable cover to prevent precipitation and surface runoff from coming in contact with areas mapped for above-ground storage or are delineated as contaminated areas	300.70(b)(1)(ii)(A) surface seals
• Store and isolate discarded containers and other debris from surface runoff and precipitation	300.68(e)(2) source control remedial actions
• Once wastes are relocated to secure area, contaminated wastewater within sumps and catchment basin downgradient of existing storage area must be removed and placed in secure containers pending final disposal	
• Existing sumps and catchment basins must be leveled, filled, and covered to prevent contamination of surface runoff and ground water	300.70(b)(1)(ii)(A) surface seal
• Treat dioxin contaminated ground surfaces to prevent contamination from becoming airborne	300.70(b)(2)(i) gaseous emissions treatment
• Sampling and analysis activities must be continued by Vertac within 30 days of receipt of EPA-approved analytical procedures, which are needed to report qualitative and quantitative characteristics of all surface flows of leachate, storm water, cooling water, and process wastewater to the ADPCE	300.66(c)(2)(iii) assessing potential for migration

Reasor-Hill/Hercules-Transvaal Areas

- Vertac must submit an engineering report no later than July 9, 1979 for construction of barriers and interceptor ditches necessary to prevent movement of subsequent waters through the waste materials buried at the Reasor-Hill site and to collect and contain subsurface waters flowing from the Reasor-Hill area for treatment as necessary. This will include soil borings, soil classification and stratigraphic logs for each boring, permeability or transmissivity of significant strata, and subsurface flows

- Vertac shall submit an engineering report no later than August 9, 1979 for construction of barriers and interceptor ditches necessary to prevent movement of subsurface waters through the waste materials buried at the Hercules-Transvaal site and to collect and contain subsurface waters flowing from Hercules-Transvaal area for treatment as necessary. The same boring data as described above are pertinent to the Hercules-Transvaal area as well

- Vertac shall submit a plan for development and implementation of ground water monitoring program prior to August 9, 1979

- Locate and map all underground waste burial areas including areas known to be or expected to be contaminated by surface or underground flow

- No exploratory drilling, coring, or excavation shall be conducted in burial areas or contaminated areas, without the express written consent and approval of the State of Arkansas

- Wastes from any exposed containers shall be placed in new containers and transported to an aboveground storage area. Any voids produced by the removal of exposed containers shall be backfilled immediately

- Once boundaries of disposal areas have been defined and mapped, Vertac shall clearly mark the limits of each site

- Dikes (approved in writing by the State of Arkansas prior to construction) shall be located and constructed to intercept and direct all surface drainage away from underground waste burial sites — 300.70(b)(1)(ii)(B)(1) dikes and berms

- Impermeable cover shall be installed to prevent infiltration and surface runoff from coming in contact with the surface of the underground waste burial sites — 300.70(b)(1)(ii)(A) surface seal

- Immediately proceed with application of clay cap at Reasor-Hill area as recommended by Shreeve Engineering Report of June 7, 1979 — 300.70(b)(1)(ii)(A) surface seal

Equalization Basin

- Within 45 days of the Administrative Order, Vertac shall submit a detailed report to the ADPCE describing alternatives to the continued use of the equalization basin.

As a result of this Administrative Order, Vertac hired McClelland Engineers of Little Rock to perform the geotechnical testing required. At EPA's request, Vertac hired Southwestern Laboratories to perform the analyses of the soil borings taken by McClelland Engineers.

One engineering report recommended that the ground atop the Hercules-Transvaal burial area be recapped. Vertac, although not required to do so by the Administrative Order, recapped the Hercules-Transvaal landfill area. — 300.70(b)(1)(ii)(A) surface seal

Under "substantial threat" provisions of RCRA and Arkansas state law, the EPA and ADPCE sued Vertac in March of 1980. On May 12, 1980, the EPA and ADPCE obtained a temporary injunction ordering Vertac to do the following:

Reasor-Hill Landfill Area

- Restore and repair the clay cap placed over the Reasor-Hill landfill area, pursuant to June 15, 1979, Administrative Order, because it had eroded — 300.70(b)(1)(ii)(A) surface seal
- Once restored, cover clay cap at Reasor-Hill landfill area with topsoil and seed — 300.70(b)(1)(ii)(D) revegetation
- Within six months, construct clay cut-off or containment walls around the north and east portions of Reasor-Hill landfill area to prevent movement of ground water through the dump area into Rocky Creek — 300.70(b)(1)(iii)(A) impermeable barriers Branch

Equalization Basin

- Submit detailed engineering plans and specifications within 60 days to the ADPCE and EPA for the development and installation of a wastewater treatment system as an alternative to the equalization basin — 300.70(b)(2)(ii)(A)(1) wastewater treatment

Hercules-Transvaal Landfill Area

- Proceed to cover the Hercules-Transvaal burial area and former above-ground barrel storage area with an impermeable clay cover within 90 days to — 300.70(b)(1)(ii)(A) surface seal prevent the penetration of underground areas by surface waters

- Cover clay cap at Hercules-Transvaal burial area and former above-ground barrel storage area with topsoil and seed — 300.70(b)(1)(ii)(D) revegetation

Blow-out Area

- Proceed to cover "blow-out" area to a distance not less than 200 feet (61m) east, north, and west of the trichlorophenol reactor vessels within 120 days; cover should be of impermeable clay material to prevent infiltration by surface waters — 300.70(b)(1)(ii)(A) surface seal

- Cover blow-out area, cap with topsoil and seed unless (in opinion of Vertac personnel) area will not support vegetation; otherwise cover with asphalt or other similarly permanent material — 300.70(b)(1)(ii)(D) revegetation

- Collect, label, and keep separate samples from each of the monitoring wells presently on the property and from the water and sediment of Rocky Branch Creek at the south fence line on a monthly basis. These samples should be delivered to the ADPCE and EPA for analysis.

Vertac submitted its plan to take the equalization basin, which was part of the process water treatment system built by Hercules in 1965, out of service. Vertac's plan was to install a new above-ground wastewater treatment system. The equalization basin was to be dewatered and the remaining sludge was to be mixed with lime to form an extremely hard phenoxy compound. The entire area was to be capped and sealed and the basin area was to be protected by an impervious barrier wall. This plan was approved by the ADPCE but was not approved by the EPA. After a hearing on September 26, 1980, the court ordered Vertac to proceed with its plan.

300.70(b)(2)(ii) direct waste treatment methods

300.70(b)(1)(ii)(A) surface seal

300.70(b)(1)(iii)(A) impermeable barrier

During 1981, negotiations took place between Vertac, Hercules, the ADPCE, and EPA to settle the EPA/ADPCE suit of March 1980. A Consent Decree was entered on January 9, 1982. It required to Vertac to do the following:

Effectiveness/Compliance

- Retain DISC as an independent consultant to conduct a study on the effectiveness of the remedial action at the Vertac facility and for contamination that has migrated from the facility to be completed within 150 days

- Submit a proposal to EPA, ADPCE, and Hercules within 60 days of receipt of DISC study to meet the goals of the Consent Decree with regard to ground water, surface water runoff, cooling water pond, and surface conditions at Vertac site

- Vertac shall implement any plans approved by EPA, ADPCE, or the court

Rocky Branch Creek/Bayou Meto

- Within 60 days, Vertac shall submit for EPA and ADPCE approval a plan and implementation schedule for a study of Rocky Branch Creek, the drainage ditch which runs from east side of plant site to Rocky Branch Creek, and Bayou Meto, which will be based in part on a three-year sampling and analysis program to be performed by the State

300.64 preliminary assessment

- Upon approval by EPA and ADPCE of the plan and schedule for the proposed study, Vertac shall complete the study

- Vertac shall pay the State $15,000 in three annual installments to help defray costs for sampling and analysis

- Vertac shall submit preliminary report to EPA and ADPCE for review within six months which summarizes data gathered in 1979, 1980, and 1981, and submit to EPA and ADPCE a complete study no later than 6 months after completion of sampling and analysis program

Lake Dupree

- Within 60 days, Vertac shall submit for EPA and ADPCE approval a plan and implementation schedule for Lake Dupree, including decontamination, removal, permanent sterilization, or containment of contaminated water and sediment

300.68(c) evaluation of clean-up proposals

- Upon EPA, ADPCE or court approval of the above plan and schedule, Vertac shall make certain that the plan is performed and completed

On-Site Maintenance

- Within 90 days, Vertac shall submit for EPA and ADPCE approval, a plan and implementation schedule for the management of accumulated chemical wastes stored at the Vertac site including an inventory of on-site wastes and containerization or recontainerization of wastes presently on-site and to be generated in the future

- Upon approval of the plan by EPA and ADPCE, Vertac shall cause the plan to be performed and completed

- Vertac shall exercise best efforts to reduce the volume of chemical wastes stored at the site in an orderly and expeditious manner. Using a list (that EPA will provide Vertac within 180 days) of names, addresses, and management methods of waste transportation; treatment; storage; or disposal facilities, Vertac will submit a report to EPA and ADPCE every 180 days describing Vertac's efforts to enter into negotiations with any facility for transportation, treatment, storage, or disposal of chemical wastes at the site

- Within 60 days, Vertac shall sample, analyze, and submit to EPA and ADPCE a report characterizing the nature, volume, and constituents of the waste-water discharge from existing system by Vertac to the Jacksonville sewage treatment plant

- Within 30 days after submission of above report, Vertac shall submit to EPA and ADPCE a set of interim discharge limitations for wastewater designed to prevent increases in pollutant levels in receiving streams over previously detected levels

- Vertac shall comply with interim discharge standards set unless modified by agreement with EPA, ADPCE or the court

- Vertac shall provide for the continuation and maintenance of effectiveness of all monitoring and remedial actions taken or to be taken at the site from the present time to a period of 30 years after closure of the manufacturing facility

- Vertac shall create a segregated trust fund of $60,000 for post closure maintenance.

Extent of Response

In addition to specifying what remedial actions were to be performed with respect to the Vertac site, the Administrative Order, Preliminary Injunction, and Consent Decree largely determined the extent of response. Remedial actions relating to the Reasor-Hill and Hercules-Transvaal landfill areas, the old above-ground storage area, the blow-out area, and the equalization basin were terminated once the legally required work was completed. Because the legal orders came one after another, they ensured that all required work was done. For example, the ADPCE Administrative Order required Vertac to submit an engineering report on alternatives to the equalization basin; this had not been done by the time of the Preliminary Injunction, so it was included as one of the Injunction's tasks. The various ongoing tasks, such as monitoring and conducting studies of off-site contamination, are continuing in expanded form in accordance with the Consent Decree. The Decree requires that Vertac undertake any future on-site or off-site remedial action indicated by these studies and ordered by the agencies or the court.

DESIGN AND EXECUTION OF SITE RESPONSE

Presently, the remedial actions at the Vertac site are ongoing. As of the time this case study was prepared, remedial actions at five major areas of contamination had been completed. These areas include the:

- Reasor-Hill landfill area
- Hercules-Transvaal landfill area
- Former above-ground storage area
- Blow-out area
- Equalization basin.

The remedial actions taken at each of these areas is described below. In all cases, Vertac acted as a general contractor and supervisor for the design and installation of remedial actions. In addition, a recycling technology, an alternative technology, and future remedial actions are discussed.

Reasor-Hill Landfill Area

The Reasor-Hill landfill area was originally capped in the latter portion of 1979 as required under the June 15, 1979 Administrative Order. The area was recapped following the May 12, 1980 injunction because there was evidence which indicated that the original cap had eroded.

300.70(b)(ii)
surface water
controls

The Reasor-Hill landfill, shown in Figure 13, contains 30,000 cubic yards (22,800 m^3) of hazardous material. The landfill was recapped with on-site clay taken from a clay pit in the northeast area of the Vertac property (see Figure 2). One foot (0.3m) of clay was used to cap the Reasor-Hill area. Trucks, backhoes, graders, and a sheepsfoot roller were used to distribute and compact the clay from the pit to the landfill area.

300.70(b)(1)(ii)
(A)
surface seal

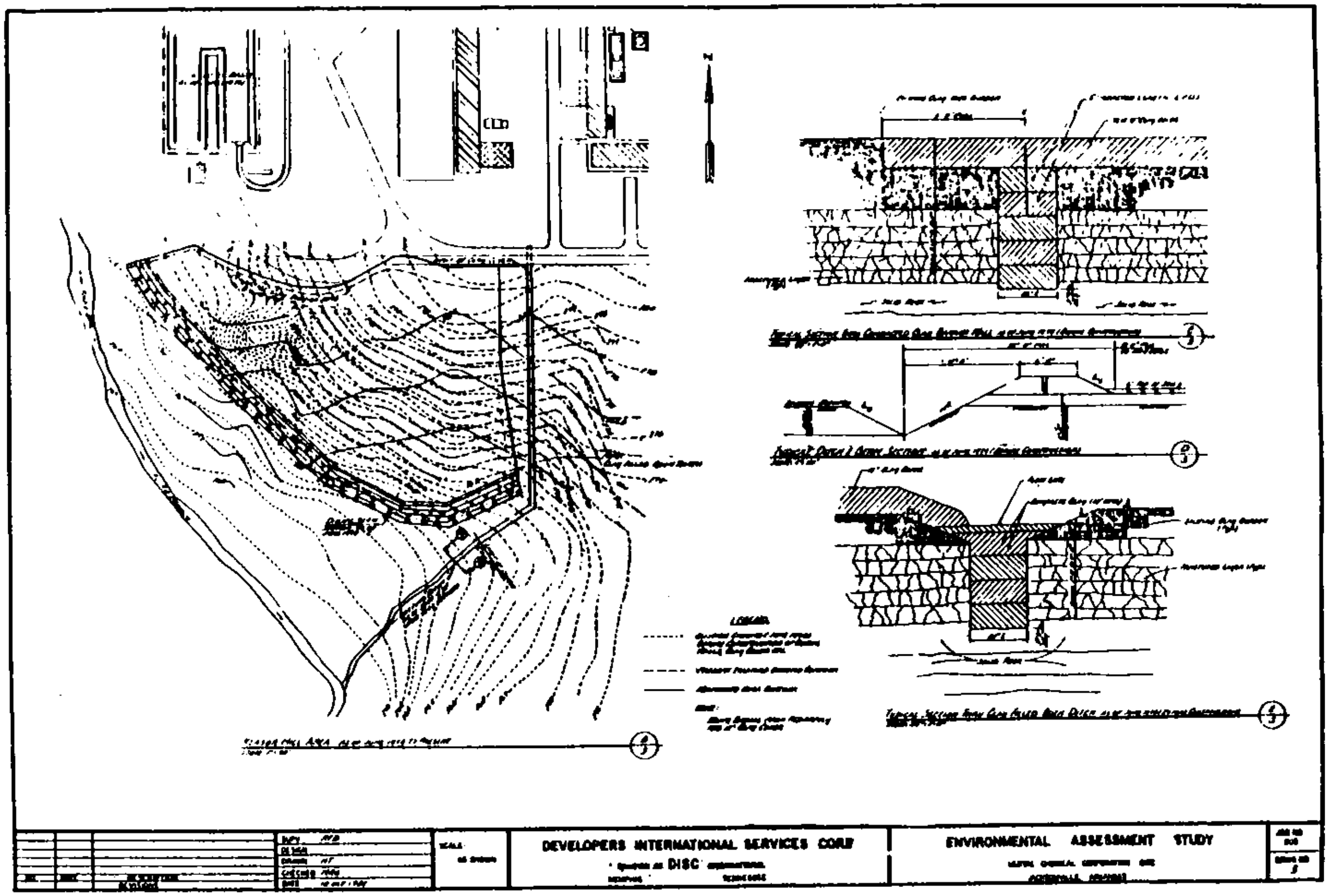


Figure 13. Details of Reasor-Hill Waste Burial Area and Barrier Walls
Soruce: Walton, 1982.

Similarly, the same equipment was used to place a 6 inch (15 cm) soil cover over the clay cap. The soil cover was seeded over and is now covered with grass. Vertac hired an excavation contractor, Helena Construction Company (Helena), to place the clay cap and soil cover on the Reasor-Hill area. 300.70(b)(1)(ii) (D) revegetation

In addition to the clay cap, the Reasor-Hill landfill area is surrounded on three sides by clay barrier walls extending from bedrock to one or two feet (0.3-0.6m) above ground level, (as seen in Figures 13 and 2) while the downgradient side was left open. This design is intended to prevent run-on of surface rainfall into the landfill to keep it free from contact with any other materials, particularly liquids. The downgradient side was left open because the area is not susceptible to flooding.

The barrier walls were also constructed by Helena. They were trenched to rock at a depth between 8 and 10 feet (2.4-3.0 m) and were then filled in and compacted using on-site clay. They are approximately 2 feet (0.6m) in width (the width of a backhoe bucket) and in combination with the clay cap, have served to contain the Reasor-Hill site area.

Hercules-Transvaal Landfill Area

Vertac voluntarily recapped the Hercules-Transvaal area in response to a recommendation made from a 1979 Shreeve Engineering Report. The procedure followed at the Hercules-Transvaal landfill area was very much like that at the Reasor-Hill area. The recapping was completed by January 1980. 300.70(b)(1)(ii) (A) surface seal

The Hercules-Transvaal landfill has a waste volume of approximately 100,000 cubic yards (76,000 m^3). An outside contractor was hired to excavate on-site clay and soil to be placed over the area for capping and soil cover, respectively. The clay cap is one foot (0.3m) deep and a 6 inch (15 cm) soil cover is maintained. The Hercules-Transvaal site is seeded over and appears to be stabilized. No barrier walls were constructed there. Figures 14a, b and c collectively show details of the Hercules-Transvaal landfill area. 300.70(b)(1)(ii) surface water controls 300.70(b)(1)(ii) (D) revegetation

Former Above-Ground Storage Area

As a result of the June 15, 1979, Administrative Order, Vertac was required to address the problem of an estimated 3,000 drums of 2,4,5-T still bottoms which were being stored in an area known as the former above-ground storage area. A severe contamination problem was found in this 300 foot by 200 foot (91 x 61m) area because many of these drums were leaking.

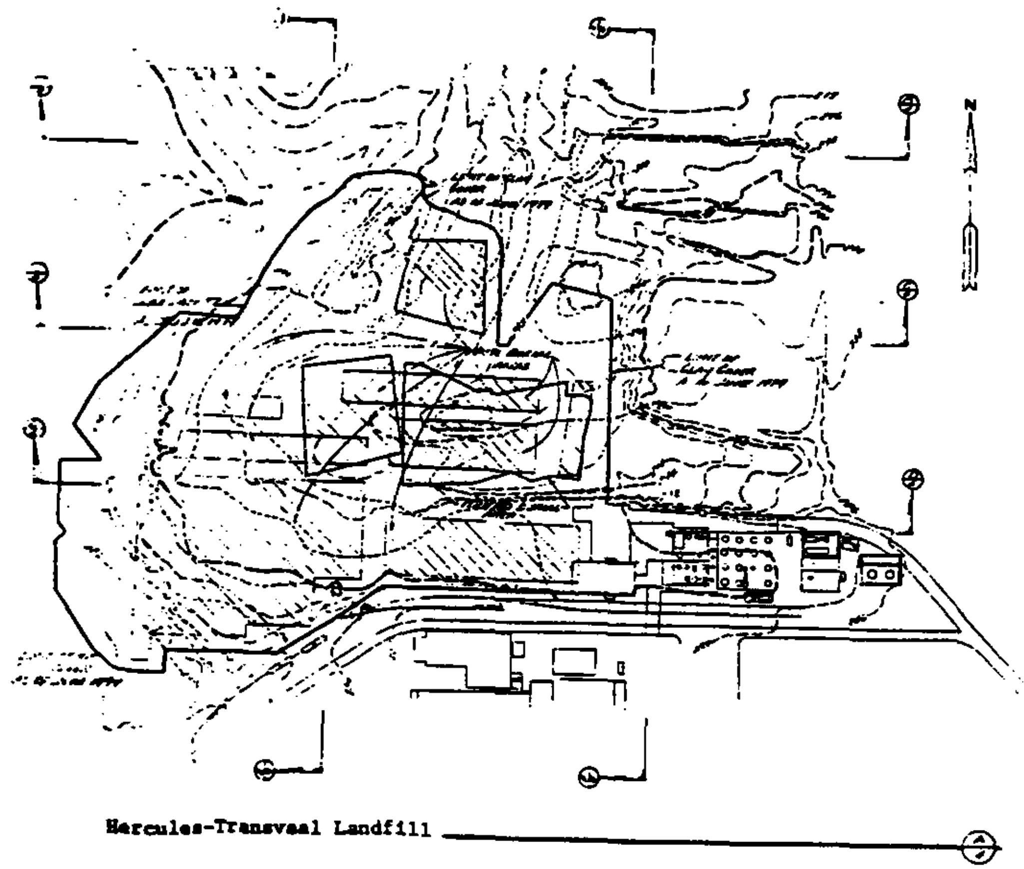


Figure 14a. Details of Hercules-Transvall Landfill
Source: Walton, 1982.

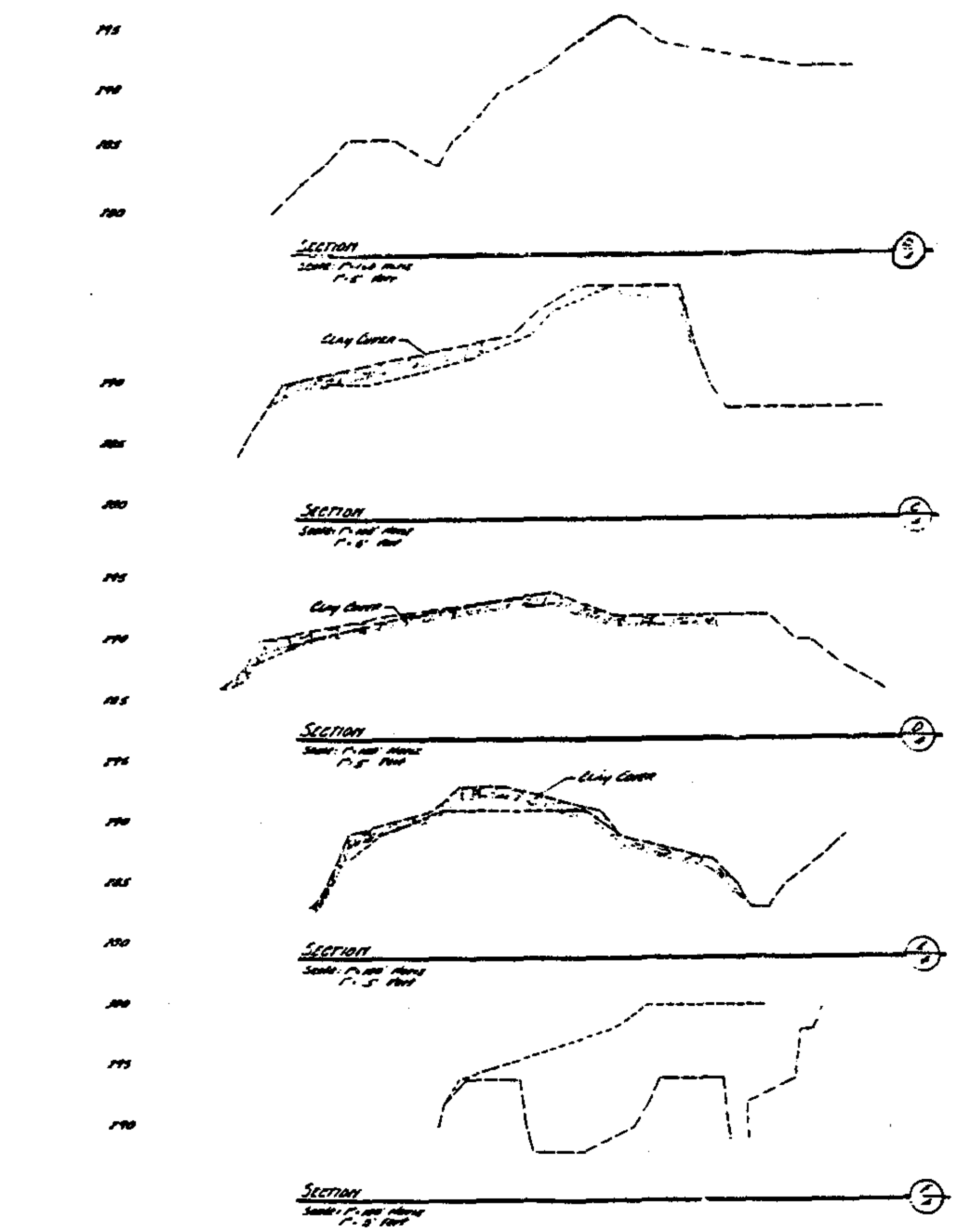
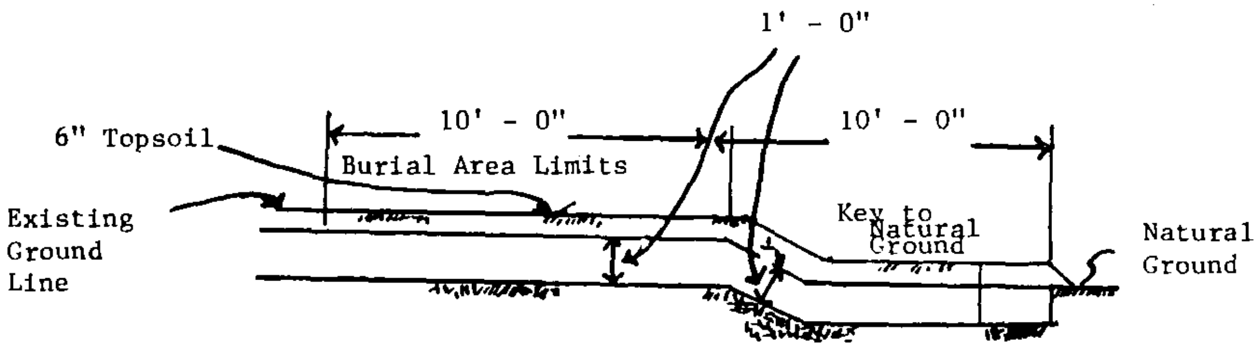


Figure 14b. Details of Hercules-Transvaal Landfill
Source: Walton, 1982.



Typical Section of Clay Cover
Not to Scale

G
4

Figure 14c. Details of Hercules-Transvaal Landfill Area
Source: Walton, 1982.

Vertac was required to build a secure on-site storage warehouse for these drums, as well as to repack those which were badly cracked and/or leaking. Additionally, any contaminated topsoil resulting from the leaking drums, had to be removed and safely secured. Therefore, Vertac containerized the contaminated topsoil along with the the drums of 2,4,5-T still bottoms that had to be repacked. Out of 3,000 drums stored in this area, approximately 2,000 were repacked. Vertac personnel repacked the drums in standard 85-gallon (323 l) overpack drums. While the special storage warehouse was being constructed during the fall of 1979, the drums and contaminated topsoil were repacked together and kept outside until the warehouse was completed in late 1979. The former aboveground storage area was filled and capped as part of the Hercules-Transvaal landfill in early 1980.

300.70(c)(2) removal of contaminated soils

300.70(b)(1)(ii)(A) surface seal

The special storage warehouse, located on the site as shown at the top of Figure 2, was built by an outside contractor at a cost of approximately $71,000. The warehouse measures 100 feet by 200 feet (30 x 61m) and consists of a concrete pad with dikes along each side and a roof of steel. Once the warehouse was completed, the repacked drums and those original drums that were intact, were moved by truck and placed in the warehouse.

At the present time these drums are still being stored in the special warehouse and inspected weekly to detect any leaks. Vertac is examining several alternatives as to the ultimate disposal of these drums. These include various types of incineration methods.

Blow-out Area

Vertac was required to cover and secure the blow-out area with asphalt or clay to prevent penetration by surface waters under the May 12, 1980 Temporary Injunction. Vertac hired outside contractors to conduct the remedial work at the blow-out area. The remedial action taken was to cover this 1.5 acre (0.6 ha) area with asphalt and clay. The asphalt was placed in a semicircle with a radius of 200 feet (61m) around the former process area. Two-thirds of the entire surface area is now covered with asphalt while one-third is covered with clay. The clay-covered portion is the outlying area that was contaminated from valve rupture blow-outs during trichlorophenol production. The capping of the blow-out area took six weeks and was completed by the fall of 1980.

300.70(b)(1)(ii)(A) surface seal

Equalization Basin

Following a September 26, 1980, court decision, Vertac went ahead with its original design for closing out the equalization basin. The equalization basin had been used to neutralize process wastewater prior to discharge to the Jacksonville sewage treatment plant. Vertac's design was to first construct a new wastewater treatment system and have that operating before closing out the equalization basin. Vertac acted as a general contractor for the work at the equalization basin using outside equipment and an outside operator for the equipment.

The location of the new wastewater treatment system in relation to the closed out equalization basin can be seen in Figure 15a. Figures 15b and c show the profile of the equalization basin in detail. The new system is an aboveground pH stabilization system whereby highly acidic 2,4-D process wastewater (pH of 1.0) is neutralized to a pH between 6 and 7 by a lime dosing apparatus. This process takes place in a monitoring house through the addition of ground lime into an effluent mixing basin. Once the wastewater has been neutralized it runs through an outfall and into the Jacksonville sewage treatment plant.

300.70(b)(2)(ii)
(B)(3);(4)
neutralization;
equalization

Once the new wastewater treatment system was on-line in January 1981, Vertac started its procedure for closing out the equalization basin. The remedial action for the equalization basin included the following steps:

- Dewatering of the basin
- Solidification of the sludge
- Installation of barrier walls and French drain
- Capping of the entire area.

The equalization basin was approximately 150 feet by 100 feet (46 x 30m) with a depth of 2 feet (0.6m). Approximately 225,000 gallons (851,718 l) of water had to removed and filtered before the remaining process sludges could be solidified. A dewatering system was devised by a Vertac engineer using equipment available at the Vertac site. Quite simply, the water from the basin was pumped through a crushed limestone filter and then a sand filter that were each enclosed in tanks that had been located at the Vertac site. The filtered water was then sent to the Jacksonville sewage treatment plant. A schmematic diagram of the dewatering system is shown in Figure 16. The dewatering process, which began in February 1981, was not completed until early May 1981.

300.70(b)(2)(ii)
direct waste
treatment
methods

As the dewatering progressed, Vertac began the solidification process. The sludges left in the equalization basin were very high concentrations of chlorophenols,

300.70(b)(2)
(iii)(C)
solidification

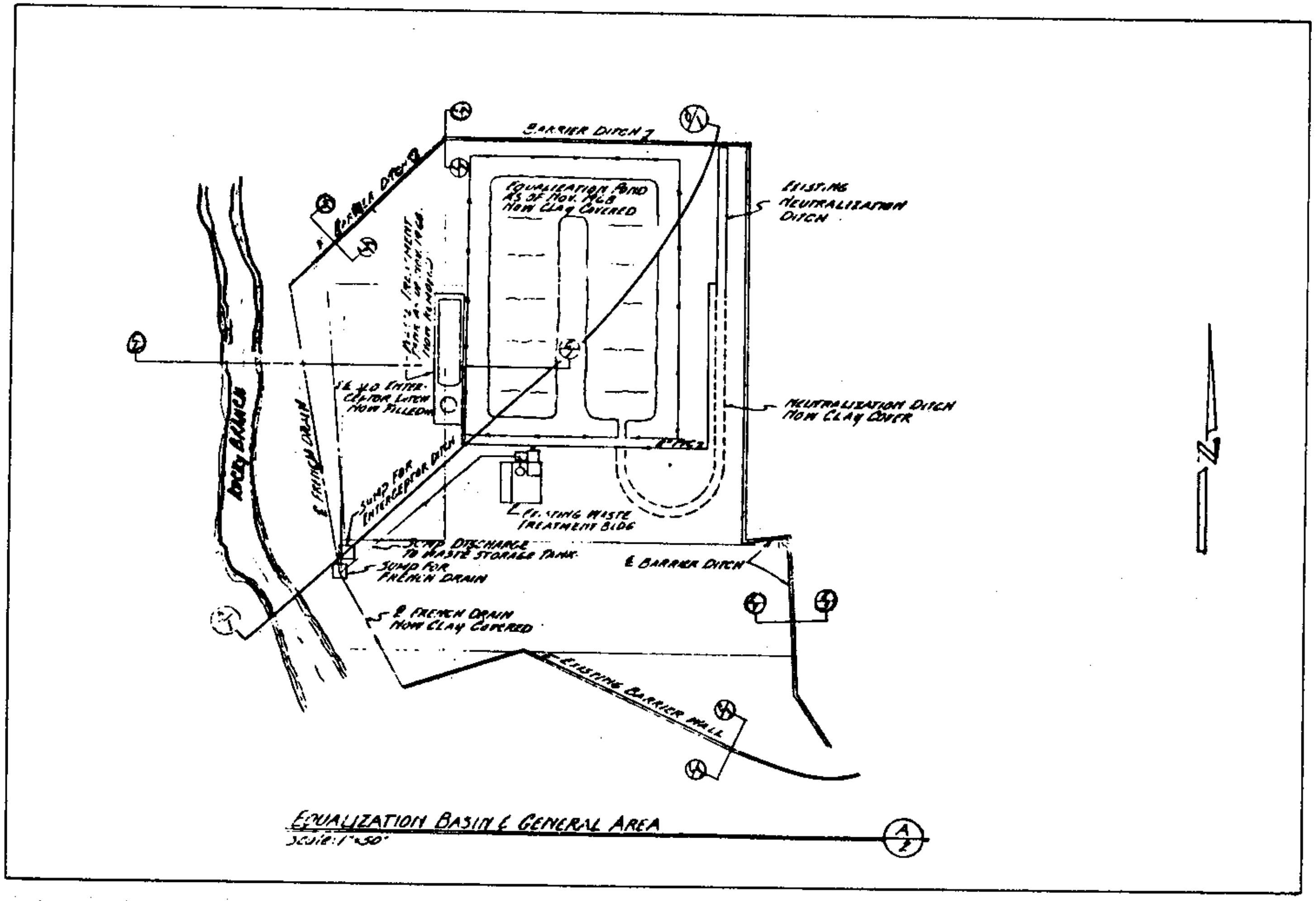
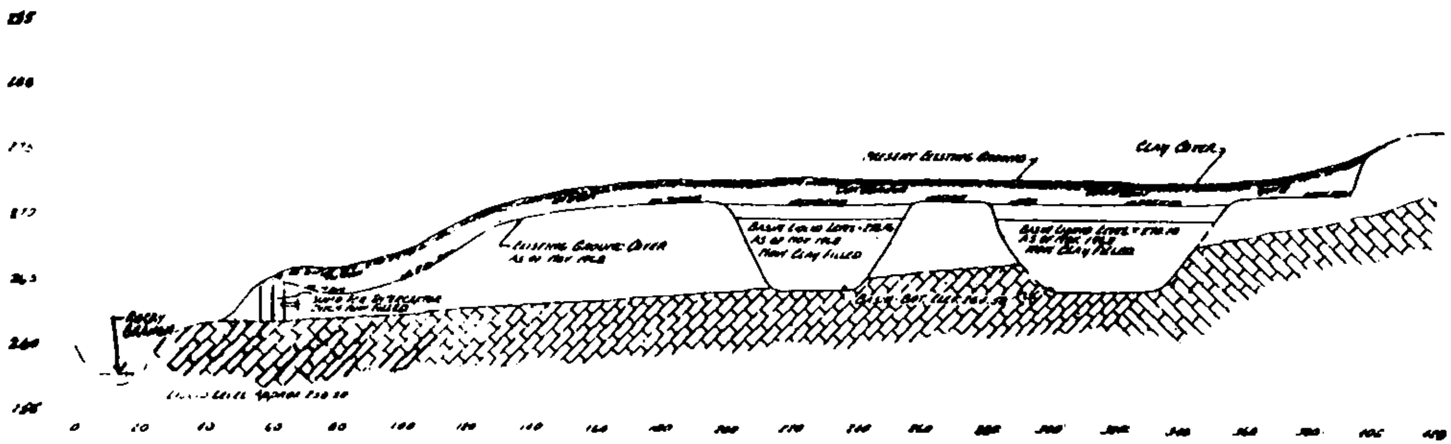


Figure 15a. Details of Closed Out Equalization Basin
Source: Walton, 1982.



Profile of Equalization Basin
Scale: 1" = 20'HORZ As of Date: (Nov. 1968)
1" = 5' VERT

Figure 15b. Details of Closed Out Equalization Basin
Source: Walton, 1982.

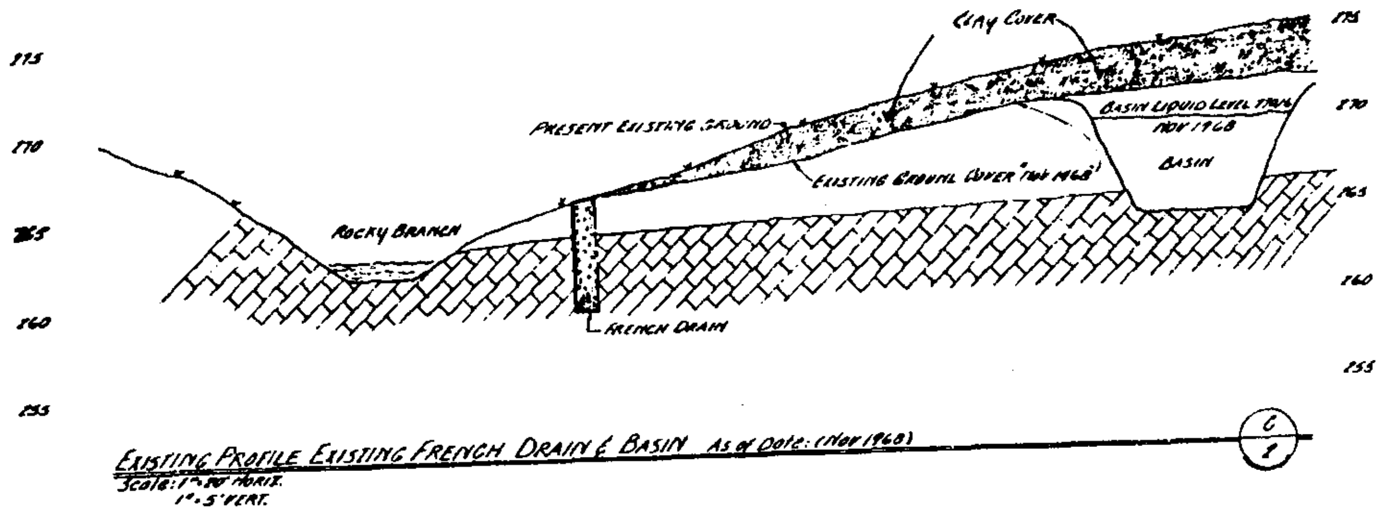


Figure 15c. Details of Closed Out Equalization Basin
Source: Walton, 1982.

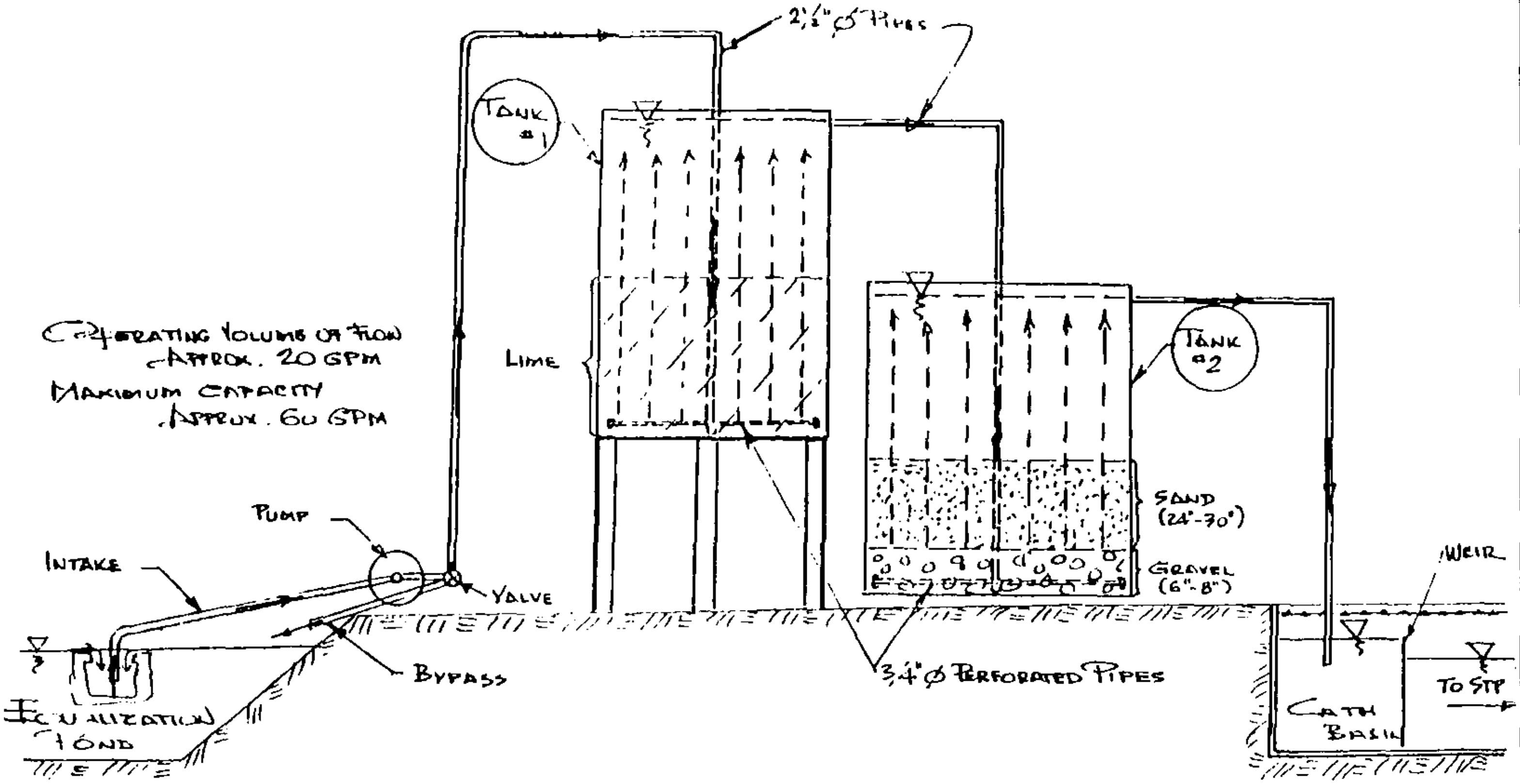


Figure 16. Schematic Drawing of Dewatering System
Source: U.S. EPA, 1982.

phenoxy acids, and other process wastes from 2,4-D production. These were solidified through the addition of lime during May 1981.

As the equalization basin was being closed out, two clay barrier walls and a French drain system were installed around the equalization basin. The barrier walls were built along the north and east sides of the closed out equalization basin. These can be seen in Figures 15 and 2. The French drain, located on the Rocky Branch Creek side of the site, was installed to collect subsurface runoff. It replaced the interceptor ditch and barrier ditches built in 1964 when the original equalization basin was installed. The French drain, designed by Vertac, discharges into a 10,000 gallon (37,854 l) storage tank. As subsurface liquid is intercepted by the drain, it is is pumped into the storage tank where it is accumulated. At the present time, an estimated 1,000 gallons (3,800 l) of leachate has been collected in the tank. The drain is approximately 40 feet (12.2m) long and is made of 6 inch (15 cm) clay pipe (It should be noted that a true French drain does not contain a pipe, however for purposes of consistency with the information gathered for this case study, this term has been retained).

300.70(b)(1)(iii)(A);(D)(1) impermeable barriers; leachate control

The entire equalization basin was backfilled and capped by June 18, 1981. The volume of the backfilled equalization basin is estimated to be 20,000 cubic yards (15,200 m^3) including the clay cover. The clay cover is approximately 2 feet (0.6m) deep. During construction, it was found that the French drain and barrier walls were being placed over weathered rock. Construction personnel packed clay into any fissures which were present along the trench as a precaution against vertical migration of leachate at the trench.

300.70(b)(1)(ii)(A) surface seal

Recycling

Another remedial action that has been taken at the Vertac site is one that has been implemented to relieve the previously mentioned cross-contamination problem. Since October 1979, Vertac has been accumulating drums of 2,4-D process wastes but has not been allowed to dispose of them because they may have been cross-contaminated with 2,4,5-T process wastes during a changeover from 2,4,5-T production to 2,4-D production because the process equipment was not changed. A special TSCA Section 6 ruling prohibited Vertac from removing any of these wastes generated prior to May 12, 1980. In response to this, Vertac developed a recovery process to separate and reuse 2,4-D still bottoms. This process has been used since July 1982 and appears to be working well. The 2,4-D wastes generated prior to May 12, 1980, have been used as raw materials for further 2,4-D production with EPA approval. Any 2,4-D production-related trash is disposed of in an approved PCB landfill. The potential for further cross-contamination has been eliminated by Vertac through the use of new process equipment.

300.70(c) off-site transport for secure disposition

Alternative Technology

Late in 1979, Vertac wanted to start up 2,4,5-T production again using a chemical destruction technology which they had patented. The idea was to manufacture 2,4,5-T from the toluene still bottoms at the site and then chemically destroy any waste that would be generated. Vertac applied for a research and development grant from EPA to pilot this technology; however, EPA had reservations about producing any more dioxin at this site which might cause further hazard, therefore the grant was not approved.

Future Remedial Actions

At the present time, Vertac is under court order to proceed with clean-up activities at the cooling pond and Lake Dupree as well as continual monitoring, inspection, and development of a hazardous waste management plan. Because these issues are ongoing and involve many legal aspects, the remedial actions being considered cannot be disclosed at this time.

COST AND FUNDING

Source of Funding

Vertac has provided most of the funds for remedial action, monitoring, and analysis at the plant site. A Vertac official estimates that the total cost as of August 1982 was approximately $1,946,000. Hercules has agreed to pay for up to $75,000 for remedial work at the Reasor-Hill landfill area and up to $40,000 for the environmental study required by the Consent Decree. Vertac has paid for the remaining costs, which are over 94 percent of the estimated total costs as of August 1982. Negotiations between the companies over cost sharing are continuing.

300.68(c) private clean-up

Selection of Contractors

Vertac served as its own general contractor, using its personnel, machinery and materials to implement the remedial action plans. This work included; redrumming 3,000 drums containing 2,4,5-T still bottoms; maintaining drums containing 2,4-D wastes for eventual recycling; developing a recycling process; developing an alternative process wastewater treatment system; developing a solidification process for the equalization basin; and monitoring, sampling, and laboratory analyses.

Vertac contracted with McClelland Engineers of Little Rock, Arkansas on a cost plus fixed fee basis to work with the State in conducting the initial subsurface investigation at the site. McClelland was selected for this work based on its reputation. Southwestern Engineers, of Little Rock, was hired by EPA to do a second subsurface investigation at the Vertac site. Subsequently, Vertac hired the firm to conduct permeability and compaction tests on the landfill caps. Vertac hired Shreeve Engineers, which is based in Little Rock, to prepare an engineering report for capping and containing the Reasor-Hill and Hercules-Transvaal landfills. Shreeve was selected because it previously had done work for Vertac at the Jacksonville plant, and was hired on a cost plus fixed fee basis.

Helena Construction Company based in West Helena, Arkansas, was selected by Vertac to excavate, transport, place, and compact clay for the landfill caps, according to specifications in the Shreeve report. Vertac selected Helena because it was the low bidder, and used a lump sum contract.

As required by the Consent Decree, Vertac hired Developers, International Services Corporation (DISC), of Memphis, Tennessee to review on-site conditions. DISC was selected based on its bid and good reputation and was hired under a cost plus fixed fee contract. Also as required in the Consent Decree, Vertac selected Environmental and Toxicological Consultants (ETC) to study and report on off-site conditions. ETC was chosen based on bid and reputation. A lump sum contract was used. Vertac hired Environmental Protection Systems (EPS), of Pensacola, Florida and Jackson, Mississippi, pursuant to the Consent Decree to do sampling and analysis on process wastewater and the cooling pond for phenol, chlorophenol, chlorobenzene, and phenoxy acids. This firm was selected because of its bid and reputation and a lump sum contract was used. Specialized Assay (SA) of Nashville, Tennessee, was hired by Vertac in accordance with the Consent Decree to perform sampling and analysis relating only to dioxin. Selected by bid and reputation, SA worked under a lump sum contract.

Project Costs

Analysis of costs for this remedial action depends on the nature and extent of data made available by Vertac

Chemical Corporation, because this is a privately financed clean-up and Vertac did much of the work itself. A Vertac representative provided summary information regarding specific remedial actions, such as for the Reasor-Hill landfill or the equalization basin, which he then broke down into the costs for outside contractors and Vertac's own costs. It should be noted that the latter figures include Vertac's overhead but that the proportion of overhead to total cost was not given. The task of cost analysis is further complicated by the fact that for a period of time (from June 15, 1979, the date of the Administrative Order, to September 22, 1979) Vertac stopped all production at the plant and shifted all suitable manpower to complying with the Order. The Federal District Court noted that this resulted in a loss to Vertac of $1 million for 1979 based on gross sales of $8 million. While it might be argued that the $1 million represents the opportunity cost of the remedial work, this does not aid the analysis of actual costs. In addition, some details relating to costs are not available, such as the number of man-days worked, types of equipment used, and amounts of materials used. Consequently, in some instances it is impossible to compute meaningful unit costs.

Nevertheless, the available data allow a general discussion of costs. These data are presented in Table 1. Cost figures supplied by a Vertac representative regarding several specific remedial actions taken at the plant total $2,016,000. Broken down according to the major areas of remedial work discussed in this study, the costs are as follows:

- Reasor-Hill landfill area ($159,500)
- Hercules-Transvaal landfill and above-ground drum storage areas ($135,000)
- Blow-out area ($37,000)
- Equalization basin ($143,000)
- 2,4,5-T waste management ($370,000)
- 2,4-D waste management ($931,000).

These cost items are discussed in more detail below.

Landfills and Above-Ground Drum Storage Area

A Vertac official estimates that a total of $295,000 was spent for chemical analysis, engineering studies and

TABLE 1. SUMMARY OF COST INFORMATION - VERTAC CHEMICAL CORPORATION, JACKSONVILLE, ARK

Task	Quantity	Actual Expenditure (a)	Unit Cost	Funding Source	Period of Performance
I. Reasor-Hill Landfill					
A. Engineering studies and chemical analysis		$63,500(b)		Vertac & Hercules	
B. Capping and barrier walls		$96,000	$2.85/cu.yd (c) ($2.18/cu.m)	Vertac & Hercules	6/15/79-12/31/79; 8/15/80-9/10/80
Subtotal		$159,500			
II. Hercules-Transvaal Landfill & old drum storage area					
A. Engineering studies and chemical analysis		$62,500(b)		Vertac	
B. Capping		$73,000	$2.85/cu.yd. (c) ($2.18/cu.m.)	Vertac	7/15/80-8/10/80
Subtotal		$135,500			
III. Blow-out area					
A. Engineering Study		$15,000(b)		Vertac	
B. Clay and asphalt capping		$22,000		Vertac	7/20/80-9/10/80
Subtotal		$37,000			
IV. Equalization basin					
A. Engineering study and chemical analysis		$45,000(b)		Vertac	
B. Lime for solidification		$10,000		Vertac	
C. Capping, barrier walls and French Drain		$38,000			
D. Construction of above ground replacement system		$50,000		Vertac	9/26/80-12/1/80
Subtotal		$143,000			

(continued)

TABLE 1. (continued)

Task	Quantity	Actual Expenditure	Unit Cost	Funding Source	Period of Performance
V. 2,4,5-T Waste Management					
A. Engineering studies and chemical analysis		$30,000(b)		Vertac	
B. Re-drumming(material and labor)	3,000 drums(c)	$269,000 (b)	$67/drum (c)	Vertac	
C. Construction of drum storage shed		$71,000 (b)		Vertac	
Subtotal		$370,000			
VI. 2,4,-D Waste Management					
A. Engineering studies and chemical analysis		$75,000 (b)		Vertac	
B. Re-drumming (material and labor)	10,000 drums(c)	$156,000 (b)	$67/drum(c)	Vertac	
C. Construction of new production proces		$700,000 (b)		Vertac	
Subtotal		$931,000			
VII. Misc. Studies					
A. Effectiveness of Remedial Actions					
1. Engineering studies and chemical analysis		$200,000 (b)		Vertac	1/9/82-8/10/82
B. Sampling and Analysis					
1. Process waste water		$15,000 (b)		Vertac	1/9/82-present
2. Cooling pond		$10,000 (b)		Vertac	" "
3. Reimbursement of state's costs		$15,000 (d)		Vertac	" "
Subtotal		$240,000			
TOTAL		$2,016,000			6/15/79-present

(a) all data supplied by Vertac
(b) includes in-house and outside work
(c) estimate by Vertac Official

plans, and remedial work on the Reasor-Hill and Hercules-Transvaal landfills and the former above-ground storage area. Of this amount, approximately $41,000 was paid to both McClelland Engineers for the subsurface investigation and Shreeve Engineers for the engineering study and plan. Vertac broke the $41,000 figure into $21,000 and $20,000 for work at the Reasor-Hill and Hercules-Transvaal areas, respectively (the company treated the drum storage area as part of the Hercules-Transvaal area cost for purposes). About $5,000 was paid to Southwestern Engineers for permeability and compaction tests on the landfill caps (since this was not broken down further, it will be assumed that the cost was divided equally between the two landfills). Vertac also estimated its in-house costs for monitoring, chemical analysis and supervision, as well as provision of an undetermined amount of labor, materials and equipment, to total $80,000, divided evenly between the landfills. Thus, the total estimated engineering and analytical costs were $63,500 for Reasor-Hill and $62,500 for Hercules-Transvaal.

There was no expenditure for the clay used to cap these areas because the clay was taken from another location on-site. Consequently, the remaining item of expense for the landfill remediation was the contract with Helena Construction Company for moving and compacting the clay caps and constructing the clay barrier walls at the Reasor-Hill landfill. The Hercules-Transvaal cap cost $73,000, while the Reasor-Hill cap and barrier walls cost $96,000. A Vertac official stated that the unit cost for this construction work was $2.85 per cubic yard ($2.18/m^3); while no figure was given for the amount of clay used, this can be computed to be approximately 25,614 cubic yards (19,584.5 m^3) for Hercules-Transvaal and 33,684 cubic yards (25,754.9 m^3) for Reasor-Hill.

Equalization Basin

Vertac designed and supervised the work on the equalization basin. The company hired outside operators and equipment on an hourly basis to do the construction, but Vertac officials could not give the names of the people or types of equipment used, nor the hourly rates charged. Total cost was estimated to be $93,000 which a Vertac official broke down as follows:

- Monitoring, chemical analysis, development of a solidification process for basin sludges, and development of an above-ground alternative treatment system-$45,000

- Lime for solidification of sludges-$10,000 for an undisclosed amount

- Capping the area with clay, topsoil and grass seed and installing the French drain and clay barrier walls-$38,000.

The total figure of $93,000 does not include the cost of building the above-ground treatment system, although a company official estimated that this cost about $56,000.

Blow-out Area

Vertac was the general contractor for remedial work on the blow-out area and hired outside personnel and equipment to construct the asphalt and clay cap. Vertac stated that the total remedial action cost was $37,000, which included: sampling and chemical analysis at $15,000 and capping with asphalt and clay at $22,000. No data are available regarding the portion of capping costs allocable to asphalt as opposed to clay capping.

Monitoring, Sampling and Analysis

Vertac has spent a substantial amount of money pursuant to administrative or court orders to determine the nature and extent of both on-site and off-site pollution. In addition to the monitoring and chemical analysis done specifically for the two landfill areas discussed previously, Vertac had additional work done on other areas. DISC performed a $125,000 study of on-site conditions such as geology, ground water, surface water runoff, surface soils, and the cooling water pond. A Vertac official estimated that Vertac spent an additional $75,000 for its own in-house sampling and analytical work related to the DISC study. Thus, a total of $200,000 was spent to study on-site conditions.

Environmental and Toxicological Consultants performed off-site monitoring and analytical work on Rocky Branch Creek, a drainage ditch running from the eastern side of the plant to Rocky Branch Creek, and Bayou Meto. This work cost $20,000. Vertac has not specified any in-house costs relating to this study.

The Consent Decree also required Vertac to have chemical analyses for dioxin performed on both cooling pond and off-site samples. This work went to Specialized Assay at a cost of $13,000. Vertac was ordered to reimburse the State of Arkansas for the costs of certain analytical work regarding dioxin, which amounted to $15,000 to be paid over 3 years. The total cost for dioxin analysis, then, was $28,000. Vertac specified no in-house costs associated with these studies.

In addition to the dioxin analysis, Vertac was required by the Consent Decree to analyze samples from the cooling pond, process wastewater, and off-site samples. Analytical work was to be performed for chlorinated phenols, chlorinated benzenes, chlorinated anisoles, toluene 2,4-D, 2,4,5-T and 2,4,5-TP. Environmental Protection Systems did this work for $15,000, which a Vertac official broke down to costs of $5,000 and $10,000 for work relating to process wastewater and the cooling pond, respectively. Vertac also identified $10,000 of in-house costs relating to analytical work on the process wastewater. In sum, the chemical analysis for the substances listed above came to $15,000 for process wastewater and $10,000 for the cooling pond.

Waste Management for 2,4-D and 2,4,5-T

The Consent Decree required Vertac to develop a waste management plan for its 2,4-D and 2,4,5-T wastes, including sampling, chemical analysis, and redrumming. Furthermore, Vertac was required to "exercise best efforts" to reduce the volume of chemical wastes stored on-site. Vertac did all of the redrumming work itself. An official estimated that about $269,000 was spent redrumming 2,4,5-T wastes and $156,000 redrumming 2,4-D wastes. These figures included materials and labor. Vertac stated that repacking drums cost about $67 each. An official estimated that it took about 2 1/2 hours per drum to do the repacking. A Vertac official estimated that the company spent $105,000 for sampling and analyzing wastes, broken down to $30,000 for 2,4,5-T wastes and $75,000 for 2,4-D wastes. The latter sum included costs of developing a process to reuse the 2,4-D wastes. Vertac reported that it also spent money to construct new facilities at its plant as well as to modify the manufacturing process in order to reduce the amount of new chemical wastes. Approximately $71,000 was spent for work associated with 2,4,5-T wastes and $700,000 for 2,4-D wastes. The former amount represents the cost of building a drum storage warehouse and the latter figure represents the cost of modifying the 2,4-D formulating process. Total figures for the various costs of managing both types of wastes are as follows:

- Sampling, analysis and development of recycling process for 2,4-D-$105,000

- Redrumming - $425,000

- Construction of new facilities or modification of process - $771,000.

Looking at these costs across waste types, it appears that managing 2,4-D wastes cost $931,000 and managing 2,4,5-T wastes cost $370,000. Total waste management cost was $1,301,000 as of August 1982.

PERFORMANCE EVALUATION

At the present time it is difficult to determine the effectiveness of the remedial action at the Vertac site, primarily because the contamination present was the result of several factors (combined in many instances), all of which have not been remedied. Furthermore, indicators of contamination off-site in locations such as Rocky Branch and Lake Dupree have yet to be cleaned up. Once they are totally cleaned up, continued monitoring will indicate whether leaching and seepage are still occurring. A proposal has recently been made to; (1) clean up Lake Dupree, (2) discontinue use of the cooling pond, (3) clean up the cooling pond, (4) establish a strict plant housekeeping plan, (5) cap the surface of the central ditch, and (6) establish a new east drainage ditch while filling in the existing ditch. The proposal also includes stipulations concerning monitoring that will be conducted at the east drainage ditch, the west branch of Rocky Branch Creek and the confluence of the branches of Rocky Branch Creek as control points to determine whether DISC's groundwater mass low balance is correct. DISC calculated that for the entire site, one pound per year of soluble pollutants would leak or flow. Therefore, an overall evaluation is difficult to make at this time. Hence, each remedial action is evaluated independently below.

Reasor-Hill Landfill Area

The clay cap and barrier walls at the Reasor-Hill landfill area have apparently reduced the infiltration of surface precipitation and are probably catching a good amount of leachate in the area; preventing it from infiltrating into or out of the Reasor-Hill site. The effectiveness of these remedial actions in mitigating vertical migration of contaminants is presently being monitored with 3 newly installed monitoring wells (#'s 9, 15 & 16), in addition to original monitoring wells 1, 2 and 3 which are nested together to monitor vertical flow. Although insitu permeability tests conducted by DISC indicate that permeability decreases with depth, there is still no monitoring data available with which a conclusion can be drawn concerning further contamination of ground water.

Hercules-Transvaal Landfill Area

The same conclusions reached concerning the effectiveness of the remedial action at the Reasor-Hill area are applicable to the remedial action at the Hercules-Transvaal area. The clay cap prevents surface infiltration; however, there is no monitoring data available with which a determination can be made concerning further vertical contaminant migration. It should also be noted that despite what monitoring results are inside this area, no barrier walls have been installed, hence the potential for both lateral and vertical movement outside the confines of the area exists.

Former Above-Ground Storage Area

The removal and repacking of the approximately 3,000 drums of 2,4,5-T still bottoms, as well as the containerization of contaminated soil into a specially built aboveground warehouse, appears satisfactory. Vertac is now choosing the ultimate disposal method for these drums. New regulations proposed on April 4, 1983 will make disposal of the 2,4,5-T still bottoms possilbe once the regulations are finalized.

The capping of the area as part of the Hercules-Transvaal landfill area was a practical remedy; however, the effectiveness of this action cannot be determined totally for the reasons mentioned above.

Blow-out Area

The objective of the remedial action at the blow-out area was to prevent the infiltration of surface precipitation which would in turn prevent runoff of contaminants to the east. The asphalt cap placed over the former process area should prove satisfactory as long as it is checked periodically for cracks. Although the asphalt is susceptible to deterioration and corrosion should any chemical spills occur at or near this area, it was selected and applied due to the heavy traffic occurring in the area. If clay were the only cap it would be much too easily worn away. The clay capped portion, on the other hand, may not be as susceptible to cracking. Furthermore, if any chemical contamination were to occur, the clay may not deteriorate as completely as the asphalt. The clay could easily be removed and replaced with on-site clays if contamination occurred, whereas replacing the asphalt would not be as readily achieved.

Equalization Basin

The equalization basin that was installed has proven to be effective as a wastewater treatment system. Constant monitoring is in progress to ensure that the pH of the wastewater is between 6 and 7 prior to discharge to the Jacksonville sewage treatment plant.

The closure procedure Vertac implemented appears to be effective as far as preventing the infiltration of surface water through the closed out area. The French drain system and barrier walls appear to be containing leachate seeps laterally; however, as stated earlier, monitoring data has not been available with which a determination can be made concerning further vertical migration of contaminants. Further, the barrier walls and the French drain were constructed over weathered rock. Although any fissures which were present under the trench were packed with clay, the effectiveness of this method over time may be questionable.

Recycling

The procedure of separating and reusing 2,4-D still bottoms for 2,4-D production has been very effective in preventing the generation of additional waste at the Vertac site. The problem of crosscontamination has been alleviated through the use of new equipment. Vertac now disposes of any wastes generated from 2,4-D production in an approved PCB landfill.

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