Sikes Disposal Pits
Crosby, Texas

002832

Feasibility Study Report
July, 1986

Submitted to:

Texas Water Commission

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In Association with:

HARDING LAWSON ASSOCIATES

002833

FEASIBILITY STUDY REPORT

SIKES DISPOSAL PITS SITE

Prepared in Cooperation with the
Texas Water Commission
and the
U.S. Environmental Protection Agency

JULY, 1986

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002834

TABLE OF CONTENTS

SIKES DISPOSAL PITS SITE

002835

TABLE OF CONTENTS (Continued)

002835

002836

TABLE OF CONTENTS (Continued)

002836

002837

TABLE OF CONTENTS (Continued)

002837

TABLE OF CONTENTS (Continued)

LIST OF FIGURES

002840

LIST OF TABLES

002840

LIST OF TABLES (Continued)

002841

EXECUTIVE SUMMARY

INTRODUCTION

This Feasibility Study (FS) identifies, develops and evaluates remedial alternatives for source control at the Sikes Disposal Pits Hazardous Waste Disposal Site near Crosby, Texas. The Sikes Disposal Pits site has been designated for remedial action under the Comprehensive Environmental Response Compensation and Liability Act of 1980 (CERCLA). The guidelines used by the U.S. Environmental Protection Agency (U.S. EPA) to carry out its responsibility on CERCLA (Superfund) sites is published as the National Oil and Hazardous Substance Contingency Plan (NCP), as amended (50 Fed. Reg. 47950, November 20, 1985) effective February 18, 1986. This FS also provides the information necessary for selection of a cost-effective remedial action alternative for source control in accordance with the NCP.

The Sikes Disposal Pits site was closed in 1967. Since 1982, the site has been studied by the U.S. EPA and the Texas Water Commission and its predecessor, the Texas Department of Water Resources. After the site was placed on the National Priorities List for remedial action under Superfund, the U.S. EPA, the Texas Water Commission and its contractors conducted a Remedial Investigation (RI) in compliance with requirements of the NCP.

This report presents the methodology used to develop source control remedial alternatives. Initially, information concerning the site was analyzed to determine whether and what type of remedial actions would be

002842

considered based on the factors set out in Section 300.68(e)(2) of the NCP. Remedial objectives were identified which would eliminate, minimize or reduce site health and environmental hazards as a result of present or future releases of contaminants. Remedial or response actions were developed for each site media to satisfy objectives. Response actions were screened to eliminate those which were infeasible or inapplicable to the site. Technologies were considered and screened for implementing each response action. The technologies and response actions were then combined into remedial alternatives. The remedial alternatives were then screened and evaluated for technical feasibility and implementability, attainment of applicable or relevant and appropriate Federal requirements and effectiveness in eliminating, minimizing or reducing damage to, and providing protection of, public health and the environment. Alternatives were subsequently screened as to their relative cost-effectiveness.

Based on the screening and evaluation process described above, and as prescribed in Section 300.68 (d) (f), five remedial alternatives plus the no-action alternative were retained and evaluated in detail.

SITE CHARACTERIZATION

The Sikes Disposal Pits Site is a 185-acre tract, located in northeast Harris County approximately two miles from Crosby, Texas and approximately 20 miles from Houston, Texas. The site is bordered by the San Jacinto River and Jackson Bayou on the west and north, and U.S. Highway 90 on the south. The immediate surrounding area is largely undeveloped, although sport fisherman and water sports enthusiasts frequent the river and bayou nearby. Commercial sand mining, conducted adjacent to the site, is the only business activity nearby. One family lives on-site. The Riverdale subdivision of approximately 100 residents, is approximately 500 feet southeast and across Highway 90 from the site. It is the only residential development near the site.

The site completely lies in the 100-year floodplain of the San Jacinto River, while portions lie within the 10- and 50-year floodplains. The site has been flooded four times since 1969.

The site locations where significant waste deposits have been identified and thus are source areas include:

- o The main waste pit
- o The main waste pit overflow area
- o Tank Lake and slough
- o Small waste pits (3)
- o Drum waste areas
- o Suspected waste areas

The main waste pit is approximately 3 acres in size and contains approximately 5600 cubic yards of sludges, 21,000 cubic yards of soils contaminated with organics above 10 ppm and approximately 4.7 million gallons of contaminated surface water.

The overflow area extends east of the main waste pit and covers approximately 8 acres. It contains approximately 43,000 cubic yards of sludges, underlain with approximately 58,000 cubic yards of soils contaminated with organics above 10 ppm.

Tank Lake contains approximately 2000 cubic yards of sludges and approximately 7 million gallons of contaminated surface water. The small waste pits, the drummed waste and suspected waste areas contain approximately 22,000 cubic yards of sludges and 1 million gallons of contaminated water.

ENVIRONMENTAL IMPACTS

Alluvial sand deposits underlying the site contain a shallow aquifer that many of the local inhabitants have relied on for drinking water. This aquifer has been heavily contaminated by organic constituents leached from wastes deposited in pits and from wastes spread on the land surface. At this time, only the shallow aquifer below the site is significantly contaminated. Groundwater contamination has not migrated beyond the site boundaries. Contaminants identified in this aquifer include benzene, chlorinated hydrocarbons, naphthalene and other polynuclear aromatics, phenols, and several heavy metals.

A second aquifer lies below the first, separated from it by approximately 65 feet of a highly plastic clay strata. This lower aquifer appears to contain trace concentrations of one or more volatile organic compounds, including: benzene, chlorobenzene, 1,1-dichloroethane, 1,2-dichloroethane and vinyl chloride.

A significant quantity of sludge material has been transported out of the main waste pit and deposited on the ground surface east of the main waste pit. This area of sludge deposits is void of vegetation. Trees and brush have not returned.

EXPOSURE PATHWAYS

The primary pathways by which people could become exposed to site contaminants are:

- o direct contact with sludges and contaminated soils
- o consumption of contaminated groundwater from the upper or lower aquifers
- o direct contact with contaminated surface waters
- o inhalation of toxic volatile organic compounds

REMEDIAL OBJECTIVES AND CRITERIA

Remedial objectives and criteria for determining achievement of objectives, were established in cooperation with the EPA and Texas Water Commission. These objectives and associated criterion formed the basis for developing the remedial alternatives. Nine site objectives were chosen and are described as follows:

1. Prevent human contact with contaminated soils and wastes.

   Criterion: No direct contact with waste containing greater than 100 mg/l (ppm) polynuclear aromatics.

2. Minimize impact of contaminated runoff.

   Criterion: Surface Water Quality Criteria: a maximum of 0.1 mg/l benzene, 0.3 mg/l vinyl chloride, 0.3 mg/l of total phenols and metals as per Section 156.19.15.002 of the Texas Water Code.

3. Prevent human contact with contaminated surface water.

   Criterion: Surface Water Quality Criteria.

4. Minimize site related degradation of the San Jacinto River and Jackson Bayou.

   Criterion: Surface Water Quality Criteria.

5. Prevent use of contaminated groundwater (Upper Aquifer).

   Criterion: Drinking Water Standards or Human Health Criteria (10^{-4} to 10^{-7} risk range)

6. Protect against contamination of the Lower Aquifer.

   Criterion: Existing background water quality in Lower Aquifer.

7. Prevent migration of waste off-site during flood events.

   Criterion: Surface Water Quality Criteria.

8. Prevent use of groundwater (Lower Aquifer) contaminated above background.

   Criterion: Existing background water quality in Lower Aquifer.

9. Minimize the potential of any adverse air discharge.

   Criterion: OSHA standards at site boundary, Federal Ambient Air Standards.

REMEDIAL ALTERNATIVE DEVELOPMENT

Initially, 13 potential remedial alternatives were developed. (A detailed description of these Alternatives is presented on p. 84). These were screened for effectiveness, engineering feasibility and cost.

Based on the results of the initial screening, seven of the 13 alternatives were rejected from further evaluation, because they either did not provide adequate protection of public health, and/or their cost was significantly greater than others without providing compensatory benefits. The remaining six remedial alternatives were:

- o Remedial Alternative 3 - Off-Site RCRA Landfilling of Sludges, On-Site Fixation of Contaminated Soils. Restoration of the Upper Aquifer

- o Remedial Alternative 5 - On-Site Incineration of Sludges, Fixation of Contaminated Soils and Ash. Restoration of the Upper Aquifer.

- o Remedial Alternative 6 - On-Site Incineration of Sludges, Off-Site RCRA Landfilling of Contaminated Soils, On-Site Fixation of Ash. Restoration of Upper Aquifer.

- o Remedial Alternative 10 - On-Site Incineration of Sludges and Contaminated Soils, Fixation of Ash. Restoration of Upper Aquifer.

- o Remedial Alternative 12 - On-Site Burial of Sludges in Pits with Slurry Walls and Caps, Fixation of Contaminated Soils. Restoration of Upper Aquifer.

- o Remedial Alternative 13 - No-Action.

These six remaining alternatives were further evaluated with respect to technical, public health and environmental and cost criteria. The results of this evaluation are presented in Table 1.

TABLE 1

SUMMARY OF DETAILED EVALUATION OF REMEDIAL ALTERNATIVES
SIKES DISPOSAL PITS SITE

Remedial Alternative	Present Worth Cost ($M) Implementation	O&M	Public Health Considerations	Environmental Considerations	Technical Considerations	Institutional Considerations
3* - Off-Site RCRA Landfilling of Sludges, On-Site Fixation of Contaminated Soils.	56.0	0.4	Removes direct contact or ingestion hazard. Low cancer risk. Use of upper aquifer banned until restored. Transportation risks.	Removes or isolates waste. Promotes aquifer restoration. Potential for leaching from fixed soils. Least time to implement.	Demonstrated technology effectiveness if fixation is effective.	Banning use of Upper Aquifer continued. Longterm groundwater monitoring required. Longterm monitoring may affect site use.
5 - On-Site Incineration of Sludges, Fixation of Contaminated Soils and Ash.	53.8	0.4	Removes direct contact or ingestion hazard. Low cancer risk. Use of upper aquifer banned until restored.	Removes or isolates waste. Promotes aquifer restoration. Potential for leaching from fixed soils. Longer implementation time than Alt. 3 & 12.	Demonstrated technology effectiveness if fixation is effective.	Use of Upper Aquifer banned. Longterm groundwater monitoring required. Longterm monitoring may affect site use.
6 - On-Site Incineration of Sludges, Off-Site RCRA Landfilling of Contaminated Soils, On-Site Fixation of Ash.	111.3	0.4	Removes direct contact or ingestion hazard. Very low cancer risk. Use of upper aquifer banned until restored. Reduced transportation risks than Alt. 3.	Destroys or removes waste. Promotes aquifer restoration. Longer implementation time than Alt. 3 and 12.	Demonstrated technologies. More reliable.	Use of Upper Aquifer banned. Longterm groundwater monitoring required. Longterm monitoring may affect site use.

TABLE 1

Remedial Alternative	Present Worth Cost ($M) Construction	O&M	Public Health Considerations	Environmental Considerations	Technical Considerations	Institutional Considerations
10 - On-Site Incineration of Sludges and Contaminated Soils, Fixation of Ash.	92.9	0.4	Achieves maximum protection against direct contact or ingestion hazard. Very low cancer risk. Use of upper aquifer banned until restored.	Destroys organic waste on-site. Provides greater protection against potential aquifer contamination than Alt. 3, 5 and 12. Longer implementation time than other alternatives.	Demonstrated technologies used. Maximum reliability.	Use of Upper Aquifer banned. Longterm groundwater monitoring required. Longterm monitoring may affect site use.
12 - On-Site Burial of Sludges in Pits with Slurry Walls and Caps. Fixation of Contaminated Soils.	23.4	1.3	Removes direct contact or ingestion hazard. Low cancer risk. Use of upper aquifer banned until restored.	Wastes isolated or immobilized but not destroyed. Leaching potential greatly reduced, although sludges left on-site.	Not totally demonstrated technology. System failure possible. Continued maintenance required. Collection and disposal of leachate required.	Use of Upper Aquifer banned. Longterm monitoring required. Use of land area prohibited.
13 - No Action	---	0.4	Continued potential for direct contact on-site and off-site. Potential ingestion hazard on-site.	Wastes remains in place. Continued potential for contaminating lower aquifer. Upper aquifer remains unsuitable for use.	Not applicable.	Direct contact and ingestion hazards continued.

002850

The alternatives collectively contain a variety of on-site and off-site treatment/disposal options, with combinations of both in several alternatives. All alternatives include excavation of sludges and contaminated soils. Sludges would either be landfilled (on- or off-site) or incinerated on-site. Contaminated soils would be either incinerated on-site, chemically fixed on-site or disposed of in a RCRA approved landfill off-site.

Restoration of the upper aquifer to drinking water quality or the (10^{-4} to 10^{-7} risk range) Human Health Criteria by natural flushing would be accomplished following removal of sludges and contaminated soils. This action is common to all remedial alternatives except the no-action alternative. Until restored, the Upper Aquifer would be banned from use.

A sensitivity analysis was made to show the effects on costs that result from variations in specific assumptions associated with the development of the alternatives, which include:

- o Volume of contaminated materials
- o Off-site disposal costs
- o Transportation Costs to a RCRA permitted landfill
- o Incineration costs
- o Discount rates

Results are shown in Table 2.

Remedial costs are more sensitive to volume of contaminated waste than any other effect, with Discount rate the second most sensitive effect.

002852

TABLE 2

TOTAL PRESENT WORTH FOR SENSITIVITY ITEMS

Alternative No.	3	5	6	10	12
Base Total Present Worth (M$)	56.4	54.2	111.7	93.3	24.8
o Change Volume of Waste:					
+25%	62.5	59.1	123.6	102.3	28.1
-25%	49.6	48.6	98.0	82.4	23.6
o Increase Cost of Off-Site RCRA Disposal Costs to: (Base Cost - $200/cu. yd)					
$250/cu. yd.	60.8	54.2	118.5	93.3	24.8
$300/cu. yd.	65.6	54.2	126.2	93.3	24.8
o Increase in Transportation Costs to a RCRA Facility: (Base Miles 150)					
450 miles	67.5	54.2	129.3	93.3	24.8
750 miles	78.9	54.2	147.8	93.3	24.8
o Increase in Incineration O&M Costs (Base Costs: Alt. 5,6 $188 per ton) Alt. 10 $172 per ton)	56.4	54.2	111.7	93.3	24.8
$235/ton	56.4	56.6	113.5	99.3	24.8
$282/ton	56.4	59.6	116.5	107.3	24.8
o Discount Rate (Base @ 10%)					
4%	59.9	57.9	120.9	100.9	26.6
7%	58.6	56.5	117.8	97.9	25.8

SECTION 1 - INTRODUCTION

The Texas Water Commission (formerly the Texas Department of Water Resources), in cooperation with the U.S. Environmental Protection Agency (EPA) initiated a program in 1983 to conduct a Remedial Investigation for the Sikes Disposal Pits Superfund site. A contract to conduct a Feasibility Study of this site was initiated in January, 1985.

The Remedial Investigation has been completed. The Feasibility Study, the subject of this report, has utilized the results of the Remedial Investigation Reports (Volumes I, II, III, and IV) to identify appropriate objectives and cleanup criteria for the problems identified at Sikes. The objective of this study has been to develop a range of alternativcs that satisfy site remedial objectives and conduct a detailed evaluation of each.

The Sikes Disposal Pits site was one of the original sites ranked under the National Hazard Ranking System and placed on the National Priorities list. Funding for the RI and FS has been made available under the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA).

This feasibility study was conducted by Lockwood, Andrews & Newnam, Inc. (LAN), in association with Harding Lawson Associates (HLA). This study was conducted in accordance with EPA's guidance document on feasibility studies under CERCLA.

1.1 SITE BACKGROUND INFORMATION

1.1.1 Location

The Sikes Disposal Pits site is a 185-acre tract, approximately 2 miles southwest of Crosby, Texas at the intersection of U.S. Highway 90 and the San Jacinto River. The site is in Harris County, about 20 miles east-northeast of Houston and approximately 17 miles northwest of Galveston Bay (see Figure 1-1). The entire Sike's site is in the 100-year floodplain of the San Jacinto River which borders the western portion of the site. Portions of the site lie within the 10- and 50-year floodplains.

1.1.2 Site History

The Sikes Disposal Pits site began operation as a waste depository in the early 1960's and closed in 1967. During this period, a variety of (see Figure 1-2) chemical wastes from area petrochemical industries were deposited on-site in several old sand pits. Numerous drums of wastes were also left on the property.

The dike around the unlined main waste pit was not adequate to withstand the periodic flooding of the site. Floodwaters have breached the dike and transported wastes across a large, low-lying area east of the main waste pit.

Preliminary sampling at the site in 1982 indicated the presence of phenolic compounds, xylene, benzene, creosote, toluene, and other organics. An Immediate Removal Action was performed at the site by the USEPA Emergency Response Branch in June of 1983. Approximately 440 cubic

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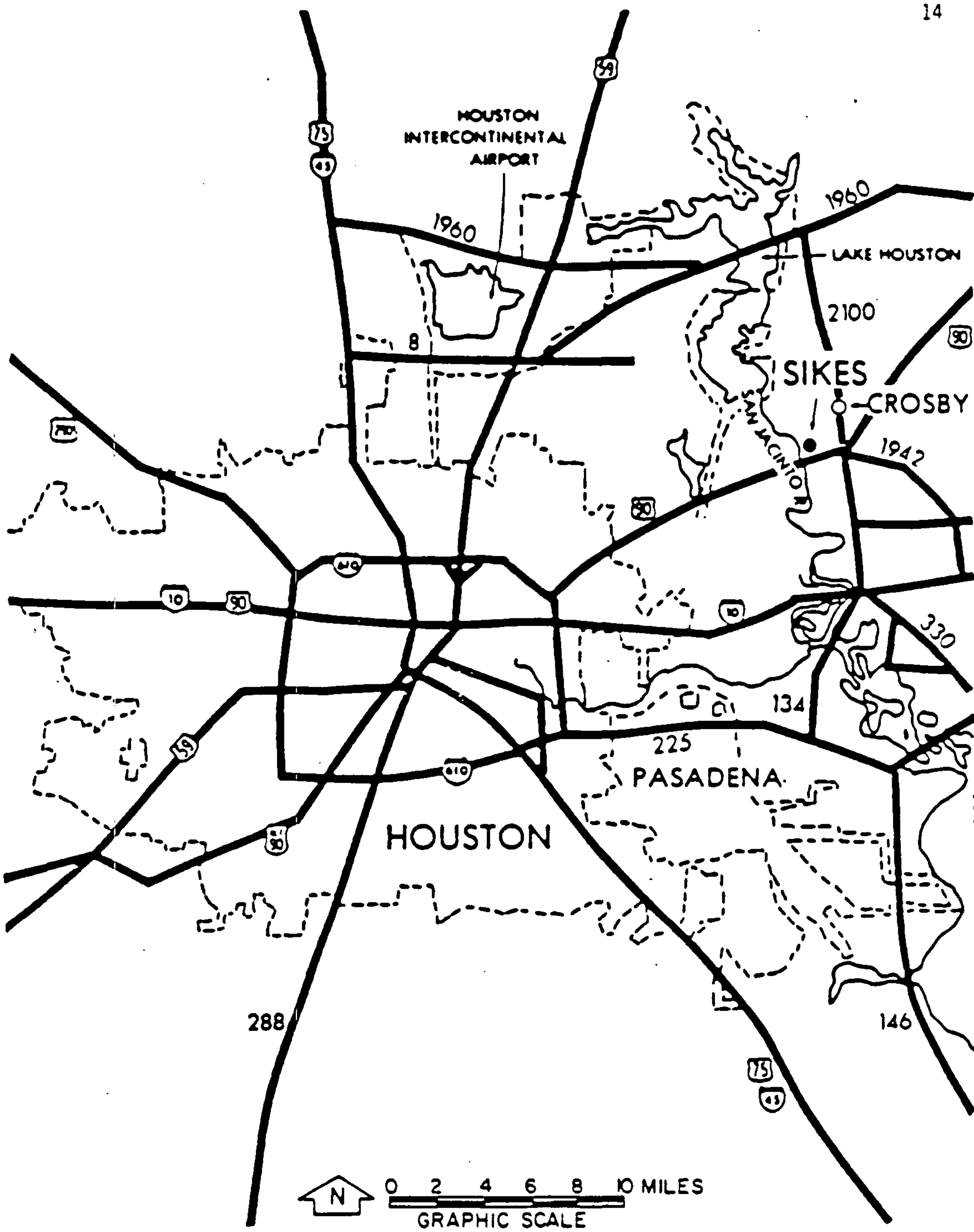

FIGURE 1-1 SIKES DISPOSAL PITS SITE LOCATION	SIKES DISPOSAL PITS CROSBY, TEXAS	Prepared for: TEXAS WATER COMMISSION lan HLA DATE: JUNE 1986 PROJECT NO.1633-20-003-000

002855

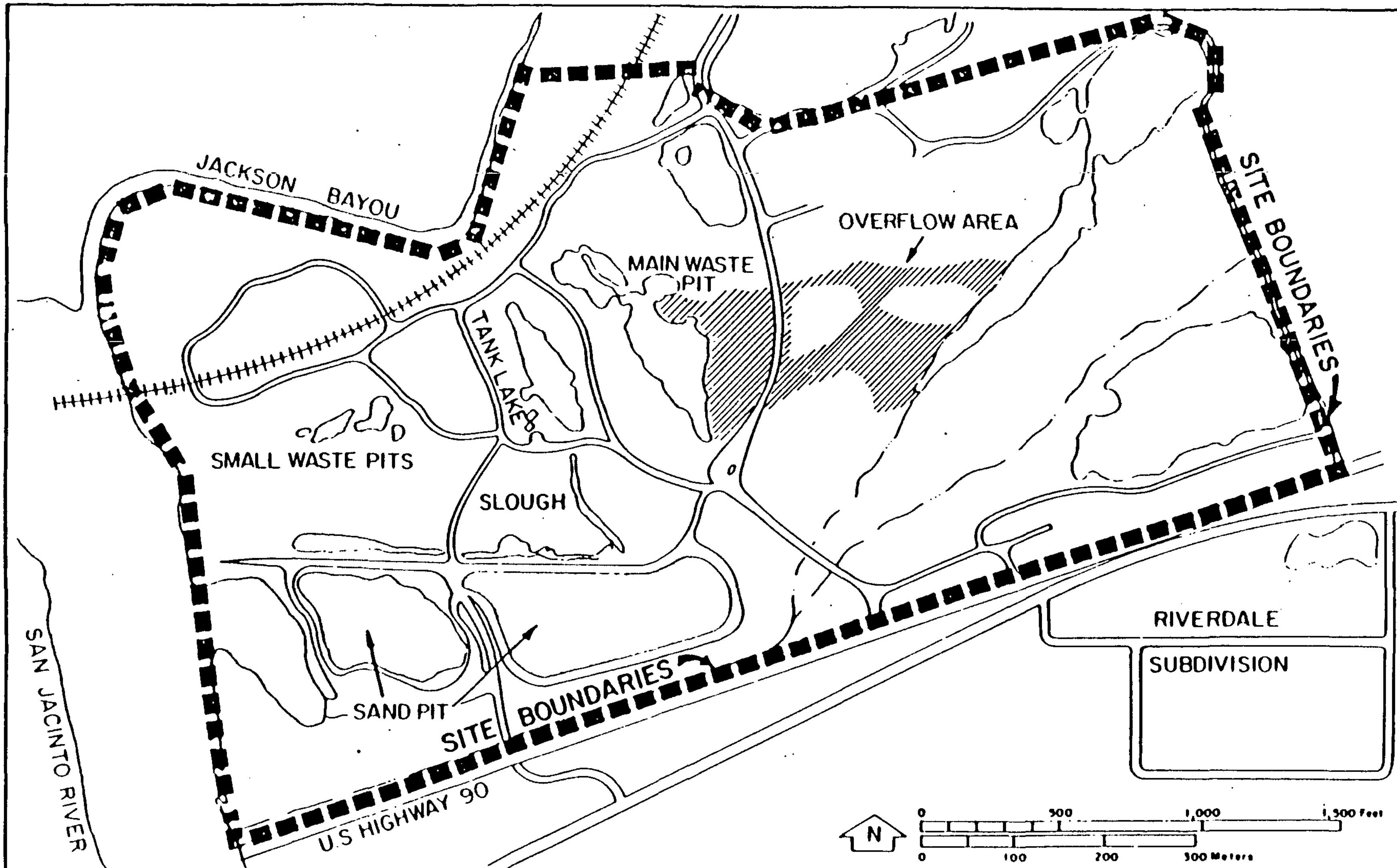

FIGURE 1-2

GENERAL PHYSIOGRAPHIC FEATURES

SIKES DISPOSAL PITS
CROSBY, TEXAS

Prepared for

TEXAS WATER COMMISSION

002856

DATE JUNE 1986 PROJECT NO 1633-20-003-000

002856

yards of phenolic tars were removed from a partially buried pit near the temporary living quarters of the Sikes family, immediately north of U.S. Highway 90. FIT teams were sent to the site again in April and August 1984. The first visit was to investigate several heavily stained seeps in the active sand pits south of the main waste pit. The second visit was made to investigate several tar seeps near the same sand pits.

The Texas Department of Water Resources (now the Texas Water Commission) contracted with Lockwood, Andrews & Newnam, Inc., Environmental Science and Engineering, Inc., and Harding Lawson Associates in January, 1983 to conduct a Remedial Site Investigation. This study has been completed and has been the principal source of site information used for the Feasibility Study.

1.1.3 Physiography

Forest canopy vegetation of this area consists of loblolly pine, slash pine, water oak, willow oak, elm, green ash, cottonwood, sweetgum, and bald cypress in the wetter areas. Deer and small mammals such as cottontail rabbit, skunk, fox, raccoon and opossum are common. Harris County is a wintering place for geese, ducks, egrets, herons, rails, ceets, gallinules, and other migratory birds.

The site lies 10 to 20 feet above mean sea level (msl). It is bordered by the San Jacinto River on the west side, Jackson Bayou on the north side, and U.S. Highway 90 on the south side. A Southern Pacific Railroad line traverses the northwest section of the site, running parallel to and just south of Jackson Bayou.

Land use in the area is divided between cropland, pasture, sand mining and forest, while most of the remaining area is urban.

1.1.4 Hydrogeology

Alluvial sand deposits, ranging from 17 to 34 feet thick, underlie the site and form a shallow aquifer. Groundwater levels in the aquifer range from approximately 2 to 10 feet below the ground surface. Groundwater enters the site generally from the northeast. If flows across the site and exits the site generally to the southwest toward the San Jacinto River. Some groundwater flows into Jackson Bayou, northwest of the site. Many of the local inhabitants rely on this aquifer for drinking water. Groundwater in the shallow aquifer (hereafter called the Upper Aquifer) has been contaminated by leaching action of organic sludges in the areas immediately surrounding the waste pits and overflow area.

Dewatering operations in local sand pits have altered the groundwater gradients and subsequently spread contaminants. At this time, contamination in the Upper Aquifer appears to be moving from the main waste pit to the south, southeast, and northwest.

A 10-foot-thick sandy-silt stratum with a piezometric surface approximately 59 feet below natural ground surface underlies the Upper Aquifer, and is separated from it by approximately 65 feet of a highly plastic clay strata. Groundwater taken from this aquifer (hereafter called the Lower Aquifer) have indicated on at least one occasion the presence of benzene, chlorobenzene, 1,1-dichloroethane, vinyl chloride, bis (2-ethyhexyl) phthalate, and di-n-octyl phthalate. The concentrations of these contaminants are all below the (10-5 risk level)

Human Health Standards. Therefore, while the implications of contamination in the Lower Aquifer are serious, the potential risks involved with human exposure to signficant concentrations of contaminants is low. Underlying the two aquifers previously mentioned, and separated by several hundred feet of clay, are the Chicot and Evangeline aquifers, one of the major drinking water sources for metropolitan Houston. These aquifers appear to be in little danger of immediate contamination.

1.2 NATURE AND EXTENT OF PROBLEMS

1.2.1 Sources of Site Contamination

Wastes have been deposited in many locations on-site. Identified locations include:

- Main waste pit and adjacent overflow area
- Tank Lake and Slough
- Small Waste Pits
- Drummed Wastes
- Suspected Waste Disposal Areas - six suspected locations

The main waste pit is approximately 3 acres in size and contains approximately 5600 cubic yards of sludges and contaminated sediments, 21,000 cubic yards of contaminated soils (containing organic contaminants above 10 ppm) and approximately 4.7 million gallons of contaminated water above the sludges. The sludges contain several volatile organic compounds and toxic metals. Soils underlying the main waste pit sludges are contaminated with similar organics and metals.

Chemical analyses of sludges, underlying contaminated soils and surface water for the waste locations identified above, are given in Tables 1-2, 1-2, and 1-3, respectively.

The main waste pit overlow area extends east of the waste pit about 1,500 feet and is approximately 500 feet across at its widest point. Approximately 43,000 cubic yards of sludges and about 58,000 cubic yards of contaminated soils are estimated for this area. The chemical composition of sludges and underlying soils is similar to sludges in the main waste pit as shown in Tables 1-1 and 1-2.

Tank Lake is a natural surface water body located approximately 250 feet west of the main waste pit. The lake was used for recreational purposes up to and during the time disposal operations were conducted. Analysis shows that approximately 2000 cubic yards of sediments are contaminated. Approximately 7.0 million gallons of contaminated surface waters overlie the sediments. Again, the contaminants are similar to those in the main waste pit sludges. Chemical analysis of Tank Lake sediments and surface water is given in Tables 1-1 and 1-3, respectively. The maximum Value reported for PCB in Tank Lake sediments (shown in Table 1-1) is 120 ppm. Wastes containing greater than 50 ppm PCB's are classified as PCB waste. PCB waste are subject to special disposal requirements under the Toxic Substances Control Act. Because of reasons given below, the reported value of 120 ppm PCB's in Tank Lake sediment is considered an analytical inconsistency and therefore these sediments have not been classified as a PCB waste for this Feasibility Study. Tank Lake sediments were sampled in February 1984 and July 1985. PCB's in the

TABLE 1-1

CHEMICAL ANALYSIS OF SLUDGES
SIKES DISPOSAL PITS SITE

(RESULTS ON DRY BASIS)

PARAMETERS	OVERFLOW AREA (COMP. 3)*	MAIN WASTE PIT (SE-27)*	SMALL WASTE PITS (SE-03&SE-26)*	TANK LAKE (CO-061)
CONVENTIONAL ANALYSIS				
Total Organic Carbon	NA	NA	NA	NA
Total Extractable Organics, TOE, mg/Kg	NA	NA	NA	NA
Total Organic Halogen, TOX, mg/Kg	15,000	91,000	29,000	NA
GC/MS VOLATILES (ug/Kg)				
Benzene	78,000	18,000	4,200	1,400
Chlorobenzene	680	12,000	320	51
Chloroform	660	<370	<320	<9.5
1,1-Dichloroethane	3,200	2,400	<270	410
1,2-Dichloroethane	250,000	<49,000	13,000	<9.5
1,2-Dichloropropane	270	450	660	<9.5
Ethylbenzene	24,000	<52,000	13,000	33
Methylene Chloride	730	1,600	1,500	<9.5
Tetrachloroethene	4,400	3,200	4,700	<9.5
Toluene	24,000	66,000	15,000	23
Trans-1,2Dichloroethene	1,000	<710	<610	140
1,1,2-Trichloroethane	86,000	<700	16,000	<9.5
Trichloroethene	<650	<870	2,200	<9.5
Vinyl Chloride	<390	<530	450	97

TABLE 1-1 (continued) Page 2
CHEMICAL ANALYSIS OF SLUDGES
SIKES DISPOSAL PITS SITE

	OVERFLOW AREA	MAIN WASTE PIT	SMALL WASTE PITS	TANK LAKE
GC/MS ACIDS (ug/Kg)				
2,4-Dimethylphenol	NA	52,000	19,000	< 2,000
Phenol	71,000	42,000	12,000	< 2,000
GC/MS BASE NEUTRALS (ug/Kg)				
Acenaphthene	52,000	58,000	110,000	< 2,000
Acenaphthylene	680,000	76,000	60,000	< 2,000
Anthracene	46,000	36,000	38,000	< 2,000
Benzo(a)Anthracene	< 42,000	< 42,000	17,000	< 2,000
Benzo(a)Pyrene	< 28,000	< 31,000	NA	< 4,000
Benzo(b)Fluoranthene	< 19,000	< 21,000	NA	< 4,000
Benzo(ghi)Perylene	< 40,000	< 45,000	NA	< 4,000
Benzo(k)Fluoranthene	< 19,000	< 21,000	NA	< 4,000
Bis(2-Ethylhexyl) Phthalate	< 17,000	< 19,000	17,000	< 2,000
Chrysene	22,000	< 6,000	10,000	< 2,000
Dibenzo(a,h)Anthracene	< 49,000	< 54,000	NA	< 4,000
Di-n-Butyl Phthlate	< 11,000	< 12,000	NA	< 2,000
Di-n-Octyl Phthlate	< 11,000	< 12,000	NA	< 2,000
Fluoranthene	138,000	36,000	77,000	< 2,000
Fluorene	230,000	100,000	120,000	< 2,000
Hexachloroethane	< 72,000	< 80,000	NA	< 2,000
Indeno (1,2,3-cd) Pyrene	< 38,000	< 42,000	NA	< 4,000
Naphthalene	1,400,000	570,000	220,000	< 2,000
Phenanthrene	260,000	100,000	220,000	< 2,000

TABLE 1-2

CHEMICAL ANALYSIS OF SOILS
SIKES DISPOSAL PITS SITE

(RESULTS ON DRY BASIS)

PARAMETERS	OVERFLOW AREA (SB06-C0125)*	MAIN WASTE PIT (PB06-C0081)*
CONVENTIONAL ANALYSIS (mg/Kg)		
Total Organic Carbon	6,000	NA
Total Extractable Organics, TOE	2,000	NA
Total Organic Halogen, TOX	< 0.01	NA
GC/MS VOLATILES (ug/Kg)		
Benzene	78,000	6,500
Chlorobenzene	< 1,900	< 6,300
Chloroform	< 1,900	< 6,300
1,1-Dichloroethane	< 1,900	< 6,300
1,2-Dichloroethane	260,000	< 6,300
1,2-Dichloropropane	< 1,900	< 6,300
Ethylbenzene	2,800	49,000
Methylene Chloride	< 1,900	< 6,300
Tetrachloroethene	6,200	< 6,300
Toluene	8,800	26,000
1,1,2-Trichloroethane	140,000	< 6,300
Trans-1,2 Dichloroethene	< 1,900	< 6,300
Trichloroethene	< 1,900	< 6,300
Vinyl Chloride	< 1,900	< 6,300

002864

TABLE 1-2 (continued) Page 2
CHEMICAL ANALYSIS OF SOILS
SIKES DISPOSAL PITS SITE

	OVERFLOW AREA	MAIN WASTE PIT
GC/MS ACIDS (ug/Kg)		
2,4-Dimethylphenol	< 20,000	< 80,000
Phenol	< 20,000	< 80,000
GC/MS BASE NEUTRALS (ug/Kg)		
Acenaphthene	< 20,000	270,000
Acenaphthylene	< 20,000	< 80,000
Anthracene	< 20,000	660,000
Benzo(a)Anthracene	< 20,000	< 80,000
Benzo(a)Pyrene	< 40,000	< 160,000
Benzo(b)Flouranthene	< 40,000	< 160,000
Benzo(ghi) Perylene	< 40,000	< 160,000
Benzo(k)Fluoranthene	< 40,000	< 160,000
Bis(2-Ethylhexyl)Phthalate	< 20,000	< 80,000
Chrysene	< 20,000	< 80,000
Dibenzo(a,h)Anthracene	< 40,000	< 160,000
Di-n-Butyl Phthlate	< 20,000	< 80,000
Di-n-Octyl Phthlate	< 20,000	< 80,000
Fluoranthene	< 20,000	330,000
Fluorene	< 20,000	290,000
Hexachloroethane	< 20,000	< 80,000
Indeno(1,2,3-cd)Pyrene	< 40,000	< 160,000
Naphthalene	< 20,000	1,200,000
Phenanthrene	< 20,000	110,000
Pyrene	< 20,000	590,000

002864

TABLE 1-2 (continued) Page 3
CHEMICAL ANALYSIS OF SOILS
SIKES DISPOSAL PITS SITE

	OVERFLOW AREA	MAIN WASTE PIT
METALS (mg/Kg)		
Beryllium	0.35	< 0.25
Cadmium	< 0.05	< 0.05
Chromium	4.0	8.0
Copper	13.0	8.5
Mercury	1.5	0.1
Nickel	3.0	1.0
Lead	4.5	9.5
Thallium	0.5	≤ 0.5
Zinc	38.0	35.0

* Sample Identification from Supplementary RI Report, Vol. III

Note: NA - Not Analyzed
mg/Kg = ppm; ug/Kg = ppb

NOTE: Not all contaminants analyzed listed in Table. Key contaminants are shown. Complete analysis for samples given in RI Report, Vol. IV, Appendix F.

002866

TABLE 1-3

SURFACE WATER CHEMICAL ANALYSIS
SIKES DISPOSAL PITS SITE

PARAMETERS	MAIN WASTE PIT SW-27	TANK LAKE SW-08	SMALL WASTE PIT SW-26	DRAINAGE TO SAN JACINTO RIVER SW-10
CONVENTIONAL ANALYSIS				
Carbon, TOC, mg/l	33.6	15.6	36.9	16
Total Organic Halogen, TOX, mg/l	NA	76	65	47
Total Phenols, ug/l	23	2	14	3
pH	6.5	7.8	3.7	7.0
Total Organic Extr., TOE, mg/l	146	< 5	28.3	< 5
GC/MS VOLATILES (ug/l)				
Benzene	9	< 1	1	< 1
Chlorobenzene	3	< 1	< 1	< 1
Chloroform	2	< 1	< 1	< 1
Chloroethane	< 2	3	< 2	< 3
1,1-Dichloroethane	37	12	7	< 1
1,2-Dichloroethane	44	13	91	< 2
Trans-1,2Dichloroethene	9	< 2	< 2	< 2
1,2-Dichloropropane	9	< 2	2	< 2
Trans-1,2Dichloroethene	< 1	< 1	< 1	< 1
Ethylbenzene	< 1	< 2	< 1	< 2
1,1,2,2-Tetrachloroethane	< 1	< 1	< 1	< 1
1,1,2-Trichloroethane	3	< 2	4	< 2
Trichloroethene	< 2	< 2	< 2	< 2
Toluene	2	< 1	< 1	< 1
Vinyl Chloride	6	< 2	1	< 2

TABLE 1-3 (continued) Page 2
SURFACE WATER CHEMICAL ANALYSIS
SIKES DISPOSAL PITS SITE

PARAMETERS	MAIN WASTE PIT SW-27	TANK LAKE SW-08	SMALL WASTE PIT SW-26	DRAINAGE TO SAN JACINTO RIVER SW-10
GC/MS ACID FRACTION (ug/l)	DL	NA	DL	NA
GC/MS BASE NEUTRAL (ug/l)				
Acenaphthene	< 74	< 1	2	< 1
Acenaphthylene	< 40	< 1	2	< 1
Bis(2-Ethylhexyl)Phthalate	< 46	< 1	37	< 1
Anthracene	< 51	< 1	2	< 1
Benzo(a) Anthracene	< 110	< 2	3	< 1
Bis(2-Chloroethyl) Ether	< 97	< 1	< 1	< 1
Benzo(b)Flouranthene	< 51	< 1	3	< 1
Benzo(a)Pyrene	< 74	< 1	2	< 1
1,4-Dichlorobenzene	< 97	< 1	< 1	< 1
1,2-Dichlorobenzene	< 110	< 2	< 2	< 1
Chrysene	58	< 1	2	< 1
Di-n-Butyl Phthalate	< 29	< 1	2	< 1
Diethyl Phthalate	< 46	< 1	< 1	< 1
Di-n-Octyl Phthalate	< 29	< 1	< 1	< 1
Flouranthene	330	< 1	7	< 1
Phenanthrene	290	< 1	13	< 1
Fluorene	< 68	< 1	3	< 1
Pyrene	190	< 1	8	< 1
Naphthalene	< 34	< 1	< 1	< 1
PESTICIDES (ug/l)	< DL	< DL	< DL	< DL

TABLE 1-3 (continued) Page 3
SURFACE WATER CHEMICAL ANALYSIS
SIKES DISPOSAL PITS SITE

PARAMETERS	MAIN WASTE PIT SW-27	TANK LAKE SW-08	SMALL WASTE PIT SW-26	DRAINAGE TO SAN JACINTO RIVER SW-10
METALS (ug/l)		NA		NA
Beryllium	< 2		< 3	
Cadmium	< 5		< 3	
Chromium	< 3		13	
Copper	< 3		< 3	
Mercury	< 0.2		< 0.2	
Nickel	< 9.0		16	
Lead	< 25		< 25	
Thallium	< 45		< 45	
Zinc	27		31	

NA - Not Analyzed
< DL - Less than Detection Limit
ug/l = ppb
mg/l = ppm

Note: Not all contaminants analyzed listed in Table. Key contaminants are shown. Complete analysis for samples given in RI Report, Vol. II, Appendix J.

February 1984 sediment composite were reported as less than the detection limit. In July 1985, four sediment core samples were composited. Two samples of the composite were analyzed. PCB's reported for these samples were 1.0 ppm and 120 ppm - a considerable difference. None of the other components reported in the samples varied by so wide a margin. To the contrary, the good agreement of the other components would rule out the potential that samples were mixed up or that the two samples analyzed were not representative of the composite. Also, a comparison of the chemical analysis shown in Table 1-1 shows that the components in the Tank Lake sediment are essentially the same components contained in the other wastes. They differ mainly in level of the components, with generally lower levels in the Tank Lake sediments - except for PCB.

Thus, to be consistent with this pattern of waste composition, the lower value of PCB at 1 ppm, would seem to be more representative of the sediment than the 120 ppm value. For these reasons, the higher value for PCB's reported in Tank Lake sediments has been classed as an analytical anomaly, and the lower value of 1 ppm accepted as being representative.

The slough, immediately south of Tank Lake, contains about 300 cubic yards of contaminated sediments and 412,000 gallons of contaminated water.

Several small waste pits scattered across the site contain up to 310 cubic yards of sludges and approximately 400,000 gallons of contaminated water. Sludge components are similar to those in the main waste pit, although the concentration of polynuclear aromatics is twice that of the main waste pit.

Numerous drums, mostly rusted out and empty, are spread throughout the site. Approximately 600 drums and waste formerly in drums totaling approximately 2600 cubic yards have been spread over an area of about one acre north of the main waste pit and the overflow areas.

In addition to the above defined waste locations, about six other areas are suspected of being waste depositories, but have not been quantitatively evaluated. A rough estimate of total waste contained in these locations (dry pits or spills) is 17,000 cubic yards. Waste composition is unknown.

1.2.2 Waste Migration Patterns

1.2.2.1 Groundwater

Contaminated wastes within the main waste pit and overflow area are the primary sources of Upper Aquifer contamination via leaching. The extent of groundwater contamination is widespread, but remains within the site boundaries. Thus, there is no immediate threat of off-site contamination of drinking water wells located in populated areas south and southeast of the site across Highway 90. Chemical analysis of ground water (Upper Aquifer) samples representing contaminated waters and groundwaters entering the San Jacinto River are shown in Table 1-4.

Contamination in the Upper Aquifer waters is a current threat to contamination of the Lower Aquifer. Even with an aquitard of 64 to 69 feet thickness apparently isolating the Upper from the Lower Aquifer, there are potential contamination pathways connecting the two aquifers. These potential pathways include unsealed manmade penetrations connecting

TABLE 1-4

GROUNDWATER ANALYSIS-UPPER AQUIFER[1]
SIKES DISPOSAL PITS SITE

(ug/l UNLESS SHOWN OTHERWISE)

PARAMETERS	NEAR WASTE PITS OR WASTE DEPOSITS GW-03	GW-17	NEAR RIVER DOWNGRADIENT GW-14	GW-15
CONVENTIONAL ANALYSIS				
Carbon, TOC, mg/l	84.3	163	2.1	14.1
Total Organic Halogen, TOX	1200	430	< 50	68
Total Phenols	260	1200	NA	9
pH (Std. Units)	5.8	5.9	5.9	5.9
Total Organic Extr., TOE, mg/l	6.9	5	< 6	5
GC/MS VOLATILES				
Benzene	10,000	2100	< 1	< 1
Chlorobenzene	< 100	39	< 1	< 1
Chloroethane	< 200	< 75	< 2	< 3
1,1-Dichloroethane	540	540	< 1	< 1
1,2-Dichloroethane	2200	< 50	< 1	< 2
Trans-1,2-Dichloroethene	< 200	82	< 2	< 2
1,2-Dichloropropane	< 100	< 50	< 1	< 2
Trans-1,3-Dichloroethene	< 100	< 25	< 1	< 1
Ethylbenzene	1700	190	< 1	< 2
1,1,2,2-Tetrachloroethane	< 100	< 25	< 1	< 1
1,1,2-Trichloroethane	390	< 50	< 2	< 2
Trichloroethene	< 200	< 50	< 2	< 2
Toluene	520	230	< 1	< 1
Vinyl Chloride	100	370	< 1	< 2

TABLE 1-4 (continued) Page 2
GROUNDWATER ANALYSIS-UPPER AQUIFER[1]
SIKES DISPOSAL PITS SITE

	GW-03	GW-17	GW-14	GW-15
GC/MS ACID FRACTION	NA	NA	NA	NA
GC/MS BASE NEUTRAL				
Acenaphthene	< 2	< 1		4
Acenaphthylene	3	< 1		< 1
Bis(2-Ethylhexyl)Phthalate	< 1	6		2
Bis(2-Chloroethyl)Ether	< 3	< 1		< 1
1,4-Dichlorobenzene	6	< 1		< 1
1,2-Dichlorobenzene	6	< 2		< 2
Di-n-Butylphthalate	< 1	1		1
Diethyl Phthalate	< 1	2		< 1
Di-n-Octyl Phthalate	1	2		1
Fluoranthene	< 1	< 1		< 1
Fluorene	< 2	< 1		5
Naphthalene	200	52		< 1
PESTICIDES	< DL	< DL		< DL
METALS		NA		NA
Beryllium	15		9	
Cadmium	770		< 3	
Chromium	44		5.4	
Copper	18		< 3	
Mercury	< DL		< 0.2	

002873

TABLE 1-4 (continued) Page 3
GROUNDWATER ANALYSIS-UPPER AQUIFER
SIKES DISPOSAL PITS SITE

	GW-03	GW-17	GW-14	GW-15
Nickel	18		< 6	
Lead	46		< 25	
Thallium	93		57	
Zinc	190		35	

[1] Sample identification and analyses from RI Report, Vol. I.

NA - Not Analyzed
DL - Less than Detection Limit
ug/l = ppb
mg/l = ppm

Note: Not all contaminants analyzed listed in Table. Key contaminants are shown. Complete analysis for samples given in RI Report, Vol. II, Appendix I the two aquifers i.e., abandoned and probably inadequately plugged oil well and potable water wells on site, connecting sand lenses, slickensided clay surface connections and natural leakage through clay layers.

1.2.2.2 Surface Water

The general surface water flow pattern at the site is southwest towards the San Jacinto River. Surface water in the pits has been contaminated either from direct contact with pit wastes or from infiltration of contaminated groundwater. The main waste pit drains to the east into the overflow area. The overflow area acts as a runoff detention area, ultimately releasing the runoff which joins with other surface drainage and discharges into the San Jacinto River or Jackson Bayou. Surface drainage may pick up contaminants as it passes over surface wastes (overflow area, drum waste areas). A portion of surface waters becomes recharge for groundwater, while the rest of the surface runoff flows to the San Jacinto River or Jackson Bayou.

1.2.2.3 Off-Site Impacts

Analytical results show that the discharge of groundwater and surface water from the site into Jackson Bayou and the San Jacinto River have not altered river water quality.

Upper Aquifer well water sampling and soil sampling show that the Riverdale Subdivision, located southeast of the site, has not experienced Upper Aquifer contamination or soil contamination as a result of flood waters flowing across the site and through part of the subdivision.

1.2.2.4 Underlying Soils

Contaminated soils containing greater than 10 ppm organics underlie sludges in most waste areas. The total quantity of contaminated soils on-site is approximately 80,000 cubic yards, exceeding the total estimated quantity of sludges on-site.

1.2.2.5 Summary of Wastes On-Site

Sikes site wastes have been classified into four media categories: sludges, contaminated soils, surface waters and groundwaters.

These are listed and totaled according to category in Table 1-5. Also given in Table 1-5 are listings showing the effects of excavation and two physical treatments on final waste volumes.

In situ sludges and contaminated soils are expected to increase in volume by 10 percent as a result of excavation swell. Stabilization is the process of adding cement or flyash to wet sludges to improve their weight bearing characteristic. A ratio of 1 part stabilizer to 1 part sludge, resulting in a volume increase of 1.85 times, is the basis for the volume change due to stabilization. Chemical fixation is the process of adding cement, silicates and/or lime to a predominantly inorganic waste to effect a chemical binding of contaminants (organics and metals) to produce a leach resistant solid. Chemical fixation is expected to increase the original volume by approximately 10%. Selected physical characteristics for main waste pit and overflow area sludges are given in Table 1-6.

002876

TABLE 1-5

APPROXIMATE WASTE VOLUMES AT

SIKES DISPOSAL PITS SITE

(July 1985)

	Waste Volumes			
Medium/Area	In-Situ	After Excavation	Stabilized	Chemically Fixed
Sludges	(Cu. Yds.)	(Cu. Yds.)	(Cu. Yds.)	
Main Waste Pit	5,600	6,200	10,400	
Tank Lake	2,000	2,200	3,700	
Small Waste Pits/Slough	600	700	1,100	
Drummed Waste*	2,600	2,900	2,600	
Overflow Area	43,300	47,000	43,300	
Suspected	16,700	19,000	23,800	
TOTAL	70,800	78,000	84,900	
Contaminated Soils	(Cu. Yds.)	(Cu. Yds.)		(Cu. Yds.)
Main Waste Pit	21,000	23,100		23,100
Overflow Area	58,300	64,100		64,100
TOTAL	79,300	87,200		87,200
Contaminated Surface Water	(Gallons)			
Main Waste Pit	4,700,000			
Small Waste Pits	417,000			
Tank Lake	7,071,000			
Slough	412,000			
TOTAL	12,600,000			

Contaminated Groundwater

271,000,000 gallons

* Formerly in drums, now in many piles spread across the site.

Note: Volume totals have been rounded to the nearest 100 cubic yards and the nearest 1000 gallons. For complete in-situ volume calculations see Appendices M, N, O, and P, Sikes Disposal Pits - Remedial Investigation Report, Volume III - Supplementary Report.

TABLE 1-6

SLUDGE CHARACTERIZATION
SIKES DISPOSAL PITS SITE

Parameter	Units	Composites From: Main Waste Pit	Composites From: Overflow Area
pH	S.U.	5.48	4.78
Alkalinity	percent	2.04	1.78
Moisture	percent	43.06	27.63
Solids	percent	56.94	72.37
Volatile Solids @ 550°C	percent	17.98	38.13
Oil and Grease	mg/l	5833	8324
BOD (dry basis)	percent	3.03	2.45
Carbon	percent	17.65	17.41
Hydrogen	percent	1.69	3.73
Nitrogen	percent	0.21	0.12
Sulfur	percent	0.57	0.52
Chlorine	percent	0.041	0.30
Sodium	percent	0.023	0.12
Potassium	percent	0.058	0.074
Phosphorus	percent	0.015	0.065
BTU per pound	--	3338	7744

mg/l = ppm

1.2.3 Target Receptors

The population most likely to be affected by the contamination described in the preceeding section include:

- o Members of the Sikes family, who have lived on-site. Some still do.
- o Riverdale Subdivision residents (approximately 100 residents)
- o Sport fisherman that frequent Jackson Bayou and the San Jacinto River.
- o Persons launching boats and/or swimming at boat ramp on San Jacinto River.
- o Employees of the nearby sand mining operations.
- o Southern Pacific Railroad maintenance personnel.

Pathways by which these people may become exposed to the contamination are:

- o Direct contact with contaminated soils and surface water.
- o Inhalation of airborne contaminated dust and vapors.
- o Ingestion of contaminated aquatic species and plants.
- o Consumption of contaminated groundwater.

The first and last pathways are the most significant.

1.3 OBJECTIVES OF REMEDIAL ACTION

1.3.1 Introduction

The identification of the objectives and criteria for the feasibility study were established in terms of general goals as well as specific goals relevant to the characterization of the Sikes Disposal Pits Site; i.e. the site problems and the pathways of contamination. The criteria for each objective were identified by considering both state and federal standards established to prevent endangerment of public health and the environment, e.g. surface water quality criteria, human health standards, drinking water quality criteria, and natural background conditions.

1.3.2 Objectives and Criteria

The following nine objectives/criteria were developed and agreed on by representatives of the U.S. Environmental Protection Agency (Region VI), the Texas Water Commission, and the project team.

Objective 1. Prevent direct human contact with contaminated soils/sediments/wastes.

Criterion: 100 ppm of total polynuclear aromatic hydrocarbons. (See ATSDR Reference)

Objective 2. Minimize impact of contaminated runoff.

Criterion: Surface Water Quality Criteria. (Table 1-7)

Objective 3. Prevent human contact with contaminated surface water.

Criterion: Surface Water Quality Criteria. (Table 1-7)

Objective 4. Minimize site related degradation of the San Jacinto River and Jackson Bayou.

Criterion: Surface Water Quality Criteria. (Table 1-7)

Objective 5. Prevent use of contaminated groundwater from the Upper Aquifer.

002880

Criterion: Drinking Water Standards and/or Human Health Criteria (10^{-4} to 10^{-7} risk range). (Table 1-8 Columns (1) & (2))

Objective 6. Protect against contamination of the Lower Aquifer.

Criterion: Existing background water quality in Lower Aquifer. (Table 1-9)

Objective 7. Prevent migration of waste off-site during flood events.

Criterion: Surface Water Quality Criteria. (Table 1-7)

Objective 8. Prevent use of groundwater (lower aquifer) contaminated above background.

Criterion: Existing background water quality in lower aquifer. (Table 1-9)

Objective 9. Minimize the potential of any adverse air emissions.

Criterion: OSHA standards at site boundary and Federal Ambient Air Standards as given in 40 CFR 50.1 - 50.12

002881

TABLE 1-7

SURFACE WATER QUALITY CRITERIA
SIKES DISPOSAL PITS SITE

Parameters	Maximum Allowable Concentrations, mg/l
Total Phenols	0.3
Vinyl Chloride	0.3
Benzene	0.1
Arsenic	0.1
Barium	1.0
Cadmium	0.05
Chromium	0.5
Copper	0.5
Lead	0.5
Mercury	0.005
Nickel	1.0
Silver	0.05
Zinc	1.0

mg/l = ppm

Reference: Texas Water Commission

TABLE 1-8

EPA AMBIENT STANDARDS AND CRITERIA FOR SUPERFUND REMEDIAL SITES

SIKES DISPOSAL PITS SITE

Chemical	Applicable or Relevant Requirements	Other Criteria, Advisories, and Guidance				
	Safe Drinking Water Act, MCLs (mg/L unless otherwise noted) (1)	Clean Water Act, Water Quality Criteria for Human Health--Fish and Drinking Water	Clean Water Act, Water Quality Criteria for Human Health--Adjusted for Drinking Water Only[a] (2)	Safe Drinking Water Act, Health Advisories (mg/L) 1-day	10-day	Chronic (longer term)
Acenaphthene		20 ug/L (organoleptic)[b]	20 ug/L (organoleptic)			
Acrolein		320 ug/L	540 ug/L			
Acrylonitrile		0 (58 ng/L)[c]	0 (63 ng/L)			
Aldrin		0 (0.074 ng/L)	0 (1.2 ng/L)			
Antimony		146 ug/L	146 ug/L			
Arsenic	0.05	0 (2.2 ng/L)	0 (2.5 ng/L)			
Asbestos		0 (30,000 fibers/L)	0 (30,000 fibers/L)			
Barium	1.0					
Benzene		0 (0.66 ug/L)	0 (0.67 ug/L)		0.23	0.07
Benzidine		0 (0.12 ng/L)	0 (0.15 ng/L)			
Beryllium		0 (3.7 ng/L)	0 (3.9 ng/L)			
Cadmium	0.01	10 ug/L	10 ug/L			
Carbon monoxide						
Carbon tetrachloride		0 (0.4 ug/L)	0 (0.42 ug/L)	0.2	0.02	
Chlordane		0 (0.46 ng/L)	0 (22 ng/L)	0.0625	0.0625	0.0075
Chlorinated benzenes						
Hexachlorobenzene		0 (0.72 ng/L)	0 (21 ng/L)			
1,2,4,5-Tetrachlorobenzene		38 ug/L	180 ug/L			
Pentachlorobenzene		74 ug/L	570 ug/L			
Trichlorobenzene		Insufficient data	Insufficient data			
Monochlorobenzene		488 ug/L	488 ug/L			
Chlorinated ethanes						
1,2-Dichloroethane		0 (0.94 ug/L)	0 (0.94 ug/L)		Insufficient data	
1,1,1-Trichloroethane		18.4 mg/L	19 mg/L			1.0
1,1,2-Trichloroethane		0 (0.6 ug/L)	0 (0.6 ug/L)			
1,1,2,2-Tetrachloroethane		0 (0.17 ug/L)	0 (0.17 ug/L)			
Hexachloroethane		0 (1.9 ug/L)	0 (2.4 ug/L)			
Monochloroethane		Insufficient data	Insufficient data			
1,1-Dichloroethane		Insufficient data	Insufficient data			
1,1,1,2-Tetrachloroethane		Insufficient data	Insufficient data			
Pentachloroethane		Insufficient data	Insufficient data			

(continued)

002882

TABLE 1-8 (continued)

Chemical	Applicable or Relevant Requirements: Safe Drinking Water Act, MCLs (mg/L unless otherwise noted) (1)	Other Criteria, Advisories, and Guidance: Clean Water Act, Water Quality Criteria for Human Health-- Fish and Drinking Water	Clean Water Act, Water Quality Criteria for Human Health-- Adjusted for Drinking Water Only[a] (2)	Safe Drinking Water Act, Health Advisories (mg/L): 1-day	10-day	Chronic (longer term)
Chlorinated naphthalenes		Insufficient data	Insufficient data			
Chlorinated phenols						
3-Monochlorophenol		0.1 ug/L (organoleptic)	0.1 ug/L (organoleptic)			
4-Monochlorophenol		0.1 ug/L (organoleptic)	0.1 ug/L (organoleptic)			
2,3-Dichlorophenol		0.04 ug/L (organoleptic)	0.04 ug/L (organoleptic)			
2,5-Dichlorophenol		0.5 ug/L (organoleptic)	0.5 ug/L (organoleptic)			
2,6-Dichlorophenol		0.2 ug/L (organoleptic)	0.2 ug/L (organoleptic)			
3,4-Dichlorophenol		0.3 ug/L (organoleptic)	0.3 ug/L (organoleptic)			
2,3,4,6-Tetrachlorophenol		1.0 ug/L (organoleptic)	1.0 ug/L (organoleptic)			
2,4,5-Trichlorophenol		2600 ug/L	2600 ug/L			
2,4,6-Trichlorophenol		0 (1.2 ug/L)	0 (1.8 ug/L)			
2-Methyl-4-chlorophenol		1800 ug/L (organoleptic)	1800 ug/L (organoleptic)			
3-Methyl-4-chlorophenol		3000 ug/L (organoleptic)	3000 ug/L (organoleptic)			
3-Methyl-6-chlorophenol		20 ug/L (organoleptic)	20 ug/L (organoleptic)			
Chlorophenoxys						
2,4-Dichlorophenoxyacetic acid (2,4-D)	0.1					
2,4,5-Trichlorophenoxy-propionic acid (2,4,5-TP)	0.01					
Chloroalkyl ethers						
bis-(Chloromethyl) ether		0 (0.0038 ng/L)	0 (0.0039 ng/L)			
bis-(2-Chloroethyl) ether		0 (30 ng/L)	0 (30 ng/L)			
bis-(2-Chloroisopropyl) ether		34.7 ug/L	34.7 ug/L			
Chloroform	0.1[e]	0 (0.19 ug/L)	0 (0.19 ug/L)			
2-Chlorophenol		0.1 ug/L (organoleptic)	0.1 ug/L (organoleptic)			
Chromium Cr+6	0.05	50 ug/L	50 ug/L			
Cr+3		170 mg/L	179 mg/L			
Copper		1 mg/L (organoleptic)	1 mg/L (organoleptic)			
Cyanide		200 ug/L	200 ug/L			
DDT		0 (0.024 ng/L)	0 (>1.2 ng/L)			
Dichlorobenzenes (all isomers)		400 ug/L	470 ug/L			
Dichlorobenzidines		0 (10.3 ng/L)	0 (20.7 ng/L)			
Dichloroethylenes						
1,1-Dichloroethylene		0 (33 ng/L)	0 (33 ng/L)	1.0		0.07
1,2-Dichloroethylene		Insufficient data	Insufficient data	4.0	0.4	(cis isomer)
				2.7	0.27	(trans isomer)

(continued)

002883

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TABLE 1-8 (continued)

Chemical	Applicable or Relevant Requirements: Safe Drinking Water Act, MCLs (mg/L unless otherwise noted) (1)	Other Criteria, Advisories, and Guidance: Clean Water Act, Water Quality Criteria for Human Health--Fish and Drinking Water	Clean Water Act, Water Quality Criteria for Human Health--Adjusted for Drinking Water Only[a] (2)	Safe Drinking Water Act, Health Advisories (mg/L): 1-day	10-day	Chronic (longer term)
Dichloromethane		See Halomethanes	See Halomethanes	13	1.3	0.15
2,4-Dichlorophenol		3.09 mg/L	3.09 mg/L			
Dichloropropanes/ Dichloropropenes						
Dichloropropanes		Insufficient data	Insufficient data			
Dichloropropenes		87 ug/L	87 ug/L			
Dieldrin		0 (0.071 ng/L)	0 (1.1 ng/L)			
2,4-Dimethylphenol		400 ug/L (organoleptic)	400 ug/L (organoleptic)			
2-4-Dinitrotoluene		0 (0.11 ug/L)	0 (0.11 ug/L)			
p-Dioxane				5.68	0.568	
1,2-Diphenylhydrazine		0 (42 ng/L)	0 (46 ng/L)			
Endosulfan		74 ug/L	138 ug/L			
Endrin	0.0002	1 ug/L	1 ug/L			
Ethylbenzene		1.4 mg/L	2.4 mg/L			
Ethylene glycol				19.0		5.5
Formaldehyde					0.03	
Fluoranthene		42 ug/L	188 ug/L			
Fluoride	1.4-2.4					
Haloethers		Insufficient data	Insufficient data			
Halomethanes		0 (0.19 ug/L)	0 (0.19 ug/L)			
Heptachlor		0 (0.28 ng/L)	0 (11 ng/L)			
Hexachlorobutadiene		0 (0.45 ug/L)	0 (0.45 ug/L)			
Hexachlorocyclohexanes						
Lindane (99% gamma-HCH)	0.004					
alpha-HCH		0 (9.2 ng/L)	0 (13 ng/L)			
beta-HCH		0 (16.3 ng/L)	0 (23.2 ng/L)			
gamma-HCH		0 (18.6 ng/L)	0 (26.4 ng/L)			
delta-HCH		Insufficient data	Insufficient data			
epsilon-HCH		Insufficient data	Insufficient data			
Technical-HCH		0 (12.3 ng/L)	0 (17.4 ng/L)			
Hexachlorocyclopentadiene		206 ug/L	206 ug/L			
n-Hexane				13	4.0	
Hydrocarbons (non-methane)						
Isophorone		5.2 mg/L	5.2 mg/L			
Kerosene/fuel oil no. 2					0.35[c] 0.23	

(continued)

002884

002884

TABLE 1-8 (continued)

Chemical	Applicable or Relevant Requirements: Safe Drinking Water Act, MCLs (mg/L unless otherwise noted) (1)	Other Criteria, Advisories, and Guidance: Clean Water Act, Water Quality Criteria for Human Health--Fish and Drinking Water	Clean Water Act, Water Quality Criteria for Human Health--Adjusted for Drinking Water Only[a] (2)	Safe Drinking Water Act, Health Advisories (mg/L): 1-day	10-day	Chronic (longer term)
Lead	0.05	50 ug/L	50 ug/L			
Mercury	0.002	144 ng/L	10 ug/L			
Methoxychlor	0.1					
Methyl Ethyl Ketone					7.5	0.750
Naphthalene		Insufficient data	Insufficient data			
Nickel		13.4 ug/L	15.4 ug/L			
Nitrate (as N)	10.0					
Nitrobenzene		19.8 mg/L	19.8 mg/L			
Nitrogen dioxide						
Nitrophenols						
2,4-Dinitro-o-cresol		13.4 ug/L	13.6 ug/L			
Dinitrophenol		70 ug/L	70 ug/L			
Mononitrophenol		Insufficient data	Insufficient data			
Trinitrophenol		Insufficient data	Insufficient data			
Nitrosamines						
n-Nitrosodimethylamine		0 (1.4 ng/L)	0 (1.4 ng/L)			
n-Nitrosodiethylamine		0 (0.8 ng/L)	0 (0.8 ng/L)			
n-Nitrosodi-n-butylamine		0 (6.4 ng/L)	0 (6.4 ng/L)			
n-Nitrosodiphenylamine		0 (4.9 ug/L)	0 (7.0 ug/L)			
n-Nitrosopyrrolidine		0 (16 ng/L)	0 (16 ng/L)			
Ozone						
Particulate Matter						
Pentachlorophenol		1.01 mg/L	1.01 mg/L			
Phenol		3.5 mg/L	3.5 mg/L			
Phthalate esters						
Dimethylphthalate		313 mg/L	350 mg/L			
Diethylphthalate		350 mg/L	434 mg/L			
Dibutylphthalate		34 mg/L	44 mg/L			
Di-2-ethylhexyl-phthalate		15 mg/L	21 mg/L			
Polychlorinated biphenyls (PCBs)		0 (0.079 ng/L)	0 (>12.6 ng/L)	0.125	0.0125	
Polynuclear aromatic hydrocarbons (PAHs)		0 (2.8 ng/L)	0 (3.1 ng/L)			

(continued)

002885

002885

TABLE 1-8 (continued)

Chemical	Applicable or Relevant Requirements: Safe Drinking Water Act, MCLs (mg/L unless otherwise noted) (1)	Other Criteria, Advisories, and Guidance: Clean Water Act, Water Quality Criteria for Human Health--Fish and Drinking Water	Clean Water Act, Water Quality Criteria for Human Health--Adjusted for Drinking Water Only[a] (2)	Safe Drinking Water Act, Health Advisories (mg/L): 1-day	10-day	Chronic (longer term)
Radionuclides						
Radium-226 and 228	5 pCi/L					
Gross alpha activity	15 pCi/L					
Tritium	20,000 pCi/L					
Strontium-90	8 pCi/L					
Other man-made	j					
Selenium	0.01	10 ug/L	10 ug/L			
Silver	0.05	50 ug/L	50 ug/L			
Sulfur dioxide						
2,3,7,8-TCDD		0 (0.000013 ng/L)	0 (0.00018 ng/L)			
Tetrachloroethylene		0 (0.8 ug/L)	0 (0.88 ug/L)	2.3	0.175	0.02
Thallium		13 ug/L	17.8 ug/L			
Toluene		14.3 mg/L	15 mg/L	21.5	2.2	0.34
Toxaphene	0.005	0 (0.71 ng/L)	0 (25.8 ng/L)			
Trichloroethylene		0 (2.7 ug/L)	(2.8 ug/L)	2.0	0.2	0.075
Trihalomethanes (total)[b]	0.1					
Vinyl chloride		0 (2.0 ug/L)	(2.0 ug/L)			
Xylenes				12	1.2	0.62
Zinc		5 mg/L (organoleptic)	5 mg/L (organoleptic)			

[a] These adjusted criteria, for drinking water ingestion only, were derived from published EPA Water Quality Criteria (45 FR 79318-79379, November 28, 1980) for combined fish and drinking water ingestion and for fish ingestion alone. These adjusted values are not official EPA Water Quality Criteria, but may be appropriate for Superfund sites with contaminated ground water. In the derivation of these values, intake was assumed to be 2 liters/day for drinking water and 6.5 grams/day for fish; human body weight was assumed to be 70 kilograms.

[b] Criteria designated as organoleptic are based on taste and odor effects, not human health effects. Health-based Water Quality Criteria are not available for these chemicals.

[c] The criterion for all carcinogens is zero; the concentration given in parentheses corresponds to a carcinogenic risk of 10^{-6}. Water Quality Criteria documents present concentrations resulting in risks from 10^{-5} to 10^{-7}. To obtain concentrations corresponding to risks of 10^{-4} and 10^{-5}, the 10^{-6} concentrations should be multiplied by 100 and 10, respectively. To obtain concentrations corresponding to risk of 10^{-7}, 10^{-6} concentrations should be divided by 10.

(continued)

002886

002886

TABLE 1-8 (continued)

[d] Annual maximum concentration not to be exceeded more than once per year.

[e] Chloroform is one of four trihalomethanes whose sum concentration must be less than 0.1 mg/L.

[f] As a guide in devising implementation plans for achieving oxidant standards.

[g] Seven-day health advisory for benzene and benzo(a)pyrene in kerosene, respectively.

[h] Annual arithmetic mean concentration.

[i] Annual geometric mean concentration.

[j] Activity corresponding to total body or any internal organ dose of 4 mrem/year.

[k] Total trihalomethanes refers to the sum concentration of chloroform, bromodichloromethane, dibromochloromethane, and bromoform.

(1) Drinking Water Standards

(2) 10^{-6} cancer risk level Human Health Criteria

002887

002888

TABLE 1-9

BACKGROUND WATER QUALITY FOR LOWER AQUIFER
(Chemical Analysis Results from Groundwater Samples Collected in Deep Monitoring Well GW23 at the Sikes Site, July, 1985)
SIKES DISPOSAL PITS SITE

Parameter	Units	GW23
Conventional Analysis		
Total Organic Halogens, TOX	ug/l	33.0
pH	s.u.	8.2
Specific Conductivity	umh/cm	540.0
GC/MS Volatiles		
Benzene	ug/l	<10.0
Chlorobenzene	ug/l	<10.0
Chloroethane	ug/l	<10.0
Chloroform	ug/l	<10.0
Trans-1,3-Dichloropropene	ug/l	<10.0
1,1-Dichloroethane	ug/l	<10.0
1,2-Dichloroethane	ug/l	<10.0
1,2-Dichloropropane	ug/l	<10.0
Cis-1,3-Dichloropropene	ug/l	<10.0
Ethylbenzene	ug/l	<10.0
Methylene Chloride	ug/l	<10.0
1,1,2,2-Tetrachloroethane	ug/l	<10.0
Tetrachloroethene	ug/l	<10.0
Toluene	ug/l	<10.0
Trans-1,2-Dichloroethene	ug/l	<10.0
1,1,2-Trichloroethane	ug/l	<10.0
Trichloroethene	ug/l	<10.0
Vinyl Chloride	ug/l	<10.0
GC/MS Acids		
2,4-Dimethylphenol	ug/l	<12.0
Phenol	ug/l	<12.0
GC/MS Base Neutrals		
Acenaphthylene	ug/l	<12.0
Acenaphthylene	ug/l	<12.0
Bis(2-ethylhexyl)phthalate	ug/l	<12.0
1,2-Dichlorobenzene	ug/l	<12.0
1,4-Dichlorobenzene	ug/l	<12.0
Diethylphthalate	ug/l	<12.0
Di-n-butyl phthalate	ug/l	<12.0
Di-n-octyl phthalate	ug/l	<12.0
Flouranthene	ug/l	<12.0
Flourene	ug/l	<12.0
Naphthalene	ug/l	<12.0
Phenanthrene	ug/l	<12.0

002888

SECTION 2 - PROCEDURE FOR DEVELOPING GENERAL RESPONSE ACTIONS

2.1 INTRODUCTION

Sections 2, 3 and 4 discuss the process involved in the development of remedial alternatives. The remedial alternatives are those actions which, if implemented, will mitigate site problems and accomplish cleanup objectives as delineated and discussed in Section 1.

Section 2 discusses the development of General Response Actions, Section 3 discusses the identification and screening of technologies and Section 4 discusses the development of Remedial Alternatives. The steps involved in this process are shown in Figure 2-1 and discussed in detail in the following subsections. This process differs somewhat from the approach suggested in the guidance document but was found to be more appropriate for this project.

2.2 IDENTIFYING MEDIA RESPONSE ACTIONS FOR EACH OBJECTIVE

A Media Response Action is an action that might be taken in response to a media specific problem to satisfy an objective. As used here, a technology is a specific method or approach used to accomplish a response action. (Technologies will be considered in Section 3.) A media response action involves a specific media and a specific objective. It is not necessarily composed of a single action. It might be a combination of three or more actions as illustrated later. Based upon the site problems and pathways of contamination developed and identified in the Remedial Investigation Study, media response actions were identified that

002890

FIGURE 2-1

REMEDIAL ALTERNATIVE DEVELOPMENT PROCESS
SIKES DISPOSAL PITS SITE

CLEANUP OBJECTIVES AND CRITERIA ARE DEFINED

↓

MEDIA RESPONSE ACTIONS DEVELOPED FOR EACH MEDIA TO SATISFY INDIVIDUAL OBJECTIVES

↓

MEDIA RESPONSE ACTIONS CONSOLIDATED TO FORM OBJECTIVE RESPONSE ACTIONS

↓

OBJECTIVE RESPONSE ACTIONS SCREENED FOR EACH OBJECTIVE

↓

INDIVIDUAL OBJECTIVE RESPONSE ACTIONS ARE COMBINED INTO GENERAL RESPONSE ACTIONS, EACH GENERAL RESPONSE ACTION MUST SATISFY ALL OBJECTIVES

↓

GENERAL RESPONSE ACTIONS ARE SCREENED

↓

TECHNOLOGIES FOR GENERAL RESPONSE ACTIONS ARE IDENTIFIED

↓

TECHNOLOGIES ARE SCREENED

↓

TECHNOLOGIES ARE COMBINED WITH GENERAL RESPONSE ACTIONS TO DEVELOP REMEDIAL ALTERNATIVES

↓

REMEDIAL ALTERNATIVES ARE SCREENED FOR PUBLIC HEALTH, ENVIRONMENTAL IMPACTS AND COST

↓

DETAILED EVALUATIONS PERFORMED FOR EACH ALTERNATIVE

002891

address the site problems and meet cleanup objectives for each media at the Sikes Site. This step is shown in Table 2-1, Media Response Actions. Note that no action is needed for some media to satisfy the objectives. This should not be confused with the "no-action" alternative, which is not included at this stage. For example, to satisfy Objective 1, no action is needed or even indicated for groundwater -- thus the reason for placing NA (not applicable) in the Objective 1-Media I matrix. In most cases a single response action is shown; however, in Objective 3 - Media II - Response Action b, two individual response actions are involved. Under some objectives and for some media, instead of a response action, a "no-action" is shown. This means that no-action is needed for that media to meet that objective.

A few media response actions were screened at this point. These were either considered too difficult to implement, take too long to implement or take too long to achieve the objective. An example of a screened out media response action is to remove or relocate people permanently to avoid direct contact with waste. This was eliminated because it was considered infeasible.

2.3 DEVELOPMENT OF OBJECTIVE RESPONSE ACTIONS

In this step, site media is no longer considered a separate entity. The media response actions listed for each media under an objective are consolidated into separate objective response actions designed to satisfy the specific objective for all media. Consolidation is the process of eliminating media response actions or similar media response actions common to a specific objective. The result of this consolidation step is shown in Table 2-2.

TABLE 2-1
MEDIA RESPONSE ACTIONS
SIKES DISPOSAL PITS SITE

	1	2	3	4	5	6	7	8	9
Remedial Objectives	Prevent Human Contact with Contaminated Soils/Sediments/Wastes	Minimize Impact of Contaminated Runoff	Prevent Human Contact with Contaminated Surface Water	Minimize Site Related Degradation of the San Jac River and Jackson Bayou	Prevent use of Contaminated Ground Water	Protect Against Contamination of the Lower Aquifer	Prevent Migration of Waste Off Site During Flood Events	Prevent Use of Lower Aquifer Water Contaminated Above Background	Minimize the Potential of Any Adverse Air Discharge
Media									
I Ground Water	NA	NA	NA	a) No action b) Isolate grd. water. c) Isolate grd. water. Contain MWP water. d) Pump & treat/dispose of U. A. water.	a) Ban use of upper aquifer water. b) Treat U.A. water at source to D.W. stds. c) a + restore aquifer to D.W. standards. d) b + restore U.A. to D. W. standards.	a) Restore U.A. to drinking water standards. b) Remove and dispose of all waste sources. Trt/dispose of impoundment water. c) a + b d) No action.	NA	a) Ban use of LA water. b) Trt L.A. water at source to existing background quality. c) a + restore L.A. to existing B.G. quality. d) b + restore L.A. to existing B.G. quality. e) No action.	NA
II Surface Water	NA	a) No action b) Collect and treat. c) Collect and dispose.	a) No action b) Remove impoundment water, treat/dispose. Backfill, cap pits. Collect R.O. and treat/discharge. c) Remove impoundment water, treat/dispose. Backfill/cap pits.	a) Contain MWP water.	NA	NA	a) Dike site above flood plain b) Remove impoundment water and treat/dispose.	NA	NA
III Sludges/Soils/Sands	a) Secure Area b) Remove surface waste & dispose. c) Cap surface waste.	a) No action b) Remove surface waste & dispose. c) Cap surface waste.	a) Cap area b) Remove all waste and dispose.	a) Remove surface waste and dispose. b) Cap surface waste.	NA	NA	a) Place surface waste in pits. b) Backfill and cap pits c) Remove all waste and dispose.	NA	NA

ABBREVIATIONS

NA - Not Applicable
RO - Run Off
UA - Upper Aquifer
DW - Drinking Water
LA - Lower Aquifer
BG - Background

002892

TABLE 2-2
OBJECTIVE RESPONSE ACTIONS
SIKES DISPOSAL PITS SITE

1	2	3	4	5	6	7	8	9
Prevent Human Contact With Contaminated Soils/Sedm./Waste	Minimize Impact of Contaminated Runoff.	Prevent Human Contact with Contaminated Surface Water	Minimize site related Degradation of the San Jac. River & Jackson Bayou	Prevent Use of Contaminated Groundwater	Protect Against Contamination of the Lower Aquifer	Prevent Migration of Waste Offsite during Flood Events	Prevent Use of Lower Aquifer Water contaminated Above Background	Minimize the Potential of Any Adverse Air Discharge
a) Remove surface waste and dispose. b) Cap surface waste sources. c) Secure site.	a) Collect and treat/dispose of runoff. b) Remove surface waste sources and dispose. c) Cap surface waste sources. d) No action.	a) Remove impoundment water. Treat or dispose. Place surface wastes in pits. Backfill & cap pits. Cap area. (All waste remains on site) b) Remove all waste sources and dispose. Treat/dispose of impoundment water. c) Remove impoundment water, treat/dispose. Backfill and cap pits. (All wastes remain on-site.)	a) Isolate ground water. b) Isolate ground water. Contain MWP water. Remove surface waste & dispose. c) Isolate ground water. Cap surface wastes. Contain MWP water. d) Pump and treat/dispose of upper aquifer water. e) Pump and treat/dispose of U.A. water. Contain MWP water. Remove surface waste. f) Pump and treat/dispose of U.A. water. Contain MWP water. CAP surface waste. g) No action.	a) Ban use of aquifer water. b) Treat U.A. water at source to drinking water standards. c) a + restore aquifer to D.W. standards. d) b + restore aquifer to D.W. standards.	a) Restore U.A. to drinking water standards. b) Remove and dispose of all waste sources. Treat/dispose of impoundment water. c) 6a + 6b	a) Dike site above flood plain. b) Remove impoundment waters and treat/dispose. Place surface wastes in pits. Backfill and cap pits. (All waste remains on site.) c) Remove all waste and dispose. Remove impoundment water, treat/dispose.	a) Ban use of lower aquifer water. b) Treat L.A. water at source to existing background quality. c) a + restore aquifer to existing background quality. d) b + restore aquifer to existing background quality. e) No action.	a) No action

ABBREVIATIONS

UA - Upper Aquifer
MWP - Main Waste Pit
MW - Drinking water
LA - Lower Aquifer

002893

In Objective 9, NA appears for all media, because there is no significant air emission problem on-site. This does not mean that there will or will not be air emission problems during cleanup. However, since there are no significant problems affecting receptors now, Objective 9 is satisfied.

At this point, the objective response actions were screened for applicability and feasibility, based on site conditions. Objective response action 6 d was eliminated. This no-action response was screened out because there was no reason to believe that the Lower Aquifer could be protected against contamination without some action being taken, given the curent level of contamination of the Upper Aquifer and the potential for passing through or bypassing the intermediate aquitard.

2.4 DEVELOPING GENERAL RESPONSE ACTIONS

General response actions are formed by combining one objective response action from each objective. Thus, a general response action might be a combination of eight objective response actions. For example, combining all the a) response actions for each objective in Table 2-2 would form a General Response Action composed of 1a+2a+3a+4a+5a+6a+7a+8a. Continuing this process for all combinations would produce all the general response actions possible from the listing of objective response actions. An important point to note here is that each general response action formed as described will satisfy all remedial objectives. The number of general response actions that would be formed from all combinations of the objective response actions is in excess of 1,000. Obviously this would be an overwhelming number to manage. However, the actual

002895

TABLE 2-3

COMBINING OBJECTIVE RESPONSE ACTIONS INTO
GENERAL RESPONSE ACTIONS

SIKES DISPOSAL PITS SITE

1. 3a + 5a + 6a + 8a

3a - Remove impoundment water, treat. Place surface waste in pits. Backfill and cap pits. Cap surface area.
5a - Ban use of Upper Aquifer water.
6a - Restore Upper Aquifer to drinking water standards.
8a - Ban use of Lower Aquifer water.

2. 3a + 5b + 6a + 8a

3a - Remove impoundment water, treat. Place surface waste in pits. Backfill and cap pits. Cap surface area.
5b - Treat Upper Aquifer at source to drinking water standards.
6a - Restore Upper Aquifer to drinking water standards.
8a - Ban use of Lower Aquifer water.

3. 3b + 5a + 6a + 8a

3b - Remove all waste sources and dispose. Treat/dispose of impoundment water.
5a - Ban use of Upper Aquifer water.
6a - Restore Upper Aquifer to drinking water standards.
8a - Ban use of Lower Aquifer.

4. 3b + 5b + 6a + 8a

3b - Remove all waste sources and dispose. Treat/dispose of impoundment water.
5b - Treat Upper Aquifer at source to drinking water standards.
6a - Restore Upper Aquifer to drinking water standards.
8a - Ban use of Lower Aquifer.

5. 1a + 3c + 5b + 6a + 8a

1a - Remove surface waste and dispose.
3c - Remove impoundment water, treat/dispose. Backfill and cap pits.
5b - Treat Upper Aquifer at source to drinking water standards.
6a - Restore Upper Aquifer to drinking water standards.
8a - Ban use of Lower Aquifer.

002896

TABLE 2-3 (continued)

6. 1b + 3c + 5a + 6a + 8a

- 1b - Cap surface waste sources.
- 3c - Remove impoundment water, treat/dispose. Backfill and cap pits.
- 5a - Ban use of Upper Aquifer water.
- 6a - Restore Upper Aquifer to drinking water standards.
- 8a - Ban use of Lower Aquifer.

7. 1b + 3c + 5b + 6a + 8a

- 1b - Cap surface waste sources.
- 3c - Remove impoundment water, treat/dispose. Backfill and cap pits..
- 5b - Treat Upper Aquifer at source to drinking water standards.
- 6a - Restore Upper Aquifer to drinking water standards.
- 8a - Ban use of Lower Aquifer.

8. 1c + 5a + 6a + 7a + 8a

- 1c - Secure site.
- 5a - Ban use of Upper Aquifer water.
- 6a - Restore Upper Aquifer to drinking water standards.
- 7a - Dike site above flood plain.
- 8a - Ban use of Lower Aquifer.

9. 1c + 5b + 6a + 7a + 8a

- 1c - Secure site.
- 5b - Treat Upper Aquifer at source to drinking water standards.
- 6a - Restore Upper Aquifer to drinking water standards.
- 7a - Dike site above flood plain.
- 8a - Ban use of Lower Aquifer.

Upper Aquifer. Also, the caps would not prevent floodwaters from infiltrating the waste deposits, and promote leaching of contaminants into the groundwater. Thus, this combination of response actions was not considered compatible for attaining site objectives.

The screening discussed above reduced the General Response Actions from nine to two. These are numbers 3 and 4 of Table 2-3. Each contains four objective response actions; however, three of the four actions in each General Response Action are identical. The General Response Actions differ only by the action used to satisfy Objective 5 - Prevent Use of Contaminated Groundwater.

SECTION 3 - IDENTIFICATION AND SCREENING OF TECHNOLOGIES FOR GENERAL RESPONSE ACTIONS

3.1 INTRODUCTION

Remedial Technologies are methods or techniques which individually, or in combination as a remedial alternative, mitigate contaminant pathways to achieve site objectives. Although each technology generally addresses one particular objective response action, it may indirectly affect several other objective response actions. For example, removing and disposing of all waste, is a single objective response action that will affect groundwater and surface water quality. The effect on groundwater and surface water quality will impact and potentially satisfy several site objectives. The right combination of technologies and objective response actions should result in a remedial alternative that effectively satisfies all site objectives and their criteria. By screening the General Response Actions to just a few (see Section 2), the potential number of technologies to consider was grossly reduced. In this case, the General Response actions have been narrowed to only two. Each General Response Action is composed of four objective response actions. Three of the four objective response actions are the same for both General Response Actions, further reducing the technologies to be considered. One of the four objective response actions needs no technology. As a result, only technologies applicable to the following objective response actions are needed:

1. Removing and disposing/treating of sludges and contaminated soils.
2. Removing and treating (if necessary) surface waters.
3. Restoring the upper aquifer.

3.2 IDENTIFICATION OF POTENTIAL REMEDIAL TECHNOLOGIES

The remedial technology list used for developing the remedial alternatives for the Sikes Site was developed in stages. The initial list of potential or candidate technologies was obtained from the National Oil and Hazardous Substances Contingency Plan, Section 300.70. These technologies were supplemented with newly developed technologies that seemed feasible and potentially applicable. An initial screening of technologies is given in Appendix A.

The General Response Actions to be met, the media involved, site characteristics and on-site and off-site application were all considered during the initial screening.

The technologies which warranted further consideration after the initial screening are presented in Table 3-1. These technologies are further classified according to media to be treated or disposed in Table 3-2 Candidate Remedial Technologies.

3.3 LIMITED ACTION TECHNOLOGIES

Limited action technologies are evaluated in Appendix A. These are technologies not specific to source control remedial actions, but are common to many or all remedial actions. Some remedial alternatives

TABLE 3-1

SUMMARY OF APPLICABLE TECHNOLOGIES*

TECHNOLOGY	OPTIONS
CONTAINMENT	
Capping	Clay; synthetic liners; multi-layer caps
Vertical Barriers	Soil-benonite slurry walls; cement-bentonite slurry wall
Surface Controls	Regrading; revegetation; collection systems
Dust controls	Water
REMOVAL	
Drums	Grapplers; forklifts; cranes; scrapers
Sludge and Cont. Soils	Backhoes; loaders; scrapers; draglines
Surface water/Groundwater	Positive displacement pumps; centrifugal pumps; Vacuum pumps/trucks
Groundwater Collection	Extraction wells
Gas Collection	Passive vents
TREATMENT	
Solids Treatment	None
Solidification/Fixation/ Stabilization	Cement based fixation; cement and flyash stabilization
Solid/Liquid Separation	Decanting; dewatering beds; mechanical filtration
Physical Treatment	Adsorbents; membrane processes; air stripping
Chemical Treatment	Neutralization, oxidation; hydrolysis
Biological Treatment	Activated sludge; aerated lagoons
In Situ Treatment	None
Thermal Treatments	Incineration
Co-Disposal Processes	Incineration
Gas Treatment	Adsorption; Incineration

DISPOSAL

Landfills	On-site RCRA; off-site RCRA; on-site Non-RCRA
Waste Water Discharge	Surface water discharge to San Jacinto River or Jackson Bayou

002901

TRANSPORT METHODS

Containers	Closed bins; closed bulk containers; bulk tanks
Transport	Truck; rail; truck and rail

RELOCATION OF RESIDENTS — Temporary; permanent

*From initial screening in Appendix A.

require monitoring of the upper and lower aquifers. Monitoring will be needed for a minimum of 30 years if the wastes remain on-site. Limited action technologies for the source would include:

- o Site Monitoring
- o Periodic Site Inspection
- o Fencing
- o Institutional Restrictions

3.4 EVALUATION AND SCREENING OF TECHNOLOGIES

Each of the candidate remedial technologies shown in Table 3-2 has been evaluated for site applicability, limitations, area impacts, and reliability. The elements of the screening/evaluation process used to narrow the remedial technologies to the Recommended Technologies shown in Table 3-3 are discussed in the Sections that follow.

No air emission control/abatement technologies are presented since air pollution is not a significant problem at this time. Air emission control/abatement technologies will be considered as required during remedial design.

TABLE 3-2

CANDIDATE REMEDIAL TECHNOLOGIES
SIKES DISPOSAL PITS SITE

Media	On-Site	Off-Site
A) Sludges, Soils		
1) Removal:	a) Excavation - Backhoe - Front-end loaders - Dragline - Drum grappler - Scraper - Dozer	N/A
2) Disposal:	a) Land Disposal - RCRA landfill - Non-RCRA landfill (slurry walls and caps)	a) Land Disposal - RCRA landfill - Non-RCRA landfill - Landfarming
3) Treatment:	a) Incineration - Rotary kiln - Fluidized bed - Multiple hearth	a) Incineration - Rotary kiln - Fluidized bed - Multiple hearth
	b) Solidification/ Chemical Fixation - Cement based	b) Solidification/ Chemical Fixation - Cement based
	c) Stabilization - Cement - Flyash	c) Stabilization - Cement - Flyash

TABLE 3-2 (Continued)

Media	On-Site	Off-Site
B) Surface Water		
1) Removal:	a) Pumps	N/A
2) Treatment: (if required)	a) Physical Treatment - Air stripping - Activated carbon - Filtration - Membrane Separation	a) Physical Treatment - Air stripping - Activated carbon - Filtration - Membrane Separation
	b) Biological Treatment - Activated sludge - Aerated lagoons	b) Biological Treatment - Activated sludge - Aerated lagoons
	c) Chemical Treatment - Oxidation - Ultraviolet/ ozonation - Hydrolysis - Neutralization	c) Chemical Treatment - Oxidation - Ultraviolet/ ozonation - Hydrolysis - Neutralization
3) Disposal:	a) Discharge to San Jacinto River or Jackson Bayou	N/A

002905

TABLE 3-2 (Continued)

Media	On-Site	Off-Site
C) Upper Aquifer		
1) Restoration:	Natural Flushing after all waste removed or isolated.	N/A
2) Removal:	Pumping	N/A
3) Treatment:	a) Physical Treatment - Air stripping - Activated carbon - Filtration - Membrane Separation	a) Physical Treatment - Air stripping - Activated carbon - Filtration - Membrane Separation
	b) Biological Treatment - Activated sludge - Aerated lagoons	b) Biological Treatment - Activated sludge - Aerated lagoons
	c) Chemical Treatment - Oxidation - Ultraviolet/ ozonation - Hydrolysis - Neutralization	c) Chemical Treatment - Oxidation - Ultraviolet/ ozonation - Hydrolysis - Neutralization
4) Disposal	a) Discharge to San Jacinto River or Jackson Bayou	N/A

N/A - Not Applicable

3.4.1 Technologies for Removal/Disposal/Treatment of Sludges and Contaminated Soils

3.4.1.1 Waste Removal Technologies

The types of solid wastes to be removed and disposed of include drum wastes, surface sludges, pit sludges, and underlying contaminated soils.

Pit sludges and contaminated soils would be excavated using a long reach dragline. Hydraulic dredging has been eliminated because it would produce large volumes of contaminated, even perhaps emulsified water, that would present complex and costly treatment problems. Surface sludges, contaminated soils and drummed waste would be removed by the most appropriate of the excavation methods listed. Waste excavation is a feasible and commonly used technology, although it can result in short-term added health, safety and environmental risks.

3.4.1.2 Waste Disposal Technologies

Incineration

Direct decontamination of organic wastes can be accomplished with on-site or off-site incineration. Incineration is the high temperature oxidation of organic materials to carbon dioxide and water. Organic chloride wastes are converted to hydrochloric acid, carbon dioxide and water. Sulfide wastes would be oxidized as well, to sulfur dioxide.

Types of incineration equipment commercially available include:

- o Rotary Kiln
- o Fluidized bed
- o Multiple hearth

Of these, the rotary kiln is the most appropriate for treating the solid wastes.

The rotary kiln is the most widely used incinerator for solid waste incineration, and is the one most used by off-site commercial disposers for solid waste incineration. The use of transportable incinerators on-site or construction of an on-site incinerator are options. Other types of incinerators, such as, the fluidized bed and multiple hearth units, were screened out either because they are not appropriate for the wastes to be disposed of or not used on remote sites. Other developmental thermal treatment technologies could be considered during the Design Phase if the technology advances far enough.

Land Disposal Technologies

Landfills are designed to store and isolate the waste contaminants from the environment. Both RCRA approved and non-approved landfills including slurry walls and caps are technologies that were retained for evaluation. Only a RCRA approved landfill may be used for off-site disposal of hazardous waste. It will be retained.

An on-site RCRA complient landfill would be designed according to the technical requirements of RCRA. These requirements include the use of a double synthetic liner with leachate collection and leak detection systems. A low permeability, multi-layer clay and synthetic membrane lined cap would be placed over the landfill. The landfill must be constructed above the high groundwater level and be protected from a 100-year flood event. The non-RCRA landfill would be similar to the RCRA design except that it would contain only one synthetic liner and have no leak detection system. It would be capped with a RCRA equivalent clay/geomembrane cap. The slurry wall and cap landfill would be placed over an existing disposal unit. The landfill would have vertical slurry walls tied into the upper clay aquiclude, and be covered with a RCRA equivalent geomembrane and clay cap that would be tied into the slurry walls to reduce the potential for infiltration.

3.4.1.3 Waste Treatment Technologies

Chemical Fixation of Contaminated Soils

Two types of chemical fixation treatments are currently in use. One group of fixation agents physically encapsulates the waste particles, while the other chemically fixes the waste components. Both of these processes mix the waste with solidifiers such as Portland cement, lime and silicates. A slight increase in volume results. Volume is increased approximately 10% by the Chemfix process, a process representative of the chemical fixation process. The objective of fixation is to reduce or prevent leaching of contaminants from the solid formed. Fixation is most effective on waste containing predominantly inorganic contaminants, i.e., metals and salts. Fixation has not been effective on waste containing concentrations of organic contaminants greater than 2 percent. Thus, the fixation of sludges has been eliminated because excessive leaching of hazardous organic contaminants could result. However, fixation of soils containing less than 1,000 ppm (0.1%) of organic contaminants should make the resultant solid resistant to leaching, thus permitting its disposal as backfill for surface depressions and pits. If the ash and contaminated soils contain hazardous metals, then fixation should fixate the metals as well as trace organics in a leach resistant inorganic solid as indicated by previous experiences on similar waste. (See Appendix A for test results). The contaminated soils are expected to meet the Texas Water Commission Class III criteria after chemical fixation.

Disposing of the contaminated soils on-site has the potential for saving significant transportation and disposal costs, besides saving considerable off-site RCRA complient landfill capacity. Long term stability of fixated wastes has not been demonstrated, although results over a 10 year period, have been very encouraging. Fixation of contaminated soils should be demonstrated through testing prior to use.

Stabilization of Sludges

Excavated sludges would be stabilized with either cement kiln dust or flyash to satisfy RCRA requirements for landfilling of hazardous wastes on-site. The pit sludges to be disposed of on-site in non-RCRA landfills (including slurry wall cells with caps) would be stabilized to increase the bearing strength of the sludges.

3.4.2 Surface Water and Ground Water Treatment Technologies

The applicable technologies shown in Table 3-2 for treating contaminated surface and ground waters are from the initial screening of the detailed listing of Section 300.70 of Subpart F, National Oil and Hazardous Substances Pollution Contingency Plan (NCP). The technologies shown include physical, biological, and chemical treatments.

Even though there is a considerable quantity of contaminated surface and groundwater on-site, most of it meets the Surface Water Quality

002909

Criteria for discharge to the San Jacinto River. Thus, it is anticipated that very little treatment of site waters for contaminant removal will be necessary, although some spot filtration of muddy surface waters may be needed. The technologies discussed below have been screened on this basis.

3.4.2.1 Physical Treatment Technologies

Physical treatment technologies considered included air stripping, activated carbon adsorption, membrane separation, and filtration.

Air stripping is used to remove volatile contaminants from the wastewater. Air stripping appears to be a technology applicable to removing contaminants from large volumes of water to satisfy Surface Water Quality Criteria. Therefore, it was retained for further evaluation.

Granular Activated Carbon (GAC) is another method used widely to remove trace organics from water. Its removal effectiveness is very good for non-polar compounds, i.e., those organic compounds that have low water solubilities. GAC is considered an applicable treatment technology and it was retained for further evaluation.

Membrane separation is a technology that concentrates the contaminants in one liquid stream while producing a relatively clean second stream. This technology is somewhat contaminant specific. The membranes themselves must be capable of transferring the contaminant without being dissolved by it. This technology must be "developed" for the waste to be treated. It appears to offer no advantages over airstripping or GAC, but would require considerable development time and likely be more expensive. Even then it is only a partial treatment. The stream of concentrated contaminants must be disposed of also. For these reasons, membrane separations was not retained for further evaluation.

3.4.2.2 Biological Treatment Technologies

Both of the biological processes listed in Table 3-2 may be effective for treating contaminated surface water and groundwater. Activated sludge is a high rate oxidation process compared to the aerated lagoon. Neither process is usually appropriate for the removal of trace organics from a waste stream of less than 100 ppm TOC as the Sikes wastewaters. Both aerobic and anaerobic processes are available, although aerobic processes typically provide higher removals. Also, these processes are sensitive to certain trace metals, pH, feed temperature and load fluctuations. Activated sludge, supplemented with activated carbon, e.g., the PACT process, frequently results in improved removals. Either biological process would require bench scale testing at least, before definite conclusions can be made concerning applicability. Biological treatment will not be retained for further evaluation because of its expected poor removal of trace organics and the expected high cost compared to other treatment technologies.

3.4.2.3 Filtration

Removal of surface waters and infiltration waters from pits may require filtration prior to other treatments to remove excessive suspended solids picked up from pit bottoms. Several choices of filters are available; however, for the low solids loading expected, cartridge filters appear to be the most appropriate.

3.4.2.4 Chemical Treatment Technologies

Chemical treatments considered for surface water and groundwater are listed in Table 3-2.

Chemical oxidation is a process by which organic contaminants are converted to carbon dioxide and water. For Sikes contaminated water, it would also convert the chlorine of the chlorinated organics to hydrochloric acid, which in turn could be converted to a salt with sodium hydroxide or lime. The process usually includes a strong oxidizing agent and a catalyst. The feasibility of this approach is very doubtful, when one considers the very low contaminant level of the waters and the criteria for the treated effluent. High temperatures and high oxidant ratios would be required to accomplish the treatment needed in a reasonable time. As a result, capital and especially operating costs, could be very high. Bench scale testing to define optimum treatment conditions would be required before a quantitative evaluation could be made. Because of these reasons, chemical oxidation was dropped from further consideration.

Ultraviolet/ozonation is another chemical oxidation process, with similar problems as described above, and was also dropped for the same reasons.

Hydrolysis is a chemical reaction wherein the chemical compound reacts with water. The reaction products are a function of the starting chemicals. In the case of some chlorinated organics, the products could be hydrochloric acid and a new chlorine free organic compound. Thus, groundwater. The objective to restore the aquifer to Drinking Water Quality or the (10^{-4} to 10^{-7} range) Human Health Standards any place under the site, would require that treatment of aquifer waters or prevention of further contaminant input, be initiated. Both of these depend on removal or isolation in-place of waste. In situ chemical and biological treatment may be applicable. With contaminant input limited, it is likely that natural flushing with clean groundwater would eventually result in restoration of the aquifer.

Natural flushing in conjunction with waste removal or isolation was retained for further evaluation. Groundwater pumping to aid natural flushing was retained for further evaluation.

3.4.3.1 Physical Treatment Technologies

Physical treatment technologies considered for treating contaminated upper aquifer waters included air stripping activated carbon adsorption, and membrane separation. Each of these technologies has been described for treating surface water. Either technology is considered capable of treating upper aquifer water to meet Surface Water Quality Criteria. Thus, upper aquifer water could be withdrawn and treated, then discharged to the river. Air stripping and GAC technologies will be retained for further evaluation.

3.4.3.2 Biological Treatment

Biological treatment of groundwater was considered. It was rejected for the same reasons given for rejecting biological treatment of surface waters.

3.4.3.3 Chemical Treatment Technologies

The chemical treatment technologies considered for treating groundwater are the same ones considered and rejected for treating contaminated surface water. They have been rejected for treating the upper aquifer for the same reasons.

3.4.3.4 Disposal Technologies

Groundwater that satisfies the Surface Water Quality Criteria would be disposed of in the San Jacinto River or Jackson Bayou.

3.4.3.5 Summary

Natural flushing in conjunction with waste removal or isolation, and disposal in the river or bayou will be evaluated. Groundwater pumping will be considered if necessary. Treatment will be evaluated if natural flushing and pumping are unsuccessful.

3.5 SELECTION OF REMEDIAL TECHNOLOGIES

A summary of remedial technologies recommended for further evaluation and/or for combining with response actions to form remedial alternatives is given in Table 3-3.

Recommended technologies for treating contaminated surface and infiltration waters will be evaluated in detail in Section 6. A "best" treatment process for contaminated water will be defined from this evaluation and used as a common element in all remedial alternatives.

SECTION 4 - DEVELOPMENT OF REMEDIAL ALTERNATIVES

4.1 INTRODUCTION

The purpose of Section 4 is to describe the process used to formulate remedial alternatives. Each remedial alternative is chosen on the basis that it will mitigate the threats to human health and environment created by the site. Each remedial alternative has been formed by combining the screened general response actions developed in Section 2 and the screened remedial technologies from Section 3. Each remedial alternative formed must satisfy all site objectives as given in Section 1.

4.2 METHODOLOGY FOR THE DEVELOPMENT OF REMEDIAL ALTERNATIVES

The methodology used to develop the remedial alternatives for the Sikes Disposal Pits Site follows the procedures given in the NCP, and in particular, 40 CFR 300.68 (f). These NCP requirements have been enlarged and illustrated more fully in "Guidance on Feasibility Studies Under CERCLA," published by EPA, June 1985.

4.2.1 NCP Alternatives Categorization

Section 40 CFR 300.68 (f) of the NCP requires that at least one remedial alternative be developed as part of the feasibility study in each of the following categories:

A. Alternatives for treatment or disposal at an off-site facility approved by EPA.

3. Contaminated soils can be chemically fixed to limit the leaching of contained organics or metals to a rate that will not prevent restoration of the Upper Aquifer within 30 years.

4. Total on-site incineration will be considered. Total off-site incineration will not be considered.

5. RCRA compliant and non-RCRA compliant landfills will not be placed on-site together.

4.3 FLOOD PROTECTION

The site is within the floodplain of the San Jacinto River as has been discussed earlier. Therefore, some type of flood protection measures will be required for each alternative. The type and degree of flood protection will depend upon many items including:

- o type of remedial activities conducted,
- o time required to complete the remedial activities, and
- o impact of flood protection measures on upstream flood water surfaces.

In addition, the local FEMA administrator (Harris County) will review and have input as to the final flood protection requirements.

For the purposes of this report, we have considered a 100-year flood protection dike around the entire working area to be a "worse case" scenario. This dike has been included in all of the Alternatives developed. The actual degree of appropriate flood protection will be determined in the design phase.

4.4 SITE REMEDIAL ALTERNATIVES

Following the remedial alternative development process described earlier, 12 remedial alternatives plus the no-action alternative were formulated for mitigating the problems at the Sikes Disposal Pits Site. These are prescreened remedial alternatives and are listed in Table 4-1.

002918

TABLE 4-1

REMEDIAL ALTERNATIVES
LISTING AND CLASSIFICATION*
SIKES DISPOSAL PITS SITE

Remedial Alt. No.	NCP Category	Alternative Description
1	A	a) Dispose of all sludges, contaminated soils in an off-site RCRA permitted landfill. b) Discharge surface waters to river or treat as necessary to meet discharge criteria.** c) Ban use of Upper Aquifer while restoring Upper Aquifer to Drinking Water Standards or (10^{-4} to 10^{-7} range) Human Health Criteria. d) Monitor Lower Aquifer and ban its use where contaminated if degradation is shown to be site related.
2	D	a) Dispose of sludges off-site in a RCRA permitted incinerator. Dispose of incinerator ash in a RCRA permitted landfill. Chemically fix contaminated soils on-site and use for backfill. b) Discharge surface waters to river or treat as necessary to meet discharge criteria. c) Ban use of Upper Aquifer while restoring Upper Aquifer to Drinking Water Standards or (10^{-4} to 10^{-7} range) Human Health Criteria. d) Monitor Lower Aquifer and ban its use where contaminated if degradation is shown to be site related.
3	D	a) Dispose of sludges off-site in a RCRA permitted landfill. Chemically fix contaminated soils and use for backfill. b) Discharge surface waters to river or treat as necessary to meet discharge criteria. c) Ban use of Upper Aquifer while restoring Upper Aquifer to Drinking Water Standards or (10^{-4} to 10^{-7} range) Human Health Criteria. d) Monitor Lower Aquifer and ban its use where contaminated if degradation is shown to be site related.

002918

TABLE 4-1 (Continued)

Remedial Alt. No.	NCP Category	Alternative Description
4	D	a) Incinerate sludges on-site. Chemically fix ash and use as backfill. Dispose of contaminated soils in on-site RCRA landfill. b) Discharge surface waters to river or treat as necessary to meet discharge criteria. c) Ban use of Upper Aquifer while restoring Upper Aquifer to Drinking Water Standards or (10^{-4} to 10^{-7} range) Human Health Criteria. d) Monitor Lower Aquifer and ban its use where contaminated if degradation is shown to be site related.
5	D	a) Incinerate sludges on-site. Chemically fix ash, contaminated soils and use on-site for backfill. b) Discharge surface waters to river or treat as necessary to meet discharge criteria. c) Ban use of Upper Aquifer while restoring Upper Aquifer to Drinking Water Standards or (10^{-4} to 10^{-7} range) Human Health Criteria. d) Monitor Lower Aquifer and ban its use where contaminated if degradation is shown to be site related.
6	B	a) Incinerate sludges on-site. Chemically fix ash and use as backfill. Dispose of contaminated soils in off-site RCRA permitted landfill. b) Discharge surface waters to river or treat as necessary to meet discharge criteria. c) Ban use of Upper Aquifer while restoring Upper Aquifer to Drinking Water Standards or (10^{-4} to 10^{-7} range) Human Health Criteria. d) Monitor Lower Aquifer and ban its use where contaminated if degradation is shown to be site related.

TABLE 4-1 (Continued)

Remedial Alt. No.	NCP Category	Alternative Description
7	B	a) Dispose of sludges, contaminated soils in an on-site RCRA landfill. b) Discharge surface waters to river or treat as necessary to meet discharge criteria. c) Ban use of Upper Aquifer while restoring Upper Aquifer to Drinking Water Standards or (10^{-4} to 10^{-7} range) Human Health Criteria. d) Monitor Lower Aquifer and ban its use where contaminated if degradation is shown to be site related.
8	D	a) Dispose of sludges in on-site RCRA landfill. Chemically fix contaminated soils and use as backfill. b) Discharge surface waters to river or treat as necessary to meet discharge criteria. c) Ban use of Upper Aquifer while restoring Upper Aquifer to Drinking Water Standards or (10^{-4} to 10^{-7} range) Human Health Criteria. d) Monitor Lower Aquifer and ban its use where contaminated if degradation is shown to be site related.
9	C	a) Incinerate sludges on-site. Remove contaminated soils to background level, combine with ash and dispose of off-site in a RCRA permitted landfill. b) Discharge all surface waters direct to the river, or treat as necessary to meet discharge criteria. c) Ban use of Upper Aquifer until it is restored to background quality. d) Monitor Lower Aquifer and ban its use where contaminated if degradation is shown to be site related.

002921

TABLE 4-1 (Continued)

Remedial Alt. No.	NCP Category	Alternative Description
10	B	a) Incinerate all sludges, contaminated soils on-site. Chemically fix ash and use for backfill. b) Discharge surface waters to river or treat as necessary to meet discharge criteria. c) Ban use of Upper Aquifer while restoring Upper Aquifer to Drinking Water Standards or (10^{-4} to 10^{-7} range) Human Health Criteria. d) Monitor Lower Aquifer and ban its use where contaminated if degradation is shown to be site related.
11	D	a) Dispose of sludges in an on-site non-RCRA landfill. Chemically fix soils and use as backfill. b) Discharge surface waters to river or treat as necessary to meet discharge criteria. c) Ban use of Upper Aquifer while restoring Upper Aquifer to Drinking Water Standards or (10^{-4} to 10^{-7} range) Human Health Criteria. d) Monitor Lower Aquifer and ban its use where contaminated if degradation is shown to be site related.
12	D	a) Place slurry walls around main waste pit and Tank Lake. Place all sludges in pits. Backfill and cap. Chemically fix contaminated soils and use as backfill. b) Discharge surface waters to river or treat as necessary to meet criteria. c) Ban use of Upper Aquifer while restoring Upper Aquifer to Drinking Water Standards or (10^{-4} to 10^{-7} range) Human Health Criteria. d) Monitor Lower Aquifer and ban its use where contaminated if degradation is shown to be site related.
13	E	No Action

* All remedial alternatives are source control remedies.
** All on-site waste disposal would be carried out in accordance with State guidelines.

4.4.1 Remedial Alternative 1 - Off-Site RCRA Landfilling of Sludges and Contaminated Soils

The major actions included in this remedial alternative are:

a) Remove all sludges and contaminated soils to criteria levels. Transport wastes off-site and dispose of in a RCRA permitted landfill.

b) Discharge all surface waters direct to river or treat as necessary to meet the established discharge criteria.

c) Ban use of Upper Aquifer, while restoring Upper Aquifer to Drinking Water Standards or (10^{-4} to 10^{-7} range) Human Health Criteria.

d) Monitor Lower Aquifer and ban its use where contaminated if degradation is shown to be site related.

Sludges would be excavated from the pits and fills with long reach draglines and backhoes as appropriate following water removal. Sludges and contaminated soils would be removed to pre-determined criteria levels. The criteria levels are 100 ppm polynuclear aromatics for sludges and 10 ppm for a single volatile organic for contaminated soils. The National Center for Disease Control and EPA have set the criteria for sludges to protect against direct contact. The contaminant concentration in soils has been set as the upper level for a single volatile organic that would allow restoration of the Upper Aquifer to Drinking Water Standards or the (10^{-4} to 10^{-7} range) Human Health Criteria within 30 years.

Pit waters would be withdrawn and treated if necessary before discharging to the river. Data from the Remedial Investigation indicates that all surface waters as well as the groundwater entering Jackson Bayou and the San Jacinto River should meet the Surface Water Discharge Criteria without treatment.

Following excavation of wastes from the pits, infiltration waters would be withdrawn and treated if necessary before discharge to the river. Estimated infiltration rate supported by observed infiltration into active sandpits on-site and nearby indicate that infiltration flow will be well within acceptable pumping rates.

The Upper Aquifer is contaminated under the site, and is not expected to meet Drinking Water Standards nor the (10^{-4} to 10^{-7} range) Human Health Criteria. Therefore, this remedial alternative proposes to ban the use of the Upper Aquifer under the site until its water quality becomes suitable for use. All on-site potable water wells and groundwater monitoring wells have been declared non-potable by the Texas Water Commission (see memos in RI Report Vol. II, Appendix P). There is no current on-site use of contaminated Upper Aquifer waters. The one potable water well on-site has not been used for over 10 years. All monitoring wells are kept locked. Banning the use of the Upper Aquifer water could be implemented with a combination of Administrative controls and Site access control. It is required that prior approval from Harris County be obtained for any development within the floodplain. Because of post remediation monitoring requirements, the site could be classified a restricted area, with access controlled by the perimeter fence and locked

002923

gates. This combination of control options should provide a method for effectively achieving a "ban" on the use of Upper Aquifer water. Restoration would be accomplished by natural groundwater flushing once the contaminant sources are removed or isolated.

Monitoring of the Lower Aquifer would be continued for up to 30 years following remediation to detect any degradation of this aquifer under the site. If results show the aquifer is being degraded by the site, the use of Lower Aquifer water would be banned until it is restored to acceptable quality.

The impacts of this remedial alternative on the site and surrounding areas would include eliminating the risks of direct human contact with sludges, contaminated soils, and/or contaminated surface waters; would enhance restoration of the Upper Aquifer, and should eliminate the risk of long term degradation of the Lower Aquifer. In addition, Remedial Alternative 1 should remove any remaining threat of contaminating off-site drinking water.

Disposal of the total waste from the site in off-site RCRA facilities will consume a considerable portion of installed commercial capacity. However, for this evaluation, it is assumed that sufficient off-site capacity will be available within a reasonable distance from the site.

In addition to the actions described above, the following support activities would be necessary to fully implement Remedial Alternative 1:

002925

1. A temporary dike would be constructed around the disposal areas to protect site activities, personnel and equipment and prevent off-site migration of contaminants from a 100-year flood event. A stormwater collection and treatment/disposal system would be installed within the dike.

2. Following completion of remedial activities, the temporary dike would be removed and used as backfill on-site.

4.4.2 Remedial Alternative 2 - Off-Site Incineration of Sludges, On-Site Chemical Fixation of Contaminated Soils

This remedial alternative consists of the following major actions:

a) Remove sludges to criteria level, transport off-site and incinerate in a RCRA permitted incinerator. Dispose of incinerator ash in a RCRA permitted landfill. Remove contaminated soils to criteria level, chemically fix and use as backfill on-site.

b) Discharge all surface waters direct to river or treat as necessary to meet the established discharge criteria.

c) Ban use of Upper Aquifer, while restoring Upper Aquifer to Drinking Water Standards or (10^{-4} to 10^{-7} range) Human Health Criteria.

d) Monitor Lower Aquifer and ban its use where contaminated, if degradation is shown to be site related.

This alternative disposes of all sludges off-site and contaminated soils on-site. As in Remedial Alternative 1, the surface water must be removed first and treated if needed before discharging to the river.

Infiltration waters would be withdrawn and treated as necessary before discharge. Aquifer restoration is described under Remedial Alternative 1. Off-site incineration in commercial facilities is an existing, demonstrated process for destroying toxic organic contaminants. The incinerator ash would be disposed of in a RCRA permitted landfill. This assumes it would be classified a hazardous waste.

The other major action is chemically fixing the contaminated soils on-site and using the resulting solid for backfilling. There are several types of fixation or solidification processes in use. The ones that are considered most applicable for the contaminated soils are the straight cementation process or the cementation plus additives processes. An example of the latter process is the Chemfix process. Chemical fixation, although waste specific, is more ideally applicable to inorganic materials than organic. For all practical purposes, the contaminated soils are inorganic, containing 10 to 1,000 ppm of organics. The objective of chemical fixation in this application is to tie up the hazardous organics in an impermeable and leach resistant solid such that groundwater would be protected from further contamination. The optimum formulation for tying-up the organics, as well as any hazardous metals, must be determined by testing. For alternatives evaluation/screening, it has been assumed that chemical fixation results in increasing the volume of the original waste material by 10%.

The impacts of this remedial alternative on the site and surrounding areas would include eliminating the risks of direct human contact with sludges, contaminated soils, and/or contaminated surface waters, would enhance restoration of the Upper Aquifer and should eliminate the risk of long term degradation of the Lower Aquifer. In addition, this Alternative should remove any remaining threat of contaminating off-site drinking water.

In addition to the actions described above, the following support activities would be needed to implement Remedial Alternative 2:

1. A temporary dike would be constructed around the disposal areas to protect the site activities, personnel and equipment, and prevent off-site migration of contaminants from a 100-year flood event. A stormwater collection and treatment/disposal system would be installed within the dike.

2. Following completion of remedial activities, the temporary dike would be removed and used as backfill on-site.

4.4.3 Remedial Alternative 3 - Off-Site RCRA Landfilling of Sludges, On-Site Chemical Fixation of Contaminated Soils

This alternative consists of the following major actions:

a) Remove sludges to criteria level, transport off-site and dispose of in a RCRA permitted landfill. Remove contaminated soils to criteria level, chemically fix and use as backfill on-site.

b) Discharge all surface waters direct to river or treat as necessary to meet the established discharge criteria.

c) Ban use of Upper Aquifer, while restoring Upper Aquifer to Drinking Water Standards or (10^{-4} to 10^{-7} range) Human Health Criteria.

d) Monitor Lower Aquifer and ban its use where contaminated, if degradation is shown to be site related.

Remedial Alternative 3 is similar to Remedial Alternative 1 except that sludges only would be diposed of off-site in a RCRA landfill, while the contaminated soils would be chemically fixed on-site and used as backfill. Chemical fixation of contaminated soils is discussed in section 4.4.2.

Surface waters would be removed from the pits prior to excavation, treated as necessary and discharged to the river. Infiltration waters would be withdrawn and treated as necessary before discharge. The Upper Aquifer would be restored as described in section 4.4.1.

Monitoring of the Lower Aquifer would be continued for up to 30 years following remediation to detect any degradation of this aquifer under the site. If results show the aquifer is being degraded by the site, the use of Lower Aquifer water would be banned until it is restored to acceptable quality.

The impacts of this remedial alternative on the site and surrounding areas would include eliminating the risks of direct human contact with sludges, contaminated soils, and/or contaminated surface waters, would enhance restoration of the Upper Aquifer and should eliminate the risk of long term degradation of the Lower Aquifer. In addition, this Alternative should remove any remaining threat of contaminating off-site drinking water.

In addition to the actions described above, the following support activities would be necessary to fully implement Remedial Alternative 3:

1. A temporary dike would be constructed around the disposal areas to protect site activities, personnel and equipment and prevent off-site migration of contaminants from a 100-year flood event. A stormwater collection and treatment/disposal system would be installed within the dike.

2. Following completion of remedial activities, the temporary dike would be removed and used as backfill on site.

4.4.4 Remedial Alternative 4 - On-Site Incineration of Sludges, On-Site RCRA Landfilling of Contaminated Soils, Chemical Fixation of Ash.

Major actions of this alternative are:

a) Remove sludges to criteria level and incinerate on-site. Chemically fix incinerator ash and use as backfill. Contaminated soils will be removed to criteria level and disposed of in an on-site RCRA landfill.

b) Discharge all surface waters direct to river or treat as necessary to meet the established discharge criteria.

c) Ban use of Upper Aquifer while restoring Upper Aquifer to Drinking Water Standards or Human Health Criteria.

d) Monitor Lower Aquifer and ban its use where contaminated if degradation is shown to be site related.

Either mobile incinerators or large transportable incinerators would be used. These units have demonstrated the ability to achieve the required RCRA combustion efficiency. A rotary kiln with afterburner, scrubber and particulate removal equipment is considered the incinerator type of choice. Sufficient organic chlorides are present in the sludges to require scrubbing for removing the hydrochloric acid produced. The incinerator ash would be chemically fixed assuming it is a hazardous material. If, however, the ash is shown to be non-hazardous, then fixation would not be necessary.

An on-site RCRA landfill would be constructed to satisfy all RCRA requirements for locating in a 100-year flood plain. About 75% of the site sludges and contaminated soils are expected to be landfilled. Incinerator ash would be used as needed to stabilize the sludges and contaminated soils prior to landfill.

By constructing the RCRA landfill to include double liners, leachate collection system and leak detection system according to 40 CFR 264.302 (Subpart N), the long term monitoring and other provisions of Subpart F (264.90-264.109) would be exempted.

Surface waters would be removed from the pits prior to excavation, treated as necessary and discharged to the river. Infiltration waters would be withdrawn and treated as necessary before discharge. The Upper Aquifer would be restored as described in Section 4.4.1.

Monitoring of the Lower Aquifer would be continued for up to 30 years following remediation to detect any degradation of this aquifer under the site. If results show the aquifer is being degraded by the site, the use of Lower Aquifer water would be banned until it is restored to acceptable quality.

The impacts of this remedial alternative on the site and surrounding areas would include eliminating the risks of direct human contact with sludges, contaminated soils, and/or contaminated surface waters, would enhance restoration of the Upper Aquifer, and should eliminate the risk of long term degradation of the Lower Aquifer. In addition this alternative should remove any remaining threat of contaminating off-site drinking water.

In addition to the actions described above, the following support activities would be necessary to fully implement Remedial Alternative 4:

1. A temporary dike would be constructed around the disposal areas to protect site activities, personnel and equipment and prevent off-site migration of contaminants from a 100-year flood event. A stormwater collection and treatment/disposal system would be installed within the dike.

2. Following completion of remedial activities, the temporary dike would be removed and used as backfill on site.

4.4.5 Remedial Alternative 5 - On-Site Incineration of Sludges, Chemical Fixation of Contaminated Soils and Ash

Major actions of this remedial alternative are:

a) Remove sludges to criteria level and incinerate on-site. Chemically fix incinerator ash (if necessary) and contaminated soils and use as backfill.

b) Discharge all surface waters direct to river or treat as necessary to meet the established discharge criteria.

c) Ban use of Upper Aquifer, while restoring Upper Aquifer to Drinking Water Standards or (10^{-4} to 10^{-7} range) Human Health Criteria.

d) Monitor Lower Aquifer and ban its use where contaminated, if degradation is shown to be site related.

Both ash and contaminated soils would be chemically fixed in this remedial alternative in contrast to the previous remedial alternative where the contaminated soils would be disposed of in an on-site RCRA landfill. No landfills are constructed for this remedial alternative. All waste would be either incinerated or chemically fixed and used as backfill. Both of these technologies have been discussed previously.

Surface waters would be removed from the pits prior to excavation, treated as necessary and discharged to the river. Infiltration waters would be withdrawn and treated as necessary before discharge. The Upper Aquifer would be restored as described in Section 4.3.1.

Monitoring of the Lower Aquifer would be continued for up to 30 years following remediation to detect any degradation of this aquifer under the site. If results show the aquifer is being degraded by the site, the use of Lower Aquifer water would be banned until it is restored to acceptable quality.

The impacts of this remedial alternative on the site and surrounding areas would include essentially eliminating the risks of direct human contact with sludges, contaminated soils, and/or contaminated surface waters, would enhance restoration of the Upper Aquifer, and should eliminate the risk of long term degradation of the Lower Aquifer. In addition, this alternative should remove any remaining threat of contaminating off-site drinking water.

In addition to the actions described above, the following support activities would be necessary to fully implement Remedial Alternative 5:

1. A temporary dike would be constructed around the disposal areas to protect site activities, personnel and equipment and prevent off-site migration of contaminants from a 100-year flood event. A stormwater collection and treatment/disposal system would be installed within the dike.

2. Following completion of remedial activities, the temporary dike would be removed and used as backfill on-site.

4.4.6 Remedial Alternative 6 - On-Site Incineration of Sludges, Off-Site RCRA Landfilling of Contaminated Soils, On-Site Chemical Fixation of Ash

The major actions included in this remedial alternative are:

a) Remove sludges to criteria level and incinerate on-site. Chemically fix incinerator ash if needed, and use as backfill. Remove contaminated soils to criteria level, transport off-site, and dispose of in a RCRA permitted landfill.

b) Discharge all surface waters direct to river or treat as necessary to meet the established discharge criteria.

002934

c) Ban use of Upper Aquifer while restoring Upper Aquifer to Drinking Water Standards or (10^{-4} to 10^{-7} range) Human Health Criteria.

d) Monitor Lower Aquifer and ban its use where contaminated if degradation is shown to be site related.

Remedial Alternative 6 differs from Remedial Alternative 5 in that the contaminated soils would be disposed of off-site in a RCRA landfill instead of being chemically fixed and used for backfill on-site. On-site sludge incineration and ash fixation would be the same as for Remedial Alternative 5.

Surface waters would be removed from the pits prior to excavation, treated as necessary and discharged to the river. Infiltration waters would be withdrawn and treated as necessary before discharge. The Upper Aquifer would be restored as described in Section 4.4.1.

Monitoring of the Lower Aquifer would be continued for up to 30 years following remediation to detect any degradation of this aquifer under the site. If results show the aquifer is being degraded by the site, the use of Lower Aquifer water would be banned until it is restored to acceptable quality.

The impacts of this remedial alternative on the site and surrounding areas would include essentially eliminating the risks of direct human contact with sludges, contaminated soils, and/or contaminated surface waters, would enhance restoration of the Upper Aquifer and should eliminate the risk of long term degradation of the Lower Aquifer. In addition, this Alternative should remove any remaining threat of contaminating off-site drinking water.

In addition to the actions described above, the following support activities would be necessary to fully implement this Alternative:

1. A temporary dike would be constructed around the disposal areas to protect site activities, personnel, equipment and prevent off-site migration of contaminants from a 100-year flood event. A stormwater collection and disposal system would be installed within the dike.

2. Following waste removal, the temporary dike would be removed and used as backfill on site.

4.4.7 Remedial Alternative 7 - On-Site RCRA Landfilling of Sludges and Contaminated Soils

Major actions included for this remedial alternative are:

a) Remove sludges and contaminated soils to criteria levels and dispose of in an on-site RCRA landfill.

b) Discharge all surface waters direct to river or treat as necessary to meet the established discharge criteria.

c) Ban use of Upper Aquifer while restoring Upper Aquifer to Drinking Water Standards or (10^{-4} to 10^{-7} range) Human Health Criteria.

d) Monitor Lower Aquifer and ban its use where contaminated if degradation is shown to be site related.

A large on-site RCRA landfill, actually an above ground vault, would be constructed with a double liner system, leachate collection system and leak detection system. Wastes would be stabilized as needed to satisfy RCRA landfilling requirements.

Surface waters would be removed from the pits prior to excavation, treated as necessary and discharged to the river. Infiltration waters would be withdrawn and treated as necessary before discharge. The upper aquifer would be restored as described in Section 4.4.1.

Monitoring of the Lower Aquifer would be continued for up to 30 years following remediation to detect any degradation of this aquifer under the site. If results show the aquifer is being degraded by the site, the use of Lower Aquifer water would be banned until it is restored to acceptable quality.

The impacts of this remedial alternative on the site and surrounding areas would include essentially eliminating the risks of direct human contact with sludges, contaminated soils, and/or contaminated surface waters, would enhance restoration of the Upper Aquifer and should eliminate the risk of long term degradation of the Lower Aquifer. In addition, this Alternative should remove any remaining threat of contaminating off-site drinking water.

In addition to the actions described above, the following support activities would be necessary to fully implement Remedial Alternative 7:

1. A temporary dike would be constructed around the disposal areas to protect site activities, personnel and equipment and prevent

002937

off-site migration of contaminants from a 100-year flood event. A stormwater collection and treatment/disposal system would be installed within the dike.

2. As necessary, drying additives (flyash, cement kiln dust) would be mixed on-site with sludges to make them acceptable for on-site RCRA landfilling as well as to improve on-site handling.

3. Following completion of remedial activities, the temporary dike would be removed and used as backfill on site.

4.4.8 Remedial Alternative 8 - On-Site RCRA Landfilling of Sludges and Chemical Fixation of Contaminated Soils

This remedial alternative consists of the following major actions:

a) Remove sludges to criteria level and dispose of on-site in a RCRA landfill. Remove contaminated soils to criteria level, chemically fix and use as backfill.

b) Discharge all surface waters direct to river or treat as necessary to meet the established discharge criteria.

c) Ban use of Upper Aquifer while restoring Upper Aquifer to Drinking Water Standards or (10-4 to 10-7 range) Human Health Criteria.

d) Monitor Lower Aquifer and ban its use where contaminated if degradation is shown to be site related.

The RCRA above ground vault for this alternative would be about two-thirds the size for Remedial Alternative 7. Chemically fixing contaminated soils, along with on-site sludge disposal, would produce a total on-site disposal alternative.

Surface waters would be removed from the pits prior to excavation, treated as necessary and discharged to the river. Infiltration waters would be withdrawn and treated as necessary before discharge. The upper aquifer would be restored as described in Section 4.4.1.

Monitoring of the Lower Aquifer would be continued for up to 30 years following remediation to detect any degradation of this aquifer under the site. If results show the aquifer is being degraded by the site, the use of Lower Aquifer water would be banned until it is restored to acceptable quality.

The impacts of this remedial alternative on the site and surrounding areas would include essentially eliminating the risks of direct human contact with sludges, contaminated soils, and/or contaminated surface waters, would enhance restoration of the Upper Aquifer and should eliminate the risk of long term degradation of the Lower Aquifer. In addition, this Alternative should remove any remaining threat of contaminating off-site drinking water.

In addition to the actions described above, the following support activities would be necessary to fully implement Remedial Alternative 8:

1. A temporary dike would be constructed around the disposal areas to protect site activities, personnel and equipment and prevent off-site migration of contaminants from a 100-year flood event. A stormwater collection and treatment/disposal system would be installed within the dike.

2. As necessary, drying additives (flyash, cement kiln dust) would be mixed on-site with sludges to make them acceptable for on-site RCRA landfilling as well as to improve on-site handling.

3. Following waste removal, the temporary dike would be removed and used as backfill on-site.

4.4.9 Remedial Alternative 9 - On-Site Incineration of Sludges and Off-Site RCRA Landfilling of Contaminated Soils and Ash

(Alternative 9 is the only remedial alternative that would exceed applicable or relevant and appropriate Federal public health and environmental requirements).

Major actions for this remedial alternative are:

a) Remove sludges to criteria level and incinerate on-site. Remove contaminated soils to background level and combine with incinerator ash, transport off-site and dispose of in a RCRA permitted landfill.

b) Discharge all surface waters direct to the river or treat as necessary to meet discharge criteria.

c) Ban use of Upper Aquifer while restoring upper aquifer to background quality.

d) Monitor Lower Aquifer and ban its use where contaminated if degradation is shown to be site related.

The above actions would leave no sludges or contaminated soils on-site. Sludge organics would be destroyed. The remaining waste, composed of ash and contaminated soils, would be moved off-site for disposal. In further contrast to the degree of cleanup provided by other remedial alternatives, this one also includes restoring the Upper Aquifer to background instead of to Drinking Water Standards or the (10^{-4} to 10^{-7} range) Human Health Criteria requirements. The action with the greatest impact is that of removing the waste to background quality. This is expected to increase the volume/weight of waste transported off-site by 25% to 50%. As such, off-site RCRA landfill capacity would be impacted significantly. To restore the Upper Aquifer to background would take much longer than for other alternatives.

Surface waters would be removed from the pits prior to excavation, treated as necessary and discharged to the river. Infiltration waters would be withdrawn and treated as necessary before discharge. The Upper Aquifer would be restored as described in Section 4.4.1.

Monitoring of the Lower Aquifer would be continued for up to 30 years following remediation to detect any degradation of this aquifer under the site. If results show the aquifer is being degraded by the site, the use of Lower Aquifer water would be banned until it is restored to acceptable quality.

The impacts of this remedial alternative on the site and surrounding areas would include essentially eliminating the risks of direct human contact with sludges, contaminated soils, and/or contaminated surface waters, would enhance restoration of the Upper Aquifer and should eliminate the risk of long term degradation of the Lower Aquifer. In addition, this Alternative should remove any remaining threat of contaminating off-site drinking water.

002940

In addition to the actions described above, the following support activities would be necessary to fully implement Remedial Alternative 9:

1. A temporary dike would be constructed around the disposal areas to protect site activities, personnel and equipment and prevent off-site migration of contaminants from a 100-year flood event. A stormwater collection and treatment/disposal system would be installed within the dike.

2. Following completion of remedial activities, the temporary dike would be removed and used as backfill on-site.

4.4.10 Remedial Alternative 10 - On-Site Incineration of Sludges and Contaminated Soils, Chemical Fixation of Ash

This remedial alternative includes the following major actions:

a) Remove the sludges and contaminated soils to criteria levels and incinerate on-site. Chemically fix ash if needed, and use as backfill on-site.

b) Discharge all surface waters direct to river or treat as necessary to meet the established discharge criteria.

c) Ban use of Upper Aquifer while restoring Upper Aquifer to Drinking Water Standards or (10^{-4} to 10^{-7} range) Human Health Criteria.

d) Monitor Lower Aquifer and ban its use where contaminated if degradation is shown to be site related.

2. Following completion of remedial activities, the temporary dike would be removed and used as backfill on-site.

4.4.11 Remedial Alternative 11 - On-Site Non-RCRA Landfilling of Sludges, On-Site Chemical Fixation of Contaminated Soils

Major actions of this alternative are:

a) Remove sludges to criteria level and dispose of in an on-site non-RCRA landfill. Remove contaminated soils to criteria level, chemically fix and use as backfill on-site.

b) Discharge all surface waters direct to river or treat as necessary to meet the established discharge criteria.

c) Ban use of Upper Aquifer while restoring Upper Aquifer to Drinking Water Standards or (10^{-4} to 10^{-7} range) Human Health Criteria.

d) Monitor Lower Aquifer and ban its use where contaminated if degradation is shown to be site related.

Remedial Alternative 11 includes a much smaller landfill than Remedial Alternative 7 and this landfill could probably be placed over part of the overflow area. Chemically fixing of contaminated soils has been discussed previously.

Surface waters would be removed from the pits prior to excavation, treated as necessary and discharged to the river. Infiltration waters would be withdrawn and treated as necessary before discharge. The Upper Aquifer would be restored as described in Section 4.4.1.

Monitoring of the Lower Aquifer would be continued for up to 30 years following remediation to detect any degradation of this aquifer under the site. If results show the aquifer is being degraded by the site, the use of Lower Aquifer water would be banned until it is restored to acceptable quality.

The impacts of this remedial alternative on the site and surrounding areas would include essentially eliminating the risks of direct human contact with sludges, contaminated soils, and/or contaminated surface waters, would enhance restoration of the Upper Aquifer and should eliminate the risk of long term degradation of the Lower Aquifer. In addition, this Alternative should remove any remaining threat of contaminating off-site drinking water.

In addition to the actions described above, the following support activities would be necessary to fully implement Remedial Alternative 11:

1. A temporary dike would be constructed around the disposal areas to protect site activities, personnel and equipment and prevent off-site migration of contaminants from a 100-year flood event. A stormwater collection and treatment/disposal system would be installed within the dike.

2. As necessary, drying additives (flyash, cement kiln dust) would be mixed with sludges to make them acceptable for on-site landfilling as well as to improve on-site handling.

3. Following completion of remedial activities, the temporary dike would be removed and used as backfill on site.

4.4.12 Remedial Alternative 12 - On-Site Burial of Sludges in Pits with Slurry Walls and Caps, On-Site Chemical Fixation of Contaminated Soils

This remedial alternative includes the following major actions:

a) Place individual slurry walls around Tank Lake and the main waste pit, tying into the uppermost aquiclude. Sludges would be placed in these pits once the water has been removed. Contaminated soils would be chemically fixed and used for backfill. Individual caps overlapping the slurry walls would be placed over both pits.

b) Discharge all surface waters direct to river or treat as necessary to meet the established discharge criteria.

c) Ban use of Upper Aquifer while restoring Upper Aquifer to Drinking Water Standards or (10-4 to 10-7 range) Human Health Criteria.

d) Monitor Lower Aquifer and ban its use where contaminated if degradation is shown to be site related.

This remedial alternative would leave sludges and contaminated soils on-site. The sludges in Tank Lake and the main waste pit would be stabilized in-place, while other site sludges would be placed in one of these pits. The combined volumes of both pits should be sufficient to contain all the known and suspected sludges on-site.

The slurry walls should minimize the leaching of contaminants into groundwater. Pumping of groundwater from within the slurry walls would be established to assure that any water passing through the slurry wall would be groundwater entering the the cell and not vice versa, thus avoiding leaching into groundwater. The withdrawn groundwater would be treated as necessary for discharge to the river or taken off-site for disposal.

Chemical fixation of contaminated soils has been described previously.

Surface waters would be removed from the pits prior to excavation, treated as necessary and discharged to the river. Infiltration waters would be withdrawn and treated as necessary before discharge. The Upper Aquifer would be restored as described in Section 4.4.1.

Monitoring of the Lower Aquifer would be continued for up to 30 years following remediation to detect any degradation of this aquifer under the site. If results show the aquifer is being degraded by the site, the use of Lower Aquifer water would be banned until it is restored to acceptable quality.

The impacts of this remedial alternative on the site and surrounding areas would include eliminating the risks of direct human contact with sludges, contaminated soils, and/or contaminated surface waters, would enhance restoration of the Upper Aquifer and should eliminate the risk of long term degradation of the Lower Aquifer. In addition, this Alternative should remove any remaining threat of contaminating off-site drinking water.

In addition to the actions described above, the following support activities would be necessary to fully implement Remedial Alternative 12:

SECTION 5 - INITIAL SCREENING OF REMEDIAL ALTERNATIVES

5.1 INTRODUCTION

The purpose of Section 5 is to screen the remedial alternatives developed in Section 4 following the guidelines given in the NCP, especially 40 CFR 300.68 (g). The objective of screening is to narrow down the 12 remedial alternatives to a smaller list of potential remedial alternatives for further detailed analysis (see Section 6). The screening criteria given in the NCP are described below:

Effectiveness

Each remedial alternative should be evaluated for its effectiveness in protecting public health, welfare and the environment.

Engineering Feasibility

Remedial alternatives should be evaluated for feasibility considering the location and conditions of the release, applicability to mitigating site problems, and whether they represent a reliable means of attaining site remedial objectives.

Cost

Comparative cost estimates should be prepared to assess the relative order-of-magnitude cost for each remedial alternative.

5.2 INITIAL NON-COST SCREENING OF REMEDIAL ALTERNATIVES

Each remedial alternative was initially screened for effectiveness and engineering feasibility.

The rating system that was used for the non-cost screening of alternatives is described below:

Rating Symbol	Definition
--	Extremely negative effects, even with mitigating measures. Alternative not worth further consideration in this category.
-	Negative effects, but not strong enough to be sole justification for eliminating an alternative; or only of moderate negative effects.
o	Of very little apparent positive or negative effects, but inclusion can be justified for some special reason; or no change from existing conditions.
+	A positive or moderately positive benefit.
++	An extremely positive benefit.

5.2.1 Remedial Alternative 1 Off-Site RCRA Landfilling of Sludges and Contaminated Soils

5.2.1.1 Effectiveness

Removing the waste from a non-secure environment to a secure off-site disposal site would protect the site and surrounding public from the threat of long term exposure to site waste or contaminated waters. Complete removal of waste to off-site could also make the site available for other uses in the future. Restoration of the Upper Aquifer would begin immediately following removal of the sludges and contaminated soils, and the attendant reduction in contaminants leached into groundwater.

The most significant environmental impacts would occur during cleanup, principally during excavation of the sludges. Excavation of wastes is a common action in all remedial alternatives except the no-action alternative. Workers must be protected against direct contact with the sludges and from breathing the hazardous organic contaminants that would be volatilized from freshly exposed sludges. The release of volatile organics is not expected to create a problem off-site. To reduce the potential of this happening, however, controls must be used for minimizing air emissions during excavation and during other on-site processing or handling of waste such as stabilization, transport, dewatering, etc. Air emission problems that may be produced from other on-site treatments will be discussed under the alternative that includes that treatment. However, the discussion concerning air emissions and excavation will not be repeated for each alternative.

Trucking waste to an off-site disposal site could create a traffic problem as well as potential exposure of residents along the truck route from spilled waste. Transporting sludges (78,000 cu. yds.) plus contaminated soils (87,000 cu. yds.) would equal 8,300 truckloads at 20 yds per truck, assuming 10 trucks per day, 5 days per week, and would take 3 years to transport the wastes to the off-site disposal site. Alternate barge transport of waste to a RCRA landfill site was considered; however, there is no access to the waste site, nor no known RCRA landfills with barge access.

Erecting a dike around the waste areas would protect site cleanup activities against flooding. This would in turn protect off-site residents from the potential short term exposure during waste excavation. This action is common to all alternatives, except the no-action alternative and this description will not be repeated for each Alternative.

This alternative would produce a positive effectiveness for all wastes. The effectiveness of this alternative for alieviating site produced environmental and public health problems and for achieving site remedial objectives has been rated a +.

5.2.1.2 Engineering Feasibility

The engineering aspects of erecting a dike are common for all alternatives. This is a feasible technology. Excavating waste can be accomplished by several methods. The approach used for evaluating alternatives, however, is to maintain a relatively dry sludge layer by pumping out water as it infiltrates, and use conventional excavation equipment; draglines or backhoes. The approximate 150,000 cubic yards of in situ site waste could be excavated in less than two years. However, excavation is not expected to control cleanup time.

The closest RCRA permitted landfill might not have the capacity to dispose of this volume of waste when disposal activities actually commence. Therefore, long range transport might be required to utilize other available capacity. Waste spillage during transport would be minimized by using totally enclosed container trucks. The engineering feasibility of removing and transporting waste off-site and for adequately treating surface and groundwater to meet site discharge criteria and/or site objectives has been rated +.

5.2.2 Remedial Alternative 2 Off-Site Incineration of Sludges, On-Site Chemical Fixation of Contaminated Soils

This alternative includes off-site incineration of sludges. Ash would be disposed in a RCRA landfill. Contaminated soils would be chemically fixed and used on-site as backfill.

5.2.2.1 Effectiveness

Source removal and off-site incineration, together with chemical fixation of contaminated soils will effectively reduce the long-term risk to public health and the environment at the site. Using the chemically fixed contaminated soils for backfill and incinerating the sludges should restore the surface of the site to approximate predisposal conditions. Upper Aquifer restoration could proceed with only a minimal threat of contamination from waste leaching.

Transporting sludges (78,000 cubic yards) to a commercial incinerator could cause a traffic problem. Approximately 3900 truckloads would be moved over public highways. Because of commercial incinerator capacity limitations, incineration of sludges could take up to 6 years at an allocated 2 tons/hour feed rate. Thus, waste transport could last many years, increasing the risk of traffic accidents and human exposure to spilled waste along the truck route.

Off-site RCRA landfill disposal of incinerator ash should pose no significant environmental risks.

Chemical fixation of the contaminated soils should prevent or control leaching of organics to an acceptable rate. Fixation of similarly contaminated waste has been accomplished with good success. After fixation, the soils are expected to meet the Texas Water Commission's criteria for a Class III waste. The effectiveness of this alternative for achieving remedial objectives, for disposing of sludge and contaminated soils, and for achieving groundwater objectives has been rated a +.

5.2.2.2 Engineering Feasibility

The feasibility of excavating waste from below the water table is a demonstrated technology.

Commercial incineration is a proven technology for destroying toxic/hazardous organic constituents. RCRA landfilling of incinerator ash should be no problem.

Chemical fixation is a practiced technology and does not require use of highly specialized equipment. Contractors are available to perform the job using proprietary chemicals and formulations. The fixation process should increase the volume of the original waste by about 10%.

Engineering feasibility for this alternative should rate a + because the application of the processes being utilized has been demonstrated.

5.2.3 Remedial Alternative 3 - Off-Site RCRA Landfilling of Sludges, On-Site Chemical Fixation of Contaminated Soils

For this remedial alternative the sludges would be disposed of in an off-site RCRA permitted landfill. The contaminated soils would be chemically fixed and used as backfill on-site.

5.2.3.1 Effectiveness

The most contaminated waste, the sludges, would be removed from the site and the less contaminated waste soils would be chemically fixed and placed in pits as backfill. The pits would be covered with clean soil (from the dike) and seeded. Surface water would be removed and treated, if needed, and discharged to the River. Thus, surface waste would be removed either to off-site or isolated from human contact in covered pits. Fixation of contaminated soils is discussed under Remedial Alternative 2.

Sludges are equivalent to 3900 truckloads at 20 cubic yards per truck. Thus, a traffic problem could be created during cleanup and last for 1.5 years.

This alternative should attain all site objectives and restore the site surface to approximate predisposal conditions. Based on the factors discussed above, this alternative has been given a rating of + for effectiveness in achieving site remedial objectives.

5.2.3.2 Engineering Feasibility

Excavation of sludges and other waste is an established practice and has been described previously. RCRA landfilling is an approved disposal technology. Fixation of contaminated soils is discussed under Remedial Alternative 2.

The feasibility of implementing the technologies for this alternative has been rated a +.

5.2.4 Remedial Alternative 4 - On-Site Incineration of Sludges, On-Site RCRA Landfilling of Contaminated Soils, Chemical Fixation of Ash

This alternative includes all on-site disposal of wastes. Sludges are incinerated, ash is chemically fixed and used as backfill, while contaminated soils are disposed of in an on-site RCRA cell.

5.2.4.1 Effectiveness

Waste removal and on-site disposal would effectively mitigate site risks to public health and the environment. The preset site objectives should be satisfied, removing the threat of human exposure to waste or contaminated waters. The Upper Aquifer should be restored in time to a drinking water source. On-site disposal eliminates the traffic problems and potential environmental threats that are associated with transporting wastes to off-site disposal sites.

Incineration of the most contaminated waste, the sludges, would eliminate the threat of human contact with hazardous organic contaminants above the acceptable criteria level. Fixation of ash to a leach resistant solid is a demonstrated technology. The fixed ash would be isolated from human contact by using it as backfill for pits with a clean soil cover.

An on-site RCRA unit should effectively isolate the contaminated soils from the environment, Any leachate would be collected and disposed of, thus minimizing any potential threats to groundwater contamination or human contact. This alternative should be effective in mitigating site environmental and public health concerns, and has been given a rating of + for effectiveness.

5.2.4.2 Engineering Feasibility

Excavation of waste can be accomplished by several methods and has been discussed previously. Construction of an on-site incinerator that can be operated to attain RCRA combustion efficiencies with acceptable on-stream times has been demonstrated. However, depending on incinerator capacity (whether one or more units) it could take several years to incinerate only the sludges. For example, at a 4 ton/hour feed rate, it would take about 3 years to incinerate the approximately 70,800 cubic yards (86,000 tons) of in situ sludges. Fixation is a practiced technology and does not require highly specialized equipment.

Constructing a landfill on-site that meets RCRA requirements may not be feasible. The major concern is whether long-term stability of the landfill can be assured because of site soil characteristics, when considering the size (550 feet long, 440 feet wide, 20 feet deep) of the landfill required in a 100-year floodplain. Assuring long term integrity of the landfill is the major concern. Engineering feasibility has been rated - because of concerns over long term integrity of the on-site RCRA cell.

5.2.5 Remedial Alternative 5 - On-Site Incineration of Sludges, Chemical Fixation of Contaminated Soils and Ash

Remedial Alternative 5 includes incineration of sludges and chemical fixation of ash and contaminated soils on-site.

5.2.5.1 Effectiveness

Removal, treatment and disposal of all waste sources on-site above criteria level should reduce the site risks to public health and environment significantly. By destroying the most contaminated waste, the sludges, which contain 94-97% of the on-site organics, the threat of exposure to on-site waste is reduced drastically. Fixing the ash and contaminated soils and placing these solids in pits with clean soil cover, effectively isolates these wastes from human contact. Fixation is expected to control the leaching of organics from the treated soils such that restoration of the Upper Aquifer is not impeded. The remediation effectiveness of this alternative has been rated a + because all remedial objectives should be achieved.

5.2.5.2 Engineering Feasibility

All the action steps for this alternative have been discussed under other remedial alternatives previously. Engineering feasibility for this alternative has been rated +.

5.2.6 Remedial Alternative 6 - On-Site Incineration of Sludges and Off-Site RCRA Landfilling of Contaminated Soils, On-Site Chemical Fixation of Ash

Sludges are removed to criteria level and incinerated on-site. Ash is chemically fixed and backfilled. Contaminated soils are removed, and disposed of off-site in a RCRA permitted landfill.

5.2.6.1 Effectiveness

Sludge destruction via incineration, ash fixation and removal of the remaining contaminated site materials to off-site effectively cleans up the surface to approximate predisposal conditions. Under this approach the upper U Aquifer should be restored, all the site objectives should be satisfied, and long term threats to public health and the environment should be essentially eliminated. Off-site transport of waste can cause traffic problems and create the potential for human exposure to contaminated soils. The contaminated soils are equivalent to approximately 4,400 truckloads of waste at 20 yds per load. Transport would extend over the same time period as incineration or about 3 years. The effectiveness of this alternative for accomplishing all site remedial objectives has been rated a +.

5.2.6.2 Engineering Feasibility

All elements of the actions used in this alternative have been discussed previously for other alternatives. The engineering feasibility of implementing all remedial actions for this alternative has been rated +.

002956

5.2.7 Remedial Alternative 7 - On-Site RCRA Landfilling of Sludges and Contaminated Soils

This alternative includes excavation of all site wastes to criteria levels and consolidation into one on-site RCRA landfill.

5.2.7.1 Effectiveness

Disposal of all site wastes in an on-site RCRA landfill would effectively mitigate the long-term site risks to public health and the environment providing the stability and integrity of the landfill was continued. All site objectives should be met following clean-up. Effectiveness of this alternative has been rated +.

5.2.7.2 Engineering Feasibility

Excavation and removal of wastes to the landfill have been discussed previously and are considered to be within established engineering practices. Constructing a RCRA landfill on-site may not be feasible. The main concern is whether long term stability of the landfill can be assured because of site soil characteristics and the size required to contain all the waste. Placement of a landfill on-site in an undisturbed area (one not previously backfilled) would be mandatory. To contain the 172,000 cubic yards of stabilized sludges and contaminated soils, a landfill in the 100-year floodplain would have the approximate dimensions of 560 feet long by 540 feet wide, and 25 feet deep. Settling of the landfill could cause failure of the artificial membrane liners. Long term effectiveness of these liners has not been demonstrated. Because of the uncertainty of maintaining long term integrity of the RCRA landfill, the feasibility of this alternative has been rated -.

5.2.8 Remedial Alternative 8 - On-Site RCRA Landfilling of Sludges and Chemical Fixation of Contaminated Soils

This remedial alternative combines two treatment/disposal technologies to accomplish an on-site disposal of all wastes. Sludges would be placed in a RCRA designed landfill. Contaminated soils would be chemically fixed and used as backfill.

5.2.8.1 Effectiveness

In contrast to Remedial Alternate 7, only sludges would be landfilled on-site. However, the major portion of site organics are contained in the sludges and would be isolated from the environment in the RCRA cell. The threats produced from exposure to and contamination of groundwater from these wastes should therefore be mitigated effectively, assuming long term stability and integrity of the landfill.

Chemical fixation of the contaminated soils should control leaching of contaminants to an acceptable rate based on the results of fixing similarly contaminated waste. Fixing the contaminated soils would result in reducing the existing site threats. Effectiveness has been rated + assuming that long term integrity of the landfill was achieved (see below, however).

5.2.8.2 Engineering Feasibility

The RCRA landfill required for this alternative is about 50% the size required for Remedial Alternative 7. This would reduce the landfill dimensions to approximately 550 feet long, 440 feet wide and 20 feet deep. Again the major concern is whether long term stability of the cell can be assured because of poor site soil characteristics and the landfill size required.

Fixation is a feasible technology to implement, using already established and demonstrated techniques. Because of the uncertainty of maintaining long term integrity of the RCRA landfill, the Engineering Feasibility has been rated - for this alternative.

5.2.9 Remedial Alternative 9 - On-Site Incineration of Sludges and Off-Site RCRA Landfilling of Soils and Ash

This alternative is one in which cleanup is accomplished to exceed applicable and relevant public health or environmental Federal standards. Wastes would be removed to background level. Sludges would be incinerated on-site and the ash combined with contaminated soils and disposed of off-site in a RCRA permitted landfill. The Upper Aquifer would be restored to background quality within 30 years instead of Drinking Water Standards or (10^{-4} to 10^{-7} range) Human Health Criteria as for all other alternatives.

5.2.9.1 Effectiveness

This is a total site cleanup, with off-site disposal. No wastes are left on-site. Long-term site risks to public health and the environment will have been eliminated. Following restoration of the Upper Aquifer, the complete site should be at its predisposal condition. By extending the cleanup time with this alternative, additional risks are created relative to other alternatives. Transportation associated risks would be increased because of the added quantity of waste to be transported for disposal. Effectiveness of this alternative would rate a ++, because it would restore the site and the Upper Aquifer to predisposal conditions, thus mitigating all current threats to public health and environment.

5.2.9.2 Engineering Feasibility

To accomplish waste removal to background levels would require removing 25-50% more waste than removed for any other alternative. The logistics for accomplishing this, although complex, is feasible. All the waste, except for the volume reduction from incineration, would be transported to a RCRA permitted landfill for disposal. The off-site RCRA landfill capacity required for the approximate 148,000 cubic yards of waste would be difficult to locate and would stress available capacity. Transportation problems would be increased. Truckloads would increase from 4400 to about 6000. Engineering feasibility for this alternative has been rated a +.

5.2.10 Remedial Alternative 10 - On-Site Incineration of Sludges and Contaminated Soils, Chemical Fixation of Ash

Remedial Alternative 10 proposes to incinerate all site wastes on-site, chemically fix the ash if needed, and use it for backfill.

5.2.10.1 Effectiveness

Long-term protection of public health and the environment would be increased significantly by this alternative. Hazardous organic destruction by incineration combined with fixing of ash should restore the site to near predisposal conditions. With this alternative, all site objectives should be achieved, including restoration of the Upper Aquifer to within 30 years. Total implementation time would be approximately 5.5 years. Incineration time would be approximately 4 years at an 8 tons per hour feed rate. Effectiveness for this alternative has been given a rating of +.

5.2.10.2 Engineering Feasibility

Engineering feasibility of on-site incineration has been disussed previously. This is the only alternative in which all site waste is incinerated. On-site incineration is a demonstrated technology. Availability of incinerator capacity to control cleanup time to below 5 years is uncertain at this point. Availability has been assumed, however, for this screening/evaluation step.

Fixing the incinerator ash is a demonstrated treatment method and implementable using already established on-site techniques. Engineering feasibility has been given a + rating for this alternative.

5.2.11 Remedial Alternative 11 - On-Site Non-RCRA Landfilling of Sludges, On-Site Chemical Fixation of Contaminated Soils

This alternative proposes to place all sludges in an on-site non-RCRA landfill, chemically fix the contaminated soils and use the fixed solids for site backfilling.

5.2.11.1 Effectiveness

This combination of treatment/disposal technologies should effectively isolate the waste from the environment. Site threats to public health and the environment should be reduced. The most concentrated waste source, the sludges, would be placed in a semi-secured landfill. This landfill has no leak detection system, but does have a leachate collection system. Thus, if a leak developed, it must be discovered after the fact via monitoring. However, with a good leachate collection system and an effective cap, the potential for leaching into groundwater is reduced significantly.

Fixation of contaminated soils has been described previously. The effectiveness of this alternative has been given a o rating because of the risk of groundwater contamination.

5.2.11.2 Engineering Feasibility

The construction of a non-RCRA landfill with capacity for sludges only within the existing overflow area may not be feasible. Landfilling the sludges would require an aboveground vault with approximate dimensions of 550 feet long, 440 feet wide and 20 feet deep. The major concern with this landfill is assuring long-term stability and integrity of the cell, because of placing the cell over a backfilled area, formerly used for a waste deposit. Additional handling of wastes is required to make a site available for the cell. This increases the potential exposure of workers to volatile organic emissions from the sludges.

Fixation of contaminated soils and using the solid material for backfill is discussed under Section 5.2.2, Remedial Alternative 2. Because of the potential problems described above, this alternative has been rated - for engineering feasibility.

5.2.12 Remedial Alternative 12 - On-Site Burial of Sludges in Pits with Slurry Walls and Caps, Chemical Fixation of Contaminated Soils

This alternative proposes to install a slurry wall around the main waste pit and Tank Lake, with each wall penetrating into the upper aquiclude. All sludges would be removed, placed in pits, and a geomembrane and clay cap placed over the pits. Contaminated soils would be fixed and used as backfill. A system (wells and pump) would be installed to withdraw groundwater and/or infiltrated stormwater that collected within the sludge burial pits. This would reduce the potential for hazardous contaminants to leach into groundwater or for their penetrating the aquiclude and contaminating the Lower Aquifer.

5.2.12.1 Effectiveness

The combination of treatment and disposal techniques included under this alternative would isolate the waste from the environment. Site threats to public health and the environment would be reduced. The most hazardous waste, the sludges, would be placed in a semi-secured landfill. The sludges would be isolated by the slurry walls, the upper aquiclude and geomembrane caps. The low permeability slurry walls should prevent or significantly restrict the flow of groundwater that would contact the sludges, thus controlling the potential for leaching hazardous contaminants into the Upper Aquifer. The geomembrane caps should prevent infiltration of normal stormwater. However, during a flood, some infiltration of the cap could occur. To avoid the accumulation of water inside the slurry wall enclosures, wells would be placed in each enclosure to facilitate periodic removal of accumulated water. By controlling the hydrostatic water level in the enclosures, the potential for liquid penetrating the aquiclude and contaminating the lower aquifer would be essentially eliminated. Also, leakage through the slurry wall would be from the outside-in, rather than inside-out.

Long-term inspection and maintenance would be required to assure continuing integrity of the system. Chemical fixation of contaminated soils should be effective in controlling leaching of contaminants into groundwater. The fixed soils would be used as backfill in pits and depressions, with clean soil overtopping the backfill. Expected effectiveness of this alternative for protecting public health and the environment has been rated 0.

5.2.12.2 Engineering Feasibility

Construction of slurry walls is relatively new, but has evolved into a widely accepted and effective technology. Tying the slurry walls into the upper clay strata should contain the sludges within a 10-7 cm/sec. permeability clay enclosure. A geomembrane cap would be placed over each pit, overlapping but tied into the slurry walls to control stormwater infiltration. Some settling of the cap would be expected and the cap would be designed to allow for settling. An erosion resistant cap must be provided to resist periodic flooding of the site. Periodic, but long-term maintenance of the cap would be required to maintain cap integrity. Engineering feasibility of this alternative has been rated +.

5.2.13 Alternative 13 - No Action

For this Alternative no action would be taken to mitigate existing site problems or attain the site objectives as presented in Section 1. Monitoring of the Upper and Lower Aquifers would be instituted on a controlled frequency.

5.2.13.1 Effectiveness

A no-action alternative does not effectively contribute to the protection of public health or the environment. Health risks would continue. Existing environmental problems would continue, with the possibility for escalation. Thus, effectiveness for this alternative has been given a rating of --.

5.2.13.2 Engineering Feasibility

Not applicable for a no-action alternative.

5.3 INITIAL COST SCREENING OF REMEDIAL ALTERNATIVES

Following the initial screening of alternatives for technical criteria, the alternatives were screened for cost. A relative order of magnitude cost for each alternative was developed.

A cost range was developed for each alternative and included a rough estimate of present value of operation and maintenance costs (10% discount rate used). Costs were estimated from technology unit costs and estimated costs for common elements, such as the perimeter dike, site preparation, health and safety monitoring, etc.

Unit costs for the various technologies and the estimated total costs for common elements are given in Table 5-1. An order of magnitude costs for each alternative is given in the Initial Alternatives Screening Summary Table, Table 5-2.

These costs were estimated using consistant assumptions strictly for alternative comparison only. No absolute accuracy of these estimates is therefore implied. Costs for the alternatives remaining after the initial screening, have been developed in detail and are presented in Section 6.

According to the NCP, an alternative whose cost is expected to significantly exceed the cost of other alternatives without a corresponding improvement in Public Health, Environmental Protection, or Technical Reliability, may be excluded from further consideration. In this evaluation, no alternative was screened from further consideration solely due to cost.

5.4 SUMMARY OF INITIAL SCREENING OF REMEDIAL ALTERNATIVES

Thirteen remedial alternatives were developed in Section 4 for initial screening. The results of this initial screening are presented in Table 5-2.

Based on this initial screening of Remedial Alternatives, the following alternatives were retained for detailed evaluation in accordance with the NCP, 40 CFR 300.68(h).

No.	NCP Category	Identification
3	D	Off-site RCRA Landfilling of Sludges, On-Site Chemical Fixation of Contaminated Soils.
5	D	On-site Incineration of Sludges, Chemical Fixation of Contaminated Soils and Ash.
6	B	On-site Incineration of Sludges, Off-Site RCRA Landfilling of Contaminated Soils, On-site Chemical Fixation of Ash.
10	B	On-site Incineration of Sludges and Contaminated Soils, Chemical Fixation of Ash.
12	D	On-Site Burial of Sludges in Pits with Slurry Walls and Caps, Chemical Fixation of Contaminated Soils.
13	E	No Action.

002966

TABLE 5-1

UNIT COST OF ALTERNATIVE TECHNOLOGIES
SIKES DISPOSAL PITS SITE

(Ref: EPA Handbook: Remedial Action at Waste Disposal Sites)

Informal quotes from Vendors.

Technologies	Unit Cost - $/Cu. Yd. Unless Shown Otherwise
o On-site RCRA Landfill	267-333
o Off-site RCRA Landfill	500-833
o On-site Non-RCRA Landfill	233-267
o On-site Incineration	215-368
o Off-site Incineration	571-714
o Fixation and Backfill	100-125
o Slurry Wall and Cap	$ 3 - 5M

o Common Element Costs - Total $7M - $8M

o Construction/Support

- Dike and Removal	- $2.2M
- Excavation	- $2M
- Water Treatment or Disposal	- $50K
- Roads	- $55K
- Fence and Lighting	- $126K
- Clearing	- $50K
- Health and Safety	- $1-2M
- On-site Lab	- $500K
- Electric Service	- $15K
- Decontamination	- $100K
- Office Facility	- $150K
- Equipment Area	- $198K
- Sludge Storage/ Dewatering	- $25K
- Facility Maint.	- $500K

TABLE 5-2
INITIAL ALTERNATIVES SCREENING SUMMARY
SIKES DISPOSAL PITS SITE

Alternative	Sludges & Contaminated Soils: Effectiveness	Sludges & Contaminated Soils: Engineering Feasibility	Shallow Groundwater: Effectiveness	Shallow Groundwater: Engineering Feasibility	Rel. Cost ($M)	Retained for further Eval.	Rationale
1. Sludges: Offsite RCRA Landfill Soils: Offsite RCRA Landfill	+	+	+	+	93-143	No	Costly; Risks during transport. Disposal capacity may not be available.
2. Sludges: Offsite incineration Soils: Fix & backfill Ash: Offsite RCRA Landfill	+	+	+	+	73-103	No	Incinerator capacity may not be available. More costly than other equitable alternatives. Risks during transport.
3. Sludges: Offsite RCRA Landfill Soils: Fix & backfill	+	+	+	+	53-83	Yes	Provides protection equal to Alternative 2 at less cost. Risk during long transport.
4. Sludges: On-site incineration Soils: On-site RCRA Landfill Ash: Fix & backfill	+	-	+	-	53-72	No	More costly than Alternative 10 with no additional protection; Site remains closed.w/landfill on-site major tech-problems; e.g. size, location, settlement, subject to flooding erosion.
5. Sludge: On-site incineration Soils: Fix & backfill Ash: Fix & backfill	+	+	+	+	33-53	Yes	Destroys worst contaminants. Immobilizes rest. Might provide equal cleanup effect as total incineration. No transport risks.
6. Sludges: On-site incineration Soils: Off-site RCRA Landfill Ash: Fix & backfill	+	+	+	+	73-113	Yes	Destroys worst contaminants. Risk during transport, but less than for Alternative 1, 2, 3.
7. Sludge: On-site RCRA Landfill Soils: On-site RCRA Landfill	+	-	+	-	53-63	No	Major technical problems; size, location, settlement subject to flooding erosion. May require long term monitoring. Risk of liner failure.
8. Sludges: On-site RCRA Landfill Soils: Fix & backfill	+	-	+	-	38-43	No	Greater risks than Alternative 4. Similar technical problems as Alt. 4,7. Less risks than Alt. 7. No transport risks.
9. Sludge: On-site incineration Soils: Off-site RCRA Landfill Ash: Off-site RCRA Landfill	++	+	++	+	108-163	No	Costly; Disposal capacity may not be available. lengthly transport time with attendant exposure risks.
10. Sludge: On-site incineration Soils: On-site incineration Ash: Fix & backfill	+	+	+	+	43-68	Yes	Destroys or renders wastes effectively non-hazardous. Only total destruction alternative. No long term monitoring due to disposal option chosen. Longer cleanup time. No transport risks.
11. Sludge: On-site Non-RCRA Landfill Soils: Fix & backfill	0	-	0	-	33-43	No	Major technical problems; e.g. size location, settlement, subject to floods. Waste remain in less than RCRA facility. Long term monitoring required.

002967

TABLE 5-2
INITIAL ALTERNATIVES SCREENING SUMMARY
SIKES DISPOSAL PITS SITE

Alternative	Sludges & Contaminated Soils Effectiveness	Sludges & Contaminated Soils Engineering Feasibility	Shallow Groundwater Effectiveness	Shallow Groundwater Engineering Feasibility	Rel. Cost ($M)	Retained for further Eval.	Rationale
12. Sludge: Slurry walls & Cap S & S: Fix and backfill	0	+	0	+	23-28	Yes	Contains or immobilizes wastes. Requires long term monitoring inspection and maintenance.
13. No Action	--		--		0-.4	Yes	Retained for comparison.

002968

SECTION 6 - DETAILED EVALUATION OF REMEDIAL ALTERNATIVES

6.1 INTRODUCTION

From the initial screening described in Section 5, six remedial alternatives were selected to meet the remedial needs of the Sikes Disposal Pits Site. These alternatives were selected to demonstrate a reasonable range of remedial actions which are applicable to the Sikes Disposal Pits Site and which are based upon technical implementability, and environmental suitability.

In Section 6, the selected remedial alternatives are further refined and developed for costing purposes, as set out in the NCP 300.68 (h). Section 6.2 presents a detailed evaluation and selection of technologies for treating groundwater and surface water, as needed, to meet the Surface Water Quality Criteria before it is discharged to the San Jacinto River. Section 6.3 provides a detailed evaluation of each alternative and its component parts.

A detailed cost analysis, including cost estimates for implementing each remedial alternative and a cost sensitivity analysis is presented in Section 6.5. Section 6.6 presents a Summary of the Detailed Evaluation of Remedial Alternatives. The On-Site Incineration and RCRA Landfill Alternative (Remedial Alternative 9) that was screened out in Section 5, will not be detailed, but will be included in the Summary, Section 6.6 to meet guidance requirements of the NCP.

002970

6.1.1 Remedial Alternatives Evaluation Criteria

Each remedial alternative will be evaluated for the following specific criteria which include Technical Feasibility, Environmental and Public Health factors:

- Performance
- Reliability
- Engineering Implementability/Constructibility
- Public Health and Welfare
- Environmental Impacts
- Institutional Factors
- Costs

A description of each evaluation criteria follows:

6.1.1.1 Performance

The performance criteria evaluates the remedial alternatives in terms of their effectiveness and useful life. Effectiveness relates to how well the alternative meets the objectives of ultimate remediation to prevent or minimize release of contamination. Useful life relates to the period of time that the effectiveness can be maintained.

6.1.1.2 Reliability

The reliability of an alternative is assessed on the basis of demonstrated performance and operation and maintenance considerations. Operation and maintenance considerations include labor availability, frequency, necessity, and complexity. Demonstrated performance is characterized by proven field performance, low probability of failure, and proven pilot scale testing.

6.1.1.3 Engineering Implementability/Constructibility

The engineering implementability of each remedial alternative is assessed based on ease of installation, time to implement the remedial alternative, and time to achieve the benefits of the remedial alternative. Constructibility refers to the applicability of the remedial alternative to site conditions, external conditions such as permits and access to disposal facilities, and equipment availability. Time to implement includes time for construction only. Beneficial results are defined as a reduction of contamination or degree of exposure necessary to attain site cleanup objectives.

6.1.1.4 Public Health and Welfare

The public health and welfare criteria evaluates the safety of each alternative during construction and operation and upon failure. The evaluation covers safety of community and environment during installation and operation. It also considers effects in the event of possible failure after remedial action implementation.

6.1.1.5 Environmental Impacts

The environmental impact criteria are evaluated in terms of short-term and long-term effects. The short-term effects are generally construction-related and refer to site pollution, site alteration, and construction debris. Site pollution refers to odor, noise, air emissions, surface water and/or groundwater contamination caused by construction activities. Site alterations relate to wildlife habitat alteration, historic site alteration, and disruption of households, businesses, and services. The construction debris evaluation considers the amount and type of debris and requirements for disposal.

The long-term impacts are also evaluated for site pollution and site alteration. The site pollution criteria considers the odor, noise, air pollution, surface and/or groundwater contamination after remedial action implementation. Long-term site alteration considers wildlife habitat alteration, threatened and endangered species, use of natural resources, parks, transportation, and urban facilities; historic site alteration; relocation of households, businesses, and services; and aesthetic changes.

6.1.1.6 Institutional Factors

The institutional evaluation considers political jurisdictions, land acquisition, and land use and zoning. Alternatives are evaluated in terms of ease of satisfying applicable institutional criteria.

6.1.2 Alternative Evaluation Rating System

Remedial Alternatives have been rated on the basis of the non-cost criteria described in Section 6.1.1. A detailed description of the rating criteria is given in Appendix B. The rating for each alternative is given at the end of the discussion for each criteria. Compilation of ratings for each remedial alternative is given in Table 6-10, which follows the detailed evaluation section.

6.1.3 Institutional Coordination

It is U.S. EPA policy that primary consideration be given to applicable or relevant and appropriate Federal requirements in selecting a remedial action at a CERCLA site. In addition, the U.S. EPA must coordinate with other Federal, State, and local agencies during the remedial action process.

002973

Table 6-1 summarizes the applicable agencies and the coordination anticipated for source control remedial actions. Table 6-2 summarizes the laws and regulations which may require compliance for each remedial alternative that will be evaluated in detail. In addition, specific provisions of these applicable or relevant and appropriate requirements are listed in Table 6-3.

002974

TABLE 6-1

FEDERAL AGENCY COORDINATION

Agency	Comments
Federal Emergency Management Agency (FEMA)	All remedial alternatives require relocation of on-site residents. When relocation becomes necessary during the course of construction for a remedial action, FEMA would be notified.
Health & Human Services (HHS)	All alternatives will be preceded by a contact with HHS to request the appropriate support from the Centers for Disease Control, Agency for Toxic Substances and Disease Registry.
U.S. Army Corps of Engineers (COE)	COE will be contacted when U.S. EPA has selected a remedial action and is prepared to proceed. COE must approve construction in wet lands and constructing the dike in a floodplain.
Occupational Safety and Health Administration (OSHA)	All alternatives will require OSHA contact prior to action to provide input and assistance if necessary.
U.S. Fish and Wildlife Service (USFWS)	USFWS has prepared an assessment of natural resource damages at the site.
Bureau of Land Management (BLM)	No on-site federal lands are involved in the implementation of alternatives.
Advisory Council on Historic Preservation	No landmarks, historic sites, or areas of historic, scientific, or cultural interest will be affected by the implementation of alternatives.
U.S. Forest Service (USFS)	No wild and scenic rivers will be affected by implementation of alternatives.
Department of Housing and Urban Development (HUD)	The site lies within the flood plain of the San Jacinto River.
Department of Transportation (DOT)	All alternatives that require off-site transportation of contaminated media will comply with DOT regulations regarding the transportation of hazardous materials.

TABLE 6-1

FEDERAL AGENCY COORDINATION

Agency	Comments
U.S. Geological Survey (USGS)	Source control remedial actions will not require coordination with the USGS.
National Response Team	All alternatives will require NRT contact prior to action to provide the appropriate support.
Heritage Conservation and Recreation Service	No landmarks, historic sites or areas of historic, cultural or recreational interest will be affected by the implementation of alternatives.

TABLE 6-2

REMEDIAL ALTERNATIVE COMPLIANCE WITH APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

Law or Regulation	Analysis	Remedial Alternative No. 3	5	6	10	12
Federal						
Resource Conservation and Recovery Act (RCRA)	Implementation of the source controls for this alternative will be consistent with current RCRA regulations, including standards for owners and operators of hazardous waste treatment, storage and disposal facilities and closure performance standards for facilities located within a 100-year floodplain.	X	X	X	X	
Department of Transportation (DOT) Hazardous Materials Transport Rules	Implementation of this alternative does not specifically require the off-site transport of hazardous materials.		X		X	X
	Implementation of this alternative requires the off-site transport of hazardous materials. Transport will be in compliance with these rules, including use of properly constructed and marked transport vehicles, use of licensed transporter, and use of hazardous waste manifests.	X		X		
Clean Air Act (CAA) and National Ambient Air Quality Standards (NAAQS)	Implementation of this alternative may result in the emission of pollutants into the air. On-site personnel will be adequately protected.	X	X	X	X	X
	Implementation of this alternative will require point source emissions to the air. Pollution control equipment will be placed on the on-site treatment facility to comply with standards.	X	X	X	X	X

TABLE 6-2

REMEDIAL ALTERNATIVE COMPLIANCE WITH APPLICABLE
OR RELEVANT AND APPROPRIATE REQUIREMENTS

Law or Regulation	Analysis	Remedial Alternative No. 3	5	6	10	12
Federal Water Quality Criteria (FWQC)	Implementation of this alternative should result in compliance with FWQC in groundwater.	X	X	X	X	X
Floodplain Management Executive Order No. 11988 May 24, 1977	Implementation of this alternative will be consistent with Floodplain Management requirements as prescribed in Executive Order 11988.	X	X	X	X	X
State						
Texas Water Commission (TWC) Surface Water Quality Criteria (SWQC)	Implementation of this alternative will produce a point source discharge. The discharge will be treated on-site as necessary to satisfy State SWQC.	X	X	X	X	X
Texas Air Control Board Regulations	Implementation of this alternative may produce a point source emission from on-site equipment. Emissions will be in compliance with State regulations.	X	X	X	X	X
Texas Solid Waste Act	Implementation of this alternative would require the transport and disposal of waste off-site. Transport and disposal will be in compliance with State requirements.	X		X		
Local						
Local Approvals	Local agency approval for implementing this alternative may be required.	X	X	X	X	X

TABLE 6-3 (cont.)

PROVISIONS OF APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

Clean Air Act: 42 U.S.C. 7401

Regulates primary air pollutants; does not address volatile organics or most toxics in air.

- o Application to site limited, possibly applies during remedial actions involving waste excavation.

D.O.T. Rules for the Transportation of Hazardous Materials: 49 CFR Parts 107, 171.11 - 171.500

Regulates the transport of hazardous wastes through licensing of qualified transporters.

Regulates hazardous waste manifesting system.

Regulates transport placarding.

EPA Groundwater Protection Strategy

Ranks aquifers in the order to be protected:

Class I - sole source aquifer
Class II - usable aquifer, other supplies available
Class III - water unfit for consumption (due to high salt content for example), or aquifer has low yield.

Contaminated groundwater is confined to the Upper Aquifer under the site, which contains a volume of about 271 million gallons. Approximately 572,000 gallons per day of uncontaminated (background quality) groundwater enters the site area and flows across the site toward the San Jacinto River or Jackson Bayou, becoming contaminated as it passes under the site.

Groundwater in portions of the Upper Aquifer, near and downgradient from surface or pit waste deposits contains one or more of the criteria components in excess of the maximum allowable concentration. Because of downgradient dilution by groundwater of background quality, the groundwater entering the river or bayou meets the Surface Water Quality Criteria.

The contaminated surface and groundwaters contain a variety of hazardous compounds, including both aromatic and chlorinated organics and metals. A listing of the typical contaminants and the highest detected concentration for each is presented in Table 6-4. Drinking Water Standards or 10^{-6} risk level Human Health Criteria and Surface Water Quality Criteria are also given for comparison. These data show the following:

1. That surface water, containing even the maximum contaminant levels shown, should satisfy the Surface Water Quality Criteria without treatment.

2. That neither groundwater nor surface water containing the maximum contaminant levels meets Drinking Water Standards and/or the (10^{-4} to 10^{-7} range) Human Health Criteria. Thus, Upper Aquifer

TABLE 6-4

MAXIMUM CONTAMINANT LEVELS IN SURFACE WATER AND GROUNDWATER
SIKES DISPOSAL PITS SITE
(in ug/l)

Parameter	Drinking Water Standards or 10-6 Human Health Criteria	Surface Water Quality Criteria	Highest Observed Levels: Ground Water	Highest Observed Levels: Surface Water
Total Phenols	3,500	300	15,000	23
Benzene	0.67	100	10,000	9
Chlorobenzene	488	---	390	3
Chloroform	0.19	---	290	2
1,2-Dichloroethane	0.94	---	2,200	91
1,1,3-Dichloropropene	87	---	9	--
Ethylbenzene	2.4	---	1,700	--
1,1,2,2 Tetrachloroethane	0.17	---	5	--
1,1,2 Trichloroethane	0.60	---	390	4
Trichloroethene	2.7	---	44	--
Toluene	15,000	---	4,300	2
Vinyl Chloride	2.0	300	400	6
Arsenic	50	100	---	<30
Barium	1000	1000	---	--
Beryllium	3.9	---	15	< 3
Cadmium	10	50	770	< 5
Chromium	50	500	44	13
Mercury	2	5	0.4	--
Nickel	15.4	1000	18	16
Lead	50	500	46	<25
Thallium	17.8	---	93	<45
Zinc		1000		31
Copper		500		3

Reference: RI Report Volumes I, II, III, IV water does not satisfy Drinking Water Standards and/or the (10^{-4} to 10^{-7} range) Human Health Criteria at all locations under the site and upgrading of groundwater quality (aquifer restoration) is required to satisfy the site objectives.

During implementation of all remedial alternatives, there will be two additional potentially contaminated waters to deal with. These are:

1. Stormwater runoff from within the diked area and
2. Pit infiltration waters.

Stormwater runoff is the stormwater that runs off the site enclosed by the perimeter dike. Runoff water would be diverted around working areas to avoid waste and drain into perimeter ditches, then flow by gravity into a collection sump. Sump water would be pumped to a drainageway outside the dike and discharged to the San Jacinto River.

Pit infiltration water is groundwater that infiltrates into the pits during excavation of pit wastes. Infiltrated water would be pumped from the pits as it collects into the perimeter ditch or sump unless it needs treatment to satisfy the Surface Water Quality Criteria. Minimizing pit water would facilitate waste excavation and minimize the free water in excavated wastes.

From soil permeability and estimated hydrostatic head differential, the rate of expected infiltration has been estimated as 7 gpm per 100 linear feet of pit perimeter. Based on this, the maximum rate of infiltration should occur for Tank Lake at approximately 80 gpm.

Collected stormwater is expected to meet the Surface Water Quality Criteria. Not all infiltrated pit waters are expected to, however. This conclusion is based on groundwater analyses at or near pits containing deposited waste, which show that groundwater contains one or more contaminants in excess of the criteria for direct discharge. For evaluating processes for treating contaminated surface water and infiltration water, the maximum contaminant levels shown in Table 6-4 will be used. These data show that, with the exception of cadmium, all metals are below Surface Water Quality Criteria levels. This value for cadmium was the only value reported greater than 3 ppb. As a result, no consideration will be given for removal of metals during contaminated water treatment.

6.2.2 Contaminated Surface Water and Groundwater Treatment Processes

Two technologies for treating contaminated surface water and groundwater were identified for further evaluation in the technology screening process: air stripping and carbon adsorption. Both are on-site treatments. Processes based on each of these technologies are described and evaluated in the sections that follow.

6.2.2.1 Granular Activated Carbon

Granular activated carbon (GAC) has been recognized as one of the most acceptable treatment technologies available for the control of organic pollutants in water. The granular carbon, activated to enhance its ability to adsorb certain organics, is placed in a vertical tank or column. The contaminated water is passed downflow through the carbon column. As the water contacts the carbon, the organic contaminants transfer from the liquid phase into the pore structure of the carbon where the organic molecule is held. Generally, the less soluble an organic compound is in water, the greater the propensity for it to be adsorbed by the carbon. Since most contaminants in the Sikes groundwater are only very slightly soluble in water, the GAC process should be an effective treatment technology. However, laboratory batch or column scale testing is necessary to quantitatively determine adsorption effectiveness. Data are available from which effectiveness can be reasonably predicted in the absence of experimental data.

Data representing the effectiveness of GAC for adsorbing or removing single organics from water are shown in Table 6-5. The data do not show the effectiveness of GAC for removing single organic compounds from water containing mixed organics such as the Sikes groundwater. The effect of mixed organics on GAC treatment would be to reduce the removal effectiveness for the poorer adsorbing organics. For example, when the single component data shows that benzene is less effectively adsorbed than the other single organics in a mixture, this means that benzene might be adsorbed less effectively in a mixture of organics. GAC removal efficiencies for benzene range from 64-90%. If the lowest value was used to predict effectiveness for treating the groundwater with the composition shown in Table 6-4, the treated effluent would not meet Surface Water Quality Criteria. Since benzene is one of the primary organics to be removed, it appears that GAC treatment alone is not an effective treatment.

TABLE 6-5

ESTIMATED REMOVAL EFFICIENCIES FOR GRANULAR ACTIVATED CARBON
SIKES DISPOSAL PITS SITE

Compound	Removal Efficiency* %
Benzene	64-90
Chloroform	64-99
Chlorobenzene	NA
Chloroethane	0-99
1,1-Dichloroethene	42-99
1,2-Dichloroethene	21-99
1,1-Dichloroethane	99
T-1,2-Dichloroethane	96-98
1,2-Dichloropropane	65-98
Ethyl Benzene	50
Methyl Chloride	0-99
Tetrachloroethene	68
Trichloroethene	58-99
Toluene	23-99
Vinyl Chloride	52
Phenol	0-98
PCB	NA
Acenaphthene	NA
Acenaphthylene	NA
Anthracene	50-97
Benzo-(A)Anthracene	NA
Bis (2-ethylhexyl) phthalate	26-66
Chrysene	NA
Di-N-Butylphthalate	0-99
Fluoranthene	88-95
Fluorene	NA
Naphthalene	51
Phenanthrene	97-99
Pyrene	95-98

NA - Not available

* EPA Treatability Manual, EPA-600/2-82-001

6.2.2.2 Air Stripping

Air stripping is essentially a mass transfer process in which the volatile organics in contaminated water are brought into intimate contact with air and allowed to come to equilibrium between the aqueous and vapor phases. The effectiveness of removing organic compounds from water by stripping is primarily dependent on these factors: contact time, air to water ratio, temperature, vapor pressure and solubility of the organics in water. The last two factors can be useful for estimating the feasibility of air stripping. For example, Henry's law can be used to estimate the effectiveness of removing organics from water as described below. Henry's law states that when dissolved, the partial pressure of a compound over a solution varies directly with its concentration in the liquid phase. Therefore, the concentration of the contaminant in the gas phase is proportional to its concentration in the liquid phase.

The Henry's law constant, sometimes called the partition coefficient, can be calculated from experimental data, or estimated from the special condition of equilibrium.

Thus, Henry's law constant, H, is proportional to the vapor pressure (Pv) divided by the solubility (S) of the contaminant in water. This relationship is expressed as: $H \quad \frac{Pv}{S}$

By converting Pv to concentration units in the gas phase, a dimensionless Henry's law constant can be calculated. Under ideal conditions, the minimum air to water ratio that would achieve complete removal of the contaminant is the reciprocal of its Henry's law constant. In practice, however, a higher air to water ratio is necessary. A listing of Henry's law constants for organic priority pollutants found at the Sikes site is given in Table 6-6.

Experience has shown that compounds with Henry's law constants greater than 0.05 can be removed easily by air stripping. However, these data indicate that phenol and polynuclear aromatics will be very difficult to remove by air stripping.

Computer simulated air stripping of a waste stream very similar to that of surface and groundwater at Sikes, indicates that very high removal efficiencies can be expected for the more volatile organic contaminants in the contaminated surface water and groundwater as shown in Table 6-7. For many of the compounds of primary interest, removal efficiencies of 94-99% are predicted; however, phenol is an exception. As indicated from the preceeding discussion, several contaminants, including phenols and polynuclear aromatics are not removed effectively by this treatment. As a result, it is improbable that this treatment process alone can be used to restore the Upper Aquifer to Drinking Water Standards and/or the (10^{-4} to 10^{-7} range) Human Health Criteria, or for treating contaminated surface water or groundwater to meet Surface Water Quality Criteria.

TABLE 6-6

DIMENSIONLESS HENRY'S LAW CONSTANTS

Compound	Henry's Law Constant
Benzene	0.249
Carbon tetrachloride	1.355
Chlorobenzene	0.175
Chloroform	0.152
1,2-dichloroethane	0.049
1,1-dichloroethene	0.244
1,2-dichloropropane	0.127
Ethylbenzene	0.289
Methylene chloride	0.143
Tetrachlorethene	1.288
Trichloroethene	0.525
Toluene	0.266
Vinyl chloride	1.615
Acenaphthene	0.005
Anthracene	0.001
Chrysene	NA*
Fluoranthene	NA
Phenanthrene	0.005
Pyrene	NA
Phenol	0.0006
Bis (2-ethylhexyl phthalate)	NA

*NA - Not Available

TABLE 6-7

REMOVAL EFFICIENCIES AS PREDICTED BY THE COMPUTER MODEL

Compound	Removal %
Benzene	99.3
Chloroform	98.9
1,1-dichloroethene	99.4
1,2-dichloroethene	93.7
1,1-dichloroethene	99.8
1,2-dichloroethene	99.6
1,2-dichloropropane	99.0
Ethylbenzene	98.9
Tetrachloroethene	99.5
Trichloroethene	99.6
Toluene	99.2
Vinyl Chloride	99.8

Reference: Draft Feasibility Study Report, French Limited Site, July, 1984 Appendix B.

Air stripping is not a disposal process. It simply transfers the volatile contaminants from the water into the air. Consideration must be given, therefore, to ensure that the organic compound emissions are low enough to avoid unacceptable environmental impacts to the air.

6.2.2.3 Process Effectiveness

Neither GAC nor air stripping alone appears capable of treating infiltration waters containing the maximum levels of contamination shown in Table 6-4 to meet the Surface Water Quality Criteria. GAC should remove phenols effectively, while air stripping should remove benzenes and other volatile organics. Thus, each method is most efficient at removing compounds the other has some difficulty removing. Therefore, it appears that both technologies are needed.

The best arrangement for combining the technologies would be to air strip first. This has the advantage of increasing the run length of the GAC columns because the adsorbable volatile compounds are not loaded onto the carbon. The two methods are very easily combined, yet one process may be bypassed when a change in influent water quality dictates. The process combining air stripping and GAC is shown in Figure 6-1.

The estimated organic air emissions from stripping infiltrated groundwater is shown in Table 6-8.

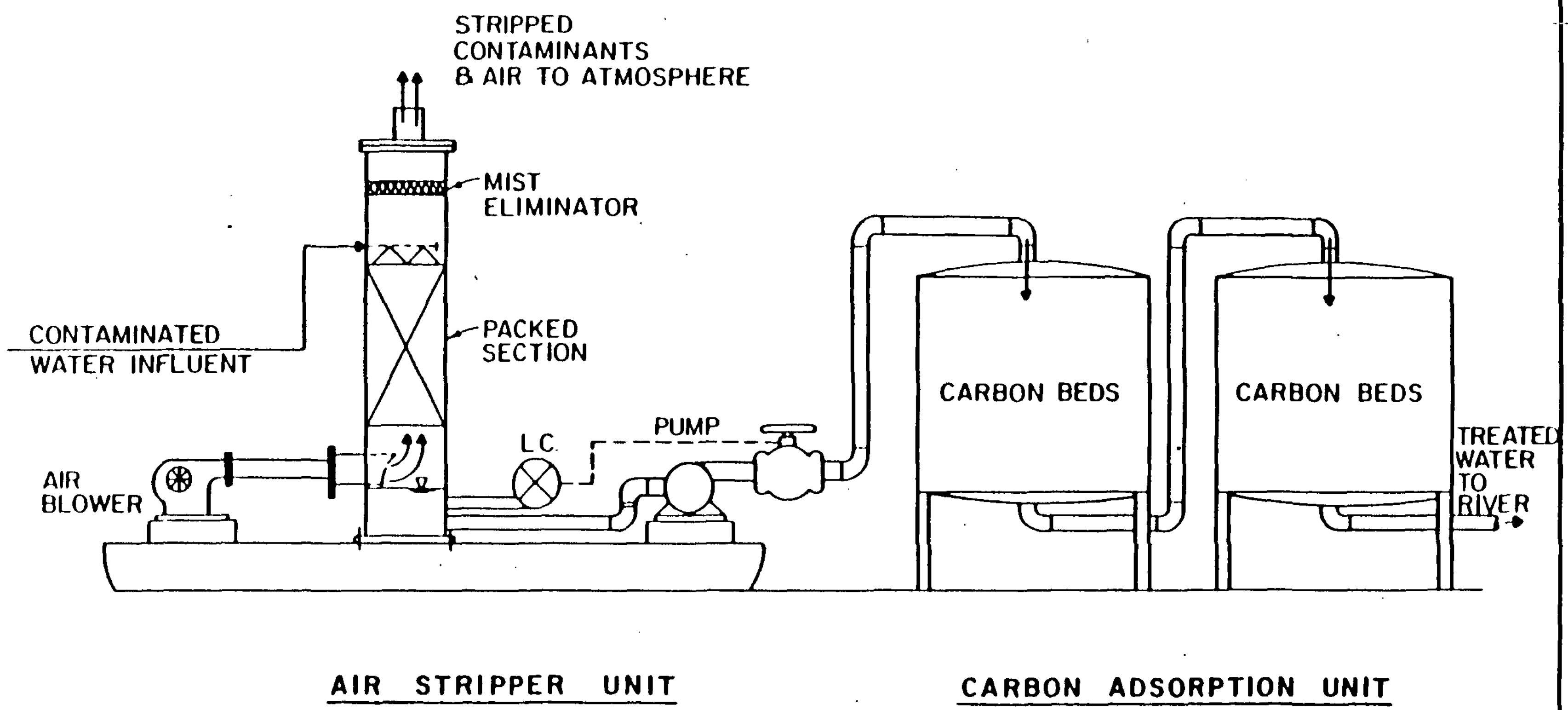

FIGURE 6-1 PROCESS FOR TREATING CONTAMINATED WATER	SIKES DISPOSAL PITS CROSBY, TEXAS	Prepared for : TEXAS WATER COMMISSION 002991 DATE : JUNE 1986 PROJECT NO 1633-20-003-000

164

002991

TABLE 6-8

ESTIMATED EMISSIONS FROM AIR STRIPPING

Compound	Pounds/Day
Benzene	12.0
1,2-Dichloroethane	0.6
1,1-Dichloroethane	2.2
Ethylbenzene	2.0
Toluene	0.6
Vinyl Chloride	0.1

This emission is based on stripping infiltrated water with the composition shown in Table 6-9, which represents groundwater containing the maximum concentration of benzene detected in a monitoring well near a waste source. The estimated emission rate corresponds to a water rate of 100 gpm and assumes 100% removal of the strippable contaminants. This emission is within the current allowable rate for general venting of volatile organics of 100 pounds per day as established by the Texas Air Control Board. However, specific approval for venting toxic organics originating from this treatment must be obtained from the Texas Water Commission in consultation with the Texas Air Control Board.

TABLE 6-9

TYPICAL UPPER AQUIFER CHEMICAL ANALYSIS
SIKES DISPOSAL PITS SITE
(Ref: GW03 - June, 1983)
(ug/l)

Parameter	Upper Aquifer Analysis	Surface Water Quality Criteria
Total Phenols	260 +	300
Benzene	10,000 +	100
Chlorobenzene	100	--
Chloroform	100	--
1,2 Dichloroethane	540	--
1,1 Dichloroethane	2,200	--
T-1,2 Dichloroethene	200	--
1,2 Dichloropropane	100	--
T-1,3 Dichloropropene	100	--
Ethylbenzene	1,700	--
1,1,2,2 Tetrachloroethane	100	--
1,1,2 Trichloroethane	390	--
Trichloroethene	200	--
Toluene	520	--
Vinyl Chloride	100	300
Acenaphthylene	3	--
1,4 Dichlorobenzene	6	--
1,2 Dichlorobenzene	6	--
Naphthalene	200	--
Barium	NA	1000
Beryllium	15	--
Cadmium	770*	50
Chromium	44	500
Copper	18	500
Mercury	0.2	5
Nickel	18	1000
Lead	46	500
Thallium	93	--
Zinc	190	1000

+ Close to or exceeds Surface Water Quality Criteria

* Not a typical value. All other samples contained less than 3.0 ug/l

6.2.2.4 Operational Considerations

Operational problems for either technology should be minimal.

Air stripping is a relatively simple system to operate. It includes only two items of operating equipment: a pump and an air blower. Start-up and normal operation should be straight-forward. Fouling of the packing from biological growth, if a problem, should be controllable with a suitable biocide. Feed filtration could be added if plugging from suspended solids became a problem. Air stripping equipment can be purchased or is probably available on a lease basis.

The GAC process may require prefiltration of the influent to avoid excessive fouling of the carbon bed. Periodic replacement of the spent carbon would be necessary. The GAC equipment would be available from a vendor as well as carbon regeneration or replacement services.

6.2.2.5 Operational Costs

The estimated cost for the combination air stripping and carbon treatment steps is $6.50 per 1000 gallons of water treated.

Contaminated water influent rate is estimated to be a maximum of 100 gpm during the cleanup period. For estimating the maximum cost of treating contaminated waters, the maximum volume of surface water and infiltration water to be treated has been estimated at 65 million gallons. Unit costs for treatment are developed in Appendix C.

6.2.3 Upper Aquifer Restoration

The Texas Water Commission has declared all wells on the Sikes Disposal Pits site in the Upper Aquifer nonpotable because the current aquifer water quality does not meet Drinking Water Standards and/or the (10^{-4} to 10^{-7} range) Human Health Criteria as shown in Table 1-8.

The technology chosen in Section 3.3.3 for restoring the Upper Aquifer to drinking water quality is natural restoration through flushing of the aquifer with background quality recharge water, after site wastes have been removed or isolated.

To determine the viability of natural restoration, a study was undertaken to establish the site conditions under which the Upper Aquifer could be restored to Drinking Water Standards and/or the (10^{-4} to 10^{-7} range) Human Health Criteria within 30 years following waste removal. From the study, it was determined that the factors that most significantly influence aquifer restoration time include:

- Concentration of contaminants in surface soils.
- Mobility of soil contaminants (a function of water solubility, soil adsorption, biotransformation).
- Aquifer recharge rate.
- Aquifer flushing efficiency.

To predict the impact of these factors on restoration time, the contaminated aquifer was considered to be a large tank containing an inventory of contaminants whose identity and individual concentrations were known from previous sampling. Tank influents would be recharge groundwater of background quality and infiltrated surface water containing leached contaminants. Tank effluent would flow into the San Jacinto River.

The most mobile contaminants, the ones that would leach most rapidly from the surface soils into the tank, were identified as benzene, 1,2-dichloroethane and naphthalene. By assuming various flushing efficiencies, leaching rates and soil contaminant concentrations, the change in concentration of contaminants in the aquifer with time was determined. The results obtained show that:

1. Aquifer water quality could be restored to Drinking Water Standards of the 10^{-5} level Human Health Criteria within 30 years for most combinations of the variables where the concentrations in the soil of benzene or 1,2-dichloroethane was 10 ppm or less.

2. Leaching of benzene or 1,2-dichloroethane by infiltrating stormwater has the greatest influence on the restoration time -- not naphthalene or other polynuclear aromatics.

3. A supplemental aquifer pumping system would not reduce the time required for restoration, because leaching of contaminants by groundwater is not significant. Infiltration flow must be increased significantly to reduce aquifer restoration time.

Based on the results of this study, the criteria for excavating contaminated soils was set at 10 ppm of any individual volatile organic contaminant: benzene, 1,2-dichloroethane or naphthalene.

6.3 ALTERNATIVES EVALUATION

This Section contains the detailed evaluation of non-cost factors for each remedial alternative. The rating system used was discussed previously in Section 6.1.1.

Facilities or activities needed to implement a remedial alternative are defined as work components. Some work components are applicable to all remedial alternatives and are described as common components. These and other applicable work components are more fully described in Appendix C. Common components are listed below and will not be repeated for each alternative. Common components include:

- o General Services
- o Site Preparation
- o Temporary Dike
- o Decontamination Pad
- o Collection and Treatment of Contaminated Surface Water
- o Natural Restoration of the Upper Aquifer
- o Post Closure Monitoring of Upper Aquifer and Lower Aquifer

6.3.1 Remedial Alternative 3 - Off-Site RCRA Landfilling of Sludges, Chemical Fixation of Contaminated Soils

6.3.1.1 Work Components

Besides the common components, the following work components are required to implement this alternative:

- o Excavation of Sludges
- o Excavation of Contaminated Soils

 002998

- Off-Site Disposal of Sludges in RCRA Landfill
- Chemical Fixation of Contaminated Soils
- Backfilling of Pits and Overflow Area with Fixed Contaminated Soils

6.3.1.2 Detailed Description

A site plan for Remedial Alternative 3 is shown in Figure 6-2. This alternative would excavate all sludges on-site, using appropriate equipment, down to a contamination level of 100 ppm PNA.

Excavation of pit sludges would be undertaken after the surface water was removed. This slightly contaminated water should meet Surface Water Quality Criteria, thus permitting the water to be discharged directly to the San Jacinto River. However, as the water level nears the sludge layer, it could become sufficiently contaminated with organics and/or suspended solids to require filtering and/or treating prior to discharge.

Infiltration of groundwater into the dewatered pits is expected once the surface water is removed. Sump pumps would be used to continuously withdraw infiltrated water and discharge it to the river or to treatment, as needed. A maximum infiltration flow of 80 gpm has been estimated. The air stripper has been sized for 100 gpm to accommodate some variability in flow.

Excavated sludges would be increased by 10% from the in situ volume due to bulking. This would increase total site sludges from approximately 70,800 cubic yards in place to a total volume of 78,000 cubic yards for off-site disposal.

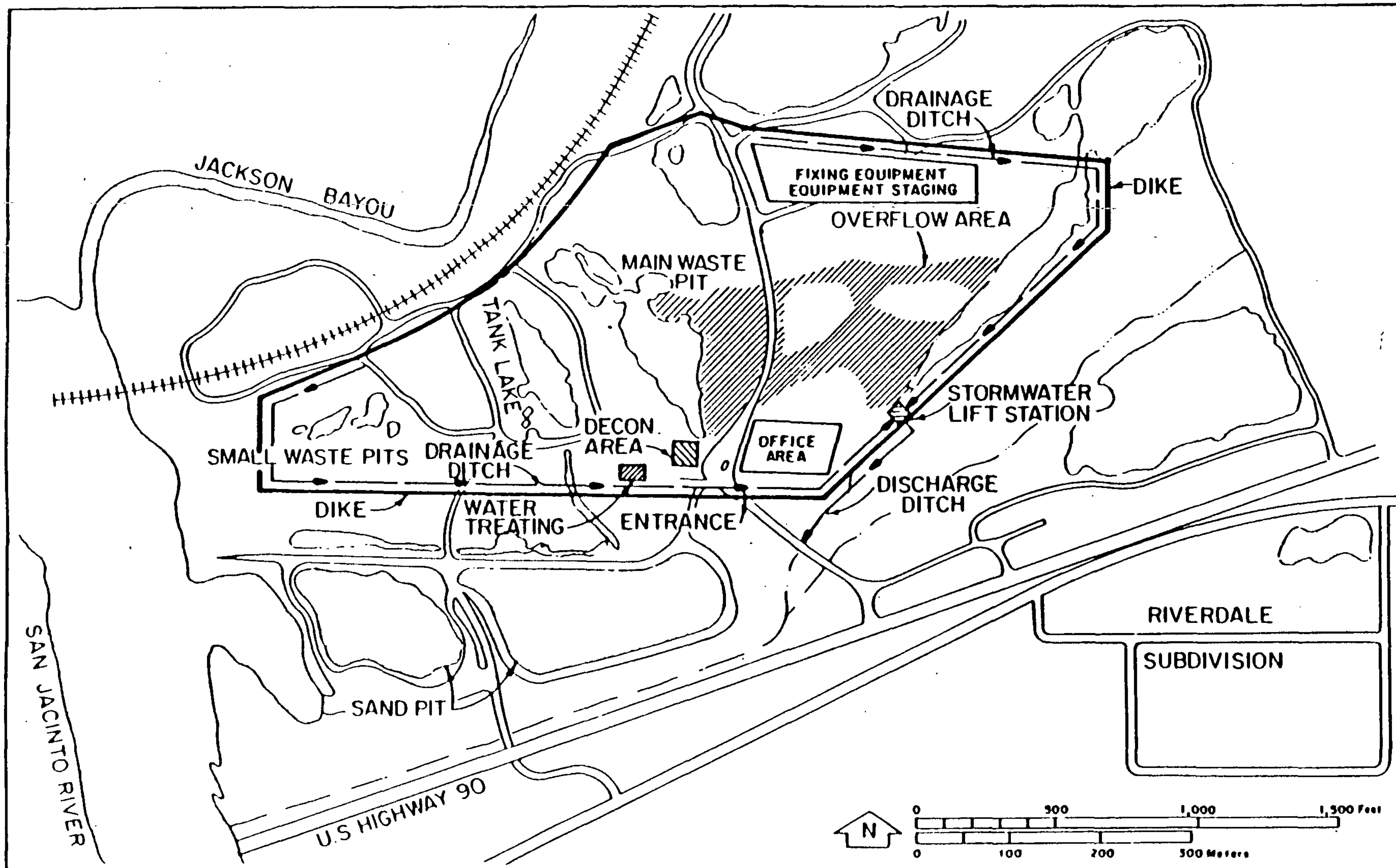

FIGURE 6-2
SITE PLAN FOR ALTERNATIVE 3

SIKES DISPOSAL PITS
CROSBY, TEXAS

Prepared for:
TEXAS WATER COMMISSION

002999

DATE JUNE 1986 PROJECT NO.1633-20-003-000

172

002999

Excavated sludges would be loaded on trucks licensed to transport hazardous waste on public roads and highways for transport to the RCRA approved landfill. For this evaluation, it was assumed that a landfill within 150 miles of the site would be used. Sludges are equivalent to 3900 truckloads at 20 cu. yds. per load.

Contaminated soils would be excavated to a level of 10 ppm volatile organics.* An analytical laboratory would be set up on site to provide these analyses.

Contaminated soils for the site are estimated at 79,300 cubic yards in place. Fixation using cement and other active ingredients should increase original volume by about 10%, while increasing weight slightly more. Thus, the volume of fixed soils would total approximately 87,200 cubic yards. After about two days, the fixed contaminated soils could be used for backfilling.

It has been assumed that the fixation step would be contracted to a firm that specializes in fixation treatment and would set up equipment on-site to perform the treatment.

Following removal of sludges and contaminated soils, each pit or depression would be backfilled using fixed soils. With all the site waste either removed or fixed, the threat of a flood causing off-site contamination is essentially eliminated. At this point, the dike is no longer needed and would be removed. It has been assumed that all the dike material would be utilized in backfilling or surface restoration.

* Volatile organics include: benzene, 1,2-dichloroethane and naphthalene.

Following completion of all remedial actions, the perimeter fence would be repaired as necessary to limit access to the site.

6.3.1.3 Performance Assessment

This alternative should be an effective method of site remediation. Removal of sludges from the site and fixing of the contaminated soils should prevent releases of contaminants and provide maximum protection to human health and the environment immediately and/or soon after the alternative has been implemented. Surface features would be restored to essentially predisposal conditions. Natural restoration of the Upper Aquifer would begin following excavation of wastes. Major remedial actions should be permanent. Based on expectations, performance criteria has been rated as follows:

- o Effectiveness +
- o Useful Life +

6.3.1.4 Reliability Assessment

This alternative should require little, if any, on-site operation and maintenance of remedial actions after implementation. The off-site RCRA landfilling of sludges should represent demonstrated performance. Fixation of contaminated soils is expected to achieve effective performance. Reliability for this alternative, based on the factors described above, has been rated as follows:

- o Operation and Maintenance +
- o Demonstrated Performance +

003002

6.3.1.5 Engineering Implementability/Constructibility

This alternative would require medium construction and medium transportation efforts. Dike construction is the major undertaking and would take up to 6 months to complete. Excavation of all wastes and transport of sludges off-site should be completed within two years after the dike is completed. Total implementation should be completed within 3 years. Beneficial results should be reflected within 1 year. Based on these expectations, the criteria for this assessment have been given the following rating:

o Ease of Construction	0
o Time to Implement	+
o Time to Achieve Benefit	+

6.3.1.6 Public Health and Welfare Assessment

Sludges should be confined and covered during on-site transfers to minimize the release of windblown solids or gaseous air emissions. There is the potential of producing gaseous air emissions during surface water treatment. Any impact, however, would be confined to the site and would not affect the nearest residential area. Sludges would be confined and covered during transport to protect against the release of wind-blown solids or of gaseous air emissions. No adverse site effects are expected following implementation since the sludges have been removed and disposed off-site and the contaminants in the soils have been fixed to control or prevent significant leaching into groundwater. Failure of the remedial action, in this case fixation, would not affect the significant reduction in site organic contaminants (94 to 97%) achieved from sludge removal to off-site. Based on these factors, the criteria for this assessment have been rated as follows:

- o Safety during Installation 0
- o Safety upon Failure +

6.3.1.7 Short-Term Environmental Assessment

Short-term site pollution effects associated with implementing this alternate would include potential release of hazardous materials during excavation and/or during transportation of the sludges from the waste site to the disposal facility. Site workers would be protected. Wastes would be transported in sealed, leak-proof containers on trucks. Site clearing and construction activities would cause significant but short-term alterations to wildlife habitat but would cause no disruptions to households or disruptions to nearby recreational activities. Local sand mining operations could be interrupted but might also be benefited, as some locally produced sands and clays might be used during remedial operations.

Emissions of hazardous organics could be produced during air stripping of contaminated surface waters. However, site workers would be protected from exposure, and no off-site effects are expected. Site air monitoring would be conducted during implementation to indicate the magnitude of emissions and the potential off-site effect.

The potential for exposing off-site residents to contaminants carried off-site during flood events would be essentially eliminated as a result of having the flood control dike protecting the site during remedial activities. Based on the environmental effects expected, the criteria ratings for short term effects from remedial actions are as follows:

- o Site pollution o
- o Site alterations +
- o Construction debris +

6.3.1.8 <u>Long-Term Environmental Impact Assessment</u>

Long-term site pollution effects of this alternative would be essentially eliminated since the sludges would be removed off-site and the contaminated soils would be fixed to reduce the threat of continuing groundwater contamination caused by leaching of organics from the contaminated soils. By removing 94-97% of hazaradous organics from the site, very little organics would remain to constitute a long-term threat. Natural restoration of the Upper Aquifer would commence. Future threats to Lower Aquifer contamination should be abated. Long-term monitoring of the aquifer should cause no significant disruptions to site use. For these reasons, long-term environmental criteria have been rated as follows:

- o Site pollution +
- o Site alterations +

003004

6.3.1.9 Institutional Assessment

The institutional issues associated with this alternative are land use and political jurisdictions. Land use and future development may be restricted for up to thirty years, or at least until groundwater monitoring is discontinued. The State of Texas would be responsible for all post-closure operation and maintenance including monitoring. This alternative should satisfy all site objectives, and comply with regulatory and agency requirements. As a result, this criterion has been rated as follows:

- Institutional +

6.3.2 Remedial Alternative 5 - On-Site Incineration of Sludges, Chemical Fixation of Contaminated Soils and Ash

6.3.2.1 Work Components

Work components needed for this alternative in addition to the common components are:

- Excavation of sludges
- Onsite incineration of sludges
- Chemical fixation of incinerator ash
- Excavation of contaminated soils
- Chemical fixation of contaminated soils
- Backfilling of pits and overflow area

6.3.2.2 Detailed Description

A typical site plan for Remedial Alternative 5 is shown in Figure 6-3.

Prior to excavating waste from the main waste pit, Tank Lake, or other pits with standing water, the surface water would be pumped off and discharged directly to the San Jacinto River providing water quality meets the established criteria, otherwise, it would be treated before discharge. Refer to Section 6.4.1.2 for further details concerning the collection and treatment of surface water.

All sludges would be excavated using appropriate equipment, down to a contamination level of 100 ppm PNA. Sludges would be conveyed to a covered dewatering staging pad adjacent to the incinerator. The pad would be sized to provide ample storage of sludges to satisfy 24-hour operation of the incinerator during wet weather and weekends, even though sludges would only be excavated during daylight hours. Sludges would be transferred from the staging area to the incinerator using an appropriate feeding system. The staging pad would be sloped and contain a collection sump in which free water separating from the sludges would be stored. Periodically, the collected water would be removed and treated on-site and discharged or disposed of off-site by a commercial disposer depending on the level of contamination. Sludges are estimated at 70,800 cubic yards; equal to about 86,000 tons. An incinerator would be constructed on-site or mobile incinerators set up capable of processing 4 tons per hour of sludge. At a 4 tons per hour feed rate, it would take about 3 years of 24-hour per day operation (85% on-stream time) to incinerate all sludges.

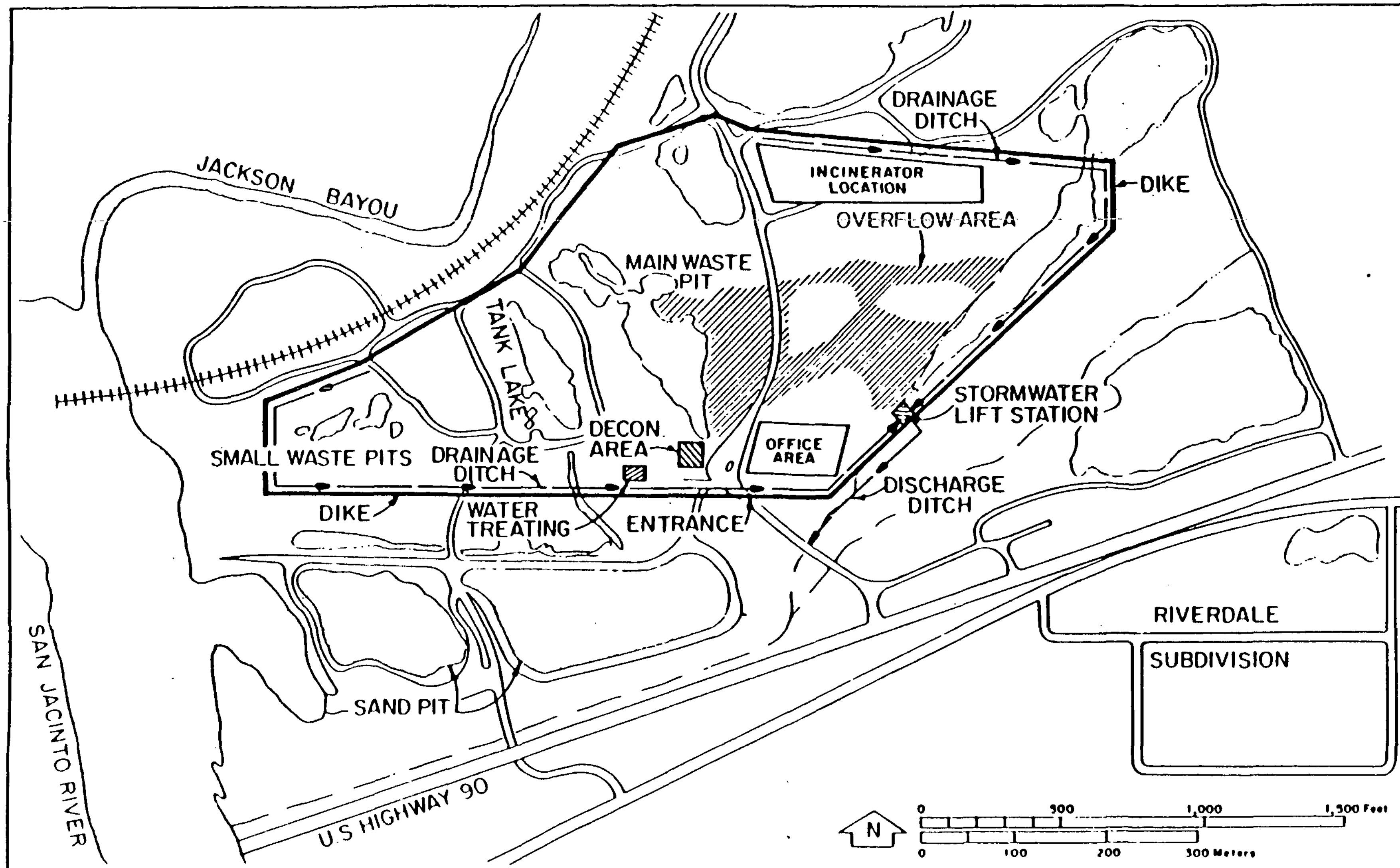

FIGURE 6-3

SITE PLAN FOR ALTERNATIVE 5

SIKES DISPOSAL PITS
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003007

DATE JUNE 1986 PROJECT NO 1633-20-003-000

180

003007

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protection once implementation was completed. Surface features would be restored to essentially pre-disposal conditions. Natural restoration of the Upper Aquifer should progress as the remediation process occurs. Remediation should be permanent once the Upper Aquifer is restored. Because this remedial action should minimize the release of hazardous materials, while adequately protecting human health and the environment, the criteria for this assessment have been rated as follows:

- o Effectiveness +
- o Useful Life +

6.3.2.4 Reliability Assessment

This alternative should require little, if any, on-site operation and maintenance of remedial actions after implementation. Sludge incineration is a demonstrated process and fixation of contaminated soils is expected to achieve effective performance. Thus, long term reliability of remediation would be expected. Based on these factors, reliability criteria have been rated as follows:

- o Operation and Maintenance +
- o Demonstrated Performance +

6.3.2.5 Engineering Implementability/Constructibility

This alternative would require medium construction efforts. These would include clearing the site, constructing the protective dike, and assembling or constructing the on-site incinerator and its ancillary facilities. The longer term excavation required by this alternative would require more complex staging and surface water controls. The time

6.3.2.7 Short-Term Environmental Assessment

The short-term environmental effects associated with the implementation of this alternative would be generally limited, controllable, and should be within acceptable limits. The construction activities would cause a short-term interruption or alteration to wildlife habits, but should not cause disruptions to households or interfere with nearby recreational activities. Local sand mining operations could be interrupted but might also be benefited, as some locally produced sands and clays might be used during remedial activities.

Some release of hazardous organic air emissions is expected from surface water treatment, sludge excavation and incinerator upsets. Site workers will be protected, and no adverse off-site effects are expected. The potential for carrying contaminants off-site during flood events would be essentially eliminated by the perimeter dike. Based on the limited and controllable impacts indicated, the short term effects have been rated as follows:

- Site pollution o
- Site alterations +
- Construction debris +

6.3.2.8 Long-Term Environmental Impact Assessment

The long-term site pollution effects of this alternative should be essentially eliminated since the sludges would be incinerated and contaminated soils fixed to control leaching. By destroying an estimated 94-97% of the hazardous organics on-site through incineration, and immobilizing the remainder plus metals in the fixed solids, threats to future

003009

Upper Aquifer contamination from leached organics should be essentially eliminated, as well as the potential for future contamination of the Lower Aquifer. Based on the factors described above, long-term environmental impacts have been rated as follows:

- o Site pollution +
- o Site alterations +

6.3.2.9 Institutional Assessment

This alternative has several institutional considerations relative to its selection. A trial burn of waste would be needed to demonstrate combustion efficiency. The State of Texas would be responsible for all post closure operation and maintenance and monitoring functions. Land use and future development of the site could be restricted because of post closure monitoring activities. This should not affect off-site property development or use. All site remedial objectives should be met. Based on these factors, this criterion has been rated:

- o Institutional +

6.3.3 Remedial Alternative 6 - On-Site Incineration of Sludges, Off-Site RCRA Landfilling of Contaminated Soils, On-Site Chemical Fixation of Ash

6.3.3.1 Work Components

Work components needed for this alternative in addition to the common components are:

- o Excavation of sludges
- o Excavation of contaminated soils
- o Off-site disposal of contaminated soils
- o On-site incineration of sludges
- o Chemical fixation of incinerator ash
- o Backfilling of pits and overflow area

6.3.3.2 Detailed Description

A typical site plan is shown in Figure 6-4. Prior to excavating waste from the main waste pit, Tank Lake, and other pits, the surface water would be pumped off and discharged direct to the San Jacinto River, providing water quality meets the established criteria. Otherwise, it would be treated before discharge. Refer to Section 6.3.1.2 for further details concerning the collection and treatment of surface water.

All sludges would be excavated down to a contamination level of 100 ppm PNA using appropriate equipment. Sludges would be conveyed to a covered dewatering, staging pad adjacent to the incinerator. Sludges would be transferred from the staging area to the incinerator using an appropriate feeding system. The staging pad would be sloped and contain a collection sump in which free water separating from the sludges would be stored. Periodically the collected water would be removed and disposed of either off-site or on-site depending on the level of contamination. Sludges are estimated at 70,800 cubic yards; equal to about 86,000 tons. Portable incinerators would be set up or an equivalent size unit constructed on-site capable of processing 4 tons per hour of sludge. At this feed rate, it would take about 3 years of 24-hour per day opera-

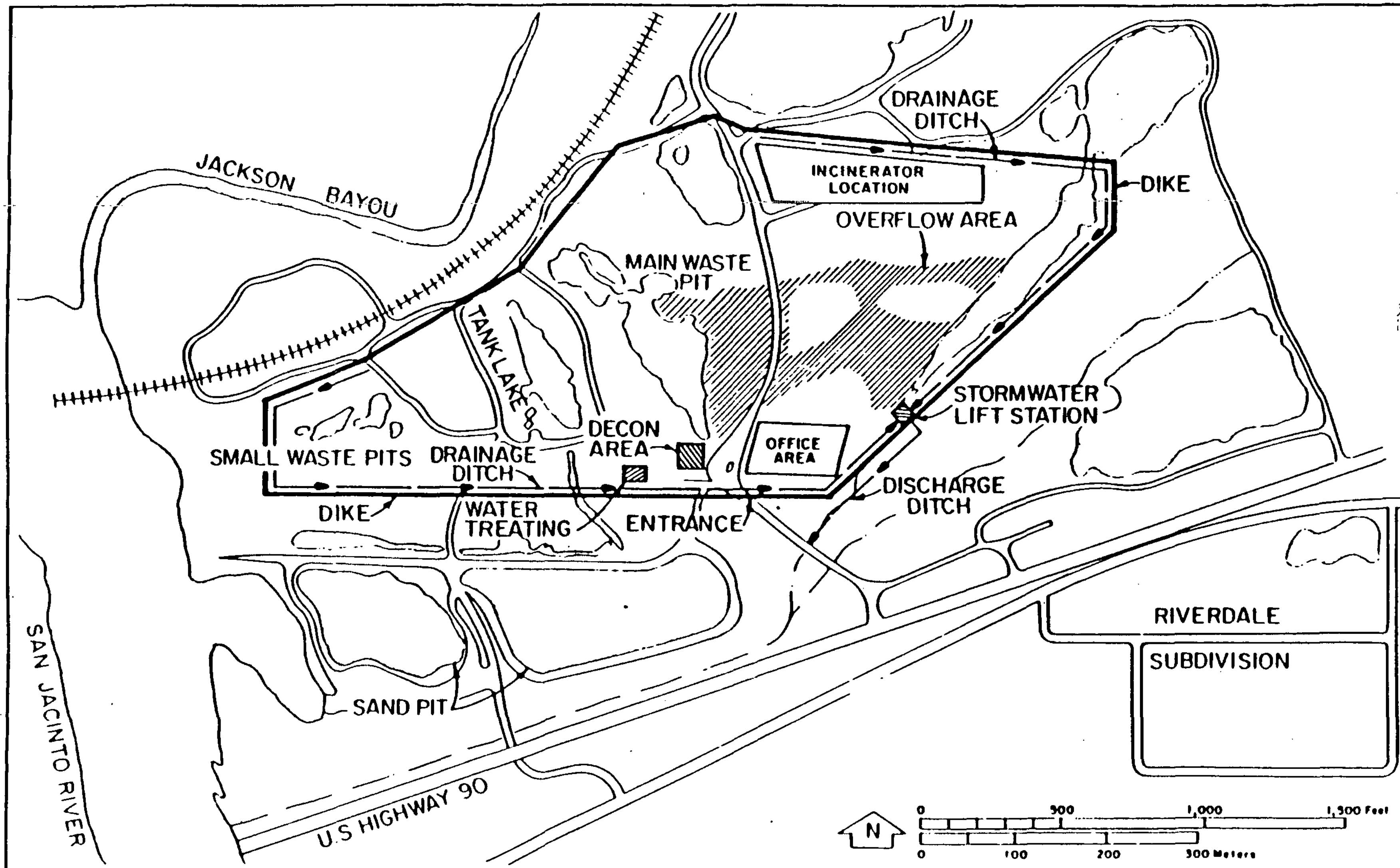

FIGURE 6-4

SITE PLAN FOR ALTERNATIVE 6

SIKES DISPOSAL PITS
CROSBY, TEXAS

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003012

DATE JUNE 1986 PROJECT NO. 1633-20-003-000

003012

tion (85% on-stream time) to complete incineration of the sludges. The ash would be cooled, and fixed if necessary, and used as backfill. Refer to Section 6.3.1.2 for further details on the fixation process.

Following removal of the sludges, the 79,300 cubic yards of contaminated soils would be excavated down to a level of 10 ppm volatile organics. The excavated contaminated soils would equal about 87,200 cubic yards after an estimated expansion of 10%. Contaminated soils would be loaded on trucks licensed to transport hazardous waste on public highways. Transporting contaminated soils would require an estimated 4350 truckloads at 20 cubic yards per load. The waste would be transported to an approved RCRA landfill within a 150 mile radius of the site.

Following removal of sludges and contaminated soils, each pit or depression will be backfilled with fixed ash. With all the site waste either incinerated, moved off-site, or fixed, the threat of a flood causing off-site contamination is essentially eliminated. At this point the dike is no longer needed and can be taken down. It has been assumed that all the dike material will be utilized in backfilling or surface restoration.

Following completion of all remedial actions, the perimeter fence will be repaired as necessary to limit access to the site.

6.3.3.3 Performance Assessment

The incineration of all sludges, and removal and disposal off-site of contaminated soils should be an effective alternative for site remediation. Hazardous constituants would either be destroyed, removed off-site or fixed, providing maximum health and environmental protection once implementation is complete. This should be a permanent solution. Natural restoration of the Upper Aquifer would commence following removal of waste. Maximum protection against contamination of the lower aquifer would result. Only monitoring of groundwater quality would be required as a continuing operational item. As a result, Performance criteria have been rated as follows:

- o Effectiveness ++
- o Useful Life ++

6.3.3.4 Reliability Assessment

This alternative should require little, if any, on-site operation and maintenance of remedial actions after implementation. Sludge incineration is a demonstrated process and fixation of ash is expected to achieve demonstrated performance results. Long-term reliability of remediation would be expected. As a result, Reliability criteria have been rated as follows:

- o Operation and maintenance ++
- o Demonstrated performance ++

6.3.3.5 Engineering Implementability/Constructibility

This alternative would require medium construction efforts. These would include clearing the site, constructing the protective dike, and assembling or constructing the on-site incinerator and its ancillary facilities. The longer term excavation required (up to 3 years) by this alternative would require more complex staging and surface water controls. Remedial actions should be completed within 4 years, controlled by the throughput capacity of the incinerator. Beneficial results should be achieved within 1 year. Implementability criteria were rated:

- o Ease of construction 0
- o Time to implement 0
- o Time to achieve benefit +

6.3.3.6 Public Health and Welfare Assessment

Sludges should be confined and covered during on-site transfers to minimize the release of wind blown solids or air emissions. There is the potential of producing air emissions during surface water treatment, but the impact would be confined to the site. There are no adverse effects indicated after implementation. The risks of failure of this alternative to achieve the goals expected should be very low. The criteria for this assessment has been rated as follows:

- o Safety during installation +
- o Safety upon failure ++

6.3.3.7 Short-Term Environmental Assessment

The short-term site environmental effects from implementing this alternative would be generally limited, controllable, and should be

003015

within acceptable limits. The construction activities would cause a short-term interruption or alteration to wildlife habits, but should not cause disruptions to households or nearby recreational activities. Local sand mining operations could be interrupted but might also be benefited, as some locally produced sands and clays might be used during remedial activities.

Some release of hazardous organic air emissions is expected from surface water treatment, sludge excavation and incinerator upsets. Site workers would be protected and no adverse off-site effects are expected. The potential for carrying contaminants off-site during flood events would be essentially eliminated by the perimeter dike.

There is the potential for release of hazardous waste during transport of the contaminated soils to the off-site disposal facility. This would be minimized by maintaining secure confinement of the waste during transport. Based on the limited and/or controllable impacts indicated, the short-term environmental criteria have been rated as follows:

o Site pollution	o
o Site alterations	+
o Construction debris	+

6.3.3.8 <u>Long-Term Environmental Impact Assessment</u>

The long-term site pollution effects of this alternative would be essentially eliminated since the sludges would be incinerated and contaminated soils removed to off-site disposal, while ash is fixed and used for on-site backfill. By destroying an estimated 94-97% of the hazardous organics on-site through incineration, and removing most of the remainder to off-site, there should be less than 3% of the original organics remaining on-site to cause future problems. As a result, threats to future groundwater contamination from leached organics should be significantly reduced, while the potential for future contamination of the Lower Aquifer should be essentially eliminated. Conditions would be improved for wildlife habitat. Long-term monitoring of the aquifers should cause no significant disruptions to site use. Based on the effects described, long-term environmental impacts have been rated as follows:

- o Site pollution ++
- o Site alterations +

6.3.3.9 Institutional Assessment

This alternative has several institutional considerations relative to its selection. A trial burn of waste is required to demonstrate combustion efficiency. The State of Texas would be responsible for long-term aquifer monitoring and operation and maintenance needs. Land use and future development could be inhibited due to post closure monitoring. All site remedial objectives should be satisfied. All regulatory and Agency requirements should be met. Based on these considerations, this assessment has been rated as follows:

- o Institutional ++

6.3.4 Remedial Alternative 10 - On-Site Incineration of Sludges and Contaminated Soils, Chemical Fixation of Ash

6.3.4.1 Work Components

Work components needed for this alternative in addition to the common components are:

- o Excavation of sludges
- o Excavation of contaminated soils
- o On-site incineration of sludges and contaminated soils
- o Chemical fixation of incinerator ash
- o Backfilling of pits and overflow area

6.3.4.2 Detailed Description

A typical site plan is shown in Figure 6-5. Prior to excavating waste from the main waste pit, Tank Lake or other pits with standing water, the surface water would be pumped off and discharged direct to the San Jacinto River providing water quality meets the established criteria. Otherwise, it would be treated before discharge. Refer to Section 6.3.1.2 for further details concerning the collection and treatment of surface water.

All sludges and contaminated soils would be excavated using appropriate equipment, down to a contamination level of 10 ppm volatile organics. Sludges and contaminated soils would be conveyed to a dewatering, staging pad adjacent to the incinerators. Excavated sludges and contaminated soils are estimated to total 165,200 cubic yards, equivalent to approximately 226,300 tons. Incineration facilities would be constructed on site capable of processing 8 tons per hour of waste. At this feed rate,

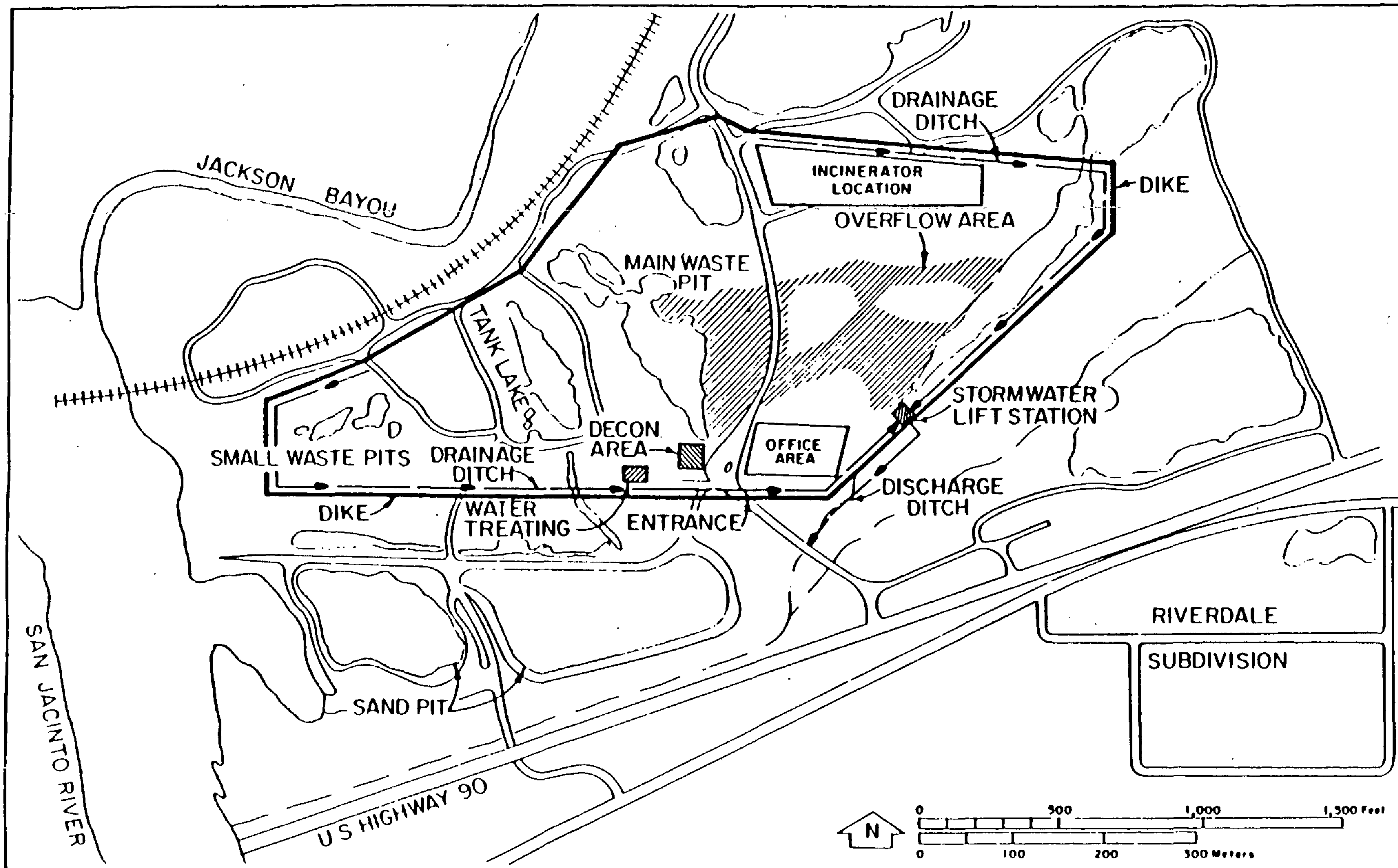

FIGURE 6-5

SITE PLAN FOR ALTERNATIVE 10

SIKES DISPOSAL PITS
CROSBY, TEXAS

Prepared for
TEXAS WATER COMMISSION

003019

DATE JUNE 1986 PROJECT NO 1633-20-003-000

194

003019

it would take approximately 4 years of 24 hour/day operations (85% on-stream time) to complete incineration of the sludges and soils.

The incinerator ash would be cooled, fixed, if necessary, and used as backfill for pits and depressions. Refer to Section 6.3.1.2 for further details on the fixation process.

Following removal of sludges and contaminated soils from the various depositories, each pit or depression will be backfilled with fixed incinerator ash. Dike materials would be used to supplement fixed ash as fill material. Since all the site waste would be incinerated or fixed, the threat of a flood causing off-site contamination would be essentially eliminated. Thus, the dike would no longer be needed and would be removed. It has been assumed that all the dike material would be used for backfilling or surface restoration.

Following completion of all remedial actions, the perimeter fence will be repaired as necessary to limited access to the site.

6.3.4.3 Performance Assessment

The incineration of all contaminated on-site wastes would be an effective alternative for site remediation. Hazardous organic constituents would be destroyed, providing maximum health and environmental protection once implementation is complete. This should be a long-term solution. Natural restoration of the Upper Aquifer would progress as waste was removed. Protection against contamination of the Lower Aquifer would result. Only periodic monitoring of groundwater quality would be required as a continuing operational item. As a result, Performance criteria have been rated as follows:

003021

- o Effectiveness ++
- o Useful Life ++

6.3.4.4 Reliability Assessment

This alternative should require no on-site operation and maintenance of remedial actions after implementation. Incineration has been shown to be a reliable method for the destruction of a wide range of hazardous organic materials. Ash fixation is expected to achieve demonstrated performance results. Long-term reliability of remediation would be expected. Reliability has been rated as follows:

- o Operation and maintenance ++
- o Demonstrated performance ++

6.3.4.5 Engineering Implementability/Constructibility

This alternative would require medium construction efforts. These would include clearing the site, constructing the protective dike and assembling or constructing the on-site incinerator and its ancillary facilities. The long term excavation process (up to 4 years) would require complex staging and surface water controls. Incineration would require approximately 4 years, at a feed rate of 8 tons per hour. For the reasons given, criteria for this assessment have been rated:

- o Ease of construction 0
- o Time to implement 0
- o Time to achieve benefit +

6.3.4.6 Public Health and Welfare Assessment

Excavated sludges should be confined and covered during on-site transfers to minimize the release of wind blown solids or air emissions. There is the potential of producing air emissions during surface water treatment. Any impact, however, would be confined to the site and would not affect surrounding residential areas. There are no adverse effects indicated after implementation. The risks of failure of this alternative to achieve the goals expected should be very low. Ratings for this criteria are:

- o Safety during implementation +
- o Safety upon failure ++

6.3.4.7 Short-Term Environmental Assessment

The short-term environmental effects associated with the implementation of this alternative would be generally limited, controllable, and should be within acceptable limits. The construction activities would cause a short-term interruption or alteration to wildlife habitats, but should not cause disruptions to households or nearby recreational activities. Local sand mining operations could be interrupted but might also be benefited, as some locally produced sands and clays might be used during remedial activities.

003022

Some release of hazardous organic air emissions is expected from sludge excavation, surface water treatment, and incinerator upsets. Site workers would be protected; and no adverse off-site effects are expected. The potential for carrying contaminants off-site during flood events would be essentially eliminated by the perimeter dike. The criteria for this assessment has been rated as follows:

o Site pollution	o
o Site alterations	+
o Construction debris	+

6.3.4.8 Long-Term Environmental Impact Assessment

The long-term site environmental effects of this alternative would be essentially eliminated since the wastes would be incinerated and the ash fixed and used for on-site backfill. By destroying all of the hazardous organics in sludges and contaminated soils through incineration, there would be no hazardous concentrations of organics remaining on-site.

As a result, threats to future groundwater contamination from leaching of organics should be reduced significantly, while the potential for future contamination of the Lower Aquifer should be essentially eliminated. Based on these factors, long-term environmental effects have been rated as follows:

o Site pollution	++
o Site alterations	+

6.3.4.9 Institutional Assessment

Several institutional considerations affect this alternative. A trial burn of waste would be required to demonstrate incinerator combustion efficiency. The State of Texas would be responsible for the long-term aquifer monitoring. Land use and future development could be inhibited due to post closure monitoring. All site remedial objectives should be satisfied. All regulatory and agency requirements would be met. This assessment has been rated as follows:

- o Institutional ++

6.3.5 Remedial Alternative 12 - On-Site Burial of Sludges in Pits with Slurry Walls and Caps, Chemical Fixation of Contaminated Soils

6.3.5.1 Work Components

Work components needed for this alternative in addition to the common components are:

- o Excavation of sludges
- o Stabilization of sludges
- o On-site burial of sludges in pits with slurry walls and caps
- o Excavation of contaminated soils
- o Backfilling of pits and overflow area
- o Chemical fixation of contaminated soils

6.3.5.2 Detailed Description

A typical site plan is shown in Figure 6-6. Prior to excavation or burial of site waste, the surface water would be pumped off and discharged direct to the San Jacinto River, providing water quality meets

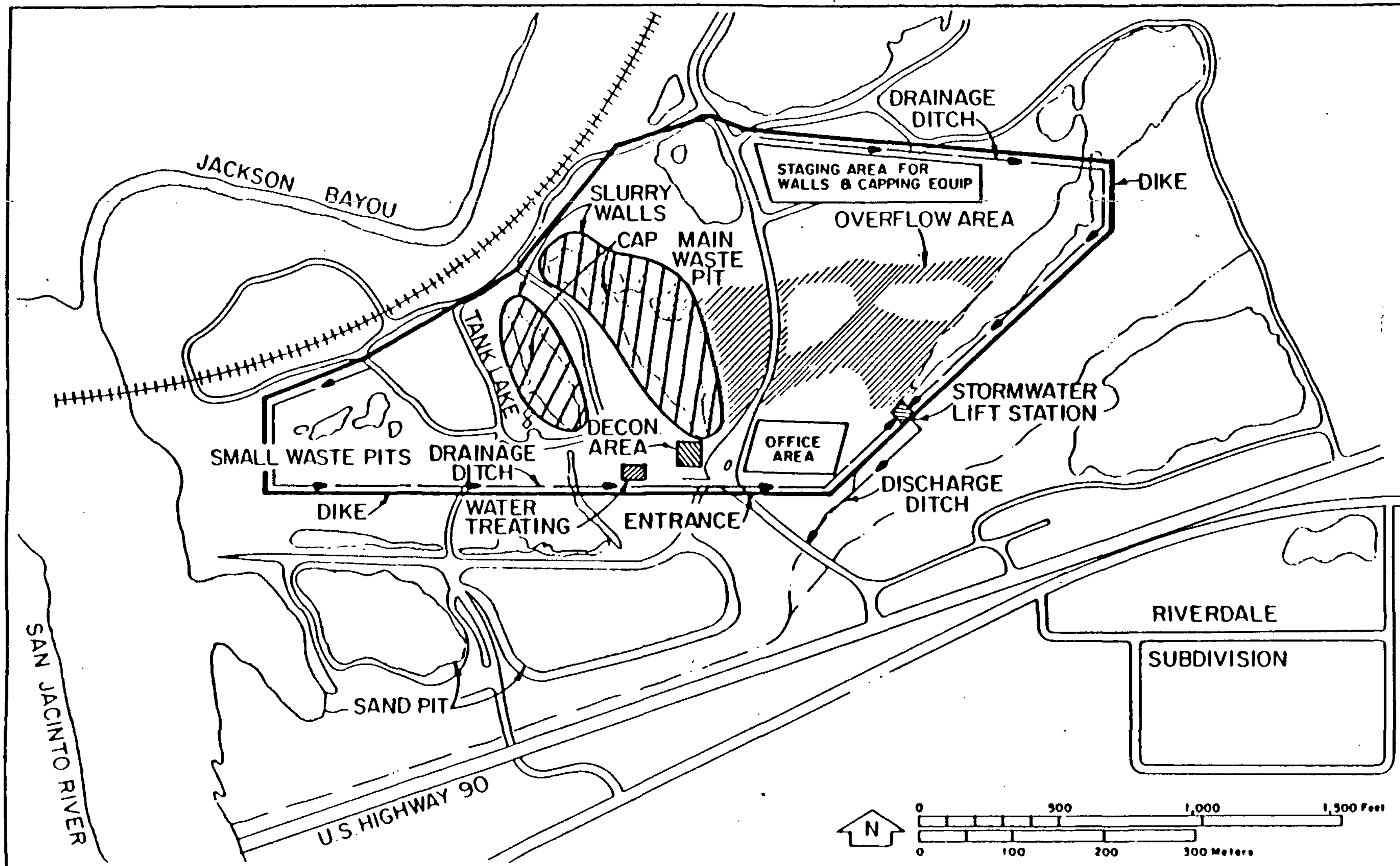

FIGURE 6-6
SITE PLAN FOR ALTERNATIVE 12

SIKES DISPOSAL PITS
CROSBY, TEXAS

Prepared for:
TEXAS WATER COMMISSION

003025

DATE: JUNE 1986 PROJECT NO. 1633-20-003-000

200

003025

the established criteria. Otherwise, it would be treated before discharge. (Refer to Section 6.3.1.2 for further details concerning the collection and treatment of surface water.)

Individual perimeter slurry walls would be placed around Tank Lake and the main waste pit. The walls would be composed of soil-bentonite. Each wall would extend downward three feet into the clay aquiclude which underlies the surficial sands at a depth of 25-30 feet. The walls would be three feet thick and designed to provide an effctive retardant to groundwater flow having a coefficient of permeability less than $1x10^{-7}$ cm/sec. With the slurry walls in place, the sludges and sediments of Tank Lake and the main waste pit would be stabilized in-place. Other site sludges would be excavated down to a contaminant level of 100 ppm PNA and placed in either Tank Lake or the main waste pit. Following the transfer of sludges, these burial pits would be covered with a multi-layer geomembrane and clay cap system. (Details are shown in Appendix C.)

A well system would be installed to withdraw groundwater and/or infiltrated stormwater that collected within the sludge burial pits. This would reduce the potential for leaching hazardous contaminants into the Upper and Lower Aquifers.

The combination slurry walls and geomembrane and clay caps should isolate sludges and prevent direct contact with hazardous materials. Future contaminant migration to shallow groundwater should be effectively controlled, thus providing protection against contamination of the Lower Aquifer.

Contaminated soils excluding Tank Lake and the main waste pit, would be excavated from 100 ppm PNA down to a contamination level of 10 ppm volatile organics. These wastes would be fixed on-site and used for primary backfill in other waste pits and depressions. With all the site contaminants either isolated by the slurry walls and caps or immobilized through fixation, the threat of a flood causing off-site contamination would be essentially eliminated. Thus, at this point, the dike is no longer needed and would be removed. It has been assumed that all the dike material would be utilized in backfilling or surface restoration.

Following completion of all remedial actions, the perimeter fence would be repaired as necessary to limit access to the site.

Long-term, periodic monitoring of groundwater quality would be continued to track Upper Aquifer restoration and Lower Aquifer water quality. Long-term (for 30 years or longer) site inspection and maintenance would be required to check the condition of, and maintain the cap in good condition.

6.3.5.3 Performance Assessment

The capping of the sludge landfill and the enclosure of the sludges within the slurry walls would minimize the release of hazardous materials since future contaminant migration into the Upper Aquifer would be controlled.

Neither the slurry wall nor the cap are expected to be leakproof. This should not produce a problem, however, for the following reasons: The system isolating the sludges from the environment must be capable of controlling the release of contaminants to less than a predetermined amount. The maximum amount is that level of release which will not exceed the maximum concentration of individual contaminants allowed in surface waters, groundwaters or soils by the different standards or criteria applicable to the site. These standards include the (10^{-4} to 10^{-7} range) Human Health Criteria and Drinking Water Standards, Surface Water Quality Criteria, and Direct Contact Criteria. The useful life of this alternative would depend on the quality of the design, quality of the original construction and materials and attention given to maintaining the installation and the liquid level in the sludge pits at a minimum. Since this site is within the 100 year flood plain, and has flooded periodically in the past, the integrity of the cap must be maintained.

Fixation of the contaminated soils should be effective in controlling if not preventing the release of contaminants into groundwater from leaching. Performance criteria has been rated as follows:

- o Effectiveness o
- o Useful Life o

6.3.5.4 Reliability Assessment

This alternative should be capable of functioning with no more than periodic attention to operation and maintenance. The slurry walls should require little if any maintenance, while the geomembrane cap system should require only periodic maintenance since major cap failure is unlikely. Repairs to the cap system could be performed as a part of a scheduled maintenance program. Both the cap system and the slurry wall have performed satisfactorily as waste site closure technologies, and have been applied to other sites where conditions were similar to those at Sikes. The ratings for this criteria are as follows:

- o Operation and maintenance o
- o Demonstrated performance o

6.3.5.5 Engineering Implementability/Constructibility

Extensive construction efforts will be necessary for this alternative. Constructing the slurry walls and installing the geomembrane cap would require considerable effort. Some difficulties would be expected in slurry wall construction, but these should not cause significant delays or result in an inferior installation. The cumulative time to implement this alternative should be 3 years. Some remediation benefits would be attained during the implementation period. Once the slurry walls were constructed and the excavated sludges placed in the pits, the potential for direct contact and/or further leaching into groundwater would be reduced significantly. Implementability criteria have been rated as follows:

- o Ease of construction 0
- o Time to implement +
- o Time to achieve benefit +

6.3.5.6 Public Health and Welfare Assessment

Very little hazardous waste would be disturbed during construction of the slurry wall. Slurry wall construction and capping would require no more than normal hazardous waste safety procedures and should pose no significant threat to off-site areas. Excavated sludges should be confined and covered during on-site transfers to minimize the release of wind blown solids or air emissions. There is the potential of producing air emissions during surface water treatment. Any impact, however, would be confined to the site and would not affect the public or surrounding sand mining activities.

Failure of the slurry wall or cap system, although not expected, would result in a reduced hazard relative to the present site hazards. Public Health and Welfare criteria have been rated as follows:

- o Safety during installation +
- o Safety upon failure 0

6.3.5.7 Short-Term Environmental Assessment

The short-term environmental effects should be limited to the site, controllable, and within acceptable limits. Expected effects are those associated with site preparation and remedial activities. Construction activities would cause short-term alterations and disruptions to wildlife, but should cause no disruptions to households or to nearby recreational activities. Local sand mining operations could be interrupted but might also be benefited, as some locally produced sands and clays might be used during remedial activities. Some release of hazardous organic emissions is expected during waste excavation and surface water treatment. Site workers would be protected and no adverse off-site effects are expected. The potential for moving contaminants off-site during remedial operations from flood events would be essentially eliminated by the perimeter dike. The criteria for this assessment has been rated as follows:

- o Site pollution +
- o Site alterations -
- o Construction debris +

6.3.5.8 Long-Term Environmental Impact Assessment

The long-term environmental effects of this alternative should be minimal as long as the caps and slurry walls remain intact. Active protection of the upper and lower aquifers is addressed through containment of the most concentrated hazardous waste within the slurry walls and fixation of the contaminated soils. Long-term controlled access to the site is required to protect against damage to the caps and to permit long term operations and maintenance.

Long-term environmental criteria have been rated as follows:

- o Site pollution +
- o Site alterations --

6.3.5.9 Institutional Assessment

This alternative will directly remediate both the surface contact and shallow groundwater public health and environmental concerns by isolating or fixing the source materials. The State of Texas would be responsible for long-term monitoring and periodic inspection and maintenance of the cap. Land use and future development would be inhibited due to the site continuing to be classified as a closed hazardous waste facility. This closure would not comply with current RCRA guidance. As a result, this assessment has been rated as follows:

- o Institutional -

6.3.6 Alternative 13 - No Action

The no action alternative would likely include future groundwater monitoring but no remedial activities.

6.3.6.1 Work Components

The site would be fenced to control access. The only work component to be applied is post closure monitoring of both the Upper and Lower Aquifiers.

6.3.6.2 Performance Assessment

The effectiveness of this alternative is very poor, since it allows the site to remain as it is. The alternative cannot be evaluated for useful life since this criterion is not applicable to the no-action alternative. The effectiveness criterion has been rated:

- o Effectiveness -

6.3.6.3 Public Health and Welfare Assessment

This alternative, by its definition, maintains a status quo at the site. Existing threats to Public Health and Welfare remain. These include the potential for human contact with the contaminated sludges, liquids, soils and drummed waste, and inhalation of hazardous vapors. In addition, the upper aquifer waters under the site will continue to be unsuitable for use because of excessive contamination, while the threat of contaminating the Lower Aquifer by Upper Aquifer contaminants remains. The potential for exposing surrounding residents to site contaminants during flood events remains.

6.3.6.4 Long-Term Environmental Assessment

There are no long-term alterations or disruptions resulting from the no-action alternative. This alternative causes significant uncontrollable and unacceptable effects on-site and has been rated:

- o Site pollution --

6.3.6.5 Institutional Assessment

This alternative would have a very poor rating relative to institutional considerations. Future land use and development will be prohibited due to the site continuing to be classified as an uncontrolled hazardous waste site. The rating given is:

- o Institutional --

6.4 SUMMARY EVALUATION OF NON-COST FACTORS

The following non-cost criteria evaluation of alternatives utilizes a standardized approach whereby each of the detailed evaluation criteria is addressed. A detailed description of the rating system is presented in Appendix B. A summary providing a compilation of the ratings for each alternative is given in Table 6-10.

TABLE 6-10

DETAILED NON-COST ALTERNATIVE EVALUATION

EVALUATION CRITERIA		Off-Site RCRA Alternative 3	On-Site Inciner. Alternative 5	On-Site Inciner. Alternative 6	Total On-Site Incin. Alternative 10	Slurry Wall Cap Landfill Alternative 12	No Action Alternative 13
Performance	Effectiveness	+	+	++	++	0	--
	Useful Life	+	+	++	++	0	N/A
Reliability	Operation/Maintenance	+	+	++	++	0	N/A
	Demon. Performance	+	+	++	++	0	N/A
Implementability	Ease of Construction	0	0	0	0	0	N/A
	Time to Implement	+	0	0	0	+	N/A
	Time to Achieve Benefit	+	+	+	+	+	N/A
Public Health and Welfare	Safety During Install.	0	0	+	+	+	N/A
	Safety Upon Failure	+	+	++	++	0	N/A
Environmental - Short Term	Site Pollution	0	0	0	0	+	N/A
	Site Alterations	+	+	+	+	-	N/A
	Construction Debris	+	+	+	+	+	N/A
Environmental - Long Term	Site Pollution	+	+	++	++	+	--
	Site Alterations	+	+	+	+	--	N/A
Institutional	--------------	+	+	++	++	-	--

N/A - Not Applicable

003036

6.5 DETAILED COST ANALYSIS

6.5.1 Introduction

In accordance with the NCP, alternatives which pass initial screening must be technically and economically evaluated to develop the most cost-effective remedial alternative. To perform a detailed cost analysis, the various major components of each alternative must be defined and estimated capital and operating costs determined for each.

Cost estimates presented herein are based on a detailed evaluation of the previously described remedial alternatives. It is normally expected that estimates of this type would be accurate to +50% and -30%. The cost estimates are presented in 1986 dollars. The actual cost of the remedial alternative will depend upon the final scope of the remedial action as designed, the schedule of implementation, competitive market conditions, and other variable factors that may impact the project costs.

6.5.2 Costing Methodology

A detailed cost evaluation of the remedial alternatives consists of the analysis of the capital costs, annual operational and maintenance costs, present worth, and sensitivity analysis.

6.5.3 Sources of Cost Information

The primary sources of information used for developing capital and operation and maintenance costs were:

- Vendor Quotes: Vendors were contacted concerning transportation and disposal costs for wastes of the types at the Sikes site.

- EPA Guidance Manuals: "Handbook for Remedial Action at Waste Disposal Sites," Municipal Environmental Research Laboratory, 1982, a document prepared by the EPA.

- Contractor Cost Estimating Guide: "Means Site Work Cost Data" - 5th edition, 1986, Adjusted for application at hazardous waste sites.

- Cost Estimates for Similar Site Activities: Costs for tasks that require personnel protection during implementation were escalated to reflect reduced working efficiencies under these conditions.

6.5.4 Capital Costs

Capital costs are those costs incurred to construct and implement the remedial alternative. Capital costs include expenditures for equipment, labor, and materials used in the remedial alternative installation, and costs for engineering, financing, permits, contingencies, etc. The criteria utilized to determine what activities constitute capital costs are:

- The cost would be incurred to control contamination at or near the source;

- The activity results in initial reduction of contaminant releases to levels that protect public health or the environment.

- The activity has a definable end-point based on the level of remediation to be achieved.

003038

- The cost associated with the activity is of limited duration.

Table 6-11 presents the categories which compose the total capital costs and presents the percentage estimates utilized. As shown in the table, only the scope contingencies vary among the alternatives. The variation shown represents the relative degree of difficulty and uncertainty in costing the various items of each alternative. These percentages were assumed based on a review of the Contractor Cost Estimating Guide. The scope contingency item was included to cover the scope changes which invariably occur during final design and implementation, since the costing is based on estimates without final design data.

003039

TABLE 6-11

CATEGORIES OF CAPITAL COST
SIKES DISPOSAL PITS SITE

Cost Categories	Alternative 3	Alternative 5, 6, 10	Alternative 12
A. Const. Subtotal	$	$	$
B. Bid Contingencies	15% of A	15% of A	15% of A
C. Scope Contingencies	20% of A	25% of A	25% of A
D. Construction Total (A+B+C)	Subtotal D	Subtotal D	Subtotal D
E. Permitting and Legal	5% of D	5% of D	5% of D
F. Bonding & Insurance	10% of D	10% of D	10% of D
G. Services During Construction	7% of D	7% of D	7% of D
H. Miscellaneous Lab Testing, Community Relations, etc.	5% of D	5% of D	5% of D
I. Total Implementation Cost (D+E+F+G+H)	Subtotal I	Subtotal I	Subtotal I
J. Engineering Design	10% of D	10% of D	10% of D
K. Total Capital Cost (I+J)	Total $	Total $	Total $

6.5.5 Operation and Maintenance Costs

Post implementation operation and maintenance (O&M) costs include the costs required to maintain effectiveness of the remedial alternative following construction and implementation. These estimates are made on an annual basis and include operating labor, post-closure maintenance and monitoring, administrative costs, taxes and insurance, etc. Major O&M costs identified include labor and materials for maintenance such as fence repair, fill replacement, cap repair, etc., and purchased services such as sampling and laboratory analysis for groundwater monitoring programs. The O&M costs do not include a replacement cost for the remedial actions, i.e. caps, slurry walls, etc., after the O&M period.

6.5.6 Present Worth Analysis

A present worth analysis of the alternatives has been conducted to evaluate expenditures that occur over an extended period of time. Present worth allows cost comparison of alternatives based on a single value. This single value, the present worth, represents the amount of money in 1986 dollars needed to cover all the expenditures associated with a remedial action alternative. Calculations for the Sikes Disposal Pits Site were made based on a 10 percent discount rate and zero percent inflation over the various remediation and monitoring periods. The discount rate and period of analysis (30 years maximum) is consistent with the recommendations of "Guidance on Feasibility Studies Under CERCLA." Some alternative costs have been discounted over the remediation period. These costs are shown for each Cost Summary under Implementation O&M, as the annual cost to be expended over the period shown for that Alternative. For example, Alternative 3 (Table 6-12) shows the cost for security as $300,000 capital and $100,000 for O&M. This means that the total implementation capital costs for security is $300,000 which results from an annual cost of $100,000 for 3 years. The present worth value for security at a 10% discount is $284,000.

6.5.7 Detailed Remedial Alternative Costs

Detailed cost estimates for each remedial alternative are presented in Tables 6-12 through 6-17. Present worth total costs for the alternatives are listed below.

Remedial Alternative No.	Total Present Worth Cost ($M)
3	56.4
5	54.2
6	111.7
10	93.3
12	24.8
13	0.4

6.5.8 Sensitivity Analysis

6.5.8.1 Introduction

A sensitivity analysis has been performed to assess the effect that variations in assumptions can have on the estimated costs of the Remedial Alternatives. The accuracy of the estimated quantities of contaminated materials being handled is a major uncertain factor. Overall costs and time for implementation would be significantly affected by quantity changes.

The variable quantity and cost factors selected for sensitivity analysis include the following:

- o volume of contaminated materials
- o off-site disposal costs
- o transportation costs to a RCRA permitted landfill

003042

TABLE 6-12
COST SUMMARY
REMEDIAL ALTERNATIVE 3
OFFSITE RCRA LANDFILLING OF SLUDGES
ONSITE FIXATION OF CONTAMINATED SOILS
SIKES DISPOSAL PITS SITE

ITEM	IMPLEMENTATION CAPITAL	IMPLEMENTATION O & M	POST IMPLEMENTATION O & M	PRESENT WORTH 10%
GENERAL				
Mobilization and Demobilization	$113,000			$113,000
Office Area *	$194,000	$15,000		$192,000
Security *	$300,000	$100,000		$284,000
Health and Safety Program *** -Air Monitoring -Report Generating	$280,000	$40,000		$269,000
Onsite Laboratory *** -Operation and Maintenance Including Technicians	$280,000	$60,000		$264,000
Parking Facility *	$20,000	$2,000		$20,000
SITE PREPARATION				
Road Construction *	$72,000	$5,500		$71,000
Decontamination Facility * -Concrete Pad -Water Storage Tank -Steam Sprayer -Sump	$216,000	$52,000		$208,000
Storm Water Collection Runoff and Disposal ***	$410,000	$20,000		$405,000
Surface Water/Infiltration Water Collection and Treatment ***	$315,000	$70,000		$296,000
Dike Construction	$1,526,000			$1,526,000
Dike Removal	$718,000			$718,000
Fencing and Lighting	$126,000			$126,000
Clearing and Grubbing	$86,000			$86,000
Equipment Area	$198,000			$198,000

003043

TABLE 6-12 CONT.

EXCAVATION AND DISPOSAL				
Excavate Waste from M.W.P., S.W.P. and Barrels	$301,000			$301,000
Excavate Waste from Tank Lake and Suspect Areas	$189,000			$189,000
Excavate Waste from Overflow Area	$637,000			$637,000
Sheet Piling	$379,000			$379,000
Dewatering and Storage	$25,000			$25,000
Fixation of Soil ***	$2,616,000	$1,308,000		$2,270,000
Transport and Dispose Sludge to an Offsite RCRA Landfill ***	$22,600,000	$11,300,000		$19,611,000
Backfill and Revegetate	$461,000			$461,000
GROUNDWATER MONITORING **	$58,000		$41,000	$445,000
CONSTRUCTION SUBTOTALS	$32,120,000		$41,000	$29,094,000
BID CONTINGENCIES (15%)	$4,818,000			$4,818,000
SCOPE CONTINGENCIES (20%)	$6,424,000			$6,424,000
CONSTRUCTION TOTALS	$43,362,000			$40,336,000
PERMITTING AND LEGAL SERVICES DURING CONSTRUCTION (5%)	$2,168,000			$2,168,000
BONDING AND INSURANCE (10%)	$4,336,000			$4,336,000
SERVICES DURING CONSTRUCTION (7%)	$3,035,000			$3,035,000
ADDITIONAL ITEMS (5%)	$2,168,000			$2,168,000
TOTAL IMPLEMENTATION COST	$55,069,000			$52,043,000
ENGINEERING DESIGN COST (10%)	$4,336,000			$4,336,000
TOTAL CAPITAL COST	$59,405,000		$41,000	$56,379,000

* Annual O & M for 3.0 Years
** Annual O & M for 30 Years
*** Annual O & M for 2 Years

003044

TABLE 6-13
COST SUMMARY
REMEDIAL ALTERNATIVE 5
ONSITE INCINERATION OF SLUDGES
ONSITE FIXATION OF CONTAMINATED SOILS AND ASH
SIKES DISPOSAL PITS SITE

ITEM	IMPLEMENTATION CAPITAL	IMPLEMENTATION O & M	POST IMPLEMENTATION O & M	PRESENT WORTH 10%
GENERAL				
Mobilization and Demobilization	$113,000			$113,000
Office Area *	$209,000	$15,000		$201,000
Security *	$400,000	$100,000		$349,000
Environmental Permitting	$300,000			$300,000
Health and Safety Program *** -Air Monitoring -Report Generating	$320,000	$40,000		$299,000
Onsite Laboratory *** -Operation and Maintenance, Including Technicians	$340,000	$60,000		$309,000
Parking Facility *	$22,000	$2,000		$21,000
SITE PREPARATION				
Road Construction *	$77,500	$5,500		$75,000
Decontamination Facility * -Concrete Pad -Water Storage Tank -Steam Sprayer -Sump	$268,000	$52,000		$241,000
Storm Water Collection Runoff and Disposal ***	$430,000	$20,000		$420,000
Surface Water/Infiltration Water Collection and Treatment ***	$385,000	$70,000		$349,000
Dike Construction	$1,526,000			$1,526,000
Dike Removal	$718,000			$718,000
Fencing and Lighting	$126,000			$126,000
Clearing and Grubbing	$86,000			$86,000
Equipment Area	$198,000			$198,000

TABLE 6-13 CONT.

EXCAVATION, INCINERATION AND DISPOSAL				
Excavate Wastes	$1,127,000			$1,127,000
Sheet Piling	$379,000			$379,000
Incinerator: -Mobilization and Demobilization of Onsite Incineration Unit	$1,192,000			$1,192,000
-Construct Drying/Holding Pad ***	$31,000	$2,000		$30,000
-Load Incinerator ***	$846,000	$282,000		$701,000
-Annual Operation and Maint. Costs ***	$16,200,000	$5,400,000		$13,429,000
Dewatering and Storage	$25,000			$25,000
Fixation of Soil ***	$3,069,000	$1,023,000		$2,544,000
Fixation of Incinerator Ash ***	$978,000	$326,000		$811,000
Backfill and Revegetate	$624,000			$624,000
GROUNDWATER MONITORING **	$58,000		$41,000	$445,000
CONSTRUCTION SUBTOTALS	$30,047,500		$41,000	$26,638,000
BID CONTINGENCIES (15%)	$4,507,000			$4,507,000
SCOPE CONTINGENCIES (25%)	$7,512,000			$7,512,000
CONSTRUCTION TOTALS	$42,067,000			$38,657,000
PERMITTING AND LEGAL SERVICES DURING CONSTRUCTION (5%)	$2,103,000			$2,103,000
BONDING AND INSURANCE (10%)	$4,207,000			$4,207,000
SERVICES DURING CONSTRUCTION (7%)	$2,945,000			$2,945,000
ADDITIONAL ITEMS (5%)	$2,103,000			$2,103,000
TOTAL IMPLEMENTATION COST	$53,425,000			$50,015,000
ENGINEERING DESIGN COST (10%)	$4,207,000			$4,207,000
TOTAL CAPITAL COST	$57,632,000		$41,000	$54,222,000

* Annual O & M for 4.0 Years
** Annual O & M for 30 Years
*** Annual O & M for 3 Years

TABLE 6-14
COST SUMMARY
REMEDIAL ALTERNATIVE 6
ONSITE INCINERATION OF SLUDGES
OFFSITE RCRA LANDFILLING OF
CONTAMINATED SOILS,ONSITE FIXATION OF ASH
SIKES DISPOSAL PITS SITE

ITEM	IMPLEMENTATION CAPITAL	IMPLEMENTATION O & M	POST IMPLEMENTATION O & M	PRESENT WORTH 10%
GENERAL				
Mobilization and Demobilization	$113,000			$113,000
Office Area *	$209,000	$15,000		$201,000
Security *	$400,000	$100,000		$349,000
Environmental Permitting	$300,000			$300,000
Health and Safety Program *** -Air Monitoring -Report Generating	$320,000	$40,000		$299,000
Onsite Laboratory *** -Operation and Maintenance, Including Technicians	$340,000	$60,000		$309,000
Parking Facility *	$22,000	$2,000		$21,000
SITE PREPARATION				
Road Construction *	$77,500	$5,500		$75,000
Decontamination Facility * -Concrete Pad -Water Storage Tank -Steam Sprayer -Sump	$268,000	$52,000		$241,000
Storm Water Collection Runoff and Disposal ***	$430,000	$20,000		$420,000
Surface Water/Infiltration Water *** Collection and Treatment	$385,000	$70,000		$349,000
Dike Construction	$1,526,000			$1,526,000
Dike Removal	$718,000			$718,000
Fencing and Lighting	$126,000			$126,000
Clearing and Grubbing	$86,000			$86,000

003047

TABLE 6-14 CONT.

Equipment Area	$198,000			$198,000
EXCAVATION, INCINERATION AND DISPOSAL				
Excavate Wastes	$1,127,000			$1,127,000
Sheet Piling	$379,000			$379,000
Incinerator: -Mobilization and Demobilization of Onsite Incineration Unit	$1,192,000			$1,192,000
-Construct Drying/Holding Pad ***	$31,000	$2,000		$30,000
-Load Incinerator ***	$846,000	$282,000		$701,000
-Annual Operation and Maint. Costs ***	$16,200,000	$5,400,000		$13,429,000
Dewatering and Storage	$25,000			$25,000
Fixation of Incinerator Ash ***	$978,000	$326,000		$811,000
Transport and Dispose Soil to an Offsite RCRA Landfill ***	$36,450,000	$12,150,000		$30,216,000
Backfill and Revegetate	$188,000			$188,000
GROUNDWATER MONITORING **	$58,000		$41,000	$445,000
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CONSTRUCTION SUBTOTALS	$62,993,000		$41,000	$53,874,000
BID CONTINGENCIES (15%)	$9,449,000			$9,449,000
SCOPE CONTINGENCIES (25%)	$15,748,000			$15,748,000
	----------			----------
CONSTRUCTION TOTALS	$88,190,000			$79,071,000
PERMITTING AND LEGAL SERVICES DURING CONSTRUCTION (5%)	$4,410,000			$4,410,000
BONDING AND INSURANCE (10%)	$8,819,000			$8,819,000
SERVICES DURING CONSTRUCTION (7%)	$6,173,000			$6,173,000
ADDITIONAL ITEMS (5%)	$4,410,000			$4,410,000
TOTAL IMPLEMENTATION COST	$112,002,000			$102,883,000
ENGINEERING DESIGN COST (10%)	$8,819,000			$8,819,000
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TOTAL CAPITAL COST	$120,821,000		$41,000	$111,702,000

* Annual O & M for 4.0 Years
** Annual O & M for 30 Years
*** Annual O & M for 3 Years

003047

003048

TABLE 6-15
COST SUMMARY
REMEDIAL ALTERNATIVE 10
ONSITE INCINERATION OF SLUDGES AND
CONTAMINATED SOILS,FIXATION OF ASH
SIKES DISPOSAL PITS SITE

ITEM	IMPLEMENTATION CAPITAL	IMPLEMENTATION O & M	POST IMPLEMENTATION O & M	PRESENT WORTH 10%
GENERAL				
Mobilization and Demobilization	$113,000			$113,000
Office Area *	$224,000	$15,000		$210,000
Security *	$500,000	$100,000		$408,000
Environmental Permitting	$300,000			$300,000
Health and Safety Program *** -Air Monitoring -Report Generating	$360,000	$40,000		$363,000
Onsite Laboratory *** -Operation and Maintenance, -Including Technicians	$400,000	$60,000		$350,000
Parking Facility *	$24,000	$2,000		$22,000
SITE PREPARATION				
Road Construction *	$83,000	$5,500		$78,000
Decontamination Facility *** -Concrete Pad -Water Storage Tank -Steam Sprayer -Sump	$77,000	$13,000		$66,000
Storm Water Collection Runoff and Disposal ***	$450,000	$20,000		$433,000
Surface Water/Infiltration Water Collection and Treatment ***	$455,000	$70,000		$397,000
Dike Construction	$1,526,000			$1,526,000
Dike Removal	$718,000			$718,000
Fencing and Lighting	$126,000			$126,000
Clearing and Grubbing	$86,000			$86,000
Equipment Area	$198,000			$198,000

003049

TABLE 6-15 CONT.

EXCAVATION, INCINERATION AND DISPOSAL				
Excavate Wastes	$1,127,000			$1,127,000
Sheet Piling	$379,000			$379,000
Incinerator:				
-Mobilization and Demobilization of Onsite Incineration Unit	$1,825,000			$1,825,000
-Construct Drying/Holding Pad ***	$66,000	$4,000		$63,000
-Load Incinerator ***	$1,112,000	$278,000		$881,000
-Annual Operation and Maint. Costs ***	$38,880,000	$9,720,000		$30,811,000
Dewatering and Storage	$25,000			$25,000
Fixation of Incinerator Ash ***	$3,596,000	$899,000		$2,850,000
Backfill and Revegetate	$585,000			$585,000
GROUNDWATER MONITORING **	$58,000		$41,000	$445,000
CONSTRUCTION SUBTOTALS	$53,293,000		$41,000	$44,385,000
BID CONTINGENCIES (15%)	$7,994,000			$7,994,000
SCOPE CONTINGENCIES (25%)	$13,323,000			$13,323,000
CONSTRUCTION TOTALS	$74,610,000			$65,702,000
PERMITTING AND LEGAL SERVICES DURING CONSTRUCTION (5%)	$3,731,000			$3,731,000
BONDING AND INSURANCE (10%)	$7,461,000			$7,461,000
SERVICES DURING CONSTRUCTION (7%)	$5,223,000			$5,223,000
ADDITIONAL ITEMS (5%)	$3,731,000			$3,731,000
TOTAL IMPLEMENTATION COST	$94,756,000			$85,848,000
ENGINEERING DESIGN COST (10%)	$7,461,000			$7,461,000
TOTAL CAPITAL COST	$102,217,000		$41,000	$93,309,000

* Annual O & M for 5.0 Years
** Annual O & M for 30 Years
*** Annual O & M for 4 Years

003050

TABLE 6-16
COST SUMMARY
REMEDIAL ALTERNATIVE 12
ONSITE BURIAL OF SLUDGES IN PITS
WITH SLURRY WALLS AND CAPS
ONSITE FIXATION OF CONTAMINATED SOILS
SIKES DISPOSAL PITS SITE

ITEM	IMPLEMENTATION CAPITAL	IMPLEMENTATION O & M	POST IMPLEMENTATION O & M	PRESENT WORTH 10%
GENERAL				
Mobilization and Demobilization	$24,000			$24,000
Office Area *	$194,000	$15,000		$192,000
Security *	$300,000	$100,000		$284,000
Health and Safety Program *** -Air Monitoring -Report Generating	$280,000	$40,000		$269,000
Onsite Laboratory *** -Operation and Maintenance, Including Technicians	$280,000	$60,000		$264,000
Parking Facility *	$20,000	$2,000		$20,000
SITE PREPARATION				
Road Construction *	$72,000	$5,500		$71,000
Decontamination Facility * -Concrete Pad -Water Storage Tank -Steam Sprayer -Sump	$216,000	$52,000		$203,000
Storm Water Collection Runoff and Disposal ***	$410,000	$20,000		$405,000
Surface Water/Infiltration Water Collection and Treatment ***	$315,000	$70,000		$296,000
Dike Construction	$1,526,000			$1,526,000
Dike Removal	$718,000			$718,000
Fencing and Lighting	$126,000			$126,000

003050

003051

TABLE 6-16 CONT.

Clearing and Grubbing	$86,000			$86,000
Equipment Area	$198,000			$198,000
Prepared Unclassified Soil Borrow Area	$60,000			$60,000
EXCAVATION AND DISPOSAL				
Excavate Waste from Small Waste Pit, and Suspect Areas and Barrels	$125,000			$125,000
Excav. Waste from Overflow Area	$637,000			$637,000
Stabilize Sludges	$2,337,000			$2,337,000
Sheet Piling	$145,000			$145,000
Dewatering and Storage	$13,000			$13,000
Fixation of Soil ***	$1,924,000	$962,000		$1,670,000
Backfill and Revegetate	$317,000			$317,000
VERTICAL CONTAINMENT				
Soil /Bentonite Slurry Wall	$960,000			$960,000
CAPPING				
Prepare Clay Borrow Area Compacted Clay Cap (24 in.) HDPE Membrane (40 mil) Sand Drainage Layer (6 in.) Filter Fabric Layer Topsoil (18 in.) Erosion Control Mat ** Vegetation **	$967,000		$25,000	$1,203,000
LEACHATE WITHDRAWAL **	$50,000		$40,000	$427,000
PASSIVE GAS VENTS **	$75,000		$35,000	$405,000
GROUNDWATER MONITORING **	$58,000		$41,000	$445,000

003052

TABLE 6-16 CONT.

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CONSTRUCTION SUBTOTALS	$12,433,000	$141,000	$13,426,000
BID CONTINGENCIES (15%)	$1,865,000		$1,865,000
SCOPE CONTINGENCIES (25%)	$3,108,000		$3,108,000
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CONSTRUCTION TOTALS	$17,406,000		$18,399,000
PERMITTING AND LEGAL SERVICES DURING CONSTRUCTION (5%)	$870,000		$870,000
BONDING AND INSURANCE (10%)	$1,741,000		$1,741,000
SERVICES DURING CONSTRUCTION (7%)	$1,218,000		$1,218,000
ADDITIONAL ITEMS (5%)	$870,000		$870,000
TOTAL IMPLEMENTATION COST	$22,105,000		$23,098,000
ENGINEERING DESIGN COST (10%)	$1,741,000		$1,741,000
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TOTAL CAPITAL COST	$23,846,000	$141,000	$24,839,000

* Annual O & M for 3.0 Years
** Annual O & M for 30 Years
*** Annual O & M for 2 Years

003053

TABLE 6-17
COST SUMMARY
REMEDIAL ALTERNATIVE 13
NO ACTION
SIKES DISPOSAL PITS SITE

ITEM	IMPLEMENTATION CAPITAL	IMPLEMENTATION O & M	POST IMPLEMENTATION O & M	PRESENT WORTH 10%
GENERAL				
GROUNDWATER MONITORING *	$58,000		$41,000	$445,000

* Annual O & M for 30 Years

003054

- o Incineration costs
- o discount rates

6.5.8.2 Volume of Contaminated Material

The present worth costs for each of the Remedial Alternatives based on a -25% volume reduction and a +25% volume addition to the present estimated quantities of materials are shown in Table 6-18. The present worth costs for Remedial Alternative 12 in the case of the 25% volume addition reflects the addition of a new disposal area with a slurry wall and cap.

TABLE 6-18

SENSITIVITY TO VOLUME OF CONTAMINATED MATERIALS
SIKES DISPOSAL PITS SITE

	Remedial Alternative	Present Worth Costs ($ Millions) -25%	Base	+25%
3	Off-site RCRA Landfilling of Sludges, On-Site Fixation of Contaminated Soils	49.6	56.4	62.5
5	On-site Incineration of Sludges, Fixation of Contaminated Soils and Ash	48.6	54.2	59.1
6	On-site Incineration of Sludges, Off-site RCRA Landfilling of Contaminated Soils, On-Site Fixation of Ash	98.0	111.7	123.6
10	On-Site Incineration of Sludges and Contaminated Soils, Fixation of Ash	82.4	93.3	102.3
12	On-Site Burial of Sludges in Pits with Slurry Walls and Caps, Fixation of Contaminated Soils	23.6	24.8	28.1*
13	No action	0.4	0.4	0.4

* An increase in quantities over the present estimate would require construction of an additional disposal area with slurry wall and cap.

6.5.8.3 Off-Site Disposal Costs

The impact on present worth costs of escalating costs at a RCRA permitted commercial landfill facility by increments of $50 and $100 per ton is shown in Table 6-19.

003057

TABLE 6-19

SENSITIVITY TO OFF-SITE RCRA DISPOSAL COSTS
SIKES DISPOSAL PITS SITE

	Remedial Alternative	Present Worth Costs ($ Millions)		
	Disposal Costs per Ton	(Base) $200	$250	$300
3	Off-Site RCRA Landfilling of Sludges, On-Site Fixation of Contaminated Soils	56.4	60.8	65.6
5	On-Site Incineration of Sludges, Fixation of Contaminated Soils and Ash	54.2	54.2	54.2
6	On-Site Incineration of Sludges, Off-Site RCRA Landfilling of Contaminated Soils, On-Site Fixation of Ash	117.7	118.5	126.2
10	On-Site Incineration of Sludes and Contaminated Soils, Fixation of Ash	93.3	93.3	93.3
12	On-Site Burial of Sludges in Pits with Slurry Walls and Caps, Fixation of Contaminated Soils	24.8	24.8	24.8
13	No Action	0.4	0.4	0.4

003058

6.5.8.4 Transportation Costs to a RCRA Facility

The effect on present worth costs of transportation distance to an approved RCRA landfill is shown in Table 6-20. This analysis is based on the distance to several currently available commercial hazardous waste landfills.

TABLE 6-20

SENSITIVITY TO TRANSPORTATION COST TO A RCRA LANDFILL
SIKES DISPOSAL PITS SITE

	Remedial Alternative	Present Worth Costs ($ Millions)		
	Mileage to Disposal Site (One Way)	(Base) 150 (1)	450 (2)	750 (3)
3	Off-Site RCRA Landfilling of Sludges, On-Site Fixation of Contaminated Soils	56.4	67.5	78.9
5	On-Site Incineration of Sludges, Fixation of Contaminated Soils and Ash	54.2	54.2	54.2
6	On-Site Incineration of Sludges, Off-Site RCRA Landfilling of Contaminated Soils, On-Site Fixation of Ash	117.7	129.3	147.8
10	On-Site Incineration of Sludges and Contaminated Soils, Fixation of Ash	93.3	93.3	93.3
12	On-Site Burial of Sludges in Pits with Slurry Walls and Caps, Fixation of Contaminated Soils	24.8	24.8	24.8
13	No Action	0.4	0.4	0.4

(1) All wastes to Carlyss, Louisiana

(2) 1/2 wastes to Carlyss, Lousiana, 1/2 wastes to Emelle, Alabama

(3) All wastes to Emelle, Alabama

003060

6.5.8.5 Incineration Costs

The effect of increased unit costs for on-site incineration is shown in Table 6-21. The incremental increase in unit costs represents a 25% and 50% increase, respectively, for Alternatives 5 and 6.

003061

TABLE 6-21

SENSITIVITY TO INCINERATION COSTS
SIKES DISPOSAL PITS SITE

	Remedial Alternative	Present Worth Costs ($ Millions)		
	Incineration Costs per Ton	(Base) $188 (1) $172 (2)	$235	$282
3	Off-Site RCRA Landfilling of Sludges, On-Site Fixation of Contaminated Soils	56.4	56.4	56.4
5	On-Site Incineration of Sludges, Fixation of Contaminated Soils and Ash	54.2	56.6	59.6
6	On-Site Incineration of Sludges, Off-Site RCRA Landfilling of Contaminated Soils, On-Site Fixation of Ash	117.7	113.5	116.5
10	On-Site Incineration of Sludges and Contaminated Soils, Fixation of Ash	93.3	99.3	107.3
12	On-Site Burial of Sludges in Pits with Slurry Walls and Caps, Fixation of Contaminated Soils	24.8	24.8	24.8
13	No Action	0.4	0.4	0.4

(1) Base Unit Cost for Alternate 5 and 6.

(2) Base Unit Cost for Alternate 10.

6.5.8.6 Discount Rates

Unknown future economic conditions may have a significant impact on the present worth of a remedial alternative. Because of this, a sensitivity analysis was performed using various discount rates.

Table 6-22 presents the present worth costs for discount rates of 4%, 7% and 10%.

003063

TABLE 6-22

SENSITIVITY TO DISCOUNT RATES
SIKES DISPOSAL PITS SITE

	Remedial Alternative	Present Worth ($ Millions)		
	Discount Rate	4%	7%	10%
3	Offsite RCRA Landfilling of Sludges, On-Site Fixation of Contaminated Soils	59.9	58.6	56.4
5	On-Site Incineration of Sludges, Fixation of Contaminated Soils and Ash	57.9	56.5	54.2
6	On-Site Incineration of Sludges, Off-Site RCRA Landfilling of Contaminated Soils, On-Site Fixation of Ash	120.9	117.8	111.7
10	On-Site Incineration of Sludges and Contaminated Soils, Fixation of Ash	100.9	97.9	93.3
12	On-Site Burial of Sludges in Pits with Slurry Walls and Caps, Fixation of Contaminated Soils	26.6	25.8	24.8
13	No Action	0.7	0.5	0.4

6.5.8.7 Summary of Sensitivity Analysis

The sensitivity of present worth costs to each of the variables evaluated is shown in Table 6-23. A three-level tier system has been used, reflecting increasing degree of sensitivity. The levels are identified as: non-sensitive (non), moderately sensitive (mod) and very sensitive (very).

TABLE 6-23

SUMMARY OF SENSITIVITY ANALYSIS
SIKES DISPOSAL PITS SITE

Remedial Alternative	Sensitivity Factor: Volume of Cont. Mat.	Off-Site Disp. Costs	Transport Costs	Discount Rate	Incin. Costs
3 Off-Site RCRA Landfilling of Sludges, On-Site Fixation of Contaminated Soils	Very	Very	Very	Mod	Non
5 On-Site Incineration of Sludges, Fixation of Contaminated Soils and Ash	Very	Non	Non	Mod	Mod
6 On-Site Incineration of Sludges, Off-Site RCRA Landfilling of Contaminated Soils, On-Site Fixation of Ash	Very	Mod	Very	Very	Non
10 On-Site Incineration of Sludges and Contaminated Soils, Fixation of Ash	Very	Non	Non	Very	Very
12 On-Site Burial of Sludges in Pits with Slurry Walls and Caps, Fixation of Contaminated Soils	Very	Non	Non	Very	Non
13 No Action	Non	Non	Non	Non	Non

Non - Non sensitive - less than 7% change
Mod - Moderately sensitive - 7-14% change
Very - Very sensitive - greater than 14% change

6.6 SUMMARY OF DETAILED EVALUATION OF REMEDIAL ALTERNATIVES

6.6.1 Overview of Detailed Evaluation

A summary of the results of the detailed technology, public health, environmental and cost criteria evaluation is presented in Section 6.6. The primary purpose of this summary is to provide concise but relevant information for comparing alternatives. From this comparative analysis, the most cost-effective remedial alternative would be chosen by the EPA for implementation. The summary presentation includes the following:

- A brief description of the alternative
- A summary of alternative costs
- A summary of the technical feasibility evaluation
- A summary of public health and environmental effects
- A summary of detailed evaluation of remedial alternatives

As specified in 40 CFR 300.68(f), the feasibility study must examine and present at least one alternative in each of the following categories:

A. Alternatives for treatment or disposal at an off-site facility approved by EPA,

B. Alternatives which attain applicable and relevant Federal public health or environmental requirements,

C. Alternatives which exceed applicable or relevant Federal public health or environmental requirements,

D. Alternatives which do not attain applicable or relevant public health or environmental requirements, but will reduce the likelihood of present or future threats from the hazardous substances and that provide significant protection to public health and welfare and the environment; and

E. No action

An alternative was evaluated in detail in each of the above categories except Category C. Remedial Alternative 9, an original Category C Alternative, failed to satisfy the initial screening criteria and was not evaluated in detail. However, it is presented for comparison purposes only.

6.6.2 Brief Description of Remedial Alternatives

The remedial alternatives developed to satisfy the remedial objectives were screened and evaluated in detail. A brief description of each remedial alternative follows.

6.6.2.1 Remedial Alternative 3 - Off-Site RCRA Landfilling of Sludges and On-Site Chemical Fixation of Contaminated Soils

This alternative includes the excavation of all sludges and contaminated soils to criteria levels. The sludges would be trucked off-site to an EPA approved RCRA landfill. The contaminated soils would be chemically fixed with a cement based agent and utilized as backfill on-site. Use of the contaminated Upper Aquifer would be banned until restored to drinking water quality through natural flushing. Both the Upper and Lower Aquifers would be monitored following the completion of remedial action and continued for up to 30 years if needed.

To accomplish these operations, several supporting work tasks (referred to as common components) must be accomplished. These include a perimeter fence, a temporary dike around the waste areas to protect against a 100-year flood, a stormwater run-on and run-off collection/disposal system and a pit surface water/infiltration water collection and treatment system. These components are common for all alternatives, and will not be repeated under each alternative description.

6.6.2.2 Remedial Alternative 5 - On-Site Incineration of Sludges, Chemical Fixation of Contaminated Soils and Ash

For this alternative, the sludges and contaminated soils would be excavated to criteria levels. The sludge organics would be destroyed by on-site incineration while the ash and contaminated soils would be chemically fixed with a cement based agent and utilized as backfill on-site.

The contaminated Upper Aquifer would be banned until restored to drinking water quality through natural flushing. Both the Upper and Lower Aquifers would be monitored for up to 30 years following the completion of remedial action.

6.6.2.3 Remedial Alternative 6 - On-Site Incineration of Sludges and Off-Site RCRA Landfilling of Contaminated Soils, On-Site Chemical Fixation of Ash

This alternative includes the excavation of sludges and contaminated soils to criteria levels. Sludges would be incinerated on-site; contaminated soils would be trucked off-site for disposal at an approved RCRA landfill. Incinerator ash would be chemically fixed on-site using a cement based agent. The resulting solid would be used as backfill. The contaminated Upper Aquifer would be banned until restored to drinking water quality through natural flushing. Both the Upper and Lower Aquifers would be monitored for up to 30 years following the completion of remedial action.

6.6.2.4 Remedial Alternative 9 - On-Site Incineration of Sludges, Off-Site RCRA Landfilling of Contaminated Soils and Ash

This alternative would incinerate all sludges on-site. Contaminated soils would be excavated to background criteria, combined with ash and transported off-site for disposal in a RCRA approved landfill. The Upper Aquifer would be restored to background water quality through natural flushing. Because of the additional waste quantity that must be removed, the estimated cost for this alternative was considered excessive and without compensating value, so it was screened out in the initial screening process.

This was the only alternative developed that would achieve better than applicable or relevant and appropriate Federal public health and environmental requirements. Since this alternative was not evaluated in detail, it is presented here for comparison only.

6.6.2.5 Remedial Alternative 10 - On-Site Incineration of Sludges and Contaminated Soils, Chemical Fixation of Ash

For this alternative, the sludges and contaminated soils would be excavated to criteria levels, combined and incinerated on-site. Ash would be chemically fixed on-site using a cement based agent and the solids produced would be used as backfill. Use of contaminated Upper Aquifer waters would be banned until the aquifer was restored to drinking water quality through natural flushing. Both the Upper and Lower

Aquifers would be monitored for up to 30 years following the completion of remedial action.

6.6.2.6 Remedial Alternative 12 - On-Site Burial of Sludges in Pits with Slurry Walls and Caps, Chemical Fixation of Contaminated Soils

This alternative involves dewatering of the main waste pit and Tank Lake. Sludges would be excavated to criteria level and placed in these two pits. Prior to dewatering and excavation, a slurry wall would be placed around both pits and tied into the upper aquitard. Following transfer of sludges into these pits, a geomembrane and clay cap would be placed over each pit and tied into the slurry walls. Contaminated soils would be excavated, chemically fixed and the solids utilized for on-site backfill. Use of the contaminated Upper Aquifer waters would be banned until the aquifer was restored to drinking water quality through natural flushing. Both the Upper and Lower Aquifers would be monitored for up to 30 years following the completion of remedial action.

6.6.2.7 Remedial Alternative 13 - No Action

This alternative includes no remedial action. The site would remain in its present state which has been determined to present potential increased health risks to the surrounding public and adverse environmental risks to users of the site.

Periodic monitoring of the Upper and Lower Aquifers would be ongoing to detect changes in Upper Aquifer contamination and areal extent, and in Lower Aquifer water quality.

6.6.3 Summary of Remedial Alternative Costs

A summary of present worth costs for implementing the Remedial Alternatives is given in Table 6-24. Detailed costs are given in Section 6.5.7.

TABLE 6-24

SUMMARY OF PRESENT WORTH COSTS FOR REMEDIAL ALTERNATIVES
SIKES DISPOSAL PITS SITE

	Remedial Alternatives	Present Worth Cost ($ MILLION)		
		Implementation Costs	Post-Closure Costs	Total Costs
3	Off-Site RCRA Landfilling of Sludges, On-Site Fixation of Contaminated Soils	56.0	0.4	56.4
5	On-Site Incineration of Sludges, Fixation of Contaminated Soils and Ash	53.8	0.4	54.2
6	On-Site Incineration of Sludges, Off-Site RCRA Landfilling of Contaminated Soils, On-Site Fixation of Ash	111.3	0.4	111.7
10	On-Site Incineration of Sludges and Contaminated Soils, Fixation of Ash	92.9	0.4	93.3
12	On-Site Burial of Sludges in Pits with Slurry Walls and Caps. Fixation of Contaminated Soils	23.4	1.4	24.8
13	No Action	---	0.4	0.4
*9	On-Site Incineration of Sludges. Off-Site RCRA Landfilling of Contaminated Soils and Ash	135.6	0.4	136.0

* This alternative eliminated in initial screening. Remedial action would achieve better than applicable or relevant standards. This is the relative cost estimate developed for the initial screening, and is not representative of the detailed costs developed for the other alternatives in Table 6-24.

6.6.4 Summary of Technical Feasibility Evaluation

Pertinent points from the technical evaluation of each alternative for performance, reliability, and accepted engineering practices are summarized in Table 6-25. Remedial Alternatives 6 and 10 represent demonstrated technologies. Remedial Alternatives 3 and 5 include demonstrated technologies for disposing of the sludges, the material containing over 94% of the hazardous organic contaminants on-site. If fixation of contaminated soils is effective as expected, then Remedial Alternatives 3 and 5 would compare closely to Remedial Alternatives 6 and 10 in effectiveness.

Remedial Alternative 12 depends on the slurry wall-geomembrane cap combination technologies that are relatively new. As a result, this technology would be considered somewhat less reliable than incineration or RCRA landfilling for disposing of sludges. Since the physical condition of the sludges is not altered under this alternative, the sludges would have the potential to become environmental contaminants in the future if the encapsulation system becomes ineffective.

Estimated implementation times for remedial actions range from 3 to 5 years. Remedial Alternatives 3 and 12 would require the least time (3 years) for implementation. On-site incineration of all wastes (Remedial Alternative 10) would require the longest time. The minimum time estimated for implementing remedial actions is 3 years, which includes the time to construct and remove the perimeter dike (1 year) plus the time needed for excavating waste (2 years). The implementation time for the incineration alternatives could be reduced by approximately one year as a

TABLE 6-25

SUMMARY OF TECHNICAL FEASIBILITY EVALUATION
SIKES DISPOSAL PITS SITE

Remedial Alternative	Effectiveness	Useful Life	Operation and Maintenance Requirements	Possible Failure Modes	Site Conditions	Time to Implement
3 - Off-Site RCRA Landfilling of Sludges, On-Site Fixation of Contaminated Soils.	Demonstrated technology if fixation is effective.	Estimated at 10+ years, limited by effectiveness of fixation.	Groundwater Monitoring. Security Inspections.	Leaching of fixed contaminated soils.	Suitable landfills available. Suitable fixation equipment and materials available.	3 years
5 - On-Site Incineration of Sludges, Fixation of Contaminated Soils and Ash.	Demonstrated technology if fixation is effective.	Estimated at 10+ years, limited by effectiveness of fixation.	Groundwater Monitoring. Security Inspections.	Leaching of fixed contaminated soils.	Assumes incinerator is available for on-site operation and fixation equipment and materials are available.	4 years
6 - On-Site Incineration of Sludges, Off-Site RCRA Landfilling of Contaminated Soils, Fixation of Ash.	Demonstrated technology.	Estimated at 30+ years.	Groundwater Monitoring. Security Inspections.	None indicated.	Assumes incinerator is available for on-site operation, and that RCRA landfill is available within 150 miles.	4 years
10 - On-Site Incineration of Sludges, and Contaminated Soils, Fixation of Ash.	Demonstrated technology.	Estimated at 30+ years.	Groundwater Monitoring. Security Inspections.	None indicated.	Assumes incinerators are available for on-site operation and that fixation equipment and materials are available.	5 years
12 - On-Site Burial of Sludges in Pits with Slurry Walls and Caps, Fixation of Contaminated Soils.	Elements are demonstrated technology,	Estimated at 10+ years, limited by effectiveness of walls and caps.	Groundwater Monitoring. Site and Security Inspections. General cap maintenance. Groundwater withdrawal and disposal.	Accumulation of liquid in the cells. Erosion caused leakage of cap. Leaching of sludges and fixed soils into groundwater.	Suitable materials available.	3 years

TABLE 6-25 (continued)

Remedial Alternative	Effectiveness	Useful Life	Operation and Maintenance Requirements	Possible Failure Modes	Site Conditions	Time to Implement
13 - No Action	Not effective in preventing existing threats to public health, welfare and the environment.	---	Periodic Groundwater Monitoring. Security Inspections.	---	---	---
9 - On-Site Incineration of Sludges and Off-Site RCRA Landfilling of Contaminated Soils and Ash.	Demonstrated technologies.	Estimated at 30+ years.	Groundwater Monitoring. Security Inspections.	None indicated.	Assumes incineration capacity available for on-site operation and that RCRA landfill is available within 150 miles.	6 years

maximum, by providing enough on-site incineration capacity (+ 13% for Alternatives 5 and 6, 100% for Alternative 10) to incinerate all the waste within 2 years.

6.6.5 Summary of Environmental and Public Health Effects

A summary comparison of the Environmental and Public Health effects associated with each of the remedial alternatives is given in Table 6-25. Of the treatment/disposal methods listed for the Remedial Alternatives, only incineration will completely destroy the hazardous organic components in the site waste. The other methods either contain the waste on-site (Alternative 12), remove waste off-site for RCRA landfilling (Alternatives 3 and 6) or fix the less contaminated soils (Alternatives 3, 5, 10, 12). The landfilling and containment alternatives have some potential for leakage of contaminants due to liner failure, improper construction and installation of the liners, or failure of the leachate collection system. Thus, this potential makes the containment options equivalent to long-term storage, not destruction.

The No-Action Alternative will do nothing to reduce actual or potential adverse effects, since there is no evidence that the wastes are degrading or being transformed into non-hazardous constituents by natural processes.

6.6.6 Summary of Detailed Evaluation of Remedial Alternatives

Information summarizing the detailed evaluation of the Sikes Disposal Pits remedial alternatives is presented in Table 6-27.

TABLE 6-26

SUMMARY OF ENVIRONMENTAL AND PUBLIC HEALTH EFFECTS
SIKES DISPOSAL PITS SITE

Alternative	Environmental Effects	Public Health Effects
3 - Off-Site RCRA Landfilling of Sludges, On-Site Fixation of Contaminated Soils.	Beneficial - Removes or isolates waste. Allows restoration of upper aquifer. Adverse - Potential for leaching into groundwater. Use of upper aquifer banned pending restoration.	Beneficial - Removes direct contact/ingestion hazard. Very low cancer risk. Adverse - Potential worker exposure during implementation. Potential public exposure during transport.
5 - On-Site Incineration of Sludges, Fixation of Contaminated Soils and Ash.	Beneficial - Destroys or isolates all contaminants. Allows restoration of upper aquifer. Adverse - Potential for leaching contaminants into groundwater. Use of upper aquifer banned pending restoration.	Beneficial - Removes direct contact/ingestion hazard. Very low cancer risk. Adverse - Potential worker exposure during implementation.
6 - On-Site Incineration of Sludges, Off-Site RCRA Landfilling of Contaminated Soils, On-Site Fixation of Ash.	Beneficial - Destroys, removes from site, or isolates all waste. Allows restoration of upper aquifer. Adverse - Use of upper aquifer banned pending restoration.	Beneficial - Removes direct contact/ingestion hazard. Very low cancer risk. Adverse - Potential worker exposure during implementation. Potential public exposure during transport.
10 - On-Site Incineration of Sludges and Contaminated Soils, Fixation of Ash.	Beneficial - Destroys organic wastes. Isolates ash metals. Adverse - Use of upper aquifer banned pending restoration.	Beneficial - Achieves maximum protection against direct contact/ingestion hazard. Provides maximum long term protection of aquifers against contamination. Adverse - Potential worker exposure during implementation.
12 - On-Site Burial of Sludges in Pits with Slurry Walls and Caps, Fixation of Contaminated Soils.	Beneficial - Isolates organic wastes from environment. Reduces migration pathways. Adverse - Potential for leakage of contaminants into groundwater. Non-RCRA landfill within 100-year floodplain. Organic waste not removed or destroyed. Use of upper aquifer banned.	Beneficial - Removes direct contact/ingestion of surface wastes. Adverse - Potential worker exposure during implementation.

003077

003077

TABLE 6-26 (continued)

Alternative	Environmental Effects	Public Health Effects
13 - No Action	Beneficial - None Adverse - Waste remains in place. Groundwater contamination continued potential for direct contact and ingestion.	Beneficial - None Adverse - Waste remains in place. Groundwater contamination continued potential for direct contact and ingestion.

003078

TABLE 6-27

SUMMARY OF DETAILED EVALUATION OF REMEDIAL ALTERNATIVES
SIKES DISPOSAL PITS SITE

Remedial Alternative	Present Worth Cost ($M) Implementation	O&M	Public Health Considerations	Environmental Considerations	Technical Considerations	Institutional Considerations
3 - Off-Site RCRA Landfilling of Sludges, On-Site Fixation of Contaminated Soils.	56.0	0.4	Removes direct contact or ingestion hazard. Low cancer risk. Use of upper aquifer banned until restored. Transportation risks.	Removes or isolates waste. Promotes aquifer restoration. Potential for leaching from fixed soils. Least time to implement.	Demonstrated technology effectiveness if fixation is effective.	Banning use of Upper Aquifer continued. Longterm groundwater monitoring required. Longterm monitoring may affect site use.
5 - On-Site Incineration of Sludges, Fixation of Contaminated Soils and Ash.	53.8	0.4	Removes direct contact or ingestion hazard. Low cancer risk. Use of upper aquifer banned until restored.	Removes or isolates waste. Promotes aquifer restoration. Potential for leaching from fixed soils. Longer implementation time than Alt. 3 & 12.	Demonstrated technology effectiveness if fixation is effective.	Use of Upper Aquifer banned. Longterm groundwater monitoring required. Longterm monitoring may affect site use.
6 - On-Site Incineration of Sludges, Off-Site RCRA Landfilling of Contaminated Soils, On-Site Fixation of Ash.	111.3	0.4	Removes direct contact or ingestion hazard. Very low cancer risk. Use of upper aquifer banned until restored. Reduced transportation risks than Alt. 3.	Destroys or removes waste. Promotes aquifer restoration. Longer implementation time than Alt. 3 and 12.	Demonstrated technologies. More reliable.	Use of Upper Aquifer banned. Longterm groundwater monitoring required. Longterm monitoring may affect site use.

003079

TABLE 6-27 (continued)

Remedial Alternative	Present Worth Cost ($M) Construction	O&M	Public Health Considerations	Environmental Considerations	Technical Considerations	Institutional Considerations
10 - On-Site Inciner-ation of Sludges and Contaminated Soils, Fixation of Ash.	92.9	0.4	Achieves maximum pro-tection against direct contact or ingestion hazard. Very low cancer risk. Use of upper aquifer banned until restored.	Destroys organic waste on-site. Provides greater protection against potential aquifer contamination than Alt. 3, 5 and 12. Longer implement-ation time than other alternatives.	Demonstrated tech-nologies used. Maximum reliability.	Use of Upper Aquifer banned. Longterm groundwater monitoring required. Longterm monitoring may affect site use.
12 - On-Site Burial of Sludges in Pits with Slurry Walls and Caps. Fixation of Con-taminated Soils.	23.4	1.3	Removes direct contact or ingestion hazard. Low cancer risk. Use of upper aquifer banned until restored.	Wastes isolated or immobilized but not destroyed. Leaching potential greatly reduced, although sludges left on-site.	Not totally demon-strated technology. System failure possible. Continued maintenance required. Collection and disposal of leachate required.	Use of Upper Aquifer banned. Longterm monitoring required. Use of land area prohibited.
13 - No Action	---	0.4	Continued potential for direct contact on-site and off-site. Potential ingestion hazard on-site.	Wastes remains in place. Continued potential for con-taminating lower aquifer. Upper aquifer remains un-suitable for use.	Not applicable.	Direct contact and ingestion hazards continued.

003080

6.6.7 Proposed Regulations

During preparation of this study, the compliance of the Remedial Alternatives with Federal requirements was based on existing laws, regulations and requirements. The potential impacts of foreseeable laws, regulations and requirements have been considered, as remedial action at the site might not occur for some period of time. Impacts of future laws, regulations and requirements cannot be completely accounted for if remediation is delayed for a long period.

A ban was proposed recently on disposal of wastes containing greater than 1,000 ppm of certain solvents (51 Fed. Reg. 1763). This ban would become effective as of November 1986 with solvent contaminated soils exempted until November 1988. Based on the contaminant constituents identified in the Sikes sludges, a ban, if instituted, could affect the sludge disposal options in Remedial Alternatives 3 and 12, Off-Site RCRA landfill and on-site containment, respectively.

The 1984 amendments to RCRA contain clauses to provide for an automatic ban on land disposal of all hazardous wastes by 1990, should EPA fail to arrive at its own standards. Thus, additional land disposal restrictions could impact Remedial Alternatives 3 and 12 even if the ban on land disposal of solvent contaminated waste does not apply.

003082

GLOSSARY

Acceptable engineering practices - technologies or practices which are technically sound, reliable, and applicable with respect to a particular site problem.

ACL - Alternative Concentration Limit

ATSDR - Agency for Toxic Substances and Disease Registry

Budget estimates - estimates of capital operation and maintenance or service costs provided by a vendor.

CAA - Clean Air Act.

CERCLA - Comprehensive Environmental Response, Compensation, and Liability Act of 1980. Also known as Superfund.

Cleanup - the elimination, reduction, or containment of pollutants from a site by a selected remedial action.

Community impacts - any change in the normal way of life, directly or indirectly attributable to the selected remedial action, including temporary or permanent relocation, initiation of health monitoring programs, formation of citizens' groups to review remedial alternatives, etc.

CWA - Clean Water Act.

Durability - the projected length of time that a designed level of effectiveness can be maintained. It is also measured in terms of the operation and maintenance requirements (parameter of reliability).

FEMA - Federal Emergency Management Agency.

Fixation - the treatment of a liquid or a solid designed to limit the solubility of, or to detoxify any hazardous constituents contained in the wastes.

Free liquids - liquids which readily separate from the solid portion of a waste by gravity.

General response action - a response action category consisting of groupings of related response technologies that may be used for a specific site problem (e.g., surface water controls, air pollution controls).

Groundwater - water below the land surface in a zone of saturation.

Hazardous waste - a waste as defined in 40 CFR260 A (261.3)

Implementability - a measure of successful prior installation of a remedial technology either on similar sites or on a research and development basis. Includes well understood installation and operational practices requiring minimal monitoring.

Institutional factors - analytical factors associated with Federal, State, and local regulations, guidance, and advisories concerning public health and welfare, environmental considerations, community relations, and other social, political, and economic concerns.

Isolation - a situation in which the transport of pollutants from a site to the surrounding environment has been stopped or slowed by the selected remedial action, but no pollutants have actually been removed.

Landfill - a disposal facility or part of a facility where hazardous waste is placed in or on land and which is not a land treatment facility or surface impoundment.

Land treatment facility - a facility at which hazardous waste is applied onto or incorporated into the soil surface.

Liner - a continuous layer of natural or manmade materials, beneath or on the sides of a surface impoundment or landfill which restricts the downward or lateral escape of hazardous waste, waste constituents or leachate.

Manifest - the shipping document originated and signed by the generator of hazardous waste which contains the information required by EPA regulations.

MCL - Maximum Concentration Limit, established under the Safe Drinking Water Act.

NAAQS - National Ambient Air Quality Standards.

NCP - National Oil and Hazardous Substances Contingency Plan.

NDD - Negotiated Decision Document; a confidential enforcement document containing a discussion of alternatives identified in the draft RI/FS, indicates preferred alternatives; serves as basis for negotiation with potential responsible parties.

NEPA - National Environmental Policy Act.

NPDES - National Pollutant Discharge Elimination System.

O&M - operation and maintenance.

003084

On-site - the same or geographically contiguous property.

Operable Unit - a discrete part of a remedial action that can function independently as a unit and contributes to preventing or minimizing a release or threat of release.

OSHA - Occupational Safety and Health Administration.

Physiography - general description of a site; for example geographic position, vegetative cover, and topography.

POTW - Publicly Owned Treatment Works.

Present worth - a summary of costs to be incurred over a period of time discounted to the present.

RCRA - Resource Conservation and Recovery Act.

Relevant or applicable standards - established Federal or State procedural requirements or limit values (such as MCLs) pertaining specifically to chemicals, environmental impacts, or technology operations conducted or anticipated at a site.

Reliability - a measure of the effectiveness and durability of a technology.

Remedial Action Alternative - a remedial technology or a combination of remedial action technologies which will prevent or mitigate site-specific contamination problems.

Remedial Action Technology ("Technology") - a general category encompassing a number of remedial action technology options that address a similar problem (e.g., capping, containment barriers, chemical treatment).

Remedial Action Technology Option ("Technology Option") - a specific process, system, or action that may be used to cleanup or mitigate contaminant problems (e.g., slurry wall, clay cap, activated sludge treatment).

REMFIT contractor - Remedial Planning and Field Investigation Teams contracted to the U.S. EPA.

Risk Level - Cancer risk level provides an estimate of the additional incidence of cancer that may be expected in a population exposed to a given contaminant. A risk of 10^{-5}, for example, indicates a probability of one additional case of cancer for every 100,000 people exposed. A risk of 10^{-7} would be one case in 10 million people exposed.

RMCL - Recommended Maximum Concentration Limit, developed under Safe Drinking Water Act.

003085

Run-off - any rainwater, leachate, or other liquid that drains over land from any part of a facility.

SDWA - Safe Drinking Water Act.

Sensitivity analysis - a test of a procedure to determine the overall changes that result from any small changes in one or more procedural elements.

Significant adverse impact - a public health or environmental effect that cannot be mitigated or ameliorated.

Site - a landfill, surface impoundment, storage facility, or any other site or facility of any kind, at which a hazardous substance is present as a result of a release of such hazardous substance from a facility as defined under CERCLA.

Social costs - perceived negative impacts resulting from a remedial action, including impacts manifested in psychological, sociological, political, legal, and organizational changes.

Stabilization - the addition of materials to hazardous waste (usually sludges or semi-solids) to improve its handling or physical characteristics.

Technology status - the state-of-the-art, relative to application to uncontrolled hazardous waste sites, of remedial alternatives; described as proven, widely used, or experimental.

TSD - treatment, storage, or disposal facility.

UIC - Underground Injection Control Programs.

Unit operation - the basic physical operations of chemical and civil engineering that may be applied as remedial actions, for example capping, groundwater pumping, biological treatment, containment barrier; a technology.

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APPENDIX A

INITIAL TECHNOLOGY SCREENING

This Appendix presents the initial screening of remedial technologies which might be applicable to the objective response actions developed in Section 2. The following criteria, as well as engineering judgement, were applied to the list of "Hazardous Waste Source Control Remedial Action Technologies" in Section 300.70 of the National Oil and Hazardous Substances Contingency Plan (NCP):

(1) Applicability of the technology to site conditions.

(2) Proven performance and reliability.

(3) Implementability and/or constructibility.

The technologies eliminated by the screening in this Appendix are considered to not have sufficient merit to contribute to the re-medial action objectives. Additional screening is presented in Section 3 of this report for those technologies which passed this initial screening.

003088

TABLE A-1

CANDIDATE REMEDIAL TECHNOLOGIES

1.0 CONTAINMENT TECHNOLOGIES

1.1 Capping
- Native Soil
- Clay
- Synthetic Membranes
- Sprayed Asphalt
- Asphaltic Concrete
- Concrete
- Multi-Layered Cap
- Chemical Sealants/Stabilizers

1.2 Vertical Barriers
- Soil-Bentonite Slurry Wall
- Cement-Bentonite Slurry Wall
- Vibrating Beams
- Grout Curtains
- Sheet Piling
- Ground Freezing

1.3 Surface Controls
- Grading
- Soil Stabilization
- Revegetation
- Diversion and Collection Systems

1.4 Dust Controls
- Water
- Organic Agents

2.0 REMOVAL TECHNOLOGIES

2.1 Drum and Debris Removal
- Drum Grapplers
- Forklifts and Attachments
- Cranes and Attachments
- Scrapers

2.2 Excavation
- Solids
  - Hand Excavation
  - Backhoes
  - Loaders
  - Scrapers

003088

003089

Semi-Solids (Non-pumpable)
  Draglines
  Clamshells
  Slurrying
Liquids
  Pumps
  Vacumn pumps/Trucks
  Garvity/Siphons
Sediments
  Technologies listed for Solids and Semi-solids
  Hydraulic dredging
  Pneumatic dredging

2.3 Groundwater Collection/Pumping
  Wells
  Subsurface collection points
    Frenchdrains
    Pipe and Media drains

2.4 Gas Collection
  Passive Vents
  Active collection systems

3.0 TREATMENT TECHNOLOGIES

3.1 Solids Treatment
Neutralization
Oxidation
Reduction
Other Chemical Modifications
Water Leaching
Solvent Leaching
Composting

3.2 Solidification, Fixation, and Stabilization
Sorption
Flyash
Kiln Dust
Lime
Limestone
Clays
Vermiculite
Zeolites
Alumina
Carbon
Imbiber Beads
Proprietary Agents
Pozzolanic Reaction
  Lime-Flyash
  Portland Cement

003090

Encapsulation
- Thermoplastics
- Asphalt
- Glassification
- Proprietary Agents

3.3 Solid/Liquid Separations
- Sedimentation
- Flotation
- Gravity Thickening
- Screens, Hydraulic Classifiers, and Scalpers
- Centrifuges
- Belt Filter Presses
- Filter Presses
- Vacuum Filtration
- Dewatering and Drying Beds
- Thermal Dryers
- Mechanical Filtration
  - Cartridges
  - Single or multi-media down flow
  - Upflow
  - Greensand

3.4 Physical Treatment (except Solid/Liquid Separations)
- Flow and Strength Equilization
- Coagulation and Flocculation
- Oil-Water Separation
- Adsorbents
  - Activated Carbon
  - Molecular Sieves
  - Proprietary Adsorbents
- Membrane Processes
  - Ultrafiltration
  - Reverse Osmosis
  - Dialysis
  - Electrodialysis
- Freezing
- Crystalization
- Air (or gas) stripping
- Steam Stripping
- Distillation
- Evaporation
- Liquid-liquid (and supercritical extraction)

3.5 Chemical Treatment
- Neutralization
- Precipitation
- Ion-Exchange
- Oxidation
- Chlorine containing agents.
- Ozone

003090

003091

Ultraviolet/Oxidant
Permaganate
Peroxide
Reduction
  Sulfur dioxide
  Inorganic Chlorine
  Dechlorination
  Boron Hydride and Others
Organic Chemical Dechlorination
Photolysis
Irradiation
Electrochemical
Hydrolysis
Other Chemical Modifications

3.6 Biological Treatment
Aerobic Biological Treatment
Activated Sludge
Pure Oxygen Activated Sludge
Trickling Filters
Aerated Lagoons
Rotating Biological Discs
Facultative/Anaerobic Biological Treatment
  Waste Stabilization Ponds
  Anaerobic Digestion
  Fermintation
  Fluidized Bed Bioreactors
  Anaerobic Filters
  Submerged Filters
  Composting
New Biotechnologies
  Enzyme
  Cultured Bacteria
  Engineered Bacteria
Land Treatment
  Land Farming
  Spray Irrigation

3.7 In Situ Treatment
  Neutralization
  Oxidation
  Reduction
  Precipitation
  Bioreclamation
    Natural
   With Oxygen (air or hydrogen peroxide) augmentation
   Other Chemical modifications
   Permeable Treatment Beds
   Vitrification

003092

3.8 Thermal Treatments
- Incineration Processes (with excess air)
  - Rotary Kiln
  - Fluidized Bed
  - Rotary Hearth
  - Radiant Heat Furnace
  - Molten Salt
- Liquid Injection
  - Land Based
  - Shipboard
- Co-Disposal Processes
  - Industrial or Power Generation Boiler
  - Cement Kiln
  - Lime Kiln
  - Municipal Sludge Incinerator
  - Municipal Refuse Incinerator
  - Combustion by-product recovery
- Pyrolysis and controlled air combustion
  - Conventional Pyrolytic Reactor
  - Ultrahigh Temperature Reactors
    - Advanced Electric Reactor
    - Plasma Arc
    - Microwave Plasma
- Wet Air Oxidation
  - Conventional U-Tube
  - Autoclave
  - Vertical tube (deep well reactor)
    - Supercritical Water
  - Vapor Thermal Treatment
    - Flares
    - Afterburners

3.9 Gas Treatment
- Condensation
- Particulate Removal
- Adsorption
- Absorption
- Chemical Reaction
- Thermal Destruction

4.0 DISPOSAL TECHNOLOGIES

4.1 Reusable Product
- Sale at Commercial Valve
- Sale with a Cost-of-Processing Support

4.2 Landfills
- RCRA Approved
- Non-RCRA approved

4.3 Surface Impoundments

4.4 Waste Piles

4.5 Containerized Storage

4.6 Deep Sea Disposal

4.7 Waste Water Discharge
- POTW
- Surface Water
- Shallow Subsurface Disposal
- Deep Injection Well

5.0 TRANSPORT METHODS

5.1 Containers
- Bulk Tanks
- Drums
- Bins
- Fabric Bags

5.2 Transport Methods
- Truck
- Railroad
- Barge
- Pipeline

6.0 OTHER ACTIONS/TECHNOLOGIES

6.1 Relocation of Residents
- Temporary/Permanent

6.2 Site Access Control
- Perimeter Fence With Gates

6.3 Groundwater Monitoring
- Wells

1.0 CONTAINMENT TECHNOLOGIES

1.1 Capping

Containment of all the source areas by capping is not considered applicable because the pits and Tank Lake cannot be capped as they are and if all known waste areas were capped, the capped area would cover many acres. There is a potential need for a cap to be used in conjunction with other technologies as a disposal option, so the technology will be retained. However, several material options for cap construction do not appear suitable as discussed below:

(1) Chemical sealants or stabilizers are considered inapplicable, as the technology is unproven for long-term containment of hazardous wastes.

(2) A sprayed asphalt cap is considered infeasible for Sikes as the waste contains aromatics and other organic solvents, which are potentially reactive with the asphalt. Also, asphalt caps would require extensive maintenance because they tend to deteriorate and crack with time and light exposure. Settlement of the waste material would also tend to crack the cap.

(3) Natural soil alone, and cement alone are unsuitable. Natural soil is permeable and would support water infiltration. Concrete is very heavy, and would tend to settle and crack.

The following material options warrant further consideration:

- o Clay
- o Synthetic Liners
- o Multi-Layer Caps

003095

1.2 Vertical Barriers:

Vertical barriers are used to seal permeable zones or layers within the substrata which are more permeable than a barrier and/or adjacent strata. Vertical barriers appear applicable at this site. The following barrier options, however, do not appear suitable because of the reasons given:

(1) Sheet pibing is not suitable as a long term barrier because of joint leakage and materials incompatibility.

(2) Grout curtain injection is unreliable for producing a non-permeable barrier over the depth needed at Sikes.

(3) Construction of a vertical barrier using ground freezing methods appears feasible, but this method is not suitable for long term application-- which is the primary need at Sikes.

The following technologies warrant further consideration:

- o soil-bentonite slurry wall
- o cement-bentonite slurry wall

1.3 Surface Controls

Surface controls pertain to the control of surface waters and/or accompanying soil errosion. Controlling dike erosion during remediation and of capped areas following remediation with revegetation are applicable.

Surface water from rainfall events during implementation of the remedial actions will be collected from within the flood protection dike and checked for contamination prior to discharge or disposal of the water.

The following technologies warrant further consideration:

- o Regrading
- o Revegetation
- o Collection Systems

1.4 Dust Controls

Dust control technologies such as application of water or organic compounds to reduce dust from the source areas are applicable to the site during implementation of a remedial action. Technologies, such as revegetation and/or capping will control dust and are more applicable to source control during the life of the facility.

Because of the nearby availability of an ample supply of clean water (San Jacinto River), water will be retained as the dust control option.

2.0 REMOVAL TECHNOLOGIES

Removal technologies for the source areas were separately evaluated based on the waste types at the site.

2.1 Drummed Waste

Removal of the wastes from drums and empty drum sections on-site may require the use of a combination of removal options to collect these wastes safely and efficiently.

The following technologies warrant further consideration:

- o Grapplers
- o Forklifts
- o Cranes
- o Scrapers

2.2 Sludges and Contaminated Soils

From the site investigation, these waste have been deposited above ground (overflow area), in pits under water (main waste pit, Tank Lake) and below ground with a soil overtopping. To excavate waste from this variety of places will likely require using a combination of technologies.

For example, backhoes and/or scrapers for the overflow area, long reach dragliners or dredges for the large pits, and draglines for the small pits. The use of hydraulic or pneumatic dredges would likely result in large scale contamination of the pit surface waters, and even perhaps the forming of stable emulsions of organics and water. Breaking the emulsion and treating the water for discharge to the river could require specialized equipment. For these reasons, the use of dredges has been rejected.

The following technologies warrant further consideration:

- o Backhoes
- o Loaders
- o Scrapers
- o Draglines

2.3 Surface Water/Infiltration Waters

Surface water includes the water layer in the pits and stormwater collected within the dike. Infiltration water is ground water that infiltrates into pits once the surface water has been removed, prior to excavating sludges or sediments. The use of surface and sump pumps appears feasible for these applications. Vacuum pumps (trucks) may be needed for special purposes during the remediation. Since the source areas are mostly below grade, gravity drainage is not feasible.

The following technologies warrant further consideration:

- o Positive-displacement pumps
- o Centrifugal pumps
- o Vacuum pumps/Trucks

2.4 Groundwater Collection/Pumping

The removal of groundwater for treating prior to discharge to the river may be needed as part of the means of restoring the Upper Aquifer to drinking water quality. The use of pumped extraction wells seems to be the most feasible option since the aquifer is to far below grade to effectively use subsurface collection points.

The following technology warrants further consideration:

- o Extraction wells

2.5 Gas Collection

The constituents of the waste sludges include volatiles which could be released from the waste if left on-site. The collection and control of gases will, therefore, be included for source control remedies. Excavation of wastes during remediation will most likely result in the release of volatile organics. However, the control of volatile organic releases during remediation will be addressed in the Imple-mentation Design Phase and as such will not be considered here.

The following technology warrants further consideration:

- o Passive vents

3.0 TREATMENT TECHNOLOGIES

The screening of treatment technologies considered the treatment of the waste sludges, contaminated soils, surface waters amd ground-waters. A wide variety of waste contaminants have been identified in the sludges, soils and groundwaters especially. Therefore, only treatment technologies that were considered feasible or applicable on a large scale to a majority of the contaminants were considered in this initial screening. Both on-site and off-site treatment would appear to be applicable. On-site treatment would be most efficient and cost effective on large quantities of similar wastes. Off-site treatment would probably be most efficient and effective for small quantities or special wastes.

3.1 Solids Treatment:

Sludges and Contaminated Soils:

The processes of neutralization, oxidation and reduction are waste constituent specific and the presence of a wide spectrum of consti-tuents in the sludges, drummed waste, and contaminated soils would reduce the effectiveness of tailored treatment processes. Therefore, treatment of the waste by oxidation or reduction appears inapplicable and in-feasible. Water or solvent leaching does not appear applicable because:

- o Extent of waste deposits
- o Waste constituents range from highly concentrated (sludges) to slightly concentrated.
- o Would require organic solvents
- o Solvent could migrate, contaminate groundwater
- o Limited application of organic solvents

3.2 Solidification, Fixation and Stabilization.

Sludges and contaminated soils: These are treatment systems that accomplish one or more of the following objectives:

- o Improve waste handling or other physical characteristics of the waste.
- o Decrease the surface area across which transfer or loss of contained pollutants can occur
- o Limit the solubility or toxicity of hazardous waste constituents.

Solidification is used to describe processes where these results are obtained primarily, but not exclusively, by production of a monolithic block of waste with high structural integrity. The contaminants do not necessarily interact chemcially with the solidification reagents, but are mechanically locked within the solidified matrix. Contaminant loss is minimized by reducing the surface area.

Chemical fixation is treatment that involves the addition of materials which chemically react with the inorganic contaminants and trap or surround the organics within the reactive matrix, to control potential leaching of both the organic and inorganic contaminants. Two commercial processes that are representative of chemical fixation are the Chemfix and Stablix processes. Both of these processes have been used to treat inorganic wastes containing low levels of organics similar to the contaminated soils. An exclusion has been granted a large petroleum company by the EPA for oil sludges containing toxic organics and heavy metals after it had been treated by the Chemfix process. The hazardous oily sludges contained low levels of volatile organics, PNA's and toxic heavy metals. After treatment the solid product was declared non-hazardous based on leach test results. See 50 FR178-37364-37368. Also, a major automobile manufacturing corporation was granted an exclusion for a hazardous waste sludge based on leach test results of the chemically fixed product. The waste contained from 1 to 2% oil and grease and toxic heavy metals. The Agency concluded that the hazardous waste was rendered non-hazardous by the fixation treatment - in that the constituents of concern would be sufficiently immobilized. See 50FRNo. 229, p. 48911 to 48922.

Treatment of the sludges by solidification or fixation technologies does not appear feasible or warranted, due to the presence of high concentrations of organics. Solidification/Fixation of organics above 2% has not been generally effective for controlling the leaching of organics. Some sludges may require stabilization for structural stability in a landfill disposal alternative.

Treatment of the contaminated soils by chemical fixation appears feasible because of its low concentration of organics (10-1000 ppm).

Stabilization, as used here, is the addition of materials to waste to improve its structural stability.

- Contaminated Surface Water and Groundwater:

These technologies are not considered applicable to wastes which consist mainly of water. To treat water, would result in very large volumes of waste, and be very costly.

The following technologies warrant further consideration for sludges and contaminated soils:

- o Cement Based Fixation of Soils.
- o Cement Stabilization of Sludges
- o Fly Ash Stabilization of Sludges
- o Other proprietary agents for fixation of contaminated soils.

3.3 Solid/Liquid Separation

- Sludges and Contaminated Soils:

A solids/liquid separation appears applicable to sludges and soils excavated from below the groundwater table, and especially from pits. Gravity separation of free water is the technology that appears most applicable because of its simplicity and low cost of operation.

- Contaminated Surface Water and Ground Waters:

Solid/liquid separation may be required for surface and groundwaters (infiltration waters) to remove solids and sediment prior to additional treatments. Separation technologies that appear most applicable for the low volume of solids containing liquid waste is mechanical filtration. The following technologies warrant further consideration:

- o Decanting
- o Dewatering beds
- o Mechanical Filtration

3.4 Physical Treatment:

- Sludges and Contaminated Soils:

None of the physical treatment technologies are considered applicable to these wastes.

- Contaminated Surface Water and Groundwater:

Physical treatment of these aqueous wastes would, in general, treat organic contamination. No inorganic con-taminants (metals) are expected to exceed allowable discharge standards. The types of organics present, and the quantity of contaminated waste water that might require treatment before discharge, indicate that air stripping, adsorbents, and membrane processes would appear most appli-cable. Waste characteristics do not indicate the need for oil/water separation. The following technologies warrant further consideration:

- o Adsorbents
- o Membrane Processes
- o Air Stripping

3.5 Chemical Treatment:

- Sludges and Contaminated Soils:

These wastes contain a wide variety of organic and inorganic com-pounds. Potential chemical treatments include oxidation, reduction, polymerization. These technologies are judged to be too developmen-tal to consider for in situ treatment or following excavation. The techniques are unproven and adequate documentation of their use is not available.

- Contaminated Surface Water and Groundwater:

Chemical treatment of contaminated water would, in general, be to remove organic contaminants. Based on waste charac-terization, neutralization of some contaminated water appears necessary for discharge. Other treatments that may be feasible include oxidation and hydrolysis.

The following technologies warrant further consideration:

- o Neutralization
- o Oxidation
- o Hydrolysis

3.6 Biological Treatment:

- Sludges and Contaminated Soils:

Biological treatment of these wastes by conventional processes is not considered feasible. Land treatment, or landfarming of sludges involves spreading wastes onto a land surface to allow natural or induced biodegradation to degrade the organic contaminants. For all hazardous wastes, in general, and for bioresistant wastes, in particular, the potential for surface water contamination is high. On-site landfarming is not feasible because site characteristics are unfavorable: site is in the 100 year flood plain and has flooded four times since 1969. The protective dike would be needed to protect against floods carrying landfarmed sludge contaminants off-site. The limited surface area available (waste deposits occupy much of site) would extend the remediation period, especially with the bioresistant and sludge constituents. Also, leaching of the sludge contaminants by rainwater would be a significant treat to restoration of the Upper Aquifer. Before land application is initiated on or off-site, a permit must be obtained from the EPA. Permit conditions, if granted at all, would likely be very restrictive, according to the requirements of RCRA 40 CFR 264 Subpart M. Off-site landfarming would require locating and gaining access to sufficient land for disposing of the large quantities of wastes within a reasonable time. A demonstration test must be run as a basis for obtaining a permit. Landfarming was not retained for further evaluation because of the reasons given above.

- Contaminated Surface Water and Groundwater

Biological treatment is considered feasible for these aqueous waste. Several types of biological treatment may be applicable, including aerobic, anaerobic and land treatemnt. Considering the level of contamination, it appears that anaerobic treatment is not feasible. Land treatment does not appear feasible on-site (within flood plain) nor off-site. Several types of aerobic treatment appear to be applicable, including:

- o Activated Sludge
- o Rotating Biological Discs
- o Trickling Filters
- o Fluidized Bed Bioreactor
- o Powdered Activated Carbon
- o Aerated Lagoons
- o Composting

Biological degradation of the contaminants is affected by bacterialmetabolic digestion of the contaminants, and has been applied in situ and after removal of the contaminated water. It is not typically appropriate for removal of trace organics, but is useful in reducing the contaminants at higher concentrations.

The activated sludge process utilizes free suspended cellular biomass in an aerated reactor to oxidize organic contaminants. The biomass is then separated in a clarifier or sedimentation tank, and reintroduced into the reactor.

Rotating biological discs (RBC) and trickling filters support media for biomass film growth, while trickling filters support biomass on granular media. The RBC is more costly than trickling filters, and appears to provide little relative advantage. Powdered activated carbon (PAC) treatment actually provides two mechanisms for organic contaminant removal. First, the colloidal carbon provides a surface for biological growth as in a trickling filter. The carbon also is an active adsorbent for the organic contaminants, and immobilizes them for biodegradation or direct removal..

Aerated lagoons are used to hold contaminated water to be mechanically aerated. When aerated, the lagoons act sim-ilarly to activated sludge units. Lagoons in general are adversly affected by shock loadings of toxics, can cause odor problems, is a lower rate oxidation process than acti-vated sludge, and requires a provision for sludge removal.

Composting and fluidized bed bioreactors are unproven tech-nologies which do not appear to offer any advantages over established processes.

The following technologies warrant further consideration:

- Activated Sludge
- Aerated Lagoons

3.7 In Situ Treatment:

- Sludges and Contaminated Soils:

Several types of in situ treatment were considered for treating the sludges and contaminated soils. These included:

- Soil Aeration
- Oxidation-Reduction
- Solution Mining
- Polymerization
- Precipitation
- Nitrification
- Bioreclamation
- Permeable Treatment Beds

Most of these technologies are unproven for this type of application. Soil aeration would be used only in combination with waste excavation and landfarming. In situ oxidation-reduction is an unproven technology and problems (e.g. uncontrolled reactions) could result from the inter-action of the contaminant and oxidizer/reducer. Solution mining is also an unproven technology for this application and could create problems by displacing the contamination to a larger area because of the increased volume of solution. Polymerization, precipitation, and nitrification are inapplicable to the contaminants identified.

Bioreclamation consists of adding selected microoganisms to contaminated media to metabolize organic contaminants. Oxygen, air and/or nutrient sources (phosphorus and nitrogen) can be added to increase microbiological activity. Considering the concentrated organics in the sludges and the likelyhood of formation plugging from biosolids if degradation was initiated, this technology does not appear to be applicable.

Permeable treatment beds would be constructed by excavating a trench in the waste areas to the depth of the shallow groundwater system. The trench would then be backfilled with appropriate treatment materials to treat the contaminants. This approach relies upon flow through treatment and would only be potentially applicable to the contaminated soils above the groundwater table. For these reasons this technology will not be retained.

- Contaminated Surface Water and Groundwater:

The technologies listed above for sludges and contaminated soils were considered for treating contaminated surface water and groundwater. Most of these technologies are unproven for treating contaminated water, with the exception of bioreclamation. Treatment of the pit waters does not appear needed to satisfy discharge requirements. Treatment of the Upper Aquifer to Drinking Water Standards and/or to satisfy the Human Health Criteria (10-4 to 10-7 range) would require a removal efficiency for trace organics of a much higher level than has been shown in conventional processes.

In situ treatments will not be retained for further evaluation.

3.8 Thermal Treatments:

Direct decontamination of organic wastes can be accomplished with onsite or offsite incineration. Incineration comprises high-temperature oxidation (combustion) at elevated temperatures and converts organic materials to carbon dioxide and water. Sulfidic wastes and chlorinated wastes would be oxidized as well to sulfur dioxide and hydrochloric acid, respectively.

- Sludges and Contaminated Soils

The types of thermal treatment equipment considered feasible for treating these wastes includes:

o Incineration

Rotary Kilns

Fluidized Beds

Multiple Hearth

o Co-Disposal Processes

Complete incineration of sludges and contaminated soils is feasible. The low heating valve of the sludges due to the high soil and water content, makes the application of co-disposal technology inappropiate. Several other thermal processes that might appear applicable, in reality require a liquid waste stream.

Pyrolysis and controlled air combustion technologies were judged to be too developmental to consider. The treatments are unproven and adequate documentation of their use is not available.

The following technology warrants further evaluation:

o Incineration

- Contaminated Surface Water and Groundwater:

Thermal treatment of wastes which are primarily water is not cost effective, even though feasible and effective, e.g. incineration. For wet air oxidation in any of its several forms to be effective would require a fuel supplement to establish the necessary reaction conditions. None of these aqueous waste contains more than trace concentrations of organics.

No thermal treatment technologies warrant further consideration for treating aqueous waste.

3.9 Gas Treatment

Gases from the source areas or treatment technologies will generally be volatile organics. Gas production during ex-cavation will be controlled and workers will be protected. Gases produced from point sources during remedial action would if necessary be adsorbed or incinerated. Other technologies such as condensation, particulate removal, absorption and chemical reaction would not be applicable or else cost more for no increase in effectiveness.

The following technologies warrant further consideration:

- o Adsorption
- o Incineration

4.0 DISPOSAL TECHNOLOGIES

4.1 Reusable Products:

Reuse of any of the waste appears infeasible based on the mixing of waste materials on receipt.

4.2 Landfills:

On-site and off-site landfill options for the sludges and contaminated soils are applicable. None of the present source areas are landfills meeting RCRA standards. Landfills are also appropiate for products generated by treatment of the wastes from the site such as incineration ash and treatment sludges.

The following technologies warrant further consideration:

- o On-site RCRA Facility
- o Off-site RCRA Facility
- o On-site non-RCRA Facility

4.3 Surface Impoundments:

Surface impoundments are inapplicable for disposal of sludges and contaminated soils.

4.4 Waste Piles:

Waste piles do not appear applicable at site as these are not permanent storage facilities. Waste piles could be used on-site as temporary storage of wastes prior to remediation.

4.5 Containerized Storage:

Containerized storage is not applicable to the site.

4.6 Deep Sea Disposal:

Deep sea disposal is only currently potentially applicable to liquid waste. The liquid waste is not sufficiently con-taminated for this technology to be cost effective.

4.7 Waste Water Discharge:

Most of the present surface water on-site would not require treat-ment before discharging to the San Jacinto River or Jackson Bayou. Groundwater from the site entering the river or bayou appears to meet surface water discharge criteria.

Discharge of contaminated surface water or groundwater to a public treatment plant does not appear applicable because the closest POTW is 2-3 miles away. Shallow subsurface disposal is not feasible, because the Upper Aquifer is already contaminated and must be restored to drinking water quality.

Deep well disposal was considered for on-site and off-site disposal of aqueous waste. An on-site well could be installed but would not be cost effective considering the small volume of water to be disposed. It must be plugged after use; another expense. Off-site injection is feasible but would require transporting up to 144,000 gallons per day of water.

The following technologies warrant further consideration:

o Surface water discharge

5.0 TRANSPORT METHODS

Evaluation of transport methods considered the transport of the sludges, contaminated soils and contaminated water.

5.1 Containers:

Transport of the sludges and contaminated soils from the site using closed bins or enclosed bulk containers appears most applicable. The use of drums or other containers is possible but appears inappropriate because it would require placing waste into a large number of non-reusable drums (261,000 to 550,000.)

The volume of water transported off-site will vary, but for the likely quantities anticipated, bulk tanks would be most appropiate.

The following technologies warrant further consideration:

- o Bins (closed)
- o Bulk Containers (closed)
- o Bulk Tanks

5.2 Transport Methods:

Transport from site would begin with trucks, although rail transport is most applicable since a rail line runs across the site. The use of barges is inapplicable as the barges cannot navigate the river to the site. the use of pipelines would be limited to only the aqueous waste. Transport of contaminated water by pipeline is not considered feasible because the estimated quantity of water to be removed continuously is relatively small and a pipeline would not be cost effective.

The following technologies warrant further considerations:

- o Truck
- o Rail
- o Truck and Rail

6.0 OTHER ACTIONS/TECHNOLOGIES

6.1 Relocation of Residents

Relocation of the Sikes family still living on-site, on a permanent or temporary basis, appears feasible. Relocation of on-site residents may only be a temporary action to reduce health hazards during excavation or other remediation of the source areas when volatiles could be released. It may , however, be necessary to relocate the site residents (one family) on a permanent basis depending on the site re-mediation plan implemented.

Relocation options for the Sikes family would be:

- o Temporary relocation
- o Permanent relocation

6.2 Site Access Control

Erecting a perimeter fence that encloses all the waste source areas seems the most appropriate action to take. The fence would contain manned or locked gates for access.

APPENDIX B

ALTERNATIVE EVALUATION RATING SYSTEM

TECHNICAL EVALUATION CRITERIA

PERFORMANCE

Performance is assessed on the basis of effectiveness and useful life. Effectiveness relates to the degree to which the alternative will prevent or minimize release of contamination to current or future public health, welfare, or environmental receptors. Useful Life relates to the length of time that the level of effectiveness can be maintained.

EFFECTIVENESS

Effectiveness is evaluated on the following scale:

++ Prevents release of all hazardous materials; provides maximum protection of human health and environment.

\+ Minimizes release of hazardous materials; adequately protects human health and environment.

o Controls release of hazardous materials; adequately protects public and environment.

\- Reduces release of most hazardous materials; limited protection of public and environment.

-- Allows release of many hazardous materials.

USEFUL LIFE

The useful life of alternatives is evaluated on the following scale:

++ All technologies and all remedial actions permanent without maintenance.

\+ Major remedial actions permanent with some remedial actions easily replaceable or repairable through routine maintenance.

o Overall long-term solution requiring only routine maintenance and is replaceable or repairable.

\- Overall short-term solution requiring significant and unpredictable maintenance; difficult to replace or repair.

-- Overall short-term solution requiring frequent extensive maintenance; repair impractical upon failure.

RELIABILITY

Reliability is assessed on the basis of Operation and Maintenance and Demonstrated Performance. Operation and Maintenance are evaluated for labor availability, frequency, necessity, and complexity. Demonstrated Performance includes proven performance, probability of failure, and pilot testing.

OPERATION AND MAINTENANCE

Operation and Maintenance is used to evaluate the frequency and/or complexity of the required services and is evaluated on the following scale:

++ Never requires operation or maintenance attention after implementation.

\+ Requires infrequent attention; capable of functioning unattended with periodic maintenance.

o Capable of functioning with no more than periodic attention.

\- Requires dedicated personnel to maintain functions and regular operation and maintenance attention by trained personnel.

-- Requires very frequent or constant attention by full-time trained personnel.

DEMONSTRATED PERFORMANCE

The Demonstrated Performance criterion is used to evaluate the applicability of the alternative to the site based on prior performance at similar sites. The criterion is evaluated on the following scale:

++ All remedial technologies proven reliable in the field under similar conditions on similar waste materials and mixtures.

\+ All remedial technologies proven reliable in the field under similar conditions on similar waste materials.

o Proven reliable but under different conditions and materials.

\- Demonstrated only in laboratory- or pilot scale studies on similar materials; reliability is not demonstrated on full scale.

-- Demonstrated only in laboratory-scale on pure substances or simple mixtures; reliability not demonstrated for practical field conditions.

ENGINEERING IMPLEMENTABILITY/CONSTRUCTIBILITY

Engineering Implementability is assessed for ease of installation and time to implement. Ease of construction relates to constructibility, applicability to site conditions, external conditions such as permits and access to offsite disposal facilities, and equipment availability.. The Time To Implement and Time To Achieve Beneficial Results are also evaluated.

EASE OF CONSTRUCTION

This criterion assesses the ease of installation in regard to physical site conditions, permit and zoning requirements, and availability of off-site facilities. The criterion is evaluated on the following scale:

++ No unusual impediments to construction.

\+ Construction effort routine; most necessary offsite facilities readily available; permits readily obtainable.

o Construction effort required is not excessive; availability of off-site facilities will not adversely affect construction schedule; permits can be obtained with reasonable effort.

\- Construction possible but major construction effort required to overcome site conditions; offsite facilities available but at great distance or expected cost; permits difficult to obtain.

-- Magnitude of construction effort exceptional; essential offsite facilities are unavailable; permits very difficult to obtain.

TIME TO IMPLEMENT

This criterion represents the time required to implement the alternative. The criterion for evaluation follows:

++ Alternative can be implemented in less than 1 year.

+ Alternative can be implemented in less than 3 years.

o Alternative can be implemented within 5 years.

- Alternative can be implemented but will require more than 5 years.

-- Alternative requires more than 10 years to implement.

TIME TO ACHIEVE BENEFICIAL RESULTS

This criterion is a measure of time to reduce contamination or degree of exposure to meet the objectives as stated in Section 1 upon implementation of the alternative. The criterion is evaluated on the following scale:

++ Immediate overall results (within brief implementation period).

+ Rapid overall results (within 1 year after start of implementation).

o Timely overall results but requires between 1 and 5 years.

- Obtaining overall results requires between 5 and 20 years.

-- Obtaining overall results requires greater than 20 years.

PUBLIC HEALTH AND WELFARE

The safety to the public health and welfare of people near the site During Installation and Operation and Upon remediation Failure is evaluated.

DURING INSTALLATION AND OPERATION

Evaluation under this criterion considers threats to the safety of community and environment during Installation and Operation of the alternative. The criterion is evaluated on the following scale:

++ All remedial actions intrinsically safe.

\+ All remedial actions very safe; no threat to surroundings.

o Safe; little or no threat to surroundings.

\- Hazardous; may possibly require emergency evacuation of homes near the site.

-- Very hazardous; requires evacuation of area homes.

UPON FAILURE

This criterion, which refers to safety in the event of remedial action failure, is evaluated on the following scale:

++ Intrinsically safe; redundant components prevent hazardous occurrence.

\+ Failure can be quickly detected and results in hazard that is less than that presented by the site prior to remediation.

o Failure can be quickly detected and results in hazard approximately equal to that presented by the site prior to remediation.

\- Failure difficult to detect and results in hazard greater than that presented by the site prior to remediation.

-- Failure very difficult to detect and results in catastrophic spread of contamination or loss of life.

ENVIRONMENTAL

SHORT-TERM EFFECTS

Short-Term Effects refer to construction related effects.

SITE POLLUTION

Site Pollution refers to odor, noise, air emissions, surface or ground-water contamination during construction, and is rated as follows:

++ Alternative causes no impact.

\+ Alternative causes effects that are contained within the site boundary.

o Alternative causes effects beyond site boundary but generally limited, controllable, and within acceptable limits.

- Alternative causes limited uncontrollable or unacceptable effects beyond site boundary.

-- Alternative causes significant uncontrollable and unacceptable effects beyond site boundary.

SITE ALTERATIONS

Site Alterations refer to wildlife habitat or historic site alterations, disruption of households, businesses, and services during construction and is considered in relation to the following scale:

++ Alternative causes no effect.

+ Alternative causes brief temporary alterations or disruptions which are returned to normal quickly.

o Alternative causes prolonged temporary alterations or disruptions which are returned to normal.

- Alternative causes slight alterations or disruptions which are permanent.

-- Alternative causes extensive alterations or disruptions which are permanent.

CONSTRUCTION DEBRIS

Disposal of construction related debris is considered in relation to the following scale:

++ Alternative produces no construction debris for disposal.

\+ Alternative produces small amounts of debris, such as packing material, which can be routinely disposed of on site or off site.

o Alternative produces small amount of debris for disposal at local sanitary landfill, or large amount of debris disposed of on site.

\- Alternative produces large amount of debris for disposal at local sanitary landfill.

-- Alternative produces debris for hazardous waste landfill.

LONG-TERM EFFECTS

Long-Term Effects refer to environmental effects after remedial alternative implementation.

SITE POLLUTION

Long-term Site Pollution refers to odor, noise, air emissions, surface or groundwater contamination after remedial alternative implementation. The alternatives are evaluated in relation to the following scale:

++ Alternative causes no impacts.

\+ Alternative causes effects that are contained within the site boundary.

o Alternative causes effects beyond the site boundary but generally limited, controllable, and within acceptable limits.

\- Alternative causes limited uncontrollable or unacceptable effects beyond the site boundary.

-- Alternative causes significant uncontrollable and unacceptable effects beyond the site boundary.

SITE ALTERATIONS

Long-term Site Alterations include wildlife habitat alteration, threatened and endangered species; use of natural resources, parks, transportation, and urban facilities; historic site alteration; relocation of households, businesses and services; and aesthetic changes to the site. The changes are considered in relation to the following scale:

++ Alternative causes no alteration or disruptions.

+ Alternative causes brief temporary alterations or disruptions.

o Alternative causes prolonged temporary alterations or disruptions.

- Alternative causes slight alterations or disruptions which are not permanent.

-- Alternative causes extensive alterations or disruptions which are permanent.

INSTITUTIONAL

Political jurisdictions, land acquisition, and land use and zoning are considered in relation to the following scale:

++ Alternative is likely to be approved by all parties in all areas.

+ Alternative is likely to be approved by all parties with reservations.

003126

o Alternative is not likely to be approved by all parties but permitted.

\- Alternative is likely to be permitted with stipulations.

-- Alternative not permittable.

APPENDIX C

COMPONENT DESCRIPTION AND COSTING INFORMATION

1.1 Cost Estimating - Bases and Assumptions

The cost estimates derived in Appendix C are based on the following:

(1) Waste volumes shown in Table 1-5.

(2) Incinerator capacities of 4 and 8 tons per hour, operating 24 hours a day, 7 days a week with downtime for maintenance and adjustments estimated at 15%.

(3) Off-site RCRA approved landfill capacity available within 150 miles of the site.

(4) Sources for clay and granular material for construction available within 20 miles of the site.

(5) Excavated sludges will increase in volume by 10% from in situ volumes.

(6) Stabilization of sludges for landfilling will require one part additive to one part in-situ sludges by volume, but the stabilized sludges would be 1.85 the volume of in-situ sludges.

(7) Chemically fixed soils will increase in volume by 10% from the in-situ volume.

(8) Interest rate used for estimating base present worth costs is 10%. Present worth costs were estimated for 4% and 7% also, and reported in the sensitivity analysis.

1.2 Cost Estimates - Unit Costs

Unit costs were derived from informal vendor and contractor estimates and cost guidance references. All cost estimates are in 1986 dollars. Cost information was adjusted by appropriate indices to 1986 equivalence.

Unit costs for construction are highly dependent upon the inefficiency resulting from personnel protection equipment required for remedial activities at hazardous waste sites. Because of this, base unit costs were adjusted by published average cost multipliers (degree-of-hazard multipliers) for the level of protection anticipated for different tasks.

1.3 Component Descriptions

1.3.1 Common Components

Common components, those applicable to all remedial alternatives, include:

- Mobilization and Demobilization

  This activity includes locating and assembling on-site the equipment needed for construction, and their removal from site after remediation is completed.

  Estimated Cost - $113,000 Capital
  (Alter. 3, 5, 6, 10)

  Estimated Cost - $ 24,000 Capital
  (Alter. 12)

- Administrative Office Facilities

  The facility includes office trailers and area lighting.

  Estimated Cost - $149,000 Capital

  Estimated Yearly Operational Cost - $15,000

- Security Personnel

  Security guards would man the entrance gates 24 hours per day for the total implementation period.

  Estimated Yearly Cost - $100,000

- Health and Safety Program

  Includes personnel and equipment to train workers and monitor site and personnel safety.

  Estimated Cost - $200,000 Capital

  Estimated Yearly Operating Cost - $40,000

- On-Site Laboratory

  Includes lab trailer and instruments needed to perform criteria analyses, a chemist and two technicians.

  Estimated Cost - $160,000 Capital

  Estimated Yearly Operating Cost - $60,000

- Parking Facility

  Parking area with 10 spaces for office area.

  Estimated Cost - $14,000 Capital

  Estimated Yearly Maintenance - $2,000

- Road Construction

  All weather roads would be provided for mobile equipment and vehicles.

  Estimated Cost - $55,500 Capital

  Estimated Yearly Maintenance Cost - $5,500

- Equipment Area

  Site prepared for siting construction equipment and disposal equipment.

  Estimated Cost - $198,000 Capital

- Perimeter Dike

  A flood protection dike would be constructed to enclose the waste deposit areas, to protect against a 100-year storm event. A cross section of the dike is shown on Figure C-1. The dike has the following dimensions:

  Length - 7735 feet long

  Top Elevation - 30 feet above MSL (includes 2 feet of free board)

  Top Width - 8 feet w/side slopes of 3H:1V

  Fill Required - 287,340 cu. yards

  The dike would be removed after remedial activities are completed.

  Estimated Construction Cost - $1,526,300

  Estimated Removal Cost - $ 718,400

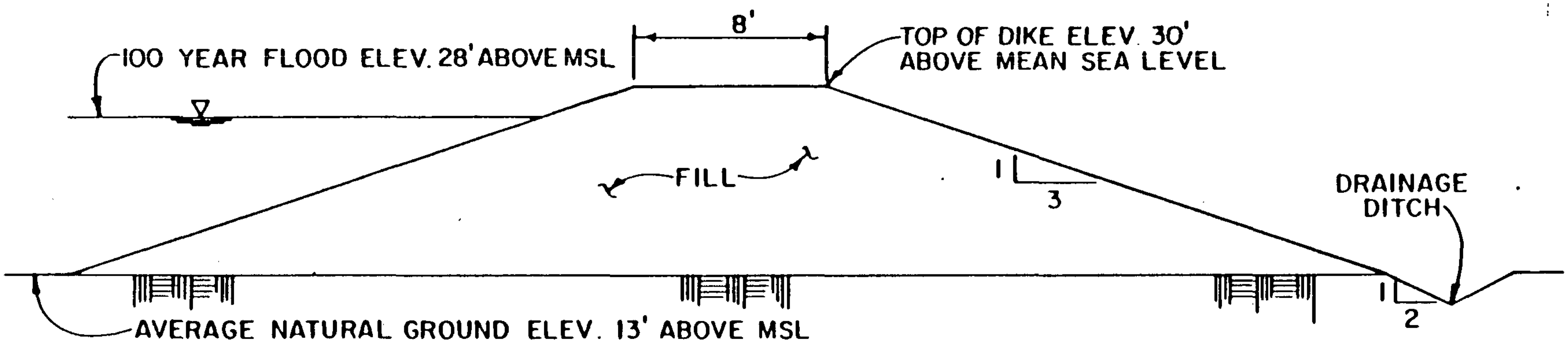

FIGURE C-1

CROSS SECTION OF PERIMETER DIKE

SIKES DISPOSAL PITS
CROSBY, TEXAS

Prepared for :
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003131

DATE . JUNE 1986 PROJECT NO 1633-20-003-000

003132

- Vehicle Decontamination Pad

  A concrete pad, with liquid storage sump, water storage tank, steam sprayer, and steam generator would be constructed to decontaminate vehicles and equipment. This facility is shown in Figure C-2.

  Estimated Construction Cost - $60,000

  Estimated Yearly Maintenance Cost - $52,000

- Surface Water/Infiltration Water Collection and Treatment

  Facilities would be provided to collect and treat all contaminated surface water and pit infiltration waters. The treatment process is shown in Figure 6-1. Specifications include:

  Surface Water to be Collected - 13 M gal.

  Infiltration Water to be Collected - 64 M gal.

  For Collection - 100 gpm sump pumps.
  - 2000 ft. of 4 in. dia. PVC pipe

  Total cumulative time to treat 77M gallons of contaminated water at 100 gpm = 1.5 years.

  Contaminated Water Treating Process:

  1 - Air Stripping unit including tower, packing, air blower, discharge pump, with flow control.

  1 - GAC Adsorption unit with two individual carbon columns.

  Estimated Capital Costs -

Air Stripping Unit plus carbon adsorption unit	$ 150,000
Collection Equipment	25,000
Total	$ 175,000

  Estimated Yearly Operating Costs - (includes labor, carbon regeneration, electricity) $ 70,000

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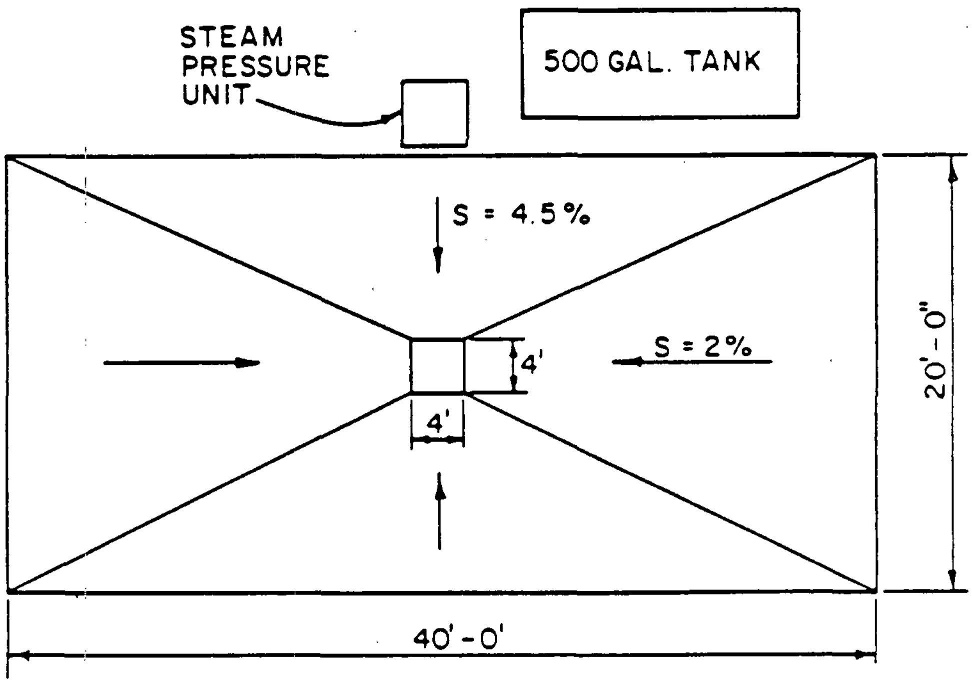

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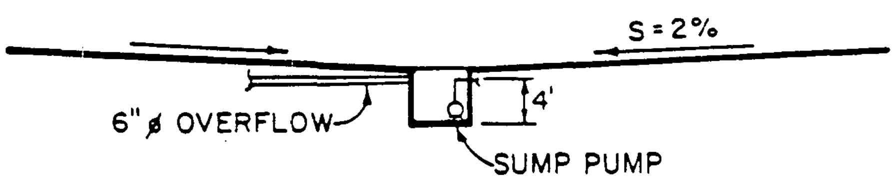

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FIGURE C-2 VEHICLE DECONTAMINATION PAD	SIKES DISPOSAL PITS CROSBY, TEXAS	Prepared for TEXAS WATER COMMISSION DATE JUNE 1986 PROJECT NO 1633-20-003-000

o Stormwater Runoff Collection and Disposal

This system is designed to collect stormwater from within the perimeter dike in ditches that drain into a lift station, which would discharge the water to the San Jacinto River. The design basis and equipment included in this component are listed below.

Designed for a 25-year storm event

Precipitation - 9.9 inches

Total runoff - 6 in. or 10.8 M gallons

Peak runoff - 125 cfs or 56,250 gpm

Ditches - 750 ft. lined, 5750 ft. unlined

Lift station with 5 pumps @ 14,000 gpm each, 20 ft. TDH.

Estimated Capital Cost - $370,000

Estimated Yearly Operating Cost - $20,000

1.3.2 Components Specific to Remedial Alternatives

o Excavation of Sludges

Sludges will be excavated for each alternative, but quantities vary with alternative. Costs will be developed by areas, then shown for each alternative. Sludges will be removed to 100 ppm PNA.

- Overflow Area

  Excavate with scraper

  Quantity - 43,300 cu. yds.

  Rate - $2.86/cu. yds.

  Hazard Multiplier - 3.37

  Excavation Cost - $271,400

- Main Waste Pit, Small Waste Pits and Barrels

  Excavate with dragline and loader

  Quantity - 8,800 cu. yds.

  Rate - $3.00/cu. yd.

  Hazard Multiplier - 3.37

  Install sheet piling 25 ft. deep to protect dragline during excavation

  Quantity - 1000 sq. ft. piling

  Setups - 10

  Rate - $8.65/sq. ft.

  Hazard Multiplier - 3.37

Excavation Cost	-	$ 89,000
Sheet Piling Cost	-	$292,000
Total		$381,000

- Tank Lake

  Excavate with dragline and loader

  Quantity - 2000 cu. yds.

  Rate - $3.00/cu. yd.

  Hazard Multiplier - 3.37

  Install sheetpiling 25 ft. deep to protect dragline during excavation.

  Quantity - 1000 sq. ft.

  Setups - 3

  Rate - $8.65/sq. ft.

  Hazard Multiplier - 3.37

003136

Excavation Cost	-	$20,200
Sheet Piling Cost	-	$87,000
Total		$107,200

- Suspected Areas

  Excavate with dragline and loader

  Quantity - 16,700 cu. yds.

  Rate - $3.00/cu. yd.

  Hazard Multiplier - 3.37

  Excavation Cost - $168,800

o Excavation of Contaminated Soils

Contaminated soils would be excavated to 10 ppm volatile organics (either benzene, 1,2-dichloropropane or naphthalene).

- Overflow Area

  Excavated with scraper

  Quantity - 58,300 cu. yd.

  Rate - $1.86/cu. yd.

  Hazard Multiplier - 3.37

  Excavation Cost - $365,400

- Main Waste Pit

  Excavated with dragline and loader

  Quantity - 21,000 cu. yds.

  Rate - $1.86/cu. yd.

  Hazard Multiplier - 3.37

  Excavation Cost - $212,300

o On-Site Incineration

Sludges would be incinerated @ 4 tons/hour. Sludges plus contaminated soils would be incinerated @ 8 tons/hour.

o Incineration of Sludges (see Figure C-3)

Basis: - 4 tons per hour (applies to Remedial Alternative 5 and 6)

- 70,800 cu. yds. or 86,400 tons @ 90 lb./cu. ft.
- 24 hour-per-day operation @ 85% OST
- tons per day incinerated - 81.6
- days to incinerate 86,000 tons - 1059

- Mobilization/Demobilization of On-Site Incinerator

  Estimated Cost - $1,192,000

- Load Incinerator with End Loader and Operator

  Rate - $800/day

  Estimated Cost - 1059 x $800 = $ 847,000
  for 3 years, annual cost = $ 282,000

- Operation and Maintenance

  Unit Cost - $188/ton

  Estimated Yearly Cost - $5,400,000

- Storage and Dewatering Pad

  This pad would be used to store incinerator waste feed for 24 hour operation.

  Estimated Cost - $25,000

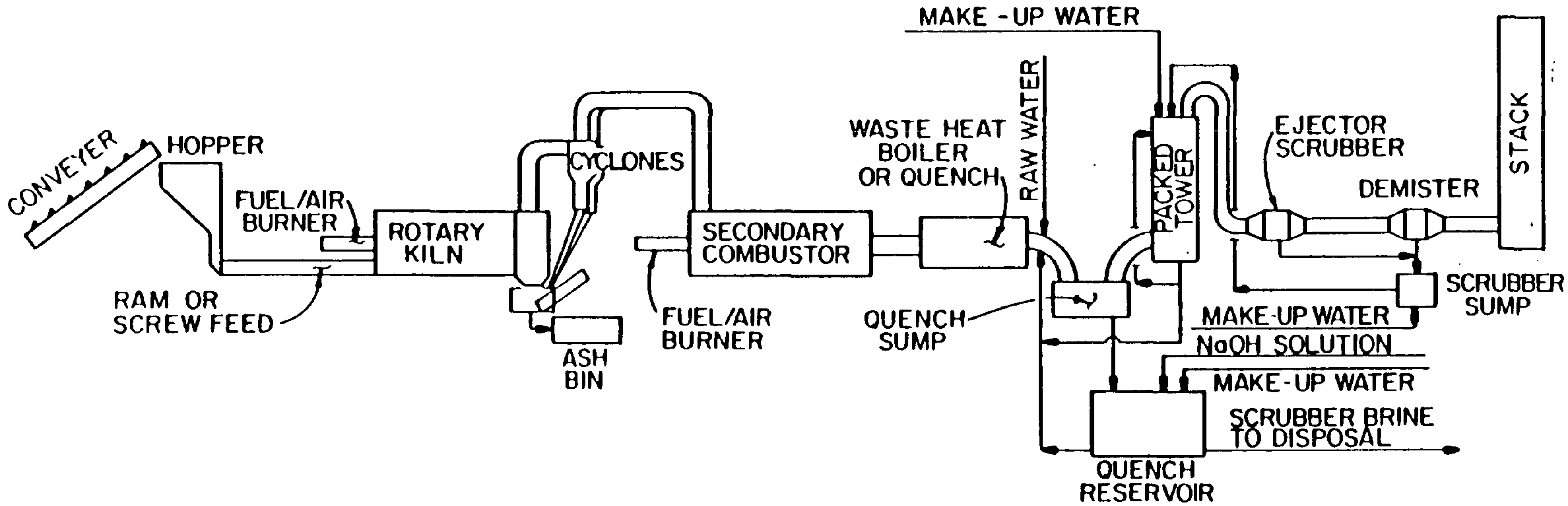

FIGURE C-3

SCHEMATIC FLOW DIAGRAM OF ON-SITE INCINERATOR

SIKES DISPOSAL PITS
CROSBY, TEXAS

Prepared for :
TEXAS WATER COMMISSION

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DATE : JUNE 1986 PROJECT NO. 1633-20-003-000 o Incineration of Sludges and Contaminated Soils (applies to Remedial Alternative 10)

Basis: Feed rate - 8 tons/hour

Sludges - 70,800 cu. yds. = 86,400 tons @ 90 lb/cu. ft.

Contaminated soils - 79,300 cu. yds. = 140,300 tons @ 131 lb/cu. ft.

Total - 226,700 tons

24 hour/day operation @ 85% OST

Tons incinerated per day - 163.2

Days to incinerate 226,700 tons = 1389

- Mobilization and Demobilization of Incinerator

  Estimated Cost - $1,825,000

- Loading Incinerator - with End Loader and Operator

  Rate - $800/day of operation

  Estimated Cost - 1389 day x $800/day = $1,100,000

  Annual Cost for 4 Years = $278,000

- Operation and Maintenance

  Unit Cost - $172/ton

  Estimated Yearly Cost - $9,720,000

- Storage and Dewatering Pad

  This pad would be used to store incinerator waste feed for 24 hour operation.

  Estimated Cost - $50,000

- Chemical Fixation of Incinerator Ash (varies with Alternative)

  - Remedial Alternatives 5 and 6

    Quantity of Ash - 46% of feed sludges
    Feed Sludges - 70,800 cu. yds.
    Ash - 0.46 x 70,800 cu. yds. = 32,600 cu. yds.

    Rate - $30/cu. yd.

    Fix over 3 years

    Estimated Total Cost = $30/cu.yd.x32,600 cu.yds = $978,000

    Estimated Yearly Cost - $326,000

  - Remedial Alternative 10

    Quantity of Ash - 32,600 cu.yds. from sludges (See Alter. 5 & 6 calculations) plus ash from soils incineration. Weight loss from soils incineration assumed to be negligible so ash from Cont. soils = 79,300 cu. yds.

    Total Ash = 32,600 cu. yds. + 79,300 cu. yds.
    = 119,800 cu. yds.

    Rate - $30/cu. yd.

    Fix over 4 years

    Total Cost = $30/cu. yd. x 119,800 cu. yds. = $3,594,000

    Estimated Yearly Cost - $898,500

- Chemical Fixation of Contaminated Soils (varies with Alternative)

  Basis: Total Contaminated Soils - 79,300 cu. yds.

  Excavated Soils - 87,200 cu. yds.

  Fixation Costs (includes materials, labor and equipment) - $30/cu. yd.

  Total Cost = 87,200 cu. yds. x $30/cu. yd.
  = $2,616,000

  - For Remedial Alternative 3

    Fix for 2 years

    Estimated Yearly Operating Cost -
    0.5 x 87,200 cu. yds. x $30/cu. yd. = $1,308,000

003141

- For Remedial Alternative 5

  Fix over 3 years, same quantity as Alternative 3

  Estimated Yearly Cost - $1,023,000

- For Remedial Alternative 12

  Quantity of contaminated soils - 58,300 cu. yds.

  Excavated contaminated soils - 64,100 cu. yds.

  Total Cost for Fixation = 64,100 cu. yds. x $30/cu. yd.
  = $1,923,000

  Fix over 2 year period

  Estimated Yearly Cost - $962,000

o On-Site Burial of Sludges in Pits with Slurry Walls and Caps (Remedial Alternative 12)

- Excavation of Sludges from small waste pits, overflow area, suspect areas, and drummed waste

  Quantity = 600 + 43,300 + 16,700 + 2600 cu. yds.
  = 63,200 cu. yds.

  Rate - $1.86/cu. yd.

  Hazard Multiplier - 3.37

  Estimated Cost = 63,200 cu. yds. x $1.86/cu. yd. x 3.37
  = $396,000

- Excavation of Contaminated Soils from overflow area

  Quantity - 58,300 cu. yds.

  Rate - $1.86/cu. yd.

  Hazard Multiplier - 3.37

  Estimated Cost = $58,300 cu. yds. x 1.86/cu. yd. x 3.37
  = $365,500

- Stabilization of Sludges

  Quantity - 77,900 cu. yds.

  Rate - $30/cu. yds.

  Estimated Cost = $77,900 cu. yds. x $30/cu. yd.
  = $2,337,000

003142

- Slurry Walls with Caps (See Figure C-4)

Main Waste Pit - Slurry Wall - 30 ft. deep,
2000 ft. long
3 ft. thick

Tank Lake - Slurry Wall - 30 ft. deep
1200 ft. long
3 ft. thick

Total Area of Walls - 96,000 sq. ft.
@ $10/sq. ft. of wall, slurry wall cost = $960,000

* Geomembrane Caps

Area of Caps:

Tank Lake - 69,600 sq. ft.
Main Waste Pit - 162,200 sq. ft.

Total - 231,800 sq. ft.

Clay Cost:

3 ft. thick - 32,866 cu. yds.
@ $17.06/cu. yd. - $560,000

Sand Cost:

1 ft. thick over area - 8585 cu. yd.
@ $13.35/cu. yd. - $115,000

Geotextile Cost:

231,800 sq. ft. @ $0.25/sq. ft. - $58,000

Topsoil Cost:

2 ft. thick - 17,170 cu. yds.
@ $5.50/cu. yd. to haul, spread and compact - $95,000

Flexible Membrane Liner Cost:

231,800 sq. ft. @ $0.60/sq. ft. - $139,000

Total Cost for Caps - $967,000

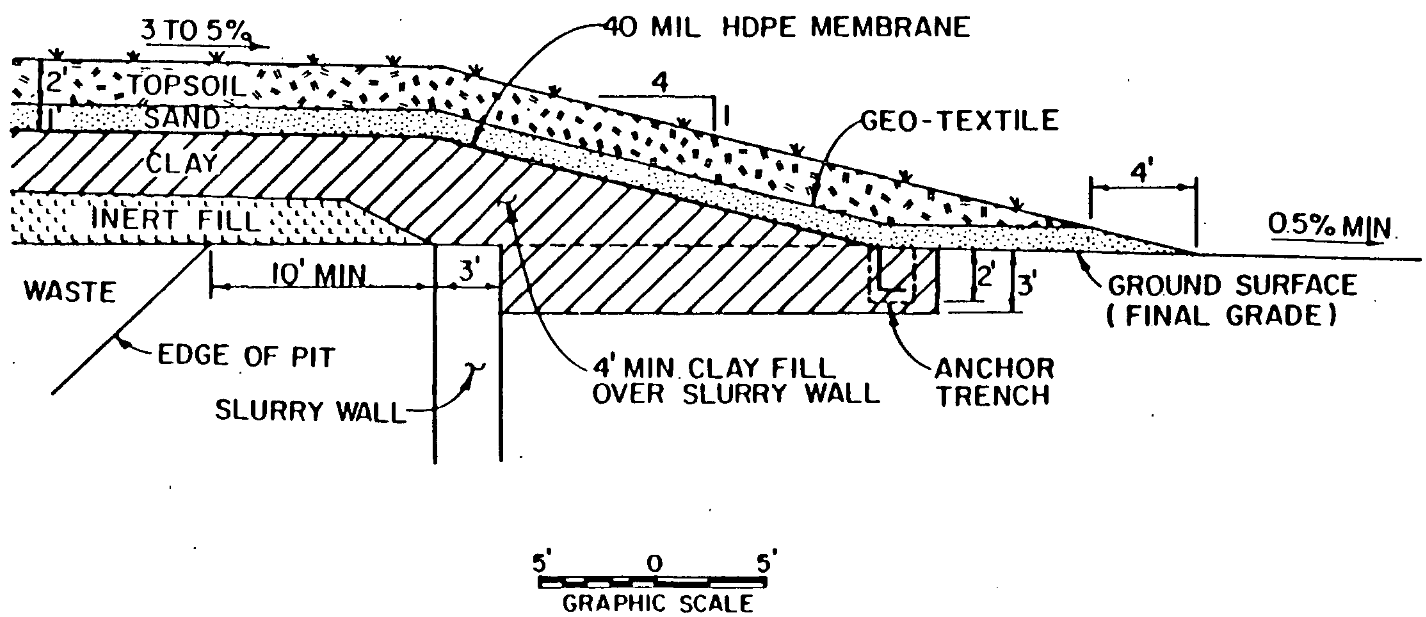

FIGURE C-4

SLURRY WALL AND GEOMEMBRANE CAP

SIKES DISPOSAL PITS
CROSBY, TEXAS

Prepared for :
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* Passive Gas Vents with Carbon Canisters for each pit:

  Estimated Cost - $75,000

  Annual Operation and Maintenance - $35,000

* Leachate Withdrawal System (Wells and Pumps in each pit enclosure)

  Estimated Capital Cost - $50,000

  Estimated Yearly Operating Cost - $40,000

o Off-Site RCRA Landfilling of Sludges (for Remedial Alternative 3)

  Quantity - 70,800 cu. yds. = 86,400 tons

  - Transportation Cost - for 150 miles

    charge - $60/ton

    cost - $5,184,000

  - Disposal Cost @ $200/ton

    cost - $17,300,000

    Total Cost - $22,460,000

    Annual Cost for 2 years - $11,300,000

o Off-Site RCRA Landfilling of Contaminated Soils (for Remedial Alternative 6)

  Quantity of Soils - 79,300 cu. yds. @ 131 lb/cu. ft. = 140,200 tons

- Transportation Cost @ $60/ton	-	$ 8,412,000
- Disposal Cost @ $200/ton	-	28,040,000
Total Cost	-	$36,452,000
Annual Cost for 3 years	-	$12,150,000

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o Backfilling and Revegetation (varies with Alternative)

- Remedial Alternative 3

  Volume to backfill:

  Fixed Soils, Vol. - 79,300 cu. yds. x 1.1
  = 87,230 cu. yds.

  Backfill Cost @ $ 5.00/cu. yd. = $436,000

  Revegetation Cost:

  Area to revegetate - M.W. Pit + overflow area + Tank Lake + suspect areas + small waste pits.

  Total Area - 700,000 sq. ft.

  Cost @ $35/1000 sq. ft. - $25,000

  Total Cost - $461,000

- Remedial Alternative 5

  Volume to backfill:

  Fixed Soils, Vol. - 87,230 cu. yds. (From Table 1-5)

  Fixed Ash, Vol. - 32,600 cu. yds. (See Remedial Alt. 5 & 6, p. C-14)

  Total - 119,830 cu. yds.

  Backfill Cost @ $5.00/cu. yd. - $599,000

  Revegetation Cost (same as Alt. 3) - $ 25,000

  Total Cost $624,000

- Remedial Alternative 6

  Volume to backfill:

  Fixed Ash - 32,600 cu. yds. (Reference given above)

  Backfill Cost @ $5.00/cu. yd. - $163,000

  Revegetation Cost - $ 25,000

  Total Cost $188,000

003145

- Remedial Alternative 10

  Volume to backfill:

  Fixed Ash - 32,600 + 79,300 cu. yds. (Refr: See Calc. for
  - 111,900 cu. yds. Rev. Alt. 5 above)

  Backfill Cost @ $5.00/cu. yd. - $560,000

  Revegetation Cost $ 25,000

  Total Cost $585,000

- Remedial Alternative 12

  Volume to backfill:

  Fixed Soils, Vol. - 58,300 cu. yds.

  Backfill Cost @ $5.00/cu. yd. - $292,000

  Revegetation Cost - $ 25,000

  Total Cost $317,000

o Post Closure Monitoring of Upper and Lower Aquifers (applies to all Alternatives)

  Estimated Capital Cost - $ 58,000
  (for new wells or
  repairing old ones)

  Estimated Annual O&M Cost - $ 41,000
  (for sampling and
  analysis, reports, etc.)

APPENDIX D

UPPER AQUIFER RESTORATION

Shallow groundwater at the Sikes Disposal Pits site has become significantly contaminated around primary waste disposal areas through leaching of sludges and potentially through infiltration of undiluted wastes into subsurface soils. Groundwater movement has resulted in the migration of the contaminants through the Upper Aquifer away from the primary disposal areas. This migration of contaminants appears to be contained within the Sikes Disposal Pits boundaries. However, as a precautionary move, the Texas Water Commission has declared all wells on site in the Upper Aquifer to be nonpotable because the current water quality does not meet Drinking Water Standards or satisfy the (10-4 to 10-7 range) Human Health Criteria as given in Table 1-8.

One of the goals of all remedial alternatives evaluated in this Feasibility Study is to restore the Upper Aquifer to drinking water quality within 30 years following completion of remedial action. Its use would be banned until this goal was attained. Each remedial alternative also includes removing, isolating, or immobilizing all wastes.

The problem was, how to accomplish aquifer restoration within 30 years in the most cost effective manner. Several approaches were screened. One approach considered was to allow the aquifer to flush itself clean with the natural groundwater that flows under the site. Based on results from the remedial investigation, the flow of recharge groundwater entering the site is approximately 572,000 gallons daily. The volume of the aquifer under the site has been estimated at 271 million gallons. Based on this data, it would take only 474 days or 1.3 years for the upper aquifer to be restored to drinking water quality providing two conditions were satisfied: total displacement flow and zero contaminant input. Unfortunately, neither of these conditions are totally attainable. The question raised by the theoretical situation just described is how closely must these two conditions be satisfied to achieve the aquifer restoration goals of quality and time defined above. Each of these conditions will be examined further in an attempt to answer the question raised.

If the wastes on-site are removed, or isolated from surface and groundwater, would an improvement in aquifer quality result? This question has been answered from the results of groundwater sampling before and after the removal of a tar pit located near the south boundary of the site in June, 1983. Prior to removal, groundwater samples from a nearby well showed high values of TOX and TOC, whereas, subsequent groundwater sampling in February 1984 indicated essentially no detectable contamination. Further indications of the aquifer's ability to flush itself is evidenced by the quality of groundwater entering Jackson Bayou and the San Jacinto River. Sampling shows that the average groundwater entering the river or bayou contains a much lower level of contaminants than is found near the waste deposits. Thus, even with the current rate of contaminant input (with all waste in place) the aquifer recharge rate is sufficient to reduce the concentration of contaminants in groundwater from well above Surface Water Quality Criteria near the waste deposits to well below it by the time the groundwater enters the river.

Based on the results described above, it appears that natural flushing could achieve the aquifer restoration goals providing the contaminant input to the aquifer could be limited sufficiently. The next step in the study process was to devise a method for showing the effect (on restoration time) of variable contaminant inputs and flush efficiencies.

Available groundwater models were reviewed, but no integral models were found for analyzing a situation where the source of contamination covers an extensive area such as the Sikes situation. Only point source models were found. As a result, a simplified point source model was derived as described below. The Upper Aquifer under the site would be considered a large rectangular shaped tank with dimensions equal to that portion of the aquifer lying under the waste deposit areas. Clean groundwater recharge containing no contaminants and infiltrating storm water containing contaminants leached from the contaminated soils left on-site would be tank influents. The tank would initially contain groundwater of the composition shown in Table 6-9. Thus, the tank would contain the highest concentrations of benzene and 1,2-dichloroethane found in groundwater on-site.

Variables would be contaminant input and flush or displacement efficiency. Contaminants would enter the tank and be accumulated for one year. At the end of the year the total contaminants in the tank would be the sum of the initial contents and the contaminants added during the year. It would be assumed that at years end, the tank contaminants would be removed in part to simulate what would have occurred in the aquifer through natural flushing. The cycle is repeated during succeeding years with a new contaminant input to the tank during the year and the fractional removal of tank contaminants at year's end. The concentration of contaminants in the tank would be determined yearly for 30 years to show the effect of the variable on tank contaminant concentration.

Contaminant input was determined as described below. During site clean-up, waste would be removed or isolated so that only slightly contaminated soils would be left underlying former waste deposits. Contaminant input to the aquifer would probably be continued, however, through the leaching of soil contaminants by infiltrating stormwaters. No significant leaching by groundwater should occur under this condition because none of the contaminated soils would be below the water table. The question raised at this point is: which contaminants would be leached and how much? The most likely contaminants to be leached will be determined first. The prime factors that should influence which contaminants would be leached preferentially are: contaminant solubility in water and contaminant soil adsorption.

Solubility is probably not a significant factor in this case, because all the contaminants are at very low concentrations, (less than 10 ppm), which is less than 5% of the water solubility limits for all soil contaminants. Soil adsorption has a significant impact. Soil adsorption factors (KOC) have been determined for a large number of the contaminants found in the soils and aquifer waters at Sikes. The soil adsorption factor is a quantitative measure of the probability for a chemical compound to be retained on or in the soil matrix. Soil adsorption data indicates that most of the GC/MS base neutral and acid compounds are highly adsorbable on the soils, while the volatile organics seem to have very low soil adsorbtivity. This indicates that the contaminants most likely to leach from the soil matrix and ultimately contaminate the groundwater are readily soluble in water, and have a low soil adsorption factor, i.e., low potential for being adsorbed on the soil. Benzene, 1,2-dichloroethane, and 1,1,2-trichloroethane are all examples of this type contaminant. The first two are the predominant contaminant in groundwaters at the site. The conclusion that benzene and 1,2-dichloroethane would be preferentially leached from soils was further confirmed by the results from leaching tests run on soil core samples. These results also indicated that of those contaminants present in the soils, the ones that would leach most readily from contaminated soils were benzene and 1,2-dichloroethane.

Now the question of how much of the contaminants would be leached from the soils will be addressed. The quantity of contaminants picked up by the clean water as it passes through the permeable soils cannot be predicted accurately. However, the rate of leaching can be categorized by assuming various rates of contaminant transfer into the infiltrating water. The transfer rate is a function of the concentration gradient between the soil and water phases. When the concentration of a contaminant is equal in both phases, the phases are described as being in equilibrium relative to the contaminant. Based on expectations, it is unlikely that the equilibrium attained during a storm event would be greater than 50%. Thus the effect of contaminant transfer rate could be determined by considering equilibrium as a variable and assume different values less than 50% as inputs to the model.

The other dimension that must be defined to determine contaminant transfer rate is the concentration of contaminant in the soil. Soil concentration could be treated as a variable also and then its effect on restoration time could be determined for various concentrations of soil contaminants.

Aquifer flushing efficiency equivalent to displacement, is the other significant factor that affects aquifer restoration time, and has been, in this case, related to displacement efficiency. Flush efficiency has been defined as that portion of the contaminants in the tank that are displaced or removed during a given time interval. For example, a 50% flush efficiency would result in removing 50% of the contaminants in the tank in a given time interval. Flush efficiencies of 60-80% are expected for the condition of laminar flow through a porous media.

The variable inputs and the values for each used to simulate aquifer flushing performance are:

Variable	Values
o Soil Contaminant Concentration, ppm	1,5,10
o Flush Efficiency, %	50,60,70
o Equilibrium (soil-water), %	10,20,50

Other factors and information used in the model include:

- o Soil thickness containing concentration of contaminants average one foot. Basis: Chemical analysis of cores taken from overflow area showed that a rapid decrease in contaminant concentration occurs within a one foot depth below 10 ppm volatile organic. The assumption that the soil concentration remains constant for a one foot depth is conservative.

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- o Aquifer water volume of 76M gallons or 630M pounds.
- o Area of contaminated soil overlying the aquifer and containing the contaminants is 670,000 sq. ft.
- o Porosity of aquifer is 30%.
- o Depth of aquifer averages 15 feet.
- o Infiltrating water flow, average - 839,328 gal. per year or 7M pounds per year.

The tank or aquifer contaminant concentration was calculated for one year intervals for all 27 combinations of the stated variables. The results are tabulated in the attached Tables, and shown graphically in Figures D-1 and D-2 for the key contaminants, benzene and 1,2-dichloroethane. (See explanation of Tables at end of discussion). These results indicate the following:

1. For all conditions considered, the aquifer can be restored within 30 years to satisfy the 10^{-4} Human Health Criteria.

2. For all soil contaminant concentrations of 5 ppm or less, the aquifer would be restored to the 10^{-5} Human Health Criteria within 30 years.

3. The 10^{-5} Human Health Criteria can be satisfied at a soil contaminant concentration of 10 ppm except for the following five conditions:

- Soil/water equilibrium of 10 percent
  Concentration in soil of 10 ppm
  Aquifer flush efficiency of 50 percent;
- Soil/water equilibrium of 20 percent
  Concentration in soil of 10 ppm
  Aquifer flush efficiency of 50 percent;
- Soil/water equilibrium of 20 percent
  Concentration in soil of 10 ppm
  Aquifer flush efficiency of 60 percent;
- Soil/water equilibrium of 50 percent
  Concentration in soil of 10 ppm
  Aquifer flush efficiency of 50 percent; and
- Soil/water equilibrium of 50 percent
  Concentration in soil of 10 ppm
  Aquifer flush efficiency of 60 percent.

From Figures C-1 and C-2, it can be seen that the aquifer restoration goals should be met for Sikes when the soils contain 10 ppm or less of benzene or 1,2-dichloroethane. This is the basis for establishing the criteria of 10 ppm or less of a volatile organic for removing contaminated soils. Thus, to restore the aquifer within 30 years, the contaminated soils should be removed down to a contaminant level of 10 ppm for either benzene or 1,2-dichloroethane.

Explanation of Tables

The following tables show the effect of time on the restoration of the Upper Aquifer for a variety of site conditions. Because of the difficulty of understanding the data presented in the Tables, the following explanation is given with the intent of making the Tables more understandable.

The factors used to determine the theoretical concentration of 1,2 dichloroethane and benzene in the Upper Aquifer are as follows:

Given Parameters:	lbs (pounds) of contaminated soil 67 10E+6 (67,000,000)
	lbs. of water in the aquifer 630 10E+6 (630,000,000)
	lbs. of water infiltrating thru contaminated soils, yearly, into the Upper Aquifer - 7 10E+6 (7,000,000)

Each column, with the exception of the given parameters, is dependent upon one or more other columns to derive its numerical value.

As stated earlier, the variable inputs and values used to simulate aquifer flushing performance are:

- o Soil Contaminant Concentration (Conc. in Soil) ppm 1,5,10
- o Flush Efficiency, % 50,60,70
- o Equilibruim, soil-water (Soil/H_2O Equil) 10,20,50

The initial concentration of contaminant in the groundwater within the tank was taken as 10 ppm (or 6300 lbs).

Step 1 - Determine lbs. of contaminants in the soil.
lbs. in soil = (Concen. in soil x lbs. of soil) - cumulative lbs. removed the preceeding year

Step 2 - Determine concentration of contamination in the soil.
Concentration in soil = lbs. of contam./lbs. of soil

Step 3 - Determine soil/water equilibrium (based upon given percent).
Soil/Water Equilibrium = Concen. in soil x soil/water equilibrium, %

Step 4 - Determine lbs. of contamination removed from the soil.
lbs. removed from soil = lbs. of water infiltrating x soil/water equilibrium

Step 5 - Determine cumulative lbs. of contaminants removed from soil.
Cumulative lbs. removed = cumulative lbs. removed during preceeding years + lbs. of contaminants removed in current year

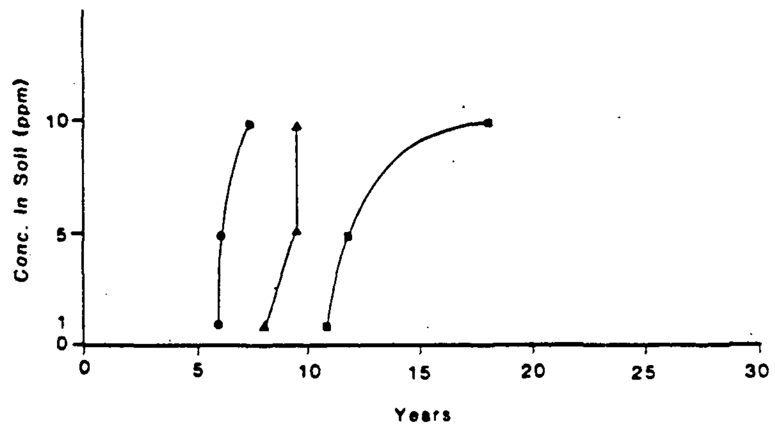
Step 6 - Determine lbs. of contaminants in the Aquifer.
lbs. of contaminant in Aquifer = [lbs. in Aquifer in preceeding year + lbs. removed from soil, current year] x % flush

Step 7 - Determine concentration of contamination in the Aquifer.
Concentration of contaminant in Aquifer = lbs. in Aquifer/lbs. of water in Aquifer

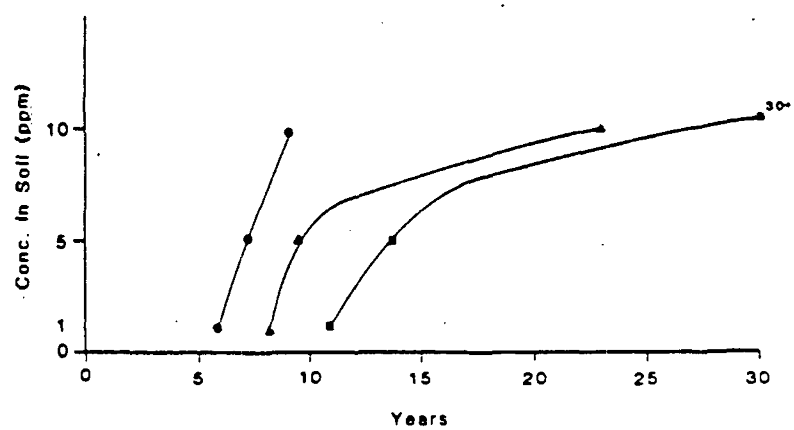
AQUIFER RESTORATION TIME VS. SOIL 1,2 DICHLOROETHANE CONCENTRATION

1,2 DICHLOROETHANE 10E-5 HHC

10% EQUILIBRIUM



20% EQUILIBRIUM



LEGEND:

- ■ 50% Flush Efficiency
- ▲ 60% Flush Efficiency
- ● 70% Flush Efficiency

50% EQUILIBRIUM

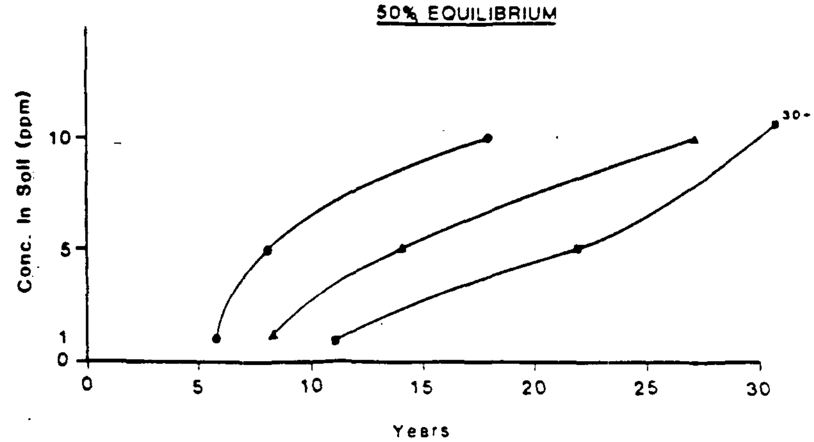
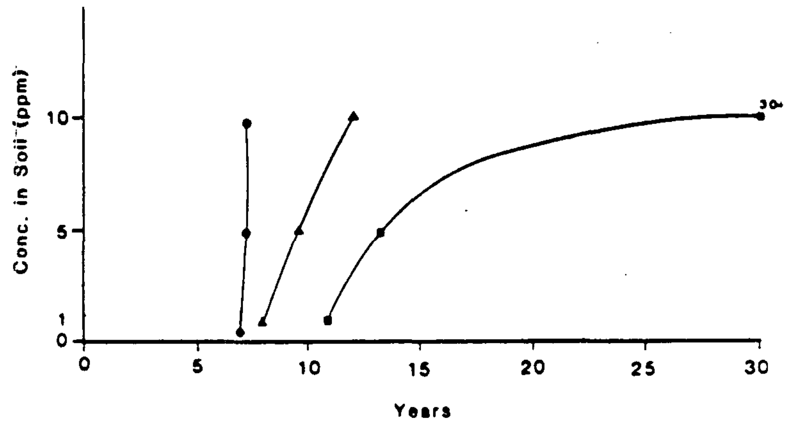


FIGURE D-1

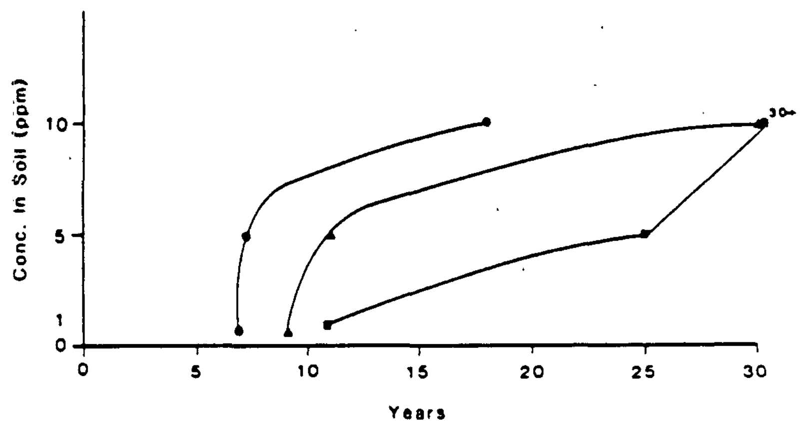
BENZENE 10E-5 HHC

AQUIFER RESTORATION TIME VS. SOIL BENZENE CONCENTRATION

10% EQUILIBRIUM



20% EQUILIBRIUM



LEGEND:

- ■ 50% Flush Efficiency
- ▲ 60% Flush Efficiency
- ● 70% Flush Efficiency

50% EQUILIBRIUM

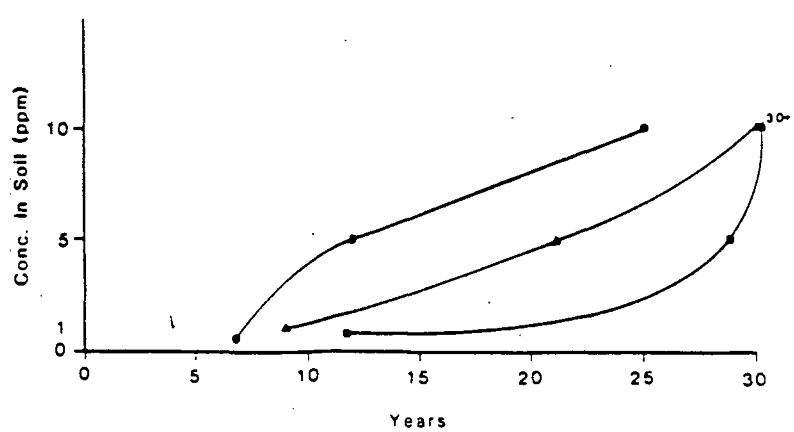


FIGURE D-2

Ground-water Restoration

1,2 Dichloroethane / Benzene

Years	Lbs in soil	Soil/H20 Equil. 10% (ppm)	Lbs Removed from Soil	Cuml. Lbs. Removed	Conc. in Soil (ppm)	Lbs. Soil 10E+6 LBS	Lbs. H20 10E+6 Lbs	Lbs in Aquifer 50% flush	Conc. in Aquifer (ppm)	Lbs H20 in Aquife 10E-6
0	67	0.1	0.7	0.7	1	67	7	6300.7	10.0011111111	630
1	66.3	0.0989552	0.6926865672	1.392686567	0.989552	67	7	3150.69634	5.0011053068	630
2	65.607313433	0.0979213	0.6854495433	2.078136110	0.979213	67	7	1575.69089	2.501096661	630
3	64.92186389	0.0968983	0.6782881302	2.756424240	0.968983	67	7	788.184592	1.2510866544	630
4	64.243575759	0.0958859	0.6712015378	3.427625778	0.958859	67	7	394.427896	0.6260760268	630
5	63.572374222	0.0948841	0.6641889844	4.091814762	0.948841	67	7	197.546042	0.3135651475	630
6	62.908185237	0.0938928	0.6572496965	4.749064459	0.938928	67	7	99.1016463	0.1573042005	630
7	62.250935541	0.0929118	0.6503829086	5.399447368	0.929118	67	7	49.8760146	0.0791682772	630
8	61.600552632	0.0919411	0.6435878633	6.043035231	0.919411	67	7	25.2598012	0.0400949226	630
9	60.956964769	0.0909805	0.636863811	6.679899042	0.909805	67	7	12.9483325	0.0205529068	630
10	60.320100958	0.0900300	0.63021001	7.310109052	0.900300	67	7	6.78927126	0.0107766211	630
11	59.689890948	0.0890893	0.6236257263	7.933734778	0.890893	67	7	3.70644849	0.0058832516	630
12	59.066265221	0.0881586	0.6171102337	8.550845012	0.881586	67	7	2.16177936	0.0034313958	630
13	58.449154988	0.0872375	0.6106628133	9.161507825	0.872375	67	7	1.38622108	0.0022003509	630
14	57.838492174	0.0863261	0.6042827541	9.765790579	0.863261	67	7	0.99525192	0.001579765	630
15	57.23420942	0.0854241	0.5979693522	10.36375993	0.854241	67	7	0.79661063	0.0012644613	630
16	56.636240068	0.0845317	0.5917219112	10.95548184	0.845317	67	7	0.69416627	0.0011018512	630
17	56.044518157	0.0836485	0.5855397419	11.54102158	0.836485	67	7	0.63985300	0.0010156397	630
18	55.458978415	0.0827745	0.5794221625	12.12044374	0.827745	67	7	0.60963758	0.0009676787	630
19	54.879556253	0.0819097	0.5733684982	12.69381224	0.819097	67	7	0.59150304	0.0009388937	630
20	54.306187754	0.0810540	0.567378081	13.26119032	0.810540	67	7	0.57944056	0.0009197469	630
21	53.738809673	0.0802071	0.5614502503	13.82264057	0.802071	67	7	0.57044540	0.0009054689	630
22	53.177359423	0.0793691	0.5555843522	14.37822492	0.793691	67	7	0.56301487	0.0008936744	630
23	52.621775071	0.0785399	0.5497797395	14.92800466	0.785399	67	7	0.55639730	0.0008831703	630
24	52.071995331	0.0777193	0.5440357721	15.47204044	0.777193	67	7	0.55021654	0.0008733596	630
25	51.527959559	0.0769074	0.5383518163	16.01039225	0.769074	67	7	0.54428417	0.0008639431	630
26	50.989607743	0.0761038	0.5327272451	16.54311950	0.761038	67	7	0.53850571	0.000854771	630
27	50.456880498	0.0753087	0.527161438	17.07028094	0.753087	67	7	0.53283357	0.0008457676	630
28	49.92971906	0.0745219	0.5216537812	17.59193472	0.745219	67	7	0.52724367	0.0008368947	630
29	49.408065279	0.0737433	0.5162036671	18.10813838	0.737433	67	7	0.52172367	0.0008281328	630
30	48.891861611	0.0729729	0.5108104944	18.61894888	0.729729	67	7	0.51626708	0.0008194716	630

Ground-water Restoration

1,2 Dichloroethane / Benzene

Years	Lbs in soil	Soil/H2O Equil. 50% (ppm)	Lbs Removed from Soil	Cuml. Lbs. Removed	Conc. in Soil (ppm)	Lbs. Soil 10E-6 LBS	Lbs. H2O 10E-6 Lbs	Lbs in Aquifer 60% flush	Conc. in Aquifer (ppm)	Lbs H2O in Aquifer 10E-6
0	670	5	35	35	10	67	7	6335	10.0555555556	630
1	635	4.7388059	33.171641791	68.17164179	9.477611	67	7	2547.26865	4.0432835821	630
2	601.82835821	4.4912564	31.438794832	99.61043662	8.982512	67	7	1031.48298	1.6372745724	630
3	570.38956338	4.2566385	29.796469729	129.4069063	8.513277	67	7	424.511780	0.6738282224	630
4	540.59309365	4.0342768	28.239937728	157.6468440	8.068553	67	7	181.100687	0.2874614082	630
5	512.35315592	3.8235310	26.7647171	184.4115611	7.647062	67	7	83.1461616	0.1319780344	630
6	485.58843882	3.6237943	25.366560237	209.7781214	7.247588	67	7	43.4050887	0.0688969663	630
7	460.22187858	3.4344916	24.041441419	233.8195628	6.868983	67	7	26.9786120	0.0428231938	630
8	436.18043716	3.2550778	22.785545225	256.6051080	6.510155	67	7	19.9056629	0.0315962904	630
9	413.39489194	3.0850365	21.595255549	278.2003636	6.170073	67	7	16.6003673	0.0263497895	630
10	391.79963639	2.9238778	20.467145185	298.6675087	5.847755	67	7	14.8270050	0.0235349286	630
11	371.33249121	2.7711379	19.397965959	318.0654747	5.542275	67	7	13.6899883	0.0217301403	630
12	351.93452525	2.6263770	18.384639379	336.4501141	5.252754	67	7	12.8298511	0.020364843	630
13	333.54988587	2.4891782	17.424247769	353.8743619	4.978356	67	7	12.1016395	0.0192089517	630
14	316.1256381	2.3591465	16.514025871	370.3883877	4.718293	67	7	11.4462661	0.0181686765	630
15	299.61161223	2.2359075	15.651352877	386.0397406	4.471815	67	7	10.8390476	0.0172048375	630
16	283.96025935	2.1191064	14.833744891	400.8734855	4.238212	67	7	10.2691170	0.0163001857	630
17	269.12651446	2.0084068	14.058847770	414.9323333	4.016813	67	7	9.73118590	0.0154463268	630
18	255.06766669	1.9034900	13.324430349	428.2567636	3.806980	67	7	9.22224650	0.0146384865	630
19	241.74323634	1.8040540	12.628378017	440.8851416	3.608108	67	7	8.74024980	0.0138734124	630
20	229.11485832	1.7098123	11.968686628	452.8538283	3.419624	67	7	8.28357457	0.0131485311	630
21	217.14617169	1.6204938	11.343456730	464.1972850	3.240987	67	7	7.85081252	0.0124616072	630
22	205.80271496	1.5358411	10.750888095	474.9481731	3.071682	67	7	7.44068024	0.0118106036	630
23	195.05182687	1.4556106	10.189274537	485.1374476	2.911221	67	7	7.05198191	0.0111936221	630
24	184.86255233	1.3795712	9.6569990023	494.7944466	2.759142	67	7	6.68359236	0.0106088768	630
25	175.20555333	1.3075041	9.1525289052	503.9469755	2.615008	67	7	6.33444850	0.0100546802	630
26	166.05302442	1.2392016	8.6744117236	512.6213873	2.478403	67	7	6.00354409	0.0095294351	630
27	157.3786127	1.1744672	8.2212708126	520.8426581	2.348934	67	7	5.68992596	0.0090316285	630
28	149.15734189	1.1131144	7.7918014418	528.6344595	2.226228	67	7	5.39269096	0.0085598269	630
29	141.36554044	1.0549667	7.3847670382	536.0192265	2.109933	67	7	5.11098319	0.0081126717	630
30	133.98077341	0.9998565	6.9989956257	543.0182222	1.999713	67	7	4.84399153	0.0076888754	630

Ground-water Restoration

1,2 Dichloroethane / Benzene

Years	Lbs in soil	Soil/H20 Equil. 20% (ppm)	Lbs Removed from Soil	Cuml. Lbs. Removed	Conc. in Soil (ppm)	Lbs. Soil 10E-6 LBS	Lbs. H20 10E+6 Lbs	Lbs in Aquifer 70% flush	Conc. in Aquifer (ppm)	Lbs H20 in Aquifer 10E+6
0	670	2	14	14	10	67	7	6314	10.0222222222	630
1	656	1.9582089	13.707462686	27.70746268	9.791044	67	7	1898.31223	3.0131940299	630
2	642.29253731	1.9172911	13.421038093	41.12850078	9.586455	67	7	573.519983	0.9103491795	630
3	628.87149922	1.8772283	13.140598491	54.26909927	9.386141	67	7	175.998174	0.2793621817	630
4	615.73090073	1.8380026	12.866018821	67.13511809	9.190013	67	7	56.6592579	0.0899353301	630
5	602.86488191	1.7995966	12.597176636	79.73229472	8.997983	67	7	20.7769303	0.0329792546	630
6	590.26770527	1.7619931	12.333952050	92.06624677	8.809965	67	7	9.93326473	0.0157670869	630
7	577.93375322	1.7251753	12.076227679	104.1424744	8.625876	67	7	6.60284772	0.0104807107	630
8	565.85752554	1.6891269	11.823888593	115.9663630	8.445634	67	7	5.52802089	0.0087746363	630
9	554.03363695	1.6538317	11.576822264	127.5431853	8.269158	67	7	5.13145294	0.0081451634	630
10	542.45681468	1.6192740	11.334918515	138.8781038	8.096370	67	7	4.93991143	0.0078411293	630
11	531.12189617	1.5854384	11.098069472	149.9761733	7.927192	67	7	4.81139427	0.0076371338	630
12	520.0238267	1.5523099	10.866169513	160.8423428	7.761549	67	7	4.70326913	0.0074655066	630
13	509.15765718	1.5198736	10.639115224	171.4814580	7.599368	67	7	4.60271530	0.0073058973	630
14	498.51854196	1.4881150	10.416805354	181.8982634	7.440575	67	7	4.50585619	0.0071521527	630
15	488.1017366	1.4570201	10.199140764	192.0974041	7.285100	67	7	4.41149908	0.0070023795	630
16	477.90259584	1.4265749	9.9860243907	202.0834285	7.132874	67	7	4.31925704	0.0068559636	630
17	467.91657145	1.3967658	9.7773611944	211.8607897	6.983829	67	7	4.22898547	0.0067126754	630
18	458.13921025	1.3675797	9.5730581247	221.4338478	6.837898	67	7	4.14061307	0.0065724017	630
19	448.56615213	1.3390034	9.3730240743	230.8068719	6.695017	67	7	4.05409114	0.0064350653	630
20	439.19312805	1.3110242	9.1771698399	239.9840417	6.555121	67	7	3.96937829	0.0063006005	630
21	430.01595821	1.2836297	8.9854080821	248.9694498	6.418148	67	7	3.88643591	0.0061689459	630
22	421.03055013	1.2568076	8.7976532863	257.7671031	6.284038	67	7	3.80522675	0.0060400425	630
23	412.23289685	1.2305459	8.6138217251	266.3809248	6.152729	67	7	3.72571454	0.0059138326	630
24	403.61907512	1.2048330	8.4338314204	274.8147563	6.024165	67	7	3.64786378	0.00579026	630
25	395.1852437	1.1796574	8.2576021072	283.0723584	5.898287	67	7	3.57163976	0.0056692695	630
26	386.92764159	1.1550078	8.0850551975	291.1574136	5.775039	67	7	3.49700849	0.0055508071	630
27	378.8425864	1.1308733	7.9161137456	299.0735273	5.654366	67	7	3.42393667	0.0054348201	630
28	370.92647265	1.1072432	7.7507024136	306.8242297	5.536216	67	7	3.35239172	0.0053212567	630
29	363.17577024	1.0841067	7.5887474378	314.4129772	5.420533	67	7	3.28234174	0.0052100663	630
30	355.5870228	1.0614537	7.4301765958	321.8431538	5.307268	67	7	3.21375550	0.0051011992	630

Ground-water Restoration

1,2 Dichloroethane / Benzene

Years	Lbs in soil	Soil/H20 Equil. 50% (ppm)	Lbs Removed from Soil	Cuml. Lbs. Removed	Conc. in Soil (ppm)	Lbs. Soil 10E+6 LBS	Lbs. H20 10E+6 Lbs	Lbs in Aquifer 50% flush	Conc. in Aquifer (ppm)	Lbs H20 in Aquifer 10E-6
0	670	5	35	35	10	67	7	6335	10.0555555556	630
1	635	4.7388059	33.171641791	68.17164179	9.477611	67	7	3184.08582	5.0541044776	630
2	601.82835821	4.4912564	31.438794832	99.61043662	8.982512	67	7	1607.76230	2.5520036633	630
3	570.38956338	4.2566385	29.796469729	129.4069063	8.513277	67	7	818.779388	1.2996498235	630
4	540.59309365	4.0342768	28.239937728	157.6468440	8.068553	67	7	423.509663	0.6722375607	630
5	512.35315592	3.8235310	26.7647171	184.4115611	7.647062	67	7	225.137190	0.3573606193	630
6	485.58843882	3.6237943	25.366560237	209.7781214	7.247588	67	7	125.251875	0.1988125003	630
7	460.22187858	3.4344916	24.041441419	233.8195628	6.868983	67	7	74.6466583	0.1184867592	630
8	436.18043716	3.2550778	22.785545225	256.6051080	6.510155	67	7	48.7161017	0.0773271457	630
9	413.39489194	3.0850365	21.595255549	278.2003636	6.170073	67	7	35.1556786	0.0558026645	630
10	391.79963639	2.9238778	20.467145185	298.6675087	5.847755	67	7	27.8114119	0.0441450983	630
11	371.33249121	2.7711379	19.397965959	318.0654747	5.542275	67	7	23.6046889	0.0374677602	630
12	351.93452525	2.6263770	18.384639379	336.4501141	5.252754	67	7	20.9946641	0.0333248637	630
13	333.54988587	2.4891782	17.424247769	353.8743619	4.978356	67	7	19.2094559	0.0304911999	630
14	316.1256381	2.3591465	16.514025871	370.3383877	4.718293	67	7	17.8617409	0.0283519697	630
15	299.61161223	2.2359075	15.651352877	386.0397406	4.471815	67	7	16.7565468	0.0265976935	630
16	283.96025935	2.1191064	14.833744891	400.8734855	4.238212	67	7	15.7951458	0.0250716602	630
17	269.12651446	2.0084068	14.058847770	414.9323333	4.016813	67	7	14.9269968	0.0236936458	630
18	255.06766669	1.9034900	13.324430349	428.2567636	3.806980	67	7	14.1257135	0.0224217676	630
19	241.74323634	1.8040540	12.628378017	440.8851416	3.608108	67	7	13.3770458	0.021233406	630
20	229.11485832	1.7098123	11.968686628	452.8538283	3.419624	67	7	12.6728662	0.0201156607	630
21	217.14617169	1.6204938	11.343456730	464.1972850	3.240987	67	7	12.0081614	0.0190605738	630
22	205.80271496	1.5358411	10.750888095	474.9481731	3.071682	67	7	11.3795247	0.0180627378	630
23	195.05182687	1.4556106	10.189274537	485.1374476	2.911221	67	7	10.7843996	0.0171180947	630
24	184.86255233	1.3795712	9.6569990023	494.7944466	2.759142	67	7	10.2206993	0.0162233323	630
25	175.20555333	1.3075041	9.1525289052	503.9469755	2.615008	67	7	9.68661411	0.015375578	630
26	166.05302442	1.2392016	8.6744117236	512.6213873	2.478403	67	7	9.18051292	0.0145722427	630
27	157.3786127	1.1744672	8.2212708126	520.8426581	2.348934	67	7	8.70089186	0.0138109395	630
28	149.15734189	1.1131144	7.7918014418	528.6344595	2.226228	67	7	8.24634665	0.0130894391	630
29	141.36554044	1.0549667	7.3847670382	536.0192265	2.109933	67	7	7.81555684	0.0124056458	630
30	133.98077341	0.9998565	6.9989956257	543.0182222	1.999713	67	7	7.40727623	0.0117575813	630

Ground-water Restoration

1,2 Dichloroethane / Benzene

Years	Lbs in soil	Soil/H20 Equil. 20% (ppm)	Lbs Removed from Soil	Cuml. Lbs. Removed	Conc. in Soil (ppm)	Lbs. Soil 10E+6 LBS	Lbs. H20 10E+6 Lbs	Lbs in Aquifer 60% flush	Conc. in Aquifer (ppm)	Lbs H20 in Aquifer 10E-6
0	670	2	14	14	10	67	7	6314	10.0222222222	630
1	656	1.9582089	13.707462686	27.70746268	9.791044	67	7	2531.08298	4.0175920398	630
2	642.29253731	1.9172911	13.421038093	41.12850078	9.586455	67	7	1017.80160	1.6155581099	630
3	628.87149922	1.8772283	13.140598491	54.26909927	9.386141	67	7	412.376883	0.6545664811	630
4	615.73090073	1.8380026	12.866018821	67.13511809	9.190013	67	7	170.097160	0.2699954933	630
5	602.86488191	1.7995966	12.597176636	79.73229472	8.997983	67	7	73.0777349	0.1159964047	630
6	590.26770527	1.7619931	12.333952050	92.06624677	8.809965	67	7	34.1646748	0.0542296425	630
7	577.93375322	1.7251753	12.076227679	104.1424744	8.625876	67	7	18.4963609	0.0293593032	630
8	565.85752554	1.6891269	11.823888593	115.9663630	8.445634	67	7	12.1280998	0.0192509521	630
9	554.03363695	1.6538317	11.576822264	127.5431853	8.269158	67	7	9.48196883	0.0150507442	630
10	542.45681468	1.6192740	11.334918515	138.8781038	8.096370	67	7	8.32675494	0.0132170713	630
11	531.12189617	1.5854384	11.098069472	149.9761733	7.927192	67	7	7.76992976	0.0123332219	630
12	520.0238267	1.5523099	10.866169513	160.8423428	7.761549	67	7	7.45443971	0.011832444	630
13	509.15765718	1.5198736	10.639115224	171.4814580	7.599368	67	7	7.23742197	0.0114879714	630
14	498.51854196	1.4881150	10.416805354	181.8982634	7.440575	67	7	7.06169093	0.0112090332	630
15	488.1017366	1.4570201	10.199140764	192.0974041	7.285100	67	7	6.90433267	0.0109592582	630
16	477.90259584	1.4265749	9.9860243907	202.0834285	7.132874	67	7	6.75614282	0.0107240362	630
17	467.91657145	1.3967658	9.7773611944	211.8607897	6.983829	67	7	6.61340160	0.0104974629	630
18	458.13921025	1.3675797	9.5730581247	221.4338478	6.837898	67	7	6.47458389	0.0102771173	630
19	448.56615213	1.3390034	9.3730240743	230.8068719	6.695017	67	7	6.33904318	0.0100619733	630
20	439.19312805	1.3110242	9.1771698399	239.9840417	6.555121	67	7	6.20648521	0.0098515638	630
21	430.01595821	1.2836297	8.9854080821	248.9694498	6.418148	67	7	6.07675731	0.0096456465	630
22	421.03055013	1.2568076	8.7976532863	257.7671031	6.284038	67	7	5.94976424	0.0094440702	630
23	412.23289685	1.2305459	8.6138217251	266.3809248	6.152729	67	7	5.82543438	0.0092467212	630
24	403.61907512	1.2048330	8.4338314204	274.8147563	6.024165	67	7	5.70370632	0.0090535021	630
25	395.1852437	1.1796574	8.2576021072	283.0723584	5.898287	67	7	5.58452337	0.0088643228	630
26	386.92764159	1.1550078	8.0850551975	291.1574136	5.775039	67	7	5.46783142	0.0086790975	630
27	378.8425664	1.1308733	7.9161137456	299.0735273	5.654366	67	7	5.35357806	0.008497743	630
28	370.92647265	1.1072432	7.7507024136	306.8242297	5.536216	67	7	5.24171219	0.0083201781	630
29	363.17577024	1.0841067	7.5887474378	314.4129772	5.420533	67	7	5.13218385	0.0081463236	630
30	355.5870228	1.0614537	7.4301765958	321.8431538	5.307268	67	7	5.02494417	0.0079761019	630

Ground-water Restoration

1,2 Dichloroethane / Benzene

Years	Lbs in soil	Soil/H20 Equil. 20% (ppm)	Lbs Removed from Soil	Cuml. Lbs. Removed	Conc. in Soil (ppm)	Lbs. Soil 10E+6 LBS	Lbs. H20 10E+6 Lbs	Lbs in Aquifer 50% flush	Conc. in Aquifer (ppm)	Lbs H20 in Aquifer 10E-6
0	670	2	14	14	10	67	7	6314	10.0222222222	630
1	656	1.9582089	13.707462686	27.70746268	9.791044	67	7	3163.85373	5.0219900498	630
2	642.29253731	1.9172911	13.421038093	41.12850078	9.586455	67	7	1588.63738	2.5216466424	630
3	628.87149922	1.8772283	13.140598491	54.26909927	9.386141	67	7	800.888991	1.2712523676	630
4	615.73090073	1.8380026	12.866018821	67.13511809	9.190013	67	7	406.877505	0.6458373099	630
5	602.86488191	1.7995966	12.597176636	79.73229472	8.997983	67	7	209.737340	0.3329164142	630
6	590.26770527	1.7619931	12.333952050	92.06624677	8.809965	67	7	111.035646	0.1762470579	630
7	577.93375322	1.7251753	12.076227679	104.1424744	8.625876	67	7	61.5559370	0.0977078366	630
8	565.85752554	1.6891269	11.823888593	115.9663630	8.445634	67	7	36.6899128	0.0582379569	630
9	554.03363695	1.6538317	11.576822264	127.5431853	8.269158	67	7	24.1333675	0.0383069326	630
10	542.45681468	1.6192740	11.334918515	138.8781038	8.096370	67	7	17.7341430	0.0281494334	630
11	531.12189617	1.5854384	11.098069472	149.9761733	7.927192	67	7	14.4161062	0.0228827083	630
12	520.0238267	1.5523099	10.866169513	160.8423428	7.761549	67	7	12.6411378	0.0200652982	630
13	509.15765718	1.5198736	10.639115224	171.4814580	7.599368	67	7	11.6401265	0.0184763914	630
14	498.51854196	1.4881150	10.416805354	181.8982634	7.440575	67	7	11.0284659	0.0175055015	630
15	488.1017366	1.4570201	10.199140764	192.0974041	7.285100	67	7	10.6138033	0.0168473069	630
16	477.90259584	1.4265749	9.9860243907	202.0834285	7.132874	67	7	10.2999138	0.0163490696	630
17	467.91657145	1.3967658	9.7773611944	211.8607897	6.983829	67	7	10.0386375	0.0159343453	630
18	458.13921025	1.3675797	9.5730581247	221.4338478	6.837898	67	7	9.80584782	0.0155648378	630
19	448.56615213	1.3390034	9.3730240743	230.8068719	6.695017	67	7	9.58943595	0.0152213269	630
20	439.19312805	1.3110242	9.1771698399	239.9840417	6.555121	67	7	9.38330289	0.0148941316	630
21	430.0159582i	1.2836297	8.9854080821	248.9694498	6.418148	67	7	9.18435548	0.014578342	630
22	421.03055013	1.2568076	8.7976532863	257.7671031	6.284038	67	7	8.99100438	0.0142714355	630
23	412.23289685	1.2305459	8.6138217251	266.3809248	6.152729	67	7	8.80241305	0.0139720842	630
24	403.61907512	1.2048330	8.4338314204	274.8147563	6.024165	67	7	8.61812223	0.0136795591	630
25	395.1852437	1.1796574	8.2576021072	283.0723584	5.898287	67	7	8.43786217	0.013393432	630
26	386.92764159	1.1550078	8.0850551975	291.1574136	5.775039	67	7	8.26145868	0.0131134265	630
27	378.8425864	1.1308733	7.9161137456	299.0735273	5.654366	67	7	8.08878621	0.0128393432	630
28	370.92647265	1.1072432	7.7507024136	306.8242297	5.536216	67	7	7.91974431	0.0125710227	630
29	363.17577024	1.0841067	7.5887474378	314.4129772	5.420533	67	7	7.75424587	0.0123083268	630
30	355.5870228	1.0614537	7.4301765958	321.8431538	5.307268	67	7	7.59221123	0.0120511289	630

D-19 003165

Ground-water Restoration

1,2 Dichloroethane / Benzene

Years	Lbs in soil	Soil/H20 Equil. 10% (ppm)	Lbs Removed from Soil	Cuml. Lbs. Removed	Conc. in Soil (ppm)	Lbs. Soil 10E-6 LBS	Lbs. H20 10E-6 Lbs	Lbs in Aquifer 70% flush	Conc. in Aquifer (ppm)	Lbs H20 in Aquifer 10E-6
0	670	1	7	7	10	67	7	6307	10.0111111111	630
1	663	0.9895522	6.9268656716	13.92686567	9.895522	67	7	1894.17805	3.0066318408	630
2	656.07313433	0.9792136	6.8544954333	20.78136110	9.792136	67	7	570.309766	0.9052535977	630
3	649.2186389	0.9689830	6.7828813019	27.56424240	9.689830	67	7	173.127794	0.2748060228	630
4	642.43575759	0.9588593	6.7120153778	34.27625778	9.588593	67	7	53.9519429	0.0856380046	630
5	635.72374222	0.9488414	6.641889844	40.91814762	9.488414	67	7	18.1781498	0.0288542061	630
6	629.08185237	0.9389281	6.5724969651	47.49064459	9.389281	67	7	7.42519403	0.0117860223	630
7	622.50935541	0.9291184	6.5038290863	53.99447368	9.291184	67	7	4.17870693	0.0066328682	630
8	616.00552632	0.9194112	6.4358786332	60.43035231	9.194112	67	7	3.18437567	0.0050545646	630
9	609.56964769	0.9098054	6.3686381102	66.79899042	9.098054	67	7	2.86590413	0.0045490542	630
10	603.20100958	0.9003000	6.3021001001	73.10109052	9.003000	67	7	2.75040127	0.0043657163	630
11	596.89890948	0.8908938	6.2362572632	79.33734778	8.908938	67	7	2.69599756	0.0042793612	630
12	590.66265221	0.8815860	6.1711023366	85.50845012	8.815860	67	7	2.66012996	0.0042224285	630
13	584.49154988	0.8723754	6.106628133	91.61507825	8.723754	67	7	2.63002743	0.0041746467	630
14	578.38492174	0.8632610	6.0428275406	97.65790579	8.632610	67	7	2.60185649	0.0041299309	630
15	572.3420942	0.8542419	5.9796935215	103.6375593	8.542419	67	7	2.57446500	0.0040864524	630
16	566.36240068	0.8453170	5.9172191116	109.5548184	8.453170	67	7	2.54750523	0.0040436591	630
17	560.44518157	0.8364853	5.8553974194	115.4102158	8.364853	67	7	2.52087079	0.0040013822	630
18	554.58978415	0.8277459	5.7942216255	121.2044374	8.277459	67	7	2.49452772	0.0039595678	630
19	548.79556253	0.8190978	5.7336849816	126.9381224	8.190978	67	7	2.46846381	0.0039181965	630
20	543.06187754	0.8105401	5.6737808102	132.6119032	8.105401	67	7	2.44267338	0.0038772593	630
21	537.38809673	0.8020717	5.6145025032	138.2264057	8.020717	67	7	2.41715276	0.0038367504	630
22	531.77359423	0.7936919	5.5558435218	143.7822492	7.936919	67	7	2.39189888	0.0037966649	630
23	526.21775071	0.7853996	5.4977973955	149.2800466	7.853996	67	7	2.36690888	0.0037569982	630
24	520.71995331	0.7771939	5.4403577212	154.7204044	7.771939	67	7	2.34217998	0.003717746	630
25	515.27959559	0.7690740	5.3835181629	160.1039225	7.690740	67	7	2.31770944	0.0036789039	630
26	509.89607743	0.7610389	5.3272724507	165.4311950	7.610389	67	7	2.29349456	0.0036404676	630
27	504.56880498	0.7530877	5.2716143804	170.7028094	7.530877	67	7	2.26953268	0.0036024328	630
28	499.2971906	0.7452196	5.2165378122	175.9193472	7.452196	67	7	2.24582114	0.0035647955	630
29	494.08065279	0.7374338	5.1620366709	181.0813838	7.374338	67	7	2.22235734	0.0035275513	630
30	488.91861611	0.7297292	5.1081049445	186.1894888	7.297292	67	7	2.19913868	0.0034906963	630

Ground-water Restoration

1,2 Dichloroethane / Benzene

Years	Lbs in soil	Soil/H_2O Equil. 10% (ppm)	Lbs Removed from Soil	Cuml. Lbs. Removed	Conc. in Soil (ppm)	Lbs. Soil 10E+6 LBS	Lbs. H_2O 10E+6 Lbs	Lbs in Aquifer 60% flush	Conc. in Aquifer (ppm)	Lbs H_2O in Aquifer 10E+6
0	670	1	7	7	10	67	7	6307	10.0111111111	630
1	663	0.9895522	6.9268656716	13.92686567	9.895522	67	7	2525.57074	4.0068424544	630
2	656.07313433	0.9792136	6.8544954333	20.78136110	9.792136	67	7	1012.97009	1.6078890424	630
3	649.2186389	0.9689830	6.7828813019	27.56424240	9.689830	67	7	407.901191	0.6474622082	630
4	642.43575759	0.9588593	6.7120153778	34.27625778	9.588593	67	7	165.845282	0.2632464804	630
5	635.72374222	0.9488414	6.641889844	40.91814762	9.488414	67	7	68.9948689	0.1095156651	630
6	629.08185237	0.9389281	6.5724969651	47.49064459	9.389281	67	7	30.2269463	0.04797928	630
7	622.50935541	0.9291184	6.5038290863	53.99447368	9.291184	67	7	14.6923101	0.0233211273	630
8	616.00552632	0.9194112	6.4358786332	60.43035231	9.194112	67	7	8.45127552	0.0134147231	630
9	609.56964769	0.9098054	6.3686381102	66.79899042	9.098054	67	7	5.92796545	0.009409469	630
10	603.20100958	0.9003000	6.3021001001	73.10109052	9.003000	67	7	4.89202622	0.007765121	630
11	596.89890948	0.8908938	6.2362572632	79.33734778	8.908938	67	7	4.45131339	0.0070655768	630
12	590.66265221	0.8815860	6.1711023366	85.50845012	8.815860	67	7	4.24896629	0.0067443909	630
13	584.49154988	0.8723754	6.106628133	91.61507825	8.723754	67	7	4.14223777	0.0065749806	630
14	578.38492174	0.8632610	6.0428275406	97.65790579	8.632610	67	7	4.07402612	0.0064667081	630
15	572.3420942	0.8542419	5.9796935215	103.6375993	8.542419	67	7	4.02148785	0.0063833141	630
16	566.36240068	0.8453170	5.9172191116	109.5548184	8.453170	67	7	3.97548278	0.0063102901	630
17	560.44518157	0.8364853	5.8553974194	115.4102158	8.364853	67	7	3.93235208	0.0062418287	630
18	554.58978415	0.8277459	5.7942216255	121.2044374	8.277459	67	7	3.89062948	0.0061756024	630
19	548.79556253	0.8190978	5.7336849816	126.9381224	8.190978	67	7	3.84972578	0.0061106759	630
20	543.06187754	0.8105401	5.6737808102	132.6119032	8.105401	67	7	3.80940263	0.0060466709	630
21	537.38809673	0.8020717	5.6145025032	138.2264057	8.020717	67	7	3.76956205	0.0059834318	630
22	531.77359423	0.7936919	5.5558435216	143.7822492	7.936919	67	7	3.73016223	0.0059208924	630
23	526.21775071	0.7853996	5.4977973955	149.2800466	7.853996	67	7	3.69118385	0.005859022	630
24	520.71995331	0.7771939	5.4403577212	154.7204044	7.771939	67	7	3.65261662	0.0057978042	630
25	515.27959559	0.7690740	5.3835181629	160.1039225	7.690740	67	7	3.61445391	0.0057372284	630
26	509.89607743	0.7610389	5.3272724507	165.4311950	7.610389	67	7	3.57669054	0.0056772866	630
27	504.56880498	0.7530877	5.2716143804	170.7028094	7.530877	67	7	3.53932197	0.0056179714	630
28	499.2971906	0.7452196	5.2165378122	175.9193472	7.452196	67	7	3.50234391	0.0055592761	630
29	494.08065279	0.7374338	5.1620366709	181.0813838	7.374338	67	7	3.46575223	0.005501194	630
30	488.91861611	0.7297292	5.1081049445	186.1894888	7.297292	67	7	3.42954287	0.0054437188	630

Ground-water Restoration

1,2 Dichloroethane / Benzene

Years	Lbs in soil	Soil/H20 Equil. 10% (ppm)	Lbs Removed from Soil	Cuml. Lbs. Removed	Conc. in Soil (ppm)	Lbs. Soil 10E+6 LBS	Lbs. H20 10E+6 Lbs	Lbs in Aquifer 50% flush	Conc. in Aquifer (ppm)	Lbs H20 in Aquifer 10E+6
0	670	1	7	7	10	67	7	6307	10.0111111111	630
1	663	0.9895522	6.9268656716	13.92686567	9.895522	67	7	3156.96343	5.011053068	630
2	656.07313433	0.9792136	6.8544954333	20.78136110	9.792136	67	7	1581.90896	2.5109666097	630
3	649.2186389	0.9689830	6.7828813019	27.56424240	9.689830	67	7	794.345922	1.260866544	630
4	642.43575759	0.9588593	6.7120153778	34.27625778	9.588593	67	7	400.528969	0.6357602683	630
5	635.72374222	0.9488414	6.641889844	40.91814762	9.488414	67	7	203.585429	0.3231514753	630
6	629.08185237	0.9389281	6.5724969651	47.49064459	9.389281	67	7	105.078963	0.1667920051	630
7	622.50935541	0.9291184	6.5038290863	53.99447368	9.291184	67	7	55.7913961	0.0885577717	630
8	616.00552632	0.9194112	6.4358786332	60.43035231	9.194112	67	7	31.1136373	0.049386726	630
9	609.56964769	0.9098054	6.3686381102	66.79899042	9.098054	67	7	18.7411377	0.0297478377	630
10	603.20100958	0.9003000	6.3021001001	73.10109052	9.003000	67	7	12.5216189	0.0198755856	630
11	596.89890948	0.8908938	6.2362572632	79.33734778	8.908938	67	7	9.37893809	0.0148872033	630
12	590.66265221	0.8815860	6.1711023366	85.50845012	8.815860	67	7	7.77502021	0.0123413019	630
13	584.49154988	0.8723754	6.106628133	91.61507825	8.723754	67	7	6.94082417	0.0110171812	630
14	578.38492174	0.8632610	6.0428275406	97.65790579	8.632610	67	7	6.49182585	0.0103044855	630
15	572.3420942	0.8542419	5.9796935215	103.6375993	8.542419	67	7	6.23575968	0.0098980313	630
16	566.36240068	0.8453170	5.9172191116	109.5548184	8.453170	67	7	6.07648940	0.0096452213	630
17	560.44518157	0.8364853	5.8553974194	115.4102158	8.364853	67	7	5.96594341	0.0094697514	630
18	554.58978415	0.8277459	5.7942216255	121.2044374	8.277459	67	7	5.88008251	0.0093334643	630
19	548.79556253	0.8190978	5.7336849816	126.9381224	8.190978	67	7	5.80688374	0.0092172758	630
20	543.06187754	0.8105401	5.6737808102	132.6119032	8.105401	67	7	5.74033227	0.0091116385	630
21	537.38809673	0.8020717	5.6145025032	138.2264057	8.020717	67	7	5.67741739	0.0090117736	630
22	531.77359423	0.7936919	5.5558435218	143.7822492	7.936919	67	7	5.61663045	0.0089152864	630
23	526.21775071	0.7853996	5.4977973955	149.2800466	7.853996	67	7	5.55721392	0.0088209745	630
24	520.71995331	0.7771939	5.4403577212	154.7204044	7.771939	67	7	5.49878582	0.0087282315	630
25	515.27959559	0.7690740	5.3835181629	160.1039225	7.690740	67	7	5.44115199	0.0086367492	630
26	509.89607743	0.7610389	5.3272724507	165.4311950	7.610389	67	7	5.38421222	0.0085463686	630
27	504.56880498	0.7530877	5.2716143804	170.7028094	7.530877	67	7	5.32791330	0.0084570052	630
28	499.2971906	0.7452196	5.2165378122	175.9193472	7.452196	67	7	5.27222555	0.008368612	630
29	494.08065279	0.7374338	5.1620366709	181.0813838	7.374338	67	7	5.21713111	0.0082811605	630
30	488.91861611	0.7297292	5.1081049445	186.1894888	7.297292	67	7	5.16261802	0.0081946318	630

Ground-water Restoration

1,2 Dichloroethane / Benzene

Years	Lbs in soil	Soil/H20 Equil. 50% (ppm)	Lbs Removed from Soil	Cuml. Lbs. Removed	Conc. in Soil (ppm)	Lbs. Soil 10E+6 LBS	Lbs. H20 10E+6 Lbs	Lbs in Aquifer 70% flush	Conc. in Aquifer (ppm)	Lbs H20 in Aquifer 10E-6
0	67	0.5	3.5	3.5	1	67	7	6303.5	10.0055555556	630
1	63.5	0.4738805	3.3171641791	6.817164179	0.947761	67	7	1892.04514	3.0032462687	630
2	60.182835821	0.4491256	3.1438794832	9.961043662	0.898251	67	7	568.556708	0.9024709661	630
3	57.038956338	0.4256638	2.9796469729	12.94069063	0.851327	67	7	171.460906	0.2721601693	630
4	54.059309365	0.4034276	2.8239937728	15.76468440	0.806855	67	7	52.2854701	0.0829928097	630
5	51.235315592	0.3823531	2.67647171	18.44115611	0.764706	67	7	16.4885825	0.0261723533	630
6	48.558843882	0.3623794	2.5366560237	20.97781214	0.724758	67	7	5.70757157	0.0090596374	630
7	46.022187858	0.3434491	2.4041441419	23.38195628	0.686898	67	7	2.43351471	0.0038627218	630
8	43.618043716	0.3255077	2.2785545225	25.66051080	0.651015	67	7	1.41362077	0.0022438425	630
9	41.339489194	0.3085036	2.1595255549	27.82003636	0.617007	67	7	1.07194389	0.0017014983	630
10	39.179963639	0.2923877	2.0467145185	29.86675087	0.584775	67	7	0.93559752	0.0014850754	630
11	37.133249121	0.2771137	1.9397965959	31.80654747	0.554227	67	7	0.86261823	0.0013692353	630
12	35.193452525	0.2626377	1.8384639379	33.64501141	0.525275	67	7	0.81032465	0.0012862296	630
13	33.354988587	0.2489178	1.7424247769	35.38743619	0.497835	67	7	0.76582482	0.0012155595	630
14	31.61256381	0.2359146	1.6514025871	37.03883877	0.471829	67	7	0.72516822	0.0011510607	630
15	29.961161223	0.2235907	1.5651352878	38.60397406	0.447181	67	7	0.68709105	0.0010906207	630
16	28.396025935	0.2119106	1.4833744891	40.08734855	0.422821	67	7	0.65113966	0.001033555	630
17	26.912651446	0.2008406	1.405884777	41.49323333	0.401681	67	7	0.61710733	0.0009795354	630
18	25.506766669	0.1903490	1.3324430349	42.82567636	0.380698	67	7	0.58486511	0.0009283573	630
19	24.174323634	0.1804054	1.2628378018	44.08851416	0.360810	67	7	0.55431087	0.0008798585	630
20	22.911485832	0.1709812	1.1968686629	45.28538283	0.341962	67	7	0.52535386	0.000833895	630
21	21.714617169	0.1620493	1.134345673	46.41972850	0.324098	67	7	0.49790986	0.0007903331	630
22	20.580271496	0.1535841	1.0750888095	47.49481731	0.307168	67	7	0.47189960	0.000749047	630
23	19.505182687	0.1455610	1.0189274538	48.51374476	0.291122	67	7	0.44724811	0.0007099176	630
24	18.486255233	0.1379571	0.9656999002	49.47944466	0.275914	67	7	0.42388440	0.0006728324	630
25	17.520555333	0.1307504	0.9152528905	50.39469755	0.261500	67	7	0.40174118	0.0006376844	630
26	16.605302442	0.1239201	0.8674411724	51.26213873	0.247840	67	7	0.38075470	0.0006043726	630
27	15.737861269	0.1174467	0.8221270813	52.08426581	0.234893	67	7	0.36086453	0.0005728009	630
28	14.915734188	0.1113114	0.7791801442	52.86344595	0.222622	67	7	0.34201340	0.0005428784	630
29	14.136554044	0.1054966	0.7384767038	53.60192265	0.210993	67	7	0.32414703	0.0005145191	630
30	13.398077340	0.0999856	0.6998995626	54.30182222	0.199971	67	7	0.30721397	0.0004876412	630

Ground-water Restoration

1,2 Dichloroethane / Benzene

Years	Lbs in soil	Soil/H20 Equil. 50% (ppm)	Lbs Removed from Soil	Cuml. Lbs. Removed	Conc. in Soil (ppm)	Lbs. Soil 10E-6 LBS	Lbs. H20 10E-6 Lbs	Lbs in Aquifer 50% flush	Conc. in Aquifer (ppm)	Lbs H2O in Aquifer 10E-6
0	67	0.5	3.5	3.5	1	67	7	6303.5	10.0055555556	630
1	63.5	0.4738805	3.3171641791	6.817164179	0.947761	67	7	3153.40858	5.0054104478	630
2	60.182835821	0.4491256	3.1438794832	9.961043662	0.898251	67	7	1578.27623	2.5052003663	630
3	57.038956338	0.4256638	2.9796469729	12.94069063	0.851327	67	7	790.627938	1.2549649823	630
4	54.059309365	0.4034276	2.8239937728	15.76468440	0.806855	67	7	396.725966	0.6297237561	630
5	51.235315592	0.3823531	2.67647171	18.44115611	0.764706	67	7	199.701219	0.3169860619	630
6	48.558843882	0.3623794	2.5366560237	20.97781214	0.724758	67	7	101.118937	0.16050625	630
7	46.022187858	0.3434491	2.4041441419	23.38195628	0.686898	67	7	51.7615408	0.0821611759	630
8	43.618043716	0.3255077	2.2785545225	25.66051080	0.651015	67	7	27.0200476	0.0428889646	630
9	41.339489194	0.3085036	2.1595255549	27.82003636	0.617007	67	7	14.5897866	0.0231583915	630
10	39.179963639	0.2923877	2.0467145185	29.86675087	0.584775	67	7	8.31825056	0.0132035723	630
11	37.133249121	0.2771137	1.9397965959	31.80654747	0.554227	67	7	5.12902358	0.0081413073	630
12	35.193452525	0.2626377	1.8384639379	33.64501141	0.525275	67	7	3.48374375	0.005529752	630
13	33.354988587	0.2489178	1.7424247769	35.38743619	0.497835	67	7	2.61308426	0.0041477528	630
14	31.61256381	0.2359146	1.6514025871	37.03883877	0.471829	67	7	2.13224342	0.0033845134	630
15	29.961161223	0.2235907	1.5651352878	38.60397406	0.447181	67	7	1.84868935	0.0029344276	630
16	28.396025935	0.2119106	1.4833744891	40.08734855	0.423821	67	7	1.66603192	0.0026444951	630
17	26.912651446	0.2008406	1.405884777	41.49323333	0.401681	67	7	1.53595835	0.0024380291	630
18	25.506766669	0.1903490	1.3324430349	42.82567636	0.380698	67	7	1.43420069	0.002276509	630
19	24.174323634	0.1804054	1.2628378018	44.08851416	0.360810	67	7	1.34851924	0.0021405067	630
20	22.911485832	0.1709812	1.1968686629	45.28538283	0.341962	67	7	1.27269395	0.0020201491	630
21	21.714617169	0.1620493	1.134345673	46.41972850	0.324098	67	7	1.20351981	0.0019103489	630
22	20.580271496	0.1535841	1.0750888095	47.49481731	0.307168	67	7	1.13930431	0.0018084195	630
23	19.505182687	0.1455610	1.0189274538	48.51374476	0.291122	67	7	1.07911588	0.0017128824	630
24	18.486255233	0.1379571	0.9656999002	49.47944466	0.275914	67	7	1.02240789	0.0016228697	630
25	17.520555333	0.1307504	0.9152528905	50.39469755	0.261500	67	7	0.96883039	0.001537826	630
26	16.605302442	0.1239201	0.8674411724	51.26213873	0.247840	67	7	0.91813578	0.0014573584	630
27	15.737861269	0.1174467	0.8221270813	52.08426581	0.234893	67	7	0.87013143	0.001381161	630
28	14.915734188	0.1113114	0.7791801442	52.86344595	0.222622	67	7	0.82465578	0.0013089774	630
29	14.136554044	0.1054966	0.7384767038	53.60192265	0.210993	67	7	0.78156624	0.0012405813	630
30	13.398077340	0.0999856	0.6998995626	54.30182222	0.199971	67	7	0.74073290	0.0011757665	630

Ground-water Restoration

1,2 Dichloroethane / Benzene

Years	Lbs in soil	Soil/H20 Equil. 50% (ppm)	Lbs Removed from Soil	Cuml. Lbs. Removed	Conc. in Soil (ppm)	Lbs. Soil 10E+6 LBS	Lbs. H20 10E+6 Lbs	Lbs in Aquifer 60% flush	Conc. in Aquifer (ppm)	Lbs H20 in Aquifer 10E+6
0	67	0.5	3.5	3.5	1	67	7	6303.5	10.0055555556	630
1	63.5	0.4738805	3.3171641791	6.817164179	0.947761	67	7	2522.72686	4.0043283582	630
2	60.182835821	0.4491256	3.1438794832	9.961043662	0.898251	67	7	1010.34829	1.6037274572	630
3	57.038956338	0.4256638	2.9796469729	12.94069063	0.851327	67	7	405.331178	0.6433828222	630
4	54.059309365	0.4034276	2.8239937728	15.76468440	0.806855	67	7	163.262066	0.2591461408	630
5	51.235315592	0.3823531	2.67647171	18.44115611	0.764706	67	7	66.3754161	0.1053578034	630
6	48.558843882	0.3623794	2.5366560237	20.97781214	0.724758	67	7	27.5648288	0.0437536966	630
7	46.022187858	0.3434491	2.4041441419	23.38195628	0.686898	67	7	11.9875892	0.0190279194	630
8	43.618043716	0.3255077	2.2785545225	25.66051080	0.651015	67	7	5.70645749	0.009057869	630
9	41.339489194	0.3085036	2.1595255549	27.82003636	0.617007	67	7	3.14639321	0.004994275	630
10	39.179963639	0.2923877	2.0467145185	29.86675087	0.584775	67	7	2.07724309	0.0032972113	630
11	37.133249121	0.2771137	1.9397965959	31.80654747	0.554227	67	7	1.60681587	0.0025505014	630
12	35.193452525	0.2626377	1.8384639379	33.64501141	0.525275	67	7	1.37811192	0.0021874792	630
13	33.354988587	0.2489178	1.7424247769	35.38743619	0.497835	67	7	1.24821468	0.0019812931	630
14	31.61256381	0.2359146	1.6514025871	37.03883877	0.471829	67	7	1.15984690	0.0018410268	630
15	29.961161223	0.2235907	1.5651352878	38.60397406	0.447181	67	7	1.08999287	0.0017301474	630
16	28.396025935	0.2119106	1.4833744891	40.08734855	0.423821	67	7	1.02934694	0.001633884	630
17	26.912651446	0.2008406	1.405884777	41.49323333	0.401681	67	7	0.97409268	0.0015461789	630
18	25.506766669	0.1903490	1.3324430349	42.82567636	0.380698	67	7	0.92261428	0.0014644671	630
19	24.174323634	0.1804054	1.2628378018	44.08851416	0.360810	67	7	0.87418083	0.0013875886	630
20	22.911485832	0.1709812	1.1968686629	45.28538283	0.341962	67	7	0.82841979	0.0013149521	630
21	21.714617169	0.1620493	1.134345673	46.41972850	0.324098	67	7	0.78510618	0.0012462003	630
22	20.580271496	0.1535841	1.0750888095	47.49481731	0.307168	67	7	0.74407799	0.0011810762	630
23	19.505182687	0.1455610	1.0189274538	48.51374476	0.291122	67	7	0.70520218	0.0011193685	630
24	18.486255233	0.1379571	0.9656999002	49.47944466	0.275914	67	7	0.66836083	0.0010608902	630
25	17.520555333	0.1307504	0.9152528905	50.39469755	0.261500	67	7	0.63344548	0.001005469	630
26	16.605302442	0.1239201	0.8674411724	51.26213873	0.247840	67	7	0.60035466	0.0009529439	630
27	15.737861269	0.1174467	0.8221270813	52.08426581	0.234893	67	7	0.56899269	0.000903163	630
28	14.915734188	0.1113114	0.7791801442	52.86344595	0.222622	67	7	0.53926913	0.0008559828	630
29	14.136554044	0.1054966	0.7384767038	53.60192265	0.210993	67	7	0.51109833	0.0008112672	630
30	13.398077340	0.0999856	0.6998995626	54.30182222	0.199971	67	7	0.48439915	0.0007688876	630

Ground-water Restoration

1,2 Dichloroethane / Benzene

Years	Lbs in soil	Soil/H20 Equil. 20% (ppm)	Lbs Removed from Soil	Cuml. Lbs. Removed	Conc. in Soil (ppm)	Lbs. Soil 10E+6 LBS	Lbs. H20 10E+6 Lbs	Lbs in Aquifer 70% flush	Conc. in Aquifer (ppm)	Lbs H20 in Aquifer 10E+6
0	67	0.2	1.4	1.4	1	67	7	6301.4	10.0022222222	630
1	65.6	0.1958208	1.3707462687	2.770746268	0.979104	67	7	1890.83122	3.001319403	630
2	64.229253731	0.1917291	1.3421038093	4.112850078	0.958645	67	7	567.651998	0.9010349179	630
3	62.887149922	0.1877228	1.3140598491	5.426909927	0.938614	67	7	170.689817	0.2709362182	630
4	61.573090073	0.1838002	1.2866018821	6.713511809	0.919001	67	7	51.5929257	0.081893533	630
5	60.286488191	0.1799596	1.2597176637	7.973229472	0.899798	67	7	15.8557930	0.0251679255	630
6	59.026770527	0.1761993	1.233395205	9.206624677	0.880996	67	7	5.12675647	0.0081377087	630
7	57.793375322	0.1725175	1.2076227679	10.41424744	0.862587	67	7	1.90031377	0.0030163711	630
8	56.585752554	0.1689126	1.1823888593	11.59663630	0.844563	67	7	0.92481078	0.0014679536	630
9	55.403363695	0.1653831	1.1576822265	12.75431853	0.826915	67	7	0.62474790	0.0009916633	630
10	54.245681468	0.1619274	1.1334918516	13.88781038	0.809637	67	7	0.52747192	0.000837257	630
11	53.112189617	0.1585438	1.1098069472	14.99761733	0.792719	67	7	0.49118366	0.0007796566	630
12	52.00238267	0.1552309	1.0866169513	16.08423428	0.776154	67	7	0.47334018	0.0007513336	630
13	50.915765718	0.1519873	1.0639115225	17.14814580	0.759936	67	7	0.46117551	0.0007320246	630
14	49.851854196	0.1488115	1.0416805354	18.18982634	0.744057	67	7	0.45085681	0.0007156457	630
15	48.81017366	0.1457020	1.0199140765	19.20974041	0.728510	67	7	0.44123126	0.0007003671	630
16	47.790259584	0.1426574	0.9986024391	20.20834285	0.713287	67	7	0.43195011	0.0006856351	630
17	46.791657145	0.1396765	0.9777361194	21.18607897	0.698382	67	7	0.42290586	0.0006712792	630
18	45.813921025	0.1367579	0.9573058125	22.14338478	0.683789	67	7	0.41406350	0.0006572437	630
19	44.856615213	0.1339003	0.9373024074	23.08068719	0.669501	67	7	0.40540977	0.0006435076	630
20	43.919312805	0.1311024	0.917716984	23.99840417	0.655512	67	7	0.39693802	0.0006300604	630
21	43.001595821	0.1283629	0.8985408082	24.89694498	0.641814	67	7	0.38864365	0.0006168947	630
22	42.103055013	0.1256807	0.8797653286	25.77671031	0.628403	67	7	0.38052269	0.0006040043	630
23	41.223289685	0.1230545	0.8613821725	26.63809248	0.615272	67	7	0.37257145	0.0005913833	630
24	40.361907512	0.1204833	0.843383142	27.48147563	0.602416	67	7	0.36478638	0.000579026	630
25	39.51852437	0.1179657	0.8257602107	28.30723584	0.589828	67	7	0.35716397	0.0005669269	630
26	38.692764159	0.1155007	0.8085055197	29.11574136	0.577503	67	7	0.34970084	0.0005550607	630
27	37.88425864	0.1130873	0.7916113746	29.90735273	0.565436	67	7	0.34239366	0.000543482	630
28	37.092647265	0.1107243	0.7750702414	30.68242297	0.553621	67	7	0.33523917	0.0005321257	630
29	36.317577024	0.1084106	0.7588747438	31.44129772	0.542053	67	7	0.32823417	0.0005210066	630
30	35.55870228	0.1061453	0.7430176596	32.18431538	0.530726	67	7	0.32137555	0.0005101199	630

Ground-water Restoration

1,2 Dichloroethane / Benzene

Years	Lbs in soil	Soil/H20 Equil. 20% (ppm)	Lbs Removed from Soil	Cuml. Lbs. Removed	Conc. in Soil (ppm)	Lbs. Soil 10E+6 LBS	Lbs. H20 10E+6 Lbs	Lbs in Aquifer 60% flush	Conc. in Aquifer (ppm)	Lbs H2O in Aquifer 10E+6
0	67	0.2	1.4	1.4	1	67	7	6301.4	10.0022222222	630
1	65.6	0.1958208	1.3707462687	2.770746268	0.979104	67	7	2521.10829	4.001759204	630
2	64.229253731	0.1917291	1.3421038093	4.112850078	0.958645	67	7	1008.98016	1.601555811	630
3	62.887149922	0.1877228	1.3140598491	5.426909927	0.938614	67	7	404.117688	0.6414566481	630
4	61.573090073	0.1838002	1.2866018821	6.713511809	0.919001	67	7	162.161716	0.2573995493	630
5	60.286488191	0.1799596	1.2597176637	7.973229472	0.899798	67	7	65.3685734	0.1037596405	630
6	59.026770527	0.1761993	1.233395205	9.206624677	0.880996	67	7	26.6407874	0.0422869643	630
7	57.793375322	0.1725175	1.2076227679	10.41424744	0.862587	67	7	11.1393640	0.0176815303	630
8	56.585752554	0.1689126	1.1823888593	11.59663630	0.844563	67	7	4.92870118	0.0078233352	630
9	55.403363695	0.1653831	1.1576822265	12.75431853	0.826915	67	7	2.43455336	0.0038643704	630
10	54.245681468	0.1619274	1.1334918516	13.88781038	0.809637	67	7	1.42721808	0.0022654255	630
11	53.112189617	0.1585438	1.1098069472	14.99761733	0.792719	67	7	1.01481001	0.0016108095	630
12	52.00238267	0.1552309	1.0866169513	16.08423428	0.776154	67	7	0.84057078	0.0013342393	630
13	50.915765718	0.1519873	1.0639115225	17.14814580	0.759936	67	7	0.76179292	0.0012091951	630
14	49.851854196	0.1488115	1.0416805354	18.18982634	0.744057	67	7	0.72138938	0.0011450625	630
15	48.81017366	0.1457020	1.0199140765	19.20974041	0.728510	67	7	0.69652138	0.0011055895	630
16	47.790259584	0.1426574	0.9986024391	20.20834285	0.713287	67	7	0.67804952	0.0010762691	630
17	46.791657145	0.1396765	0.9777361194	21.18607897	0.698382	67	7	0.66231425	0.0010512925	630
18	45.813921025	0.1367579	0.9573058125	22.14338478	0.683789	67	7	0.64784802	0.0010283302	630
19	44.856615213	0.1339003	0.9373024074	23.08068719	0.669501	67	7	0.63406017	0.0010064447	630
20	43.919312805	0.1311024	0.917716984	23.99840417	0.655512	67	7	0.62071086	0.0009852553	630
21	43.001595821	0.1283629	0.8985408082	24.89694498	0.641814	67	7	0.60770066	0.0009646042	630
22	42.103055013	0.1256807	0.8797653286	25.77671031	0.628403	67	7	0.59498639	0.0009444229	630
23	41.223289685	0.1230545	0.8613821725	26.63809248	0.615272	67	7	0.58254742	0.0009246785	630
24	40.361907512	0.1204833	0.843383142	27.48147563	0.602416	67	7	0.57037222	0.0009053527	630
25	39.51852437	0.1179657	0.8257602107	28.30723584	0.589828	67	7	0.55845297	0.0008864333	630
26	38.692764159	0.1155007	0.8085055197	29.11574136	0.577503	67	7	0.54678339	0.0008679102	630
27	37.88425864	0.1130873	0.7916113746	29.90735273	0.565436	67	7	0.53535790	0.0008497745	630
28	37.092647265	0.1107243	0.7750702414	30.68242297	0.553621	67	7	0.52417126	0.0008320179	630
29	36.317577024	0.1084106	0.7588747438	31.44129772	0.542053	67	7	0.51321840	0.0008146324	630
30	35.55870228	0.1061453	0.7430176596	32.18431538	0.530726	67	7	0.50249442	0.0007976102	630

Ground-water Restoration

1,2 Dichloroethane / Benzene

Years	Lbs in soil	Soil/H20 Equil. 20% (ppm)	Lbs Removed from Soil	Cuml. Lbs. Removed	Conc. in Soil (ppm)	Lbs. Soil 10E+6 LBS	Lbs. H20 10E+6 Lbs	Lbs in Aquifer 50% flush	Conc. in Aquifer (ppm)	Lbs H20 in Aquifer 10E+6
0	67	0.2	1.4	1.4	1	67	7	6301.4	10.0022222222	630
1	65.6	0.1958208	1.3707462687	2.770746268	0.979104	67	7	3151.38537	5.002199005	630
2	64.229253731	0.1917291	1.3421038093	4.112850078	0.958645	67	7	1576.36373	2.5021646642	630
3	62.887149922	0.1877228	1.3140598491	5.426909927	0.938614	67	7	788.838899	1.2521252368	630
4	61.573090073	0.1838002	1.2866018821	6.713511809	0.919001	67	7	395.062750	0.627083731	630
5	60.286488191	0.1799596	1.2597176637	7.973229472	0.899798	67	7	198.161234	0.3145416414	630
6	59.026770527	0.1761993	1.233395205	9.206624677	0.880996	67	7	99.6973146	0.1582497058	630
7	57.793375322	0.1725175	1.2076227679	10.41424744	0.862587	67	7	50.4524687	0.0800832837	630
8	56.585752554	0.1689126	1.1823888593	11.59663630	0.844563	67	7	25.8174287	0.0409800457	630
9	55.403363695	0.1653831	1.1576822265	12.75431853	0.826915	67	7	13.4875555	0.0214088183	630
10	54.245681468	0.1619274	1.1334918516	13.88781038	0.809637	67	7	7.31052367	0.0116040058	630
11	53.112189617	0.1585438	1.1098069472	14.99761733	0.792719	67	7	4.21016531	0.0066828021	630
12	52.00238267	0.1552309	1.0866169513	16.08423428	0.776154	67	7	2.64839113	0.0042037954	630
13	50.915765718	0.1519873	1.0639115225	17.14814580	0.759936	67	7	1.85615132	0.0029462719	630
14	49.851854196	0.1488115	1.0416805354	18.18982634	0.744057	67	7	1.44891593	0.0022998666	630
15	48.81017366	0.1457020	1.0199140765	19.20974041	0.728510	67	7	1.23441500	0.0019593889	630
16	47.790259584	0.1426574	0.9986024391	20.20834285	0.713287	67	7	1.11650872	0.0017722361	630
17	46.791657145	0.1396765	0.9777361194	21.18607897	0.698382	67	7	1.04712242	0.0016620991	630
18	45.813921025	0.1367579	0.9573058125	22.14338478	0.683789	67	7	1.00221411	0.0015908161	630
19	44.856615213	0.1339003	0.9373024074	23.08068719	0.669501	67	7	0.96975826	0.0015392988	630
20	43.919312805	0.1311024	0.917716984	23.99840417	0.655512	67	7	0.94373762	0.0014979962	630
21	43.001595821	0.1283629	0.8985408082	24.89694498	0.641814	67	7	0.92113921	0.0014621257	630
22	42.103055013	0.1256807	0.8797653286	25.77671031	0.628403	67	7	0.90045227	0.0014292893	630
23	41.223289685	0.1230545	0.8613821725	26.63809248	0.615272	67	7	0.88091722	0.0013982813	630
24	40.361907512	0.1204833	0.843383142	27.48147563	0.602416	67	7	0.86215018	0.0013684924	630
25	39.51852437	0.1179657	0.8257602107	28.30723584	0.589828	67	7	0.84395519	0.0013396114	630
26	38.692764159	0.1155007	0.8085055197	29.11574136	0.577503	67	7	0.82623035	0.0013114768	630
27	37.88425864	0.1130873	0.7916113746	29.90735273	0.565436	67	7	0.80892086	0.0012840014	630
28	37.092647265	0.1107243	0.7750702414	30.68242297	0.553621	67	7	0.79199555	0.0012571358	630
29	36.317577024	0.1084106	0.7588747438	31.44129772	0.542053	67	7	0.77543514	0.0012308494	630
30	35.55870228	0.1061453	0.7430176596	32.18431538	0.530726	67	7	0.75922640	0.0012051213	630

Ground-water Restoration

? Dichloroethane / Benzene

Years	Lbs in soil	Soil/H20 Equil. 10% (ppm)	Lbs Removed from Soil	Cuml. Lbs. Removed	Conc. in Soil (ppm)	Lbs. Soil 10E+6 LBS	Lbs. H20 10E+6 Lbs	Lbs in Aquifer 70% flush	Conc. in Aquifer (ppm)	Lbs H20 in Aquifer 10E+6
0	67	0.1	0.7	0.7	1	67	7	6300.7	10.0011111111	630
1	66.3	0.0989552	0.6926865672	1.392686567	0.989552	67	7	1890.41780	3.0006631841	630
2	65.607313433	0.0979213	0.6854495433	2.078136110	0.979213	67	7	567.330976	0.9005253598	630
3	64.92186389	0.0968983	0.6782881302	2.756424240	0.968983	67	7	170.402779	0.2704806023	630
4	64.243575759	0.0958859	0.6712015378	3.427625778	0.958859	67	7	51.3221942	0.0814638005	630
5	63.572374222	0.0948841	0.6641889844	4.091814762	0.948841	67	7	15.5959149	0.0247554206	630
6	62.908185237	0.0938928	0.6572496965	4.749064459	0.938928	67	7	4.87594940	0.0077396022	630
7	62.250935541	0.0929118	0.6503829086	5.399447368	0.929118	67	7	1.65789969	0.0026315868	630
8	61.600552632	0.0919411	0.6435878633	6.043035231	0.919411	67	7	0.69044626	0.0010959465	630
9	60.956964769	0.0909805	0.636863811	6.679899042	0.909805	67	7	0.39819302	0.0006320524	630
10	60.320100958	0.0900300	0.63021001	7.310109052	0.900300	67	7	0.30852091	0.0004897157	630
11	59.689890948	0.0890893	0.6236257263	7.933734778	0.890893	67	7	0.27964399	0.0004438794	630
12	59.066265221	0.0881586	0.6171102337	8.550845012	0.881586	67	7	0.26902626	0.0004270258	630
13	58.449154988	0.0872375	0.6106628133	9.161507825	0.872375	67	7	0.26390672	0.0004188996	630
14	57.838492174	0.0863261	0.6042827541	9.765790579	0.863261	67	7	0.26045684	0.0004134236	630
15	57.23420942	0.0854241	0.5979693522	10.36375993	0.854241	67	7	0.25752785	0.0004087744	630
16	56.636240068	0.0845317	0.5917219112	10.95548184	0.845317	67	7	0.25477493	0.0004044047	630
17	56.044518157	0.0836485	0.5855397419	11.54102158	0.836485	67	7	0.25209440	0.0004001498	630
18	55.458978415	0.0827745	0.5794221625	12.12044374	0.827745	67	7	0.24945496	0.0003959603	630
19	54.879556253	0.0819097	0.5733684982	12.69381224	0.819097	67	7	0.24684704	0.0003918207	630
20	54.306187754	0.0810540	0.567378081	13.26119032	0.810540	67	7	0.24426753	0.0003877262	630
21	53.738809673	0.0802071	0.5614502503	13.82264057	0.802071	67	7	0.24171533	0.0003836751	630
22	53.177359423	0.0793691	0.5555843522	14.37822492	0.793691	67	7	0.23918990	0.0003796665	630
23	52.621775071	0.0785399	0.5497797395	14.92800466	0.785399	67	7	0.23669089	0.0003756998	630
24	52.071995331	0.0777193	0.5440357721	15.47204044	0.777193	67	7	0.23421799	0.0003717746	630
25	51.527959559	0.0769074	0.5383518163	16.01039225	0.769074	67	7	0.23177094	0.0003678904	630
26	50.989607743	0.0761038	0.5327272451	16.54311950	0.761038	67	7	0.22934945	0.0003640468	630
27	50.456880498	0.0753087	0.527161438	17.07028094	0.753087	67	7	0.22695326	0.0003602433	630
28	49.92971906	0.0745219	0.5216537812	17.59193472	0.745219	67	7	0.22458211	0.0003564795	630
29	49.408065279	0.0737433	0.5162036671	18.10813838	0.737433	67	7	0.22223573	0.0003527551	630
30	48.891861611	0.0729729	0.5108104944	18.61894888	0.729729	67	7	0.21991386	0.0003490696	630

Ground-water Restoration

1,2 Dichloroethane / Benzene

Years	Lbs in soil	Soil/H2O Equil. 10% (ppm)	Lbs Removed from Soil	Cuml. Lbs. Removed	Conc. in Soil (ppm)	Lbs. Soil 10E-6 LBS	Lbs. H2O 10E+6 Lbs	Lbs in Aquifer 60% flush	Conc. in Aquifer (ppm)	Lbs H2O in Aquifer 10E+6
0	67	0.1	0.7	0.7	1	67	7	6300.7	10.0011111111	630
1	66.3	0.0989552	0.6926865672	1.392686567	0.989552	67	7	2520.55707	4.0008842454	630
2	65.607313433	0.0979213	0.6854495433	2.078136110	0.979213	67	7	1008.49700	1.6007889042	630
3	64.92186389	0.0968983	0.6782881302	2.756424240	0.968983	67	7	403.670119	0.6407462208	630
4	64.243575759	0.0958859	0.6712015378	3.427625778	0.958859	67	7	161.736528	0.256724648	630
5	63.572374222	0.0948841	0.6641889844	4.091814762	0.948841	67	7	64.9602868	0.1031115665	630
6	62.908185237	0.0938928	0.6572496965	4.749064459	0.938928	67	7	26.2470146	0.041661928	630
7	62.250935541	0.0929118	0.6503629086	5.399447368	0.929118	67	7	10.7589590	0.0170777127	630
8	61.600552632	0.0919411	0.6435878633	6.043035231	0.919411	67	7	4.56101875	0.0072397123	630
9	60.956964769	0.0909805	0.636863811	6.679899042	0.909805	67	7	2.07915302	0.0033002429	630
10	60.320100958	0.0900300	0.63021001	7.310109052	0.900300	67	7	1.08374521	0.0017202305	630
11	59.689890948	0.0890893	0.6236257263	7.933734778	0.890893	67	7	0.68294837	0.001084045	630
12	59.066265221	0.0881586	0.6171102337	8.550845012	0.881586	67	7	0.52002344	0.000825434	630
13	58.449154988	0.0872375	0.6106628133	9.161507825	0.872375	67	7	0.45227450	0.000717896	630
14	57.838492174	0.0863261	0.6042827541	9.765790579	0.863261	67	7	0.42262290	0.00067083	630
15	57.23420942	0.0854241	0.5979693522	10.36375993	0.854241	67	7	0.40823690	0.0006479951	630
16	56.636240068	0.0845317	0.5917219112	10.95548184	0.845317	67	7	0.39998352	0.0006348945	630
17	56.044518157	0.0836485	0.5855397419	11.54102158	0.836485	67	7	0.39420930	0.0006257291	630
18	55.458978415	0.0827745	0.5794221625	12.12044374	0.827745	67	7	0.38945258	0.0006181787	630
19	54.879556253	0.0819097	0.5733684982	12.69381224	0.819097	67	7	0.38512843	0.000611315	630
20	54.306187754	0.0810540	0.567378081	13.26119032	0.810540	67	7	0.38100260	0.000604766	630
21	53.738809673	0.0802071	0.5614502503	13.82264057	0.802071	67	7	0.37698114	0.0005983828	630
22	53.177359423	0.0793691	0.5555843522	14.37822492	0.793691	67	7	0.37302619	0.0005921051	630
23	52.621775071	0.0785399	0.5497797395	14.92800466	0.785399	67	7	0.36912237	0.0005859085	630
24	52.071995331	0.0777193	0.5440357721	15.47204044	0.777193	67	7	0.36526325	0.000579783	630
25	51.527959559	0.0769074	0.5383518163	16.01039225	0.769074	67	7	0.36144603	0.0005737239	630
26	50.989607743	0.0761038	0.5327272451	16.54311950	0.761038	67	7	0.35766931	0.0005677291	630
27	50.456880498	0.0753087	0.527161438	17.07028094	0.753087	67	7	0.35393229	0.0005617973	630
28	49.92971906	0.0745219	0.5216537812	17.59193472	0.745219	67	7	0.35023443	0.0005559277	630
29	49.408065279	0.0737433	0.5162036671	18.10813838	0.737433	67	7	0.34657523	0.0005501194	630
30	48.891861611	0.0729729	0.5108104944	18.61894888	0.729729	67	7	0.34295429	0.0005443719	630

Ground-water Restoration

1,2 Dichloroethane / Benzene

Years	Lbs in soil	Soil/H20 Equil. 50% (ppm)	Lbs Removed from Soil	Cuml. Lbs. Removed	Conc. in Soil (ppm)	Lbs. Soil 10E+6 LBS	Lbs. H20 10E+6 Lbs	Lbs in Aquifer 70% flush	Conc. in Aquifer (ppm)	Lbs H20 in Aquifer 10E+6
0	670	5	35	35	10	67	7	6335	10.0555555556	630
1	635	4.7388059	33.171641791	68.17164179	9.477611	67	7	1910.45149	3.0324626866	630
2	601.82835821	4.4912564	31.438794832	99.61043662	8.982512	67	7	582.567086	0.9247096607	630
3	570.38956338	4.2566385	29.796469729	129.4069063	8.513277	67	7	183.709066	0.2916016933	630
4	540.59309365	4.0342768	28.239937728	157.6468440	8.068553	67	7	63.5847013	0.1009280974	630
5	512.35315592	3.8235310	26.7647171	184.4115611	7.647062	67	7	27.1048255	0.0430235326	630
6	485.58843882	3.6237943	25.366560237	209.7781214	7.247588	67	7	15.7414157	0.0249863742	630
7	460.22187858	3.4344916	24.041441419	233.8195628	6.868983	67	7	11.9348571	0.0189442177	630
8	436.18043716	3.2550778	22.785545225	256.6051080	6.510155	67	7	10.4161207	0.0165335249	630
9	413.39489194	3.0850365	21.595255549	278.2003636	6.170073	67	7	9.60341287	0.0152435125	630
10	391.79963639	2.9238778	20.467145185	298.6675087	5.847755	67	7	9.02116741	0.0143193134	630
11	371.33249121	2.7711379	19.397965959	318.0654747	5.542275	67	7	8.52574001	0.0135329207	630
12	351.93452525	2.6263770	18.384639379	336.4501141	5.252754	67	7	8.07311381	0.0128144664	630
13	333.54988587	2.4891782	17.424247769	353.8743619	4.978356	67	7	7.64920847	0.0121416008	630
14	316.1256381	2.3591465	16.514025871	370.3883877	4.718293	67	7	7.24897030	0.0115063021	630
15	299.61161223	2.2359075	15.651352877	386.0397406	4.471815	67	7	6.87009695	0.0109049158	630
16	283.96025935	2.1191064	14.833744891	400.8734855	4.238212	67	7	6.51115255	0.0103351628	630
17	269.12651446	2.0084068	14.058847770	414.9323333	4.016813	67	7	6.17100009	0.0097952382	630
18	255.06766669	1.9034900	13.324430349	428.2567636	3.806980	67	7	5.84862913	0.0092835383	630
19	241.74323634	1.8040540	12.628378017	440.8851416	3.608108	67	7	5.54310214	0.0087985748	630
20	229.11485832	1.7098123	11.968686628	452.8538283	3.419624	67	7	5.25353663	0.008338947	630
21	217.14617169	1.6204938	11.343456730	464.1972850	3.240987	67	7	4.97909800	0.0079033302	630
22	205.80271496	1.5358411	10.750888095	474.9481731	3.071682	67	7	4.71899583	0.0074904696	630
23	195.05182687	1.4556106	10.189274537	485.1374476	2.911221	67	7	4.47248111	0.0070991764	630
24	184.86255233	1.3795712	9.6569990023	494.7944466	2.759142	67	7	4.23884403	0.0067283239	630
25	175.20555333	1.3075041	9.1525289052	503.9469755	2.615008	67	7	4.01741188	0.0063768443	630
26	166.05302442	1.2392016	8.6744117236	512.6213873	2.478403	67	7	3.80754708	0.0060437255	630
27	157.3786127	1.1744672	8.2212708126	520.8426581	2.348934	67	7	3.60864536	0.0057280085	630
28	149.15734189	1.1131144	7.7918014418	528.6344595	2.226228	67	7	3.42013404	0.0054287842	630
29	141.36554044	1.0549667	7.3847670382	536.0192265	2.109933	67	7	3.24147032	0.005145191	630
30	133.98077341	0.9998565	6.9989956257	543.0182222	1.999713	67	7	3.07213978	0.0048764124	630

Ground-water Restoration

1,2 Dichloroethane / Benzene

Years	Lbs in soil	Soil/H20 Equil. 20% (ppm)	Lbs Removed from Soil	Cuml. Lbs. Removed	Conc. in Soil (ppm)	Lbs. Soil 10E+6 LBS	Lbs. H20 10E+6 Lbs	Lbs in Aquifer 50% flush	Conc. in Aquifer (ppm)	Lbs H20 in Aquifer 10E+6
0	335	1	7	7	5	67	7	6307	10.011111111	630
1	328	0.979104477	6.853731343	13.85373134	4.895522388	67	7	3156.926865	5.0109950249	630
2	321.14626866	0.958645578	6.710519046	20.56425039	4.793227890	67	7	1581.818692	2.5108233212	630
3	314.43574961	0.938614177	6.570299245	27.13454963	4.693070889	67	7	794.1944958	1.2606261838	630
4	307.86545036	0.919001344	6.433009410	33.56755904	4.595006721	67	7	400.3137526	0.6354186549	630
5	301.43244095	0.899798331	6.298588318	39.86614736	4.498991656	67	7	203.3061704	0.3227082071	630
6	295.13385264	0.880996575	6.166976025	46.03312339	4.404982875	67	7	104.7365732	0.166248529	630
7	288.96687661	0.862587691	6.038113839	52.07123722	4.312938456	67	7	55.38734354	0.0879164183	630
8	282.92876277	0.844563471	5.911944296	57.98318152	4.222817354	67	7	30.64964391	0.0486502284	630
9	277.01681847	0.826915876	5.788411132	63.77159265	4.134579380	67	7	18.21902752	0.0289190913	630
10	271.22840734	0.809637036	5.667459257	69.43905191	4.048185184	67	7	11.94324339	0.0189575292	630
11	265.56094808	0.792719248	5.549034736	74.98808665	3.963596240	67	7	8.746139063	0.0138827604	630
12	260.01191335	0.776154965	5.433084756	80.42117140	3.880774826	67	7	7.089611910	0.0112533522	630
13	254.57882859	0.759936801	5.319557612	85.74072902	3.799684008	67	7	6.204584761	0.0098485472	630
14	249.25927098	0.744057525	5.208402677	90.94913169	3.720287626	67	7	5.706493719	0.0090579265	630
15	244.0508683	0.728510054	5.099570382	96.04870208	3.642550273	67	7	5.403032050	0.0085762414	630
16	238.95129792	0.713287456	4.993012195	101.0417142	3.566437282	67	7	5.198022123	0.0082508288	630
17	233.95828572	0.698382942	4.888680597	105.9303948	3.491914712	67	7	5.043351360	0.0080053196	630
18	229.06960513	0.683789866	4.786529062	110.7169239	3.418949330	67	7	4.914940211	0.0078014924	630
19	224.28307606	0.669501719	4.686512037	115.4034359	3.347508598	67	7	4.800726124	0.0076202002	630
20	219.59656403	0.655512131	4.58858492	119.9920208	3.277560657	67	7	4.694655522	0.0074518342	630
21	215.00797911	0.641814863	4.492704041	124.4847249	3.209074315	67	7	4.593679781	0.0072915552	630
22	210.51527507	0.628403806	4.398826643	128.8835515	3.142019030	67	7	4.496253212	0.0071369099	630
23	206.11644842	0.615272980	4.306910862	133.1904624	3.076364901	67	7	4.401582037	0.0069866382	630
24	201.80953756	0.60241653	4.216915710	137.4073781	3.012082650	67	7	4.309248873	0.0068400776	630
25	197.59262185	0.589828721	4.128801053	141.5361792	2.949143609	67	7	4.219024963	0.006696865	630
26	193.4638208	0.577503942	4.042527598	145.5787068	2.887519713	67	7	4.130776281	0.0065567877	630
27	189.4212932	0.565436696	3.958056872	149.5367636	2.827183480	67	7	4.044416577	0.0064197089	630
28	185.46323633	0.553621601	3.875351206	153.4121148	2.768108004	67	7	3.959883891	0.00628553	630
29	181.58788512	0.542053388	3.794373718	157.2064886	2.710266942	67	7	3.877128805	0.0061541727	630
30	177.7935114	0.530726899	3.715088297	160.9215769	2.653634498	67	7	3.796108551	0.0060255691	630

Cround-water Restoration

1,2 Dichloroethane / Benzene

Years	Lbs in soil	Soil/H20 Equil. 10% (ppm)	Lbs Removed from Soil	Cuml. Lbs. Removed	Conc. in Soil (ppm)	Lbs. Soil 10E+6 LBS	Lbs. H20 10E+6 Lbs	Lbs in Aquifer 70% flush	Conc. in Aquifer (ppm)	Lbs H20 in Aquifer 10E+6
0	335	0.5	3.5	3.5	5	67	7	6303.5	10.005555555	630
1	331.5	0.494776119	3.463432835	6.963432835	4.947761194	67	7	1892.089029	3.0033159204	630
2	328.03656716	0.489606816	3.427247716	10.39068055	4.896068166	67	7	568.6548832	0.9026267988	630
3	324.60931945	0.484491521	3.391440650	13.78212120	4.844915215	67	7	171.6138971	0.2724030114	630
4	321.2178788	0.479429669	3.356007688	17.13812889	4.794296698	67	7	52.49097146	0.0833190023	630
5	317.86187111	0.474420703	3.320944922	20.45907381	4.744207031	67	7	16.74357491	0.026577103	630
6	314.54092619	0.469464068	3.286248482	23.74532229	4.694640689	67	7	6.008947019	0.0095380111	630
7	311.2546777	0.464559220	3.251914543	26.99723684	4.645592204	67	7	2.778258468	0.0044099341	630
8	308.00276316	0.459705616	3.217939316	30.21517615	4.597056166	67	7	1.798859335	0.0028553323	630
9	304.78482384	0.454902722	3.184319055	33.39949521	4.549027221	67	7	1.494953517	0.0023729421	630
10	301.60050479	0.450150007	3.15105005	36.55054526	4.501500071	67	7	1.393801070	0.0022123827	630
11	298.44945474	0.445446947	3.118128631	39.66867389	4.454469473	67	7	1.353578910	0.002148538	630
12	295.33132611	0.440793024	3.085551168	42.75422506	4.407930240	67	7	1.331739023	0.0021138715	630
13	292.24577494	0.436187723	3.053314066	45.80753912	4.361877237	67	7	1.315515927	0.0020881205	630
14	289.19246087	0.431630538	3.021413770	48.82895289	4.316305386	67	7	1.301078909	0.0020652046	630
15	286.1710471	0.427120965	2.989846760	51.81879965	4.271209658	67	7	1.287277701	0.0020432979	630
16	283.18120034	0.422658508	2.958609555	54.77740921	4.226585079	67	7	1.273766177	0.0020218511	630
17	280.22259078	0.418242672	2.927698709	57.70510792	4.182426728	67	7	1.260439466	0.0020006976	630
18	277.29489208	0.413872973	2.897110812	60.60221873	4.138729732	67	7	1.247265083	0.0019797858	630
19	274.39778126	0.409548927	2.866842490	63.46906122	4.095489272	67	7	1.234232272	0.0019590988	630
20	271.53093877	0.405270057	2.836890405	66.30595163	4.052700578	67	7	1.221336803	0.0019386298	630
21	268.69404837	0.401035893	2.807251251	69.11320288	4.010358930	67	7	1.208576416	0.0019183753	630
22	265.88679712	0.396845965	2.777921760	71.89112464	3.968459658	67	7	1.195949453	0.0018983325	630
23	263.10887535	0.392699814	2.748898697	74.64002334	3.926998139	67	7	1.183454445	0.0018784991	630
24	260.35997666	0.388596980	2.720178860	77.36020220	3.885969800	67	7	1.171089991	0.001858873	630
25	257.6397978	0.384537011	2.691759081	80.05196128	3.845370116	67	7	1.158854722	0.0018394519	630
26	254.94803871	0.380519460	2.663636225	82.71559751	3.805194607	67	7	1.146747284	0.0018202338	630
27	252.28440249	0.376543884	2.635807190	85.35140470	3.765438843	67	7	1.134766342	0.0018012164	630
28	249.6485953	0.372609843	2.608268906	87.95967360	3.726098437	67	7	1.122910574	0.0017823977	630
29	247.04032639	0.368716905	2.581018335	90.54069194	3.687169050	67	7	1.111178673	0.0017637757	630
30	244.45930806	0.364864638	2.554052472	93.09474441	3.648646388	67	7	1.099569343	0.0017453482	630

003179

Ground-water Restoration

1,2 Dichloroethane / Benzene

Years	Lbs in soil	Soil/H20 Equil. 10% (ppm)	Lbs Removed from Soil	Cmi. Lbs. Removed	Conc. in Soil (ppm)	Lbs. Soil 10E+6 lBS	Lbs. H20 10E+6 Lbs	Lbs in Aquifer 60% flush	Conc. in Aquifer (ppm)	Lbs H20 in Aquifer 10E+6
0	335	0.5	3.5	3.5	5	67	7	6303.5	10.005555555	630
1	331.5	0.494776119	3.463432835	6.963432835	4.947761194	67	7	2522.785373	4.0044212272	630
2	328.03656716	0.489606816	3.427247716	10.39068055	4.896068166	67	7	1010.485048	1.6039445212	630
3	324.60931945	0.484491521	3.391440650	13.78212120	4.844915215	67	7	405.5505956	0.6437311041	630
4	321.2178788	0.479429669	3.356007688	17.13812889	4.794296698	67	7	163.5626413	0.2596232402	630
5	317.86187111	0.474420703	3.320944922	20.45907381	4.744207031	67	7	66.75343449	0.1059578325	630
6	314.54092619	0.469464068	3.286248482	23.74532229	4.694640689	67	7	28.01587319	0.04446964	630
7	311.2546777	0.464559220	3.251914543	26.99723684	4.645592204	67	7	12.50711509	0.0198525636	630
8	308.00276316	0.459705616	3.217939316	30.21517615	4.597056166	67	7	6.290021764	0.0099841615	630
9	304.78482384	0.454902722	3.184319055	33.39949521	4.549027221	67	7	3.789736327	0.0060154545	630
10	301.60050479	0.450150007	3.15105005	36.55054526	4.501500071	67	7	2.776314551	0.0044068485	630
11	298.44945474	0.445446947	3.118128631	39.66867389	4.454469473	67	7	2.357777273	0.0037425036	630
12	295.33132611	0.440793024	3.085551168	42.75422506	4.407930240	67	7	2.177331376	0.0034560816	630
13	292.24577494	0.436187723	3.053314066	45.80753912	4.361877227	67	7	2.092258177	0.0033210447	630
14	289.19246087	0.431630538	3.021413770	48.82895289	4.316305386	67	7	2.045468779	0.0032467758	630
15	286.1710471	0.427120965	2.989846760	51.81879965	4.271209658	67	7	2.014126215	0.0031970257	630
16	283.18120034	0.422658508	2.958609555	54.77740921	4.226585079	67	7	1.989094308	0.0031572926	630
17	280.22259078	0.418242672	2.927698709	57.70510792	4.182426728	67	7	1.966717207	0.0031217733	630
18	277.29489208	0.413872973	2.897110812	60.60221873	4.138729732	67	7	1.945531208	0.0030881448	630
19	274.39778126	0.409548927	2.866842490	63.46906122	4.095489272	67	7	1.924949479	0.0030554754	630
20	271.53093877	0.405270057	2.836890405	66.30595163	4.052700578	67	7	1.904735953	0.0030233904	630
21	268.69404837	0.401035893	2.807251251	69.11320288	4.010358930	67	7	1.884794882	0.0029917379	630
22	265.88679712	0.396845965	2.777921760	71.89112464	3.968459658	67	7	1.865086657	0.002960455	630
23	263.10887535	0.392699814	2.748898697	74.64002334	3.926998139	67	7	1.845594142	0.0029295145	630
24	260.35997666	0.388596980	2.720178860	77.36020220	3.885969800	67	7	1.826309201	0.0028989035	630
25	257.6397978	0.384537011	2.691759081	80.05196128	3.845370116	67	7	1.807227313	0.0028686148	630
26	254.94803871	0.380519460	2.663636225	82.71559751	3.805194607	67	7	1.788345415	0.0028386435	630
27	252.28440249	0.376543884	2.635807190	85.35140470	3.765438843	67	7	1.769661042	0.0028089858	630
28	249.6485953	0.372609843	2.608268906	87.95967360	3.726098437	67	7	1.751171979	0.0027796381	630
29	247.04032639	0.368716905	2.581018335	90.54069194	3.687169050	67	7	1.732876125	0.002750597	630
30	244.45930806	0.364864638	2.554052472	93.09474441	3.648646388	67	7	1.714771439	0.0027218594	630

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Ground-water Restoration

1,2 Dichloroethane / Benzene

Years	Lbs in soil	Soil/H20 Equil. 10% (ppm)	Lbs Removed from Soil	Cuml. Lbs. Removed	Conc. in Soil (ppm)	Lbs. Soil 10E+6 LBS	Lbs. H20 10E+6 Lbs	Lbs in Aquifer 50% flush	Conc. in Aquifer (ppm)	Lbs H20 in Aquifer 10E+6
0	335	0.5	3.5	3.5	5	67	7	6303.5	10.005555555	630
1	331.5	0.494776119	3.463432835	6.963432835	4.947761194	67	7	3153.481716	5.005526534	630
2	328.03656716	0.489606816	3.427247715	10.39068055	4.896068166	67	7	1578.454482	2.5054833049	630
3	324.60931945	0.484491521	3.391440650	13.78212120	4.844915215	67	7	790.9229613	1.255433272	630
4	321.2178788	0.479429669	3.356007688	17.13812889	4.794296698	67	7	397.1394845	0.6303801342	630
5	317.86187111	0.474420703	3.320944922	20.45907381	4.744207031	67	7	200.2302147	0.3178257377	630
6	314.54092619	0.469464068	3.286248482	23.74532229	4.694640689	67	7	101.7582316	0.1615210025	630
7	311.2546777	0.464559220	3.251914543	26.99723684	4.645592204	67	7	52.50507307	0.0833413858	630
8	308.00276316	0.459705616	3.217939316	30.21517615	4.597056166	67	7	27.86150619	0.044224613	630
9	304.78462384	0.454902722	3.184319055	33.39949521	4.549027221	67	7	15.52291262	0.0246395438	630
10	301.60050479	0.450150007	3.15105005	36.55054526	4.501500071	67	7	9.336981337	0.0148206053	630
11	298.44945474	0.445446947	3.118128631	39.66867389	4.454469473	67	7	6.227554984	0.0098850079	630
12	295.33132611	0.440793024	3.085551168	42.75422506	4.407930240	67	7	4.656553076	0.0073913541	630
13	292.24577494	0.436187723	3.053314066	45.80753912	4.361877237	67	7	3.854933571	0.0061189422	630
14	289.19246087	0.431630538	3.021413770	48.82895289	4.316305386	67	7	3.438173670	0.0054574185	630
15	286.1710471	0.427120965	2.989846760	51.81879965	4.271209658	67	7	3.214010215	0.0051016035	630
16	283.18120034	0.422658508	2.958609555	54.77740921	4.226585079	67	7	3.086309885	0.0048989046	630
17	280.22259078	0.418242672	2.927698709	57.70510792	4.182426728	67	7	3.007004297	0.0047730227	630
18	277.29489208	0.413872973	2.897110812	60.60221873	4.138729732	67	7	2.952057555	0.0046858056	630
19	274.39778126	0.409548927	2.866842490	63.46906122	4.095489272	67	7	2.909450023	0.0046181746	630
20	271.53093877	0.405270057	2.836890405	66.30595163	4.052700578	67	7	2.873170214	0.0045605876	630
21	268.69404837	0.401035893	2.807251251	69.11320288	4.010358930	67	7	2.840210732	0.004508271	630
22	265.88679712	0.396845965	2.777921760	71.89112464	3.968459658	67	7	2.809066246	0.0044588353	630
23	263.10887535	0.392699814	2.748898697	74.64002334	3.926998139	67	7	2.778982472	0.0044110833	630
24	260.35997666	0.388596980	2.720178860	77.36020220	3.885969800	67	7	2.749580666	0.0043644138	630
25	257.6397978	0.384537011	2.691759081	80.05196128	3.845370116	67	7	2.720669873	0.0043185236	630
26	254.94803871	0.380519460	2.663636225	82.71559751	3.805194607	67	7	2.692153049	0.0042732588	630
27	252.28440249	0.376543884	2.635807190	85.35140470	3.765438843	67	7	2.663980119	0.0042285399	630
28	249.6485953	0.372609843	2.608268906	87.95967360	3.726098437	67	7	2.636124513	0.0041843246	630
29	247.04032639	0.368716905	2.581018335	90.54069194	3.687169050	67	7	2.608571424	0.0041405896	630
30	244.45930806	0.364864638	2.554052472	93.09474441	3.648646388	67	7	2.581311948	0.0040973206	630

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Ground-water Restoration

1,2 Dichloroethane / Benzene

Years	Lbs in soil	Soil/H20 Equil. 20% (ppm)	Lbs Removed from Soil	Cuml. Lbs. Removed	Conc. in Soil (ppm)	Lbs. Soil 10E-6 LBS	Lbs. H20 10E+6 Lbs	Lbs in Aquifer 60% flush	Conc. in Aquifer (ppm)	Lbs H20 in Aquifer 10E+6
0	335	1	7	7	5	67	7	6307	10.011111111	630
1	328	0.979104477	6.853731343	13.85373134	4.895522388	67	7	2525.541492	4.0087960199	630
2	321.14626866	0.958645578	6.710519046	20.56425039	4.793227890	67	7	1012.900804	1.607779055	630
3	314.43574961	0.938614177	6.570299245	27.13454963	4.693070889	67	7	407.7884415	0.6472832406	630
4	307.86545036	0.919001344	6.433009410	33.56755904	4.595006721	67	7	165.6885803	0.2629977466	630
5	301.43244095	0.899798331	6.298588318	39.86614736	4.498991656	67	7	68.79486748	0.1091982024	630
6	295.13385264	0.880996575	6.166976025	46.03312339	4.404982875	67	7	29.98473740	0.0475948213	630
7	288.96687661	0.862587691	6.038113839	52.07123722	4.312938456	67	7	14.40914049	0.0228716516	630
8	282.92876277	0.844563471	5.911944296	57.98318152	4.222817354	67	7	8.128433917	0.0129022761	630
9	277.01681847	0.826915876	5.788411132	63.77159265	4.134579380	67	7	5.566738019	0.0088360921	630
10	271.22840734	0.809637036	5.667459257	69.43905191	4.048185184	67	7	4.493678911	0.0071328237	630
11	265.56094808	0.792719248	5.549034736	74.98806665	3.963596240	67	7	4.017085458	0.0063763261	630
12	260.01191335	0.776154965	5.433084756	80.42117140	3.880774826	67	7	3.780068086	0.0060001081	630
13	254.57882859	0.759936801	5.319557612	85.74072902	3.799684008	67	7	3.639850279	0.0057775401	630
14	249.25927098	0.744057525	5.208402677	90.94913169	3.720287626	67	7	3.539301182	0.0056179384	630
15	244.0508683	0.728510054	5.099570382	96.04870208	3.642550273	67	7	3.455548626	0.0054849978	630
16	238.95129792	0.713287456	4.993012195	101.0417142	3.566437282	67	7	3.379424328	0.0053641656	630
17	233.95828572	0.698382942	4.888680597	105.9303948	3.491914712	67	7	3.307241970	0.0052495904	630
18	229.06960513	0.683789866	4.786529062	110.7169239	3.418949330	67	7	3.237508413	0.0051389022	630
19	224.28307606	0.669501719	4.686512037	115.4034359	3.347508598	67	7	3.169608180	0.0050311241	630
20	219.59656403	0.655512131	4.58858492	119.9920208	3.277560657	67	7	3.10327724	0.0049258369	630
21	215.00797911	0.641814863	4.492704041	124.4847249	3.209074315	67	7	3.038392512	0.0048228453	630
22	210.51527507	0.628403806	4.398826643	128.8835515	3.142019030	67	7	2.974887662	0.0047220439	630
23	206.11644842	0.615272980	4.306910862	133.1904624	3.076364901	67	7	2.912719409	0.0046233641	630
24	201.80953756	0.60241653	4.216915710	137.4073781	3.012082650	67	7	2.851854048	0.0045267525	630
25	197.59262185	0.589828721	4.128801053	141.5361792	2.949143609	67	7	2.792262040	0.004432162	630
26	193.4638208	0.577503942	4.042527598	145.5787068	2.887519713	67	7	2.733915855	0.004339549	630
27	189.4212932	0.565436696	3.958056872	149.5367636	2.827183480	67	7	2.676789091	0.0042488716	630
28	185.46323633	0.553621601	3.875351206	153.4121148	2.768108004	67	7	2.620856119	0.0041600891	630
29	181.58788512	0.542053388	3.794373718	157.2064886	2.710266942	67	7	2.566091935	0.0040731618	630
30	177.7935114	0.530726899	3.715088297	160.9215769	2.653634498	67	7	2.512472093	0.0039880509	630

Ground-water Restoration

1,2 Dichloroethane / Benzene

Years	Lbs in soil	Soil/H20 Equil. 20% (ppm)	Lbs Removed from Soil	Cuml. Lbs. Removed	Conc. in Soil (ppm)	Lbs. Soil 10E+6 LBS	Lbs. H20 10E+6 Lbs	Lbs in Aquifer 70% flush	Conc. in Aquifer (ppm)	Lbs H20 in Aquifer 10E+6
0	335	1	7	7	5	67	7	6307	10.011111111	630
1	328	0.979104477	6.853731343	13.85373134	4.895522388	67	7	1894.156119	3.0065970149	630
2	321.14626866	0.958645578	6.710519046	20.56425039	4.793227890	67	7	570.2599915	0.9051745897	630
3	314.43574961	0.938614177	6.570299245	27.13454963	4.693070889	67	7	173.0490872	0.2746810908	630
4	307.86545036	0.919001344	6.433009410	33.56755904	4.595006721	67	7	53.84462899	0.0854676651	630
5	301.43244095	0.899798331	6.298588318	39.86614736	4.498991656	67	7	18.04296519	0.0286396273	630
6	295.13385264	0.880996575	6.166976025	46.03312339	4.404982875	67	7	7.262982365	0.0115285434	630
7	288.96687661	0.862587691	6.038113839	52.07123722	4.312938456	67	7	3.990328861	0.0063338553	630
8	282.92876277	0.844563471	5.911944296	57.98318152	4.222817354	67	7	2.970681947	0.0047153682	630
9	277.01681847	0.826915876	5.788411132	63.77159265	4.134579380	67	7	2.627727923	0.0041709967	630
10	271.22840734	0.809637036	5.667459257	69.43905191	4.048185184	67	7	2.488556154	0.0039500891	630
11	265.56094808	0.792719248	5.549034736	74.98808665	3.963596240	67	7	2.411277267	0.0038274242	630
12	260.01191335	0.776154965	5.433084756	80.42117140	3.880774826	67	7	2.353308607	0.0037354105	630
13	254.57882859	0.759936801	5.319557612	85.74072902	3.799684008	67	7	2.301859865	0.0036537458	630
14	249.25927098	0.744057525	5.208402677	90.94913169	3.720287626	67	7	2.253078762	0.0035763155	630
15	244.0508683	0.728510054	5.099570382	96.04870208	3.642550273	67	7	2.205794743	0.0035012615	630
16	238.95129792	0.713287456	4.993012195	101.0417142	3.566437282	67	7	2.159642081	0.0034280033	630
17	233.95828572	0.698382942	4.888680597	105.9303948	3.491914712	67	7	2.114496803	0.0033563441	630
18	229.06960513	0.683789866	4.786529062	110.7169239	3.418949330	67	7	2.070307759	0.0032862028	630
19	224.28307606	0.669501719	4.686512037	115.4034359	3.347508598	67	7	2.027045939	0.0032175332	630
20	219.59656403	0.655512131	4.58858492	119.9920208	3.277560657	67	7	1.984689257	0.0031503004	630
21	215.00797911	0.641814863	4.492704041	124.4847249	3.209074315	67	7	1.943217989	0.003084473	630
22	210.51527507	0.628403806	4.398826643	128.8835515	3.142019030	67	7	1.902613389	0.0030200213	630
23	206.11644842	0.615272980	4.306910862	133.1904624	3.076364901	67	7	1.862857275	0.0029569163	630
24	201.80953756	0.60241653	4.216915710	137.4073781	3.012082650	67	7	1.823931895	0.00289513	630
25	197.59262185	0.589828721	4.128801053	141.5361792	2.949143609	67	7	1.785819884	0.0028346347	630
26	193.4638208	0.577503942	4.042527598	145.5787068	2.887519713	67	7	1.748504245	0.0027754036	630
27	189.4212932	0.565436696	3.958056872	149.5367636	2.827183480	67	7	1.711968335	0.0027174101	630
28	185.46323633	0.553621601	3.875351206	153.4121148	2.768108004	67	7	1.676195862	0.0026606284	630
29	181.58788512	0.542053388	3.794373718	157.2064886	2.710266942	67	7	1.641170874	0.0026050331	630
30	177.7935114	0.530726899	3.715088297	160.9215769	2.653634498	67	7	1.606877751	0.0025505996	630

Ground-water Restoration

1,2 Dichloroethane / Benzene

Years	Lbs in soil	Soil/H20 Equil. 50% (ppm)	Lbs Removed from Soil	Cuml. Lbs. Removed	Conc. in Soil (ppm)	Lbs. Soil 10E+6 LBS	Lbs. H20 10E+6 Lbs	Lbs in Aquifer 50% flush	Conc. in Aquifer (ppm)	Lbs H20 in Aquifer 10E+6
0	335	2.5	17.5	7	5	67	7	6317.5	10.027777777	630
1	328	2.447761194	17.13432835	24.13432835	4.895522388	67	7	3167.317164	5.0274875622	630
2	310.86567164	2.319893072	16.23925150	40.37357986	4.639786143	67	7	1591.778207	2.5266320759	630
3	294.62642014	2.198704627	15.39093239	55.76451225	4.397409255	67	7	803.5845701	1.2755310637	630
4	279.23548774	2.083846923	14.58692846	70.35144072	4.167693846	67	7	409.0857492	0.6493424592	630
5	264.64855928	1.974989248	13.82492473	84.17636546	3.949978496	67	7	211.4553370	0.3356433921	630
6	250.82363454	1.871818168	13.10272717	97.27909263	3.743636336	67	7	112.2790320	0.1782206859	630
7	237.72090736	1.774036622	12.41825635	109.6973489	3.548073244	67	7	62.34864422	0.0989661019	630
8	225.30265101	1.681363067	11.76954147	121.4668904	3.362726134	67	7	37.05909284	0.0588239569	630
9	213.53310954	1.593530668	11.15471467	132.6216051	3.187061336	67	7	24.10690376	0.0382649266	630
10	202.37839486	1.510286528	10.57200570	143.1936108	3.020573057	67	7	17.33945473	0.027522944	630
11	191.80638916	1.431390963	10.01973674	153.2133475	2.862781927	67	7	13.67959573	0.021713644	630
12	181.78665241	1.356616809	9.496317663	162.7096652	2.713233618	67	7	11.58795670	0.0183935821	630
13	172.29033475	1.285748766	9.000241367	171.7099066	2.571497533	67	7	10.29409903	0.0163398397	630
14	163.29009338	1.212582786	8.530079505	180.2399861	2.437165572	67	7	9.412089269	0.0149398242	630
15	154.76001388	1.154925476	8.084478336	188.3244644	2.309850953	67	7	8.748283803	0.0138861648	630
16	146.67553554	1.094593548	7.662154841	195.9866193	2.189187097	67	7	8.205219322	0.0130241577	630
17	139.0133807	1.037413288	7.261893021	203.2485123	2.074826577	67	7	7.733556172	0.012275486	630
18	131.75148768	0.983220057	6.882540401	210.1310527	1.966440114	67	7	7.308048286	0.0116000766	630
19	124.86894727	0.931857815	6.523004708	216.6540574	1.863715631	67	7	6.915526497	0.0109770262	630
20	118.34594256	0.883178675	6.182250731	222.8363081	1.766357351	67	7	6.548888614	0.0103950613	630
21	112.16369183	0.837042476	5.859297334	228.6956055	1.674084952	67	7	6.204092974	0.0098477666	630
22	106.30439450	0.793316376	5.553214638	234.2488201	1.586632753	67	7	5.878653806	0.0093311965	630
23	100.75117986	0.751874476	5.263121336	239.5119414	1.503748953	67	7	5.570887571	0.0088426787	630
24	95.488058526	0.712597451	4.988182161	244.5001236	1.425194903	67	7	5.279534866	0.0083802141	630
25	90.499876365	0.675372211	4.727605481	249.2277291	1.350744423	67	7	5.003570174	0.0079421749	630
26	85.772270883	0.640091573	4.480641016	253.7083701	1.280183147	67	7	4.742105595	0.0075271517	630
27	81.291629867	0.606653954	4.246577679	257.9549478	1.213307908	67	7	4.494341637	0.0071338756	630
28	77.045052187	0.574963076	4.024741532	261.9796893	1.149926152	67	7	4.259541584	0.0067611771	630
29	73.020310655	0.544927691	3.814493840	265.7941831	1.089855382	67	7	4.037017712	0.0064079646	630
30	69.205816815	0.516461319	3.615229236	269.4094124	1.032922639	67	7	3.826123474	0.0060732119	630

Ground-water Restoration

1,2 Dichloroethane / Benzene

Years	Lbs in soil	Soil/H20 Equil. 50% (ppm)	Lbs Removed from Soil	Cuml. Lbs. Removed	Conc. in Soil (ppm)	Lbs. Soil 10E+6 LBS	Lbs. H20 10E+6 Lbs	Lbs in Aquifer 60% flush	Conc. in Aquifer (ppm)	Lbs H20 in Aquifer 10E+6
0	335	2.5	17.5	7	5	67	7	6317.5	10.027777777	630
1	328	2.447761194	17.13432835	24.13432835	4.895522388	67	7	2533.853731	4.0219900498	630
2	310.86567164	2.319893072	16.23925150	40.37357986	4.639786143	67	7	1020.037193	1.6191066558	630
3	294.62642014	2.198704627	15.39093239	55.76451225	4.397409255	67	7	414.1712502	0.6574146829	630
4	279.23548774	2.083846923	14.58692846	70.35144072	4.167693846	67	7	171.5032714	0.272227415	630
5	264.64855928	1.974989248	13.82492473	84.17636546	3.949978496	67	7	74.13127848	0.117668696	630
6	250.82363454	1.871818168	13.10272717	97.27909263	3.743636336	67	7	34.89360226	0.0553866703	630
7	237.72090736	1.774036622	12.41825635	109.6973489	3.548073244	67	7	18.92474344	0.0300392753	630
8	225.30265101	1.681363067	11.76954147	121.4668904	3.362726134	67	7	12.27771396	0.0194884349	630
9	213.53310954	1.593530668	11.15471467	132.6216051	3.187061336	67	7	9.372971457	0.0148777325	630
10	202.37839486	1.510286528	10.57200570	143.1936108	3.020573057	67	7	7.977990863	0.0126634776	630
11	191.80638916	1.431390963	10.01973674	153.2133475	2.862781927	67	7	7.199091044	0.0114271286	630
12	181.78665241	1.356616809	9.496317663	162.7096652	2.713233618	67	7	6.678163483	0.0106002595	630
13	172.29033475	1.285748766	9.000241367	171.7099066	2.571497533	67	7	6.271361940	0.0099545428	630
14	163.29009338	1.218582786	8.530079505	180.2399861	2.437165572	67	7	5.920576578	0.0093977406	630
15	154.76001388	1.154925476	8.084478336	188.3244644	2.309850953	67	7	5.602021965	0.0088920984	630
16	146.67553554	1.094593548	7.662154841	195.9866193	2.189187097	67	7	5.305670723	0.0084216996	630
17	139.0133807	1.037413288	7.261893021	203.2485123	2.074826577	67	7	5.027025497	0.0079794056	630
18	131.75148768	0.983220057	6.882540401	210.1310527	1.966440114	67	7	4.763826359	0.0075616291	630
19	124.86894727	0.931857815	6.523004708	216.6540574	1.863715631	67	7	4.514732427	0.0071662419	630
20	118.34594256	0.883178675	6.182250731	222.8363081	1.766357351	67	7	4.278793263	0.0067917353	630
21	112.16369183	0.837042476	5.859297334	228.6956055	1.674084952	67	7	4.055236239	0.0064368829	630
22	106.30439450	0.793316376	5.553214638	234.2488201	1.586632753	67	7	3.843380350	0.0061006037	630
23	100.75117986	0.751874476	5.263121336	239.5119414	1.503748953	67	7	3.642600674	0.0057819058	630
24	95.488058526	0.712597451	4.988182161	244.5001236	1.425194903	67	7	3.452313134	0.0054798621	630
25	90.499876365	0.675372211	4.727605481	249.2277291	1.350744423	67	7	3.271967446	0.0051935991	630
26	85.772270883	0.640091573	4.480641016	253.7083731	1.280183147	67	7	3.101043385	0.0049222911	630
27	81.291629867	0.606653954	4.246577679	257.9549478	1.213307908	67	7	2.939048425	0.0046651562	630
28	77.045052187	0.574963076	4.024741532	261.9796893	1.149926152	67	7	2.785515983	0.0044214539	620
29	73.020310655	0.544927691	3.814493840	265.7941831	1.089855382	67	7	2.640003929	0.0041904824	630
30	69.205816815	0.516461319	3.615229236	269.4094124	1.032922639	67	7	2.502093266	0.0039715766	630

D-

003185

Ground-water Restoration

1,2 Dichloroethane / Benzene

Years	Lbs in soil	Soil/H20 Equil. 50% (ppm)	Lbs Removed from Soil	Cuml. Lbs. Removed	Conc. in Soil (ppm)	Lbs. Soil 10E+6 LBS	Lbs. H20 10E+6 Lbs	Lbs in Aquifer 70% flush	Conc. in Aquifer (ppm)	Lbs H20 in Aquifer 10E-6
0	335	2.5	17.5	7	5	67	7	6317.5	10.027777777	630
1	328	2.447761194	17.13432835	24.13432835	4.895522388	67	7	1900.390298	3.0164925373	630
2	310.86567164	2.319893072	16.23925150	40.37357986	4.639786143	67	7	574.988865	0.9126807381	630
3	294.62642014	2.198704627	15.39093239	55.76451225	4.397409255	67	7	177.1139392	0.2811332369	630
4	279.23548774	2.083846923	14.58692846	70.35144072	4.167693846	67	7	57.51026030	0.0912861275	630
5	264.64855928	1.974989248	13.82492473	84.17636546	3.949978496	67	7	21.40055551	0.0339691357	630
6	250.82363454	1.871818168	13.10272717	97.27909263	3.743636336	67	7	10.35098480	0.0164301346	630
7	237.72090736	1.774036622	12.41825635	109.6973489	3.548073244	67	7	6.830772348	0.0108424958	630
8	225.30265101	1.681363067	11.76954147	121.4668904	3.362726134	67	7	5.580094145	0.0088572923	630
9	213.53310954	1.593530668	11.15471467	132.6216051	3.187061336	67	7	5.020442646	0.0079689566	630
10	202.37839486	1.510286528	10.57200570	143.1936108	3.020573057	67	7	4.677734504	0.0074249754	630
11	191.80638916	1.431390963	10.01973674	153.2133475	2.862781927	67	7	4.409241375	0.0069987958	630
12	181.78665241	1.356616809	9.496317663	162.7096652	2.713233618	67	7	4.171667711	0.0066216948	630
13	172.29033475	1.285748766	9.000241367	171.7099066	2.571497533	67	7	3.951572723	0.0062723377	630
14	163.29009338	1.218582786	8.530079505	180.2399861	2.437165572	67	7	3.744495668	0.0059436439	630
15	154.76001388	1.154925476	8.084478336	188.3244644	2.309850953	67	7	3.548692201	0.0056328448	630
16	146.67553554	1.094593548	7.662154841	195.9866193	2.189187097	67	7	3.363254113	0.0053384986	630
17	139.0133807	1.037413288	7.261893021	203.2485123	2.074826577	67	7	3.187544140	0.0050595939	630
18	131.75148768	0.983220057	6.882540401	210.1310527	1.966440114	67	7	3.021025362	0.0047952784	630
19	124.86894727	0.931857815	6.523004708	216.6540574	1.863715631	67	7	2.863209021	0.0045447762	630
20	118.34594256	0.883178675	6.182250731	222.8363081	1.766357351	67	7	2.713637925	0.0043073618	630
21	112.16369183	0.837042476	5.859297334	228.6956055	1.674084952	67	7	2.571880578	0.0040823501	630
22	106.30439450	0.793316376	5.553214638	234.2488201	1.586632753	67	7	2.437528564	0.003869093	630
23	100.75117986	0.751874476	5.263121336	239.5119414	1.503748953	67	7	2.310194970	0.0036669761	630
24	95.488058526	0.712597451	4.988182161	244.5001236	1.425194903	67	7	2.189513139	0.0034754177	630
25	90.499876365	0.675372211	4.727605481	249.2277291	1.350744423	67	7	2.075135586	0.003293866	630
26	85.772270883	0.640091573	4.480641016	253.7083701	1.280183147	67	7	1.966732980	0.0031217984	630
27	81.291629867	0.606653954	4.246577679	257.9549478	1.213307908	67	7	1.863993198	0.0029587194	630
28	77.045052187	0.574963076	4.024741532	261.9796893	1.149926152	67	7	1.766620419	0.0028041594	630
29	73.020310655	0.544927691	3.814493840	265.7941831	1.089855382	67	7	1.674334277	0.0026576735	630
30	69.205816815	0.516461319	3.615229236	269.4094124	1.032922639	67	7	1.586869054	0.0025188398	630